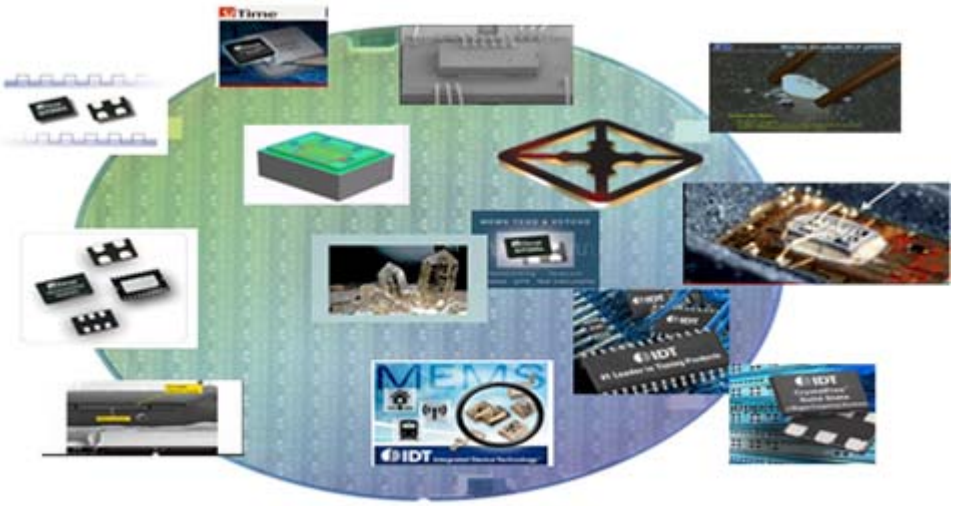

WORLDWIDE SEMICONDUCTOR TIMING

CY2015 – 1H CY2016

Combined Semiconductor Report & Analysis…

Consulting Services & Associates LLC

A Mainstream Market Report

FULL spectrum coverage for all of WW Semiconductor Timing:

- ***Crystals and Oscillators**
- ***Semi Clock & Timing**
- ***Die Sales**
- ***RF Timing Components & Modules**

Semiconductor Clock & Timing CY2015-16

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Semiconductor Timing; CY2015-16

PREFACE

From the Desk of Mark Sherwood, CEO. CS &A LLC

Mark Sherwood, CS &A LLC CEO and Founder

Global chip sales are off to a sluggish start in 2016, according to new figures from the Semiconductor Industry Association (SIA). Worldwide sales of semiconductors reached $26.9 billion in January, down 2.7% from December and down nearly 6% from the same period in 2015. "Global semiconductor sales decreased in January across most regional markets and product categories, largely due to softening demand and lingering macroeconomic headwinds," said John Neuffer, president and CEO of the SIA. "Despite these challenges, modest market growth is projected for 2016, following essentially flat sales last year."

What goes for Semiconductors as a whole, goes for Semi Timing too. In terms of trending anyway… We all have heard and know that the Processor is the ***"Brain"*** behind the system, but few understand that it is the Clock signal that acts as the ***Heart***, and the clock signal is the engine that steps each move the Processor makes. Categorized as an Analog Mixed Signal Semiconductor design, when looking at the markets, use cases and applications or doing any research and/or analysis you must first consider exactly what you are counting in the mixes…

CS &A LLC has, over the more than 10 years since we made entry, been very careful when looking at the whole or sub-segments that actually make up this high valued Analog Mixed Signal Semi TAM. As such we have developed a now widely accepted set of definitions, associations and segmenting that has become known and accepted as the most accurate model today for Semiconductor Timing.

Representing a WW TAM in excess of ~$4.8 Billion USD for CY2015, we continue to see evolution and change to this dynamic semi segment.

Since the Electronics Industry was founded, Semi Timing has expanded from traditional simple Quartz based designs into several technologies and designs. At the high water mark, in 2005, the Semi Timing Industry alone supported 166 suppliers in the Worldwide supply chain, creating, manufacturing, and producing extremely high volumes since you find Semi Timing Solutions in 100% of all Synchronous Systems across multiple Timing Domains ranging from the Processor/Memory, to Hi speed serial I/O, to Physical layer and MAC Timing, and especially Time of Day (TOD), where the 32KHz frequency reference along with the Real Time Clock (RTC) dominates in volumes and has become a ubiquitous item in most systems today.

