



# OBJECTIVE ANALYSIS

## Semiconductor Market Research

### 2015 REFLECTIONS AND 2016 OUTLOOK

*Current Events, Economic Conditions, Interesting Applications, and CapEx for Memories Lead to Semiconductor Growth*

The electronics industry in 2015 was marked with continued effort to assemble the infrastructure, platforms, and things of the Internet of Things (IoT), consolidation of semiconductor and technology companies large and small with relatively few high-tech Initial Public Offerings (IPOs), steady-ing of the smart phone and PC markets, and the evolution of products with more consumer than industrial focus.

From an external standpoint, the financial markets in the second half of 2015 became very volatile, somewhat reflecting greater economic concerns. 2016 is likely to continue seeing wild swings in market dynamics, on both the financial and the product and services side. [Objective Analysis](#) holds an optimistic outlook for 2016 with a 10% growth forecast over 2015, but with variability during the year and across markets.

#### A Good Year, Maybe Toppy

2015 surprised most pundits with lower-than-expected economic growth, financial markets experiencing wild swings, closing the year near the levels where they started, and suspected stalling of the markets and industry of China. Yet the United States' central bank, the Federal Reserve, felt confident enough in the US economy to raise the prime interest rate from near-zero for the first time in over

7 years. Some of those high-tech consolidations may have taken place at just the right time. After a long run up, the price of oil dropped to lows not seen for decades.

In electronics, as well as the greater economy, 2016 is likely to continue as a transitional year. While every marketer believes their product is ready to be the next big thing, reality is far more sedate. The IoT may be transformational, but it is really an evolutionary movement and

will take more time to hit full stride. Mean-time, not all the products and services proposed for the IoT will succeed. Smart watches quickly turned lackluster and

the connected home has not moved much past government-subsidized smart meters, although those markets continue to show high activity and visibility – and are growing.

While Tesla is creating an exciting new category of automobile, Uber and Lyft are shaking up the taxi cab business like bad shocks on an urban shortcut. But the shameful scandal where Volkswagen deliberately sidestepped emissions standards has pushed the lofty reputation of engineers off a cliff, with the precision workmanship implicit in “German engineering” falling hardest of all. Still, car production is up and electronic content therein is growing ever more. The auto industry may soon get a further

2015  
2016

boost as people shift back to more powerful engines as they always do when gasoline prices are low. Car prices well north of \$30,000 and even higher interest rates don't seem to stem the desire for a shiny new model car.

In the end, each product's benefits and convenience must outweigh its cost and complexity. A few issues influencing the electronics industry in 2016 will now be reviewed to help explain the rationale behind Objective Analysis' semiconductor revenue forecast.

### ***The IoT – A Driving Force, but a Long Haul***

The Internet of Things (IoT) continues to be in the megaphone of every technology spokesperson – and with good reason. But this next stage of the Internet is neither a flash-in-the-pan nor is its ultimate role fully clear or established. It will still take 5 to 10 years for the IoT to be widely implemented and robust. While everybody seems to be working on the IoT, even if they were working together on the same grand plan, it would still take 5 years to put the key pieces in place and work the kinks out.

**T**here is no single application that is fueling the IoT, the way cellular technology shifted telecommunications to the whole new dimension of mobility, radically changing development of wireless technologies, and eventually leading to the multi-functional platform of the smart phone. It's amazing where those early 35¢-per-minute flip phones of the 1990's have taken us.

Rather, the way a vast network offers many paths for communication compared to the singular route of point-to-point wiring, the Internet offers numerous ways that a multitude of applications can connect sensing or actuating Things to utilize distant data, processing, and control facilities.

The Internet is already in place, but with the IoT, nearly every existing electronic application plus thousands of new applications are clamoring to take advantage of benefits of the vast information, connectivity, and control possible through networking. Not all IoT products and companies will succeed – there are so many – but the possibilities of the IoT will inspire and enable widespread technological innovation over the next many years, and will provide the drive that will keep electronics, and the semiconductors at their heart, as very vibrant industries.

However, most of the issues on the IoT [discussed a year ago](#) are still unsettled with a few gathering increased support, but with just as many new issues added to the mix. The promise of the IoT will finally explode when a vast array of products built by many different makers exhibit *true interoperability* through the network, but today the complete vision still seems a few years off.

### ***Industry Consolidation – Take Advantage of Finances***

High tech has always been fueled with a cycle of idea spark, start-up company, catch market's fancy, grow, license, company stock offering to public, extend with more products to new markets, and eventually sell or merge the company. Many companies skip, add, or rearrange the steps and many trip and fail along the way, selling assets for pennies or returning to dust, perhaps trolling for intellectual property (IP) opportunities.

Semiconductor companies in 2015 had an unusually busy year of high-profile mergers and acquisitions (M&A). Some are listed in Table 1. The consolidation reflects the industry's difficulties as some markets grow while others struggle to get a toe-hold over several years.

