OPPENHEIMER

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TECHNOLOGY/SEMICONDUCTORS & COMPONENTS

Semiconductors: Technology and Market Primer 7.0

SUMMARY

The Oppenheimer *Semiconductors: Technology and Market Primer 7.0* provides a complete overview of the semiconductor industry, both from a technology and market perspective.

- The Oppenheimer *Semiconductors: Technology and Market 7.0* is an updated version of the comprehensive "one-stop-shop" resource for the dynamic and complex semiconductor industry. It is designed for investors new to the space as well as for those seeking a better understanding of key technological and market elements.
- Inside you will find plain-English discussions of the technology behind the semiconductor industry and its major end markets. We discuss the major drivers of sector fundamentals, its cyclicality, and emerging trends. Finally, we dive into the individual product and end market segments, including forecasts and competitive positioning for both semiconductor vendors and their hardware customers.

Rick Schafer
720-554-1119
Rick.Schafer@opco.com

Shawn Simmons
212 667-8387
Shawn.Simmons@opco.com

Jason Rechel
212-667-7178
Jason.Rechel@opco.com

Introduction

The Oppenheimer *Semiconductors: Technology and Market Primer 7.0* is an updated version of the comprehensive “one-stop-shop” resource for the dynamic and complex semiconductor industry we first issued in June 2003 and updated in October 2004, December 2005, January 2007, January 2008, and December 2009.

The report is targeted to those investors new to the sector as well as those looking for a comprehensive resource to help them better understand key technological or market elements within the industry. We also suggest it as a “desk reference” for more experienced investors, as it has lots of forecast and market share data as well as in-depth discussions of many of the important trends affecting the semiconductor industry.

We start with basic semiconductor definitions and a simple review of manufacturing processes. We then discuss the semiconductor cycle and key fundamental indicators, and introduce some important concepts. We follow with a discussion of the major semiconductor product groups, including revenue forecasts and market share data. We then take a deep dive into the most important end markets served by the semiconductor industry, highlighting key players and company market shares for each application.

Product summaries cover analog, microcomponents, logic, memory and discrete devices. End market summaries cover computing, networking, telecom/datacom, wireless, digital consumer and automotive semiconductors. We have also included a section on “emerging technologies,” where we briefly discuss seven technologies that are just getting off the ground and that will be exciting to watch in 2011 and beyond.

Any comments that will help us make this a more successful document are welcome.

Rick Schafer
Managing Director
Shawn Simmons
Associate Director
Jason Rechel
Associate Director

Oppenheimer & Co.
Semiconductor Equity Research

Note on this version: All historical data on companies is current as of 2Q11; and industry sales, unit, and utilization data is also current up to July 2011. Market share data has been updated to reflect the most recent third-party sources and our internal estimates. All forecasts have been updated as well, and were also extended to 2015 (from 6.0’s 2013). There were also changes to formatting and the report structure to make it more readable.

Acknowledgments

We would like to acknowledge the contributions of our research colleagues at Oppenheimer whose help was invaluable in the preparation of this report.

Communication Technology
Ittai Kidron
George Iwanyc

Enterprise Software
Brad Reback
Arvind Rajamohan

Communications and Infrastructure Software
Shaul Eyal
Hugh Cunningham

Emerging Technology & Services
Andrew Uerkwitz

Specialty Semis & Enabling Technology
Srini Sundararajan

Communications & Cloud Services
Timothy Horan
Ned Baramov
Xavier Olave

Internet
Jason Helfstein

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Section I: Semiconductor Basics

This section deals with the basics of semiconductors

Topics include:

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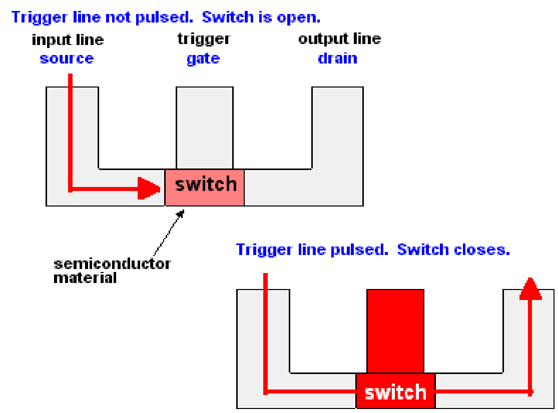
- Semiconductor manufacturing process
- CMOS
- Lithography & Moore's Law
- Wafer Size
- Manufacturing Strategies
- Geographic Trends
- Semiconductor Capital Equipment

Semiconductor Definitions

A **semiconductor** is a solid-state substance that is halfway between a conductor and an insulator. When charged, the substance becomes conductive; when the charge is eliminated, it loses its conductive status.

By combining conductive material, semiconductor material, and insulators in a pre-determined pattern, the movement of electricity can be precisely controlled. Semiconductors are therefore ideal for building devices that control the operation of electronic equipment.

A **transistor** is the basic element used in building semiconductor devices. A transistor is fashioned from semiconductor material and acts as an on/off switch, which opens and closes when electrically activated.



Source: Computer Desktop Encyclopedia, Oppenheimer & Co.

A semiconductor is a solid-state substance that is halfway between a conductor (which conducts electricity very well) and an insulator (which doesn't conduct electricity at all). When charged with electricity or light, the substance becomes conductive, allowing electricity to flow through it. When that charge is eliminated, it loses its conductive status, and electricity cannot flow through. By combining conductive material, semiconductor material, and insulators in a pre-determined pattern, the movement of electricity can be precisely controlled. Semiconductors are therefore ideal for building devices that control the operation of electronic equipment.

The basic element used in constructing semiconductor devices is the transistor. A transistor is essentially a tiny on/off switch fashioned from semiconductor material, which sits between two charged regions known as a "source" and a "drain." The switch can open and close when electrically activated, allowing current to flow from source to drain (when the switch is closed or "on"), or blocking the current's passage (when the switch is open or "off"). A third region, the "trigger gate," controls whether the switch is open or closed. By manipulating the gates within a semiconductor device, the system can accurately control the movement of electricity.

Semiconductor Definitions

The simplest semiconductor devices are comprised of a single transistor; these are called **discretes** and are usually used to control the flow of signals and power within a larger electronic device.

More complex semiconductor devices are built by combining multiple transistors and conductive **interconnect** material to form **logic gates**. These logic gates are arranged in a pre-defined pattern to perform more complex processing or storage functions. These devices are called **integrated circuits (ICs)**. The most integrated of these devices are known as **system-on-a-chip devices**, or **SoCs**.

The simplest semiconductor devices are comprised of a single transistor. These devices are referred to as discretes, and they are used in all types of electronic equipment to control the flow of signals and power within a larger electronic system.

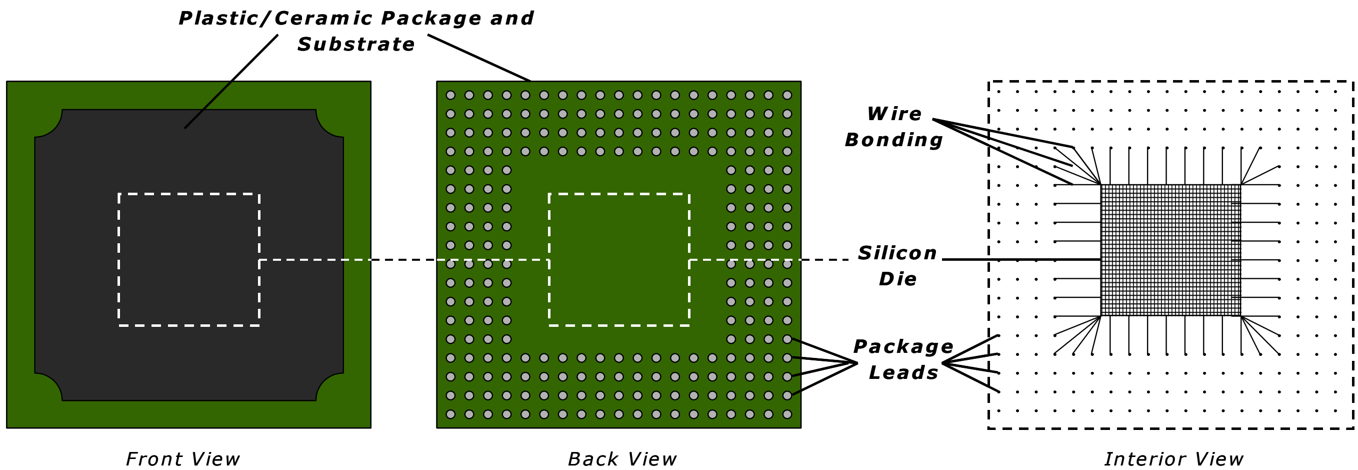
When many transistors are combined, an integrated circuit is created that can be used to process or store data signals in an electrical format. Engineers design pathways using transistors and conductive interconnect material set in logical arrangements (called “logic gates”) to perform specific functions, and these pathways become the circuit architecture etched onto the surface of the chip. Modern semiconductor devices can perform a variety of different functions on a single chip, and many electronic devices are powered by highly integrated system-on-a-chip (SoC) devices.

All electronic devices are built around semiconductors—transistors make up logic gates, logic gates make up circuits and circuits make up electrical systems. Key end applications are computing, telecommunications, data networking, wireless communications, consumer electronics, automobiles, industrial equipment, and aerospace/military.

Semiconductor Device Structure

Semiconductor devices contain a **transistor array**, which is etched onto a rectangular piece of **silicon** called a **die**. The die is encased in a plastic or ceramic **package**, and tiny wires called **wire bonding** are used to connect the input/output gates on the chip to the leads on the outside of the package.

Typically, the cost split for a fully packaged IC is roughly 85% for the silicon and 15% for the package.



Source: Oppenheimer & Co.

Typically, semiconductor devices are sold as standalone, fully functional packaged products that are ready to be implemented in an electrical system. The transistor array (or in the case of a discrete, the lone transistor), which is etched onto a rectangular piece of silicon (called a “die”) during the wafer fabrication process, is housed in a plastic or ceramic package. Tiny wires called “wire bonding” are used to connect the input/output gates on the die to the leads on the package. The semiconductor device is snapped or soldered onto a printed circuit board, with the leads attached to conductive pathways along the board.

For most semiconductor devices, the split in manufacturing value for a fully packaged semiconductor device is roughly 85% for the silicon and 15% for the package, although this can vary with the type of package and complexity of the device. Lower end devices such as discretes can have 30% or more of its value in the package given the maturity of the transistor process used at the trailing edge. On the other end of the spectrum, high-end devices such as microprocessors sometimes need more complex packages to deal with the speed and heat dissipation of the device, and therefore derive a higher value from the package as well.

Note that in many cases, IC vendors offer the same die in a variety of packages to accommodate different feature sets, power requirements, device characteristics, platforms or customers. Depending on the design, the type of package used can have a dramatic impact on the speed, power consumption, heat dissipation and footprint of the device. Some devices will even be “pin-for-pin” compatible with devices from competitors, usually at the request of the customer.

Semiconductor Devices In Systems

Getting Designed In

Semiconductor devices are used as components in larger electrical systems designed by an **original equipment manufacturer (OEM)**. Chip vendors **sample** their devices to OEMs, and are awarded **design wins** as the OEM designs the part into their systems. The chip vendor then provides production versions of the device, which are **qualified** by the OEM before going to full production.

Semiconductor devices can be custom designed for a specific customer and platform; these are called **ASICs** and are usually designed in cooperation with the OEM. Merchant devices called **ASSPs** are not designed for specific customers and can therefore be used by multiple OEMs. For the most generic components, OEMs will often buy **off-the-shelf** components, many of which are sold through the distribution channel.

Semiconductor devices are used as components in larger electrical systems designed by an original equipment manufacturer (OEM). Chip vendors supply samples of their devices to OEMs, sometimes based on specifications dictated by the customer. They are then awarded design wins as the OEM designs the part into their systems. The chip vendor will then provide production versions of the device, which will be qualified by the OEM before going to full production. This entire process can be as short as several weeks or as long as a year or even more.

Semiconductor devices can be custom designed for a specific customer and platform; these are called application-specific integrated circuits (ASICs) and are usually designed in cooperation with the OEM. ASICs are generally used when performance is key (e.g., a core router) or when volume on a single device is significant enough (e.g., a game console). Merchant devices called application specific standard products (ASSPs) or simply "standard products" are not designed for specific customers and can therefore be designed in by multiple OEMs. ASSPs are generally used when time-to-market and cost are key (e.g., PCs, smartphones). For the most generic components, OEMs will often buy off-the-shelf components, many of which are sold through the distribution channel. This includes not only memory but also standard logic, analog and discrete devices.

Customer engagements take many forms. Sometimes the OEM issues straight purchase orders; other times they will have a deeper engagement with a formal supply contract or even a technology partnership. The deeper the engagement, the more customization the OEM will typically expect from the chip designer. Note that design wins are awarded not only based on the performance of the device; factors such as pricing, software, service, support, existing relationship, track record, strength of the roadmap, scalability and other factors are often just as important.

Semiconductor Devices In Systems

System IP and Standards

For more complex electronic systems, semiconductor vendors will incorporate system **IP (intellectual property)** directly into their ICs. Often, they will try to integrate as many logic functions as possible into a single **SoC (system-on-a-chip)** or **chip set** in order to reduce the OEM's **bill of materials**. The IC vendor's system knowledge will be critical in winning the design.

Chip vendors design their devices to conform to the needs of their target customer set. Sometimes, the OEM will supply specifications directly to their chip vendors. In mature, high-volume markets, the devices will often adhere to specifications as defined by a **standard**, set forth by a **standards body**. This allows multiple chip and equipment vendors to compete more easily, speeding time-to-market and lowering the cost of the technology implementation.

When dealing with more complex systems, semiconductor vendors will incorporate system intellectual property (IP) directly into the device, either in the form of logic gates or in software or firmware that runs on top of the device. This is especially true in the case of application specific standard products, which get sold into multiple platforms at multiple vendors. By incorporating the system IP, the chip vendor lowers the design cost for the OEM and also speeds time-to-market, two factors that often matter more than simple performance or device pricing.

IC designers will usually try to integrate as many logic functions as possible into a single IC in order to reduce the OEM's bill of materials. Sometimes, it will prove too difficult or too costly to integrate certain functions, and the IC vendor will offer a chip set, either internally or with a partner. In any case, the IC vendor's system knowledge will be critical to winning the design.

Chip vendors will design their devices to conform to the needs of their target customer set. Sometimes, the OEM will supply specifications directly to its chip vendors, either in an ASIC arrangement or when multiple vendors compete for a standard product win. In the more mature, high-volume markets, devices will often adhere to specifications as defined by a standard, set by a standards body such as International Organization for Standardization (ISO) or the Institute of Electrical and Electronics Engineers (IEEE). This allows multiple vendors to compete, speeds time-to-market, and lowers the cost of the technology implementation across the supply chain. Chip vendors maintain seats on the standards bodies alongside their OEM customers in order to influence the outcome of standards negotiations.

Semiconductor Devices In Systems

The Evolving Electronics Supply Chain

The electronic equipment industry supply chain continues to evolve, as OEMs increasingly outsource aspects of the production and procurement process. **Electronics manufacturing services (EMS)** companies build products for their OEM customers. **Original device manufacturers (ODM)** companies go a step further, taking over portions of the design process. **Distributors** sit both between OEMs and end customers and between component suppliers and OEMs to smooth the supply chain.

Semiconductor vendors must maintain relationships with their OEM customers' outsourcing partners. Component decisions are increasingly being pushed toward the ODMs and EMS providers, favoring companies with strong supply chain relationships.

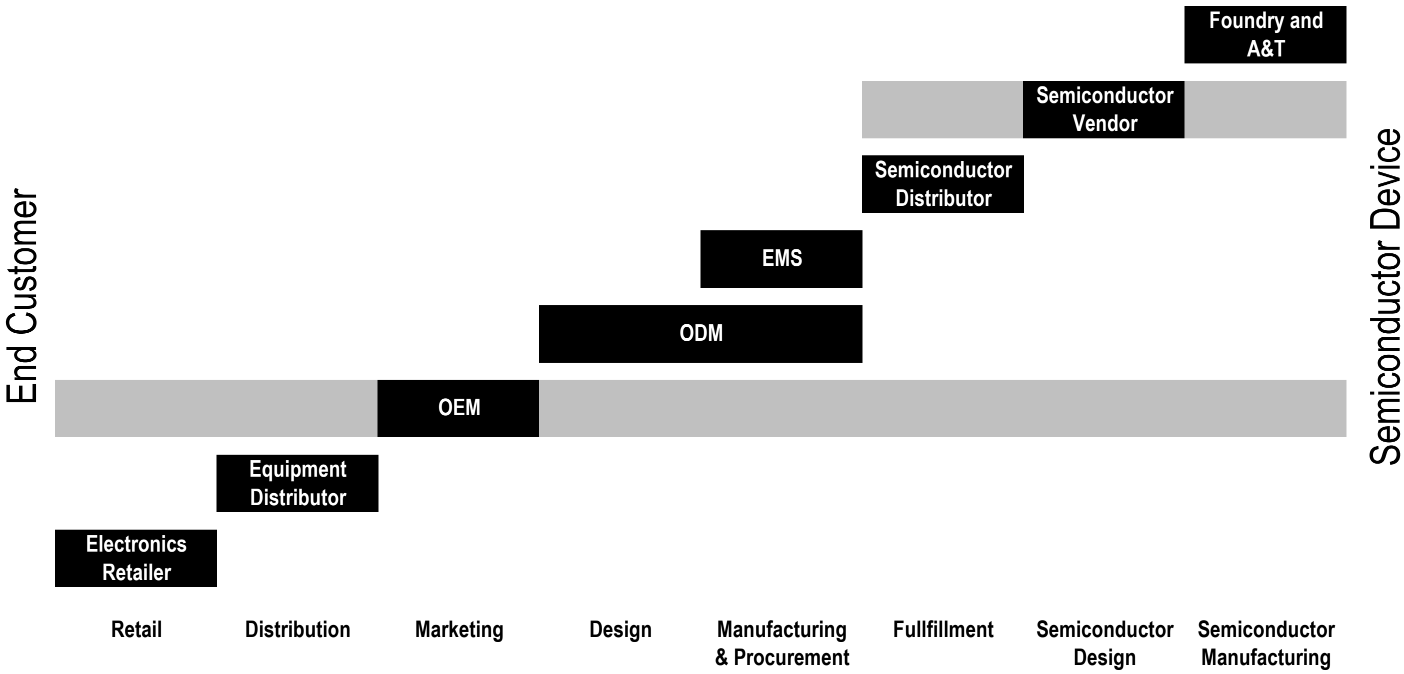
The electronic equipment industry supply chain has undergone some significant changes in the last decade. Enterprise and service provider equipment OEMs have shifted their business models away from chasing hardware margins and increasingly toward cultivating software and service businesses. Consumer device OEMs have focused on speeding time-to-market and on new channels to reach customers. Those that maintain large hardware operations are increasingly focused on design and marketing activities as opposed to hardware manufacturing and assembly. The trends have driven hardware prices lower and increased focus on costs.

In addition to shifting production to low-cost regions like Asia, OEMs are increasingly looking to outsource some aspects of the production process. Electronics manufacturing services (EMS) companies are now responsible for a big piece of PC, wireline, and wireless equipment production. Original device manufacturer (ODM) companies take it a step further, taking over some aspects of the design process. The PC industry also has a large and mature motherboard sector that serves both PC OEMs and the distribution channel, while notebooks are predominantly assembled by third parties. Distributors sit both between OEMs and end customers and between component suppliers and OEMs to smooth the supply chain and to simplify export processes in an increasingly global electronics industry.

In order to keep pace with the evolving supply chain, semiconductor vendors must maintain relationships with their OEM customers' outsourcing partners. Component decisions are increasingly being pushed toward the ODMs and EMS, favoring semiconductor suppliers with strong channel relationships. In the PC market, for example, servicing the motherboard makers is just as important as winning designs with OEMs back in the U.S. and Japan. In the handset market, ODMs are just as important as OEMs. In the analog market, having the right distributor relationships plays a tremendous role in who wins and who loses.

In the diagram below, we display the different roles played by different classes of companies in delivering a semiconductor device into the hands of the end customer. Note that we display the primary function in black, with some additional functions that they can also perform in gray. We follow the diagram with a description of each class.

Electronics Equipment Industry Supply Chain Diagram



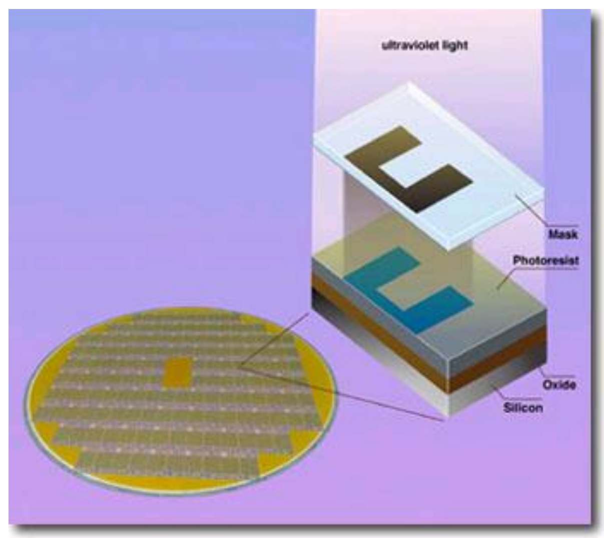
Source: Oppenheimer & Co.

- **Foundry and Assembly and Test (A&T):** These companies perform manufacturing of semiconductor devices. They are discussed in greater depth later in this report. Examples include TSMC, UMC, ASE, and Amkor.
- **Semiconductor Vendor:** Semiconductor vendors perform chip design and marketing. Some vendors perform their own manufacturing, others use foundries and assembly and testers, and still others use a mix. On the other side, semiconductor vendors can either sell their parts directly to OEMs, ODMs, or EMS, or they can use a distributor (in practice, most use both). Examples include Intel, Texas Instruments, Broadcom, and Maxim.
- **Semiconductor Distributor:** These distributors perform three important functions: 1) they carry inventory to help smooth the supply chain, 2) they handle import logistics to simplify international shipments, and 3) they reach smaller customers that the chip vendor cannot service directly. Examples include Avnet and Arrow.
- **Electronics Manufacturing Services (EMS):** EMS companies perform manufacturing on behalf of OEMs. In some cases they can handle procurement of components as well. Examples include Flextronics and Jabil.
- **Original Device Manufacturer (ODM):** ODMs are similar to EMS companies except they go a step further, taking over some aspects of the design and procurement process. ODMs partner with OEMs or service providers, who perform marketing and distribution. Examples include Hon Hai, BenQ, Compal, and Quanta.
- **Original Equipment Manufacturer (OEM):** OEMs are the electronics providers who design and market branded products to end customers and service providers. OEMs can pursue a wide variety of vertical integration models; some (like IBM or Fujitsu) do it all, from chip design and manufacturing all the way to direct sales to customers. Others (like NetGear) focus on marketing and some aspects of design, but outsource or partner for most other functions. Examples include HP, Dell, Apple, Cisco, Alcatel-Lucent, Nokia, Motorola, Sony, and Samsung.
- **Equipment Distributor:** These distributors help OEMs reach customers, servicing individual retailers or chains as well as selling directly to customers (through catalog or Internet). Examples include CDW and Ingram Micro.
- **Electronics Retailer:** Retailers provide outlets for individual consumers to buy electronics. Examples include Best Buy and Ultimate Electronics.

Semiconductor Manufacturing

Semiconductor devices are manufactured in specialized factories called **wafer fabs** using a process known as **wafer fabrication**. Circular wafers of silicon are put through a cycle of chemical processes in order to etch an ion-charged transistor array as patterned on a set of **masks**. On top of the transistor array, layers of metal **interconnect** form pathways between the transistors; the layers are insulated by a **dieletric** material.

After wafer processing, the finished wafer is put through a **dicing** process, where individual **die** are separated. These are sent to a **back end** facility for **packaging and assembly** and final **test**.



Source: IBM

Semiconductor devices begin the manufacturing process in specialized factories called “wafer fabs” using a process known as “wafer processing,” “wafer fabrication,” or “front end” manufacturing. In this set of processes, circular wafers of silicon are put through a cycle of chemical processes in order to etch a transistor array pattern on the wafer. During this process, a stepper will image the circuit pattern from a set of masks that contain the device design. Through stages of deposition, masking, etching and implantation using advanced photolithography, a series of intricate transistor arrays are formed on the surface of the wafer (multiple units are etched onto each wafer; they are later separated into individual devices).

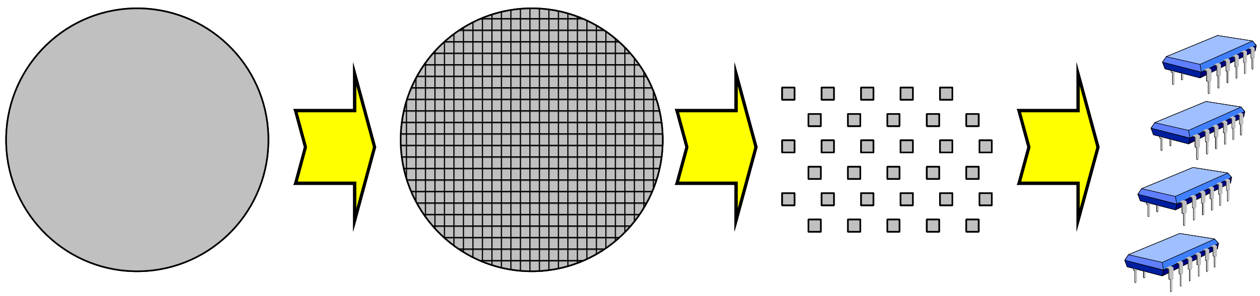
Once the transistor array is complete, the interconnect layers are built on top of the silicon transistors. These, too, are patterned on a set of masks and are created through multiple cycles of deposition, masking and etching using photolithography. Interconnect is applied layer by layer, with an insulating dielectric material deposited in between. The interconnect material is usually aluminum or copper, while a variety of non-conductive materials are used for the dielectric.

Once wafer processing is complete, the wafer is sliced into individual die with a diamond drill through a process called dicing. The individual die is then transferred to a “back end” facility for final packaging and assembly, followed by a final test cycle.

Semiconductor Manufacturing

Semiconductor Manufacturing Flow Diagram

Wafer Manufacturing	Wafer Processing	Dicing	Assembly & Packaging



Key Steps:	**Key Steps:**	**Key Steps:**	**Key Steps:**
Crystal Pulling	Chemical Vapor Deposition	Dicing	Die Attach
Crystal Slicing	Coating		Wire Bond
Wafer Lapping and Polishing	Align and Expose		Encapsulation and Finishing
Cleaning	Develop and Bake		Final Test
Oxidation	Etch and Strip Resist		
	Ion Implantation		
	Physical Vapor Deposition		
	Chemical Mechanical Planarization (CMP)		
	Passivation		
	Wafer Probe/Test		

Source: Oppenheimer & Co.

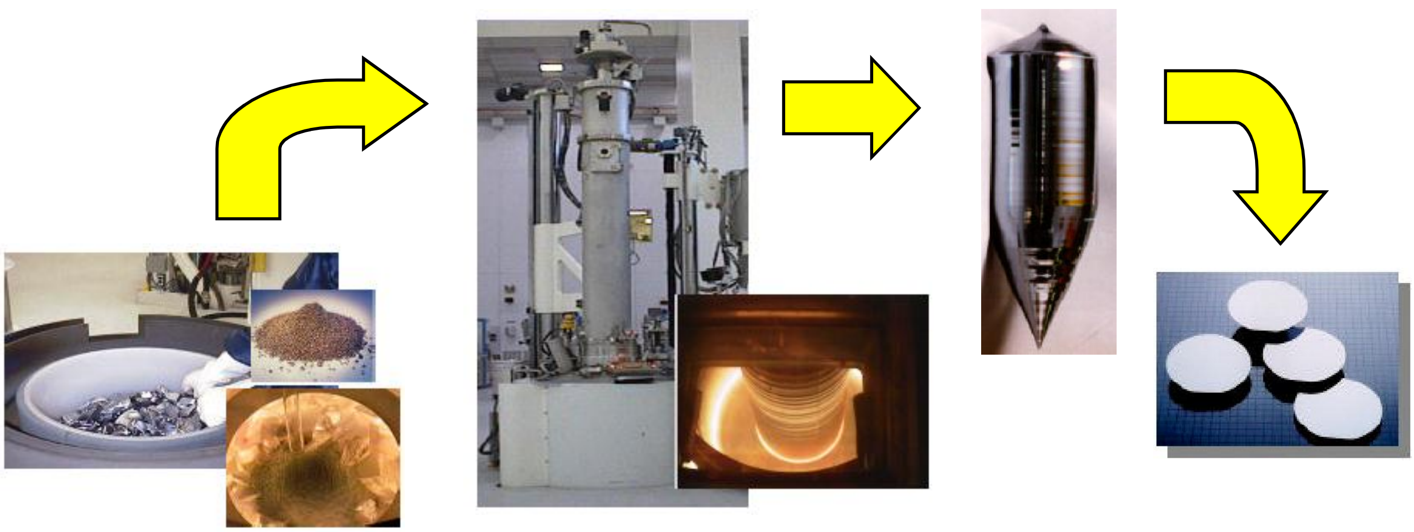
Semiconductor manufacturing can be divided into four relatively discrete stages. These include wafer production, wafer processing, dicing, and back end assembly and test.

- **Wafer production:** In this stage, silicon wafers are created from raw silicon. Separate wafer companies perform this process; few semiconductor device makers produce their own wafers.
- **Wafer processing:** Wafers are run through a series of chemical and lithographical processes to etch the transistor array and interconnects. Also called front end processing, this is the longest, most complex and most costly stage of semiconductor manufacturing. “Fabbed” semiconductor producers and foundry suppliers perform this process.
- **Dicing:** The processed wafer is chopped into individual die using a diamond drill. This is done at the beginning of the back end process.
- **Assembly and test:** Individual die are placed into a plastic or ceramic package and tiny wire bonding is used to connect the input/output gates on the chip to the leads on the outside of the package. The finished device is then tested. Assembly is done either by fabbed semiconductor producers or by third-party outsourcers; test is usually done in-house by both fabbed and fabless chip producers but can be outsourced.

The steps are discussed in further detail on pages 15-19.

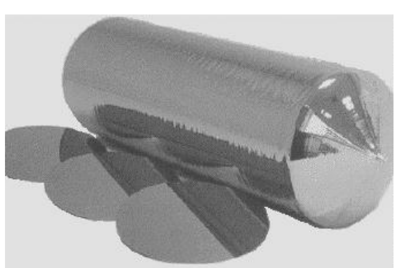
Wafer Manufacturing

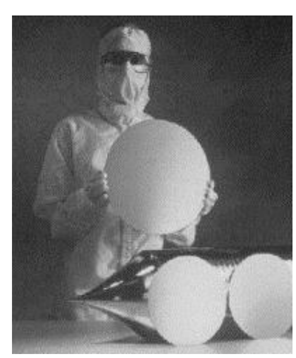
Silicon wafers are produced by heating a mixture of silica and carbon in a furnace, creating wafer-grade silicon. A seed is then dipped into the molten silicon and is slowly twisted and pulled out. This creates a cylindrical **ingot** several feet long, which is ground to an appropriate diameter (200mm, 300mm, etc). The ingot is then sliced into thin wafers for shipment to IDMs and foundries.



Source: MEMC, Oppenheimer & Co.

The first step in building a semiconductor device is the manufacture of silicon wafers. A mixture of silica and carbon is heated in a furnace, creating a molten mixture of wafer-grade silicon. A silicon seed is dipped into the melt and slowly pulled out. This creates a cylindrical ingot several feet long, which is ground to the proper diameter (200 mm, 300 mm, etc.). The ingot is then sliced into thin wafers for shipment to IDMs (integrated device manufacturers) and foundries. The pictures below display crystals, ingots and finished wafers.



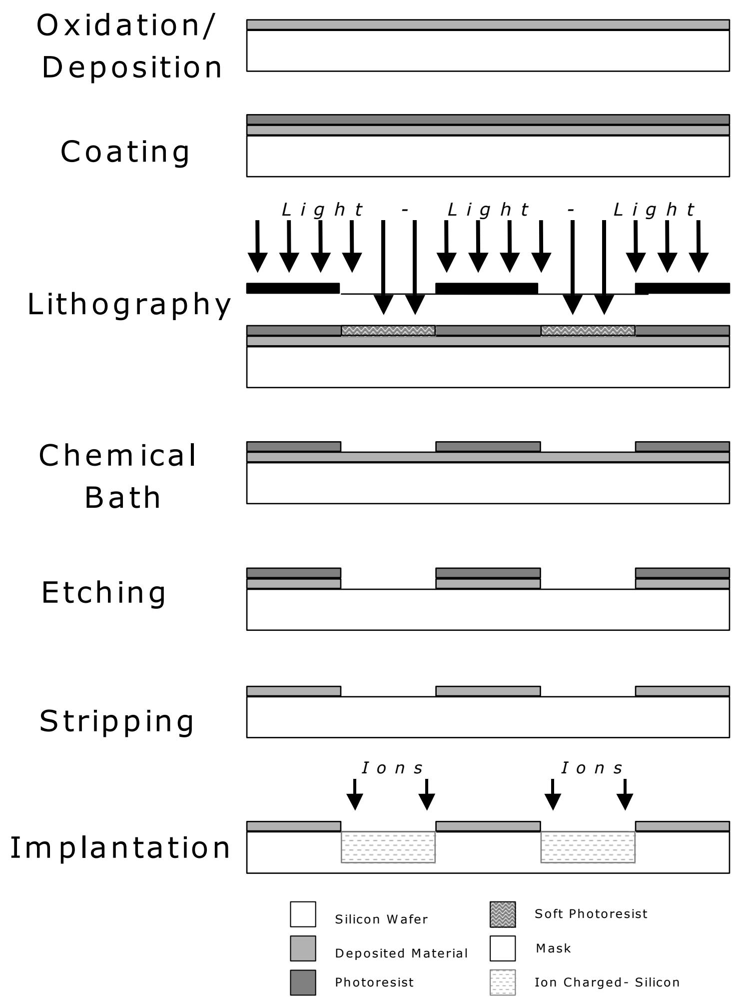


Source (all pictures): MEMC, IBM, Texas Instruments, Computer Desktop Encyclopedia

Wafer Processing: Pre-Metal

In the pre-metal stage, wafers are put through an intense cycle of chemical processes in order to etch a transistor array patterned on a set of **masks.**

Through cycles of **deposition/oxidation, photolithography, etching**, and **ion implantation**, the transistor array is created. Charged ions are then deposited to enable transistor functionality.



Source: Oppenheimer & Co.

The first half of the front end process is called the pre-metal stage. In this stage the transistor array is etched onto the wafer and ions are deposited in selected areas beneath the surface of the silicon.

Oxidation/deposition: In this first step, oxide material is deposited onto the surface of the wafer. This can be done through oxidation, which involves the heating of the wafer in a furnace filled with oxide gas, or through physical (PVD) or chemical (CVD) deposition of the material onto the surface of the wafer.

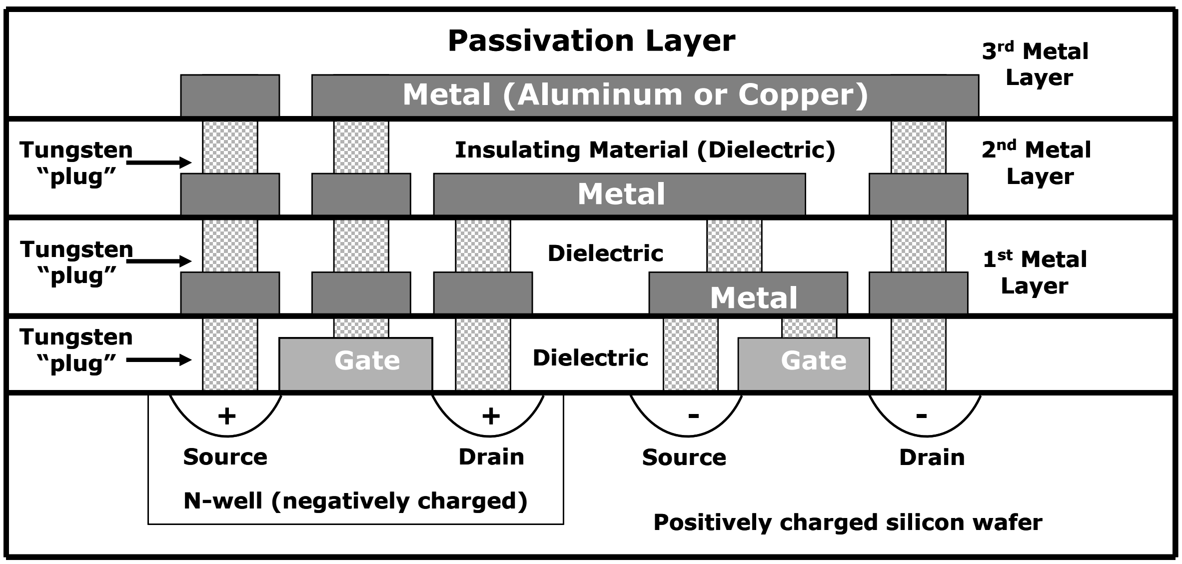
Photolithography: The wafer is then coated with a layer of photoresist—a material that is sensitive to light. A stepper then focuses an intense beam of light through a pre-formatted mask, softening the photoresist material in certain areas of the wafer according to the pattern of the mask in front of the light source. The wafer is then sent through a chemical bath to dissolve the soft photoresist.

Etching: Etching tools then remove the oxide material that is not still covered by photoresist. Once etched, the remaining photoresist material is stripped away using special chemicals.

Ion implantation: At various stages throughout the process, implantation equipment creates charged regions within the silicon wafer to enable transistor functionality. Ionic materials known as dopants are shot into the wafer, where they remain under the surface of the silicon. Both positive and negative dopants are used.

Wafer Processing: Interconnect

After the transistors are created, they are connected together to form logic gates using an **interconnect** material, usually aluminum or copper. The metal layers are built with stages of deposition, lithography, and etching, similar to the pre-metal stage but using separate equipment and masks. Dielectric material is deposited between the layers to insulate them from one another.

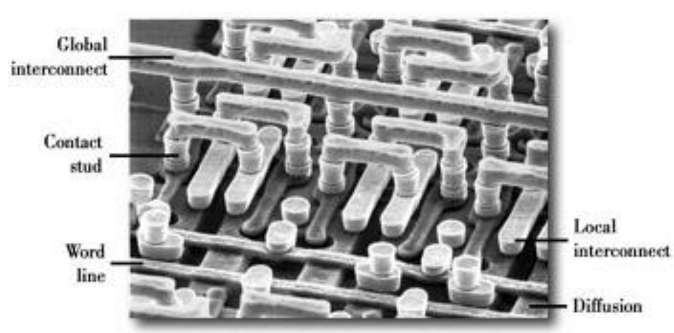


Source: Oppenheimer & Co.

After the transistor array is created, the wafer is moved to the metal area of the fab, where interconnect layers are deposited and etched to create the logic gates. The metal interconnect layers are created through cycles of deposition, photolithography and etching, similar to the pre-metal stage but with separate equipment. In between each of the metal layers, dielectric material is deposited to insulate the metal layers from one another. A final passivation layer is added above the top metal layer to protect the circuitry.

Most devices use aluminum or copper for the interconnect layers. Aluminum tends to resist the flow of electricity as wires are made thinner and narrower; therefore, most device manufacturers shifted to higher performance copper interconnects when they began 0.13-micron production. The number of metal layers varies by device; the highest performance devices can have as many as nine metal layers.

The picture below displays an IBM-fabricated SRAM cell with the insulating oxide films removed.

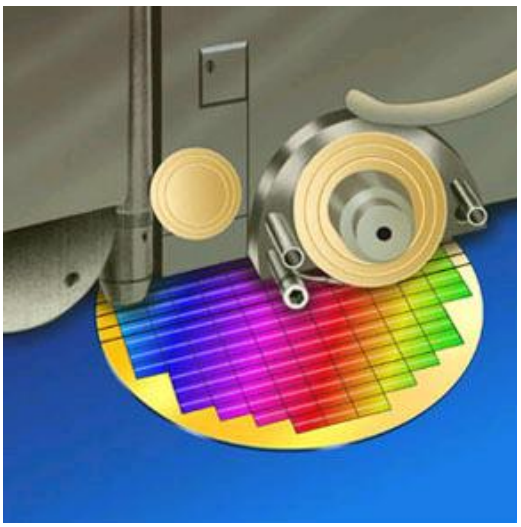


Source: IBM

Dicing

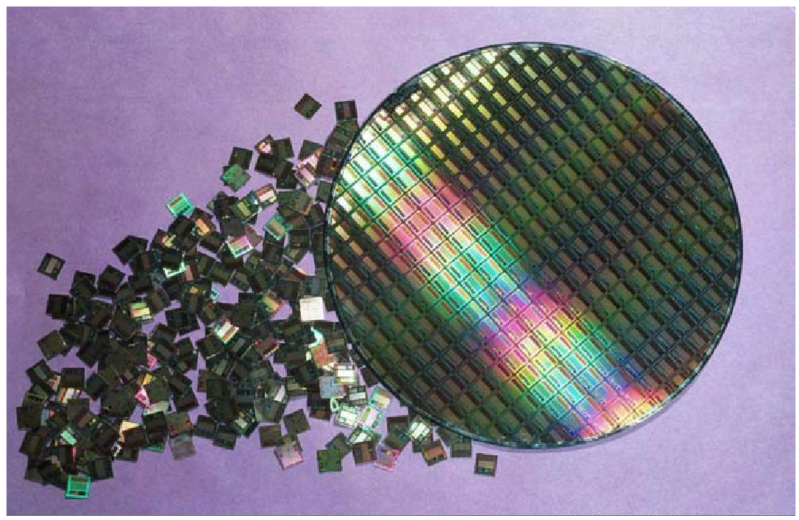
After the wafer is processed, a diamond drill is used to slice the wafer into individual **die**. Each die is tested before being sent to the back end facility.

Semiconductor Dicing Diamond Drill



Source: IBM

Finished Wafer and Individual Die

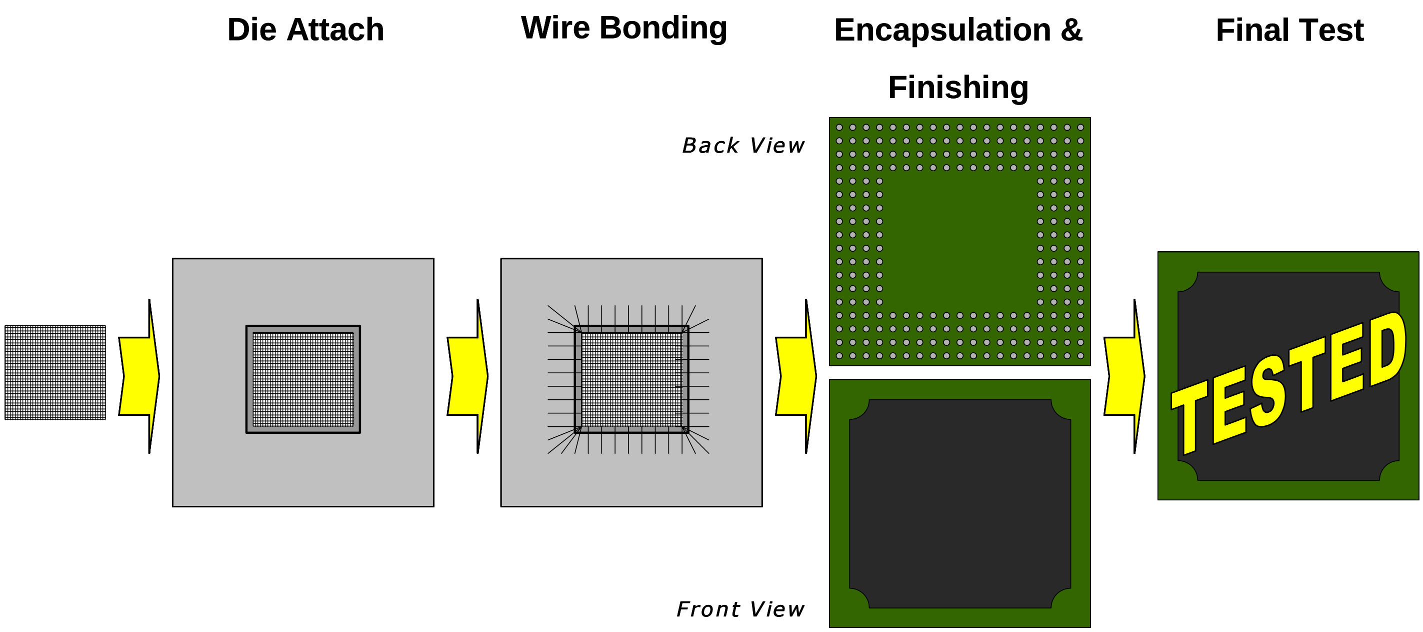


Source: LSI Logic, Denali Software

Once the wafer is fully processed and all pre-metal, metal and inter-metal layers are built, a diamond circular saw is used to separate the individual die. The die are then tested for defects and the good die are sent to a back-end line for packaging and final test.

Back End: Assembly & Test

The individual die are sent to a back end assembly facility, where they are **attached** to a package, **wire bonded**, **encapsulated**, and run through **final test**.

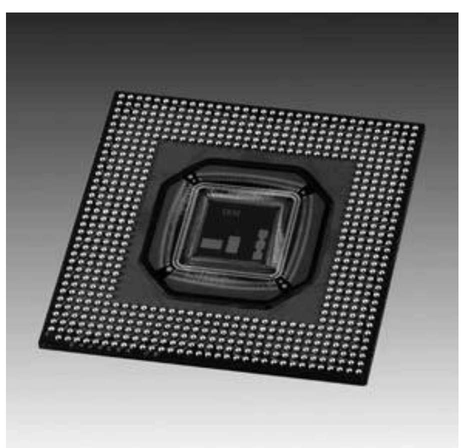


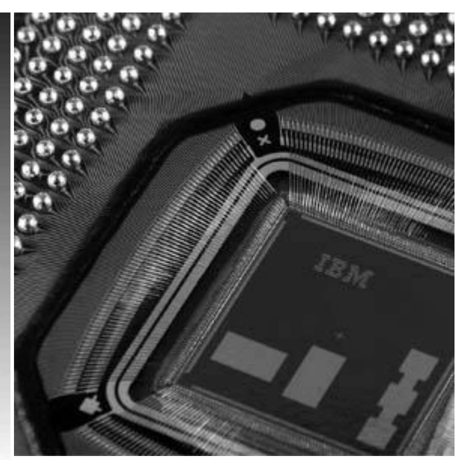
Source: Oppenheimer & Co.

Once diced, the individual die are then packaged and tested. Each die is first attached to a package, and wire bonding is used to connect the input/output gates on the die to the leads on the outside of the package. The device is then encapsulated, sealed and markings are affixed. A final test is conducted before shipment.

Note that many devices are now using a process called flip chip, where the die is flipped during packaging. This increases the performance of the device but is also more costly.

The pictures to the right display an IBM semiconductor package, with a close-up displaying wire bonding.





Source: IBM

Manufacturing: CMOS

CMOS (Complementary Metal Oxide Semiconductor) is the most widely used type of semiconductor design and manufacturing process. CMOS processes use standard silicon wafers and combine both positive and negative transistors.

In general, devices fabricated in CMOS will be **cheaper** to manufacture and will consume **less power** than other devices. Designs done in CMOS are also **easier to scale** to smaller transistor sizes.

Most semiconductor designers and manufacturers will use standard CMOS wherever possible. However, certain high-performance or specialized applications require the use of **bipolar** or **compound semiconductor** manufacturing processes.

CMOS (pronounced "see-mos"), which stands for complementary metal oxide semiconductor, is the most widely used type of semiconductor design process in production today. The CMOS process uses standard silicon wafers and combines PMOS (positive) and NMOS (negative) transistors in specific ways, so that the final product consumes less power than PMOS-only or NMOS-only circuits. Devices fabricated in CMOS are cheaper to manufacture and consume less power than devices fabricated using other processes, and CMOS is therefore generally used whenever possible.

Other types of manufacturing involve certain compounds more suited to specific types of applications, primarily for high-speed communications, power management, or amplification. Silicon germanium (SiGe) is a commonly used compound for high-speed physical layer devices in wireline communications. Gallium arsenide (GaAs) is used in wireless handsets and set-top boxes, as it is better suited to high-voltage RF (radio frequency) applications. It is also used in optoelectronic devices for wireline communications. Other exotic semiconductor processes include silicon bipolar (BiCMOS), indium phosphide (InP), indium gallium phosphide (InGaP) and indium gallium arsenide (InGaAs). In general, these specialized processes are more costly to design and manufacture than standard CMOS and are more difficult to scale down to smaller process technologies (see the section on lithography starting on the next page). Therefore, wherever possible, designers tend to choose CMOS over these processes.

Although CMOS should represent the bulk of manufacturing in the near future, we note that several large IDMs, including Intel, IBM and Texas Instruments, have developed a process known as strained silicon, which allows for the use of silicon germanium transistors alongside standard CMOS transistors.

Manufacturing: Lithography

Lithography, also known as **geometry** or simply **process technology**, describes the level of **"smallness"** the manufacturing process can achieve, which determines the size of the transistors on the die.

Smaller transistors mean:

1) electrons move quicker between them → ***faster*** devices

2) more transistors per square inch → smaller die sizes → ***cheaper*** devices

3) less electricity needed to power them → ***lower power*** consumption

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Lithography, as mentioned in the section on wafer processing, is a general term used for the set of processes that transfer the transistor array and interconnect design from the mask onto the silicon wafer. The level of "smallness" the manufacturing process can achieve is therefore determined by the lithography equipment; this in turn determines the size of the transistors on the die. The industry continually shrinks transistor size, also known as feature size, by moving to more advanced lithography equipment. On average, the industry moves to a new process geometry node every two years.

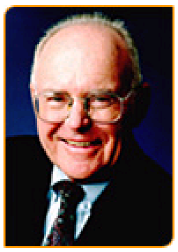
The advantages of moving to smaller lithography are threefold. First and foremost, smaller transistors mean faster devices. The smaller the transistor, the less time it takes for the electrical charge to move across it. Second, smaller transistors mean smaller overall die size, which means more devices per wafer, which translates into lower cost per device. The ability to integrate additional logic, analog, discrete and memory content more cost-effectively stems from this as well. Third, smaller transistors mean lower power consumption and therefore cooler running devices.

In order to achieve smaller geometries, manufacturers must invest in new lithography equipment while chip designers must alter their designs to take advantage of the new transistors. Certain technology challenges also need to be addressed (in addition to the normal yield issues that result from any new manufacturing process), such as current leakages, increased source and drain resistance and difficulty in sending thinner laser light through glass. Most recently, the industry has required innovations such as copper interconnect and low-K dielectrics in order to meet these challenges; future innovations include high-K dielectric and extreme ultra-violet (EUV) lithography.

Manufacturing: Lithography

Moore's Law

Advancement towards finer lithography, which enables smaller and smaller transistors, is the primary driver behind the dramatic improvement in semiconductor device performance over the past few decades.



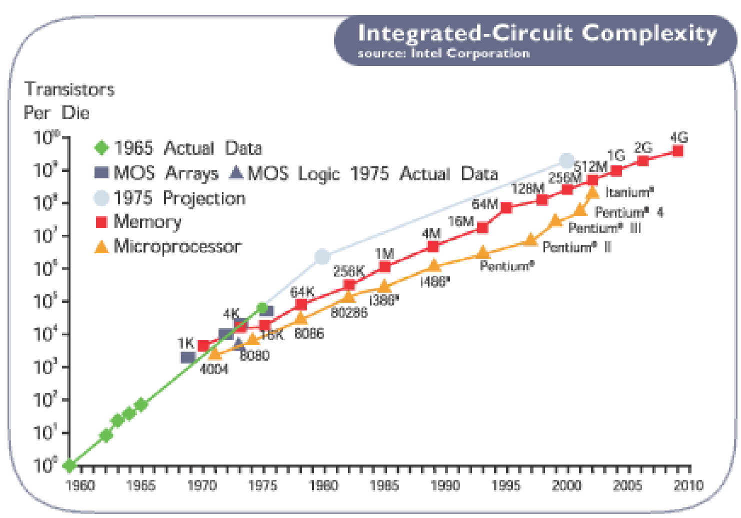
Moore's Law states that the number of transistors on a chip doubles about every two years. The phenomenon was first noticed by Intel founder Gordon Moore, and has held basically true for the past 40 years or so.

In addition to the doubling of transistor density, each new lithography generation usually brings 0.7X minimum feature scaling, 1.5X faster transistor switching speed, reduced chip power, and reduced chip cost.

The continuing push toward more advanced lithography, which enables smaller and smaller transistors, is the primary driver behind the dramatic improvement in semiconductor device performance over the past few decades.

These advancements drive Moore's Law, which states that the number of transistors on a chip doubles about every two years. Intel co-founder and industry legend Gordon Moore first noted the trend in DRAM densities, and the law has held true for the past 40 years or so. Intel introduced 3D transistors in 2011 to extend Moore's law going forward.

Moore's Law also drives chip performance. In addition to the doubling of transistor density, each new generation usually brings 0.7X minimum feature scaling, 1.5X faster transistor switching speed, reduced chip power, and reduced cost.

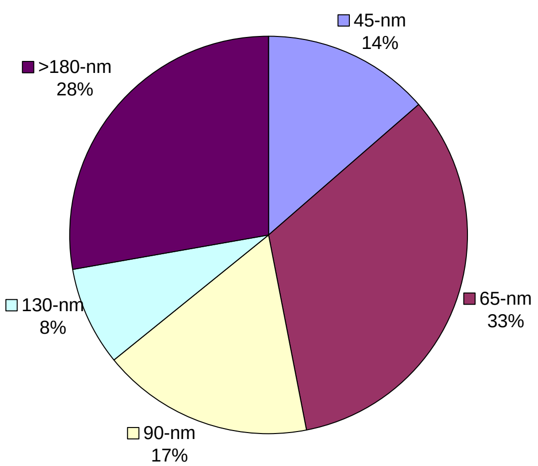


Source: Intel Corporation

Manufacturing: Lithography

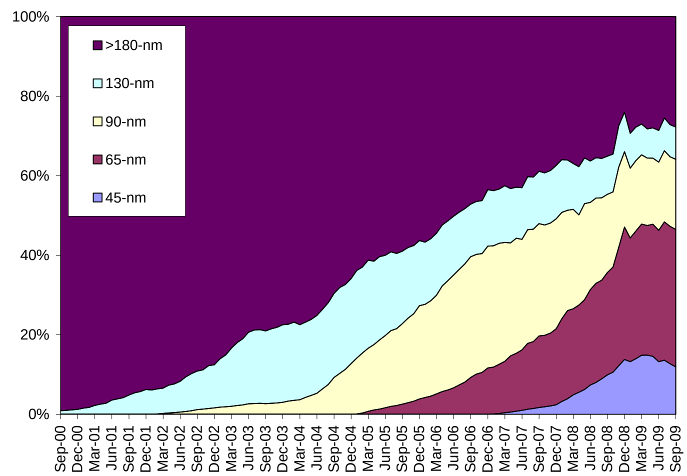
Transistor sizes are measured in **microns** or **nanometers** (1 micron = 1,000-nm). About 28% of wafer production in 2009 was at geometries of 0.18-micron and above; mostly discretes and analog ICs. More complex logic uses 0.13-micron and 90-nm (0.09 micron), while the most advanced devices use 65-nm (0.065-micron) or bleeding edge 45-nm (0.045-micron) and 32-nm (0.032-micron).

2009 Production By Process Technology



Note: Data displayed in MSI (millions of square inches of wafer) Source: VLSI, Oppenheimer & Co.

Monthly Production By Process Technology



Note: Data displayed in MSI (millions of square inches of wafer) Source: VLSI, Oppenheimer & Co.

Transistor size is measured in microns, or one millionth of a meter, although it is increasingly being quoted in nanometers (abbreviated "nm"). Most advanced digital devices built today use deep sub-micron transistors such as 0.13-micron or 90-nm (0.09-micron), with the most advanced of these using 65-nm (0.065-micron) or 45-nm (0.045-micron). On average, the industry moves to a new process geometry node every two years and 32-nm (0.032-micron) products first became commercially available in 2009 and ramped in volume during 2010. Next-generation 28-nm & 22-nm are expected to ramp in volume production in 2012.

Traditionally, high-volume processor and logic (usually DSP and ASIC) manufacturers lead the charge at each transistor node; these are the manufacturers that are in 65-nm volume today. High volume commodity DRAM and NAND flash providers are a half-step behind, though memory processes are typically much simpler (fewer metal layers, etc.) than processors and logic, so at times memory vendors may actually pull ahead of logic vendors.

Just behind the logic and memory manufacturers are the leading edge foundries, which typically load their most advanced fabs with graphics and PLD chips as well as DSPs. The advanced foundries today are in volume production on 40-nm, ramping 28-nm with select lead customers in 2012. The foundries are followed by SRAM and NOR flash memory producers, though many of these have been moving to an outsourcing model in the past few years.

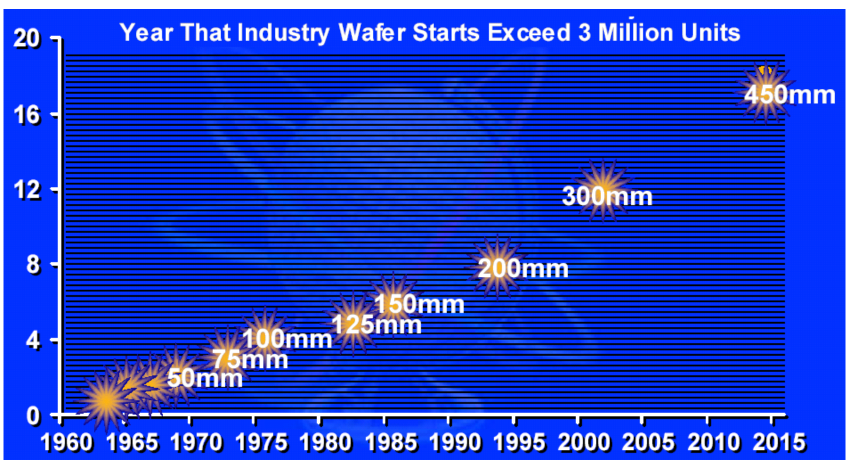
Sitting at the trailing edge are discrete device manufacturers, today mostly at 0.13-micron and above. Analog semiconductor production generally takes place on separate processes, typically several generations behind.

Manufacturing: Wafer Size

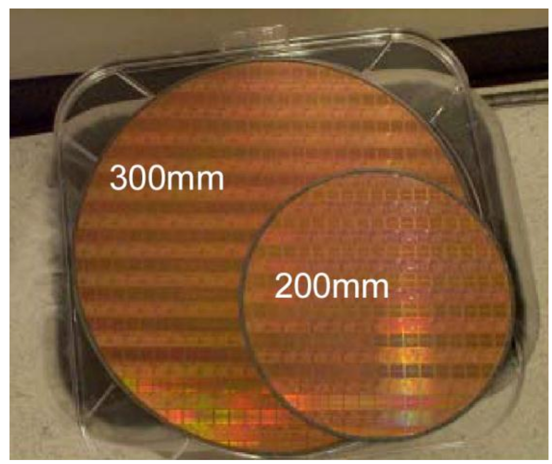
Wafer size is the diameter of the wafer used in manufacturing.

Larger wafers → more die per wafer → lower cost per die

Most fabs today use 200-mm (8-inch) or 300 mm (12-inch) wafers; the larger wafers yield more than twice the die per wafer of a 200 mm equivalent.



Source: VLSI Research, Intel.



Source: Promos

Wafer size refers to the diameter of the silicon wafer used in manufacturing. The majority of manufacturers use 200-mm (8-inch) or 300 mm (12-inch) wafers; 300-mm (12-inch) wafers are reserved for the most advanced, highest volume production.

The advantages of using larger wafers are purely lower cost: the larger the wafer size, the more die can fit on a single wafer with a less than proportional increase in cost per wafer. No additional chip performance is attained; just more die are produced at lower average cost per die (once the process reaches volume production and start-up costs are amortized).

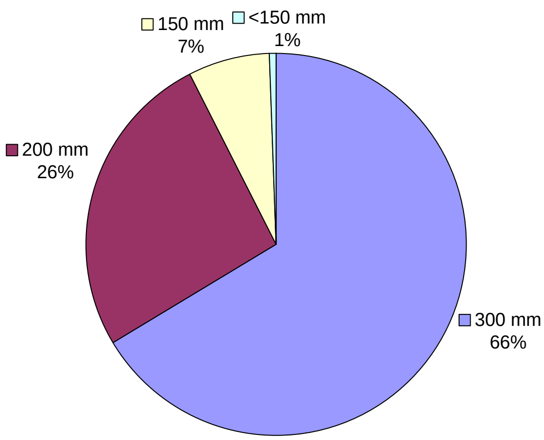
Presently, the industry is moving from 200-mm wafers to 300-mm wafers. Note that the 50% increase in wafer diameter translates to a 2.25X increase in usable wafer area (remember that the area of a circle is determined by πr^2; some additional gains are realized on the periphery of the wafer, where the larger circumference yields smoother curves). For example, a 200-mm process running a die size of 12-cm x 12-cm would yield 180 gross die per wafer; a 300-mm process running the same die would yield 432 gross die.

In order to move to larger wafer size, most equipment in the fab must be replaced, and in many cases, an entirely new facility must be constructed. Consequently, moves to larger wafers occur once every few years and the time between moves has been steadily rising (the next move, to 450-mm (18-inch) wafers, will not happen until 2015 at the earliest).

Manufacturing: Wafer Size

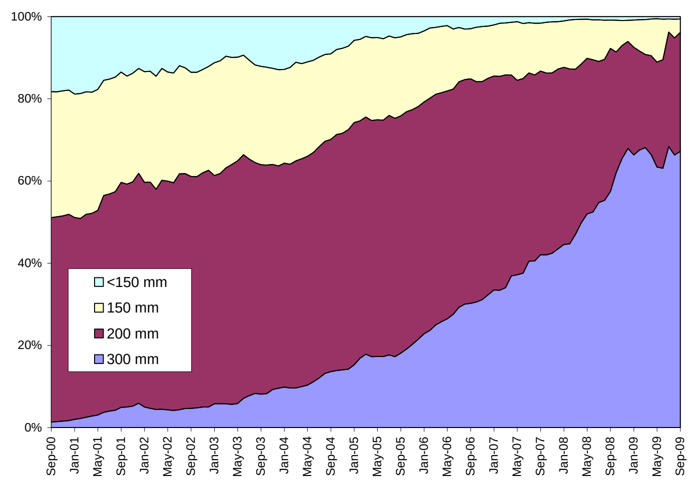
The ramp of 300 mm continues at a steady pace, with new fabs coming on-line from logic and memory manufacturers as well as foundries. 300 mm wafers represented roughly 66% of total industry production in 2009, a 20% increase from the previous year. Most manufacturers have paired 300 mm wafers with their most advanced lithographies.

2009 Production By Wafer Size



Note: Data displayed in MSI (millions of square inches of wafer) Source: VLSI, Oppenheimer & Co.

Monthly Production By Wafer Size



Note: Data displayed in MSI (millions of square inches of wafer) Source: VLSI, Oppenheimer & Co.

The ramp of 300-mm continues at a steady pace; 300-mm wafer production increased 20% in 2009 and represented 66% of the industry's overall production. Note that 300-mm wafers represented an even larger percentage of the leading edge production, as most manufacturers have paired 300-mm wafers with their most advanced lithographies.

In general, the companies that have led the charge are both manufacturers of the highest-volume products and companies for whom manufacturing is a key competitive advantage. The most aggressive 300-mm manufacturers include Intel, Texas Instruments, Global Foundries, Samsung, TSMC, UMC and Elpida.

Manufacturing: Strategies

Integrated Device Manufacturers (IDMs) manufacture their own devices. Typically, these are mature vendors dealing in high volume products. IDMs have lots of operating and cyclical leverage.

Examples: Intel, Texas Instruments, Samsung, Toshiba, Renesas

Fabless companies design devices themselves but contract the manufacturing to others. These companies are more focused on design, and enjoy more margin and earnings stability as well as lower capital requirements.

Examples: Broadcom, Qualcomm, NVIDIA, Xilinx, Marvell, MediaTek

Foundries and **Assembly and Testers** are specialized third-party manufacturers that perform wafer fabrication or back-end processing for others on a contract basis.

Examples (foundry): Taiwan Semiconductor, UMC, Global Foundries

Examples (assembly and test): ASE, Amkor, Siliconware Precision

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Semiconductor companies can be divided along manufacturing lines into three segments: IDMs, fabless and foundries. IDMs design and manufacture their own devices, fabless companies design their devices but don't manufacture them and foundries perform manufacturing but no design. Increasingly, IDMs are moving toward hybrid strategies, retaining some manufacturing in-house while contracting out for some additional capacity. These hybrid strategies offer more production flexibility while minimizing the level of critical capacity investments. Others have given up on manufacturing altogether and are going fabless.

Front End Manufacturing Strategies

Integrated Device Manufacturers

Integrated device manufacturers, or IDMs, design and manufacture their own devices. Typically, these will be the more mature semiconductor manufacturers that deal in very high-volume products. These vendors also typically consider manufacturing expertise a key competitive advantage and a core competency for their businesses, either for technology reasons (e.g., they want to be first to market with next generation lithography, or they have specialized processes, etc.), to leverage economies of scale, to control their supply, or for a host of other reasons.

IDMs enjoy high margins in the boom part of the cycle as their fixed costs do not change, but suffer low margins in the trough of the cycle as capacity goes unused. This effect should not be underestimated, as fixed costs (including depreciation and fixed material and labor costs) can run as high as 80% of semiconductor manufacturing costs. IDMs must also maintain large capital expenditure budgets to stay ahead of the competition in order to ensure that they do not suffer performance or cost disadvantages; consequently, their ongoing cash needs are greater.

Key examples of IDMs include Intel, Samsung, Micron, as well as nearly all the Japanese semiconductor suppliers. We also consider partial-outsourcers like Texas Instruments, STMicroelectronics, Infineon, Freescale, and NXP to be IDMs, as manufacturing is still a big part of what these companies do.

Fabless

Fabless companies are those that design devices themselves but contract the manufacturing to third parties. These vendors typically focus on design, leaving manufacturing competencies to others. The benefits of a fabless model include a lack of fixed costs, which translates into lower capital investment requirements, more consistent margins and better earnings predictability. Fabless companies have the opportunity to gain share vs. IDMs in the downturn (since wafer costs for them will decline while unit costs for IDMs rise with declining output) and will lose share at the peak of the cycle (because of the opposite effect). This effect can be neutralized if all direct competitors are fabless.

Key fabless vendors include Broadcom, Qualcomm, Marvell, Xilinx, Altera, NVIDIA, Mediatek, and PMC-Sierra. The list of fabless companies has been growing nicely, as the vast majority of semiconductor start-ups are fabless. Also, a number of IDMs have gone fabless in the past few years, including AMD, LSI, AMCC, and Vitesse.

Foundry

Foundries are specialized third-party manufacturers that perform wafer fabrication for others on a contract basis. Foundries do not design any devices themselves; rather they manufacture the designs of fabless companies and IDMs. Key foundries include Taiwan Semiconductor (TSMC) and United Microelectronics (UMC) in Taiwan, Global Foundries and IBM Microelectronics in the U.S., and DongbuAnam in Korea.

Hybrid Strategies

As mentioned above, many semiconductor companies use a hybrid manufacturing strategy. Most IDMs use external foundries for at least some of their production, usually when in-house capacity becomes tight or for specific leading edge devices. This trend accelerated at the beginning of this decade, as IDMs found themselves burned by too much capacity in the 2001 and 2008 downturn. As mentioned above, big-name IDMs like Texas Instruments, STMicroelectronics, Infineon, and Freescale all outsource a significant portion of their production.

Others use a “fab-light” strategy, outsourcing most of their manufacturing but keeping some in-house. Usually, the in-house facility will be used either for older, more mature manufacturing or for specialized processes.

Another hybrid strategy, though less common, is where IDMs manufacture their own designs and also utilize the excess capacity as a foundry for additional revenue.

Back End Manufacturing Strategies

On the assembly and test side, the same three types of companies exist: those with internal facilities, those that outsource, and specialty assembly and test outsourcers. We note that very few IDMs will do 100% of the packaging themselves, as packaging types in the industry number in the hundreds and most IDMs are unwilling to invest in all the necessary equipment. Further, many IDMs (particularly high performance IC manufacturers) will focus on leading edge packaging technologies in-house, but will leverage low-cost outsourcers in Asia for the mainstream processes. Still others (particularly low cost producers) will do most of the bulk processes in-house but will contract out some of the higher performance packages.

Test functions are often conducted in the same facility as packaging and assembly. However, many fabless companies will outsource the packaging of their devices but will perform testing in-house; this allows them to more quickly identify design flaws.

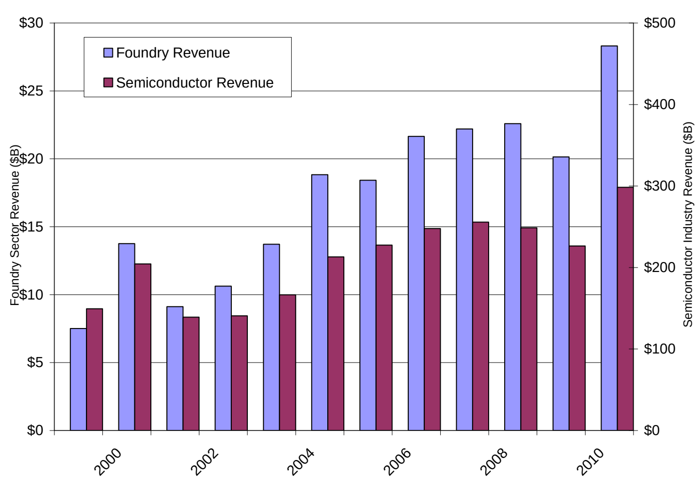
The outsourced assembly and test market is less consolidated than the foundry market, with key vendors being ASE Test, Amkor Technology, Siliconware Precision, and STATS-ChipPAC. Almost all test activity is conducted in Asia, as it is more labor-intensive than front-end processes and also carries less stringent clean room requirements.

Manufacturing: Strategies

Foundries

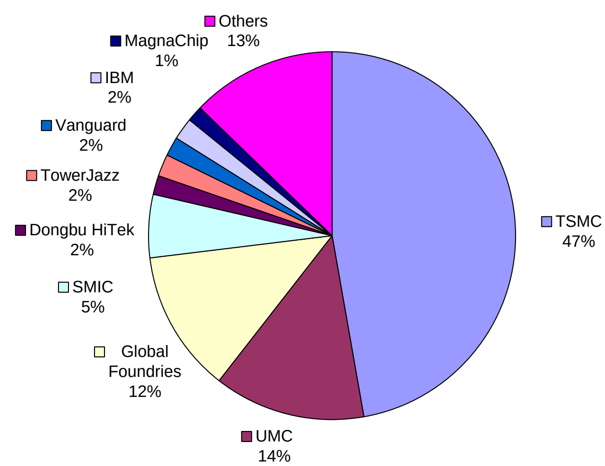
The rising costs of semiconductor factories have made it prohibitively expensive for all but the largest vendors to do their own manufacturing. This has accelerated the trend towards outsourcing. The major foundries—TSMC, UMC, SMIC and Global Foundries—therefore nicely outpaced industry revenue growth for the past several years.

Foundry vs. Semiconductor Revenue



Source: Dataquest, WSTS, Oppenheimer & Co.

2010 Semiconductor Foundry Market Share



Source: Dataquest, Oppenheimer & Co.

The rising costs of semiconductor factories and equipment over the past few years have made it prohibitively expensive for all but the largest semiconductor vendors to do their own manufacturing. This has forced many high-volume players to search for partners to do their wafer fabrication. Fabless designers have also grown in importance, and even control certain sub-segments of the semiconductor industry (graphics, PLDs, etc.); and since they are 100% outsourced, the foundries have had to grow to meet their supply needs.

At the same time, the major foundries have done an excellent job of ramping leading edge capacity with world-class yields. The traditional top-three foundries—TSMC, UMC, and Global Foundries (acquired Chartered)—were all very aggressive in getting to 0.13-micron and have carried that through to 40-nanometer as well. Shanghai start-up foundry SMIC has also gained a lot of ground with logic and memory producers and is considered a top-tier foundry.

Revenue growth trends tell the story well: foundry revenue growth has outpaced semiconductor industry growth in four of the last seven years, and over that period has risen by 117% vs. the industry's 79%. Going forward, we expect foundry revenue growth to continue to outpace the overall industry, though the rate will likely decelerate.

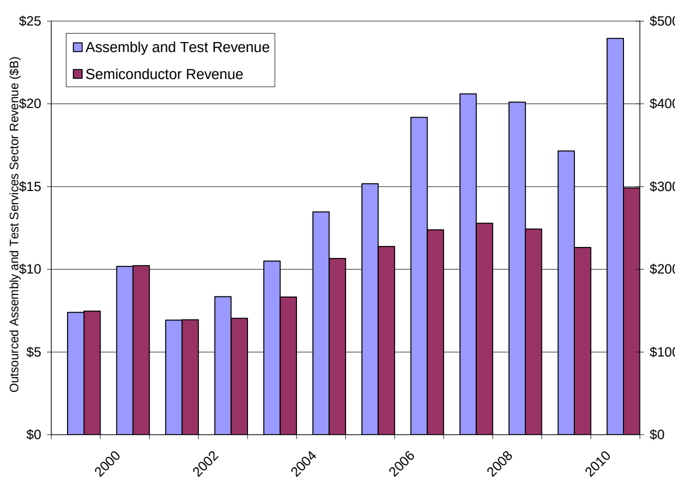
In terms of market share, TSMC was the leading foundry provider in 2010, with 47% overall revenue share. UMC followed with 14%. Global Foundries and SMIC held 12% and 5%, respectively. Other vendors include DongbuAnam, Magnachip (which spun out from Hynix), Vanguard International, X-Fab, IBM, MagnaChip, compound semiconductor foundry TowerJazz, and Japanese IDMs Fujitsu, Toshiba, and K-Micro.

Manufacturing: Strategies

Assembly and Test Services

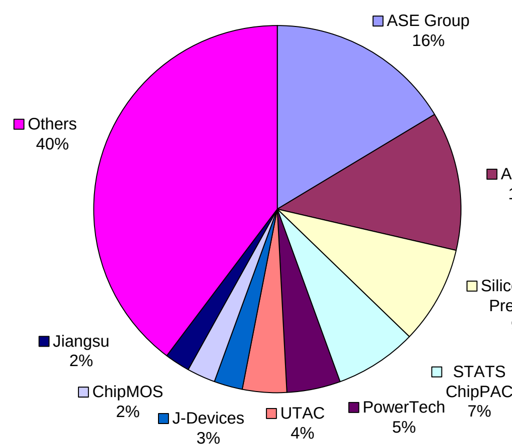
The trend toward outsourcing has also benefited back end providers, though not as dramatically as the foundries. IDMs often keep back end production in-house because they can realize lower costs, though fabless companies usually outsource. Top assembly and test houses include ASE, Amkor, Siliconware Precision, and STATS-ChipPAC.

Assembly and Test vs. Semiconductor Revenue



Source: Dataquest, WSTS, Oppenheimer & Co.

2010 Assembly and Test Market Share



Source: Dataquest, Oppenheimer & Co.

Assembly and test providers have also benefited from the trend toward outsourcing, especially in the last couple of years. The effect has not been quite as strong as we have seen with the foundries, as some IDMs have opted to keep back end production in-house because they can realize lower costs and the capital investment required is not nearly as large.

As mentioned above, however, very few IDMs do 100% of the packaging themselves, as packaging types in the industry number in the hundreds and most IDMs are unwilling to invest in all the necessary equipment. Further, many IDMs (particularly high performance IC manufacturers) focus on leading-edge packaging technologies in-house, but leverage low-cost outsourcers in Asia for the mainstream processes. Still others (particularly low-cost producers) do most of the bulk processes in-house but contract out some of the higher performance packages.

The outsourced assembly and test market is less consolidated than the foundry market. Almost all assembly and test activity is conducted in the Far East, with the top two vendors in 2010 being ASE (Taiwan) and Amkor (Korea), with 16% share and 12% share, respectively. Rounding out the top vendors were Siliconware Precision with 9% share and STATS-ChipPAC with 7%. Other key vendors include PowerTech, UTAC, J-Devices, ChipMOS, Jiangsu and KYEC.

Manufacturing: Geographic Centers

The largest geographic centers for semiconductor front end production are Japan and Asia, each about 1/3 of total production, with the final 1/3 split roughly evenly between North America and Europe.

Asia has grown in importance over the past two decades: Korea is a major center for memory, displays, and commodities, and Taiwan hosts the largest foundries as well as some memory producers. China is also ramping up with several fabs under construction.

	Japan	North America	Europe and Israel	Taiwan	Korea	China
Key IDMs	Renesas Toshiba NEC Electronics Sharp Spansion Matsushita Sony Elpida	Intel Texas Instruments Freescale IBM Micron Analog Devices	Infineon STMicro NXP AMD Intel Robert Bosch	Winbond Nanya Powerchip Promos	Samsung Hynix Magnachip	
Major Foundries	Toshiba Seiko-Epson Fujitsu	IBM Jazz Semi Global Foundries	X-Fab Tower Semi	TSMC UMC	Magnachip DongbuAnam	SMIC ASMC Grace
Key Products	Microcontrollers Discretes Memory Logic, ASSPs Analog	MPUs, MCUs, DSPs Logic, ASSPs Analog Memory Discretes	Logic, ASSPs Analog MPUs Discretes Memory	Logic, ASSPs Memory Display Drivers	Memory Logic, ASSPs Display Drivers	Memory Logic

Source: Oppenheimer & Co.

The largest geographic centers for semiconductor front end production are Japan and Asia. Japanese electronics OEMs have historically been vertically integrated and thus retain fabs for their own semiconductor production. They are also large suppliers of microcontrollers, discretes, general purpose logic, and analog ICs to the broader market. DRAM, a big priority in Japan in the 1980s, has shifted away from Japan for the most part, but flash has ramped up for both NOR and NAND. Still, in 2008 Japan accounted for about 32% of semiconductor capacity.

Asia ex-Japan has clearly grown in importance over the last two decades, now greater than Japan at 41% of capacity. Korea (12% of total) is a major center for memory, displays and commodities and electronics giant Samsung continues to invest and grow in importance. Taiwan (12% of total) hosts the largest foundries as well as some memory producers. China (12% of total) is also ramping up, mostly with foundry production for memory and logic.

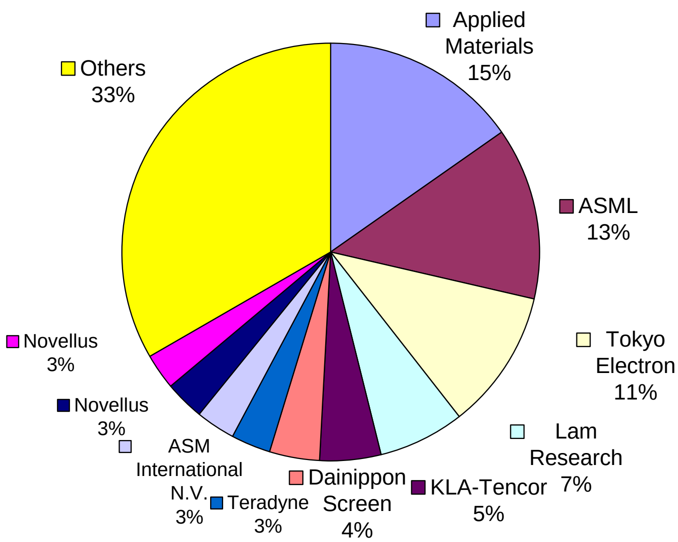
The U.S. (Americas equal 15% of total) is still the most important region for high-end logic, with most CPU and DSP production as well as microcontrollers and ASSPs. Custom ASICs, a wide array of memories, analog ICs and commodities also have a large presence. Europe (12% of total, including fabs there owned by U.S. companies) has a similar mix; Infineon, STMicroelectronics, and NXP are large diversified players that compete across these categories, and Intel runs large microprocessor fabs in the region (Ireland and Israel).

Note that back end factories are more weighted toward Asia due to the large labor component. Back end facilities are spread throughout the region, not only in Taiwan and Korea but also in China, Malaysia, Singapore, and elsewhere.

Semiconductor Equipment

The semiconductor industry has a large and relatively independent supporting industry that supplies equipment for front and back end processing.

Top equipment suppliers include Applied Materials, ASM Lithography, Tokyo Electron, Lam Research, KLA-Tencor and Dainippon Screen.



Source: Dataquest, Oppenheimer & Co.

Front End

Applied Materials
ASML
Tokyo Electron
Lam Research
KLA-Tencor
Dainippon
Nikon

Automation and Process Control

KLA-Tencor
Applied Materials
Hitachi
Nanometrics
Rudolph

Packaging & Assembly

ASM Intl.
Kulicke & Soffa
BE Semi
Tokyo Seimits
Applied Materials
Delta Design

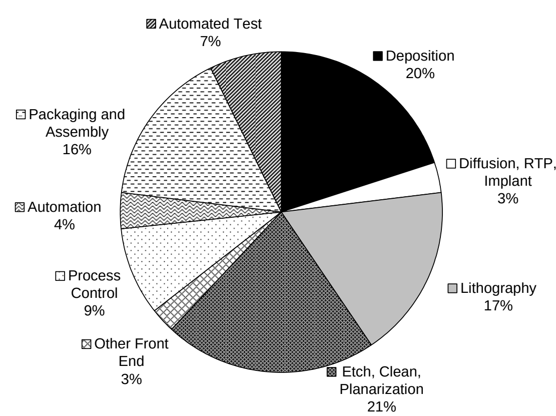
Automated Test

Teradyne
Advantest
Verigy
LTX
Yokogawa

The semiconductor industry has a large and relatively independent supporting industry that supplies wafer fabrication, assembly, and test equipment as well as factory automation and process control software and hardware. Few IDMs or foundries make their own equipment, though some of the larger manufacturers will partner with equipment suppliers to help define the functionality of next-generation tools.

In 2010, the semiconductor capital equipment industry soared 143%, and 33% when compared with 2008, to $40.6 billion in sales. Approximately 64% of this total was for front-end fab equipment, which includes CVD and sputtering deposition, diffusion/oxidation and RTP, lithography and ion implantation. Another 4% was for factory automation and 9% was for process control. About 23% of equipment spending was for back-end equipment, including packaging, assembly and automated test equipment. The exhibit to the right displays this breakdown.

Semiconductor Equipment Spending, 2010



Source: Dataquest, Oppenheimer & Co.

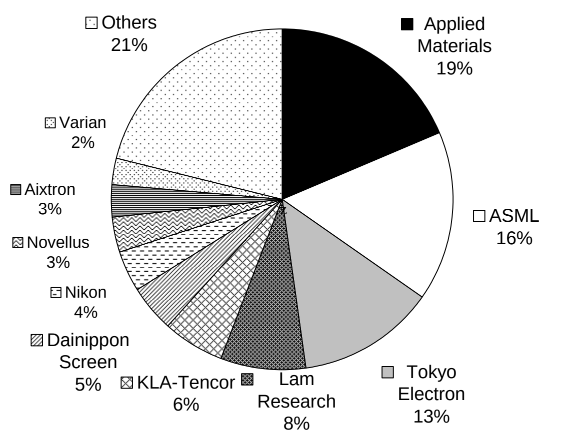
Top front end equipment suppliers include Applied Materials, strong in deposition, RTP (rapid thermal processing), CMP (chemical mechanical planarization), and etch; Tokyo Electron, prominent in thermal diffusion, photoresist processing, and etch; ASML Lithography, dominant in lithography scanners; Lam Research in etch; and KLA-Tencor, dominant in process control. Together, these top 5 vendors account for 62% of total front end equipment.

On the process control front and automation front, top vendors include KLA-Tencor, strong in wafer and reticle inspection/metrology; Hitachi, also strong in wafer metrology; Brooks Automation, dominant in tool automation hardware and software; and Applied Materials mostly in defect review. These top-3 vendors control nearly 80% of the market.

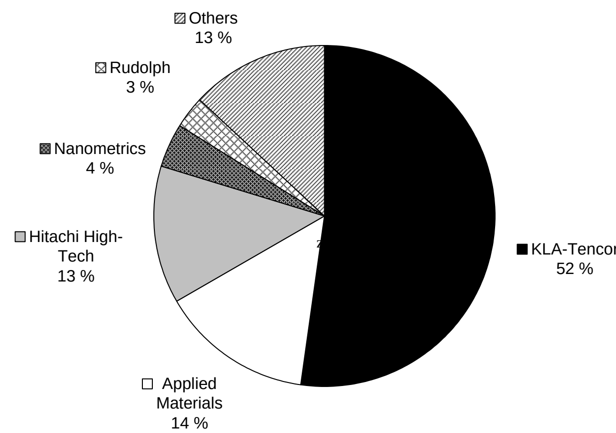
Back-end equipment suppliers include assembly and packaging equipment makers Tokyo Seimitsu, ASM International, Disco, Delta Design, BE Semiconductor, Advantest, Towa and Kulicke & Soffa. On the test side, the key vendors are Advantest, Teradyne, Verigy (the spinout from Agilent), LTX-Credence, and Yokogawa.

The exhibits below display fab equipment market shares for front end and back end equipment as well as automation and process control.

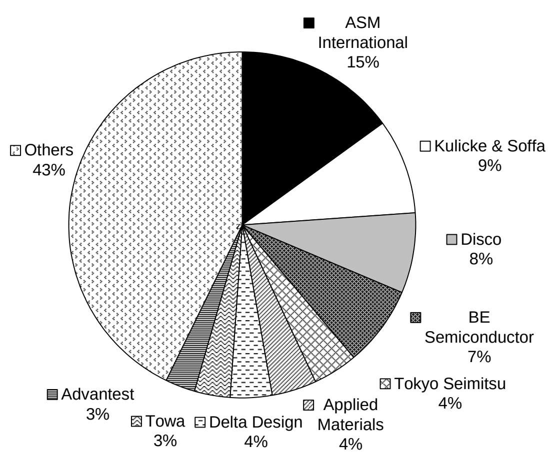
2010 Front End Equipment Market Share



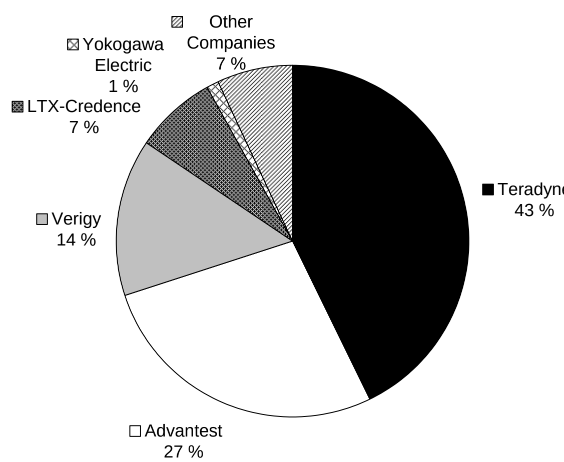
2010 Automation and Process Control Market Share



2010 Packaging and Assembly Market Share



2010 Automated Test Equipment Market Share



Source: Dataquest, Oppenheimer & Co.

Section II: The Semiconductor Market

This section discusses the semiconductor market, industry fundamentals, and the semiconductor cycle

Topics include:

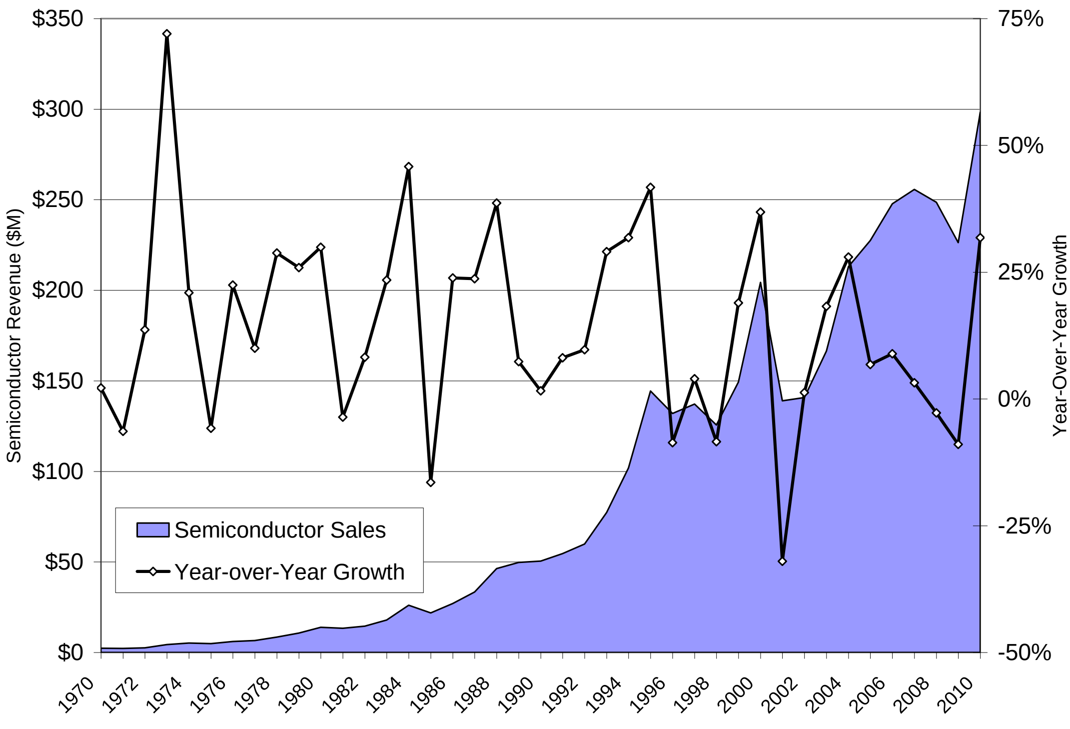
Industry Basics

The Semiconductor Cycle

Fundamentals

Industry Basics: 40 Years of Growth

As the enablers of electronic hardware, semiconductors have been at the heart of the technology revolution. The market has grown significantly over the past 40 years, approaching $300 billion in 2010.

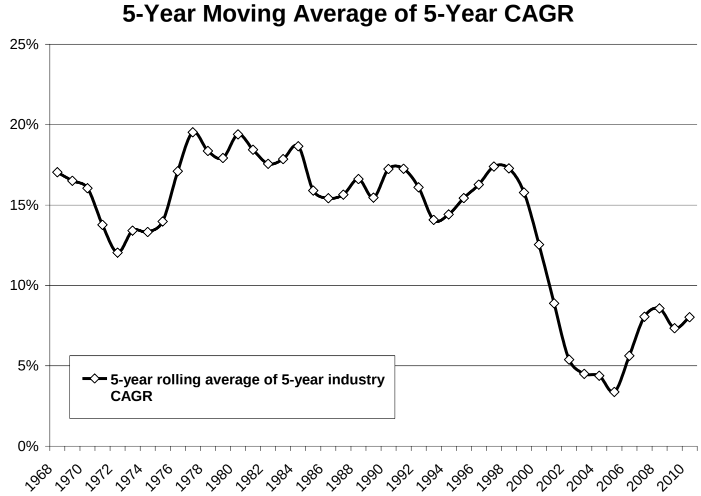


Source: WSTS, Oppenheimer & Co.

As the enablers of electronic hardware, semiconductors have been at the heart of the technology sector. The market has grown significantly in the past 40 years, sustaining a CAGR of 13% over that period of time.

Growth has been slowing, however, as the industry has grown and matured. We have plotted a 5-year moving average of the industry's 5-year CAGR on the graph to the right. After hovering in the mid-to-high teens for more than two decades, we see the average dropping in the post-bubble period. We would expect the CAGR to drift upward as we roll off the difficult comps of the bubble, but for growth to remain in the single digits.

5-Year Moving Average of 5-Year CAGR

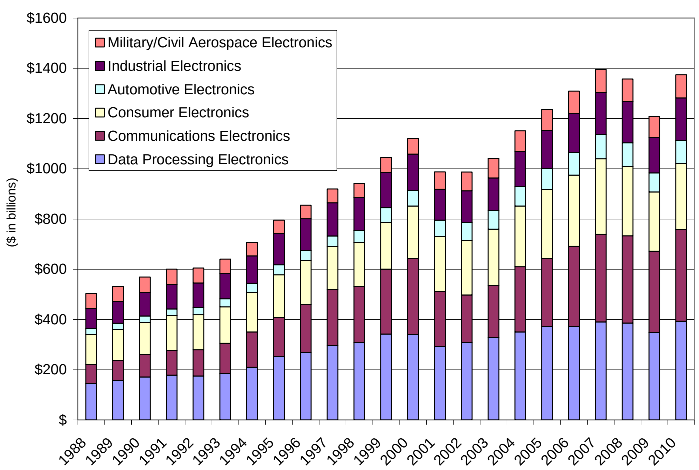


Source: WSTS, Oppenheimer & Co.

Industry Basics: Demand

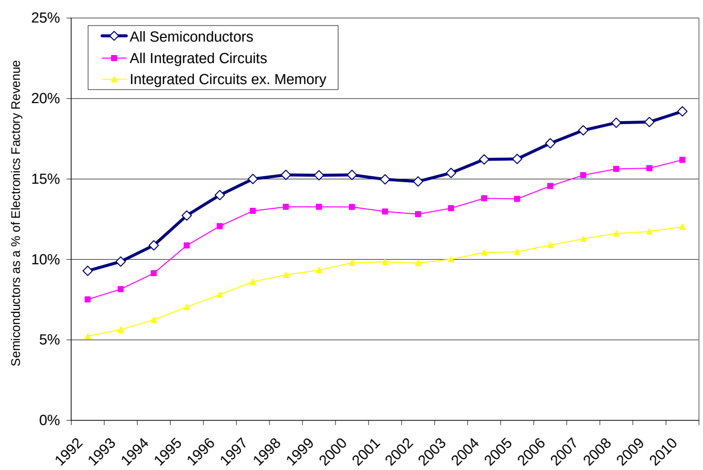
Semiconductor industry demand is closely tied to the demand for electronics. The largest consumers of semiconductors are the computing/data processing, communications, and consumer electronics markets. Semiconductor revenue has also been growing as a percentage of electronics revenue as chipmakers have absorbed more and more system IP into their devices.

Electronics Revenue By End Market



Source: Dataquest, Oppenheimer & Co.

Semi Revenue as a Percentage of Electronics



Note: Data displayed is five-year average to smooth price volatility.
Source: Dataquest, WSTS, Oppenheimer & Co.

Semiconductor companies support the large and diverse electronics industry. Semiconductor demand is thus a function of the demand for electronic equipment along with the percentage of electronic equipment bill-of-materials devoted to semiconductors.

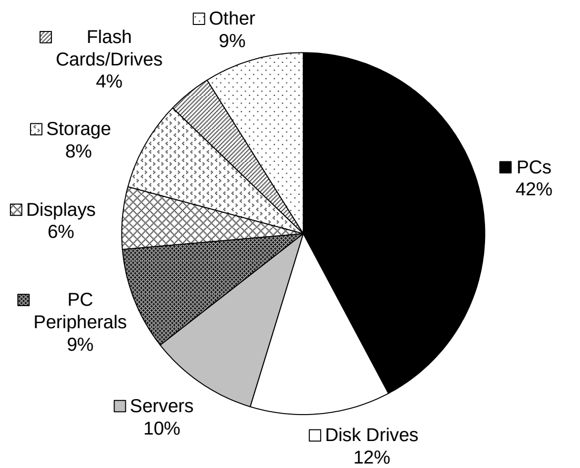
Electronics Demand

The electronics industry totaled about $1.4 trillion in 2010, up 14% from 2009. Note that electronics revenue in 2010 exceeded the 2000 bubble year's by 23%, with much healthier fundamentals behind it.

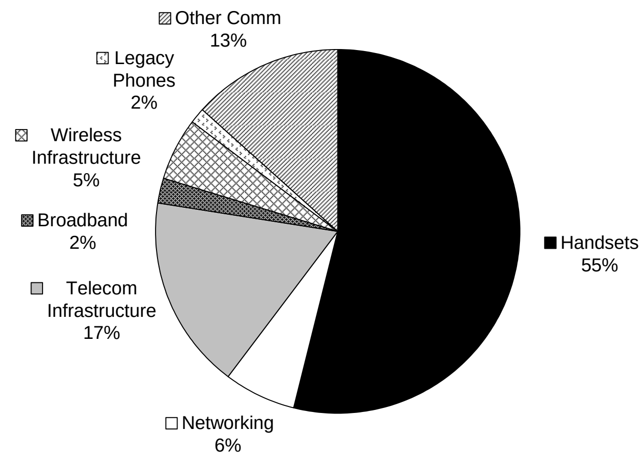
By end market, the most important applications are computing/data processing, communications and consumer electronics. In 2010, 28% of electronics revenue was derived from data processing, which includes PCs and servers, PC peripherals, handheld devices, displays and storage. Twenty-seven percent was derived from communications, including cellular handsets, networking equipment, telecom and wireless infrastructure, and voice and data access equipment. Nineteen percent was derived from consumer electronics, including analog and digital TVs, audio/visual equipment, game consoles, set-top boxes, appliances and white goods. Another 12% was derived from industrial electronics, 7% from military and aerospace and 7% from automotive.

The exhibits on the following page detail electronics revenue by application.

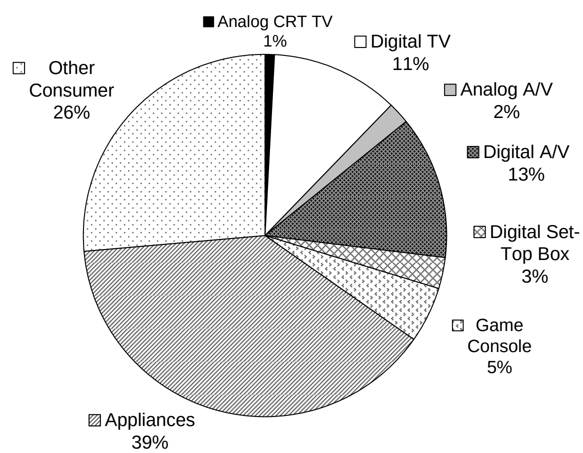
2010 Data Processing Equipment Revenue (28%)



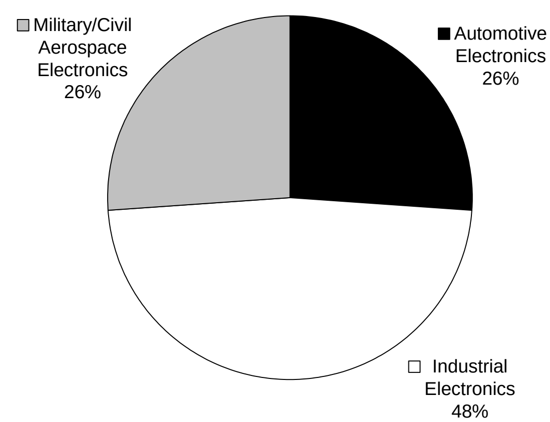
2010 Communications Equipment Revenue (27%)



2010 Consumer Electronics Revenue (19%)



2010 Other Electronic Equipment Revenue (26%)



Source: Dataquest, Oppenheimer & Co.

<u>Semiconductors as a Percentage of Electronics</u>

On top of electronics demand, semiconductor revenue has been growing as a percentage of the bill-of-materials and of total electronics revenue. In 2010, this ratio was approximately 22%, having climbed steadily from the 10% range in the early 1990s. This increase has been due to a number of factors, including:

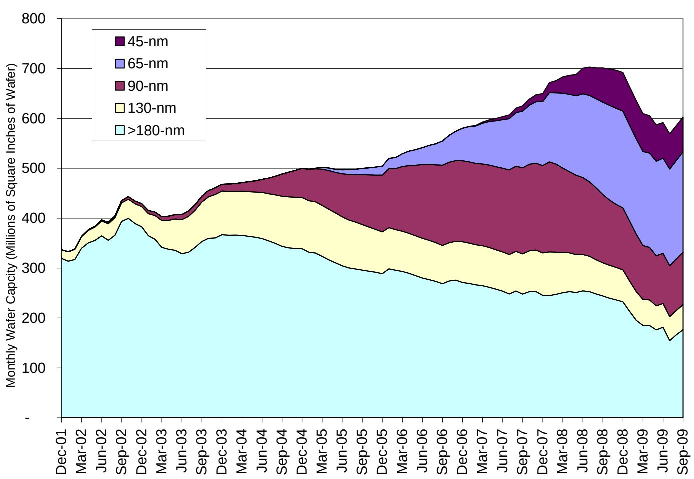
- Chipmakers have absorbed more and more system IP into their devices. Chip prices increasingly include software components and other costs.
- Outside of the memory market, chipmakers have for the most part retained pricing power in their devices, whereas OEMs have been subject to tough competition, pressuring their pricing.
- OEMs have been able to take costs out of the box through outsourcing, just-in-time inventory, etc. Chipmakers have benefited from Moore’s Law, but fab costs have continued to rise, as have R&D costs.
- OEMs have increasingly diversified their revenue streams by charging their customers for software, services, maintenance contracts and other non-equipment products. This has allowed them to charge lower margins on equipment. Semiconductor vendors, in contrast, continue to charge only for actual physical product (though they provide some software, this is usually embedded in the price of the IC).

Industry Basics: Supply

Semiconductor supply is driven primarily by wafer fab capacity. Long construction and equipment installation cycles and high cost of plant and equipment mean that capacity plans must be put into place far in advance, causing inevitable periods of surplus and shortage.

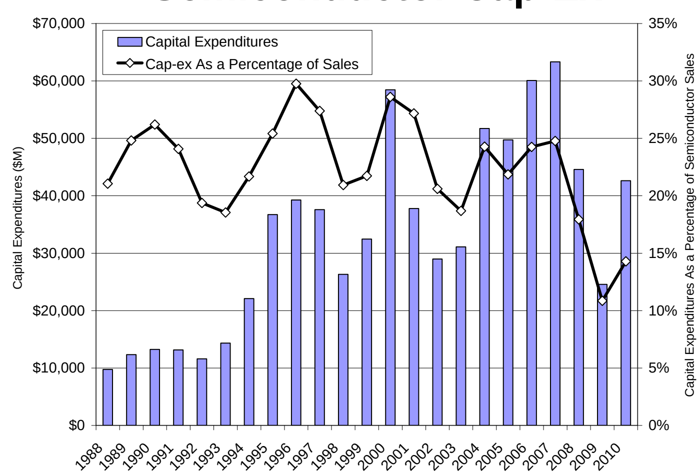
While IDMs and foundries try to match supply to demand, wafer capacity moves very slowly in both directions, and capital expenditure budgets can be volatile.

Wafer Fab Capacity



Source: VLSI Research, Oppenheimer & Co.

Semiconductor Cap-Ex



Source: Company reports, Oppenheimer & Co.

Semiconductor supply is primarily a function of wafer fab capacity. Long construction and equipment installation cycles as well as high cost of plant and equipment mean that capacity plans must be put into place far in advance, causing inevitable periods of surplus and shortage. While IDMs and foundries try to match supply to demand, wafer capacity moves very slowly in both directions, much slower than changes in demand. Capital expenditure budgets can therefore be very volatile as chip suppliers adjust to the changes in demand.

Note that the costs of a leading edge fab have risen dramatically over the past few years, leading to a consolidation of wafer supply in the hands of just a few players. Gone are the days when all semiconductor companies did their own manufacturing; now a company will only choose to do their own manufacturing if:

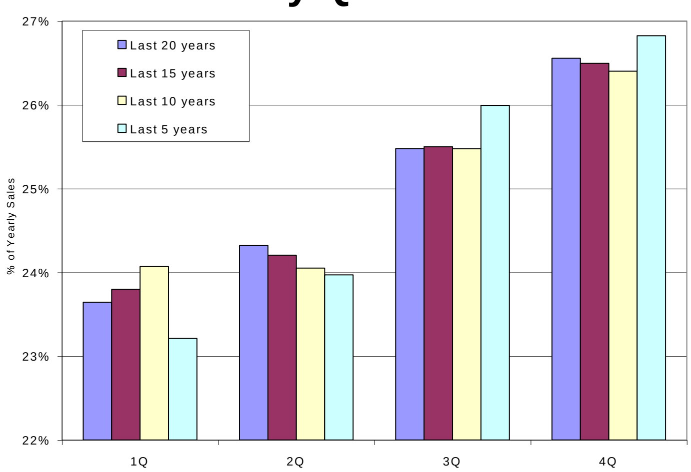
1) Access to leading edge technology is core to their business model (e.g., Intel, TI, Samsung, Micron).
2) They run such high volume that they can absorb the fixed costs (e.g., Samsung, Intel, TI, Freescale, Micron).
3) They utilize niche processes (e.g., Maxim, Linear, RF Micro Devices, Anadigics).
4) They have a low-cost strategy that involves manufacturing (e.g., Fairchild, On Semiconductor, BCD Semicondcutor, Cypress).

The industry as a whole targets a long-term cap-ex to sales ratio of roughly 20%-25%. When cap-ex rises above (or below) this range for too long, oversupply (or shortage) usually results. Note that due to improvements in capital efficiency, the cap-ex rate has drifted lower, from 25-30% in the 1980s-1990s to around 15%-20% today.

Industry Basics: Seasonality

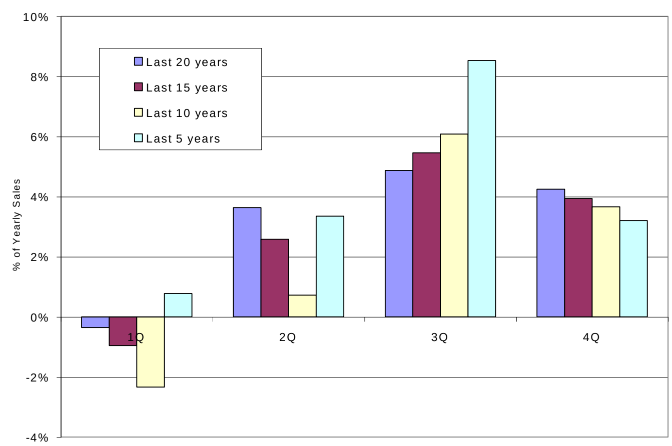
The semiconductor industry is somewhat seasonal, based on demand patterns for electronics. Typically, 47%-48% of sales fall in the first half of the year, while 52%-53% fall in the second half. On a quarter-to-quarter basis, sales typically fall in Q1, rise a bit in Q2 and rise more strongly in Q3 and Q4. In general, devices sold into consumer channels (CE, handsets, PCs) are typically more seasonal than those sold to commercial customers.

Percentage Of Yearly Sales By Quarter



Source: WSTS, Oppenheimer & Co.

Historical Quarterly Sequential Growth



Source: WSTS, Oppenheimer & Co.

The semiconductor industry is somewhat seasonal, based on demand patterns for electronics but with a slight lead due to the time it takes to build, test and ship the end product (semiconductors will usually go on the board in the early stages of production). These demand patterns tend to favor Q4, which sees a bump in demand for the holiday selling season; and also for Q3, which sees the “holiday build” as well as a somewhat less significant “back to school” season. This is especially true for devices sold into the consumer channel, including consumer electronics, handsets and PCs. Demand for semiconductors sold into enterprise, service provider, and industrial applications will likely see smoother demand, though there can sometimes be a budget flush at the end of the year.

Typically, 47%-48% of sales fall in the first half of the year, while 52%-53% fall in the second half. On a quarter-to-quarter basis, sales typically fall in Q1, are up a bit in Q2, and rise more strongly in Q3 and Q4. Note that we have witnessed a slight muting of the Q4 and Q1 sequential changes as electronics consumption in Asia becomes more meaningful; Asian consumers have a holiday selling season around the Chinese New Year, which usually occurs in late January or early February.

The Traditional Supply-Based Cycle

The semiconductor industry has historically been characterized by supply-based cycles lasting 4-6 years on average. Wafer capacity was the key variable driving these cycles. Demand fluctuations were of course a factor, but not nearly as important as the state of supply.

	Phase One "The Downturn"	Phase Two "The Recovery"	Phase Three "The Expansion"	Phase Four "The Peak"
		Fundamentals		
Macroeconomics				
Economic activity	Recession or Slower Growth	Picking up	Expansion	Stable growth
Pricing				
Logic	Decreasing	Decreasing to stable	Increasing	Stable
Analog	Decreasing	Decreasing	Stable to increasing	Increasing
Commodities	Decreasing rapidly	Decreasing	Increasing	Peaking
Lead times				
Analog/logic	Contracting	Stable	Stable to expanding	Expanding to peaking
Commodities	Contracting rapidly	Contracting to stable	Expanding	Peaking - on allocation
Capital additions				
Production line additions	No (over-capacity)	Some	Yes	Yes (too many)
New capacity additions	No (over-capacity)	None	Yes	Yes (too many)
OEM/distributors				
Orders	Falling rapidly	Picking up	Strong	Frenzied
Double ordering	No	No	No	Yes
Order cancellations	Accelerating	Falling	Very few, if any	Limited
Inventory levels	Too high	Low	Too low	Building
Vertical end markets				
Sell-through	Even slower	Growing	Strong	Slowing
Forward outlook	Cautionary	Cautionary	Cautiously optimistic	Optimistic

Source: Oppenheimer & Co.

The semiconductor industry has historically been characterized by supply-based cycles lasting four to six years, on average. Wafer capacity was the key variable driving these cycles. Demand fluctuations were of course a factor, but not nearly as important as the state of supply. This traditional cycle can generally be broken down into four key phases:

- **Downturn**: This phase follows the peak of the previous cycle and is usually sparked by slowing economic conditions coupled with oversupply. Orders dry up and cancellations appear. OEMs start to work through too-high inventories. ASPs begin to fall as capacity built during the boom period pressures pricing against weaker demand. IDMs and foundries cancel pilot line additions and even close down or consolidate trailing-edge fabs.
- **Recovery:** The recovery is a period of stabilization following the free-fall of the downturn. Utilization rates level off after the drop, and manufacturing rationalization continues. Prices stabilize but remain at low levels. Orders begin to pick up and cancellations abate. Inventories subsist at low levels after a long burn-off.
- **Expansion:** Eventually, supply and inventory correct sufficiently to drive a new expansion. Economic activity drives end demand, which causes stronger orders. Utilization and then prices begin to rise and IDMs begin to cautiously add capacity to meet increasing output forecasts. Lead times stretch and order visibility improves.
- **Peak:** Eventually, enough capacity is added to meet surging demand. Some of this demand is based on double ordering, and so as vendors catch up with deliveries, inventory builds in the channel. Prices and lead times start to peak out. Eventually, double-ordering abates as vendors realize they have too much capacity.

The Evolving Cycle

The semiconductor cycle has evolved since the tumultuous 2000-2001 boom-bust:

- The growing use of foundries by both fabless and IDMs has removed leverage from semiconductor business models
- Diversification of the semiconductor industry's end market lessens the dependence on PC cycles
- Fractured supply chain spreads risk
- Law of large numbers

Key Implications:

- New cycles are based more on inventory than supply
- Shorter cycles with shallower ups and downs
- Gross margin less relevant for all but a handful of producers
- Memory cycles much more independent from the broader semiconductor cycle
- Industry revenues grow even in weak fundamental periods so long as macro economy is healthy

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The cyclical nature of the semiconductor industry has driven vendors to restructure and re-work their business models from cycle-to-cycle. This was especially true in the period following the 2000-2001 boom-bust, which featured the traditional supply-based peak and downturn exacerbated by the overhang from excess Y2K and telecom/Internet infrastructure spending.

A key component of this evolution has been the growing use of foundries by not only fabless semiconductor vendors, but by IDMs as well. Large producers such as Texas Instruments, STMicroelectronics, Freescale, and Infineon began to outsource a significant portion of their production to foundries. This shifted a sizeable amount of supply risk for the industry into the hands of just a few leading-edge foundries, which have proven that they can invest more prudently than individual players (who often overbuild to support projected market share gains, which often don't materialize).

As a result, the industry has seen much less over-building during periods of strong demand, and much less under-investment during weak periods. IDMs have been able to keep expensive digital logic fabs full most of the time, leveraging foundries for overages.

The net effect of the increased outsourcing has been a much more muted connection between wafer supply and other industry metrics, such as lead times, order rates, pricing, etc. IDMs view supply much in the same way fabless vendors do: as a steady component of their business rather than a huge capital drain which needs to be constantly adjusted up and down.

Consequently, semiconductor industry cycles are no longer primarily driven by wafer supply directly. Instead, they have become driven by an indirect aspect of supply: specifically inventories. Downturns which used to be driven by over-supply are now driven by excess inventories in the supply chain, which usually result from a slowdown in demand. Expansions are driven by inventory re-builds, which are usually a result of an increase in demand against a backdrop of a tight supply chain.

The new inventory cycle is now shorter—roughly 2-3 years from peak-to-peak—and has shallower ups and downs. The phases of the cycle are harder to identify. Industry revenues can grow in both strong (expansion/re-build) and weak (downturn/correction) periods, as long as the broader macro economy and overall demand for electronics is healthy.

We believe the primary source of the cycle's evolution lies in the wafer outsourcing detailed above, but we also see secondary drivers as well. Greater diversification of the industry's end demand has certainly contributed some additional stability. The industry used to live and die by PC cycles, since such a huge portion of semiconductor demand was driven by PCs. Today's semiconductor industry is well-balanced between computing, communications, and consumer electronics applications, while the end use is spread among enterprises, service providers, and consumers. Geographically, emerging markets have grown to represent a huge consumer of semiconductors, which used to be an industry dominated by the US, Japan, and Europe. This diversification leads to much smaller swings in demand based on factors in any one application, economic sector, end market, or region, and hence greater stability and less cyclicality overall.

An additional factor is the fractured nature of the modern electronics supply chain. Semiconductor vendors, foundries, OEMs, ODMs, EMS players, and distributors are each important constituents within the supply chain. Each has matured and has learned to play a stabilizing role within the greater whole. This spreads risk among a greater number of players and lessens the shock potential from any one segment of the supply chain.

Finally, the law of large numbers and a general maturity is clearly setting in for the semiconductor industry. Industry sales in 2010 approached $300 billion, and global per capita consumption of semiconductors now tops $40 for every man, woman, and child (much higher in developed nations). Mid-to-high teens growth rates are simply hard to come by off this high base, and the lower growth rates are also producing smaller changes year-to-year in terms of growth. This has muted a major input for the cycle: semiconductor demand.

Note that the evolution of the cycle described here is inclusive of most analog and digital ICs, with one notable exception: memory. The memory sector remains mired in the traditional supply-driven cycle, owing to 1) the vertically integrated business models that remain the norm among top players, 2) the lack of diversification in end application that continues for each memory type (e.g. DRAM still dominated by PCs, NAND by consumer, NOR by handset, etc.), and 3) the commodity nature of most memory types, which naturally breed the supply-driven economics. It is even possible for one type of memory to be experiencing an expansion while another type is caught in a downturn, based on the supply-demand dynamics of the individual memory type.

The New Inventory-Driven Cycle

Structural changes in the semiconductor industry have produced a new cycle, one that is inventory-driven. Inventory is the key variable along with demand; wafer supply is relegated to a secondary input. Cycles are shorter (2-3 years) with shallower peaks and valleys.

	Phase One Inventory Correction	Phase Two Steady State	Phase Three Inventory Build
Fundamentals			
Macroeconomics			
Economic activity	Slower growth or recession	Stable growth	Stable growth or expansion
Sell-through in verticals	Slow	Growing	Strong
Forward outlook	Cautionary	Cautiously optimistic	Cautiously optimistic
Inventories			
On hand	Too much	Low but managemeable	Too little
Posture	Reduction	Conservative restocking	Double ordering
Pricing			
Logic	Decreasing	Decreasing to stable	Increasing
Analog	Decreasing	Decreasing	Stable to increasing
Commodities	Decreasing rapidly	Decreasing	Increasing
Lead times			
Analog/logic	Contracting	Stable	Stable to expanding
Commodities	Contracting rapidly	Contracting to stable	Expanding
Capacity			
Availability	Widely available	Widely available	Tightening, espcially at the high-end
Foundry pricing	Declining	Stable	Firm
Orders			
Order rates	Falling rapidly	Strong	Frenzied
Double ordering	No	No	Yes
Order cancellations	Accelerating	Very few, if any	Limited

Source: Oppenheimer & Co.

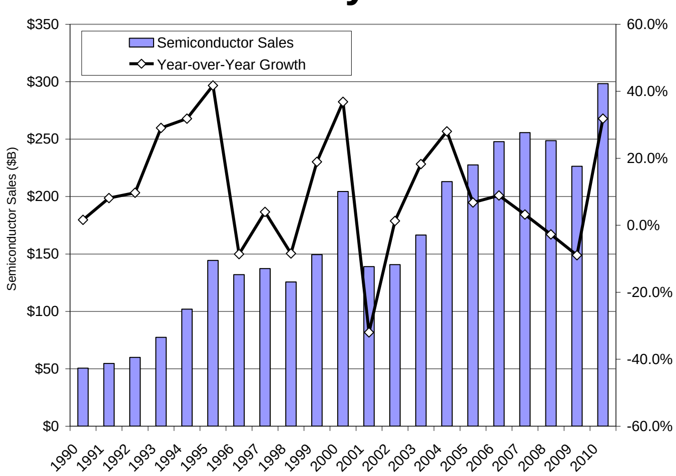
Structural changes in the semiconductor industry have produced a new cycle, one that is inventory driven. Inventory is the key variable along with demand; wafer supply is relegated to a secondary input. Cycles are shorter (two to three years) with shallower peaks and valleys. This new cycle can be broken down into three key phases:

- **Inventory Correction**: This phase follows the peak of the previous cycle and is usually sparked by slowing economic conditions against a backdrop of an inventory glut in the supply chain. OEMs and distributors seek to reduce inventories, and reduce orders or even cancel orders at semiconductor vendors. ASPs for more commoditized products begin to fall. The foundries (and to a lesser extent the IDMs) scale back on capacity additions until the true level of demand is determined.
- **Steady State:** The steady state phase is a period of stabilization following the steep declines of the inventory correction. Orders begin to pick up and cancellations abate. Growth rates appear more “normal,” approximating growth in end equipment. Inventories subsist at low levels after a long burn-off, and may even be managed lower. Utilization rates level off after the drop in production, but lead times remain short.
- **Inventory Build:** Eventually, inventories at OEMs and distributors get too low, and they begin to re-order. Lead times begin to stretch out. A pick-up in economic activity drives end demand, and in some cases, causes double-ordering. Utilization improves and foundries begin to slow price declines to their customers. Prices for commodities begin to rise. Eventually, inventory builds up on excess of demand, sparking the next correction.

Fundamentals: Sales

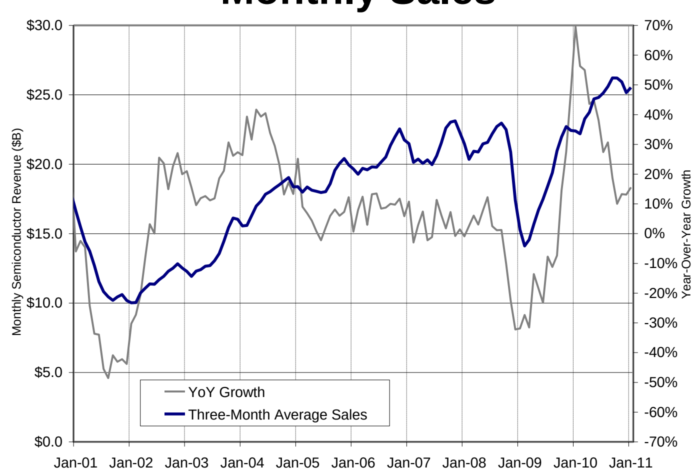
Semiconductor industry sales surged to $298 billion in 2010. The industry had experienced four consecutive years of record sales until a contraction in 2008 and 2009 led to revenues falling below $250 billion. Structural changes during that recovery have replaced the supply-driven cycle with the inventory-driven cycle, and we have seen year-over-year growth rates settle into a more consistent and manageable range as a result.

Yearly Sales



Source: WSTS, Oppenheimer & Co.

Monthly Sales



Source: WSTS, Oppenheimer & Co.

The breakout growth of electronic hardware has driven dramatic growth in semiconductor sales over the long term. Semiconductor industry sales in 2010 totaled $298 billion. After four straight years of record sales for the industry following the long downturn and recovery period of 2001-2003, the industry experienced a contraction in 2008 and 2009. Semiconductor sales bounced back sharply in 2010, as end demand recovered faster than anticipated and OEMs restocked inventory.

Still, the cyclical nature of the semiconductor industry has caused phenomenal boom periods and destructive downturns. Fundamental industry characteristics such as long product production cycles, the quick pace of innovation (funded by increasingly tech-centric capital markets), volatile pricing, inventory effects and capacity builds have caused wild sales volatility year-to-year.

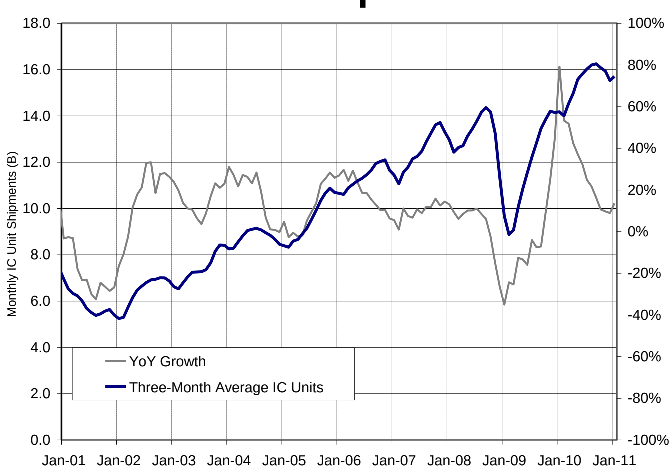
The 2001 downturn was so destructive that it motivated the big industry players to make real structural changes to their business models. This has caused the profile of the semiconductor cycle to change as well, as detailed on prior slides. The “new” cycle is primarily inventory-driven as opposed to supply-driven, and though the ups and downs of the cycle remain, the magnitude and duration of these swings is much reduced. As a result, we have seen year-over-year growth rates, in general, settle into a more consistent and manageable range.

Fundamentals: Units and ASPs

Unit shipments are slightly less volatile than sales and have historically had a more upward slope. Still, unit shipments are subject to double ordering and inventory corrections, and so still swing around during the cycle.

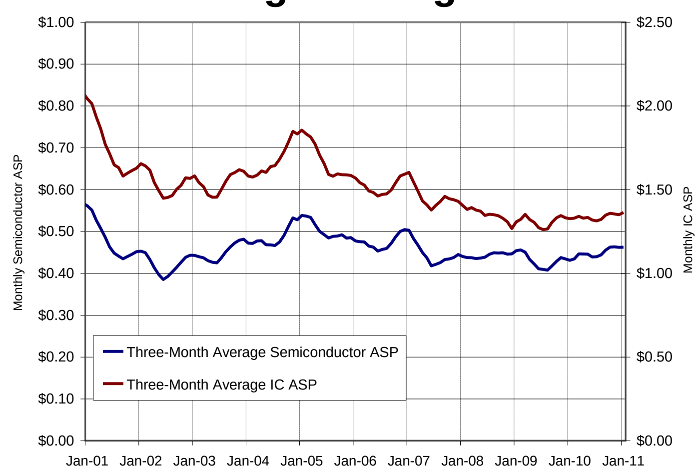
ASPs have remained volatile and generally add to the boom during periods of strong unit demand (and when inventories build) and exacerbate the downturn when demand softens (and inventories decline).

Unit Shipments



Source: WSTS, Oppenheimer & Co.

Average Selling Price



Source: WSTS, Oppenheimer & Co.

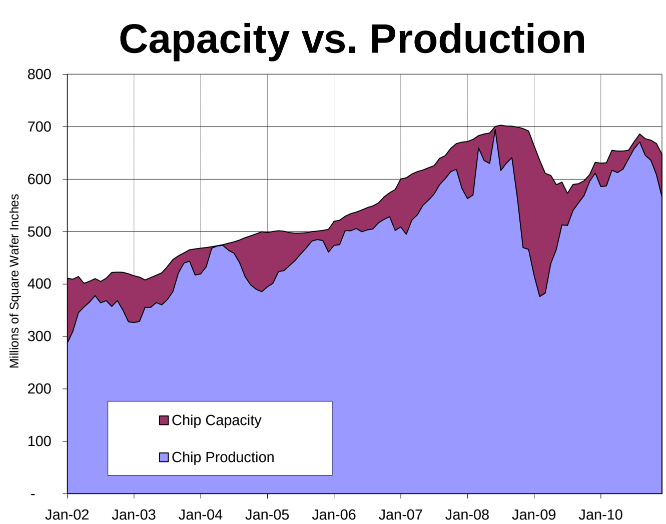
Semiconductor unit shipments have also proven volatile, though they generally show a bit more stability and a more upward long-term slope than revenues. Still, shipments are affected by periods of double-ordering and subsequent inventory corrections, which exaggerate more muted ups and downs in true end demand. As with sales, the swings in unit shipments have softened as the cycle has evolved from a supply-based cycle to an inventory–based one.

Pricing also moves around with the cycle, and in general has had a downward slope as vendors pass economies of scale and the benefits of Moore's Law onto customers. The slope has been leveling off to some degree, however, as a major long-term trend of integration has allowed semiconductor vendors to slow the pace of ASP declines on individual components.

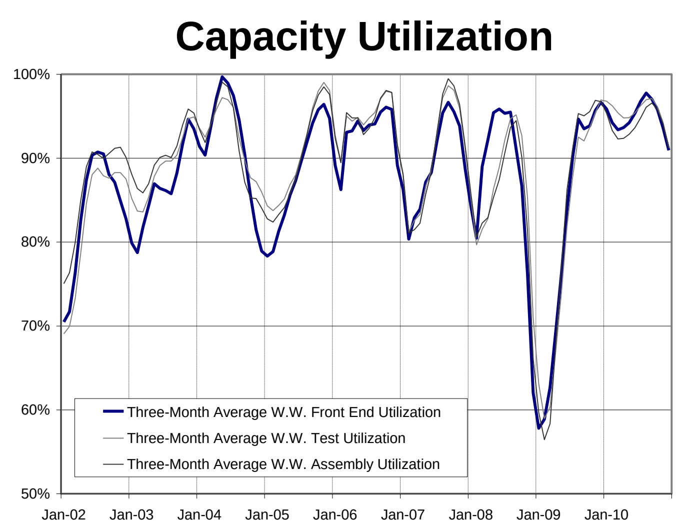
Pricing was a major factor in supply-based cycles, adding to the boom during periods of strong unit demand and exacerbating the downturn when demand decelerates. The commoditization of memory products like DRAM and flash has added to this phenomenon as it represents such a large percentage of industry sales. Note that the evolution of the cycle has mitigated ASP volatility to some extent, as has the general maturity of the industry. Still, commodity and even logic and analog pricing can have wild swings on demand and supply fluctuations.

Fundamentals: Capacity Utilization

Capacity utilization is the key measure of supply in the semiconductor industry. It also provides the link between units and ASPs. As unit production rises, capacity utilization also rises, and producers slow down price decreases (or even raise prices). Eventually, new capacity comes on line to meet demand. When demand slows, capacity becomes a liability as IDMs and foundries try to fill up their fabs by offering price concessions. Eventually, restructuring removes excess capacity and prices stabilize.



Source: VLSI, Oppenheimer & Co.



Source: VLSI, Oppenheimer & Co.

Capacity utilization is the key measure of supply availability in the semiconductor industry. Utilization is tracked for front end (wafer processing), assembly, and test, but front end utilization is by far the most important since 1) cycle times for the front end are the longest, 2) it is most difficult to add and remove front end capacity, 3) front end fabs are by far the most costly to build and operate, and 4) the number of producers is by far the smallest for front end.

Utilization also provides the link between units and ASPs. During periods of strong demand, rising unit production pushes utilization higher and IDMs offer less price concessions to customers, while foundries slow price declines for wafers. This causes price curves for high-volume products slow down or even rise, especially for commodities. Since the positive pricing effects happen at the same time as increasing units, revenue is doubly affected. Note that lead times also stretch out during this period, as OEMs are forced to order further in advance to guarantee supply.

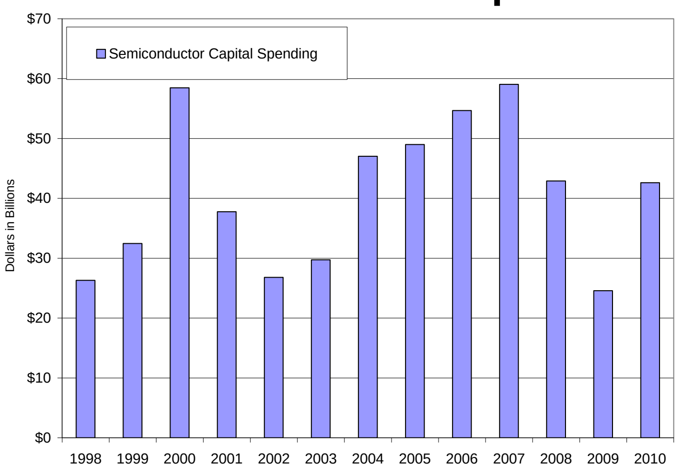
Rising utilization and prices generally spark IDMs and foundries to bring on more capacity to meet the demand. As this capacity ramps, prices usually stabilize at the higher output level. When unit demand slows, this additional capacity becomes a liability and IDMs begin to offer lower prices to win competitive business in order to fill up their fabs. Foundries also offer lower wafer prices. Prices begin to fall; as this happens at the same time as unit demand declines (or slows), revenue is doubly affected. Lead times usually contract, as component availability improves and OEMs begin to place orders closer to their needs to take advantage of falling prices. Producers eventually take steps to restructure their manufacturing, first by cutting heads, then consolidating facilities or even disposing of old equipment. Eventually, unit demand returns to absorb the lower capacity, prices improve, and we start again.

Fundamentals: Capital Spending

Capital spending is a very important industry metric, as chips are produced in hugely expensive fabs which take significant time and resources to build. A rough target for spending is 23%-25% of semiconductor revenues.

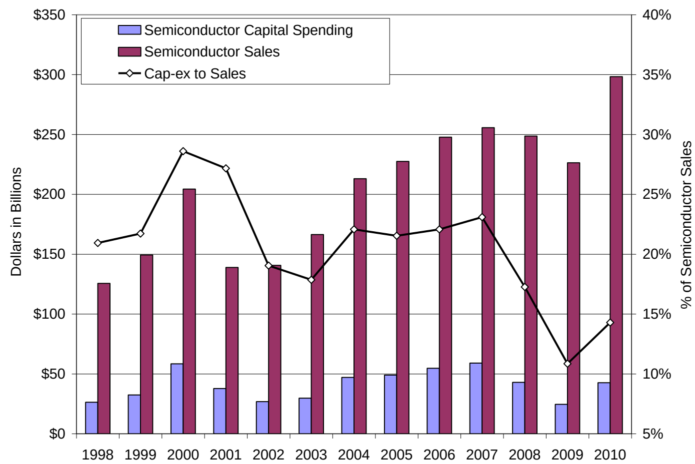
Historically, capital spending was the primarily driver of the supply-driven semiconductor cycle. Increased outsourcing has shifted supply risk to the foundries, shifting the key cyclical driver from supply to inventory.

Semiconductor Cap-ex



Source: VLSI, Oppenheimer & Co.

Sales and Cap-ex



Source: VLSI, WSTS, Oppenheimer & Co.

Capital spending is a very important metric for the semiconductor industry, as semiconductor devices are produced in hugely expensive fabs which take significant time and resources to build. In general, we view 23%-25% of sales to be a “normal” level of capital spending for the industry as a whole. When the ratio sits outside this range for any length of time, over/under capacity usually results.

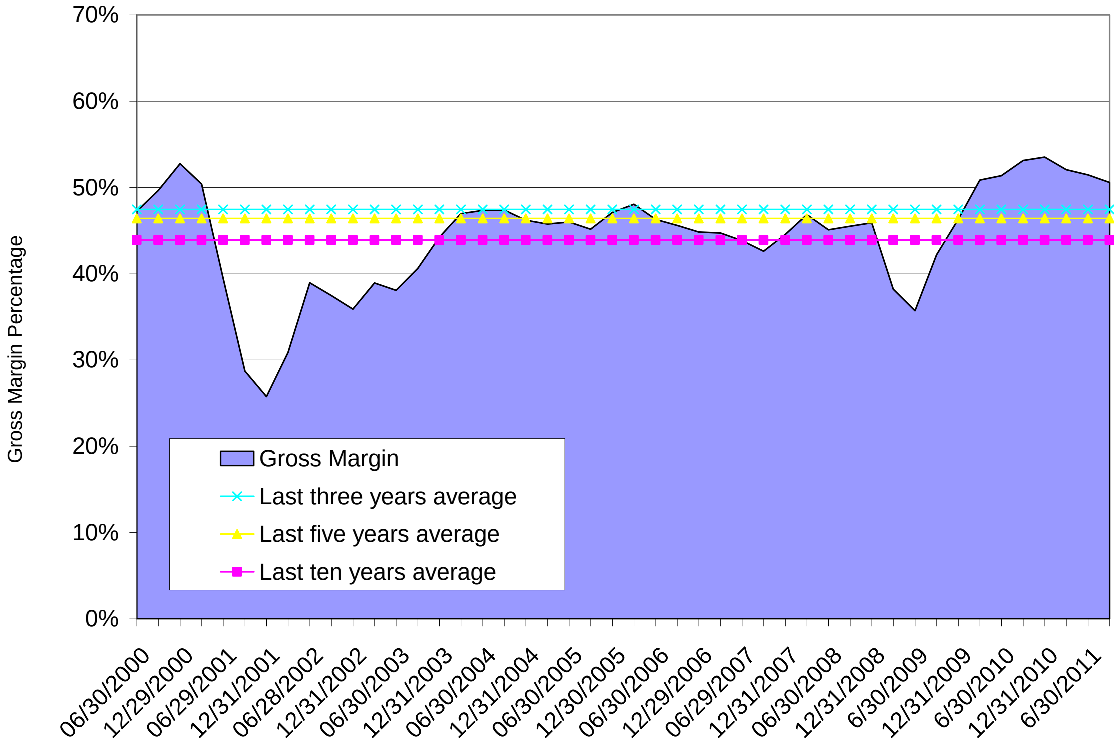
When cycles were primarily supply-driven, cap-ex was the main source of the industry’s cyclicality. During booms, IDMs and foundries increased spending on capacity to meet rising demand. End demand for electronics is difficult to predict and fabs take years to build; consequently producers inevitably overspent. As soon as demand would falter, price deflation would result as unit demand slowed at the same time that new capacity was coming online.

The downturn would then bring a wave of restructuring, as IDMs and foundries looking to conserve cash would slash capital spending. The length of the downturn is always difficult to predict, and further, the deeper the downturn, the less available incremental funds become for new capital projects. Thus, IDMs inevitably spent too little in the downturn, sparking a new cyclical expansion.

Increased outsourcing has shifted supply risk to the foundries, insulating device makers from supply shocks to some degree. The foundries have also been a lot more prudent and rational with capital spending. This has helped to shift the key cyclical driver from supply to inventory. It has also helped bring stability to the semiconductor capital equipment industry, which was historically even more dramatically cyclical than the semiconductor industry.

Fundamentals: Gross Margin

Gross margins for the industry are generally in the mid-40% range, though they compress during periods of low utilization or difficult pricing. Outsourcing trends have resulted in less margin volatility since the 2000 bubble.



Source: FactSet, Oppenheimer & Co.

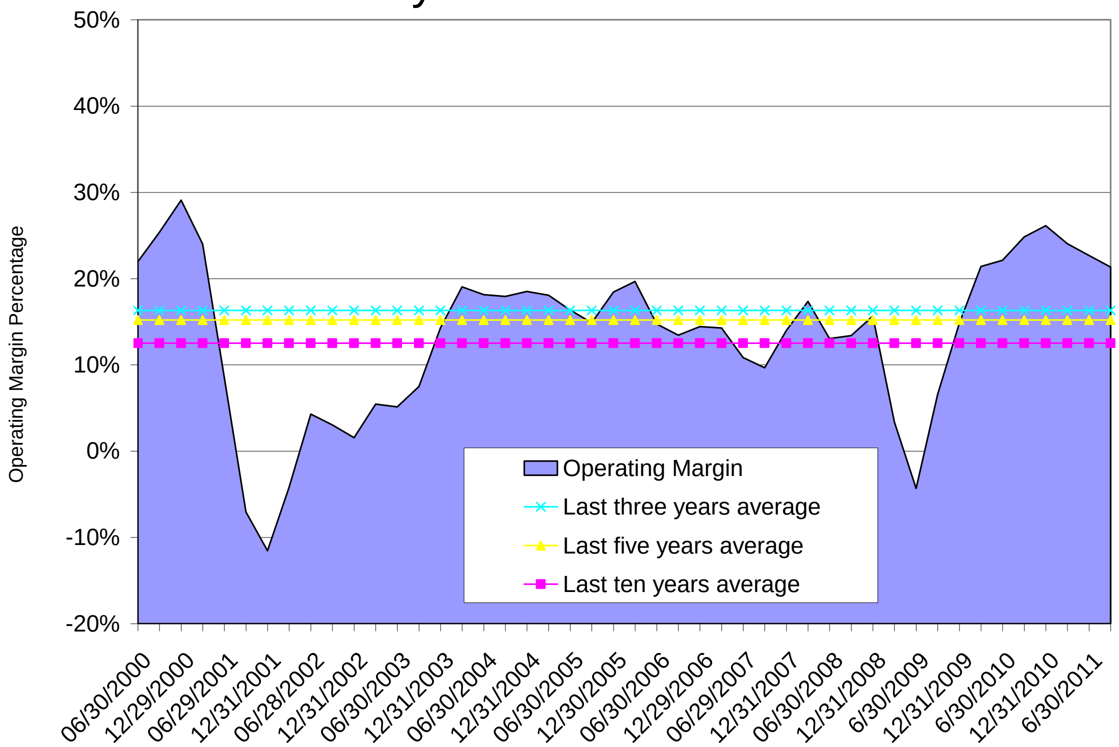
Gross margins for semiconductor companies have generally hovered in the 40%-50% range. A hefty portion of COGS is driven by depreciation of plant and equipment, with the remainder in fixed and variable labor and material costs. In general, companies whose products are more differentiated and proprietary tend to have higher margins; this would include vendors of analog and mixed signal ICs, PC microprocessors, DSPs, FPGAs, and special purpose logic (ASSPs). Companies whose products are more commoditized and thus differentiate themselves based on their manufacturing competencies tend to have lower margins; this would include vendors of memory, microcontrollers, discretes, optoelectronics and general purpose logic.