Personally, I have had the pleasure of working in Semi Timing in one aspect or another for most of my career. I have been described by my peers as: "**BC**", or ***before chips***, and yes, I go back even beyond solid state too, and started with Tube theory and we had some new germanium diodes in the lab, but our designs were all discreet mixed signal designs… Things in this arena have evolved, expanded, been added to, and have been, for the most part, fully characterized; so today we have a mature, well balanced industry with stable mature processes, technologies, manufacture, assembly, testing, and distribution channels into a standalone, high valued Semiconductor Segment today, as noted worth more than $5 Billion USD. Things though, have changed…

In 2016 we see a contracted supplier base with fewer than **70** suppliers worldwide. Not through failure, but almost exclusively via MnA activities at unprecedented levels yielding a mature, streamlined segment. Today from a Technology standpoint, we have gained a lot of experience and knowledge surrounding SAW, and Quartz, and continue to learn as we go pushing the envelope, especially with MEMS and Compensated CMOS as well. We have seen use cases expand recently that have continued to open markets and application to levels of stability with variances measured in the low ppb! STRATUM 3, 2, and STRATUM 1 compliance can be achieved today with either of these technologies, most in some form of ovenized situation and design, and indeed we do see MEMS products in this space now with more coming in 2016.

In the end, TAM numbers reflect what you count, where and how you count it, and how you validate as well…

At CS &A LLC, we have split Semiconductor Timing into three distinct sub segments that when combined, have coverage for all targeted segments. Widely accepted by Industry and academia, these definitions have withstood test after test.

1. **Crystals and Oscillators**

Supports; XO's, TCX's, VCXO's, OCXO/OCSO's and all Quartz in play (AT cut, SC Cut, Std Parallel Fundamentals, High frequency Fundamentals, Inverted MESA, Harmonic OT (3rd and 5th OT)… Alone, we still find more than $3Billion USD in $$Revenues last year, so we continue to see shrinkage in volume and Revenues here, but looking mostly flat YoY, with cost reductions, more high valued solutions in the market, and further streamlining of the supplier base, can continue to grow despite pressures coming from all sides that could also limit the WW markets and continue the trend towards shrinkage…

2. **Semiconductor Clock and Timing** – This is the IC end of the business where for the most part, these are IC (Inline, Quad, BGA's etc.) based designs supporting;

Oscillators, Synthesizers / Frequency Generators, Zero Delay Buffers, Non-Zero Delay Buffers, Real Time Clocks, and Specialty Solutions for Programmable Skew, Redundancy and FailSafe, Waveform Integrity (Jitter Attenuators), Atomic Clocks, and more. We also include Die Sales to FCP (Oscillators and PLL based multipliers), also includes the RF Segment since volume is found in use cases supporting Applications that utilize primarily IC based Timing in order to get maximum flexibility out of the design which in turn is developed into Multi Chip Modules.

3. **RF Timing components and Modules;** here we include the plumbing that for high frequency, has major impact and effect.

Synthesizers, Frequency Generators, waveform integrity, splitters, mixers, modulators, demodulators, and now Data Acquisition has entered as a high valued target Market for precision and Ultra Precision class Semi Timing.

Semiconductor Timing has basic and fundamental specifications that determine the Value Added. These are multi-layered and include; Clock Synthesis, Frequency Range, Frequency Stability measured in ppm or ppb, and Accuracy focused in Jitter / Phase Noise, and various symmetry specs (Duty Cycle, Tr/Tf, etc.).

CS &A has defined the different levels of classes for these key specs. This could be/ should be considered a critical listing and definitions for some suppliers where pricing and value added is directly associated with these levels/classes. These include; Commodity, Complex Commodity, Precision, Precision Class 1, and Ultra-Precision classes. From a range of class viewpoint, consider that Commodity solutions see pricing granularity in pennies ($0.01), and fractions of pennies, to Precision class in Quarters ($0.25 USD), and Ultra-precision class valued in Dollars and not dimes…

*** Standard Timing Frequency Range= DC to 800 MHz, Traditionally, RF Timing begins, Typically at 1GHz…*

Simplified Definitions; Class of Solution; SEMI TIMING

CLASS OF SOLUTION	PERIOD STABILITY	ACCURACY	
Commodity	±100 / ± 50 PPM	*Jitter specs; Cycle to Cycle, Half Period, Designed in support of "Register to Register" transfers*	NON - ACCUMULATED JITTER
Complex commodity	±100 / ± 50 / ±20 PPM	*Integrated Phase Noise; ≤ pS RMS, 1.875MHz - 20MHz*	
Precision	±50 / ±20 / ±10 PPM	*Integrated Phase Noise; ≤ 350fS RMS, 12KHz - 20MHz*	ACCUMULATED JITTER
Precision Class 1	±50 ±20 ±10 / ±1 / ±0.5 PPM	*Integrated Phase Noise; ≤ 100fS RMS, 12KHz - 20MHz*	
ULTRA-PRECISION	±20 / ±10 / ±1 / ±0.5 PPM / ±0.1 PPB	*Integrated Phase Noise; ≤ 10fS RMS, 8KHz - 20MHz*	