**Table 1. Recent Semiconductor Mergers and Acquisition (M&A) Announcements**

Primary	To Acquire	Key Attractions
NXP	Freescale	Automotive, MCU, Networking
Intel	Altera	FPGA
Microchip	Micrel	Linear, power mgmt, LAN
Microchip	Atmel	MCU
Dialog	Atmel	MCU
Cypress	Atmel	MCU
China Electronics Corp.	Atmel	MCU
Avago (once H-P)	LSI Technology	Communications
Avago	Broadcom	Mobile
Lam Research	KLA-Tencor	Chip manufacturing yields
Western Digital	SanDisk	Embedded Flash for SSD
Seagate	Avago/LSI Techn (part)	Controllers & Flash for SSD
ON Semi	Fairchild	Analog
China Resources Holdings Co.	Fairchild	Analog, patents
Renesas	NEC, Hitachi, Mitsubishi	Automotive, MCU
Microsemi	PMC-Sierra	
Uphill (China)	ISSI	Special memories (Cypress also bid)
Hua Capital Management (China)	Omnivision	CMOS Image sensors
Unichip (China)	Micron Technology	DRAM, memory

Notes: Not all shown M&As closed; some still bidding. MCU=microcontrollers. SSD=solid-state drive  
 FPGA=field programmable gate array ISSI=Integrated Silicon Solutions Inc. LAN=local area network

Source: *Objective Analysis, 2016*

This is an industry where high production volume is a requirement for success, the sophistication and complexity of the electronic chips is extreme, and it is very expensive to design the hardware, develop the software and ecosystems, and market such circuits to win customers.

There is high risk that modern systems-on-a-chip (SoC) miss their mark in timeframe, functionality, or price, and don't pay back their development costs. The difficulty is to stay ahead of all the complexity and costs, while producing a desirable, high quality product. This leads companies to seek out bulk acquisitions of resources.

A quick way to gain systems expertise, resources (including people), design and development tools, intellectual property

(IP) rights, and software is to buy a company that already has those resources and knowledge in the area desired. Buying is preferred over partnering because it better dedicates those resources to the acquiring company which can limit competition. It also strongly leads the acquired company's existing customers and partners to the buying company.

Hopefully the designs and products of two merging companies blend together nicely, letting the resulting corporation sell more of a customer's system components or bill of materials (BOM), which can benefit both vendor and customer.

Most of the last year's acquisitions add missing parts to the buying company's portfolio. Most obviously, while Intel is

very strong on high-performance instruction-set processors, its customers often use field programmable gate arrays (FPGAs) along with their Intel central processing unit (CPU). Thus, buying FPGA-vendor [Altera gives Intel](#) this second category of high-price, high-profit products to sell to their CPU customers.

Also, since Altera is #2 in the FPGA market, their existing customers and applications can now be called on by Intel sales people who can strongly encourage the use of Intel processors, opening more new-sales possibilities.

Sometimes the two companies' products overlap (each company has a chip that essentially serves the same function) and this redundancy in the joined company's portfolio brings uncomfortable conflicts. Altera FPGAs, for instance, can contain processor cores from ARM, Ltd. – and generally the ARM architecture is an arch-rival to Intel X86 in the processor world. Altera uses ARM-A9 pairs as well as very-high-performance 64-bit ARM-A53 cores in quads. While they will be sales that tally into Intel's accounts, clashing ARM processors with Intel X86 processor behemoths must cause great angst to hard-core Intel architects in Santa Clara, even if they are often used for different functions.

### ***Merging Microcontrollers***

Microchip Technology carefully spends its capital buying companies with products that complement its own, to obtain better coverage for new applications and markets. Microchip's 2015 purchase of Micrel fits this pattern, picking up analog, linear, and networking resources. Previous year acquisitions included Supertex (high voltage), ISSC (wireless), Roving Networks (wireless), Standard Microsystems (SMC) (mixed-signal), and earlier the [Flash resources of SST](#).

As far back as 2008, Microchip tried to buy MCU competitor Atmel but was shunned, and in recent months has again wrestled to buy the company. Atmel would bring ARM-based MCUs into Microchip, which has fought the architecture with a vengeance in the past.

Atmel seems to be one of those houses down the street that perennially has a tattered "For Sale by Owner" sign hanging out front, but never changes hands. One assumes the wife wants to sell the house but at the last minute the husband just can't bear to part with it or overvalues each and every piece beyond what anyone will pay for the lot. Meantime, the paint starts to peel and the lawn and gardens grow long.

Netherlands' chip vendor NXP (once part of Philips) [acquired Freescale](#) Semiconductors (once part of Motorola) in 2015 and has the more typical overlapping-products scenario. Both companies have a significant number of products that address the automotive market and general-purpose MCU markets. Watch for products combined under one roof to be pared down where overlap exists even if more automotive applications can be served by the ultimate NXP portfolio.

Analog semiconductors are more art than the logic and science of digital chips. Discrete and analog semis typically utilize older, more robust fabrication technology than digital circuits are made from and can handle much higher voltage and currents. This makes it almost impossible to put the best digital circuits on the same piece of silicon as the best analog components.

Companies that make analog chips tend to be much smaller than those that make digital, and analog companies have been acquired to round out the offerings of many digital companies. ON Semi (spun out of Motorola many years ago) is one of the latest suitors for Fairchild,

one of the earliest semiconductor companies. ON warded off various groups of Chinese investors for the company.