Gross margins tend to compress rapidly during periods of difficult pricing or low utilization and expand quickly when prices firm and utilization is on the rise. The effect can be exaggerated by industry accounting practices employed by many IDMs, whereby fixed costs are allocated to inventory each quarter at an estimated standard utilization rate and excess fixed costs (positive or negative) are charged to the cost of goods line. In periods of low utilization, actual production trails the estimate, hurting gross margin in the current period. In periods of high utilization, actual production leads the estimate, leading to negative charges to cost of goods and a boost to gross margin.

Note that outsourcing trends have mitigated margin volatility since the 2001 downturn, and now only a handful of semiconductor vendors (mostly memory vendors) do not outsource at least 10% of their supply needs. This eliminates much of the margin leverage we are used to seeing in IDM business models. Even amid challenging conditions in the 2004 and 2006 inventory downturns, industry gross margins still held above 40%. During the 2008-2009 correction, industry gross margins dipped slightly below 40%. Industry margins have since rebounded and are trending lower towards the long-term average.

Fundamentals: Operating Margins

Operating margins have historically averaged under 15%. Margins turned negative in 2009, and recovered above historical averages as sales rebounded more quickly than spending. Even in a choppy, inconsistent demand environment, companies remain heavily invested in R&D and SG&A.



Source: FactSet, Oppenheimer & Co.

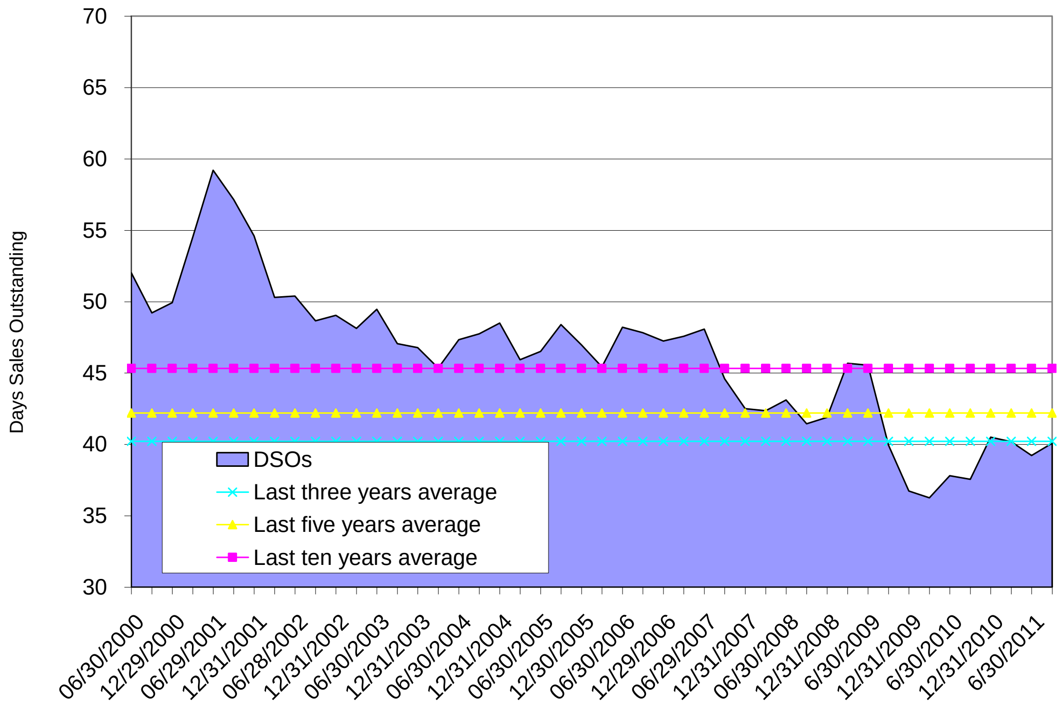
Operating margins for semiconductor companies have historically averaged in the 10%-15% range, with the average company spending about 25%-30% of sales on R&D and SG&A expenses. Operating margins above 20% are not uncommon, however, especially for best-in-breed companies; or even for laggards in peak periods of the cycle.

Operating margins for the industry turned negative during both the 2001 and 2008/2009 downturns. Post 2009 however, operating margins have recovered to comfortably above 20%, a sign that revenue has rebounded more quickly than companies have increased hiring and spending activities. Operating margins will likely decline towards historical averages over the next several quarters as trends begin to normalize.

Many semiconductor vendors have exhibited an increased focus on maintaining profitability through a move to more variable costs. Most have undertaken some level of restructuring, including the move to more flexible outsourcing models, headcount reductions, and strategy shifts. Still, the overwhelming majority of companies remain determined to succeed by staying heavily invested in R&D and SG&A, producing sub-standard margins for such a large and mature industry. This shows up noticeably when demand compresses, as it did in 1H09.

Fundamentals: Receivables

Receivables at semiconductor vendors have recently begun to decline from the historical 45-50 days. Receivable days sometimes spike during demand downturns as OEMs conserve cash, stretching payment cycles, but they usually correct after a couple of quarters.



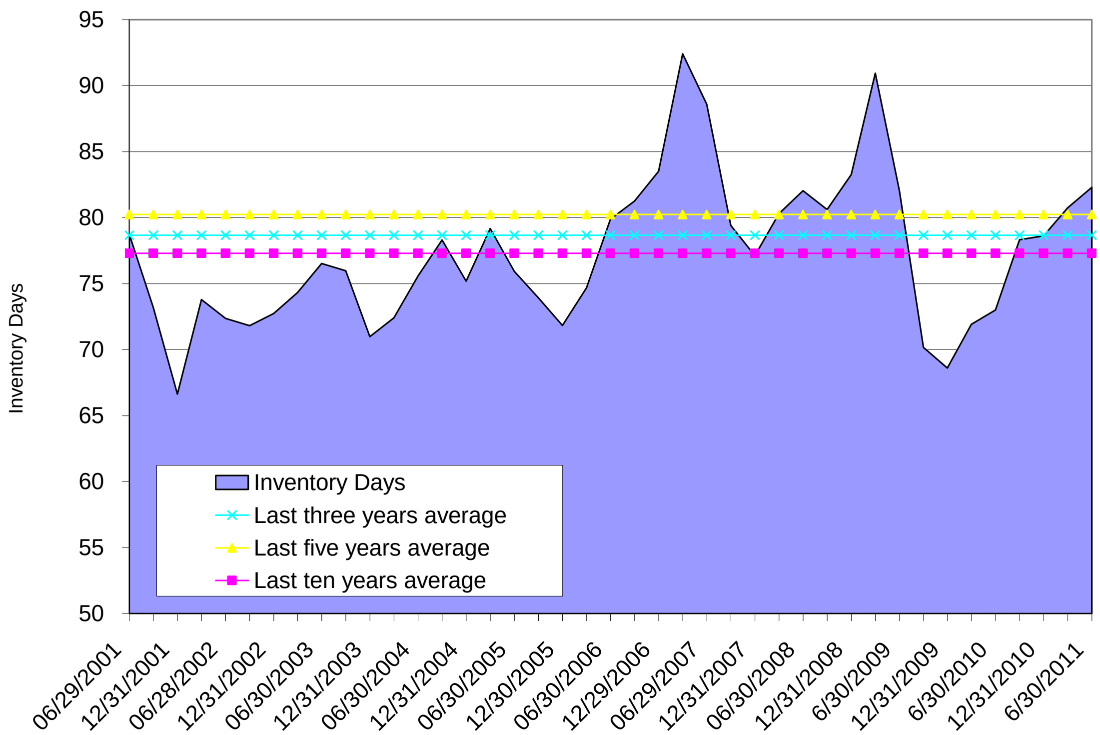
Source: FactSet, Oppenheimer & Co.

Turning to the balance sheet, receivables at semiconductor vendors have historically held at around 45-50 days and are to some degree seasonally affected. During demand downturns, receivables can spike as OEMs look to conserve cash by stretching payment cycles.

The DSO (days sales outstanding) ratio can also be affected by the quick jump or drop in the sales denominator. Thus, we see DSOs spike when demand falters and fall when it recovers quickly.

Fundamentals: Inventories

Inventories at semiconductor vendors have trended up over the past few years. OEMs are reluctant to hold inventories except in the tightest supply environment. At the same time, the rise in outsourcing allows chip vendors to hold more inventory with less risk.



Source: FactSet, Oppenheimer & Co.

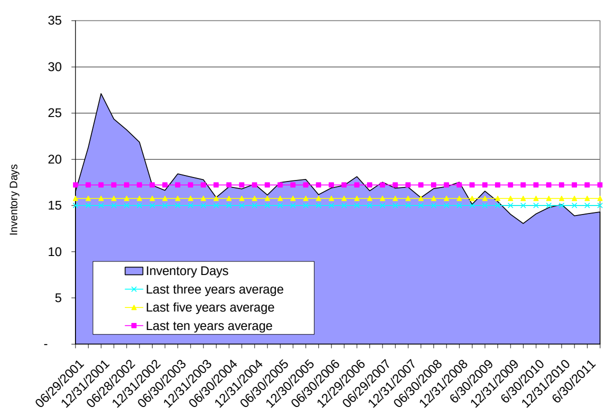
Inventory days at semiconductor vendors have varied considerably over the past few cycles. Inventory days rose dramatically during the 2001 downturn, as the cost of sales denominator declined rapidly on declining end demand and as OEMs worked through their own excess inventories, which combined to produce an unprecedented wave of order pushouts and cancellations. Inventories began to trend down in 2002 and 2003 as vendors held production firm as the demand environment improved, but then surged again in both 2006 and 2008 as IC vendors put stocks in place to support more optimistic forecasts for demand in the peak of the cycle. After being aggressively deplted at the trough of the 2008/2009 cycle, inventory has steadily risen through 2Q11 when it rested slightly above historical trend lines.

Semiconductor vendors have shown increased focus on developing an inventory strategy to meet their customers' desire to minimize risk. IC vendors are holding more inventory on their books on behalf of their OEM customers, in some cases even under a consignment relationship. This may mean relatively high inventory stocks at semiconductor vendors for the foreseeable future. The rise of outsourcing, however, supports this increased inventory with less risk.

Fundamentals: Inventories

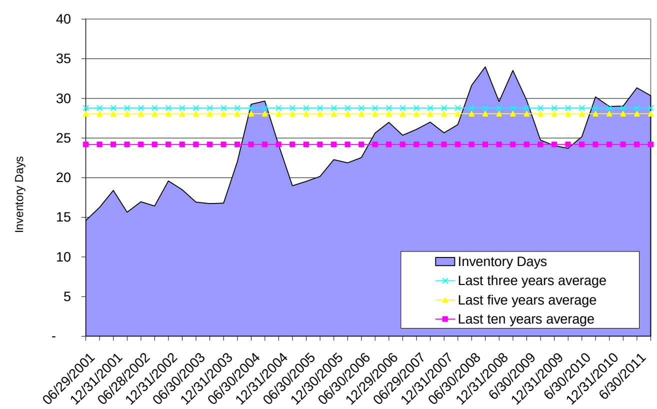
Even more important than inventories at semiconductor vendors themselves are inventories downstream, at the OEMs, EMS providers, and distributors. This is the key variable driving the cyclicality of the industry at this point. When these inventories run too low, OEMs tend to double-book in order to guarantee supply to meet demand forecasts. When they run too high, OEMs tend to cancel and push out orders until end demand returns.

PC & Server OEMs



Source: FactSet, Oppenheimer & Co.

Hard Disk Drive OEMs



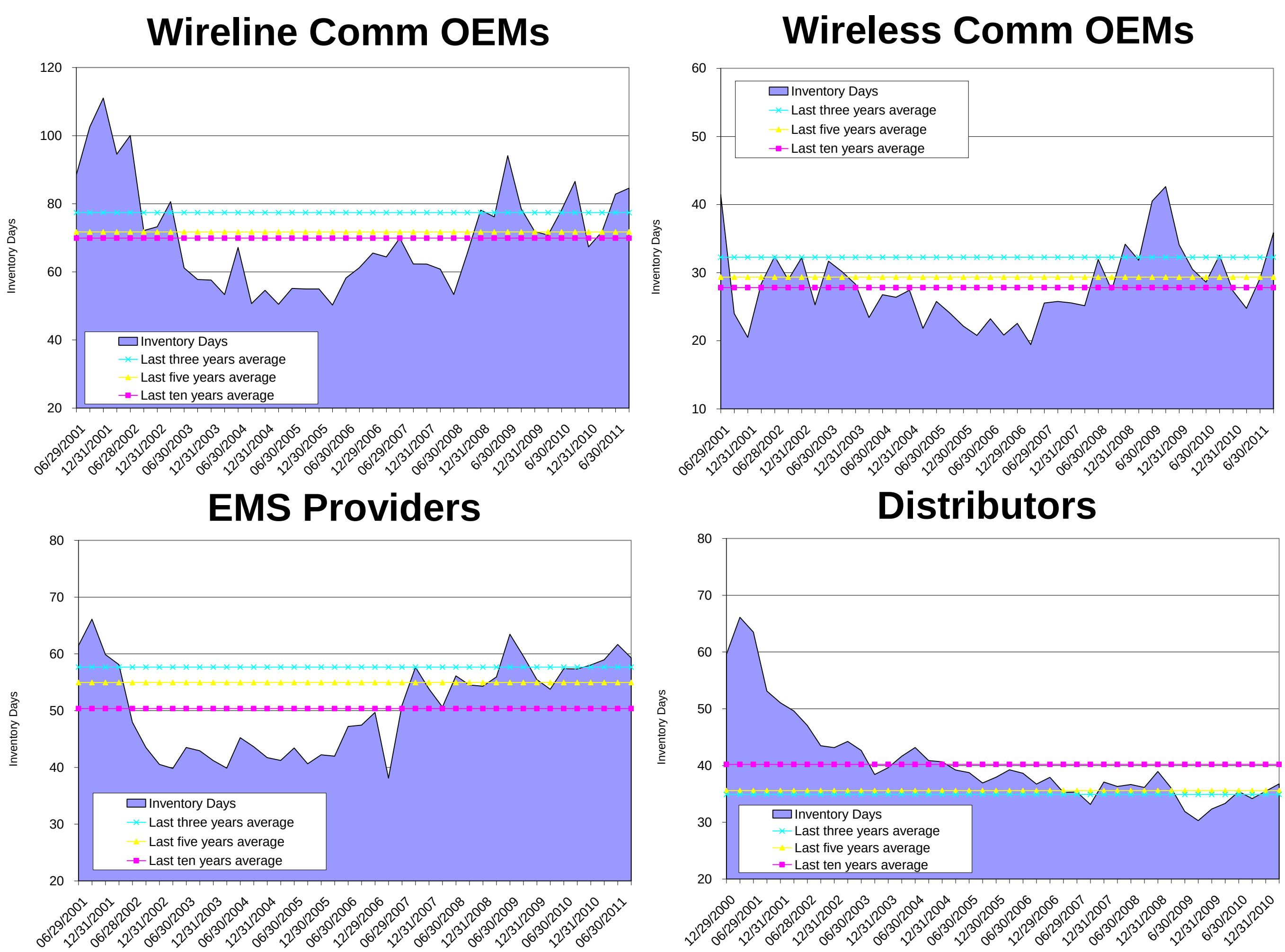
Source: FactSet, Oppenheimer & Co.

Continued...

More important than inventories at semiconductor vendors are inventories downstream, at the OEMs and EMS providers, which are key variables driving the cyclicality of the industry today. When these inventories run too low, OEMs tend to double-book to guarantee that supply meets demand forecasts, lifting sales for semiconductor vendors. When they run too high, OEMs cancel and push out orders until end demand returns, causing semiconductor sales to fall off, often abruptly. We summarize below (and on the next page) the state of inventories by end market:

- *PC and Server OEMs*: The decline in inventory days at PC and server OEMs has been remarkable, with inventory days dropping from 50 (excluding Dell) days to 15-20 days during the past 10 years. This drop has been critical in reducing PC price points and retaining profit margins, especially since the cost of microprocessors and DRAM—two major components in the PC—are among the fastest dropping in the industry (when measured on a per-GHz or per-bit basis). The move to JIT (just in time) inventory has also played a big role, and the impact of Dell alone—with 7-10 days of inventory on hand—has affected the industry figure significantly. At present, PC and server hardware OEM inventories are at below average levels.
- *Hard Disk Drive*: HDD drive inventory days tend to be relatively low—near 25 days—but can move considerably as OEMs contend with choppy demand and manage the shift to larger densities and more integrated designs—events that don't always coincide with the ramp of new PC models. Most recently, HDD inventory sits at 30 days, at the high end of historical ranges.

Fundamentals: Inventories

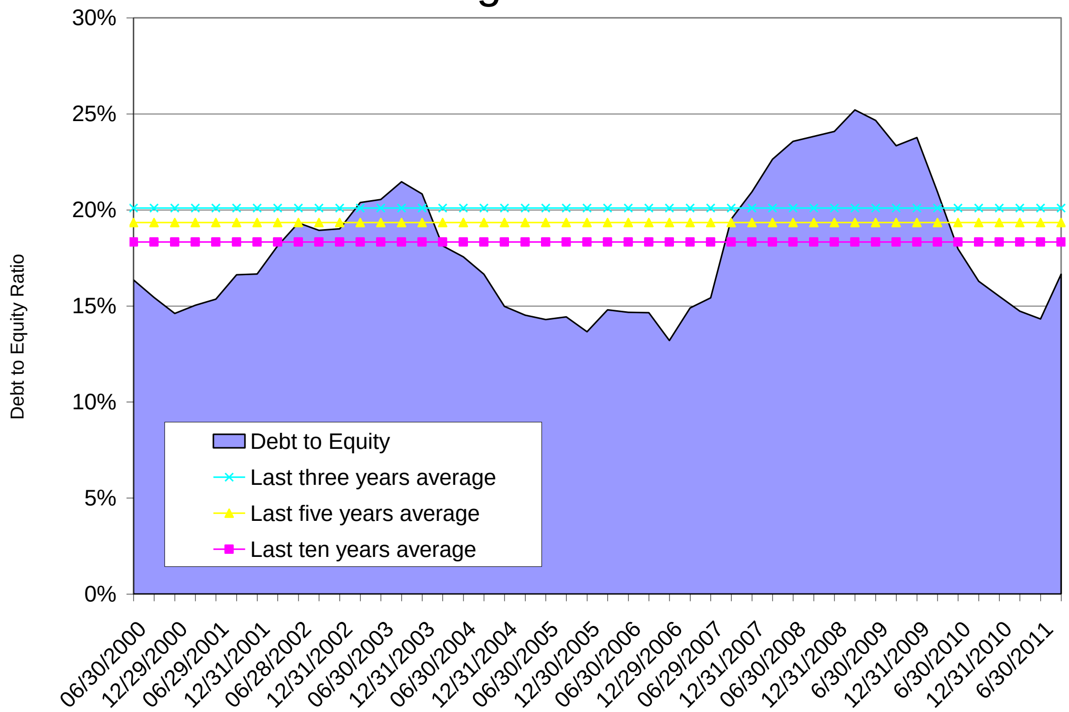


Source: FactSet, Oppenheimer & Co.

- *Wireline OEMs*: Given the long product design and life cycles associated with wireline infrastructure equipment, wireline OEMs have traditionally held higher levels of inventory (65-75 days range) than many tech peers. Note that inventory levels were at their worst in 2000/2001 due to the telecom meltdown (>100 days), but have since been managed much more prudently. OEMs have adjusted purchasing behavior and have taken advantage of shorter lead times from suppliers. Currently, OEM inventories are slightly below historical norms at 62 days.
- *Wireless OEMs*: Inventories at wireless OEMs have historically ranged around 20-35 days and have been declining over time. They tend to be choppy given the pace of new standard introductions, and there is some seasonality too—inventories usually jump in Q1, stabilize during the year, and decline sharply in Q4. Inventories are now slightly above historical norms at 25 days.
- *EMS Providers:* EMS inventories have historically ranged around 40-50 days. Inventory was strong through most of 2004 and 2005, but has been building since that time as OEMs have shifted the burden of carrying inventory to EMS partners. EMS inventory days are now at 59, near a historical high.
- *Distributors:* Distributors build their businesses around efficient inventory management and have been able to limit inventories historically to 35-45 days. Inventory last spiked in 2000/2001 (near 65 days) due to double-ordering. Since then, distributor inventories have been quite healthy and currently sit at 36 days.

Fundamentals: Debt

Given the long-term nature of manufacturing assets, the industry has maintained some level of debt, with debt/equity ratio fluctuations driven mostly by changes in the equity line. More recently, accelerated buybacks and large debt issues are becoming more common.



Source: FactSet, Oppenheimer & Co.

Given the long-term nature of semiconductor manufacturing assets, the industry has historically maintained some level of debt, primarily (though not exclusively) concentrated in the hands of IDMs and outsourcers. The fluctuations in debt/equity ratios have tended to be driven more by changes in the equity denominator than any firm trend on the debt side. For example, in 1999 and 2000, the debt/equity ratio penetrated 15% as fabless and IDM semiconductors alike took advantage of inflated multiples in the equity market to raise capital.

As valuations fell, however, the attractiveness of issuing further equity diminished. The ratio was also affected by write-downs of the equity denominator during the 2001 downturn; this included not only inventories and manufacturing assets but a significant amount of intangible assets (primarily acquisition-related), as well as investments in public and private affiliates and even deferred tax assets. The debt/equity ratio thus rose to over 23% in 2003, its highest level in ten years.

After peaking in 2003, the debt/equity ratio trended down, mostly as a result of renewed profitability (boosting retained earnings), along with a considerable wave of M&A (boosting intangibles and shareholders' equity).

In 2007, however, we saw a dramatic change. Buybacks increased across the industry and some companies even recapitalized using debt. This drove the debt/equity line higher. Following the 2008-2009 downturn, semiconductor companies' appetite for debt has decreased. Although debt-equity levels are below historical ranges at ~17%, we have seen some companies use debt to fund acquisitions recently. With solid cash flow growth and record low interest rates, this trend may continue.

Section III: Market Segments

This section summarizes the major product and end market segments of the industry as well as the competitors within each market.

<u>Topics include:</u>

Semiconductor Device Types

- Analog vs. Digital: "How a device WORKS"
- SIA Framework: "What a device IS"
- Oppenheimer Framework: "What a device DOES"

Key Competitors

- By Product
- By End Market

Semiconductor Device Types

Analog vs. Digital

"How a device WORKS"

Analog – Analog semiconductor devices deal in precise electric properties, most commonly voltages. Transistors within the device are designed to measure and manipulate these properties. Analog devices are well suited to processing real-world signals, as electronic patterns are used to directly represent the original.

Digital - Digital devices do not deal in the values of actual voltages; rather they simply detect the presence or absence of a voltage. The presence of a voltage is represented digitally as a "1," with the absence represented as a "0." These 1s and 0s can be processed and manipulated digitally with great flexibility.

Mixed Signal – These devices include both analog and digital circuitry. Mixed signal devices are difficult to design and build but can bring the benefits of both analog and digital processing together.

Semiconductor devices are routinely described as "analog" or "digital," which explain how the devices work from a fundamental level. Analog semiconductor devices deal in precise electric properties, most commonly voltages but also frequency, current, or charge. Transistors within the device are designed to measure and manipulate these properties. Analog devices are well suited to processing real-world signals, as electronic patterns are used to directly represent the original (the word "analog" is related to "analogy"). Since an analog signal has a theoretically infinite resolution, it will always have a higher resolution than any digital system where the resolution is in discrete steps.

Digital devices do not deal in the values of actual voltages (or other properties); rather they simply detect the presence or absence of a voltage. The presence of a voltage is represented digitally as, a "1," with the absence represented as a "0." The 1s and 0s can be easily manipulated and processed, and since they are universal they can be used to represent almost anything and perform virtually any electrical function. Often, analog devices will convert a signal to digital (a process known as "quantization") for more intense processing in a digital format—techniques such as compression and error correction cannot be performed in an analog fashion. Certain processes are also inherently digital, such as processing of a computer programming language.

Increasingly, we are seeing semiconductor vendors build mixed-signal devices, which include both analog and digital functionality. These devices are difficult to design and build but can bring the benefits of both analog and digital processing together.

Semiconductor Device Types

The SIA Framework

"What a device IS"

Discretes, Optoelectronics, and Sensors - Includes all non-integrated circuit semiconductor devices. A discrete is a single transistor in a package. Sensors are discrete devices that measure real-world input. Optoelectronics are discrete devices that produce or measure light.

Analog - Devices used to process real-world signals using electronic voltage patterns that represent the original. Includes SLICs (standard linear components) and ASSPs (application-specific analog ICs).

Microcomponents - All digital processors, including microprocessors (MPUs), microcontrollers (MCUs), and digital signal processors (DSPs).

Logic - All non-microcomponent digital logic. Includes ASICs (custom logic), ASSPs (standard specialty logic products), FPGAs (programmable logic), display drivers, and general purpose logic.

Memory - Memory devices are used to store data either for short periods of time or permanently. Includes volatile (DRAM, SRAM) and non-volatile (flash, ROM) memory.

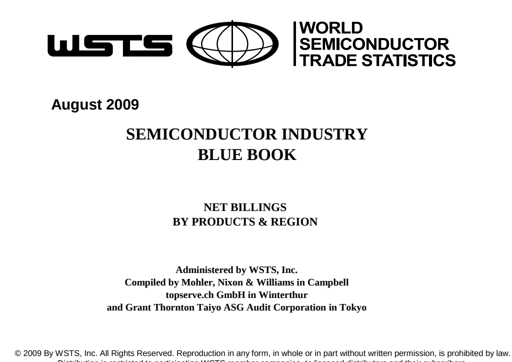
The Semiconductor Industry Association (SIA), the industry body that reports monthly semiconductor industry sales, divides the industry into five broad categories and generally focuses on identifying the type of device sold. When we discuss industry segmentation in terms of the type of semiconductor product, we will generally use the SIA framework.

- **Discretes, Optoelectronics and Sensors:** Includes all non-integrated circuit semiconductor devices. Discretes are devices that contain just a single transistor in a package. These include diodes, small signal and switching transistors, power transistors, rectifiers, thyristors and other discretes.

  Optoelectronics include displays, lamps, couplers, laser devices, image sensors, infrared and other optoelectronics.

  Sensors include those devices that measure temperature, pressure, displacement, velocity, acceleration, stress, strain, or any other physical, chemical, or biological property. The segment also includes actuators, which are responsible for movement.

The SIA Monthly "Blue Book," Which Tracks Monthly Billings Data


WSTS
WORLD SEMICONDUCTOR TRADE STATISTICS

August 2009

SEMICONDUCTOR INDUSTRY
BLUE BOOK

NET BILLINGS
BY PRODUCTS & REGION

Administered by WSTS, Inc.
Compiled by Mohler, Nixon & Williams in Campbell
topserve.ch GmbH in Winterthur
and Grant Thornton Taiyo ASG Audit Corporation in Tokyo

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- **Analog:** Analog circuits are those used to process real world analog signals, using electronic voltage patterns within the device to represent the original signal (the word analog is related to "analogy").

  Analog circuits are divided into two broad categories: SLICs and ASSPs. Standard linear integrated circuits (SLICs) are standard analog components used in multiple applications. Though they perform a specific function, they are not tailored to any individual application. SLICs are usually purchased "off the shelf," often through distribution. Key types are amplifiers, interface circuits, voltage regulators, data converters and comparators.

  ASSPs are more specialized—they are targeted at individual applications (though not individual customers or platforms—that would be classified as a custom ASIC). Analog ASSPs are segmented by application, specifically: automotive, consumer, computer, telecom, industrial and other.

- **Microcomponents:** This includes digital processors, including microprocessors, microcontrollers and DSPs. Digital devices do not deal in the specific voltages of electrons, and instead deal in "1s" and "0s"—"1" being the presence of a voltage and "0" being the absence of a voltage. The "1s" and "0s" can be used to represent just about anything, as long as they conform to some predefined pattern or code as dictated by software. Note that since digital processors deal only in digital signals, any real world input must be converted to digital before it can be processed by a digital device.

  The microcomponent segment includes the more generic digital ICs—programmable devices that can be used in a variety of applications for computation or signal processing. Microprocessors (CPUs or MPUs) are large, complex processors found in computing and other compute-intensive applications, and typically form the brains of an entire electrical system.

  Microcontrollers (MCUs) are smaller, stand-alone processors that perform dedicated or embedded compute functions within a system. They are usually designed with on-chip RAM, ROM and logic in order to minimize support chip count.

  Digital signal processors (DSPs) are specialized digital processors typically used to process real-time data.

  We note that until 2001, the microcomponents category also included microperipherals, which are dedicated logic devices used to augment MPU or MCU system performance, such as graphics controllers, PC chipsets, Ethernet and modem controllers and hard disk drive controllers. These devices are now classified in the special purpose logic category.

- **Logic:** This segment includes all non-microcomponent digital logic circuits, including gate array and standard cells (ASICs), field programmable logic devices (PLDs or FPLDs), display drivers, general purpose logic and special purpose logic/microperipherals (which are somewhat synonymous with ASSPs).

- **Memory:** Memory devices are used to store data in silicon, either for short periods of time or permanently.

  Volatile memory includes those memory devices that lose stored information when the power is lost. DRAM (Dynamic Random Access Memory) and SRAM (Static Random Access Memory) are the two main types.

  Non-volatile memory retains the stored information when the system is powered off. The two main types are NOR and NAND flash. Older types include mask programmable ROM, EPROM and EEPROM.

Semiconductor Device Types

The Oppenheimer Framework

"What a device DOES"

Analog Processing - Devices used to process real-world signals. Includes SLICs (standard analog components) and ASSPs (application-specific ICs).

Digital Processing - All digital devices used to process signals converted from the analog world. Includes digital signal processors (DSPs), custom and standard digital logic and micro-peripherals, some microcontrollers, and any other digital device not responsible for system control or memory storage.

System Processors - All processors that control the electronic device at the system level, including all microprocessors (MPUs) and most microcontrollers (MCUs).

Memory - All volatile (DRAM, SRAM) and non-volatile (EPROM, flash) memory. Identical to SIA category.

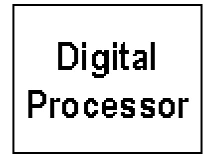
System Enabling Devices – All analog, digital, and discrete devices used as enabling devices on the board. Includes power circuits, glue logic, switches, clocks, discretes, optoelectronics, and sensors.

While the SIA framework is an accurate segmentation of the industry by device type, we often look at the semiconductor industry by end market, with an eye toward system-level design. For this purpose, we prefer to use a simpler, more functional segmentation to help investors understand the various devices and how they fit together in an electrical system.

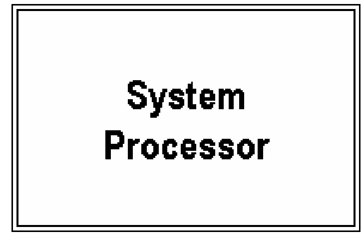
In this framework, we segment the market into five types of devices, based on the function they perform within the system. Note that we display an icon next to each type of device, which we will consistently use in all block diagrams:

- **Analog Processing:** This includes all analog devices used to process real world signals. Analog ICs deal with complex input from the real world in the form of electrical signals, including sound, light, video, radio waves, temperature, pressure, displacement, velocity, acceleration, stress, strain, or any other physical, chemical, or biological property. They sometimes convert them to digital signals for processing by digital processors or the system CPU. This category would include most of what is found in the SIA product category for analog devices, but would exclude some enabling analog devices such as power management and timing circuits, whose function is secondary to the function of the overall system.

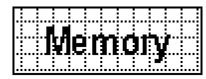
- **Digital Processing:** This includes all digital devices used to perform specialized processing of signals converted from the analog world. It incorporates DSPs used in wireless and broadband, specialized logic used in datacom and telecom, audio/video processors in consumer electronics, or any other digital processor that does not perform overall system control. Typical functions would be encode/decode, compression/decompression, and acceleration functionality. This category would generally include most of the SIA's MOS logic category (excluding general purpose logic), along with most DSPs and some MCUs.



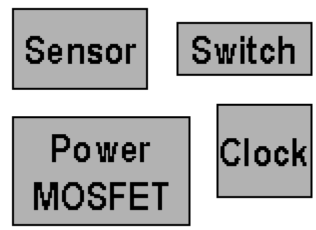
- **System Processors:** This includes processors that perform system control. They are usually highly programmable and run the system software, where applicable. Examples are PC microprocessors, application processors in cellular phones, control plane processors in networking equipment, and microcontrollers that control the majority of system functions. This category would include all microprocessors, most microcontrollers and some DSPs and logic components, depending on how they are used in the system.



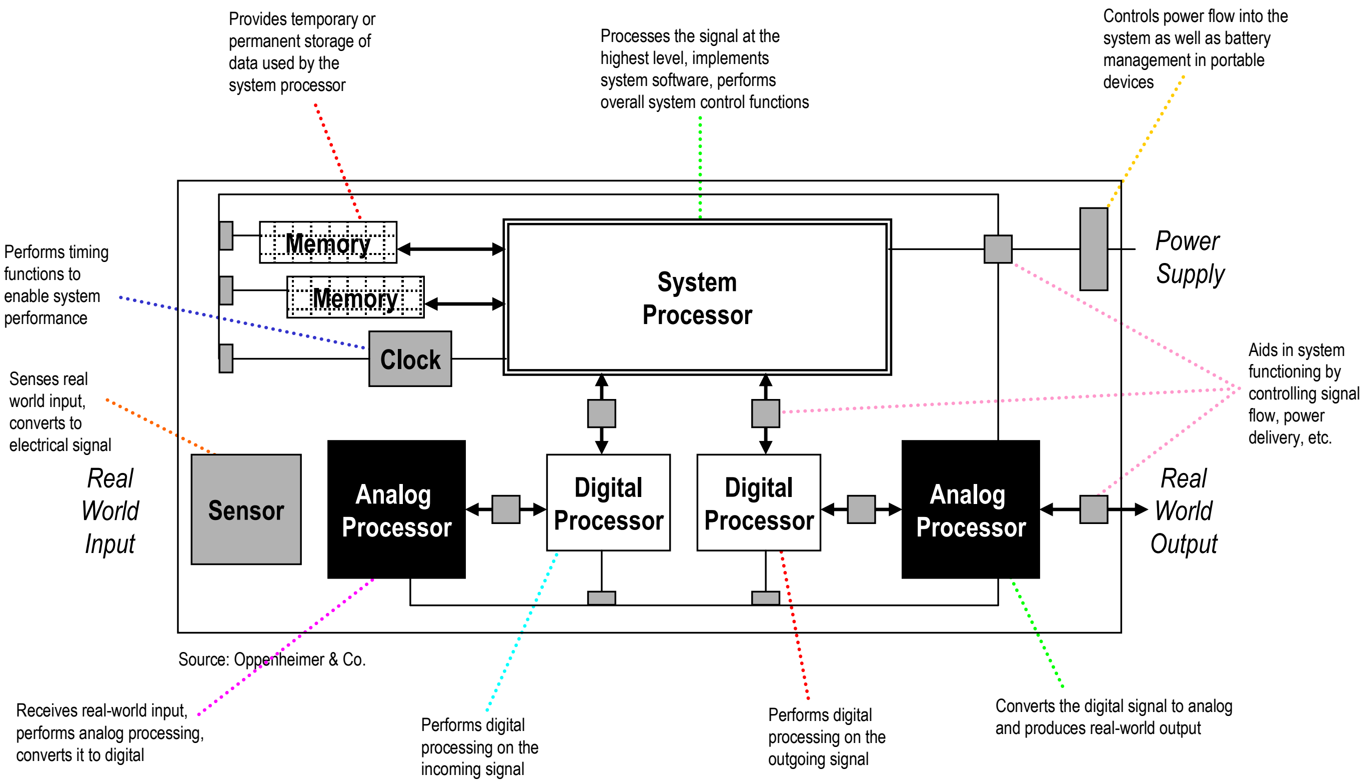
- **Memory:** Identical to the MOS memory category described in the SIA framework, this category includes all volatile and non-volatile memory. Volatile memories like DRAM and SRAM are used by digital processors and system processors, while non-volatile memories are used to store system operating code, boot instructions, and user data.



- **System Enabling Devices:** This includes all discrete, analog and digital devices that are used on the board as enabling devices, rather than for processing or storage. Typical functions include switching signals between ICs on the board, stepping up or stepping down voltages, performing system timing and sensing outside input. Examples of enabling devices include discretes, optoelectronics and sensors, as well as power circuits, timing devices, glue logic and some programmable logic devices.



Example: A Basic Electrical System



Source: Oppenheimer & Co.

The diagram above depicts an electrical system and identifies the devices on the board using the Oppenheimer framework. In the diagram, some real world input is received, interpreted by a sensor (an enabling device), which converts it to an electrical signal, and is then processed in an analog format by an analog processor. The analog processor converts the signal to digital and passes it to a digital processor, which performs some more intensive digital processing on the signal. The digital processor then passes it to the system processor, which, using software, decides what to do with the signal and can make any changes to it if needed. At some point, the processor sends out the signal to another digital processor, which performs some digital processing and passes the signal on to an analog processor, which converts the signal to analog and produces some real world output.

Devices not directly in the signal chain include memory, which is used for short-term or long-term storage of signals, and other enabling devices, such as power management, discretes, timing devices, switches, display drivers, etc.

A simple example would be a digital camera. When the shutter button is activated, an image sensor (enabling device) receives the visual input, which is processed by an analog front end (analog processor) and converted to a digital format. A DSP or an ASIC (digital processor) then encodes and compresses the signal and tells a microcontroller or microprocessor (system processor) that a picture has arrived. The picture file is then stored in flash memory (memory), and the microcontroller tells an LCD controller (digital processor) to produce an image on the LCD screen. The LCD controller then directs signals from row and column drivers to produce the image on the screen. The table on the following page displays additional examples.

End Market Application	Analog Processors	Digital Processors	System Processor	Memory	System Enabling Devices
Computing					
Desktop PC	Graphics interface, sound interface, Ethernet PHY, modem line driver	Chipset, graphics processor, sound processor	Microprocessor	DRAM, ROM, flash	Power ICs, clocks, switches, discretes
Notebook PC	Graphic/sound interface, Ethernet PHY, modem, WLAN/Bluetooth radio, power management	Chipset, graphics processor, sound processor, WLAN/Bluetooth baseband/MAC	Microprocessor	DRAM, ROM, flash	Power ICs, clocks, switches, discretes, LCD drivers
Hard disk drive	Read channel, preamp, motor driver	Servo ASIC, hard disk controller	Microcontroller (embedded in hard disk controller)	DRAM, SRAM, flash	Magnetic sensors, power ICs, clocks, switches, discretes
Communications					
Wireless handset	Power amp, radio (RF/IF), audio codec, Bluetooth radio, analog baseband	Digital baseband (DSP), Bluetooth baseband/MAC, Camera image processor, Multimedia processor	Applications processor (can be embedded in DSP)	Flash, SRAM, low-power DRAM	Sensors, power ICs, clocks, switches, discretes, LCD drivers
Ethernet switch	Ethernet PHY	Ethernet MAC, switch chipset, packet processor, programmable logic	MIPS/PowerPC processor	SRAM, DRAM, ROM	Power ICs, clocks, switches, discretes
Wireless LAN access point	Radio (RF/IF), power amp	Baseband/MAC	MIPS/ARM/PowerPC processor	DRAM, SRAM	Power ICs, clocks, switches, discretes
SONET/SDH line card	PMD, CDR, SONET transceiver/PHY, backplane SerDes	Framer, FEC, network processor, traffic manager	MIPS/PowerPC processor	DRAM, SRAM	Power ICs, clocks, switches, discretes
Cable/DSL modem	Tuner/line driver, analog front end	DOCSIS MAC/processor (cable modem), data pump DSP (DSL)	Communications processor	DRAM, SRAM, flash	Sensors, power ICs, clocks, switches, discretes
Fibre Channel Host Bus Adapter (HBA)	Fibre Channel SerDes/PHY	Fibre Channel controller ASIC	Microprocessor (can be integrated into FC controller)	SRAM, flash	Power ICs, clocks, switches, discretes
Consumer					
Digital set-top box/DVR	Tuner, analog front end (mux/demux)	MPEG decoder/encoder, graphics processor	Microcontroller	DRAM, flash, ROM	Power ICs, clocks, switches, discretes
Digital still camera	A/D converter, Bluetooth/ WLAN radio	Digital image processor, ASICs, Bluetooth/WLAN baseband/MAC	Microcontroller, Microprocessor	Flash, DRAM	CCD/CMOS image sensor, power ICs, clocks, switches, discretes, LCD drivers
PMP/MP3 player	Audio driver, D/A converter	DSP, audio/video processor/ASSP	Microcontroller	Flash	Power ICs, clocks, switches, discretes, LCD drivers
DVD player	Laser driver, spindle driver, servo driver, D/A converter	Front end decoder, servo processor, CD/DVD read channel DSP, MPEG decoder, audio decoder	Microcontroller	DRAM, SRAM, flash	Optoelectronics, power ICs, clocks, switches, discretes
Video game console	Audio DAC, video DAC, Bluetooth/WLAN radio, Ethernet PHY	Graphics processor, system I/O, Bluetooth/WLAN baseband/MAC, Ethernet MAC	Microprocessor	DRAM, SRAM, flash	Sensors, power ICs, clocks, switches, discretes, LCD drivers (handheld)

Source: Oppenheimer & Co.

Key Semiconductor Competitors

Semiconductor Market Top 10 Competitors

Intel (US)—The largest semiconductor manufacturer in the world at about 14% of the market, Intel dominates the PC microprocessor segment (with about 80% unit share) and is also a top supplier of PC chipsets, embedded microprocessors, and PC networking components. The company also acquired Infineon's wireless business in 2010.

Samsung (Korea)—The diversified electronics giant is No. 1 in DRAM, SRAM, NAND flash, and display drivers; it also supplies microcontroller and logic devices.

Toshiba (Japan)—The semiconductor unit of the electronics conglomerate, Toshiba is the top supplier of discretes and is No. 2 in NAND. It is also a major supplier of ASICs, optoelectronics, and standard logic.

Texas Instruments (US)—The top supplier of analog ICs and DSPs. TI is also a player in PC peripherals, VoIP, cable modems, and digital consumer, and has smaller efforts in microcontrollers, ASICs, and standard logic. TI also has a MEMS division called "DLP" which supplies projectors and digital TVs.

Renesas (Japan)—The merged, spun-out semiconductor businesses of Hitachi and Mitsubishi, Renesas is the No. 1 supplier of microcontrollers and is also strong in ASICs, discretes, display drivers, and embedded MPUs. The company also acquired NEC Electronics in April 2010.

Hynix (Korea)—Hynix is the No. 2 supplier of DRAM and is rapidly building a position in NAND, now No. 5 worldwide. In 2005, Hynix spun out its LCD driver, image sensor, MCU, and foundry businesses as a new company, Magnachip.

STMicroelectronics (Switzerland)—ST is a top supplier of ASSPs and ASICs, strong in wireless, PC peripherals, automotive, and consumer. ST is also a big supplier of discretes, flash, EPROM, EEPROM, standard logic, and microcontrollers.

Micron Technology (Japan)—Micron propelled itself into the top 10 semiconductor suppliers in 2010 largely through the acquisition of NOR supplier Numonyx. The company is currently the No. 4 supplier of DRAM and NAND.

QUALCOMM (US)—QUALCOMM is the leading supplier of handset ICs. It has a No. 1 position in digital basebands in 2010 and was also the No. 1 supplier of analog basebands.

Infineon/Qimonda (Germany)—The spin-out from Siemens is a major player in analog and digital ASSPs, especially for communications and automotive, and also supplies discretes, microcontrollers, and EEPROM. Infineon carved out its memory unit, Qimonda, in May 2006—the company is a leading provider of DRAM and has been building a presence in NAND as well.

Key Semiconductor Competitors

Semiconductor Market Top Competitors By Product

Analog

Analog SLICs		Analog ASSPs	
Texas Instruments	Linear Tech	STMicro	Renesas
Analog Devices	STMicro	Infineon	Qualcomm
Maxim	Intersil	Texas Instruments	RF Micro Devices
National Semi	ON Semi	NXP	Skyworks
		Freescale	Broadcom
		Intersil	Semtech
		Monolithic Power	Maxim

Memory

DRAM	SRAM	Flash	
		NOR	**NAND**
Samsung	Cypress	Micron/Numonyx	Samsung
Hynix	Samsung	Spansion	Toshiba
Elpida	Renesas	Samsung	SanDisk
Micron	GSI Technology	Macronix	Micron
Nanya	Integrated Silicon	Winbond	Hynix
Powerchip	Micron	Toshiba	Intel
	IDTI		

Mask ROM	EPROM	EEPROM	
Macronix	Rohm	STMicro	Rohm
	STMicro	Atmel	Seiko
		NXP	ON Semi
		Microchip	

Microcomponents

Microprocessors		Microcontrollers	DSPs
PC & Server	**Embedded**		
Intel	Intel	Renesas	Texas Instruments
Marvell	Freescale	Freescale	Analog Devices
AMD	AMD	Samsung	Toshiba
IBM	Cavium	Microchip	Freescale
Via	Netlogic	Atmel	
	AMCC	Texas Instruments	
	Marvell	Infineon	
	IBM	STMicro	
	Renesas	Fujitsu	
	PMC-Sierra	NXP	

Discretes and Optoelectronics

Discretes		Sensors	
Infineon	Mitsubishi	Robert Bosch	Allegro Micro
Toshiba	Rohm	Infineon	Analog Devices
STMicro	Fairchild	STMicro	Mitsubishi
Vishay	NXP	Denso	NXP
Renesas	ON Semi	Freescale	Knowles

Optoelectronics

Image Sensors		All Other Optoelectronics	
Sony	Samsung	Nichia	Sharp
Omnivision	Panasonic	OSRAM	Philips
Aptina	STMicro	Avago	Cree
Sharp	E2V	Samsung	Everlight
Toshiba		Seoul Semi	Panasonic

Digital Logic

Special Purpose Logic

PC-Related	Communications	Storage	Consumer
Intel	Qualcomm	Marvell	STMicroelectronics
NVIDIA	Broadcom	LSI	NXP
AMD	NXP	Mediatek	Broadcom
Via	Texas Instruments	STMicroelectronics	Sony
SiS	Infineon	Renesas	Toshiba
Broadcom	Conexant	NEC	Sanyo
	Intel	PMC-Sierra	Renesas
	CSR		Mediatek
	Marvell		Zoran

ASICs	PLD	GP Logic	Display Drivers
IBM	Xilinx	Texas Instruments	Samsung
Samsung	Altera	NXP	Renesas
Renesas	Lattice	Toshiba	Novatek
Toshiba	Microsemi/Actel	Fairchild	Himax
Fujitsu		STMicro	Raydium
LSI		ON Semi	Magnachip
Rohm		IDTI	Sharp
Sony			Sitronix
			Orise
			Seiko Epson

Source: Dataquest, IDC, Forward Concepts, Databeans, Oppenheimer & Co.

Key Semiconductor Competitors

Semiconductor Market Top Competitors By End Market

Computing

PCs

CPU	PC DRAM	Graphics	Clocks/Buffers	I/O Controller	Analog Modem	PC Ethernet	PC Wireless LAN	Power Mgmt
Intel	Samsung	NVIDIA	IDT	Standard Micro	Conexant	Broadcom	Intel	Texas Instruments
AMD	Hynix	AMD	Intel	Winbond/National	Silicon Labs	Intel	Qualcomm Atheros	Maxim
	Elpida		Realtek	ITE	LSI	Realtek	Broadcom	Intersil
Chipsets	Micron	**BIOS**	Cypress			Marvell		Richtek
Intel	Nanya	Winbond	Maxim	**Audio**		Qualcomm Atheros		ON Semi
NVIDIA	Winbond	Micron	Semtech	Creative				Monolithic
AMD	Powerchip	Macronix		Realtek			**PC Bluetooth**	Linear Tech
SiS		Spansion		IDT			Broadcom	Global Mixed
		Atmel		Conexant			Qualcomm Atheros	Volterra
		Samsung					CSR	

Computing

PC Displays: LCD Controllers	PC Displays: LCD Drivers	Hard Disk Drives	Optical Drives: Controllers	Optical Drives: Optoelectronics	Printers/MFPs
M-Star	Samsung	Marvell	MediaTek	Sharp	STMicro
Realtek	Novatek	LSI	Renesas	Avago	Texas Instruments
Novatek	Himax	Texas Instruments	Panasonic	Stanley Electric	Marvell
	Raydium	STMicro	NEC	Sony	Conexant
	Magnachip	Renesas	Ricoh	Toshiba	Zoran
	Renesas		Rohm		PMC-Sierra
	Toshiba				NEC
					Toshiba
					LSI

Networking

Ethernet: PC Controllers	Ethernet: PHY & Switch ASSPs	Ethernet: ASICs	Wireless LAN	Bluetooth	Enterprise Storage: HBA/SAN ASICs	Enterprise Storage: RAID Processors/ Controllers	Enterprise Storage: Disk Array ICs
Broadcom	Broadcom	LSI	Broadcom	Broadcom	LSI	Intel	PMC-Sierra
Intel	Marvell	IBM	Qualcomm Atheros	CSR	IBM	LSI	LSI
Realtek	Intel	Avago	Marvell	Mediatek	Mindspeed	Freescale	IBM
Marvell	Realtek	TI	Texas Instruments	RDA Micro	Broadcom	AMCC	Vitesse
Vitesse	PMC Sierra	Fujitsu	Ralink	Texas Instruments		Marvell	Maxim
	AMCC		Intel	STMicro		Vitesse	
	Cortina					PMC-Sierra	

Telecom/Datacom

CO Line Cards	Analog Modem	DSL	Cable Modem	PON	VoIP
Infineon	Conexant	Broadcom	Broadcom	PMC-Sierra	Texas Instruments
Legerity	Silicon Labs	Infineon	Texas Instruments	Broadcom	Silicon Labs
STMicro	LSI	Conexant	Microtune	TranSwitch	Broadcom
IDT	Analog Devices	Ikanos		Cortina	Zarlink
Freescale		Lantiq		Mindspeed	Mindspeed
NEC					Infineon
					LSI
					Freescale

Telecom/Datacom

Communications Infrastructure

T/E	SONET/SDH	ATM	Comm Processor	Network Processing: ASICs	Network Processing: NPUs	Network Processing: CAM/NSEs	Network Processing: Other	Switching: ASICs	Switching: ASSPs
Infineon	LSI	PMC-Sierra	Freescale	IBM	Intel	Netlogic	Cavium	IBM	Dune Networks
PMC-Sierra	PMC-Sierra	Mindspeed	Intel	Avago	LSI	Renesas	Exar	Fujitsu	Broadcom
Maxim	Vitesse	Cortina	Cavium	Texas Instruments	Wintegra		Safenet	LSI	AMCC
Mindspeed	AMCC	TranSwitch	Netlogic/RMI	Hisilicon	Ezchip		Broadcom		PMC-Sierra
LSI	Cortina		LSI	STMicro	AMCC		LSI	**Interconnect**	Vitesse
Exar	Broadcom		PMC-Sierra		Bay Micro		Vitesse	PLX	
Freescale	Mindspeed		Applied Micro		Exar			Intel	
	TranSwitch							Tundra	
								Pericom	

Source: IDC, Dataquest, Oppenheimer & Co.

Key Semiconductor Competitors

Semiconductor Market Top Competitors By End Market

Wireless

Handset ICs					Infrastructure			
Digital Baseband	**Analog Baseband**	**App. Processor**	**RF & PA**	**Memory**	**Baseband ASIC**	**Baseband DSPs**	**Transceiver/ Converter**	**Power Amp**
Qualcomm	Qualcomm	Texas Instruments	Qualcomm	Samsung	Qualcomm	Texas Instruments	Analog Devices	Freescale
Texas Instruments	ST Ericsson	Apple	Skyworks	Toshiba	Texas Instruments	Freescale	Texas Instruments	Fujitsu
Mediatek	Intel (Infineon)	Marvell	RF Micro Devices	Micron/Numonyx	LSI	LSI	NEC	NXP
Intel (Infineon)	Dialog	Renesas	Intel (Infineon)	Hynix	NEC	Analog Devices	IBM	Sirenza
ST Ericsson	Toshiba	Samsung	Mediatek	Elpida			Maxim	Infineon
Spreadtrum		Broadcom	TriQuint	Spansion				
Freescale		Qualcomm	ST Ericsson	SanDisk				
		NVIDIA	Renesas	Intel				
			Avago					
			ANADIGICS					

Digital Consumer

Set-Top Box	Digital TV	DVD	Digital Camera	MP3/PMP	Videogame	Memory Card	
			Image Sensor			**NAND**	**Controller**
STMicro	Samsung	Mediatek	Sony	Samsung	NEC/Renesas	Samsung	SanDisk
Broadcom	NXP	Zoran	Sharp	Toshiba	IBM	Toshiba	Kingston
Sigma Designs	Toshiba	Broadcom	Aptina	Hynix	Sony	SanDisk	Toshiba
Intel	Panasonic	Sigma Designs	Toshiba	Texas Instruments	Sharp	Micron	Samsung
Trident	Himax	SunPlus	Omnivision	NXP	Samsung	Hynix	Transcend
MaxLinear	Mediatek	Renesas	Samsung	STMicro	NVIDIA	Intel	A-Data
Sony	Sony	Sony	Panasonic	Micron	AMD		Micron
Samsung	STMicro	Samsung	E2V	Freescale	Marvell		
	Broadcom	Panasonic			Qualcomm Atheros		
	MaxLinear				Broadcom		
	Zoran						
	Trident						

Automotive

Automotive			
Auto MCUs	**ASICs/ASSPs**	**Auto SLICs**	**Auto Discretes**
Renesas	STMicro	Analog Devices	Renesas
Freescale	NXP	Linear Tech	Infineon
Texas Instruments	Infineon	Sanken	NXP
Denso	Robert Bosch	ON Semi	Rohm
STMicro	Texas Instruments	Maxim	Vishay
Fujitsu	Freescale	Renesas	Mitsubishi
Infineon	Panasonic	National Semi	Denso
Microchip			
Toshiba			

Source: IDC, Dataquest, Oppenheimer & Co.

Section IV: Product Summary

This section discusses the major product segments of the semiconductor market

For each product we discuss:

Product Definitions

Market Forecast

Competitive Environment

The Semiconductor Market

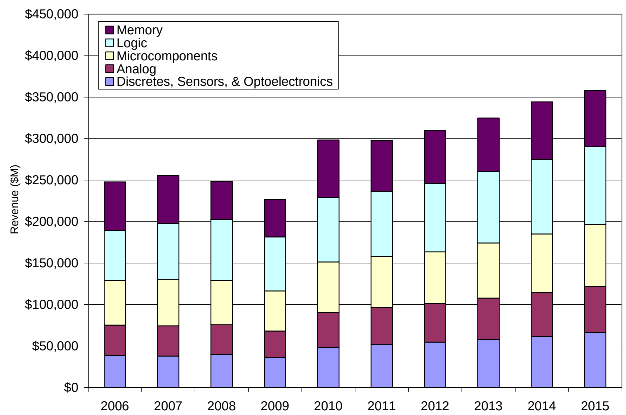
Semiconductor Industry Revenue Forecast

•The semiconductor industry totaled $298 billion in sales in 2010, up 32% from 2009.

•Revenue increased 32% in 2010 owing to a sharp snapback in demand from the financial crisis.

•We are expecting growth rates to moderate going forward following a quick recovery in 2010.

•Overall, we expect a 5-year CAGR of 4%, with sales increasing from $298 billion in 2010 to $358 billion in 2015.



Source: WSTS, Oppenheimer & Co.

Product Forecast Highlights

•Microcomponents should grow at a 4% CAGR, led by PC-related MPU growth of 6%. MCUs should grow at 4% while DSPs decline at 1%.

•Analog should grow at a 6% CAGR. Standard linear ICs should grow at a 6% CAGR while application-specific analog should increase at a 5% CAGR.

•Logic should grow in line with the market at 4%. FPGAs will outgrow the market at 8% while special purpose logic should increase in line at 4%.

•Memory should underperform the overall market with a -1% CAGR and will show the most volatility. DRAM is expected to lead the decline at 3%, while NAND offsets slightly growing at 5%.

•Despite perpetual price pressure, discretes, sensors, and optoelectronics should outgrow the overall industry CAGR given their multi-market application at 6%.

The semiconductor industry totaled $298 billion in sales in 2010, a 32% year-over-year increase. The rebound was predominately due to a snapback in demand from the financial crisis and inventory restocking. For 2011, we are estimating flattish semiconductor sales as mature economies (US, Europe, etc.) experience a slowdown in demand. Overall, we estimate a 2010-2015 five-year CAGR of 4%. By segment, we expect:

- Microcomponents should grow at a 4% CAGR, led by moderate PC-related MPU growth of 6%. MCUs should grow roughly in line with microcomponents at 4%, while DSPs should trail the market with a -1% CAGR.
- Analog should grow at a 6% CAGR. Standard linear should grow at a 6% CAGR, while application-specific analog should deliver a 5% CAGR.
- MOS Logic is expected to grow at a 3% CAGR, relatively in line with the overall market. FPGAs will outgrow the market at a 8% CAGR, while special purpose logic should increase in line at 4%.
- Memory should decline at a modest 1% CAGR, and will likely continue to exhibit volatility; up the most in boom years and down the most in downturns. Growth in NAND is expected to be outweighed by declines in DRAM, SRAM and NOR.
- Despite an always-difficult pricing environment, discretes, sensors, and optoelectronics should outgrow the overall semiconductor industry CAGR given their multi-market application.

Product Summary

The semiconductor market can be divided into five key product areas

Five Key Markets:

Analog

Microcomponents

Digital Logic

Memory

Discretes and Optoelectronics

We first examine the semiconductor industry by product group. The industry can be divided into five segments:

- **Analog:** Analog circuits are used to process real world signals, using electronic voltage patterns within the device to represent the original signal. Standard linear integrated circuits (SLICs) are standard analog components used in multiple applications, usually purchased "off the shelf," often through distribution. Analog application-specific standard products (ASSPs) are more specialized analog devices targeted for a specific application.
- **Microcomponents:** These programmable devices perform intensive compute processing and system control. Microcomponents include microprocessors, microcontrollers and DSPs.
- **Digital Logic:** Logic devices perform specialized digital processing, and include gate arrays and standard cells (ASICs), programmable logic (PLDs, FPGAs), display drivers, general purpose logic and special purpose logic.
- **Memory:** Memory devices are used to store data either for short periods of time or permanently. Volatile memory loses stored information when the power is lost; key types are DRAM and SRAM. Non-volatile memory retains the information when the system is powered off; key types are flash, mask ROM, EPROM and EEPROM.
- **Discretes, Optoelectronics and Sensors:** This category includes all non-integrated circuit semiconductor devices. Discretes contain just a single transistor in a package. Optoelectronics are specialized discretes designed to emit and detect light. Sensors measure physical, chemical or biological properties.

Analog

Analog:

Devices designed to process, convert, and create analog real world signals

Two Key Markets:

Analog SLICs

Analog ASSPs

Analog ICs are devices used to process, convert, and create real world signals. Whereas digital circuits operate by determining the absence or presence of an electrical charge (the "1s" and "0s" of the digital world), analog circuits are concerned with the actual voltages (or other electrical properties) in circuits. When electronic systems interact with the real world, analog circuits represent this real world input in the form of voltage/current strength (the electrical charges in the device form an "analogy" of the real world input—hence the term "analog"). They can also convert the signal to a digital form for processing. Conversely, when the device creates real world output, analog circuits convert the digital instructions to analog voltages/currents to create an electrical output.

Analog circuits are divided into two broad categories: **SLICs** and **ASSPs**.

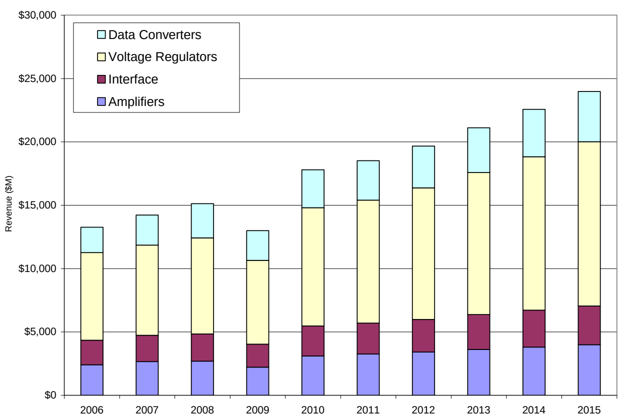
- **SLICs** (standard linear integrated circuits) are standard analog components that are used in multiple applications. Although designed for a specific function within a system, a SLIC is not optimized for particular types of systems. Key types are amplifiers, interface circuits, voltage regulators, data converters and comparators.
- **ASSPs** (application specific standard products) are more specialized analog devices targeted for a specific application. These devices are often designed as multiple SLICs that are integrated and then modified to serve a specific function in a particular end market; but they can also be designed from the ground up. Examples include radio frequency (RF) ICs in cellular phones, interface ICs for networking, read channels in HDDs, tuners and demodulators in set-top boxes, battery management in notebooks and power train control devices in automobiles.

Analog SLICs

<u>Analog SLICs (Standard Linear Integrated Circuits)</u> - Standard analog components used in multiple applications. While designed to perform a specific function, SLICs are not optimized for any particular type of system.
Key Types: Amplifiers, interface drivers, voltage regulators, data converters (analog-to-digital, digital-to-analog, codec), comparators.

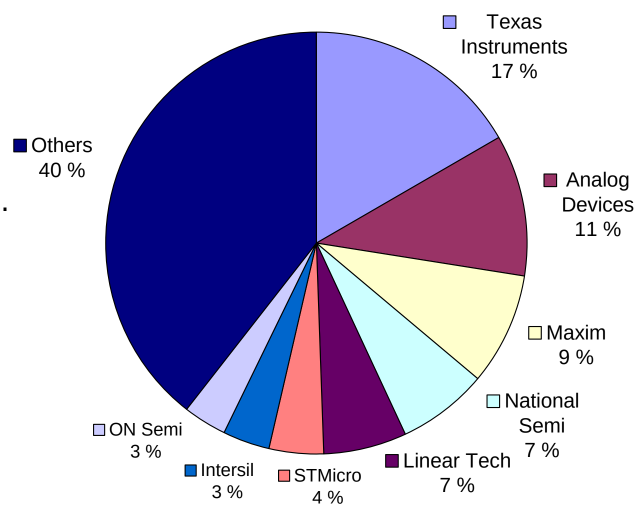
Market Forecast

•Analog SLICs are expected to grow at a 5-year CAGR of 6%, rising from $17.8 billion in 2010 to $24.0 billion in 2015.
•Voltage regulators should lead growth, with interface and amplifiers both trailing.
•Data converters are expected to grow in line at 6%.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Analog SLICs (standard linear integrated circuits) are general purpose analog components that can be used across multiple types of electronic systems. Although designed to perform a specific function within a system, SLICs are not optimized for particular applications. For example, a line driver (a type of interface SLIC) is designed to produce or receive a signal on a copper wire, but can be used in any application that requires this function (e.g., a telephone set, an analog modem, etc.). Similarly, a video ADC (analog-to-digital converter) is designed to convert analog video signals to digital, but can be used in any video application (e.g., digital camera, digital TV, set-top box, etc.).

SLICs can be sub-divided into five types of devices:

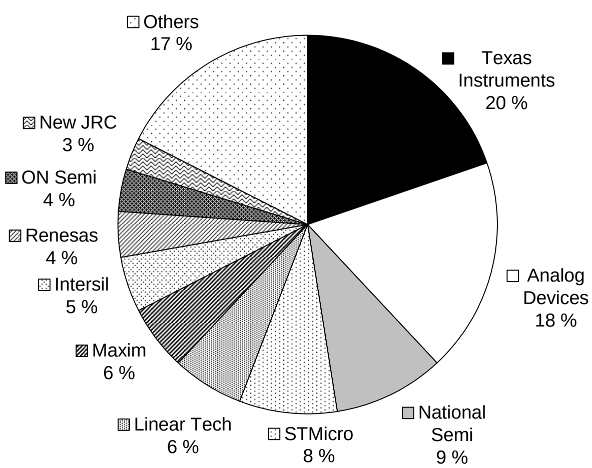
- **Amplifiers**: ICs designed to amplify a signal, also can be configured to perform certain related operations.
- **Interface**: ICs that produce output or receive input in the transmission of signals to and from systems.
- **Voltage Regulators**: Devices that control power flow by providing a stable flow of current at a particular voltage.
- **Data Converters**: Includes “mixed signal” (analog/digital) devices designed to convert a signal from analog to digital (an ADC) or from digital to analog (a DAC). A codec combines the two functions in a single device.
- **Comparators**: ICs used to compare two quantities, usually used in power management. This category of devices is often grouped with amplifiers, as it is a small market and is similar in nature to amplifiers.

Market Forecast: The market for analog SLICs is expected to grow at a 6% CAGR over the next five years. While most electronics OEMs and semiconductor companies are focused on driving the performance of the digital portion of the system, most applications still require significant analog content to interface with the real world. In total, we expect the market to grow from $17.8 billion in 2010 to $24.0 billion in 2015. Voltage regulators should lead growth at a 7% CAGR, while amplifiers and interface drivers are slightly trailing at 5% CAGRs. Data converters are expected to grow in line with the overall analog market at 6%.

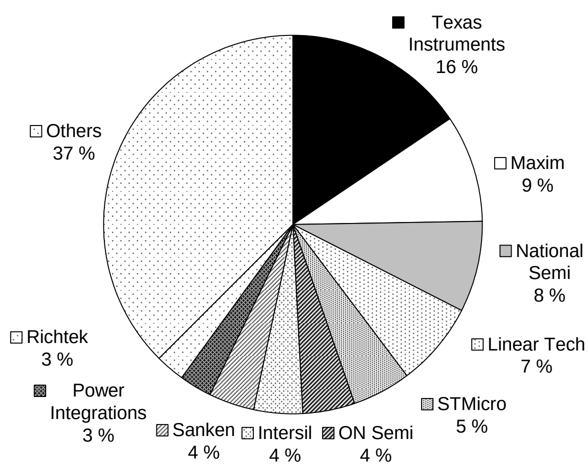
Competitive Environment: The SLIC market is one of the most stable and profitable segments in the semiconductor industry. Barriers to entry in the standard linear market remain extremely high, due in part to the nature of analog SLIC device design. Analog engineering is more of a refined art rather than a school-taught competency, with most analog engineers honing their craft over years of real world design. While digital devices are more dependent on scaling processing architectures and migrating to smaller geometries, SLICs are more dependent on a deep knowledge of the intricacies of the particular medium for which the device is being designed (e.g., sound waves, light waves, heat, etc.). The pool of analog design engineering talent is therefore more limited than for digital devices, and a multitude of SLIC vendors have been able to develop defensible franchises. Further, as SLICs are extremely diverse in application, the supplier chain is very fragmented.

Only two vendors held above 10% market share in the analog SLIC segment in 2010. Texas Instruments held 17%, with a leadership position in amplifiers, voltage regulators and interface ICs and a strong No. 2 position in converters. Analog Devices held 11%, with a dominant 40% share of data converters and a strong amplifier position. Maxim, the high-performance standard linear pure-play, held 9% and was No. 2 in interface ICs and voltage regulators, and No. 3 in converters. National Semiconductor (now acquired by Texas Instruments) was fourth with 7%, No. 3 in voltage regulators and amplifiers, and No. 4 in interface ICs. Rounding out the top 5 was Linear Technology with 7%. Other major vendors include On Semi, Intersil, and STMicroelectronics. We provide additional competitive detail in the charts below.

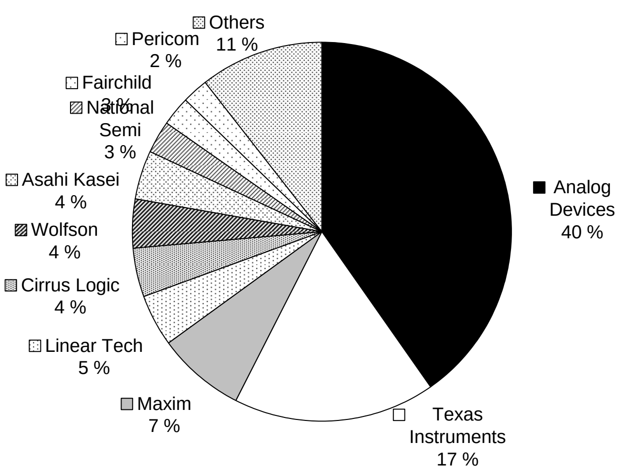
Amplifiers and Comparators



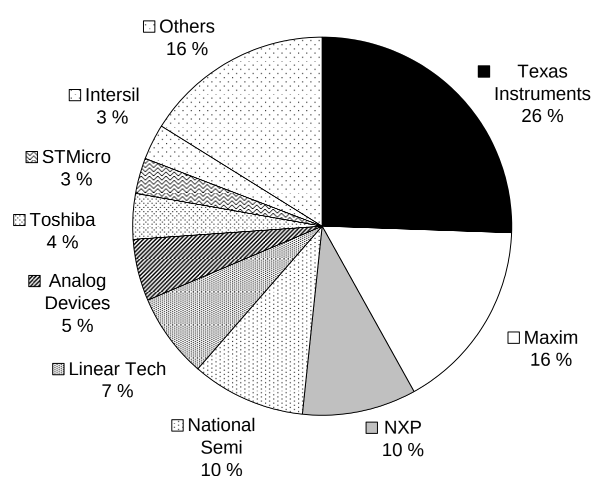
Voltage Regulators



Converters



Interface Circuits



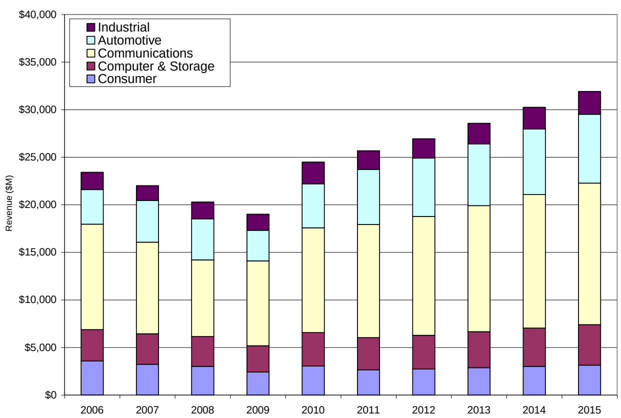
Source: Gartner, Oppenheimer & Co.

Analog ASSPs

Analog ASSPs (Application Specific Standard Products) - Specialized analog ICs targeted for a specific application. Often integrate multiple SLICs or even some digital circuitry. Often called "mixed signal" analog.
Key Types: Computer, communications, consumer, automotive, industrial.

Market Forecast

•Analog ASSPs are expected to grow at a 5% CAGR, rising from $24.5 billion in 2010 to $31.9 billion in 2015.
•The trend toward integration in the digital logic segment continues to weigh on application-specific analog, particularly in the communications segment.
•Growth to be led by Automotive and Communications ASSPs.



Source: WSTS, Oppenheimer & Co.

Key Competitors

STMicro
Infineon
Texas Instruments
NXP
Freescale
Renesas
Qualcomm
RF Micro Devices
Broadcom
Intersil
Monolithic Power
Semtech
Maxim

Source: Oppenheimer & Co.

Analog ASSPs (application specific standard products) are analog components designed to service a particular application. These are sometimes designed as multiple SLICs that are integrated to serve a specific function in a particular end market, but can also be designed from the ground up. They often include some digital circuitry, and hence are sometimes referred to as "mixed signal analog."

Key examples of analog ASSPs include radio frequency (RF) ICs in cellular phones, physical layer interface devices for networking applications, read channels in hard disk drives, demodulators in consumer electronics, battery management ICs in notebook computers, and engine and power train control devices in automobiles.

Unlike analog SLICs, analog ASSPs are not usually sold through the distribution channel, and instead go through a design process at OEMs which is similar to the one used for digital ASSPs. In fact, many of the highest volume electronics applications are served by a chipset that includes one or more analog ASSPs paired with one or more digital ASSPs offered by the same vendor, or by multiple vendors on a single reference design. The analog and digital ASSPs are thus designed in, and subsequently purchased by the OEM, at the same time.

As mentioned above, some analog ASSPs actually incorporate mixed signal and digital functionality, often blurring the line between analog ASSP and special purpose logic. Further, the same vendors who design digital ASSPs are now increasingly the vendors who design analog ASSPs. While the SIA has for now kept the line between analog and digital ASSPs, some third-party research firms like Gartner Dataquest have done away with this distinction and group all application-specific analog and digital devices as simply "ASSPs."

Analog ASSPs are divided into five categories by application:

- **Automotive**: ASSPs designed for use in automobile engine, safety, comfort, entertainment and power controls.
- **Consumer**: ASSPs used in audio/video equipment and home appliances, usually for production, reception, or processing of audio and video input and output.
- **Computer**: ASSPs used in computing applications, most notably storage devices like hard disk and optical drives.
- **Communications**: ASSPs used in wireless, telecom, and datacom client and service provider devices and equipment. Often used in the production and reception of transmission signals (i.e., optical, electrical and radio).
- **Industrial and Other**: ASSPs used in industrial equipment and other applications.

Market Forecast: The market for analog ASSPs is expected to grow at a 5% CAGR, rising from $24.5 billion in 2010 to $31.9 billion in 2015. Analog ASSPs are expected to match overall semiconductor industry growth despite integration pressure from logic-based SoCs (system-on-a-chip), which limit the TAM (total available market) for discrete analog components. A prime example of this is in the communications market (45% of total), which is currently experiencing the most significant drive toward integration. Wireless handsets, a large consumer of RF, analog baseband and power management ICs, are starting to utilize single-chip solutions that integrate analog functions into digital SoCs. In total, we estimate communications ASSPs should be growing at 7% through 2015 (note that outside of wireless, certain networking technologies should drive some communication ASSP growth, such as 10G Ethernet, Fibre Channel, etc.). Automotive, PC and consumer are markets that are expected to grow relatively in line with the market at a 6% CAGR. Consumer benefits from consistent unit growth, but is subject to more pricing pressures as well as the trend to pull analog functions into the digital SoC. Computing has already undergone an integration cycle, specifically in HDDs, and so should see a growth rate closer to that of units going forward.

We expect more consistent growth from industrial segment, increasing at CAGR of 7%. Industrial benefits from the increasing complexity of electrical systems and a mix shift toward systems with greater semiconductor content; there is also less integration pressure as FPGAs are the main digital IC in an industrial stem, as opposed to a digital SoC.

	Communications	Computing	Consumer	Auto/Industrial
Key device types	Analog basebands Handset power management RF transceivers Power amplifiers DSL front ends	Printer front ends and cartridge heads HDD read channels, preamps, and motor controllers ODD front ends PC interface ICs	Demodulators Tuners Audio/video interface Digital camera front end Blu ray front end	Engine control Automotive audio Climate control Motor control
Key Competitors	STMicroelectronics Qualcomm Skyworks RF Micro Devices Texas Instruments Infineon Renesas Freescale NXP Broadcom Peregrine	Texas Instruments STMicroelectronics Mediatek Renesas Rohm Marvell LSI Freescale	Sony Panasonic NXP STMicroelectronics Renesas Micronas Broadcom Freescale Conexant Texas Instruments	STMicroelectronics NXP Infineon Renesas Robert Bosch Freescale Texas Instruments Toshiba

Source: Dataquest, Oppenheimer & Co.

Microcomponents

Microcomponents:

Devices designed to perform intensive compute processing and system control

Three Key Markets:

Microprocessors

Microcontrollers

Digital Signal Processors

Microcomponents include all digital processors, including microprocessors, microcontrollers and DSPs. These devices are built around the famous ones and zeroes of the digital world and are designed to be programmable; i.e., they run software which is very customizable and can change the function of the device.

Microprocessors (CPUs or MPUs) are the largest, most complex processors, and are generally found in computing and other compute-intensive applications; they typically form the brains of an entire electrical system. Raw performance is generally the most important metric for microprocessors, though increasingly performance per watt is becoming important as well. Little integration is done in the microprocessor market beyond on-chip cache & I/O, as they almost always sit within a larger system with other ICs to handle supporting functions.

Microcontrollers (MCUs) are smaller stand-alone processors that perform dedicated or embedded computer function within a system and usually contain on-chip RAM, ROM, I/O logic and timers in order to minimize cost and to speed design and implementation cycles. Integration is most important, followed by power consumption and performance; though performance will usually vary by application given the diverse use of MCUs.

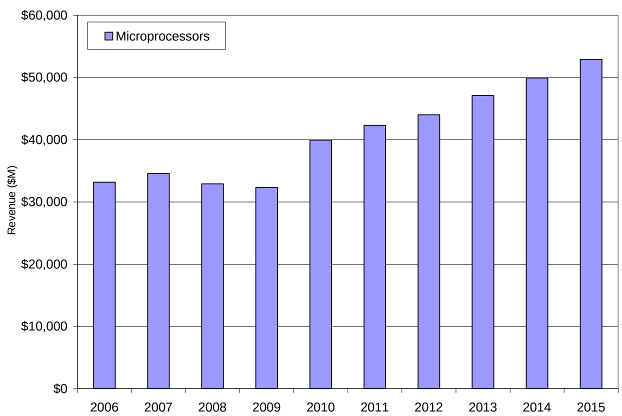
Digital signal processors (DSPs) are specialized high-speed digital processors typically used to process real-time data. Performance and power consumption are of equal importance. Integration has also been critical in driving DSPs into select applications (like handsets), though many systems use a DSP as a stand-alone high-speed processor.

Microprocessors

Microprocessors (MPUs) - Digital processors that execute instructions and perform system control functions as programmed with an assembly language. MPUs are optimized for general purpose data processing.
Key Types: x86, PowerPC, ARM, MIPS. 16-, 32-, and 64-bit external bus.

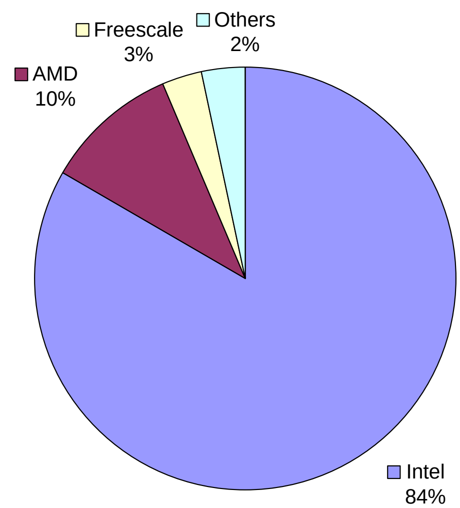
Market Forecast

- Microprocessors are expected to grow from $39.9 billion in 2010 to $52.9 billion in 2015, a 6% CAGR.
- The market is almost entirely PC-based and is tied to PC unit growth and the mix between desktop, notebooks, netbooks and servers.



Source: WSTS, IDC, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

PC	Server	Embedded	
Intel	Intel	Intel	NetLogic
AMD	AMD	Freescale	AppliedMicro
Via	Sun	AMD	Marvell
		Cavium	IBM

A microprocessor (MPU) is a programmable digital processor that executes external instructions and performs system control functions as programmed via software with an assembly language. The architecture is optimized for general purpose data processing and includes an instruction decoder, arithmetic logic unit, registers, cache memory, and additional logic to support operation as determined by the assembly language. An MPU can receive input commands, manipulate data, direct storage of data and initiate application commands to other parts of a system.

The PC and server market represents over 90% of microprocessor revenues. Most PC microprocessors use the x86 CISC (Complex Instruction Set Computer) architecture, which uses microcode to execute very comprehensive instructions. Instructions may be variable in length and use a variety of addressing modes, requiring complex circuitry to decode them. Both Intel and AMD, the major PC microprocessor suppliers, have added their own enhancements to the x86 architecture, both in the actual processor core and the surrounding logic. These enhancements optimize certain common features used in the PC, such as operating system tasks, multimedia functions, Internet functions, etc.

Microprocessors used for PC peripheral, communications and digital consumer applications—usually referred to as "embedded" processors—generally use either a generic x86 processor or one of many RISC (Reduced Instruction Set Computer) architectures. RISC cores reduce chip complexity by using simpler instructions and keeping the instruction size constant without microcode layer or associated overhead. There are several mainstream RISC architectures, most notably MIPS, PowerPC and ARM. These architectures usually require a license.

Microprocessors are also classified according to bit width, which defines the size of the instructions sent over the external bus (some processors use a higher bit-width on the interior of the processor; only the external bus is used for classification). Most PC CPUs use a

32-bit external bus, but can support 64-bit extensions. AMD first introduced 64-bit extension in 2003 and Intel followed suit in 2004; virtually the entire market has transitioned at this point.

In the server space, low-end and mainstream servers use standard 32-bit processors with 64-bit extensions prevalent in the PC market, while high-end servers use proprietary or licensable 64-bit processors (e.g., Sun Microsystems' SPARC or IBM's PowerPC). Intel also offers a standard 64-bit processor for this market (branded Itanium), but has had trouble gaining share from proprietary systems.

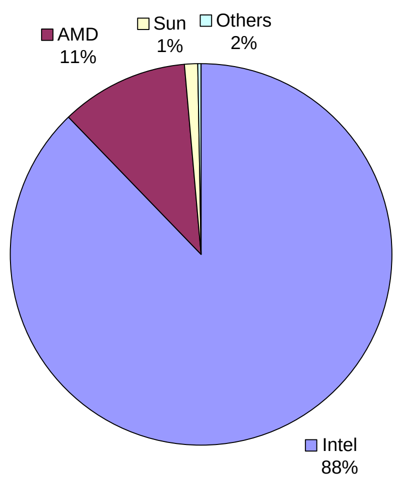
In the embedded market, processors use a mix of 8-, 16-, 32-, or 64-bit processors, depending on the application. The highest end processors would be used in communications infrastructure equipment like core routers, switches or firewalls, while the lowest end would be used in consumer electronics or industrial applications. Note that only discrete microprocessors are included in this segment. Most non-PC applications that require a microprocessor actually integrate a licensable RISC core into another ASSP within the system; these are not captured here.

Market Forecast: Microprocessors are heavily tied to the PC market and thus are more dependent on demand for this one application than on broader semiconductor or electronics demand. Overall, we expect microprocessors to grow from $39.9 billion in 2010 to $52.9 billion in 2015, a 6% CAGR.

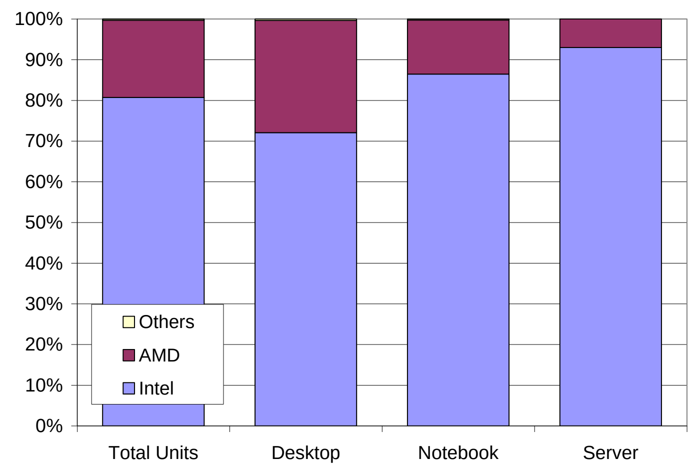
Competitive Environment: The microprocessor market is one of the most concentrated markets in semiconductors. Intel has effectively maintained a near-monopoly on the PC and server microprocessor market, and therefore held 84% MPU revenue share overall in 2010. Intel's share of the PC and server microprocessor market is 88%, with a somewhat lower unit share (81%), since its microprocessor ASPs are higher than its competitors'. AMD held 10% revenue share in 2010, with 11% share in PCs and servers (19% unit share). AMD competes with Intel in all market segments. Other PC/server microprocessor vendors include Sun and Via.

The diagrams below depict revenue and unit share in the PC and server microprocessor markets for 2010.

2010 PC and Server Microprocessor Revenue Share



2010 PC and Server Microprocessor Unit Share

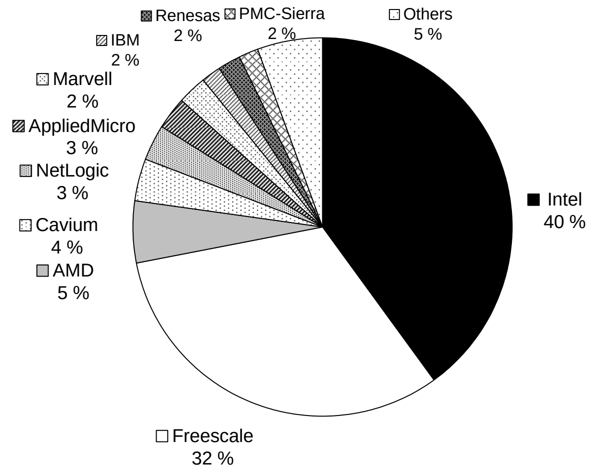


Source: IDC, Oppenheimer & Co.

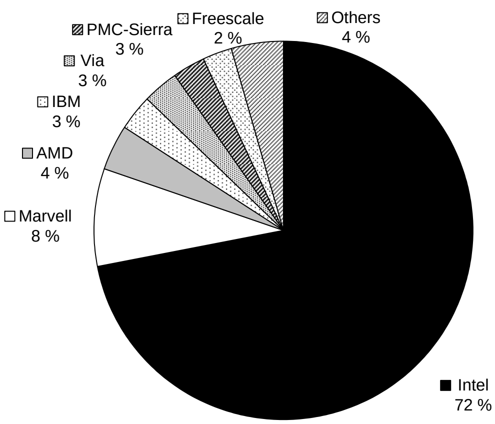
The embedded microprocessor market is somewhat more fragmented, not surprising given the number of competing architectures and the diversity of applications served. Again, we are counting only discrete MPUs. Intel is the largest player overall with 40% market share within this segment. Intel's PC processors find lots of use in non-PC applications; typically these will be the lower end or lower-voltage versions of its product portfolio. Freescale boasted the No. 2 position with 32% share in 2010, giving the company 3% share of the overall microprocessor market. Within embedded, Freescale held the top position in the communications, consumer, and "other" categories.

AMD followed as the No. 3 supplier of embedded processors with 5% share and the No. 3 position in PC and consumer. Cavium followed with 4% as the company has been rapidly taking share in embedded comms market with its multicore product offering. NetLogic (recently announced to be acquired by Broadcom) rounded out the top 5 at 3% share. The company has also increased its share in embedded comms market with its acquisition of RMI. Rounding out the top 10 are AppliedMicro, Marvell, IBM, Renesas and PMC-Sierra.

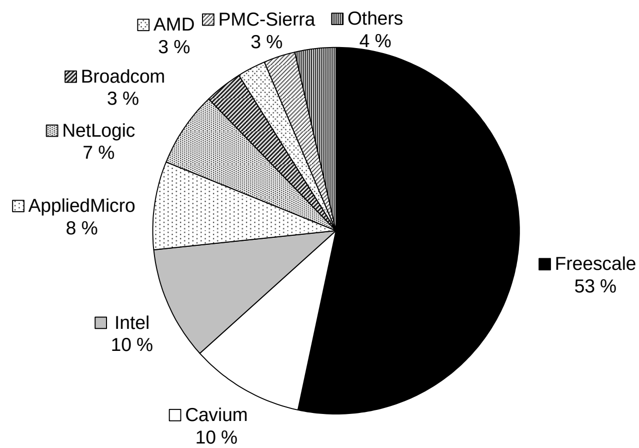
2010 Embedded Processor Market Share



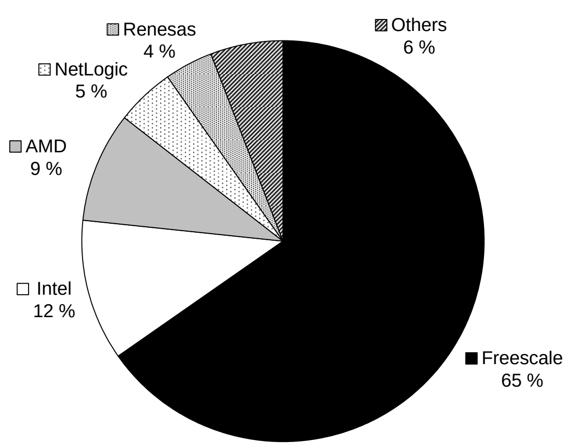
2010 Computing Embedded MPU Market Share



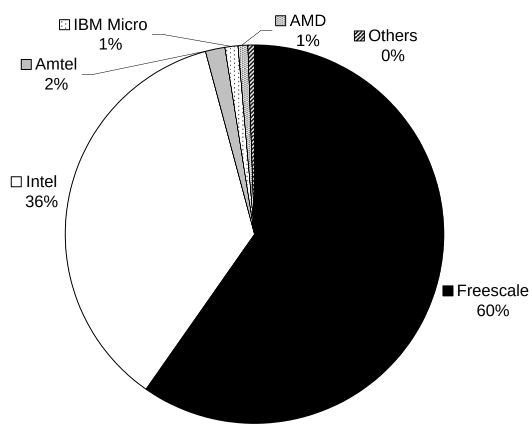
2010 Comm Embedded MPU Market Share



2010 Consumer Embedded MPU Market Share



2010 Other Embedded MPU Market Share



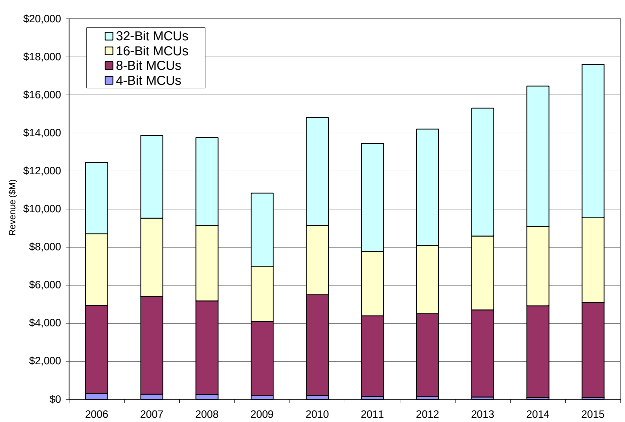
Source: Dataquest, Oppenheimer & Co.

Microcontrollers

Microcontrollers (MCUs) – Stand-alone devices that perform dedicated or embedded compute functions within an overall system. MCUs contain single or multiple processing mini-architectures, as well as on-chip RAM, ROM, and I/O logic.
Key Types: 4-, 8-, 16-, 32-bit (or greater). Automotive, consumer, computer, IC card, wireless communication, wired communication.

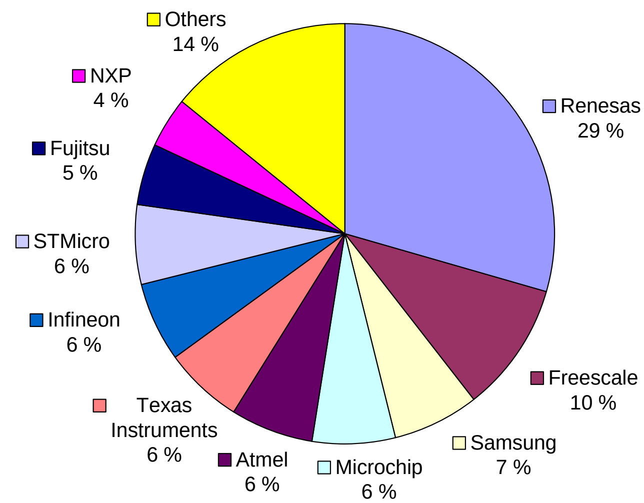
Market Forecast

•Microcontrollers are expected to grow at a 4% CAGR, from $14.8 billion in 2010 to $17.6 billion in 2015.
•Growth to be led by 32-bit MCUs.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

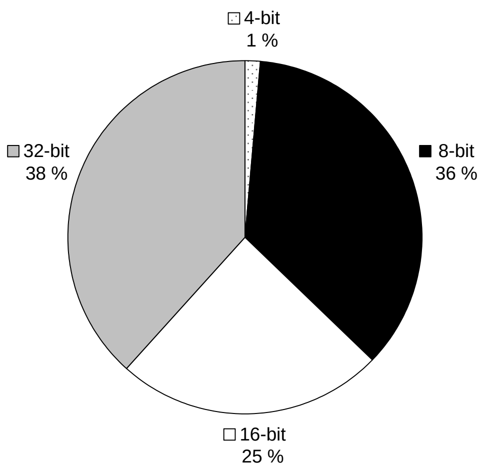
Microcontrollers are stand-alone computation devices that perform dedicated or embedded compute functions within a system. Microcontrollers incorporate simpler processing architectures than microprocessors and are often used to perform only a specific function within a system. They contain some form of RAM and ROM memory as well as additional I/O logic on-chip, and thus can perform relatively simple processing tasks without the need for traditional support ICs found in more complex systems. This lowers the system cost and speeds design and implementation.

Like microprocessors, microcontrollers are classified by external bit width. 4-bit devices are still in use, primarily to control the simplest electronic devices (e.g., a toaster oven) or for very simple embedded functions within a larger system (e.g., raise or lower a car window). Eight-bit devices are the second largest single segment in revenue terms at 36% of total microcontroller revenue in 2010 and represented roughly 45% of all microcontroller units shipped. Sixteen-bit microcontrollers totaled 25% of revenue, and 32-bit MCUs have grown rapidly to 38% of total revenue.

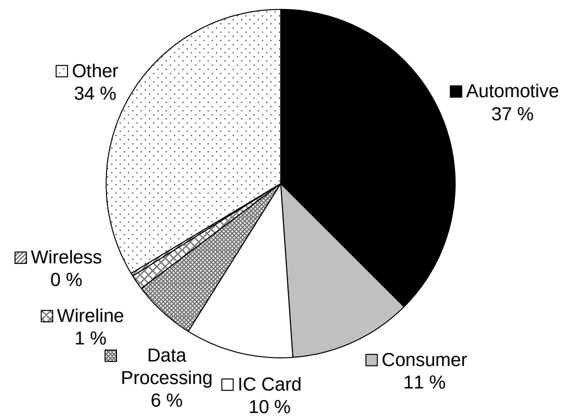
By end market, the largest single consumer of microcontrollers is the automotive market, which accounted for 37% of total microcontroller sales in 2010. Automotive electronics systems perform a diverse array of relatively simple tasks (though higher end cars have more complex systems), perfectly suited for microcontrollers. Consumer devices followed at 11% of sales; this includes the simple consumer appliances controlled by MCUs as mentioned above, as well as embedded functions within more complex devices. Smart cards accounted for 10%. Data processing accounted for 6% and wireline and wireless each accounted for 1% or less, as these devices tend to use dedicated ASSPs and DSPs.

The exhibits below display microcontroller revenue share by bit width and application.

2010 Microcontroller Revenue Share By Bit Width



2010 Microcontroller Revenue Share By Application



Source: WSTS, Oppenheimer & Co.

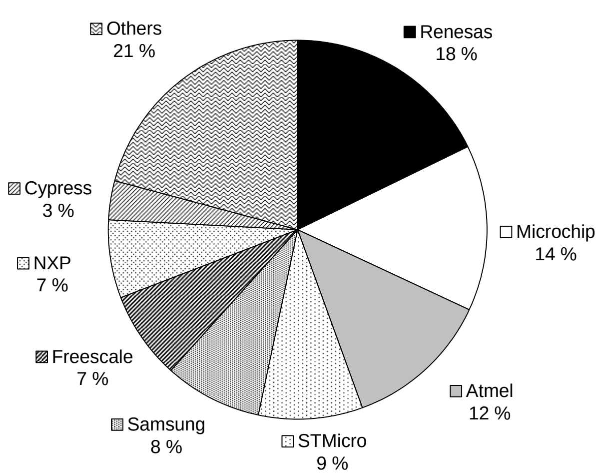
Market Forecast: Microcontrollers are expected to see healthy growth given their broad exposure to the electronics landscape. Overall, we expect microcontrollers to grow from $14.8 billion in 2010 to $17.6 billion in 2015, a 4% CAGR. The increasing complexity of automotive and consumer systems should continue to favor the higher bit width segments. Eight-bit and 32-bit (or greater) devices are each expected to grow at a -1% and 7% CAGR, respectively. Sixteen-bit devices are expected to grow 4% through 2015, while 4-bit is expected to trail the overall market with a -14% CAGR.

Competitive Environment: The microcontroller market is highly fragmented due to the diversity of applications served. The largest supplier in 2010 was Renesas (acquired NEC), with 29% market share. Renesas is the No. 1 supplier of 8-bit, 16-bit and 32-bit MCUs. Renesas is also the leading supplier to automotive applications.

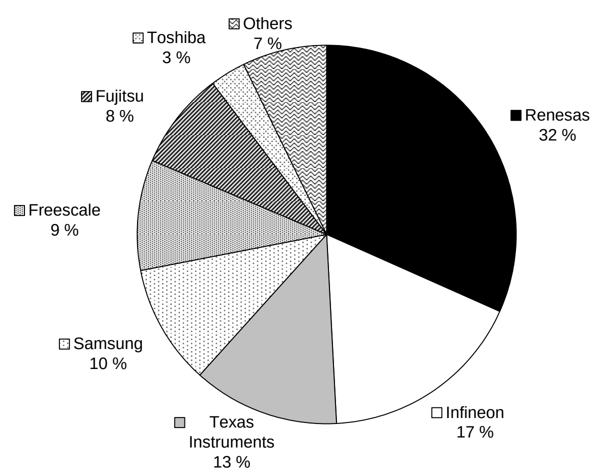
Freescale was the No. 2 supplier with 10% share and the No. 2 and No. 5 supplier of 32-bit and 16-bit microcontrollers, respectively; Freescale is also the No. 2 supplier in automotive applications. Samsung was the No. 3 provider of microcontrollers with 7% share and the No. 4 and No. 5 supplier of 16-bit and 8-bit MCUs, respectively. Samsung is also the leading provider of Consumer microcontrollers and No. 3 supplier of Consumer MCUs. Microchip and Atmel rounded out the top five with 6% each. Other major suppliers include Texas Instruments, Infineon, STMicroelectronics, Fujitsu and NXP.

The exhibits below display microcontroller market share, first by bit width and then by application.

2010 8-bit and below MCU Market Share



2010 16-bit MCU Market Share



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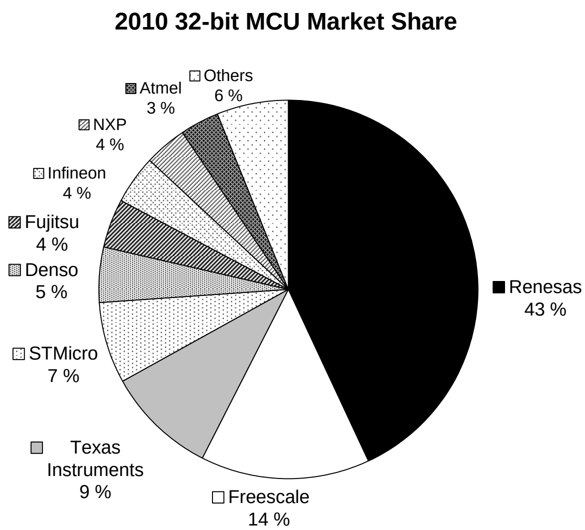
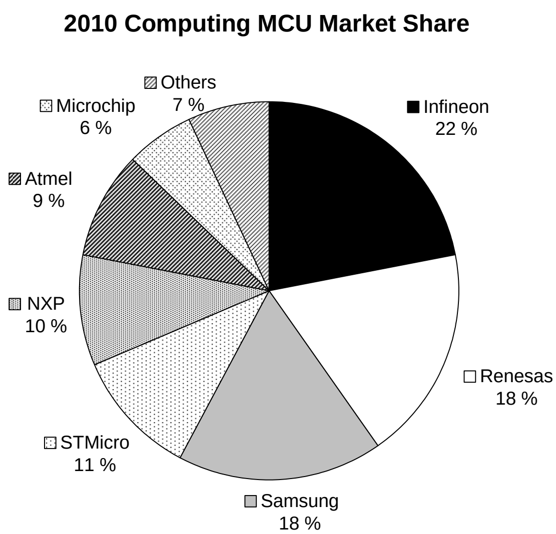
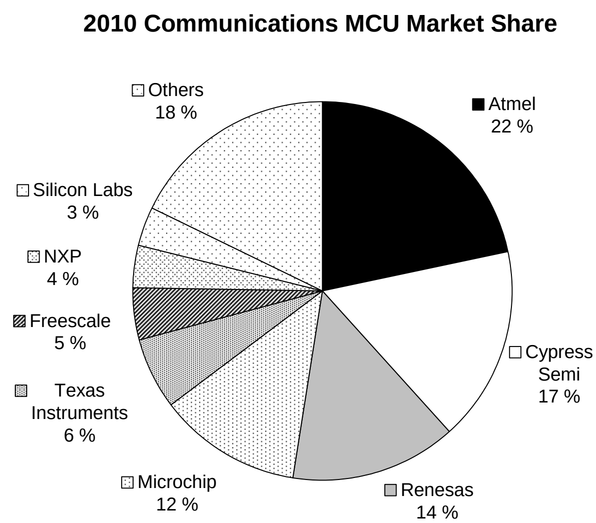
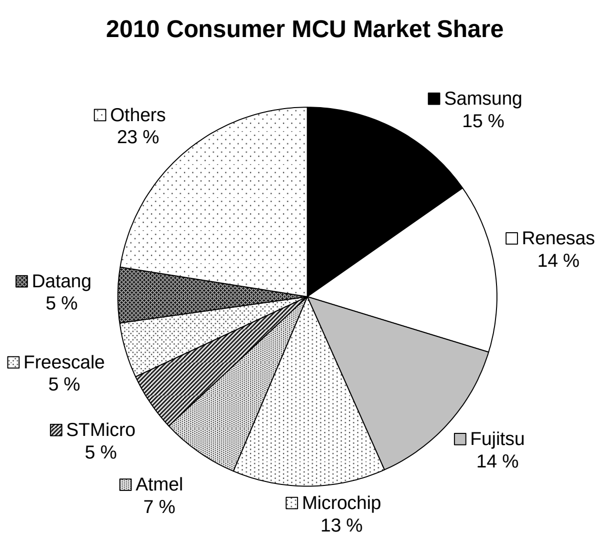
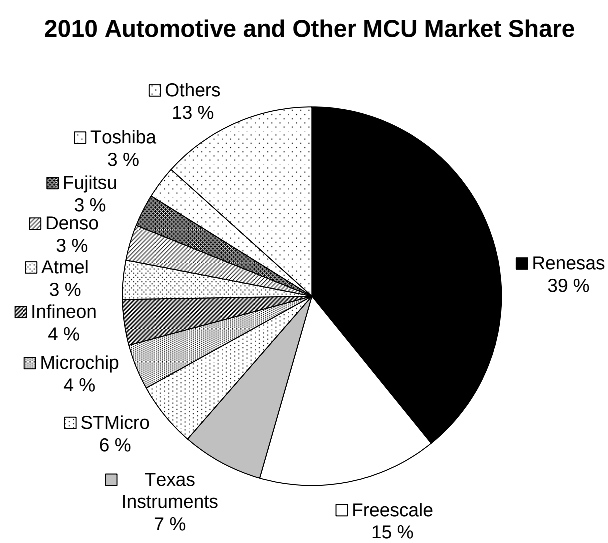


Source: Dataquest, Oppenheimer & Co.









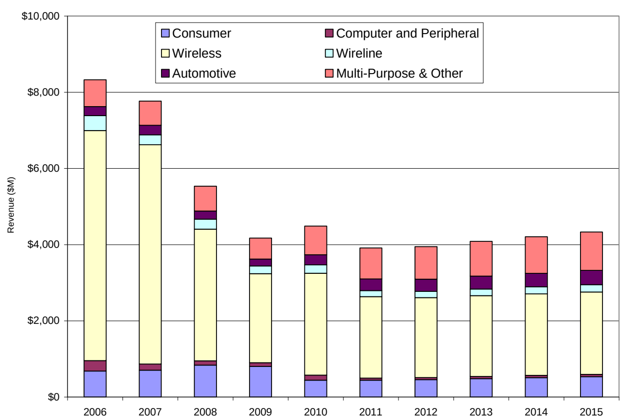
Source: Dataquest, Oppenheimer & Co.

Digital Signal Processors

Digital Signal Processors (DSPs) - Specialized high speed programmable processors designed to perform real-time processing of digital signals, such as digital voice and video.
Key Types: Cellular basebands, basestation DSPs, VoIP processors, automotive DSPs.

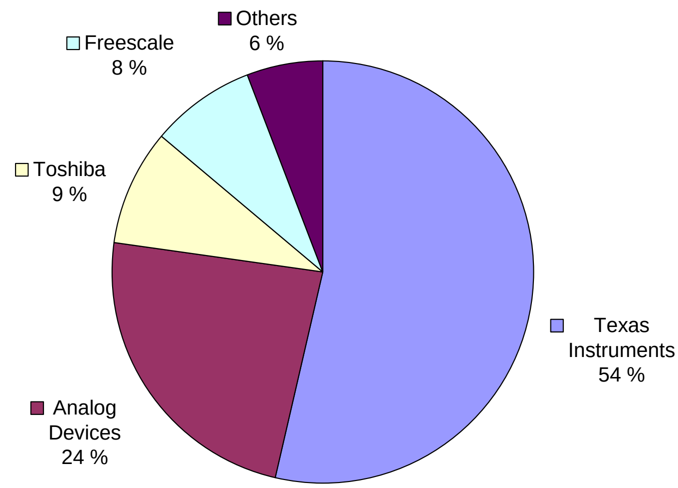
Market Forecast

•DSPs are expected to decline at a 1% CAGR, rising from $4.5 billion in 2010 to $4.3 billion in 2015.
•DSPs should trail the overall market as wireless handset share shifts to vendors of logic based basebands.
•Consumer and Automotive remain growth areas.



Source: WSTS, Oppenheimer & Co.

Key Competitors



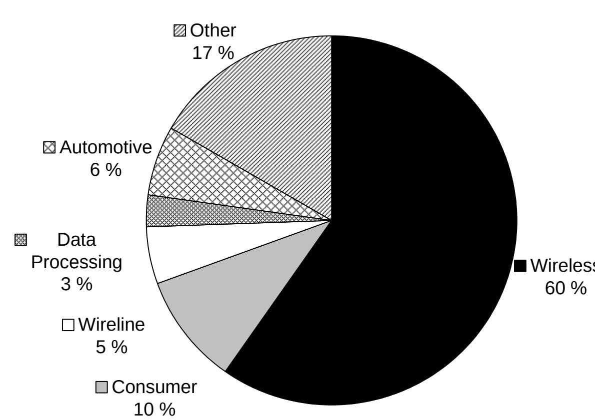
Note: Includes DSPs that are customized for specific applications, but excludes digital logic circuits with embedded DSPs.

Dataquest, Oppenheimer & Co.

Digital signal processors (DSPs) are high-speed programmable specialized digital processors that are optimized for performing intensive computations typically required in communications and multimedia applications. DSPs are almost always used in applications that require real-time processing of digital signals. Examples include handset basebands, digital camera image processors, IPTV decoders, and VoIP processors.

By end market, 60% of all DSP revenue is derived from the wireless market, both from handsets and basestations. Another 10% is derived from the consumer market, primarily for portables like digital cameras and MP3 players as well as high-end consumer devices like Blu Ray recorders; 5% sell into wireline, mostly broadband modems; 3% sell into the computing market; and 6% is derived from automotive. The exhibit to the right displays 2010 revenue share in DSPs by application.

2010 DSP Segmentation by Application



Source: WSTS, Oppenheimer & Co.

Market Forecast: We expect DSPs to trail the overall semiconductor market declining at a 1% CAGR, falling from $4.5 billion in 2010 to $4.3 billion in 2015. Though handset units are growing nicely, a change in competitive dynamics in the wireless market (which as mentioned above represents the largest end market for DSPs), is shifting share to vendors of special purpose logic solutions versus DSPs. One key example of this is Nokia, which has historically used TI as its primary baseband supplier for handsets, and is now adding Broadcom, STMicro, and Infineon as suppliers. TI's technology is classified as DSPs, while the others are classified as special purpose logic (TI tends to wrap logic around its standard programmable DSP core; thus, it is classified as a DSP, while others design a baseband ASSP from the ground up and incorporates a DSP-engine; thus, its devices are usually classified as special purpose logic). We expect wireless DSPs to decline by 4% through 2015 as this transition takes place.

Despite these wireless trends, DSPs remain at the core next generation audio and video devices. They are fast, easy to program, extensively libraried and inexpensive. Many consumer devices such as digital cameras, portable media players, and IP set-top boxes use DSPs as the core multimedia engine, though in many cases OEMs have transitioned to hard-wired ASSPs with embedded DSPs. The newest devices, however, tend to be based on DSPs as ASSPs do not yet exist. In total, we expect consumer-related DSPs to grow at a 4% CAGR, from $442 million in 2010 to $532 million in 2015.

DSPs should see a modest increase in penetration in automotive electronics following the 2008-2009 downturn, as the product cycles within the automotive market are quite lengthy. This market is expected to grow by 7% through 2015, potentially increasing to 9% of the total DSP market revenue through 2015.

Competitive Environment: The DSP market is highly concentrated, with four players controlling nearly 95% of market revenue in 2010. TI held the No. 1 position in 2010 with 60% market share, with its leadership position in GSM, GPRS, and UMTS baseband chips and its strong ties to handset leaders Nokia, Motorola, and RIM. TI also classifies its OMAP brand of application processors as DSPs. Outside of handsets, TI has a leading presence in all embedded segments, and is particularly strong in 3G basestations and VoIP equipment.

Analog Devices was No. 2 with 24% share in 2010. Note that Analog Devices sold its handset business in 2007 to Mediatek, but is still a significant supplier of DSPs for the infrastructure market.

Toshiba was the No. 3 provider of DSPs in 2010 with 9% share. Freescale was No. 4 with 8% share in 2010, much of it derived from its relationship with its former parent company, Motorola. Freescale also represents TI's chief competition for high-end embedded designs. Other vendors include Renesas, Cirrus Logic, Sunplus, and Fujitsu.

Note that most special purpose logic devices (discussed later) incorporate some DSP circuits. Most mainstream market segmentations of DSPs exclude these devices, though the lines of distinction are somewhat subjective. For instance, both Texas Instruments and Qualcomm make digital baseband chips for cellular handsets, but TI's devices are considered DSPs and Qualcomm's are considered special purpose logic. As mentioned above, the defining line usually rests on how the device is designed. In the case of digital basebands, TI tends to wrap logic around its standard programmable DSP core; thus, it is classified as a DSP. The same goes for Freescale, Agere, and Analog Devices. Qualcomm, on the other hand, designs a baseband ASSP from the ground up and incorporates a DSP-engine; thus, its devices are usually classified as special purpose logic. The same applies to baseband suppliers like NXP, Infineon, Mediatek, Marvell, and Broadcom.

Digital Logic

Digital Logic:

Devices designed to perform specialized digital processing within a system

Five Key Markets:

Special Purpose Logic

Display Drivers

General Purpose Logic

ASICs

FPGAs/PLDs

Digital logic includes all non-microcomponent logic devices. These devices contain more “hard-coded” logic circuits as compared to microcomponents, and thus typically are designed from the ground up for a particular function. Some software programmability is always incorporated, but it is usually to adjust certain details about the device’s core functioning (e.g., which features to turn on, how fast to run the device, etc.). In general, logic devices trade the benefits of programmability for better performance, lower cost, and better power management.

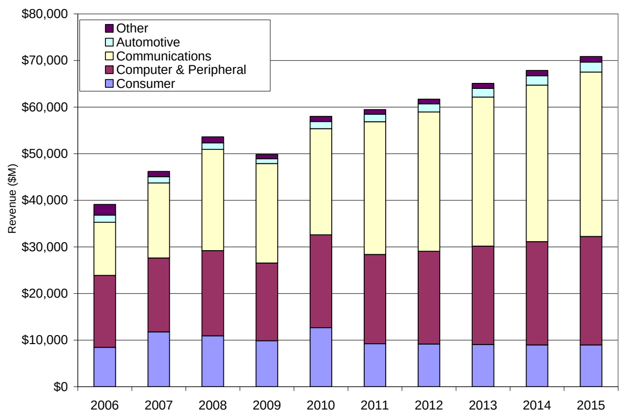
The largest sub-segment of digital logic is known as special purpose logic, which includes specialized ASSPs designed for a specific application. Only standard, “off the shelf” (sometimes referred to as “merchant”) devices are included, though some of these ASSPs are customized for a specific OEM customer when there is a large volume opportunity. The other sub-segments within the digital logic category are display drivers, general purpose commodity logic, custom logic (gate array and standard cells, also called ASICs), and field programmable logic devices (PLDs and FPGAs).

Special Purpose Logic

<u>Special Purpose Logic</u> - Application specific digital ICs sold as standard products, designed to service a particular application. Includes ASSPs for PC, display, communication, consumer, and automotive applications.
Key Types: PC core logic, GPUs, HDD SoCs, WLAN/Bluetooth baseband, Ethernet controllers, audio/video decoders, video back end ICs.

Market Forecast

•We expect special purpose logic to grow at a 4% CAGR, from $58.0 billion in 2010 to $70.8 billion in 2015.
•Market growth boosted by integration trends, as digital SoCs suck in discrete, memory, and analog.
•Growth to be led by communications and automotive ASSPs.



Source: WSTS, Oppenheimer & Co.

Key Competitors

PC and Server
Intel
NVIDIA
AMD
Via
Broadcom

Storage and Peripheral
Marvell
LSI
Mediatek
STMicroelectronics
Renesas

Communications
Qualcomm
Broadcom
NXP
Texas Instruments
Intel/Infineon
Conexant
CSR
Marvell
LSI

Consumer
STMicroelectronics
NXP
Broadcom
Sony
Toshiba
Renesas
Mediatek
CSR/Zoran

Special purpose logic devices are digital logic circuits sold as standard products, usually designed specifically for a particular application (though not for a specific socket—those are classified as custom ASICs). Designers typically incorporate some degree of system-level knowledge in the architecture, as these devices typically form the core of the equipment into which they are designed.

As discussed in the section on analog ASSPs, many of the highest volume electronics applications are served by a chipset that includes one or more analog ASSPs paired with one or more digital logic devices or ASSPs offered by the same vendor, or by multiple vendors on a single reference design. The analog and digital ASSPs are thus designed in, and subsequently purchased by the OEM, at the same time. A great example of this would be a wireless LAN chipset, where most vendors offer a chipset that includes an analog RF chip along with a digital baseband/MAC device. In almost all cases, a design win is awarded for the entire chipset as opposed to individual components. For purposes of this discussion, only the digital device within the chipset would be included.

As in the analog ASSP segment, the special purpose logic category is segmented by application; i.e., consumer, communications, computing and peripheral, automotive and multipurpose. In 2010, computing and peripheral logic represented roughly 34% of total market revenue. Communications and consumer logic represented 39% and 22%, respectively, and automotive and other logic totaled 5%. The automotive and other segments are understandably small, as these equipment types are often implemented with microcontrollers as opposed to hard-wired special purpose logic devices.

Market Forecast: The market for special purpose logic is expected to outpace overall semiconductor growth as electronic devices use an increasing amount of specialized processing power. There is also a boost from integration, as it is common for digital ASSP vendors to integrate increasing amounts of general purpose logic, embedded memory, and analog circuits into their devices over time. Overall, we expect the market to grow at a 4% rate, rising from $58.0 billion in 2010 to $70.8 billion in 2015. Automotive and communications should see the strongest CAGRs at 9% and 7%, respectively, followed by PC at 3%. Consumer is expected to decline at a 7% CAGR.

Competitive Environment: Given the broad set of applications and customers that use special purpose logic, the market is large and rather fragmented. The top suppliers for PC applications include chipset and graphics vendors Intel, NVIDIA, AMD, Via, and Broadcom. For storage and peripheral, top vendors include Marvell, LSI, Mediatek, STMicroelectronics, Renesas, Panasonic, M-Star, and Genesis.

Top consumer electronics IC vendors include STMicroelectronics, NXP, Sony, Broadcom, Toshiba, Sanyo, Renesas, Mediatek, Zoran, Sunplus, Genesis, and Trident. Note that many of the big, vertically integrated Japanese IC makers that supply the consumer electronics market are excluded since their products would be classified as custom ASICs; the same goes for most suppliers into the video game console and handheld markets.

Top vendors for communications include wireless IC leaders Qualcomm, NXP, Intel/Infineon, Broadcom, Marvell and Mediatek. Note that the segment excludes much of the wireless handset revenue of TI, Freescale, LSI, and Analog Devices as basebands from these companies are generally classified as DSPs. On the wireline side, key ASSP vendors include Broadcom, Conexant, Texas Instruments, Intel, Marvell, CSR, LSI, PMC-Sierra, and Qualcomm/Atheros.

The table below provides additional detail, listing some high-volume special purpose logic devices and their vendors.

Market Segment	Device	Key Vendors
Computing & Peripheral	PC core logic	Intel, NVIDIA, AMD, Via, Broadcom
	Graphics controllers	NVIDIA, AMD
	PC display controllers	M-Star, Realtek, Novatek, Pixelworks
	HDD SoCs & hard disk controllers	Marvell, LSI, STMicroelectronics, Infineon, Renesas
	ODD controller	Mediatek, Renesas, Panasonic, Ricoh, Rohm, Pioneer, NXP
	Printer SoC	STMicroelectronics, Texas Instruments, Marvell, PMC-Sierra, Conexant, LSI, CSR/Zoran
Communications	Cellular baseband	Qualcomm, NXP, Intel/Infineon, Broadcom, Marvell, and Mediatek. Note that most of the handset baseband products offered by TI and Freescale are excluded as they are classified as DSPs.
	Ethernet controllers and switch ICs	Broadcom, Marvell, Intel, Realtek, Avago, Standard Micro, Vitesse
	Wireless LAN baseband/MAC	Broadcom, Qualcomm/Atheros, Intel, Marvell, Texas Instruments, Ralink/Realtek, CSR
	Bluetooth baseband/MAC/SoC	CSR, Broadcom, Qualcomm/Atheros, Texas Instruments, Infineon, NXP, STMicroelectronics, Marvell
	Modem CPE SoC	Broadcom, Infineon, Intel, LSI, Ikanos
	Telecom/Datacom	PMC-Sierra, LSI, Infineon, AppliedMicro, Vitesse, Cortina, Mindspeed, Mellanox, TranSwitch
	Digital Cordless	NXP, Infineon
Consumer	Set-top box back-end	STMicroelectronics, Broadcom, NXP, Sigma Designs
	Digital TV back end	NXP, Trident, Sharp, Genesis, Mediatek, CSR/Zoran, Renesas, Broadcom, Pixelworks
	DVD decoder/encoder	Mediatek, SunPlus, CSR/Zoran, Magnum LSI, ESS, Cheertek
	Digital camera image processor	TI, CSR/Zoran, Ambarella, SunPlus, Renesas
	MP3/PMP decoder	NVIDIA, Broadcom, NXP, TI

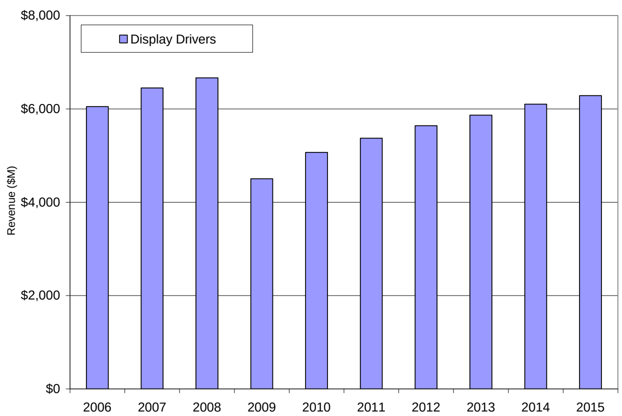
Source: IDC, Dataquest, Oppenheimer & Co.

Display Drivers

<u>Display Drivers</u> - Standard logic devices designed to control and drive flat panel displays such as LCD or plasma.
Key Types: LCD driver, plasma display driver, source driver, gate driver.

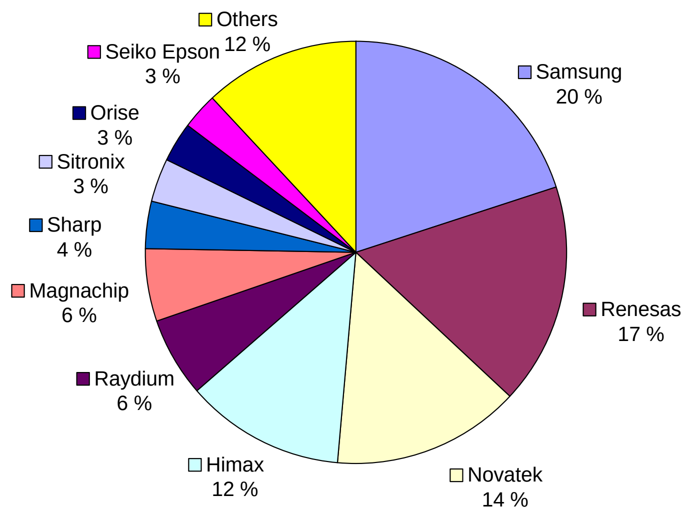
Market Forecast

•We expect display drivers to grow at a 4% CAGR, from $5.1 billion in 2010 to $6.3 billion in 2015.
•Unit shipments should remain strong through 2015, though pricing pressure will mute revenue growth.
•Flat panel TV, notebook monitors, wireless handsets, and portable gaming are the primary growth drivers.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Display drivers are specialized logic devices designed to control and drive flat panel displays such as LCD or plasma. Traditional CRT display technology uses a phosphorous coated screen to trap light flashed from a light source; flat panel displays, on the other hand, use semiconductor driver ICs to manipulate pixels on an LCD or plasma screen.

There are two basic kinds of drivers: source and gate. Source drivers sit across the top of the panel and generate signals that penetrate individual columns of pixels. Three source drivers are needed for each column of pixels: red, green and blue. Gate drivers run along the side of the panel and manipulate individual rows of pixels. Signals generated by the gate drivers intersect signals driven by the source drivers, turning individual pixels on or off.

Market Forecast: We expect display drivers to grow at a 4% CAGR, from $5.1 billion in 2010 to $6.3 billion in 2015. In some cases, growth is being driven by a migration from CRT—such as desktop monitors and LCD/plasma TV. In other cases, LCD screens are an integral part of a category that itself is growing nicely, such as notebooks, wireless handsets, and portable gaming. In all cases, price pressure is a major factor weighing on the revenue CAGR.

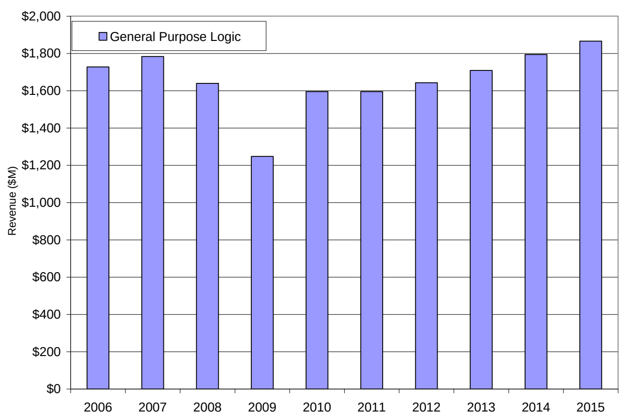
Competitive Environment: Display drivers are quasi-commodity parts, though driver performance does differentiate products from one vendor to the next. The top suppliers in 2010 included Samsung with 20% market share, Renesas with 17%, Novatek with 14%, Himax with 12%, and Raydium with 6%. Other significant suppliers include Magnachip, Sharp, Sitronix, Orise and Seiko Epson.

General Purpose Logic

General Purpose Logic - Standard commodity catalog logic parts designed for use in multiple applications in various end markets.
Key Types: Simple gates, flip-flop circuits, switches, registers.

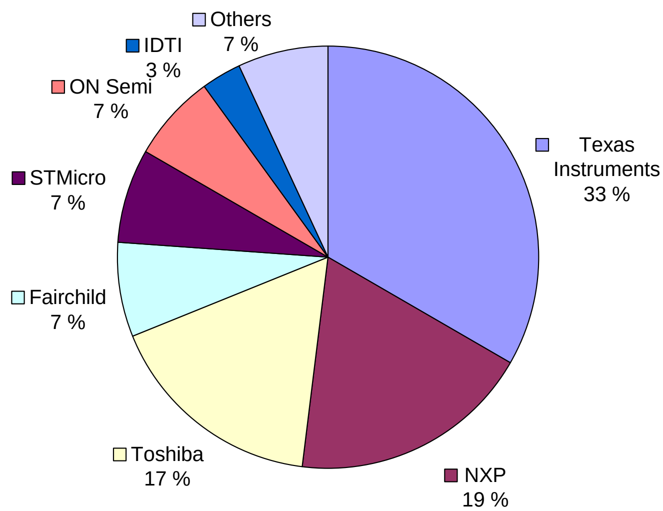
Market Forecast

•We expect general purpose logic to grow at a 3% CAGR over the next few years, rising from $1.6 billion in 2010 to $1.9 billion in 2015.
•Growth should trail overall semi market growth as integrated ASSPs eliminate the need for separate logic circuits in many applications.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

General purpose logic includes standard logic parts designed for use in multiple applications in various end markets. Though designed to perform a specific function, these ICs are not tailored for use in any one application. Parts in this category are usually very low ASP, very high-volume devices; examples include simple gates, flip-flop circuits and registers; they are typically used to assist the functioning of larger logic or processing devices. Many of these parts are commodities, though some are more proprietary.

Market Forecast: The market for general purpose logic is heavily tied to the overall semiconductor cycle, as these devices sell into every end market and application in the electronics landscape. They are also heavily commoditized and pricing can compress severely in down-cycles and rise in up-cycles. We expect growth in this segment to trail that of the overall semiconductor sector, as ASSP vendors continue to integrate additional functionality into their devices that eliminate the need for external general purpose circuits in many applications. Overall, we expect a 3% CAGR through 2015, with the market growing from $1.6 billion in 2010 to $1.9 billion in 2015.

Competitive Environment: The general purpose logic category includes a wide variety of device types, but most are commodities, and thus a few dedicated players dominate the market. Most of these are vertically-integrated IDMs that use standard logic as a fab filler, though a few niche players are fabless. The top standard logic producer in 2010 was Texas Instruments, with 33% market share. NXP was second with 19%; Toshiba was third with 17%; Fairchild was fourth with 7%; and STMicro rounded out the top five also with 7%. Other significant competitors include ON Semi and IDTI.

ASICs

ASICs (Application Specific Integrated Circuits) - Customized ICs designed for specific customers to be used in specific platforms.
Key Types: Standard cell, gate array.

Market Forecast

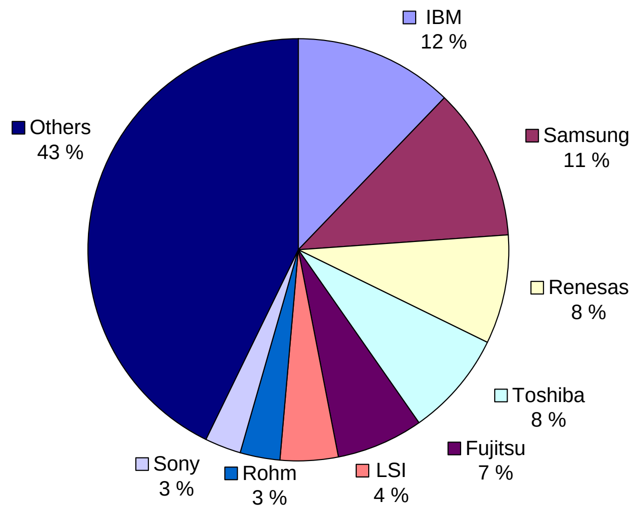
•We expect the ASIC market to grow at a 3% CAGR, from $8.0 billion in 2010 to $9.3 billion in 2015.

•Game consoles are a volatile driver; in most other applications the trend away from ASICs should continue.

•The shift from gate arrays to standard cells should continue as OEMs demand higher performance devices.

Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Moving away from standard logic devices and into the custom-designed realm, the ASIC (application specific integrated circuit) market includes all customized integrated circuits designed for specific customers to be used in a specific platform. The key distinction with an ASIC is that the OEM takes a heavy role in designing the device. The most prominent examples of ASICs come from the game console market, where most silicon is designed for a single platform, which, given the high volume it is likely to generate, justifies the cost of designing a custom chip. Note that despite being classified under the logic category, ASICs can include analog, digital, or memory circuits, as long as they are custom designed. Most ASICs, however, are pure logic devices anyway.

ASIC devices can either be designed by the equipment manufacturer internally—many OEMs maintain sizable chip design teams—or contracted out to an ASIC house. The level of cooperation between an OEM and an ASIC house can vary from program to program.

In terns of classification, ASICs are divided into two broad categories:

- **Gate Arrays**: Circuits consisting of fixed and regular arrangements of transistor cells forming a matrix of logic gates of various standard densities. An OEM using a gate array uses a series of software tools and macro libraries to design the mask for the top layers of the device, which determines its functionality.
- **Standard Cells**: Also known as "cell-based ICs," these circuits consist of user-specified arrangements of predefined and fixed sub-circuits of any function (analog, logic, memory). These ICs are designed from the ground up and use standard dimensions of components or gates to pack them together more uniformly. These are more costly than gate arrays but are more efficient.

ASICs tend to be the first solutions to be used in emerging electronic equipment markets, as most electronic devices require some level of specialized digital or analog processing, but few standard, off-the-shelf components exist during the introduction phase of the technology life cycle. These ASICs tend to be costly to design, but usually deliver the performance necessary to power the device given the custom design; and the costs can be spread over the life of the product if it takes off. Also, given the early stage of the technology life cycle, the OEM is likely earning high margins, justifying the cost of the ASIC.

As the technology matures and the market grows, other OEMs will enter the market with competitive offerings that either improve upon existing platforms or offer the same functionality at lower cost, or both (usually both). These competitive offerings will sometimes use newer ASIC solutions. Other times, they will leverage standard products (ASSPs) that may have come to market a few years into the life cycle of the emerging technology by IC vendors who were attracted by the growth prospects of the market as it took off. Over time, more and more OEMs will migrate to ASSP solutions, and the ASICs will disappear (and the ASIC vendors will be on to the next new market).

Although there will always be a need for ASICs, most OEMs will choose a standard product if it is available. This is the primary reason why the transition from ASICs to ASSPs is a constant theme in semiconductors (though it varies from market to market based on the stage of maturity). There are two notable exceptions: the first is where a single platform is likely to do so much volume that it justifies having a custom part designed for it. A prime example of this is the game console application mentioned above. The second case is where silicon performance is such a differentiating factor for the OEM that, to retain its competitive advantage, OEMs will develop ASICs instead of leveraging outside IC designers. A good example is Cisco, which views the performance of its switches and routers to be so integral to its strategy that it employs several hundred ASIC engineers.

Market Forecast: Overall, we expect the market for ASICs to grow at a 3% rate through 2015, rising from $8.0 billion in 2010 to $9.3 billion in 2015. We expect the ASIC CAGR to trail that of other logic segments, largely due to slow but steady cannibalization of the ASIC market by ASSPs and FPGAs. Still, the market should grow modestly through 2015, primarily due to increased ASIC content in the latest round of game consoles (Microsoft Kinect/Xbox 360, Nintendo Wii, Sony PS3, etc.). Were it not for the game console market, the overall ASIC market would show a slow but steady decline over time.

Within ASICs, we expect the trend toward standard cell-based ICs to continue as the market continues to favor higher performance devices (with lower performance devices most susceptible to ASSPs or FPGAs). Gate arrays should remain less than 5% of total ASIC revenue over time.

Competitive Environment: As described above, there are a number of different types of relationships in the ASIC market. Some OEMs are vertically integrated, and design and manufacture their own ASICs completely internally (this is common in Japan). On the other end of the spectrum, some OEMs contract with ASIC houses and leave chip design and manufacturing to the partner. Others fall somewhere in the middle, with the OEM maintaining an internal semiconductor design team, but partnering with an ASIC vendor for some of the IP as well as for gate construction and fabrication. This yields a vendor list that includes both OEMs (IBM, Toshiba, Fujitsu, Sony), IDMs (Renesas, Texas Instruments), and even fabless chip makers (LSI).

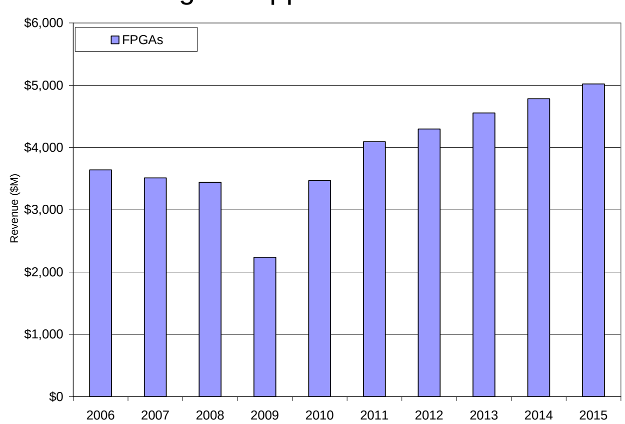
The largest ASIC house in 2010 was IBM, with 12% total share and a major presence in the game console market as well as in ASICs for wireline and storage applications. Samsung was second with 11%, and Renesas was third with 8%. Toshiba followed with 8%, and Fujitsu held 7%. Other significant ASIC suppliers include LSI, Rohm and Sony.

FPGAs/PLDs

Programmable Logic Devices (PLDs) – Devices that contain arrays of programmable logic gates that can be configured into higher level logic devices by the customer during system integration.
Key Types: Programmable Array Logic (PAL), Field Programmable Gate Array (FPGA), Complex Programmable Logic Device (CPLD).

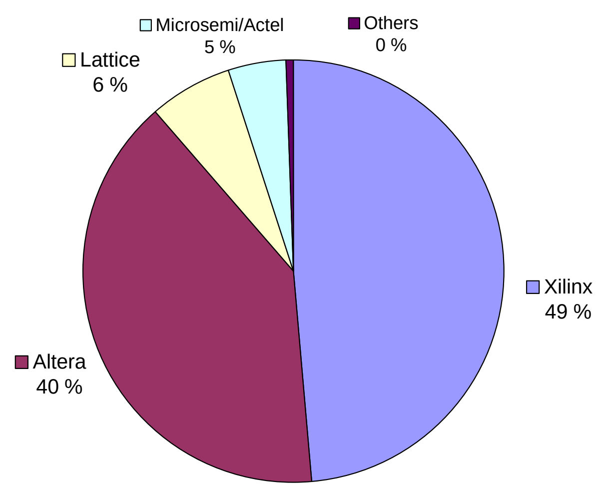
Market Forecast

•We expect FPGAs to grow at an 8% CAGR, rising from $3.5 billion in 2010 to $5.0 billion in 2015.
•While communications will remain a major driver, the emergence of low-cost, high-density FPGAs is broadening the application base for FPGAs.



Source: WSTS, Oppenheimer & Co.

Key Competitors



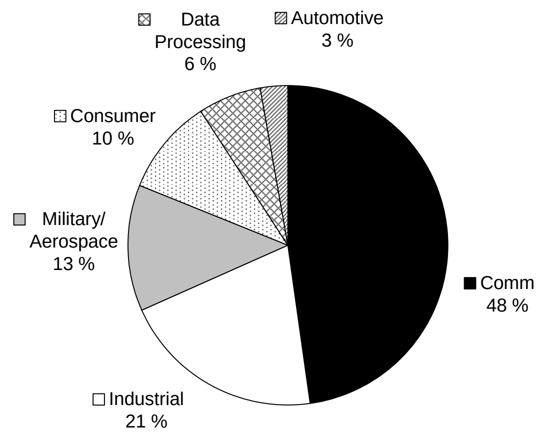
Source: Dataquest, Oppenheimer & Co.

Programmable logic devices (PLDs) consist of arrays of programmable logic gates that can be configured into higher level logic patterns by the customer during system integration. With a PLD, the OEM purchases a catalog part and uses the PLD vendor's software to design and configure the top layers of the device to perform the desired function. The OEM then inputs the architecture into the device, which stores it and adopts it for permanent use (some PLDs can be programmed multiple times). PLDs therefore provide the customizability of an ASIC without the need to design and fabricate ("fab") new devices for each platform. There are several key types of PLD devices:

- **Programmable Array Logic (PAL)**: Simple PLD devices with a small number of gates and a set number of inputs and outputs. Often used for glue logic.
- **Complex Programmable Logic Device (CPLD)**: High-density PLD consisting of macrocells that are interconnected through a central Global Routing Pool. This type of architecture provides high speeds and predictable performance, and is generally the preferred architecture for implementing high-speed logic.
- **Field Programmable Gate Array (FPGA)**: High-density PLD containing small logic cells interconnected through a distributed array of programmable switches. This type of architecture produces statistically varying results in performance and functional capacity, but offers high register counts.