Simplified, the above chart gives some guidance to these critical definitions since they directly impact the positioning and the associated $Value Added Appreciation Factor, which creates and sets the trending for the effective $Pricing, and also impacts the resulting device $ASP over volume… What CS &A says is to maintain your value added! Anyone can cut the price to meet comp, and it takes little to no planning to do so, especially if one considers the current socio economic conditions as well, and how this seemingly small event can cause ripples all the way thru the fabric of our industry. This is, we consider to be, a drastic action, and an unhealthy one at best. There is much to say both for and against

Each and every year, in support of creation of these Market Reports, CS &A spends a lot of time, resources, monies, and efforts on research into and across all markets and most all use cases and applications for Semiconductor Timing. We created special Supplier surveys and send them out to the supplier base each year that note Volumes, $$Revenues, technologies in play, and more, all by the defined Oscillator Product Buckets *(I.e.: XO, TCXO, VCXO, OCXO, etc.…)*. Combine with channel research (channel inventories, players), and our own in house developed special paths for market technology, vendor intelligence, Channel updates, and very large OEM/ODM/CM's interviews and an active level of participation in the industry (*CS &A provides direct Marketing Support for many OEM Semi Timing players*), then you will have a much more solid foundation for our Market Reporting with understanding of how, where, why and what we included, and counted in our analysis, then, factored the numbers for our reality checks, and subsequently positioned / repositioned back into the market based upon the actual measured performance of the product /and the actions of the company…

All during the calendar year we make the time to attend industry specific Conferences and events that are relevant and have a direct impact on the business. CES, MEMS conferences *(MEPTEC, MEMS Congress, and more)*, JEDEC, ANSI, IEEE, IDF, Regional RF groups, The Small Cell Forum, are just a few of the efforts we make every year in support of our research and intelligence gathering. We utilize what we call a ***"Top down, Bottoms up"*** method for reporting our consumption numbers for OEM suppliers…

As noted, a key differentiator for us has CS &A working as an *active participant* in Semi Timing today, working as a provider of specific and key Marketing Support Services to several suppliers and OEM high volume consumers of Semiconductor Timing. Today, these efforts range from; focused competitive research projects, to product definition with support committed thru roll out to first $xM in Revenues. All of our consults are considered as a "Dedicated, Limited effort", with work done onsite and in our offices, or our captive laboratory.

Some recent CS &A Consult Clients in the US, APAC, and Eurmea regions include; *IDTI, Avago, ADI, Avrio-PDI, CTS, Multigig, Silicon Clocks, Silicon Laboratories, Cypress Semiconductor, Vectron, Taitien, TXC, Hitachi (Japan), SiTime / Megachips*, and others… We actively continue these efforts thru the 2016 calendar year, and consider CS &A when and if you have a project in mind or have questions in this regard, please write to me directly at; *mark@timing-is-everything.net.*

2015 proved to be a real challenge for many suppliers in Semi Timing with pressure coming from; aggressive price erosion, currency valuations and conversions, increased Share (SOM) for MEMS and the

All Silicon Oscillator (ASO) (*using compensated CMOS Technology*), increased pressure from Target Socket Overlap between the Xtal and Oscillator suppliers and the leading Clock and Timing Players on the IC side (*include IDT, ADI, TI, Pericom, Cypress Semi, Micrel, and others*), and increased levels of Integration of the timing function into the ASIC/ASSP/SoC (*the Qualcomm Smartphone chipset as an example*). BUT, I take this opportunity to point out that the Qualcomm IP stays with their chipset and reference design, and most importantly, not every SmartPhone provider is using that IP. In fact, most do not so the TCXO remains viable in support of the GPS function *(*10-26MHz, 0.5ppm, and low cost; ~$0.38)*.

This trending will continue and is evident as we close this first quarter of CY2016. Price erosion thru competitive situations will remain at an aggressive level. The value added levels of appreciation have been all but lost in the low end with almost any Commodity Class Semi Timing Solution, while at the high end with many synthesizer/frequency generators, waveform Integrity for Jitter Attenuation at the input of the PLL Multiplier, and the fanout distribution buffers too. All of these high end categories remain fertile ground for Semi Timing Suppliers with high performance product families that fit well into these defined buckets… High end designs with output Frequencies actually in use cases as Frequency References up to 800MHz are delivering performance in terms of stability of that output below STRATUM class levels using a Fractional N, Sigma Delta Digital Hybrid PLL complete with inherently low noise (at the noise floor, 20MHz out) and set the standards in play today for close in Integrated Phase Noise where we can honestly say that the quality of the clock signal at this particular node, is key to the System BER (Bit Error Rate). This one test is very long and expensive to run. Consider that we are talking about a system level spec that typically says:" that a failure would occur if the system lost more than one (1) single bit in 30 hours of high speed serial I/O data running over the interface (*sending and receiving big files will do it*)."