Various organizations and companies in China have made offers on high-tech companies in the US, Europe, and Japan. Closing such deals can be more difficult and time-consuming with the governments of foreign countries scrutinizing the technology that would be turned over, since China's political and military position is still being established.

Compared to others, companies in China may have more to learn from the established companies they acquire – rapidly gaining the knowledge, expertise, and resources – perhaps more broadly and deeply than traditional semiconductor and electronics companies would. There is much to gain in intellectual property (IP) and patent rights for newer companies, let alone access into the expanded customer base of the Western world and Japan.

### ***Large Scale Integration***

Two decades ago the industry moved from more vertically-integrated device (semiconductor chip) manufacturers (IDMs) to a very disaggregated industry where more companies were involved, each focusing more carefully on a smaller part of the food chain. Here, various intellectual property (IP) developers fed significant pre-designed blocks to chip designers who conceptually built the circuits that went to chip foundries to produce the chips that the over-arching chip vendor tried to get designed-in to an electronic application at a customer or two in the hopes that the final systems caught the eye of the target market.

This disaggregation has worked well as each step in the process has grown in sophistication over time. Success would pay off in the needed high volume demand but the aggressive and very com-

petitive electronics industry always closes in soon, rendering most high-volume (high-revenue) opportunities fairly short-lived (2-5 years).

Some companies buck the trend to disaggregation. While Apple shifted its partnerships around for many years, the last few years has seen the company buy processor design houses (PA Semi, Intrinsicity) so it could take more control over the applications processor chips that are central to its cell phones, tablets, music players, and TVs. The evolution of those chips has been a key factor in Apple's leading edge in those devices).

Apple also became more flexible in the foundries where it produces its processors and most recently has bought a fab for itself (though most likely for sensor and analog chips and not aggressive digital processor fabrication). It looks like Apple is moving more to an old-school vertically-integrated device manufacturer (IDM), not that they sell chips externally. It has certainly kept the key software for its i-products in-house.

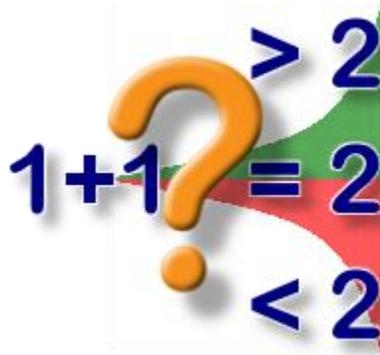
On the other hand, Apple nemesis Samsung has not changed much from its strategy that closely resembled an IDM. However, Samsung is [a bit peculiar](#) about how it runs the different groups: operating them as almost independent operations, at times selling more to competitors than to groups within Samsung.

Consolidation in the semiconductor and electronics industries at this time is spurred by difficulties many companies faced after the recession that started in 2008, the historically low interest rates on borrowed money, and healthy companies making the best use of their cache of cash (financial muscle). It has been a good time to invest in some resources that were previously in other companies.

Nearly all M&A's involve cutting of projects and people as cost-saving measures when two companies combine. The easy part often falls under the accounting category of sales, general, and administrative expenses (SG&A). There is usually duplication in corporate functions, management, organizational structure, accounting, sales, marketing, and information technology (IT) that can be thinned out.

More difficult and more troubling to engineers is the crawl through every product and project to justify its existence, verify that it falls in the scope of the new company's strategy, and scrutiny by a new set of eyes to ask "why are we doing this?" Nearly everybody is touched by this process which leads to shifting some people around, laying off numerous employees, shutting down R&D projects, rendering poorly-selling products obsolete, and selling offices and buildings. Wall Street unilaterally likes these actions, but employees and even customers can be severely impacted by such cut-back measures, in addition to adjusting to the new corporate culture.

**Consolidation – Semiconductor Context:** Higher volume sales in total and on individual products always wins in semiconductors due to increased efficiencies from economies of scale. If joining two chip companies results in greater sales in total (  $1 + 1 > 2$  ), then real manufacturing costs can be reduced, which can spur additional sales in more cost-sensitive markets and improve quality and performance of the chips, benefitting all users of the company's products. Fortunately, the electronics industry has always valued the improved performance and new features of more advanced chip designs, furthering sales in the original markets.



The first year or two of an acquisition can be turbulent as the companies try to fit together. The real key is whether a single unified company can increase sales revenue faster than the sum of the two separate companies, had they stayed independent, and grow its total market influence. However, the resources (and brand) of many acquired companies can also eventually collapse anyway, hopefully without taking down the buying company too.

### ***Changing Currency Coddling Commerce***

Did the European Union unify currency a few years back? Great Britain, Deutschland, and Greece probably have different views on the effectiveness of the Euro as a common currency. The last year or two has seen changes under foot for the means of paying for goods and services, involving a lot more software if not electronic hardware, with the advent of BitCoins, Apple Pay, Android Pay, Square, and other changes from the norm of paying for goods with cash (coin and notes), check, debit card, or the ubiquitous credit card.

PayPal may have been the first to deviate, if ever so slightly, from the standard credit card as a means to pay for goods and services, particularly over the Internet, coming along about the time eBay and Amazon started to take advantage of what was soon called e-Commerce.