In terms of end market use, PLDs are closely tied to the communications and industrial markets, which represented 48% and 21% of 2010 PLD revenue, respectively. Consumer applications have not historically been large users of PLDs, though newer flat panel TVs and advanced set-top boxes are adopting them, and in 2010 consumer represented 10% of the PLD market. Military/aerospace and data processing, primarily storage and server applications each consumed an additional 13% and 6% of 2010 revenue, respectively. Automotive represented just 3% of the market. The exhibits below display the end market usage for PLDs as well as top PLD applications by end market.

2010 PLD Revenue Share By Application



Top PLD Applications, By End Market

Data Processing
- Servers
- Enterprise storage
- Printers

Wireless
- Infrastructure (baseband subsystem)

Wireline
- Routers
- Broadband infrastructure
- OTN
- SONET add/drop multiplexers
- MSPPs
- LAN switches
- SAN switches
- CO switches
- PBXs
- VoIP gateways

Consumer
- LCD TV
- Plasma TV
- Digital CRT TV
- DVD recorders
- DVRs
- Set-top boxes
- Digital cameras/ camcorders

Industrial
- Manufacturing systems
- Instruments
- Medical equipment
- Security/ energy management

Source: IDC, Dataquest, Oppenheimer & Co.

Market Forecast: Programmable logic has become an important solution in advanced wireline and wireless communications, with this end market representing the largest chunk of PLD revenue (~48% of PLD revenues in 2010). As a result, demand for PLDs was very volatile over the last decade, hit especially hard in 2001 and 2002 as demand for components in the wired telecom infrastructure market declined significantly. The market rebounded strongly in 2003, and subsequent years have been characterized by more consistent demand as wireline and wireless infrastructure demand stabilized.

Looking ahead, PLD vendors remain focused on the communications market, but are also broadening their product offerings to include smaller, lower cost PLDs to compete in consumer, industrial, data processing applications that have traditionally favored ASICs or ASSPs. While communications should continue to outweigh this opportunity, these new markets should add to the long-term SAM (served available market) for PLDs. In total, we expect programmable logic revenues to grow at an 8% rate, rising from $3.5 billion in 2010 to $5.0 billion in 2015.

Competitive Environment: The PLD market is highly concentrated and has undergone a fair amount of consolidation in the past few years as the complexity and size (in terms of number of transistors) has steadily increased. In 2010, the top three vendors held 95% share. Xilinx was the No. 1 vendor in 2010 with 49% share. Altera followed at No. 2 with 40% share and Lattice held 6%. Other PLD vendors include Actel (acquired by Microsemi in 2010), Cypress, Quicklogic and Atmel.

Memory

Memory:

Devices designed to store electrical data, either temporarily or permanently

Five Key Markets:

Volatile Memory	Non-Volatile Memory
DRAM	NOR Flash
SRAM	NAND Flash
	Legacy Non-Volatile Memory

Memory devices are digital semiconductor devices designed to store data in an electronic format on either a temporary or permanent basis. Though they are digital in nature, the manufacturing processes used to build memories are often quite different from a bulk CMOS process, especially in the case of DRAM and NAND flash. In nearly all cases, they are optimized for cost and high-volume production.

Volatile memory includes those memory devices that lose their stored information when they lose power. The most important types are DRAM (dynamic random access memory) and SRAM (static random access memory).

Non-volatile memory retains the stored information when the system is powered off. The most important types are NOR flash, NAND flash, mask ROM, EPROM and EEPROM (we group the latter three in a “legacy” category).

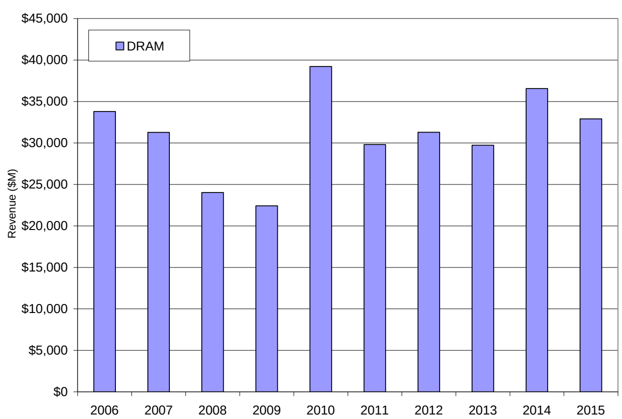
Note that semiconductor-based storage is often referred to as “solid state” storage, in contrast to magnetic (hard disk drive), optical (CD and DVD), or tape storage. Semiconductor-based storage is more expensive on a per-bit basis than all of these media, but it is faster and far more flexible in terms of its use.

DRAM

<u>DRAM (Dynamic Random Access Memory)</u> - The most common type of volatile memory, used primarily as system memory in PCs and servers.
Key Types: SDRAM (Synchronous DRAM), DDR (Double Data Rate), DDR2, DDR3, QDR (Quad Data Rate), RDRAM (Rambus DRAM).

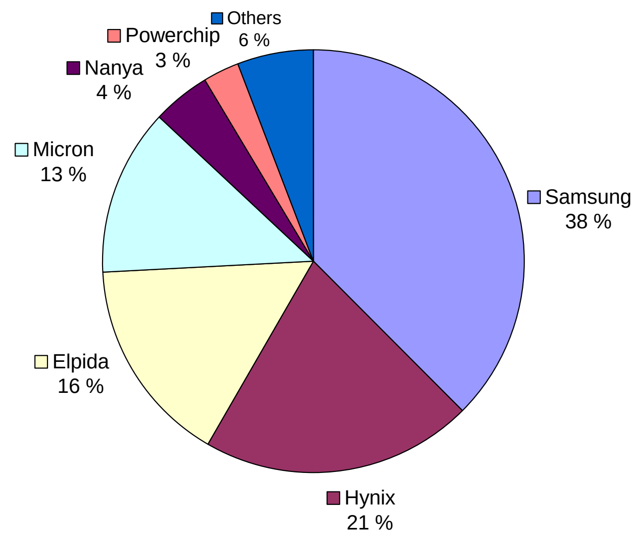
Market Forecast

- We expect DRAM revenue to decline at a 3% CAGR, from $39.2 billion in 2010 to $32.9 billion in 2015.
- The market should remain volatile, up the most in boom years and down the most in downturns; pricing has historically swung wildly based on supply/demand trends.
- DRAM should remain heavily PC-based.



Source: WSTS, Oppenheimer & Co.

Key Competitors



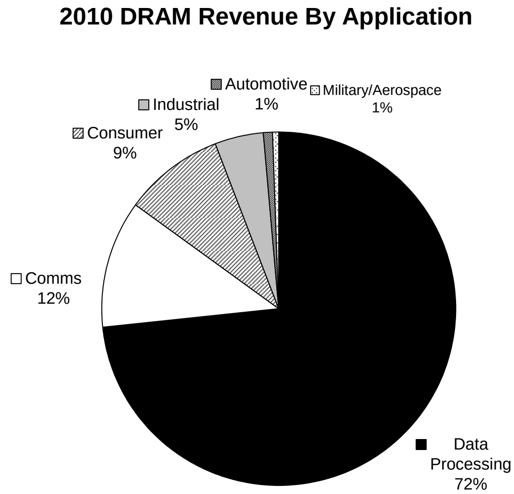
Source: Dataquest, Oppenheimer & Co.

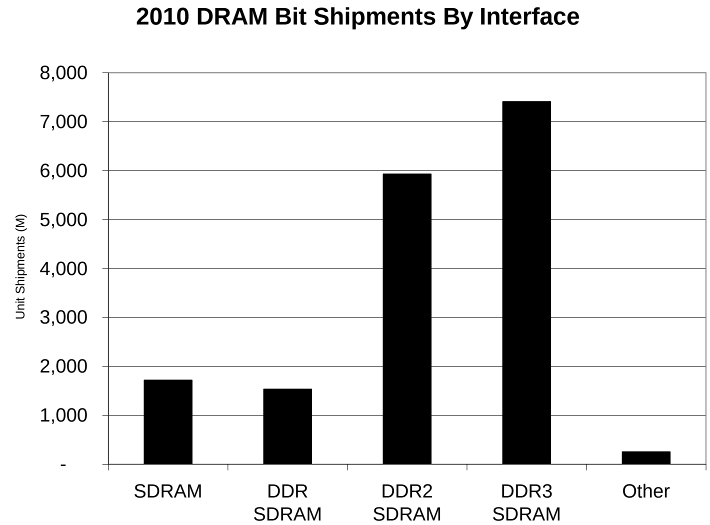
DRAM (dynamic random access memory) is the most common type of volatile memory, which is digital memory that loses its stored information once the power is removed. The "dynamic" heading means that DRAM, unlike SRAM, must be continually refreshed by the system, slowing down memory access, but allowing for a low-cost design and easy scalability to large densities. Like most memory, bit words in DRAM can be written, stored and read in any sequence.

DRAM is used in all electronics markets, but has an especially high concentration in computing applications, which also tend to use the fastest and highest density DRAM devices. In 2010, over 70% of DRAM revenue was derived from PCs and servers. Industrial, consumer and communications applications each represented 15% or less of DRAM revenue, as these applications consume relatively small amounts of DRAM or are better suited to SRAM.

In terms of memory type, the most common type of DRAM is DDR3. This DRAM first launched in 2007 as the successor to DDR2 and represented approximately represented 44% of bits in 2010. DDR2 was the second most common type of DRAM in 2010. This DRAM first appeared in 2003 and represented approximately 35% of bits in 2010. The earlier incarnation of DDR represented 9% of bits in 2010. Standard SDRAM still accounts for 10% of bits, but this is derived from PC peripheral, consumer and other embedded applications as opposed to PCs and servers. Other types such as EDO and Rambus DRAM have basically withered away as they have lost support from Intel on its chipset designs.

The exhibits below display 2010 DRAM unit shipments by application and by interface.

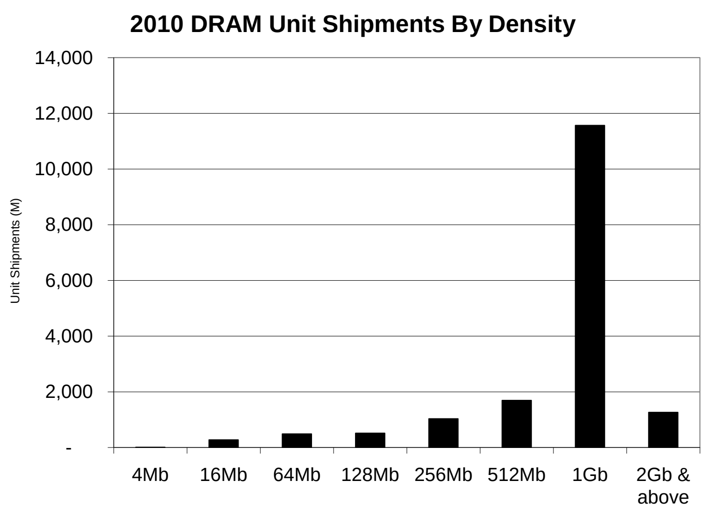


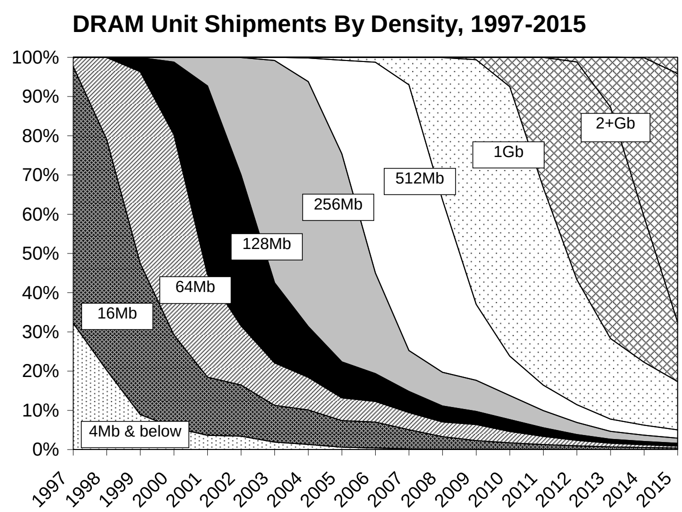


Source: Dataquest, IDC, Oppenheimer & Co.

In addition to being classified by interface type, DRAM is quoted by density or bit capacity, with the most common size in use today being 1 Gb (69% of units in 2010). Devices of 512 Mb represented 10% of units in 2010, though they are being phased out of mainstream PCs and are moving into embedded applications. Still used today, 256 Mb and below devices are found in non-PC applications. Note that the memory requirements of PCs have increased with the introduction of Microsoft's 7 operating system; 1 GB devices ramped meaningfully in 2008 and surpassed 512 Mb devices in 2009.

The exhibits below display 2010 DRAM unit shipments by density, as well as historical and forecast unit shipment data showing the constant migration to larger densities over time.



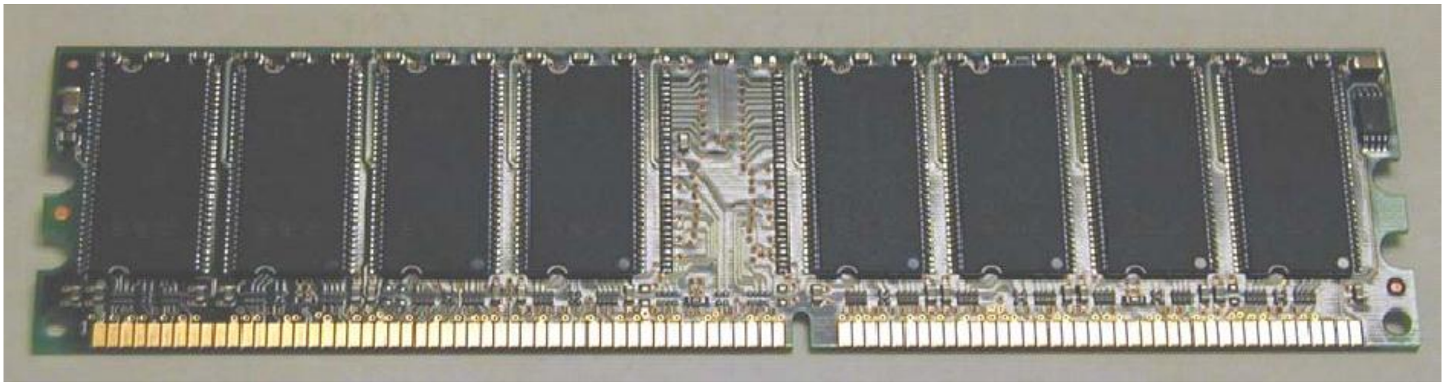


Source: Dataquest, Oppenheimer & Co.

Note that most DRAM sold into PCs and servers is not sold in chip form, and instead is soldered onto memory modules. A standard SIMM or DIMM module is a small PCB (printed circuit board) containing eight or 16 DRAM chips (there are eight bits to a byte, so, for example, a 256 MB DRAM module would usually have eight 256 Mb DRAM chips or 16 128 Mb DRAM chips). A DRAM module is pictured on the next page.

In the server market, memory must be more reliable and robust, and therefore generally includes an extra DRAM IC for buffering along with a timing device to perform register functions; these are known as registered DIMM (R-DIMM) modules. In 2006, Intel-based servers began migrating to fully buffered DIMMs (FB-DIMMs), which replace the register with a high-speed serial I/O interface IC known as an AMB (Advanced Memory Buffer) directly on the module for interface to the server chipset.

PC DRAM Module



Source: LSI, Denali Software, Oppenheimer & Co.

Market Forecast: DRAM is a commodity product with most ICs conforming to specific industry-standard densities, interfaces and power metrics. There are high fixed costs in its production, and most vendors make investments in manufacturing well in advance of actual demand, and run their factories close to full. As such, the market is subject to periods of steep price inflation during expansions as capacity tightens, and precipitous price declines during downturns as vendors drop prices to levels that approach variable cost.

In 2001, the DRAM market saw its worst year ever, as DRAM demand dropped on weak PC sales against a backdrop of significant oversupply; prices cratered as vendors continued to fill their fabs despite slower demand. The market recovered in 2003-04 as PC demand rebounded and as OEMs took advantage of the low cost of DRAM by aggressively ramping the number of megabytes per PC. The market worsened slightly in 2005 despite relatively healthy PC demand, as pricing softened due to moderate oversupply. The year 2006 was a very strong year for DRAM, up 32%, as memory pricing increased in anticipation of the launch of Vista. The year 2008 was especially difficult (-23% y/y) following a strong consumer pullback in spending. After the 2008-2009 downturn, capacity tightened and demand snapped back, leading to DRAM increasing an impressive 75% year-over-year in 2010.

Looking ahead, the DRAM market should remain volatile, up the most in boom years and down the most in downturns; pricing should be volatile, varying with supply trends. Overall, we expect the market to decline modestly from record 2010 levels, from $39.2 billion in 2010 to $32.9 billion in 2015, a CAGR of -3%. Note that our forecast assumes a cyclical peak in 2010 at $39.2 billion.

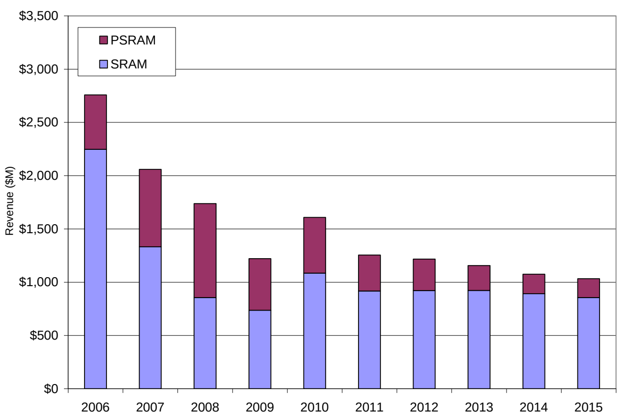
Competitive Environment: With the exception of Micron in the United States, all major DRAM vendors are located in Asia. The top vendor in 2010 was Samsung, which held an impressive 38% share. Hynix held 21% share and Elpida, the combined DRAM units of NEC and Hitachi, was No. 3 with 16%. Micron followed with 13% and rounding out the top vendors are two Taiwanese DRAM players: Nanya (4% share) and PowerChip (3%).

SRAM

SRAM (Static Random Access Memory) - A type of volatile memory that is configured in a flip-flop circuit, allowing cells to remain without being refreshed. A higher performance memory than DRAM, used mostly in communications applications and for high-speed data caching.
Key Types: Synchronous, asynchronous, PSRAM, FIFO, multi-port, CAM.

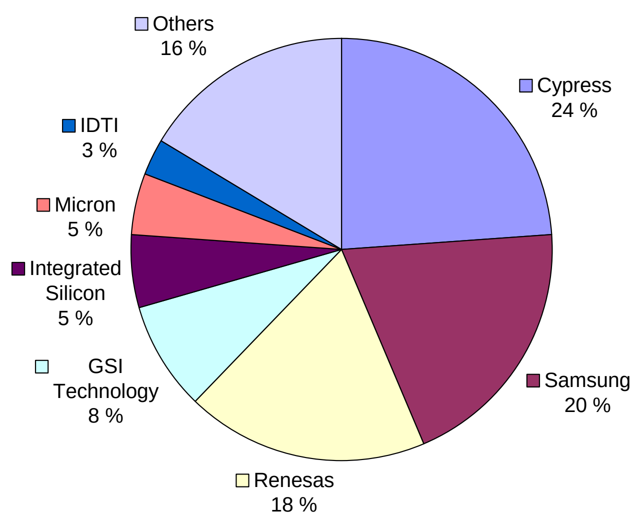
Market Forecast

•We expect the SRAM market to decline at an 8% CAGR, from $1.6 billion in 2010 to $1.0 billion in 2015.
•Handsets have largely shifted from SRAM to PSRAM; going forward, they likely will shift completely away from SRAM solutions as DRAM power consumption improves.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

SRAM (static random access memory) is a type of volatile memory, which, like DRAM, loses stored information when powered down. SRAMs also support random access, which means that locations in memory can be written to or read in any order. Unlike DRAM, however, SRAM stores data bits in a flip-flop circuit using a minimum of four transistors, as opposed to the single transistor/single capacitor design used in DRAM. This allows current to flow through one side or the other based on which of the two transistors is activated, allowing for faster access time. The structure of SRAM means that it does not need to be refreshed, making it suitable for high-performance communications applications. It also consumes far less power than traditional DRAM, which has suited it well for the handset market.

Unlike DRAM, there is significant product sub-segmentation within SRAM beyond just density. Asynchronous SRAMs perform read and write operations sequentially, while synchronous SRAM overlaps reads and writes. Some SRAMs have multiple I/O ports or support advanced features such as ZBT (zero bus turnaround) or syncBurst (speeds up write operation), which make them ideal for high-end communications applications.

A sizeable segment of the SRAM market is actually not technically SRAM at all: PSRAM (Pseudo SRAM) is actually DRAM modified to behave like SRAM. PSRAM has built-in refresh and address control circuits to mimic SRAM, but leverages the low-cost and high-density benefits of DRAM. These cost and density advantages have allowed PSRAM to displace standard SRAM in most handsets. Note that since PSRAM is sold into the same sockets as SRAM (primarily wireless), we include revenue and market share data here rather than in the discussion of DRAM.

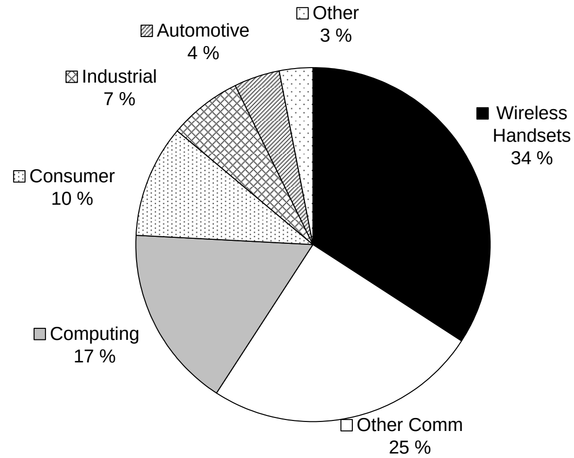
SRAM finds heavy usage in the computing market as a cache for PC and server microprocessors. However, these SRAM cells are located directly on the CPU die; no discrete SRAM ICs are used. In terms of discrete SRAM, 34% of market revenue is derived wireless handsets, with 25% from other communications applications. Seventeen percent is used in computing applications (mostly in peripherals), 10% is used in consumer and 7% is used in industrial.

SRAM is classified by both density and speed. The most common densities are 8 and 16 Mbs, used primarily in mainstream handsets. SRAMs of 32 Mbs and 64 Mbs are used in high-end handsets and in high-performance communications applications. Lower density SRAMs tend to be used in computing, industrial and consumer applications.

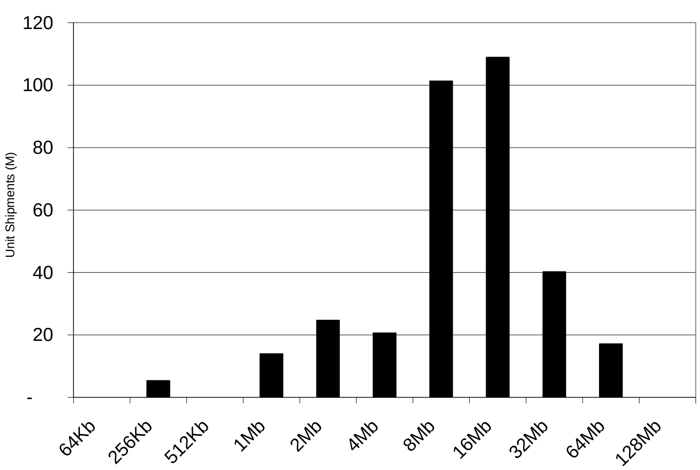
On the speed front, high-performance communications applications typically require the fastest access times, typically 10-19 nanoseconds and below. Other applications tend to use cheaper SRAMs with slower access times. On a shipment basis, standard SRAM is actually dwarfed by PSRAM.

The exhibit to the right displays SRAM revenue by application; the exhibit below displays unit shipments by density.

2010 SRAM Revenue By Application



2010 SRAM Unit Shipments By Density



Source: Dataquest, WSTS, Oppenheimer & Co.

Market Forecast: The SRAM market is less commoditized than the DRAM market given the more differentiated product offerings required for communication applications. Still, it can see aggressive price declines during periods of demand weakness or overcapacity, as it did during the 2001-2002 downturn (down 42% and 32%, respectively). Demand recovered in 2003 and 2004 during the industry's cyclical expansion, but it has since struggled. The TAM for SRAM has been shrinking as DRAM has been able to effectively compete in certain applications. Looking ahead, we expect this trend to accelerate as the core wireless handset market moves away from SRAM and PSRAM to DRAM. Overall, we expect the market to decline, falling from $1.6 billion in 2010 to $1.0 billion in 2015 following a revenue peak in 2010 of $1.6 billion.

Competitive Environment: Despite its smaller size, SRAM sells in a variety of densities and speeds, and thus is a more fragmented market than DRAM. It includes several vendors of NOR flash which include SRAM in their multi-chip packages for wireless handsets. The top supplier in 2010 was Cypress, with 24% market share. Samsung was second, with 20% share, followed by Renesas (18%) and GSI Technology (8%). Integrated Silicon, Micron, and IDTI round out the seven suppliers 5%, 5% and 3% share, respectively.

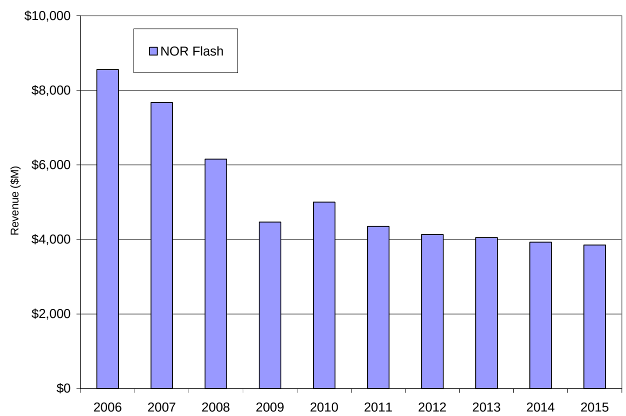
Although by definition still SRAM, certain types of proprietary memory warrant special mention, as they incorporate richer design content and are thus less commoditized than general SRAM. These include FIFO and multiport SRAMs, non-volatile SRAMs, CAMs and FRAMs. The leaders in this group include NetLogic, Cypress and Renesas.

NOR Flash

NOR Flash – Type of non-volatile rewritable memory supporting random access and execute-in-place. Used primarily for code storage.
Key Types: SLC, MLC.

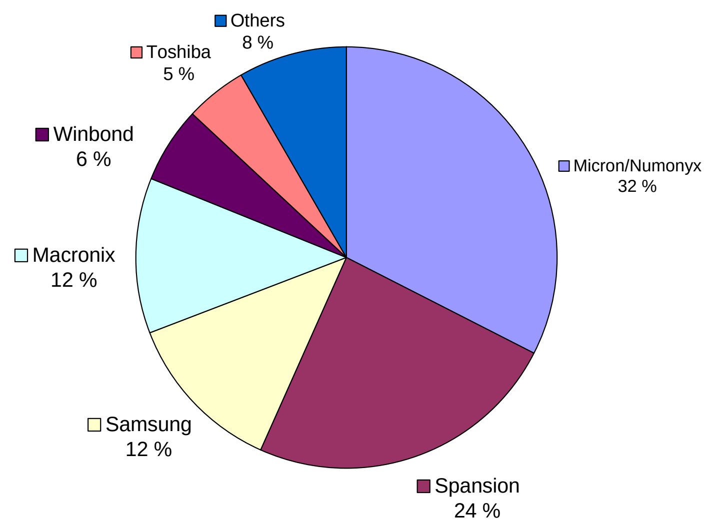
Market Forecast

•We expect the NOR flash market to decline at a 5% CAGR, from $5.0 billion in 2010 to $3.8 billion in 2015.
•NAND is increasingly encroaching on NOR in its core handset market.
•Pricing remains under intense pressure, especially as higher density sockets move to NOR.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Flash memory is the most common type of non-volatile memory, which can store data continuously in its cells even when a power supply is removed. Like DRAM and SRAM, flash can be written and rewritten, but when the system is powered down, the memory cells retain all the information stored. Flash memory is used primarily in devices that are frequently turned on and off, but must keep its stored information intact because the device lacks an external storage device (like a hard disk drive). Fitting this profile are a number of very high-volume markets, notably wireless handsets and consumer portables, which use flash memory to store the system operating software as well as user data. Flash is also used to store boot-instructions in a variety of electronic devices, including PCs.

A large portion of flash memory is also sold as external flash cards, to be used for external storage of user data, primarily for digital consumer devices and PDAs. Handsets are increasingly moving in this direction as well. These use a variety of standard interfaces in order to make them compatible with a wide set of electronics from multiple vendors. Another application is USB flash drives, which combine flash memory and a USB controller to form a small external storage device for PCs.

Two main types of flash memory exist. NOR memory (17% of total flash revenue in 2010) is the most reliable and versatile flash memory, supporting random access and memory card program execution, known as “execute in place.” Writing and erasing can take several seconds, but reading is fast. For all these reasons, NOR is primarily used for program and code storage.

NAND flash (75% of total flash revenue in 2010) is cheaper than NOR and also somewhat less reliable. It does not support execute in place. It does, however, support faster read and write times and greater densities than NOR. NAND is therefore primarily used for data storage as opposed to code storage. We discuss NAND on the next page.

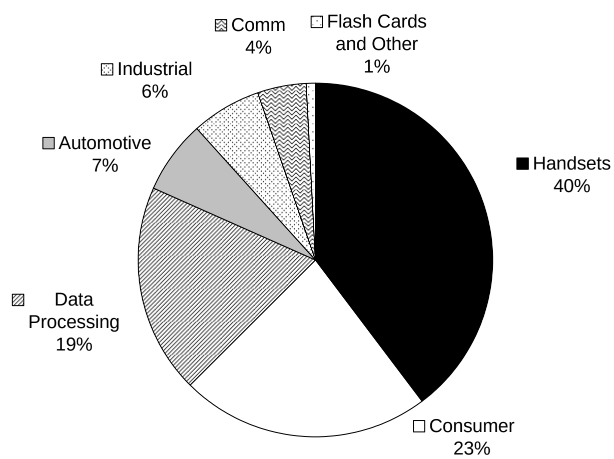
In terms of its architecture, NOR flash uses cells that resemble a standard transistor, except that it has two gates instead of just one. The presence of the second gate allows for electrons to become trapped within the cell, hence the ability to retain data when power is removed from the host device. First generations of NOR flash stored one information bit per memory cell in an architecture referred to as SLC "single level cell." Advanced architectures permitting the storage of two or more bits per memory cell are referred to as MLC or "multi-level cell" architectures.

The largest application for NOR flash is wireless handsets, which accounted for approximately 40% of revenue in 2010. Consumer was another 23%, followed by data processing at 19% and automotive and industrial, at 7% and 6%, respectively. Other communications and flash cards represented the remaining 5%.

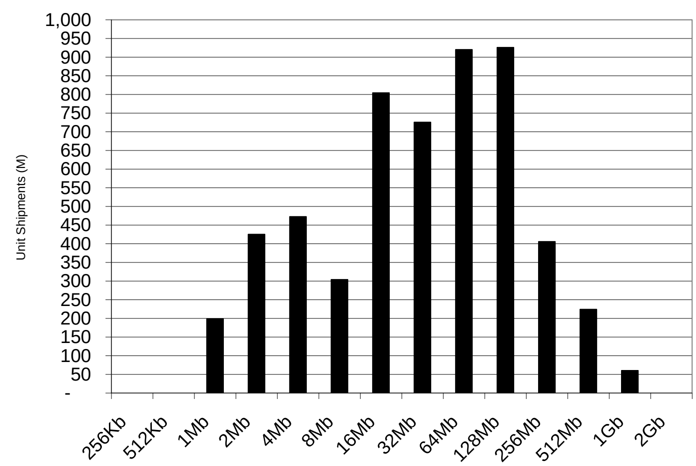
In terms of density, NOR flash comes in all sizes ranging from 1MB to 2Gb. The highest volume densities in terms of units are 128 MB, 64 MB and 16 MB, respectively. These densities are mostly used in handsets, with the highest densities used in smartphones. The lower density units are used primarily in non-handset applications.

The exhibits below display 2010 NOR flash revenue by application, alongside unit shipments by density.

2010 NOR Flash Revenue By Application



2010 NOR Flash Unit Shipments By Density



Source: Dataquest, SIA, Oppenheimer & Co.

Market Forecast: The NOR flash market is largely driven by demand for memory in wireless handsets, which represent the largest single use of NOR flash. The market saw good growth in 2003 and 2004 as handset unit shipments grew at a brisk pace, and the move to 2.5G and multimedia handsets drove a nice uptick in flash per handset. In 2005, however, over-supply caught up with the industry, and continued bit demand growth was more than offset by price declines. These dynamics continued in 2006, but with net positive growth for the industry, buoyed by a big year for memory-hungry 3G handsets. The global economic slowdown in 2008 hindered the industry significantly as the NOR market contracted by 20% in 2008. The market for NOR cratered further in 2009 and decreased 27% year-over-year. NOR rebounded 12% in 2010, significantly underperforming the 32% increase the semiconductor industry enjoyed.

Looking ahead, we expect NOR to decline at a 5% CAGR, from $5.0 billion in 2010 to $3.8 billion in 2015. The key lever is not just pricing vs. bit demand, but also the cannibalization of NOR in the handset by NAND. NAND has gained traction over the past few years in handset designs, and this should only accelerate as multimedia capability (and the data storage capacity it needs) continues to be a priority for handset makers. Note that embedded in our forecast is some incremental growth from the cannibalization of mask ROM, EPROM, and to a lesser extent EEPROM, though the bulk of this transition has already taken place.

Competitive Environment: The top vendor of NOR flash in 2010 was Micron/Numonyx, with 32% revenue share. Numonyx was spun out of Intel and sold to Micron in early 2010. Spansion held the No. 2 position with 24% share. Spansion was originally created as a flash manufacturing JV between AMD and Fujitsu known as FASL; in 2003 the two companies spun off the JV as a separate entity, contributing all aspects of operations including R&D, sales and marketing.

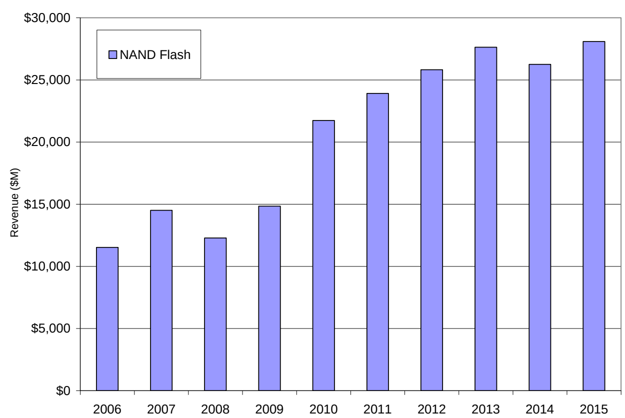
Samsung held the No. 3 position with 12% share. Rounding out the top 5 in 2010 were Macronix with 12% share, Windbond with 6% and Toshiba with 5%.

NAND Flash

NAND Flash – Type of non-volatile rewritable memory that has very fast read and write times, but is accessed in blocks and so cannot support execute-in-place. Used primarily for bulk data storage.
Key Types: SLC, MLC.

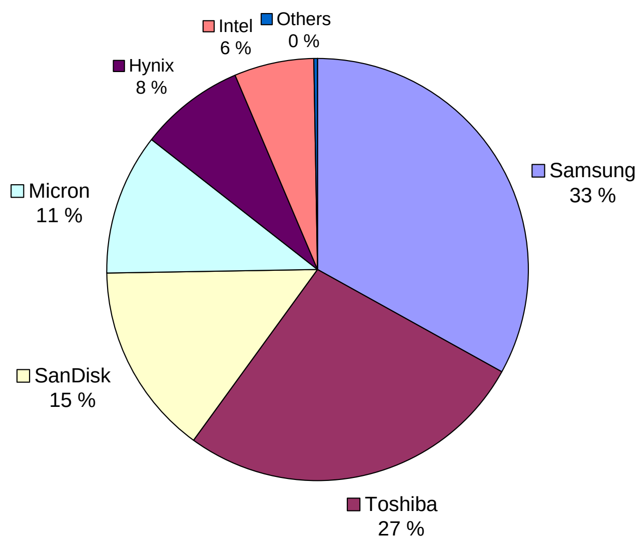
Market Forecast

- We expect the NAND flash market to grow at a 5% CAGR, from $21.7 billion in 2010 to $28.1 billion in 2015.
- NAND is benefiting from the growth of digital consumer devices and is also encroaching on NOR in handsets.
- NAND and DRAM cycles are related as fabs are easily converted from one to the other as demand fluctuates.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

The other type of flash memory is known as NAND flash (about 83% of total flash revenue in 2010). Although they were both invented by Toshiba and share the name "flash," NAND is quite different from NOR in its construction and operation. NAND cells use tunnel injection for writing and tunnel release for erasing, and are organized in blocks of 512 or 2,048 bytes. The blocks are accessed in series similar to hard disk drives, and therefore cannot support random access or execute-in-place.

NAND is far cheaper to produce than NOR and scales more easily to larger densities. The manufacturing process is actually somewhat similar to a DRAM process, and many NAND flash fabs are actually converted DRAM fabs. NAND also supports faster read and write times and greater densities than NOR. NAND is therefore the primary solution used for storage of user data, but is not as commonly used for storage of code.

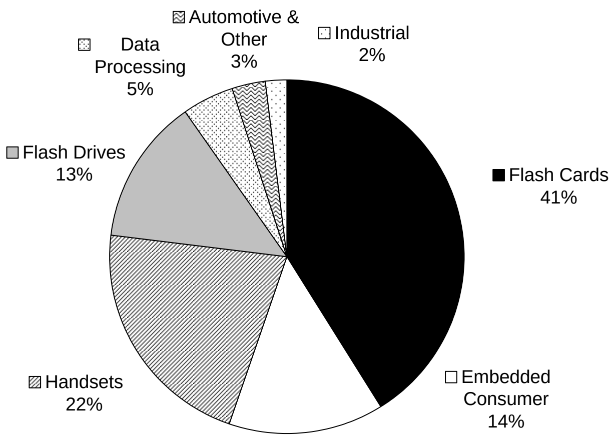
In fact, in 2010, roughly 41% of NAND flash (by revenue) was sold into flash memory cards, with another 13% sold into flash drives. These two applications are pure data-storage applications, as they are removable from the host device.

The balance of the NAND market services embedded applications, primarily for data but also for code storage. About 14% was derived from NAND embedded directly into consumer devices, principally portable media players and tablets. Of NAND revenue, 22% was derived from handsets, as NAND has started to meaningfully ship alongside NOR in multimedia handsets. The remaining 10% was derived from automotive, industrial, data processing and other applications.

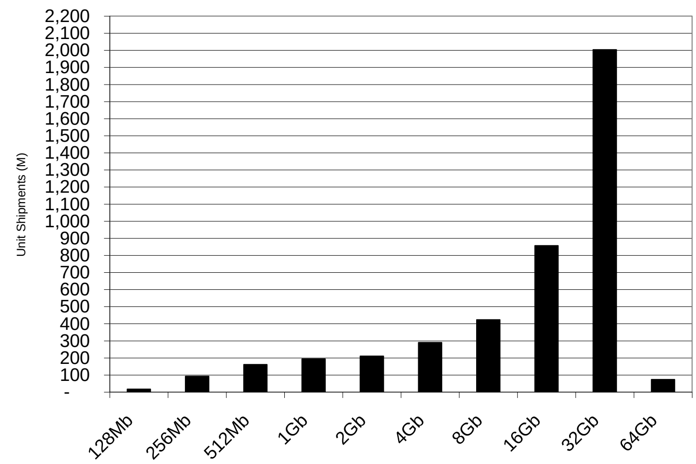
In terms of density, most NAND flash in 2010 was sold in densities of 512Mb and above, with 32Gb and 16Gb representing the majority of shipments. There is a constant push upward as data storage demand in consumer portables is far above what can be economically supplied with today's NAND chips and is continually rising as these devices become more complex.

The exhibits below display 2010 NAND flash revenue by application, alongside unit shipments by density.

2010 NAND Flash Revenue By Application



2010 NAND Flash Unit Shipments By Density



Source: Dataquest, Oppenheimer & Co.

Market Forecast: The NAND market has grown steadily over the past few years, as a relatively small number of competitors served a dramatically growing need for solid state data storage, particularly in portable devices. Memory card demand is in the hundreds of millions of units, with digital cameras and wireless handsets driving most of the demand, while portable media players have shown a steady increase in unit demand, a need for greater storage capacities and a profound preference for solid-state vs. HDD-based storage. Only in the past couple of years has supply caught up with demand as new fabs have been built and new competitors have entered the market.

Looking ahead, NAND should benefit from continued strong demand in consumer electronics, both for external storage cards and embedded applications like tablets. NAND should also begin to take a more significant bit and revenue share from NOR in handsets, especially in smartphones. Finally, NAND will begin to show up in PCs, both as a cache to boost performance and in some cases in solid state drives, which serve as a replacement for hard disk drives. In total, we expect NAND to grow at a 5% CAGR, rising from $21.7 billion in 2010 to $28.1 billion in 2015.

Competitive Environment: The top NAND flash memory maker in 2010 was Samsung, with 33% revenue share. Toshiba was second with 27%, followed by a SanDisk with 15% share. Micron and South Korean maker Hynix, rounded out the top players with 11% and 8% shares, respectively. Other players in NAND include Intel with 6% share.

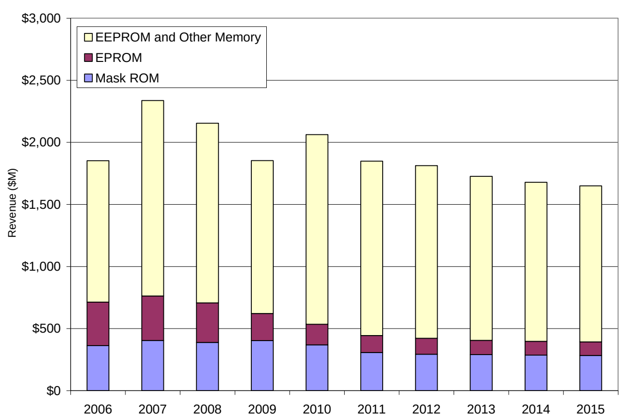
Legacy Non-Volatile Memory

Mask ROM (Read-Only Memory) - Read-only memory that is locked in a permanent position during the fabrication process.
EPROM (Electronically Programmable ROM) - ROM that is programmed by electrical means during system integration.
EEPROM (Electronically Erasable Programmable ROM) - EPROM that can be erased and reprogrammed electronically.

Market Forecast

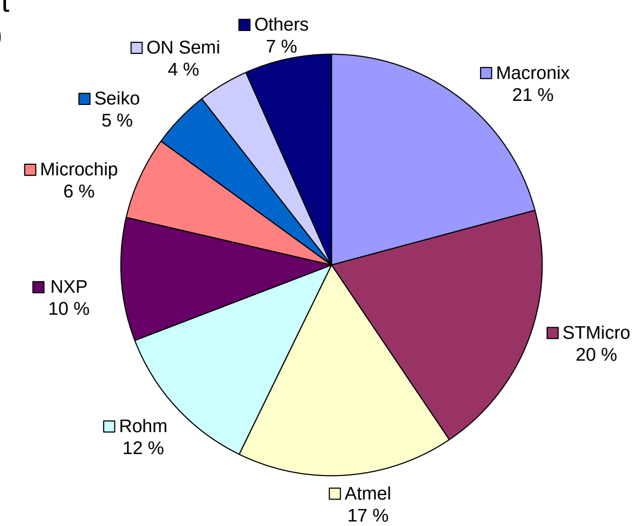
•We expect the legacy non-volatile memory market to decline at a 4% CAGR, from $2.1 billion in 2010 to $1.6 billion in 2015.

•EPROM and Mask ROM should face pressure from flash.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Although flash has grown to dominate the non-volatile memory market, older technologies such as Mask ROM, EPROM and EEPROM have remained for applications that require long-term memory storage, but don't necessarily need the easy re-writability of flash. Although similar in basic design, these devices differ slightly in composition and function:

- **Mask ROM** (mask read only memory): Mask ROM is read-only memory that is locked in a permanent position during the fabrication process through the use of a custom mask. Mask ROM is typically used for boot instructions and is most commonly found in consumer appliances and printers.
- **EPROM** (electronically programmable read only memory): EPROMs are similar to mask ROMs except that they are programmed in the field by the user using electrical means rather than a mask. This includes OTP (one-time programmable) and re-writeable devices that can be reprogrammed using ultra-violet light. EPROM is most commonly found in consumer electronics, game consoles, industrial applications and some PC peripherals.
- **EEPROM** (electronically erasable programmable read only memory): EEPROMs are similar to re-programmable EPROMs but can be erased and reprogrammed using electrical means. EEPROM is found in a wide variety of consumer, computing, automotive and industrial devices.

In 2010, 15% of the non-volatile memory category was mask ROM and another 6% from EPROM. EEPROM represented 79% of the non-volatile memory category in 2010.

Market Forecast**:** The market for legacy non-volatile memory has achieved most growth for a few years leading up to 2007 despite pressure from flash memory (mostly NOR), which has penetrated many of the applications that utilize legacy non-volatile memory. EPROM has historically faced the most pressure versus flash. Mask ROM has been able to compete effectively versus flash at the low end, but is losing ground at higher densities. EEPROM has been insulated from competition to some degree as these devices typically sell into very low-density applications (mostly 128-Bit to 64Kb), where flash does not participate as much. EEPROM has also eaten into EPROM and Mask ROM.

Going forward, we expect the legacy non-volatile memory market to decline by 4% CAGR from 2010 to 2015, to $1.6 billion in revenue by 2015. We believe revenues peaked in 2007 at $2.3 billion and should decline steadily thereafter. EEPROM should decline at a 4% CAGR and stay at roughly 76% of the market. Mask ROM should decline by a 5% CAGR to roughly 17% of the market, and EPROM should decline at 8% to represent 7% of the market.

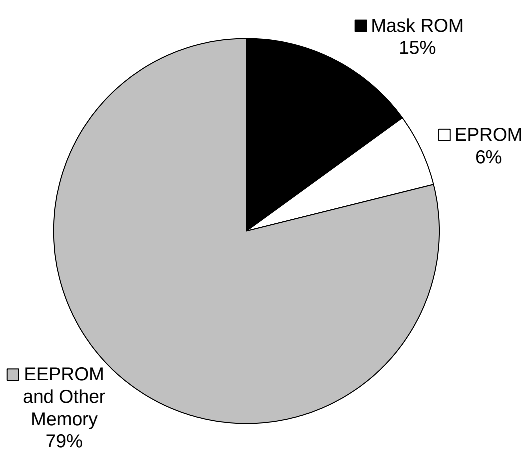
Competitive Environment**:** The market for mask ROM is dominated by Macronix with a 98% share in 2010 with Atmel holding the remaining 2% market share.

In EPROM, Rohm has 77% market share through 2010, while STMicro held the remaining 23%.

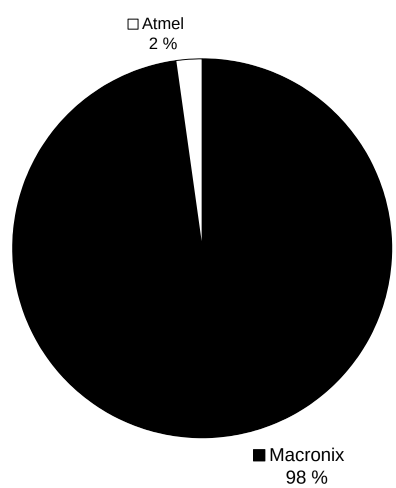
In EEPROM, the market leaders are STMicroelectronics and Atmel, at 25% and 23% of 2010 revenue, respectively. NXP was third with 14%, followed by Microchip (9%) and Rohm (8%). Seiko and ON Semi round out the top seven suppliers.

The exhibits below display market share data for mask ROM, EPROM and EEPROM.

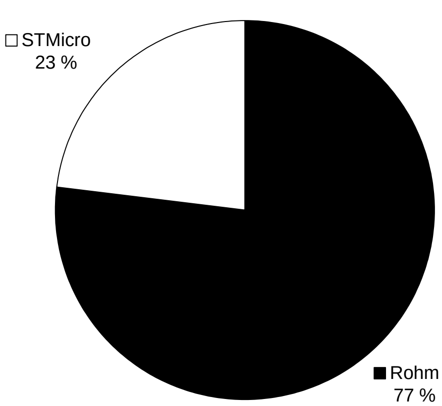
2010 Other Non-Volatile Memory Revenue Share



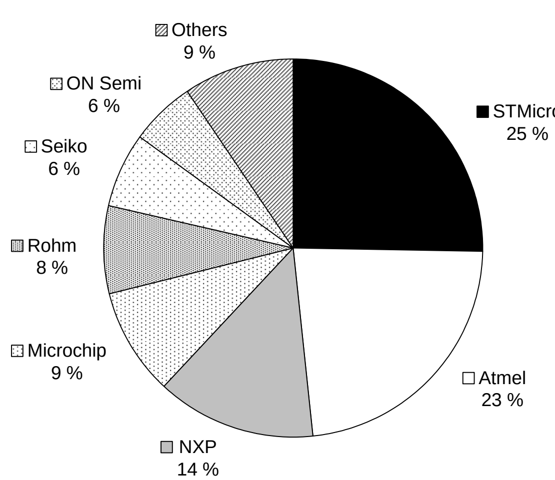
2010 Mask ROM Market Share



2010 EPROM Market Share



2010 EEPROM Market Share



Source: Dataquest, Oppenheimer & Co.

Discretes and Optoelectronics

Discretes:

Semiconductor devices that consist of a single transistor in a package

Three Key Markets:

Discretes

Sensors and Actuators

Optoelectronics

This section deals with all types of discretes, which are semiconductor devices consisting of a single transistor in a package (i.e., not an integrated circuit). These devices sell in very high volume (hundreds of billions per year) at very low ASPs (sometimes as low as a penny each). They are used in all types of electrical systems primarily as enabling devices—helping to move signals around the board or alternatively providing the bridge between the electronic system and the outside world. These devices are generally application agnostic, and are almost always sold through distribution. We discuss the three key types below:

Discretes: Discretes are semiconductor devices consisting of a single transistor in a package. They are often used to direct signals around a board and to control power flow in a system.

Sensors and Actuators: Sensors are specialized discrete semiconductor devices whose electrical properties can be translated into measurements of external stimuli. These include things like temperature, pressure, displacement, velocity, acceleration, stress, strain, or any other physical, chemical or biological property. Actuators are the opposite of sensors; actuators create mechanical motion by converting various electrical signals to rotating or linear mechanical energy.

Optoelectronics: Optoelectronics are semiconductor devices designed to produce and receive light waves. This includes displays, lamps, couplers and other opto-sensing and emitting semiconductor devices. Note that sensors that measure light and capture images are grouped with optoelectronics.

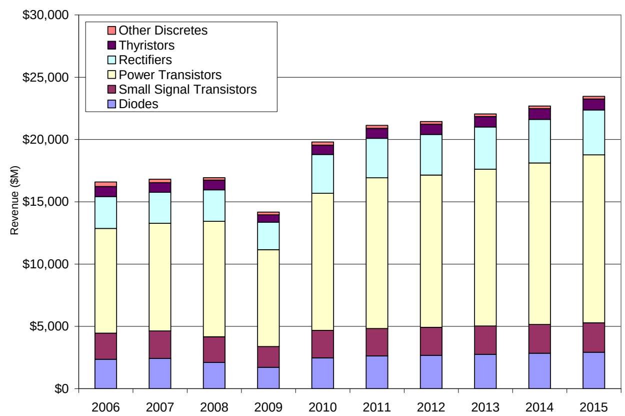
Discretes

Discretes - Discretes are semiconductor devices consisting of a single transistor in a package. They are used as enabling devices within larger systems, and are generally application agnostic.

Key Types: Diodes, small signal transistors, switching transistors, power transistors, rectifiers (power diodes), thyristors.

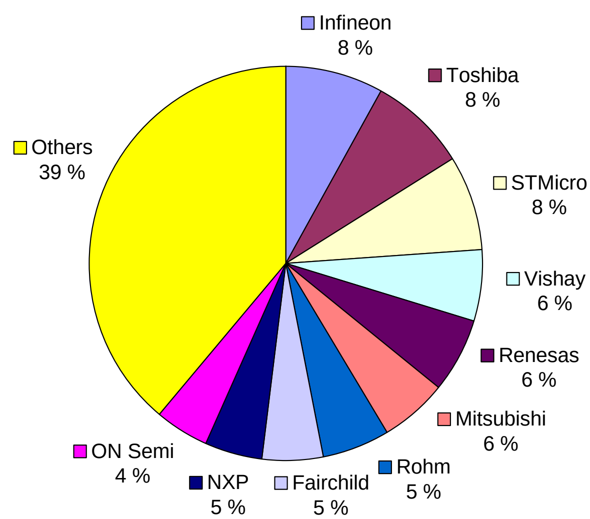
Market Forecast

- We expect the market for discretes to grow at a 3% CAGR, from $19.8 billion in 2010 to $23.5 billion in 2015.
- Growth for these multi-market devices should slightly trail the broader industry as ASSPs seek to integrate discretes in some high volume applications.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

Discretes are semiconductor devices consisting of a single transistor in a package. These devices sell in very high volume (hundreds of billions per year) at very low ASPs. They are used in all types of electrical systems primarily as enabling devices—helping to move signals around the board as well as to control power flow—and are generally application agnostic. There are several major categories of discrete devices, including:

Diodes: Devices that act as a one-way valve. Key types include small signal diodes, zener diodes, transient protection diodes and RF/microwave diodes.

Small Signal and Switching Transistors: Transistors with power dissipation of less than 1W.

Power Transistors: Transistors with power dissipation of more than 1W. Key types include RF/microwave power transistors, bipolar general purpose transistors and insulated gate bipolar transistors (IGBTs) and modules.

Rectifiers (Power Diodes): Devices used to convert AC (alternating current) to DC (direct current). These devices are classified by the amount of current supported.

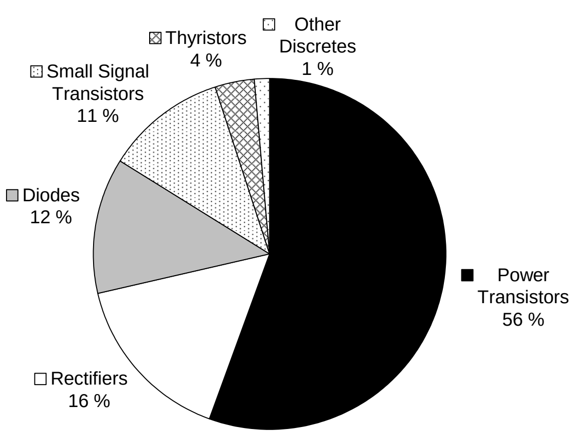
Thyristors: Devices that can turn on when activated by a gate signal.

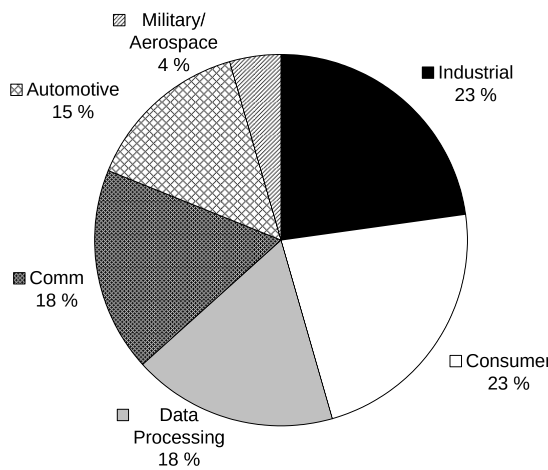
Other Discretes: These include varactor tuning diodes, selenium rectifiers and other polycrystalline devices.

On a revenue basis, more than half of discrete sales are power transistors, at 56% of total in 2010. Rectifiers, diodes and small signal transistors had a market share of 16%, 12%, and 11%, respectively. Thyristors and other discretes represent the remaining 5% of the market. Note that on a unit basis, diodes and small signal transistors total 71% of discrete shipments, as these devices generally have very low ASPs.

In terms of application, discretes go into every electronic device produced. In 2010, the revenue split was 23% industrial, 23% consumer, 18% communications, 18% data processing, 15% automotive, and 4% aerospace.

The exhibits below display discrete semiconductor revenue share by product type and application.





Source: WSTS, Dataquest, Oppenheimer & Co.

***Market Forecast*:** Discretes sell into every electronic application and are therefore tied to the semiconductor cycle and to demand for electronics in general. Many of these products are commodities and thus are subject to rapid changes in pricing as fab capacity rises and falls with the semiconductor cycle. Countering this effect, however, is the fact that discretes do not see the same concentration in compute-intensive digital equipment like PCs and handsets, which cause a lot of volatility for the big dollar segments such as microcomponents, digital logic, and memories. Discretes therefore tend to have more stable unit demand than the semiconductor market as a whole. At the same time, they tend to "miss out" on the growth generated by those advanced products.

Overall, we expect the market to grow from $19.8 billion in 2010 to $23.5 billion in 2015, a CAGR of 3%.

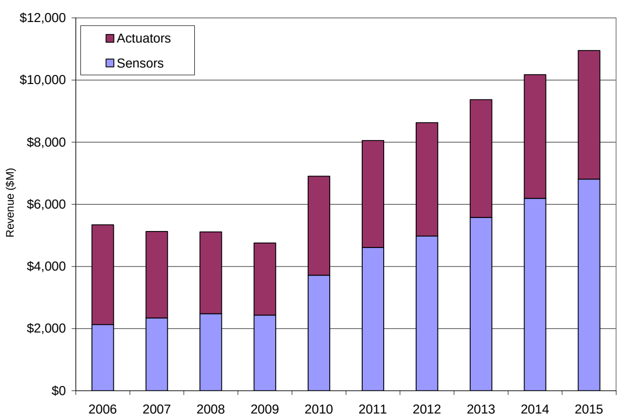
***Competitive Environment*:** The market for discretes is large and fragmented. The largest vendors in 2010 were Infineon, Toshiba and STMicro all with 8% each. Vishay, Renesas and Mitsubishi were next with 6% each. Other important vendors include Rohm, Fairchild, NXP, and ON Semi. Most of the other large Japanese semiconductor manufacturers compete here as well.

Sensors and Actuators

Sensors – Specialized discrete semiconductor devices that translate real world input into electrical signals.
Actuators - Actuators are the opposite of sensors, taking electrical signals and translating them into some form of real world output.
Key Types: Temperature sensors, pressure sensors, acceleration and yaw rate sensors, magnetic field sensors, LEDs, motors, solenoids, speakers.

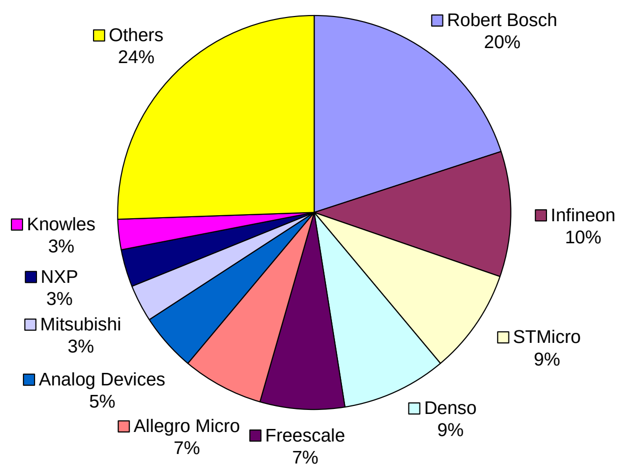
Market Forecast

•We expect the market for sensors and actuators to grow at a 10% CAGR, rising from $6.9 billion in 2010 to $10.9 billion in 2015.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Note: Market share data is for sensors, and excludes actuators.
Source: Dataquest, Oppenheimer & Co.

Sensors are specialized discrete semiconductor devices whose electrical properties can be translated into measurements of external stimuli. These include things like temperature, pressure, displacement, velocity, stress, strain, acceleration, or virtually any other physical, chemical or biological property. The category also includes actuators, which translate signals into movement, acting as the opposite of a sensor (the mechanisms that move the head assembly on a disk drive or an arm of a robot are two examples of actuators).

In 2010, actuators represented 46% of total sensor and actuator revenue. Magnetic field sensors represented 15% of the total; accelerate & yaw sensors were 25%, pressure sensors were 12% and temperature sensors were 2%. Note that image sensors are not included in this category and are instead grouped with optoelectronics.

***Market Forecast*:** The market for sensors and actuators is expected to grow at a 10% CAGR over the next five years, from $6.9 billion in 2010 to $10.9 billion in 2015. The growing digitization of devices, especially in automobiles, as well as the move to silicon-based sensors from other materials is expected to drive this growth.

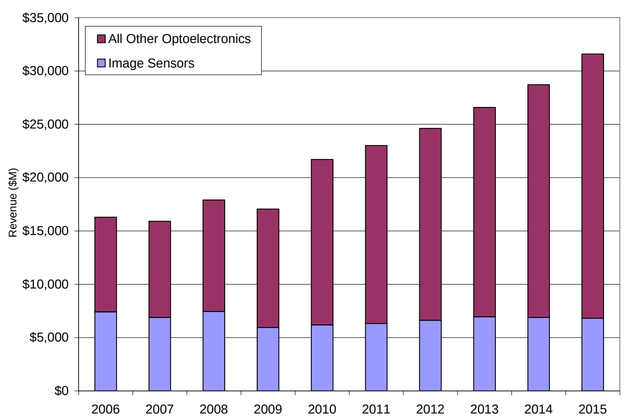
***Competitive Environment*:** The market for sensors is smaller and thus less fragmented than for general discretes, but many niche players have been able to build defensible positions. The largest vendor in 2010 was Robert Bosch with 20%, followed by Infineon with 10%. STMicro and Denso each held 9%, while Freescale and Allegro Micro held 7% each. Other suppliers include Analog Devices, Mitsubishi, NXP and Knowles. Note that this market share data does not include a breakout for actuators (data for this segment is not available).

Optoelectronics

Optoelectronics - Semiconductor devices designed to produce and receive light waves, including displays, lamps, couplers, image sensors, and other opto-sensing and emitting devices.
Key Types: Displays, lamps, couplers, laser devices, image sensors (CCD, CPD, SSP, CMOS), infrared devices.

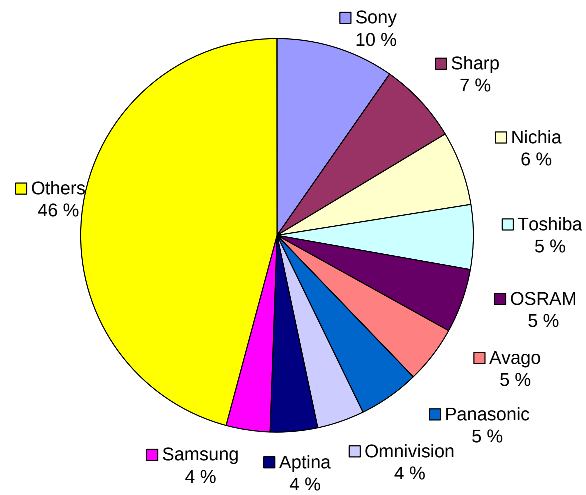
Market Forecast

- We expect optoelectronics to grow at an 8% CAGR, rising from $21.7 billion in 2010 to $31.6 billion in 2015.
- We expect image sensors to see a more modest CAGR of 2%, with faster growth from other devices.



Source: WSTS, Oppenheimer & Co.

Key Competitors



Source: Dataquest, Oppenheimer & Co.

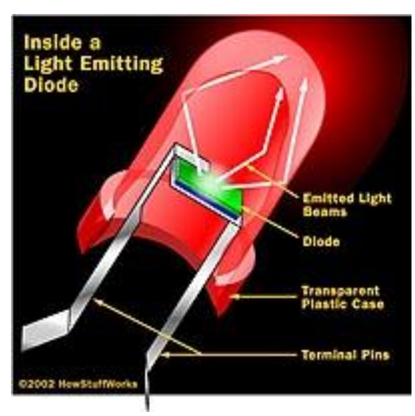
Optoelectronics are semiconductor devices designed to produce and receive light waves. This includes displays, lamps, couplers and other opto-sensing and emitting semiconductor devices. Only semiconductor devices are included here; however, the category excludes liquid crystal devices and displays, incandescent lamps and displays and other non-semiconductor optoelectronics components.

The best-known type of optoelectronic device is the LED (light emitting diode), a diode that emits light when charged. LEDs are housed in a small “bulb” and are used in all kinds of readouts (see diagram). Even traffic lights have begun to use LEDs instead of less efficient, traditional filament bulbs.

About 39% of optoelectronics revenue is actually derived from image sensors, including CCDs and CMOS image sensors. These optoelectronics sensors perform image pickup for digital cameras and camera phones.

Of the remaining 61%, 40% is derived from lamps, 8% from couplers and 3% from laser displays. The remaining 10% includes laser pickup and infrared devices and laser transmitters.

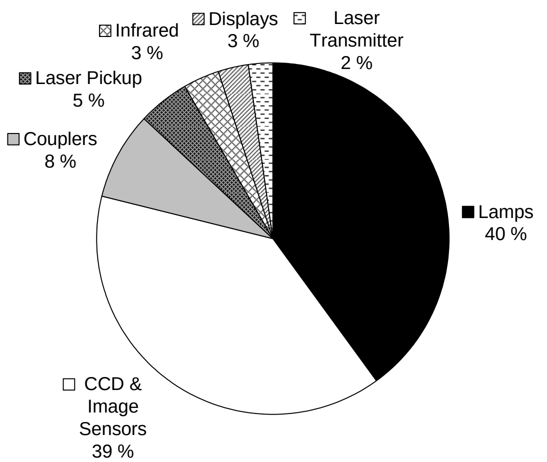
Light Emitting Diode

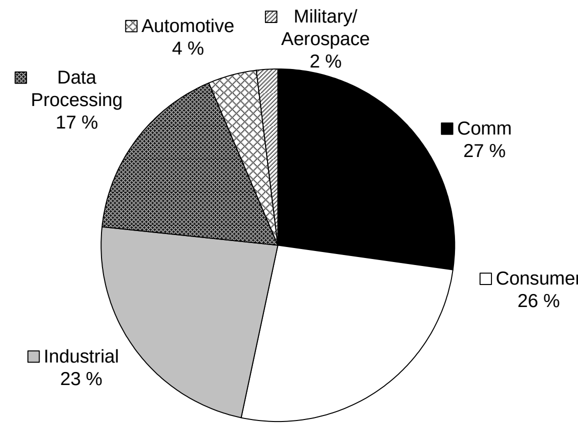


Source: I. Weiss, Oppenheimer & Co.

Like discretes, optoelectronics are application agnostic, though they are more heavily tied to the communications and industrial markets, which were 27% and 23% of sales in 2010, respectively. Some 26% of sales were derived from the consumer market, 17% from data processing and the remaining 6% from automotive and military/aerospace.

The exhibits below display optoelectronics revenue by device type and application.



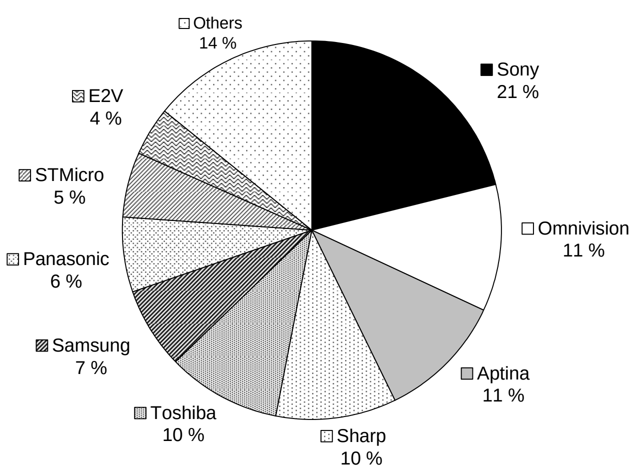


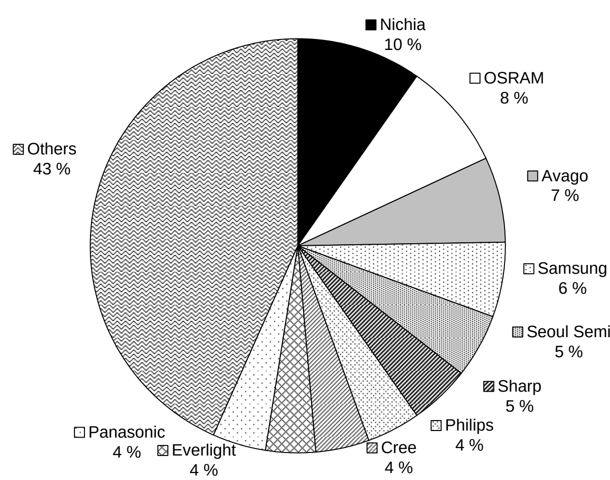
Source: WSTS, Dataquest, Oppenheimer & Co.

***Market Forecast*:** The market for optoelectronics is expected to outpace the overall semiconductor industry through 2015, growing at an 8% rate. After several years of rapid growth driven by digital cameras and camera phones, we expect image sensors to see a more modest CAGR as pricing pressure partially offsets continued unit growth. Overall, optoelectronics revenue is expected to grow from $21.7 billion in 2010 to $31.6 billion in 2015.

***Competitive Environment*:** The market for optoelectronics is large and highly fragmented. The top producer in 2010 was Sony with 10% market share, derived from its No. 1 position in image sensors. Sharp, the No. 4 supplier of image sensors, was second with 7% share. Nichia Chemical, the No. 1 vendor of LEDs, was third with 6% share. Rounding out the top five were Toshiba and OSRAM, each with 5% share. Other significant vendors include Avago, Panasonic, Omnivision, Aptina, and Samsung.

The exhibits below display market share data for image sensors and all other optoelectronics.





Source: WSTS, Dataquest, Oppenheimer & Co.

Section V: End Market Summary

This section discusses the major semiconductor end markets

For each end market we discuss:

Key technologies & end market fundamentals

End market unit forecast

Semiconductor revenue forecast

Semiconductor block diagram

Competitive environment

Semiconductor trends

End Market Summary

The semiconductor sector serves a number of important end markets

Six Key End Markets:

Computing

Wireless

Networking

Consumer

Telecom/ Datacom

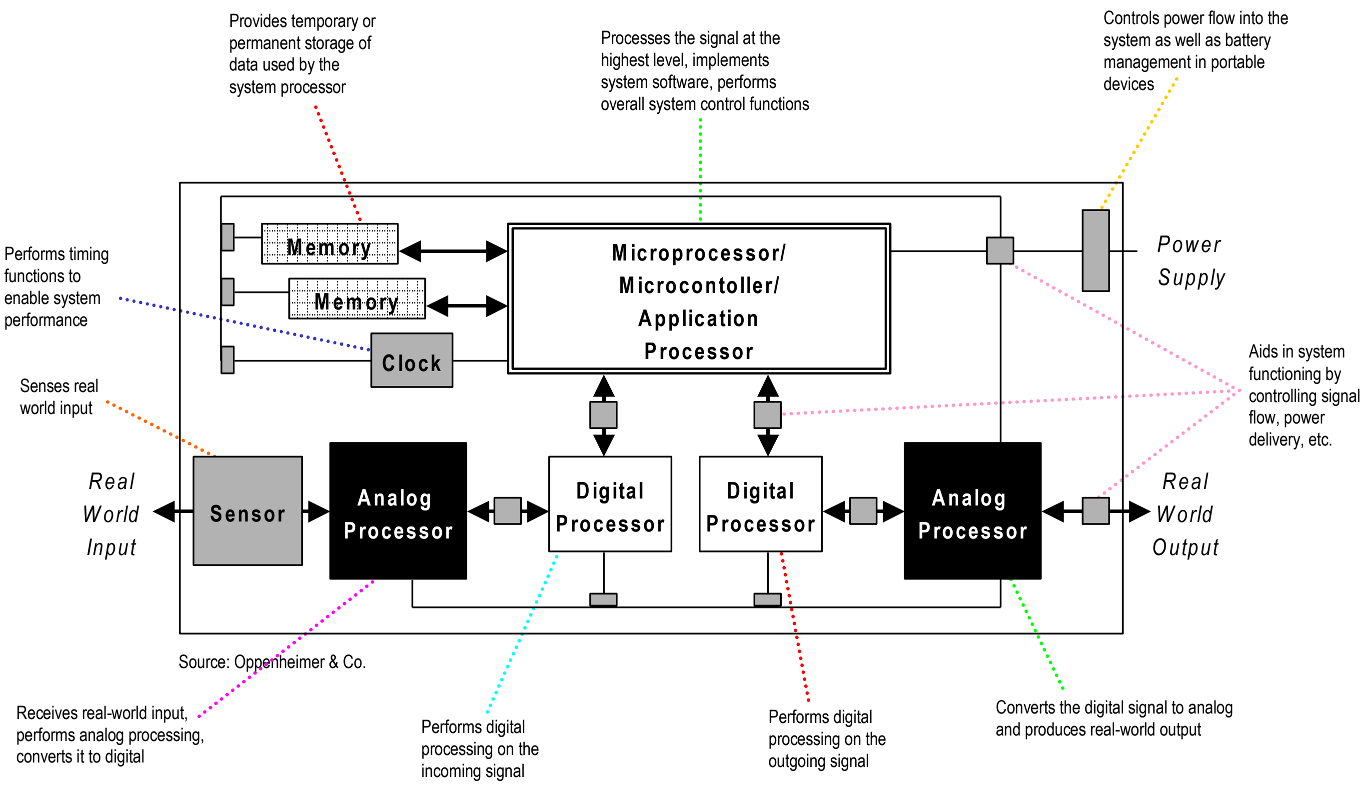
Automotive

We now move from a discussion of semiconductor devices to the electronic systems that use them. We discuss several key equipment types grouped into six end market categories, and for each type of equipment, we discuss the end market unit forecast, our semiconductor revenue forecast, the competitive environment for both equipment and ICs, and market and technology trends. Note that in general, we limit the equipment types we discuss to those that are implemented primarily using application specific standard and/or custom ICs. There are a multitude of electronic devices that are implemented using mostly generic components—e.g., analog SLICs, microcontrollers, general purpose logic, discretes, etc.—which, while they may ship in significant volume, do not present themselves as opportunities for specialization. We break down the key semiconductor end markets into the following categories:

- **Computing**: Equipment used in personal computing and data processing, including PCs, tablets and servers, PC displays, hard disk drives, and printers/multi-function peripherals.
- **Networking**: Client and infrastructure equipment for local area, wireless, personal area and storage networks.
- **Telecom/Datacom:** Service provider and enterprise equipment used to implement voice and data networks.
- **Wireless**: Cellular handsets and wireless infrastructure equipment. WiMAX and LTE are also discussed.
- **Consumer**: Digital consumer devices, such as set-top boxes, DVD and Blu-ray players, PMP players, game consoles, etc.
- **Automotive**: Electronic systems and subsystems used in automobiles.

Block Diagram Example: A Basic System

In the sections that follow, we will use block diagrams to identify key semiconductor opportunities.
A typical electrical system block diagram looks like this:



Source: Oppenheimer & Co.

The diagram above, which we showed earlier in Section III when we introduced the different types of semiconductor devices, displays a generic electronic system. In the sections that follow, we show application specific electronic systems using the same format. We will use black to denote analog devices and white to denote digital devices. Double borders denote microcomponents, while a checkered pattern denotes memory. Note that in most cases, we will not show the multitude of enabling devices (gray) that populate the board.

Computing

Four Key Markets:

PCs and Servers

PC Displays

Hard Disk Drives

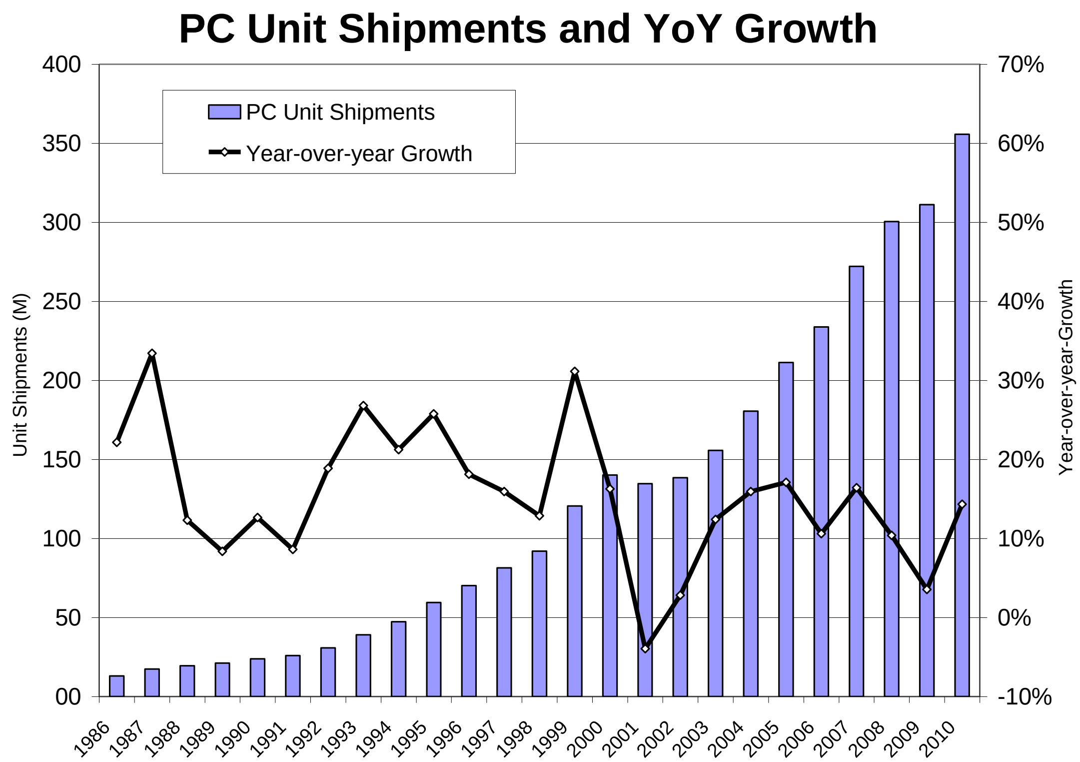
Printers and Multi-Function Peripherals

Computing remains the largest single application for semiconductors and includes equipment such as desktop PCs, notebooks, tablets, servers, displays, hard disk drives, printers and other peripherals. Although these devices are pervasive in the United States, Western Europe and Japan, emerging markets are major growth opportunities. In discussing the end markets for computing semiconductors, we focus on four key product areas:

- **PCs and Servers:** Includes all semiconductor devices—including memory—that are used on desktop and notebook motherboards and in industry-standard servers. This area excludes semiconductors sold into subsystems and peripherals, such as hard disk and other mass storage devices, displays, printers and other peripherals. These devices are discussed separately.
- **PC Displays:** Includes all displays designed specifically for use with PCs, including CRT, desktop LCD, and notebook LCD screens.
- **Hard Disk Drives:** All hard disk drives used in PCs and servers, enterprise storage, and consumer applications.
- **Printers and Multi-Function Peripherals:** All laser and inkjet based printers. Includes multi-function peripherals, which include printer, scanner, and fax functions.

PCs and Servers

PCs remain the largest single consumer of semiconductors and a huge portion of technology spending. After stalling during the post-Y2K tech downturn, growth has resumed, mostly in notebooks, netbooks, servers, and emerging markets.



Source: IDC, Oppenheimer & Co.

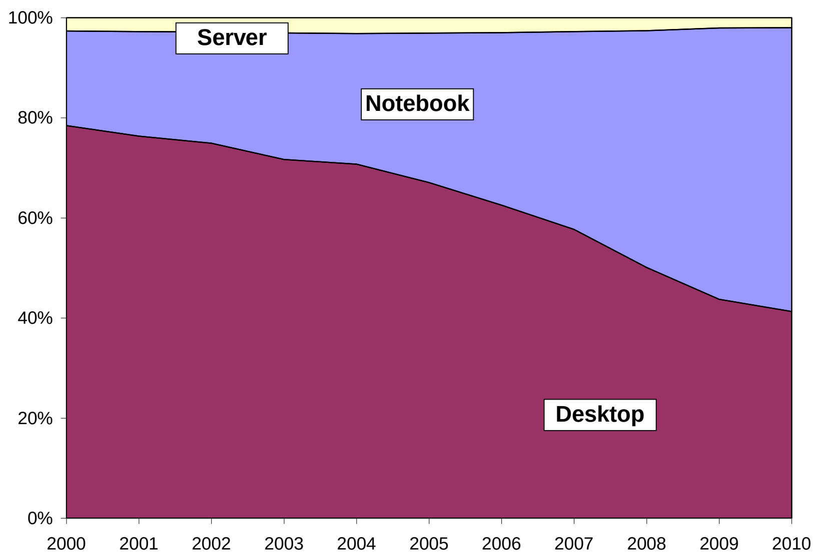
PCs remain at the center of the technology universe and are a huge portion of IT and home technology spending. The market has matured a great deal over the past decade, with the commoditization of PCs forcing consolidation in the industry and average selling prices declining rapidly as system differentiation diminishes. Growth has slowed in the developed markets as corporate PC penetration has peaked, and consumer PC adoption has decelerated.

Still, emerging markets present growth opportunities for PC makers and there is still a healthy replacement market in the developed regions. After the post-Y2K tech downturn drove anemic PC sales in 2001 and 2002, unit growth recovered nicely from 2003 to 2005 (averaging 15% per year), led by strong notebook growth. Growth decelerated slightly in 2006 to 2008 but still approximated 12% per year on a global basis eclipsing 300 million units. The emergence of low cost netbooks fueled 4% growth in 2009, more than offsetting a 10% decline in desktops. The PC industry saw a return to more normal growth rates in 2010, with units climbing 14% to approximately 356 million.

PCs and Servers

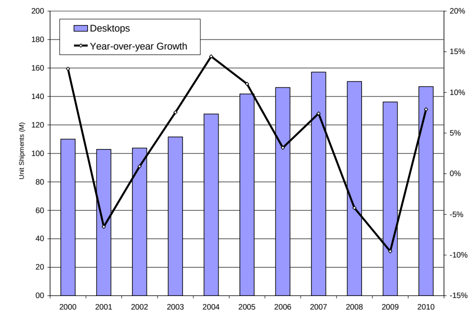
Desktops are the most mature market, seeing relatively modest growth. Notebooks have gained significant ground against desktops as mobility trends have seen solid consumer acceptance; servers have seen consistent growth.

PC & Server Unit Share

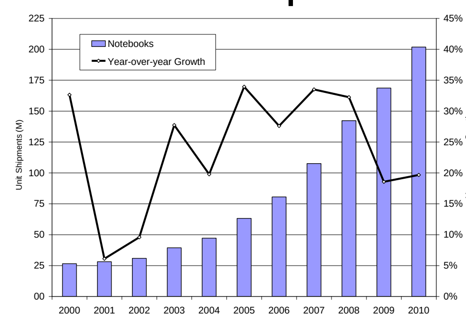


Source (all graphs): IDC, Oppenheimer & Co.

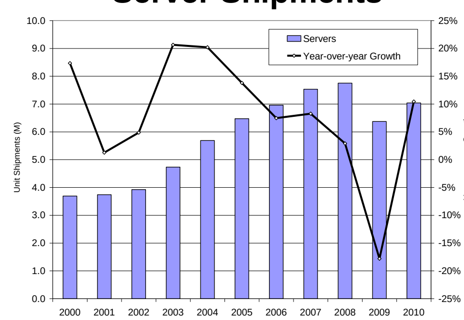
Desktop Shipments



Notebook Shipments



Server Shipments



By platform, desktops have historically been the largest market. In 2009, notebooks surpassed desktops as the largest segment of the PC market. Today, desktops represent 41% of total units shipped. Desktops are also the most mature market, having grown just at a 1% CAGR over the past five years vs. the total market at 11%. In general, growth in desktops is being driven by emerging markets, as PC penetration in the developed world is pretty stagnant at present.

Notebooks have grown at a much faster rate—26% over the past five years—and now represent 57% of shipments. This has resulted primarily from desktop replacement in both corporate and consumer PC channels. Notebooks have also increased the total market for PCs by offering the advantages of mobility, opening up new applications for PCs, primarily with thin-and-light notebook offerings and the emergence of the netbook.

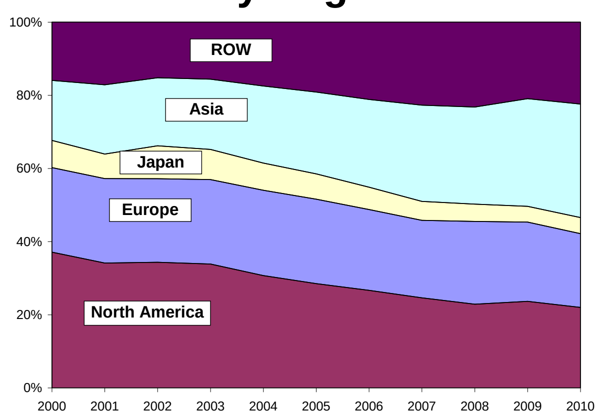
x86 servers have underperformed the market, growing 2% over the past five years—though still small at 2% of total unit shipments. Server OEMs have done an excellent job of packing more performance and functionality and improving ease-of-use into low-end and mid-range servers over the past few years, opening the market to more small and medium-sized businesses, which have historically depended on either custom-built systems or simple small-business software running on a normal desktop PC. x86 servers are also cannibalizing the mid- and high-end proprietary server market, offering cost and configurability advantages over proprietary systems from OEMs like IBM and HP. Many industry participants believe that virtualization will limit server unit growth over time, which may be behind the drop in year-over-year growth rates in 2008-2010 (averaging -4% per year).

PCs and Servers

PC shipments are shifting from the mature markets of North America, Western Europe, and Japan to developing economies in Asia, Eastern Europe, and Latin America. The distribution channel is growing in importance, serving local consumers in these fast-growing emerging markets.

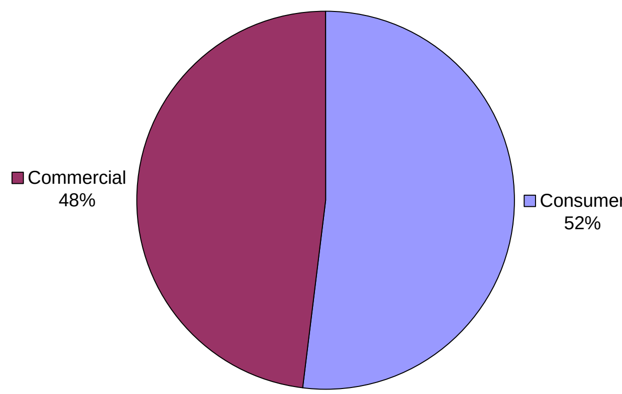
By customer type, PCs are split roughly 52% consumer and about 48% enterprise or commercial.

PC Unit Shipment Share By Region



Source: IDC, Oppenheimer & Co.

2010 PC Unit Shipments By Customer Type



Source: Dataquest, Oppenheimer & Co.

Looking at the market by geography, PCs have shown a sustained shift away from mature markets and toward developing economies, especially in Asia. North America was overtaken as the largest market for PCs in 2007 by Asia, now representing 22% of total shipments in 2010. This market has grown at a CAGR of 5% over the past five years, having re-accelerated following the post-Y2K malaise in 2001 and 2002. Growth in Western Europe—20% of PC shipments—has been a bit better at 8% over the past five years, notably led by notebooks. Japan was the weakest region, with a 1% CAGR over the past five years and declining to just 4% of total shipments.

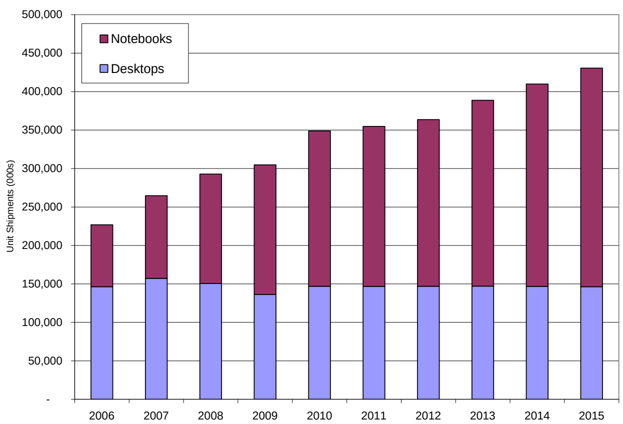
Asia and the other emerging markets, on the other hand, have seen runaway PC growth. Unit shipments have grown at an 18% CAGR over the past five years in Asia and 15% in the rest of world segment. As a percentage of total shipments, Asia and rest of world account for 31% and 22% of unit shipments, respectively.

In terms of customer base, 52% of PC unit shipments in 2010 were sold into the consumer channel, with 48% sold into the commercial channel. These percentages have been relatively stable for the past few years, only slightly favoring the consumer PC market, due to two offsetting factors: 1) the consumer PC market in the US and Europe has grown faster than the mature corporate sector, favoring consumer PCs; and 2) Asia/Pacific has been the strongest area of growth, primarily for large and small enterprises, favoring commercial PCs.

PCs and Servers

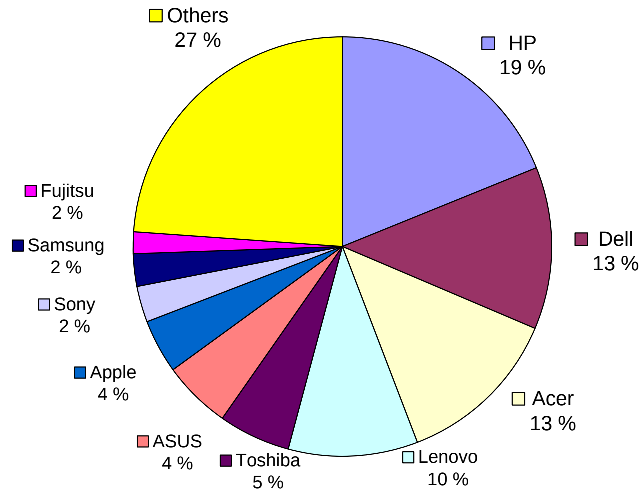
Desktop and Notebook PC Unit Forecast

- •Total PCs growing 4%, from 349 million units in 2010 to 430 million units in 2015.
- •Desktops declining slightly, from 147 million units in 2010 to 146 million units in 2015.
- •Desktop shipments in developed markets are set to decline through 2015, with growth coming from Asia and ROW.
- •Notebooks growing 7%, from 202 million units in 2010 to 284 million units in 2015.
- •Notebooks should grow in all regions, though less in Japan given high penetration rates today.



Source: IDC, Gartner, Oppenheimer & Co.

Desktop and Notebook PC Suppliers



Desktops	***Notebooks***
HP	HP
Dell	Acer
Lenovo	Dell
Acer	Lenovo
Apple	Toshiba
Fujitsu	ASUS
Tongfang	Samsung
ASUS	Apple

Source: IDC, Oppenheimer & Co.

PC Unit Forecast: The past several years have seen a solid recovery in PC unit shipments following the challenging post-Y2K years of 2001-02. Unit growth has been double-digits in 2003 to 2010 (excluding 2009), and approximated 14% in 2010. Corporate replacement has resumed at a normal pace, developing markets have been flocking to new lower-priced and full-featured notebooks, and emerging market growth has continued unabated.

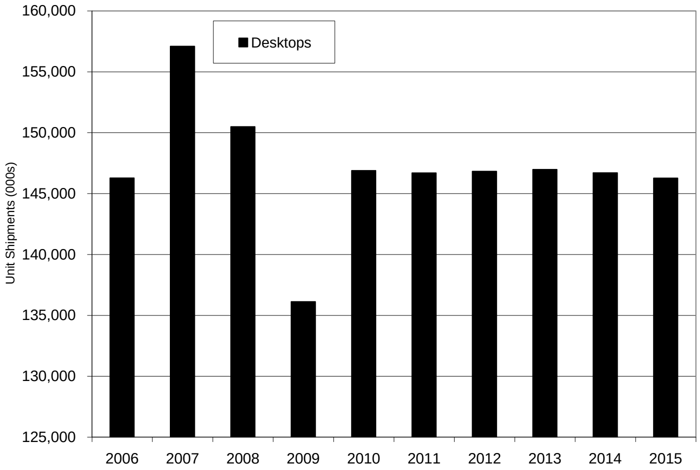
Going forward, we expect PC unit growth to settle in at a 4% CAGR, growing from 349 million units in 2010 to 430 million units in 2015. We expect the trend away from desktops to continue, declining slightly through 2015; overall we expect desktop PCs to decrease from 147 million units in 2010 to 146 million units in 2015. Note that the US, Western Europe, and Japan should each see negative CAGRs in desktop, with growth in Asia and the rest of the world.

We expect mobile, which is becoming more of a focus at every major PC and PC component supplier worldwide, to outperform with a 7% CAGR, rising from 202 million units in 2010 to 284 million units in 2015. Some of this growth will be driven by emerging markets, which should finally begin to see meaningful desktop replacement toward the back half of the forecast period. We highlight the ever-increasing interest in tablets is starting to impact notebook growth rates. Over time, we believe tablets will continue to cannibalize notebook growth.

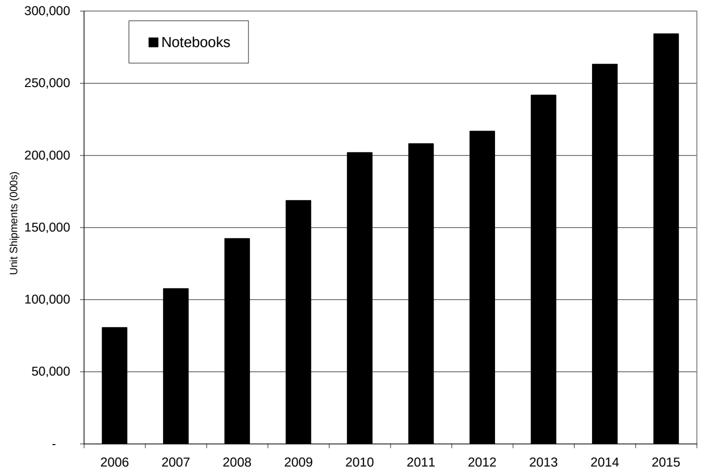
Within each platform, we expect the shift to lower price points to continue, though not as sharply as in the past few years. We believe most PC vendors have come to terms with the lack of elasticity in the market; i.e., their price cuts can be successful in winning market share but have been less than effective in growing unit demand for the industry as a whole. We also believe the market is sufficiently consolidated, with top OEMs in control of pricing.

The exhibits below display our unit shipment forecast for desktops and notebooks.

Desktop PC Unit Shipments, 2006-2015E



Notebook PC Unit Shipments, 2006-2015E



Source: IDC, Dataquest, Oppenheimer & Co.

PC Suppliers: The PC market is served by three large double-digit share holders, HP, Dell and Acer, along with a number of tier-2 OEMs as well as a few notebook specialists. In total, the top ten vendors comprised 73% of the PC market in 2010. A huge base of small “white box” or “clone” PC makers and system integrators, most of which operate in emerging markets, supply the remaining 27%.

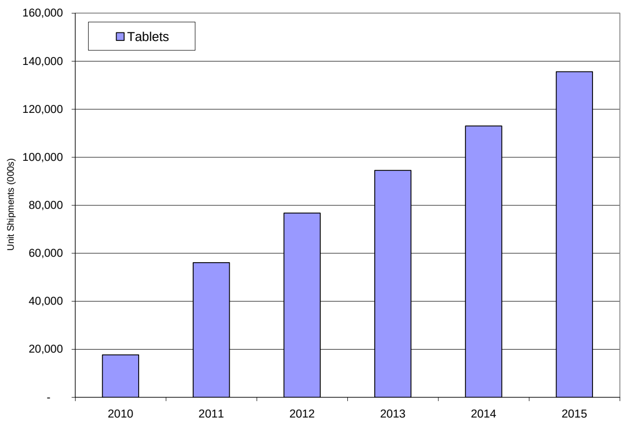
In 2010, HP and Dell held 19% and 13% unit share, respectively. Dell was overtaken by HP as the No. 1 vendor in 2007 and has held onto that position. In terms of systems, HP was No. 1 in both desktops and notebooks in 2010.

Acer trailed Dell slightly for the No. 3 position in 2010 with 13% share and remained the No. 2 supplier in notebooks. In 2007, Acer acquired Gateway and Packard Bell. Lenovo remained at the No. 4 position in 2010 with 10% share; Lenovo purchased IBM’s PC business in 2005. Toshiba followed with 5%, while ASUS, Apple, Sony, Samsung and Fujitsu all held 4% or less each.

PCs and Servers

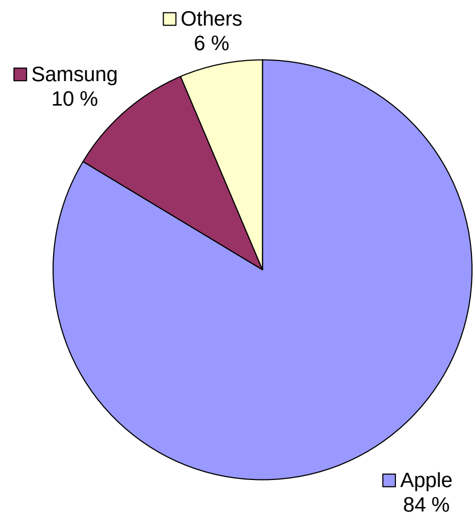
Tablet Unit Forecast

•Total tablets growing at a 50% CAGR, from 18 million units in 2010 to 136 million units in 2015.
•Non-Apple tablets have had difficulty gaining traction to date; we expect increased penetration of these devices, particularly Android- and Windows-based tablets, as price points become more competitive.
•While Apple will likely cede some share over time, we believe the company will still represent over 70% of the tablet market in 2015.



Source: IDC, Oppenheimer & Co.

Tablet Suppliers



Source: IDC, Oppenheimer & Co.

Tablet Unit Forecast: Apple has maintained 75%+ share of the tablet market since the launch of the iPad, and the market has yet to establish a viable competitor; many have tried at the high end and many have failed. The low-end white box market in emerging nations has recently begun to experience explosive growth as aspirational consumers seek a viable (and cheap) alternative to the iPad. At the high end of the market, differentiation and OS (thereby “apps”) will remain key. The Android market remains extremely fragmented and the market for apps is growing; but an OEM has yet to offer differentiation hardware capabilities from the iPad.

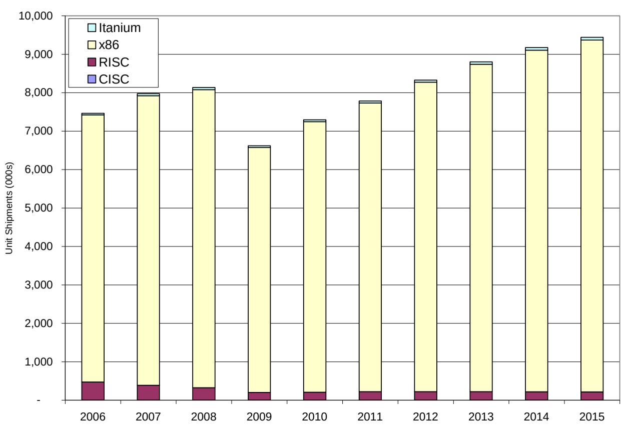
We expect the tablet market to grow from 18 million units in 2010 to 136 million units in 2015, a 50% CAGR. We expect Apple to maintain its dominant share position and retain over 70% of the tablet market in 2015.

Tablet Suppliers: The tablet market is dominated by Apple as the company was first to market with the launch of the iPad in April 2010. Apple garnered ~84% of the market in 2010. Samsung was the No. 2 supplier with roughly 10% share. Many handset and PC OEMs have announced tablets in 2011, including Motorola Mobility, Amazon, ASUS, Acer, RIM, Toshiba, Sony, HTC, HP, Dell, among others.

PCs and Servers

Server Unit Forecast

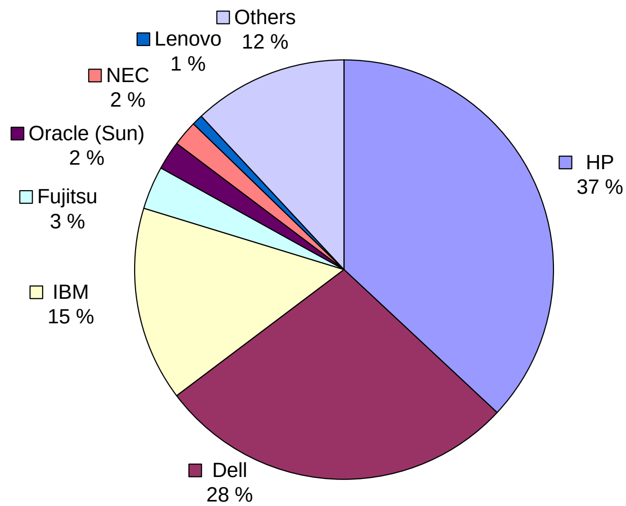
•Total servers growing at a 5% CAGR, from 7.3 million units in 2010 to 9.4 million units in 2015.
•Virtualization trends weigh on unit shipments in forecast years as IT managers can do more with less.
•x86 servers already represent 97% of the market in 2010 and should hold steady as a percentage through 2015.
•Itanium is expected to grow to 1.0% of total shipments by 2015.
•RISC shipments likely peaked in 2004 and should see a 1% CAGR, declining to 2% of total shipments in 2015.



Source: IDC, Oppenheimer & Co.

Server Suppliers

Industry Standard Servers (x86)



Low- and Mid-Range Proprietary	*High-End Proprietary*
IBM	IBM
HP	HP
Sun	Sun
Fujitsu	Fujitsu
NEC	Groupe Bull

Note: The semiconductors used in proprietary servers are not discussed in this document given their custom nature; however, we provide unit forecast and vendor data for context.
Source: IDC, Oppenheimer & Co.

Server Unit Forecast: The server market has undergone a lot of change over the past decade, as the market has shifted away from proprietary systems designed from the silicon up by server OEMs. The market is now composed of a mix of proprietary RISC/CISC systems for high performance applications and industry standard (x86-based) servers used for mainstream IT infrastructure. As of 2010, industry standard servers had grown to 97% of unit shipments, though they were only around half of server industry revenue due to the dominance of RISC/CISC at the high end.

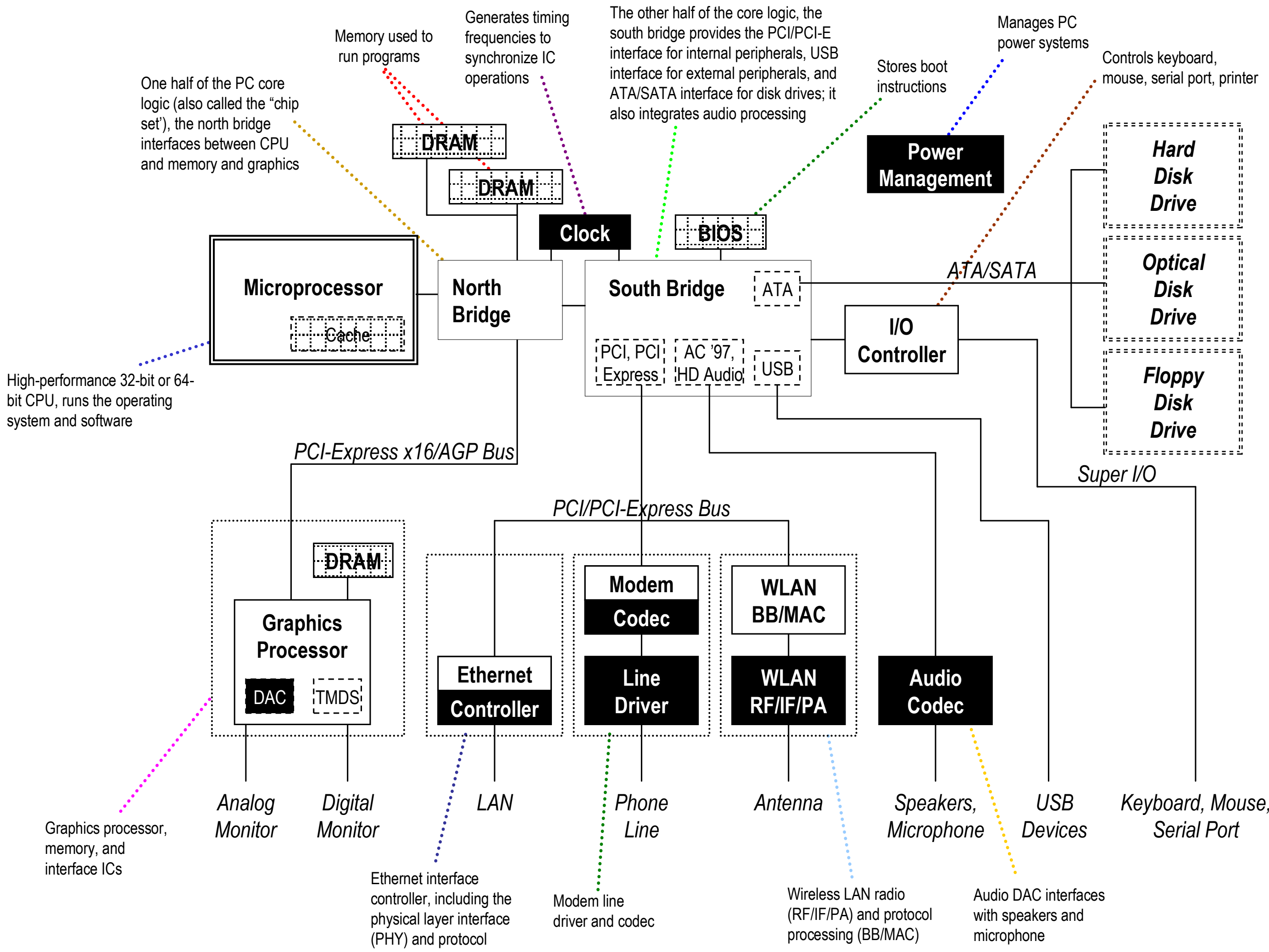
Like the PC market, server shipments were sluggish in 2001 and 2002 but grew double digit from 2003 to 2005. In 2008, however, unit growth dropped to just 2%. IT budgets started being slashed as the global recession took full force in late 2008. The market struggled throughout 2009 and market declined 19% year-over-year. A corporate refresh cycle helped push 2010 growth to 10% year-over-year, partially driven by Intel's Westmere and Nahalem Xeon platforms for dual-processing (DP) and multi-way processing (MP), respectively. Looking ahead, we expect a 5% CAGR for server units, with the market growing from 7.3 million units in 2010 to 9.4 million units in 2015.

x86 servers should continue to dominate the market; RISC has likely peaked in 2004, and should see a 1% CAGR through 2015. Itanium should grow to 1.0% of total shipments by 2015 from a small base.

Server Suppliers: The x86 server market is served by three key players: HP with 37% unit share in 2010, Dell with 28%, and IBM with 15%. The rest of the market remains fragmented, with Fujitsu, NEC, Oracle (acquired Sun) and Lenovo each holding less than 5% and representing approximately 8% of the market in aggregate.

The proprietary server market is served by IBM, Oracle (Sun), and HP for low-end and mid-range and IBM, HP, Sun, and a number of small high-performance specialists at the high end.

PCs and Servers



Source: Oppenheimer & Co.

Note: The diagram above shows a typical full-featured desktop PC. Notebook PCs contain some additional semiconductor content, including battery management and PC card controllers. Servers look slightly different in that they can have multiple processors, more memory, larger and less integrated chipsets and less multimedia content.

The nature of computing requires a variety of powerful devices with diverse functionality to handle a wide set of data types. The easiest way to think of a PC is to draw an analogy to the human body. The CPU (central processing unit), a microprocessor, performs all high-level processing, essentially the high-level brain functions of critical thinking and problem solving. RAM (random access memory) acts as short-term memory, used by the CPU as a workspace to process its instructions. BIOS, another form of memory, stores boot instructions (similar to autonomic nerves), while a clock provides synchronization functions, keeping all systems in check. The chipset (includes north bridge and south bridge) acts as the base of the spinal cord, relaying instructions to and from the CPU and connecting it to the rest of the PC over the system bus (usually PCI or PCI-Express), which functions as the spinal column. The hard disk, floppy disk and CD/DVD drives provide long-term storage, which is retrieved by the CPU and moved into RAM when needed, similar to a human being's long-term memory. Together, these systems function as a cohesive central nervous system, powerful enough to perform complex computations and versatile enough to handle a wide variety of inputs.

Outside these core systems, various peripheral devices perform the specific input and output processing to connect the PC to the outside world. The I/O controller interfaces with simple input devices such as the keyboard, mouse, parallel and serial ports (used by older, pre-USB printers and other peripherals). Graphics processor and interface chips produce the visual image displayed on the monitor (allowing the computer to draw pictures for display), while audio controllers and codecs produce sound (allowing the computer to literally speak and be spoken to). Ethernet, modem and wireless LAN/Bluetooth ICs connect the PC with other data sources (analogous to a person placing a phone call) and USB/Thunderbolt ports interface with additional peripherals (e.g., scanners, MP3 players, digital cameras).

PC and Server Semiconductor Device Summary

Processing

- **Microprocessor:** The central processing unit (CPU) in a PC is a high-performance 32- or 64-bit microprocessor. It performs all major processing of software code and communicates with all other devices in the system. It uses a modified CISC (Complex Instruction Set Code) architecture to process the lengthy sets of instruction used in typical computer software. Aside from this compute “core,” the CPU usually includes on-chip memory called a “cache” as well as additional logic “extensions,” which are embedded instructions designed to optimize the execution of certain types of critical functions (i.e., multimedia, security). Most mainstream CPUs now use multiple cores, usually two or sometimes even four. Microprocessor performance is measured in clock speed, usually in Gigahertz (GHz), which measures the number of instructions per second (in billions) the processor can handle. Examples of PC processors are Intel’s Core i7 and AMD’s Phenom II. Note that desktop and notebook PCs usually have a single CPU, while servers can have two or more.

Chipset, BIOS, Clock and I/O

- **Chipset (North Bridge and South Bridge):** The chipset supports the CPU by performing some related processing functions and by connecting the CPU out to the rest of the system. The north bridge connects the CPU out to main memory and also to the graphics processor (many include a graphics processor on-chip). The south bridge is the gateway to other PC interfaces (besides graphics) and provides access to the hard disk drives and optical drives via the ATA/SATA, as well as I/O, networking, multimedia, and other peripherals via the PCI or PCI-Express bus.
- **USB Controller and USB Host** (integrated into south bridge): The USB host sits in front of the USB port and receives input from and sends output to a peripheral device using USB (Universal Serial Bus). USB has been widely adopted for its ease and speed: devices connect seamlessly and sometimes require no drivers. USB 2.0 can run at speeds up to 480 Mbps.
- **IEEE 1394/Firewire Controller and Host** (not shown): An alternative standard to USB is IEEE 1394/Firewire. Chipset leader Intel has not pushed this standard; thus most PCs that support Firewire use discrete controllers.
- **BIOS:** BIOS stores boot instructions read by the microprocessor whenever the computer starts up. BIOS is usually implemented with low density NOR flash memory.
- **Clock:** Motherboard clocks provide timing and synchronization functions, keeping all systems in the PC working together. Examples include clock families from IDT, Cypress, and Realtek.
- **I/O Controller:** The I/O controller interfaces the south bridge with the PC’s primary simple input and output devices, including the keyboard, mouse, floppy drive, printer and serial devices.
- **PC Card Controller** (not shown, only used in notebooks): This controller is a specialty I/O device that provides the interface with PCMCIA cards. Controllers are only found in notebook PCs. Note that notebooks that support PCI-Express cards do not need a discrete controller, since this is integrated into the south bridge.

Memory

- **DRAM (Dynamic Random Access Memory):** PCs use DRAM to store program data in use by the CPU at any given time. DRAM is blank when the computer boots up and goes blank again when the computer is shut down. DRAM is implemented on modules that can be inserted and removed from the PC motherboard. DRAM is a commodity measured in MBs, segmented by interface (SDRAM, DDR, DDR-II, etc.).
- **Memory Register or AMB I/O** (not shown, only used in servers): Servers typically use higher performance memory modules than PCs. These higher performance parts are known as registered DIMM modules, and they include register ICs (similar to a timing IC) directly on the module. Newer fully-buffered DIMMs include a specialty I/O IC known as an AMB I/O IC directly on the module, which manages the interface to the server chipset, which would include AMB I/O logic on chipset. Future memory architectures may use buffers directly down on the server motherboard.
- **NAND Cache** (not shown, began to appear in 2007): PC OEMs are beginning to add a memory cache comprised of NAND flash to store frequently used operating system commands and other files.

Graphics and Audio

- **Graphic Processor (GPU):** The graphics processor is a digital processor optimized to produce 2D and 3D graphics images. In desktops, GPUs are found on separate add-in cards (these cards usually contain DRAM specifically used for graphics); in notebooks they are down on the motherboard. GPUs connect up to the north bridge using PCI-Express x16, though older cards still use the specialized AGP graphics bus. Note that many systems eliminate the GPU by integrating graphics functionality into the chipset. Examples of GPUs include NVIDIA’s GeForce and AMD’s Radeon family.
- **Sound Processor:** (not shown, integrated into south bridge, can also be a discrete add-in board): The sound processor is a digital processor that produces stereo and surround sound audio processing. Sound processors were originally implemented with add-in boards, and a minority of high-performance PCs implement separate PCI or PCI-Express sound cards with discrete audio processors. Most PCs, however, utilize the sound processor integrated into the south bridge, with discrete controllers reserved for multimedia desktops and notebooks.

- **Audio Codec:** The audio codec is a specialized digital-to-analog/analog-to-digital converter and amplifier that performs the conversion of audio signals from the digital sound processor to an analog format for use with speakers/headphones (output) and microphones (input).

Networking

Note: Networking ICs, including devices found in PCs and servers, are discussed in further detail later on in the networking section.

- **Analog Modem Codec and Line Driver:** The modem codec encodes digital signals from the PC into analog signals for transmission over the phone line and vice versa. The line driver is the analog chip that interfaces with the RJ-11 phone line. In many PCs, a “soft modem” is used, eliminating the need for the discrete codec; a discrete line driver, however, remains.
- **Ethernet Controller:** The Ethernet controller is a single-chip integrated device that interfaces between the PC and the Ethernet local area network. It integrates both the MAC and PHY. The Ethernet MAC encodes data from the PC into Ethernet frames and affixes overhead and vice versa. The PHY (physical layer) interfaces with the RJ-45 Ethernet cable and converts the serial Ethernet stream into parallel digital form for processing and vice versa.
- **Wireless LAN Baseband/MAC and RF/IF/Power Amp:** Many PCs include 802.11 (WiFi) wireless networking functionality, especially notebooks. In most implementations, a baseband/MAC chip encodes data from the PC into 802.11 or Bluetooth format and interfaces with the radio. The RF/IF and power amp performs the radio transmission and reception and interfaces with the antenna. Note that we have displayed the chipset as a 2-chip solution; in reality chipsets can be less integrated and will split up some of the functions (separate power amps, multiple radios, specialized MACs, etc.); others will include the solution on a single chip.
- **Bluetooth SoC (not shown in diagram):** Some PCs include Bluetooth personal area networking technology for connectivity to peripherals and headsets. Bluetooth is usually implemented with a single chip SoC containing baseband, RF, IF, and power amp. Though they could connect to the chipset using PCI/PCIe, most PC Bluetooth uses an internal USB socket.

Power Management

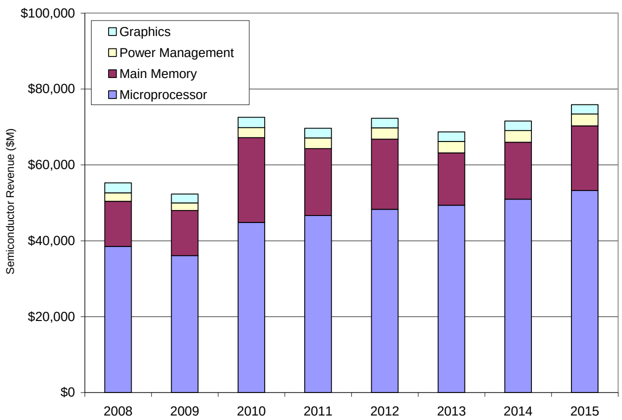
Note: Our block diagram does not show specific power management components; these are used throughout the board and on add-in boards as well as within and around the PC power supply.

- **Power Management:** Power management content in a PC includes both analog ICs and discretes. Key types include power transistors, power diodes, AC/DC regulator ICs, PFC pre-regulator ICs, linear regulator ICs, battery charging and management ICs, hot-swap controllers and MOSFET driver ICs.

PCs and Servers

PC and Server Semiconductor Forecast

•PC and server ICs growing 1%, from $72.5 billion in 2010 to $75.8 billion in 2015.
•Microprocessors to grow 4% as unit growth is tempered by pricing pressure.
•DRAM to decline 5% with a peak in 2010.
•Graphics faces integration and price pressure.
•Power management growing 4%, boosted by notebook unit growth.



Source: Gartner, Oppenheimer & Co.

Note: Our entire discussion of PC and server ICs includes chips used in desktop PCs, notebooks, and x86 servers. It excludes chips used in proprietary RISC/CISC servers, as these are typically custom solutions that are difficult to cost within the server bill of materials. It also excludes LCD drivers used in notebook PCs, as these are included in our PC display forecast. Also note that our forecast includes all PC and server-related ICs used in full systems, add-in boards, and the retail after market.

***PC and Server Semiconductor Forecast*:** We estimate the computing semiconductor market—which includes desktop, notebook and x86 server semiconductors—totaled $72.5 billion in 2010, up 39% year-over-year. The market benefited from healthy growth in PC units.

Looking to 2015, we expect the combination of PC unit growth, stabilization of microprocessor ASPs, and the continuing shift to notebooks (which generally have higher component BOMs than desktops) will drive continued growth for PC semiconductors, though the CAGR will be somewhat dampened by a negative cyclical environment for DRAM. In total, we forecast the market to reach $75.9 billion in 2015, a 1% CAGR.

Drilling down further, we segment the market by subsystem. The largest device segment in 2010 was microprocessors, at $45.0 billion, roughly 62% of industry revenues by our estimate. Given that the microprocessor is the core processing device of the computing industry, we would normally expect microprocessor revenue to grow in line with the overall market; however, PC CPUs have begun integrating graphics, boosting CPU ASPs slightly. We therefore expect PC CPU revenue to grow at a 4% CAGR, to $53.3 billion in 2015, or 70% of total IC revenue.

Main memory totaled $22.4 billion in 2010, up 88% from 2009 as DRAM prices rose due to supply constraints and a snapback in PC demand. DRAM is expected to remain a volatile market, peaking at $22.4 billion in 2010 and declining to $17.6 billion in 2015, yielding a -5% CAGR over the forecast.

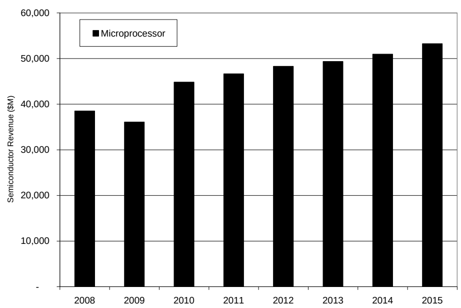
The graphics subsystem, at $2.7 billion in 2010, is expected to decline slightly to $2.5 billion in 2015. Discrete GPUs should see a negative CAGR of 2% as low-end GPUs are cannibalized by CPUs with integrated graphics (e.g., INTC's Sandy Bridge).

Finally, power management is expected to grow at a 4% CAGR, from $2.6 billion in 2010 to $3.1 billion in 2015. The chief driver is the faster growth in notebooks, which include more power management content than desktops. Price erosion in this market is also less severe than many other component markets given the high analog content.

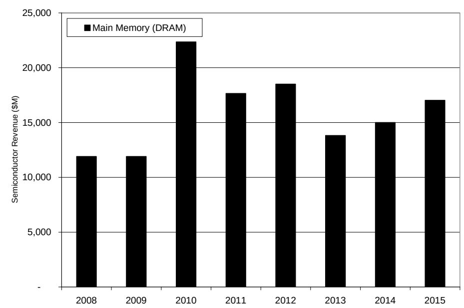
The exhibits below depict our forecasts for the various PC and server semiconductor sub-systems. On the following page, we display individual device forecasts by platform (desktop, notebook and server).

PC & Server Semiconductor Subsystem Forecasts

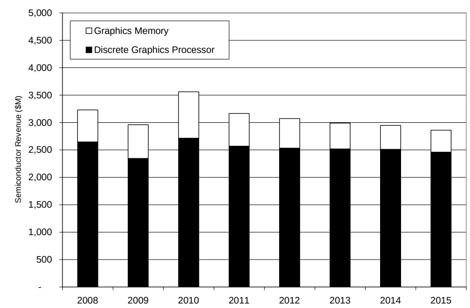
Microprocessor



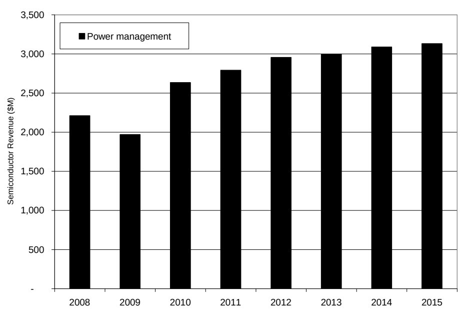
Memory



Graphics and Audio

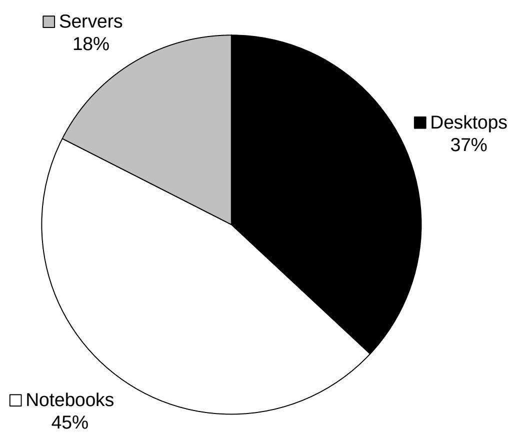


Power Management

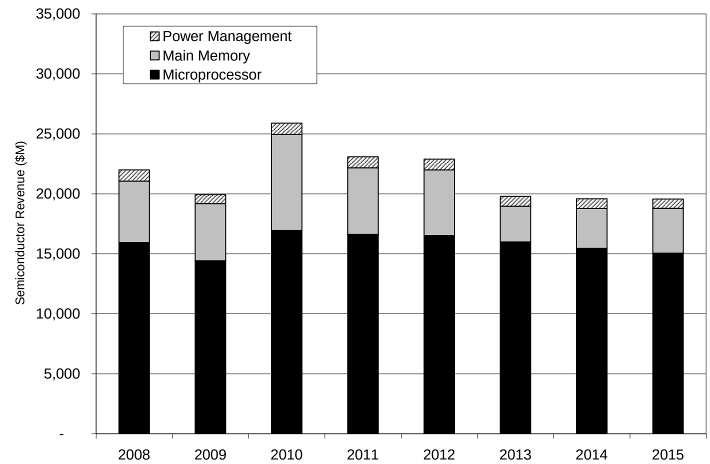


Source: IDC, Dataquest, Oppenheimer & Co.

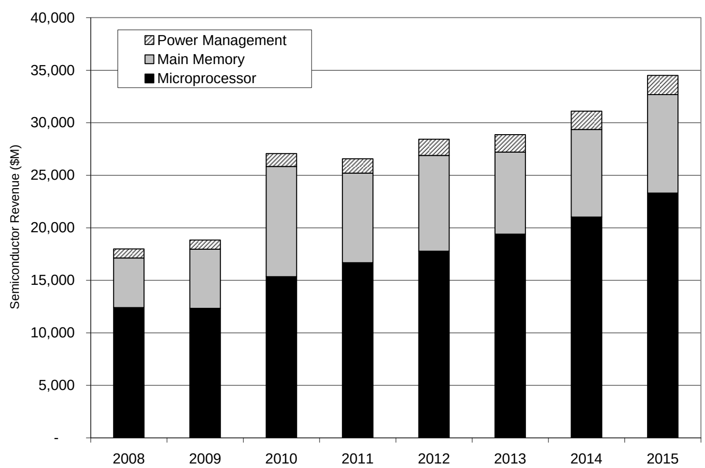
2010 PC Semiconductor Revenue By Platform



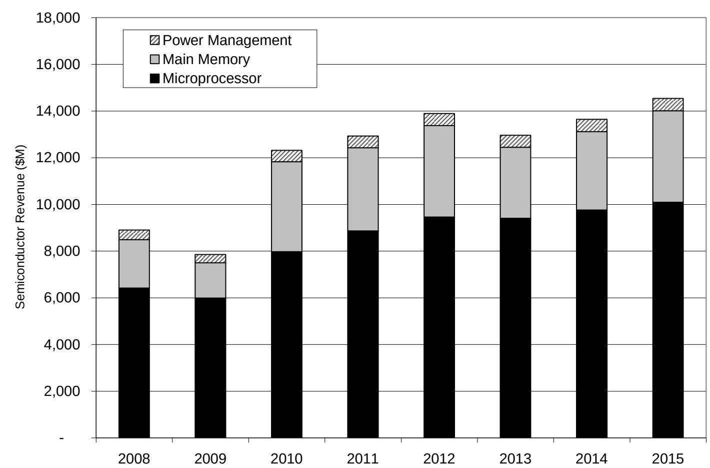
Desktop PC Semiconductor Forecast



Notebook PC Semiconductor Forecast



x86 Server Semiconductor Forecast

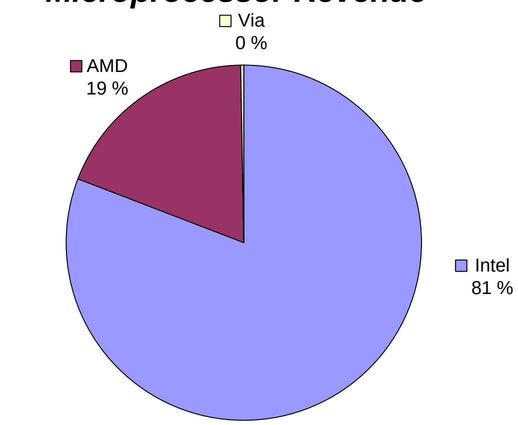


Source: IDC, Dataquest, Oppenheimer & Co.

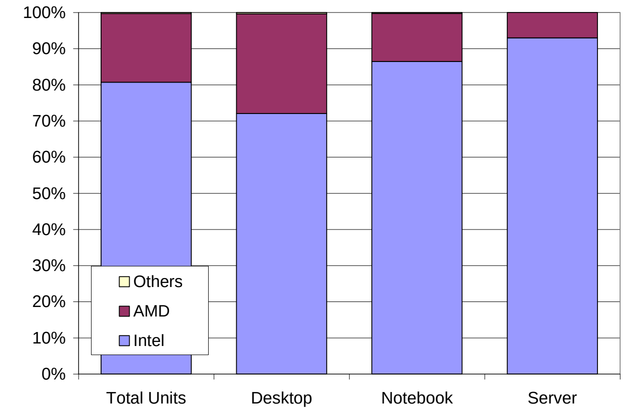
PCs and Servers

PC Semiconductor Market Key Competitors

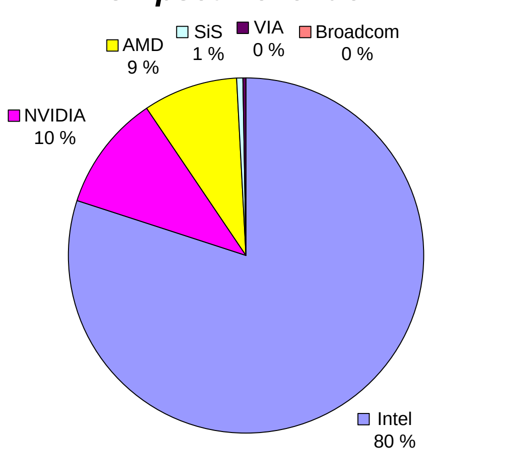
Microprocessor Revenue



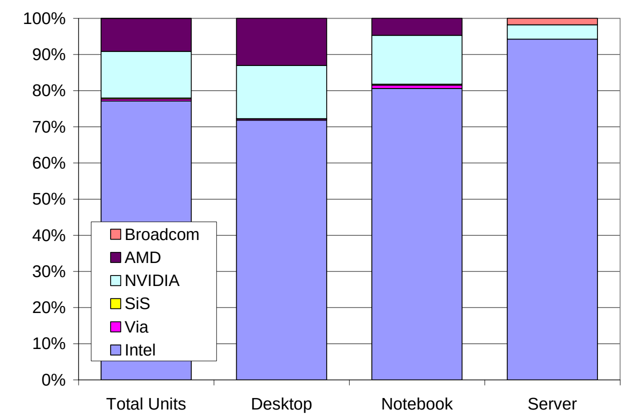
CPU Unit Share



Chipset Revenue



Chipset Unit Share



Source: IDC, Oppenheimer & Co.

The PC semiconductor competitive environment is divided firmly along the lines of devices and subsystems. Although many vendors play in several devices within the PC, the standards, design competencies and competitive dynamics in each subsystem are sufficiently different to warrant separate discussion of each subsystem. In the exhibit above, we display 2010 revenue market share data for microprocessors and chipsets, as well as unit data for desktop, mobile, and server. On the next page, we display discrete graphics controllers, DRAM, BIOS, and power management.

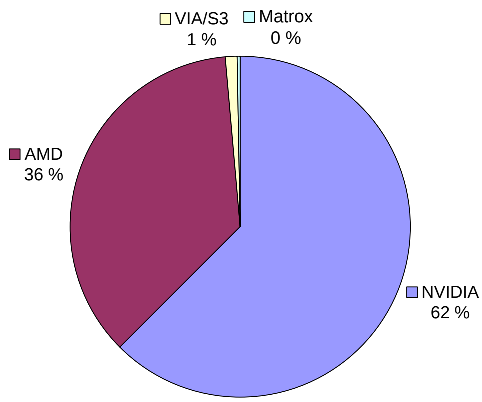
Microprocessors: The PC CPU market is among the most concentrated in the semiconductor industry. In 2010, Intel held roughly 88% revenue share and 81% unit share, up from 87% and 80%, respectively, in 2009. AMD saw its position in the PC CPU market decline to 11% revenue share and 19% unit share from 13% and 20%, respectively. AMD remains well positioned in consumer desktop, with a strong presence at both the low end and also for the very high end for gamer systems. AMD's presence in mobile decreased slightly and its share in server declined as well in 2010; OEMs serving the corporate desktop market are also beginning to offer AMD based systems. Other microprocessor vendors (Via) held less than 1% revenue share and 1% unit share.

Chipsets: Intel dominates the PC chipset market, with 80% revenue share in 2010. The balance is split between graphics leaders NVIDIA and AMD (acquired ATI in 2006) and Taiwanese chipset maker Via and SiS. For servers, Intel and AMD each supply chipsets for their processors, and Broadcom and NVIDIA also support AMD.

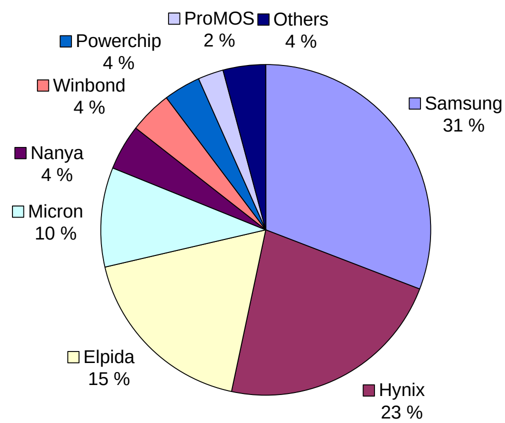
PCs and Servers

PC Semiconductor Market Key Competitors

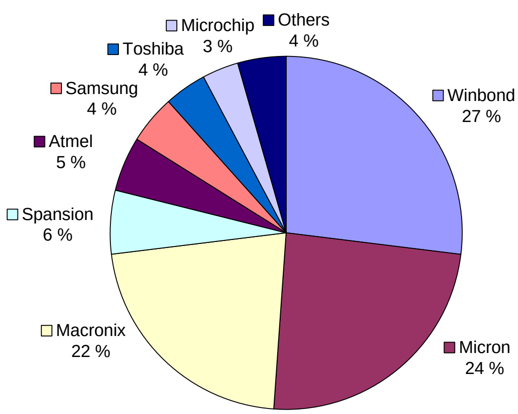
Graphics



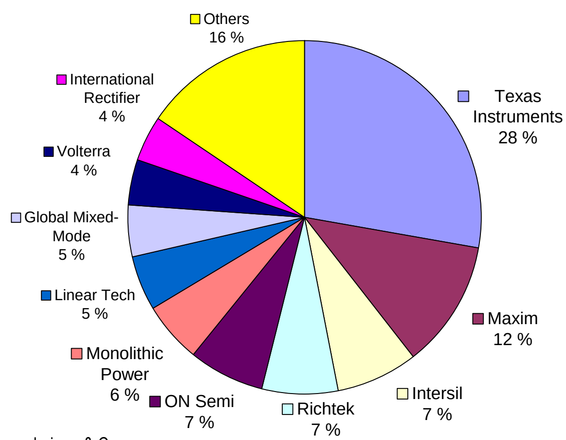
DRAM



PC BIOS (NOR Flash)



Power Management



Source: Dataquest, Oppenheimer & Co.

Graphics: The discrete graphics market has consolidated over the past few years into the hands of two key players: NVIDIA and AMD. Excluding integrated graphics chipsets, NVIDIA held 62% revenue share in 2010, slightly losing share from rival AMD. AMD grew to 36% of total revenue.

Memory: The top vendor of DRAM for PCs in 2010 was Samsung, which held 31% share. Hynix was No. 2 with 23%, followed by Elpida and Micron with 15% and 10% share, respectively. Other vendors include Nanya (4%), Windbond (4%), Powerchip (4%) and ProMOS (2%). Note that this data differs slightly from the numbers for DRAM as a whole, which includes non-PC DRAM (generally lower density and lower speed).

BIOS: BIOS is generally implemented with low density NOR flash. The top vendors for PCs in 2010 included Windbond at 27%, Micron (acquired Numonyx) at 24%, Macronix (22%), Spansion (6%), Atmel (5%), Samsung (4%), Toshiba (4%) and Microchip (3%). Again, share differs from the broader NOR market.

Power Management: The PC power management market, which includes vendors of analog and discrete power components, is highly fragmented. The top vendors of PC power components in 2010 were Texas Instruments and Maxim, with 28% and 12% share, respectively. Intersil, Richtek, and ON Semi followed with 7% share each, while Monolithic Power and Linear Tech held 6% and 5% share, respectively. Other significant vendors include Volterra, Global Mixed-Mode, and International Rectifier.

PCs and Servers

PC Semiconductor Market Trends

- •Microprocessors have moved to dual and multi-core.
- •Intel and AMD now compete head-to-head in all major segments of the microprocessor market.
- •Integrated graphics chipsets now dominate all but the highest end notebooks along with corporate and value consumer desktops.
- •Co-processing is changing the look of PC.
- •Memory controllers have moved into the CPU for faster memory access.
- •Intel and AMD launched CPUs with integrated graphics.
- •The north bridge is disappearing as graphics and memory access are integrated into the CPU.
- •The memory bus is transitioning to DDR3.
- •Gigabit Ethernet pervades the corporate desktop and is ramping in the consumer PC.
- •Wireless LAN is now a standard feature in notebooks; Bluetooth penetration has been sluggish but BT 3.0 should be pervasive.
- •USB 2.0 is pervasive; USB 3.0 is on the horizon.
- •Power consumption is becoming a major issue for all component suppliers into PCs and servers.
- •SSD penetration is still ramping.

- **Microprocessors have moved to dual and multi-core.** Historically, Intel and AMD have achieved greater performance with their microprocessors by focusing on driving Moore's Law in order to ramp up clock speeds for their devices, as well as by boosting the cache size and increasing the pipeline. Intel moved forward with high-k metal gate technology beginning with the 45nm node in 2007. This technology has allowed Intel to push clock speeds to 2.4GHz. In addition to high-k, both Intel and AMD have opted to increase the number of compute cores on their CPUs, allowing parallel processing to take the place of raw speed. This move alleviates the challenge of spiraling heat dissipation figures as they ramp clock speed.

  Intel first introduced dual core for the desktop in 1H05, and followed with a server model in 2H05. AMD did the reverse; dual core server chips launched before desktops. Both vendors have aggressively pushed the technology, and mainstream desktops and notebooks now predominantly feature dual-core, as do nearly all servers. Intel launched quad-core chips in 2H06, and AMD followed in 2007; these were initially targeted at higher-tier servers and ultra-performance desktops, but have been working their way into the mainstream.

- **Intel and AMD now compete head-to-head in all major segments of the microprocessor market.** Historically, Intel and AMD competed aggressively in the desktop segment of the market as well as in the desktop replacement notebook market. With the launch of its new Nehalem architecture, complete with integrated memory controller, Intel has capitalized on an on-going 'server cycle' which started in 2010.

- **Integrated graphics chipsets now dominate all but the highest end notebooks along with corporate and value consumer desktops.** The shift to integrated graphics chipsets (IGP) has been strong and mostly steady over the past few years, with IGP stabilizing around two thirds of the graphics market. The gap between IGP/chipset and discrete GPU's remains significant, although IGP quality has improved (see NVIDIA's ION chipset). IGP is seen as "good enough" for the majority of corporate desktop users, who don't care much about graphics, as well as value consumer desktops, which favor cost over performance.

Notebooks initially flocked to IGP, but GPU attach in portable PC has been on the rise. Attach in desktop remains much higher than notebook. For now the market seems to have struck a balance between discrete and integrated graphics, however longer term trends in PC architecture could force change. One such trend is co-processing.

- **Co-Processing is changing the look of the PC.** Co-processing allows the CPU and GPU to work in tandem, with each being assigned those tasks best suited to their respective serial or parallel strengths. Co-processing allows for better, more efficient performance. OS launches from Microsoft and Apple (Windows 7 and Snow Leopard) each include an API, allowing designers/programmers to utilize co-processing.

- **Memory controllers have moved into the CPU for faster memory access.** AMD was first, but Intel – with its "Tick-Tock'"strategy – was a fast follower. The traditional model for PC memory access used a memory controller as an intermediary between the CPU and memory. The memory controller historically formed the base of the north bridge IC within the PC core logic. As memory access speeds accelerated, the memory controller became a bottleneck. CPU vendors responded by integrating memory access directly into the CPU. AMD was first to provide this feature back in 2003, and for a short time was able to take the performance crown from Intel. Intel reclaimed the crown with the launch of its 45-nm Nehalem processor.

- **Intel and AMD both launched CPUs with integrated graphics.** A primary driver of AMD's ATI acquisition was the integration of graphics onto the CPU. Intel, for its part, actually tried this many years ago as a way to reduce costs for low end PCs, but ultimately shelved the project. As the company has migrated down the process technology curve, however, transistor real estate has freed up to the point where a full GPU can be integrated into the CPU, and it plans to pursue this architectural shift with parts due early in 2010.

- **The north bridge is disappearing as graphics and memory access are integrated into the CPU.** As mentioned above, microprocessor vendors are moving the memory controller into the CPU. They are integrating graphics into the CPU as well. These two components make up the main functions of the PC north bridge. Over time, we could see the north bridge disappear completely, with the core PC logic comprised of a CPU/GPU/memory controller and a south bridge.

- **The memory bus is transitioning to DDR3.** After a big transition from SDRAM to DDR memory, the market began yet another memory transition with DDR2. As in previous transitions, DDR2 first penetrated the performance desktop segment and over time has moved into mainstream desktops, servers, and notebooks. DDR3 came to market in 2007, but high prices limited its penetration. Intel's Nehalem architecture and a smaller price differential gap with DDR3 drove an inflection in 2010.

  An additional transition has taken place on the server front. In the past, x86 servers used registered DIMM (R-DIMM) which include register ICs (similar to timing ICs) directly on the module. Newer fully-buffered DIMMs include a specialty I/O IC known as an AMB I/O IC directly on the module, which manages the interface to the server chipset, which would include AMB I/O logic on chipset.

- **Gigabit Ethernet now dominant.** Gigabit Ethernet has successfully overtaken 10/100 Fast Ethernet across all segments of the PC market. 10GB Ethernet is the next step, but the lack of bandwidth requirements at the client level will likely relegate 10GB to switches and high-performance computing and storage devices for the foreseeable future.

- **Wireless LAN is now a standard feature in notebooks; Bluetooth penetration has been sluggish but BT3.0 should be pervasive.** Nearly all notebooks now integrate wireless LAN networking. This trend began with the standardization of 802.11b and accelerated with Intel's Centrino platform, which included wireless LAN with a chipset and processor. 802.11g and now 11n have been successful follow-ons, quickly adopted by PC makers. Bluetooth is gaining traction in both desktops and notebooks, primarily to support PC peripherals. Ultra wide band (UWB) was expected to be the next major transition, but efforts have floundered and it appears that BT 3.0 + HS could be the winner, due to the combination of 802.11n data transfer rates and mature BT protocols and profiles.

- **USB 2.0 is pervasive; USB 3.0 ramping.** For peripheral interface, USB has proven to be a huge success, with nearly all PC peripherals standardizing around USB in the late 1990s. USB 2.0 provided much higher throughput (480 Mbps vs. 12 Mbps for USB 1.0) and has been included in Intel's chipsets for some time; most peripherals have moved this way as well. IEEE 1394/FireWire has also gained some popularity, but lacks the support of Intel and thus is implemented with a separate host today. Over time, this interface will likely disappear. USB 3.0 Promoter Group completed the version 3.0 spec (5 Gbps) in November 2008, but consumer products are now expected here shortly. Intel's support will again be crucial to adoption, though Intel's chipsets will not include USB 3.0 until 2012 with the launch of Ivy Bridge.

- **Power consumption is becoming a major issue for all component suppliers.** This is true not only for notebooks (with the focus on battery life), but also for desktops and servers. Note that the trend to dual- and multi-core was in part driven by power consumption issues. ARM-based solutions are being launched in conjunction with Windows 8 scheduled for late 2012. We expect NVDA, TXN, and QCOM to be the primary beneficiaries.

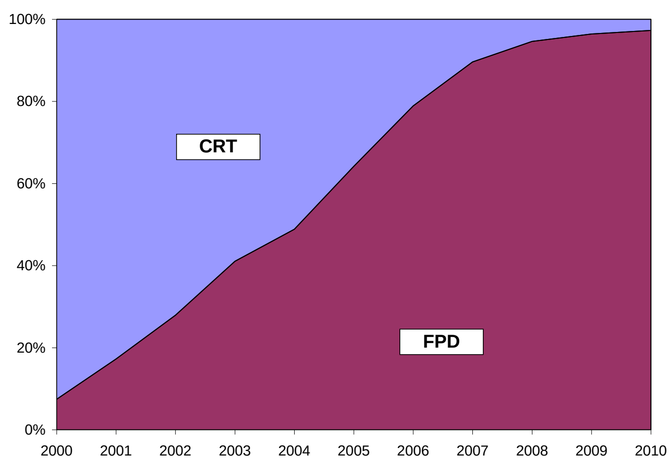
- **SSD penetration still ramping.** The promise of SSDs and NAND memory cache has been long in the making, but short on results. A major advantage of NAND is quicker boot-up time, as the system could store critical boot instructions and a portion of the OS on the NAND cache as opposed to the HDD. It also provides power savings for notebooks, as the system could access the hard drive less frequently. Netbooks were early adopters of SSDs, primarily for the cost savings of a 4 or 8-GB SSD relative to even the lowest priced HDDs. Consumers, however, preferred HDDs and the memory-hogging Windows OS and the price/GB differential has yet to fall sufficiently to spur rapid uptake of SSDs.

PC Displays

The PC display market, long an afterthought, has become important again as flat-panel display (FPD) monitors have reached mainstream price points. FPD adoption has surged in recent years, with desktop LCD penetration at 97% in 2010.

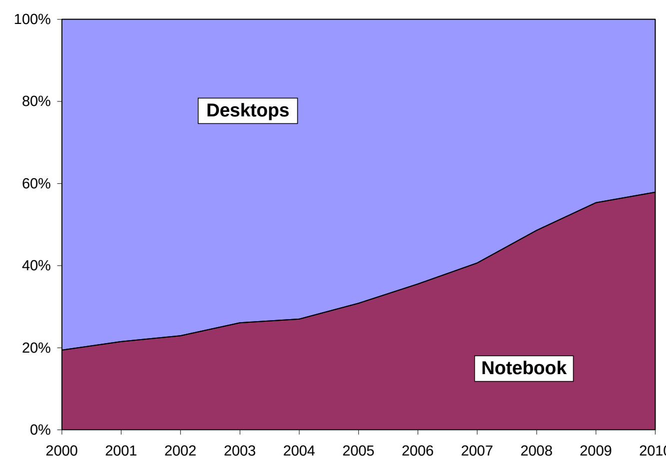
Notebook penetration has also surged as mobility trends have accelerated and lower FPD prices allowed the notebook premium vs. desktops to compress.

FPD Desktop Penetration



Source: DisplaySearch, IDC, Gartner, Oppenheimer & Co.

Notebook Penetration



Source: IDC, Oppenheimer & Co.

Up until a few years ago, the PC monitor was an afterthought for PC OEMs. Although differentiated high-end monitors have represented a consistent percentage of the market (for workstations, etc.), PC OEMs have historically focused on supplying the lowest cost monitor possible in an effort to drive down the total system cost of a PC.

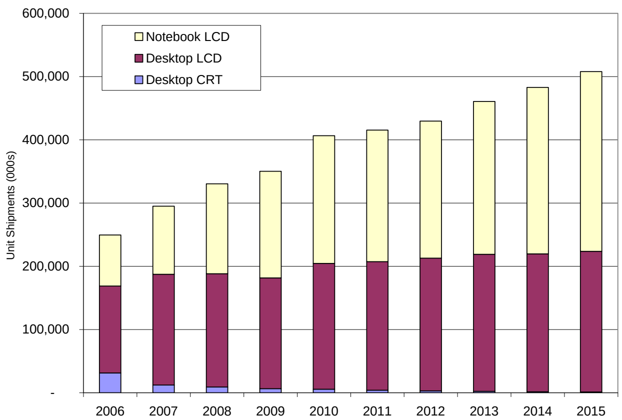
This paradigm changed dramatically as LCD technology has matured and become more cost effective. Flat-panel LCD panels have been available for years, but have been primarily reserved for the notebook market, as low yields and constrained LCD glass capacity had kept prices high—enough to warrant a significant cost differential between otherwise comparably-equipped desktop and notebook PCs. With the increase in LCD capacity and an influx of competition, the price of large-area LCD displays dropped dramatically, spurring demand for both notebooks and desktop LCD monitors. This caused a new twist in the PC paradigm; the display is once again becoming an important part of the PC buying decision, and dozens of OEMs, primarily in Asia, moved in to meet the demand.

In terms of units shipped, FPDs have been adopted more rapidly than most analysts had originally anticipated as LCD prices continue to decline, spurring demand. Flat panel display penetration in desktops, which was 97% in 2010, is still increasing. Supply seems to be growing nicely and should be able to support continued strong notebook demand, further penetration of FPDs in the desktop market and the volume deployment of LCD TVs.

PC Displays

PC Display Unit Forecast

•Total PC displays growing at a 5% CAGR, from 406 million units in 2010 to 508 million units in 2015.
•Desktop CRT monitors continue in a downward spiral, from 5.5 million units in 2008 to 1.2 million units in 2015.
•Desktop LCD monitors are expected to grow at a 2% CAGR, from 198 million in 2010 to 222 million in 2015.
•Mobile LCD monitors growing 7%, from 202 million units in 2010 to 284 million units in 2015.



Source: IDC, DisplaySearch, Dataquest, Oppenheimer & Co.

LCD Monitor Suppliers

Samsung
Dell
HP
Acer
LG
Lenovo
ViewSonic
BenQ
AOC

CRT Monitor Suppliers

Samsung
LG
Lenovo
AOC
HP
Acer
ViewSonic
Philips
Dell

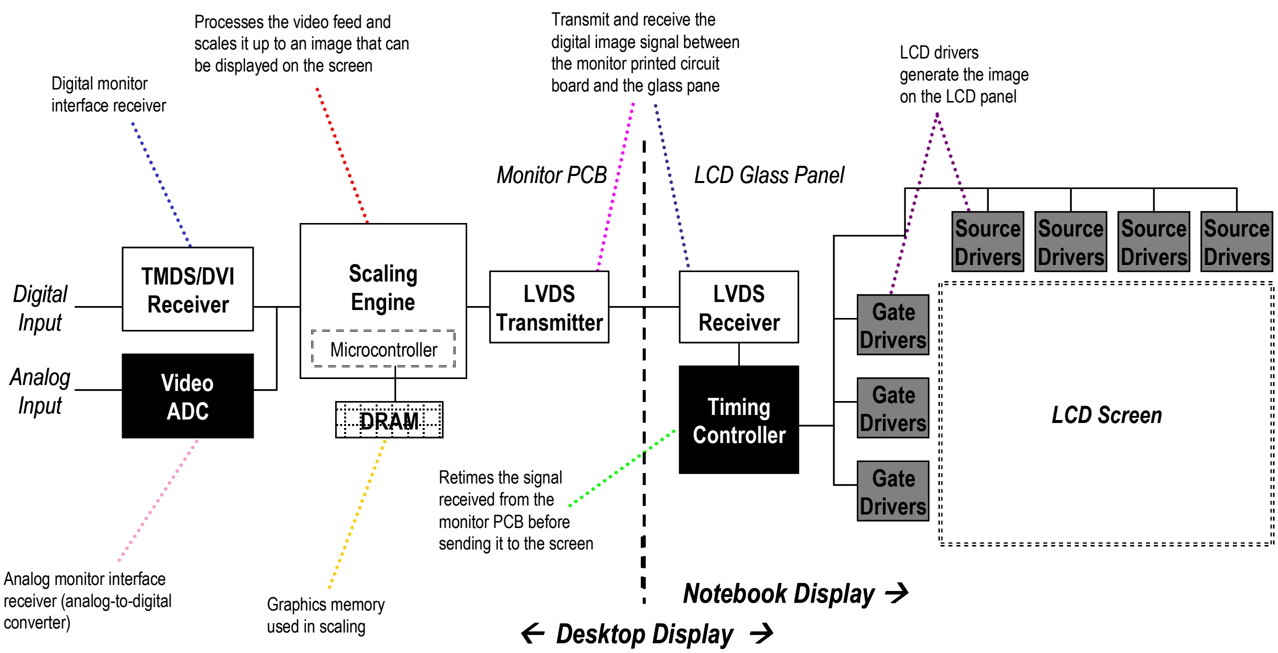
Source: Oppenheimer & Co.

***PC Display Unit Forecast*:** The market for PC displays includes desktop CRT and flat panel displays and the LCD screens attached to notebooks. For desktops, total monitor shipments actually exceed desktop PC unit shipments by about 15-20%, due to: 1) an upgrade cycle for LCD monitors, as some users upgrade their monitor while keeping the same PC; and 2) the rising use of dual-display systems. Notebook displays, on the other hand, ship 1:1 with notebooks. In 2010, we estimate total PC monitor shipments were 406 million units. Looking ahead, we expect displays to grow 5% through 2015, rising to 508 million units.

The big story in displays is the migration to flat panel, which has accelerated as falling LCD prices have spurred demand. In 2010, desktop flat panel penetration increased to 97% of desktop monitor shipments. As penetration rates stay relatively stable, we expect desktop LCD monitors to increase slightly during the forecast period to 222 million units. Notebooks are also growing quickly, and approximated 50% of total PC monitor shipments in 2010. Notebook displays should mirror notebook shipment growth, from 202 million units in 2010 to 284 million units in 2015, a 7% CAGR. CRTs are expected to decline 27% through 2015 to less than 1% of desktop monitor shipments.

***PC Display Suppliers*:** The top suppliers of desktop LCD displays in 2010 were Samsung, Dell, and HP. Other LCD display suppliers include LG, Acer, Lenovo, AOC, ViewSonic, NEC, BenQ and Phillips. In CRT, Samsung, Lenovo and LG were the top suppliers in 2010. Other CRT suppliers include AOC, HP, Acer, ViewSonic, Phillips and Dell.

PC Displays



Source: Oppenheimer & Co.

Note: The diagram above and the discussion below focus on flat panel (LCD) displays, which represent a much larger opportunity for semiconductor vendors than does the CRT market. Note that desktop and notebook LCD displays differ somewhat; in desktop monitors, the image is received from an external source and then scaled; in a notebook the digital image is sent directly to the glass panel via LVDS.

Semiconductor devices in flat panel displays are found in two places: on the monitor board and in the monitor panel. The monitor board receives the signal from the PC and scales the image and then transmits it to the glass panel digitally over LVDS (Low Voltage Differential Signaling). Devices in the glass panel/CRT receive the signal, retime it and produce the image.

Notebook displays employ a simpler design, since the monitor is directly attached to the source of the image. No scaler is needed in a notebook display; instead the digital image is sent directly to the display panel via LVDS.

We discuss below the key devices found in desktop and notebook flat-panel displays.

Monitor Board (desktop monitor only)

- **Video ADC:** This analog-to-digital converter receives analog video input from the PC and converts it to a digital stream to be received by the scaler. This device is usually integrated into the scaling engine.
- **TMDS/DVI Receiver:** This device receives digital video signals from the PC. Most monitors with a digital receiver also have a legacy analog receiver. Like the analog receiver, this device is increasingly being integrated into the scaling engine.

- **DisplayPort I/O** *(not shown in diagram):* Future monitors will include an I/O device for the DisplayPort standard, currently under development. DisplayPort is targeted to eventually completely replace all other analog and digital I/O in the PC monitor market.
- **Scaling Engine:** The scaler processes the video feed and scales it up to an image that can be displayed on the screen. It typically includes an integrated microcontroller for system control. The scaling engine is at the heart of integrated monitor controller SoCs that now include interface and control circuits.
- **DRAM:** Most scalers require external memory to help process the video image.
- **LVDS Transmitter:** The LVDS transmitter sends the scaled image from the monitor board to the LCD panel in a digital format. Note that other types of transmission methods may be used; LVDS is a popular standard in notebook LCD screens and in desktop flat panels. Like the receiver chips, this device is increasingly being integrated into the scaling engine.

Notebook Base (notebook only)

- **LVDS Transmitter:** The LVDS transmitter sends the image from the graphics processor to the LCD panel in a digital format. This can be integrated into the PC graphics processor or chipset.

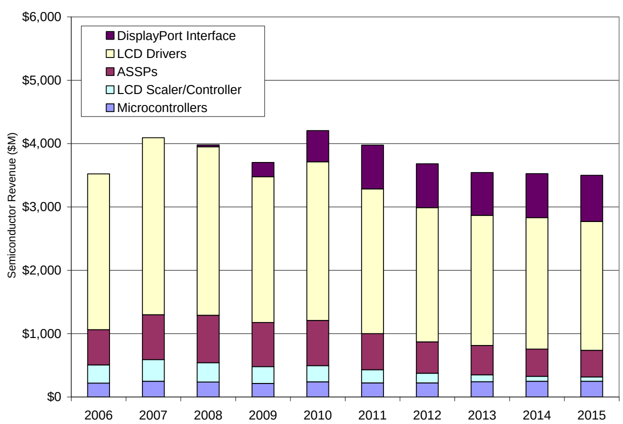
LCD Panel

- **LVDS Receiver:** The LVDS receiver receives the scaled image from the monitor board or notebook base.
- **Timing Controller:** This device retimes the signal received from the monitor board before sending it to the LCD row and column drivers. It is typically implemented as a custom ASIC.
- **LCD Row/Column Drivers:** LCD row (gate) and column (source) drivers are placed around the LCD panel, producing the viewable image. Source drivers usually sit across the top of the panel and generate signals that penetrate individual columns of pixels. Three source drivers are needed for each row of pixels: red, green and blue. Gate drivers usually run along the side of the panel and manipulate individual rows of pixels. The gate drivers intersect the signals driven by the source drivers, turning individual pixels on or off.

PC Displays

PC Display Semiconductor Forecast

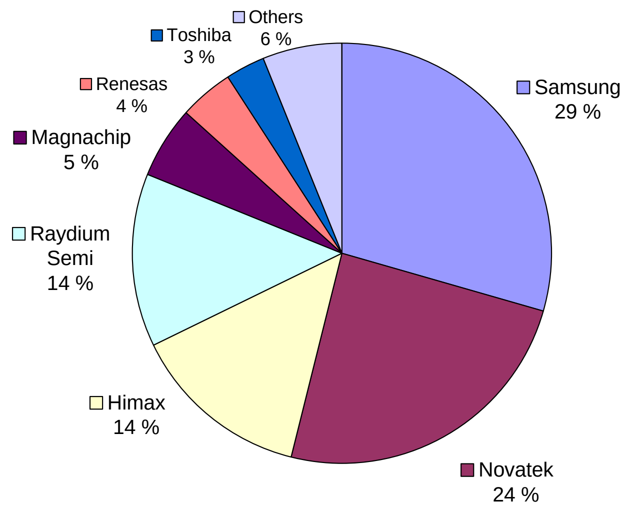
•PC display semiconductors are expected to decline from $4.2 billion in 2010 to $3.5 billion in 2015.
•LCD drivers are declining at a 4% CAGR, staying at 58% of total IC market revenue.
•LCD controllers ICs should see a negative CAGR of 24% as tough price competition continues to outweigh unit growth of desktop LCD monitors.
•DisplayPort I/O represents an avenue of growth.



Source: IDC, DisplaySearch, Dataquest, Oppenheimer & Co.

PC Display Semiconductor Competitors

LCD Row and Column Drivers



Source: Dataquest, Oppenheimer & Co.

PC Display Semiconductor Forecast: We expect PC display semiconductors to decline 4% through 2015, dropping from $4.2 billion in 2010 to $3.5 billion in 2015. LCD drivers should decline at a 4% CAGR, as still-rising desktop LCD and notebook penetrations and the positive effects of increasing screen sizes are more than offset by intense price competition. We expect LCD drivers to decline to 58% of total PC display IC by 2015.

LCD controllers, 6% of the total market in 2010, should decline at a 24% CAGR through 2015; intense price competition in this market continues to overwhelm unit growth in desktop LCD monitors (most of the IC vendors have shifted their attention to the LCD market in the process). Microcontrollers, 6% of IC revenue in 2010, should stay relatively flat while other ICs (mostly timing controller ASSPs) should decline at a 10% CAGR. The most exciting longer-term opportunity should be that of DisplayPort I/O, which began to appear in volume in 2009.

PC Display Semiconductor Competitors: The top suppliers of drivers for large-panel PC LCD panels in 2010 include Samsung, with 29% market share and Novatek and Himax with 24% and 14%, respectively. Radium held 14% share, while Magnachip held 5%. Other vendors include Renesas (acquired NEC), Toshiba and Sharp.

PC Displays

PC Display Semiconductor Market Trends

•Integration has become critical for low cost FPD monitor designs: scalers now integrate digital ADC & DVI interface receivers, microcontrollers, and memory.

•Digital interface attach rates are increasing.

•DisplayPort adoption as the default digital interface standard, well on its way.

•OEMs are adopting smart panel designs, integrating all devices onto a single PCB in the monitor panel.

•Desktop FPD monitors and notebooks screen sizes are increasing and also going wide-screen, requiring additional LCD driver ICs.

•LCD source driver channel density is on the rise as panel makers look to reduce costs.

- **Integration has become critical for low cost FPD designs.** IC vendors now integrate more functionality into the scaler chip, including digital and analog input receivers, microcontrollers, memory, and the LVDS transmitter.
- **Digital interface attach rates are increasing; DisplayPort represents the next digital interface standard.** Digital interfaces have taken some time to penetrate the mainstream monitor market, but continue to see growth. DisplayPort is being developed to replace all analog and digital interfaces in the monitor market.
- **OEMs are adopting smart panel designs, integrating all devices onto a single PCB in the monitor panel.** An emerging trend is that of smart panels, which includes monitor inputs, scalers, timing devices and LCD drivers on a single circuit board in the monitor panel. This eliminates the need for a second PCB and reduces the number of connectors (and associated transceiver ICs) and even simplifies the manufacturing process.
- **Desktop FPD monitors and notebooks screen sizes are increasing and also going wide-screen.** This requires additional LCD driver IC content and more advanced scaling ICs.
- **LCD source driver channel density is on the rise as panel makers look to reduce costs.** Greater channel density reduces the number of drivers needed for a given resolution. For example, moving from 480 channels (mainstream today) to 642 channels (used in newer designs) reduces the number of source drivers for a typical 1280 x 1024 monitor from nine to six (recall that three are needed per pixel: one for each RGB color). Note that gate drivers face less pressure since they are lower cost to begin with, and only one driver is needed per pixel.

Hard Disk Drives

Hard disk drives (HDDs) are still closely tied to the PC market, but drives have dramatically “outgrown” the 1:1 ratio with PCs as enterprise storage networks, consumer devices, and personal storage are providing new opportunities for mass storage.

In enterprise, terabytes are growing at a 50%+ CAGR. Networked systems are enabling the separation of processing and storage, allowing for easy, inexpensive capacity additions as corporate data needs grow.

In consumer, STBs and video game consoles are proving to be an effective usage model for HDDs as these markets require capacity points that cannot be served adequately by NAND flash.

Personal storage is a fast-growing application, as increased familiarity with digital content is driving demand for solutions to manage that content.

Hard disk drives (HDDs) are the primary data storage devices used in data processing applications. The drives, usually integrated within larger host devices, use a set of rigid disks to magnetically store bits of data in extremely large quantities at very high speeds. All PCs ship with at least one hard disk drive, which stores the computer’s operating system and software applications and the user’s files. They are fast, cheap, carry very large capacities, and conform to industry-standard form factors. They have therefore become an integral part of PCs and servers.

Though still closely tied to the PC market, hard disk drives have dramatically “outgrown” the 1:1 ratio with PCs. Enterprise storage, consumer devices, and personal storage are providing new opportunities for mass storage. On the enterprise side, IT managers can supplement their individual PC storage with enterprise storage systems to store and manage common-use applications and files. In these systems, arrays of drives are incorporated into special arrays or networks designed specifically for data storage traffic, which can be accessed by servers on the data network. This dramatically increases storage capacity and performance and also allows the IT manager the option to manage processing and storage independently. Terabytes of enterprise storage continue to grow in excess of 50% per year.

On the consumer side, the rise of digital content has created new opportunities for HDDs in consumer electronics, though flash has presented an alternative to HDDs in certain applications (PMP players, for example). Set-top boxes (STBs) and game consoles are proving to be effective usage models for HDDs as these markets require capacity points that cannot be served adequately by flash; other smaller opportunities exist as well. A related driver is personal storage, as consumer familiarity with digital content drives demand for storage solutions to manage and protect that content.

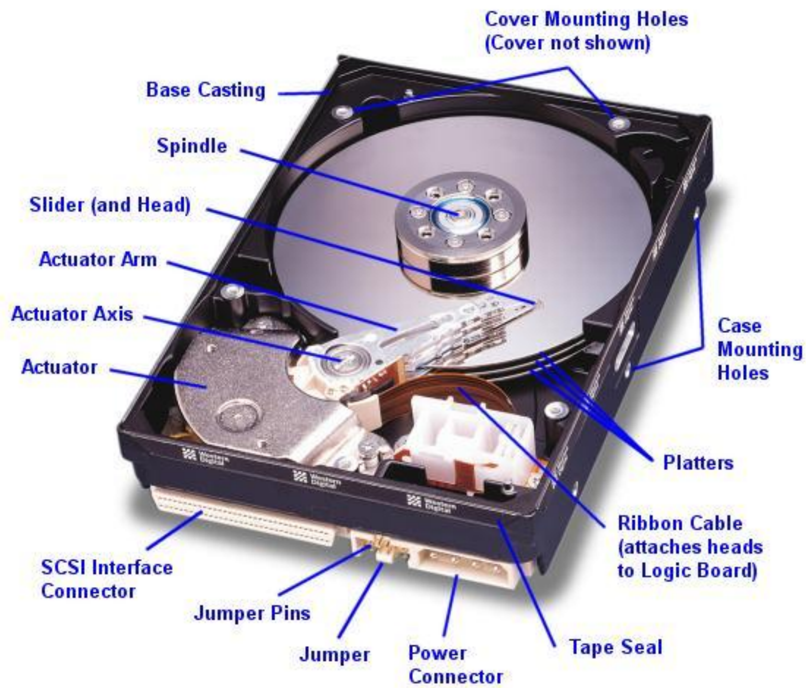
Hard Disk Drives

Hard disk drives are self-contained devices that use rigid disks coated with a magnetic material to store bits of data. They are available in standard form factors using standard interfaces, differentiated by storage capacity, speed, power consumption, and reliability.

Desktop drives are designed for the highest capacity at the lowest cost.

Mobile drives are smaller and consume less power.

Enterprise drives focus on speed, performance and durability.



Source: Western Digital

Hard disk drives are self-contained devices that use one or more rigid disks coated with a magnetic material to store bits of data. They are available in standard form factors using standard interfaces, but are differentiated by storage capacity, speed, power consumption and reliability.

A hard disk drive has three basic subassemblies:

- **A set of platters—which are flat, round, rigid disks—used as the storage media.** Each platter is made up of a substrate that is coated with a special media material designed to store data in the form of magnetic patterns. The platters can be double-sided and are mounted on a spindle, which is attached to a spindle motor that spins the platters at high speed.
- **A mechanical device known as an actuator**, which sits in the corner of the drive and controls a set of arms that reach out over the surface of the individual platters. Mounted on the end of each arm is a slider and a specialized electromagnetic read/write device called a "head." The read/write heads, which are in essence tiny electromagnets that perform the conversion from electrical signals to magnetic signals, are the interface between the magnetic physical media on which data are stored and the other electronic components on the hard disk, recording data to the disk and reading from it. Hard disk drives need one head for each platter surface (i.e., two are needed for a double-sided platter).
- **A printed circuit board, which contains all the logic needed to run the drive system.** Devices on the board include a preamp, which amplifies signals between the head and the drive logic; a read channel, which performs read and write functions; and a hard disk controller and microprocessor, which control the system and implement the interface protocol. The disk drive also has some memory and motor control ICs for the spindle motor and the actuator.

Disk Drive Classes

While the technologies used are very similar across platforms, hard disk drives fall into three basic categories:

- **Desktop.** Desktop-class hard disk drives are used in desktop PCs and low-end workstations and servers. They have standard physical dimensions: 4” wide by 5.75” deep by 1” high (though some drives are less than 1” high) and are generally referred to as “3.5-inch drives.” Most desktop drives use the ATA/SATA interface and have one or two platters.
- **Mobile.** Mobile-class hard drives are used in notebook PCs and small form factor desktops. They are smaller than desktop drives; the standard size has dimensions of 2.75” wide, 3.95” deep and 0.37” high and is generally referred to as a “2.5-inch drive.” Some are even smaller and are often referred to as “micro-drives”; these drives are found in consumer devices such as portable media players. Most mobile drives use the ATA/SATA interface and have one or two platters; they typically consume less power than other drives.
- **Enterprise**. Enterprise-class hard drives are used in workstations, servers, networked storage systems and high-end desktop PCs. Most have similar physical dimensions to desktop drives, though some high-capacity drives can be greater than 1” in height while others adopt the 2.5-inch mobile form factor. Most enterprise drives use the SCSI interface, though drives designed for network storage often use Fibre Channel. Newer drives are implementing SAS (serial-attached-SCSI), the follow-on to SCSI. Most enterprise drives have more than one platter.

Note that the vast majority of hard disk drives are internal drives, meaning that they are designed to be implemented inside a PC or enterprise system or other “host” device. These generally conform to the specifications indicated above. External drives are sold as standalone units, which are fully enclosed and incorporate additional interfaces such as USB, FireWire, or Ethernet.

A growing application for hard disk drives is the consumer electronics market. The larger HDD vendors have all introduced modified versions of their desktop and mobile drives specifically for this market. These drives can vary from standard HDDs in form factor, power consumption, speed, and cost, but generally fall into the same drive classes described above.

Drive Storage Capacity

Storage capacity in a hard disk drive is measured in gigabytes—colloquially known as a billion bytes but actually 1,073,741,824 bytes (computer specifications usually use binary numbers; therefore, a kilobyte is 1024 bytes, a megabyte is 1024 kilobytes and a gigabyte is 1024 megabytes, which gets us to 1,073,741,824 bytes). Note that a byte is eight bits, which are the 1s and 0s of the digital world.

Desktop class drives generally have the highest capacity points over the greatest range, catering to corporate PCs, consumer PCs, and the retail market. Most DVRs and personal storage solutions use desktop class drives as well. Mobile drive capacity points are slightly lower and have a tighter range; these are primarily used in notebook PCs but are also found in portable media players, game consoles, and other consumer electronics. Enterprise drives typically trail desktop drives in capacity, and also have a tighter range.

A drive’s capacity is a function of: 1) the amount of bytes that can be stored on each platter (this in turn is determined by the size of the platter and the platter’s areal density); and 2) the number of platters in the drive. In general, drive vendors seek to maximize the amount of bytes that can be stored on each platter (the first factor) and to minimize the number of platters in the drive (the second factor). In the end, however, the final platter and density implementation will depend on a number of tradeoffs that include engineering constraints, cost dynamics and marketing requirements.

Drive Speed

The speed of a hard disk drive is usually measured on two fronts: transfer speed—which refers to the rate at which data is transferred from the disk to the host system and vice versa; and positioning speed—the rate at which the drive system can hop around the disk in search of the desired data. While many components within the drive affect these metrics, one of the most significant is the strength of the spindle—so much so that spindle speed is usually quoted right after drive capacity when describing a drive and is also the most commonly used specification used to classify different drives by performance. Spindle speed describes the rate at which the platters in the disk drive turn, expressed in revolutions per minute (RPM). The faster a platter spins, the faster the transfer rate when reading or writing as well as the positioning when searching for the correct track and sector.

Spindle speed differs for different classes of drives. In the desktop market, most drives spin at 7,200 RPM, though some higher-end desktop drives spin at 10,000 RPM. Mobile drives spin at speeds ranging from 5,400 RPM to 7,200 RPM (the notebook market requires drives of varying power consumption to meet the different platform requirements). Enterprise drives also vary in speed: from 7,200 RPM at the low end to 15,000 RPM at the very high end, with the most common being 10,000 RPM.

Interface

Hard disk drives use one of several standard interfaces to send data between the drive and the host system. Up until the last few years, the most common interface was IDE (Integrated Development Environment), also known as ATA (Advanced Technology Attachment), which was used in most desktop and mobile drives. ATA drives are configured as master or slave using jumper pins on the drive itself, allowing for two drives to connect into each ATA interface controller on the host. They use wide 80-pin ribbon cables (18” in length) and connect directly to PC motherboards (most PC chipsets include one or more ATA controllers embedded in the south bridge). The data transfer rate for ATA increased over time to 133 Mbps.

The evolution of the IDE interface is known as Serial ATA (SATA), which has quickly displaced ATA. SATA changes the physical architecture from master-slave to point-to-point, so each drive is connected to its own interface. SATA also changes the cable interface to a narrow four-wire cable and extends the length to one meter. Transfer rate was increased to 150 Mbps in the first implementation, with 300 Mbps coming to market now and a roadmap planned to 600 Mbps. SATA is also able to use lower voltage power supplies.

While ATA/SATA has quickly become the most popular PC disk drive interface due to its lower cost, SCSI (pronounced “scuzzy”) remains an important interface in the enterprise market as well as in high-end desktops. The SCSI interface uses a “daisy chain” architecture allowing for up to 15 peripherals to be connected to a single interface controller (each peripheral has a second port to connect to the next device). SCSI has also consistently maintained a transfer rate advantage over ATA, with most SCSI drives in use today carrying a transfer rate of 320 MBps. Further, SCSI was the first interface to support RAID (Redundant Array of Inexpensive Disks) configurations. For all of these reasons, SCSI dominates the enterprise hard disk drive market, though the advent of Serial ATA may change the dynamics somewhat. Note that as with ATA, SCSI drive cables connect to a SCSI controller on the PC or server motherboard; unlike ATA, however, chipset vendors have not integrated this functionality into the PC chipset. Servers and SCSI-enabled desktops therefore require a separate controller chip or add-in board to support SCSI drives.

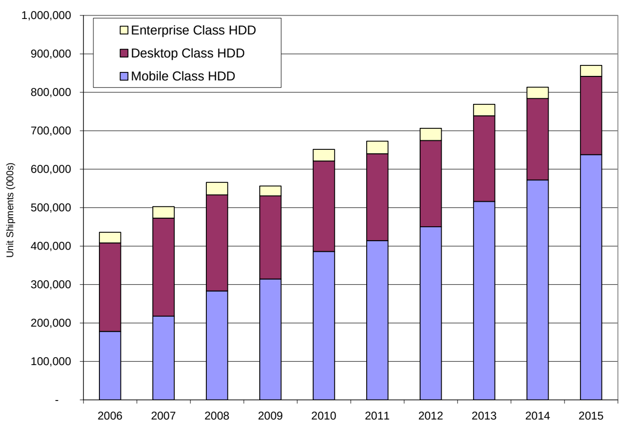
The follow-on to SCSI—known as Serial Attached SCSI (SAS)—is ramping now. SAS expands the number of supported devices to 128, uses smaller cable connections (like Serial ATA) and provide universal interconnect compatibility with SATA while retaining the reliability, performance and manageability advantages of SCSI.

About 25% of high end drives incorporate support for Fibre Channel, a high-speed transport technology used in storage area networks. Fibre Channel serializes SCSI commands into Fibre Channel frames, which can be sent at high speed (1.0625 Gbps, 2.125 Gbps, 4.25 Gbps, or even 10.625 Gbps) either point-to-point or through a switched network of Fibre Channel switches. Most Fibre Channel networks, along with their associated arrays of hard disk drives, are set up independent of the network of servers used for data processing, allowing any server to access data stored on any hard disk drive without a direct connection. See the discussion of enterprise storage in the networking section of this report for a more in-depth discussion of Fibre Channel.

Hard Disk Drives

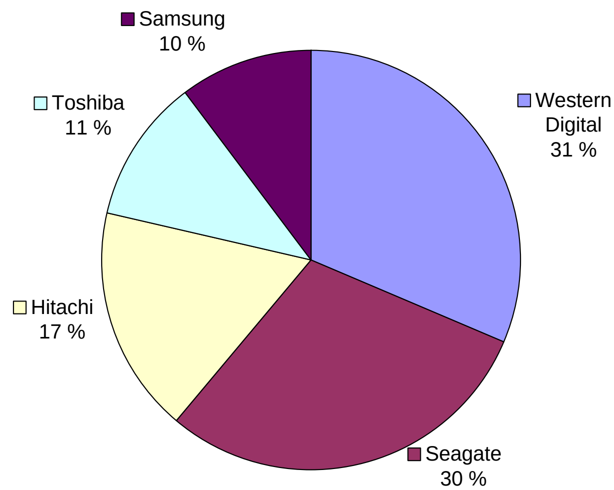
HDD Unit Forecast

- We expect the HDD market to grow at a 6% CAGR, from 651 million drives in 2010 to 870 million drives in 2015.
- Mobile drives should grow 11%, tied to the growth in notebook PCs and personal storage; some incremental units will likely shift over to solid state drives later in the forecast.
- Desktop class drives should decline 3% with the shift to notebook.
- Enterprise class drives should decline 1%.



Source: IDC, Oppenheimer & Co.

HDD Suppliers



Desktop	***Mobile***	***Enterprise***
Western Digital	Western Digital	Seagate
Seagate	Hitachi	Hitachi
Hitachi	Toshiba	Toshiba
Samsung	Seagate	
	Samsung	

Source: IDC, Oppenheimer & Co.

Hard Disk Drive Unit Forecast: Though it originated as a computer storage subsystem, the market for hard disk drives is significantly larger in unit terms than that of PCs. In addition to the 1:1 unit shipments going into PCs, the market includes drives sold into mass storage arrays to support servers and data centers, SAN and NAS systems (two types of networked storage systems), personal storage solutions, and emerging applications in the consumer, automotive and industrial markets. There is also a significant retail market for add-on HDDs, both internal and external. In total, we estimate the market for hard disk drives totaled 651 million units in 2010, over 85% larger than the PC market.

The hard disk drive market has also grown faster than the PC market. On the enterprise side, the number of multi-drive enterprise storage systems continues to increase, as does the number of drives per storage system. This is being enabled by more mature large enterprise storage solutions, the industry transition to SATA for the low and mid-end (which enables cheaper storage systems for enterprise and SMB), as well as the emerging market for personal storage systems. On the consumer electronics side, digital media devices are incorporating hard disk drives, most notably DVRs and game consoles.

Looking ahead, we expect these trends, which favor unit growth in excess of PCs, to continue. Offsetting these trends, however, should be slower growth of desktops and servers compared to notebooks, as desktops and servers often use multiple drives compared to notebooks. The emergence of solid state drives (SSDs) should also steal some units in the later years of the forecast, primarily from the mobile segment. Though they will likely remain more expensive than HDDs on a price/MB basis, SSDs have benefits in terms of performance and power consumption that will justify the premium in certain applications.

With these trends in mind, we expect the hard disk drive market to grow from an estimated 651 million units in 2010 to 870 million units in 2015, a CAGR of 6%. By drive class, we estimate that 36% of drives shipped in 2010 were desktop class, 59% were mobile class—including small form factor—and 5% were enterprise class. Looking ahead, we expect mobile drives to lead growth with an 11% CAGR and to represent 73% of total units in 2015, driven principally by notebook growth and also by the use of notebook drives in small form factor desktops. Personal storage is also contributing to growth for the mobile segment. Desktop drives should decline at a 3% CAGR with the shift to notebook. We forecast enterprise drives to decline at a 1% CAGR. Lower-end enterprise storage systems are in some cases being populated with desktop (or even mobile) class drives leveraging SATA (which we regard as desktop class), but SAS offerings are improving and coming down in price, and will continue to dominate the enterprise.

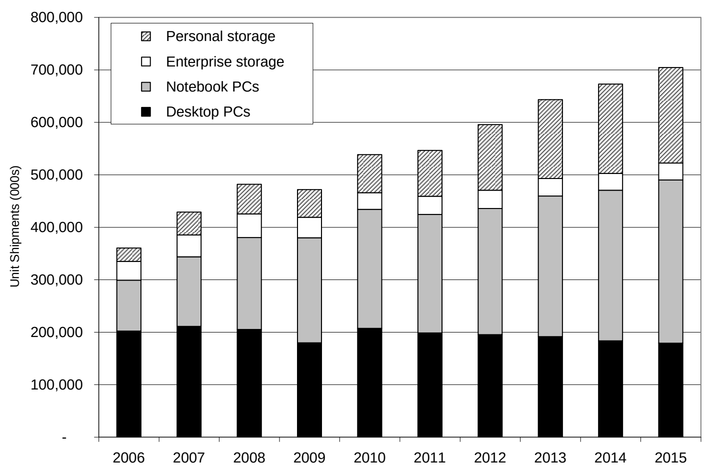
Looking at the end application for HDDs, computing represented the largest opportunity in 2010 at 86% of total shipments, with consumer applications representing the balance. We expect both the consumer and computing segments to grow at a 6% CAGR through 2015.

Within computing, notebook PCs represented 42% of shipments, followed by desktop at 39%, personal storage at 13% and enterprise at 6%. Looking forward, drives that sell into notebooks and desktops should grow 7% and -3% respectively, remaining near 70% of the market in 2015. Drives that sell into enterprise storage (including all drive classes) should remain relatively flat and represent 5% of the market in 2015. Personal storage should grow the fastest at a 20% CAGR, to represent ~26% of the market in 2015. Note that outside of a minority percentage of notebooks and ultra-mobile PCs, we do not expect to see SSDs eat into the computing market in too meaningful a way during the forecast period.

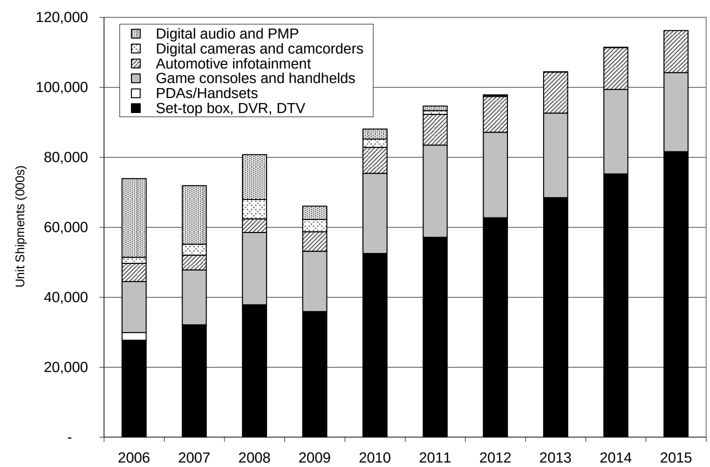
The consumer market represented the remaining 14% of HDD units in 2010. The largest segments were set-top boxes and DVRs, at 60% of total units, followed by game consoles at 26% and auto infotainment at 8%. Portable media players and digital cameras/camcorders were small percentages. Looking ahead, we expect digital audio to decline as flash replaces HDDs in all but the largest capacity players. The other segments, however, should each grow at CAGRs of between 0% and 10%.

The exhibits below display our computing and consumer hard disk drive unit forecast.

Computing HDD Unit Forecast



Consumer HDD Unit Forecast



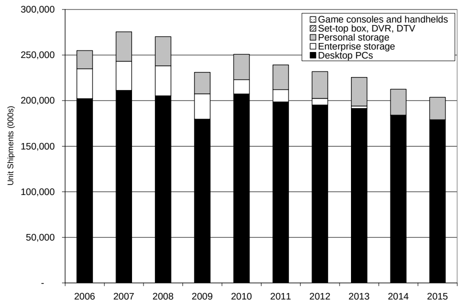
Source: IDC, Oppenheimer & Co.

We can also segment the market by drive size. In 2010, 43% of HDDs shipped were 3.5-inch drives, 56% were 2.5-inch, and only 1% were 1.8-inch and below. 3.5-inch drives dominate desktop PCs, enterprise storage systems, personal storage solutions, and DVRs. 2.5-inch drives dominate notebook PCs and automotive applications, and have begun to dominate game consoles. 2.5-inch is also becoming an important form factor in the enterprise, and is also becoming popular in small form factor desktops and portable personal storage solutions. 1.8-inch and below used to dominate portable media players but is now giving way to flash. Today, 1.8-inch and below still has a small presence in portable media players and digital cameras and camcorders.

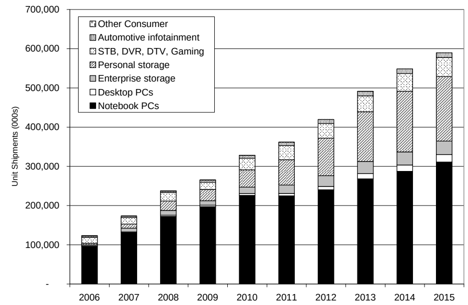
In terms of growth rates, 3.5-inch drives should decline at a 4% CAGR, as a general shift to 2.5-inch drives occurs, which are penetrating desktop, server, and enterprise storage applications. 2.5-inch should grow at an impressive 12% rate, driven by moderating notebook growth (7% CAGR) and increasing penetration of 2.5-inch in desktop (32% CAGR), enterprise storage (16% CAGR), and DVRs and gaming consoles (10% CAGR). 2.5-inch drives are also seeing good growth in personal storage markets. 1.8-inch and below drives should be out of production by the end of 2013 as a general shift to 2.5-inch drives occurs.

The exhibits below display our HDD unit shipment forecast by application for each size segment.

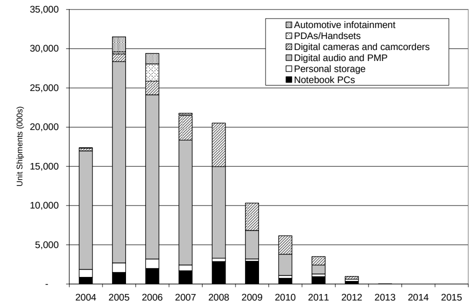
3.5" HDD Unit Forecast



2.5" HDD Unit Forecast



1.8" and Below HDD Forecast



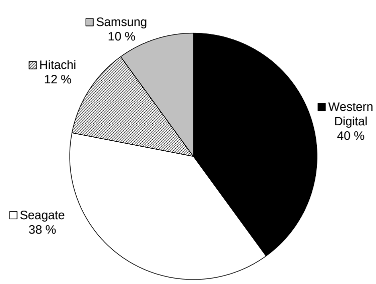
Source: IDC, Oppenheimer & Co.

***Hard Disk Drive Suppliers*:** Western Digital surpassed Seagate as the No. 1 provider of HDD's in 2010 with 31% total unit share; WD is No. 1 in mobile drives and desktop drives. Consolidation in the industry continues to be a theme with Western Digital's acquisition of Hitachi's HDD division earlier this year.

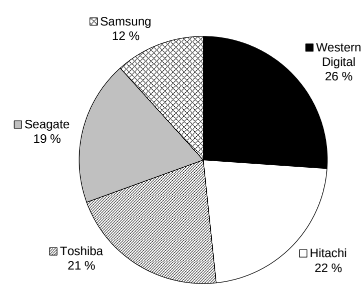
Seagate was No. 2 in 2010 with 30% total unit share. Seagate acquired Maxtor in 2006, though most of these platforms were shut down and were not absorbed into Seagate's product portfolio. The company recently announced the proposed acquisition of Samsung's HDD business. Seagate was No. 2 in desktop, No. 4 in mobile, and a dominant No. 1 in enterprise. Hitachi (acquired by WDC in 2011), which was created in the merger of Hitachi's and IBM's hard disk drive business a few years ago, was No. 3 overall with 17% unit share; Hitachi is No. 2 in mobile and is No. 3 in desktop and No. 2 in enterprise. Toshiba was No. 4 in 2010 with 11% share, a specialist in mobile and enterprise. Toshiba acquired Fujitsu's hard disk drive division in 2008. Rounding out the top 5 is Samsung (acquired by Seagate in 2011), with 10% total unit share and a strong presence in desktop. Going forward, the industry has consolidated to three main suppliers: Western Digital, Seagate, and Toshiba.

The exhibits below display 2010 unit share data for desktop, mobile, and enterprise hard disk drives.

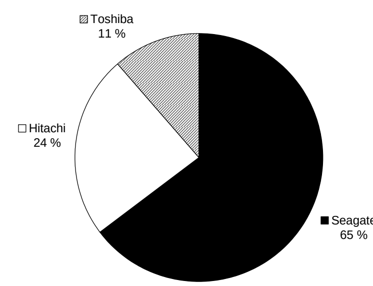
2010 Desktop HDD Unit Share



2010 Mobile HDD Unit Share

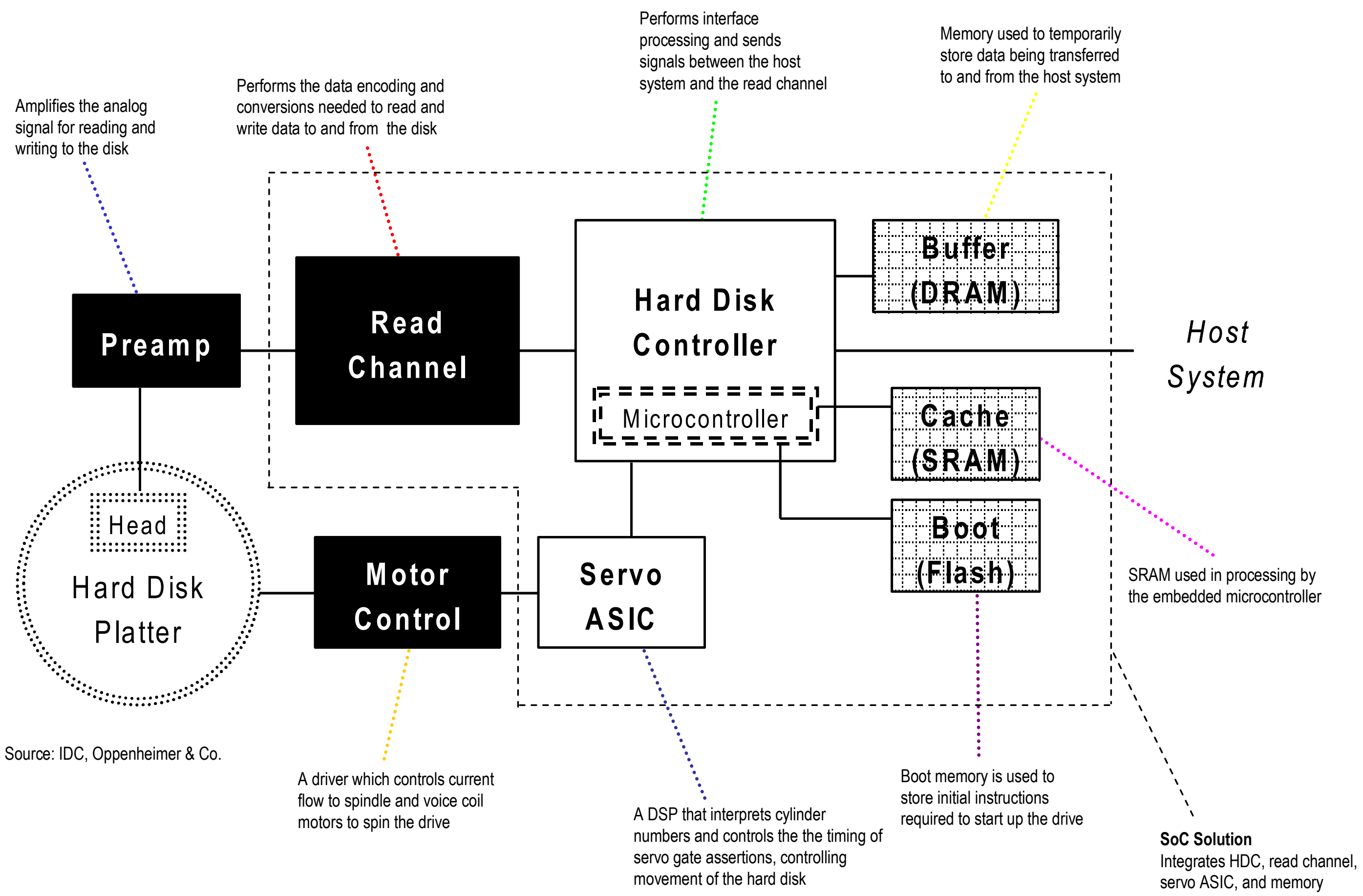


2010 Enterprise HDD Unit Share



Source: IDC, Oppenheimer & Co.

Hard Disk Drives



Source: IDC, Oppenheimer & Co.

Note: the diagram above shows a hard disk drive implemented with discrete ICs for each separate function of the system. In practice, most HDDs are implemented with an SoC solution which combines read channel, HDC, servo ASIC, and memory in a single IC.

Semiconductors in hard disk drives perform two basic functions: control of the movement of the hard disk spindle and actuator, and read/write of data to and from the hard disk.

Hard Disk Read/Write

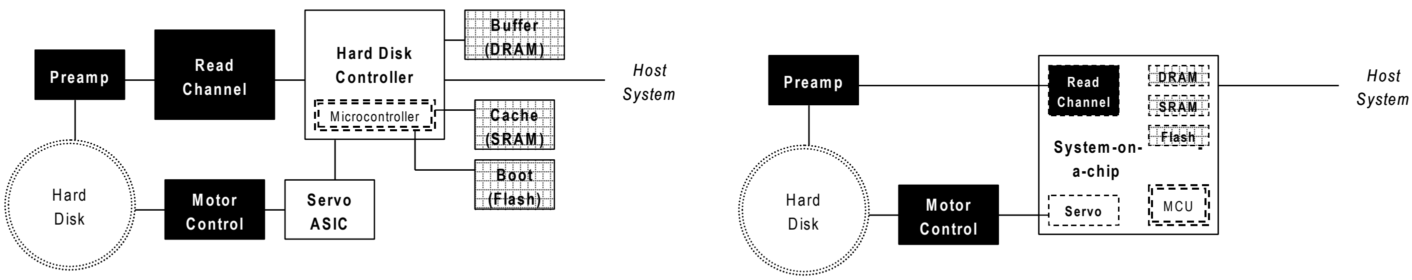
- **Preamp:** The preamp amplifies the analog signal from the read/write heads on the platter and sends the data to the read channel.
- **Read Channel:** The read channel performs the data encoding and conversions needed to read and write the data to and from the hard disk.
- **Hard Disk Controller (HDC):** This controller is the interface processor that sends instructions from the host system to and from the servo ASIC and the read channel. It also determines when to raise and lower read, write and servo gates and is responsible for defect management and error correction. Hard disk controllers usually include a microcontroller to run the entire HDD system.
- **Buffer Memory (DRAM):** Buffer memory temporarily stores the data being transferred to and from the host system.
- **Cache Memory (SRAM):** Cache memory is used to store processor instruction code once the drive is up and running.
- **Code/Boot Memory (Flash):** Boot memory is used to store initial instructions required to start the drive.

- **System-On-a-Chip (SoC)** (not pictured in block diagram above): As mentioned above, most HDDs incorporate an SoC solution that includes most of the read/write functions on a single IC. Most SoCs today incorporate the read channel, HDC, servo ASIC and code and cache memory. Some SoCs also integrate buffer memory, removing the need for a separate DRAM module. The exhibits below display block diagrams without and with SoCs.

Hard Disk Movement Control

- **Motor Control:** The motor control IC controls the amount of current to the spindle motors and the voice coil motor (used to move the head stack), controlling drive commutation and speed. Motor controllers sold as ASSP solutions are specifically designed for hard disk drives.
- **Servo ASIC:** The servo ASIC is a DSP that interprets cylinder numbers and controls timing of servo gate assertions and events during the assertion periods. This digital device is most often integrated into the hard disk controller or SoC.

Hard Disk Drive Without SoC Integration | **Hard Disk Drive With SoC Integration**



Source: IDC, Oppenheimer & Co.

Hard Disk Drives

Hard Disk Drive Semiconductor Market Trends

•Solid State Drives (SSDs) are a hot topic as falling NAND prices make these drives an economically feasible option.

•The transition to SoC continues; adoption exceeded 95% in 2010 and should reach 100% by 2015.

•Enterprise SoCs gaining traction in 2010.

•SATA now dominates the desktop and notebook and is enabling new low-cost enterprise systems.

•The transition from SCSI to SAS in the enterprise has begun.

•1” drives are dead, and 1.8” drives are being successfully challenged by flash in portable media players.

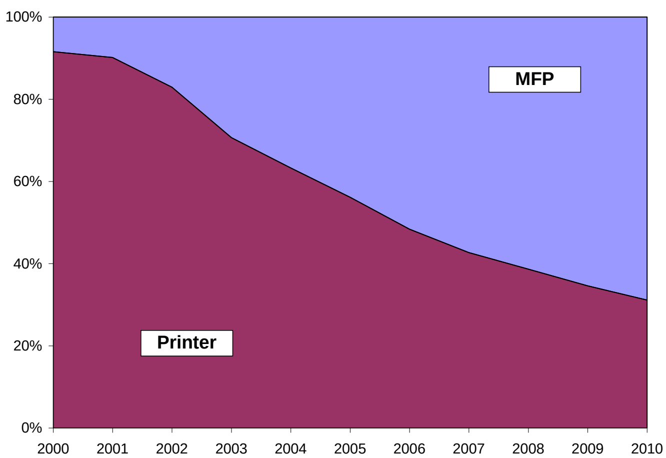
- **SSDs are a hot topic.** Falling NAND prices have made these drives economically feasible. Ultra-portable notebooks should adopt SSDs, but costs likely will keep SSDs out of desktops and most mainstream notebooks.
- **SoC adoption was above 95% in 2010 and should reach 100% by 2015.** SoC solutions pervade HDD designs; by 2008 all major desktop and mobile drive vendors had adopted SoCs for all of their volume. SoC adoption should get another boost when enterprise drives begin gaining traction in SoCs in 2010.
- **SATA now dominates the desktop and notebook and is enabling new low-cost enterprise systems.** Though it had a slow start when initially launched, SATA has now taken over the mainstream desktop and notebook PC market. We are also seeing SATA drives penetrate the enterprise market in new low-cost systems.
- **The transition from SCSI to SAS has begun.** For the enterprise market, HDD OEMs are migrating their SCSI product lines to SAS.
- **One-inch drives are dead, and 1.8” drives are being successfully challenged by flash in portable media players.** Flash provides many benefits vs. HDD for portables, and where capacities make economic sense, flash is heavily favored. Apple has been a leader here, first with the iPod Nano and then with the iPod Touch.

Printers and MFPs

The printer market has seen continued innovation despite its maturity. The "razor" business model continues to produce affordable printers for consumer and enterprise.

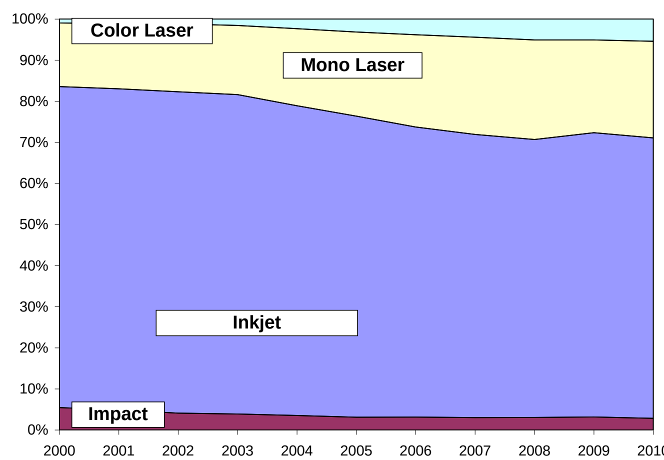
Multi-function peripherals, which include printing, fax, scanner, and copier functions, have enjoyed tremendous market acceptance, now nearly 70% of total shipments. Photo printers have grown just as quickly, and are a big reason why inkjet has remained dominant over laser.

Printers vs. MFPs



Source: DisplaySearch, IDC, Oppenheimer & Co.

Printer Type



Source: IDC, Oppenheimer & Co.

The printer market has seen continued innovation despite its maturity. OEMs have focused on driving steady replacement by packing additional functionality as well as improving print quality and lowering cost. The "razor" business model continues to produce affordable printers for consumer and enterprise—OEMs continue to subsidize the initial cost of printers and rely on high-margin replacement toner and ink for profitability. This model drives a huge focus on unit share which drives the installed base and therefore future purchases of ink cartridges.

One main vector of innovation has been the move to multi-function peripherals. OEMs are incorporating printing, fax, scanner, and copier capabilities into all-in-one devices, known as multi-function peripherals, or MFPs. In 2006, MFPs crossed the 50% penetration mark for the first time and now represent 69% of total shipments in 2010.

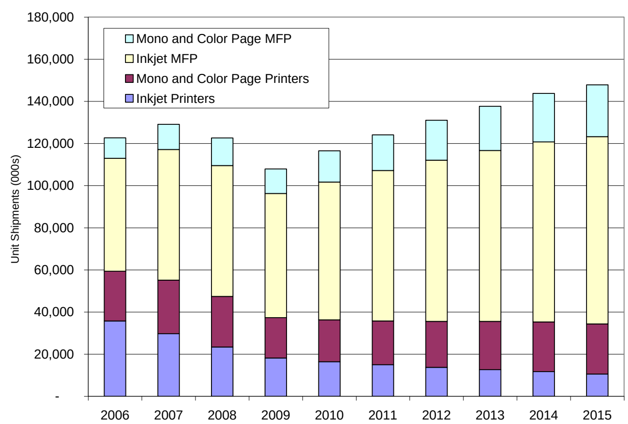
Advancements in digital photography have also driven increased demand for photo printing solutions, and OEMs have been more than willing to meet this need (the better to sell expensive photo ink cartridges). More than half of all inkjet printers sold in 2010 were photo capable, and this trend has helped maintain the dominance of inkjet over laser. OEMs even offer small form factor printers designed to print photos only.

Note that the MFP and photo printer trends are not mutually exclusive—many MFPs are photo-capable. Over time, we would expect MFP penetration to continue to rise at a steady pace. Photo printers (and MFPs) should rise even more rapidly until they represent nearly all consumer shipments.

Printers and MFPs

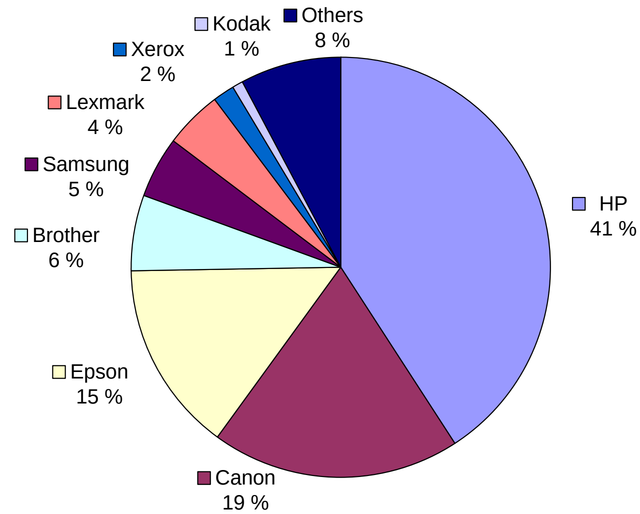
Printer and MFP Unit Forecast

- •We expect printers and MFPs to grow at at a 5% CAGR, from 117 million units in 2010 to 148 million units in 2015.
- •MFPs should grow at a 6% CAGR, from 56% of units in 2010 to 60% in 2015.
- •Inkjet printers should decline at an 8% CAGR, giving way to MFPs.
- •Mono and color page MFPs should be the fastest growing segment as prices come down.



Source: IDC, Oppenheimer & Co.

Printer and MFP Suppliers



Printers	***MFPs***
HP	HP
Canon	Canon
Epson	Epson
Samsung	Brother
Lexmark	Lexmark
Brother	Samsung
Xerox	Kodak
Oki	Xerox

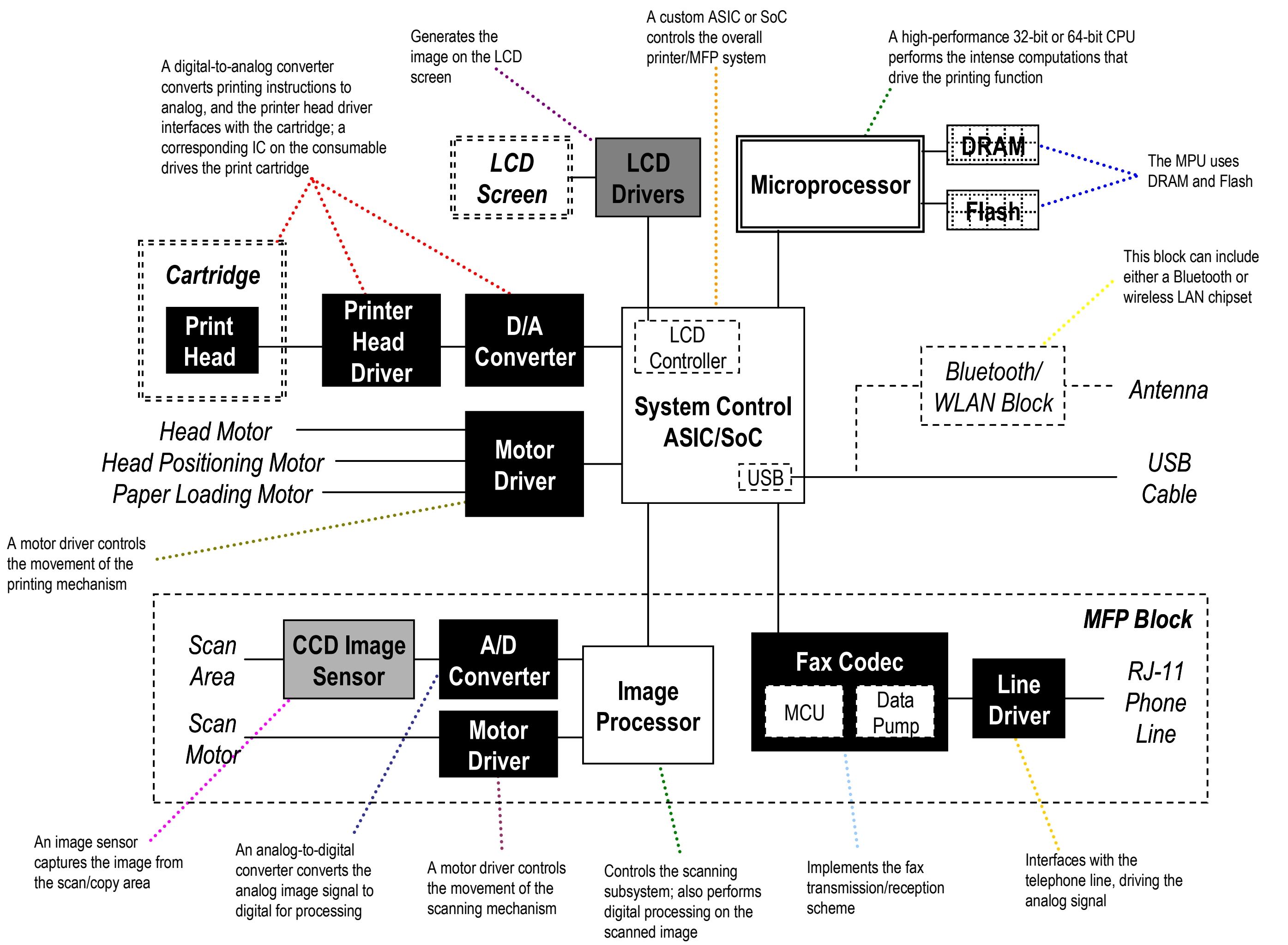
Source: IDC, Oppenheimer & Co.

Printer and MFP Unit Forecast: Though clearly tied to the PC market, printers represent a somewhat separate purchase for enterprise and consumer PC users and do not track PC shipments all that closely. In recent years, printer shipments have bounced between 33% and 54% of PC shipments. MFPs and photo printers have generated some additional demand, driving several years at the high end of the range. This effect has been waning, and in 2010 the printer ratio dropped to 33%. In total, we expect printer shipments to grow inline with PCs, increasing at a 5% CAGR, from 117 million units in 2010 to 148 million units in 2015.

The fastest growth segment is expected to be mono and color page MFPs, though this should remain a high-end niche. Inkjet MFPs are growing at a 6% CAGR. Together, these segments should represent 77% of total units in 2015. In terms of traditional printers, mono and color page printers should grow at the rate of 4%, with particular strength in the color laser segment as aggressive pricing by OEMs spurs increased adoption in the enterprise. Standard inkjet printers should decline at an 8% rate, representing just 7% of units in 2015.

Printer and MFP Suppliers: HP dominated the printer market in 2009 with 41% unit share; HP is the market leader in both stand-alone printers and MFPs. Canon followed with 19% and held the No. 2 position in printers and MFPs. Epson followed with 15% share and held the No. 3 position in printers and MFPs. Brother was No. 4 with 6% share. Other major suppliers include Samsung (4%), Lexmark (4%), Xerox (2%), and Kodak (1%). Oki, Dell, Lenovo, Sharp, and Konika Minolta also participate in the market.

Printers and MFPs



Source: STMicroelectronics, NEC, TDK, Oppenheimer & Co.

Printing Block

- **System Control/ASIC/SoC**: A custom ASIC or SoC controls the primary printing function. In mainstream inkjet or mono laser printers, the ASIC/SoC usually integrates a microprocessor to perform the intense computations involved in printing.
- **Microprocessor:** In high-end color laser printers, a discrete high-performance 32-bit or 64-bit CPU performs the intense computations that drive the printing function.
- **DRAM and Flash:** The embedded or discrete microprocessor uses DRAM and flash.
- **D/A Converter (DAC)**: A DAC converts digital printing instructions to analog and interfaces with the print head.
- **Printer Head Driver:** The printer head driver interfaces with the print cartridge. These are typically custom to individual OEMs, as a means to ensure only OEM-branded print cartridges can be used.
- **Motor Driver:** The motor driver controls the movement of the printing mechanism.

MFP Block – Scanner/Copier

- **CCD Image Sensor:** The image sensor receives the image from the scan/copy area.
- **A/D Converter:** The ADC converts the image from analog to digital for processing, printing, and storage.
- **Motor Driver:** The motor driver controls the movement of the scanning mechanism.

- **Image Processor:** An image processor controls the scanning subsystem and performs image processing.

MFP Block – Fax

- **Fax Codec**: The Fax AFE/codec performs the analog-to-digital conversion to generate the fax signal. Similar to analog modem codecs, they are specialized mixed-signal processors and typically include a data pump and embedded microcontroller.
- **Line driver**: This analog SLIC interfaces with the RJ-11 copper twisted pair (phone line), performing transmission and reception functions.

Interface and Display

- **USB/1394 Controller** (usually integrated, not shown in diagram)**:** A USB/Firewire controller manages the interface to the PC. Many printed ASIC/SoCs integrate this function.
- **Bluetooth Baseband and RF/IF** (not pictured in diagram) –Bluetooth-enabled printers can interface wirelessly with a PC via a personal area network. They can also use Bluetooth to connect directly to a digital camera to print out photos images. In a Bluetooth chipset, the baseband performs the digital processing and protocol encoding and the RF/IF performs the radio transmission/reception.
- **Wireless LAN Baseband/MAC and RF/IF/PA** (not pictured in diagram): Wireless LAN-enabled printers can interface wirelessly with a PC or camera via an 802.11 wireless LAN in order to transfer images. In an 802.11 chipset, the baseband/MAC performs digital processing and protocol encoding and the RF/IF/PA performs the radio transmission/reception and power amplification.
- **Display Drivers**: Display drivers produce the image on the LCD screen.

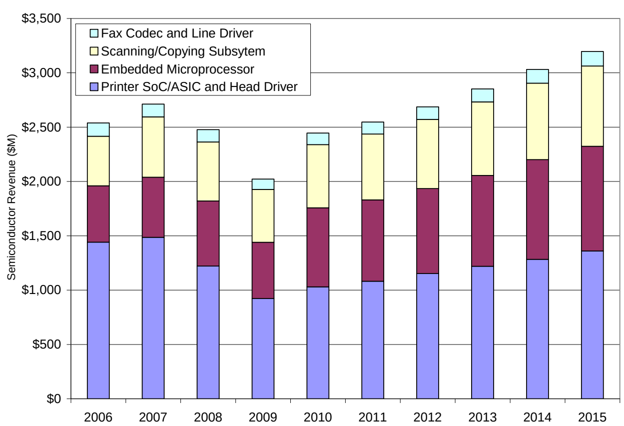
Print Cartridge/Consumable

- **Print Head:** A specialized print head IC sits on each individual print cartridge and controls the functioning of the cartridge. Like the head driver on the printer, these are typically custom to individual OEMs, as a means to ensure only OEM-branded print cartridges can be used.

Printers and MFPs

Printer and MFP Semiconductor Forecast

•We expect the market to grow at a 6% CAGR, from $2.4 billion in 2010 to $3.2 billion in 2015.
•ICs should slightly outpace units as mono and color laser printers outpace inkjet, driving higher ASIC/SoC ASPs and greater microprocessor content.
•Still-rising MFP penetration should drive additional growth in ICs that enable scanning/copying and fax functions, though some of this is being sucked into the printer ASIC.



Source: IDC, Dataquest, Oppenheimer & Co.

Printer and MFP IC Competitors

STMicroelectronics
Texas Instruments
Marvell
Conexant
Zoran
LSI
Renesas
PMC-Sierra
Toshiba
Seiko-Epson
NXP

Source: Oppenheimer & Co.

Printer Semiconductor Forecast: We expect the market for printer and MFP semiconductors to grow at a 6% CAGR, from $2.4 billion in 2010 to $3.2 billion in 2015. Semiconductor revenue should slightly outpace units due to the rising penetration of laser vs. inkjet, both in the printer category and in MFPs. These laser printers use more robust SoCs, and in the case of high-end or color laser, also include significant discrete microprocessor content.

Note that the rapid growth of MFPs has generated significant growth on the IC side, as these units require image processing and analog ICs to enable scanning and copier functions as well as the codecs and line drivers ICs for fax capability. In 2010, we estimate these two IC opportunities combined yielded almost $690 million in market revenue. Much of the IC growth generated by this trend is now behind us, however, as OEMs shift focus to lowering the cost of these features, primarily through integration. We expect the revenue associated with these two IC sub-segments to grow at a 5% CAGR, remaining accretive to the overall IC CAGR.

Printer Semiconductor Market Share: The printer IC market is dominated by a number of large, diversified semiconductor vendors with design competencies in SoC/ASIC, microprocessing, and analog design. Major vendors in this space include STMicroelectronics, Texas Instruments, Conexant, Marvell (Marvell acquired Avago's printer business in 2006), Zoran (acquired by CSR), LSI, Renesas (acquired NEC), PMC-Sierra, Toshiba, Seiko-Epson, and NXP. A second set of companies provides fax ICs into MFPs; these include Conexant, Silicon Labs, LSI, Austria Microsystems, and Analog Devices.

Printers and MFPs

Printer and MFP Semiconductor Market Trends

•The market remains heavily ASIC-based as OEMs continue to value control over the design to keep out standardized ink cartridges.

•The rise of multi-function peripherals has opened up opportunities for imaging and communication ICs.

•All but the highest-end printers are moving to SoC solutions.

•802.11 and Bluetooth are both candidates for wireless connectivity within printers.

- **The market remains heavily ASIC-based as OEMs continue to value control over the design to keep out standardized ink cartridges.** To preserve the economics of the "razor" business model, OEMs need to preserve the proprietary nature of their designs, especially with regards to the print cartridge. They have therefore kept their printer designs predominantly ASIC-based.
- **The rise of multi-function peripherals has opened up opportunities for imaging and communication ICs.** MFPs can include printing, scanning, copying, and fax functions, and therefore require specialized ICs to enable these functions. Note that while the core printing functions in MFPs are enabled by ASICs, as mentioned above, imaging and communications functions has allowed merchant suppliers to penetrate the printer market.
- **All but the highest-end printers are moving to SoC solutions.** Integration is a major focus for OEMs, especially considering they usually lose money on printer hardware. The market has seen many discrete ICs move into the core ASIC/SoC over the past few years, in particular the microprocessor. At this point, only high-end color laser printers utilize a discrete MPU, and while this market is growing now with the rising penetration of color laser, it saw a major drop just a few years ago as inkjet and mono laser printers moved to SoC.
- **802.11 and Bluetooth are both candidates for wireless connectivity within printers.** Though not included in our IC forecast, we expect to see wireless networking technology move into printers over time. Penetration thus far has been slow, but we expect it to pick up with the emergence of combo chip solutions.

Networking

The computing applications we have discussed generally allow users to manipulate data stored locally within a single device, such as a PC, a server, or a peripheral. We now move on to networking applications, which enable the transfer of data between these devices.

A variety of technologies are used to connect individual computing clients, with a key factor being distance. This section deals primarily with equipment used to connect networking clients in a single physical location, e.g., a small business, a single corporate branch office, or a home network environment.

Equipment used to send data over longer distances (e.g., modems) typically utilizes public telecom and cable infrastructure or corporate wide area networks and are discussed later in the section on telecom and datacom. Cellular networks are also discussed separately.

The computing applications we have discussed generally allow users to manipulate data stored locally within a single device, such as a PC, a server, or a peripheral. We now move on to networking applications, which enable the transfer of data between these devices.

A variety of technologies are used to connect individual computing clients, with a key factor being distance. This section deals primarily with equipment used to connect PCs, servers and storage in a single physical location—e.g., a small business, a single corporate branch office, or a home network environment. Given the close ties to computing, networking equipment is usually designed with the PC in mind. Metrics like speed, ease of install and configurability and low maintenance cost generally take precedence over factors such as ensuring quality of service or multiple classes of service support (a situation that is reversed in telecom networks).

Equipment used to send data over longer distances typically utilizes public telecom and cable infrastructure or corporate wide area networks and is discussed separately (in the section on telecom and datacom). This equipment is designed to leverage the existing voice or video infrastructure to send data rather than act as a standalone network, though some standalone wide area data networks do exist. The economics are also different, as telecom and datacom equipment is tied to service provider capital expenditures, while networking is tied more closely to IT spending.

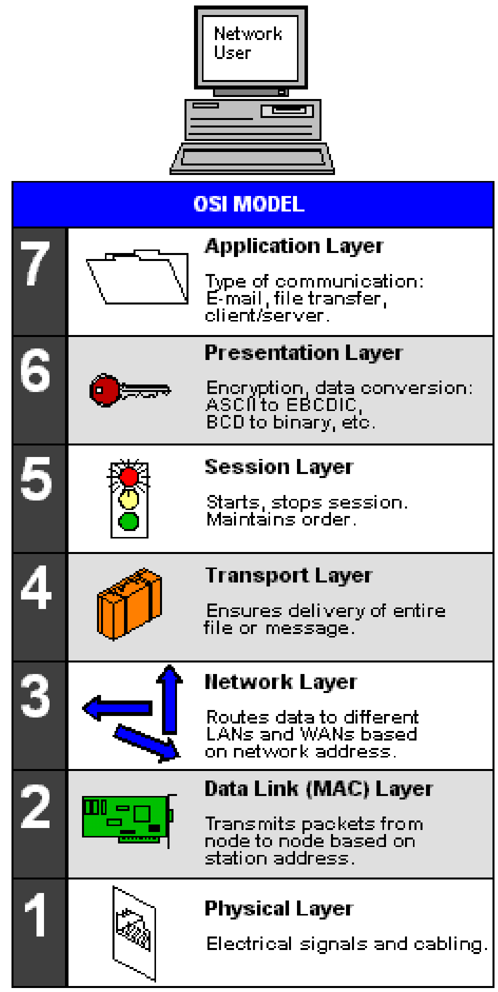
Cellular technologies are also discussed separately in the section on wireless, as the technology and economic factors driving those technologies are worthy of separate attention.

Networking

The OSI Reference Model

The OSI reference model provides a framework for the development of networking technologies and standards.

The model divides networking functions into seven layers, all of which can be designed independent of each other. The upper layers (4-7) deal with user applications, and function independently of the type of physical network used to carry information. The lower layers (1-3) are dedicated to issues relating to the actual transport of information around the network.



Source: Computer Desktop Encyclopedia, The Computer Language Co.

Networking technologies are designed to share data between computing devices. These devices connect using a wide variety of terminal equipment and operate using disparate communications protocols, transmission media and data transfer rates. Given the disparate technologies, the challenge of internetworking becomes how to connect these networks such that data can be reliably transmitted among them.

In order to meet the challenges of internetworking, network architects began to segment communications tasks into separate and self-contained layers of functionality. Each layer is designed to perform a certain task or range of tasks and is independent of the layers above and below it. This process was formalized in 1984 by the International Organization for Standardization (ISO) with the publication of a seven-layer reference model. The reference model governs how information from a user application in one computer is transmitted across a network or inter-network to a user application in another computer. In this way, it provides a framework for the coordination of standards development, allowing existing and evolving standards to be set within a common framework. The OSI model has therefore become the primary architectural model for internetworking communications.

The layers of the OSI reference model can be grouped into two categories: upper layers (4-7) and lower layers (1-3). The upper layers deal with actual user software applications (like Microsoft Outlook or Internet Explorer), and function independently of the type of physical network used to carry information. The upper layers are typically implemented in software running on the networked device. The lower layers are dedicated to data transport issues and can be implemented in either software or hardware.

In order to understand the function of each layer of the model, we can look at the process of sending an email from a PC. A computer is a layer 7 device, meaning that it can operate from the highest layer (which is where applications are run) to the lowest layer (the PC can put signals directly onto a network cable plugged into a port). At the application layer (7), Outlook (or another email client) deals with the composition of the E-mail, including formatting, attachments, and security features. At the presentation layer (6), the email is converted into a standard format compatible with all email programs. At the session layer (5), a channel is opened between the PC and the network for message transmission. At the transport layer (4), the operating system passes the email to the computer's networking subsystem. At the network layer (3), the system makes sure it has a clear path to the rest of the data network. At the link layer (2), a network address for the email is attached to the message. Finally, at the physical layer (1), the PC sends out the actual signal over the network cable. In receiving an E-mail, the process is reversed, though the functions performed are the same.

The OSI Reference Model: Layer 1-7 Summary

The Physical Layer (1)

This layer defines the electrical, mechanical and functional specifications for transmitting a data signal over a network link. The physical layer is also responsible for establishing, maintaining and terminating the physical signal between network devices. Physical layer protocols typically define parameters such as voltage level, shape or template of transmission signal, data transfer rates, maximum transmission distances and physical connectors.

The Data Link Layer (2)

The data link layer controls the transfer of data across a physical network link. As such, data link layer protocols define the characteristics of network links including network topology, physical addressing, frame formats, frame sequencing, error notification and flow control. The IEEE (Institute of Electrical and Electronics Engineers) further subdivides the link layer into two sub-layers: logical link control (LLC) and media access control (MAC). The LLC sub-layer manages communications between devices separated by a physical link, while the MAC sub-layer manages access to the physical network medium.

The Network Layer (3)

The network layer is responsible for establishing, maintaining and clearing a network-wide connection between two transport layer entities. The network layer principally provides routing and other functions that enable data to be transmitted over disparate physical links. The network layer provides both connection-oriented and connectionless service to layers above it. Most network layer protocols are routing protocols. Note that network layer routing functions are based on logical addressing rather than physical addressing.

The Transport Layer (4)

This layer functions as the interface between the application-oriented upper layers and their underlying network-dependent layers, providing transparent yet reliable inter-network data transport services to the higher layers. Effectively, the transport layer hides the detailed operation of the underlying network from the upper layers. Transport layer functions include flow control, multiplexing, virtual circuit management and error correction. Flow control manages the rate of data transmission between two entities such that the transmitting devices do not send data at a rate greater than what the receiving entity can process. Multiplexing allows several communications channels to be carried over the same physical link without any data loss. Virtual circuit management involves the creation, maintenance and termination of virtual circuits (a virtual circuit is a lower speed channel carried over a higher speed physical link). Finally, error checking involves mechanisms for the identification and correction of transmission errors.

The Session Layer (5)

This layer is responsible for establishing, managing and terminating a communication channel between presentation layer entities through a series of communications requests and responses. In addition, the session layer determines whether communication will be half-duplex (two-way transmission, but only one direction at a time) or full-duplex (simultaneous two-way transmission), maintains synchronization between communicating entities, and performs exception reporting.

The Presentation Layer (6)

This layer is concerned with the syntax of data during transfer, i.e., it ensures that data is formatted using a common interface for user applications. To achieve network interoperability, a number of transfer syntaxes have been defined. The presentation layer negotiates and selects the appropriate transfer syntax for each communication so that data transmitted may be understood by both systems. If the transfer syntax differs from the application syntax, the presentation layer performs the necessary conversion. Some common transfer syntaxes include the ASCII and EBCDIC for text and data, motion picture experts group (MPEG) and QuickTime for video and graphics interchange format (GIF), joint photographic experts group (JPEG) and tagged image file format (TIFF) for graphics images. The presentation layer also performs data compression/decompression and encryption/decryption if required.

The Application Layer (7)

This layer interacts with and provides services directly to user software applications. It deals directly with the communications component within an application (e.g., the "Inbox" in Microsoft Outlook) and provides the interface to the services of the network. Functionality provided by this layer typically includes identification of communication partners, determination of network resource availability, synchronization, file transfer, message interchange services such as email, agreement of privacy (encryption) standards and identification of constraints on data syntax.

Networking Equipment, Components, and the OSI Model

Though it all seems technical and theoretical, it is important to understand the layers of the OSI model in order to identify the intended functionality of the various types of networking equipment. For instance, a layer 1 device would deal only with actual physical signaling. An example of a layer 1 device would be a repeater (a device used to boost a signal over a length of cable), which simply receives a signal (at the physical layer [1]) and spits it back out.

Layer 2 deals with addressing. An example of a layer 2 device would be a switch, which receives traffic (at the physical layer [1]), checks the address of the traffic (at the data link layer [2]), and sends the traffic out again (at the physical layer [1]) over the proper channel to reach the recipient.

Layer 3 deals with routing. An example of a layer 3 device would be a router, which receives traffic (at the physical layer [1]), checks the address of the traffic (at the data link layer [2]), determines the best route for the data to take to its destination (at the network layer [3]) and then re-addresses and sends out the traffic (at the data link [2] and physical [1] layers).

We won't carry the example all the way up to layer 7, but it is clear why we called a networked PC a layer 7 device. It can do all the functions of a switch, router, or other more complicated devices because of its robust and flexible operating system and processing hardware. In fact, layer 4-7 network devices are often designed as specialized servers designed to run networking software.

We can also carry the analysis forward to the component world (though we are skipping ahead a bit). An Ethernet PHY is a physical layer (1) device, as it deals with reception and transmission of the signal over copper wire or optical fiber. Every piece of equipment that physically connects to an Ethernet network must therefore contain an Ethernet PHY, from a repeater (a layer 1 device) up to a load balancing device or a networked PC (a layer 4-7 device).

An Ethernet MAC is a data link layer (2) device, as it applies and removes an address to a data packet. An Ethernet MAC would be found in every piece of Ethernet equipment that operates at layer 2 and above, such as an Ethernet switch or NIC card all the way up to the load balancer.

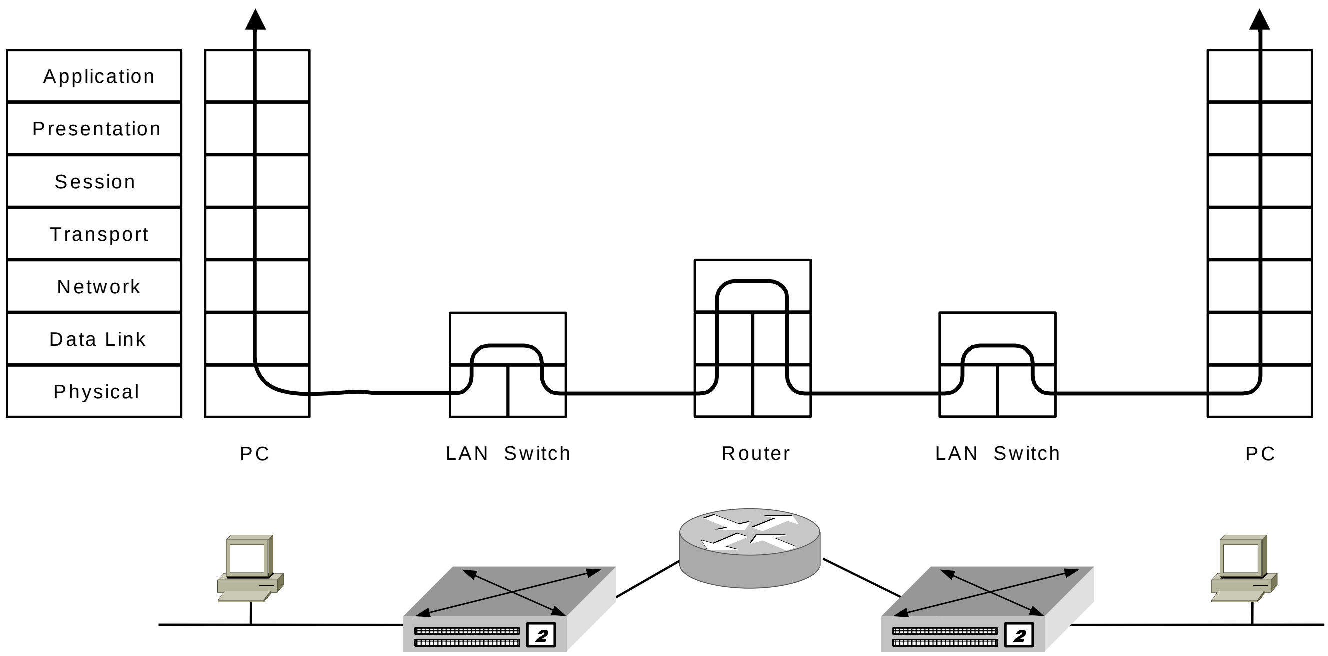
A packet forwarding engine is a network layer (3) device, as it looks up addresses in a route table and forwards packets on to their destinations. A packet forwarding engine would be found in Ethernet equipment that operates at layer 3 or above, from routers up to our load balancer.

As mentioned above, layer 4-7 devices are generally implemented in software running on a specialized networking OS. For high-performance equipment, OEMs often use a combination of microprocessors, specialized ASICs, ASSPs, and FPGAs to perform these tasks.

Networking

Communications Flow in the OSI Reference Model

For two PCs to communicate, data must travel down the layer stack to the physical layer so it can be passed between nodes in the network. At each node, the packet is processed and forwarded; how far up the layer stack it is processed depends on the function served by the node.



Source: Oppenheimer & Co.

We now look at the OSI reference model in action, and track how it governs communication between networked devices. For data to be transferred from a user application program (e.g., Outlook or Internet Explorer) on one computer (or other connected computing device) to a user application program on another computer, it must pass through each of the OSI layers on both the transmitting and receiving computers. This is because user applications operate at layer 7 of the OSI model, while the port used to transmit the data operates at layer 1.

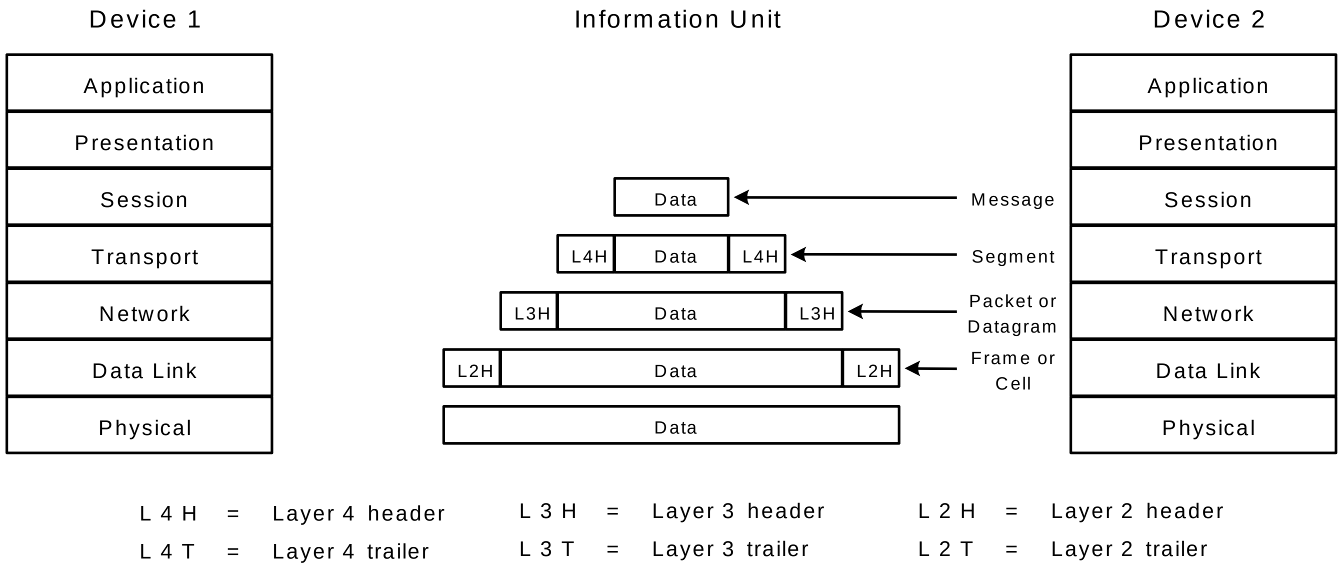
To get the data from layer 7 to layer 1 on the transmitting device, control is passed from one layer to the next, starting at the application layer, down through the middle layers until it reaches the physical layer. The data then travels as layer 1 traffic over the physical network link to the receiving device and back up the layer hierarchy.

If more than one physical link separates communicating devices, for instance if the devices are on different floors in an office building, the information contained within the transmitted signal will be processed by each intermediate node sitting on the network between those two devices. These nodes can be hubs, switches, routers, servers, or anything else connected to the network. How far up the OSI layer stack the information will be processed depends on the function served by the node. For instance, LAN switches tend to process information at layer 2, meaning that the information will travel up the layer stack from layer 1 to layer 2, will be processed by the switch at layer 2 and then will go back down to layer 1 within the switch before it is sent on its way. Routers process data at layer 3; the path is similar except that the information will travel as high as layer 3 before being sent back down. More complex devices operate at layers 4-7, as they need to look at the type of data being transmitted in order to perform their functions.

Networking

Encapsulation in the OSI Reference Model

Each layer of the OSI model can communicate directly with peer devices at the same layer. In order to communicate with layers above and below, control information in the form of headers and trailers is used. Higher layer headers and trailers are treated as payload data for lower layers. This technique is known as encapsulation.



Source: Oppenheimer & Co.

Each layer in the OSI model can communicate with only three other places in the network: the layer directly above it within the device, the layer directly below it in the device and its peer layer in other networked devices.

The latter process, communication with peer devices, is straightforward: at any given layer, networked devices use the same protocols and are designed to interact together. This is dictated by the standards that govern the networking protocol. In order to communicate with other layers, however, control information in the form of headers and trailers prepended or appended to the payload data stream is used. Each layer uses the information in the header/trailer below it in order to process the received payload data. As information travels up the stack, each OSI layer removes the header attached by its corresponding peer layer and forwards the remaining information to the next higher layer. On the way down, each layer will add its own headers and trailers; these will be treated as payload data by lower layers. This is known as encapsulation.

Some common terminology used in referring to the information units passed between OSI layers is defined below.

- *Message:* An information unit whose source and destination layers lie above the network layer.
- *Segment*: An information unit, including header/trailer, whose source and destination layers are transport layer entities.
- *Packet or Datagram:* An information unit, including header/trailer, whose source and destination layers are network layer entities. Datagrams are used in connectionless services.
- *Frame or Cell:* An information unit, including header/trailer, whose source and destination layers are data link layer entities. A frame is of variable length while a cell has a fixed length (like in an ATM network).

Encapsulation Demonstration

To demonstrate the principles of encapsulation, we will follow an email as it makes its way through the PC, and will complete the process by sending it over the network and opening the email on the recipient's PC. An email application at layer 7 on the transmitting PC generates the email and tells the system to send it over the network (that's Microsoft Outlook telling Windows it has an email to send). The PC initiates a session (Windows accesses the communications software on the Ethernet NIC/LOM connection) and puts headers and trailers on it and sends it to the lower layers. As it travels down the network stack (within the NIC/LOM at this point), each layer adds headers and trailers to the outside of the previous layer until a fully stacked frame or cell is created. The frame or cell is then placed on the network by the physical layer device (the PHY device on the NIC card).

The frame or cell, encapsulated in some physical layer protocol (e.g., Ethernet), is then read by the physical layer and data link layers of all other devices to determine if the frame or cell was intended for it. In the case of switches and routers, the devices will forward the frames out toward other network devices (the distinction being that switches will dump the frame out the port closest to the destination, whereas a router will actually find the best route for the frame and forward it on).

Once it finally reaches its destination, the cell will travel up the layer stack. Each layer (starting with those in the NIC card, then the communications software, then Windows) will strip off the headers and trailers from the layer below and pass the data up until it reaches the application (Outlook again or some other email client).

Networking

Four Key Markets:

Ethernet (LAN)

The most pervasive local area networking protocol, Ethernet is used to connect PCs and other networked devices in a single physical location.

Wireless LAN (802.11)

Wireless LANs connect users in a single location using radio waves, usually used in conjunction with a LAN or broadband Internet connection.

Bluetooth

The most common personal area networking protocol, Bluetooth connects two devices in close proximity wirelessly. Bluetooth is particularly prevalent in the handset market.

Storage

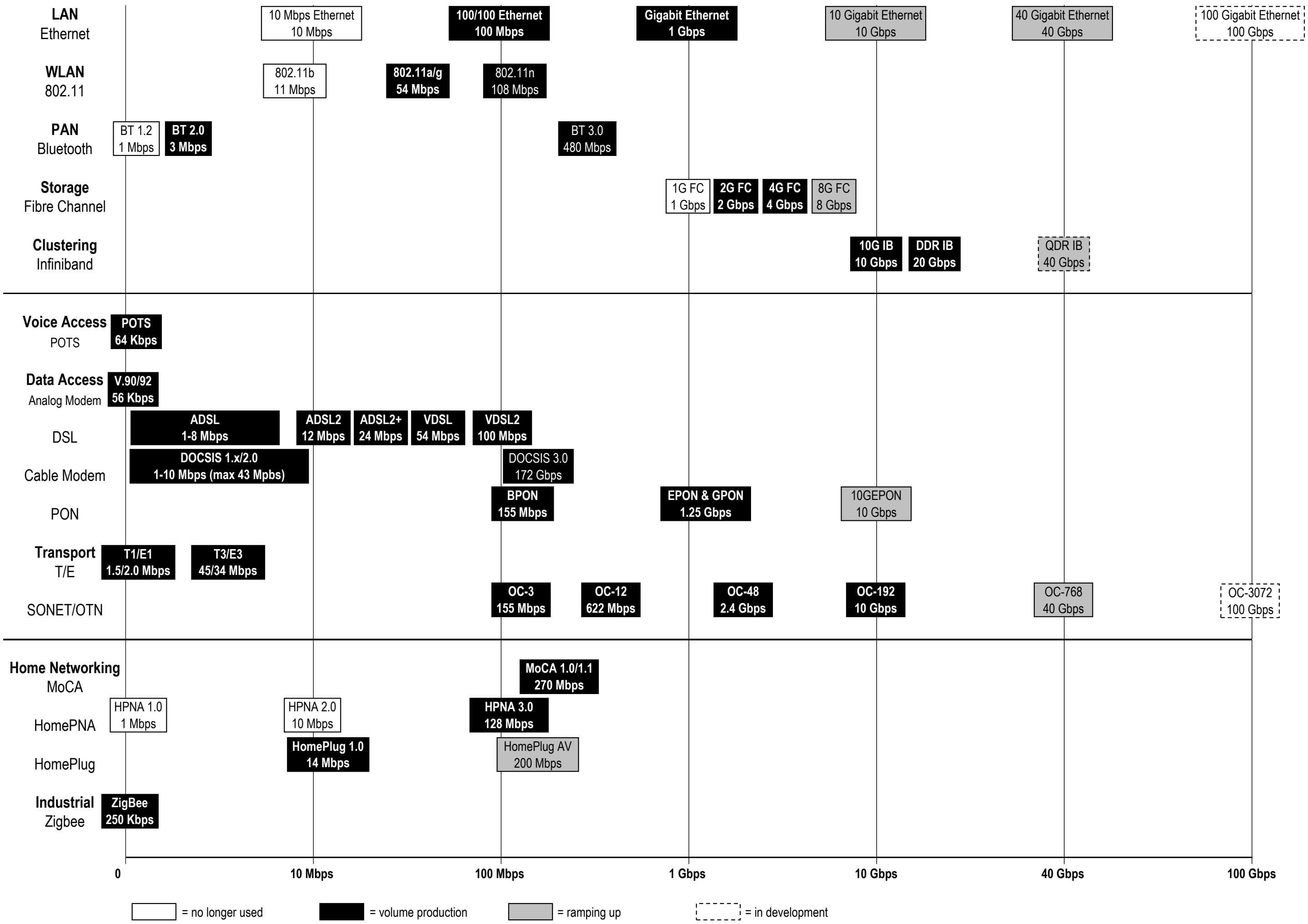
Enterprise storage systems, including direct attached storage (DAS), storage area networks (SAN), and network attached storage (NAS).

This section deals with pure data network technologies used to connect multiple PCs, peripherals, or storage devices in a single physical location. Networking equipment is usually designed around the needs of corporate IT networks, though consumer networking has gained significant traction in the past few years. Key technologies include:

- **Ethernet**: The primary wired data networking technology for computers and servers, Ethernet is a fast, scalable, cost-effective technology used to connect PCs in a corporate or home network.
- **Wireless LAN (802.11)**: Wireless LAN mimics a wired LAN but replaces the copper cable with radio waves—allowing for the networking of devices at distances up to 300 feet without wires. It is usually used in conjunction with a LAN or broadband Internet connection. 802.11 uses unlicensed spectrum, primarily 2.4 GHz and 5 GHz.
- **Bluetooth:** A personal area networking technology, Bluetooth is a fast, cheap, low-power wireless protocol used to connect two devices in close proximity. Bluetooth is particularly prevalent in the handset market.
- **Storage:** Enterprise storage, while primarily implemented via direct-attached hard drives today, is increasingly moving to Fibre Channel-based storage area network and network attached storage systems, mimicking an Ethernet network and providing increased efficiency, manageability, scalability and upgradeability.

Throughout the networking section, we will be quoting a variety of speed grades that can be difficult to keep track of. The chart below displays the major networking technologies along with the sub-protocols of each. We also include telecom/datacom, home networking, and industrial networking technologies for comparison purposes. We include only true networking technologies; interface technologies such as USB, SATA, SAS, PCI-Express, RapidIO, HyperTransport, and a whole host of others are not included.

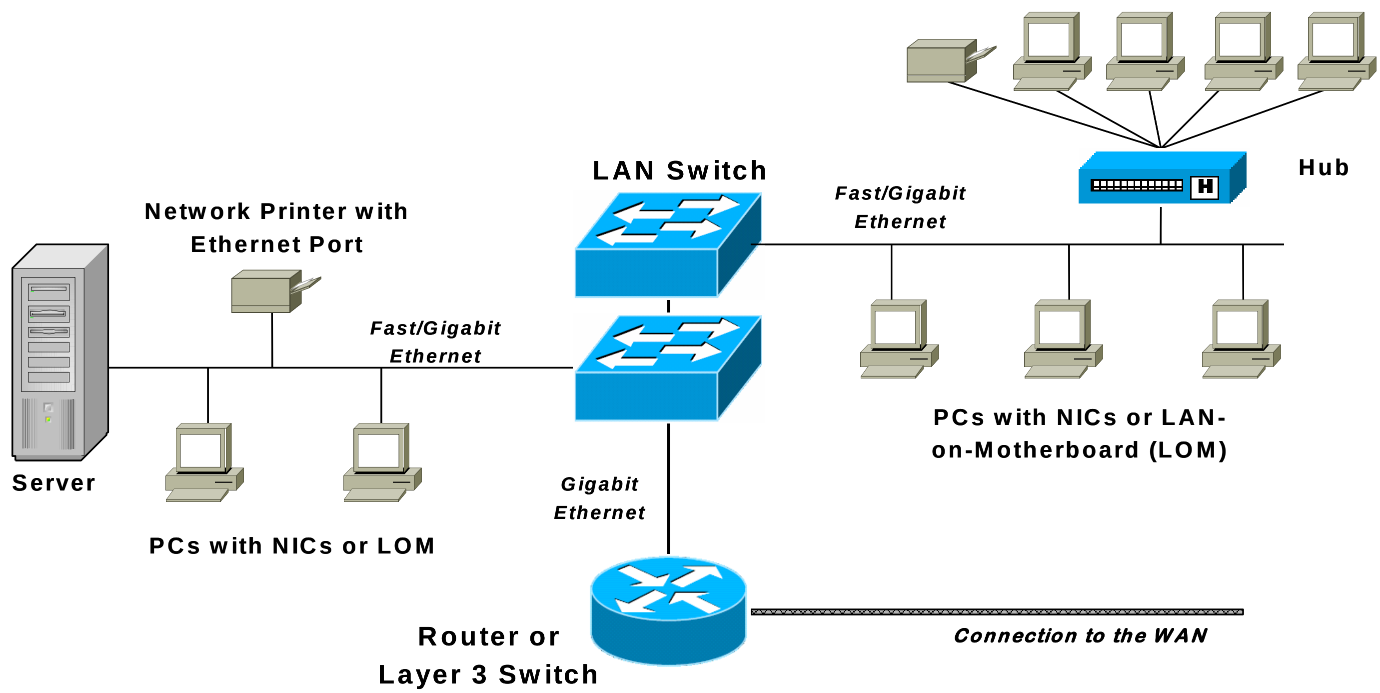
Networking Protocol Speed Chart



Note: In most cases, speeds quoted correspond to the maximum data rate (sometimes called the “PHY rate)” achievable according to the standard. Most networking protocols have a usable data rate that is meaningfully less than the quoted rate, though the magnitude of this difference can vary significantly depending on the protocol.
Source: Company reports and Oppenheimer & Co.

Ethernet

Ethernet is the most popular protocol used in local area networks. PCs, servers, and printers equipped with Ethernet ports connect to switches that direct traffic around the network. Data packets bound for locations outside the LAN are addressed and forwarded by routers.



Source: Cisco Systems, Oppenheimer & Co.

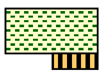
Ethernet is the most pervasive networking protocol used in local area networks. Ethernet is a packet-switched frame-based broadcast technology, meaning that it sends addressed information out over the network rather than establish a dedicated line between two devices (we discuss packet-switched and circuit-switched networks in more detail in the datacom/telecom section). To get data from one device to another, the transmitting device (e.g., a PC) "broadcasts" the data, along with the recipient's address, over the network. All devices attached to that network (known as "client devices") link read the address; if the packet is bound for that device it extracts the payload; otherwise that packet is ignored. In practice, most Ethernet networks use a switched architecture, meaning that switches are used to forward traffic between clients on the network; this cuts down on redundant traffic and frees up bandwidth on the network.

To connect to an Ethernet network, client devices require a network interface card (NIC). Most PCs today ship with a LAN-on-motherboard (LOM) solution, which is essentially a single-chip NIC implementation soldered directly onto the PC motherboard. Each client connects via Category 5 cable up to an Ethernet switch (fiber can also be used). As client devices broadcast Ethernet frames, the switch reads the addresses and determines which of its ports the recipient sits on and broadcasts the packet out on that port, where it is received and opened by the recipient client.

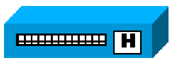
Switches in the LAN are generally connected to one another via uplink ports (an uplink port is the same as a standard Ethernet port but is sometimes a higher speed port) to form a LAN backbone. This LAN backbone allows communication between clients throughout the wider LAN and also interfaces with a router to send and receive data to locations farther away, such as another LAN or the public Internet.

Ethernet

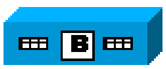
Types of Ethernet Equipment



NIC (Network Interface Card) - Add-in card installed in PCs, servers, and other Ethernet clients to connect the device to the network. Most client devices have migrated to LAN-on-motherboard solutions.



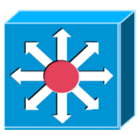
Hub - Simple LAN device that connects multiple clients by forwarding Ethernet traffic to each port without any intelligent switching.



Bridge - Simple LAN interconnect device used to connect two LANs.

Layer 2 Switch - The basic network building block, layer 2 switches connect LAN clients together and switch traffic between them, forwarding Ethernet frames between specific ports based on the network address.

Router - Intelligent packet forwarding device that operates at layer 3 of the OSI stack. Routers are placed strategically within a network and communicate with each other to determine the optimal route through the network for packet forwarding. Routers also perform protocol translation.



Layer 3 Switch - Adds routing capability to the basic Ethernet switch, eliminating the need for packets to be routed centrally.

Layer 4-7 Switch - Performs packet forwarding and routing based on deeper packet information (as per layers 4-7 of the OSI model), enabling multiple classes of service (CoS) and better quality of service (QoS). These switches can also do load balancing and intelligent provisioning.

Types of Ethernet Equipment

Network Interface Card (NIC): Network interface cards are add-in cards that provide individual clients with an interface to the LAN. NICs operate at the lowest two layers of the OSI reference model. They are responsible for segmenting and framing the user data stream (data link layer functions) and for signal shaping and conditioning (physical layer functions) required to transmit data over the LAN medium. IEEE compliant NICs ship with a predefined, hard-coded MAC address that uniquely identifies the terminal device from all others connected to the LAN.

LAN-on-Motherboard (LOM): Most PCs now ship with a LAN-on-Motherboard solution. These single-chip solutions essentially capture the entire functionality of a NIC card on a single device, which is soldered on the PC motherboard.

Hub: Hubs connect multiple network clients but do not perform any intelligent switching. Basically, a hub simply forwards Ethernet traffic to each port in order to extend the LAN to additional clients. They provide congestion control in LANs and also serve as a point of data aggregation in the LAN.

Bridge: Bridges are simple LAN interconnection devices that connect two bus-based LANs running the same protocol. Like hubs, bridges operate at the lowest two layers of the OSI reference model (the data link layer and the physical layer) and forward traffic from one LAN segment to another.

Switch: Switches connect LAN clients together and are the basic building blocks of a local area network. Like hubs and bridges, switches operate at the data link layer and physical layer of the OSI reference model and provide traffic forwarding based on destination addresses (known as MAC addresses). Switches differ from bridges and hubs, however, by offering intelligent traffic forwarding between multiple input ports and multiple output ports through a central switch fabric. They therefore prevent network congestion on LAN segments that do not include either the originating or receiving device. Furthermore, switches allow multiple simultaneous communications across the fabric on a point-to-point basis.

Router: Routers are intelligent packet forwarding devices that operate at the three network dependent layers (physical, data link and network layers) of the OSI reference model and serve two basic functions: determining optimal routes or paths through the network, and packet forwarding. Routers typically serve to interconnect LAN segments as well as to connect LAN segments to the WAN. As such, routers typically support multiple data networking protocols, such as T1/E1, T3/E3, Ethernet, Token-Ring, FDDI, Frame Relay, ATM and SONET/SDH. Routers, especially high speed routers, perform the packet routing in hardware in order to provide the greatest possible performance.

Unlike switches that view the network on a link-to-link basis, routers view the network on a global basis and have knowledge of neighboring routers. Routers dynamically maintain network topology data, including neighboring routers, route distance, route delay and route congestion levels, and update this information as network conditions change. In addition, routers are self-learning devices. When introduced into a network, a router exchanges information as to network topology with neighboring routers. In this process, the newly introduced router learns the topology of the network from its neighbors, while simultaneously allowing its neighbors to update their view of the network to reflect the existence of the new router. When making packet forwarding decisions, routers depend on this accumulated network intelligence. Routing decisions may be based on such factors as destination address, payload type, packet priority level (contained in the IP header), least-cost route, route delay and route congestion levels.

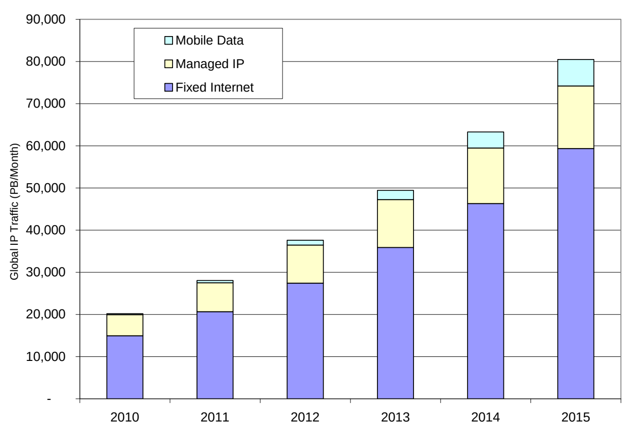
Layer 3 Switch: As discussed, switching of Ethernet frames between clients on the LAN typically takes place at layer 2 of the OSI reference model. By adding layer 3 functionality to a switch, a hybrid switch/router is created that can forward and switch packets at layer 3, choosing a specific route for the packet to follow through the network to its destination. By making intelligent routing decisions when the packet is switched, the number of network routers may be reduced, thereby limiting the number of router peers with which each router must interact.

Layer 4-7 Switch: Layer 4-7 switching operates at the transport layer (layer 4) and above of the OSI reference model. Layer 4-7 switching goes beyond IP to transport layer protocols such as TCP or UDP to make packet forwarding decisions. Layer 4-7 switches are able to look deep into data packets to extract information regarding the packet content and the application protocols exchanging the data packet. Using this information, together with details about network congestion, delay and loss, the layer 4-7 switch makes packet forwarding decisions. With the ability to differentiate classes of traffic, layer 4-7 switches have the ability to prioritize those flows with more strict requirements, thereby meeting quality of service demands. They also perform load balancing functions, keeping congestion down to manageable levels.

Ethernet

IP Traffic Driving Demand

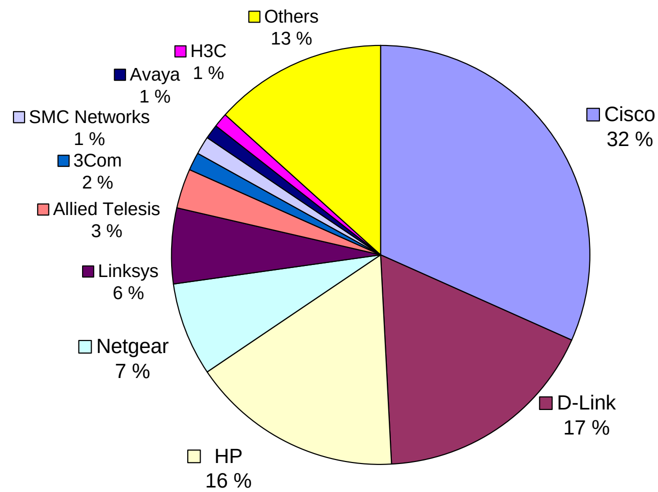
- Global IP traffic is expected to rise from 20,151 PB/month in 2010 to 80,456 PB/month in 2015, a 32% CAGR.
- The surging number of mobile connected devices and expanding video and multimedia capabilities is driving demand for new Ethernet infrastructure.
- Switch ports are still growing from both new LAN buildouts and healthy upgrades; networking OEMs continue to pack better performance and more advanced security.
- Non-PC clients should be a big driver; these include printers, game consoles, set-tops, modems and other PC peripheral and consumer devices.



Source: Cisco Visual Networking Index, Oppenheimer & Co.

Ethernet Equipment Suppliers

Ethernet Switches



PCs	***Servers***
HP	HP
Dell	Dell
Acer	IBM
Lenovo	Fujitsu/F-S
Toshiba	NEC
ASUS	Sun

Source: Dell'Oro, IDC, Oppenheimer & Co.

IP Traffic Is Driving Demand*:* With the surging number of mobile connected devices and subsequent usage demands, global IP traffic is poised to quadruple through 2015. This is pushing the bandwidth and efficiency limits of current network infrastructure and Ethernet has emerged as the de facto standard to enable this surge in traffic.

A major opportunity to capitalize on this growth is Ethernet switches, which include simple layer 2 switches (simpler devices that switch and forward packets), layer 3 switches (which add routing functionality) and layer 4 and above switches (switches with higher layer intelligence, for load balancing, QoS, and other management capabilities).

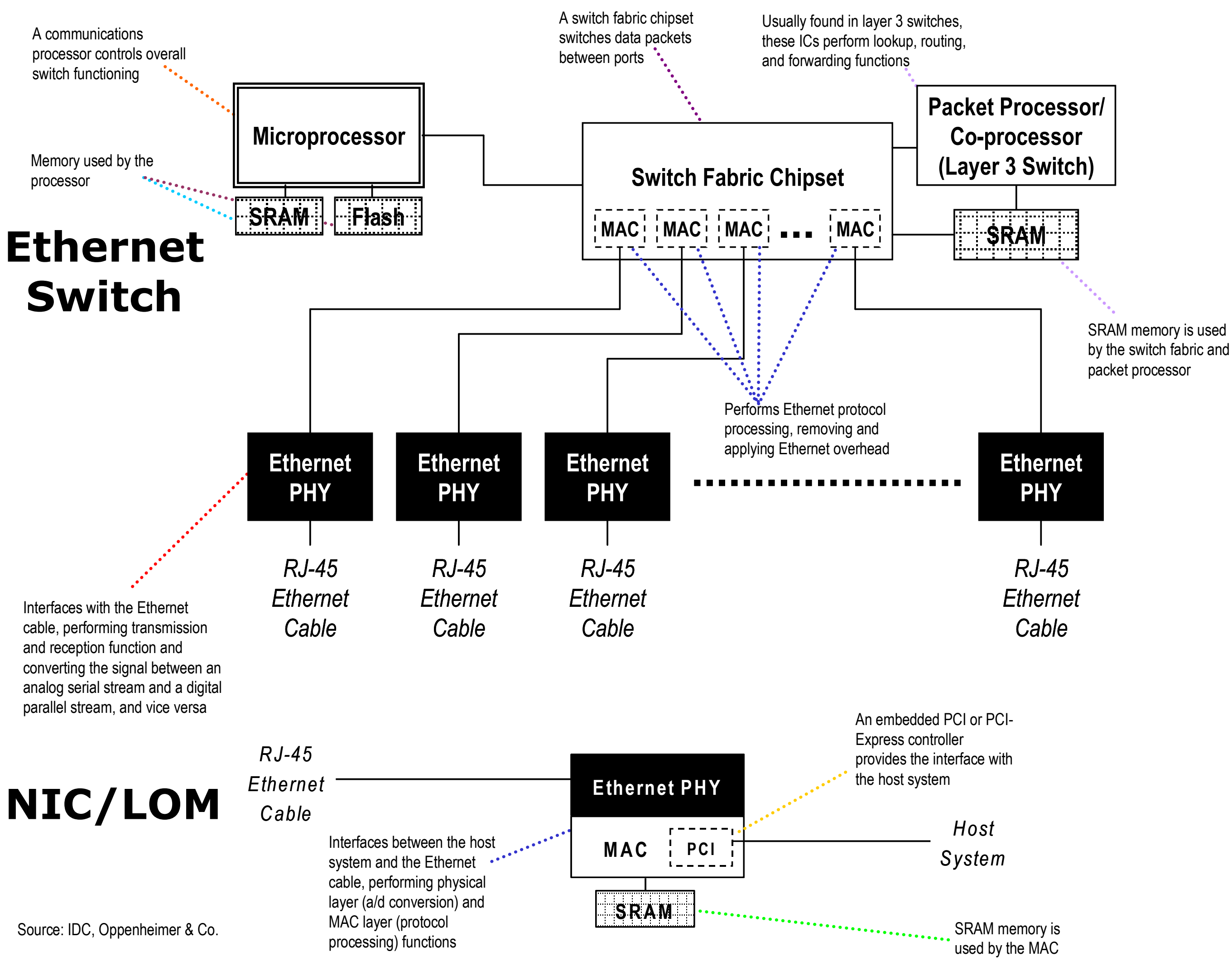
Infrastructure equipment, which includes blade servers, storage networking devices (iSCSI), broadband infrastructure (DSLAMs, CMTS, etc.), and other telecom equipment, is also likely to experience robust growth through 2015.

Ethernet Equipment Suppliers*:* Cisco was the dominant supplier of Ethernet switches in 2010 with 32% port share. D-Link followed with 17% share, while HP was third with 16% share; market share has been consolidating among the top three players over the past three years. Rounding out the top five were Netgear and Linksys with 7% and 6%, respectively. All other suppliers of Ethernet equipment each held 3% share or less, including Allied Telesis, 3Com, SMC Networks, Avaya and H3C.

PC and server vendors (for NIC/LOM solutions) include HP, Dell, Acer, Lenovo, Toshiba, Fujitsu/F-S, Apple, IBM and Sun.

Vendors of non-PC client devices include manufacturers of modems, printers, game consoles, set-top boxes, and a variety of other PC peripherals and consumer electronics devices.

Ethernet



Source: IDC, Oppenheimer & Co.

Ethernet Port *(NIC and Switch)*

- **Ethernet PHY**: Sometimes called a transceiver, the PHY interfaces with the RJ-45 Ethernet cable (or optical fiber) and converts the serial analog stream to a digital parallel stream and vice versa. In a switch, these are implemented as multi-port (quad, octal, etc.) PHYs. In a NIC/LOM, they are part of the Ethernet controller.
- **Ethernet MAC, SRAM**: The MAC, sometimes called simply the "controller," assigns and removes Ethernet headers and overhead. In a switch, these are usually integrated into the switch fabric chipset. In a NIC/LOM, they are part of the Ethernet controller. MACs typically use a small quantity of SRAM memory.

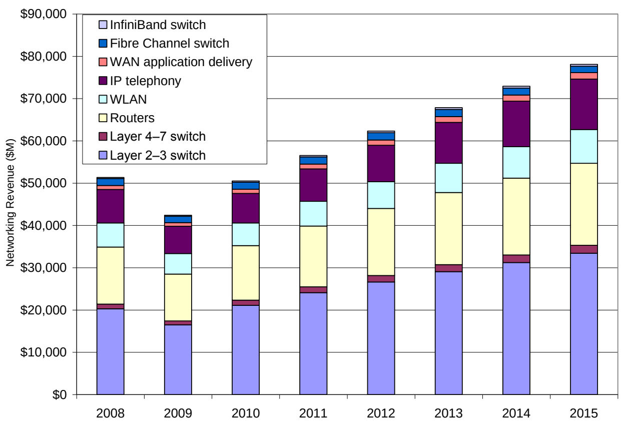
Switching Block (Switch Only)

- **Switch Fabric:** The switch fabric receives packets from the various Ethernet ports and switches them between ports or sends them to the uplink port (if the destination is a port on another switch or the WAN or Internet).
- **Packet Processor/Co-processor** (layer 3 switch only): Found in layer 3 switches, packet processors perform routing and forwarding functions. A packet co-processor (NSE/CAM) performs intelligent lookups.
- **Microprocessor, SRAM, Flash**: This block—which can contain a microprocessor, FPGAs, SRAM and flash—controls the overall system and performs high-end functions.

Ethernet

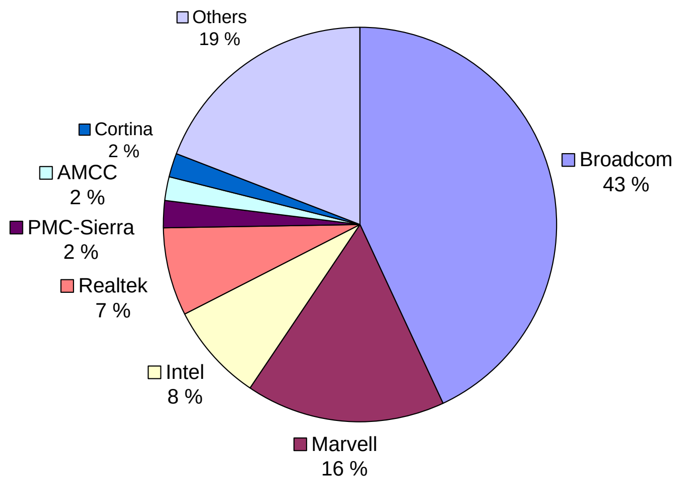
Ethernet Semiconductor Forecast

- We expect the total enterprise networking market to grow from $51.3B in 2010 to $78.0B in 2015, a 9% CAGR.
- Layer 2-3 switches will remain the largest infrastructure revenue driver, while fibre channel switches are likely to decline.
- The IP and optical convergence will continue to drive the transition to Optical Transport Networks (OTN).



Source: IDC, Oppenheimer & Co.

Ethernet Semiconductor Competitors



Note: ASSPs Only

Source: IDC, Oppenheimer & Co.

Enterprise Networking Forecast: The total enterprise networking market is expected to grow at a 9% CAGR, rising from $51.3 billion in 2010 to $78.0 billion in 2015. Semiconductor Ethernet suppliers will continue to benefit from several ongoing upgrade cycles, including the transition from SONET/SDH to OTNs. The IEEE 802.3ba 40G/100G Ethernet standards were ratified in 2010, and Ethernet will continue to play an ongoing role in the buildout of the cloud and in datacenters—all major data center vendors (Mellanox, QLogic, etc.) now support either standalone or integrated Ethernet solutions.

Ethernet Semiconductor Competitors: The top suppliers of Ethernet semiconductors are Broadcom and Marvell. These two players represent the only competitors that play in every segment of the market, including PCs, switching, and embedded applications; for PHYs, controllers, and switches.

The No. 1 supplier in 2010 was Broadcom, which held 43% share. Broadcom serves all segments, as mentioned above, and is particularly dominant in the server NIC and Gigabit switching segments, where its share is well north of 50%. Marvell was No. 2 with 16% share, a leader in Gigabit PHYs and a strong No. 2 to Broadcom in Gigabit switching. Marvell also supplies the PC client market, both as an independent merchant supplier and in cooperation with Intel.

The No. 3 and No. 4 players in Ethernet semiconductors are both PC-oriented merchant suppliers. Intel, with 8% share, predominantly serves the PC market with Ethernet controllers. The company had some significant product lines in the PHY, switch, and aggregation areas serving the infrastructure market, but most of these were sold to Cortina in 2006. Realtek, with 7% share, also mostly serves the PC, with dominant share in 10/100 controllers and growing share in Gigabit. Realtek has also been growing a switching business from the low end. Other major vendors include PMC-Sierra, Applied Micro and Cortina, each with 2% market share in 2010.

Ethernet

Ethernet Semiconductor Market Trends

•Increasing data traffic is driving the transition from SONET/SDH to Optical Transport Networks (OTNs).

•10GbE adoption is likely to accelerate in 2012 and beyond; 40G/100G gaining momentum.

•The eventual transition to 4G LTE in the wireless market will push the migration to IP-based voice services, and, Carrier Ethernet as the underlying technology.

•With the rise in cloud computing, converged Ethernet will likely come from the convergence of the Enterprise and Carrier networks.

•All but the largest switch vendors have moved to ASSP solutions.

- **Increasing data traffic is driving the transition from SONET/SDH to optical transport networks (OTNs).** Data traffic is undergoing an exponential growth phase, expected to increase four-fold through 2015. Driven by the dearth of mobile connected devices and the new ability for consumers to constantly stream video, share photos, etc., carriers are under increasing pressure to implement cost-effective capacity expansion. OTN has emerged as the Layer 1 protocol of choice, and for semiconductor vendors, this means the $TAM will likely expand at an estimated 45% CAGR through 2015.
- **10GbE adoption is likely to accelerate in 2012 and beyond; 40G/100G gaining momentum.** 10GbE semiconductor revenue rose ~50%+ in 2010 and the market remains just one-fourth the size of total GbE revenue. As Fast Ethernet appears to be in terminal decline, we expect the market to continue to transition to 10GbE at an accelerating rate over the next two to three years, and would look for the initial adoption of 40G/100G solutions to gain incremental momentum. We look for the transition to GbE to continue in datacenter and enterprise applications, where 10Gbps speeds aren't yet required, and expect 40G/100G to first penetrate service provider networks as they scramble to meet soaring wireless bandwidth demand.
- **The eventual transition to 4G LTE in the wireless market will push the migration to IP-based voice services, and, carrier Ethernet as the underlying technology.** As service providers rush to meet growing video and data requirements on the wireless networks, the transition to 4G has occurred faster than any previous network upgrade cycle. LTE is expected to ultimately migrate to using IP as the standard communication protocol, and carrier Ethernet will be the underlying technology standard. This may not be a meaningful driver of near-term growth as network operators rely on legacy 2G/3G voice capabilities, but we would expect the transition to occur over the next five to ten years.

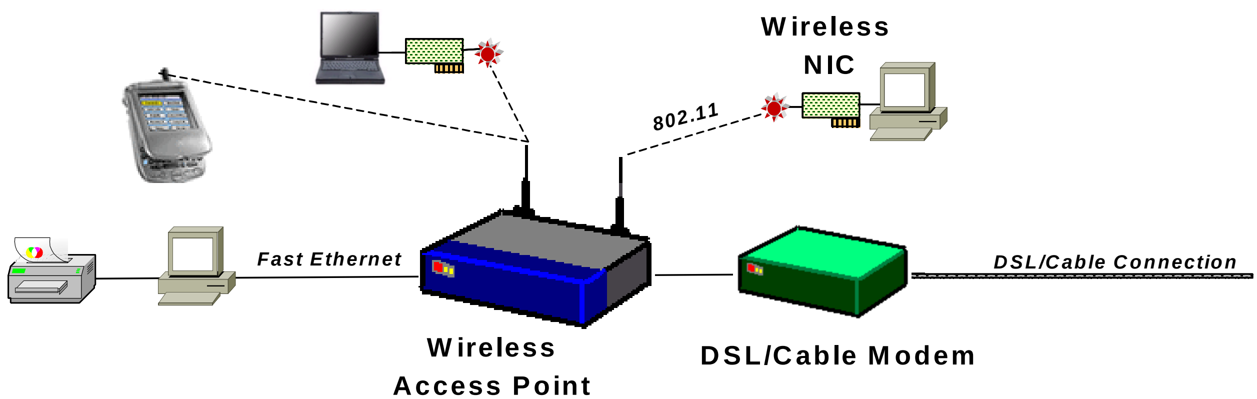
- **With the rise in cloud computing, converged Ethernet will likely come from the convergence of the enterprise and carrier networks.** The explosion of cloud computing has begun to move enterprise applications and data into secure hosted applications which can be accessed from multiple points and form factors. This substantially increases the demand for data centers to build out high-bandwidth, high-reliability networks that can interconnect this infrastructure. Converged Ethernet will likely result as the carrier and enterprise networks meet at the edge of the cloud, driving further demand for semiconductor solutions.
- **All but the largest switch vendors have moved to ASSP solutions.** As the market has continued to move to Gigabit, most switch vendors have moved or are moving to ASSP solutions. The major ASSP vendors have been introducing more advanced switch fabric chipsets, with integrated MACs, layer 3-7 functionality (for routing support) and built-in support for uplink ports. Next-generation designs incorporate network search engines for more robust routing.

Wireless LAN

Wireless LANs use the **802.11** protocol to send data traffic over unlicensed **2.4 GHz** and **5 GHz** radio waves, mimicking Ethernet but with a wireless connection.

Wireless LAN has seen runaway success in home networking, specifically for distributing a broadband Internet connection wirelessly around the home. The technology got a big boost from Intel's Centrino program, which has driven notebook penetration well north of 95%.

Wireless LAN in a Home Application



Source: Oppenheimer & Co.

Wireless LANs connect multiple PCs (or other connected devices) in a single location and provide the ability to share files, hardware and resources in a fashion similar to traditional wireline Ethernet LANs. The distinction, of course, is that no physical wiring is needed to connect any single client PC to its neighbor (or to servers, or printers, or PDAs, etc.). Instead, wireless LAN encodes data using the 802.11 protocol and broadcasts it over unlicensed spectrum.

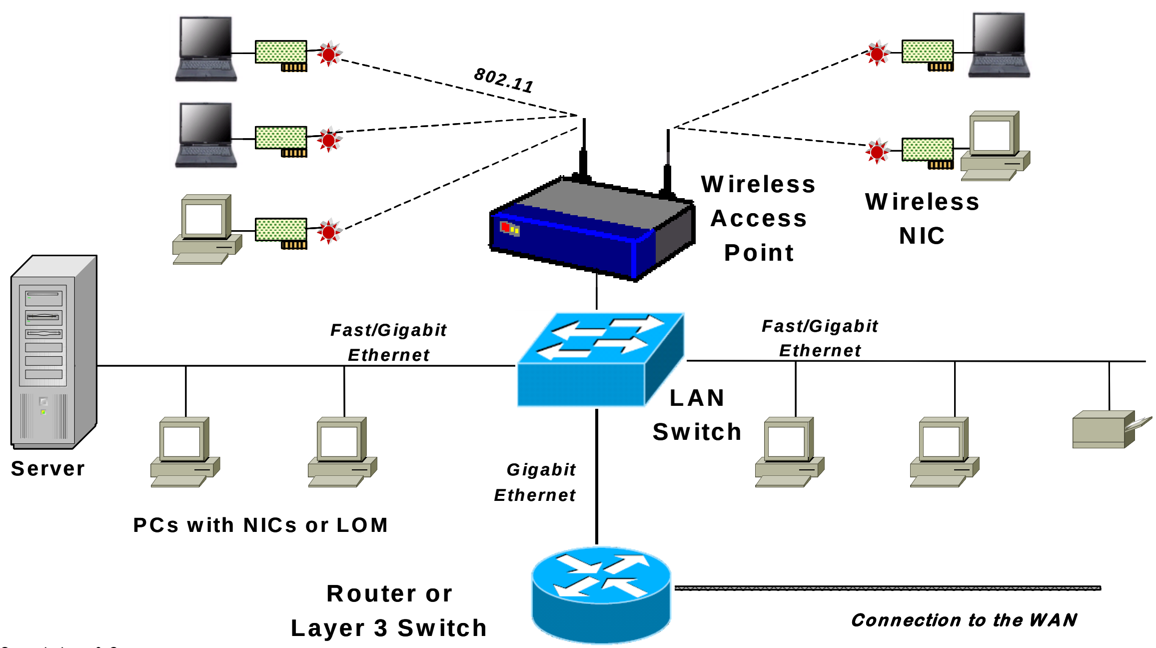
Most networking technologies to date have been geared to corporate networks. Wireless LAN, on the other hand, has really been driven by the home networking market. In fact, it is the connected home that has really driven wireless LAN sales to date. In the home setting, 802.11 acts as a wireless medium for sharing a broadband Internet connection. Wireless routers designed for the home interface directly with a cable or DSL modem (using Ethernet) and distribute the bandwidth to wireless-enabled PCs.

Wireless LAN is transforming into a home media distribution system, used to send video, voice and data around the home wirelessly. Under this topology, modems, PCs, set-top boxes, game consoles and VoIP-enabled phones are networked together wirelessly, with the ability to share content and an Internet connection between them. Voice service is distributed wirelessly to WLAN-enabled VoIP phones. Video is distributed from connected PCs, handsets and digital camcorders and digital TVs. Gaming is live with multiple connected participants. The home, and all the devices in it, is now truly connected.

Wireless LAN

In the corporate environment, 802.11 can be used to extend the LAN without wires, allowing for greater mobility among users. We have seen slow but steady uptake as security, bandwidth, handoff, and channelization concerns have been addressed.

Wireless LAN in a Corporate Application



Source: Cisco, Oppenheimer & Co.

In the corporate setting, a WLAN is meant to augment the connection from user to user currently accomplished with a wired Ethernet LAN. It is not designed to replace the traditional LAN switch and backbone architecture, as it requires this equipment to switch and route data and to provide the interface to access and edge routers and out to the WAN. Rather, 802.11 "extends" the LAN without wires. In a typical corporate setting, wireless-enabled PCs access specialized wireless access points distributed at regular geographic intervals throughout the building or campus. Access points act both as transmit/receive bases and as a connection between the wireless and wired LAN.

Wireless LAN technology presents even greater utility when used in a campus setting. Wireless LANs provide true mobility throughout the campus and can be used to provide intranet and Internet access to notebook computers, PDAs and other handheld devices across the campus with no need to connect or configure equipment. They are especially popular with campuses that have inherently mobile users, such as universities and airports.

In terms of adoption, enterprise wireless LAN has been slow to gain steam. This was originally due to IT concerns over issues like security, bandwidth, handoff, and channelization. The major enterprise networking OEMs, however, have made a lot of progress addressing these issues. Tougher security standards have been implemented directly into the 802.11 standard, and computing and networking software have additional safeguards as well. 802.11n offers more bandwidth and channelization. Switch management software and hardware solutions are now coming to market to support dynamic roaming between access points. Power-over-Ethernet is enabling easier access point deployments. We are seeing steady progress in corporate WLAN.