BitCoin is essentially a digital form of currency backed neither by gold nor the "full faith and credit of" any sovereign nation. For a long time loyal customers of Mobil (and now Exxon) gas stations could pass a special RFID tag by a reader to buy gasoline at the pump. Most recently, Apple, Samsung (Figure 1), Android, retailers from Walmart to

Neiman Marcus (Figure 3), and various other businesses promote their own “mobile payment” systems that allow customer-users to pay for goods and services utilizing their smart phone.



Figure 1. Samsung draws in customers

Many of these ride on the Apple Pay or Android Pay structure that is designed to let users tap or pass their smartphone to make a purchase. They may use contactless Near Field Communications (NFC), fingerprint verification, and assorted encryption techniques to provide security for the transmission of personal information to the infrastructure. Traditional credit card systems ultimately sort out the actual financial transaction. Not surprisingly, Visa, MasterCard, American Express, and Discover and banks associated with them are likely to be directly entering the mobile pay space soon, too, to more firmly hold onto their 2.7% fees.

**I**n another corner of the market, thousands of small businesses have been able to take credit card payments in a new way. By adding a tiny reader device (Figure 2) from Square, Inc. to an iPhone or Android device, a local vendor can swipe credit cards on a Point of Sale (POS) terminal like big stores do. Besides eliminating the need for a pricey card reader, Square’s availability and fees are attractive to low-price or low-volume mom-and-pop businesses, making credit and debit card sales practical and portable.

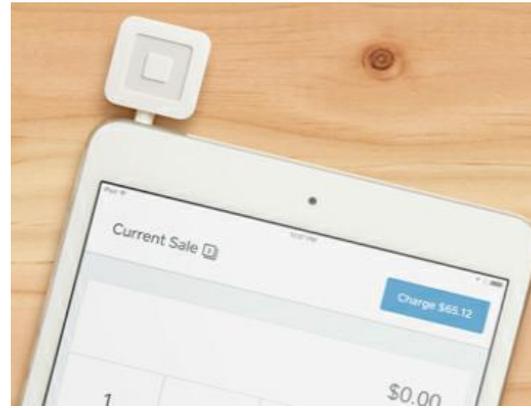


Figure 2. Square takes Credit Cards

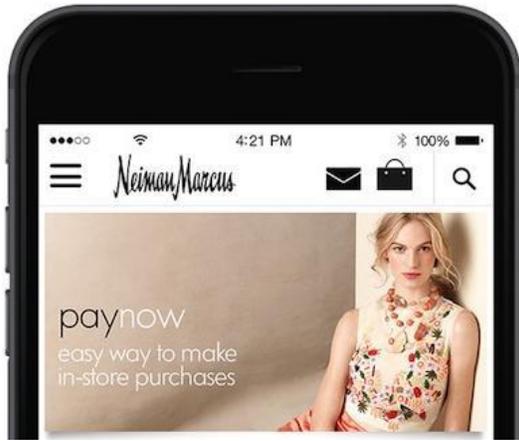
## Upwardly Mobile?

New electronic means of paying for goods and services have been proposed for some time now.<sup>1</sup> They have struggled to gain acceptance for numerous typical reasons including the chicken-and-egg paradox: Which phones or tags offer it, which retailers or Web sites accept it, where does the invoice appear, is credit necessary, do users trust it, and where does fraud liability rest?

The popularity of iPhones and Android phones give some hope for success of transactions associated with those devices. However, only the latest devices are adequately equipped. At the retailer end, changes, upgrades, and rollout of software and hardware will have to take place and be managed. What is the benefit to the retailer; wouldn’t the customer pay one way or another, anyway?

Odd as it may sound to Europeans who have used smart-card-secured bank cards for nearly two decades, in the USA, only in the last few months have credit card terminals in retail stores been upgraded beyond magnetic stripe “swiping” to read smart card credit cards, or more formally, the far-more-secure EMV cards (Europay, Mastercard, Visa).

<sup>1</sup> See “Payment Applications Make E-Commerce Mobile”, Neal Leavitt, [Computer Magazine](#), IEEE Computing Society, December, 2010



**Figure 3. High-Fashion Electronic Wallet**

Retailers may not be too keen to turn around so quickly to shell out for yet another terminal that will handle NFC-enabled financial transactions, let alone the back-end software, to allow the new tap-and-go mobile payments. Some of the recently-upgraded terminals already have NFC capabilities, but many do not and many retailers are still just swiping (magnetic) cards, and implicitly accepting the liability



EMV

The credit card companies like Visa, MasterCard, and American Express live on their 2.7% transaction fee and exchange rate variations. Sharing those morsels with Apple or others in an expanded food chain is probably not very enticing. On the other hand, Visa, MasterCard, American Express and Discover are likely to directly enter the mobile pay space soon, since they essentially back all private retail credit cards today.

Like many new ideas the uptake of a mobile payment service will be a true test of the value it offers versus its cost. The value may be “convenience”, but how hard is it really to fish a credit card or cash out of a leather wallet. It’s not like a person would be able to leave their

real wallet behind, because 80% of the merchants around town probably cannot take the specific electronic payment.

On the other hand the cost of using mobile payments, assuming that a person bought the iPhone 6 for other reasons, may just be the time and effort put into setting it all up and keeping the information up-to-date. Some e-wallets may be yet another bank account to keep topped up and balanced. This nuisance to the user may be the reason that Amazon, the massive company whose entire existence is the epitome of e-commerce, closed its Amazon Wallet less than a year after it opened the program.

As with the Loyalty Programs that so many retailers offer, that allow users’ cards to accumulate points, at some point the consumer wonders “how much do I really benefit from all this?” and “can’t I make do with just one or two of these?” It takes too long to earn rewards or discounts, which turn out to be tricky to use, yet the user is constantly being contacted with annoying messages. Will mobile pay or electronic wallets be more satisfying?

**Mobile Pay – Semiconductor Context:**

To operate, the older RFID key fobs and recent mobile pay-by-phone schemes need security hardware/software, some processing power, a support system of RFID or NFC receivers, and connectivity to the existing backbone of financial transaction systems. By adding the NFC hardware and software to the already-increasing security features on smart phones and tablets, mobile payments can just be one more app in an arsenal of tools in the mobile device.

Coupled with the terminals at retailers, mobile pay could be a boost for a little RF (radio frequency), security, and maybe fingerprint or other biologic sensors hardware sales, both initially as mobile pay gains interest and ongoing should the concept really gain wide-

spread acceptance. But one assumes that cost will quickly be the dominating factor in these systems, so mobile pay will not be a top-25 revenue generator for the electronics industry.

### ***Not Your Father's 8-mm Film Camera***

Few consumers are buying cameras as standalone products now, the way they were a few years ago, opting to use the reasonable quality camera built in to their always-at-the-ready smartphone. The oblong shape of smartphones results in inconveniently shaped pictures, but the instant connectivity of the phone allows immediate image upload to social media or distribution by email. There is a smaller selection of digital still cameras on the market now, marking the demise of yet another once-prolific consumer electronics product category.

However, image sensors, photographs, and video are not going away; they're becoming far more an ever-present part of our lives. Safety, security, remote sensing, (almost one category, really) and specialization are now the driving forces for image sensors plus the processors and software massaging the pictures, with displays trying to keep pace.

**T**he GoPro has been a stand-out specialty camera, as Objective Analysis [noted last year](#), giving action junkies a pricey way to capture and share their exciting if dangerous activities. There should almost be a button on them to insert a “hey, guys, watch this” announcement (with a fine print “don't try this at home” warning).

However, as also anticipated, GoPro – the company – may have hit a wall in 2015, possibly saturating the bulk of its market while fighting competing products from lower-cost up-starts. Sales seem to have stalled out, and the company's stock price dropped in 2015 from the \$60's to under \$20, after an IPO near

\$35 just 18 months earlier. But 4K may start some churn in the action camera business where the higher resolution allows capturing a bigger field-of-view or better post-production zooming.



**Figure 4. GoPro Stock Price from July 2014 (IPO) through December 2015**

3-D cameras have largely faded away although more start-ups keep trying to make them work – and there are some possibilities. The plot line to “The Martian” was no better when the movie was watched in 3-D, even in the theatre and a stark landscape looks no more barren in 3-D than in black (or red) and white 2-D. The childhood innocence of a Charlie Brown program is just as heart warming in the original flat hand-drawn cartoon as when rendered in 3-D-shadowed graphics. Bulky headgear will continue to scare away all but the most particular viewers and the lost-in-their-own-world virtual reality (VR) fans.

**G**oogle Cardboard (Figure 5) may not be as sleek and high-tech as the old Google Glass, but holds possibilities for easing people into 3-D still pictures and video on the cheap, no matter how clumsy the box looks. Cardboard is only a simple display structure, but, coupled with a smartphone, Cardboard may re-open opportunities for 3-D photography for the masses and even VR and spherical imagery. However, there still needs to be a mechanism (second lens) to take a stereoscopic photo.



**Figure 5. Semiconductor-free Google Cardboard – an electronic ViewMaster / VR goggle wannabe**

Cameras on drones are certainly growing in interest but the market is very fragmented and the aviation authority and the public's tolerance for intrusive drones and invasion of privacy have yet to be fully resolved. The place for surround / 720° / 3-axis – perhaps best called “spherical” – camera systems has yet to work itself out, but may end up as a subset of the GoPro market, possibly tied-in with VR goggles, or a version for automotive or security applications.

### **Bright for Imagery**

Perhaps the richest opportunities for digital photography and videos are in expanding markets in automotive and safety, security, and remote viewing. The quality of camera needed for the automotive environment (rugged, long-lasting, vast dynamic range), the horsepower required for the real-time processing of the streaming images, the algorithms detecting and categorizing features accurately, and the tens of millions of vehicles being produced annually creates a rich market for the winning components in automotive imaging applications, many associated with Advanced Driver Assistance Systems (ADAS). Sensors for radar and imaging beyond the visible light spectrum also help determine proximity, temperature, density, distances, and speeds – further multiplying opportunities for design activity.