Wireless LAN

Wireless LAN Protocols

802.11b – The first wireless LAN standard to take off, 802.11b runs at 11 Mbps and operates in the 2.4 GHz band.

802.11a – 802.11a runs at 54 Mbps and operates in the 5 GHz band, and offers more channels than 802.11b. It was never a success as a standalone protocol, but is still included in multi-band (a/b, a/g) solutions.

802.11g – 802.11g adds additional modulation schemes to 802.11b, increasing speeds to 54 Mbps while remaining in the 2.4 GHz band. Backward compatible with 802.11b.

802.11n – The newest standard, which boosts throughput to 108 Mbps or higher. 802.11n uses MIMO technology in both the 2.4 and 5 GHz bands.

Although most wireless LAN technologies use the same topology, they can vary widely in terms of standard, each with its own frequency band, data transfer rate and modulation scheme. A major hurdle holding up volume wireless LAN deployments was the lack of a clear standard for the equipment makers to center on. Until about five years ago, two key standards, IEEE 802.11 and HomeRF, were competing for OEM adoption. However, aggressive actions by OEMs and chip manufacturers, together with the formation of the Wireless Ethernet Compatibility Alliance (WECA), which is now know as the Wi-Fi Alliance, helped the industry settle on 802.11 as the dominant standard.

Within 802.11, the first sub-standard to take off was 802.11b, an 11 Mbps technology that operates in the 2.4 GHz band (the same band used by other consumer devices such as cordless telephones, microwave ovens and Bluetooth devices). This band is free from government regulation, allowing users to set up wireless LANs without license or approval. The FCC has defined three spectrum ranges, known as ISM bands, for use by unlicensed continuous operation up to 1 Watt: industrial (902-928 MHz), scientific (2.4-2.4835 GHz) and medical (5.15-5.35 GHz and 5.725-5.825 GHz). 802.11b was the first wireless LAN standard, operating in the 2.4 GHz ISM band, though it was quickly replaced with the faster 802.11g. 802.11g uses the same frequency—and thus remains backward compatible with 802.11b products—but supports data rates of up to 54 Mbps.

Another sub-standard, 802.11a offers data transfer rates up to 54 Mbps using the less crowded (but still unlicensed) 5 GHz band. 802.11a received a lot of attention but never much deployment as a standalone technology. The primary advantage of 802.11a, which offers similar data transfer rates as 802.11g, is its higher channel density that provides better average user throughput in congested networks. However, because of its 5 GHz frequency, 802.11a suffers from narrower range and greater power consumption than 802.11g. It is also not compatible with the large installed base of 802.11b and 802.11g. As a result, 802.11a deployment has been included as a second band in multi-band implementations (a/b, a/g solutions), but as mentioned above, very little 802.11a-only equipment ever shipped.

The newest WLAN standard is 802.11n, which uses both the 2.4 GHz and 5 GHz bands and leverages MIMO (multiple input multiple output) radio technology to boost bandwidth to 108 Mbps or higher. 802.11n is expected to be an effective solution for both the home and enterprise. The first products, which were sold as "pre-n" or "draft-n" solutions, came to market in 2006. Several drafts have been approved, and products are shipping now using the 802.11n designation.

The exhibit below displays WLAN standards and working groups.

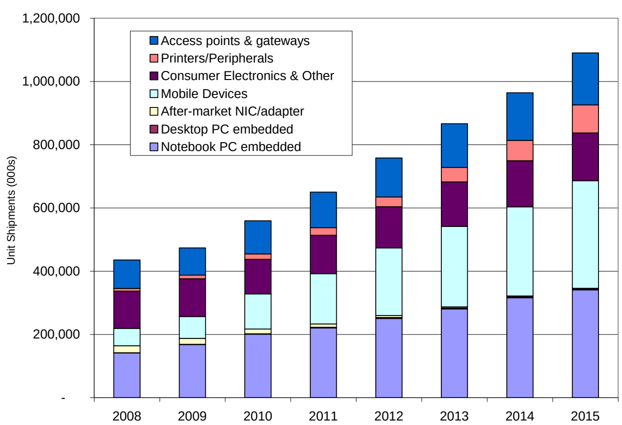
IEEE Standards	
802.11a	The first 5 GHz wireless standard, 802.11a, operates at speeds up to 54 Mbps. The standard employs a more advanced modulation scheme than 802.11b, called orthogonal frequency division multiplex (OFDM), than 802.11b that allows data to be encoded on multiple radio frequencies concurrently. Products based on 802.11a currently deliver a much shorter range than 802.11b/g because of the higher frequency band, though there is less interference as this band is less crowded.
802.11b	The first standard to gain wideband adoption, 802.11b operates in the 2.4 GHz band at speeds up to 11 Mbps. The standard uses one of several Direct Sequence Spread Spectrum (DSSS) modulation schemes, including Complementary Code Keying (CCK). 802.11b products typically have a range of 200-300 feet. 802.11b has been mostly replaced by 802.11g.
802.11d	802.11d enables mobile client access between additional countries.
802.11e	The 802.11e standard adds a MAC enhancement for quality of service (QoS) features and multimedia support that are critical for voice, video and audio delivery over wireless LAN. This standard is seen as a critical enhancement toward wide-scale usage in the networked home.
802.11g	802.11g operates at 2.4 GHz, but uses the OFDM modulation scheme for speeds above 11 Mbps to boost data rates. 802.11g-based equipment runs at data rates of up to 54 Mbps, making it competitive with 802.11a. A key advantage of 802.11g is that it is backward compatible with 802.11b; thus, 802.11b NICs will operate with 802.11g access points, though only at 11 Mbps and vice versa.
802.11h	Enhancements incorporated in 802.11h automate frequency band conformance and tuning, employing dynamic frequency selection (DFS) and transmit power control (TPC). The technology enables 5 GHz compatibility in Europe and is also included in HiperLAN/2.
802.11i	802.11i adds security features to improve on WEP and supports 802.1x authentication, Temporal Key Integrity Protocol (TKIP) and advanced encryption standard (AES).
802.11j	802.11j includes extensions for Japan.
802.11n	The next-generation 802.11 standard should support speeds of 108 Mbps or higher, and theoretically can evolve to 540 Mbps over time. 802.11n builds upon previous 802.11 standards by adding MIMO (multiple-input multiple-output). MIMO uses multiple transmitter and receiver antennas to allow for increased data throughput and range.
802.11p	A working group that is extending the 802.11 standard to automobiles. As part of a dedicated short range communications (DSRC) system, 802.11p operates in the 5.9 GHz band and deals with roaming from cell to cell in a fast-moving vehicle.
802.11ac	Coordinated access point currently under development. IEEE ratification is expected in late 2012.

Source: IEEE, Wi-Fi Alliance, Wikipedia, TechWeb Encyclopedia, company reports and Oppenheimer & Co.

Wireless LAN

WLAN Unit Forecast

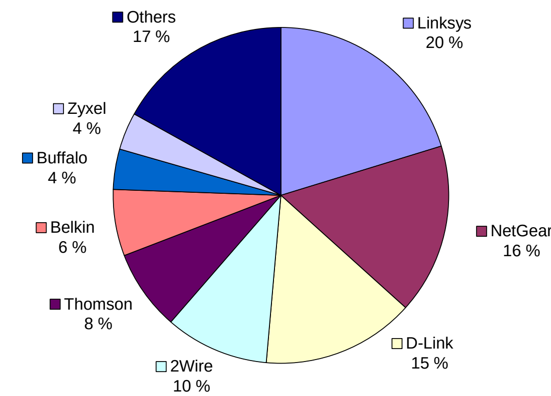
•Wireless LAN units are expected to grow at a 14% CAGR, from 549 million units in 2010 to 1.1 billion in 2015.
•PC peripheral devices to lead growth with a 39%+ CAGR.
•PC connections should grow 11% as notebook growth continues and desktop WLAN penetration increases; after-market PC adapters should decline 38%.
•Mobile WLAN devices should grow 21%, roughly in-line with the smartphone market.



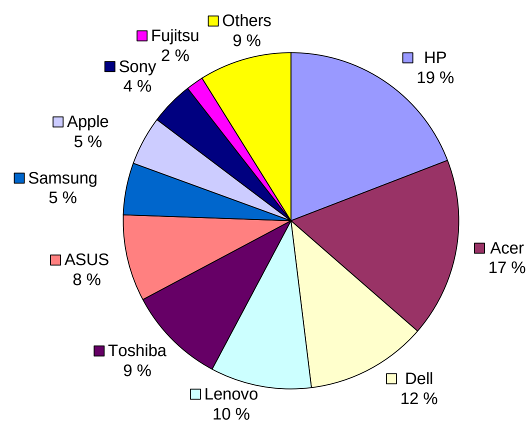
Source: IDC, Oppenheimer & Co.

WLAN Equipment Suppliers

WLAN NICs and Access Points



Notebook PCs



Source: Dell'Oro, IDC, Oppenheimer & Co.

Wireless LAN Unit Forecast: We forecast continued breakout growth of wireless LAN units over the next few years as the market moves beyond PCs into the realm of consumer devices and wireless handsets. Access points and residential gateways are still growing at fairly solid clips, and mobile handsets grow at roughly the rate of smartphone units. Consumer electronics, PC peripherals, PDA, and wireless handset OEMs are all beginning to integrate wireless LAN into their devices and plan for an increased number of models using the technology over time. By 2015 the WLAN handset market should roughly equal the PC market in unit size. Declining chipset price points and improved power consumption should bolster this trend. Overall, wireless LAN units are expected to grow at a 14% rate, from 549 million units in 2010 to 1.1 billion units in 2015.

Note that we forecast faster growth for wireless LAN clients than for access point devices. This is a function of the growing number of client devices over and above the PC that will leverage the existing access points and gateways currently in use in homes, corporate networks, and public access points and hot spots. There should still be healthy access point replacement in the home driven by newer standards (e.g., 802.11n) plus continued growth in the enterprise market, but clients are still growing at a faster clip. In total, we expect wireless LAN clients to grow at a 15% CAGR, from 450 million units in 2010 to more than 950 million units in 2015. Access points and gateways are growing at a 9% CAGR, from 105 million units in 2010 to 164 million in 2015.

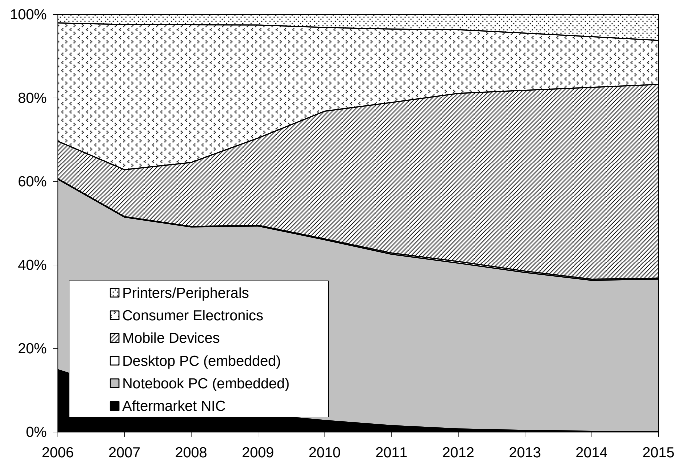
In terms of application, we expect PCs and PC adapters to grow at a healthy rate, but to decline as a percentage of the market over time, from 36% of total wireless LAN clients in 2010 to 31% in 2015. Notebooks represent the bulk of these units, and should benefit from full market penetration—in total we forecast an 11% CAGR through 2015.

Consumer, mobile, and PC peripheral applications should become more meaningful as 802.11 is incorporated into such devices as game consoles, wireless handsets, tablets, digital cameras, MP3 players, set-top boxes, and printers. In aggregate, we expect these devices to grow at a 20% CAGR through 2015, growing from 52% of client connections in 2010 to 63% in 2015. Note that nearly half of total 2015 units are forecast to be derived from the handset and converged mobile device market with its huge unit TAM, though our forecast assumes only 50% penetration in handsets by 2015.

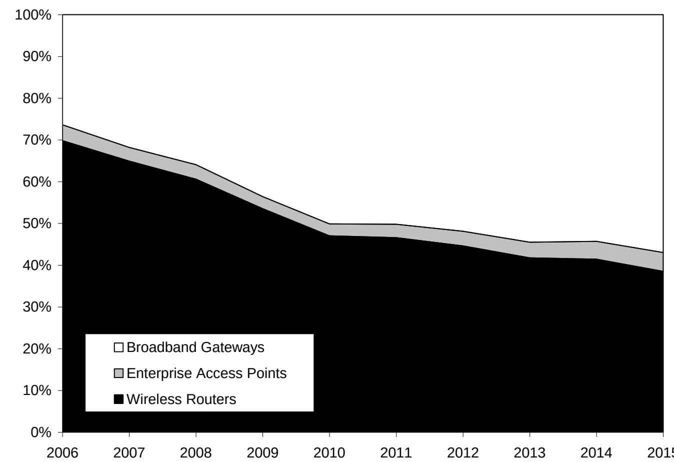
On the access point and gateway side, we forecast a 9% CAGR, as mentioned above, with the market growing from 105 million units in 2010 to 164 million in 2015. About 55% of all access points in 2015 are expected to be broadband gateways, 41% wireless routers, and 4% are expected to be enterprise-class access points.

The exhibits below display unit share for NICs and access points by application.

Wireless LAN NIC Unit Share By Application



Access Point Unit Share By Application

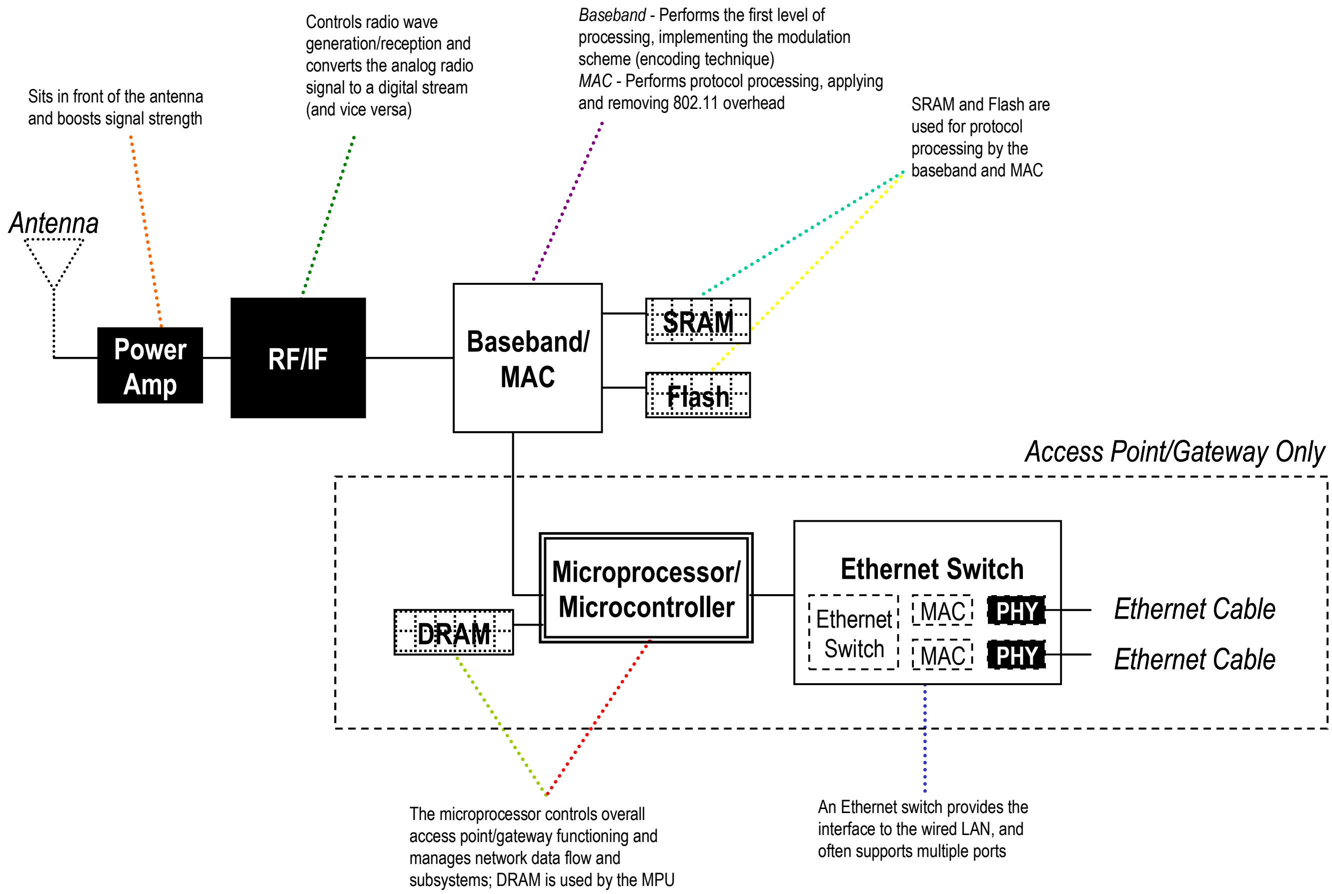


Source: IDC, Oppenheimer & Co.

Wireless LAN Equipment Suppliers: The top supplier of dedicated wireless LAN equipment (NICs, access points, and gateways) in 2010 was Linksys (a subsidiary of Cisco) with 20% unit share. Netgear was next with 16% share, followed by D-Link with 15%. Other major players include 2Wire, Technicolor (Thomson), Belkin, Buffalo and Zyxel.

As embedded notebook wireless LAN represents a huge chunk of all wireless LAN shipments, it is important to note the top suppliers of notebook PCs. In 2010, the top notebook suppliers were HP with 19% share, Acer with 17% share, Dell with 12%, and Lenovo with 10%. Toshiba and ASUS followed with 9% and 8%, respectively. Samsung and Apple each held 5% in 2010.

Wireless LAN



Source: IDC, Oppenheimer & Co.

Wireless LAN client implementations and access points blend devices from the Ethernet and wireless handset worlds. The WLAN signal is received and transmitted through the RF block, which includes a power amp, RF and IF transceiver. The signal is processed by a baseband, which implements the modulation scheme, and then an 802.11 MAC removes or applies 802.11 overhead (the baseband and MAC are usually integrated into a single digital IC). Data packets are then relayed to the host system (in a NIC/client) or to a processor (in an access point or gateway).

Note that the diagram above (and discussion below) shows the core 802.11 chipset (PA, RF/IF, and baseband/MAC), as well as the additional silicon that would be required to enable an access point or a gateway. In a broadband gateway, there would be even more content to enable the modem. Note that our forecast and market share discussion of wireless LAN semiconductors focuses only on wireless LAN-specific ICs, i.e., the 802.11 chipset.

***RF** (Client and Access Point/Gateway)*

- **Power Amp**: The power amp sits in front of the antenna and boosts signal strength.
- **RF/IF Converter (RF)**: The RF front end controls the radio wave generation on the transmit side and receives the radio wave signal on the receive side, translating between low-frequency analog signals used by the system (specifically by the IF transceiver) to high-frequency RF signals used in radio communications. In newer implementations, the RF converter and IF are integrated in a single direct conversion transceiver, as shown in the block diagram above.

- **I/Q Modem (IF)**: The IF performs all quadrature modulation of "I" and "Q" baseband signals, converting the analog radio signal to a digital stream to be processed by the baseband and vice versa. In most implementations, the IF is integrated with the RF in a single direct conversion transceiver, as shown in the block diagram.

Baseband/MAC *(Client and Access Point/Gateway)*

- **Baseband Processor**: The baseband processor performs the first level of digital processing on the signal, implementing the modulation scheme (encoding technique). The baseband and MAC are usually integrated in a digital protocol IC, as shown in the block diagram.
- **MAC**: As in wired Ethernet, the MAC applies and removes overhead and implements the 802.11 protocol. Note that some wireless LAN chipsets implement additional security, QoS, and multimedia functions on top of the base 802.11 standard; the logic that facilitates these features is integrated into the MAC. The MAC is usually integrated with the baseband in a single ASSP, as shown in the block diagram.
- **SRAM and Flash**: These memories are used by the 802.11 MAC.

Gateway Block *(Access Point/Gateway Only)*

- **Processor:** An embedded microprocessor performs control functions in the access point along with some limited data path functions. In most residential gateways they are integrated into the baseband/MAC. Enterprise-class access points tend to have discrete microprocessors, needed to perform advanced access control, security, and management functions not found in consumer wireless LAN.
- **DRAM**: DRAM is the primary memory used by the embedded processor.
- **Ethernet Switch:** Though the basic wireless access point needs only one Ethernet port to interface with the PC or wired network, most access points are actually gateway devices which usually include multiple Ethernet ports. These are usually implemented with a single-chip Ethernet switch, which includes Ethernet PHY, MAC, and switch functions. Most gateways have 4-5 ports of 10/100 Ethernet, though this can vary.

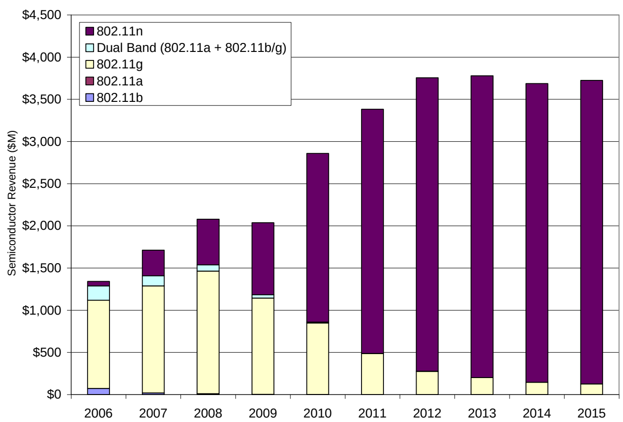
Modem Block *(Broadband Gateway Only – ICs not shown in block diagram)*

- **DSL Line Driver** (used in DSL gateways): A DSL line driver interfaces with RJ-11 telephone line.
- **DSL Data Pump/SoC** (used in DSL gateways): A DSL modem SoC implements the DSL protocol; it has an integrated DSP data pump to implement the DSL protocol and an analog front end to interface with a line driver.
- **Cable Tuner** (used in cable modem gateways): A tuner interfaces with the coax and tunes the cable RF frequency for transmission and reception.
- **DSL Data Pump/SoC** (used in cable modem gateways): A cable modem SoC implements modem functions, and has an integrated front end processing (QPSK/QAM modulation for transmission and QAM demodulation for reception) and a DOCSIS MAC.
- **VoIP DSP:** A VoIP packet processor DSP performs the TDM-to-IP conversion on IP-based phone calls. Integrated codecs perform the analog-to-digital and digital-to-analog conversion.
- **Line Driver/SLIC:** This SLIC is a line driver that interfaces with the telephone line, sending and receiving the analog signals to and from analog telephones.

Wireless LAN

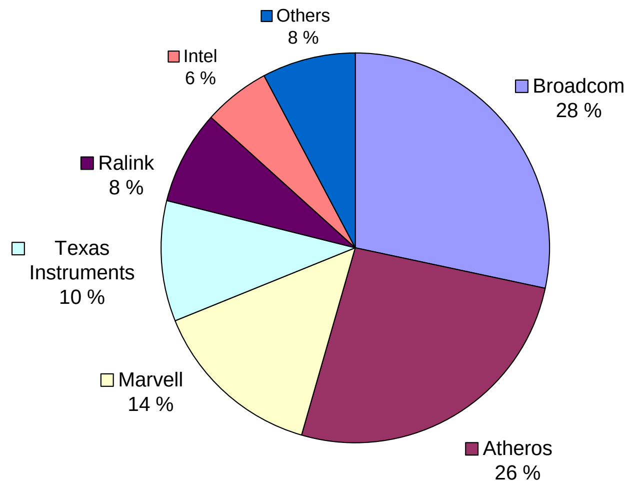
WLAN Semiconductor Forecast

•We expect wireless LAN semiconductors to grow 5% through 2015, from $2.9 billion in 2010 to $3.7 billion in 2015. We expect the total revenue opportunity to plateau in 2012/13.
•802.11g peaked in 2008; 802.11n should continue to ramp in unit terms, offsetting maturity of the market and further price declines.
•Industry consolidation is well underway, particularly as WLAN becomes integrated into combo chip solutions for handsets.



Source: IDC, Oppenheimer & Co.

WLAN Semiconductor Competitors



Router and NIC	***Embedded PC Chipset***	***Consumer & Handset***
Broadcom	Intel	Broadcom
Atheros	Atheros	Marvell
TI	Broadcom	TI
Marvell	Marvell	Atheros
Ralink	Ralink	NXP
Realtek	Realtek	STMicro

Source: IDC, Oppenheimer & Co.

Wireless LAN Semiconductor Forecast: Although the focus on connectivity and mobility pushed wireless LAN into the mainstream, it is now combo chip solutions that are likely to drive unit growth going forward. Wireless LAN is increasingly being offered in combo chips (ex. BT + WLAN + FM), particularly in mobile handset smartphones. The effect on the market is twofold, creating a substantially larger unit TAM, but increasingly driving down costs. Aggressive price declines should continue to partially offset unit growth, but we still expect a 5% CAGR for wireless LAN ICs through 2015, most of which will occur through 2012, at which time we expect the market to plateau. Overall, we expect the market to grow from $2.9 billion in 2010 to $3.7 billion in 2015.

Wireless LAN chipsets are generally segmented by protocol. In 2010, 802.11n surpassed 802.11g for the first time as the dominant protocol, accounting for 69% of IC revenue, up from 41% in 2009. 802.11g, which represented 78% of the total market as recently as 2006, is likely to materially decline throughout our forecast period as 802.11n is now dominant and likely to surpass 90% share of the market in 2012 and to represent 95%+ of the market thereafter.

Consistent with our unit forecast, we expect WLAN client silicon to outgrow access point silicon, a reflection of rising penetration across the array of consumer devices that now demand constant connectivity. Client silicon should rise from 81% of the semiconductor TAM in 2010 to 85% in 2015, yielding a 15% revenue CAGR. Access point silicon should drop from 19% in 2010 to 15% in 2015, yielding a 9% CAGR.

Wireless LAN Semiconductor Competitors: The rapid growth we've seen in wireless LAN has been made possible by the large number of vendors offering competitive solutions. And this rapid growth and strategic focus on wireless LAN going forward has given way to acquisitions of two of the five largest competitors in the space by much larger semiconductor vendors. In early 2011, Qualcomm purchased Atheros for $3.1 billion, and just months later, MediaTek acquired Ralink in a share-swap transaction valued at $616 million at the time.

The largest supplier of wireless LAN chipsets in 2010 was Broadcom with 28% revenue share. Note that Broadcom was only a minor player in the early days of the market, and really made its mark with the transition to 802.11g and subsequently 802.11n. Atheros was second with 26% share; like Broadcom, Atheros is strong in 802.11g (and dual band) and 11n. This success was clearly not lost on Qualcomm. Rounding out the top three was Marvell with 14% share, primarily due to exposure in gaming consoles, Sony's PSP/PS3 and Microsoft's Xbox 360, where Marvell is the sole supplier. Marvell has made embedded platforms a focus for the company.

Texas Instruments followed with 10% share in 2010; TI has moved away from PC applications and is instead focusing on handsets and residential gateways. Ralink followed with 8% share.

Wireless LAN

Wireless LAN Semiconductor Market Trends

•The market began to consolidate in 2011; Qualcomm purchased Atheros and Mediatek acquired Ralink.

•802.11g peaked in 2008; 802.11n is now dominant and remains on track to becoming the de facto wireless standard.

•WLAN has reached maturity in the PC market.

•For chipset vendors, the handset and tablet markets are clearly the next leg of volume growth.

•Within handsets, combo chips remain en vogue, but integration unlikely to occur with the baseband.

- **The market began to consolidate in 2011; Qualcomm purchased Atheros and Mediatek acquired Ralink.** As connectivity becomes an increasingly large theme in the global economy, large semiconductor vendors quickly realized the benefits of bringing advanced WLAN capabilities in house. Atheros, with the No. 2 market share in WLAN, and surging success in the PC and gaming verticals, was an obvious target, which Qualcomm acquired for $3.1 billion. Following a similar blueprint just months later, Asian baseband vendor Mediatek scooped up No. 5 WLAN player Ralink for $616 million. These two acquisitions highlight two important concepts: 1) that everything with electronic content will be connected and 2) silicon providers realize the benefits of integration.
- **802.11g peaked in 2008; 802.11n is now dominant and remains on track to becoming the de facto wireless standard.** 802.11n leverages MIMO technology in both the 2.4 GHz and 5 GHz bands and 11n boosts the throughput to 108 Mbps and could eventually reach speeds approaching 540 Mbps. The shift has been a boon to ASPs and to early adopters like Broadcom and Atheros. 802.11n is on track to becoming the de facto wireless standard, and now accounts for ~80% of all WLAN shipments in revenue dollars. While unit penetration is closer to ~65%, this clearly indicates that the ASP mix shift higher is likely to continue, benefiting semiconductor suppliers in the near term.
- **WLAN has reached maturity in the PC market.** We now estimate that upwards of 99% of notebooks now ship with embedded wireless LAN. While desktop penetration is likely to creep higher through 2015, the WLAN PC market as a whole has reached the point of maturity, growing roughly in line with total notebook units. However, because the notebook market is expected to grow considerably faster than the desktop market, this may not be so bad; we forecast WLAN PC units to grow 11% ; a combination of 11% annual growth in notebooks and rising penetration in the desktop market, which is likely to be half the size of the notebook market by 2015.

- **For chipset vendors, the handset and tablet markets are clearly the next leg of volume growth.** Chipset vendors are working hard to enable the consumer electronics and handset wireless LAN connection discussed in our unit forecast. Low-cost, low-power, small-form factor wireless LAN chipsets are the key here for the mobile handset market; WLAN is more or less a standard in smartphones. While combo chip solutions are becoming increasingly common and integration risk remains on the cost side, chipset vendors must offer WLAN to remain competitive in the handset market. This in turn is increasing penetration and presents enormous unit opportunity growth through 2015.
- **Within handsets, combo chips remain en vogue, but integration unlikely to occur with the baseband.** Chip vendors have had astounding success in the smartphone market with combo chip integrating Wi-Fi on the same chip as Bluetooth, GPS and FM. Not only does this lower cost, but also size, and allows smartphone vendors to move quickly to market with new designs by sourcing all connectivity demands from a single vendor. QCOM has also been active in the integration of RF functions, incorporating GPS and Bluetooth with its basebands. WLAN may be close to entirely-combo chip by 2015. However, the integration risk stops there, in our opinion. The technology curve changes much more rapidly in connectivity than in baseband, meaning that rapid smartphone design cycles can capitalize on increased connectivity in the absence of a change to the baseband. By *not* integrating connectivity (with the rare exception of GPS, which has a slow technical curve), handset OEMs can capitalize on rapidly changing connectivity technology and now be hindered by the slower development of new basebands. This may ultimately change, but in the near to medium term, WLAN (and connectivity) is safe from baseband integration and ever greater pricing pressure.

Bluetooth

Bluetooth is a **personal area networking** technology, used to send data between devices in close proximity at rates of up to 3 Mbps.

Bluetooth has found its primary volume application in the handset market, where it functions as a reliable protocol to connect the handset to other devices, including wireless headsets, PCs, and consumer devices. PC peripherals and consumer portables are also using Bluetooth as a cable replacement for connection to the PC, or to connect to one another without the PC.

Bluetooth is one of the leading personal area networking technologies, a short-range, low-power, high-bandwidth wireless transmission protocol aimed at connecting wireless handsets, PC peripherals and consumer devices. Bluetooth is standards-based, universal and cost-effective, offering relatively high bandwidth (up to 3 Mbps) over a short distance (30-300 feet, depending on the device class) in an unregulated frequency band (2.4 GHz), with extremely low power consumption and low implementation cost.

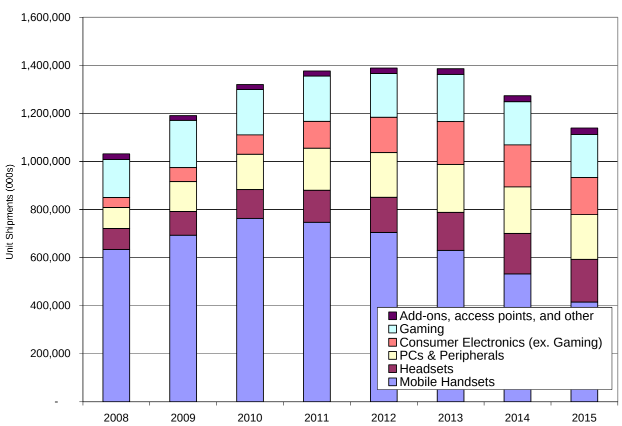
Bluetooth has found its primary volume application in the wireless market, where it functions as a reliable protocol to connect the handset to other devices, including wireless headsets, automotive stereo systems, PCs and consumer devices. Smart handheld devices, PC peripherals, and consumer portables are also using Bluetooth to perform data transfers without wires; and in many cases the entire PC can be removed from the equation (e.g., a digital camera can print straight to a Bluetooth printer, a smartphone can transfer video directly to a connected TV, etc.). Game consoles are also beginning to use Bluetooth to communicate between console and controller.

In terms of protocol, Bluetooth version 1.2 supported a data transfer rate of 1 Mbps, but was replaced by Bluetooth 2.0, and now, version 3.0. The Bluetooth 3.0 link is used for negotiation and establishment of the signal, but the actual data traffic is carried over a co-located 802.11 transfer. Bluetooth 4.0 includes Classic Bluetooth, Bluetooth High Speed and Bluetooth Low Energy, but is commonly referred to as BLE, or Bluetooth Low Energy.

Bluetooth

Bluetooth Unit Forecast

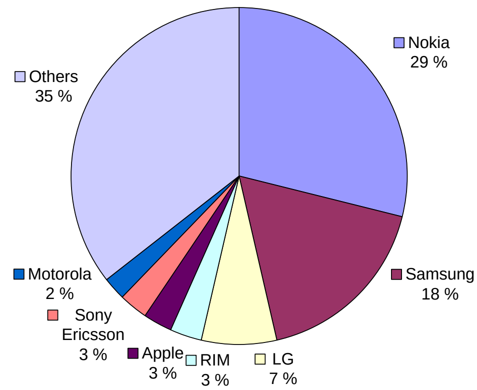
- We expect Bluetooth units to decline at a 3% CAGR, from 1.3 billion units in 2010 to 1.1 billion units in 2015, and to peak in 2013.
- Bluetooth in wireless handsets is expected to decline from 763 million units in 2010 to 415 million units in 2015.
- Other significant applications include headsets, PCs, peripherals, consumer electronics, and gaming.
- Bluetooth will be implemented almost entirely in silicon, with little additional content added by OEMs.



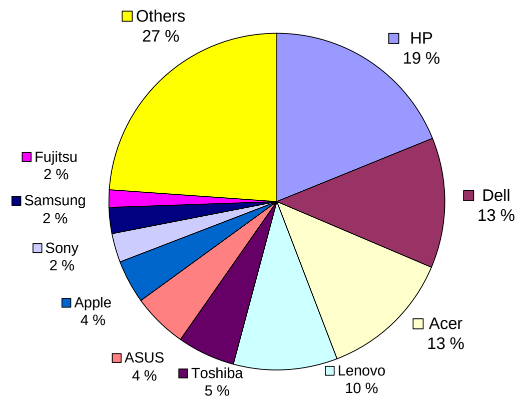
Note: Forecast excludes combo solutions incorporating Bluetooth. Combo solutions (e.g., Wi-Fi + BT) are included in our WLAN forecast.

Source: ABI Research, IDC, Oppenheimer & Co.

Handset Suppliers



PC Suppliers



Source: IDC, Gartner, Oppenheimer & Co.

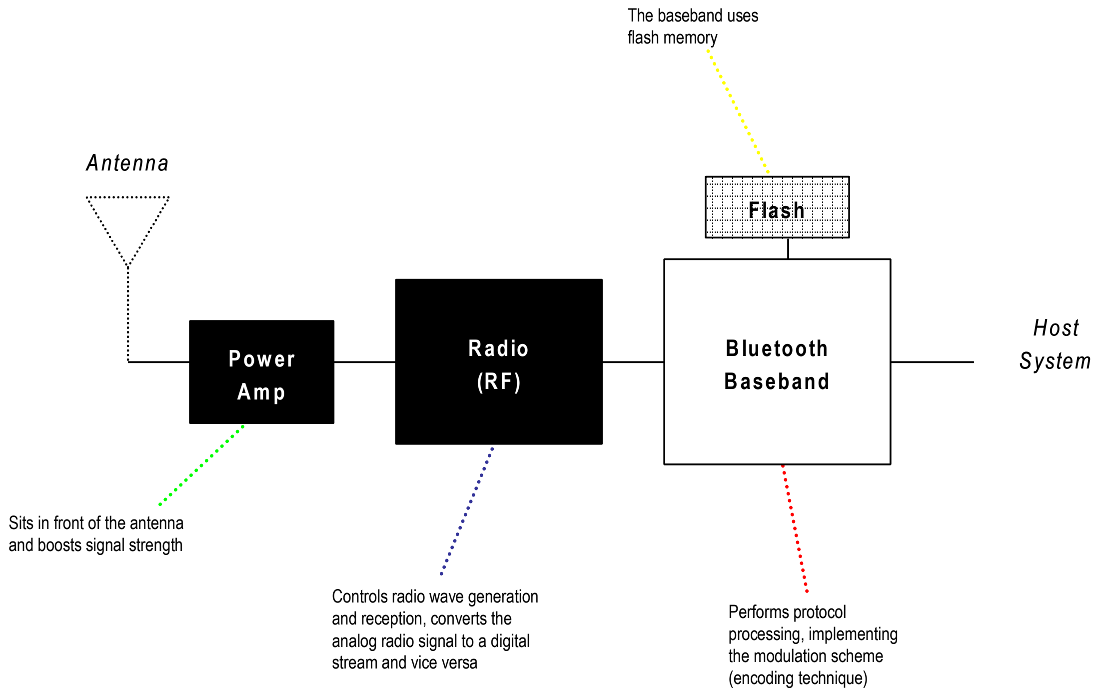
Bluetooth Unit Forecast: We estimate that Bluetooth unit shipments totaled approximately 1.3 billion in 2010, up 11% year-over-year. Of these, over 67% sold into cellular handsets and wireless headsets. The remainder found homes in PCs, peripherals, consumer devices, and add-on devices. With the integration of Bluetooth into baseband processors and into combo chips (e.g., Wi-Fi + BT), we expect stand-alone Bluetooth shipments to peak in 2012 at nearly 1.4 billion units and trend downward thereafter. Overall, we expect the market for Bluetooth to decline at a 3% CAGR, from just over 1.3 billion units in 2010 to 1.1 billion units in 2015. The primary driver should be declining standalone Bluetooth penetration in handsets; these should represent 36% of the 2015 total compared to 58% in 2010. Gaming and consumer devices, which represented 20% of the market in 2010, should slightly offset declining handset shipments and represent 30% of total units in 2015. PCs and peripherals should rise from 11% of units in 2010 to 16% in 2015 as combo chip penetration rates rise in notebooks, but volume of Bluetooth-enabled mice and keyboards increase.

Bluetooth Suppliers: Bluetooth is almost always implemented as an embedded solution within a larger system, and therefore "Bluetooth equipment" is a somewhat misleading term. As handsets represented 58% of Bluetooth unit shipments in 2010, it is important to note the leading handset vendors. In 2010, the top handset suppliers were Nokia with 29% unit share, Samsung with 18%, and LG with 7%. Market share, however, is fluid and evolving based on smartphones and OS supremacy.

The top suppliers of Bluetooth headsets are these same handset OEMs, all of which sell branded headsets to go with their phones (though they are interoperable with any Bluetooth-enabled handset). Third-party headsets are also available from vendors like Logitech, Plantronics, Philips, Jabra, Nextlink, and dozens of other smaller players.

PCs are also a large end market for Bluetooth; top PC makers in 2010 were HP, Dell, Acer, Lenovo, Toshiba, ASUS, Apple, Fujitsu, and Sony. On the gaming side, consoles from Sony, Microsoft and Nintendo integrate Bluetooth.

Bluetooth



Source: Oppenheimer & Co.

Bluetooth modules have similar configurations to those of wireless LAN client implementations. A power amp interfaces with the antenna and relays signals to a radio (RF) chip. The radio chip processes the RF signal and passes it to the Bluetooth baseband, which implements the Bluetooth modulation scheme (the encoding technique) and extracts the data packet. On the transmit side, the process is reversed: the baseband encapsulates the data using the Bluetooth modulation scheme and sends it through the RF and power amp to the antenna.

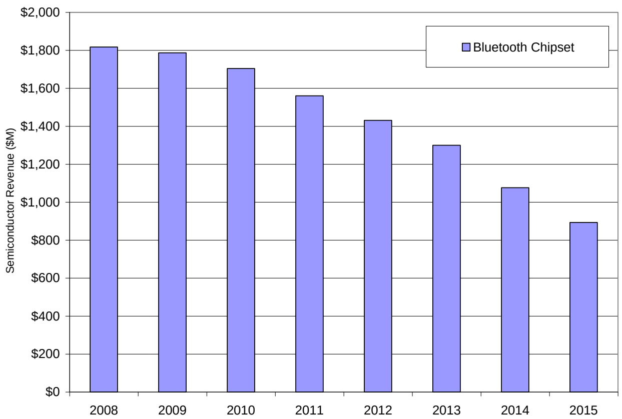
Note that most Bluetooth solutions combine all functions on a single chip, sometimes leaving out the power amp but still integrating the RF and baseband. Other implementations use just a Bluetooth RF, integrating baseband functionality with a host processor (e.g., Qualcomm integrates the Bluetooth baseband in its handset baseband IC).

- **Power Amp:** The power amp sits in front of the antenna and boosts signal strength.
- **Radio (RF)**: The RF controls radio wave generation on the transmit side and receives the radio wave on the receive side.
- **Baseband Processor**: The baseband processor implements the Bluetooth modulation scheme, extracting the packet from the Bluetooth frame on the receive side and encapsulating in on the transmit side.
- **Flash**: The baseband usually uses a small quantity of flash memory.

Bluetooth

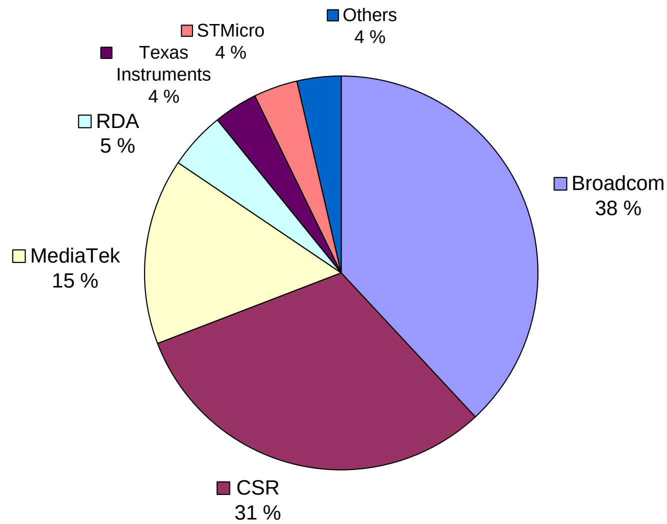
Bluetooth Semiconductor Forecast

•We expect Bluetooth semiconductor revenue to decline at a 12% CAGR, from $1.7 billion in 2010 to $900 million in 2015.
•Aggressive cost curves that made Bluetooth mainstream are likely to continue, only to be exacerbated by declining units.
•Bluetooth integration into combo solutions, coupled with pricing pressure, should deter standalone Bluetooth revenue growth.



Source: IDC, Oppenheimer & Co.

Bluetooth Semiconductor Competitors



Source: IDC, Oppenheimer & Co.

Bluetooth Semiconductor Forecast: Bluetooth penetration across a broad array of devices is likely to continue, just not as standalone BT. Because we do not include combo chips in our Bluetooth forecast, we believe the market for standalone Bluetooth chipsets is in a steady state of decline. Falling chipset ASPs will exacerbate the nominal decline in unit shipments. Overall, we expect the market to decline from $1.7 billion in revenue in 2010 to $900 million in 2015, a negative, and accelerating, 12% CAGR.

Bluetooth Semiconductor Competitors: The emerging Bluetooth competitive landscape has consolidated, with a few suppliers winning out among a wide variety of competitive solutions first available to the market. The largest supplier in 2010 was Broadcom with 38% share, but we suspect Broadcom will be a share loser over time as it increasingly focuses on combo chips, where it can drive higher dollar content and push the value of its integration capabilities. CSR had 31% share in 2010, down from 38% in 2008, and has continued to lose share given its dependence on Nokia in the handset market.

Mediatek took meaningful share in 2009 and 2010, rising to 15% of the market as it pushed Bluetooth solutions in emerging Asian economies. Its focus on connectivity is clear, as demonstrated by the 2011 Ralink acquisition. Other vendors in the space include RDA Microelectronics, Texas Instruments and STMicroelectronics.

Bluetooth

Bluetooth Semiconductor Market Trends

•Combo chips (ex. BT + WLAN + FM) are becoming the de facto standard of the handset market, driving down the total unit opportunity for standalone Bluetooth solutions.

•Notebook PCs are also adopting combo chip solutions.

•Bluetooth has penetrated the consumer electronics market, particularly in gaming devices.

•With combo chips becoming standard, ASPs declines have accelerated and exacerbated the total decline in units.

•BT3.0 + HS and BT4.0, BLE, likely to be dominant unit drivers.

- **Combo chips (ex. BT + WLAN + FM) are becoming the de facto standard of the handset market, driving down the total unit opportunity for standalone Bluetooth solutions.** The center of the Bluetooth universe is clearly the handset market, with the technology having proliferated across all major OEMs. While Bluetooth remains a standalone solution in many feature phones, wireless combo chips have become the de factor standard of smartphones which are rapidly penetrating the overall handset market. As combo chips become more prevalent, and as smartphones overtake feature phone sales in many regions across the globe, the total unit opportunity for standalone Bluetooth solutions in handsets is poised to drop dramatically. We do not expect a material decline in headset solutions, which will continue to utilize Bluetooth to connect with the handset.
- **Notebook PCs are also adopting combo chip solutions**. As noted in our discussion of the wireless market, the global consumer is becoming increasingly connected, and this in turn is driving rapid adoption of connectivity solutions across the total spectrum of consumer devices. To keep up with this technology curve and to help fuel a stagnating PC market, notebook PCs are also adopting combo-chip solutions. We believe standalone penetration continues in the desktop market and that the unit opportunity in PC peripherals (printers, etc.) will continue to rise, offsetting the decline in notebook standalone BT units.
- **Bluetooth has penetrated the consumer electronics market, particularly in gaming devices.** In a world without wires, Bluetooth is now common in all physical gaming platforms. Gaming controllers that connect to the console each embed Bluetooth; however, the online gaming community is expanding rapidly, which may limit the number of physical gaming consoles being sold going forward. This is more of a risk and not yet a trend, as gaming consoles (PS3, Xbox 360, Wii, etc.) have yet to experience material declines in sales as the result of online games.

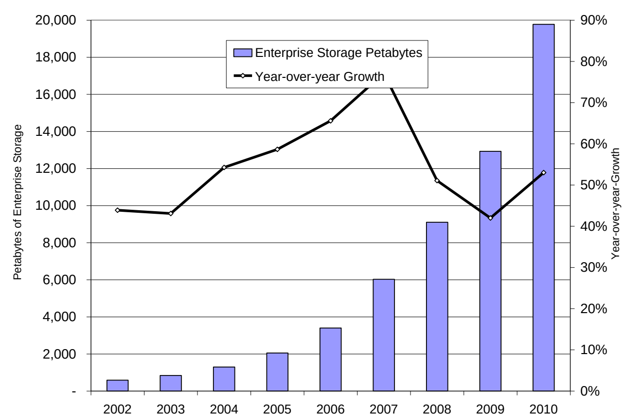
- **With combo chips becoming standard, ASP declines have accelerated and exacerbated the total decline in units.** As BT becomes increasingly integrated into combo chips and standalone BT becomes less prevalent, particularly in the mobile handset market, prices have declined meaningfully. As is common in the semiconductor industry, OEMs consistently push for additional functionality at the same cost point, and a WLAN + BT combo chip, for example, has materially weighed on the price that semiconductor vendors can push for standalone BT. As units decline, we suspect that ongoing pricing pressure and integration risk will increasingly weigh on dollar TAM.
- **BT3.0 + HS and BT4.0, BLE, likely to be dominant unit drivers.** BT + HS, or high speed Bluetooth, and BLE, or Bluetooth Low Energy, are poised to be the dominant drivers of growth in the standalone Bluetooth market going forward. BT + HS theoretically supports far higher data transfer speeds, but the BT link itself only negotiates and establishes the connection while the actual data traffic is carried over an 802.11 link. BLE is a subset of Bluetooth 4.0, and essentially allows for two types of implementation, either single mode or dual mode. In single mode, the low energy protocol stack is implemented solely. In dual mode, BLE functionality is integrated into an existing Bluetooth controller. Either way, BLE is likely to take off in very low power applications.

Storage

The buildout of high-performance computing infrastructure, adoption of higher-bandwidth LAN and WAN connections, new applications offering richer content, and increased focus on data security and redundancy have driven continued strong demand for high-capacity storage in the enterprise. Petabyte shipments continue to grow over 50% per year.

Storage systems are evolving to meet ever-rising needs of IT managers. More complex direct-attached RAID systems and networked topologies like **SAN** and **NAS** offer greater scalability, manageability, and performance for the modern enterprise.

Enterprise Storage Petabyte Shipments



Source: IDC, Oppenheimer & Co.

The three preceding networking technologies we have discussed in this section are all used in the transference of data between computing devices. We now turn from data networking to enterprise storage, which is used "behind the scenes" in the enterprise network for the storage, retrieval, backup, and management of corporate software and data.

Over the past few years, storage equipment makers have attempted to bring the benefits of networking to enterprise data storage. The legacy model, which stores applications and data files on disk drives within individual servers, is being replaced by newer networked storage systems. By treating storage as a separate resource from processing, enterprise IT managers are realizing greater efficiency, reliability, scalability and upgradeability in their infrastructure.

There is a wide variety of storage topologies and technologies employed in enterprise IT systems today. Most systems use a direct attached storage (DAS) architecture, which connects servers directly to drives and drive arrays. Though they do not offer the flexibility, scalability, manageability, and performance of networked storage, DAS systems are robust and easy to set up and maintain, and therefore remain an important part of the IT infrastructure.

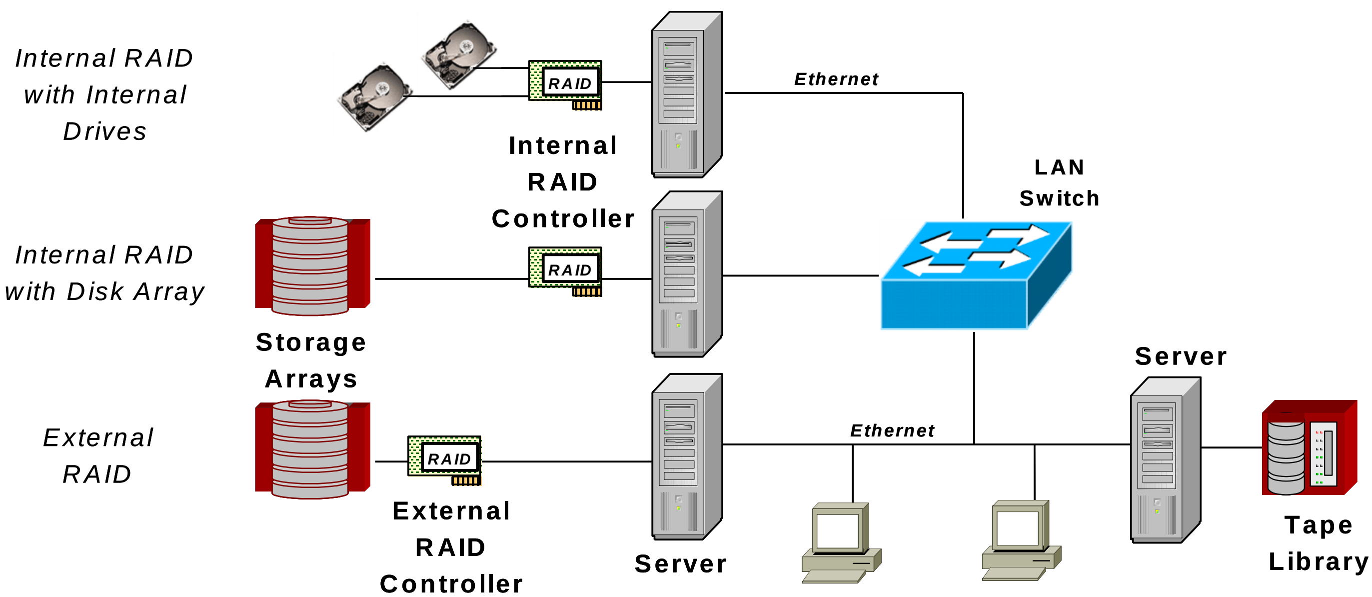
High-performance and high-reliability storage systems use storage area networks (SAN), predominantly based on the Fibre Channel protocol. These mimic the LAN topology, using specialized storage switches and adapter cards. SANs are the topology of choice for the highest end storage applications.

Some simpler IT systems use network-attached storage (NAS), which connects drive appliances directly to the Ethernet network. This brings the benefits of networked storage while leveraging the LAN (no new SAN network is needed).

Storage

Direct Attached Storage

Direct attached storage systems are primarily implemented with RAID controllers, which are directly connected to disk array systems or internal drives. The cheapest, simplest, and easiest to implement, direct attached is the most widely used storage topology.



Source: Oppenheimer & Co.

Direct attached storage systems are the cheapest, simplest and easiest to implement and are currently the most widely used storage topology. In a DAS system, servers are connected via standard hard disk drive cables either to enterprise-class hard disk drives within the server or to storage arrays that contain multiple drives. The interaction between the server and the disks is controlled by RAID (redundant array of independent disks), a set of protocols for data stripping, duplication, and drive management. A RAID controller, which sits between the server and the individual disks, implements the RAID software stack to enable these features, and allows the server to access an array of hard disk drives as if it were a single, huge drive.

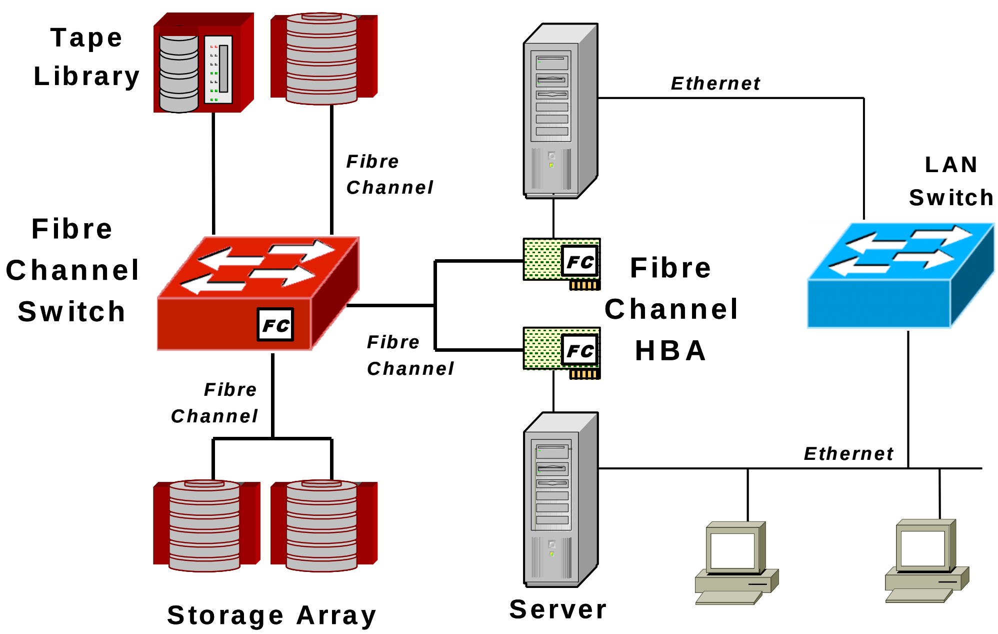
RAID controllers can be either internal or external. In an internal configuration, the RAID controller is housed inside the server and connects to drives within the server or to simple disk arrays like JBODs (just a bunch of disks). In an external configuration, the RAID controller is housed inside the disk array itself, and the server connects to the disk array over a standard hard disk drive cable.

As mentioned above, DAS systems are cheap, simple and easy to implement. The multiple flavors of the RAID standard allow for varying degrees of redundancy and performance enhancement. However, they have limitations in terms of reliability, scalability and manageability that make DAS systems difficult to support as capacity grows larger. SANs have made major headway against large DAS systems over the past few years, especially for the highest-end storage applications.

Storage

Storage Area Networking (SAN)

In a SAN environment, separate Fibre Channel networks switch storage traffic between disk arrays and servers. Storage is managed as a single resource, and tasks such as backup and disk maintenance can often be performed without any processing by host servers or PCs.



Source: Oppenheimer & Co.

Storage area networks (SANs) are implemented with disk arrays sitting on a high-speed storage-focused network separate from the data network. In this way, processing functions are separated from storage, which is well-suited to large corporate networks. SANs allow IT managers to treat all storage as a single resource and also allow tasks such as backup and disk maintenance to be performed without any processing by host computers.

In a SAN, servers do not connect directly to drives or arrays; they instead connect to a storage-specific network designed to carry storage traffic using the Fibre Channel protocol. These storage networks serialize SCSI traffic into Fibre Channel frames for high speed transport. Fibre Channel is somewhat similar to Ethernet, but is optimized for mass transfers of data as opposed to IP packet routing. The protocol uses optical fiber interconnects and runs at 1.0, 2.0 Gbps, 4.0 Gbps, or 8.0 Gbps.

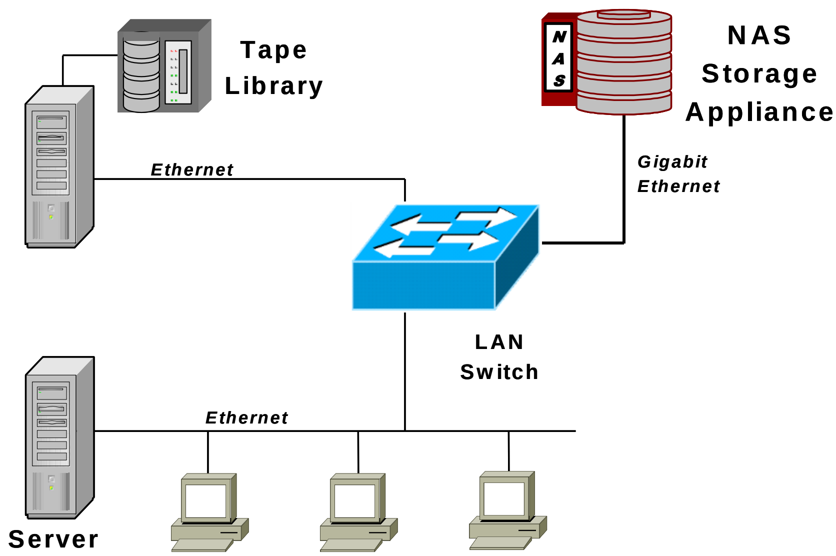
To connect to the SAN, each server is outfitted with a Fibre Channel host bus adapter (HBA), which connects to a network of specialized Fibre Channel switches. These switches provide the connection between servers and storage arrays, which also have to be specialized to run over Fibre Channel. Tape libraries can also be connected to the SAN, allowing for backup to take place without the use of servers on the data network.

Note that as SANs have evolved, OEMs have begun building more intelligent appliances to help manage the network such as SAN routers which interconnect between islands of storage in disparate locations. As these are used in only the highest end implementations, we do not picture them in our network diagram.

Storage

Network Attached Storage (NAS)

In a NAS, storage appliances are connected directly to the Ethernet local area data network. Instead of a full-blown operating system, NAS systems use a slim microkernel OS specialized for handling only file reads and writes. NAS systems operate like mini-SANs in that they are self contained storage servers.



Source: Oppenheimer & Co.

In a NAS environment, storage appliances are connected directly to the Ethernet LAN. NAS appliances operate like mini-SANs in that they are self-contained storage servers. They can be added to the IT infrastructure simply by plugging them into the Ethernet LAN, like any other Ethernet client.

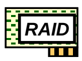
NAS systems usually contain a number of hard disks, often arranged into logical, redundant storage containers or RAID arrays. Instead of a full-blown operating system, NAS systems use a slim microkernel OS specialized for handling only file reads and writes. Storage capacity is added by connecting NAS appliances to the Ethernet network as simply as if a new PC or server were being added.

Note that NAS technology has begun penetrating the consumer market in recent years, sparked by the rise of digital content and home networks. Home NAS appliances can do more than simple USB external HDDs, as they allow for direct access by more than one PC or connected device on the network, and can also connect to other drive arrays for automatic backup. Note that Gigabit Ethernet will be an important enabler for this market, as 10/100-based devices were dramatically outpaced by USB 2.0 at 480 Mbps or Firewire 800 in terms of raw data transfer.

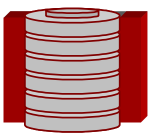
Storage

Types of Storage Equipment

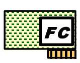
Enterprise Hard Disk Drive - Enterprise hard disk drives are the highest-performance drives on the market. They are usually housed either inside servers, in storage arrays, or inside NAS appliances, and use the SCSI or SAS protocol. Enterprise drives are included in our forecast for HDDs.



RAID Controller – A client card used to connect servers to storage arrays; they can be housed either in the server (internal) or in the array (external).

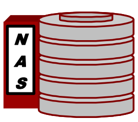


Storage Array - Storage appliance with multiple hard disk drives used in enterprise storage applications. In DAS systems, they either incorporate RAID controllers or connect to internal RAID controllers inside servers. In SAN systems, they connect to Fibre Channel switches.

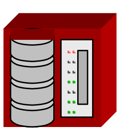


Fibre Channel HBA - A client card used to connect servers to the Fibre Channel network. Analogous to a NIC in an Ethernet network.

Fibre Channel Switch - The basic SAN building block, Fibre Channel switches connect and switch storage traffic between servers and storage arrays.



NAS Appliance - NAS appliances integrate storage and LAN connectivity. They include multiple HDDs and a slim OS to manage data transfers.



Tape Library – Tape library appliances are optimized for backup functions in an enterprise IT infrastructure system. They are implemented independently of the storage topology.

<u>Types of Storage Equipment</u>

Enterprise Hard Disk Drive: Similar to HDDs used in PCs, enterprise hard disk drives are the highest performance drives on the market. They are usually housed either inside servers, storage arrays, or NAS appliances. Hard disk drives used in storage systems are not included in our forecast, and are instead discussed in the section on HDDs.

RAID Controller: A client card used to connect servers directly to storage arrays. They can be housed either in the server (internal) or in the array (external), and use standard hard disk drive interfaces like SCSI, ATA, SATA, or SAS.

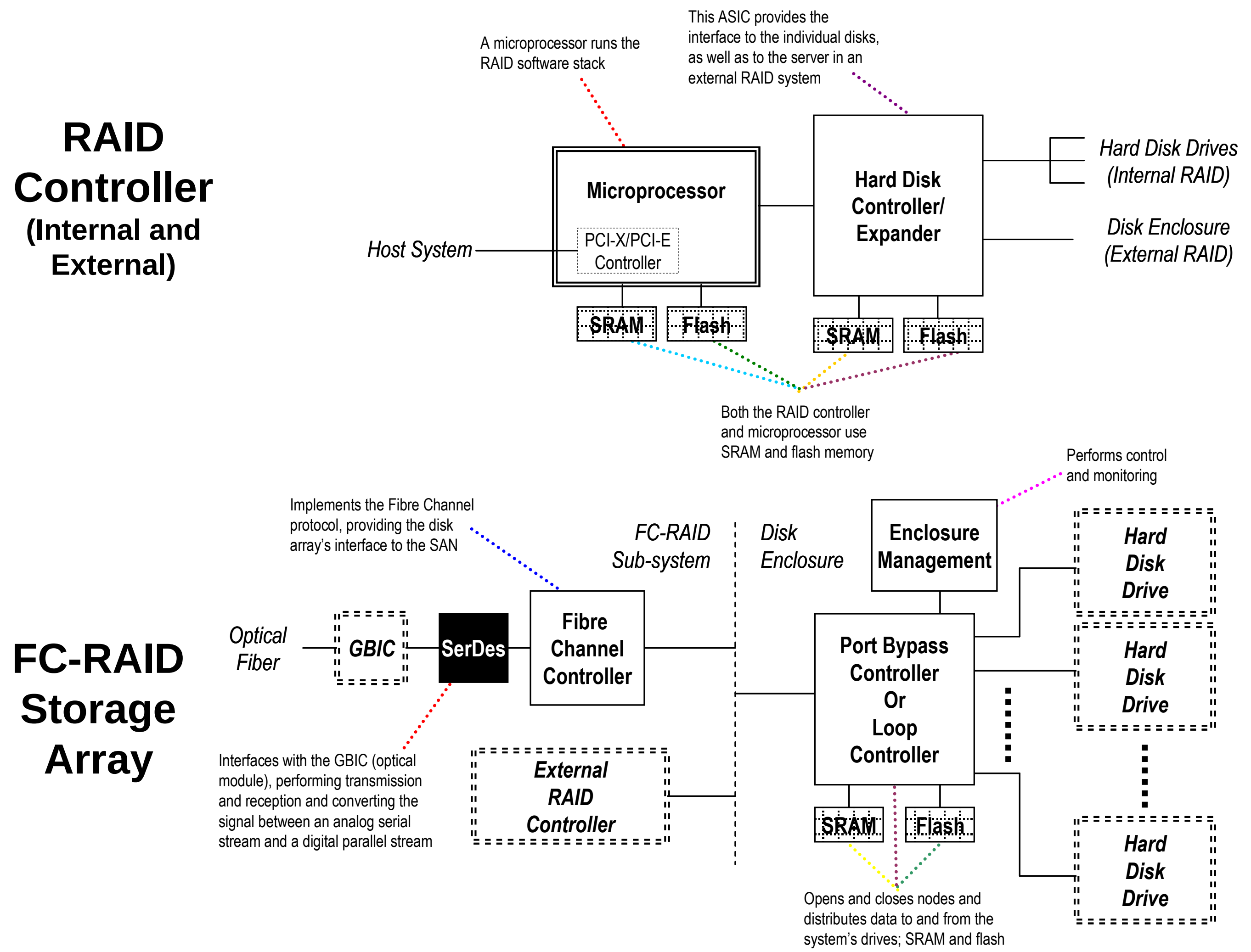
Storage Array: Storage appliance with multiple hard disk drives used in enterprise storage applications. In DAS systems, they either incorporate RAID controllers or connect to internal RAID controllers inside servers. In SAN systems, they include Fibre Channel connectivity to connect up to SAN switches.

Fibre Channel HBA and Switch: An HBA is a client card used to connect servers to the Fibre Channel network. A Fibre Channel switch is the basic SAN building block used to connect and switch storage traffic between servers and storage arrays.

NAS Appliance: A mass storage array optimized for NAS systems, NAS appliances integrate storage with Ethernet LAN connectivity and can be added directly to the Ethernet network to provide enterprise storage.

Tape Library: Storage appliance optimized for backup functions in an enterprise IT infrastructure system.

Storage



Source: IDC, Oppenheimer & Co.

RAID systems enable critical storage functions such as data redundancy, striping (for performance), and disk management. Their architecture and implementation vary widely, from low-end systems that control just a few disks within a single server, targeted for small/medium business, all the way to large switched disk arrays managing thousands of drives used in large corporate enterprises.

At the core of a RAID system is the RAID controller, which performs the compute-intensive calculations needed to implement the RAID stack at high speed. A RAID controller is usually implemented as a separate add-in board. In internal RAID systems, the RAID controller is used directly inside the server, and is attached directly to the drives, which are also located within the server.

In an external RAID system, the RAID controller is implemented within an array of disks as a subsystem to perform RAID processing. Larger disk arrays will usually have a number of subsystems, including a Fibre Channel subsystem to interface with a Fibre Channel SAN and a disk enclosure to manage the communication with individual disks.

RAID Controller – Internal *(used in servers)*

- **IOP/Microprocessor**: A microprocessor runs the RAID protocol stack, enabling the striping, redundancy, and disk management features of RAID. The microprocessor in an internal RAID implementation is sometimes called an I/O processor (IOP). These processors are usually optimized for high-speed RAID processing, and usually include the interface to the host controller, which is usually PCI-X or PCI-Express based.
- **Hard Disk Controller:** The hard disk controller provides the interface to the individual drives.

- **ROC (RAID-on-Chip**, not shown in above diagram): A ROC chip includes both the IOP and hard disk controller. ROC solutions can be used either on discrete RAID controller cards, but are mainly targeted for ROM (RAID-on-motherboard) implementations.
- **SRAM and Flash**: SRAM and flash are used by the microprocessor as well as by the hard disk controller ASIC.

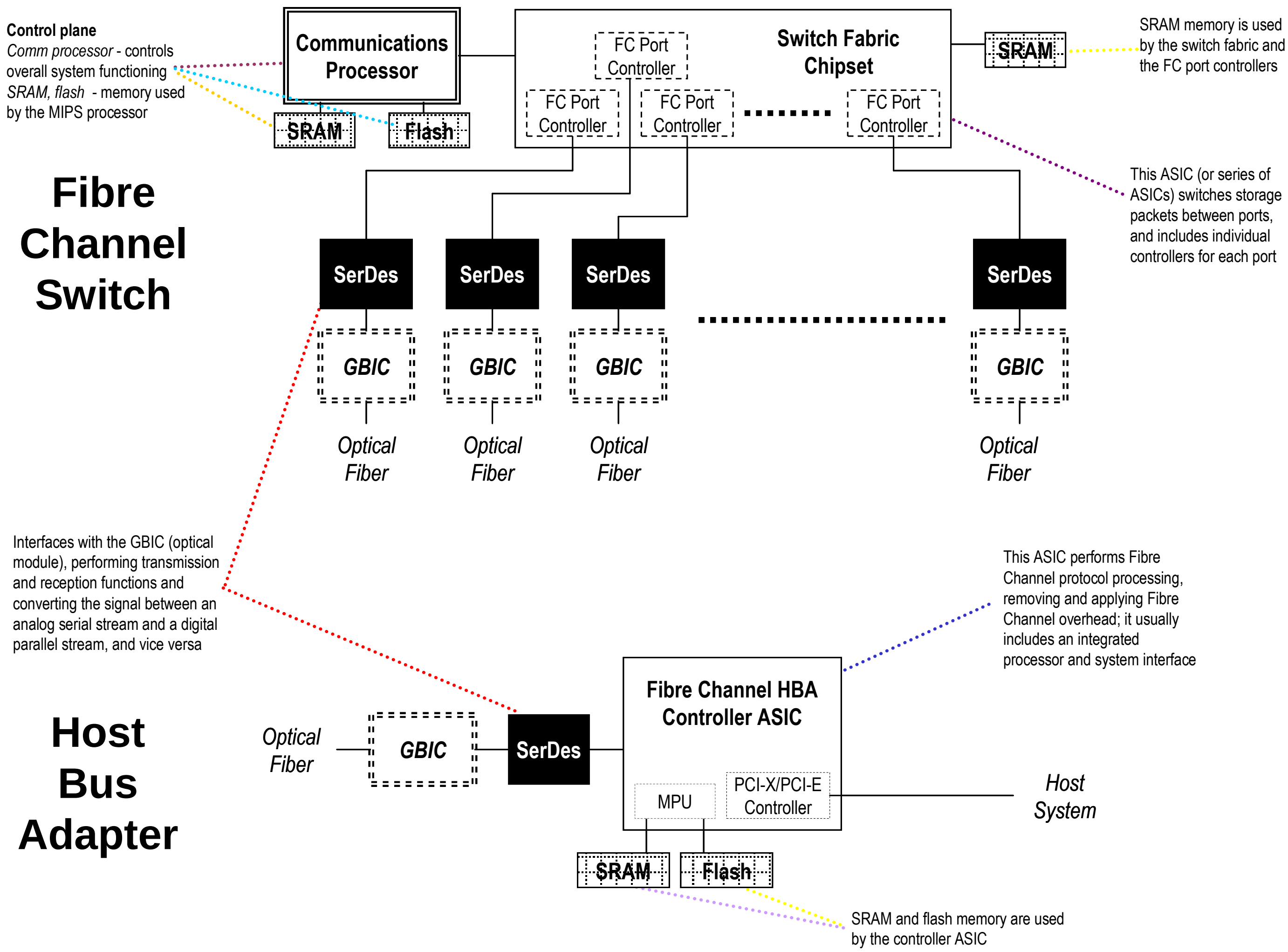
RAID Controller - External *(used within disk arrays)*

- **Microprocessor**: A microprocessor runs the RAID protocol stack, enabling the striping, redundancy, and disk management features of RAID. In higher end systems, multiple high-performance processors are sometimes used.
- **Hard Disk Controller:** The hard disk controller performs the SCSI/ATA processing to communicate with the drives within the enclosure. In lower end PATA/SATA/SAS RAID systems that do not have separate interface cards, this controller also interfaces with the server on the front end. In higher end systems (especially Fibre Channel), this is not needed since a separate controller card performs this interface.
- **SRAM and Flash**: SRAM and flash are used by the microprocessor as well as by the hard disk controller ASIC.

FC-RAID Storage Array

- **SerDes:** The SerDes interfaces with the optical module, performing transmission and reception and converting the signal between an analog serial stream and a digital parallel stream.
- **Fibre Channel Controller**: A Fibre Channel controller ASIC implements the Fibre Channel protocol, providing the interface to the SAN.
- **Port Bypass Controller (PBC)**: The primary logic device in the disk enclosure, a PBC opens and closes nodes between drives, distributing data to and from the system's drives.
- **Loop Controller**: More complex Fibre Channel disk arrays use loop controllers for a switched architecture instead of a PBC.
- **Enclosure Management**: In high-end systems, enclosure management chips monitor and control the drives in the storage array.
- **SRAM and Flash**: SRAM and flash are used by the port bypass controller or loop controller.
- **Expander** (used in SAS/SATA-based arrays, not shown in the diagram)**:** An expander IC, used in serial arrays like SAS or SATA (instead of a PBC or loop controller), increases the number of drives that can be included in the array. Note that SAS expanders can support both SAS and SATA drives; therefore, most IC designers are focusing on SAS expanders.

Storage



Source: IDC, Oppenheimer & Co.

Fibre Channel Switch

- **SerDes**: The SerDes converts the serial analog stream from the GBIC to a digital parallel stream and vice versa.
- **Switch Fabric Chipset**: The switch fabric chipset is a set of ASICs that switch storage traffic between switch ports. The chipset usually has integrated port controllers that interface with the SerDes on the front of the switch.
- **Communications Processor, SRAM and Flash**: A processor, usually MIPS or PowerPC based, performs control plane functions. The processor will usually use SRAM and flash, while some additional SRAM is also used by the switch fabric chipset in switching and port control.

Host Bus Adapter (HBA)

- **SerDes**: The SerDes converts the serial analog stream from the GBIC to a digital parallel stream and vice versa.
- **Fibre Channel Controller ASIC**: The controller ASIC performs protocol processing on the Fibre Channel stream, applying and removing Fibre Channel overhead to storage packets. The controller usually incorporates a processor, though the HBA can have a discrete MPU as well. It also usually includes a host interface.
- **SRAM and Flash**: SRAM and flash are used by the controller ASIC and the embedded microprocessor.

Storage

Storage Semiconductor Market Trends

•2010 end user spending on internal and external storage systems rose at the fastest pace since data collection began.

•File serving storage capacity is likely to grow 2.5x the rate of block storage over the next five years.

•NAS is growing most rapidly and will likely have the largest share of new terabytes shipped by 2015.

•ROC solutions seek to integrate the IOP and hard disk controller, and are enabling RAID on the motherboard.

•SANs continue to grow rapidly in the mid-high- end with the adoption of IP-based storage systems.

•Storage arrays are getting more intelligent, especially as Fibre Channel-based arrays increase in penetration.

•OEMs are looking to merge IP with SCSI and Fibre Channel.

- **2010 end user spending on internal and external storage systems rose at the fastest pace since data collection began.** Following severe global disruption in 2009, the total storage market rebounded handily in 2010, rising by 18% and surpassing total spending during 2008, according to data from market researchers IDC. External storage rose 18.2% in 2010 and internal storage rose 17.6%, driven primarily by a broader rebound in the server market. IDC estimates that total enterprise storage spending will grow at a 3.9% CAGR through 2015 to $37.3 billion. We expect external storage to grow faster than internal over this time.

- **File serving storage capacity is likely to grow 2.5x the rate of block storage over the next five years.** As discussed throughout various other sections of this report, data usage/creation continues to be driven by the surging demands from both the consumer and enterprise markets. This video and high-quality digital data is in turn pushing the demand for file-based storage systems. According to IDC, 83% of total shipped storage capacity will soon be in support of file data, an increase from 66% in 2010. To take this share, file storage is likely to grow at 2.5x the rate of block storage through 2015.

- **NAS is growing most rapidly and will likely have the largest share of new terabytes shipped by 2015.** Driven by the rapid growth of file based storage systems, NAS, as the de facto choice for external file servers, is poised to see incremental growth. The rapid push to Gigabit Ethernet, move towards IP-based storage systems, rise of business analytics in developed markets and the growing middle class (and small-medium business) in emerging markets will each contribute to this growth. End user spending on NAS grew 46% in 2010 and will likely have the largest share of new terabytes shipped by 2015.

- **ROC solutions seek to integrate the IOP and hard disk controller, and are enabling RAID on the motherboard.** ROC (RAID-on-chip) solutions integrate the disk interface, embedded microprocessor (IOP), and PCI-X/PCI-E functionality on a single chip. These designs are now in the market from a number of vendors, especially for newer SATA and SAS controllers. They primarily target the internal RAID market, and are specifically intended to enable RAID-on-motherboard (ROM). ROM takes ROC one step further, by incorporating RAID functionality directly on the motherboard. This reduces bill-of-material costs for the server and also allows for smaller form factor server designs. We believe these solutions will be used primarily at the high-volume end of the server market.

- **SANs continue to grow rapidly in the mid-high- end with the adoption of IP-based storage systems.** The most obvious trend in storage has been the growth of Fibre Channel-based storage area networks. These are more robust than direct attached solutions and thus have been gaining traction in the high-end enterprise. We last wrote that SANs had begun to rapidly take share at the high end—but they are now gaining incremental traction in the upper midrange of the market. This has partially been a result of the general migration to upper-mid range architecture as the performance-at cost has declined, and partially due to the adoption of IP-based systems.
- **Storage arrays are getting more intelligent, especially as Fibre Channel-based arrays increase in penetration.** Most storage arrays connect via direct attached topologies and thus support only SCSI, ATA, SATA or SAS. As SANs have gained traction, however, more and more arrays sit within Fibre Channel networks and thus need to support the more robust features of the SAN. This is creating additional opportunities for IC providers, which are serving this market with port bypass controllers, loop controllers, and enclosure management ICs.
- **OEMs are looking to merge IP with SCSI and Fibre Channel.** OEMs are now developing systems based on iSCSI, FCIP and other protocols to merge the advantages of Fibre Channel SAN systems and IP. The technology challenges are substantial, however, as Ethernet/IP networks approach most traffic with a “best case” effort in mind and as a result don’t meet the predictable performance requirements of storage. Note that there is likely only an opportunity for iSCSI silicon in disk arrays, as the protocol leverages the Ethernet data network for transport. The server connection will have to change to support iSCSI as well, but this will likely be done as an enhancement to the Ethernet NIC (e.g., Broadcom’s C-NIC) rather than a discrete iSCSI HBA or controller IC.

Telecom/Datacom

We now move from networking equipment used in singular locations to wide area communications technologies used to cross long distances. The WAN blends legacy equipment initially designed for voice telecom with newer technologies designed for data. Although the transmission media used is similar, the technologies and equipment that sit behind it are different: voice networks are generally **circuit-switched** while data networks are generally **packet-switched**.

The wide area network can be thought of in three segments: **long-haul**, used for city-to-city or country-to-country transport, **metro**, used for intra-city transport, and **access**, used to connect individual enterprise and residential customers to the network. In each case, the traditional voice infrastructure has been overlaid with data networking equipment used to switch, route, and transport data alongside voice.

We now move from networking equipment used in singular locations to the telecom and datacom realm, the "wide area networks" (WANs) that move voice and data traffic over longer distances. These networks are a lot older than the data-centric networks we have discussed so far; they are also a lot more challenging to design, build, and maintain. An extra layer of complexity is added with the blending of legacy technology originally designed specifically for voice telecommunications with newer technologies designed to send data traffic over the public telecom network.

Voice Networks

Wide area networks began as strictly voice networks, designed to offer local and long distance telephone service. As such, they emphasize the requirements of high-reliability voice telecommunications. In these networks, quality-of-service is key, as tolerance for latency, information loss and variations in speed of delivery are extremely low in a voice call. Further, information must be delivered strictly in the order it is received and it must be able to flow in both directions simultaneously (known as full-duplex). On the other hand, bandwidth requirements for voice are minimal and usage patterns are stable and predictable. Thus, while voice networks have historically been expensive to install and run, they can be operated at close to full capacity, reducing the need for extensive headroom in the network.

Voice networks have historically been circuit-switched; the transmission is enabled by establishing a dedicated communication channel (a closed circuit) between devices on a network. Such channels are established on demand and as available and provide continuous and exclusive access between the terminal devices until the connection is terminated. In other words, upon initiation of a telephone call, a dedicated channel through the network and switching matrices is established and a prescribed level of bandwidth is guaranteed for the duration of the connection.

Data Networks

With the growth of Internet data technologies such as e-mail, World Wide Web, instant-messaging and e-commerce, service providers have made significant investments to layer data network technologies on top of their voice infrastructure. Though the expertise and expense required to run data over voice-centric networks are significant relative to pure data networks, providers saw this as a better option than building entirely new data-only networks. We therefore find a public data network with a blend of voice and data equipment.

In general, data traffic travels over the same pathways that voice traffic does in the WAN, though the equipment that handles data traffic at each point-of-presence (POP) may be different. Data networks do not require the same quality-of-service that voice networks do, and in fact data traffic does not necessarily need to be delivered in the same order it was sent. On the other hand, bandwidth requirements are large and extremely variable (often referred to as “bursty”) and usage patterns are very unpredictable, requiring lots of headroom in the network.

In general, data traffic is better suited to packet-switched networks, which involve encapsulating data in fixed- or variable-length packets and sending them across a shared network. Each packet contains headers encoded with a destination address and is switched at each node in the network over the most appropriate and available physical circuit. No direct circuit or channel is established between sender and recipient as in a circuit-switched network; instead, data packets bounce around in the network until they reach their destination addresses.

That is the big difference between circuit-switched and packet-switched networks. Packets travel through the network independent of each other, and in fact, multiple packets sent from one sender addressed to the same destination may travel different physical paths, depending on the availability of network segments and the level of congestion across each network segment. As the route through the network is constantly changing, different packets may meet with varying levels of delay during transmission through the network. As a result, packet switching does not guarantee a prescribed level of bandwidth and packets are transmitted on a “best efforts” basis only; however, they are generally more efficient, as equipment is shared across a greater number of transmissions and as less “dead air” is transmitted.

Network Segments, Speeds and Protocols

The wide area network is usually thought of in three segments: long-haul, used for city-to-city or country-to-country transport; metro, used for intra-city transport; and access, used to connect enterprise and residential customers to the network. The protocols used to traverse these networks vary somewhat, though there is a lot of overlap. In each case, the traditional voice infrastructure (which of course remains in use for voice) has been overlaid with data networking equipment used to switch, route and transport data such as e-mail, Web, and VPN. In the case of the access network, traditional cable video networks have been overlaid with data equipment in a similar fashion.

In general, the closer to the core (long-haul portion) of the network, the faster the transmission speed. This is because fewer fiber connections are laid between cities than within them and thus the level of aggregation—which translates into higher bandwidth requirements and faster speeds—is greater for networks that span longer distances.

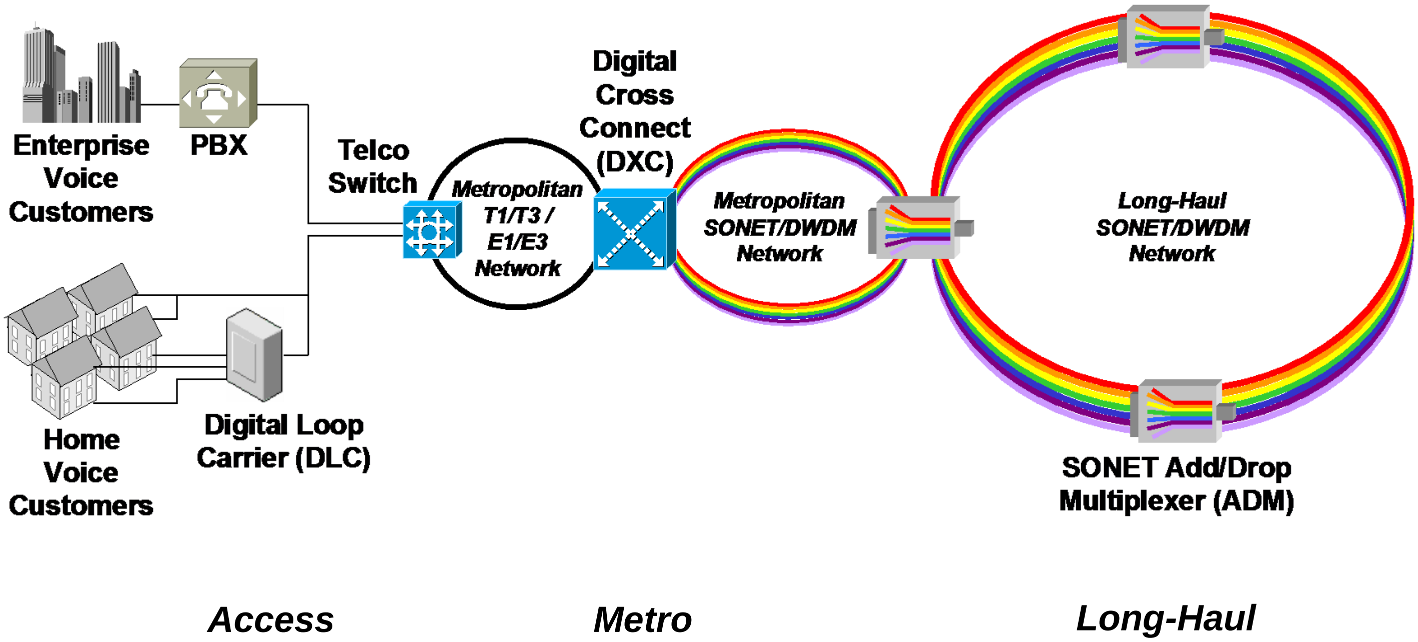
Long-haul networks typically employ transport equipment that can transmit at 10 Gbps (OC-192), 40 Gbps (OC-768), or even 100 Gbps (OC-3072), and use the SONET/DWDM protocol for transport over optical fiber. Metro networks also use SONET for transport, usually at speeds that range from 155 Mbps (OC-3) to 2.5 Gbps (OC-48). Some portions of the metro network use slower T3/E3 (45/34 Mbps) or even T1/E1 (1.5/2.0 Mbps) lines running on copper wire or optical fiber. Carriers also use these T/E lines to connect to wireless basestations to reach cellular customers, and for large enterprise customers that want a direct connection to the WAN. Running on top of these SONET and T/E transport networks might be other protocols such as ATM, which is used for multi-service switching of data, voice, and video.

The access network is a bit different, as it casts a much wider net and is used to reach individual voice and data customers. Speeds and protocols include 64 Kbps analog voice (over copper wire), 56 Kbps analog modems (over the same copper wire), 384 Kbps-24 Mbps DSL (again over the same copper wire but using separate frequencies), 1-30 Mbps cable modems (over coaxial cable), or newer 50-1000 Mbps PON/FTTH (over fiber).

Depending on the source, destination and access technology, information sent over the WAN may employ a number of protocols in order to reach its destination. For example, an e-mail sent from our Oppenheimer offices in New York City to a friend on the West Coast will first exit our corporate LAN via an access router, travel over a T1/T3 line in Verizon’s (or another LEC’s) network, be aggregated into an OC-3 or OC-12 SONET signal for transport to a larger network node, where it will be further aggregated (multiplexed) into a higher speed OC-48 or OC-192 SONET signal for transport over Sprint’s (or some other IXC’s) long-distance network. Once it reaches the West Coast, the SONET signal will be disaggregated (demultiplexed) into a lower speed SONET signal in AT&T’s (or another LEC’s) network, and switched on an ATM network into a DSL signal for transport to the recipient.

Telecom/Datacom

The Voice Network



Source: Cisco Systems, Oppenheimer & Co.

The voice network was originally designed to provide circuit-switched communication between telephone users connected to a worldwide public network. It is designed for connection-oriented service, in which a user desiring service initiates a call by dialing the intended number, establishes a connection once the recipient picks up, and then begins transmitting and receiving until one party hangs up, breaking the connection. As discussed above, this is a circuit-switched network; when the caller inputs the number, the service provider determines where on the network the recipient is located and allots the appropriate amount of bandwidth (usually 64 Kbps) over each segment of the call path for the duration of the call. This ensures a consistent, uninterrupted connection.

Individual consumer telephones are connected to the public switched telephone network (PSTN) via copper twisted pair wire run from telephone poles or underground conduits directly into the home or office. These POTS (plain old telephone service) lines connect up to a line card within a telco switch housed in a carrier's central office (CO) via a dedicated line. This telco switch acts as the gateway between the individual telephone user and the PSTN.

Sometimes, multiple telephone lines will be aggregated before transport to the central office. In residential networks, a digital loop carrier somewhere in the neighborhood aggregates many lines and forwards them to the CO. In a corporate environment, an enterprise PBX (private branch exchange) handles calls between extensions within the corporate system and forwards external calls to the CO. These voice aggregation devices will usually contain POTS line cards on the front end and a T1/E1 network uplink on the back end, which will connect directly into the service provider's network.

Once the call reaches the central office, the telco switch (also called a class-5 switch or a CO switch) aggregates and switches calls. Calls headed to a local-area recipient will be connected at this juncture. Calls bound for destinations not connected to that central office are sent into the metro area network (MAN), which uses T/E lines or SONET for transport. Digital cross connects located on the MAN aggregate and switch this traffic, and calls headed to recipients in the same city will be switched and sent to the recipient's central office for call termination. These cross connects also interface with the long-haul network, which uses higher-speed SONET transport equipment. The long-haul SONET ring will connect the call to other MANs around the country to enable long distance service.

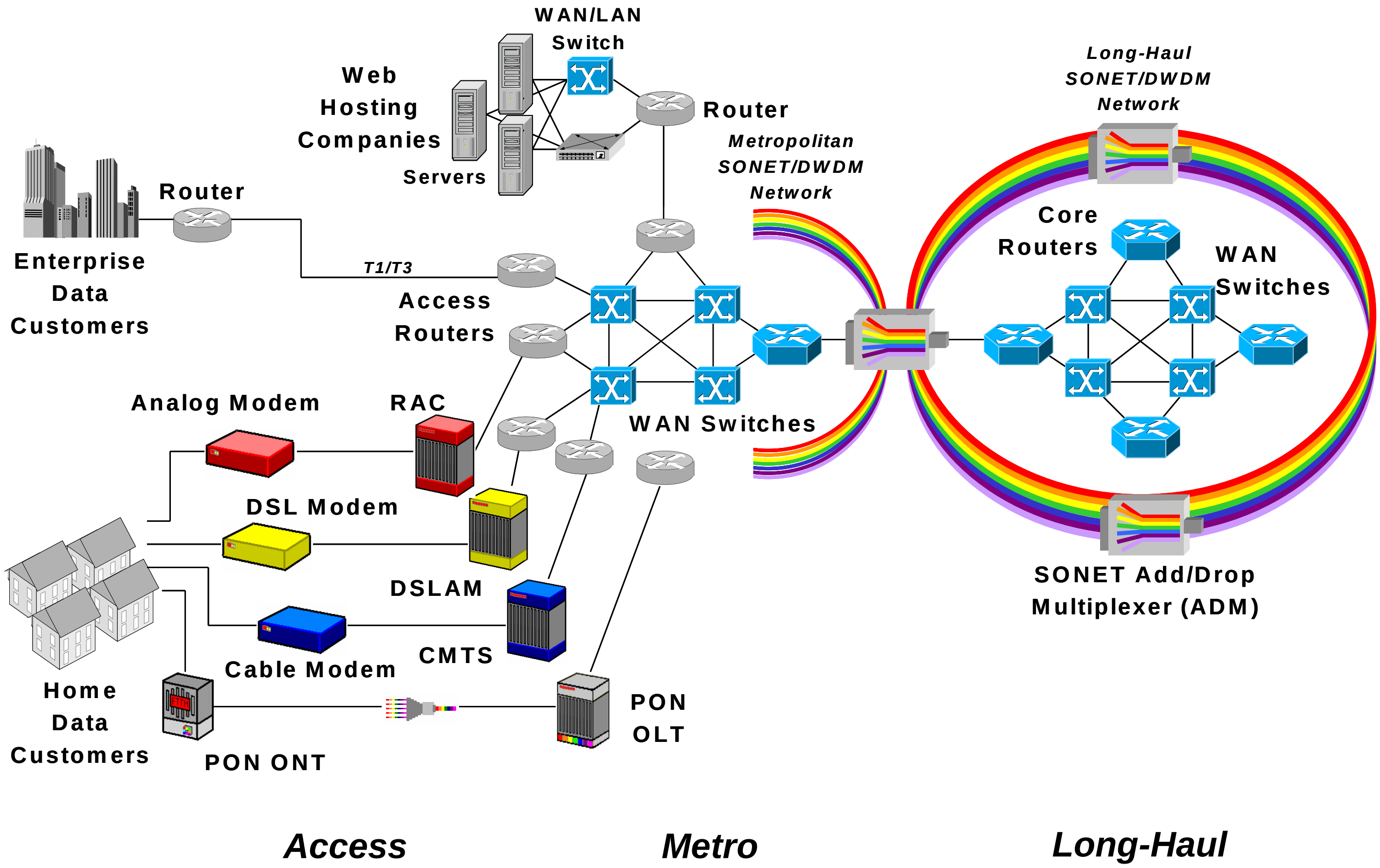
Next-Generation Voice Network Technologies (Includes Transport)

Note that our network diagram shows a simplified representation of the traditional public voice network. A number of new technologies are being implemented to make the network faster and more efficient. Note that many of these are motivated by the desire to make voice networks more flexible when handling data and voice traffic, and thus are not pure voice or transport technologies. Some examples include:

- **Multi-Service Provisioning Platforms (MSPPs):** MSPPs enable the evolution of the optical network to support increasingly data- and voice-centric traffic streams. They combine SONET add/drop multiplexer, digital cross connect, switching, and even routing functions in a single device, and are used throughout the carrier metro network as well as the edge of the core network.
- **Optical Cross Connects (OCCs):** Optical cross connects switch optical signals without performing the optical-electrical-optical (OEO) conversion that is performed in SONET add/drop multiplexers or digital cross connects. All switching is done in the optical realm. These switches tend to be used in the core of the network, where little intelligence is required to move signals around the network.
- **VoIP for Transport:** Voice-over-IP (VoIP) brings the benefits of packet-switched networking to traditional voice telephony. With VoIP technology, calls are digitized and translated into packets, and then are addressed like data packets and sent out over the data network. Most VoIP implementations to date have been behind the scenes within service provider networks for transport, especially for international calls. Service providers simply convert standard TDM-based voice calls to IP once the call reaches their network; they then transport the packets over the data network and switch them back to TDM somewhere near the destination for call termination. This leverages the efficiency of the data network and is transparent to the customer.
- **Enterprise VoIP:** VoIP is slowly replacing the traditional PBX model in the enterprise. Instead of using traditional PSTN-based phones connected to a PBX, specialized VoIP phones connect to the Ethernet LAN, and packetized voice traffic travels alongside data packets over the LAN. A softswitch or IP PBX located somewhere in the network enables call features, and the corporate access router forwards VoIP traffic to the service provider alongside WAN-bound data traffic.
- **Residential VoIP:** Carriers are looking to offer lower cost residential voice service by implementing VoIP at the customer premise, leveraging the installed base of analog phones and copper wire but moving call transport over to lower cost IP networks. Under this model, traditional analog phones hook into a specialized VoIP gateway device at the customer premise (sometimes called a VoIP terminal adapter or VoIP CPE device) that is connected to the customer's broadband modem (which we discuss in the data network section on the next page). This gateway translates voice into IP and sends it over the broadband connection. Back in the carrier's network, a specialized voice server known as a softswitch enables call features. As in the pure-IP enterprise implementation, calls placed over the IP network bound for a recipient not on the network must be terminated by the service provider; if the recipient is on a TDM network, the call must be translated back to TDM using a media gateway in the carrier's network.
- **Cable Voice:** Cable MSOs are rapidly moving toward triple-play services, offering voice service in addition to the video and data they provide today. The long-term topology for this functionality is VoIP, with a terminal adapter or voice-enabled cable modem at the customer premise packetizing voice traffic and sending it out over the DOCSIS network. Many MSOs are rolling out this service today. In the interim, however, many MSOs have rolled out a bridge solution using circuit-switched voice; under this topology, a Network Interface Device (NID) is installed at the customer premise, which feeds traditional telephony signals over the coax network. The MSO then strips the voice signal out at the head end, and uses traditional class-5 switches and digital cross connects to enable voice service. Sometimes branded "digital voice," this service is rapidly giving way to full cable VoIP.

Telecom/Datacom

The Data Network



Source: Cisco Systems, Oppenheimer & Co.

The public data network uses the same physical network as the voice network does, but overlays data equipment both at the customer and at service provider points-of-presence to enable data capability. Conceptually, data equipment sits “behind” voice equipment at every point in the network, and uses the voice telecom equipment discussed in the preceding section for transport between network nodes.

In the data network, the POTS and fiber infrastructure run by the RBOCs and the coaxial cable infrastructure run by the MSOs are used by consumers to connect to the public data network. Consumers can use analog or DSL modems to connect over the POTS infrastructure, cable modems to connect over the coaxial cable infrastructure, or PON ONTs or ONUs (passive optical networking optical network terminals or units) to connect over new FTTH deployments by telcos. These lines connect into remote access concentrator, DSL access multiplexer (DSLAMs), cable modem termination system (CMTS), or PON OLT (optical line terminal) data traffic aggregators located at the central office or cable headend. Collectively, this represents the residential portion of the access segment of the data network.

On the enterprise side, corporate customers will usually have their own access links, connecting directly to the public network over a T/E line or metro Ethernet. The more sophisticated data security, reliability, and bandwidth requirements of corporate enterprises warrant these always-on connections. Note that these T/E lines can carry both voice calls and data traffic and are usually sold as a package by telco providers.

Once in the public data network, data packets are routed and switched by access routers and carrier-class WAN switches located at network POPs. These switches will typically use ATM, though newer designs use Ethernet. The transport protocol here would normally be T/E or low-speed SONET, as switching protocols like ATM and MPLS operate at layer 2 and therefore need to be encapsulated into a layer 1 technology like T/E, SONET, or Ethernet.

If the destination address is in a distant part of the WAN, packets are forwarded to the long-haul network, where core routers and larger WAN switches direct the traffic around the network. In the long-haul network, high-speed SONET is used for transport. Packets that are bound for World Wide Web addresses are forwarded to web hosting companies or corporate web servers, which connect the public data network via enterprise-class switches and routers the same way enterprise LANs do.

As discussed above, data networks are generally packet-switched, meaning that rather than establishing a dedicated pathway between sender and recipient, packets are addressed and sent out onto the network, where they are routed and switched until they reach their destinations. In a pure data network like an Ethernet LAN, both the switching and transport technologies are designed to use a packet-switched topology. This makes for a very efficient network, since resources are only allocated when they are needed (i.e., the network only "lights up" when there is data to send).

In WAN networks, however, voice-centric technologies like T/E and SONET are used for transport over long distances, and these are circuit-switched by design. This means that data packets sent over the WAN will be switched with packet-based technologies at network points of presence, but will actually be transported over a circuit-switched network. This concept is made even clearer when we consider access technologies, which by definition use dedicated lines between the user and the service provider.

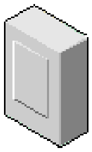
Next-Generation Data Network Technologies

Note that our network diagram shows a simplified representation of the traditional public data network. A number of new technologies are being implemented to make the network faster and more efficient, but did not make it into our diagram or the discussion above. Some examples include:

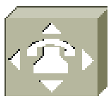
- **MPLS (Multi Protocol Label Switching):** MPLS is a unified data-carrying service designed to carry packet-switched data over circuit-switched networks. It can be used to carry many different kinds of traffic, including IP packets, as well as native ATM, SONET, and Ethernet frames. MPLS dispenses with the cell-switching and signaling-protocol baggage of ATM, while preserving the traffic engineering and out-of-band control that made it an attractive technology for large-scale networks. MPLS works in conjunction with IP, and is generally considered a layer 2.5 technology.
- **Carrier Ethernet:** As carriers migrate their networks to IP, they are naturally attracted to using Ethernet as a switching mechanism due to its close technology tie with IP. However, carriers require a more robust solution than traditional enterprise-focused Ethernet equipment provides. New equipment is now coming to market specifically to address these issues, with the goal of enabling carrier-grade Ethernet. Carrier Ethernet leverages the low cost and packet-switching advantages of Ethernet while adding an extra layer of intelligence—specifically for QoS for SLA (service-level agreement) enforcement, availability and redundancy, and network security—that is required in the service provider network.
- **MSPPs:** Discussed in the voice network discussion above, multi-service provisioning platforms are designed to better handle data traffic over the voice network.
- **Metro Ethernet:** Service providers now offer Ethernet-based access lines to enterprise customers to replace their T/E lines. Not to be confused with carrier Ethernet.
- **Video Servers and IPTV Set-Top Boxes:** Next-generation IPTV services will require video servers to be installed in the metro network to deliver video content. IP set-top boxes are required at the customer premise to turn the data packets into video signals.
- **IMS (IP Multimedia Subsystem):** IMS is an attempt at creating a telephony standard infrastructure for IP services that is expected to evolve to a replacement to circuit-switched voice. The goal of IMS is to provide today's telephony services along with all the services, current and future, that can be found on the Internet. IMS uses Internet Protocols (IP and SIP) to accomplish this goal. Service providers would like to use IMS infrastructure to provide ubiquitous access to services via wireline, wireless, and cable.

Telecom/Datacom

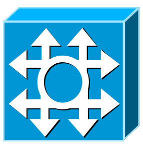
Types of WAN Equipment - Voice Networks



Digital Loop Carrier (DLC) - An aggregation device used in telecom networks to combine multiple telephone lines and send them over a single line to the central office. DLCs sit between the central office and customers.

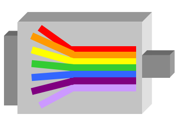


Private Branch Exchange (PBX) - An in-house telephone switching system used in enterprise networks to interconnect telephone extensions to each other and to the public switched telephone network.



Telco Switch - Also called a “class 5 switch,” or a “CO switch,” these are the primary carrier access devices used in legacy voice networks. They are large-scale network devices containing thousands of line cards used to connect directly to voice customers.

Digital Cross Connect (DXC/DCC/DCS) - Network device used by telecom carriers and large enterprises to switch and multiplex low-speed signals onto high-speed lines and vice versa. Typically used to aggregate several T/E lines into higher speed optical SONET lines.



SONET Add/Drop Multiplexer (ADM) – Optical device used in fiber-based networks to enable new SONET signals to come in and existing signals to go out. ADMs are placed in intermediate positions on the SONET ring and serve as on/off ramps to other rings. Note that SONET ADMs are increasingly being replaced by Multi-Service Provisioning Platforms (MSPPs), which add digital cross connect, switching, and routing functions.

Types of Voice Networking Equipment

Digital Loop Carrier (DLC): An aggregation device used in residential telecom access networks to combine multiple telephone lines and send them to the central office. DLCs sit between the central office and customers.

Private Branch Exchange (PBX): An in-house telephone switching system used in enterprise networks to interconnect telephone extensions to each other and to the public switched telephone network.

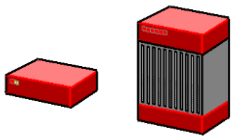
Telco Switch: Also called a “class 5 switch” or “CO switch,” these are the primary carrier access devices used in legacy voice networks. These large-scale systems contain thousands of line cards that connect directly to customers.

Digital Cross Connect (DXC/DCC/DCS): Network device used by telecom carriers and large enterprises to switch and multiplex low-speed signals onto high-speed lines and vice versa. They are often used to aggregate several T1/T3 lines into higher speed optical SONET lines.

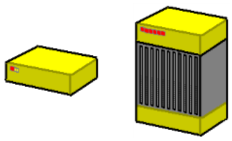
SONET Add/Drop Multiplexer (ADM): Optical device used in fiber-based telecom networks to enable new SONET signals to come in and existing signals to go out. As signals pass through the device, some are "dropped" by splitting them from the line, others can be "added" and directed to other destinations. ADMs are placed throughout the SONET ring and serve as on/off ramps to other rings. Note that SONET ADMs are increasingly being replaced by multi-service provisioning platforms (MSPPs), which add digital cross connect, switching, and routing functions.

Telecom/Datacom

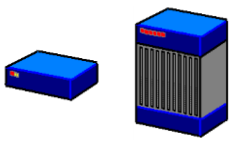
Types of WAN Equipment - Data Networks



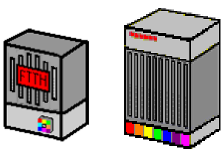
Remote Access Concentrator (RAC) & Analog Modem CPE - Equipment used to send data traffic over POTS lines in an analog format at speeds of up to 56Kbps. The RAC is housed at the central office while the modem CPE resides at the customer, embedded in a PC.



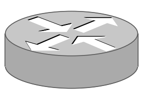
Digital Subscriber Line (DSL) Access Multiplexer (DSLAM) and DSL Modem CPE - Equipment used to send data traffic over POTS lines in a digital format at speeds of 1 Mbps or more.



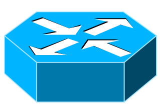
Cable Modem Termination System (CMTS) and Cable Modem CPE - Equipment used to send data traffic over coaxial cable in a digital format at speeds of up to 10 Mbps.



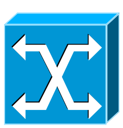
Passive Optical Networking (PON) Optical Line Terminal (OLT) and Optical Network Terminal (ONT) - Equipment used to send data over fiber-to-the-home networks at speeds of 50-1000 Mbps. The ONT resides at the customer with the OLT in the carrier network.



Access Router - Intermediate-speed router used at the edge of the network, both for enterprise network access and within service provider points-of-presence for routing in the metro network.



Core Router - High-speed router used in the core of the network.



WAN Switch - Network device that switches data, voice, and video traffic, used in carrier and large enterprise network backbones. Most WAN switches today use the ATM protocol and can support MPLS, though newer switches use Ethernet.

Types of Data Networking Equipment

***Remote Access Concentrator (RAC) and Analog Modem CPE (Customer Premise Equipment)**:* Access equipment used to send data traffic over POTS twisted pair copper wire in an analog format at speeds up to 56Kbps.

***Digital Subscriber Line (DSL) Access Multiplexer (DSLAM) and DSL Modem CPE**:* Access equipment used to send DSL data traffic over the POTS copper twisted pair infrastructure in a digital format at speeds of 1 Mbps or more.

***Cable Modem Termination System (CMTS) and Cable Modem CPE**:* Access equipment used to send DOCSIS cable modem traffic over coaxial cable video networks in a digital format at speeds of up to 10 Mbps or more.

***Passive Optical Networking (PON) Optical Line Terminal (OLT) and Optical Network Terminal (ONT)**:* Equipment used to send data over fiber-to-the-home networks at speeds of 50-1000 Mbps or more. The ONT resides at the customer with the OLT in the carrier network.

Access and Core Routers: Service provider routers move traffic around the wide area data network. Access routers (1-10 Gbps) are used at the edge, both for enterprise network access and within service provider points-of-presence for routing in the metro network. Core routers (10 Gbps+) are used in the core of the network.

WAN Switch: Sometimes called a “multi-service switch,” this device switches data, voice, and video traffic in carrier and enterprise network backbones. They are multiprotocol devices, usually incorporating ATM, MPLS, and Ethernet.

Telecom/Datacom

Service Providers – Major Issues

- **Technologies driving the industry**
  - Focus remains on consolidating voice/data/video onto one network
  - Next generation access technologies – EPON in Asia; BPON/GPON in the U.S.; ADSL2+, VDSL, and VDSL2 worldwide
  - Moving intelligence from the core of the network to the edge
  - IP networks with the customers controlling more features and functionality
  - Wireless will continue to drive demand for increased bandwidth
- **Cable remains the biggest threat**
  - MSOs preparing for broader rollouts of voice-over-cable
  - The cable companies and telcos have much to lose from aggressive price wars and both sides have some advantages
- **"Triple Play," bundling and flat rate pricing are focuses**
  - Triple play includes voice, video, and data service
  - Increases revenue per household
  - Increases the TAM over time
- **Consolidation and Regulatory issues**
  - Heavy consolidation in the U.S. is now behind us: Verizon-MCI, SBC-AT&T-Bellsouth, Sprint-Nextel, Level 3-Wiltel-Broadwing, AT&T-T-Mobile (Pending) & Others
  - Inter-carrier compensation – especially for VoIP
  - Universal Service Funding

The telecom industry remains in a state of transition as carriers address increasingly data-centric connectivity demands and attempt to fight off competition from cable and satellite. All service providers are moving toward triple play services, looking to provide voice, video, and data. The major issues facing carriers include:

Technology issues: Service providers are squarely focused on consolidating voice/data/video onto one network in order to lower the cost for existing services and branch into new services. This has required the adoption of next-generation access technologies, including EPON in Asia, BPON/GPON in the U.S., and next-generation DSL worldwide. Behind the scenes, carriers continue to move their networks to more flexible IP-based equipment, and are moving intelligence from the core of the network to the edges. Wireless is the largest growth driver for the industry, but the explosion of wireless data traffic has presented data congestion problems; "tiered" data plans will be an increasing focus going forward.

Threats: The biggest threat facing carriers is from cable voice, as cable MSOs prepare for broader rollouts of VoIP, and from internet calling services like Skype and Google Voice. Cable, offering live content streaming, may carry a competitive edge as the importance of data content and aggregation rises as consumption goes mobile. Note that the cable companies and RBOCs have much to lose from aggressive price wars and both sides have some advantages, which should prevent more aggressive behavior.

Market factors: Carriers remain focused on ARPU, in particular adding services to increase the TAM (total available market) over time, but are now cognizant of the total bandwidth available for data. On the cost side, cap-ex frugality has eased, but maintenance and other variable costs remain an important focus area.

Consolidation and regulatory issues: There has been massive consolidation in the U.S. market. On the regulatory front, inter-carrier compensation and Universal Service Funding are still issues as carriers try to fend off VoIP.

Telecom/Datacom

Telecom Equipment Revenue Outlook

While the total telecom equipment revenue outlook is not the most rapidly growing of markets, there are still pockets of growth.

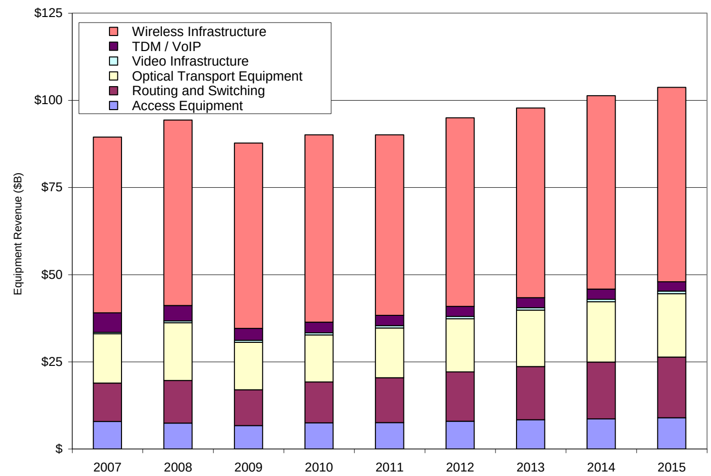
-Wireless infrastructure accounted for 60% of all telecom equipment revenue in 2010 and we expect it to be flattish through 2015. However, this comes despite a negative 20% CAGR in WiMAX.

-Within TDM / VoIP, we expect IMS (VoIP) to grow at a 27% CAGR through 2015 to $1.7B – offsetting a negative 31% decline in legacy TDM revenue.

- We expect optical transport equipment spending to grow at a 6% CAGR through 2015, driven by a 26% CAGR in POTP to $4.8B. This offsetts a negative 18% CAGR in legacy SONET/SDH.

- IP routers are expected to grow at a 9% CAGR through 2015 to $13.3B, driving 8% total growth in routing and switching.

Global Telecom Equipment Revenue



Ex-Recurring Revenue

Source: IDC, Oppenheimer & Co.

Carriers are cautious to over-spend when their own revenue growth expectations are limited, thereby limiting the total top-line growth of the telecom equipment market. However, within the nearly $100B annual market, there are pockets of growth that are likely to offset terminal declines in SONET/SDH networks, ATM switching, and WiMAX, to name a few. The fastest-growing pockets of telecom equipment through 2015 will likely be in EAD access equipment, IP routers, OTN and IMS (VoIP).

In total, we expect telecom infrastructure revenue, excluding recurring revenue streams, to rise from $90.1B in 2010 to $103.7B in 2015. Growth will likely be muted in North America and other developed economies, and be driven primarily by China, India and other emerging nations. APAC currently holds 33% share of the telecom equipment market, and we expect this share to increase over time.

We now move on to examine in more detail four key markets within Telecom and Datacom.

Telecom/Datacom

Three Key Markets:

Modems

Data access devices used to connect individual residential customers to the service provider network over POTS copper wire or coaxial cable networks. We also include faxes due to their similarity to analog modems.

PON

Fiber access technology used to connect residential customers to the Internet using optical fiber.

Communications Infrastructure

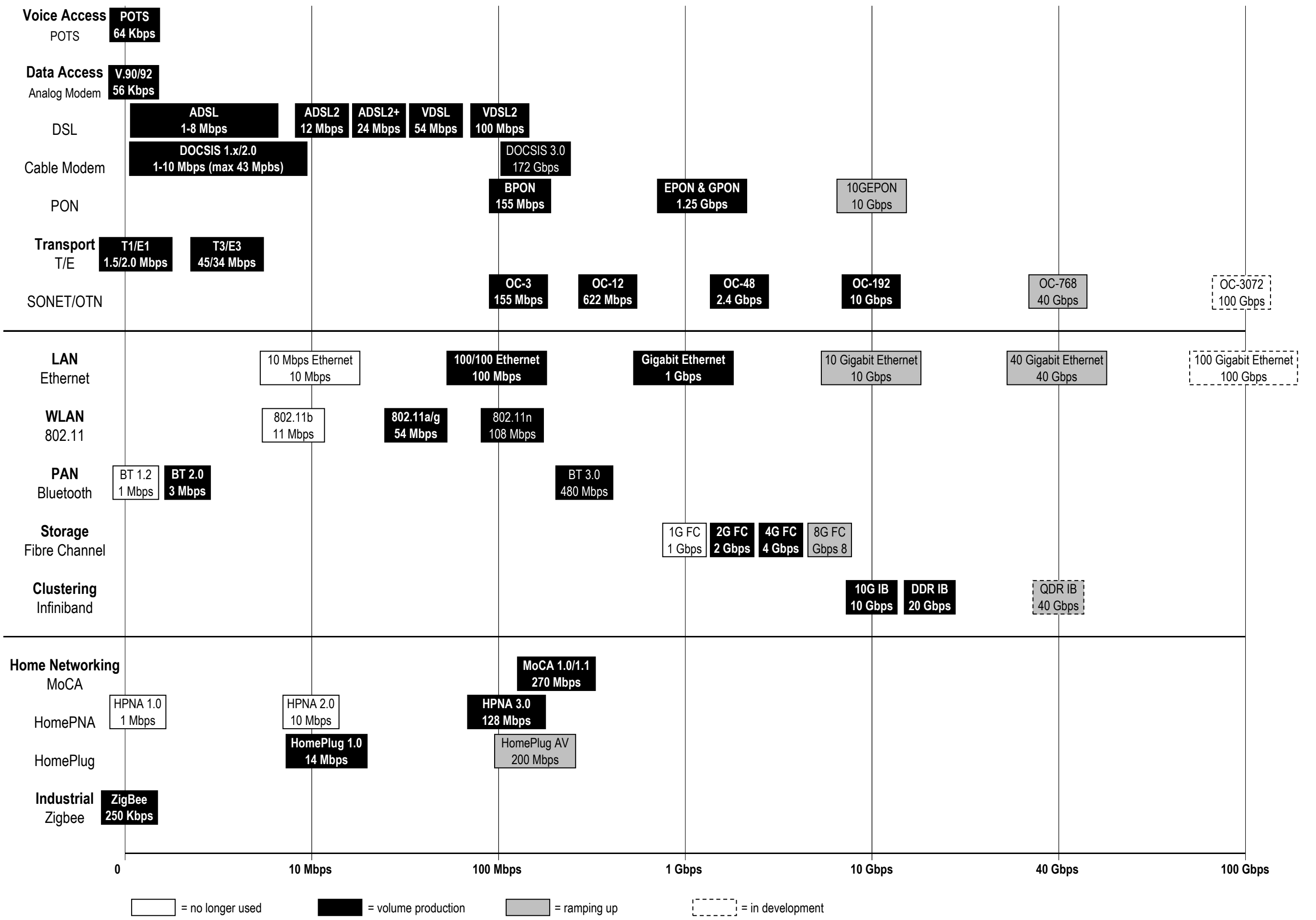
A broad category of infrastructure equipment used for switching, aggregation, routing, and transport in voice and data networks.

We divide telecom and datacom equipment into three key segments. The first two are access technologies with transparent applications: modems and PON for data access. The third is a broad category we term communications infrastructure, which includes switching, aggregation, routing, and transport equipment used in voice and data network infrastructure.

- **Modems** (includes fax): Datacom access devices that connect individual users to the service provider network. Analog and DSL modems use the POTS telephone infrastructure; cable modems use coaxial cable networks.
- **PON:** Fiber access technology used to connect residential customers to the Internet using optical fiber.
- **Communications Infrastructure:** A broad category of equipment used for switching, aggregation, routing, and transport in voice and data networks. Note that equipment included in this category is used both in service provider networks and in enterprise networks for trunking, backhaul, and access to the public network. We chose to include all infrastructure equipment here (rather than in the networking section) due to its similarity to service provider equipment and the difficulty in distinguishing between multi-use equipment.

As in the networking section, we will be quoting a variety of speed grades throughout the datacom/telecom section that can be difficult to keep track of. The chart below displays the major telecom/datacom technologies along with the sub-protocols of each, similar to the chart found on page 161.

Networking Protocol Speed Chart



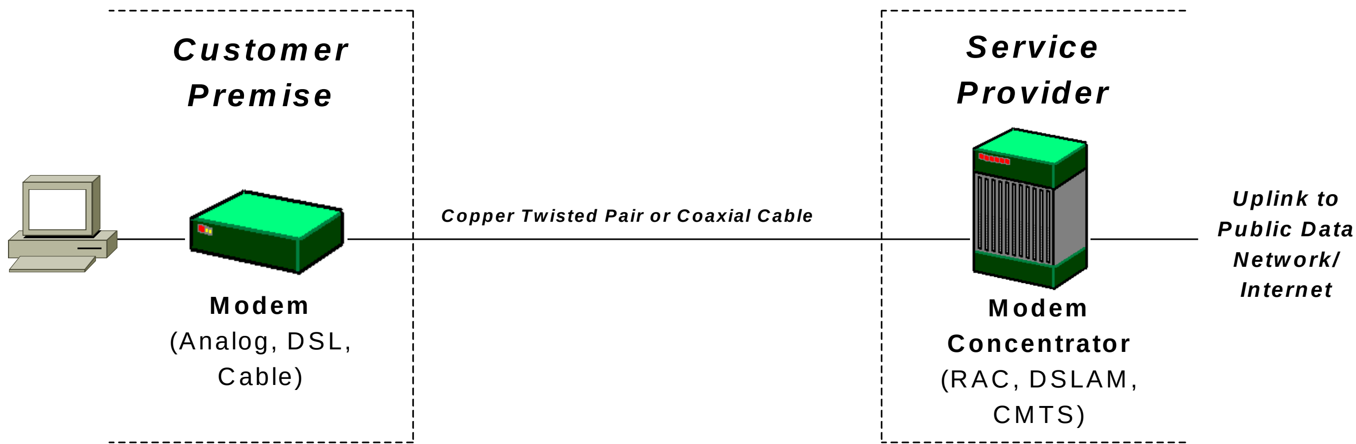
Note: In most cases, speeds quoted correspond to the maximum data rate (sometimes called the "PHY rate)" achievable according to the standard. Most networking protocols have a usable data rate that is meaningfully less than the quoted rate, though the magnitude of this difference can vary significantly depending on the protocol.

Source: Company reports and Oppenheimer & Co.

Modems

Modems are used to connect individual PCs or small consumer/SOHO networks to the Internet.

Modem CPE (consumer premise equipment) on the client side connects via copper twisted pair that has historically provided voice service or via coaxial cable that has historically provided video service. On the service provider side, a modem concentrator enables the data service and interfaces with the public data network.



Source: Oppenheimer & Co.

Modems are the most common remote data access device, used to connect individual PCs or small consumer or SOHO networks to the public data network and the Internet. Unlike pure data networking equipment like Ethernet, modems are designed to send data traffic over networks that were originally intended for either voice or video.

Modem CPE (consumer premise equipment) on the client side connects via copper twisted pair (from the traditional voice network) or coaxial cable (from the traditional cable video network) to a modem concentrator in the service provider network. The modem concentrator acts as the gateway to the public data network. The service provider can be a traditional telecom carrier (Verizon, AT&T), a cable MSO (Comcast, Time Warner Cable), or a specialized Internet service provider (America Online).

Modems

Three key types of modems exist:

Analog Modems - Analog modems use a traditional telephone line to place a call, which is received by the service provider modem, and transmits data in an audible analog format (like a fax machine). Transmission speed is typically 56 Kbps.

Cable Modems - Cable modems use the existing coaxial cable network to transmit data in a digital format. Transmission rates vary with user congestion, but can reach 10 Mbps downstream and 1 Mbps upstream.

DSL - Digital Subscriber Line uses the existing POTS infrastructure, but transmits data in a digital format using a higher, inaudible frequency "on top" of the traditional analog voice signal. Symmetric DSL (SDSL) transmits and receives data at the same rate, while Asymmetric DSL (ADSL) carries faster downstream rates than upstream rates. Newer, faster asymmetric protocols are referred to as VDSL (very high bit rate DSL). DSL speeds vary widely between a 1-10 Mbps for SDSL and ADSL and 50+ Mbps for VDSL/VDSL2.

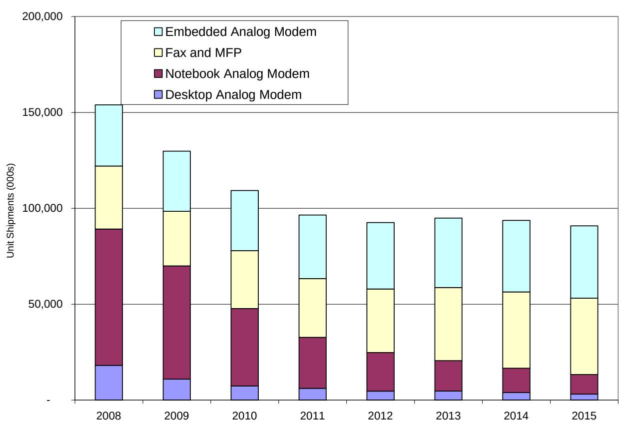
Three key types of modems exist:

- **Analog Modems:** Analog modems use a traditional POTS phone line to place a call, which is received by the service provider modem housed in a remote access concentrator (RAC). Analog modems transmit data in an audible analog format, which is why you can hear it if you pick up the phone line, similar to a fax machine. Top transmission speed is typically 56 Kbps. Phone lines are designed to transmit 64 Kbps of voice (the 8 Kbps difference accounts for overhead). Analog modem CPE is usually embedded on the motherboard within the PC.
- **Cable Modems:** Cable modems use the existing coaxial cable network to transmit data in a digital format using the DOCSIS protocol, over the same infrastructure used to transmit video. Transmission rates vary with user congestion (slower when more users are online), but can reach 10 Mbps downstream and 1 Mbps upstream.
- **DSL:** Digital subscriber line technology uses the existing POTS infrastructure, but transmits data using a digital format in a higher, inaudible frequency "on top" of the traditional analog voice signal. On the service provider side, lines connect to a DSL access multiplexer (DSLAM), which connects directly to the public data network, usually using ATM or IP as a backhaul protocol. Two basic forms of DSL exist: symmetric, which transmits and receives data at the same rate; and asymmetric, which carries faster downstream rates. Newer, faster asymmetric protocols are referred to as VDSL (very high bit rate DSL). DSL speeds vary widely between 1-10 Mbps for SDSL and ADSL and 50+ Mbps for VDSL/VDSL2.

Modems

Analog Modem and Fax Unit Forecast

•We expect analog modems and fax units to decline at a 4% CAGR from 109 million units in 2010 to 90 million units in 2015.
•PC modem penetration and consumer demand have each fallen off as broadband has become pervasive.
•MFPs should continue to generate some incremental growth.



Source: IDC, Dell'Oro, Dataquest, Oppenheimer & Co.

Analog Modem and Fax Suppliers

Desktops

HP
Dell
Lenovo
Acer
Apple
Fujitsu/F-S

MFPs

HP
Canon
Epson
Lexmark
Brother
Samsung

Satellite STB

Thomson
Echostar
Pace
Tongda
Humax

Notebooks

HP
Acer
Dell
Toshiba
Lenovo
ASUS

Fax

HP
Brother
Panasonic
Sharp
Lexmark
Canon

Source: IDC, Dataquest, Dell'Oro, Oppenheimer & Co.

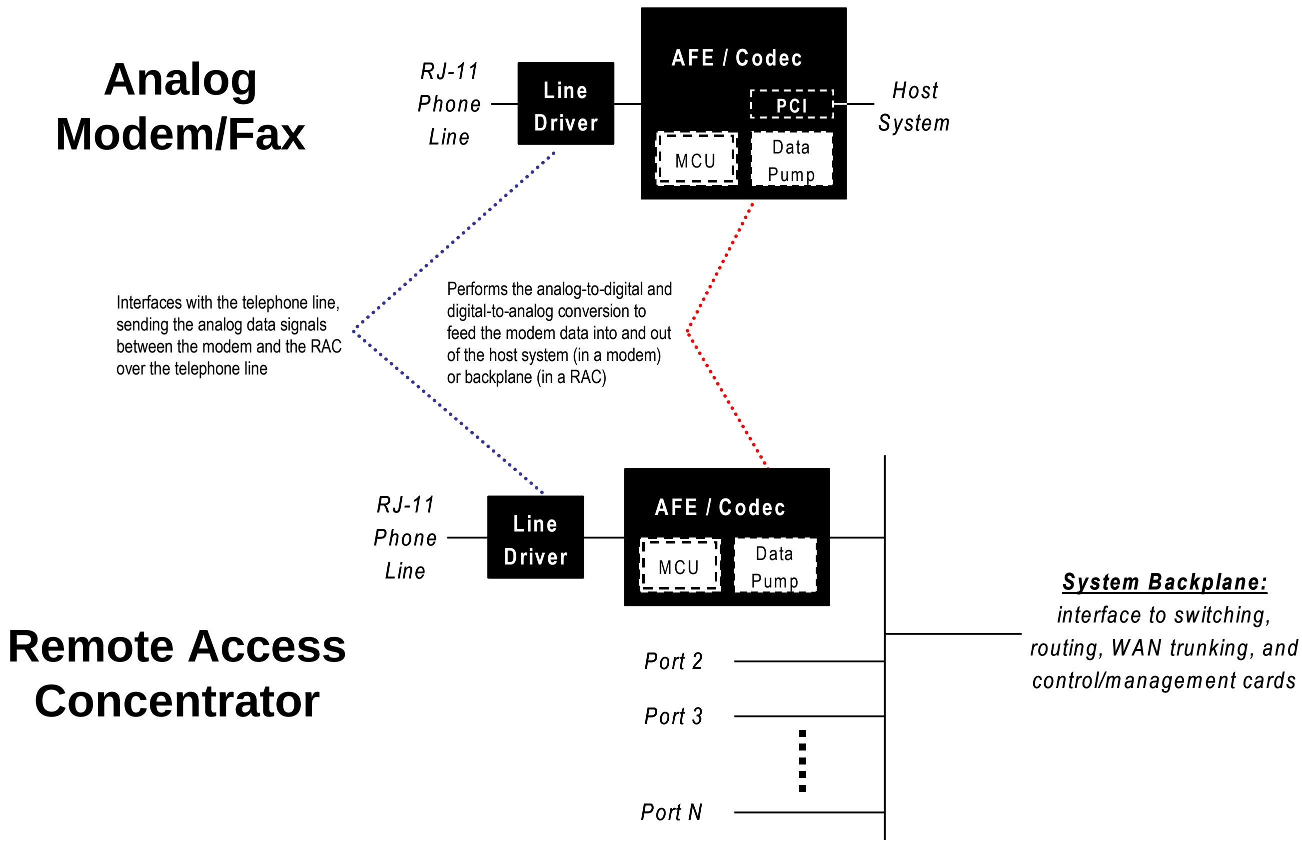
Analog Modem and Fax Unit Forecast: We expect the market for analog modems to face pressure as PC modem penetration rates drop to near-zero. Analog modem penetration in both desktop and notebook PCs has fallen dramatically as global broadband increases.

Outside of PCs, analog modems and faxes should see modest growth, primarily from multi-function peripherals which incorporate printer, scanner, copier, and fax functions in a single device. Embedded applications like satellite set-top boxes, vending machines, and point-of-sales devices should also see modest growth.

In total, we expect analog modems and fax units to decline at a 4% CAGR, from 109 million units in 2010 to 90 million units in 2015. Shipments peaked in 2005 at 188 million, but the negative CAGR will likely stabilize in 2012 when PCs become disproportionately small relative to embedded, fax and MFP.

Analog Modem and Fax Suppliers: Analog modems ship into a variety of applications including PCs, MFPs, faxes, and RACs. From a unit perspective, PCs have historically been the largest market, but will likely be surpassed by RACs in 2011. Hence, the largest modem "suppliers" are and have been PC makers HP, Dell, Lenovo, Acer, Toshiba, and Fujitsu/Fujitsu-Siemens. Outside of PCs, MFPs and faxes are also big consumers of modems and top suppliers include HP, Canon, Epson, Lexmark, Brother and Samsung. Top satellite set-top box makers include Thomson, Echostar, Pace, Tongda and Humax. On the infrastructure side, top suppliers of RACs include Alcatel-Lucent, Nortel, HP, Cisco, and UTStarcom.

Modems



Source: Oppenheimer & Co.

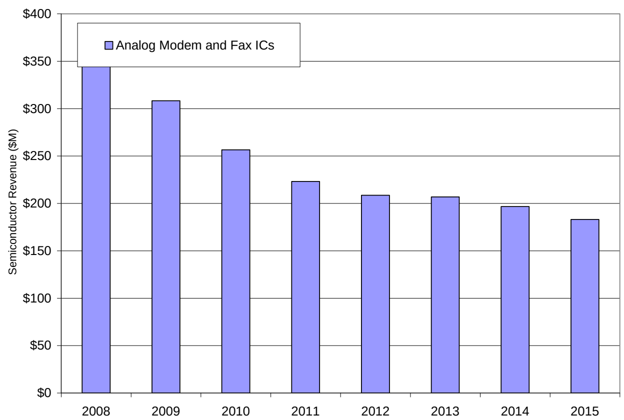
Note: Our modem block diagrams, semiconductor forecast, and associated discussion include all semiconductors included in modem CPE, in embedded modem/fax subsystems within MFPs, set-top boxes, fax machines, and other embedded fax/modems, as well as those modem-specific ICs found on remote access concentrator line cards. We do not include those devices used in switching, routing, WAN trunking, and control/management cards, as these are not protocol dependent and can vary greatly depending on the functionality of the system. We discuss these ICs separately in the communications infrastructure section.

- **Line Driver**: This analog SLIC interfaces with the RJ-11 copper twisted pair (phone line), performing transmission and reception functions.
- **Analog Front End (AFE)/Codec**: The AFE/codec performs the analog-to-digital conversion, interfacing between the line driver and the host system (in a PC modem) or switch fabric (in a RAC). Modem codecs are specialized processors and typically include a data pump, embedded microcontroller and PCI interface. Fax codecs are similar but will often incorporate different software and features.

Modems

Analog Modem and Fax Semiconductor Forecast

•We expect analog modem and fax ICs to decline over the next 5 years as units drift downward before stabilizing as PC penetration nears zero.
•ASPs should edge lower, as the positive mix shift away from desktop PCs is more than offset by the steady move to embedded applications.
•Overall, we expect IC revenue to decline from $256 million in 2010 to $183 million in 2015, a negative 7% CAGR.



Source: IDC, Dell'Oro, Dataquest, Oppenheimer & Co.

Analog Modem and Fax Semiconductor Competitors

Conexant
Silicon Laboratories
LSI
Austria Microsystems
Analog Devices
STMicro
Winbond
Freescale

Source: Dataquest, Oppenheimer & Co.

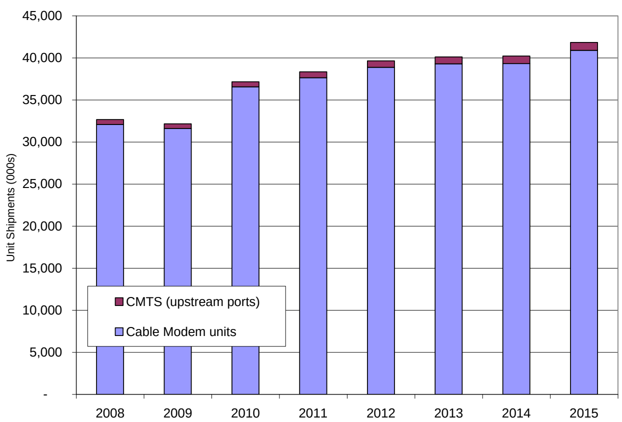
Analog Modem and Fax Semiconductor Forecast: We expect analog modem and fax ICs to decline over the next five years as unit shipments shrink and semiconductor price declines chip away at market revenue. The positive mix shift away from desktop analog modems to higher-ASP embedded modems should be more than offset by the move to softmodems in some embedded applications (we saw this happen in 2008 in set-top boxes). Overall, we expect IC revenue to decline at a 7% rate, from $256 million in 2010 to $183 million in 2015.

Analog Modem and Fax Semiconductor Competitors: The market for analog modem and fax ICs is highly mature and consolidated. The top vendors included Conexant, Silicon Labs, and LSI. Other analog modem vendors include Austria Microsystems, Analog Devices, STMicroelectronics, Winbond Electronics, and Freescale.

Modems

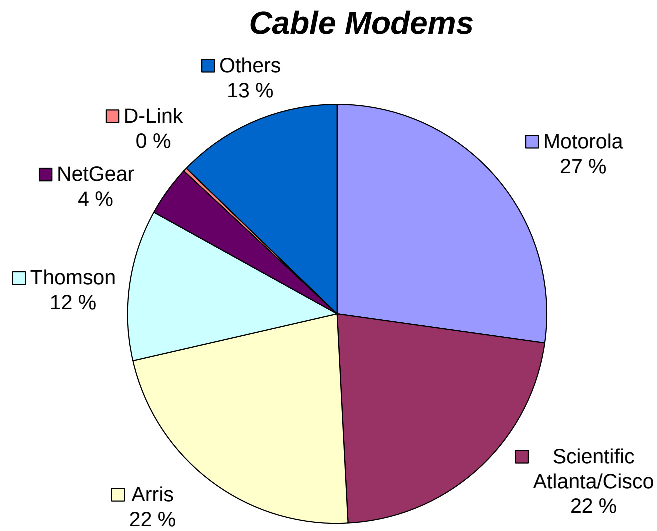
Cable Modem Unit Forecast

•We expect cable modem unit shipments (includes CMTS ports) grow slowly, from 37.1 million units in 2010 to 41.8 million units in 2015.
•Growth has slowed as penetration rates plateau; competing technologies such as VDSL and FTTX may also play a factor.
•Cable modems incorporating WLAN and VoIP will drive some incremental churn.
•DOCSIS 3.0 rollouts are underway.



Source: Dell'Oro, IDC, Dataquest, Oppenheimer & Co.