Automotive also has a fairly small number of Tier-1 customers to serve so each

solid design-win will pay off in high volume production for chip and component vendors. This volume-customer situation can be very different in most consumer product categories where there can be hundreds of makers each requiring disparate engineering support.

Whether an image sensor is in an automobile or in a security system, image processing might take place at the camera or up a cable in a network, in the back office, or in The Cloud. Each configuration has different performance, energy, data transport, storage, and response characteristics.

**W**ith each passing year, image processing algorithms improve the ability to identify key characteristics about what is in the field of view – without the assistance of a human. This allows alerts to be raised (if humans are needed) and action to be taken. The amount of research, development, implementation, and productization of image- and vision-related sensing, processing, and classification is the highest it has ever been and should continue to evolve over the next 5-10 years in areas barely imaginable a decade ago. Coupled with network access to cheap sensors and cameras in ubiquitous smart phones as well as to growing databases of use-cases, the possibilities become almost scary.

World-wide terroristic threats and outspoken concern for interactions between criminals and law-enforcement in the United States has policemen, firemen, and other emergency personnel (“first-responders”) being asked to wear video cameras on their person (“body-cams”) to supplement those that may be mounted in their vehicles (“dash-cams”). Such devices must record high quality video and audio in very difficult circumstances without being cumbersome, distracting, or intrusive. They must be rugged and dependable.

The activities they capture may need to be reliable enough to be used in a court of law, yet those activities may also be very private to the participants. Nonetheless, like red-light cameras, airport checkpoints, drone cameras, photo-bombed selfies, and viral videos, more imaging technology will be crawling into the lives of everyday citizens, perhaps without their knowledge and consent. Even cheap consumer grade dash-cams are starting to capture road-rage incidents and accidents-in-progress.

#### **Imaging – Semiconductor Context:**

There are numerous electronic design opportunities surrounding cameras specifically and sensors generally, even if they are in non-traditional forms. Many of these prospects will be high-value products, much in real-time as well as post-processing software, and may require large quantities of storage. Specialization leaves room for significant differentiation, and makes a very attractive market.

#### ***Concern – Bubbles in the Air***

In the late 90's everyone was trying to figure out how to shift commerce over to the Internet. But "everyone" is too many people and more will fail than will succeed. That became the "dot-com" bubble that burst with a messy "pop" just about the time people were sidetracked with a non-issue known as "Y2K".

Today everybody is chasing the Internet of Things. There is still much to work out as a business model that encompasses all the individual parts of the IoT, while producing products and services that consumers and businesses feel are worth the price. Add connectivity to a \$20 thermostat and somehow this device keeping your nest warm costs \$200. Some new devices will incur a monthly service charge and pile up mountains of data that allow businesses to track a person's behavior. Let the cable guy into

the house with a Set-Top Box (STB) and soon there's a \$200/month bill that includes security footage and the refrigerator ordering milk for delivery.

Numerous IoT products will not survive in this nascent unproven marketplace and the companies that make them will suffer as a result. Caution should be exercised when evaluating IoT-rooted systems and the companies promoting them.

**S**ometimes, in isolation, an individual connected device makes sense – maybe a camera that uploads a picture to Facebook with just a button push. But how much did adding that instant-connectivity feature cost? It is more difficult to assess whether a dozen Things at home or work connected to the Internet, all relying on a central gateway, remote server, or service provider all prove to be worthwhile and justify the cost of the multimodal system.

The best situation is when one key element can justify the initial investment outlay – the many channels of TV in the early days of cable and satellite – with additional components that can be added later at minimal extra cost. But the common platform is critical to the long term success – of all the associated products. The smart phone platforms of Apple and the Android OS provide a similar backbone.

#### ***Concern – The China Syndrome***

China has been a cheap manufacturing engine for the developed world for nearly a decade while becoming a significant, billion-person market of its own, coming into the modern world. Yet the country's rapid growth and seemingly endless money supply may be starting to falter. A breakdown in China's economy could have disastrous effects on the rest of the world.

The strong central government in China follows its own ideas for managing China's economy as it emerges from its closed system to join the world markets. It is perhaps the most controlling of the major markets' governments, yet has the least experience dealing with the established outside, capitalist world. The dynamics of international commerce are very complex and it is difficult for countries and companies to stay afloat in the global markets, even when they have spent decades actively participating in them.

China is still a communist country, now playing heavily in the capitalistic external market. Meanwhile, companies from free-market nations have been working within the strictly-regulated Chinese markets. The government controls its currency, its banks, its stock market, and the companies operating within its borders in its own way – as all countries do. However, the motivations for and transparency into the way China operates is often difficult for outsiders to understand. It is hard to ascertain whether the country is on economically solid ground and there are rising concerns that the market and businesses in China are slowing down and in worse shape than previously believed.

Today, the electronics industry is one of many that depends on China both for sources of raw material and production, as well as a new market for consumption of finished goods. If China stumbles as a supplier, a financier, or a consumer of electronics at this point would surely upset the careful balance of the economy of many advanced nations.

**China and IoT Overcrowding– Semiconductor Context:** It is time to consider the risk of so many products and companies counting on the IoT and on China for their growth as well as their sustenance, and the ramifications of delays or stumbling of today's large, inter-

twined markets. Analyze carefully how those products and companies stack up against their competitors, and then evaluate what would happen when many of the products designed around the IoT fail to draw customers, or the markets go soft in China or production becomes expensive or unreliable. The semiconductor forecast presented next assumes business-as-usual with regards to the IoT and China.

## **Memory Market Cues the Semiconductor Forecast**

There are two parts to a semiconductor forecast – supply and demand. Current demand drivers and industry consolidation have been highlighted so far, along with a couple of concerns. Some of the factors that influence chip supply will be examined in this section, looking at CapEx and memory, leading to a memory and semiconductor revenue forecast for 2016.

### ***How Suppliers Match Demand Growth***

Demand for semiconductors grows relatively steadily. New and more demanding applications team up with expanding markets to drive a continually-increasing demand for transistors.

Chip suppliers use two tools to match their output to this growth: They produce more wafers and they squeeze more transistors onto each wafer. More wafers can be produced by adding manufacturing capacity; which only takes money, also known as capital spending or capital expenditure (CapEx). It is more difficult to fit a steadily-increasing number of transistors onto a wafer. In general, process shrinks do the trick, as embodied in Moore's Law. This takes a lot of R&D, while increasing capital spending since expensive new tools must be added to scale to the finer geometries of the new process.

Advancing either of these tools too soon can result in an oversupply of output, or too slowly can create a shortage. Most of the past several cycles have been driven by too much or too little capital spending, so CapEx deserves a review.

## **CapEx Drives Most Semiconductor Cycles**

Contrary to conventional wisdom, semiconductor cycles are still influential, so the key to providing a good forecast is to understand when and how the industry will undergo supply/demand mismatches, and to understand the outcome of the transitions into and out of an oversupply.

During a typical semiconductor cycle, mismatched CapEx in one year drives a product shortage or oversupply two years down the road. Most of the swing comes from the memory sector, which is an undifferentiated commodity requiring a high capital intensity. In other words:

1. Nobody really cares whose DRAM or NAND flash they buy, as long as it's cheap.
2. Memory fabs (wafer fabrication plants) cost \$8-10 billion to build and equip.

Objective Analysis relies heavily on CapEx to predict how the semiconductor market will behave. This has led to a consistent level of accuracy in our forecasts as shown over the past eight years (see Table 2). These forecasts, given at the end of the preceding year, were very close to the actual outcome.

Each of these forecasts was modeled with a focus on capital spending without trying to predict macroeconomic phenomena. The global financial collapse in late 2008 created a demand lapse in the first quarter of 2009 that this methodology could not anticipate, resulting in the only year in which the Objective Analysis forecast was significantly in error. Such demand reductions are rare,

having only occurred in 2001 (Internet bubble burst), 1985 (PC demand collapse), and 1975. The global financial collapse caught everyone in the developed world by surprise, not just semi-conductors.

**Table 2. Objective Analysis' Forecast Accuracy**

Year	Forecast	Actual
2008	Zero growth at best.	-3%
2009	Growth in the mid-teens	-9%
2010	Should approach 30%	32%
2011	Muted revenue growth: 5%	0%
2012	Revenue drop as much as -5%	-2.7%
2013	Revenues increase nearly 10%	4.9%
2014	Revenues up 20%+	9.9%
2015	Revenues up ~10%	TBD

Our prediction of roughly 10% growth in 2015 was also hit by a minor demand lull, but not enough of one to make the DRAM market unprofitable. Late in 2015, the year seems poised for zero growth, stemming, in part, from a mild oversupply driven by smartphone and PC sales that fell below predictions.

Another factor was the devaluation of both the Euro and China's RMB. In fact, the European Semiconductor Industry Association (ESIA) was careful to point out that the region's revenues showed growth when measured in Euros, and only looked negative when revenues were converted to dollars.

Objective Analysis is proud of its forecast track record. Our high degree of accuracy stems from a sound methodology that takes into account a number of critical factors and embodies them in a field-proven model. The net result is a forecast that is based on science, rather than art, and is the most consistently-accurate forecast in the industry.

This year the role CapEx plays on the semiconductor outlook is different as will be explained.

### 3D NAND and Moore's Stall

As mentioned, increasing the number of transistors per wafer is one of the ways that semiconductor makers match output to demand. That can cause issues.

Since semiconductor makers plan to match demand growth through both increased wafer starts and increased transistors per wafer, then a shortage can stem from a delay in producers' ability to increase the number of transistors they can print onto a wafer. This doesn't happen very often, but when it does, it causes a shortage. On the other hand, there is no case where the transistor count increased too rapidly to cause an oversupply.