Cable Modem Suppliers

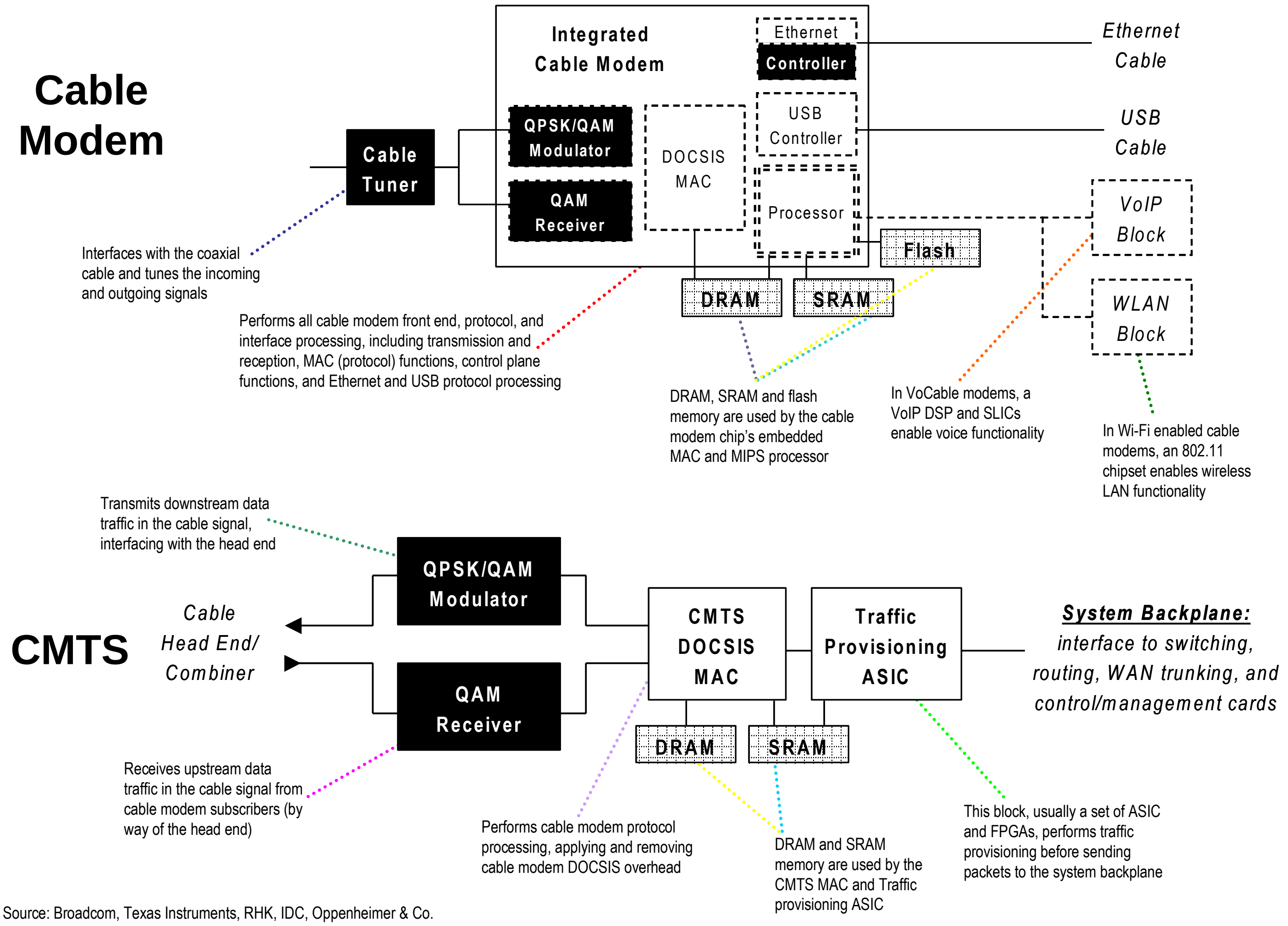


Source: Dell'Oro, Oppenheimer & Co.

Cable Modem Unit Forecast: Cable modem demand surged in the decade through 2008 as MSOs rolled out additional services and penetration neared the point of saturation. From under one million units shipped in 1998, the market reached 37.1 million units in 2010. Going forward, we expect more moderate as cable modem service penetration peaks (note that cable is primarily a U.S. phenomenon). Competing technologies such as VDSL and FTTX may also play a factor in muting growth prospects as U.S. telecom providers bolster the performance of their broadband offerings. However, as cable modems increasingly integrate WLAN and VoIP, and with the rollout of DOCSIS 3.0, we continue to expect incremental growth in total units. In total, we expect modems to grow slightly from 37.1 million units in 2010 to 41.8 million units in 2015.

Cable Modem: In 2010, Motorola led the cable modem market with 27% unit share. Cisco (Scientific Atlanta) followed with 22%. Arris was third with 22%, and Thomson rounded out the top vendors with 12% share. Other suppliers include NetGear and D-Link.

Modems



Source: Broadcom, Texas Instruments, RHK, IDC, Oppenheimer & Co.

Note: As in the analog modem section, our cable modem block diagrams, semiconductor forecast, and associated discussion include all application-specific semiconductors found in cable modem CPE and on CMTS line cards. We do not include those devices used in switching, routing, WAN trunking, and control/management cards, as these are not protocol dependent and can vary greatly depending on the functionality of the system. We discuss these ICs separately in the communications infrastructure section.

Also note that in most block diagrams in this report, we separate out IC functionality as if there were no integration to better illustrate what functions designers need in order to implement a specific application. Cable modems, however, are almost entirely based on integrated cable modem chip designs. Therefore, we picture the modem as such above.

Cable Modem CPE

- **Cable Tuner**: The tuner tunes the cable RF frequency for transmission and reception to and from the cable system. Older models use a can tuner, while newer designs use silicon tuners or a tuner block integrated into the cable modem chip.
- **Integrated Cable Modem**: The integrated cable modem includes front end processing (QPSK/QAM modulation for transmission and QAM demodulation for reception), the DOCSIS MAC (media access controller), an embedded processor and interface controllers (usually an Ethernet MAC/PHY and a USB controller). Newer cable modem chips sometimes include an integrated tuner.
- **SRAM, DRAM, flash**: Memory used by the embedded processor and DOCSIS MAC within the cable modem chip.

- **Ethernet PHY** (not shown in diagram): Some older cable modem SoC designs incorporate only the Ethernet MAC, requiring an external PHY IC to interface between the cable modem system and the Ethernet cable.
- **Ethernet Switch** (not shown in diagram): Though the basic cable modem needs only one Ethernet port to interface with the PC or wired network, newer residential gateways that include voice and wireless LAN functionality alongside the modem often include multiple Ethernet ports. These are usually implemented with a single-chip Ethernet switch, which includes Ethernet PHY, MAC, and switch functions; sometimes these functions are included in the cable modem SoC. Most gateways have 4-5 ports of 10/100 Ethernet, though this can vary.

VoIP Block *(VoCable Modem Only)*

- **VoIP DSP** (not shown in diagram): A VoIP packet processor DSP performs the TDM-to-IP conversion on IP-based phone calls. Integrated codecs perform the analog-to-digital and digital-to-analog conversion. Note that newer cable modem SoC designs often include a VoIP DSP.
- **Line driver/SLIC** (not shown in diagram): This SLIC is a line driver that interfaces with the telephone line, sending and receiving the analog signals to and from analog telephones.

Wireless LAN Block *(Wi-Fi Enabled Cable Modem Only)*

- **Power Amp** (not shown in diagram): The power amp sits in front of the antenna and boosts signal strength.
- **RF/IF Converter (RF)** (not shown in diagram): The RF front end controls the radio wave generation on the transmit side and receives the radio wave signal on the receive side, translating between low-frequency analog signals used by the system (specifically by the IF transceiver) to high-frequency RF signals used in radio communications. In newer implementations, the RF converter and IF are integrated in a single direct conversion transceiver, as shown in the block diagram above.
- **I/Q Modem (IF)** (not shown in diagram): The IF performs all quadrature modulation of “I” and “Q” baseband signals, converting the analog radio signal to a digital stream to be processed by the baseband and vice versa. In most implementations, the IF is integrated with the RF in a single direct conversion transceiver, as shown in the block diagram.

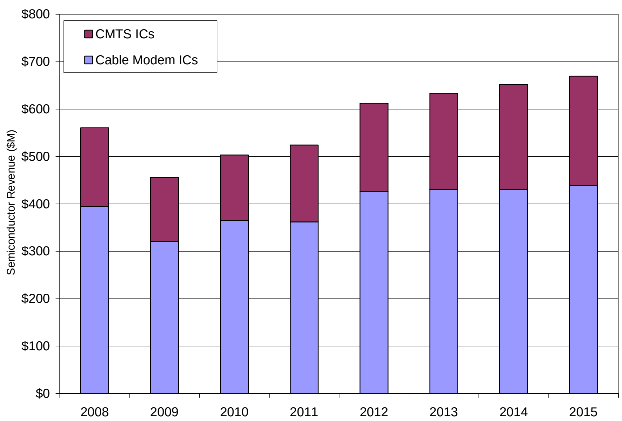
Cable Modem Termination System (CMTS)

- **QAM Receiver/Demodulator**: The QAM demodulator receives upstream data traffic in the cable signal from cable modem subscribers.
- **QPSK/QAM Modulator**: The QPSK/QAM modulator transmits downstream data traffic in the cable signal.
- **CMTS DOCSIS MAC**: The MAC performs protocol processing, assigning and removing DOCSIS overhead on the data packet.
- **Traffic Provisioning ASIC**: This block, usually a series of ASICs and FPGAs, performs traffic provisioning before forwarding packets to the system backplane.
- **DRAM and SRAM**: DRAM and SRAM memory is used both by the DOCSIS MAC and the traffic provisioning ASIC.

Modems

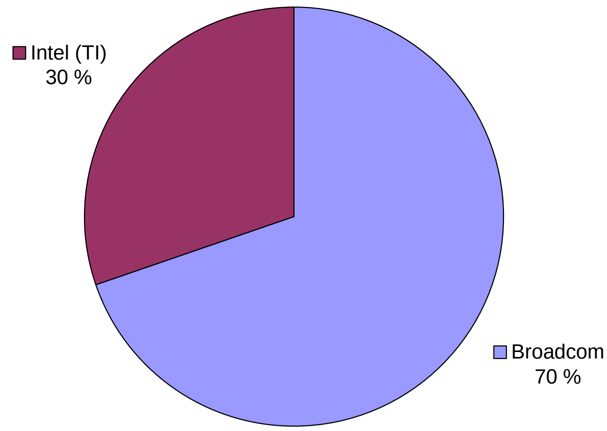
Cable Modem Semiconductor Forecast

- We expect cable modem IC revenue to grow at a 6% CAGR, from $503 million in 2010 to $669 million in 2015.
- ASPs should remain relatively stable on the modem side as VoIP, WLAN and additional radio functionalities are integrated into the SoC.
- Some functionality, particularly for #2 Intel, will remain discrete to capitalize on component supplier performance advantages.



Note: Discrete WLAN and VoIP ICs used in cable modems are captured in our semiconductor forecasts for those categories.
Source: IDC, Dataquest, Dell'Oro, RHK, Oppenheimer & Co.

Cable Modem Semiconductor Competitors



Note: Market share data excludes discrete WLAN and VoIP components as well as ICs for the CMTS.
Source: Linley, Oppenheimer & Co.

Cable Modem Semiconductor Forecast: We expect cable modem ICs to grow at a modest rate over the next few years on account of the slow unit growth. Semiconductor revenue should actually outpace units, as IC suppliers slowly but steadily integrate more functionality into the cable modem SoC, specifically VoIP and WLAN. Penetration of these functions is already quite healthy today and is rising quickly, aided by the deployment of DOCSIS 3.0 in developed markets. We believe that modem SoCs will continue to penetrate the market over time, gradually increasing ASPs.

Infrastructure ICs should remain roughly flat, as ASP declines and denser solutions offset growth in ports.

In total, we expect the market for cable modem semiconductors to grow at a 6% rate, from $503 million in 2010 to $669 million in 2015. Modem ICs should remain around 70% of this revenue, with CMTS representing the balance.

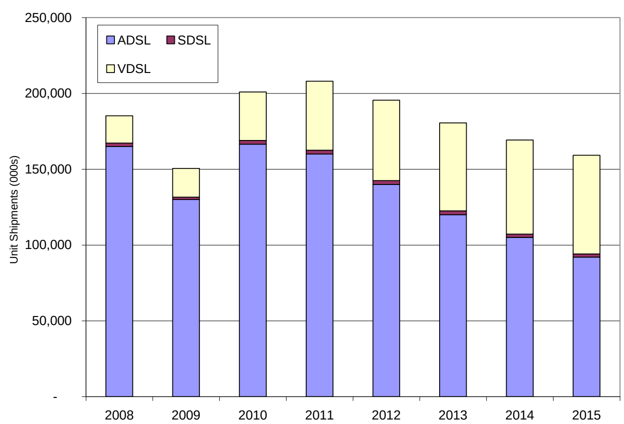
Cable Modem CPE Semiconductor Competitors: The market for cable modem semiconductors has remained very concentrated; with Broadcom commanding a 70% share of cable modem IC revenue in 2010 (excludes discrete WLAN, VoIP, and CMTS). Broadcom's flagship customer is Motorola, though the company also supplies Cisco, Thomson and Samsung as well as several ODMs. Intel bought the TI business and holds the No. 2 position with the remaining 30% share; INTC has begun to pick up incremental share from BRCM as it sources multiple component suppliers of tuners/demods/RF etc. that are able to offer superior performance relative to BRCM.

On the CMTS side, Broadcom dominates the market for merchant silicon, competing mostly with custom ASICs.

Modems

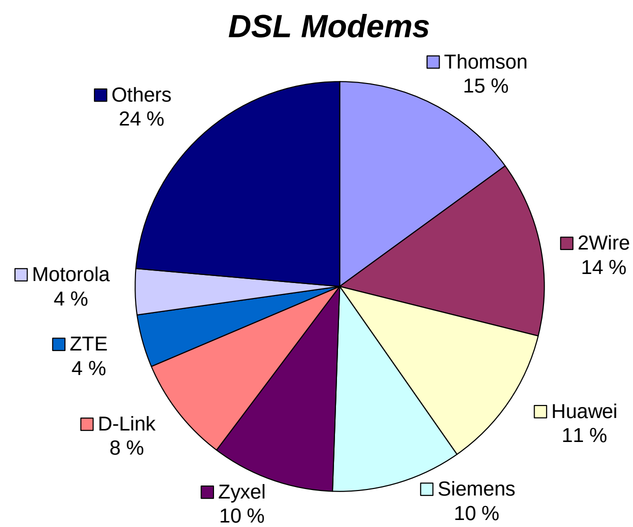
DSL Modem Unit/Port Forecast

•We expect DSL modem port shipments to decline at a 5% CAGR through 2015, falling from 200 million in 2010 to 159 million in 2015.
•ADSL units peaked in 2007 and will likely decline at an 11% CAGR through 2015.
•VDSL units saw explosive growth in 2010 and YTD 2011, but growth will likely slow as North America matures and Asia opts for fiber.



Source: Linley, IDC, Oppenheimer & Co.

DSL Modem Suppliers

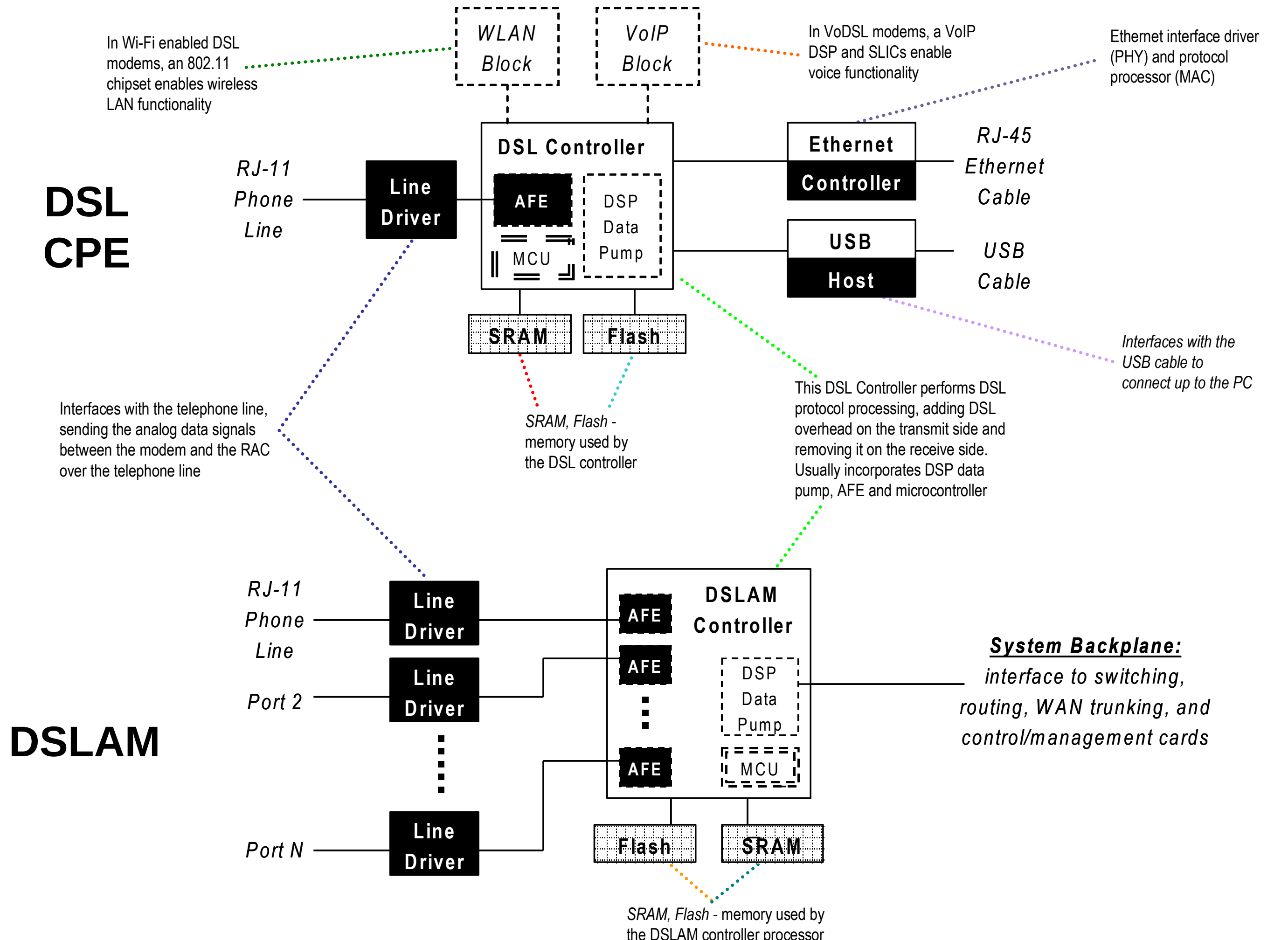


Source: Dell'Oro, Oppenheimer & Co.

DSL Modem Unit/Port Forecast: DSL demand surged through 2010 as voice telephony providers worldwide embraced residential broadband service and ultimately began to migrate from ADSL to high speed VDSL. The DSL market likely has, however, reached near saturation in most developed telecom markets. Looking ahead, we expect the market will peak in 2011, after which shipments should decline modestly driven by ADSL. While ADSL is clearly a mature and declining technology, pockets of growth remain in VDSL. VDSL is experiencing strong demand in Europe, but will likely be flat to declining in North America as the AT&T U-Verse rollout virtually stalls beginning in late 2011. VDSL is losing to fiber in Asia, likely stunting the total growth of VDSL going forward. In total, we expect DSL ports to decline at a 5% CAGR from 200 million in 2010 to 159 million in 2015.

DSL Modem CPE and Infrastructure Suppliers: The DSL modem market is highly fragmented. The largest suppliers in 2010 were Thompson with 15% unit share and 2Wire (acquired by Pace) with 14%. Huawei held 11%, while Siemens and Zyxel each held 10%. Other major suppliers included D-Link with 8% and ZTE and Motorola, with 4% each.

Modems



Source: IDC, Oppenheimer & Co.

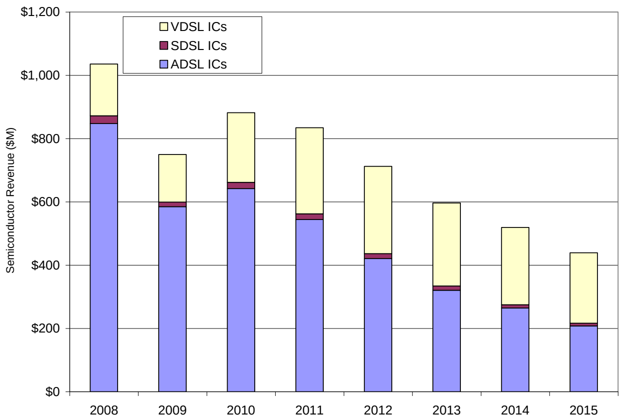
Note: As in the other modem sections, our DSL block diagrams, semiconductor forecast, and associated discussion include all semiconductors included in DSL modem CPE, as well as those on DSLAM line cards. We do not include those devices used in switching, routing, WAN trunking, and control/management cards, as these are not protocol dependent and can vary greatly depending on the functionality of the system. We discuss these ICs separately in the communications infrastructure section.

- **Line Driver**: The line driver interfaces with the RJ-11 phone line.
- **DSL/DSLAM Controller**: This controller includes a DSP data pump and analog front end. It also typically includes an embedded microcontroller or microprocessor for system control. DSLAM controllers include the same functions but can include multiple AFEs and a more robust DSP.
- **SRAM and Flash:** SRAM and flash memory are used by the DSL/DSLAM controller.
- **Ethernet Controller**: An Ethernet controller provides the interface between the modem and the PC or network.
- **USB Host**: Found in USB-enabled modems, the USB host interfaces between the modem and the host PC.
- **WLAN and VoIP block:** See the cable modem diagram on pp. 216-217 for a description of the devices found in these blocks.

Modems

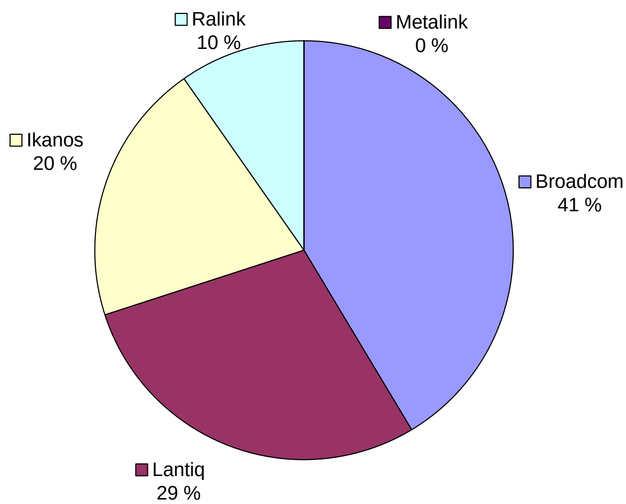
DSL Semiconductor Forecast

•We expect DSL IC revenue to decline 13% through 2015 to $439 million.
•A shift to higher-ASP VDSL should help offset some of the normal ASP erosion in this cost-sensitive market.
•VDSL IC revenue will likely peak in 2012 before succumbing to ASP declines and slower unit growth.
•ASPs will also be helped by the slow but steady integration of VoIP and WLAN functionality into the modem SoC.



Note: WLAN and VoIP ICs used in DSL modems are captured in our semiconductor forecasts for those categories.
Source: IDC, Linley Oppenheimer & Co.

DSL Semiconductor Competitors



Note: Market share excludes discrete WLAN and VoIP ICs.
Source: Linley, Oppenheimer & Co.

DSL Modem Semiconductor Forecast: We expect DSL IC revenue to decline at a 13% CAGR to $439 million in 2015. A steady decline in ADSL (negative 20% CAGR through 2015) should be offset slightly by a shift to higher ASP VDSL, which should peak in 2012 before succumbing to slower growth and ASP pressure. VDSL is likely to represent more than 50% of the market in 2015.

Similar to the trend in cable, IC suppliers are slowly but steadily integrating more functionality into the cable modem SoC, specifically VoIP and eventually WLAN. Penetration of these functions has risen quickly, though this has been mostly accomplished with discrete ICs. Like in cable, we believe OEMs will continue to use discrete ICs, though with each passing year a larger percentage of modem SoCs will include this function.

DSL Semiconductor Competitors: The DSL semiconductor landscape has undergone monumental consolidation since our last *Primer*. Broadcom has come to dominate both ADSL and VDSL and had 41% total market share in 2010. Lantiq is the spin-off of Infineon's wired-comm. business and held 29% share in 2010.

Ikanos acquired the DSL businesses of Centillium, Conexant and Texas Instruments; however, Ikanos' sales have declined since acquiring these assets and the combined entity has continued to lose market share to the two market share leaders. Ikanos has leveraged its future share on delivering fiber over traditional copper wires.

Ralink, which acquired TrendChip in 2010 to get into the DSL business, was itself acquired by the much larger Mediatek in early 2011. Ralink held the remaining 10% of the market in 2010. Market consolidation will likely continue as total IC revenue opportunity declines through 2015.

Modems

Modem Semiconductor Market Trends

•Pure play broadband semiconductor vendors are all but squeezed out.
•Wireless LAN and VoIP integration are becoming more important.

Analog Modem and Fax Semiconductors

•PC analog modem penetration continues to decline.
•Embedded modems are increasingly being implemented in software.

Cable Modem Semiconductors

•Churn and DOCSIS 3.0 are driving the market
•DOCSIS 3.0 deployments rapidly gained momentum and are driving a positive ASP mix shift for semiconductor suppliers
•The INTC acquisition of legacy TI cable modem business is pushing support for x86 set top box chips

DSL Modem Semiconductors

•Market share consolidation is happening quickly.
•Broadcom is the new 500lb gorilla.
•VDSL CPE port shipments were ~20% of the market in 2010 and growing.
•Multi-port data pumps are enabling higher density DSLAM line cards.
•DSLAMs are moving away from ATM backhaul toward IP.

- **Pure-play broadband semiconductor vendors are all but squeezed out.** The major modem vendors are adopting a diversified approach that includes DSL, cable, wireless LAN, and VoIP. Broadcom moved from cable modems to wireless LAN and DSL and also supplies VoIP ICs. Centillium, which struggled as a pure-play DSL vendor, and Conexant which had an emerging VDSL business, were each acquired by Ikanos. With less scale and less ability to integrate, however, the much smaller Ikanos has been squeezed by the larger Broadcom and Lantiq—and Ralink was acquired by Mediatek.
- **VoIP integration is becoming more important.** Voice-over-IP has started to gain steam as a residential service, as cable MSOs look to voice to drive additional revenue and, ultimately, as service providers explore Voice-over LTE wireless solutions. Most implementations to date have required that the modem (or home router) be connected to a VoIP terminal adapter, which interfaces with traditional analog telephones and provides voice service. Newer modem designs, however, incorporate VoIP functionality directly into the modem.
- **Wireless LAN is increasingly found in modems and will see some integration over time.** Wireless LAN technology has proven enormously popular for home networking, as consumers seek to share their broadband connection among the now vast array of connected devices. Newer modem designs are incorporating wireless LAN functionality directly into the modem. Most modem IC vendors have therefore aligned their chipset offerings to include an easy interface to wireless LAN chipsets. Some newer designs are sucking wireless LAN functionality directly into the modem IC.

Trends in Analog Modem and Fax Semiconductors

- **PC analog modem penetration continues to decline.** Broadband has taken a big bite out of analog modems—accelerated by aggressive pricing from service providers. Still, the majority of units are tied to PCs, and penetration should decline as broadband becomes even more pervasive.
- **Embedded modems are increasingly being implemented in software.** While some analog modem implementations (primarily in the embedded market) still include a discrete codec or controller IC, many new designs mimic the PC softmodem model, perform processing in software, leaving only the line driver/DAA external.

Trends in Cable Modem Semiconductors

- **Churn and DOCSIS 3.0 are driving the market.** According to market research firm Linley, the number of new cable subscribers grew roughly 11% in 2010 while shipments of cable modems grew 15%. While churn is likely to consistently drive some unit growth, the push for DOCSIS 3.0 drove, and is driving, incremental unit growth.
- **DOCSIS 3.0 deployments rapidly gained momentum and are driving a positive ASP mix shift for semiconductor suppliers.** Both Intel and Broadcom have seen adoption of DOCSIS 3.0 to date and remain the only two players in the market. Broadcom has begun to integrate components (WLAN, RF, etc.) into the modem, pushing ease-of-use, while Intel has remained a more discrete architecture, sourcing components from 3rd party semiconductor vendors and pushing performance advantage. In both scenarios, there is a lack of competition and the adoption of DOCSIS 3.0 is proving positive for ASPs.
- **The INTC acquisition of legacy TI cable modem business is pushing support for x86 set top box chips.** Intel acquired the TI cable modem business not exclusively for the cable modem business; but to begin to combine this with x86 STB architecture.

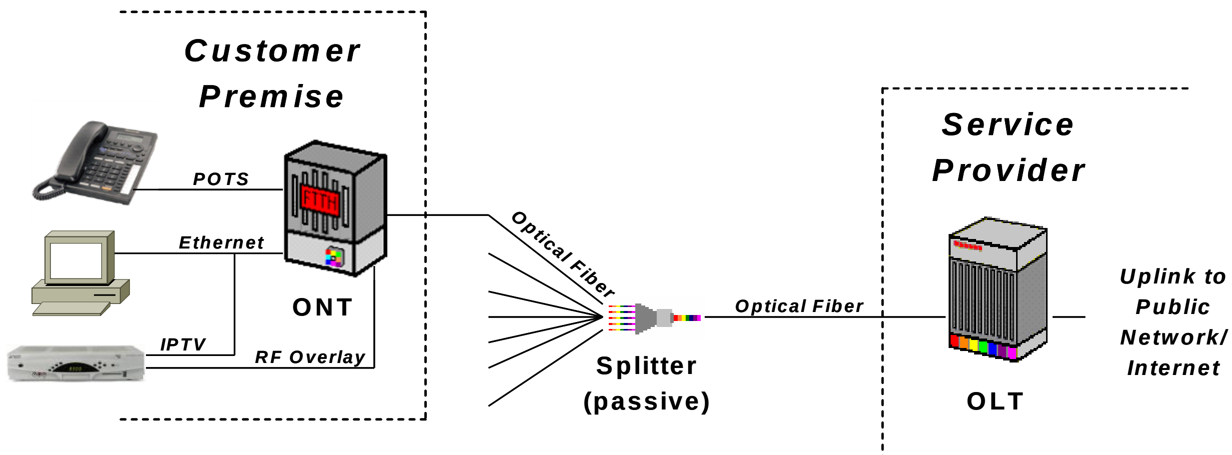
Trends in DSL Semiconductors

- **Market share consolidation is happening quickly.** Recognizing the declining state of the market and benefits of integration, the DSL market has consolidated market share since 2009. Lantiq was spun out of Infineon's wired communications business. Ralink first acquired TrendChip before itself being acquired by Mediatek. And Ikanos bought the DSL businesses of Centillium, Conexant and TI, consolidating the market to three primary players in addition to market share leader Broadcom.
- **Broadcom is the new 500lb gorilla.** Broadcom was a late arrival to the DSL market, but has continued to gain share and is now the dominant player in DSL. Broadcom has recently been the winner in both infrastructure and CPE; both ADSL and VDSL. Broadcom has won at the high end while Lantiq and Ralink have won at the low end, recently squeezing Ikanos in the middle.
- **VDSL CPE port shipments were ~20% of the market in 2010 and growing.** According to data from Linley, VDSL CPE port shipments were ~20% of the market in 2010, and VDSL port shipments experienced a record in 1Q11. VDSL has experienced strong growth in Asia and benefited in North America from the rollout of AT&T's U-Verse platform.
- **Multi-port data pumps and DSL PHYs are enabling higher density DSLAM line cards.** These high-density cards are enabling lower-cost DSLAMs.
- **DSLAMs are moving away from ATM backhaul toward IP.** This trend is discussed in the communications infrastructure section, since it does not really affect DSL-specific ICs as much as it affects backhaul ICs.

PON

Passive Optical Networking (PON) is a fiber-based access technology that allows service providers to deploy super-fast broadband access over optical fiber, usually referred to as Fiber-To-The-Home (FTTH). Passive splitters can be used in the field to split the optical signal into 16, 32, or even 64 channels without active switching components, dramatically lowering the cost vs. traditional metro Ethernet services.

FTTH Service Using PON



Source: Oppenheimer & Co.

Passive optical networking (PON) is a high-speed access technology that enables broadband access over optical fiber, sometimes called fiber-to-the-home (FTTH). The optical signals used in fiber-based networks are capable of achieving much higher data rates than the electrical signals that use the copper network (both the traditional POTS and coaxial cable networks). This allows for super-fast data access with a roadmap for IP-based video down the road.

In a PON system, access units called OLTs (optical light terminals) are installed in the service provider network, usually at the central office. Fiber runs from the OLT to a passive splitter out in the field, which splits the optical signal into 16, 32, or even 64 channels. Each channel is meant for an individual subscriber. Individual strands of fiber run from the splitter to customer premise units called ONTs (optical network terminals), which are installed on the exterior of the customer's home or apartment building. The ONT extracts the data (as well as TDM phone calls) from the PON signal and distributes it to the home PC or LAN over Ethernet (and POTS for the voice signals).

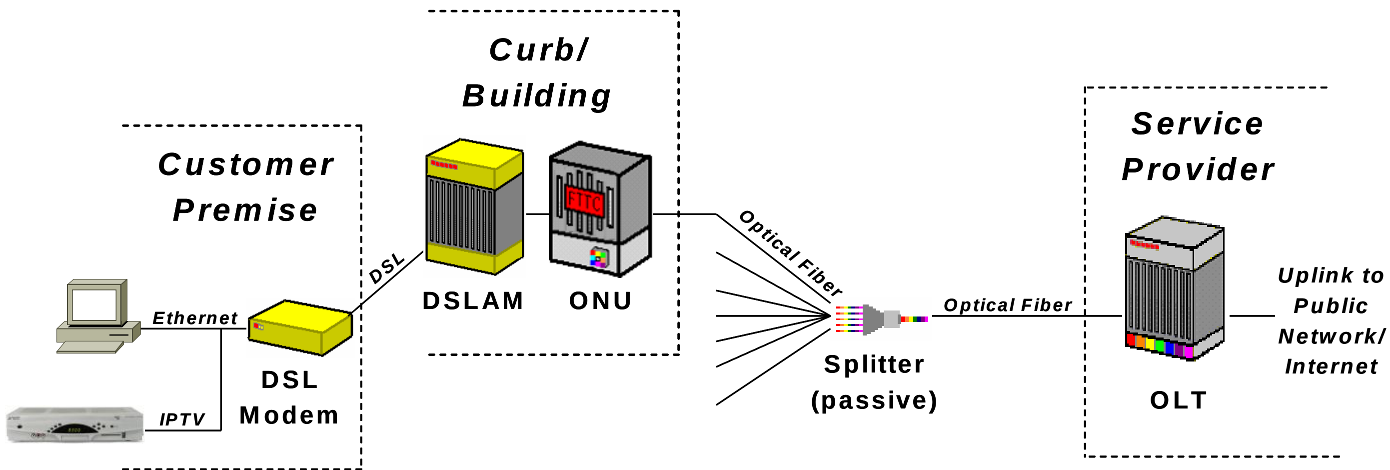
The key to PON technology is the use of passive splitters. These allow service providers to split off signals to individual subscribers without active switches, dramatically lowering the cost vs. traditional switched metro Ethernet services. It does, however, mean that bandwidth must be shared among all subscribers connected to the OLT.

A major driver for FTTH is the ability to provide video over the telecom network. This ideally is accomplished via IPTV, which would require an IP set-top box that is connected to the ONT. A less revolutionary option is an RF overlay; traditional RF cable signals are transmitted over the PON, and cable set-top boxes are connected to the ONT.

PON

Some service providers are hesitant to roll out full FTTH, but still want to bring fiber closer to their customers to boost data rates. In these Fiber-To-The-Curb (FTTC) or Fiber-To-The-Node (FTTN) networks, PONs extend the fiber network to within a few hundred feet of the customer, and high-speed DSL makes the final connection.

FTTC/FTTN Service Using PON



Source: Oppenheimer & Co.

Some service providers are hesitant to roll out full FTTH because of the high cost of ONTs and laying fiber around the neighborhood. They still want to bring fiber closer to their customers to boost data rates, however, and are able to leverage PON technology using a slightly different topology.

In these fiber-to-the-curb (FTTC) or fiber-to-the-node (FTTN) networks, PON technology extends the fiber network to within a few hundred feet of the customer, and high-speed DSL makes the final connection. Instead of ONTs at individual subscriber premises, the service provider installs ONUs (optical network units) in the neighborhood, at the curb, or even in the basement of a multiple dwelling unit. These ONUs interface with a small DSLAM, which distributes the signal to individual customers. Service providers are currently use VDSL2, ADSL2+, and bonded ADSL to provide this final connection, and OEMs are coming to market with equipment that merges the ONU and the DSLAM in a robust, flexible platform.

Note that FTTC/FTTN networks are capable of supporting IPTV video service, assuming the final connection has enough bandwidth to deliver the IPTV stream. They cannot, however, support the RF video overlay as in an FTTH network, since the RF overlay needs to be extracted at the customer premise.

PON

There Are Three Main PON Standards:

EPON/GE-PON – Ethernet/Gigabit Ethernet PON is based on Ethernet LAN technology. Upstream and downstream speeds can reach 1.25 Gpbs and can be split into 16 channels. EPON is now being deployed aggressively in Japan and Korea; Taiwan and China are also likely to deploy EPON.

BPON – Broadband PON is the most common ATM-based PON technology in place today and is set by the ITU. BPON supports upstream and downstream speeds of 155 Mbps or 622 Mbps, and can be split into 32 channels. BPON can also support an RF overlay for video. BPON is seeing deployment in the U.S.; Japan had BPON service but has since moved to EPON.

GPON – Gigabit PON is the successor to BPON. GPON supports downstream speeds of 1.24 Gbps and 2.5 Gbps and upstream speeds of 155 Mbps, 622 Mbps, 1.2 Gbps, and 2.5 Gbps. GPON can be split into 64 channels, and also supports an RF overlay. Carriers in the US and Europe are planning to deploy GPON.

There are three main standards of PON being deployed or developed:

EPON/GE-PON—Ethernet/Gigabit Ethernet PON is based on Ethernet LAN technology and is controlled by the IEEE, the same standards body that controls Ethernet and wireless LAN. Downstream speeds can reach 1.25 Gps and use the 1500-nm wavelength. Upstream speeds can also reach 1.25 Gps and use the 1310-nm wavelength. An EPON signal can be split into 16 channels with a maximum range of around 12 miles; it does not support an RF overlay. EPON is now being deployed aggressively in Japan and Korea; Taiwan and China are also likely to deploy EPON.

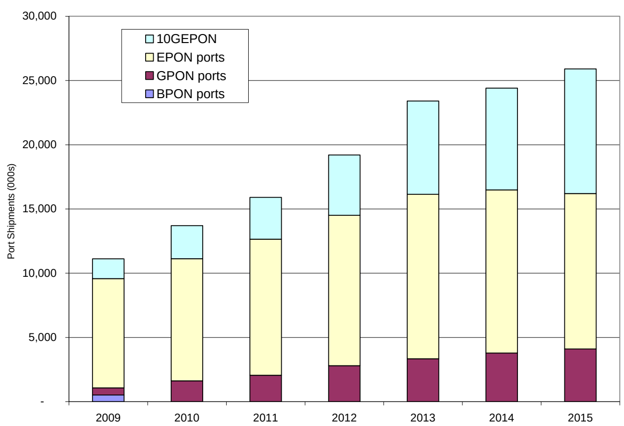
BPON—Broadband PON is the most common ATM-based PON technology in place today and is set by the ITU. BPON supports downstream speeds of 155 Mbps or 622 Mbps, and use wavelengths of 1480-1500-nm. Upstream speeds are 155 Mbps or 622 Mbps, and use wavelengths of 1260-1360-nm. BPON can be split into 32 channels with a range of about 12 miles; it can also support an RF overlay for video using the 1550-nm wavelength. BPON is seeing deployment in the U.S.; Japan had BPON service but has since moved to EPON.

GPON—Gigabit PON is the successor to BPON. GPON supports downstream speeds of 1.24 Gbps or 2.5 Gbps, and like BPON uses wavelengths of 1480-1500-nm. Upstream speeds are 155 Mbps, 622 Mbps, 1.24 Gbps or 2.5 Gbps, and use wavelengths of 1260-1360-nm. GPON can be split into 64 channels with a range of about 37 miles; like BPON it can support an RF overlay for video using the 1550-nm wavelength. Carriers in the US and Europe are finalizing plans to deploy GPON.

PON

PON Port Forecast

•We expect total port shipments to grow at a 14% CAGR, rising from 13.7 million in 2010 to 25.9 million ports in 2015.
•Early EPON deployments happened in Japan and Korea; China is transitioning from EPON to GPON.
•10GEPON port shipments are likely to grow most rapidly, at a 30% CAGR to 9.7 million port shipments in 2015.



Source: IDC, Linley, Oppenheimer & Co.

PON Equipment Suppliers

BPON/GPON

Tellabs
Motorola
Alcatel-Lucent
Entrisphere/Ericsson
Calix
Terawave
Wave7
Flexlight
Hitachi

EPON

Japan	*Korea*
Mitsubishi/Melco	Dasan
Sumitomo	Tellion
UTStarcomm	Samsung
Fujitsu	Corecess
NEC	
Oki	*Others*
Hitachi	Huawei
	ZTE
	FiberHome
	Allied Telesyn
	Wave7

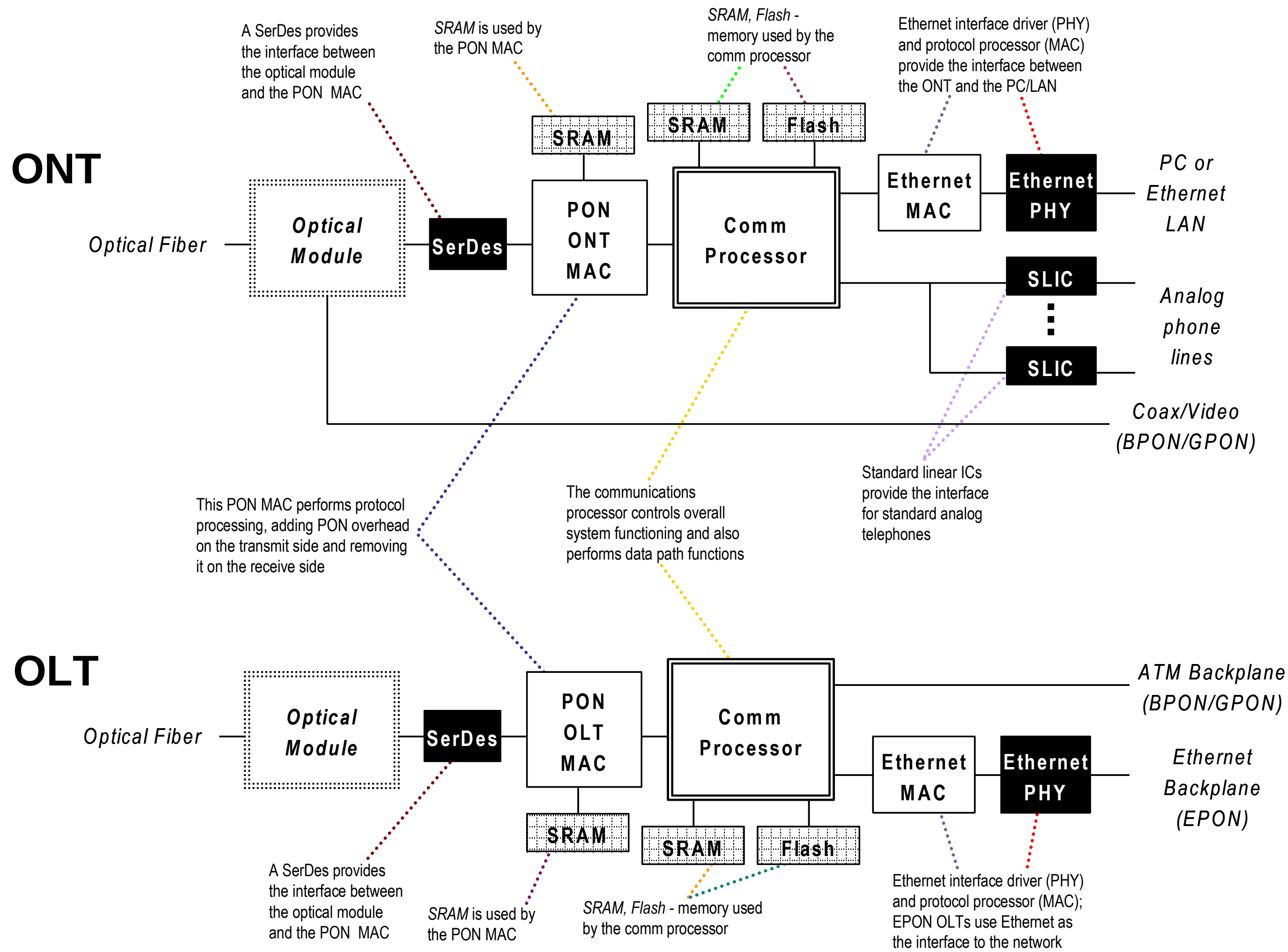
Source: Dell'Oro, IDC, Oppenheimer & Co.

PON Port Forecast: The PON market has strong growth prospects as carriers have become more aggressive with fiber deployments. Japan and Korea were early to deploy EPON, China will continue to roll out both EPON and GPON. 10Gigabit EPON deployments are likely to come from US cable operators and, later, from upgrades in Japan and Korea.

In total, we expect PON port shipments to grow at a 30% CAGR, from 13.7 million ports in 2010 to 25.9 million units in 2015. This includes both infrastructure and CPE. EPON should decline slightly as a percentage, from 69% in 2010 to 47% in 2015, with 10GEPON rising from 19% to 37% and GPON representing the bulk of the rest. From an equipment perspective, we expect the ONT/OLT ratio to modestly decline from 19:1 in 2008 to 18:1 in 2015.

PON Equipment Suppliers: There are currently two PON standards being deployed today, EPON for the Asian market and BPON/GPON for U.S. deployments; with a discrete set of suppliers for each. The top suppliers of EPON equipment in Japan are Mitsubishi/Melco, Sumitomo, UTStarcom, Fujitsu, NEC, and Oki, while Korea is served by Dasan, Tellion, Samsung, and Corecess. The top suppliers of BPON/GPON equipment are Tellabs, Motorola, and Alcatel, as well as several start-ups.

PON



Source: Ovum-RHK, Oppenheimer & Co.

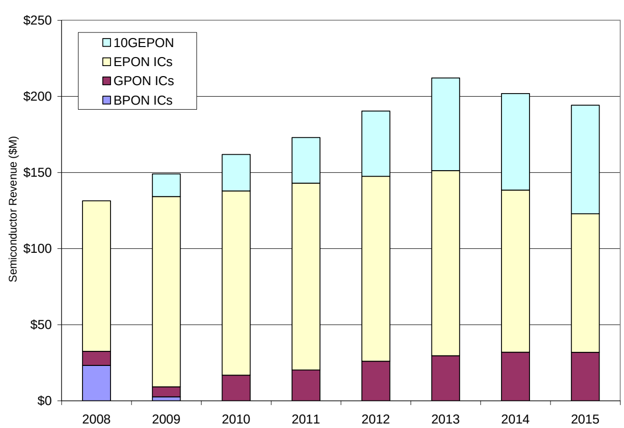
The devices found in PON equipment are not dissimilar from those in traditional broadband modems. The big exception is the optical module, which interfaces with the optical fiber.

- **PMD ICs** (inside optical module, not shown in diagram): Physical Medium Dependent (PMD) ICs like laser drivers, limiting amps, and transimpedence amps are found inside the optical module and control the interface.
- **SerDes:** The SerDes provides the interface between the optical module and the PON MAC. In newer ONT designs, the SerDes is integrated with the MAC.
- **PON MAC:** The PON MAC performs basic protocol processing, adding PON overhead on the transmit side and removing it on the receive side.
- **Comm. Processor:** The comm. processor controls overall system functioning and some data path functions.
- **SRAM and Flash:** Memory used by the communications processor; the PON MAC also uses some SRAM.
- **Ethernet MAC and PHY:** In an ONT, the Ethernet MAC and PHY provide the interface between the ONT and the host PC or Ethernet LAN. The Ethernet MAC is sometimes integrated with the PON MAC/processor. In an OLT, the Ethernet MAC and PHY feed traffic into the WAN (they are only used in EPON systems).
- **SLIC** (ONT only)**:** Standard linear ICs interface with analog telephone lines, allowing traditional telephones to be used over the PON.

PON

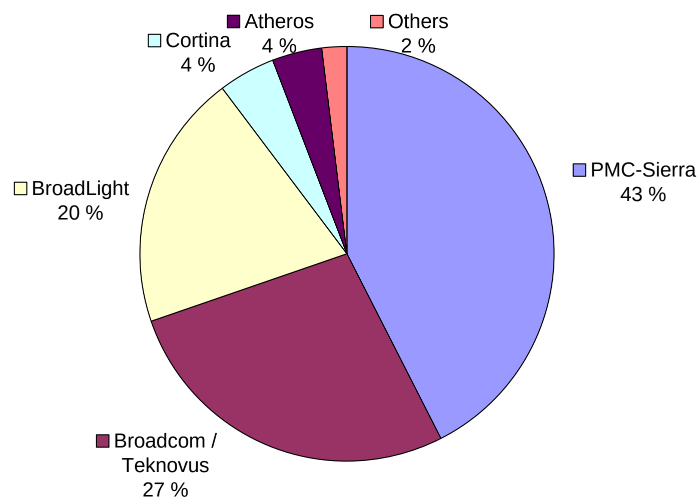
PON Semiconductor Forecast

- We expect the PON IC market to grow at a 4% CAGR, from $162 million in 2010 to $194 million in 2015; revenue is expected to peak in 2013.
- EPON ICs represented most of the growth over the past few years as PON ramped in Asia and will continue with strength in GEPON.
- GPON has experienced traction in the US with the rollout of Verizon's FTTH network.
- By 2015, we expect EPON IC revenue to represent most of the total market revenue, at 84%.



Source: IDC, Linley, Oppenheimer & Co.

PON Semiconductor Competitors



Source: Linley, Oppenheimer & Co.

PON Semiconductor Forecast: PON semiconductor revenue ramped quickly through 2010, driven by aggressive PON deployments in Japan, U.S. and Asia. Moving forward with slowing growth in total port shipments and ongoing price declines, we forecast just a CAGR of 4%, from $162 million in 2010 to $194 million in 2015. An ongoing shift into 10GEPON with new deployments and upgrades will likely have a positive effect on ASPs through 2013 before giving way to market pricing.

PON Semiconductor Suppliers: The top supplier of PON semiconductors in 2010 was PMC-Sierra, with 43% revenue share, down from 51% share as recently as 2008. The top three market players have consolidated 13% market share in the past two years, taking 90% in 2010 compared with 77% in 2008. Broadcom's acquisition of Teknovus helped it gain ten points of share through 2010, with big wins in the Asian EPON market and the integration of moca home networking into GPON for the North American market. Broadlight followed with 20%, while Cortina and Atheros (now Qualcomm) each held 4%.

PMD suppliers for PON optical modules include Mindspeed, Maxim, and Vitesse.

PON

PON Semiconductor Market Trends

•IC vendors are targeting the U.S. market with GPON solutions.

•10GEPON deployments are likely to gain steam from US cable operators and upgrades in Japan and Korea.

•MAC solutions are evolving into PON SoCs with integrated SerDes, communications processors, and memory.

•FTTC networks will use “cabinet” solutions that integrate a PON ONU with a DSLAM.

- **IC vendors are targeting the U.S. market with GPON solutions.** The U-Verse and FiOS offerings from AT&T and Verizon saw strong growth through mid-2011 but are likely to slow into 2012. IC vendors are attempting to capitalize on the move to higher speed GPON, a list that includes those coming from the BPON world (e.g., Broadlight and Broadcom) and the EPON world (e.g., PMC-Sierra). Google’s fiber buildout will be another key driver to keep an eye on.
- **10GEPON deployments are likely to gain steam from US cable operators and upgrades in Japan and Korea.** Driven by adoption from US cable operators, and ultimately, EPON network upgrades in Korea and Japan, the 10GEPON market will likely be the most rapidly growing PON market through 2015. 10GEPON will likely represent 37% of port shipments in 2015.
- **MAC solutions are evolving into PON SoCs with integrated SerDes, communications processors, and memory.** Though earlier designs were built with discrete MAC, SerDes, and processor ICs, the major PON IC vendors are now in the market with SoC solutions that include these functions on a single chip.
- **FTTC networks will use “cabinet” solutions that integrate a PON ONU with a DSLAM.** OEMs targeting service providers that are adopting a FTTC (fiber to the curb) approach (e.g., AT&T) are developing “cabinet” systems that integrate a PON ONU with a DSLAM (ADSL2+ or VDSL/VDSL2). This will leverage the speed of PON without requiring a fiber connection all the way to the home.

Communications Infrastructure

This section covers communications infrastructure equipment, a broad category that includes equipment used to switch, route, and manage voice and data traffic in both service provider and enterprise networks.

Included are a wide variety of dedicated infrastructure equipment, such as routers, digital cross connects, add/drop multiplexers, and multi-service switches.

We also include here the switching, routing, traffic management, and control plane functions (and their semiconductors) that are embedded in data networking, access, and wireless infrastructure devices that are also discussed in other sections of this report. Key examples include routing functions in layer 3+ switches, aggregation, routing, and WAN interface functions in modem concentrators, PON OLTs, and central office switches, and backhaul for wireless basestations.

This section covers communications infrastructure equipment, a broad category that includes equipment used to switch, aggregate, route, and manage voice and data traffic in both service provider and large enterprise networks. Included are a wide variety of dedicated infrastructure equipment, such as routers, digital cross connects, ATM switches, multi-service provisioning platforms, and optical transport equipment.

We also include here the switching, aggregation, routing, traffic management, and control plane functions that are embedded in data networking, access, and wireless infrastructure devices that are also discussed in other sections of this report. Key examples of this include routing functions in layer 3+ switches, backhaul for wireless basestations, and WAN interface functions in modem concentrators, PON OLTs, central office switches, and PBXs. One notable exception is the switching function used in Ethernet LAN equipment; we include those ICs in the Ethernet section instead of here, as LAN switching is highly specialized for that application.

Note that a unit forecast is somewhat irrelevant; we therefore display our forecast for infrastructure equipment (both for carrier and enterprise) in revenue terms. On the semiconductor side, we forecast revenue for specific ICs, e.g., T/E and SONET framers and PHYs, ATM UNIs and SARs, NPUs, and switch fabrics. Note that in all cases, the forecast excludes all protocol-dependent ICs that are discussed in other sections (e.g., DSLAM PHYs, analog line card SLICs, PON OLT MACs, baseband ASICs); while the other sections exclude all ICs used in switching, routing, traffic management, and system control (e.g., network processors, control plane processors). Again, the one notable exception is Ethernet LAN switching, where we include switch fabric ICs in the Ethernet section instead of here.

Communications Infrastructure

The Primary Functions of Infrastructure Equipment

Though communications infrastructure equipment vary widely in application and capability, the functions they can perform are common across equipment types:

•**Transport** – moving traffic between network nodes, using copper, fiber, or coax network links external to the device.

•**Switching** – forwarding traffic between ports within a given piece of equipment.

•**Aggregation** – combining multiple smaller, slower streams into larger, faster streams.

•**Routing** – forwarding traffic by first determining the optimal path through the network.

•**Traffic Management** – prioritizing the movement of traffic based on content type, service level agreements, or other rules/algorithms.

•**Security/Access Control** – determining if a given packet or data stream should be allowed access to the network.

•**Control Plane** – management of the overall system including sub-systems listed above.

Communications infrastructure equipment can vary widely in terms of capability and application. The functions they can perform, however, are pretty common across device types. These include:

- **Transport** –moving traffic between network nodes, over network links external to the device. Most of the equipment discussed in this section uses optical fiber for transport, though copper can be used at lower speeds.
- **Switching**—forwarding traffic between ports within a given piece of equipment. This can be done either over a backplane or within a separate switching sub-system.
- **Aggregation** (also called multiplexing)—combining multiple smaller, slower streams into larger, faster streams.
- **Routing**—determining the optimal path through the network, and directing traffic accordingly.
- **Traffic Management—**prioritizing the movement of traffic based on content type, service level agreements, or other rules/algorithms. Traffic management is related to “QoS” (quality of service); infrastructure equipment can only insure a certain level of quality of service by managing the flow of traffic based on what is in the data stream.
- **Security/Access Control**—determining which packets or data streams should be allowed access to the network.
- **Control Plane—**management of the overall system, including sub-systems that perform the above-mentioned transport, switching, aggregation, routing, security, and traffic management.

Communications Infrastructure

Line Card and Chassis Systems

Infrastructure equipment is often implemented in a chassis/line card configuration. Individual cards drive transport links, and can also add switching, routing, traffic management, and system control functionality.

Telecom and datacom equipment OEMs design their carrier and large enterprise offerings to be robust, redundant, and extremely flexible. Carriers need to adjust the voice and data capabilities of their network nodes depending on local factors, and need to be able to change these capabilities as those factors change. On the enterprise side, IT managers need to have a great deal of control over the allocation of network resource among users; they also need a network that is scalable, secure, and easy to upgrade and manage. In either case, system flexibility, scalability, security, and upgradeability can be just as important as performance and general robustness of the system.

This has prompted OEMs to design their large enterprise carrier grade systems in a chassis/line card configuration instead of enclosed discrete devices like modems or access routers. Using this architecture, carriers install a chassis, which is essentially an empty metal box equipped with a backplane, power supply, and cooling system; and populate the system with line cards to suit the needs of the network node. Cards can be installed and removed at will, protecting the initial investment in the platform while allowing for future upgradeability.

Line Cards

There are four main types of line cards found in infrastructure equipment. Each line card contains a backplane interface used to communicate with the other cards within the overall system and to pass traffic back and forth.

- **I/O Line Cards:** These cards include one or more ports used to send traffic back and forth over the broader network. These can include fiber or copper ports for POTS, DSL, DOCSIS, T/E, SONET, Ethernet, PON, or any other networking technology. Some I/O line cards support shorter-range technologies like ATM UNI or Infiniband for communication with other equipment within the network node.

- **Switching Cards:** These cards include switch fabric arrays, and are used to switch traffic between the I/O cards in the chassis.
- **WAN Trunking Cards:** For systems that interface with individual users (like modem aggregators or class 5 switches), a WAN trunking card provides the high-speed uplink into the larger network. The WAN trunking card can contain routing functionality on it, though sometimes routing functions are integrated on individual line cards or conversely on a central routing card.
- **Management/Control Cards:** These cards are used to control the overall system. They can also perform special functions on the data path when there are exceptional packets. Security/access control can be performed by the management card or on a discrete security card. Traffic monitoring can be implemented in the same fashion.

Besides I/O, switching, trunking, and management, other line cards or modules can be added to perform periphery functions. Examples include LAN interface cards, test cards, and modules with optical drives embedded in them.

The type of line cards used in each system will depend on the functionality of the system and its location in the network. An add/drop multiplexer will likely have several high-speed line cards and a switch card, along with the management card. A digital cross connect will likely have a variety of line cards of varying speeds along with a set of robust switch cards, and the management card. A class 5 switch will have hundreds of individual line cards for POTS access, a switch card, a WAN trunking card for interface to the PSTN, and the management card. A DSLAM will have several multi-port DSL I/O cards, a switch card, a WAN trunking card, and the management card. A wireless base station will have several transceiver cards (essentially I/O line cards, but wireless), a WAN uplink card, a management card, and several cards that are specific to wireless (like baseband processing and power amplifier cards). A core router will have several high-speed I/O cards, several switch cards, and a robust set of management/control cards.

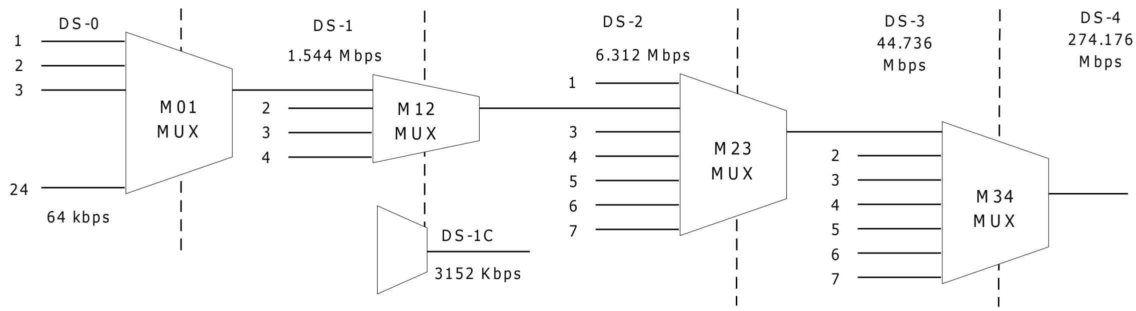
In terms of our forecast, we include all the content on switching cards, WAN trunking cards, and management cards. We also include the content on line cards for SONET, T/E, and ATM. We exclude, however, content on line cards for DSL, DOCSIS (cable modem), PON, Ethernet LAN, and wireless basestations, as these are all included in other sections of this report.

Note that in some cases, our forecast includes communications infrastructure ICs sold into applications other than communications infrastructure equipment. Examples would include discrete communications processors sold into wireless LAN access points, switching ICs sold into blade servers, and content processors sold into high-end servers. The impact to our forecast is small but relevant.

Communications Infrastructure

T/E Carrier

T-carrier is the first level of aggregation calls go through when being transported over the PSTN



Signal Level	Number of DS-0 Channels	Transmission Rate	Geography
DS-0	1	64 kbps	North America, Europe and Japan
DS-1/T1/J1	24	1.544 Mbps	North America and Japan
E1	30	2.048 Mbps	Europe
DS-1C	48	3.152 Mbps	North America and Japan
DS-2/T2/J2	96	6.312 Mbps	North America and Japan
E2	120	8.448 Mbps	Europe
J3	480	32.064 Mbps	Japan
E3	480	34.368 Mbps	Europe
DS-3/T3	672	44.736 Mbps	North America
DS-3C	1,344	91.053 Mbps	North America
DS-3C	1,440	97.728 Mbps	Japan
E4/DS-4E	1,920	139.264 Mbps	Europe
DS-4/T4	4,032	274.176 Mbps	North America
J4	5,760	397.200 Mbps	Japan
E5	7,680	565.148 Mbps	Europe

Note: Each DS-0 channel represents a single 64 Kbps phone line
Source: Oppenheimer & Co.

T-carrier is the first level of aggregation that telephone calls or data traffic go through when being transported over the PSTN (public switched telephone network). A basic DS-1/T1 signal multiplexes 24 DS-0 (each DS-0 is a single phone call, which is a 64 Kbps signal) channels into a single 1.544 Mbps signal, called a DS-1 or T1. The next level up is DS-2/T2, which multiplexes 4 DS-1s together in a 6.312 Mbps stream (in practice, DS-2 is rarely used), followed by DS-3/T3, which multiplexes 28 DS-1 signals into a 44.736 Mbps DS-3 or T3 signal.

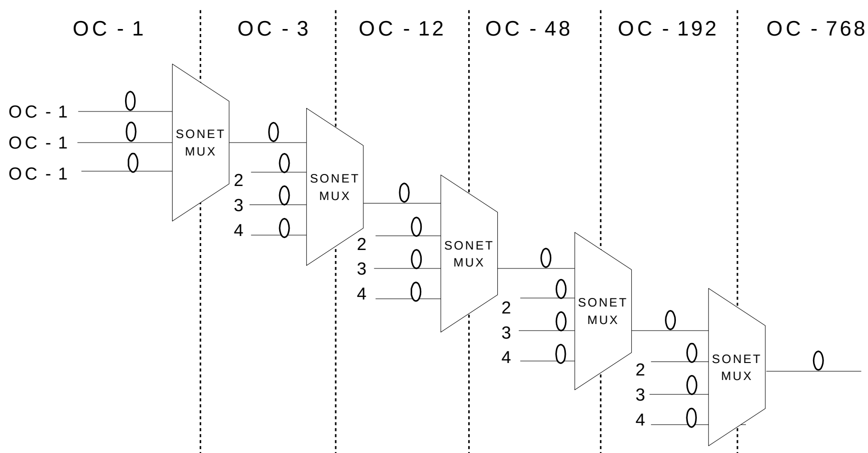
DS-1 and DS-3 signals are used by service providers when sending voice traffic around the metro or wide area network. Businesses also typically lease T1 (or T3) lines from the service provider that can provide a constant 1.544 Mbps (or 44.736 Mbps) channel, enough for 24 (or 672) simultaneous phone calls, which will be aggregated at the customer premise and sent as a digital signal (the “DS” in DS-1 and DS-3) to the PSTN. The bandwidth can also be used for the corporate data network in its interaction with the public WAN and the Internet.

Note: Although we mostly focus on signal rates found in North America, it is important to note that the European digital hierarchy, represented with an “E” rather than a “DS” or “T,” multiplexes a different number of DS-0 signals at each level of the hierarchy. For example, an E1 signal multiplexes 30 DS-0s instead of 24. From the E1 signal rate and higher, each subsequently higher signal is formed by multiplexing four signals from the preceding digital signal level; an E2 signal consists of four multiplexed E1 signals and an E3 signal consists of four multiplexed E2 signals.

Communications Infrastructure

SONET/SDH

SONET/SDH has historically been the primary optical transport protocol used in telecommunications



Optical Carrier Level (OC-N)	SONET STS Level (STS-N)	SDH STM Level (STM-N)	Transmission Rate	Equivalent Channels		
				DS-3	DS-1	DS-0
OC-1	STS-1	N/A	51.84 Mbps	1	28	672
OC-3	STS-3	STM-1	155.52 Mbps	3	84	2,016
OC-12	STS-12	STM-4	622.08 Mbps	12	336	8,064
OC-48	STS-48	STM-16	2488.32 Mbps	48	1,344	32,256
OC-192	STS-192	STM-64	9.953 Gbps	192	5,376	129,024
OC-768	STS-768	STM-256	39.812 Gbps	768	21,504	516,096

Note: Each DS-0 channel represents a single 64 Kbps phone line
Source: Oppenheimer & Co.

Synchronous optical networking (SONET) and synchronous digital hierarchy (SDH) have historically been the primary protocols used by carriers for optical transport (SONET is in North America, SDH in Europe). SONET can reach much higher transmission rates than T/E-carrier, as it is specifically designed to run over optical fiber. SONET equipment can handle a wide range of speeds and therefore is used throughout the service provider network. Lower-speed SONET is used to send traffic within the metropolitan area between central offices, while higher-speeds are used to send traffic between metro areas or even countries. Voice calls and data traffic are aggregated into SONET frames that travel around the network, picking up and dropping signals as calls are placed, all at high speeds.

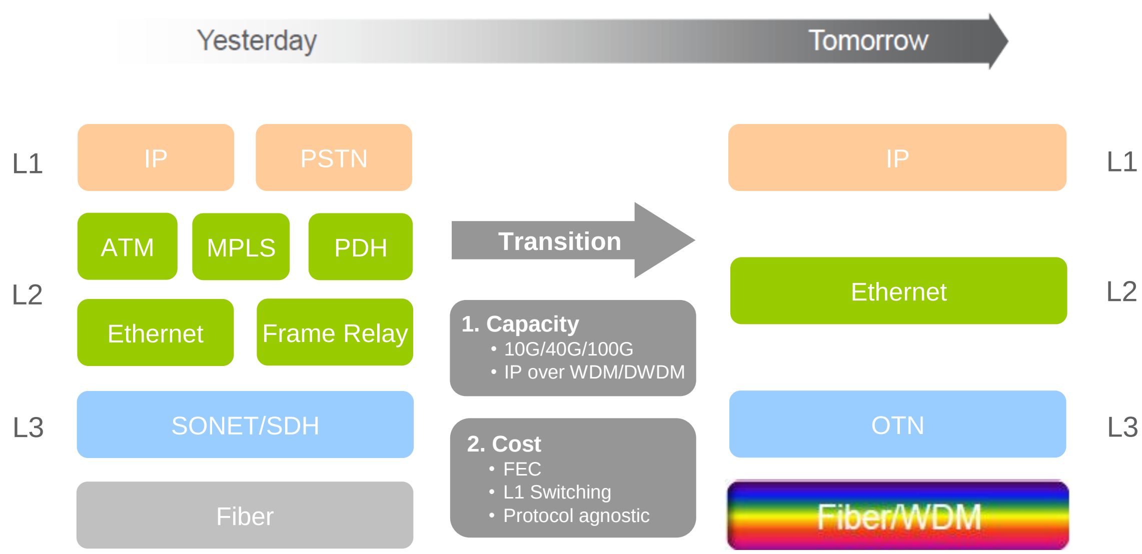
The basic building block in SONet networks is the STS-1 frame, also called an OC-1. The frame has 51.84 Mbps of bandwidth, enough to hold an entire DS-3 signal plus the SONET overhead. When STS-1s are aggregated, they are transmitted at faster rates, such as 155 Mbps (OC-3), 622 Mbps (OC-12), 2.5 Gbps (OC-48), 10 Gbps (OC-192), or 40 Gbps (OC-768). Most metro area SONET equipment uses OC-3 or OC-12, while long-haul uses OC-48 or OC-192.

The SONET/SDH network, however, is being transitioned to OTN; OTN has emerged as the protocol of choice to enable the transition from voice optimized SONET/SDH network to the next generation data-optimized network. The OTN transition began in equipment for the Core and Metro and will eventually move to Edge/Access.

Communications Infrastructure

OTN

As data traffic explodes, networks are under increasing pressure to expand capacity, and OTN has emerged as the protocol of choice to enable the transition from SONET/SDH to the data-optimized next generation network.



Note: Each DS-0 channel represents a single 64 Kbps phone line
Source: Oppenheimer & Co.

Optical Transport Network (OTN) is a set of optical transport standards established by the International Telecommunications Union (ITU) for the transmission of information across an optical network, officially known as ITU Standard G.709. OTN allows carriers to bridge the transition from circuit-switched, legacy transmission of voice data to Internet Protocol (IP) or packet-switched transmission of data over optical fiber. OTN, also called digital wrapper technology, has emerged as the physical layer interface protocol of choice to replace the voice optimized SONET standard in North America and Japan and the SDH standard in the rest of the world.

In general, data traffic is better suited to packet-switched networks, which involve encapsulating data in fixed or variable length packets and sending them across a shared network. Each packet contains headers encoded with a destination address and is switched at each node in the network over the most appropriate and available physical circuit. No direct circuit or channel is established between sender and recipient as in a circuit-switched network; instead data packets bounce around in the network until they reach their destination addresses.

OTN specifications provide for a robust management overhead analogous o SONET/SDH; therefore, network operators do not have to sacrifice the ability to manage at both the payload and service levels. An OTN payload can fully encapsulate a SONET/SDH frame without terminating the SONET DCC so that Add/Drop Multiplexers (ADMs) can continue to be management in the same manner, and topology discovery will still work between customer equipment.

Communications Infrastructure

ATM (Asynchronous Transfer Mode)

ATM is a switching protocol used primarily in service provider data and multi-service networks. The topology uses switches that establish a logical circuit from end-to-end, guaranteeing quality of service (QoS), but unused bandwidth can be appropriated when needed.

ATM uses fixed-length 53-byte cells, and can switch voice, video, or data traffic at high speeds. Routers and modems feed traffic into the carrier network, which uses a series of ATM switches to handle the traffic and send it back out.

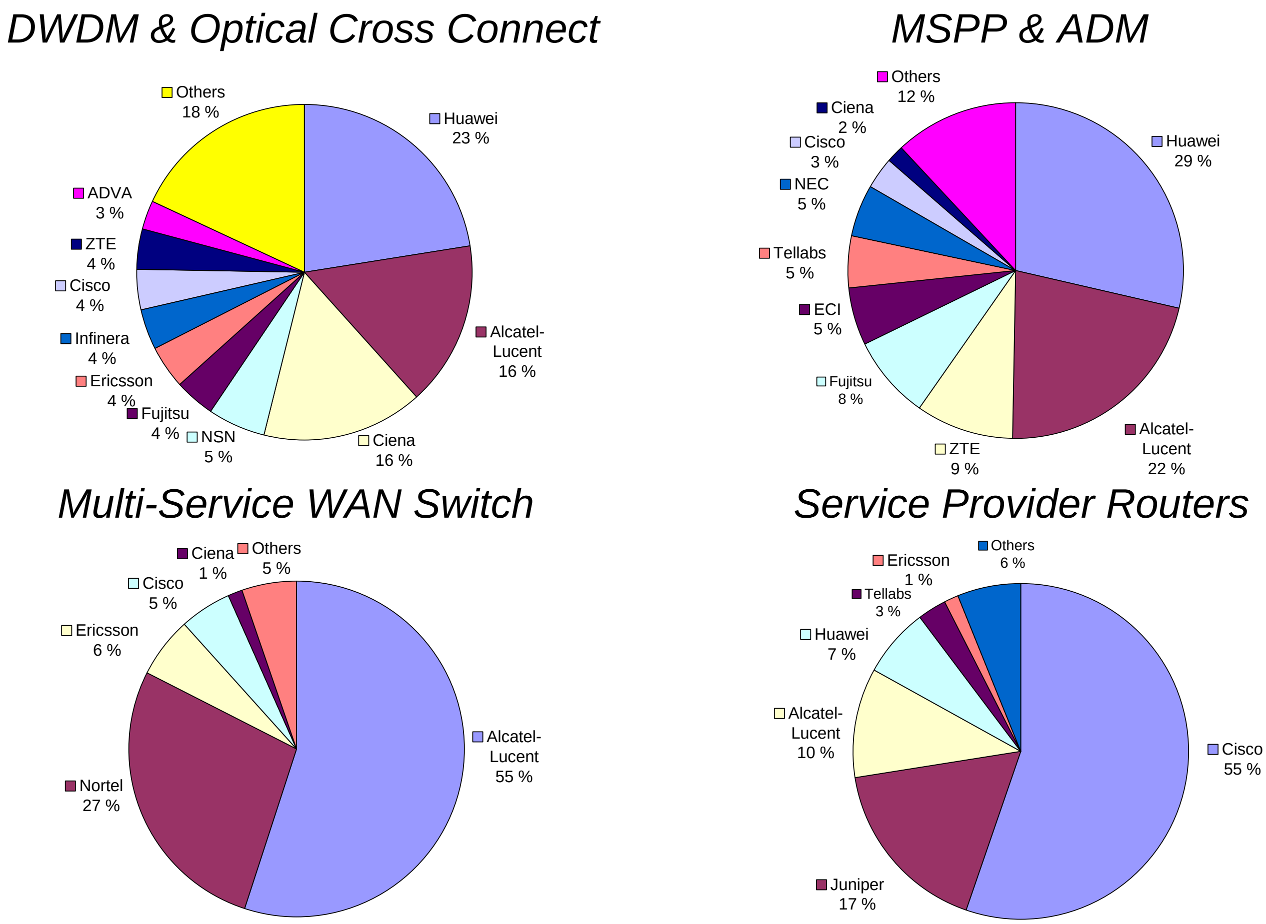
ATM is a layer 2 protocol. Cells can travel between line cards or even between switches in a single network node using point-to-point links, but need to sit inside a layer 1 protocol such as SONET or T/E to travel over the WAN.

T/E and SONET area both efficient transport protocols for the WAN, but they cannot perform the important switching functions that direct traffic around the network. Most service providers employ the switching technology ATM (asynchronous transfer mode) in the core and edge of the network in order to switch voice, data, and even video traffic. Based on a cell-switching and multiplexing technology, ATM is a connection-oriented protocol for the transfer of fixed length cells, which can carry many different types of traffic. ATM equipment can specify different levels of quality of service for different cells; this is a key feature in making it the preferred choice for multi-service networks. It is highly scalable and supports transmission speeds equivalent to those of SONET.

Unlike other data link layer protocols, ATM units are not variable in length, but consist of fixed 53-byte cells. ATM switches establish a logical circuit from end to end, which guarantees quality of service. However, unlike true circuit-switched protocols that dedicate circuits end to end, unused bandwidth in ATM's logical circuits can be appropriated when needed. In this way, ATM combines the benefits of circuit switching, including constant network latency/delay and guaranteed bandwidth, with those of packet-switching, including flexibility and better network utilization. The small, fixed cell size is ideal for the transfer of voice, video and other real-time traffic, as these types of traffic are not tolerant of the long download delays associated with long, variable length packets.

Communications Infrastructure

Carrier Infrastructure Equipment Suppliers



Source: Dell'Oro, IDC, Oppenheimer & Co.

This chart above (and the two following it) includes market share figures for several classes of communications infrastructure equipment. Though not an exhaustive list of equipment included in this category, it gives a good sense of the key OEM players. Data from 2009 is the most recent available. Note that all market share figures are in revenue terms as opposed to ports, lines, or units.

DWDM & Optical Cross Connect Suppliers: The top DWDM and OCC supplier in 2009 was Huawei with 23% share. Alcatel-Lucent and Ciena followed with 16% share each. Nokia Siemens held 5%, with Fujitsu, Ericsson, Infinera, Cisco and ZTE at 4%.

Multi-Service Provisioning Platform & Add/Drop Multiplexer Suppliers: The top supplier of MSPP and ADM equipment in 2009 was share-gainer Huawei with 29% share. Alcatel-Lucent was 2nd with 22% share, followed by ZTE with 9%. Fujitsu followed with 8% share, while ECI, Tellabs and NEC each held 5%. Other suppliers include Cisco and Ciena.

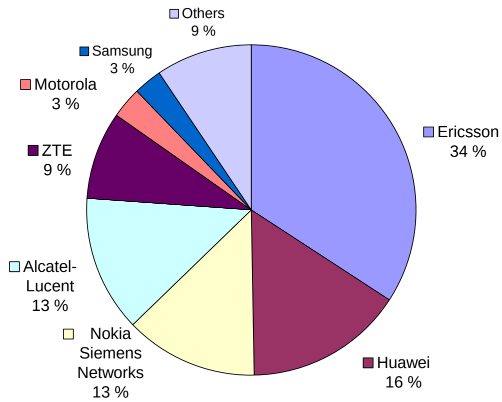
Multi-Service WAN Switch Suppliers: The top suppliers of multi-service WAN switches (includes ATM switches) in 2009 were Alcatel-Lucent and Nortel, with 55% and 27% share, respectively. Ericsson held 6% share, while Cisco held 5%. Other major suppliers include Ciena and Tellabs.

Service Provider Router Suppliers: Cisco was the No. 1 supplier of service provider routers in 2009 with 55% share. Juniper was a strong No. 2 with 17% share, though it lost ground. Alcatel-Lucent was No. 3 with 10%, followed by Huawei with 7%, and Tellabs at 3%.

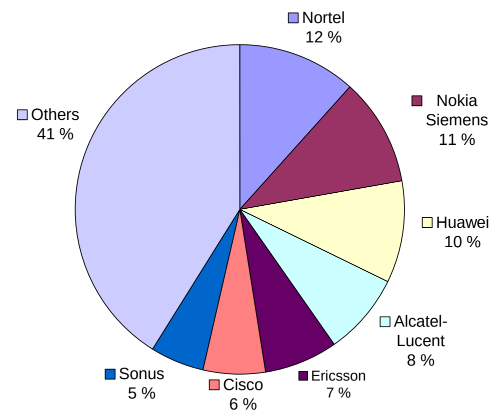
Communications Infrastructure

Wireless and Wireline Access Equipment Suppliers

Wireless Infrastructure

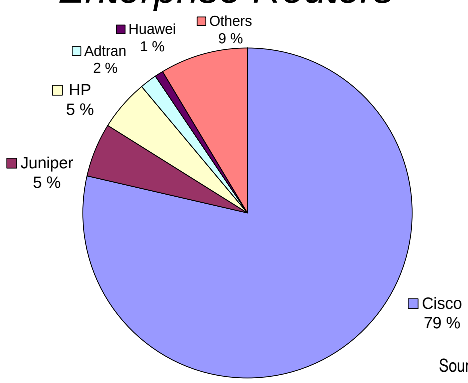


Carrier VoIP

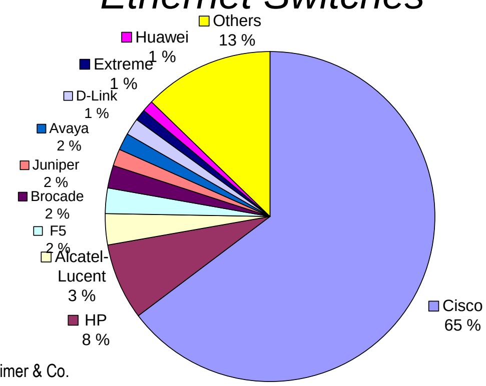


Enterprise IT Infrastructure Equipment Suppliers

Enterprise Routers



Ethernet Switches



Source: Dell'Oro, Dataquest, Oppenheimer & Co.

Wireless Infrastructure Suppliers: Ericsson was the top supplier of wireless infrastructure equipment in 2010, with 34% revenue share. Huawei followed with 16% share. Nokia Siemens was third with 13% share. Alcatel-Lucent was fourth with 13% share. ZTE rounds out the top five with 9% share. Other vendors include Motorola and Samsung. Note that we include a whole host of gear in the wireless infrastructure segment, including basestations, RNCs, backhaul, switching, and routing.

Carrier VoIP: The top supplier of carrier-oriented VoIP equipment, which includes primarily media gateways and softwitches, was Nortel, which held 12% revenue share in 2009. Nokia Siemens held 11%, with Huawei and Alcatel-Lucent at 10% and 8%, respectively. Ericcson held 7%, while Cisco held 6% and Sonus had 5% share. A large portion (41%) of this emerging technology is served by a variety of others, including Genband, Italtel, Acme Packet, Metaswitch, Audiocodeds, Veraz and others.

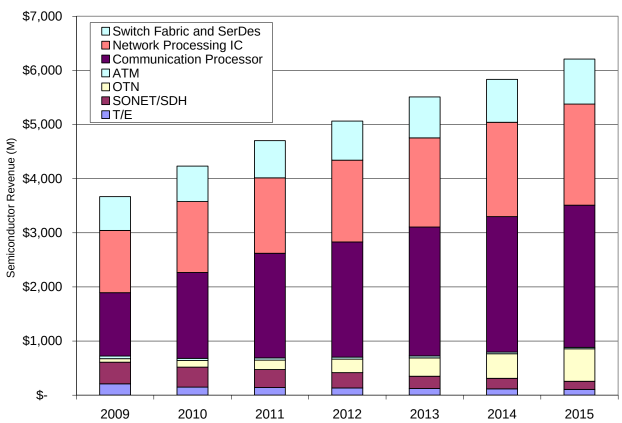
Enterprise Router Suppliers: The enterprise router market is dominated by Cisco with 79% revenue share in 2010. Juniper, which has struggled to move into the enterprise, was next with 5% share. HP gained share and held 5%. Other vendors include Adtran and Huawei.

Ethernet Switches: Cisco was the dominant supplier of Ethernet switches in 2010 with 65% revenue share. HP and Alcatel Lucent were a distant No. 2 and No. 3 with 8% and 3%, respectively. Other vendors include F5, Brocade, Juniper, Avaya, D-Link, Extreme and Huawei. Note that the share data listed here differs from the Ethernet section of this report, which deals in port shipments.

Communications Infrastructure

Comm Infrastructure Semiconductor Forecast

•We expect communications infrastructure semiconductor revenue to grow at an 8% CAGR, from $4.2 billion in 2010 to $6.2 billion in 2015.
•T/E, SONET/SHD and ATM should each decline as they are replaced/upgraded with newer infrastructure.
•Higher-layer and system-level ICs should grow 8% led by NPUs, co-processors, and standard interconnect; communications processors should grow nicely at 11%.



Source: IDC, Dataquest, Oppenheimer & Co.

Line Card ICs
•T/E-carrier declining 7%, from $148 million in 2010 to $105 million in 2015.
•SONET/SDH declining 17%, from $370 million in 2010 to $150 million in 2015. This will be offset by 42% growth in OTN to $600 million in 2015.
•ATM ICs declining 9%, from $42 million in 2010 to $27 million in 2015.

Higher-Layer and System-Level ICs
•Comm processors growing 11%, from $1.6 billion in 2010 to $2.6 billion in 2015.
•Network processing ICs growing 7%, from $1.2 billion in 2010 to $1.8 billion in 2015.
•Switching ICs growing 5%, from $655 million in 2010 to $832 million in 20135.

Note: each of the six sub-segments above is discussed separately in the slides that follow.

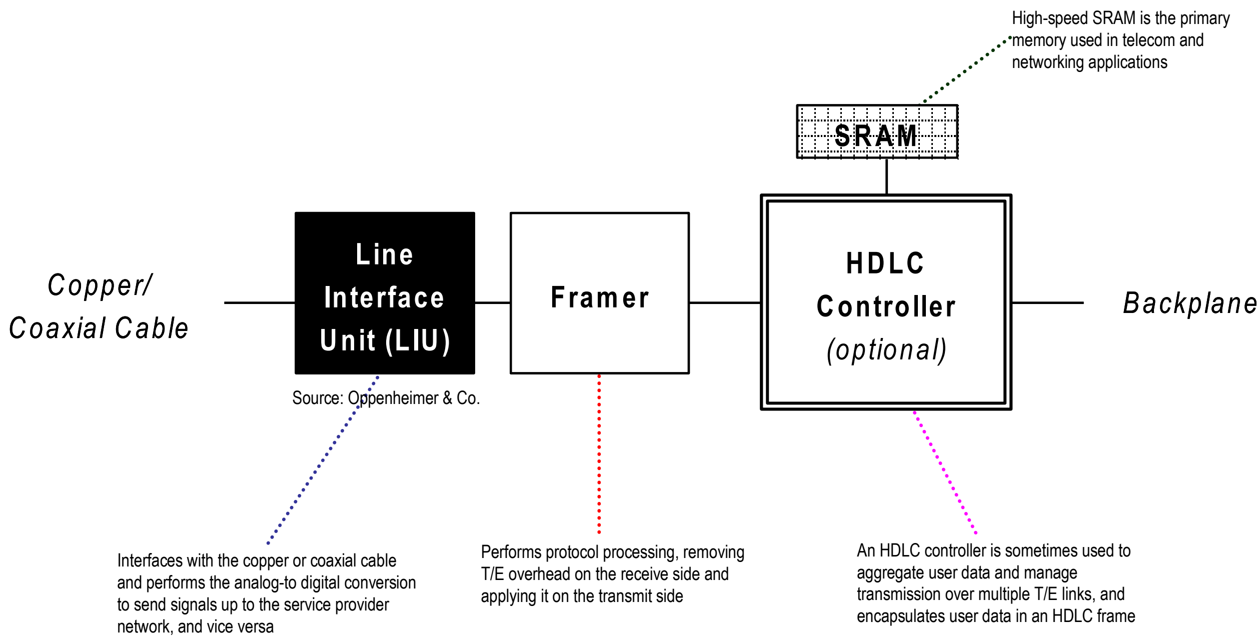
Communications Infrastructure Semiconductor Forecast: We estimate that the market for communications infrastructure semiconductors totaled $4.2 billion in 2010. Roughly 19% of this total was derived from WAN line card ICs, which we define as protocol-dependent ICs usually found on individual line cards and, to a lesser extent, WAN trunking cards. The remaining 81% was derived from higher-layer and system-level ICs, which can be either control plane ICs or in the data path, but are not protocol specific. This latter segment includes communications processors, network processing ICs, and switch fabrics, which are found on switch, control/management, and WAN trunking cards and to a lesser extent on individual line cards. Note that line card ICs such as DSL, cable modem, PON, and Ethernet are not discussed here, though the higher-layer ICs that sit behind them are, skewing the data a bit.

Looking ahead, we expect the market to grow at an 8% CAGR, from $4.2 billion in 2010 to $6.2 billion in 2015. Line card ICs should grow at a 5% CAGR, with 42% growth in OTN offsetting declines in T/E, SONET and ATM. Higher-layer and system-level ICs should grow 8%, benefiting from the additional intelligence OEMs are seeking to pack into their product offerings at each node in the network. Growth should be led by NPUs and co-processors, with communications processors also growing at a healthy 11% CAGR.

Note: each of the six IC sub-segments is discussed separately in the pages that follow. The graphic above is meant as a summary to size the opportunity for communications infrastructure ICs. In practice, the design competencies required to address each sub-segment of the market are highly specialized and thus require separate attention.

Communications Infrastructure

T/E Carrier Line Card



Source: Oppenheimer & Co.

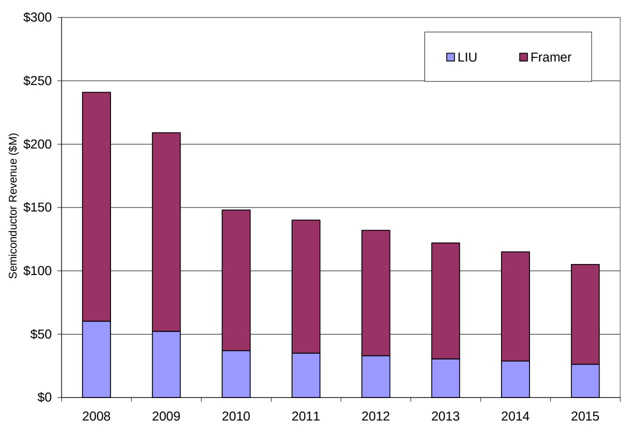
T-carrier semiconductors transmit and receive T/E-based signals over the PSTN. The LIU receives data from the transmission medium—usually copper twisted pair or coaxial cable—and converts it to a digital format for processing. The framer removes or applies T-carrier overhead (recall that overhead is the additional bits of data attached to the signal payload that helps transport the data, but is not part of the original data stream). The system can also run the data through an HDLC controller for further channel management.

- **Line Interface Unit (LIU)**: The LIU interfaces with the transmission medium and converts it to and from the digital format for processing. The LIU is sometimes referred to as a PHY.
- **Framer**: The framer applies and removes T-carrier overhead, preparing the payload data for transmission over the network and extracting it from an encoded form on the receive side.
- **HDLC Controller**: An HDLC controller is sometimes used to aggregate user data and manage transmission over multiple T1/E1 or T3/E3 links. It encapsulates user data into HDLC (high-level data link control) frames and prepends header information that is used to manage network connections. Note that an HDLC controller is usually implemented as a communications processor; though we show it in the diagram above, the revenue associated with it is included in the forecast for communications processors.
- **SRAM**: High speed SRAM is the most commonly used memory in wireline applications.

Communications Infrastructure

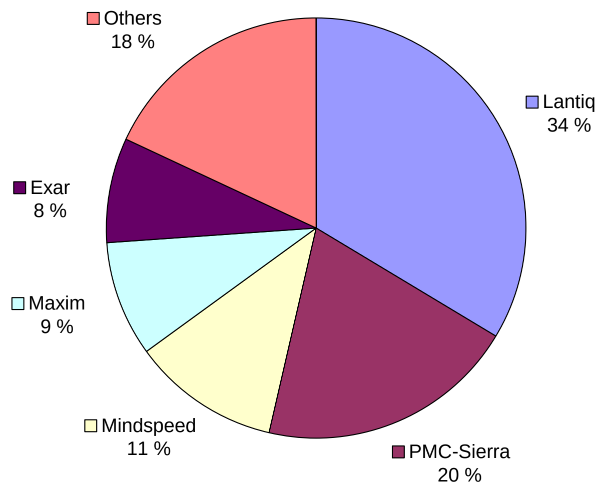
T/E Carrier Semiconductor Forecast

•T/E carrier ICs are expected to decline at a 7% CAGR, from $148 million in 2010 to $105 million in 2015.
•The market is seeing a slow erosion as optical links and Ethernet displace T-carrier on the margin.
•Still, T-carrier remains and important technology for wireless backhaul, corporate data access, and metro/access aggregation and transport.
•Framers represent 75% of revenue, with PHYs/LIUs the balance.



Source: IDC, Dataquest, Oppenheimer & Co.

T/E Carrier Semiconductor Competitors



Source: Linley, Oppenheimer & Co.

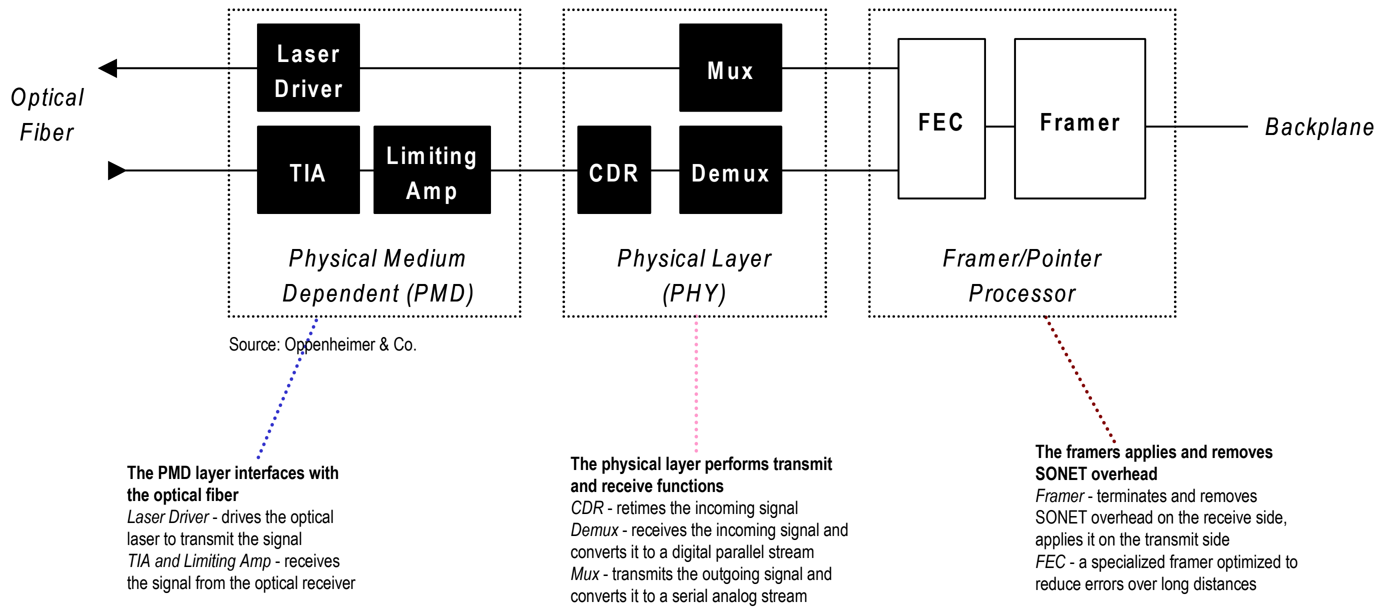
T/E carrier Semiconductor Forecast: T/E carrier semiconductors, as the basic building block of service provider metro and access networks, enjoy consistent demand from applications such as wireless basestations, corporate data access, and aggregation/transport links around carrier access and metro networks. Over time, however, we expect to see continued slow displacement of lower-speed copper T/E links with higher-speed optical links or even metro Ethernet, pressuring the T/E market. We also expect to see continued ASP declines, as IC vendors provide denser multi-port solutions and higher levels of integration.

Overall we expect T/E semiconductors to decline at a 7% rate, from $148 million in 2010 to $105 million in 2015. In terms of individual devices, we expect framers to remain roughly 75% of IC content, with LIUs the balance.

T/E carrier Semiconductor Competitors: The top supplier of T-carrier semiconductors in 2010 was Lantiq, the spin-off of Infineon's wired business, with 34% market share. PMC-Sierra was second with 20% share, followed by Mindspeed and Maxim, with 11% and 9%, respectively. Exar was next with 8% share.

Communications Infrastructure

SONET/SDH Line Card



Source: Oppenheimer & Co.

SONET line cards are found in high-speed optical transport and switching systems used in metro, edge, and core networks. In a typical line card implementation, the optical signal comes off the fiber and interfaces an optical module containing a block of ICs known as the physical medium dependent (PMD) block, which controls the optical receptor and sends the analog signal into the system. Physical layer (PHY) devices sitting behind the optical module then convert the signal to a digital bit stream for processing. The framer removes SONET overhead and sends the signal to the network processing block, which classifies, modifies and manages the packet before switching. On the transmit side, the process is reversed, with the framer applying overhead, the PHY converting the signal to analog and transmitting it through the PMD devices in the optical module over the fiber.

Physical Medium Dependent (PMD)

- **Transimpedence Amplifier (TIA) and Limiting Amp**: The transimpedence amp and limiting amp receive the signal from the optical receiver.
- **Laser Driver**: On the transmit side, the laser driver controls the optical laser that sends the SONET signal across the fiber.

Physical Layer (PHY)

- **Clock and Data Recovery (CDR)**: On the receive side, the CDR retimes the signal from the PMD layer and prepares it for analog processing by the transceiver.
- **Demultiplexer (Demux)**: The demultiplexer acts as the receiver and converts an incoming signal from an analog serial bit stream to a digital parallel stream for processing by the system.
- **Multiplexer (Mux)**: The multiplexer acts as the transmitter and converts the signal from the digital parallel stream used by the system to the analog serial stream used by the optical components.
- **Transceiver** (not shown in diagram): A transceiver is an integrated physical layer device that performs clock and data recovery, mux, and demux functions on a single chip. Integrated transceivers are typically found supporting the slower, more mature speeds (OC-3 and OC-12), while faster next-generation speeds (OC-48, OC-192, OC-768, OC-3072) require discrete components to perform physical layer functions.

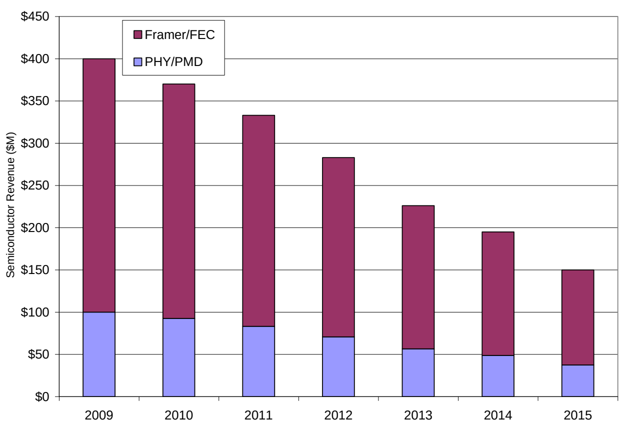
Framer Layer

- **Framer**: The framer terminates and removes SONET overhead on the receive side and applies it on the transmit side. The framer also breaks out the SONET stream into smaller bandwidth signals for more granularity in processing (e.g., it can break an OC-48 into four OC-12s or twelve OC-3s, etc.).
- **Mapper** (not shown in diagram): A mapper is similar to a framer but includes the capability to translate between speeds or protocols. Mappers are often used in systems which provide transport for other protocols, such as ATM or Ethernet, over a SONET link.
- **Forward Error Correction (FEC)**: Also called a digital wrapper, the FEC is a specialized framing device that uses the g.709 protocol to encapsulate the packet in an additional FEC frame for more reliable transmission over longer distances. FEC devices are only found in those systems designed to support g.709, generally higher speed long-haul equipment.

Communications Infrastructure

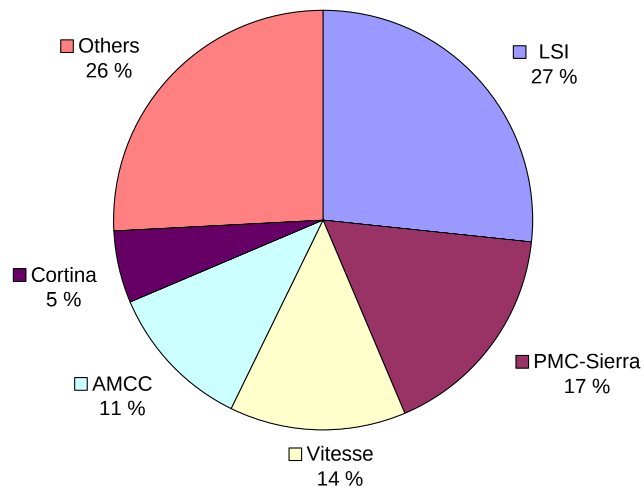
SONET/SDH Semiconductor Forecast

•We expect SONET ICs to decline at a 17% CAGR, falling from $370 million in 2010 to $150 million in 2015.
•Framers should remain about 75% of IC content, with FEC devices growing fastest due to their high penetration in higher-speed SONET links.
•PHY and PMD components represent roughly 25% of IC content.



Source: IDC, RHK, Oppenheimer & Co.

SONET/SDH Semiconductor Competitors



Source: Linley, Oppenheimer & Co.

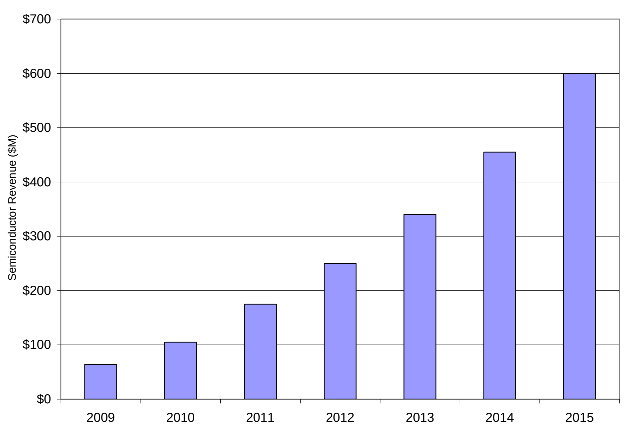
SONET Semiconductor Forecast: We expect SONET semiconductor revenue to decline at a 17% CAGR, from $370 million in 2010 to $150 million in 2015. The voice-centric SONET network has been blindsided by the explosion of data traffic. Global data traffic is rising so rapidly that networks are being forced to upgrade to data-centric infrastructure—and that means a sharp transition away from SONET. OTN has emerged as the physical layer interface protocol of choice to replace SONET in North America and Japan and SDH in the rest of the world.

SONET Semiconductor Competitors: The top SONET IC vendor in 2010 was LSI with 27% market share, followed by PMC-Sierra with 17%. Vitesse was third with 14% share. AMCC was fourth with 11% and was followed by Cortina with 5%. Other smaller suppliers include Transwitch, Mindspeed, Lantiq, Galazar, and Exar.

Communications Infrastructure

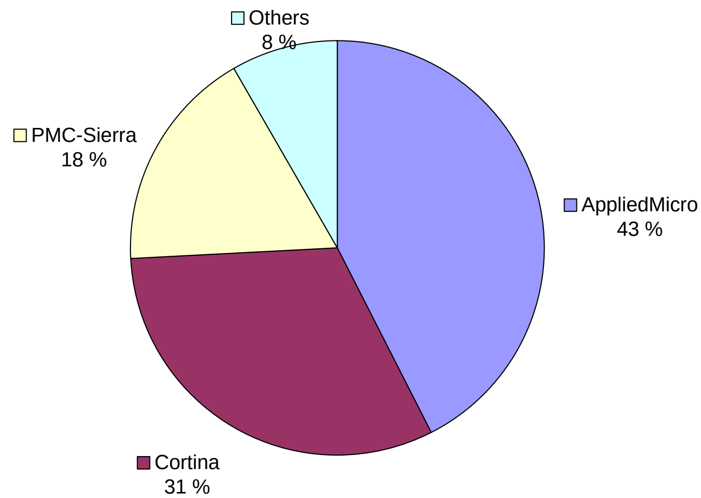
OTN Semiconductor Forecast

- We expect OTN ICs to grow at a 42% CAGR, rising from $105 million in 2010 to $600 million in 2015.
- OTN is poised for significant growth as it becomes the interface standard of choice to replace the voice-centric SONET network.
- ASPs will initially benefit from the lack of major competition – with just four primary market players.



Source: IDC, RHK, Oppenheimer & Co.

OTN Semiconductor Competitors



Source: Linley, Oppenheimer & Co.

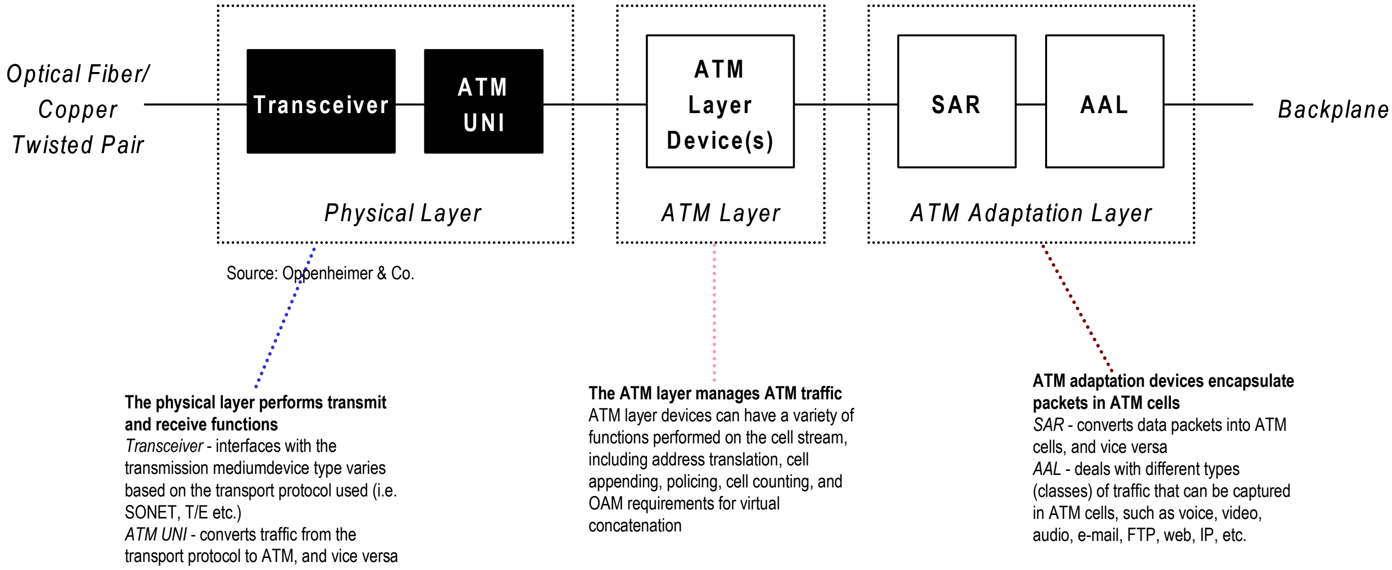
OTN Semiconductor Forecast: The voice-centric SONET network has been blindsided by the explosion of data traffic. Global data traffic is rising so rapidly that networks are being forced to upgrade to data-centric infrastructure—and that means a sharp transition away from SONET. OTN has emerged as the physical layer interface protocol of choice to replace SONET in North America and Japan and SDH in the rest of the world. In total, we expect OTN ICs to grow at a 42% CAGR, rising from $105 million in 2010 to $600 million in 2015.

There are two primary factors driving the migration from legacy SONET networks to the OTN standard; capacity and cost. Because the legacy SONET TDM networks are not as efficient in handling packet data traffic, networks are required to upgrade to support exponential growth in data traffic. Second is cost, whereby Ethernet has become the protocol of choice for transporting IP data, voice and video, and is driving adoption of Carrier Grade Ethernet and Metro Ethernet services as layer 2 medium of choice.

OTN Semiconductor Competitors: The OTN market remains markedly free of competition, with just four primary players. AMCC had 43% market share in 2010 and Cortina held 31%, down from 47% in 2009. PMC-Sierra emerged as a major threat in 2010 and captured 18% share of the market, and Vitesse consists of substantially all "other" revenue after having held 6% share in 2009.

Communications Infrastructure

ATM (Asynchronous Transfer Mode) Line Card



ATM-based equipment is a bit different than other types of carrier network equipment in that it applies the ATM protocol inside of another transport protocol (such as T/E or SONET). The transceiver can therefore be a variety of devices: a SONET transceiver, a T/E LIU, etc. On the receive side, the signal is passed from the transceiver to an ATM UNI (User Network Interface), which takes the digital signal from the transceiver and implements the ATM physical layer interface. It then goes to the ATM layer, where traffic management functions are performed, and then to the ATM adaptation layer, where traffic is translated from ATM cells into data packets and sent to the backplane for switching. The data packets are then sent back to a switching card, where they are switched, transformed back into ATM cells and sent out to another port.

Physical Layer

- **Transceiver**: The transceiver is the primary interface between the ATM line card and the transmission medium. The transceiver in an ATM system can be any number of devices depending on the transport protocol, including SONET/SDH transceivers, T1/E1 or T3/E3 LIUs. Alternatively, pure ATM traffic can be sent over point-to-point links between switches using standard ATM PHYs, though these links are usually used for intra-switch or switch-to-switch signaling.
- **ATM UNI (User Network Interface)**: The ATM UNI converts traffic from the transport protocol (T/E, SONET, etc.) to the ATM protocol and vice versa.

ATM Layer

- **ATM Layer Device(s)**: ATM systems can have a variety of functions performed on the cell stream performed at the ATM layer. This can include VPI/VCI address translation, cell appending, policing, cell counting and OAM requirements for virtual connections.
- **IMA: (Inverse Multiplexer for ATM)** (not shown in diagram): IMAs are used in ATM uplinks to manage ATM traffic over multiple lower-speed T/E and DSL physical links.

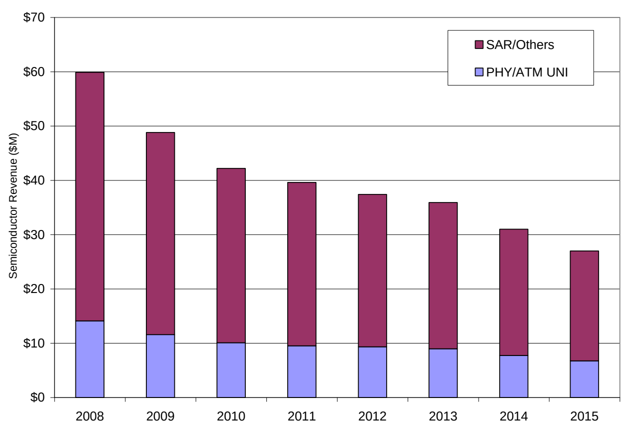
ATM Adaptation Layer (AAL)

- **SAR (Segmentation and Reassembly)**: The SAR converts data packets into ATM cells and vice versa.
- **AAL (ATM Adaptation Layer)**: The AAL device deals with the different types of data traffic that can be captured in ATM cells, also called Classes-of-Service (CoS). Classes of service can include compressed and uncompressed voice, video, audio, e-mail, FTP, World Wide Web, IP, etc.

Communications Infrastructure

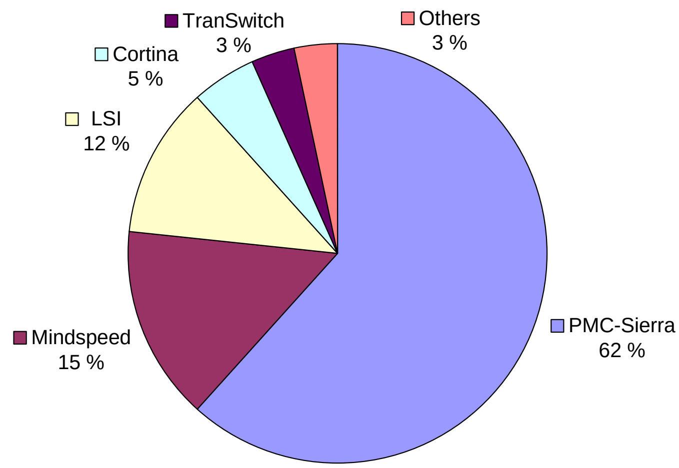
ATM Semiconductor Forecast

•We expect ATM semiconductors to decline at a 9% CAGR, from $42 million in 2010 to $27 million in 2015.
•ATM has been actively displaced by IP and there are no companies currently making new investments; ATM is in a terminal decline for end-of-life products.
•PHY and UNI ICs should remain roughly 25% of revenue, the balance should be SAR and other ICs.



Source: IDC, Linley, Oppenheimer & Co.

ATM Semiconductor Competitors



Source: Linley, Oppenheimer & Co.

ATM Semiconductor Forecast: We believe the market for ATM semiconductors is in a terminal state of decline with end-of-life products likely to continue generating some level of declining revenue throughout our forecast period. No companies are investing in new products for the market, as ATM has been actively displaced by IP-based technology. We expect the total market to decline at a 9% CAGR from $42 million in 2010 to $27 million in 2015.

ATM Semiconductor Competitors: The dominant vendor of ATM semiconductors is PMC-Sierra. PMC-Sierra continued to lead the category in 2010 with 62% share. Mindspeed followed with 15% share and LSI was third with 12%. Cortina and TranSwitch are players as well, with 5% and 3% share, respectively.

Communications Infrastructure

Communications Processors

Equipment used in communications infrastructure usually includes specialized microprocessors which perform control plane functions, both on individual line cards and on “management” or “supervisor” cards.

Usually an x86-, PowerPC-, or MIPS-based device, a communications processor sits above the data path and performs control plane functions, managing the functionality of the line card or the entire system.

Note that in addition to control plane functions, communications processors are often used to perform functions within the data path as programmed by software. Sometimes referred to as Integrated Communications Processors (ICPs), these devices are essentially fully-programmable network processors and are generally found on lower speed line cards.

Communications infrastructure equipment usually includes specialized microprocessors which perform control plane functions, both on individual line cards and on “management” or “supervisor” cards. Usually an x86-, PowerPC-, or MIPS-based device, a communications processor sits outside the data path and performs control plane functions, managing the functionality of the line card or the entire system. As they are fully programmable, communications processors are ideal for overall system control, which needs to be extremely flexible to support increasingly sophisticated OEM operating systems, a constantly evolving set of features, and varied customer preferences.

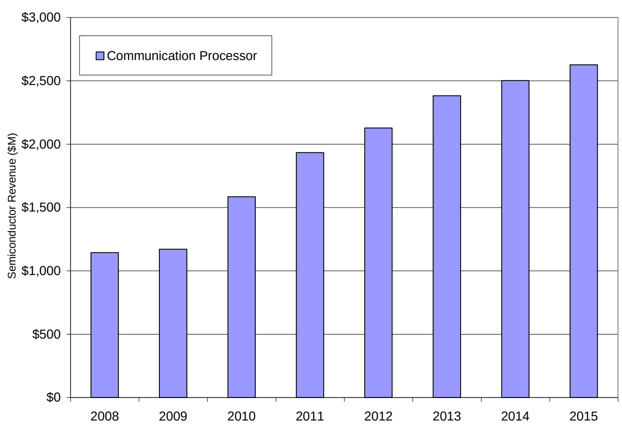
In addition to their function as the control plane processor, communications processors are often used to perform functions within the data path. Sometimes referred to as Integrated Communications Processors (ICPs), these devices are essentially fully-programmable network processors (discussed in the following section) and are generally used on lower speed line cards. These ICPs often include specialty network processing logic around the processor core, making them look to some extent like SoCs, but with a robust processor at the core.

Note that this section includes standalone microprocessors used in large telecom and enterprise systems. It does not address processors used in modem CPE, wireless LAN access points, and other consumer networking devices, though the processors used in those applications are very similar to those found in infrastructure equipment. The market for standalone processors sold into CPE devices is quite small anyway, as processor cores are usually embedded into SoCs designed specifically for those markets.

Communications Infrastructure

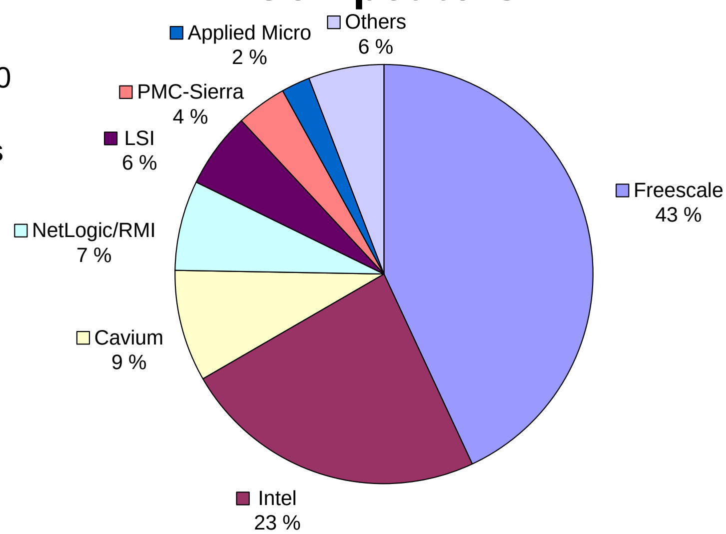
Communication Processor Forecast

•We expect communications processors to grow at an 11% CAGR from $1.6 billion in 2010 to $2.6 billion in 2015.
•X86-, MIPS-, and PowerPC-based processors should all continue to see wide adoption in telecom and enterprise infrastructure equipment.
•Processors continue to perform many critical data path functions, and have not lost much ground to NPUs or other dedicated ASSPs.



Source: IDC, Oppenheimer & Co.

Communication Processor Competitors



Note: Excludes processors sold into networking CPE as well as into enterprise storage equipment.
Source: Linley, Oppenheimer & Co.

Communications Processor Forecast: Communications processors are pervasive in infrastructure equipment, included both on line cards and management cards that run the overall system. In 2010, we estimate that the market totaled $1.6 billion. Looking ahead, we expect OEMs to continue to pack additional functionality into their high-end offerings—much of which gets implemented in software—driving demand for increased processing. The trend is moving distinctly towards multicore processors. In total we expect an 11% CAGR through 2015, with the market growing to $2.6 billion.

Communications Processor Competitors: The market for communications processors is served by vendors of x86-, PowerPC- and MIPS-based processors. Freescale has long been the dominant supplier, but has lost ground in recent years with the lack of a competitive multicore offering; Freescale maintained 43% of the market in 2010. Intel followed with 23% share. Cavium, with 9%, has gained substantial market share over the past three years by broadening beyond security accelerators to offer an extensive line of multi-core MIPS processors. NetLogic, which intends to be acquired by Broadcom, held 7% share. Other players include LSI, PMC-Sierra and Applied Micro. Though some of these have been aggressive in attempts to gain share vs. the leaders, most have concluded that the investment needed to compete for high-end sockets is too high, and have pulled back from this market.

Communications Infrastructure

Network Processing ICs

Communications infrastructure equipment incorporates ASICs and specialized network processing devices to perform data path processing functions. These devices primarily relate to routing and traffic management and can be included on line cards, management cards, switch cards, or WAN trunking cards.

Network Processor (NPU) - A standard programmable processor optimized for packet classification, modification, and traffic management.

Packet Classifier - A co-processor designed to classify packets based on content, usually helping to implement routing tables and QoS.

Packet Co-processor (CAM/NSE) - A specialized SRAM-based co-processor designed to quickly look up routing addresses.

Traffic Manager - A co-processor designed to manage traffic flow and implement QoS.

Security Co-processor - A co-processor designed to accelerate networking security protocols, such as IPSec.

ASICs – Custom ASICs can perform any or all of the above functions.

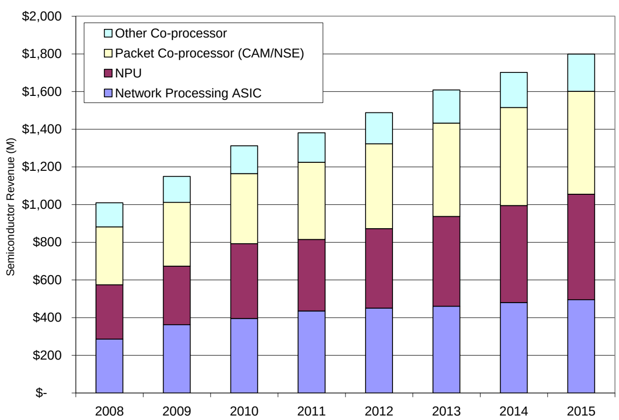
Communications infrastructure equipment incorporates specialized network processing devices to perform data path processing functions. These devices primarily relate to routing and traffic management and show up on control cards, switch cards, WAN trunking cards, or individual line cards, depending on the system. Key types of devices include:

- **Network Processor (NPU):** A network processor is a standard programmable processor designed specifically to perform packet classification, modification and traffic management. Software is still a major component.
- **Packet Classifier:** A packet classifier is a co-processor designed to classify packets based on content, usually helping implement routing tables and QoS.
- **Packet Co-processor (NSE/CAM):** These specialized SRAM-based devices are designed to quickly look up routing addresses. They are sometimes called “network search engines” or “Knowledge Based Processors.”
- **Traffic Manager:** A traffic manager is a co-processor designed to manage traffic flow and implement QoS. First used in ATM-based equipment, traffic management is now a common feature in most network devices.
- **Security Co-processor:** A security co-processor accelerates networking security protocols such as IPSec. These processors often occupy their own line cards within larger systems or servers to implement security protocols.
- **Network Processing ASICs:** Custom ASICs can perform one or all of the above functions.

Communications Infrastructure

Network Processor and Co-processor Forecast

•Network processing ICs are expected to grow at a 7% CAGR, from $1.3 billion in 2010 to $1.8 billion in 2015.
•ASICs should lag at a 5% CAGR; NPUs, NSEs, and co-processors should each grow at rates of 6%+.



Source: IDC, RHK, Linley Group, Oppenheimer & Co.

Network Processor and Co-processor Competitors

ASICs	NPUs	Co-processors
IBM	Intel	NetLogic
Fujitsu	LSI	Renesas
LSI	EZchip	
	PMC-Sierra	
	AMCC	
	Xelerated	
	Broadcom	

Source: IDC, Linley Group, Oppenheimer & Co.

Network Processor and Co-processor Forecast: The market for data path network processing ICs is driven not only by port/unit shipments of wireline equipment, but also by the level of "intelligence" required in these devices. Simple transport or switching equipment do not require much outside of physical layer and protocol processing; the addition of routing, QoS, traffic management, security, or other higher layer functionality, however, requires significant incremental silicon content. With most OEMs moving toward more intelligent edge and access designs, we expect the market for network processors to see healthy growth, with double-digit growth in next-generation ASSP segments. In total, we expected the market to grow at a 7% CAGR, from $1.3 billion in 2010 to $1.8 billion in 2015.

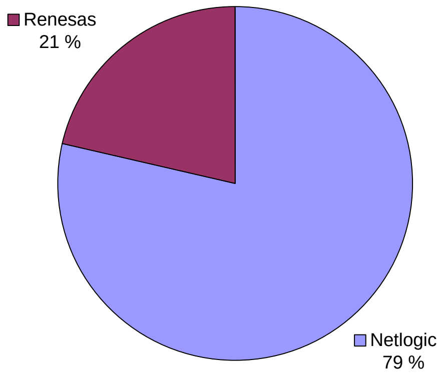
Note that a significant portion of the network processing IC market is still ASIC-based. Going forward, we expect a continued migration from ASIC solutions to ASSPs, with ASICs shrinking to 28% of the overall market in 2013.

Network Processor and Co-Processor Key Competitors: The market for standard programmable NPUs was originally dominated by a handful of start-ups, most of which have been acquired; most recently PMC-Sierra's 2010 acquisition of Wintegra. Today, most of these products are produced by the larger comm IC vendors. In 2010, Intel was the market leader with 29% market share, down from 35% in 2009. Intel was followed by LSI at 17%. Ezchip held 16%, followed by PMC-Sierra (via its Wintegra acquisition) with 16% and AMCC with 5%. Other significant NPU vendors include Xelerated and Broadcom.

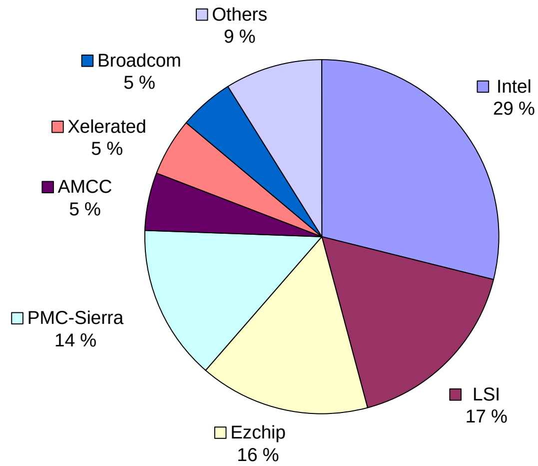
In the co-processor market, we segment the market between packet co-processors (NSE/CAM) and all other co-processors. Note that the latter category is mostly security co-processors, as most packet classifier and traffic manager ICs have been folded into the larger network processing units or chipsets which are included in the NPU segment. Cavium Networks has been the share gainer in Network-Security Accelerators and now accounts for ~50% of the $63 million market. LSI and NetLogic are also large players in this market. In packet co-processors, two vendors dominate the market: NetLogic was the market leader in 2010 with 79% share, followed by Renesas with 21%.

The exhibits below display market shares for network processing NPUs and co-processors in 2010.

2010 Packet Co-processor (NSE/CAM) Market Share



2010 Network Processor (NPU) Market Share



Source: IDC, Oppenheimer & Co.

Communications Infrastructure

Comm Infrastructure IC Market Trends

Line Card ICs

•OEMs are flocking to multi-port T/E devices at the lower speeds.

•IC vendors are increasingly integrating the T/E LIU with the framer.

•OTN has emerged as the protocol of choice to enable the transition away from legacy voice-enable SONET/SDH networks.

•ATM is being challenged by IP-based solutions.

•DSLAMs have moved from ATM to IP, basestations are also ramping.

Higher-Layer and System-Level ICs

•Communications processors are integrating advanced networking logic.

•NPUs are gaining traction, especially in access and metro applications.

•Packet co-processors continue to penetrate the LAN backbone and are being used in service provider networks as well.

•Security processors are gaining traction in routers and LAN backbones.

•IPv6 is driving the need for more advanced network processing ICs.

•Standard interconnects are gaining traction as OEMs leverage open standards like PCI-Express, RapidIO, and Hypertransport.

•AdvancedTCA is starting to gain momentum.

T/E-Carrier Semiconductor Market Trends

- **OEMs are flocking to multi-port devices at the lower speeds.** Over the past few years, OEMs have increasingly chosen multi-port LIUs and framers for their T1/E1 line cards, with configurations of up to 8 or 12 ports per device. T3/E3 designs are also going this direction, but the design is more challenging.

- **IC vendors are increasingly integrating the PHY with the framer.** Several vendors offer integrated PHY/framers for T1/E1 and T3/E3, reducing bill-of-material costs and saving board space. SONET designs will be more challenging and will likely be relegated to the lower speeds.

SONET/OTN Semiconductor Market Trends

- **SONET PHY and framer ASICs continue to get squeezed out; the trend toward outsourcing is moving steadily up the layer stack.** Optical networking OEMs traditionally competed on performance and have therefore chosen to do much of their silicon as custom-designed ASICs. As the market has matured and cost and time-to-market have become more important, however, OEMs have steadily moved to standard products. Today, the majority of PHY devices and framers are implemented as standard products. Higher layer devices such as network processors and switch fabrics continue to remain primarily ASIC-based, though even this is starting to change. The availability of larger, faster and more extensively libraried FPGAs is also cannibalizing ASICs.

- **Integrated SONET transceivers are becoming industry standard.** With each new speed deployment, IC vendors enter the market with discrete CDR, mux and demux chips, which they then follow up with integrated transceivers that perform all physical layer functions. At present, integrated OC-192 and OC-768 transceivers are standard in most new designs.
- **OTN has emerged as the protocol of choice to enable the transition away from legacy voice-enabled SONET/SDH networks.** With the birth of smartphones, mobile streaming and the explosion of the mobile connected consumer, global data traffic has reached an inflection point; according to the Cisco Visual Networking Index, it has increased eightfold over the past five years and will increase fourfold over the next five years. Carriers have come under increasing pressure to implement capacity expansion and OTN has emerged as the Layer 1 protocol of choice to enable the transition from voice-optimized SONET/SDH networks to a data-optimized next generation. The transition is likely to result in a substantial decline in SONET/SDH revenues and explosive growth in OTN revenues over the next five years.

ATM Semiconductor Market Trends

- **ATM has replaced Frame Relay in most carrier switching networks, but is being challenged by IP-based solutions.** Frame Relay is a legacy protocol originally designed to interconnect LANs and to be a high-speed WAN protocol. As data networks have scaled, however, Frame Relay has been replaced by Ethernet in the LAN and by ATM in the WAN. Though ATM will remain a mainstream WAN switching choice for some time, newer networking equipment is being designed to work with IP and Ethernet.
- **DSLAMs are moving from ATM to IP for backhaul.** ATM has been a natural fit for DSL backhaul, as it was fast, scalable, and able to handle both the voice and data traffic sent over the copper wire. ATM equipment also operates at the same speeds as SONET, making for an easy interface to the public WAN. With the growth of IP in the WAN, however, the major DSLAM vendors have migrated to IP for backhaul, eliminating ATM from the DSLAM. As with all technology shifts in carrier networks, the complete effect of this trend is taking several years time to play out, but it is an important driver behind the negative CAGR in our ATM forecast.
- **IP basestations are also ramping.** As in the DSLAM market, ATM has been an effective solution for backhaul in wireless basestations, especially to support 2.5G and 3G services which mix voice and data. The increased focus on data services at wireless carriers should provide some incremental demand for ATM ICs for several years, helping to buffer the effects of the transition away from ATM in DSLAMs, which is currently in progress. IP is beginning to replace ATM in basestations as well, which further contributes to the decline of ATM.

Communications Processor, Network Processor and Switching Market Trends

- **Communications processors are beginning to integrate more advanced networking logic, blurring the line between comm processors and NPUs, and validating the multi-core model.** Cavium has been at the forefront of pushing the multi-core transition, arguing that more cores and higher traffic capabilities could handle varied tasks more efficiently as a monolithic chip. Fellow MIPS player NetLogic has followed a similar path; NetLogic has agreed to be acquired by Broadcom. Incumbent Freescale has also followed suit, evolving its PowerQUICC comm processor line to the QorIQ, which includes Integrated Communications Processors (a term it coined when it was part of Motorola). AMCC is evolving its product line to include IP from the company's network processors with its multi-core Titan chip.
- **NPUs are gaining traction, especially in access and metro applications.** Merchant solutions for network processing have not lived up to original rosy expectations, especially at the high-end where they were originally targeted. In recent years, however, IC vendors have refocused on the lower speeds, and have been successful in displacing ASICs in access and metro applications. Intel, AMCC, LSI, EZchip and others all have mature product lines with design wins at tier-1 OEMs, and start-up Wintegra (acquired by PMC-Sierra) has built a very successful and profitable business in DSLAMs, basestations, and other applications which require bandwidth below 1 Gbps. Meanwhile, lack of traction forced vendors such as Bay Microsystems and Exar to halt NPU investment. Note that the momentum behind AdvancedTCA (discussed below) should help accelerate the trend towards standard network processors, as the greater modularity of those systems works well with standard components offered by NPU vendors.
- **Packet co-processors continue to penetrate the LAN backbone and are being used in service provider networks as well.** Cisco has been aggressive in its use of packet co-processors in its higher-end switching and routing platforms, and has increasingly proliferated hardware-based lookup functionality across its product line. This has led to a strong growth rate for packet co-processor products over the past few years, a trend that is expected to continue through the forecast period. Vendors outside of Cisco, including ALAXALA, Alcatel-Lucent, Foundry, Huawei, Arris and others, are also beginning to use these products in their devices. Besides additional customer traction, we are seeing these products move from their home in the enterprise into service provider networks, riding the trend towards IP in the carrier space.
- **Security processors are gaining traction in routers and backbone equipment.** IT security is a clear priority in enterprise networks today, and historically has been implemented with a variety of dedicated hardware and software solutions. More recently, we have seen networking OEMs move to implement security as a feature within other network building blocks, which dramatically increases the SAM for security processors. Cisco has been particularly aggressive on this front in its pursuit of a growing TAM.
- **IPv6 is driving the need for more advanced network processing ICs.** IPv6 (Internet Protocol version 6) is the next generation IP addressing scheme, which increases the size of IP addresses from 4 octants to 16 (which increases the total number of available addresses from 4.3 billion [or 4.3 x 10^9] with IPv4 to 340 billion billion billion billion [or 2.4 x 10^{38}]. IPv6 will take a long time to implement, as it requires that a massive upgrade cycle of routers to support it, but OEMs are now beginning to

ramp IPv6 into their product offerings. Note that on the IC side, more robust network processing ICs will be required to implement IPv6; this is especially true for the compute-intensive classification and packet co-processor ICs.

- **Switch fabric IC vendors are focusing on higher capacity fabrics.** IC vendors, namely Broadcom, are designing switch fabrics with greater capacity as well as the ability to scale more efficiently. The largest capacity fabrics are predominantly ASICs today; as merchant vendors such as Dune and Broadcom ramp the capacity of their offerings we could see them encroach on the high-end of the market.
- **Standard interconnects are gaining traction as OEMs leverage open standards like PCI-Express, RapidIO, and HyperTransport.** Over time the use of open standards should breed low cost, high-performance solutions that will also simplify system design. Note that in addition to communications infrastructure, these products find heavy usage in server (especially blade server) and storage applications.
- **AdvancedTCA is starting to gain momentum.** The AdvancedTCA (Advanced Telecom Computing Architecture) architecture seeks to standardize the designs of communications infrastructure equipment by segmenting out the most common functions used in these systems and providing for interconnect standards between subsystems. Modularity, through the use of mezzanine cards, is a big feature of AdvancedTCA, and it has therefore been endorsed by merchant component suppliers (most prominently Intel) looking to displace ASIC content in OEM systems. Though there will always be a hefty amount of customization done by OEMs and chip designers in this market, where it is used, AdvancedTCA can lower the cost of system design and speed time to market.

Wireless

The cellular communications market has been the most dynamic industry of the past several years, radically transforming the way consumers communicate, connect and share.

Global consumers are now always on and always connected. The smartphone upgrade cycle is in the early innings and soaring data usage and emergence of mobile 'apps' has accelerated the pace of infrastructure upgrades.

The market for wireless communications has emerged as one of the most important in electronics. Serving both the needs of business users and consumers, wireless has not only enhanced voice telecommunications, but also changed the way people live. Wireless communications is no longer a luxury. Several years ago, enterprise communications and emails via BlackBerry were the high end of the wireless market. Today, consumers and their insatiable demand to text, chat, share, tweet, Facebook and stream live video are driving the mobile computing revolution. Consumers are always on, always connected, and are sharing and uploading mobile content at an accelerating rate; OEMs, application ("apps") developers and telecom service providers are struggling to keep up.

The "killer app" is no longer voice. According to the Cisco Visual Networking Index, global mobile data traffic is poised to grow at a 92% CAGR through 2015, led by 110% annual growth in mobile consumer gaming and 108% annual growth in mobile consumer internet video traffic. The high end of the smartphone market has become the new mobile computing platform, and content providers, consumer electronics providers, wireline telecom and cable companies, networking OEMs and application developers are rapidly evolving their business models to meet the new mobile reality. Following the initial success of the BlackBerry OS, subsequent strength of the iPhone (iOS) and now the rising dominance of the open sourced Android ecosystem, the wireless market and the consumer landscape has forever changed.

The traditional computing environment has been blurred beyond recognition, and the rising demands of the mobile consumer are changing the landscape for a variety of industries and traditional business models. Smartphones, and more importantly, the apps which make them "smart," have changed the way consumers connect, communicate and live. All 350 pages of this report may have been dedicated wholly to mobile software or mobile apps or services or daily deals or group chatting or tweeting or video sharing, were it not that this is a report on semiconductors and the technology that enables these things.

Wireless

Wireless Communications Technologies

TDMA, iDEN, GSM, PDC (2G) – The first digital cellular networks were based on time division multiplexing, with TDMA being used in the U.S. and Latin America, GSM in Europe and Asia, and PDC in Japan. TDMA and GSM have for the most part migrated to 2.5G GPRS, and PDC has gone straight to 3G W-CDMA. iDEN is used by Sprint/Nextel for push-to-talk in the U.S.

CDMA/CDMA2000 1xRTT (2G/2.5G) - Pioneered by Qualcomm, CDMA technology is used by Verizon and Sprint in the U.S. and several carriers in Asia. The 2G version of CDMA has already given way to 2.5G CDMA2000 1xRTT.

GPRS and **EDGE** (2.5G/2.75G) – GPRS is an update to GSM that supports data packets. Most GSM carriers are now fully GPRS-capable. EDGE is an enhancement that increases data throughput to 384 Kbps.

CDMA2000 1xEV-DO, Rev-A/B & UMB (3G/3.5G/4G) **-** EV-DO is the CDMA 3G implementation. 3.5G Rev-A and Rev-B boost data throughput, UMB is 4G.

W-CDMA/UMTS, TD-SCDMA and **HSPDA/HSPA+** (3G/3.5G/3.75G) –
W-CDMA/UMTS is the 3G standard that is replacing GSM/GPRS and PDC around the world. TD-SCDMA is a variant being developed for China. HSDPA is an enhancement for faster downlink, while HSPA+ boosts the uplink.

WiMAX (4G) – IEEE wireless broadband standard that grew out of fixed wireless and is being targeted for mobile broadband wireless as well.

LTE (4G) – The “Long Term Evolution” standard is targeted at replacing W-CDMA/UMTS networks around the world.

Wireless Communications Technologies

2G

- **TDMA**: One of the original cellular standards when wireless went from analog to digital, TDMA divides call spectrum into different time slots to transmit multiple calls simultaneously. TDMA networks have already been overlaid with the global GSM standard, and most have also been and upgraded to support GPRS and in some cases EDGE.
- **iDEN**: iDEN is a TDMA-based technology that also supports data, short messaging and dispatch radio (two-way radio). Nextel in the U.S. uses the iDEN standard, though with the acquisition by Sprint, Nextel’s subscribers have been migrated to CDMA-based technologies.
- **GSM**: GSM is a global TDMA-based technology that uses SIM cards to identify individual subscribers. GSM is the predominant 2G standard in use throughout Europe, Asia and the Middle East and Africa, though nearly all GSM carriers have added 2.5G GPRS across the network and are adding EDGE as well. These networks will eventually migrate to W-CDMA/UMTS, and many carriers are well under way with their network upgrades.
- **PDC**: PDC was the dominant 2G standard used in Japan. Carriers in Japan have already upgraded their PDC networks to W-CDMA and are actively migrating their subscriber bases, skipping the 2.5G node entirely.
- **CDMA**: Pioneered by Qualcomm, CDMA uses a spread spectrum technique to overlap every transmission on the same carrier frequency, assigning a unique code to each signal. This requires fewer cell sites for the same number of calls. 2G CDMA

networks (sometimes referred to as CDMAone) have already moved to 2.5G CDMA2000 1xRTT and are also migrating to 3G CDMA2000 1xEV-DO.