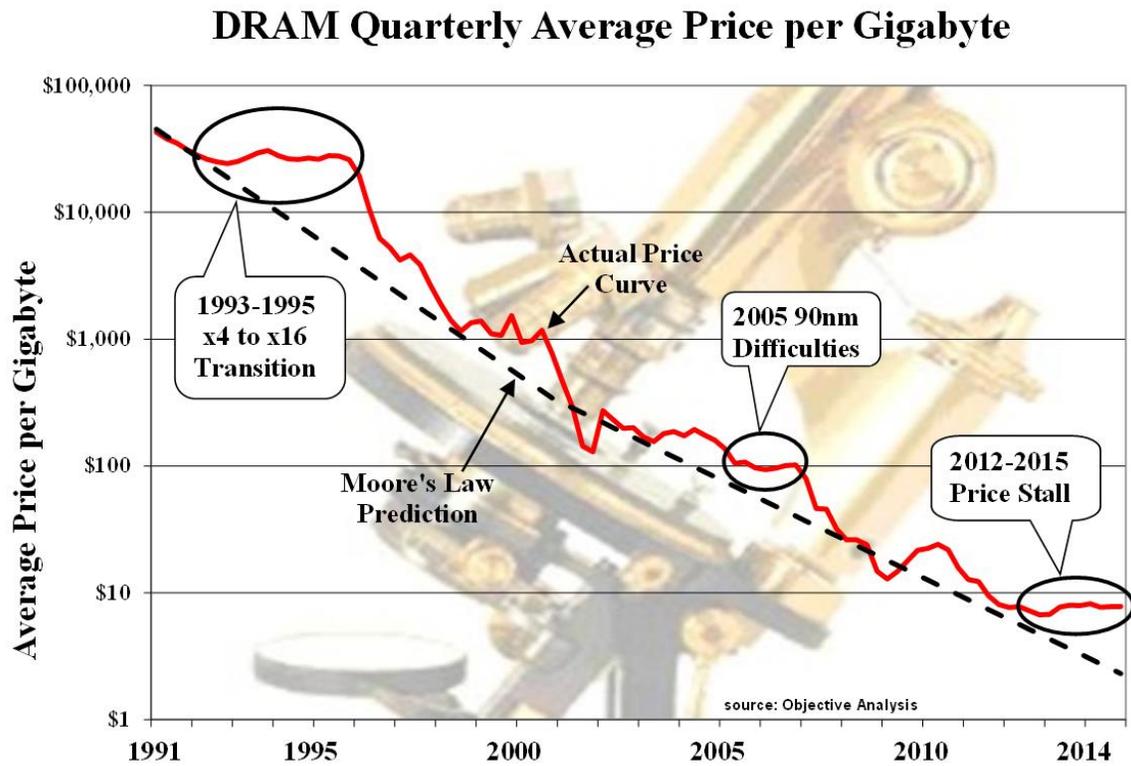
Figure 6 provides a good illustration of the results of such delays. It charts DRAM average cost per gigabyte from 1991 through 2014. DRAM is used because it provides a very simple picture: DRAM's production cost generally follows a Moore's Law trend, decreasing at

an average annual rate of 32%. DRAM is also a good proxy for NAND flash, since both are commodity memory chips, and trends are likely to recur in both markets.

Prices flatten during a shortage, collapse to cost at the onset of an oversupply, and then follow the cost curve until the next shortage develops.

Three periods of extended stable pricing are circled in the graph of Figure 6:

1. The 1992-1995 shortage that was caused by the conversion of DRAM interfaces from 4-bits to 8-bit and 16-bit widths.
2. The 2003-2006 shortage was protracted by a full year from difficulties migrating to the 90nm process node. No prior process migration caused so many problems for the industry.
3. Prices flatten from mid-2012 until the end of 2014. If 2015 prices were added to this chart there would have



Source: Objective Analysis, 2016

Figure 6. DRAM Average Price over Time

been an important price fall in the second half of 2015, but prices would still be above the cost line similar what is seen in 2004.

Note that each of the first two periods of flat pricing were extended by a single difficulty that caused DRAM supply to fall short of demand. Each of these single difficulties lengthened an existing shortage by one to one and a half years.

The chart reveals the future of NAND flash. Currently, NAND flash faces a dozen or more new and significant changes that will stall its migration from planar to 3D volume production. This will not cause a 12-year delay, but will cause delays of over one year and will result in shortages.

As semiconductor process technology approaches the physical limits of atoms, more of these “Moore’s Stalls” will delay or halt the ability to shrink transistors.

NAND will end up in a shortage of growing severity until every single one of these dozen changes has been solved. As this plays out, some DRAM capacity is likely to be temporarily converted to NAND flash production, which will cause a companion DRAM shortage.

Prices for both will flatten, with DRAM bit shipments increasing about 20%, and

NAND flash bit shipments growing about 35% in 2016. Revenues are the product of these flat prices and growing bit consumption, resulting in memories undergoing 14% revenue growth over the course of 2016.

As always occurs, the swings in memory will drive a smaller semiconductor market swing, giving the overall semiconductor market a growth rate approaching 10% in 2016.

## Happy New Year 2016

Semiconductor revenues trailed off in the second half of 2015, and 2016 is likely to continue to be soft, aggravated by negative worldwide economic conditions. There are many applications like automotive and imaging that should keep the electronics market vibrant.

Meantime, keep an eye out for unsustainable overcrowding in the IoT markets while trying to understand what is really happening in China as an economy, a producer, and a market. All-in-all, after looking at CapEx, Objective Analysis holds an optimistic outlook, and forecasts that semiconductor revenues will grow nearly 10% in 2016.

*Tom Starnes and Jim Handy, January 2016*

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