2.5G & 2.75G

- **GPRS**: GPRS is an update to GSM that supports data packets. Most GSM carriers are now fully GPRS-capable, with GPRS handset shipments now far outpacing 2G GSM shipments.
- **EDGE**: EDGE is an enhancement that increases data throughput to 384 Kbps. While GPRS is considered 2.5G, EDGE is sometimes referred to as 2.75G.
- **CDMA2000 1xRTT**: CDMA2000 is a set of standards evolving from the original CDMA technology. 1xRTT is the 2.5G version which has fully replaced 2G CDMA around the world, adding enhanced data capabilities and throughput.

3G

- **W-CDMA/UMTS**: W-CDMA is the 3G standard that is replacing GSM/GPRS (including the old TDMA networks) and PDC. W-CDMA, as the name implies, brings CDMA technology to the GSM world, and thus, it requires new network hardware in addition to different handsets (whereas GPRS was a mostly a software upgrade in the network). Carriers in Japan and Europe have already rolled out W-CDMA and are actively migrating their subscriber bases from older technologies; the US is as well but is moving more slowly.
- **CDMA2000 1xEV-DO**: EV-DO is the mainstream 3G CDMA standard that boosts throughput for the data side of the handset. The EV-DO buildout has accelerated, and EV-DO services are now available from carriers in the U.S. and Asia. Revisions of EV-DO (known as Rev-A and Rev-B) are under way to boost data throughput and to add compatibility with WiMAX over time.
- **CDMA2000 1xEV-DV**: EV-DV was an alternate 3G CDMA standard intended to boost throughput for both the voice and data sides of the handset. Qualcomm (and therefore its handset customers and carriers) shelved plans for EV-DV chipsets and instead focused exclusively on EV-DO.
- **TD-SCDMA**: 3G standard developed from the ground up for China. The Chinese Ministry of Information Industry is spearheading the effort to drive this standard along with Chinese carriers, networking OEMs, and handset vendors.

3.5G and 3.75G

- **HSDPA**: HSDPA is an enhancement to W-CDMA/UMTS that boosts data throughput to 1.8 Mbps or 3.6 Mbps in the downlink. Further steps to 7.2 MBit/s and beyond are planned for the future.
- **HSPA+**: HSPA+ will boost the upload speed of HSDPA up to 21 Mbps. While HSDPA is considered 3.5G, HSPA+ is sometimes referred to as 3.75G.
- **CDMA2000 1xEV-DO Rev-A and Rev-B**: Rev-A is a set of enhancements to EV-DO that will boost downlink data rates up to 3.1 Mbps and uplink data rates up to 1.8 Mbps in a radio channel dedicated to carrying high-speed packet data. Rev-B is in development and will add compatibility to WiMAX over time.

4G

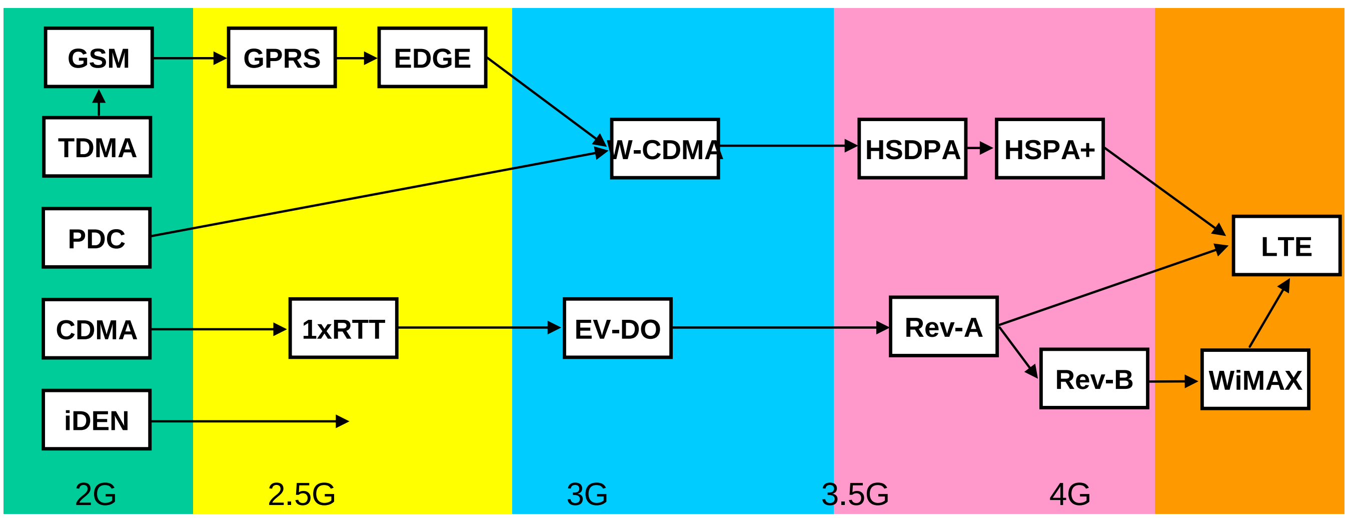
- **WiMAX**: WiMAX is an IEEE wireless broadband standard that grew out of fixed wireless and is being targeted for mobile broadband wireless as well. The Sprint/Clearwire network is the largest and most well-known WiMAX network to date, but there are now more than 600 network deployments globally.
- **LTE**: The “Long Term Evolution” standard will be targeted at replacing W-CDMA around the world. LTE will use OFDM (Orthogonal Frequency Division Multiplexing) and MIMO (multiple-input multiple-output) antenna technology that is currently used in the more advanced wireless data LANs.
  - **TDD-LTE:** Time Division Duplex LTE does not require paired spectrum and can dynamically change uplink/downlink capacity. Because it does not require paired spectrum, TD-LTE networks are a natural evolution of TD-SCDMA networks and need not be “backwards compatible” with legacy 2G/3G networks. TD-LTE will be most prominently deployed in emerging economies.
  - **FDD-LTE:** Frequency Division Duplex LTE requires different frequencies to isolate transmit/receive signals and capacity is not affected by individual uplink/downlink demands. FD-LTE is a natural migration from 2G/3G networks and requires backwards compatibility for voice signals, making it the solution for developed markets with existing infrastructure.

Wireless

Cellular Upgrade Paths

•GSM and TDMA systems have successfully migrated from 2.5G, and many are also adding EDGE. For 3G, these carriers are implementing W-CDMA/UMTS; U.S. and European carriers are deploying these networks now, while the Japanese skipped 2.5G and have been deploying W-CDMA for several years. HSDPA and HSPA+ will boost the speed of W-CDMA, and LTE represents the 4G upgrade.

•CDMA systems have already implemented 2.5G 1xRTT, and the migration to 3G EV-DO is now well under way. Some carriers will follow the CDMA2000 path to WiMAX or LTE.



Source: Oppenheimer & Co.

With 3G/4G spectrum auctions long complete, most carriers have positioned themselves for gradual upgrades to LTE over the next few years. As evidenced in the U.S. by AT&T's (proposed) bid for T-Mobile USA, advanced spectrum is at a high premium in developed markets and, increasingly, in emerging economies. Most carriers decided to implement 2.5G standards before moving to 3G, as the investment and technology hurdles were far lower than for 3G. 3G is now fully deployed in the major developed markets around the world and 3.5G/4G is now gaining global momentum as consumers increasingly utilize next-generation mobile networks as the primary, or even exclusive, point of access to the Internet.

Looking at each of the major network technologies by themselves, we find that GSM systems have, for the past few years, been migrating to 2.5G GPRS. This took place first in Europe and Asia, but the U.S. quickly followed, and the upgrade is now complete. Some of these systems are also implementing EDGE. Though it took some time, carriers are now well under way rolling out 3G UMTS and initial deployments of LTE.

Looking beyond 3G, UMTS carriers have implemented HSDPA and HSPA+ to boost data rates on the down and up link, and eventually will migrate to the LTE standard now in development. TD-SCDMA handsets are finally beginning to gain traction in Asia, and 4G WiMAX/LTE networks from the U.S. to Europe to Asia are being deployed at an accelerating pace. Developed markets with existing mobile infrastructure have begun the deployment of FD-LTE infrastructure, while China, India and others are preparing for the launch of TD-LTE services with planned launches beginning in late 2012.

Wireless

Three Key Markets:

Wireless Handsets

Wireless Infrastructure

LTE / WiMAX

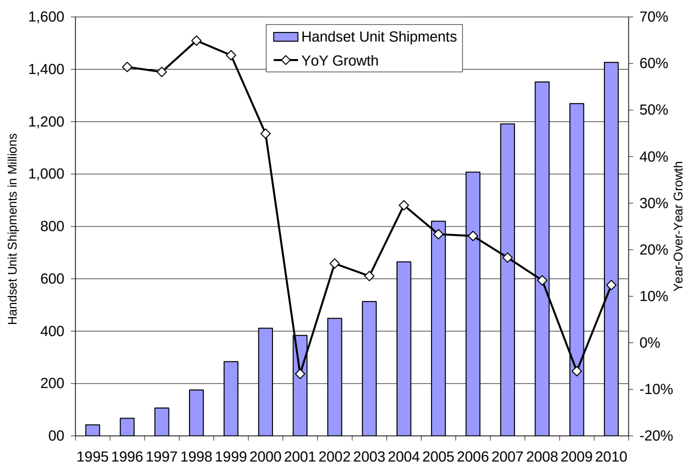
Although they are intimately connected, we segment wireless communications equipment between handsets and infrastructure equipment. They are two sides of the same coin, yet the market drivers are different: handset sales are driven by consumer (and to a lesser extent enterprise) demand in the form of both new subscribers and handset replacements, and infrastructure sales are driven by carrier build-out programs and network upgrades. In fact, the design of infrastructure systems requires competencies from the wireline infrastructure world, and many of the OEM and IC vendors discussed in the telecom/datacom section also play in wireless infrastructure (whereas the handset vendors are generally different).

WiMAX and LTE, commonly known as 4G, represent the next frontier of the broadband wireless market and are likely to be key growth drivers for infrastructure vendors first, followed by handset vendors. Stemming from fixed wireless, the market had high hopes for WiMAX, going public initially with the deployment of Sprint/Clearwire in the U.S. However, LTE is now widely viewed as the 4G network of choice. LTE offers substantially greater upload/download speed and provides consumers with a true mobile broadband experience.

Wireless Handsets

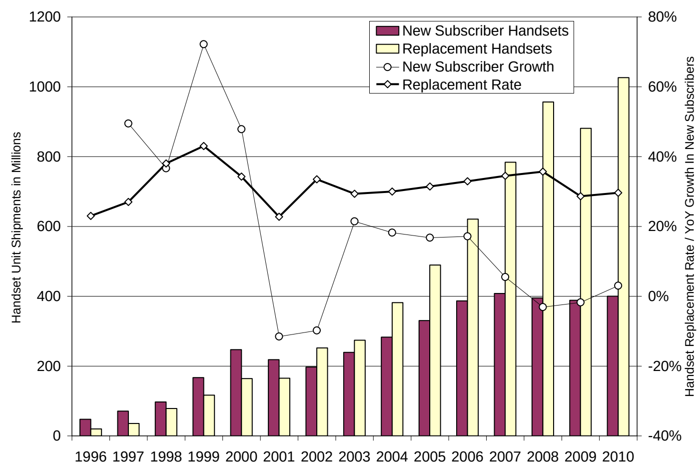
Wireless handsets have seen one of the strongest adoption curves in the history of technology. Prior to taking a slight pause in 2009, handset shipments had experienced double-digit growth each year since 2001. Handsets grew 12% in 2010 and eclipsed 1.4 billion units. Emerging market penetration continues to rise, and global replacement rates have stabilized near 30%. Handset OEMs continue to deliver an improving feature set and lower costs.

Handset Unit Shipments



Source: Oppenheimer & Co.

Replacement vs. New Sub



Source: Oppenheimer & Co.

Wireless handsets have seen one of the strongest adoption curves in the history of technology. The late 1990s saw unfettered growth culminating in nearly 400 million handsets shipped in 2000, which seemed like a lot at the time. Since taking a slight pause in 2001, the market has roared back with a vengeance. With double-digit growth rates for seven prior years, the market stuttered (-6% Y/Y) in 2009. In 2010, handset shipments eclipsed the 1.4 billion mark (1.43 billion units by our estimate).

On the new subscriber handset side, two double-digit negative years in 2001 and 2002 were followed by growth rates of an average 16% in 2003-2007 and falling off by a negative 3% in 2008 by our estimates due to the worldwide recession. Just as industrialized regions were plateauing, emerging market penetration began to pick up dramatically, particularly in Asia, Latin America, and Eastern Europe. Wireless has clearly become a global phenomenon.

Just as importantly, the replacement rate has stabilized near 30%, and replacement handsets have thus grown right alongside the installed base the past few years, with the exception of 2008 and 2009. This is not an insignificant trend, as the replacement rate has not dropped from the mid to high 20% range even as the installed base broadened to include developing regions like China and India, where subscribers have lower discretionary income. We expect the annual replacement rate to remain ~30% through 2015.

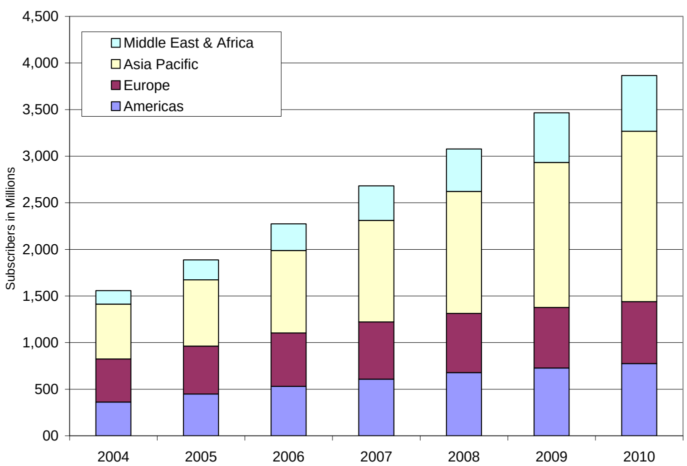
The largest driver of both handset unit growth and replacement rates over the next 2-3 years is likely to be global LTE rollouts and the unparalleled impact of smartphones. Developed market consumers have integrated the smartphone into the way of life, upgrading at a remarkable rate as new smartphones with new features are unveiled. Emerging market consumers are driving demand for low-cost smartphones that in many cases serve as the exclusive portal for Internet access. Smartphones are in many ways eclipsing demand for PCs and have so far transformed how the world interacts. And while smartphones have penetrated just 20%-25% of the global handset market, there remains ample headroom for growth of both the high end and low-cost variety.

Wireless Handsets

The Wireless Subscriber Base

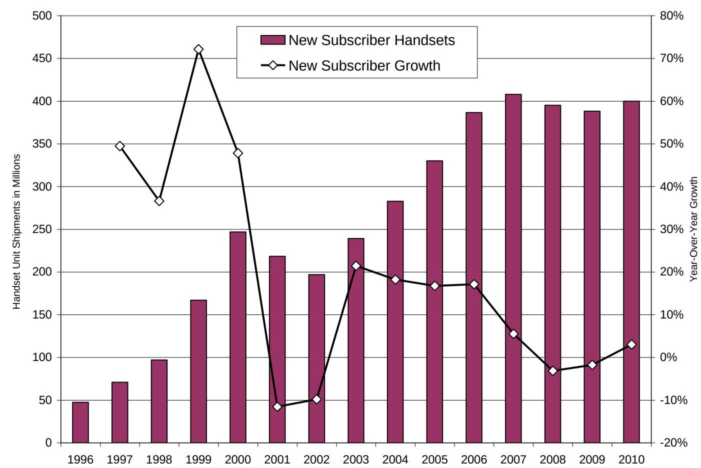
Wireless subscribers continue to grow worldwide. Though subscriber additions trailed off in 2001-02 as penetration plateaued in developed regions, the market has since recovered with strong global subscriber growth, particularly in emerging markets. New low-cost handsets and ODM supply chain models are playing an important role in equipping these very cost sensitive consumers.

Wireless Subscribers



Source: Oppenheimer & Co.

New Subscriber Handsets



Source: Oppenheimer & Co.

After several years of 35%+ growth in the late 1990s, wireless subscriber additions trailed off in 2001-2002 (down 12% and 10%, respectively) as penetration plateaued in developed regions. The market has since recovered with subscriber growth increasing by an average 26% from 2003-2006 followed by 17% growth in 2007 and a decrease of 12% in 2008. Emerging markets like Asia, Latin America, and Eastern Europe have been particularly strong. The “white box” market, comprised of low-cost ODM handsets, has exploded in emerging markets driving incremental subscriber growth where service may have otherwise been unaffordable.

Though subscriber addition growth is still at healthy rates even after many years of robust growth, global penetration is rising and new subscriber additions will eventually taper off. There should still be pockets of strength in markets like Eastern Europe and China, but on the whole additions should begin to drop over the coming years. Growth in the handset market will therefore become more dependent on replacement rates and the ongoing mix shift to smartphones, both high-end and low-cost.

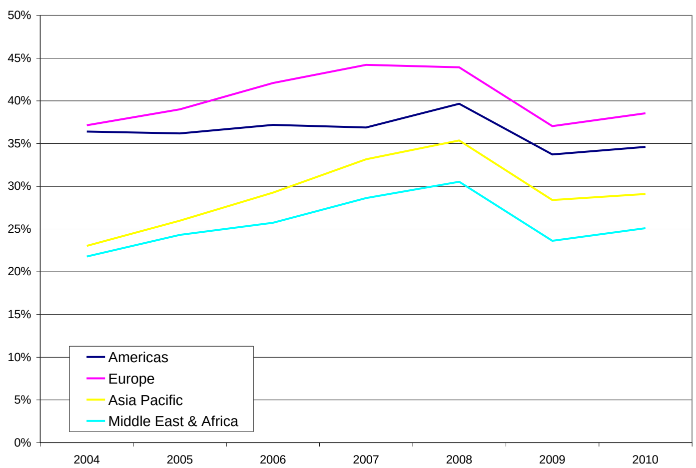
In terms of the subscriber base, we find that in 2010, 20% of the world’s 3.9 billion wireless subscribers were found in North and South America, 17% were in Europe, 47% in Asia-Pacific including Japan and 15% in the Middle East and Africa. Over time, the Americas and Europe have declined as a percentage of total while APAC and MEA have increased. Still, both the Americas and Europe regions have underpenetrated markets (particularly Latin America and Eastern Europe), which should allow the subscriber base to grow on an absolute basis.

Wireless Handsets

Handset Replacement Market

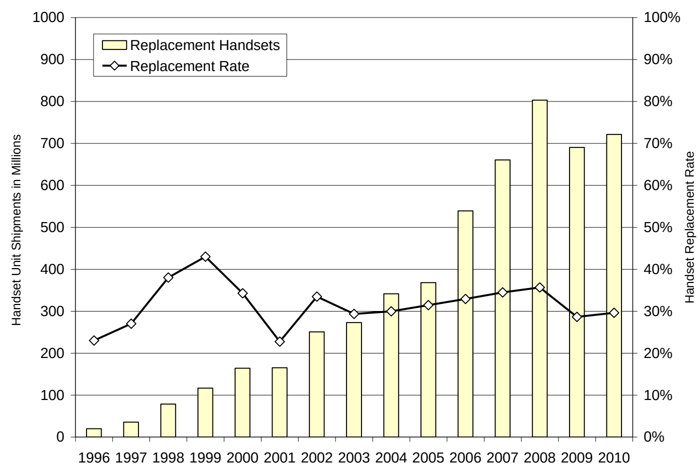
As the handset market has matured, replacement rates have come down, but are still quite healthy at 30% worldwide. OEMs remain focused on adding multimedia and data connectivity features as well as improving battery life and industrial design, all while reducing cost.

Handset Replacement Rate By Region



Source: Oppenheimer & Co.

Replacement Handset Unit Shipments



Source: Oppenheimer & Co.

Though subscriber growth has proved remarkably robust over the past few years, OEMs and service providers have for years anticipated wireless moving to more of a replacement market. As subscriber growth declines with rising global penetration, the replacement handset market should pull away from new subscriber handset market in terms of unit shipments.

The handset replacement rate—which is a simple ratio of replacement handsets sold divided by the total subscriber base—ramped hard in the late 1990s as digital service became more pervasive and increased competition sparked frequent carrier switching (helped along by generous carrier handset subsidies). Replacement trends then declined sharply in 2000 and 2001, as users began to stretch the lives of their handsets; weaker economic conditions in 2001 clearly had an effect.

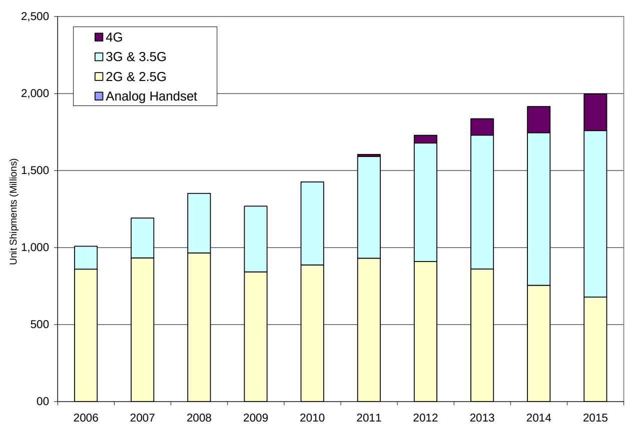
Handset replacement has since stabilized in the 30%-35% range as the market has matured. This occurred even as the installed base broadened to include developing regions like China and India, where subscribers have lower discretionary income. Handset OEMs have focused on improving the feature sets of their offerings while driving down cost and time to market. As smartphones have garnered momentum, handset OEMs have had to increasingly tether themselves to a mobile operating system, with Android moving to the market share pole position. Hardware features have in many ways become second fiddle to the availability of apps as offered on the chosen operating system.

OEMs continue to pay close attention to the features demanded by a new wireless-savvy consumer base and have been willing to sacrifice margin by offering more expensive models at stable, consumer-friendly price points to keep the subscriber base hooked on a quick replacement cycle. Over the next several years, rapid shifts in mobile phone OS market shares, the increasing importance of mobile “apps,” and lightning-fast transition to 4G networks are likely to further decrease time of the average OEM design cycle, ultimately pushing the pace of the handset replacement rate.

Wireless Handsets

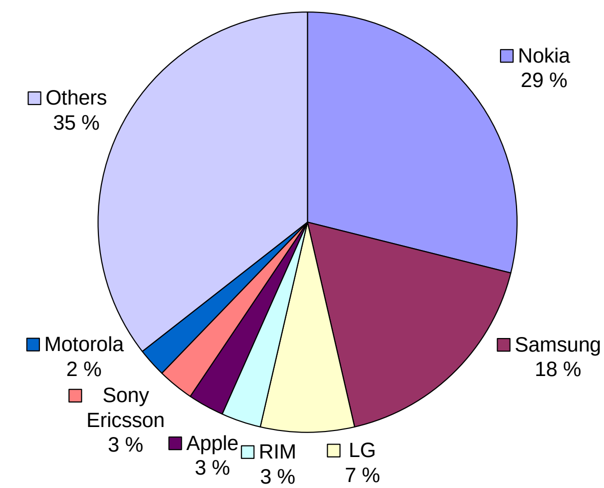
Wireless Handset Unit Forecast

•We expect wireless handsets to grow at a 7% CAGR, from 1.4 billion units in 2010 to just under 2.0 billion units in 2015.
•3G & 3.5G shipments should grow steadily through 2015, when they should represent 54% of total shipments.
•2G & 2.5G should decline at a 5% CAGR with a peak in 2011 as the 3G/4G shift takes hold.
•4G is expected to ramp from a small base in 2010 and represent 12% of total shipments in 2015.



Source: Oppenheimer & Co.

Wireless Handset Suppliers



Source: Dataquest, Oppenheimer & Co.

Wireless Handset Unit Forecast: Since bottoming in 2001, the handset market has seen solid growth driven both by increased subscriber growth and healthy handset replacement rates. Handset unit shipments in 2010 totaled 1.4 billion, up 12% year-over-year. This followed a slight pause (-6% Y/Y) in 2009, but 13% growth in 2008 and an 18% uptick in 2007.

In terms of segmentation, 2G and 2.5G handsets—which include GPRS, CDMA 1xRTT, and EDGE—represented 62% of shipments in 2010. 3G—which includes W-CDMA and CDMA 1xEV-DO (and in the future will include HSDPA, HSPA+, TD-SCDMA, and LTE)—represented 32% of total. Legacy 2G standards totaled just 1% of unit shipments.

Looking ahead, we forecast handsets to grow at a 7% rate, rising from 1.4 billion units in 2010 to 2.0 billion units in 2015. By 2013, we expect 2G/2.5G handsets to represent 34% of total shipments, with 3G/3.5G to represent 54% and emerging 4G handsets to account for 12%.

Wireless Handset Suppliers: The handset market has undergone substantial share changes with the emergence of low-cost Android based smartphones and surge in Asian white box sales; the market on a whole has become increasingly fragmented. The top supplier of handsets in 2010 was Nokia, with 29% unit share overall, down from 36% in 2009. Samsung was second with 18%, increasingly focused on Android-based smartphones. LG was third with 7% share, while Apple, Research in Motion and Sony Ericsson each held 3% share.

The astonishing growth of smartphones has forever changed the landscape of handset suppliers. Apple continues to gobble up market share, and early Android adopters Samsung and HTC are rapidly gaining share in the high end of the market. ZTE, Huawei and Chinese white-box players have emerged as major players in the low-end smartphone market and are taking substantial share from traditional suppliers LG, RIM, Motorola and Nokia. Market share has changed so dramatically in 2011 that 2010 market share has already become materially outdated.

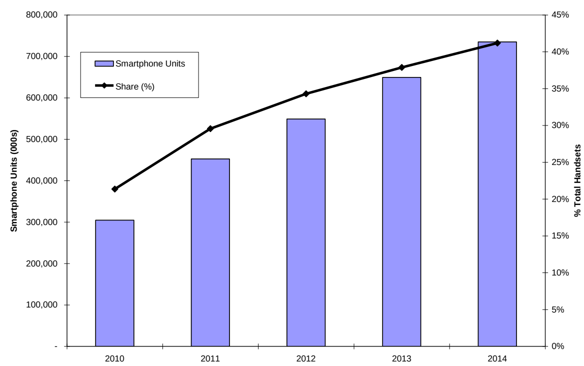
Wireless Handsets

Rising Penetration of Smartphones

•We expect smartphones to grow at a 25% CAGR, from 304 million units in 2010 to 734 million units in 2014. This while traditional handsets decline at a 1.6% CAGR.

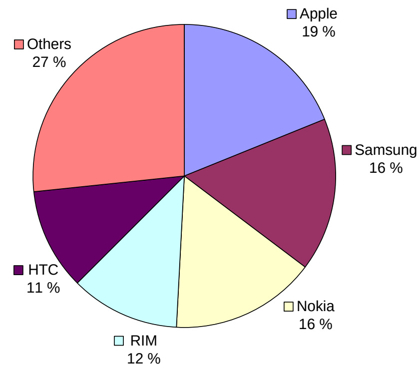
•Smartphone penetration of the total handset market is expected to rise from 21% in 2010 to 41% in 2014.

•Android and iOS have all the current momentum and appear poised to continue taking share at the expense of Symbian, BlackBerry OS and Windows Mobile.



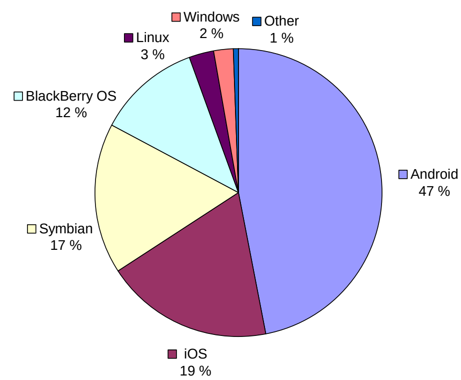
Source: IDC, Oppenheimer & Co.

Smartphone Suppliers



Source: 2Q11, IDC, Oppenheimer & Co.

OS Share Leaders



Source: 2Q11, IDC, Oppenheimer & Co.

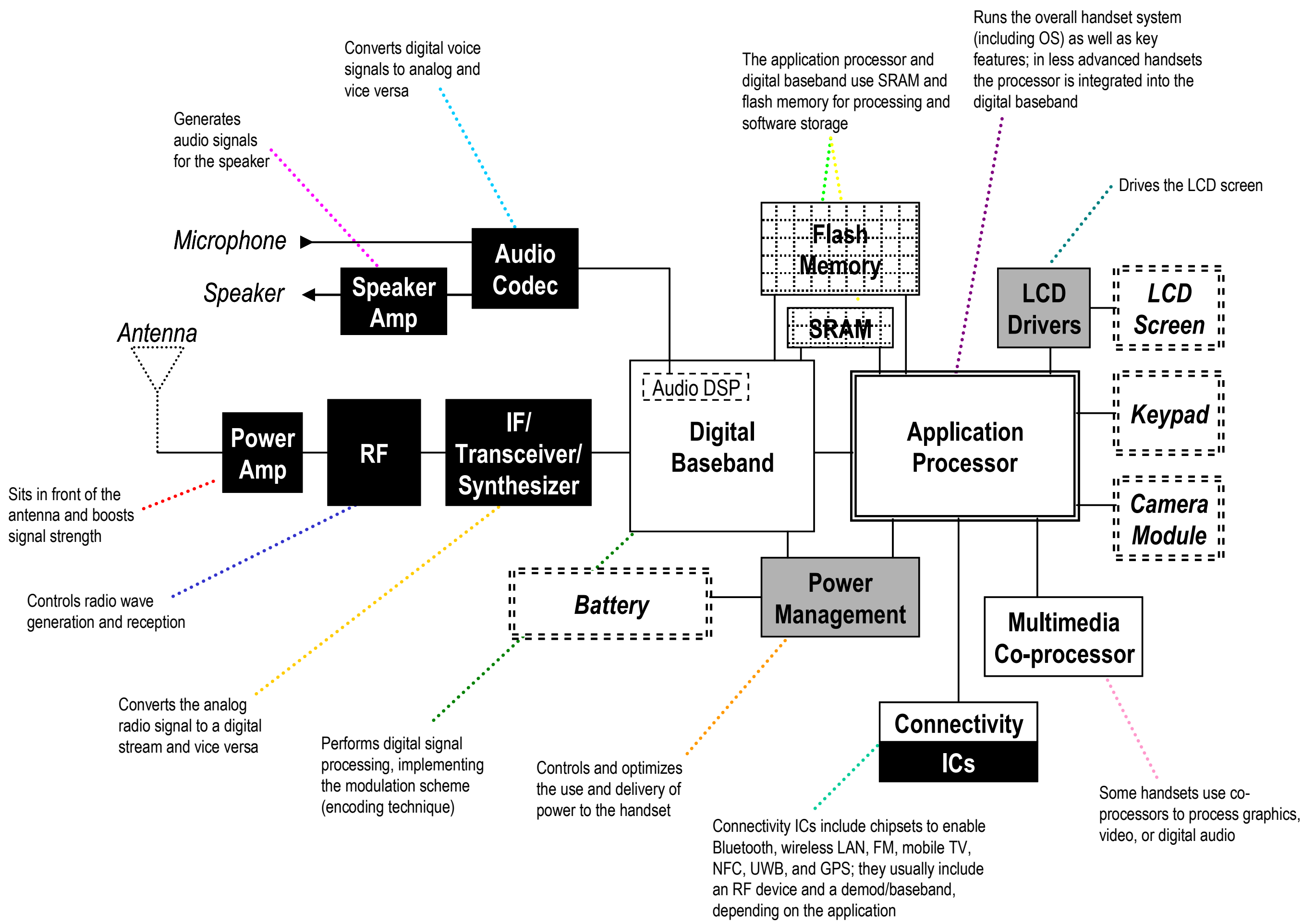
Smartphone Market Share: The landscape of the handset market forever changed with the introduction of the iPhone. In an incredibly short period of time, Apple has risen to market share leader, with 19% of the global smartphone market. Samsung and HTC, as strong early adopters of the Android platform, have surged to 16% and 11%, respectively, at the expense of share-losers Nokia and RIM. Smartphones first began outselling feature phones in early 2011 in the US and in 2Q11 in Europe.

Android OS now accounts for nearly 50% of the total market. Early adopters Samsung and HTC have consolidated a large amount of this share, but ZTE, Huawei and Chinese white box players are accounting for a growing number of low cost Android smartphones in emerging markets. Proliferation of these low end smartphones across emerging economies will likely be one of the largest drivers of handset unit growth through 2015. The rising smartphone tide is likely to benefit all smartphone players through 2015.

Semiconductor Implications: Smartphones accounted for just 10% of the global handset market in 2007, doubled this penetration rate to 21% in 2010 and are expected to again double penetration to 41% by 2014. While high-end smartphones are clearly re-defining the mobile computing market in developed markets, the emergence of low-cost smartphones, particularly those running the Android OS, has become a new leg of growth. Much of the focus in the smartphone market has moved away from OEM brand recognition to OS brand recognition–growth of the Android OS has been both spectacular and unprecedented.

Semiconductor demands on connectivity, processing, battery life and increased complexity of the radio have increased multiple times over for high end smartphones when compared with feature phones. This presents rising dollar content opportunity for mobile semiconductor suppliers, particularly as low-cost smartphones, with up to 5x the content of feature phones, cannibalize and ultimately replace the traditional handset market. Adding additional bands to the radio as LTE garners momentum is also a near term boon to suppliers–all in all, creating a far richer mix of semiconductor content to offset ongoing price concessions.

Wireless Handsets



Source: Texas Instruments, Oppenheimer & Co.

The semiconductors used in wireless handsets can vary greatly by model, especially when additional multimedia features are added, but the primary functions are essentially the same. Voice traffic is captured by the antenna and processed by the RF block, which includes a power amp, an RF and an IF transceiver, which converts the analog signal to a digital bit stream. A digital baseband processes the encoded signal into voice signals and sends it through an audio DSP to the speaker. On the transmit side, the process is reversed: the microphone sends audio signals to the audio DSP, which are processed by the baseband and sent through the RF block to the antenna.

In addition to these devices, an application processor controls the system and runs the phone operating system and other software; this processor is integrated into the digital baseband in mainstream phones. More advanced handsets will also contain discrete ICs or chipsets to enable features like the camera, graphics, Bluetooth, wireless LAN, GPS, or mobile TV. The system also uses significant flash memory, SRAM and power management devices.

RF Block

- **Power Amp**: The power amp sits in front of the antenna and boosts signal strength.
- **RF**: The RF front end controls the radio wave generation on the transmit side and receives the radio wave signal on the receive side, translating between low-frequency analog signals used in the handset (specifically by the IF transceiver) and high-frequency RF signals used in radio communications.
- **IF/Transceiver/Synthesizer**: The IF performs all quadrature modulation of “I” and “Q” baseband signals, converting the analog radio signal to a digital stream to be processed by the baseband and vice versa.

Baseband and Audio Processing, Power Management

- **Digital Baseband**: The baseband processor performs digital processing on the signal, implementing the wireless modulation scheme (the encoding technique, e.g., GSM, GPRS, EDGE, CDMA, CDMA2000 etc.), encoding and extracting voice signals in and out of the transmission protocol. It is usually implemented as a DSP or an ASSP with embedded DSP.
- **Audio DSP**: The audio DSP is integrated into the digital baseband and processes the audio signals, converting the stream into voice signals and vice versa.
- **Audio Codec**: On the receive side, the audio codec converts the digital voice signals to analog signals to be sent to the speaker amp; on the transmit side, it receives and converts voice signals from microphone to digital for processing by the audio codec.
- **Speaker Amp**: The speaker amp drives the audio signals in the handset speaker or headset.
- **Power Management**: Power management ICs regulate, control, manipulate and optimize the use and delivery of battery power to handset components.
- **Analog baseband** (not shown in diagram): The audio DSP, codec, and speaker amp are often integrated into a single IC known as the analog baseband. Many analog basebands also include power management.

Application Processor and Memory

- **Application Processor**: The application processor runs the phone operating system and other software and controls overall handset functionality. Most mainstream handsets integrate the processor into the digital baseband; more advanced handsets use a discrete application processor such as TI's OMAP or ST's Nomadik.
- **Flash Memory**: Flash memory is the primary memory used by the handset for storage of system software, phone book entries and other user data. In traditional handset designs the flash memory used is high-density NOR flash, though NAND is making inroads alongside NOR, especially in multimedia handsets.
- **SRAM, PSRAM, or Mobile DRAM:** The digital baseband and application processor use some volatile memory for processing functions. In traditional handset designs, this has been SRAM, though we are increasingly seeing a mix of PSRAM (Pseudo-SRAM) and mobile DRAM.
- **Stacked Memory** (not shown in diagram): Stacked memory is a module containing flash memory and SRAM (or PSRAM or M-DRAM) in a single package. Also called MCP (multi-chip package) memory. It is also sometimes offered with an application processor in-package.
- **Multimedia and Connectivity ICs**: These ICs or chipsets are used in advanced phones to implement multimedia and connectivity functions. These features will usually be implemented with a chipset that includes digital processors plus an analog front end as described below. Note that some of this logic can be loaded onto the application processor or an intelligent co-processor, eliminating the need for discrete ICs.
    - **Camera:** Camera modules usually include a CMOS or CCD image sensor and an image processing IC.
    - **Advanced Graphics:** Some handsets include a graphics co-processor, though many application processors can also perform this function.
    - **Bluetooth:** Bluetooth functionality requires an additional radio and baseband, usually implemented as a single-chip Bluetooth SoC or integrated with Wireless LAN.
    - **Wireless LAN**: 802.11 functionality requires an additional radio and baseband.
    - **GPS:** GPS functionality requires an additional radio and baseband.
    - **Near Field Communications (NFC)**: Mobile payment system is now available in many high-end smartphones.
    - **FM Tuner:** FM tuning requires a discrete tuner, though this is sometimes integrated with Bluetooth and Wireless LAN.
    - **Mobile TV** (e.g. DVB-H): TV tuning requires a digital TV tuner and demodulator. Analog tuners have gained considerable traction in emerging markets.
    - **MP3 Audio Decoding**: MP3 audio decode can be done with a separate digital audio processor or on the application processor.
    - **MPEG-4 Video Processing**: MPEG-4 video decode and encode can be done with a separate digital video processor but can also be performed by an application processor or graphics co-processor.

Wireless Handsets

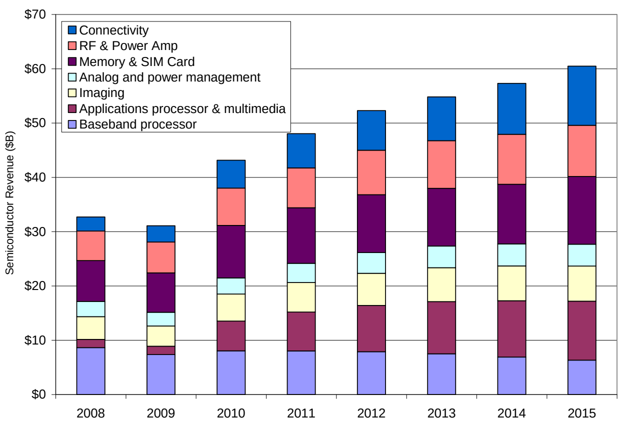
Handset Semiconductor Forecast

•Handset ICs expected to grow at a 7% CAGR from $43.1 billion in 2010 to $60.4 billion in 2015.

•Basebands should decline at a 5% CAGR as integrated baseband/apps processor grows at a 15% CAGR.

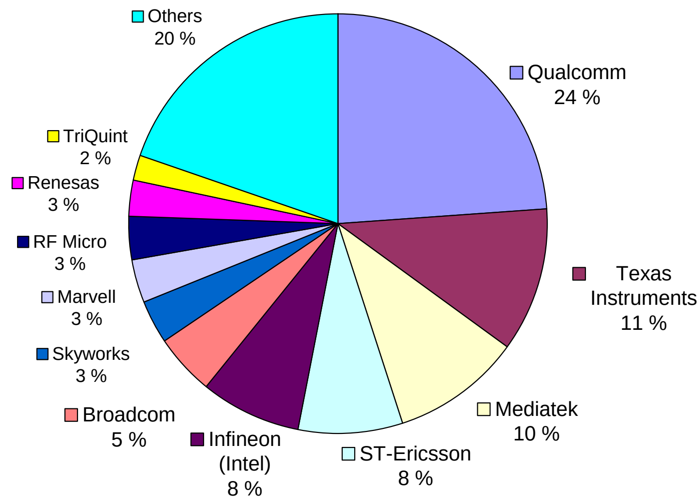
•RF/power amps to rise 7% as the move to multi-mode and multi-band offsets a move to integrated/converged solutions.

•Connectivity ICs to grow at a 16% CAGR, representing 18% of IC revenue in 2015.



Note: Includes memory.
Source: IDC, Oppenheimer & Co.

Handset Semiconductor Competitors



Note: Market share pie excludes memory sold into handsets.

Baseband & AP	***RF & Power Amp***	***Handset Memory***
Qualcomm	Qualcomm	Samsung
TI	Skyworks	Numonyx
Mediatek	RF Micro Devices	Toshiba
Infineon (Intel)	Intel (Infineon)	Spansion
ST-Ericsson	MediaTek	Hynix
Marvell	TriQuint	Elpida
Freescale	ST-Ericsson	Micron

Source: IDC, Dataquest, Oppenheimer & Co.

Wireless Handset Semiconductor Forecast: The wireless semiconductor market totaled $43.1 billion in 2010, representing 39% growth over 2009. With a richer mix of 3G/4G handsets, the move to multi-mode multi-band devices and rising connectivity demands across the spectrum of wireless devices, we believe wireless semiconductor revenue as a whole will rise roughly in line with units, offsetting pricing declines and increased integration. There are, however, multiple areas affecting this revenue growth:

- *Phone generation:* 3G/4G phones need more advanced (and more expensive) baseband and RF ICs.
- *Multi-mode capability:* multi-mode phones sometimes need more expensive basebands and additional radios.
- *Multimedia feature set:* multimedia phones can require applications processors, co-processors, camera modules and additional memory; advanced screens also need more LEDs and battery management solutions.
- *Connectivity:* handsets incorporating Bluetooth, WLAN, GPS and NFC require additional ICs.
- *Memory content:* more memory is needed to run advanced software and for data storage.

A quick glance points to an increasing semiconductor bill-of-materials (BOM). Although handsets remain a consumer-driven market that is extremely sensitive to price, the proliferation of smartphones has created an interesting pricing dynamic. As smartphones increasingly double as mobile computing devices, consumers have shown a greater willingness to pay for extremely high end devices. And carriers have demonstrated a willingness to substantially subsidize the price of a smartphone so they can collect incremental data usage fees. As the smartphone market continues to penetrate the handset market as a whole, a richer mix of semiconductor content can drive an increasing BOM. However, pricing pressure, particularly in low end emerging market feature phones, and increasingly integrated solutions will limit the growth of total semiconductor content. Some areas, such as connectivity and RF content, should benefit disproportionately to others, such as baseband processors (integration) and memory (pricing).

Looking ahead, we would expect the total wireless semiconductor market to grow at a 7% CAGR through 2015, roughly in-line with our assumed 7% growth rate in handset unit shipments. We note that this growth in semiconductor content excludes tablets, which are included in computing but benefit most of the wireless semiconductor vendors rather than traditional PC vendors. In total, we expect handset semiconductor sales to rise from $43.1 billion in 2010 to $60.4 billion in 2015.

In terms of device categories, in 2010 we estimate that digital basebands represented 19% of IC content, with application processors another 13%. In 2009, basebands represented 24% of total revenue and application processors just 5%. Memory, including SIM cards, was 22% of revenue. Imaging ICs was another 12%, followed by analog basebands and power management at 7%. On the radio side, RF and power amps represented 16% of total. Connectivity solutions, such as Bluetooth, represented just 12% of IC market revenue in 2010.

Looking ahead, we expect to see some shift in device content, driven by new multimedia and connectivity features and also by integration. We expect baseband and application processors to grow at a 5% CAGR through 2015, as 1) attach rate of application processing grows, a negative for pricing; 2) 3G/4G penetration rises; and 3) baseband ICs integrate in analog and RF capability. Note that within this digital processing sub-segment, application processors soar 15% while discrete basebands are declining 5%; this is a result of baseband processors that integrate application functionality and a move away from discrete basebands.

Moving to other parts of the baseband sub-system, we expect memory to grow 5% as increased demand on memory components is offset by fierce pricing pressure. Analog and power management ICs should grow 6% as some of this functionality is integrated into single-chip SoCs, usually classified as basebands.

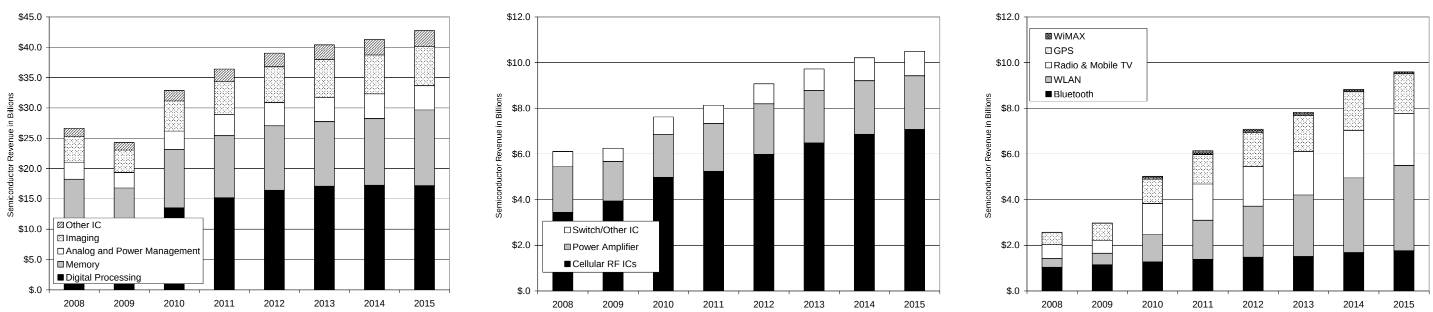
On the radio side, cellular RF and power amp ICs should grow at a 7% CAGR through 2015. The demand boost from tri-band and 4G handsets should be offset by single-chip cell phone designs that include the RF. A rise in front end modules and recently-introduced converged front end architecture will likely weigh on pricing and somewhat offset additional band requirements.

Connectivity ICs should grow rapidly, a 16% CAGR, growing from just 12% of the market in 2010 to 18% in 2015. Bluetooth, wireless LAN, GPS, and NFC should all contribute meaningfully, although combo-chip solutions (WLAN) will be the largest growth driver.

The exhibits below display handset semiconductor revenue forecast by device type.

Handset Semiconductor Forecast

Baseband (includes memory) | **Radio** | **Connectivity**



Source: IDC, Oppenheimer & Co.

Wireless Handset Semiconductor Competitors: The large volume and diverse nature of devices required to enable a wireless handset have ensured that, besides the-exception-that-proves-the-rule Qualcomm and a few niche players such as RF Micro Devices and Skyworks, the majority of handset semiconductors are supplied by large, diversified DSP and analog semiconductor suppliers. These vendors possess not only analog and digital IC design, but also system level expertise; and, often, in-house manufacturing to drive the product to high volume. The market is becoming increasingly crowded, however, as it appears poised to become one of the largest growth drivers in semis over the next 3-5 years.

The two market leaders in handset ICs in 2010 were Qualcomm, with 24% total market share, and Texas Instruments, with 11% share. Mediatek followed with 10% share and St-Ericsson and Infineon (Intel) rounded out the top 5 with 8% share apiece. Each of these vendors derived more than $2.0 billion from handsets in 2010.

Several vendors have 5% share or less but with more than $500 million in revenue in 2010, including Broadcom, Skyworks, Marvell, RF Micro Devices, Renesas and TriQuint. Note that this long list still excludes memory suppliers (discussed below) and suppliers of connectivity ICs.

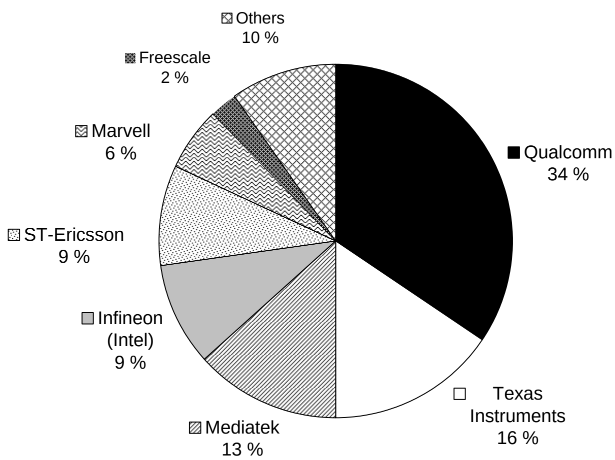
Looking at the market by subsystem, the baseband market is led by Qualcomm, which held 34% share of all baseband components (excluding memory) in 2010, owing to its dominant share in CDMA and a growing position in UMTS. Qualcomm held a 24% share of the discrete baseband market and 41% of baseband analog ICs; the structure of Qualcomm's chipset precludes application processors.

Texas Instruments was No. 2 overall with 11% share. TI is the No. 2 supplier of discrete baseband components with 21% share and leads the application processor segment with 30% share. TI is unlikely to maintain its leadership in the application processor segment given Apple's substantial share gains throughout 2011.

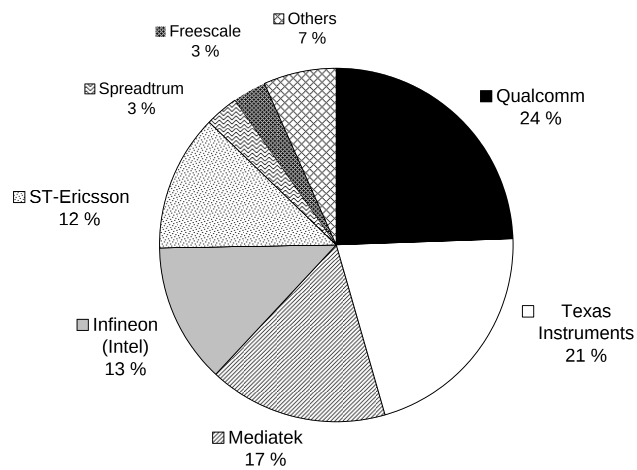
Mediatek leaped to the No. 3 market share position in 2010, driven by strong handset unit growth throughout the year and rapid growth of the Chinese white box handset market. Mediatek and emerging baseband supplier Spreadtrum Communications have each continued to experience strong baseband demand from Asian ODMs.

Note that the relationships between baseband IC vendors and their OEM customers vary greatly. Suppliers like Qualcomm and NXP primarily sell packaged chipsets that include software, protocol stacks, and reference designs. Other IC suppliers partner more closely with their customers, customizing their solution to the needs of the individual customers. Note that this latter set of companies also pursues full system solutions with reference designs in order to serve other OEMs and ODMs outside of their core customer set.

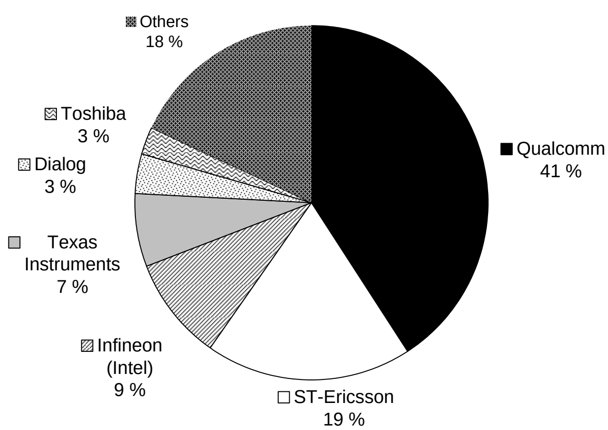
2010 Total Baseband IC Market Share



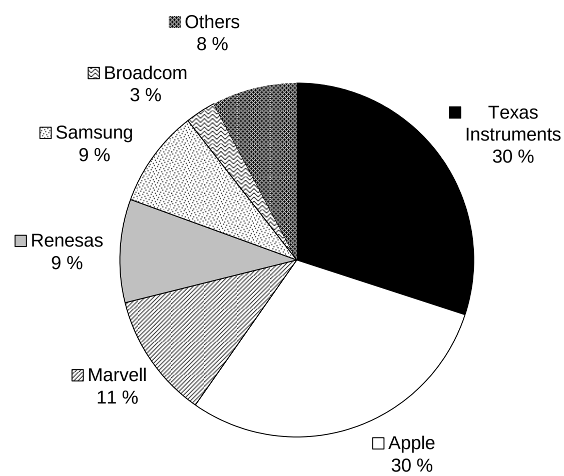
2010 Discrete Baseband Market Share



2010 Baseband Analog Market Share



2010 Wireless Application Processor Market Share

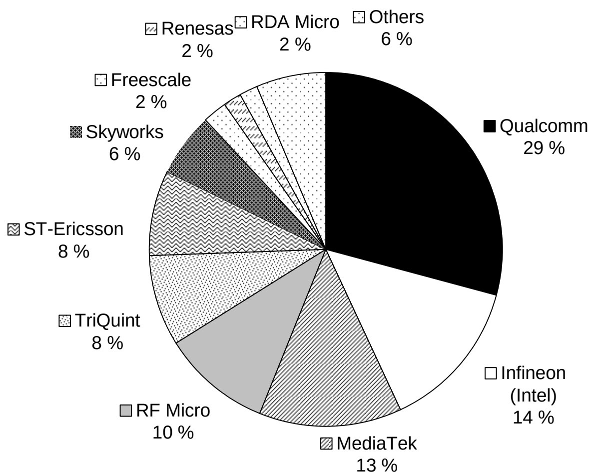


Source: IDC, Oppenheimer & Co.

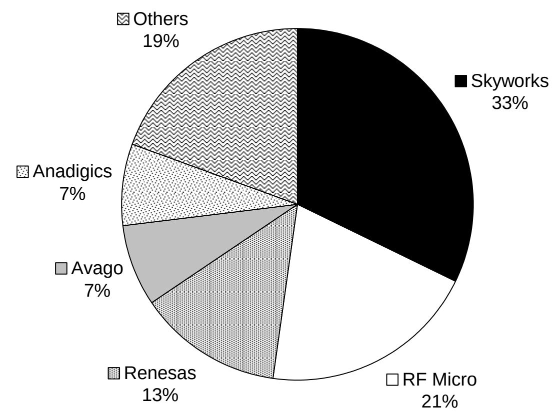
On the RF and power amp side, the market is somewhat more fragmented, with only one vendor holding more than 20% share. Qualcomm was the No. 1 supplier overall in 2010 with 22% share, due to its 29% share of the RF transceiver market, where it supplies RF components to go with its basebands. Qualcomm does not supply power amps and instead partners with third parties to offer these to customers on its reference design.

Skyworks was second with 14% share, owing to its leading 33% share of the power amp market, its strong and growing relationship with Qualcomm and a historically strong partnership with Apple. Skyworks eclipsed RF Micro Devices for the share lead in the PA market during 2010. Rounding out the top vendors were Infineon (Intel), Mediatek and TriQuint, with 11%, 10% and 8% share, respectively. Other significant suppliers include ST-Ericsson, Renesas, Avago and ANADIGICS. The exhibits below display RF transceiver and power amp market shares individually.

2010 Handset RF Transceiver Market Share



2010 Handset Power Amp Market Share



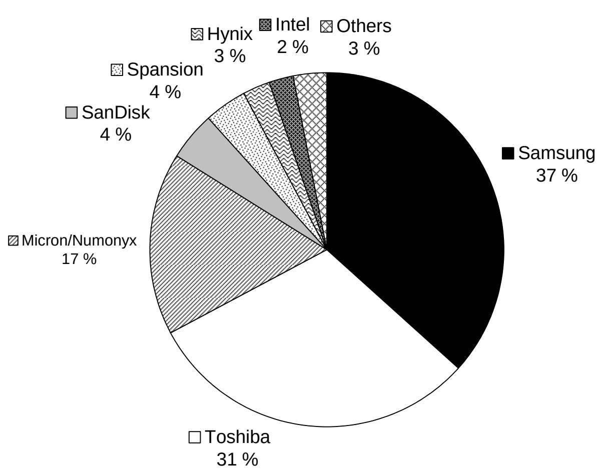
Source: IDC, Oppenheimer & Co.

Also participating in the handset semiconductor market are the vendors of flash memory and SRAM. On the flash side, the top makers of flash for handsets are Samsung, Toshiba, Micron/Numonyx, SanDisk, Spansion, Hynix and Intel. Suppliers of NAND flash are becoming more prevalent in handsets with the growth of smartphones.

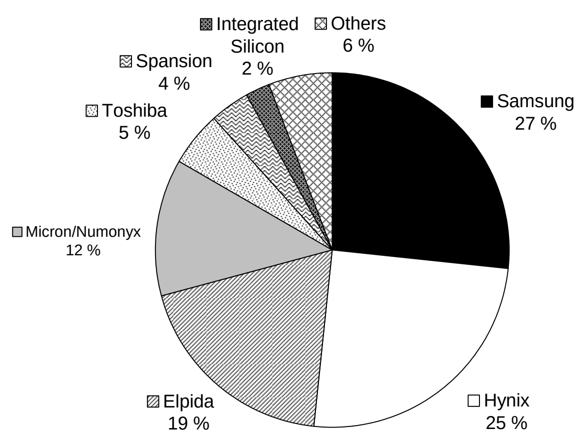
On the SRAM side, the top suppliers into handsets are Samsung, Hynix, Elpida, Micron/Numonyx, Toshiba, Spansion, and Integrated Silicon. Note that this includes vendors of multi-chip package memories that include flash and SRAM (many of these vendors source some of their SRAM externally and resell it).

The exhibits below display flash and SRAM market shares for wireless handsets individually.

2010 Handset Flash Memory Market Share



2010 Handset SRAM Market Share



Source: Gartner, Oppenheimer & Co.

Wireless Handsets

Wireless Handset Semiconductor Market Trends

- The market is clearly focused on 3G/3.5G and the transition to LTE.
- Feature rich handsets require additional application processing:
  - Application processors common in smartphones
  - Integrated baseband/application processors are in volume
- Connectivity ICs are the fastest growing segment:
  - Mobile devices are becoming "mobile hotspots"
- Increased complexity driving RF component trends:
  - The move towards multi-mode, multi-band devices
  - Power amp modules integrating switch, power, and filter
  - Complete RF front end modules are increasingly common
- Multi-SIM solutions are exploding in emerging markets.
- New features are emerging such as NFC and fingerprint recognition.
- ODMs now an integral part of the supply chain with growth in white box market.
- More advanced handsets require more memory and a more efficient battery.

- **The market is clearly focused on 3G/3.5G and the transition to LTE.** The 2G/2.5G market is likely in a terminal state of decline with 3G handsets expected to grow at an 18.5% CAGR through 2015, surpassing 1.0 billion units that year. Total 4G handset units seem poised to grow from nothing to more than 200 million units in 2015, more than a 100% CAGR. IC vendors have been squarely focused on this opportunity, particularly with HSPA. FD-LTE has already begun to ramp, with Verizon leading the charge in developed markets, and TD-LTE poised to layer on growth beginning late in 2012.

- **Feature-rich handsets require additional application processing.** Newer handsets, especially those with advanced multimedia and data capability, require more advanced application processing. Particularly as the lines blur between smartphones and tablets, semiconductor suppliers have rushed to chase the business. It is a battle of heavyweights from Qualcomm (Snapdragon) to Marvell (Armada), NVIDIA (Tegra) and TI (OMAP). Leading smartphone vendors Apple and Samsung, however, primarily use in-house application processors. This segment of the market is one of the largest differentiators between high end phones and mid-low- end phones.

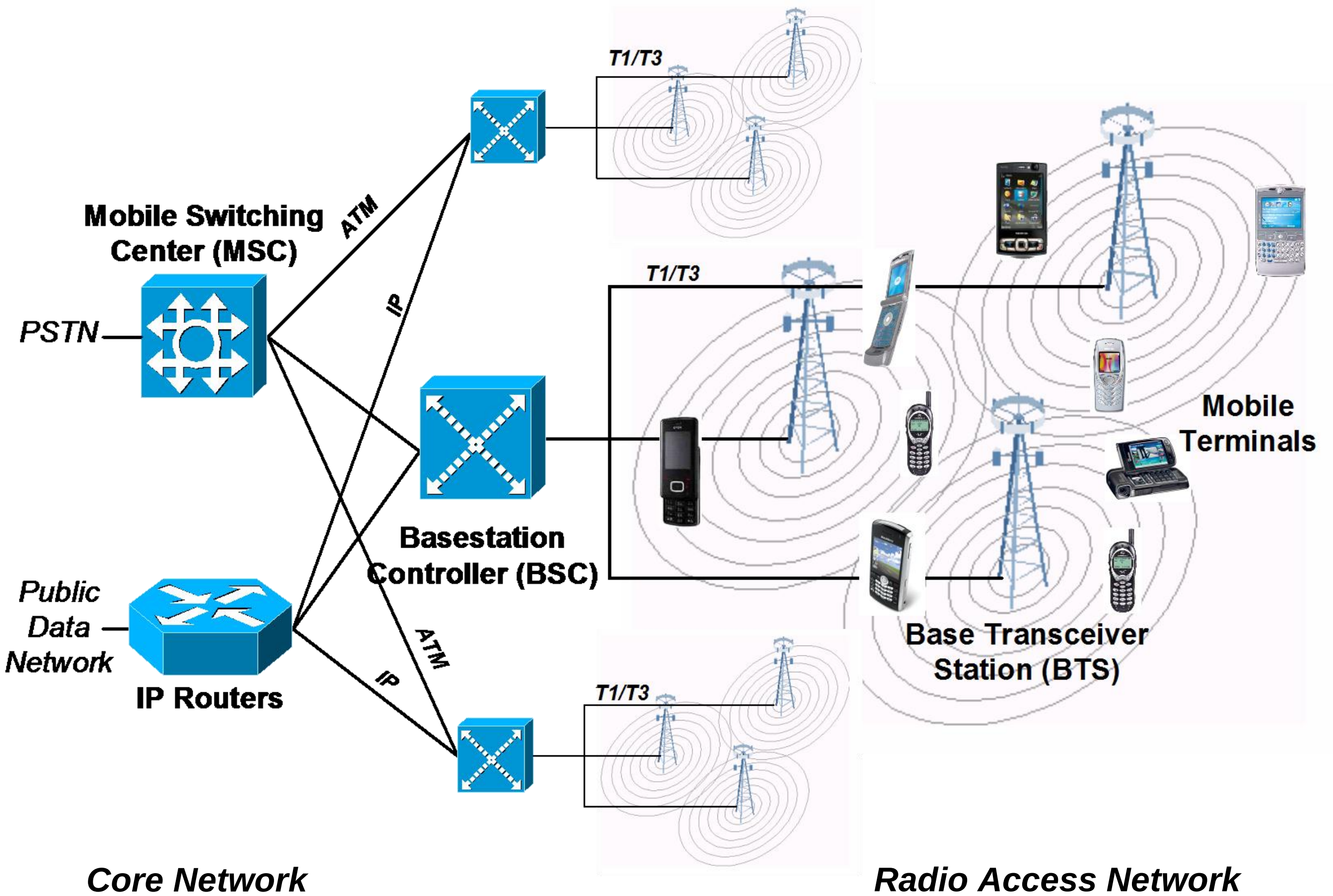
- **Integrated baseband/application processors are in volume.** Tied in with the application processor trend are new integrated baseband/application processor designs. These solutions have been and will continue to be effective in low-mid-range phones, with discrete apps/baseband processors remaining the choice at the high end of the market, where differentiation and performance remain paramount.

- **Connectivity ICs are the fastest growing segment.** The market for low-end smartphones has just begun to take shape, and we believe OEMs now view this segment as the fastest growing and most important piece of the handset pie. Smartphones are uniquely different from feature phones in that they maximize mobile connectivity and have begun to leverage mobile apps that are location-aware–allowing consumers to be keenly aware of friends' locations and to capitalize on local discounts, specials and advertising. The largest opportunities today are for imaging (camera phone) as mobile uploads soar, Bluetooth for headset connectivity, GPS for location-based services, WiFi for "mobile hotspots" and handset graphics for gaming and advanced video. The ability of high-end smartphones to wirelessly connect other mobile devices to the network has increased the functionality of the phone and reduced demand for broadband wireless data cards, among others.

- **Increased complexity driving RF component trends**. As the market moves towards a far richer mix of 3G/3.5G/LTE smartphone devices, the RF front end of the phone is becoming increasingly complex. Phones must now support multiple modes and multiple cellular bands, driving richer and more complex semiconductor content. Integrated solutions, and complete front-end modules are now common across a range of devices, but vary greatly depending on OEM, phone model, and the type of connection required. Discrete RF components remain en vogue at the high end, where greater performance and differentiation are required. This segment is likely to also be one of the fastest growing semiconductor markets in the handset space as the transition to LTE devices happens more quickly than any previous cellular transition.
- **Multi-SIM solutions are exploding in emerging markets.** Roaming charges are expensive, particularly in emerging markets where carrier coverage areas can generally be smaller and more fragmented. Stemming from this, low-cost baseband suppliers Spreadtrum Communications, MediaTek, M-Star and others have developed multi-SIM solutions that can support multiple SIM cards for multiple phone numbers on multiple networks. This in turn has helped bring down the total cost to users, making handsets more affordable in emerging markets with fragmented carrier service. The multi-SIM solution has been targeted as an area of key strategic focus for many suppliers in 2012.
- **New features are emerging such as NFC and fingerprint recognition.** Near Field Communications, NFC, has long been discussed but slow to be implemented. The newest high end smartphones nearly all now include the mobile payment technology, and Google has begun the push to make it mainstream. Fingerprint recognition technology has been developed to offset consumer fears of piracy and mobile theft, allowing smartphone users to lock and unlock their device using fingerprint recognition. NFC and fingerprint recognition technology may ultimately ramp simultaneously in handsets as mobile payment systems become more prevalent and as consumers look to protect themselves from mobile theft.
- **ODMs now an integral part of the supply chain.** ODM suppliers in Taiwan, China, and Korea have risen to become a very important constituency in the handset market in the last few years. ODMs also play a role similar to OEMs in some cases in that they sell either their own branded phones or sell directly to operators. From a component perspective, ODMs tend to demand complete chipset solutions, but at the same time do not require the same level of customization as OEMs. The unbranded, or white box, portion of the cellular handset market has exploded in China, India, Africa and other emerging markets, particularly with the explosive growth of low-cost Android handsets.
- **More advanced handsets require more memory and a more efficient battery.** High end smartphones have dramatically increased the demand for memory capacity and the constraint strain of mobile application use and data streaming has stretched battery life thin. As smartphone form factors remain largely unchanged yet semiconductor content within the phones increases, the demands on memory and battery are to become more efficient with a shrinking physical footprint. Memory and battery suppliers must constantly pack more capacity/life into the same or smaller form factor.

Wireless Infrastructure

2.5G/3G Wireless Infrastructure System



Source: IDC, Computer Desktop Encyclopedia, Oppenheimer & Co.

Wireless voice and data service is enabled by dedicated wireless networks that act as extensions of the public wireline telecom/datacom network. Wireless carriers often overlap their coverage areas to compete with one another; they can also offer service to each other's subscribers (known as "roaming").

The public wireless network is divided into two segments: the radio access network and the core network. The radio access network consists of base transceiver stations (BTSs), which are often referred to as "cell towers" or just "basestations." Each BTS has a defined range and sends and receives digitally encoded voice and data traffic to and from mobile terminals in its coverage area (sometimes called a cell, as in "cellular"). When a connected terminal passes out of the basestation's coverage area, the call is passed to a nearby BTS (coverage areas generally overlap), allowing for an uninterrupted signal as users move around within the carrier's network.

Base transceiver stations are managed by a network of basestation controllers (BSCs), which sit between the radio access network and the core network. BSCs pass traffic back and forth between BTSs and also forward calls to and from the core network. The core network manages the interface between the greater wireless network and the public wired telecom network. Nodes in the core network include mobile switching centers that handle voice traffic (interfacing with the PSTN, or public switched telephone network) and IP routers that handle data traffic (interfacing with the carrier's data network and the Internet).

Wireless Infrastructure

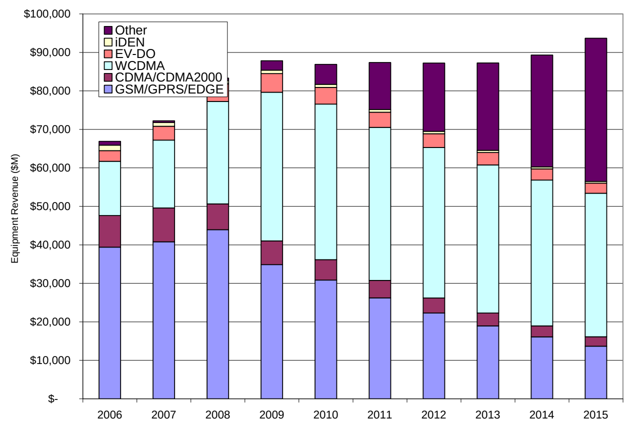
Wireless Infrastructure Equipment Forecast

•Following years of rapid growth as carriers built out coverage worldwide, we expect wireless infrastructure equipment revenue growth to slow over the next few years.

•We forecast the market to grow at a 2% CAGR, from $86.9 billion in 2010 to $93.7 billion in 2015.

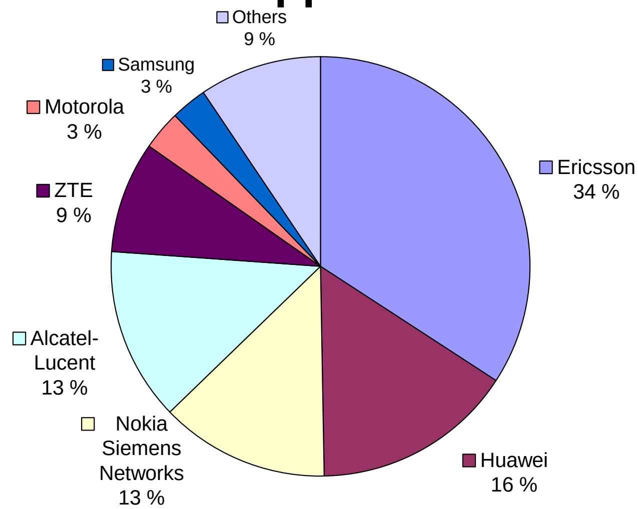
•Worldwide Wireless 3G and LTE buildouts should offset declines in both CDMA and GSM/GRPS.

•“Other” (LTE) should rise from 1% of spending in 2008 to 40% in 2015; GSM/GPRS should steadily decline and represent only 15% in 2015.



Source: Dataquest, IDC, Oppenheimer & Co.

Wireless Infrastructure Suppliers



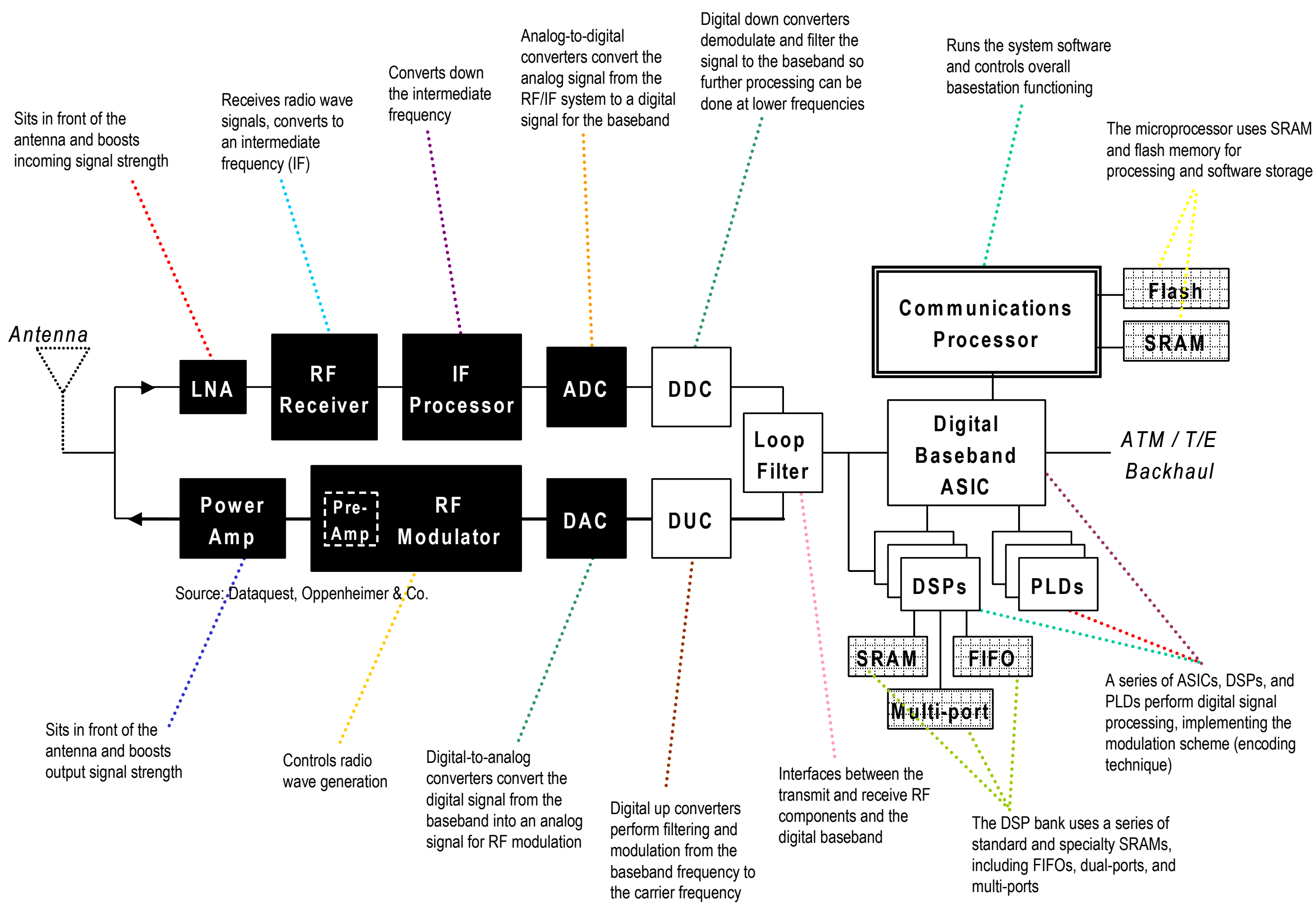
Forecast and market share is on a revenue basis and includes all wireless infrastructure, not just basestations.
Source: Gartner, Oppenheimer & Co.

Wireless Infrastructure Equipment Forecast: Infrastructure spending surged through 2009 before leveling off. The sharp increase occurred on two fronts: carriers in emerging markets raced to build out coverage areas, and carriers in developed markets were implementing 3G networks. Since this surge, carriers have begun the replacement cycle, with carriers in developed markets focused on building out WCDMA and 4G WiMAX/LTE networks.

Looking ahead, we expect the market to remain flattish as carriers continue the replacement cycle. LTE network rollouts should help offset some of the macro pressures and pricing declines. In total, we expect the market to grow slightly, increasing from $86.9 billion in 2010 to $93.7 billion in 2015. W-CDMA is set to remain the biggest contributor to our forecast through 2015. W-CDMA was 44% of total spending in 2010 and we expect this to slowly decline to 40% by 2015. For GSM, we expect spending to decrease from 35% of total in 2010 to 15% in 2015. The LTE build is well under way, and we expect momentum to continue to accelerate as the pace of adoption increases in emerging markets beginning late 2012. We expect the LTE will represent approximately 40% of the total market in 2015.

Wireless Infrastructure Suppliers: Ericsson was the top supplier of wireless infrastructure in 2010, with 34% revenue share. Ericsson remains the incumbent in GSM/GPRS and WCDMA, with 44%+ share of North America and Europe. Huawei took advantage of strong Chinese market growth to take over the No. 2 spot, with 16% share. Nokia Siemens and Alcatel-Lucent each had 13% share. Rounding out the top five was ZTE, who like Huawei, was the beneficiary of strong Chinese demand. Neither Huawei nor ZTE had any meaningful share to speak of in the North American market in 2010, presenting a meaningful opportunity for the two emerging players to continue to grow.

Wireless Infrastructure



Note: *Basestation systems usually separate functions such as RF transmission and reception, power amplification, baseband processing, system control and backhaul transport on separate cards within the basestation. The diagram above depicts a simplified system that would contain all of these functions on a single card—we do not actually find systems like the one depicted above in the field.*

Also note *that unlike our other block diagrams, most basestation systems are actually less integrated than depicted in our block diagram, often breaking out what is represented in our diagram as a single device into a block of separate devices.*

Finally, note that *we do not display the ICs that perform backhaul and the interface to the wireline network. Though these systems are a significant portion of wireless equipment spending (and are included in our equipment forecast on the previous slide), the devices used in these equipment types are actually more similar to wireline ICs and are therefore included in our discussion of communications infrastructure. This is similar to what we did in the broadband section, including broadband-specific ICs but leaving the network interface ICs out of the discussion at that point.*

The semiconductors used in wireless infrastructure systems can vary by protocol and by the OEM's architectural design, but they are largely similar across platforms in terms of their function. Voice and data traffic is transmitted and received to and from individual handsets by the antenna and processed by the RF block, which includes power amp and RF modulation components on the transmit side and LNA, RF receiver and IF processing components on the receive side. A digital baseband subsystem performs protocol processing, translating the voice signals into encoded digital signals for transmission—the baseband subsystem will usually include a series of ASICs, DSPs, PLDs, and memories. Wireline ICs implement the backhaul, ferrying traffic calls back and forth between the PSTN (public switched telephone network) and the basestation, while control plane processors control the overall system.

Baseband and System Control

- **Digital Baseband ASIC**: The baseband processor performs digital processing on the signal, implementing the wireless modulation scheme (the encoding technique, e.g., GSM, CDMA, GPRS, W-CDMA, etc.), encoding and extracting voice signals in and out of the transmission protocol.
- **Communications Processor:** A communications processor manages and controls basestation transceiver system functions. Though only one is shown in our block diagram, each subsystem in a basestation could have its own processor or processors, and a separate control card may be used within the system as well to manage the overall system.
- **DSPs:** Given the number and complexity of high-speed signals processed in a basestation system, discrete DSPs are used in conjunction with the baseband ASIC.
- **PLDs:** PLDs are often used within the baseband system, as the multitude of wireless standards makes late-stage customization critical in base station design.
- **FIFO, Dual-Port, and Multi-Port SRAM:** These specialty SRAMs are used for queuing of signals and as glue logic between the DSPs.
- **SRAM:** SRAM is used by the DSP banks and system control processor.
- **Flash:** Flash memory is used by the system processor.

Transceiver and Power Amp Subsystems - Transmit Side

- **Loop Filter:** The loop filter interfaces between the transmit and receive RF components and the digital baseband.
- **Digital Up Converter (DUC)** (transmit side): A digital converter that performs filter and modulation functions from the baseband frequency up to the carrier frequency.
- **Digital-to-Analog Converter (DAC)** (transmit side): A high-performance digital-to-analog converter converts the digital signal from the baseband system to an analog signal for the RF subsystem.
- **RF Modulator** (transmit side): The RF modulator performs radio wave generation on the transmit side, translating between low-frequency analog signals used in the basestation to high-frequency RF signals used in radio communications. It usually includes a preamp to amplify the signal before sending it to the power amp.
- **Power Amp** (transmit side): One of the most important functions in basestation platforms, power amp ICs are high-power specialized ICs that sit in front of the antenna and boosts signal strength on the way out.

Transceiver Subsystem - Receive Side

- **LNA (Low Noise Amplifier):** The LNA is a power amp that receives the signal from the antenna and boosts it for processing by the system.
- **RF Receiver**: The RF receiver down converts the radio signal for processing by the system, translating between the high-frequency RF signals used in radio communications and low-frequency analog signals used in the basestation, usually by an IF transceiver.
- **IF Processor**: The IF processor performs all quadrature modulation of “I” and “Q” baseband signals, converting the radio signal down from the intermediate frequency (IF) to an analog signal for use by the system.
- **Analog-to-Digital Converter (ADC)**: A high-performance analog-to-digital converter converts the analog signal from the RF subsystem to a digital signal for the baseband.
- **Digital Down Converter (DDC)**: A digital converter that performs filtering and demodulation so that baseband functions can be performed at lower frequencies.
- **Loop Filter** (also listed on the transmit side): The loop filter interfaces between the transmit and receive RF components and the digital baseband.

WiMAX

WiMAX is an IEEE standard that grew out of fixed wireless, targeted to become a standards-based solution for last mile wireless broadband access as an alternative to cable and DSL. Mobile WiMAX began deployment with the goal being full mobile broadband data access.

As LTE ramps with the largest global carriers, however, WiMAX market growth is likely to pale in comparison. It has thus been pegged as a relatively niche 4G market.

WiMAX (Worldwide Interoperability for Microwave Access) is an IEEE standard that grew out of fixed wireless, with the goal of becoming a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. Though networks are organized in a similar architecture to cellular, WiMAX employs OFDM techniques that are the basis of Wi-Fi, and operates in a mix of licensed and unlicensed spectrum. WiMAX essentially takes over where Wi-Fi leaves off, acting as a long-range, secure data connection over a wider area.

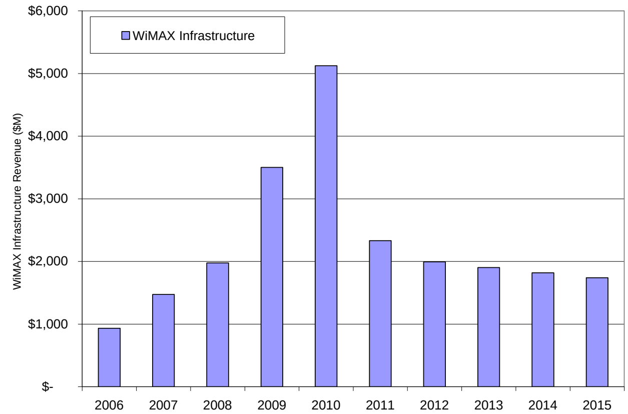
The first commercial deployments were fixed WiMAX, targeted at emerging markets or rural areas without adequate wired broadband infrastructure. Clearwire (Sprint) rolled out a large WiMAX network, with substantial initial success, in the U.S. as a differentiated wireless offering; the WiMAX network helped Sprint/Clearwire reverse a negative subscriber loss trend. Operators in Korea, India and Africa have also deployed, and the WiMAX ecosystem now supports more than 20 million subscribers globally.

Unfortunately, where WiMAX was the first true 4G network to be deployed, the real network muscle is behind LTE. The market is likely to continue to grow at a faster-than-average rate, but its growth will pale in comparison with the explosion of LTE infrastructure spending and handset unit growth. Global LTE infrastructure spending surpassed WiMAX infrastructure spend for the first time in the second quarter of 2011.

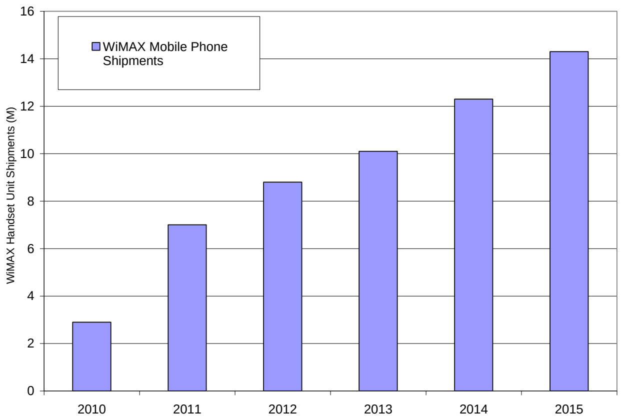
WiMAX

WiMAX Market Forecast

•WiMAX infrastructure spending likely peaked in 2010 as carriers began to focus on the deployment of LTE networks.
•WiMAX handset units are likely to continue to rise, however, as more networks are deployed and carriers push WiMAX as a differentiated service. Sprint/Clearwire, for example, has continued to publicly support its WiMAX network.



Source: IDC, Oppenheimer & Co.



Source: IDC, Oppenheimer & Co.

Handset OEMs

HTC
Motorola
Samsung

Baseband & RF

Sequans
GCT
Broadcom (Beceem)
Skyworks (SiGe)

WiMAX Infrastructure Revenue Forecast: WiMAX spending soared in 2010 before beginning to fall off meaningfully in 2011. We expect infrastructure spending to continue to decline as carriers transition to LTE.

WiMAX Handset Forecast. WiMAX handset growth is likely to continue through 2015 as the networks themselves mature, coverage increases, and carriers increasingly offer WiMAX as a differentiated solution to LTE and other advanced networks. HTC was the first to release a mass market WiMAX smartphone, and has taken a large amount of share via the Sprint/Clearwire network, while Motorola and Samsung each have WiMAX handsets now available. Sequans Communications, GCT Semiconductor, Broadcom (via its acquisition of Beceeem) and Skyworks (via its acquisition of SiGe) are the dominant suppliers of WiMAX semiconductor solutions. This growth, coverage and subscriber base, however, is likely to pale in comparison with LTE networks.

LTE

Long Term Evolution (LTE) has taken over as the dominant 4G standard going forward. As consumers transition to a richer mix of handheld devices, networks are being forced to rapidly upgrade to keep up with soaring data usage.

Two varieties of LTE will ramp. Time Division Duplex LTE, TDD-LTE, does not require paired spectrum, is a natural evolution of TD-SCDMA networks, and will be deployed primarily in emerging markets. Frequency Division Duplex LTE, FDD-LTE, requires paired spectrum and is a natural evolution of legacy WCDMA/UMTS networks that have been deployed in developed markets.

FDD-LTE has begun deployments in developed markets, led by Verizon Wireless in the U.S. The FD-LTE variety requires paired spectrum and cannot support voice capabilities on its own, thus requiring backwards voice compatibility with legacy 2G/3G networks and the eventual overlay of VoIP. Because of this voice requirement, FD-LTE is likely to deploy as an evolution of WCDMA/UMTS networks in developed markets.

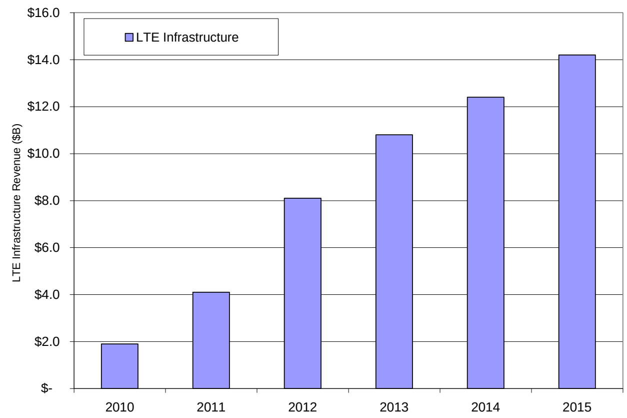
Network strain has forced the hand of wireless providers to roll out next generation coverage quickly, beginning with Verizon Wireless in late 2010. AT&T, LightSquared and MetroPCS have each accelerated LTE plans in response, and most networks now have plans to have LTE deployed nationwide by the end of 2015. While global carriers like Vodafone and NTT DoCoMo have deployed LTE networks, the transition to LTE outside the U.S. will likely be more gradual in nature, with carriers, particularly in Europe, in no rush to abandon HSPA+. So while “LTE” is the new must-have in the United States, global adoption is likely to occur over the span of the next 3-7 years.

TDD-LTE will deploy primarily in emerging markets. TDD-LTE takes a different technical approach from FDD-LTE, using a single frequency to share the transmission and reception, spacing them apart by multiplexing the two on a real-time basis. Because mobile devices are generally thought of as consumption devices, TDD-LTE systems can allocate the number of time slots to uplink/downlink, allowing the network to adjust for demand in either direction. As the natural evolution of the TD-SCDMA network deployed by China Mobile, TDD-LTE is likely to first deploy in China and follow thereafter in other emerging markets like Russia, India and Africa.

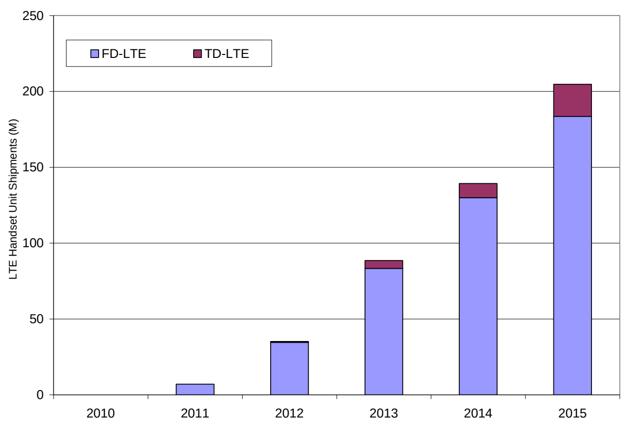
LTE

LTE Market Forecast

- LTE infrastructure spending is in its infancy, with carrier upgrades likely to begin acceleration in 2012 and beyond. We estimate LTE infrastructure spending will grow at a 96% CAGR from \$1.9 billion in 2010 to \$14.2 billion in 2015.
- FD-LTE handset shipments have already commenced, led by Verizon Wireless in the U.S. With initial TD-LTE shipments expected in 2012, we estimate total handset shipments will grow at a 133% CAGR from 7 million in 2011 to 204.7 million units in 2015.



Source: IDC, Oppenheimer & Co.



Source: IDC, Oppenheimer & Co.

Handset OEMs	***Baseband & RF***
HTC	Qualcomm
Samsung	Samsung
Motorola	Skyworks
LG	RF Micro Devices
	GCT Semiconductor
	Sequans

LTE Infrastructure Revenue Forecast: The LTE infrastructure build is in the early innings, with an expected CAGR of 96% through 2015 and, even then accounting for less spending than HSPA+. Initial spending is concentrated primarily in developed markets, with incremental spending likely to take place on emerging TD-LTE networks. However, according to market researchers IDC, the market for HSPA spending will likely not peak until 2020, at which time the global LTE market will take over as the dominant revenue generator for wireless infrastructure vendors.

LTE Handset Forecast. While still a relatively minor part of the total handset market, LTE handsets are likely to experience hyper-growth through 2015, growing at a 133% CAGR from 2011-2015. Because LTE is still so relatively small, it has yet to be a major revenue driver of larger wireless semiconductor vendors, but substantially every wireless supplier has some type of LTE product either revealed or in development, an early indication of just how large the perceived market opportunity is. Baseband vendor Qualcomm has an LTE chipset on the Snapdragon roadmap, ST Ericsson, Samsung and Motorola all have solutions either shipping or under development, and 4G pure plays Sequans and GCT are highly dependent on the eventual growth of LTE. We expect the handset market to take hold on a global scale in 2013.

Consumer Devices

Seven Key Markets:

Digital Set-Top Boxes

Digital TVs

DVD Players and Recorders

Digital Cameras

MP3/PMP

Video Game Consoles

Flash Memory Cards

The consumer electronics market includes a diverse array of devices centered on audio and video entertainment. To date, most consumer electronic devices have been analog, meaning that functionality was enabled by analog devices with some limited digital support for system control—and thus have not required much computing power. These devices have historically been implemented with standard semiconductor parts such as analog SLICs, microcontrollers, standard logic and discretes. When application specific digital devices were needed, they were usually custom devices, consistent with the practices of the Japanese electronics OEMs that dominate the market.

With the increasing digitization of consumer electronics, however, the paradigm is rapidly changing. The content itself has migrated to digital formats, and the devices used to process them have moved into the digital realm. The analog content is still there, but in many cases an analog ASSP replaces the SLIC. On the digital side, the microcontroller may still be there but it takes a back seat to a DSP or digital microperipheral that performs digital processing and in most devices, some form of digital encode/decode. These digital processors almost always have to comply with standards, facilitating the use of merchant silicon solutions by OEMs. It has also sped time-to-market for OEMs and has enabled increasing competition from non-Japanese suppliers in the U.S., Europe and, increasingly, in Asia.

For this report, we have selected a few key consumer electronics markets undergoing this paradigm shift, where there exist significant application-specific semiconductor markets. We include **set-top boxes, digital TVs, DVD players and recorders**, **digital cameras**, **MP3 and portable media players**, and **video game consoles**. We also include a discussion of **flash memory cards**, which find most of their usage in digital consumer devices.

Digital Set-Top Boxes

Set-top boxes have enjoyed strong growth as the key enablers of premium video services in the home. Cable, satellite, and IPTV service providers are all deploying advanced set-top boxes to their subscribers to enable premium features like HD content and DVR. They are able to charge both a service fee and additional rental fees to offset the higher costs of these boxes, and at the same time deliver a higher-quality experience to the customer to increase retention.

In addition to these service-based units, some set-top boxes are sold at retail directly to the customer. Free-to-air boxes allow consumers to watch terrestrial digital broadcasts—this is very common outside the US. Standalone DVR has become a niche, as most service providers now offer these directly to their subscribers.

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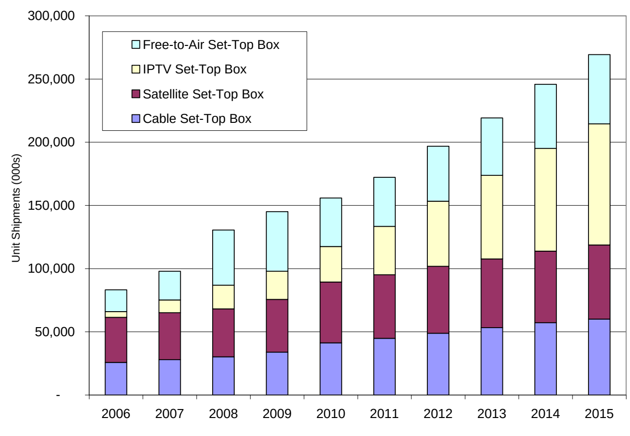
In addition to these service-based units, some set-top boxes are sold at retail directly to the customer. Free-to-air boxes allow consumers to watch terrestrial digital broadcasts, as most TV sets are able to tune only analog terrestrial signals (though this is changing). Free-to-air, or "digital terrestrial" as it is sometimes called, is very common outside the US, and should become more common domestically as the analog shut-off deadline approaches.

Standalone DVR has become a niche, as most service providers now offer these directly to their subscribers. TiVo and others still sell standalone DVRs, but they tend to serve consumers with specific tastes or needs.

Digital Set-Top Boxes

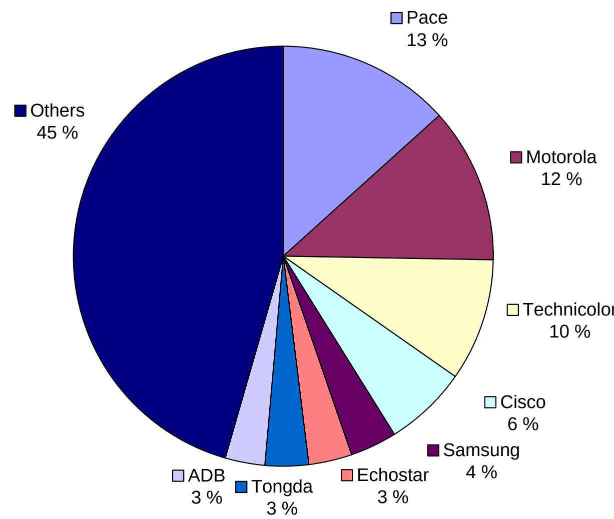
Set-Top Box Unit Forecast

•We expect set-top boxes to grow at a 12% CAGR, from 156 million units in 2010 to 269 million units in 2015.
•Cable should grow 8%, driven by an HD and DVR upgrade cycle and new cable rollouts in China.
•Satellite remains an important market but faces tough competition from cable.
•IPTV is starting to gain real traction, and should reach 36% of units in 2015.
•Free-to-air remains a very large opportunity in international markets.



Source: IDC, Gartner, Oppenheimer & Co.

Key Set-Top Box Suppliers



Satellite	***Cable***	***IPTV***
Technicolor	Motorola	Pace
Pace	Pace	Sagem
Echostar	Cisco	Cisco
Tongda	Samsung	Motorola
ADB	Technicolor	Samsung

Source: Gartner, Oppenheimer & Co.

Digital Set-Top Box Unit Forecast: The market for digital set-top boxes (STBs) has experienced rapid growth during the past few years, as a number of new technologies pervaded the market, driving strong upgrade cycles across multiple service providers. In total, we estimate the market totaled 156 million units in 2010.

In cable, multiple system operators (MSOs) have embraced high definition content as a differentiator, and have been able to charge additional fees for this content to an increasingly HD-savvy public. HD services require entirely new set tops and more sophisticated infrastructure. Analog replacement continues to be a driver for cable as well, as service providers are highly motivated to upgrade their legacy analog customers to digital in order to save on transmission costs.

In satellite, providers have begun moving to 8PSK for the front end and MPEG-4 encoding for the back end to save bandwidth; this requires new set-tops. Satellite has also been moving to HD, though at a slower pace than cable. The satellite providers in the US have conjoined the MPEG-4 and HD migrations in order to allow HD services without adding material bandwidth (satellite launches are very expensive).

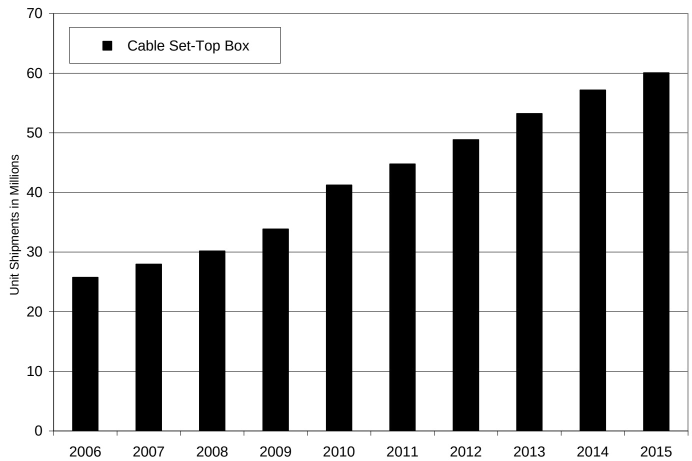
After a long development period, IPTV has begun to gain momentum in Europe and Asia, with the US on the horizon. IPTV remains the long term solution for telecom providers looking to add video services to drive revenue growth; these services require an entirely new rollout of set-top boxes.

Finally, free-to-air digital set-tops remain a large market internationally, allowing consumers to receive digital broadcasts without a service fee. This should become more common in the US as the analog shut-off happened last year.

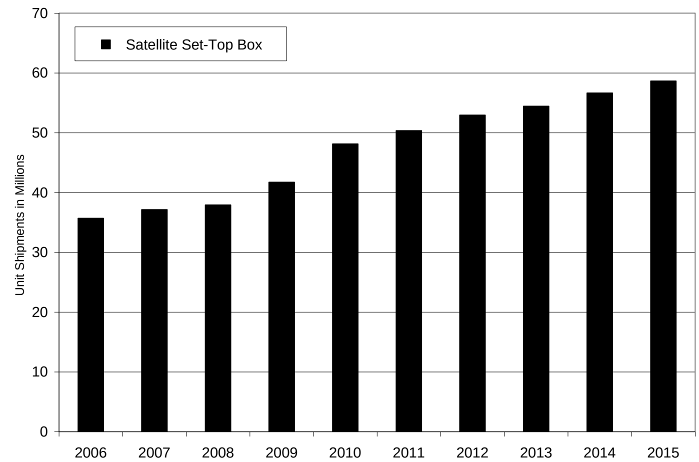
Then there is the trend toward digital video recorders (DVRs), which have enjoyed tremendous consumer reception and also make the carrier happy because they can charge additional fees. Though DVRs started as standalone boxes a few years ago, they have been embraced by all of the major cable and satellite carriers and will be a part of the IPTV rollout as well. Service-based DVRs now dwarf those sold at retail for either standalone or terrestrial use.

Overall, we estimate the market is growing at a 12% CAGR, from 156 million boxes in 2010 to 269 million in 2015. Cable should grow slightly below the market with an 8% CAGR, driven by HD and DVR upgrade cycles in developed regions and digital cable rollouts in new markets like China. Satellite should experience modest growth of 4%, boosted by HD and DVR but mitigated by competition from cable, and later in the forecast from IPTV. IPTV, which represented 22% of unit shipments in 2010, should grow at a 28% CAGR to represent 36% of unit shipments in 2015. Free-to-air should grow at a 7% CAGR and remain an important segment for emerging markets, representing 20% of total in 2015. The exhibits below display set-top box for each market.

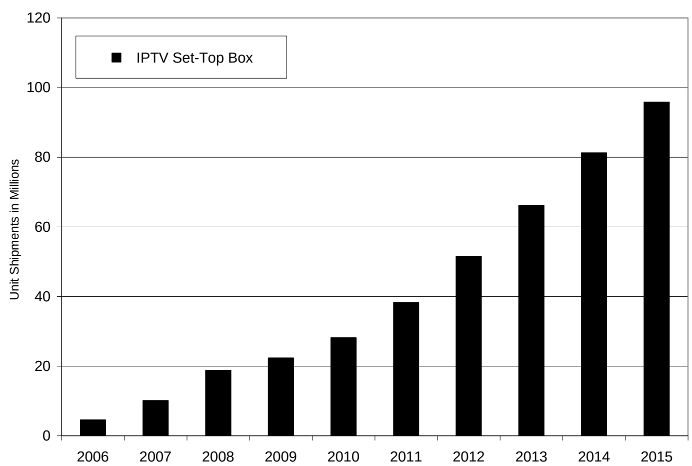
Cable Set-Top Box Unit Shipments



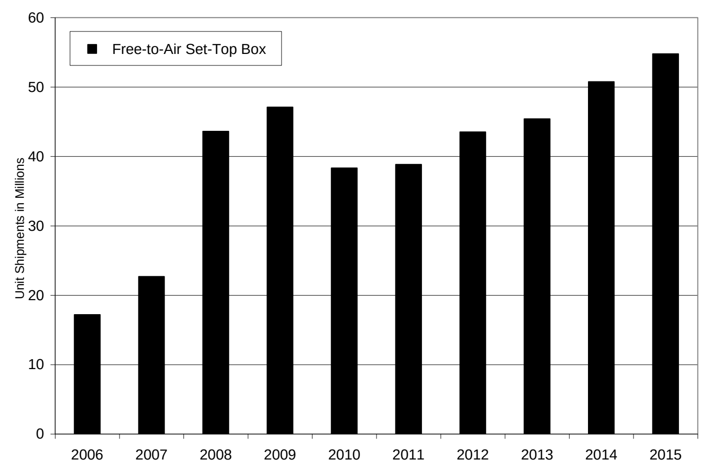
Satellite Set-Top Box Unit Shipments



IPTV Set-Top Box Unit Shipments



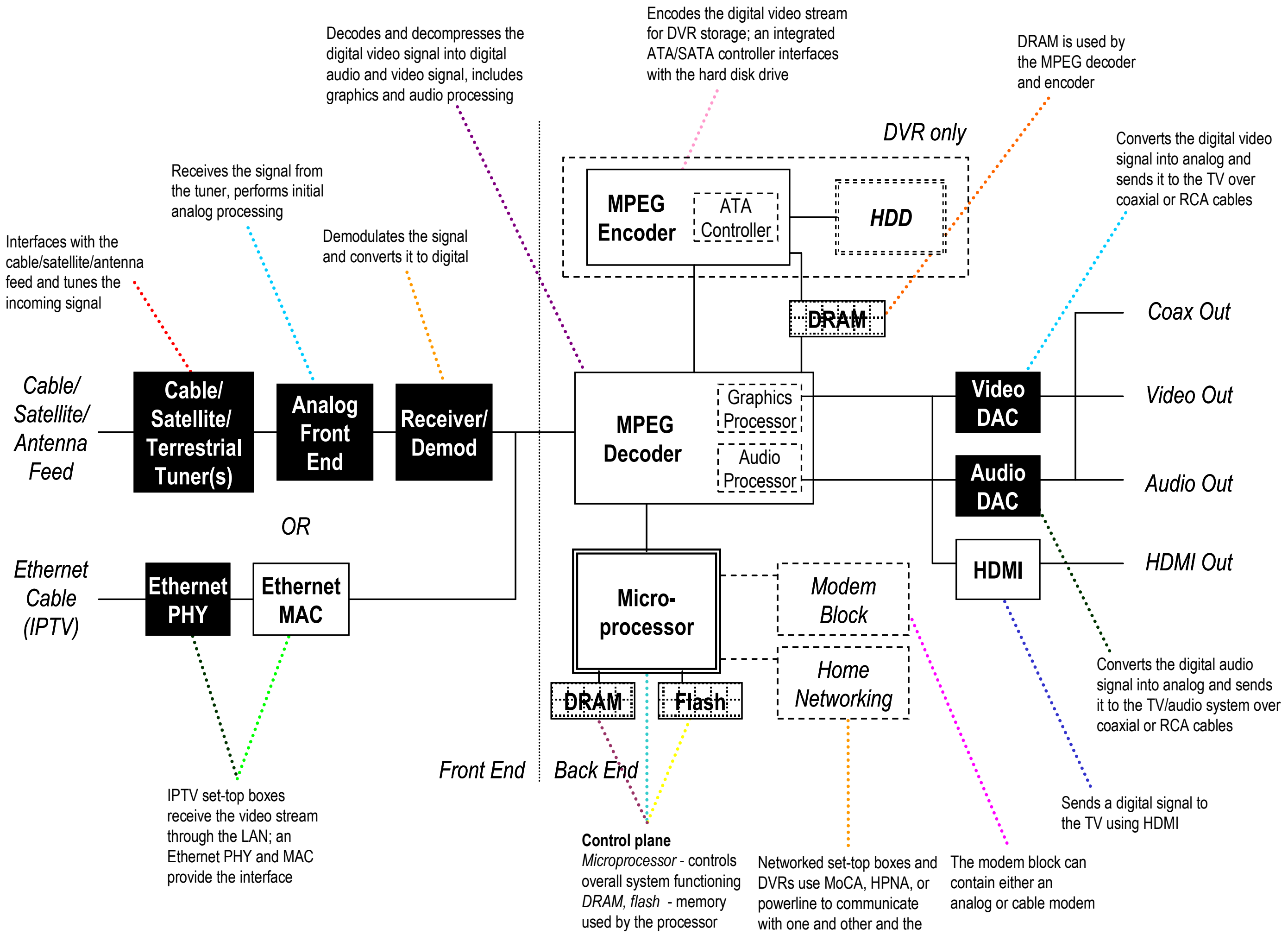
Free-to-Air Set-Top Box Unit Shipments



Source: Gartner, IDC, Oppenheimer & Co.

Digital Set-Top Box Suppliers: The top supplier of set-top boxes in 2010 was Pace with 13% share; Pace is No.1 in IPTV and No. 2 in cable and satellite. Motorola was second with 12% share, due to its No. 1 position in cable and No. 4 4 position in IPTV. No. 1 satellite supplier Technicolor (formerly Thomson) was No. 3 overall with 10% share, and was followed by No. 3 IPTV and cable player Scientific Atlanta (owned by Cisco) at 6% overall. Samsung was next with 4%, followed by Echostar, Tongda and ADB all at 3% each. Other vendors include Funai, Sagem, LG, Sony, Panasonic, Siemens, Toshiba, Huawei, TiVo, and 2Wire.

Digital Set-Top Boxes



Source: IDC, Oppenheimer & Co.

A set-top box looks very much like a modem with additional audio and video processing functionality. Front end ICs (tuner, AFE, demodulator) receive the signal from the network, and back end ICs (MPEG decoder, graphics and audio processors) decode it. The key difference is that instead of a data stream, the set-top decodes a video signal.

Set-top box semiconductors blend devices from the communications and digital video worlds. A tuner receives and tunes the signal from the coaxial cable, which is processed by an analog front end and demod, which converts the analog signal to digital. The signal is then decoded by an MPEG decoder, which can then adjust and add to the stream with integrated graphics and audio processors. The decoded signals are then sent to the television either digitally using HDMI or in an analog format over RCA or component cables (the latter requires a conversion back to analog).

In a DVR, additional ICs are added in to support MPEG encoding as well as hard disk drive interface control. ICs found in the hard disk drive are not discussed here, as they are captured in our discussion of HDDs earlier in the report.

Front End

- **Tuner**: The tuner receives the signal from the coaxial cable, satellite feed, or terrestrial antenna and tunes it to the proper RF frequency. Most set-top boxes have just a single tuner, though some boxes have multiple tuners to support picture-in-picture or other advanced features. DVRs require at least one additional tuner.
- **Analog Front End**: The analog front end receives the signal from the tuner and performs the front-end analog processing.
- **Receiver/Demod**: The receiver chip demodulates the signal and converts it to digital for decode and processing by the set-top box. It is sometimes integrated with the analog front end for an integrated front end ASSP.

- **Ethernet PHY and MAC** (IPTV set-top box only): IPTV set-tops receive a packetized video stream over the LAN as opposed to a direct feed. They therefore do not have tuners, AFEs, or receivers, but add Ethernet ICs to provide the LAN interface. The PHY interfaces with the Ethernet cable; the MAC performs protocol processing.

Back End

- **MPEG Decoder**: The MPEG decoder decodes and decompresses the encoded digital signal into audio and video signals. Most set-top boxes use the MPEG-2 standard, though newer satellite and IPTV boxes are moving to MPEG-4, which offers tighter signal compression.
- **Graphics Processor/Encoder**: The graphics processor performs digital image generation, adding graphic items associated with the interactive guide, on-demand menus, and other services. It also includes an encoder to perform any additional processing on the video signal before it is sent to the TV, such as NTSC, PAL, etc. It is usually integrated into the MPEG decoder.
- **Audio Processor**: The audio processor is a DSP that performs digital audio generation, as well as any additional audio encoding, such as Dolby Digital, DTS, etc. Also usually integrated into the MPEG decoder.
- **Microprocessor**: A microprocessor performs control plane functions and runs the set-top box software. It is sometimes embedded in a back-end ASSP, though more advanced boxes will use a discrete processor.
- **Flash/DRAM**: The MPEG decoder and microprocessor use a variety of memories.

Back End Interface

- **Video D/A Converter**: A video digital-to-analog converter converts the video signal to analog format to send it to the TV over coaxial or RCA or component cables.
- **Audio D/A Converter**: An audio digital-to-analog converter converts 16-bit stereo samples into left and right alternating-current audio signals and sends them to the TV over coaxial, optical, or RCA cables.
- **HDMI Interface IC:** More advanced set-top boxes include an HDMI (High Definition Multimedia Interface) interface, which is an all-digital, high-definition standard that supports both video and audio with digital rights management capabilities. An HDMI IC is needed to support this interface.

Modem

- **Analog Modem SLIC and Codec** (not pictured in diagram): Some set-top boxes incorporate the ability to send upstream signals (such as an order for a pay-per-view program) to the service provider over an analog modem. The SLIC drives the signal over the RJ-11 telephone line and the codec performs the digital-to-analog and analog-to-digital conversion for the modem.
- **Single-Chip Cable Modem** (not pictured in diagram): Some newer high-end digital cable set-top boxes incorporate cable modem functionality by adding a single-chip cable modem device and an additional tuner.

Digital Video Recorder (DVR)

- **MPEG encoder**: An MPEG encoder chip converts video signals back into the MPEG format for storage on the hard drive. The encoder can be implemented as a separate device or it can be integrated in with the MPEG decoder.
- **ATA/SATA Controller**: This controller provides the interface to the hard disk drive. It is usually integrated into the MPEG encoder. Some DVRs support an external SATA HDD in addition to the internal HDD.

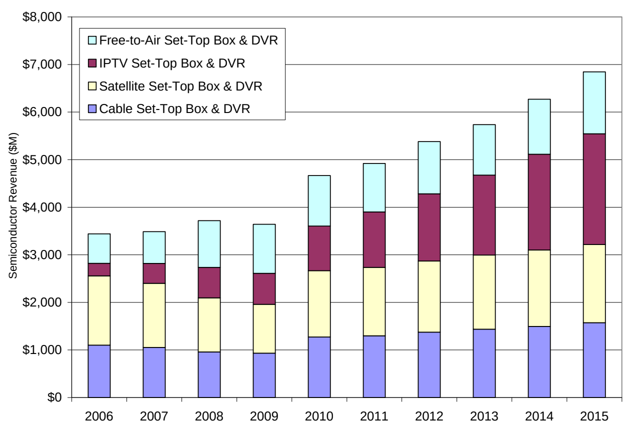
Home Networking

- **MoCA, HPNA, Powerline Chipset** (not pictured in diagram): Newer set-top boxes contain home networking capability to allow the set-top boxes to communicate with one another and with the home gateway. MoCA uses coax, HPNA uses phone line and coax, and HomePlug, UPA and HDPLC uses powerline. These are discussed in more detail in the emerging technologies section at the back of this report.

Digital Set-Top Boxes

Set-Top Box Semiconductor Forecast

•With strong unit growth and features like HD and DVR boosting the BOM, set-top box semiconductor revenues have more than doubled over the past five years.
•We expect an 8% CAGR through 2015.
•IPTV will lead the way, reaching $2.3 billion in 2015, a 20% CAGR.
•Cable should grow 4%, while satellite and free-to-air should be pressured by declining ASPs and lower unit growth.



Note: Excludes DVR/DVD-R boxes and place-shifting units without a tuner (e.g. SlingBox).
Source: IDC, Gartner, Oppenheimer & Co.

Set-Top Box Semiconductor Competitors

STMicro
Broadcom
Sigma Designs
Intel
Trident
MaxLinear
Sony
Samsung

Source:IDC, Oppenheimer & Co.

Digital Set-Top Box Semiconductor Forecast: With strong unit growth and features like HD and DVR boosting the semiconductor bill-of-materials, set-top box IC revenues have more than doubled over the past five years. Cable and IPTV were the primary drivers, with satellite contributing as well. In 2010, the market totaled $4.7 billion.

Looking ahead, we expect normal price pressure to set in and outweigh rising DVR and HD penetration. Still, we expect healthy growth, with the revenues rising at a 9% CAGR to $7.0 billion in 2015. Note that excluded from our forecast are ICs for box-to-box networking protocols such as WiFi, MoCA and HPNA; these are discussed in the emerging technologies section of this report and would be additive to our forecast.

Digital Set-Top Box Semiconductor Competitors: The set-top box IC market is highly concentrated among the top two vendors: STMicro and Broadcom. STMicro is a dominant player in satellite (DirecTV, Echostar, international), in free-to-air and a significant player in cable (Scientific Atlanta). Broadcom is one of the top providers in cable (dominates Motorola) and is a top provider in satellite as well (Echostar, DirecTV, Sky Networks). Other vendors include Intel, Trident (acquired NXP's business), IPTV specialist Sigma Designs, MaxLinear, Samsung, and Sony.

Digital Set-Top Boxes

Set-Top Box Semiconductor Market Trends

•Mainstream set-top box designs are moving to single-chip SoC.

•DVRs are providing increased content for IC suppliers.

•Cable has led the charge in HDTV; satellite is catching up quickly.

•Satellite has transitioned to MPEG-4 for tighter compression.

•IPTV is starting to get some real traction.

•Set-top boxes are increasingly incorporating multiple tuners.

•Momentum is building for MoCA, HPNA and PLC for box-to-box networking, key to enabling multi-room DVR.

•Set-top box IC suppliers are looking to expand into digital TV and high-definition DVD.

High End HD and DVR Set Top Boxes

- **Set-top box designs are moving to single-chip SoC.** Competitive pressures in the set-top box IC market have sparked a new crop of integrated devices. Designs integrating the front and back end into a single-chip SoC have benefited from the move to lower manufacturing process geometries, replacing the two-chip ASSP designs of yesteryear.
- **DVRs are providing increased content for IC suppliers.** Though originally a standalone opportunity, DVRs have now penetrated every major type of set-top box and are offered by all major service providers. This has provided increased content for IC suppliers.
- **Cable has led the charge in HDTV; satellite has aggressively followed.** After several years of unfulfilled promises, HDTV has finally become a reality. According to Nielsen, as of November 2010, 56% of U.S. households owned an HD capable TV. As HD-capable TV sets moved into mainstream price points, cable MSOs moved in to provide HD content in an effort to differentiate their offerings from satellite. MSOs aggressively rolled out HDTV services across their footprints, which also necessitated new HD-capable set-tops (which they provided to customers as they signed up for HD services, for which they pay a premium). Satellite vendors followed quickly behind to provide HD, including the launch of new satellites to increase bandwidth. From the IC vendor's perspective, HD has increased the ASP for their devices (especially the back end ASSP) as well as solidifying their positions with key customers.
- **Satellite has transitioned to MPEG-4 for tighter compression.** MPEG-4 employs more advanced encoding techniques than MPEG-2, which allows it to use less bandwidth for a comparable video stream, or a similar amount of bandwidth for a more advanced video stream (like HD). Satellite service providers have been quick to embrace MPEG-4, as they are naturally bandwidth-limited given their use of expensive satellites. In most cases, satellite service providers are launching MPEG-4 and HD services at the same time, which allows them to essentially swap out the box at the customer's request (they can usually charge them for this when they sign up for HD). Note that in addition to driving box churn and therefore unit growth, MPEG-4 is also

driving a share shift at the IC level, as incumbent satellite set-top IC supplier STMicroelectronics was late in getting its solution to market and allowed Broadcom and Conexant (later acquired by NXP and then Trident) to win some major designs at its customers.

- **IPTV is still in the early stages but is clearly a focus at IC vendors.** IPTV is still in the early phases, with deployments primarily taking place in Europe and Asia. In 2010, IPTV grew nicely to approximately 44 million subscribers from 28 million in 2009, but household penetration remains only about 1%. Note that IPTV requires a completely new set-top box design, with the analog front end replaced by digital ICs that strip video streams from IP packets, and back end ICs that support IPTV codecs (like VC-1). The major set-top IC vendors are all looking to IPTV for the next leg of growth, with Broadcom, STMicroelectronics, and Trident (through acquisition of NXP/Conexant) all offering solutions to the market. With the backing of Microsoft, media processing specialist Sigma Designs has made progress, while DSP vendors like Texas Instruments and Analog Devices also look to gain traction.

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- **Set-top boxes are increasingly incorporating multiple tuners.** Many set-top box OEMs are incorporating multiple tuners in their high-end boxes to support multiple channels of video (for picture-in-picture and DVR) or for data traffic. Tuner IC vendors are meeting this challenge by integrating multiple tuners on a single IC.

- **Momentum is building for MoCA, HPNA and PLC for box-to-box networking.** Box-to-box networking allows set-top boxes to communicate with each other within the home, usually using the coax infrastructure, in the case of MoCA and HPNA (HPNA can also use POTS infrastructure), or the power network, in the case of PLC (Power Line Communication). This allows features such as DVR-sharing, and is also a critical component for on-demand services in video services using PON RF overlay. Though some OEMs have developed proprietary solutions, standards such as MOCA and HPNA are set to replace these as the application matures. Already, we have seen Verizon's FiOS TV leverage MoCA to enable on-demand services, while AT&T's Project Lightspeed incorporates HPNA into the gateway and set-top boxes. PLC has seen adoption primarily with European Telcos. The ITU is also working on a next-gen standard called G.hn, with the intention of creating a standard to utilize coax, POTS, and power line infrastructure in the home.

- **Set-top box IC suppliers are looking to expand into digital TV.** With the tremendous growth of digital TV, we have seen IC vendors with IP and design competencies in set-tops moving to address this large and growing related opportunity. Broadcom, for one, has upped its ante in the digital TV market with the acquisition of ATI's DTV business. Competition should be fierce here, however, as they will be met by IC vendors moving in from the display scaler, graphics, and DVD markets, including Taiwanese players Mediatek and MStar, as well as Zoran (acquired by CSR) and Trident (which recently acquired STB business from NXP/Conexant). Cost pressures, of course, will continue to be brutal in this consumer-oriented market.

- **Traditional ASIC vendors are being marginalized, though ASSP vendors are adopting an ASIC-like approach.** Vendors like LSI, Fujitsu, IBM, and Toshiba used to have sizable businesses in set-top boxes. Over the past few years, however, these players have been squeezed out by ASSP vendors like STMicroelectronics and Broadcom. At the same time, the ASSP vendors have grown closer to their top customers, adopting an ASIC-like approach to top players while serving smaller customers with standard products.

Digital TV

The television market is undergoing significant changes on a number of fronts. In addition to high-definition content and new services like on-demand and digital video recording, the display technology is changing as well. An additional complication is the FCC mandate for digital terrestrial broadcasting, which necessitates additional functionality for digital tuning inside the TV.

TVs can be classified as either analog or digital. Digital TVs can display images encoded using digital modulation schemes, while analog TVs only support analog signals.

Digital TVs can be further classified as "digital ready" or "integrated digital." The distinction is found in how the TV receives the video signal—digital ready TVs require a set-top box to tune and decode digital content, while integrated digital TVs incorporate a digital tuner, and can receive signals broadcast over the air and decode them without the need for an external set-top box.

The television market is undergoing significant changes on a number of fronts. In addition to high-definition content and new services like on-demand and DVR, the display technology is changing as well. An additional complication is the FCC mandate for digital terrestrial broadcasting, which necessitates additional functionality for digital tuning inside the TV. Consumers are now faced with a dizzying array of choices: wide-screen (16:9) vs. standard (4:3); standard vs. HDTV; digital ready vs. integrated digital; flat screen vs. "big box;" LCD vs. Plasma; CRT vs. DLP vs. rear-projection LCD; the list goes on. We will try to distinguish between TV technologies on the most important vectors.

TVs can be classified as either analog or digital. Digital TVs can display digitally compressed images encoded using digital modulation schemes, while analog TVs only support analog signals. Our discussion of analog TVs ends here.

One very important distinction between digital TVs is whether they include a digital tuner or not; i.e., are they "digital ready" or "integrated digital." Digital-ready TVs utilize digital processing algorithms to display the image on the screen, but do not include the capability to tune and decode digital broadcasts. They require a set-top box to perform this function. Integrated digital TVs incorporate a digital tuner, and can receive digital signals directly and decode them without the need for an external set-top box. The major digital terrestrial modulation schemes in use today are ATSC (Advanced Television Systems Committee, used in North America, Korea, Taiwan and Argentina), DVB (Digital Video Broadcasting, used in Europe and Asia), and ISDB (Integrated Services Digital Broadcasting, used in Japan). Note that the distinction between digital-ready or integrated digital is completely independent of the display technology used or whether the TV supports HDTV, EDTV, or SDTV.

Digital TV

Digital vs. High Definition

There is some confusion between the terms "digital" and "High Definition." They are not the same.

High Definition (HD) is a set of digital formats that support the highest quality video. To view HD, both the TV and the content must be high definition. Some digital TVs support HD but not all.

Standard Definition (SD) is a more basic digital image, similar in quality to DVD. Enhanced Definition (ED) is an intermediate choice.

Digital TV Formats

HDTV – The highest quality video formats, HD supports 720p at 24, 30, and 60 frames per second (fps), 1080i at 30 fps, and 1080p at 24 and 30 fps.

EDTV – ED supports 480p at 24, 30, and 60 fps.

SDTV – Basic digital picture, SD supports 480i at 30 fps.

"p" = progressive scan, "i" = interlaced

There is some confusion between the terms "digital" and "High Definition." They are decidedly not the same thing. Digital signifies that the TV can display video using digital processing algorithms. High Definition, along with its counterparts Enhanced Definition and Standard Definition, refers to the quality of the digital video signal itself.

High Definition (HD) is a set of digital formats that support the highest quality video. To view HD, both the TV and the content must be high definition. Some digital TVs support HD but not all. One step below HD is enhanced definition (ED); one step below that is standard definition (SD).

- **HDTV** – The highest quality video formats, HD supports 720p at 24, 30, and 60 frames per second (fps), 1080i at 30 fps, and 1080p at 24 and 30 fps. All equipment that is quoted as "HD" must support both 720p and 1080i, while 1080p support is optional (and usually specified when present).
- **EDTV** – An intermediate-quality video format, ED supports 480p at 24, 30, and 60 fps.
- **SDTV** – A lower quality video format, SD supports 480i at 30 fps.

Note that the "i" distinction signifies that the signal is interlaced, which reduces the bandwidth required for signal transmission by transmitting only half the picture per frame. In an interlaced signal, each frame displays either the odd lines or even lines (they alternate at each frame; this fools the eye into thinking it is seeing the entire picture). The "p" signifies that the signal is progressive scan, which means that the entire signal is transmitted for every frame.

Digital TV

Display Technologies

CRT – The incumbent “big box” display technology, CRTs use cathode ray guns that shoot electrons through a tube onto a screen coated with luminous phosphors.

LCD – LCD uses liquid crystals in between two coated sheets of glass. LCD enables high-quality displays with thin form factors and, in our opinion, is the most promising display technology.

Plasma – Plasma is a flat-screen technology that uses tiny cells lined with phosphor that are full of inert ionized gas.

OLED – OLEDs are made by placing a series of organic thin films between two conductors. When electrical current is applied, a bright light is emitted. The OLED materials emit light and do not require a backlight (unlike LCDs).

DLP – A MEMS-based technology that uses tiny mirrors to reflect an image onto the screen. Enables large screen TVs that are thinner and lighter than CRTs, but not flat.

LCoS – LCoS uses liquid crystals coated over the surface of a silicon chip to produce a tiny image, which is then enlarged and projected onto the TV screen.

HTPS-LCD – These displays use small, transmissive LCD screens augmented by backlights to produce an image, which is then enlarged and projected onto the TV screen.

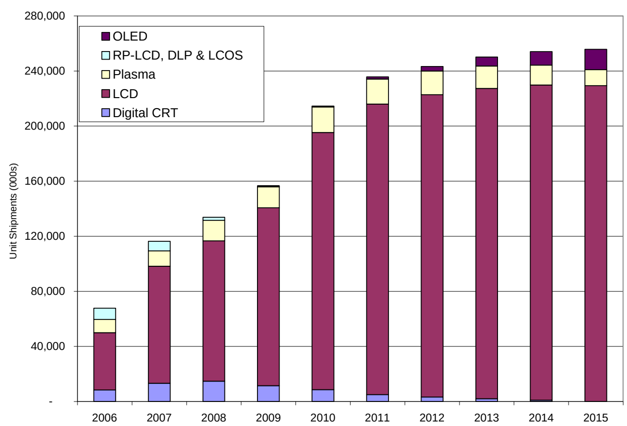
A number of display technologies are used in the digital TV market today. Again, the display technology is completely independent of whether a TV supports HD or ED or SD, or whether it has a digital tuner or is even digital at all (most CRTs are analog, while most of the others are digital; this is due to market factors, not technology factors).

- **CRT** (cathode ray tube) – The incumbent “big box” display technology, CRTs use cathode ray guns that shoot electrons through a tube onto a screen coated with luminous phosphors.
- **LCD** (liquid crystal display) – LCD uses liquid crystals in between two coated sheets of glass. LCD enables high-quality displays with thin form factors and is the most promising display technology.
- **Plasma** – Plasma is a flat-screen technology that uses tiny cells lined with phosphor that are full of inert ionized gas.
- **OLED** (Organic Light Emitting Diodes) - OLEDs are made by placing a series of organic thin films between two conductors. When electrical current is applied, a bright light is emitted. The OLED materials emit light and do not require a backlight (unlike LCDs).
- **DLP** (digital light processing) - A MEMS-based technology that uses tiny mirrors to reflect an image onto the screen. Enables large-screen TVs that are thinner and lighter than CRTs, but not flat.
- **LCoS** (liquid crystal on silicon) – LCoS uses liquid crystals coated over the surface of a silicon chip to produce a tiny image, which is then enlarged and projected onto the TV screen.
- **HTPS-LCD** (high-temperature polysilicon LCD) – This technology, generally deployed in projectors, passes light through miniaturized transmissive LCD screens to produce an image, which is then enlarged and projected onto the TV screen.

Digital TV

Digital TV Unit Forecast

- •We expect moderate growth in digital TVs sparked by HD content, FCC mandates for digital broadcasting, and falling prices for components, especially LCD panels.
- •We expect total digital TV units to grow from 215 million in 2010 to 256 million units in 2015, a 4% CAGR.
- •LCDs should be the biggest growth driver, rising from 187 million units in 2010 to 229 million units in 2015.
- •Plasma should decline at a 9% CAGR and will remain under 10% of units; CRT and microdisplay should decline to zero by 2015 and 2012, respectively.



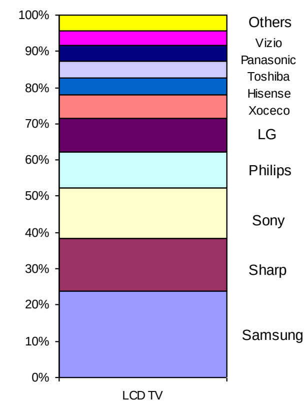
Source: Display Search, Gartner, Oppenheimer & Co.

Key Digital TV Suppliers

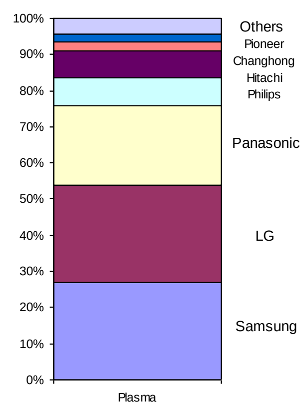
Microdisplay TV

Samsung
Technicolor
LG
Mitsubishi
Philips
Sony
JVC
Hitachi

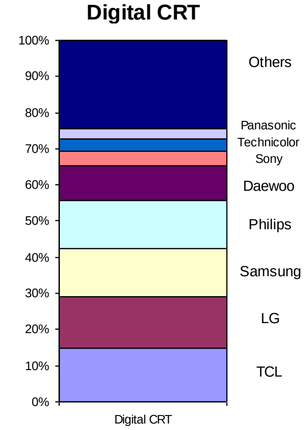
LCD TV



Plasma TV



Digital CRT



Source: Gartner, Oppenheimer & Co.

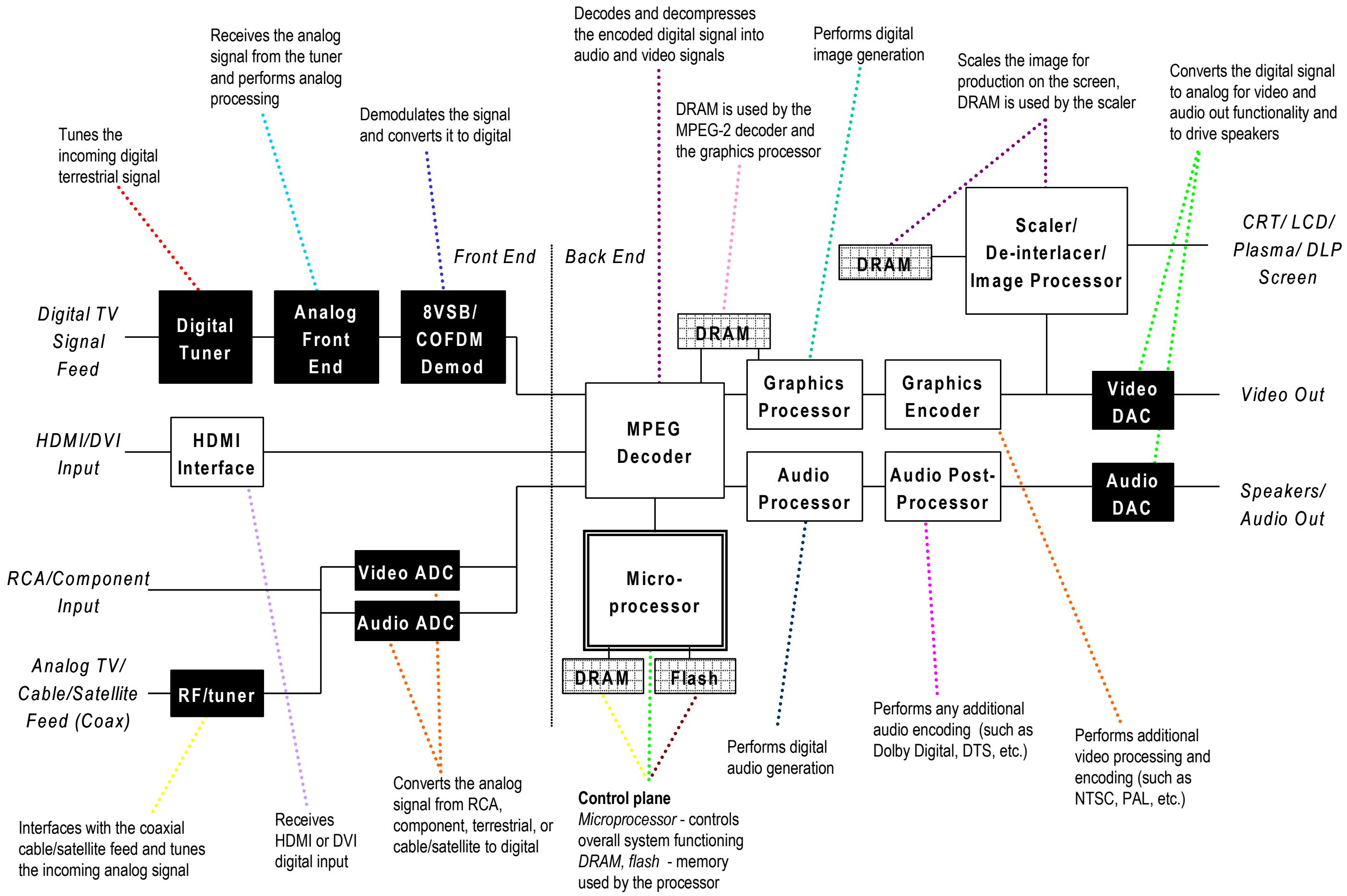
Digital TV Unit Forecast: We expect rapid growth in digital TVs sparked by HD content, FCC mandates for digital broadcasting, and falling prices for components, especially LCD panels. We expect digital units to grow from 215 million in 2010 to 256 million units in 2015 a 4% CAGR. By 2015, we expect over 95% of all TVs shipped to be digital.

LCDs are already the largest category in unit terms and should see the lion's share of the growth. We forecast a 4% CAGR, with shipments rising from 187 million units in 2010 to 229 million units in 2015. The market should benefit as gen 8+ LCD glass fabs come online, driving panel prices lower.

Plasma, the most direct competitor with LCD, should decline at a 9% CAGR and will remain under 10% of units. OLED (Organic Light Emitting Diodes) TVs should experience robust growth, rising from a small base in 2008 to nearly 15 million units in 2015. Digital CRT, once the largest segment, should decline as a percentage of total from 4% of units in 2010 to 0% in 2015.

Digital TV Suppliers: Dozens of players serve the digital TV market, including incumbent analog TV makers in Japan, Europe, and Korea, as well as new ODMs in Asia. Top suppliers of LCD TVs include Samsung, Sharp, Sony, Philips, LG, Xoceco, and Hitense. Top suppliers of plasma TVs include Samsung, LG, Panasonic, Philips, Hitachi, Pioneer, and Changhong. Top suppliers of microdisplay TVs (DLP, LCOS, HTPS) are Samsung, Technicolor, LG, Mitsubishi, Philips, and Sony. Top suppliers of digital CRT include TCL, LG, Samsung, Philips, Daewoo, Sony, Technicolor, and Panasonic.

Digital TV



Source: Oppenheimer & Co.

Note: The block diagram above and the discussion below apply to integrated digital TVs, which use the maximum amount of semiconductor content. Digital ready TVs have a similar back end, but the front end lacks the digital tuner and associated analog front end components.

Digital TV designs are similar to those of set-boxes, with a few architectural differences. First, the front end is specifically designed for digital terrestrial signals, from the tuner to the analog front end to the demodulator. Analog tuners and ADCs are included as well to handle legacy analog input. The back end ICs are largely the same as a set-top, with the addition of scaler, deinterlacer and cone filters to produce the actual image on the screen. These image processing functions are similar to those found in a PC flat panel display and are usually performed on a single IC.

Other ICs found in a digital TV include those that produce the actual image. We do not include these in our block diagram, as they vary markedly based on the display technology. For example, LCD and HTPS TVs require LCD drivers and timing ASICs, plasma screens require plasma drivers, DLP TVs require a DLP MEMS array and controller chipset, and LCoS TVs require an LCoS engine.

Front End

- **Digital Tuner** (only used in integrated digital TVs): The digital tuner receives the digital terrestrial signal from either an antenna or digital terrestrial receiver and tunes it to the proper RF frequency. TVs can have multiple tuners to support picture-in-picture or other functionality.
- **Analog Front End** (only used in integrated digital TVs): The analog front end receives the signal from the tuner.

- **8VSB/COFDM Demodulator** (only used in integrated digital TVs): The demodulator chip demultiplexes the 8VSB/COFDM signal and converts it to a digital stream for decode and processing by the digital back end. This chip can be integrated with the analog front end for an integrated digital TV front end ASSP.
- **RF/Tuner**: An analog tuner receives input from either an antenna or from a cable/satellite set-top box.
- **Video A/D Converter**: A video analog-to-digital converter converts the video signal received from either the RF/tuner or RCA/component/S-Video input to digital.
- **Audio A/D Converter**: An audio analog-to-digital converter converts the audio signal received from either the RF/tuner or RCA input to digital.
- **HDMI/DVI interface IC** (only used in TVs that support HDMI or DVI): A specialized interface IC receives HDMI or DVI digital input. Note that in the case of HDMI, the audio signal is transmitted alongside the video; in DVI, the audio is taken in separately via RCA cables.

Back End

- **MPEG Decoder**: The MPEG decoder decodes and decompresses the digital signal into audio and video signals.
- **Graphics Processor**: The graphics processor performs digital image generation, adding graphic items associated with on-screen menus and other features. Usually integrated into the DTV back-end ASSP.
- **Graphics Encoder**: The graphics encoder performs additional processing and encoding on the video signal, such as NTSC, PAL, etc. Also usually integrated into the DTV back-end ASSP.
- **Audio Processor**: The audio processor is a DSP that performs digital audio generation. Also usually integrated into the DTV back-end ASSP.
- **Audio Post-Processor**: The audio post-processor performs any additional audio encoding, such as Dolby Digital, DTS, etc. Also sometimes integrated into the DTV back-end ASSP.
- **Microprocessor**: A microprocessor performs control plane functions and runs the DTV system software including menus, features, and effects. It is sometimes embedded in a DTV back-end ASSP, though more advanced TVs will use a discrete processor.
- **Flash/DRAM**: The MPEG decoder and microprocessor use a variety of memories.

Back End Image Processing

- **Image Processor**: An image processor performs scaling, deinterlacing and cone filter functions. In newer designs, the image processor is integrated with the back end decode processor for a full DTV back-end SoC.
- **DRAM:** The image processor uses DRAM memory.

Back End Interface

- **Video D/A Converter**: A video digital-to-analog converter converts the video signal to analog format for video out functionality over RCA cables.
- **Audio D/A Converter**: An audio digital-to-analog converter converts 16-bit stereo samples into left and right alternating-current audio signals for audio out.

Digital TV

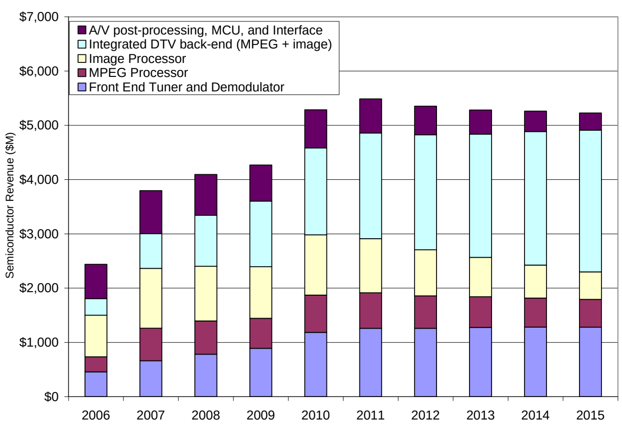
Digital TV Semiconductor Forecast

•Digital TV semiconductors should decline slightly, falling from $5.3 billion in 2010 to $5.2 billion in 2015.

•Front end ICs should grow at a 2% CAGR, benefiting from both unit growth and rising penetration of digital tuners.

•Integrated DTV back ends should grow at a 10% CAGR as they replace standalone MPEG decode and image processors in mainstream DTVs.

•Interface ICs should face price and integration pressure.



Source: IDC, Dataquest, Oppenheimer & Co.

Digital TV Semiconductor Competitors

Samsung
NXP
Toshiba
Panasonic
Himax
MediaTek
Sony
STMicro
Broadcom
Max Linear
Zoran
Trident

Source: IDC, Oppenheimer & Co.

Digital TV Semiconductor Forecast: The market for digital TV semiconductors should experience healthy growth, driven by strong unit shipments and the increased penetration of digital tuners and associated front end ICs. Note that revenue growth will trail units due not only to normal ASP pressure, but also due to integration trends, principally in the back end. In total, we expect the market to decline slightly, falling from $5.3 billion in 2010 to $5.2 billion in 2015.

By device type, front end ICs should grow at a 2% CAGR, benefiting from rising penetration of digital tuners. Integrated DTV back ends should grow 10% as they replace standalone MPEG decode and image processors in mainstream DTVs. Discrete MPEG processors should decline 15% as pricing pressure arises in this niche high-end product. Discrete image processors, MCU, and interface ICs face price and integration pressure and should decline despite unit growth.

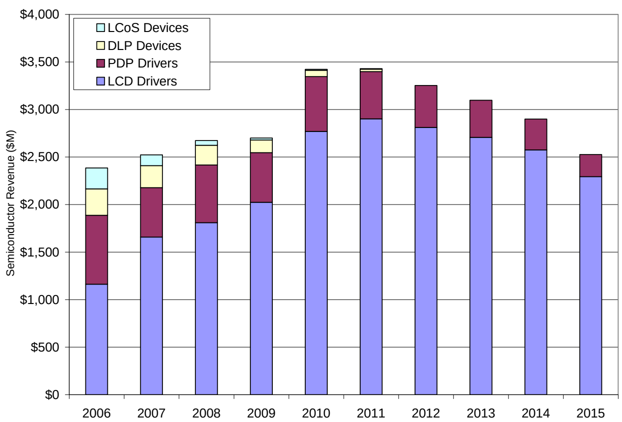
Digital TV Semiconductor Competitors: The digital TV semiconductor market was once served primarily by ASIC suppliers selling internally in Japan and Europe, though their positions have been eroding over time as ASSP suppliers have entered the market with competitive solutions. Note that vertically integrated OEMs will likely still embrace the ASIC model at the high end in an effort to better differentiate their products.

The largest vendors of digital TV semiconductors include Samsung, NXP, Toshiba, MediaTek, Himax, Sony, Broadcom, STMicro, Max Linear, Zoran (acquired by CSR), and Trident.

Digital TV

Digital TV Display Semiconductor Forecast

•Semiconductors sold into the display mechanism within a digital TV are a separate market from signal and image processing, warranting separate discussion.
•We expect the market decline from $3.4 billion in 2010 to $2.5 billion in 2015, a -6% CAGR.
•LCD drivers are declining at a 4% CAGR, as unit growth is more than offset by ASP declines.
•Plasma should decline at 17%, while DLP/LCoS should cease production by 2012.



Source: Dataquest, Oppenheimer & Co.

Digital TV Display Semiconductor Competitors

LCD/PDP Drivers

Samsung	Renesas
Renesas	Magnachip
Himax	Sunplus
Panasonic	Toshiba
Novatek	Solomon Systech
Oki Electric	Sanyo
Sharp	Seiko Epson

DLP

Texas Instruments

LCoS

JVC
Sony

Source: Dataquest, Oppenheimer & Co.

Digital TV Display Semiconductor Forecast: Semiconductors sold into the display mechanism within a digital TV are a separate market from signal and image processing (discussed on the previous page), warranting separate discussion. This market is driven by the shift from CRT to advanced display technologies like LCD which require more semiconductor content than legacy technologies. We expect the display market to slightly trail the signal and image processing market, as unit growth trends are more than offset by pricing pressure and the decline in DLP and LCOS markets. In total, we expect the market to decline at a 6% CAGR, falling from $3.4 billion in 2010 to $2.5B in 2015.

By device type, LCD drivers are the largest market and are expected to decline at a -4% CAGR, as pricing pressure ultimately overtakes unit growth in the latter years of the forecast. Plasma should decline moderately at an 17% CAGR as it loses share to LCD over time. DLP and LCoS have been relegated to niche markets, and should exit the market completely by 2012; note that revenue for this segment peaked in 2006 as large screen flat panel TV pricing became more competitive, eroding the growth rate for DLP and LCoS.

Digital TV Display Semiconductor Competitors: The digital TV display semiconductor market is served by vendors of LCD and PDP drivers, DLP MEMS devices, and LCoS engines. Besides the notable exception of Texas Instruments, the top suppliers of these components are all based in Asia and Japan. The top suppliers of LCD/PDP drivers include Samsung, Renesas (NEC acquisition), Himax, Panasonic, Novatek, Oki, Sharp, Renesas, Magnachip, SunPlus, and Toshiba. Texas Instruments is the sole supplier of DLP chipsets, while JVC and Sony produce LCOS engines.

Digital TV

Digital TV Semiconductor Market Trends

•Sparked by FCC mandates, integrated digital TVs continue to penetrate the U.S. market.

•Digital penetration is set to ramp globally as other countries gradually shut off analog transmission.

•Japanese and Korean OEMs which lead the TV space remain committed to internal ASICs for the high end, but are increasingly leveraging merchant solutions for mainstream models.

•Image processing remains a key focus for semiconductor vendors.

•Integrated solutions for front and back end are driving down cost.

•Incumbents in the digital set-top box, DVD, graphics, and display IC markets have rushed into digital TV.

•HDMI is now a standard feature on advanced TVs.

•OEMs are exploring home networking solutions to connect digital TVs to set-tops, PCs, A/V devices, and peripherals.

- **Sparked by FCC mandates, integrated digital TVs continue to penetrate the U.S. market.** The mandate by the FCC to end all analog transmission occurred in June 2009 and in support of the mandate, all TVs sold in the United States as of July 2007 were required to have an integrated digital tuner. Though the shipments are a bit behind this mandate, and other countries will move on different schedules (see the next point), the trend is the same; and increasing penetration of digital tuners is driving additional opportunity for IC vendors.
- **Digital penetration is set to ramp globally as other countries gradually shut off analog transmission.** Global dates for analog shutoff vary significantly by region (Denmark in 2009, Japan in 2011, Brazil and other emerging markets in 2011/12 and beyond, etc.). Note that certain regions may experience early penetration of digital TV in advance of the planned analog shutoff date. Digital penetration also relates to LCDs replacing CRTs, which is largely a function of pricing. The pricing of LCDs has declined significantly over the past couple of years.
- **Japanese and Korean OEMs which lead the TV space remain committed to internal ASICs for the high end, but are increasingly leveraging merchant solutions for mainstream models.** ASICs will likely continue to play an important role in the digital TV market, as many of the large TV OEMs pursue ASICs in order to meet higher picture performance metrics and to better differentiate their product offerings.
- **Image processing remains a key focus for semiconductor vendors.** Image processing remains a key focus for chip vendors, especially as screens become larger (problems with image quality become more noticeable on larger screens). 1080p, 3D motion processing, and multiple MPEG streams also present technical challenges. Frequency and refresh rates are becoming the next

key focus of semiconductor vendors, as consumers desire higher quality motion picture and move beyond 60Hz, particularly for watching sports.

- **Integrated solutions are driving down cost.** DTV ASSPs now in the market look similar to set-top box front and back end ASSPs, but include the additional content unique to digital TV, such as terrestrial demodulation functions on the front end and scaling and deinterlacing functions on the back end.
- **Incumbents in the digital set-top box, DVD, graphics, and display IC markets have rushed into digital TV.** The list of component suppliers includes vendors from the set-top box (Broadcom, Sigma Designs, STMicroelectronics), DVD (Zoran, Mediatek), graphics (Trident) and display (Genesis, Pixelworks) segments.
- **HDMI (High-Definition Multimedia Interface) is now a standard feature on advanced TVs.** HDMI is the digital interface standard for the consumer electronics industry and has throughput of up to 5 Gbps, ideal for HDTV applications. Today HDMI is implemented mostly with discrete I/O ICs, though this functionality is gradually being integrated into the image processor for mid-level DTVs. High end DTVs will likely continue to use discrete HDMI ICs for performance reasons as OEMs target image quality rather than cost savings—these TVs now include multiple HDMI inputs.
- **OEMs are exploring home networking solutions to connect digital TVs to set-tops, PCs, A/V devices, and peripherals.** Candidates being tested include wireless technologies like 802.11n, powerline networking like HomePlug, and coax networking technologies like MoCA and HPNA.

DVD

DVD has emerged as one of the fastest growing and most pervasive consumer electronics technologies ever, with over 80 million standalone players shipped in 2010, along with 335 million PC drives (includes Blu-ray).

Consumers have demonstrated a willingness to pay for the superior quality of commercial read-only movies. Compatibility with PC and game console media formats has also helped ubiquitize DVD.

The DVD usage model is now evolving on a number of fronts. New home theater and digital TV systems regularly incorporate DVD functionality. Automotive and portable DVD have gained considerable consumer adoption. DVD recording has had some traction, both standalone and with DVR/DVD-recorder units that have come to market. Next generation Blu-ray should provide an avenue of growth going forward.

DVD has emerged as one of the fastest ramping consumer electronics technologies ever, with more than 95 million consumer players and recorders shipped in 2008, not to mention more than 300 million drives sold into PCs, game consoles, and other embedded markets. Sales have been driven primarily by strong consumer demand for the superior quality of commercial read-only movies for the home. Oddly enough, PC DVD adoption has been largely driven by the same trend, as consumers often use the DVD drive for little more than watching DVDs on their PCs (though this is changing).

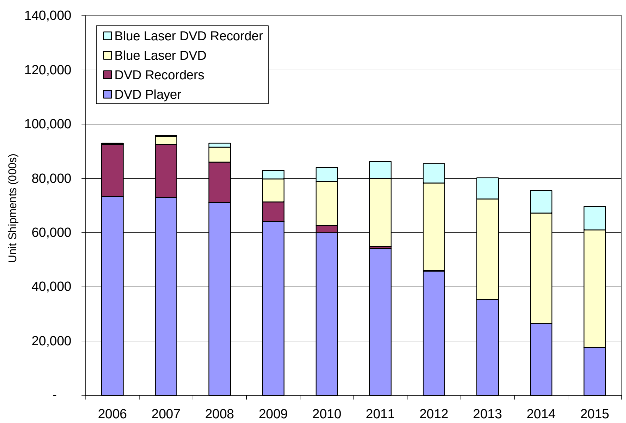
The DVD usage model is now evolving on a number of fronts. New home theater and even some digital TV systems regularly incorporate DVD functionality. Automotive and portable DVD has gained considerable consumer adoption. DVD recording has had some traction, both standalone and with DVR/DVD-recorder units that have come to market. DVD audio is in the early stages but represents a future driver.

On another vector, we are starting to see DVD players used to play user-generated content. Many DVD players support CD-R and DVD+/-R discs, and can play MPEG, MP3, JPEG, DIVX, and a multitude of other file formats. Consumers can load home videos and pictures as well as content downloaded from the Internet onto recordable discs on their PCs and then play them on their DVD players.

DVD

DVD Player and Recorder Unit Forecast

•We expect DVD players and recorders to decline from 84 million units in 2010 to 70 million units in 2015, a -4% CAGR.
•Blue laser DVD player prices are dropping quickly and sparked strong adoption in 2010; we forecast 43 million units by 2015.
•DVD player units should decline as blue laser takes off; DVD recorders have disappointed and remain a niche.



Source: Gartner, IDC, Oppenheimer & Co.

Key DVD and Blu-ray Player Suppliers

DVD Players

Funai	Orion
Toshiba	Magnavox
Sony	JVC
Cyberhome	Pioneer
Samsung	Philips

Blu-ray Players

Sony	Sharp
Samsung	Toshiba
Panasonic	Onkyo
Insignia	Vizio
LG	Orion

Source: Company reports, Oppenheimer & Co.

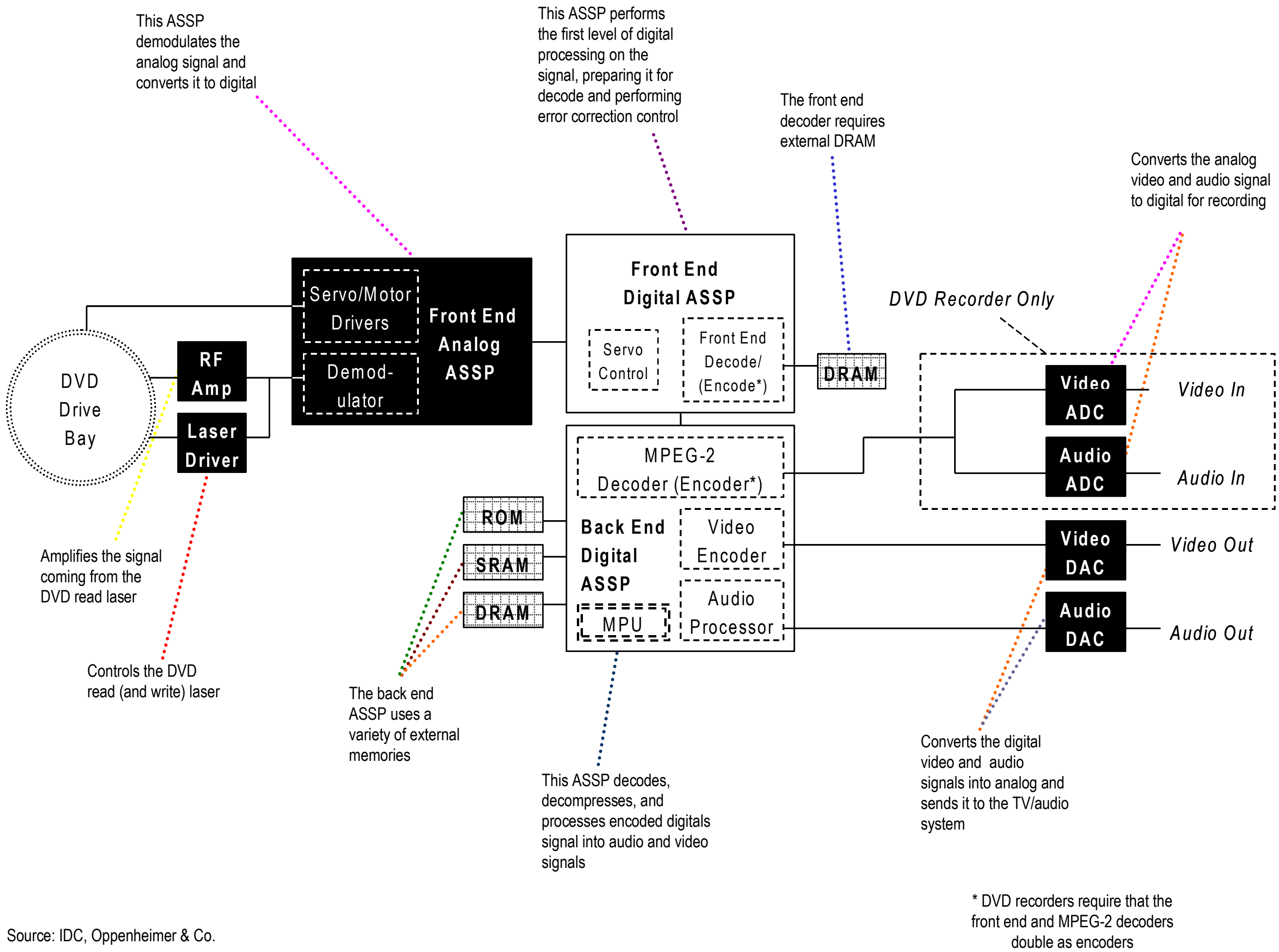
DVD Player and Recorder Unit Forecast: DVD unit growth has been very strong over the past several years, as OEM and ODMs have met consumer demand with inexpensive players. This helped drive a big upgrade cycle vs. VCRs and, in fact, grew the market well beyond VCRs in unit terms. Note that growth has been noticeably decelerating as penetration has risen quickly worldwide.

Going forward, we expect units to decline at a 4% CAGR, from 84 million in 2010 to 70 million in 2015. Growth is predominantly concentrated in blue laser players, as falling player prices have already sparked strong adoption in 2010. We forecast blue laser DVD shipments of nearly 43 million units by 2015—this excludes embedded players such as Sony's PS3. Standard DVD players should decline at a 12% CAGR as blue laser takes over, while DVD recorders—once a very promising category—will be out of production by the end of 2013.

DVD Player and Recorder Suppliers: The DVD market is highly fragmented and has undergone some significant share shifts as ODMs have commoditized the market. The largest supplier of DVD players is Japanese ODM Funai, which produces DVD players for many of the recognizable Japanese brands. Branded players LG, Sony, and Samsung were next, followed by a number of ODMs (Cyberhome, Orion, TCL). Branded players like Panasonic, Philips, Magnavox, Toshiba, and JVC also participate but tend to use ODMs for actual player production.

On the Blu-ray player side, most of the large electronics OEMs produce their own. Top vendors include Sony, Samsung, Panasonic, LG, Insignia, Toshiba, Onkyo, Vizio and Orion.

DVD



Source: IDC, Oppenheimer & Co.

Like set top boxes, DVD player semiconductors can be broken down into a front end block and a back end block. The front end reads the DVD and performs analog to digital conversion and preliminary decoding, as well as drive bay and laser control. The back end decodes the signal and processes it into video and audio signals for transmission to the TV. In a DVD recorder, additional silicon is required to take in video and audio and the back end and front end decoders double as encoders.

Note that PC-based DVD drives use similar ICs but end at the front end; back end processing is done on the host PC processor. The market for PC-based DVD drives is discussed earlier in this document in the section on optical drives.

Front End

- **Laser Driver**: The laser driver controls the DVD read (and write) laser.
- **RF Amp**: The RF amp amplifies the signal coming off the DVD laser.
- **Front End Analog ASSP:** The front end analog IC includes the demodulator and servo/motor driver. The demodulator receives the signal from the RF amp and converts it to a digital format to be processed. The servo/motor driver controls the movement of the drive bay. Note that blue laser DVD analog front ends are considerably less integrated than standard DVD, and typically use more than one IC to perform these functions, at least for now.
- **Front End Digital ASSP:** The front end digital IC includes the servo control, read channel DSP, and front end decoder. The servo control DSP controls the servo driver and is also responsible for error correction control. The read channel DSP and front end decoder perform the first layer of digital processing on the digital signal and prepare it for back end video/audio processing.

In a DVD recorder, it also encodes the MPEG-2 stream and writes it to the DVD. Like the front end analog ASSP, blue laser digital front ends are less integrated than standard DVD and may use more than one IC to perform these functions.

- **DRAM**: DRAM memory is used by the front end decoder.

Back End

- **Back End Digital ASSP:** The back end digital IC includes an MPEG-2 decoder, video encoder, audio processor, and embedded microprocessor. The MPEG-2 decoder decodes and decompresses the digital signal into audio and video signals. In a DVD recorder, it also encodes the video and audio signal and compresses it into the MPEG-2 format. The video encoder performs additional processing and encoding on the video signal before it is sent to the TV, such as NTSC, PAL, etc. The audio processor is a DSP that performs digital audio generation. The microprocessor performs system control plane functions and runs the DVD player software. Like the front end, blue laser back ends are less integrated than standard DVD and may use more than one IC to perform these functions. Note also that both Blu-ray and HD-DVD support VC-1 and h.264 in addition to MPEG-2, so digital back end ASSPs need to decode these
- **ROM, SRAM, DRAM**: The back end IC uses a variety of memories.

Progressive Scan *(only found in Progressive Scan DVD players)*

- **Video De-interlacer** (not shown in diagram): This DSP breaks the signal down into separate rows for progressive scan video. It is usually integrated with the progressive video encoder.
- **Progressive Video Encoder** (not shown in diagram): This encoder implements the Progressive Scan format and sends the signal out to the TV. It is usually integrated with the video de-interlacer; in some cases both the interlacer and encoder are integrated in with the back end digital ASSP to create a progressive scan-capable back end ASSP.
- **DRAM** (not shown in diagram): The video deinterlacer uses DRAM memory.

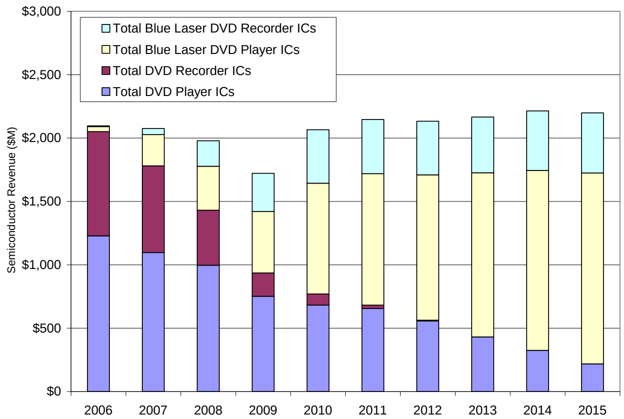
Back End Interface

- **Video and Audio D/A Converters (DACs)**: Video and audio digital-to-analog converters convert the video and audio signal to analog format to send it to the TV over RCA cables.
- **Video and Audio A/D Converters (ADCs)** (DVD recorder only): Video and audio analog-to-digital converters receive the analog video and audio input to be recorded.
- **ATA/SATA Controller** (hard disk drive-enabled DVD recorder only): Some DVD recorder decks include hard disk drive functionality. In these drives, an ATA/SATA controller interfaces between the back end IC and the hard disk drive.

DVD

DVD Semiconductor Forecast

•We expect DVD semiconductors to increase at a 1% CAGR, growing from $2.1 billion in 2010 to $2.2 billion in 2015.
•Growth in Blu-ray players, which command a higher semiconductor bill-of-materials, is more than offsetting a unit decline in DVD players.



Source: IDC, Gartner, Oppenheimer & Co.

DVD and Blu-ray Semiconductor Competitors

MediaTek
Zoran
Broadcom
Sigma Designs
SunPlus
Renesas
Sony
Samsung
Panasonic

Source: IDC, Oppenheimer & Co.

DVD Semiconductor Forecast: We expect DVD semiconductors to grow at a 1% CAGR, from $2.1 billion in 2010 to $2.2 billion in 2015. We expect growth in Blu-ray players, which command a higher semiconductor BOMs, will more than offset a unit decline in DVD players and recorders.

Looking deeper at the forecast, we forecast double digit declines for both DVD players and recorders, as price pressure remains considerable in those markets. DVD player ICs should decline at a 20% CAGR, falling from $682 million in 2010 to just $218 million in 2015. DVD recorder ICs should be out of production by the end of 2013. Blue laser DVD players and recorders should more than offset the decline, however, reaching nearly $2.0 billion in 2015.

DVD Semiconductor Competitors: Vertically integrated system houses utilizing internal ASICs, primarily in Japan, originally dominated the DVD semiconductor market. As the market has grown, however, cost has become the focus, driving the market to merchant ASSP solutions. Vendors of DVD semiconductors include MediaTek, Zoran, SunPlus, Renesas, Sony, Samsung and Panasonic.

Note that the blue laser market is developing its own IC supply landscape. Sigma Designs and Broadcom each supply back end devices, while most of the front end is done internally by the OEMs, at least for now.

DVD

DVD Semiconductor Market Trends

•DVD players have moved to integrated single-chip designs.

•DVD back-end ASSPs are incorporating more high-end processing and encoding.

•The recorder market has been a big disappointment for IC vendors.

•Integration in the DVD recorder IC market is happening at a slower pace than for DVD player ICs.

•DVR/DVD-Recorder decks represent the next generation of consumer video appliances.

•Blu-ray won the standards battle over HD-DVD

•Set-top box players have entered the DVD IC market with the move to blue laser formats.

- **DVD players have moved to integrated single-chip designs.** The major ASSP suppliers have been aggressive with their integration roadmaps. Most designs use a single digital ASSP with front and back end functions along with an analog front end ASSP; while others take it a step further with single-chip DVD players. Note that integration in the DVD recorder IC market is happening at a slower pace than for DVD player ICs.
- **DVD back-end ASSPs are incorporating more high-end functionality.** Examples include support for progressive scan, in-motion zooming, DVD audio, MP3 encoding, high performance graphics processing, MPEG-4 and DivX video, copy protection, NTSC/PAL decoding and USB/flash card interfaces.
- **The recorder market has been a big disappointment for IC vendors.** With margins compressing on the player side, most back end vendors quickly turned their attention to the recorder market. This market never evolved beyond a niche, however, and has been a perennial disappointer.
- **Blu-ray won the standards battle over HD-DVD.** Set-top box players have entered the DVD IC market with the move to blue laser formats. Blu-ray requires VC-1 and h.264 decode, standards which are used today in satellite and IPTV set-top boxes. Broadcom and Sigma Designs have leveraged their set-top technology to gain footholds in blue laser DVD.

Digital Cameras

One of the first consumer electronics applications to broadly and successfully "go digital," digital cameras have surged past 35 mm cameras globally, as have digital camcorders.

Digital cameras and camcorders now address all segments of the market, from the value segment to the professional market. The rise of internet photo sites like Snapfish and Kodak Gallery, along with the pervasiveness of photo-capable printers, is ushering in an all-digital world for photography.

One of the first consumer electronics applications to broadly and successfully "go digital," digital cameras have surged past 35 millimeter analog cameras globally, as have digital camcorders. Digital models now address all segments of the market, from the value segment to the professional market.

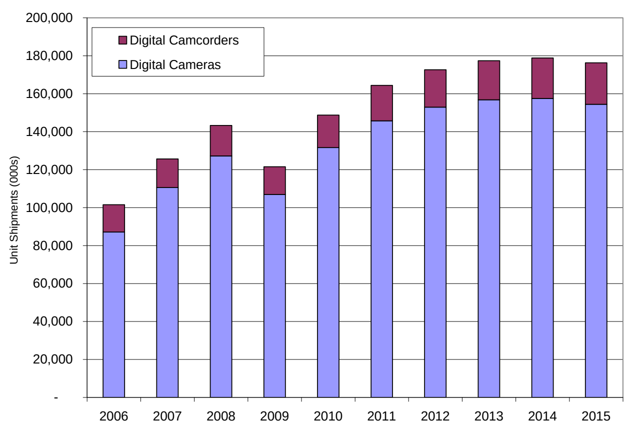
As the market has matured, the industry has made strides in addressing the lack of a pervasive and efficient digital photofinishing infrastructure, which represented the biggest advantage of 35 mm cameras over digital. Digital photofinishing stations are now routinely located alongside traditional photo developing concessions. Online printing services like Snapfish and Kodak Gallery (formerly Ofoto) offer the consumer an even easier experience, as do photo-capable printers that are now pervasive. These are all expediting the death of the analog camera.

The market for digital cameras, however, has begun to change with the permeation of smartphones with embedded high-quality digital cameras and camcorders. Capturing digital images on a smartphone enables instantaneous uploading and sharing. The digital camera market is at risk as high-end phones integrate higher resolution cameras/video recorders.

Digital Cameras

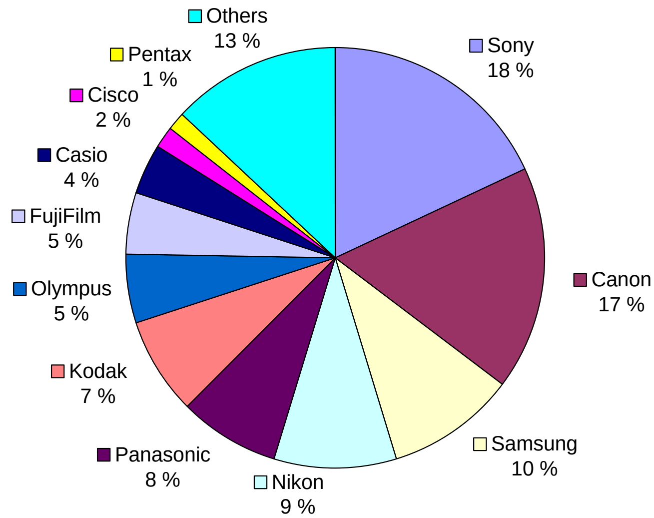
Digital Camera Unit Forecast

- •We expect digital still cameras and camcorders to grow at a 3% CAGR, rising from 149 million units in 2010 to 176 million units in 2015.
- •Digital still cameras should remain about 88-89% of unit shipments with digital camcorders representing the balance.



Source: IDC, Dataquest, Oppenheimer & Co.

Key Digital Camera Suppliers



Digital Still Camera		***Digital Camcorder***
Canon	Panasonic	Sony
Sony	Olympus	Cisco
Nikon	FujiFilm	Panasonic
Samsung	Casio	Canon
Kodak	Pentax	JVC

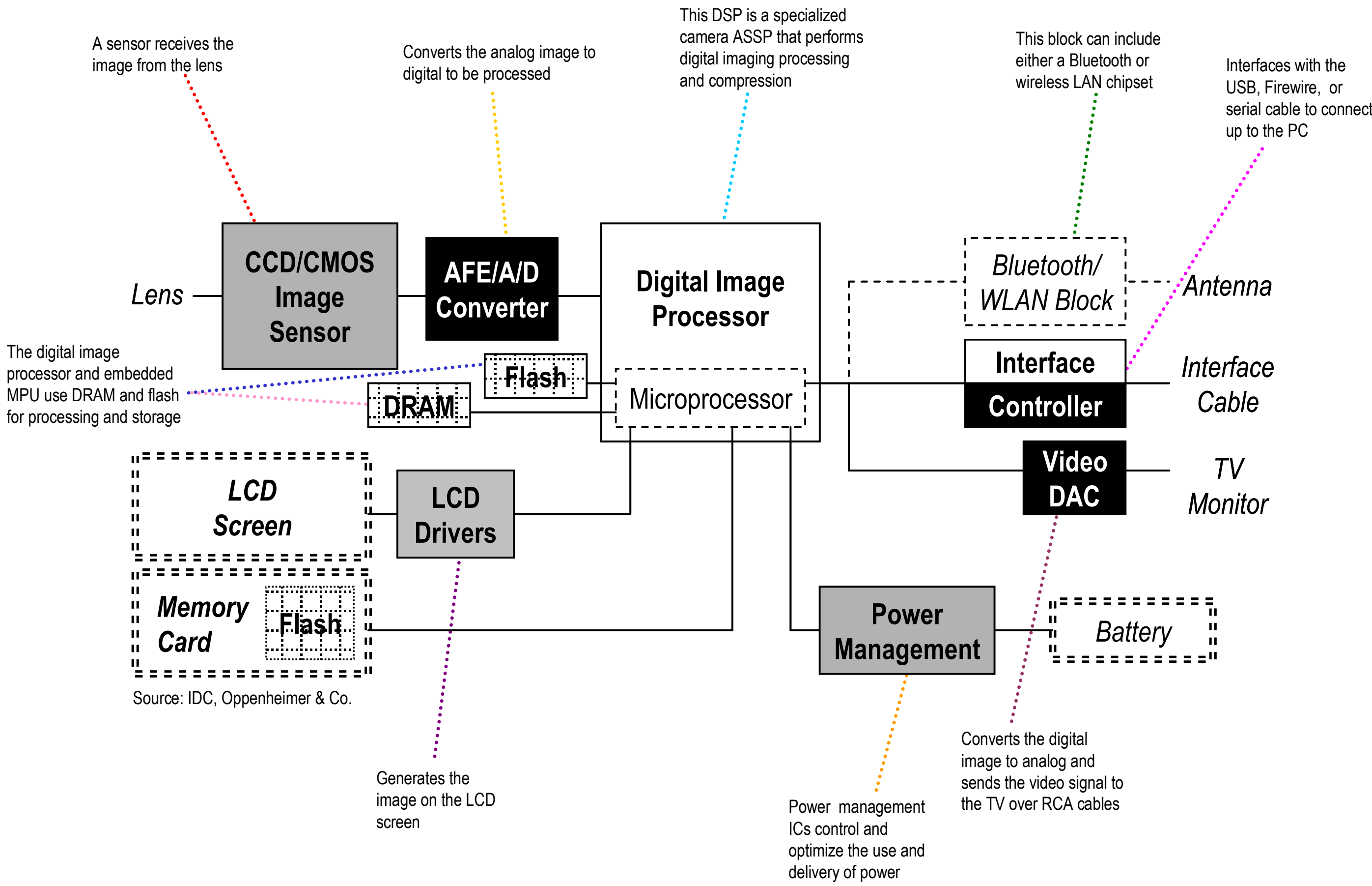
Source: IDC, Oppenheimer & Co.

Digital Camera and Camcorder Unit Forecast: The digital camera market includes two distinct classes of devices: digital still cameras (DSCs) and digital camcorders. The technology used in these devices is remarkably similar, and in fact many digital still cameras are able to record short videos while many camcorders can take digital stills as well. The market, however, has done a good job of clearly delineating the primary function of these devices, and our forecast is consistent with that distinction.

In total, we expect digital still cameras and camcorders to grow at a 3% CAGR, rising from 149 million units in 2010 to 176 million units in 2015. Digital still cameras should remain approximately 88-89% of unit shipments; 132 million units in 2010 growing to 154 million units in 2015, a 3% CAGR. Digital camcorders represent the balance; 17 million units in 2010 growing to 22 million units in 2015, a 5% CAGR. However, we expect the market to peak in 2014 as high resolution cameras begin to proliferate other consumer devices, notably smartphones and tablets.

Digital Camera and Camcorder Suppliers: The market for digital cameras supports a number of players from the traditional photography, consumer electronics, and computing worlds. In 2010, the market leader was Sony with 18% share overall, with the No. 2 position in DSCs (18% share) and the top position in digital camcorders (with 22% share). Canon was No. 2 overall with the top position in DSCs (19% share) and the No. 6 position in digital camcorders (6% share). Nikon, Samsung and Panasonic held 11%, 10% and 8% share, respectively, in 2010. Other major suppliers include Kodak, Olympus, FujiFilm, Casio, Cisco and Pentax.

Digital Cameras



Digital camera semiconductors have come a long way in just a few short years as IC vendors have recognized the large unit opportunity available once cameras hit reasonable price points. Although most devices are designed internally as custom ASICs, the level of integration and specialization in the analog, digital and even image sensor ICs has been remarkable.

In a typical camera implementation, an image sensor receives the image from the lens and passes it to an analog front end, which converts the image to a digital format. A digital image processor DSP then processes the image and stores it in a flash memory card, usually with some level of file compression. The image can then be passed to a host computer either through an interface cable (usually USB) or Bluetooth or wireless LAN, or it can be displayed on a TV monitor. Most cameras also have an on-board LCD screen for image display and manipulation and for camera setting and memory bank management.

Front End

- **CCD/CMOS Image Sensor**: The image sensor receives the image from the lens. It can either be a CCD (Charged Coupled Device) or a CMOS-based (silicon) image sensor.
- **Analog Front End(AFE) / Analog-to-Digital-Converter (ADC)**: This ADC converts the image from analog to digital for processing and storage.

Back End

- **Digital Image Processor**: This DSP is a specialized ASSP that processes the image signal. It usually has an embedded microprocessor to run the camera software and LCD display.
- **DRAM and Flash**: The embedded microprocessor and the DSP use DRAM and flash memory.

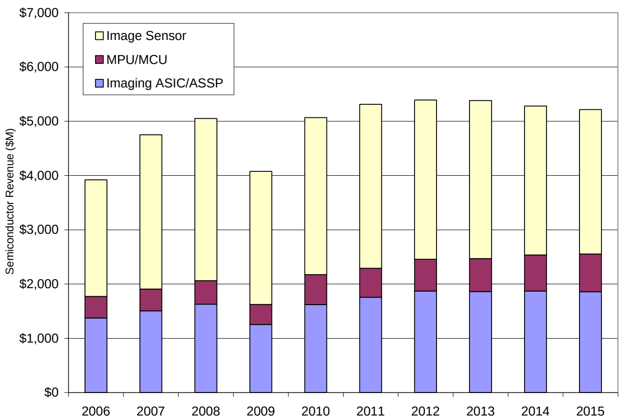
Interface, Power Management and Display

- **Interface Controller**: Most digital cameras have some sort of short-wire interface to hook up to a PC, either USB, Firewire, or a proprietary interface through the PC serial port.
- **Video Digital-to-Analog Converter (DAC)**: Some digital cameras and most camcorders allow for hookup to a television or other monitor through an RCA cable. This signal is converted and driven by a video DAC.
- **Bluetooth Baseband and RF/IF** (not pictured in diagram) –Bluetooth-enabled cameras can interface wirelessly with a PC via a personal area network in order to transfer images. They can also use Bluetooth to connect directly to a photo printer to print out images. In a Bluetooth chipset, the baseband performs the digital processing and protocol encoding and the RF/IF performs the radio transmission/reception.
- **Wireless LAN Baseband/MAC and RF/IF/PA** (not pictured in diagram): Wireless LAN-enabled cameras can interface wirelessly with a PC via an 802.11 wireless LAN in order to transfer images. In an 802.11 chipset, the baseband/MAC performs digital processing and protocol encoding and the RF/IF/PA performs the radio transmission/reception and power amplification.
- **Power Management**: Power management ICs control and optimize the use and delivery of power in the camera and manage the battery.
- **Display Drivers**: Display drivers produce the image on the LCD screen.

Digital Cameras

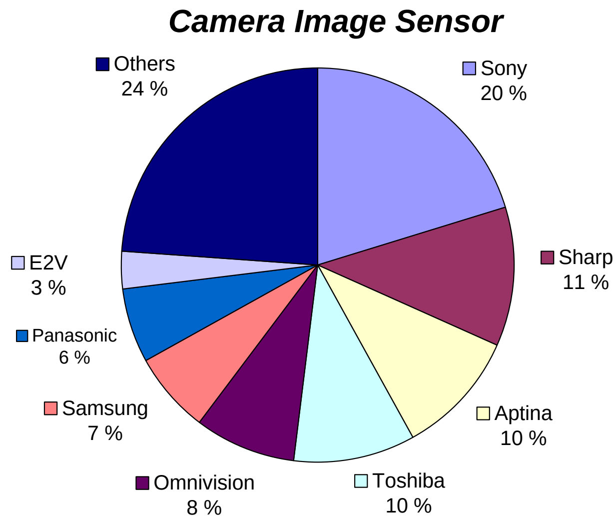
Digital Camera Semiconductor Forecast

- We expect digital camera ICs to increase at a 2% CAGR, from $5.1 billion in 2010 to $5.2 billion in 2015.
- Image processors should increase at a 3% CAGR as OEMs increasingly utilize more advanced processors to keep up with rising megapixel density and to add new features such as image stabilization.
- Discrete microcomponents continue to find a home in high-end cameras.
- Image sensors should remain over 50% of market revenue.



Source: IDC, Dataquest, Oppenheimer & Co.

Digital Camera Semiconductor Competitors



Source: IDC, Oppenheimer & Co.

Digital Camera and Camcorder Semiconductor Forecast: We estimate that the digital camera IC market totaled $5.1 billion in 2010 (excludes memory, which is usually implemented with external flash cards). Nearly 60% of this revenue was derived from image sensors, with the balance derived from image processing and microcomponents.

Looking ahead, we expect digital camera ICs to increase at a 2% CAGR to $5.2 billion in 2015. Image sensors should decline at a 2% CAGR as the ramp of higher megapixel cameras cannot mitigate pricing pressure. Image processors should increase at a 3% CAGR over the forecast period, as OEMs increasingly utilize more advanced processors to keep up with rising megapixel density and to add new features such as image stabilization, on-camera editing, and digital zoom. Discrete MPUs/MCUs continue to find a home in higher-end cameras and camcorders, and should increase to 13% of revenue by 2015.

Digital Camera and Camcorder Semiconductor Competitors: The top digital camera image sensor supplier in 2009 was Sony with 20% share. Sharp, Toshiba and Aptina were next, with 11%, 10% and 10% share, respectively. Omnivision held 8%, while Samsung and Panasonic held 7% and 6% respectively. Other vendors include EV2 and Samsung.

Digital Cameras

Digital Camera Semiconductor Market Trends

•Merchant image processing solutions have gained significant ground vs. custom ASICs.

•A shift towards an ODM model to drive lower costs has further fueled this trend.

•The march toward multi-megapixel cameras continues.

•Camera makers are increasingly differentiating their products with advanced image processing features.

•Digital SLR is starting to take share in the professional market.

•CMOS image sensors are seeing strong adoption in digital SLRs as well as camcorders, but are being phased out of mainstream point-and-shoot digital cameras where CCD reigns.

•Digital cameras should see increased penetration of Bluetooth and wireless LAN.

- **Merchant image processing solutions have gained significant ground vs. custom ASICs.** TI, Zoran, and SunPlus have been the most successful with merchant solutions, and have made some impressive strides at top tier OEMs in addition to second string players. The trend toward using ODMs has accelerated these share shifts.
- **The march toward multi-megapixel cameras continues.** In 2010, the DSC market continued its move towards multi-megapixel, with 6+-megapixels going from two-thirds of units in 2007 to three-quarters in 2008. Over the next few years, mainstream cameras should begin to adopt 10+-megapixel sensors, with only the low end below that node. Digital SLR should also represent a growth area as it takes share from analog in the professional market.
- **OEMs are differentiating their products with advanced image processing.** Megapixels are still a key factor, but camera makers are also differentiating their products with features such as video recording, image stabilization, face recognition, blur-correction, and digital zoom. Advanced DSPs/ASSPs enable these functions.
- **CMOS image sensors are seeing strong adoption in digital SLRs as well as camcorders.** CMOS image sensors dominate the camera phone market but have made little progress breaking into mainstream digital cameras, where CCDs reign. CMOS has done well in digital SLRs, and is starting to gain share in digital camcorders.
- **Cameras should see increased penetration of wireless connectivity.** Cameras with Bluetooth or WLAN are already on the market and will grow over time.

Portable Media Players

The MP3 format has dramatically changed the music industry, causing headaches for content owners while being a boon for consumer electronics providers. With NAND flash prices continuing to fall and with consumer HDDs readily available, MP3 player sales have taken off. On the content side, business models continue to evolve to support legal downloads of music.

OEMs and content owners are already addressing the next frontier: video. Portable media players support a multitude of formats, and the content ecosystem for video is following closely behind the music industry.

MP3 technology has dramatically changed the entertainment industry and has caused innumerable headaches for content owners. Content providers have struggled to maintain control of content distribution, as progress in DRM (digital rights management) technology has been relatively inconsistent, difficult to enforce, and naturally has no consumer pull. Business models continue to evolve to support the legal download of music over the Internet, with some success.

Though it presents a challenge for content owners, MP3 technology has actually been a boon for consumer electronics providers, as MP3 moved from software run on PCs to stand-alone hardware in the form of digital audio/media players. Though these players were originally limited by the high price of memory used for content storage, falling prices for NAND flash and availability of high capacity consumer drives have enabled the market to take off.

OEMs and content owners are already addressing the next frontier: video. MP3 players are evolving into full portable media players (PMPs) that include photo and video functionality. Market-leader Apple first introduced this to the public in its high end offerings, but has now migrated it to its mainstream players; Apple’s competitors are following as well. The content ecosystem—both legal and illegal—for video is following closely behind that of the music industry. It is still unclear how successful content owners will be in monetizing consumption of video relative to the music industry, but they are clearly trying to learn from the mistakes of their music counterparts in approaching this trend.

Portable Media Players

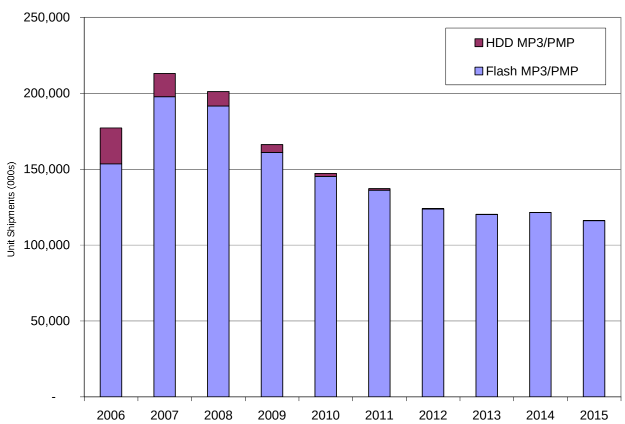
PMP Unit Forecast

•After several huge growth years, the portable media player market has matured; we expect a declining 5% CAGR through 2015, with shipments peaking in 2007.

•Total market shipments should decline from 147 million units in 2010 to 116 million units in 2015.

•HDD-based players will increasingly serve only the niche market as capacity points of flash-based players increase.

•We forecast that nearly all players will be flash-based in 2015.



Source: Dataquest, Oppenheimer & Co.

PMP Suppliers

Apple
SanDisk
Samsung
Creative
Sony

Source: IDC, Oppenheimer & Co.

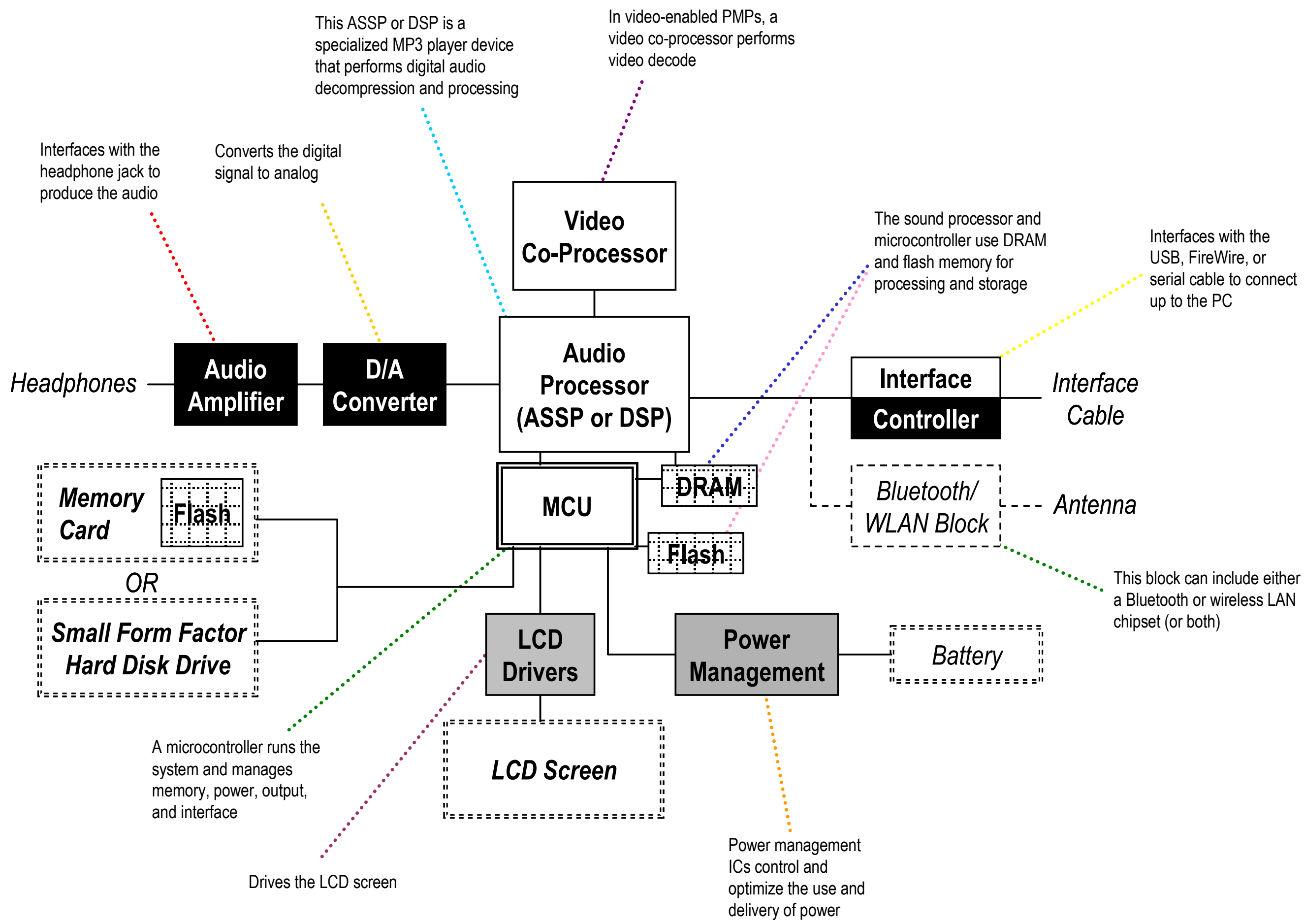
Portable Media Player Unit Forecast: The portable media player market has experienced three consecutive years of unit declines since 2007, with units falling by 6%/17%/11% for 2008/2009/2010, respectively. However, this followed three years of 20%-plus growth, with 2007 growing 20%, 2006 growing 31% and 2005 growing more than 230%. Though the high-capacity HDD-based players get much of the attention, flash-based players have represented more than 90% of unit shipments and an even greater percentage of the growth. These players meet lower price points, and therefore sell well in the US and Europe but absolutely dominate emerging markets.

Looking ahead, the market has matured and is likely to decline modestly from here. We forecast a negative 5% CAGR through 2015, when shipments will drop to 116 million units; units likely peaked in 2007, at 213 million units. Note that one important driver of the weak CAGR is cannibalization of demand by smartphones and tablets.

In terms of player type, we see HDD-players declining rapidly as capacity points of flash-based players increase as a percentage of the total market, serving the needs of all but the most demanding consumers. We believe HDD players will be less than 1% of total in 2015.

Portable Media Player Suppliers: Flash and HDD-based MP3 players are two distinct products, but most of the top volume suppliers participate in both segments. The largest supplier is Apple, with the top position in both flash and HDD based players. Other major vendors include SanDisk, Samsung, Creative, Sony and Microsoft. We note that the majority of the market (50%-plus) is derived from hundreds of marginal flash player suppliers, mostly in emerging markets.

Portable Media Players



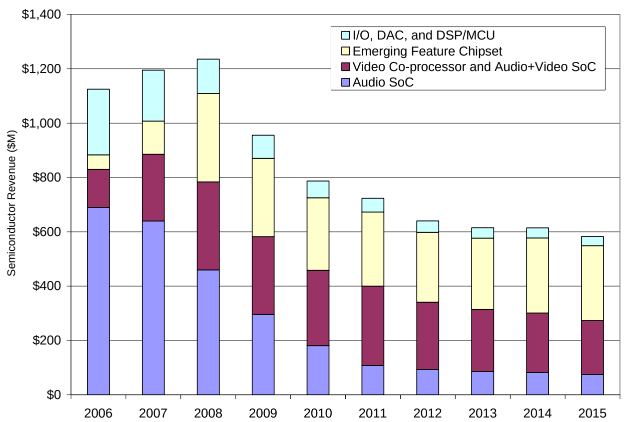
Source: IDC, Oppenheimer & Co.

- **Audio Decoder**: This DSP or ASSP decompresses MP3 files. Increasingly, MP3 SoCs are built with a sound processor DSP with microcontroller, analog audio, and power management functions integrated around it.
- **Video Co-processor** (only used in video-enabled PMPs): In video-enabled PMPs, a specialized co-processor performs video decode. Audio and video decode are starting to be integrated into a single SoC.
- **Audio Digital-to-Analog Converter (DAC) and Audio Amplifier**: The DAC converts digital output from the sound processor to analog audio, while the amplifier drives the sound over the headphone wire. In practice, either a single analog ASSP performs these functions or else they are integrated into the sound processor SoC.
- **Microcontroller:** A microcontroller runs the system and manages memory, power, output and interface. Discrete MCUs are used only at the high-end; most mainstream players integrate them into the audio processor. Note that clickwheel-enabled players will often have a separate controller just for this function.
- **DRAM/Flash**: The DSP and microcontroller use DRAM and flash memory.
- **Power Management**: Power management ICs control and optimize the use and delivery of power in the MP3 player and manage the battery.
- **Interface Controller**: This IC enables the interface for PC connectivity, usually over USB or Firewire.

Portable Media Players

PMP Semiconductor Forecast

•We expect PMP ICs (excluding flash) to decline through 2015, at $583 million, with a peak in 2008 at $1.2 billion.
•Intense price pressure in the audio SoC market should continue to be a factor, and the quick integration of audio and video processors will further weigh on SoC market revenue.
•Emerging feature chipsets represent the lone growth opportunity; these include touchscreen, FM, Bluetooth, Wi-Fi, satellite radio, camera, and mobile TV.



Source: IDC, Dataquest, Oppenheimer & Co.

PMP Semiconductor Competitors

Samsung
Toshiba
Hynix
Texas Instruments
NXP
STMicro
Micron
Freescale

Source: IDC, Oppenheimer & Co.

Portable Media Player Semiconductor Forecast: We expect portable media player semiconductors to decline steadily over the next five years, dropping to roughly $583 million by 2015. The market likely peaked in 2008 due to an expected unit decline, pricing pressure, and integration—principally of discrete audio and video processors into a single IC. Note that the rising penetration of video capability should mitigate this somewhat, as even integrated ICs carry higher ASPs than standalone audio processors.

By device, we expect video co-processors and integrated audio/video ICs to decline at a 6% CAGR, while audio-only SoCs should see a decline (a -16% CAGR) as they give way to these integrated processors. Audio-only should continue to see demand at the low end. Emerging feature chipsets have ramped from a low base in 2006 to nearly $267 million in 2010. We expect the market for emerging feature chipsets to grow slightly and represent 47% of total market revenue in 2015; these include touchscreen controllers, FM radio, Bluetooth, wireless LAN, UWB, satellite radio, image sensors, mobile TV, and DVR capability.

Portable Media Player Semiconductor Competitors: The top supplier of PMP silicon in 2010 was Samsung. Samsung holds a prominent position at Apple. Other PMP silicon providers include Toshiba, Hynix, Texas Instruments, NXP, STMicro, Micron and Freescale.

Portable Media Players

PMP Semiconductor Market Trends

•Video has arrived; HDD-based players were the first to support video in volume but flash-players now support video as well.

•Video co-processors are quickly giving way to integrated audio/video SoCs.

•The low end market is consolidating around ASSP vendors that can offer low cost and integration.

•Discrete codecs, MCUs, and power management chips are increasingly being integrated into the audio/video SoC.

•Support for digital rights management schemes are critical in winning future audio decode designs.

•OEMs are differentiating their products with new features:

- •Touchscreens
- •Bluetooth and wireless LAN
- •FM, satellite radio
- •Mobile TV, DVR
- •Camera, video capture

•Multimedia handsets threaten to cannibalize the PMP market.

- **Video capability has arrived and is growing.** Most HDD-based players offer video support, and new flash-based players do as well. At the outset, separate processors were used for audio and video decode; but the market is quickly moving to integrated processors that support both.
- **The low end is consolidating around ASSP vendors that can offer low cost and integration.** OEMs have moved away from more costly DSP+analog solutions and have flocked to dedicated MP3 ASSPs widely available from a multitude of competitors. Note that the SoC trend is also eroding the opportunities for discrete audio codecs and power management ICs, as most new SoCs integrate these features.
- **Support for digital rights management schemes is critical in winning future designs.** Though Apple seems to be sticking with its AAC format for DRM, most other players are adopting DRM schemes like Janus (DRM 10) to be compliant with the Microsoft-led Play4Sure initiative. IC vendors will have to offer hardware and software solutions to support DRM to remain competitive in the developed geographies.
- **OEMs are differentiating their products with new features.** These include touchscreens; Bluetooth and wireless LAN; FM and satellite radio; mobile TV and DVR; and camera/video capture capability.
- **Multimedia handsets and tablets threaten to cannibalize the PMP market.** Niche product lines like Sony-Ericsson's Walkman phones and Motorola's ROKR have been around for years, but this trend has started to accelerate now that Apple's iPhone and other Smartphones (e.g., Android phones) are shaking up the PMP market.

Video Game Consoles

The video game console market has consolidated to just three suppliers: Sony, Nintendo, and Microsoft.

Sony - Sony was the market leader in game consoles with the PS2, and launched its updated version, the PS3, in late 2006. The PS3 is the most advanced gaming system on the market, and includes a Blu-ray drive and advanced networking features. Sony is also No. 2 in handheld gaming market with its PSP.

Nintendo - Nintendo has regained much of its lost glory in the console market with the introduction of the Wii in 2006; a key distinguishing feature is its motion sensitive controller. Nintendo also leads the handheld segment with its DS/DSi and Game Boy product lines.

Microsoft - Microsoft entered the gaming market in 2001 with the Xbox, and was able to cut time-to-market using standard PC components. Xbox 360 launched in 2005; the new platform employs a more custom design. Xbox and Xbox 360 primarily target adult (18-34) gamers. Microsoft introduced the Kinect, a motion control system, in November 2010.

Source: Microsoft, Sony, Nintendo, Oppenheimer & Co. Inc.

The video game market has come into its own in the past few years, with console and handheld sales in excess of 100 million units in 2008 and software revenues exceeding movie industry revenue. The market has consolidated to three players: Sony—which derives a huge chunk of its corporate profits from gaming; Nintendo—the pure-play that helped develop the market in the 1980s; and Microsoft—attempting to leverage its software capabilities in a new market.

Sony was the market leader in the prior generation of consoles with the PlayStation 2 which followed the wildly popular PlayStation and dominated all major channels. The PS2 was a highly specialized device with an elegant design; nearly all components are designed in-house by Sony. The PS3, launched in late 2006, includes technology from IBM and NVIDIA and a Blu-ray drive, Bluetooth, wireless LAN, and Ethernet connectivity. On the handheld side, Sony entered the market late in 2004 with the PSP, a high-end device that also plays movies.

Nintendo lost much of its early glory during the 1990s as Sega and then Sony emerged as stiff competitors (Sega is now gone). In the most recent generation of consoles, Nintendo was relegated to serving the Japanese market along with younger gamers with the GameCube. This has changed as Nintendo launched its wildly popular Wii console in late 2006. The Wii is distinguished by its motion sensitive wireless controller and the system's affordability. In handhelds, Nintendo is by far the market leader with its GameBoy Advance and DS/DSi platforms. The company launched its latest handheld device, the 3DS, in March 2011.

Microsoft entered the gaming market in 2001 with the Xbox, and followed with the Xbox 360 in late 2005. Xbox 360 was a year ahead of competitors, but is now challenged by the Wii and PS3.

Video Game Consoles

Sony PlayStation 2

With an installed base of over 150 million units, Sony's PS2 is the best-selling game console ever. Sony designed all components in-house. Software support is top-notch with a number of exclusive franchises.

Sony PlayStation 3

Sony introduced the PS3 in late 2006. The core of the console is the "Cell" processor jointly designed with IBM and Toshiba, with graphics by NVIDIA. PS3 includes a Blu-ray and HDD drive, plus memory slots and networking features like USB, wireless LAN, Bluetooth, and GigE. The PS3 has shipped more than 48 million units to date.

Nintendo Wii

Launched in late 2006, the Wii uses a PowerPC CPU from IBM with graphics from ATI/AMD. Wii's chief differentiator is its motion sensing controller. Bluetooth and Wi-Fi are included. The Wii has currently shipped over 85 million units to date.

Microsoft Xbox 360

Xbox 360 launched in late 2005 and has an installed base in excess of 50 million. It uses a custom IBM CPU and graphics from ATI/AMD. USB ports and memory card slots are included; an HDD is optional and wireless LAN is external via a dongle. Microsoft launched the Kinect, a motion control system, for the Xbox 360 in November 2010. The company has already shipped more than 10 million units since its launch.

Video Game Handhelds

Nintendo Gameboy Advance

Nintendo's Gameboy has dominated the handheld segment for years; and its current Gameboy Advance platform has shipped more than 81 million units to date.

Nintendo DS/DSi

Nintendo's newer handheld includes a clamshell design and two screens, one of which has a unique pen interface. Wi-Fi is also included. The DS has shipped well over 145 million units to date. Nintendo released the DSi in late 2008 and later the DS Lite and DSi XL. The 3DS was released in March 2011.

Sony PSP

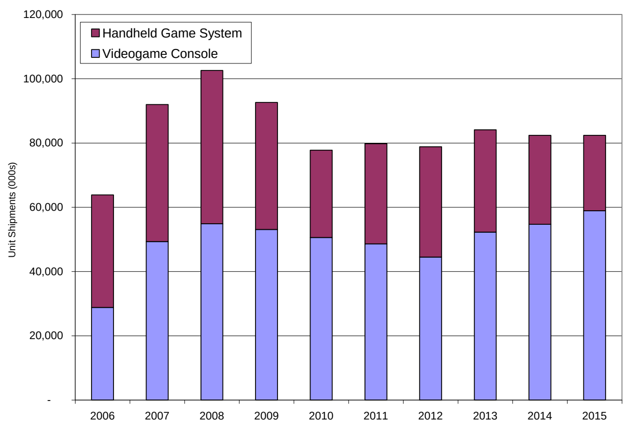
Sony's PSP has gained some significant share and has shipped more than 52 million units to date. PSP plays premium games as well as movies, and includes embedded WLAN.

Source: Oppenheimer & Co., Nintendo, Microsoft, and Sony.

Video Game Consoles

Video Game Hardware Unit Forecast

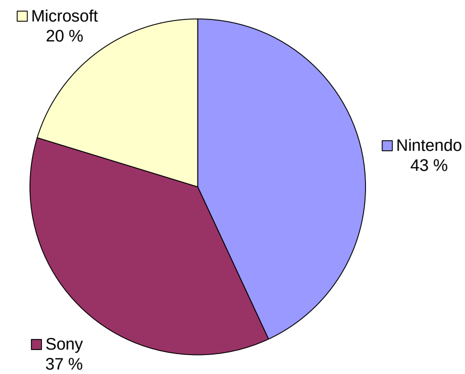
•The video game market moves in its own cycle, driven by new product introductions.
•A new handheld cycle began in 2004 with the PSP and DS; shipments should start to decline with increased competition from smartphones.
•A new console cycle went under way in 2007; Xbox 360 was early but was joined by PS3 and Wii; units likely peaked in 2008.
•Overall, we expect the market to grow from 78 million units in 2010 to 82 million in 2015, a 1% CAGR.



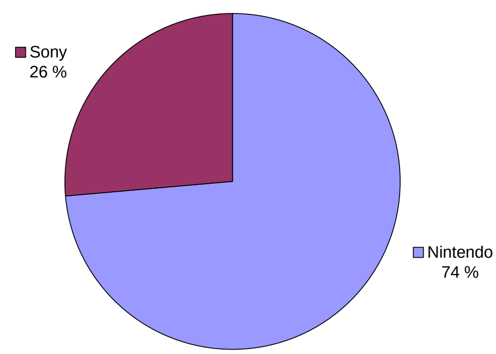
Source: Gartner, Oppenheimer & Co.

Video Game Hardware Suppliers

Console



Handheld



Source: IDC, Oppenheimer & Co.

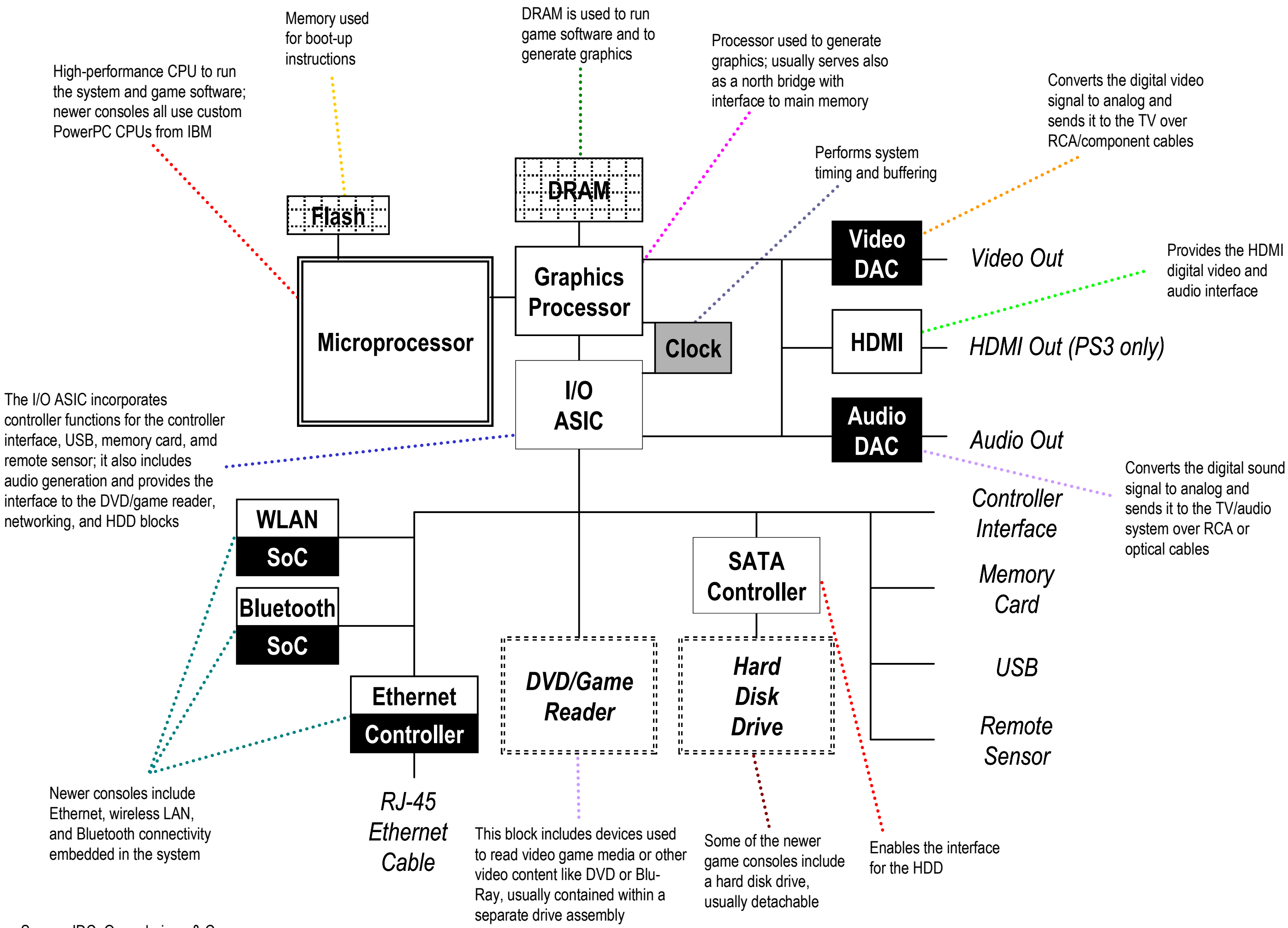
Video Game Hardware Unit Forecast: The video game market moves in its own cycle driven by new console introductions. Shipments declined in 2003 and 2004 as the last cycle wound down and the market waited for new systems. Shipments rebounded sharply in 2005 (up 28% year-over-year) driven by the start of a new handheld cycle (PSP and DS) and a PS2 product refresh (slimmer version), and shipments grew again in 2006. The new console cycle kicked off in 2005 with the Xbox 360, and got under way more significantly in 2006-2007 with the PS3 and Wii. During 2008, shipments grew 17%, while 2007 experienced 44% growth. Both 2009 and 2010 experienced declines (10% and 16%, respectively). The video game market, particularly handhelds, is coming under increased pressure from smartphone and tablet competition.

Overall, we expect the market to increase slightly from 78 million units in 2010 to 82 million in 2015. The mix between consoles/handhelds should fluctuate from 45% to 55% based on timing of new hardware introductions. The near-term peak should have come in 2008 at 103 million units—the heart of the current console cycle. We expect both new consoles and new handhelds will be ramping in 2012-2013.

Video Game Hardware Suppliers: Market share in video game systems bounces around from year to year based on the timing of system launches and ramps. Nintendo was the market leader in consoles in 2010 with a 43% unit share, up from only 18% three years ago in 2006 as the Wii has gained significant traction in the marketplace against Sony's PS3 and Microsoft's Xbox 360. Sony was No. 2 with a 37% share; up slightly from 2008 but up significantly vs. prior years due to the ramp of the PS3, which launched in late 2006. Microsoft was No. 3 with a 20% share; down from prior years as Sony's and Nintendo continue to take share away from Microsoft.

On the handheld side, Nintendo held a 75% share in 2010. Sony was second with a 25% share.

Video Game Consoles



Source: IDC, Oppenheimer & Co.

Note: The chart above displays a block diagram for a typical game console. Handhelds are more focused on cost and power consumption rather than performance, and typically use a smaller set of more highly-integrated ICs operating under a custom architecture. They tend to lack the add-on features like DVD and HDD support and most networking features (aside from wireless LAN), though they will include additional ICs for the LCD display and battery management.

Today's video game consoles have evolved into full-featured multimedia computing platforms, essentially specialized PCs optimized to run high-quality video and graphics. They have microprocessors, memory, graphics and I/O processors, hard disk drives, DVD drives and memory slots for storage, and networking functionality. One major difference between a game console and a PC, however, is that most of these components are custom-designed for the platform and do not leverage open standards given the inflexibility inherent in game console design.

Processing and Memory

- **Microprocessor**: The central processing unit in a video game console is a high-performance single- or multi-core microprocessor, which performs system control and runs the game software. The three new game consoles each use a customized CPU designed by IBM: the Xbox 360 uses the triple-core 3.2 GHz G5 processor, the Wii uses the IBM Broadway chip, and the PS3 uses the Cell processor designed jointly by IBM, Sony, and Toshiba (the first version of the PS3 included a second processor, Sony's Emotion Engine, to run PS2 games). On the handheld side, Nintendo uses Sharp for the Gameboy Advance and DS while Sony uses an internal design for the PSP.

- **DRAM**: Game consoles use DRAM to store program data in use by the console and for graphics processing. Sony, Nintendo, and Microsoft each use a specialized form of DRAM (GDDR3, XDR, and eDRAM) for their next-gen consoles, and the quantity used varies by platform. Video game handhelds tend to use a relatively small quantity of DRAM.
- **Flash**: Flash memory acts as BIOS, storing and loading boot instructions for the microprocessor.

Video, Sound and I/O

- **Graphic Processor (GPU)**: The graphics processor is a specialized digital processor optimized for producing 3D graphics images. The GPU in a game console will usually include north bridge functions, interfacing between the CPU and main memory. Nintendo uses the Hollywood custom GPU ASIC designed by ATI/AMD, the Xbox 360 uses the "Xenos" custom GPU, also from ATI/AMD, and Sony uses the NVIDIA RSX ASIC for the PS3. On the handheld side, NEC supplies the graphics IC for the Nintendo DS, while Sony's design is internal.
- **I/O ASIC**: Game consoles have an I/O ASIC that acts as a south bridge, interfacing between the processor and audio, DVD/game reader, networking ICs and hard disk drive subsystems. Like in a PC, this I/O ASIC usually includes audio generation, though this can be done on an external DSP as well. The I/O ASIC also enables peripheral systems such as game controllers, memory cards, USB interface, and remote RF.
- **SATA Controller**: The interface to the hard disk drive can be enabled by a discrete SATA controller (as in the PS3) or by controller logic integrated into the I/O ASIC (as in the Xbox 360).
- **Clock**: A clock chip, similar to one used in a PC, performs system timing functions. Microsoft and Sony use timing ICs from IDT and Cypress, Nintendo uses an integrated clock.
- **Video D/A Converter (DAC)**: A video digital-to-analog converter converts the video signal to analog format to send it to the TV over coaxial or RCA cables.
- **Audio D/A Converter (DAC)**: An audio digital-to-analog converter converts 16-bit stereo samples into left and right alternating-current audio signals and sends them to the TV over coaxial or RCA cables.
- **HDMI Interface IC:** The high-end version of the PS3 includes an HDMI (High Definition Multimedia Interface) interface, which is an all-digital, high-definition standard that supports both video and audio with digital rights management capabilities. A Silicon Image HDMI 1.3 interface IC drives this interface.
- **Microcontrollers, Analog ICs, Power Management** (not shown in diagram): Individual peripherals each use a variety of microcontrollers and analog SLICs to control functions such as the LCD readout, display, game controller and memory card interface. The consoles also include significant power management content to handle power flow and battery management in handhelds.

Networking

- **Ethernet Controller**: The Xbox 360 and PS3 include Ethernet connectivity. The Xbox 360's Ethernet controller is embedded in the I/O ASIC, while the PS3's is embedded in a specialized networking ASIC.
- **Wireless LAN SoC:** The PS3, PSP, Wii, and Nintendo DS include embedded wireless LAN functionality supplied by Marvell, Broadcom, Mitsumi, and RF Micro Devices. The Xbox 360 supports an external adapter to enable wireless LAN functionality, as did the older version of the Nintendo DS.
- **Bluetooth SoC:** The PS3 and Wii include single-chip Bluetooth solutions.

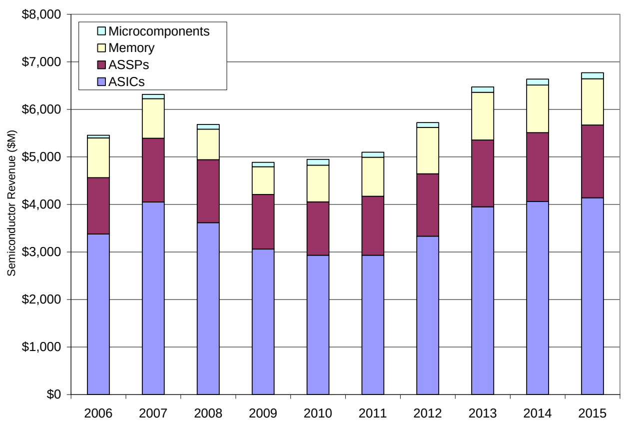
Drives

- **DVD/Game Reader Block**: This block contains all the components usually found in a PC optical drive. These ICs are discussed in the section on optical drives earlier in this report. The Xbox 360's drive can play DVD videos, and an attachment is available for HD-DVD. The PS3's drive can play DVD and Blu-ray video.
- **Hard Drive ICs**: The Xbox 360 and PS3 each support detachable HDDs (the original Xbox had an embedded HDD). The ICs used in these drives are discussed in the section on hard disk drives earlier in this report.

Video Game Consoles

Video Game Semiconductor Forecast

•We expect video game semiconductors to grow at a 6% CAGR, rising from $4.9 billion in 2010 to $7.7 billion in 2015.
•Semiconductor content should outpace unit shipments as hardware makers ramp the processing capabilities of their consoles and add connectivity and multimedia features.
•Communications ICs are growing fastest, but will be followed closely by core system ICs which drive gaming and graphics performance.



Source: Gartner, Oppenheimer & Co.

Video Game Semiconductor Competitors

NEC/Renesas
IBM
Sony
Sharp
Samsung
Nvidia
AMD
Marvell
Atheros
Broadcom

Microprocessors	***Graphics***
IBM (Xbox 360)	ATI/AMD (Xbox 360)
IBM (Nintendo Wii)	ATI/AMD & NEC (Wii)
IBM/Sony/Toshiba (PS3)	NVIDIA (PS3)
Sharp (Game Boy, DS)	Sony (PS2)
Sony/Toshiba (PS2, PSP)	NEC (Nintendo DS)

Logic, I/O, Analog, Communications

Sony	Broadcom	Texas Instruments
SiS	CSR	STMicroelectronics
NEC/Renesas	IDT	Analog Devices
Marvell	Cypress	Silicon Image

Source: IDC, Oppenheimer & Co.

Video Game Semiconductor Forecast: The video game semiconductor market should outgrow unit shipments over the next few years. Though OEMs demand steep price curves for components on any given console, newer consoles tend to have much higher content and boost the semiconductor market as they launch. The increased content is driven not only from increased computing and graphics performance, but also from added connectivity and multimedia content. Vendors are trying to position their consoles at the center of the digital home, and are loading them with features to interface with PCs, consumer devices, storage devices, and the Internet. Overall, we are forecasting the market to increase at a 6% CAGR, growing from $4.9 billion in 2010 to $7.7 billion in 2015.

Video Game Semiconductor Competitors: The top supplier of video game ICs in 2009 was NEC. NEC has benefited from the market share gains of Nintendo's Wii as NEC supplies ASICs for Nintendo. IBM followed and supplies the processors for all three game consoles. Sony was next, driven from internal ASICs for the PS2, PS3, and PSP. Sharp followed due to its ASIC relationship with Nintendo. Rounding out the top vendors was NVIDIA, which supplies graphics technology for the PS3 (and used to supply the graphics and I/O chipset for the original Xbox).

Other major component suppliers include I/O specialist SiS (Xbox 360); networking IC vendors Marvell (PSP, PS3, Xbox 360), Broadcom (Wii), CSR (PS3), and RF Micro Devices (Nintendo DS); HDMI supplier Silicon Image (PS3), clock vendors IDT and Cypress; and several analog ASSP companies including Texas Instruments, STMicroelectronics, and Analog Devices. Memory and standard analog, logic, and discrete ICs are excluded from this data.

Video Game Semiconductor Summary By Hardware OEM

The video game semiconductor market is specific to each platform. Once a vendor wins a socket, it is unlikely to change through the life of the console. We provide a list of the component suppliers for the three hardware suppliers.

Microsoft

- While the Xbox was designed similar to a low-end PC, using standard PC components with some ASIC content, the Xbox 360 employs a more custom (and more powerful) design.
- The Xbox 360 uses an IBM PowerPC-based CPU with three symmetrical cores running at 3.2 GHz each. It includes 1 MB of L2 Cache. IBM and Chartered fab this IC. The Xbox used a 733 MHz Pentium III microprocessor.
- The Xbox 360's GPU is ATI/AMD's "Xenos" processor, a custom device running at 500 MHz with a unified shader architecture with 48 pixel shader pipelines and 10 MB of embedded DRAM. TSMC fabs this GPU, while ATI/AMD receives a royalty. The Xbox GPU was NVIDIA's f-Force, which is a custom version of the nForce IGP north bridge with integrated graphics.
- The Xbox 360 uses 512 MB of GDDR3. The Xbox used 128 MB of DDR at launch, boosted to 256 MB mid-cycle.
- The Xbox 360's I/O ASIC is a custom south bridge IC from SiS in Taiwan. The I/O ASIC supports 10/100 Ethernet, three USB 2.0 ports, and two memory slots. The Xbox used NVIDIA's MCPX, a custom version of the nForce south bridge.
- The Xbox 360 uses timing devices provided by Integrated Device Technology and Cypress, as did the Xbox.
- The Xbox 360 supports a detachable 20 GB or 120 GB hard disk drive. The Xbox included a hard disk drive. The Xbox 360 has a DVD drive, as did the Xbox.
- A wireless LAN dongle is sold separately for the Xbox 360 and uses a Marvell chipset.

Sony

- While Sony designed nearly all IC content in-house for the PS2 and PSP, it brought IBM and NVIDIA in on the PS3.
- The PS3 uses the much hyped "Cell" processor, designed by IBM and Sony and to be fabbed by Toshiba and Sony. The PS2 CPU was the "Emotion Engine" ASIC, designed by Sony and fabbed by Sony and Toshiba—a version of this device was also used in the PS3 at launch to support PS2 games. The PSP CPU is also a Sony design.
- The PS3 uses an NVIDIA-designed GPU (fabbed by Sony, NVIDIA receives a royalty). The PS2 GPU ASIC is internally designed by Sony. The PSP microprocessor is also a Sony design.
- The PS3 uses 256 MB of Rambus XDR DRAM and 256 MB of GDDR3. The PS2 used a pair of 128 Mb Rambus DRAM chips.
- The PS3 I/O controller is custom designed by Sony with Toshiba. A separate SATA controller is supplied by Marvell. The PS2 I/O controller was designed and fabbed by LSI.
- The PS3 includes a Gigabit Ethernet controller supplied by Marvell and Bluetooth SoC supplied by CSR. A wireless LAN chipset supplied by Marvell is included in the high-end version of the PS3 and in the PSP.
- The PS3 uses timing devices from IDT. The PS2 and PSP use timing devices from Cypress and IDT.
- The PS3 includes a Blu-ray DVD drive. The PS2 includes a DVD drive.
- The PS3 supports a detachable 20 or 60 GB HDD supplied by Seagate.

Nintendo

- The Wii microprocessor is IBM's PowerPC-based "Broadway" CPU. The Gamecube microprocessor was IBM's PowerPC 750 microprocessor. The GameBoy Advance and DS use a custom Sharp microprocessor.
- The Wii uses ATI/AMD's "Hollywood" GPU (ATI/AMD receives a royalty). The Gamecube GPU was also from ATI. The Nintendo DS also includes a graphics ASIC from NEC and a wireless LAN chip from RF Micro Devices. Nintendo's DSi includes a wireless LAN chip from Atheros.
- The Wii uses 512 MB of GDDR3 from Qimonda, 4-Gig NAND flash from Samsung, 16 MB of SDRAM from Elpida, and 24 MB of 1T-SRAM from MoSys. Gamecube used 24 MB of SRAM and 16 MB of DRAM.
- The Wii uses a specialized optical drive that plays only Nintendo game media.
- The Wii includes wireless LAN and Bluetooth, both using a Broadcom chipset.
- Wii's motion sensitive controller uses accelerometer and motion control ICs from Analog Devices and STMicro.

Video Game Consoles

Video Game Console IC Market Trends

- Next generation consoles have some of the most advanced CPUs in the industry, powered with technology from IBM.
- GPU vendors were able to leverage their positions in PC graphics to penetrate consoles.
- ASIC suppliers have entrenched positions and remain difficult to unseat; new entrants have had some success in networking.
    - IBM provides custom CPUs for each console; NVIDIA and AMD provide custom GPUs.
    - Sony, Toshiba, and NEC all remain key ASIC partners.
    - Success by merchant vendors centered around networking silicon, now in all major platforms.
- Connectivity a major factor in new consoles.
    - Ethernet LAN for Internet access and PC connectivity.
    - Wireless LAN either embedded or external.
    - Bluetooth for peripheral interface and wireless controllers.
- Interaction with PC and digital media a key objective but not yet mature.
- New consoles include HDD and flash card storage.

- **Next generation consoles have some of the most advanced CPUs in the industry, powered with "bleeding-edge" technology from IBM.** Sony spent years designing its multi-core "Cell" processor with IBM and Toshiba, and plans to cascade the design for other digital media products. IBM's CPU for the Xbox 360 uses three cores at 3.2 GHz.
- **GPU vendors were able to leverage their positions in PC graphics to penetrate consoles.** ATI/AMD and NVIDIA each derive significant revenue from game consoles. NVIDIA supplied a graphics and I/O chipset for the Xbox and earns licensing fees for the RSX processor used in the PS3; ATI/AMD earns licensing fees from the Xbox 360 as well as the Nintendo Wii and Gamecube.
- **ASIC suppliers have entrenched positions and likely will be difficult to unseat.** Video game consoles are perfectly suited to the ASIC model: each OEM designs a single platform, which must show a high level of performance at an acceptable cost level and requires little to no upgrade or scalability support. For years, Sony has relied on its internal ASIC group as well as partners Toshiba and LSI for the core of its system, only bringing in IBM, NVIDIA and Marvell with the PS3—and even in that case, the devices are heavily custom to Sony. Nintendo has relied on Sharp, NEC, and IBM. Microsoft deviated from the ASIC model to get to market quicker with the Xbox, but followed Sony and Nintendo with a more custom design for the Xbox 360. We expect ASICs to dominate this large market going forward.
- **Success by merchant vendors centered on networking silicon, now in all major platforms.** Probably the only area where console makers are deviating from the ASIC model is in their sourcing of networking silicon, not surprising since these ICs are based around open industry standards and thus support multiple suppliers of low-cost chipsets. Marvell is supplying Gigabit Ethernet, wireless LAN, and SATA components to Sony and a wireless LAN chipset to Microsoft for the Xbox 360 dongle;

Broadcom is supplying wireless LAN and Bluetooth to Nintendo for the Wii; CSR is supplying Bluetooth to Sony for the PS3; and Atheros is supplying wireless LAN to Nintendo for the DSi.

- **Connectivity a major factor in new consoles.** As discussed above, all the new consoles include significant networking functionality. The PS3 supports Gigabit Ethernet, wireless LAN, and Bluetooth; the Xbox 360 supports Ethernet and wireless LAN (through a dongle); and the Wii supports Bluetooth and wireless LAN. All consoles also include multiple USB ports and memory cards.
- **Interaction with PC and digital media a key objective but not yet mature.** Sony and Microsoft each view their consoles as the center of the digital home, and are including the ability to interact with PCs, external storage, and digital media devices. They can play music and videos and display pictures. The PS3 can even act as an IPTV set-top box. The applications are not yet mature, but will clearly be a focus on the software side following the establishment of an installed base.
- **New consoles include HDD and flash card storage.** Hard disk drives and memory cards are used for storage of game data (stats, saved games, etc.) as well as the potential for downloaded add-ins. User content can also be stored on these drives and played on the console. Note that the Xbox was the first to include an HDD, the Xbox 360 and PS3 support detachable drives. All new consoles support memory cards as mentioned above.

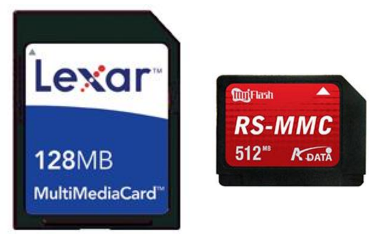
Flash Memory Cards

Flash memory cards are sold as accessories to digital cameras, handheld devices, handsets, MP3 players, and other portable digital devices that require data storage.
A multitude of form factors exist, primarily due to the fragmentation of the consumer electronics market, with OEMs endorsing a variety of interface standards.

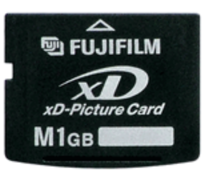
Secure Digital, MiniSD, MicroSD

Memory Stick Pro, Duo, & Micro/M2

MultiMediaCard & RS-MMC



xD Picture Card



CompactFlash

SmartMedia

Source: SanDisk, Lexar, Sony, Fujitsu, Oppenheimer & Co. Inc.

Flash memory cards are sold as accessories to digital cameras, handheld devices, handsets, MP3 players, and other portable digital devices that require data storage. A multitude of form factors exist, primarily because of the fragmentation of the consumer electronics market, with OEMs endorsing a variety of interface standards.

- **Secure Digital**: Contains up to four flash chips and an on-board controller. It is the leading form factor in the digital camera market. MiniSD and SDmicro are the new smaller versions.
- **Memory Stick**: Promoted by Sony, Memory Stick contains flash and an onboard controller and has excellent security and copyright protection features. Memory Stick Duo is a smaller version, while Memory Stick Micro (also called M2) is the newest and smallest.
- **MultiMediaCard:** Contains flash and an on-board controller and can be used in devices that support SD. Strong OEM support and lack of royalties have driven adoption. RS-MMC and MMCmicro are reduced size versions.
- **CompactFlash**: Contains flash memory and an on-board controller IC, which does not allow the host system to directly access the flash memory. CompactFlash has been largely displaced by other form factors.
- **xD Picture Card**: Promoted by Fuji and Olympus, this small form factor is targeted at digital cameras.
- **SmartMedia**: SmartMedia cards contain NAND flash memory without a controller IC, making it a lower-cost option compared with CompactFlash. SmartMedia has seen limited adoption due to capacity limitations.

Flash Memory Cards

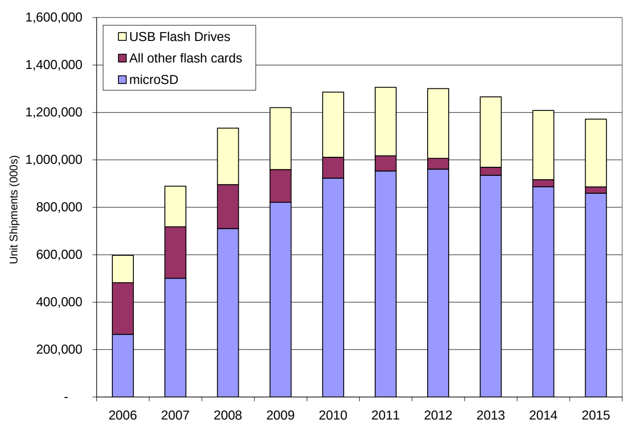
Flash Card Unit Forecast

•We expect flash cards to decline at a 2% CAGR, falling from 1.3 billion units in 2010 to 1.2 billion units in 2013.

•Flash cards should decline 3%, while USB flash drives should grow 1%.

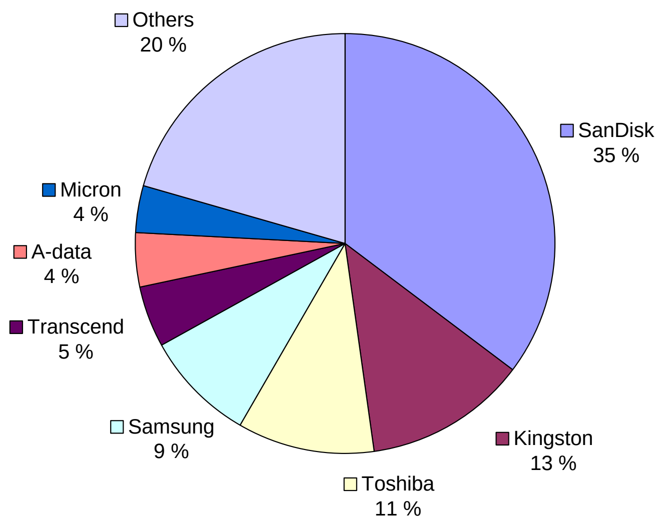
• Within flash cards, microSD should decline slightly and represent 74% of shipments in 2015; other card formats should decline steadily.

•Handsets have overtaken digital cameras as the No. 1 application driver for flash cards, and No. 1 in the next 5 years.



Source: Dataquest, Oppenheimer & Co.

Flash Card and Drive Suppliers



Flash Cards	***Flash Drives***
SanDisk	Kingston
Toshiba	SanDisk
Samsung	A-Data
Kingston	Transcend
Transcend	Micron
A-data	Toshiba

Source: Dataquest, Oppenheimer & Co.

Flash Card and USB Flash Drive Unit Forecast: Shipments of flash cards and drives totaled 1.3 billion units in 2010, up 5% year-over-year following 8% growth in 2009 and 28% growth in 2008. The market still had a strong tie to digital cameras, though handsets and USB flash drives for PCs were significant drivers as well.

In terms of card type, in 2010 79% of units were flash cards, with the remaining 21% USB flash drives. Among the many flash card types, 91% were microSD cards, 6% were Memory Stick and Memory Stick Duo/Micro, less than 1% were MMC and RS-MMC, and 3% were other types (including CompactFlash, xD, and SmartMedia).

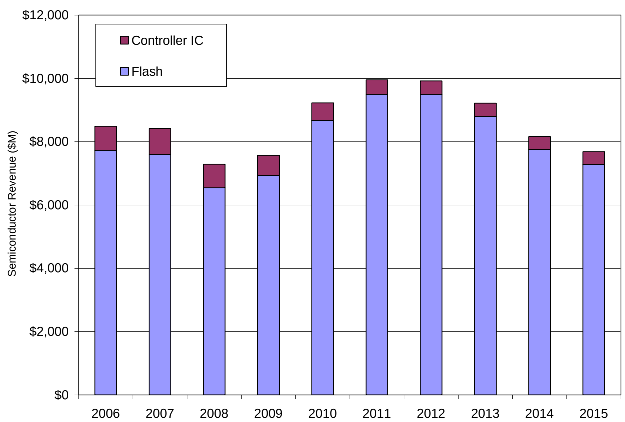
Looking ahead, we forecast a negative 2% CARG, with shipments dropping from 1.3 billion units in 2010 to 1.2 billion units in 2015. USB drives should slightly outperform flash cards (+1% CAGR vs. -3%). Within flash cards, microSD should decline at a 1% CAGR and represent 74% of total unit shipments by 2015.

Flash Card and USB Flash Drive Suppliers: The largest vendors of flash cards and USB drives are vertically integrated suppliers who produce their own flash, followed by fabless suppliers who focus on packaging and distribution. The largest supplier of flash cards and USB drives in 2010 was SanDisk, with a commanding 35% unit share. Kingston and Toshiba followed with 13% and 11% share, respectively. Note that all of the top three vendors supply a variety of card types as well as USB drives. Rounding out the top five were Samsung and Transcend with 9% and 5% share, respectively. Other major suppliers include A-data and Micron.

Flash Memory Cards

Flash Card Semiconductor Forecast

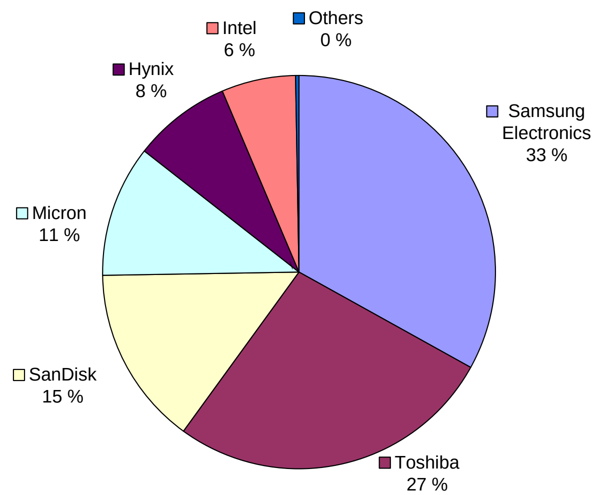
- •We expect flash card semiconductors to decline at a 4% CAGR, from $9.2 billion in 2010 to $7.7 billion in 2015.
- •Revenue will be heavily tied to the cyclical NAND flash market; controller/interface ICs will be more stable and unit driven.
- •Price/MB for NAND flash is rapidly declining as manufacturers attempt to drive volume and achieve scale.
- •Cards and drives should decline as a percentage of total NAND flash as embedded applications like smartphones and tablets ramp.



Source: WSTS, Dataquest, IDC, Oppenheimer & Co.

Flash Card Semiconductor Suppliers

NAND Flash



Source: Dataquest, Oppenheimer & Co.

Flash Card Semiconductor Forecast: Flash memory card and USB flash drive semiconductor revenue totaled $9.2 billion in 2010. The market included more than 90% of all NAND flash sold along with more than $550 million of revenue derived from specialized controller ICs. Total market revenue was down in 2008, as strong unit shipments and density increases were offset by steep price declines (ASP/MB).

Looking ahead, we expect the market to decline at a 4% CAGR to $7.7 billion in 2015. Revenue will be heavily tied to the cyclical NAND flash market and its influence on MB pricing, though flash card NAND should trail overall NAND revenues as embedded applications (in particular portable media players and handsets) ramp up as big consumers of NAND flash. We are forecasting a cyclical peak in 2011, when the market will be ~$10.0 billion.

Flash Card Semiconductor Competitors: The primary semiconductor component used in flash cards and drives is NAND flash, which currently accounts for approximately 94% of the semiconductor bill-of-materials. In 2010, Samsung was the No. 1 supplier of NAND for flash cards and drives, with a 33% share. Toshiba was second at 27%, followed by SanDisk at 15% and Micron at 1%. Other suppliers include Hynix and Intel.

Flash Memory Cards

Flash Memory Card Semiconductor Market Trends

•Handsets have overtaken digital cameras as the largest consumer of memory cards.

•Second and third generation “mini” and “micro” versions of the major form factors are rapidly replacing larger versions.

•Popularity of USB flash drives has prompted PC vendors to eliminate floppy disk drives.

•USB drives are being used as a NAND cache for PCs with Windows 7, though longer term NAND may get embedded.

•U3 adds code execution functionality to USB flash drives.

•SD and Memory Stick are gaining share, though there will still be a market for other card types.

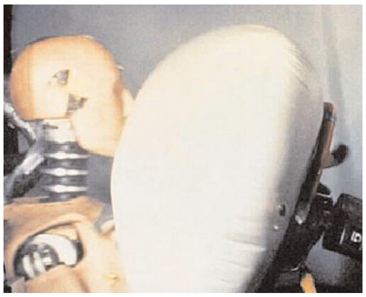
•NOR and DRAM suppliers have quickly penetrated the NAND market.

- **Digital cameras have given way to handsets as the largest consumer of memory cards.** New handsets now routinely bundle with an external memory slot, usually mini/micro-SD.
- **Second and third generation “mini” and “micro” versions of the major form factors are rapidly replacing larger versions.** This is especially important for handsets and small-form factor cameras.
- **USB flash drives are a mainstream accessory for PCs.** They have already prompted PC vendors to eliminate floppy disk drives, as USB drives are cheap and easy to use and offer far more storage than a floppy disk drive. They can also be used as a NAND cache for PCs with Windows 7, though longer term NAND may get embedded.
- **U3 adds code execution functionality to USB flash drives.** U3 technology allows USB flash drives to execute software directly on the drive. Hardware is now shipping and applications are being developed to leverage U3.
- **SD is gaining share, though there will still be a market for other card types.** Among the many flavors of memory cards, SD is gaining the most traction in consumer electronic and handsets. We expect them to benefit from almost all of the market growth. Still, there will be a market for other card types, though in some cases there will be a strong tie to just a handful of OEMs.
- **NOR and DRAM suppliers have quickly penetrated the NAND market.** Hynix, Micron, and Intel are now major players in the NAND market, joining Samsung, Toshiba, and SanDisk.

Automotive

Automotive Electronics Systems

Airbags



Anti-lock Brakes

Remote Entry

Stereo System

Climate Control

GPS/Navigation System

Engine Control

Dashboard Electronics

Source: Kenwood, Mercedes, Oppenheimer & Co. Inc.

The 100+ year old automobile industry appears on the surface to be the epitome of a mature market, with low single-digit unit growth each year tracking population. Inside the car, however, change is taking place at a sweeping pace. A key driver has been the increase in electronics content in the car, primarily for engine control, safety and comfort/entertainment. We estimate that, in the past five years alone, automobile electronics systems content increased from $1,262 per car in 2002 to $1,564 per car in 2010.

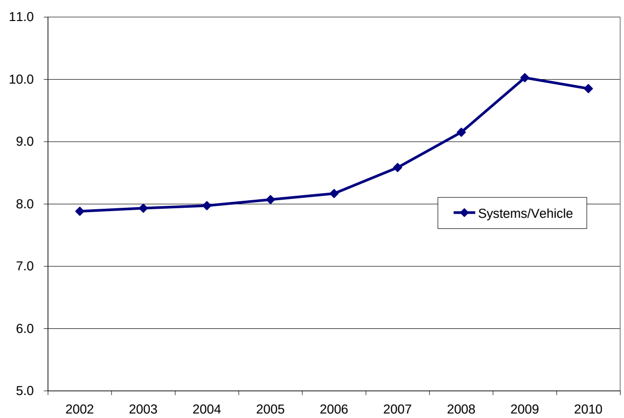
Key electronics systems included in modern automobiles include:

- Airbags (drive, passenger and side airbags)
- Airbag satellite crash sensors
- Antilock braking systems (ABS)
- Auto stereo (AM/FM radio, cassette player, CD player and changer, satellite radio)
- Climate control
- Dashboard instrument cluster
- Engine control
- Remote/keyless entry
- GPS/navigation system (fixed and portable)

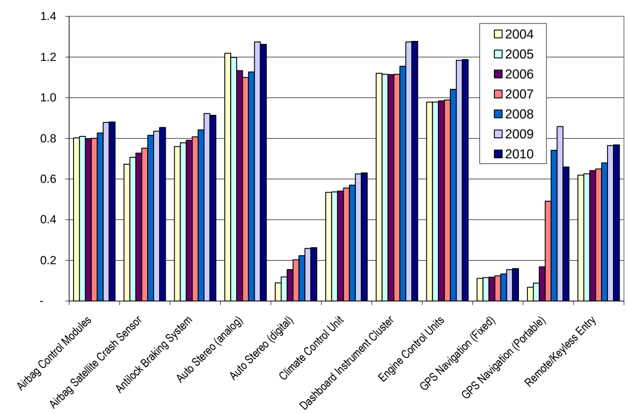
Automotive

The number of automotive systems in an average automobile is seeing a steady increase as safety and emission standards get tougher and as car and truck manufacturers look to add comfort and entertainment features to differentiate their model offerings. The average car included 9.9 discrete electrical systems in 2010, up from 7.9 in 2002.

Automotive Electrical Systems/Vehicle



Source: Dataquest, Oppenheimer & Co.



Source: Dataquest, Oppenheimer & Co.

As a mature market, automobile units grow at a low single-digit rate annually. Automotive electronic systems, however, are growing slightly faster than units. One factor has been increased safety and emission standards, which often require electrical systems to implement them. Another is consumer driven; automotive consumers now demand advanced comfort, convenience, and entertainment features in their new cars, and automobile manufacturers have responded with offerings to meet this demand.

Looking at the numbers, the average car included 7.9 discrete electrical systems in 2002. By 2010, this number had quickly climbed to 9.9, and is expected to be relatively steadily over the next few years.

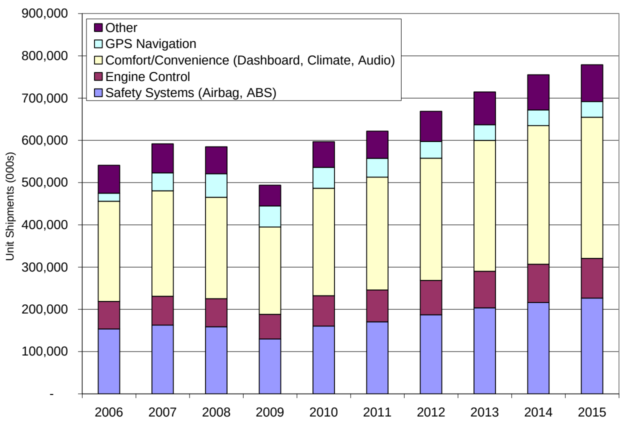
Automotive

Automotive Electronics Unit Forecast

•We expect automotive electronic systems to grow at an 5% CAGR, rising from 596 million systems in 2010 to 778 million in 2015.

•Comfort/convenience systems and safety systems should remain the largest categories.

•Navigation systems are declining at a 6% CAGR, as a falloff in PNDs more than offsets growth in fixed GPS systems.



Source: Dataquest, Oppenheimer & Co.

Automotive Electronics Suppliers

Americas

Delphi Automotive
Johnson Controls
Garmin
TRW
Visteon
Lear Corporation
Harman
Arvin Meritor
Eaton
Stoneridge
Key Safety Systems
Magellan

Europe

Robert Bosch
Continental
TomTom
Autoliv
Magneti Marelli
Hella
Valeo Electronics
Kostal
Marquardt
Haldex
Behr-Helia
Kiekert Group

Japan & Asia

Denso
Aisin
Mitsubishi Electric
Panasonic
Hitachi Automotive
Pioneer
JVC Kenwood
Calsonic Kansei
Alpine Electronics
Mitac
Fujitsu-Ten
Clarion
Takata
Hyundai Autonet
Alps Electric
Sanyo

Source: Dataquest, Oppenheimer & Co.

Automotive Electronics Unit Forecast: As the automobile market recovers from the sharp declines in 2008 and 2009, we expect the number of cars sold to outpace the number of systems as portable navigation devices experience sharp declines in the coming years. In total, we expect a 5% CAGR, with the number of systems rising from 597 million in 2010 to 779 million in 2015.

On a per car basis, this is equivalent to roughly 9.9 systems per car in 2010 falling to 8.9 systems per car in 2015. On a system-by-system basis, this will likely be driven by the decline in penetration of GPS portable devices, which are expected to drop from 0.7 in 2010 to 0.2 in 2015. Auto stereo should drop from 1.5 to 1.3 and should experience a slight shift from analog to digital. Other systems that should decline in penetration include dashboard instrument cluster from 1.3 to 1.2, engine control units from 1.2 to 1.1, and remote/keyless entry from 0.8 to 0.7. Systems that should maintain their ratios include airbag satellite crash sensor at 0.9, climate control at 0.6, fixed GPS devices at 0.2, and ABS at 0.90.

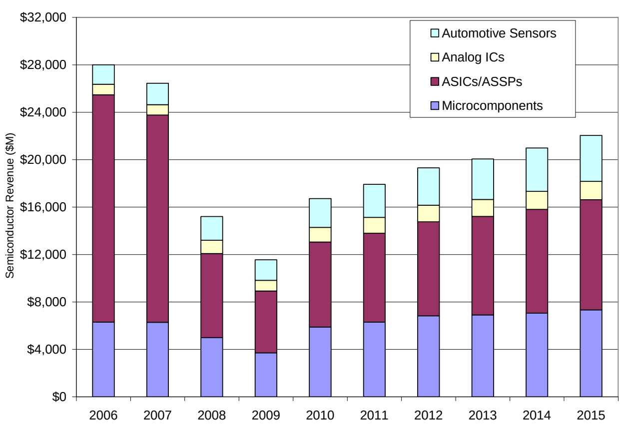
Automotive Electronics Suppliers: The automotive industry has experienced a prolonged and steep contraction which started in 2008, impacting companies up and down the automotive supply chain. As economic conditions continued to deteriorate in late 2008, the United States Federal Government decided to bail out the “Big 3” automotive manufacturers: General Motors, Ford, and Chrysler. Even with the aid of the U.S. Government, General Motors was forced to file for Chapter 11 (reorganization) bankruptcy protection in 2009. General Motors emerged from bankruptcy in late 2009.

Top suppliers of automotive electronics include Robert Bosch, Continental Automotive, Denso, Delphi Automotive, Johnson Controls, Garmin, TomTom, Aisin, Autoliv, Mitsubishi Electric, TRW, and Visteon. Note that market share in each geography is highly skewed toward regionally located vendors; we display top vendors by region in the slide above.

Automotive

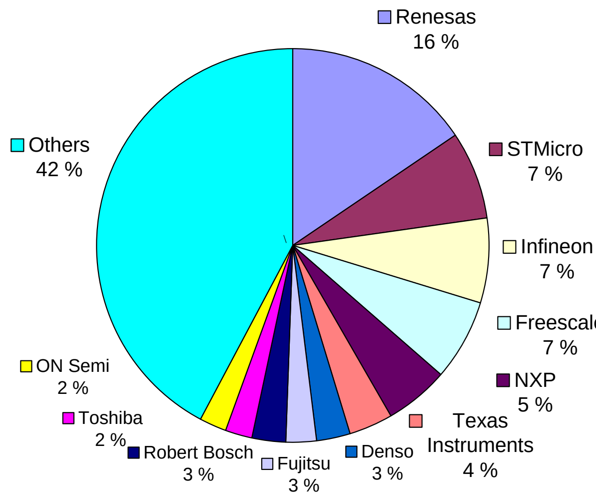
Automotive Semiconductor Forecast

•We expect the automotive semiconductor market to increase at a 6% CAGR, growing from $16.7 billion in 2010 to $22.0 billion in 2015.
•Automotive sensors should see the highest growth, rising at a 10% CAGR.
•Simpler electronic systems still rely heavily on microcontrollers, while more complex systems use MCUs along with ASICs, ASSPs, DSPs, and FPGAs.
•Our forecast excludes memory, standard logic, discretes, and optoelectronics.



Source: Dataquest, Oppenheimer & Co.

Automotive Semiconductor Competitors



MCUs	*ASIC/ASSP*	*Analog*	*Discretes*
Renesas	STMicro	ADI	Renesas
Freescale	NXP	Linear Tech	Infineon
TI	Infineon	Sanken	NXP
Denso	Robert Bosch	ON Semi	Rohm
STMicro	TI	Maxim	Vishay
Fujitsu	Freescale	Renesas	Mitsubishi
Infineon	Panasonic	National Semi	Denso
Microchip	Renesas	Rohm	Fuji
Toshiba	Cambridge Semi	Infineon	ON Semi

Note: Market share includes automotive microcomponents, ASICs/ASSPs, analog ICs, and discretes.
Source: Dataquest, Oppenheimer & Co.

Automotive Electronics Semiconductor Forecast: The market for automotive semiconductors saw a steep contraction in 2008 and 2009 as the global economic crisis impacted the industry severely. Although we expect the number of electronic systems in the car to increase (as discussed above), we expect automotive IC content per system to decrease due to ASP erosion. This should be driven by both the increasing complexity of each automotive electrical system and a slight mix shift towards systems with greater semiconductor content, such as GPS navigation systems and digital stereo systems.

We estimate that the automotive IC market totaled $16.7 billion in 2010, including microcomponents, ASICs & ASSPs, analog ICs, and automotive sensors. We expect the market to increase at a 6% CAGR through 2015 to $22.0 billion. Note that if we were to include memory, standard logic, discretes, and optoelectronics, the market would total $22.4 billion in 2010, increasing at a 7% CAGR to $31.4 billion in 2015.

Automotive Electronics Semiconductor Competitors: Automotive semiconductors are supplied primarily by the larger, diversified semiconductor suppliers. In 2010, there was one 10%-plus share player. Renesas, following its acquisition of NEC, was No. 1 with a 16% total share, including 44% of the automotive microcontroller market and No. 1 position in automotive discretes. STMicro, the top vendor of automotive ASSPs/ASICs, was next with a 7% share overall, followed by Infineon, the No. 2 and No. 3 vendor of discretes and ASIC/ASSP solutions, respectively, with 7% total share. Freescale was the top North American supplier with 7% share, followed by NXP and Texas Instruments with 5% and 4% share, respectively. Other suppliers include Denso, Fujitsu, Toshiba, Robert Bosch, and ON Semi.

Automotive

Automotive Semiconductor Market Trends

•Simpler automotive electronic systems still rely heavily on microcontrollers, while more complex systems use microcontrollers along with ASICs, ASSPs, DSPs, and FPGAs.

•The diversified semiconductor vendors dominate the segment.

•Regional players continue to do well in their home markets (i.e., Freescale, TI in the U.S.; ST, Infineon, NXP in Europe; and Renesas and Toshiba in Japan). Japan is starting to seek alternative sources after recent supplier consolidation (Renesas/NEC) and supply chain disruptions from the March 2011 earthquake.

•Power efficiency is growing in importance, both for fuel economy and environmental concerns.

•Some IC vendors are pursuing module solutions.

- **Simpler automotive electronic systems still rely heavily on microcontrollers, while more complex systems use microcontrollers along with ASICs, ASSPs, DSPs, and FPGAs.** The growth of advanced systems like GPS and digital audio favors this latter group of devices.
- **The diversified semiconductor vendors dominate the segment.** This reflects both the standard components used in automotive systems and the high volume manufacturing required to service the market. Regional players continue to do well in their home markets; e.g. Freescale and TI in the U.S.; STMicroelectronics, Infineon and NXP in Europe; and Renesas, Toshiba and Fujitsu in Japan. However, within Japan, we look for automotive manufacturers to seek alternative sources following the consolidation of Japanese suppliers (Renesas/NEC) and earthquake in March 2011, particularly MCUs. We believe Freescale will be the primary beneficiary as the largest supplier of automotive MCUs outside of Japan.
- **Power efficiency is growing in importance, both for fuel economy and environmental concerns.** IC vendors are focusing more on power consumption as their customers seek to differentiate their systems.
- **Some IC vendors are pursuing module solutions.** OEMs are open to outsourcing some level of design and IC vendors are offered the opportunity to maximize their own content.

Emerging Technologies

Key Emerging Technologies:

Tablet Computing

NFC

40G & 100G

Connected Home

Picocells/Femtocells

Ultrabooks

Context Aware Computing

This section deals with emerging technologies, those where the market is just beginning to come together and volume deployments are about to begin or are in the very early stages. It is likely that many of these technologies will move from this section closer to the front of the document in future updates; in fact, many of these are already mentioned peripherally in earlier sections.

For each section, we attempt to give just a brief introduction to the technology, its targeted application, and the major semiconductor players to watch.

Emerging Technologies

Tablet Computing

The iPad, and subsequent rush of “Me-Too” tablets, has revolutionized the way consumers think about computing. But do we really know the future of the tablet?

Source: Apple

Potential Competitors to the Dominant Apple iPad

ASUS	HTC
Acer	Samsung
Dell	Research in Motion
Amazon	Motorola / Google
Hewlett-Packard	Sony

If you are reading this report, you know the story of the iPad and the tablet computing market. As recently as our latest primer, in December 2009, the concept was a mere afterthought. Computing, mobile computing, sharing and connecting in 2011 do not resemble computing, mobile computing, sharing and connecting in 2009. The market went into a frenzy when the iPad was launched in April 2010 and nearly every competing OEM rushed to create their own version of a tablet. But in March 2011, iPad 2 was released, further distancing Apple from its would-be competition. The tablet has clearly taken the consumer and enterprise markets by storm, but following a whirlwind 18 months on the market, what do we really know about the future of the tablet computing market and what its effect will be on the PC and handset markets?

What we know is that a tablet is primarily a content-consumption device that lies somewhere between a smartphone and a PC in size. To date, the iPad (which has maintained 75%+ share of the total tablet market since launch) has yet to cannibalize the smartphone market. If anything, it has galvanized sales, particularly for the iPhone. To the vast majority of consumers, a tablet is complementary to a smartphone and used primarily for consuming—not creating—content.

The web becomes more entangled when examining the effects on the PC market. The common perception is that tablets will materially cannibalize the netbook market. But PCs? Intel and others have remained steadfast in their belief that tablets will not cannibalize PCs. They may push out, or delay, the purchase of a new PC by consumers, but because tablets are not fundamentally designed to create content, they cannot take the place of a PC in the long term. PC sales have been sluggish since the introduction of the iPad. Is this because of tablet cannibalization? Or because of a sluggish economy?

There is clearly demand for tablets at both the high-end and low-end. The iPad 2 cannot keep up with demand. And when HP shuttered its tablet operation (because it couldn’t compete with the iPad) and put its devices on firesale, opportunistic consumers snapped them up in a matter of days. The concept, form factor, and capability of a tablet are all in a constant state of change, and the biggest question market that remains is how the market evolves, and how it affects the PC market, in a healthy economy.

Tablet OEM Landscape: Apple has maintained 75%+ share of the tablet market since the launch of the iPad, and the market has yet to establish a viable competitor; many have tried at the high end and many have failed. The low-end white box market in emerging nations has recently begun to experience explosive growth as aspirational consumers seek a viable (and cheap) alternative to the iPad. At the high end of the market, differentiation and OS (thereby “apps”) will remain key. The Android market remains extremely fragmented and the market for apps is growing; but an OEM has yet to offer differentiation hardware capabilities from the iPad.

It remains to be seen where the most viable competition will arise; from PC OEMs or from handset OEMs. The two very different groups of manufacturers have each targeted the suddenly hot market with varying degrees of success. Initially, it was tablets from Motorola (now Google), HTC, Samsung and Research in Motion that created all the expectations. Since summer 2011, traditional PC OEMs Acer, ASUS and others have garnered momentum. More recently, the Amazon Fire has become the most viable threat to the iPad, based on initial pre-sale projections.

Semiconductor Landscape: Because performance differentiation is paramount at the high end of the tablet market, a high premium has been placed on the application processor and nearly every major semiconductor vendor is chasing the space. The traditional PC power Wintel (Windows + Intel) is on the outside looking in, for now, while the mobile semiconductor vendors and those with an enhanced focus on ARM-based processors (NVIDIA – Tegra/Kal-El) are in the driver’s seat. The tablet market generally has two varieties, those with basic WiFi capability and those with 3G/4G connectivity. In either case, suppliers like Broadcom and Qualcomm benefit, but the RF suppliers begin to disproportionately benefit from voice-enabled tablets.

Emerging Technologies

NFC

Near Field Communications, NFC, was first introduced in a mobile phone in 2006. NFC allows for simplified data exchange between two devices that are in close proximity to one another. What would primarily be used as a mobile payment system has yet to go mainstream.

However, surging smartphone sales, Android OS, and Google's "Mobile Wallet" have helped push the technology to consumers. NFC will likely be adopted in most next-generation smartphones and reach an inflection point in integration and usage as point-of-sale infrastructure becomes available.

Key Semiconductor Competitors	Key OEMs	
NXP	Google	Nokia
Broadcom	Apple	LG
Intel	HTC	Huawei
Qualcomm	Samsung	Research in Motion

Near Field Communications, NFC, has been discussed for many years but has yet to be implemented across a multitude of consumer devices. NFC is a series of short range wireless communications; operating at 13.56MHz at rates ranging from 106Kbs to 424Kbs that always involves two devices, generally required to be within 4cm of one another. These two devices can share data between one another, such as sharing contact information, a boarding pass, ID, or payment. With the proliferation of smartphones and rising focus on "mobility," NFC has begun to permeate the consumer landscape.

Google Wallet was introduced in 2011 as an application to create a virtual wallet, initially only on a single NFC-enabled smartphone, but under development for several next-generation smartphones. Now with support from credit card companies Visa and MasterCard, Google Wallet will likely spur further adoption of NFC. When the technology hits a critical mass within smartphones, NFC will likely become more than just a mobile payment system and begin to require a further build of location-based infrastructure.

NFC Semiconductor Competitors: The technology was co-developed by NXP and Sony in 2002, and the NFC Forum was created thereafter to produce a standardized body. Going forward, in addition to NXP, Qualcomm (Atheros), Intel and Broadcom are those companies that will likely lead the charge. As NFC becomes adopted in smartphones, it is likely to become integrated into a combo chip with WLAN, BT, etc. But a connection must be made at the point-of-sale, creating another area of growth for vendors who will need to make NFC available at shopping centers, restaurants and anywhere else a transaction or payment may be made.

Emerging Technologies

Connected Home

The home is turning into its own network, with appliances, multiple set-top boxes, media gateways, home control (lights, locks, doors etc.) and consumer devices all connected; and all with the ability to be controlled wirelessly from a remote location. There is increasing semiconductor content everywhere! From MoCA to PLC to G.hn and platforms like AT&T's U-verse, the home is connecting like never before.

Semiconductor Vendors With the Most Direct Benefit

Broadcom	Intel
Qualcomm Atheros	Realtek
Entropic	Trident
Sigma Designs	Maxlinear
Marvell	STMicro

With the growth of digital connectivity and digital media in the home, everything within the home is being turned into an electronic device that can be connected to the core home network. With an average of 3-4 appliances, 1-4 STBs, 2-3 media gateways and 5-20 home control devices, this presents a meaningful opportunity for connectivity. Locks, doors, lighting, heating/cooling systems and everything else in the home has been connected and controlled from remote smartphones or connected devices.

In terms of standards, the leading solutions are MoCA, HPNA, Homeplug, UPA, and HDPLC. MoCA uses the coax infrastructure and is being favored by a number of cable and satellite set-top OEMs, most notably Verizon in North America. HPNA, which uses both phone line and coax, was selected for AT&T's Project Lightspeed as well as cable and satellite set-top makers. Homeplug, UPA and HDPLC are powerline technologies being used by IPTV operators for set-top-to-gateway communications. They are also being targeted for consumer electronics, Ethernet adapters, and power grid monitoring.

Connected Home Semiconductor Competitors: In the last version of our Primer, we detailed each technology standard, which vendors would benefit, and which standards would become pervasive in the home over time. The home, however, has really become increasingly standard agnostic with the pervasive prevalence of WiFi, WLAN etc. Multiple standards can exist and still be continuously controlled on a single network. By adding appliances, home cooling systems, lighting and locks to the mix with STBs and media gateways, the total semiconductor content can rapidly increase in a new "standard connected home." The saturation of smartphones and the ability to control this network remotely has increased the reality that the whole home is remotely connected, in addition to demand for such services.

The primary satellite, cable, connectivity and media processor semiconductor vendors are poised to benefit from the connection of home appliances to the grid. Broadcom, Entropic, Intel, Marvell, Maxlinear, Qualcomm (Atheros), Realtek, Sigma Designs, STMicro and Trident are each likely to most directly benefit from this trend.

Emerging Technologies

Picocells and Femtocells

Picocells are smaller versions of base stations, used in cellular networks to provide additional coverage over a small area. Picocells are usually used to extend coverage to indoor areas where outdoor signals do not reach well, or to add network capacity in areas with very dense phone usage, such as train stations.

Femtocells provide smaller, more focused coverage than picocells, targeting consumers. Femtocells are installed by home users to get better indoor voice and data coverage, supporting up to 5 voice/data connections.

Picocell/Femtocell Semi Competitors

Broadcom
Freescale
Qualcomm
Picochip
NEC

Picocells are small versions of base stations, ranging in size from a laptop computer to a suitcase. Although picocells historically have been used primarily in cellular networks, the design also has been used in WiMax networks. Besides providing a wireless signal in tough-to-reach pockets, picocells also are frequently used to add voice and data capacity—a capability that repeaters and antenna systems cannot satisfy.

Picocells will support multiple wired and wireless backhaul technologies and can help smooth the transition for wireless carriers as they migrate to more advanced networks. The most suitable market is comprised of establishments with between 20 and 100 employees.

Femtocells are the precursor to picocells in that they are intended to serve a smaller group of users (2-5 users). They are most commonly utilized in next generation network infrastructure technologies such as UMTS LTE. Deployments amongst femtocell vendors have been lower than anticipated over the early years of its development as macroeconomic weakness has limited widespread adoption thus far.

Semiconductor Competitors: Broadcom (through it's acquisition of Percello in 2010), Freescale, Picochip, Qualcomm, and NEC represent the companies with the greatest presence within this relatively nascent space.

Emerging Technologies

40G & 100G

10 Gigabit Ethernet is rapidly being adopted, particularly at the core and edge of Telecom networks. As the transition takes place, OEMs and component suppliers are looking ahead to the next node: 40 Gbps and then 100 Gbps.

Today, 40 Gbps OC-768 is used for core and metro transport, as well as for box-to-box interconnect over short distances. 802.3ba Ethernet to support both 40 and 100 Gbps will eventually be implemented.

40G & 100G Semiconductor Competitors

Altera	PMC-Sierra
Avago Technologies	Semtech
Broadcom (& Netlogic)	Vitesse Semiconductor
Marvell	Inphi
	Intel

Networks are rapidly transitioning to 10 Gigabit Ethernet to keep up with exploding data usage and bandwidth requirements. As the transition takes place, OEMs and component suppliers are looking ahead to the next node: 40 Gbps and then 100 Gbps.

Today, 40 Gbps OC-768 is used for core and metro transport, as well as for router-to-router or switch-to-switch interconnect over short distances. 802.3ba Ethernet to support both 40 and 100 Gbps will eventually be implemented.

40G and 100G Semiconductor Competitors: The nascent state of the 40/100G market has bred just a few merchant competitors, most of them start-ups or acquired start-ups. Many of these began R&D programs in the late 1990s, when the 40G market was expected to be much larger than it turned out to be post-bubble. ASICs and FPGAs will likely also play an important role as the market gets going.

Prominent suppliers to the space include Altera, Avago Technologies, Broadcom (and also Netlogic, which Broadcom has acquired), Inphi, Intel, Marvell, PMC-Sierra, Semtech and Vitesse Semiconductor.

Emerging Technologies

Ultrabooks

With the rising popularity of Apple's MacBook Air and tablets, Intel created the Ultrabook; an ultra-thin, ultra-lightweight PC that it hopes will capitalize on increasing consumer mobility. Faster, with integrated graphics, enhanced connectivity features and flash-SSDs, the Ultrabook may be exactly what's needed to kickstart a sleepy PC market.
It may not.

Source: ASUS

Leading Ultrabook OEMs	***Semiconductor Beneficiaries***
Acer	Intel
ASUS	AMD
Lenovo	NVIDIA
Toshiba	Broadcom
Hewlett Packard	Qualcomm Atheros

As tablets increasingly eat away at netbooks and the low end of the notebook market and as the MacBook air garners popularity among consumers for its super-mobile features, Intel was left searching for a solution to help kickstart the sluggish PC market. Its answer: the Ultrabook—an ultra-thin, ultra-lightweight PC that packs additional connectivity features with integrated graphics and flash storage to better capitalize on increasingly mobile consumer demands. Just now beginning production from early-adopter OEMs Acer, ASUS, Lenovo, Toshiba and Hewlett Packard, the 2011 holiday season will be the measuring stick for the success of Ultrabooks. Intel expects the market to be 40% of the total PC market by the end of 2012.

The Ultrabook has high expectations and may indeed be the future direction of the PC landscape. With such negativity surrounding the PC market on a go-forward basis, maybe this is exactly what is needed to get consumers to pay attention again. But priced at a premium to most traditional notebooks, and more in-line with MacBooks, will the Ultrabook just carve out a niche at the high end?

Ultrabook Semiconductor Competitors: The traditional PC vendors will benefit from any resurgence in the PC market, with several exceptions. There is no optical drive, and no HDD storage. And with incremental connectivity features, PC connectivity leaders Broadcom and Qualcomm Atheros are likely to reap increased content.

Emerging Technologies

Context Aware Computing

Context aware computing uses information about a person to proactively anticipate the user's needs to serve available content, products or services. This has already hit consumers in the form of mobile advertising and location-based ads.

For a device to be aware of its user and familiar with preferences and patterns, computing speed and memory must keep up in real-time. Happening primarily in mobile devices, this means smarter and more powerful processors.

Early Movers

Apple
Google
Facebook
Microsoft
Nokia

Semiconductor Beneficiaries

Intel
Qualcomm
Broadcom

Our devices, particularly smartphones, are already context aware; be it Google Maps, OnStar, GPS or mobile Facebook updates, our devices know what we are doing, and where we are going. Google does not receive income from Android—it receives revenue from mobile, location-precise advertising. As smartphones further penetrate the consumer market, and enhanced connectivity, memory and processing power penetrate smartphones, consumer devices are becoming increasingly aware of their users. This happens where the hardware/software line becomes blurred to create the enhanced user experience.

Based on past dining patterns, shopping patterns, activities, email contacts, or recent friend requests, consumer devices can begin to know "who we are." This makes them context aware and able to specifically target recommendations based on a personal user experience. From a semiconductor perspective, processing power, memory and connectivity must keep up in real-time in order to accomplish this task. While the trend is generally just toward "smarter" devices, this clearly benefits the dominant semiconductor vendors with a presence across the entire consumer electronics market.

For More Information…

Questions?
Comments?
Suggestions?

Rick Schafer
(720) 554-1119
rick.schafer@opco.com

Shawn Simmons
(212) 667-8387
shawn.simmons@opco.com

Jason Rechel
(212) 667-7178
jason.rechel@opco.com

We hope you enjoyed reading our semiconductor primer and welcome your questions, comments, and suggestions.

Some of the forecast data in this report is available in excel format.

Stock prices of other companies mentioned in this report (as of 10/10/2011):

Acer (2353-TAI, 33.75 TA, Not Rated)
Alcatel-Lucent (ALU, $2.73, Not Rated)
Altera (ALTR, $34.41, Not Rated)
ANADIGICS (ANAD, $2.26, Not Rated)
Analog Devices (ADI, $34.97, Not Rated)
ASUSTek (2357-TAI, 215.00 TA, Not Rated)
Atmel Corp. (ATML, $8.83, Not Rated)
Avago Technologies (AVGO, $33.66, Not Rated)
Canon (7751-JP, 3480.00, Not Rated)
Clearwire Corp. (CLWR, $1.27, Not Rated)
Compal Electronics (2324-TAI, 27.50 TA, Not Rated)
CSR (CSR.L, 1.95 GBP, Not Rated)
Cypress Semiconductor (CY, $15.61, Not Rated)
Dell Inc. (DELL, $16.10, Not Rated)
DISH Network (DISH, $27.56, Not Rated)
e2v Technologies Plc (e2v.L, 0.92 GBP, Not Rated)
Ericsson (ERIC, $10.54, Not Rated)
Exar Corp. (EXAR, $6.23, Not Rated)
Emulex (ELX, $6.78, Not Rated)
Entropic Communications (ENTR, $4.75, Not Rated)
Fairchild Semiconductor (FCS, $12.12, Not Rated)
Ford (F, $11.21, Not Rated)
Hitachi, Ltd. (HIT, $49.90, Not Rated)
Hittite Microwave (HITT, $51.62, Not Rated)
Hewlett-Packard Co. (HPQ, $24.74, Not Rated)
Hynix (000660.KS, 21,950.00 KD, Not Rated)
HTC Corp. (2498-TAI, 687.00 TA, Not Rated)
Ikanos (IKAN, $0.89, Not Rated)
Infineon Technologies (IFX-DE, 6.04 SWE, Not Rated)
Inphi Corp. (IPHI, $8.81, Not Rated)
International Business Machines (IBM, $188.62, Not Rated)
Integrated Device Technology (IDTI, $5.61, Not Rated)
International Rectifier (IRF, $21.57, Not Rated)
Lenovo (0992.HK, 5.10 HKD, Not Rated)
LSI Corp. (LSI, $5.58, Not Rated)
MaxLinear (MXL, $5.95, Not Rated)
MediaTek (2454-TAI, 310.50 HKD, Not Rated)
Mindspeed Communications (MSPD, $5.31, Not Rated)
Nintendo (7974-JP, 117,900.00 JPY, Not Rated)
NTT (DCM, $24.33, Not Rated)
O2Micro (OIIM, $3.98, Not Rated)
OCZ Technology (OCZ, $5.72, Not Rated)
On Semiconductor (ONNN, $7.31, Not Rated)
Pericom Semiconductor (PSEM, $7.53, Not Rated)
Philips (PHG, $19.66, Not Rated)
PLX Technologies (PLXT, $3.03, Not Rated)
PMC-Sierra (PMCS, $6.55, Not Rated)
QLogic (QLGC, $13.79, Not Rated)
Quanta Computer (2382-TAI, 59.60 TA, Not Rated)
RDA Microelectronics (RDA, $8.10, Not Rated)
Realtek (2379-TAI, 50.20 TA, Not Rated)
Samsung Electronics (005930.KS, 4,000.00 KD, Not Rated)
Seagate (STX, $11.08, Not Rated)
Sigma Designs (SIGM, $8.16, Not Rated)
Silicon Image (SIMG, $6.21, Not Rated)
Silicon Laboratories (SLAB, $34.50, Not Rated)
Sony (SNE, $19.00, Not Rated)
Sequans Communications (SQNS, $4.54, Not Rated)
Spansion (CODE, $13.31, Not Rated)
Spreadtrum Communications (SPRD, $19.26, Not Rated)
STMicroelectronics (STM, $7.36, Not Rated)
Taiwan Semiconductor (2330-TAI, 69.10 TA, Not Rated)
Toshiba (6502-TK, 320.00 JPY, Not Rated)
Transwitch (TXCC, $2.33, Not Rated)
TriQuint Semiconductor (TQNT, $5.90, Not Rated)
United Microelectronics (2303-TAI, 11.92 TA, Not Rated)
Vitesse (VTSS, $2.46, Not Rated)
Winbond Electronics (2344-TAI, 5.82 TA, Not Rated)
Western Digital Corp. (WDC, $27.93, Not Rated)
Xilinx (XLNX, $29.56, Not Rated)
ZTE (000063.SZ, 21.35 TA, Not Rated)

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Stock Prices as of October 13, 2011

Aeroflex Holding Corp. (ARX - NYSE, 10.30, PERFORM)
Advanced Micro Devices (AMD - NYSE, 4.97, PERFORM)
AppliedMicro (AMCC - Nasdaq, 6.27, OUTPERFORM)
BCD Semiconductor (BCDS - Nasdaq, 4.74, PERFORM)
Broadcom Corporation (BRCM - Nasdaq, 37.02, OUTPERFORM)
Cavium Networks (CAVM - Nasdaq, 30.78, PERFORM)
Cirrus Logic (CRUS - Nasdaq, 17.58, PERFORM)
Freescale Semiconductor (FSL - NYSE, 12.51, OUTPERFORM)
Intel Corp. (INTC - Nasdaq, 23.39, PERFORM)
Intersil (ISIL - Nasdaq, 11.93, PERFORM)
Linear Technology Corp. (LLTC - Nasdaq, 31.36, PERFORM)
Monolithic Power Systems (MPWR - Nasdaq, 11.74, PERFORM)
Marvell Technology Group (MRVL - Nasdaq, 15.13, PERFORM)
Microsemi Corp. (MSCC - Nasdaq, 18.24, OUTPERFORM)
Maxim Integrated Products (MXIM - Nasdaq, 25.14, PERFORM)
NetLogic Microsystems, Inc. (NETL - Nasdaq, 48.30, NOT RATED)
NVIDIA Corp. (NVDA - Nasdaq, 15.46, OUTPERFORM)
Semtech Corp. (SMTC - OTC, 23.70, OUTPERFORM)
Texas Instruments (TXN - NYSE, 30.40, OUTPERFORM)
Volterra Semiconductor (VLTR - Nasdaq, 21.48, PERFORM)
Brocade Communications (BRCD - Nasdaq, 4.42, PERFORM)
Cisco Systems (CSCO - Nasdaq, 17.42, OUTPERFORM)
Juniper Networks, Inc. (JNPR - Nasdaq, 20.43, PERFORM)
QUALCOMM Incorporated (QCOM - Nasdaq, 53.31, OUTPERFORM)
Applied Materials (AMAT - Nasdaq, 11.58, OUTPERFORM)
KLA-Tencor (KLAC - Nasdaq, 43.76, OUTPERFORM)
Micron Technology (MU - NYSE, 5.52, PERFORM)
SanDisk (SNDK - Nasdaq, 45.93, OUTPERFORM)

Nanometrics (NANO - Nasdaq, 17.45, OUTPERFORM)
Apple Inc. (AAPL - Nasdaq, 408.43, OUTPERFORM)
Research In Motion Limited (RIMM - Nasdaq, 23.61, PERFORM)
Motorola Mobility Holdings (MMI - NYSE, 38.16, PERFORM)
Nokia Corporation (NOK - NYSE, 6.29, PERFORM)
OmniVision Technologies, Inc. (OVTI - Nasdaq, 17.60, OUTPERFORM)
Skyworks Solutions, Inc. (SWKS - Nasdaq, 21.43, OUTPERFORM)
RF Micro Devices, Inc. (RFMD - Nasdaq, 7.21, OUTPERFORM)
Microsoft Corporation (MSFT - Nasdaq, 27.18, OUTPERFORM)
Google, Inc. (GOOG - Nasdaq, 558.99, OUTPERFORM)
Amazon.Com, Inc. (AMZN - Nasdaq, 236.15, OUTPERFORM)
Sprint Nextel (S - NYSE, 2.78, PERFORM)
AT&T, Inc. (T - NYSE, 29.10, OUTPERFORM)
Verizon (VZ - NYSE, 37.02, OUTPERFORM)
Comcast (CMCSA - Nasdaq, 23.56, OUTPERFORM)
Best Buy Co. Inc. (BBY - NYSE, 25.55, PERFORM)
NetApp, Inc. (NTAP - Nasdaq, 38.65, PERFORM)
EMC Corporation (EMC - NYSE, 22.72, OUTPERFORM)
F5 Networks (FFIV - Nasdaq, 87.45, PERFORM)
CEVA Inc. (CEVA - Nasdaq, 27.41, OUTPERFORM)
VMware, Inc. (VMW - NYSE, 90.61, PERFORM)

All price targets displayed in the chart above are for a 12- to- 18-month period. Prior to March 30, 2004, Oppenheimer & Co. Inc. used 6-, 12-, 12- to 18-, and 12- to 24-month price targets and ranges. For more information about target price histories, please write to Oppenheimer & Co. Inc., 300 Madison Avenue, New York, NY 10017, Attention: Equity Research Department, Business Manager.

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Distribution of Ratings/IB Services Firmwide

			IB Serv/Past 12 Mos.	
Rating	**Count**	**Percent**	**Count**	**Percent**
OUTPERFORM [O]	337	56.10	149	44.21
PERFORM [P]	253	42.10	80	31.62
UNDERPERFORM [U]	11	1.80	4	36.36

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