This accelerated rate of integration requires some high density processes to support this high level of integration of what is a complex analog mixed signal function. Most solutions today deal with an LC based Oscillator circuit design and as such are sensitive to interference both radiated and received with considerations in design and in physical layout for tolerance to radiated fields, and modulation domain effects, which result in some keep out areas and restrictions on the ASIC and can also prove sensitive towards compliance to what used to be called the Belcore standards dealing with;

- Jitter Generation
- Jitter Tolerance
- Jitter Transfer

As this calendar year progresses, from both a technology and Semi Timing portfolio viewpoint, I fully expect to see the market settle down rapidly as the supplier base evolution slows a bit limited by the markets themselves.

Technology inflection points remain lacking (at zero!) so we can continue to create solutions without a change in fundamental driving technologies (Quartz, MEMS, CMOS). Remember that the truly high volume lies in products that are mature in production with typically 3-5 years in the market before reaching said high volume. I expect the changes to be more subtle moving forward for the year, and we expect continued supplier base consolidation as MnA activity slows, but does not end. Today the list of available entities has been cut down to a truly short list…

2.1.1 MacroTiming becomes more widely accepted

We noted last year, the entry of a new Semi Timing Product Category dubbed: "Macro Timing", where high levels of integration of the key functional blocks were / are now available in a single package. Options exist for both Partial and Fully Integrated versions with a high value added appreciation level. Legacy is achieved by providing this solution with a standard feature Set in a Quad or BGA package with pinouts supporting the fanout buffer… This is a virtual drop in, and no modification to the targeted PCB is required… This is a significant and compelling item with high revenue potential for whoever takes that plunge and makes the commit for the functionality – delivering the needed frequencies, and at the same or better AC specs.

2.1.2 SiTime acquisition still reverberating loudly

Last year we witnessed the largest MnA deal in the history of Semi Timing with the SiTime acquisition for $200M USD, by Mega Chips, Japan for an effective >11X Revenue multiplier… Significant in many ways, the biggest of which is the way Japan invested in SiTime and continue to operate it independently. Just about 1 year from the closing of the deal, we can again congratulate the team at SiTime with

acknowledgement about doubling of $revenues to the $38-42 Million USD range with volumes doubling YoY to >120M units… In fact, these numbers place the company, and MEMS based Semiconductor Timing as the WW leader in Programmable XO type solutions (Single Output, SMD or CSP packaged Programmable fixed frequency Oscillator). A significant milestone and a noted achievement now behind them in business, and also from a technology standpoint; should we continue to refer to MEMS a Disruptive Semi Timing solution? Perhaps not anymore, but we do offer our hardiest congratulations on the achievement.

MEMS Based Semiconductor Timing

OK, so what is happening in the MEMS based Timing segment? Well, we already talked a bit about the current leading MEMS based Timing supplier; SiTime, who moved swiftly and loudly into the top tier in Programmable Oscillators in 2015. Today there are only a handful of suppliers providing any measureable level of MEMS based timing Participation at all. On this short list today include what is called the list of 10;

1. *SiTime*
2. *Micrel / Discera*
3. *Maxim*
4. *Vectron*
5. *TXC*
6. *SIEKO EPSON (QMEMS™)*
7. *MURATA (VIA THE ATI ACQUISITION)*
8. *CYMATICS LABORATORIES*
9. *NXP SEMICONDUCTOR.*
10. *Abracon*

This short list includes entities shipping today and in pre-production. Some additional development may be required, and some may be seeking a strategic and tactical partnership… Note that no priority is intimated nor any rankings by this list. Line item number assignments were 100% random…

2016 has already bolstered volumes across the Industry with increases in volume for some key drivers crossing and spanning multiple Market Segments from Consumer Electronics in Wearables, in Computing for both Motherboard and Non Motherboard use cases like Printers and MFP's, Gaming and Servers too. Industrial with some in double digit % growth YoY with more than one Timing Domain helping to push volumes and the mix, upwards. We have to do much more than hope for better. Indeed, my personal Mantra is related and I have been quoted time and time again saying that Hope is good, but Hope is simply NOT a good strategy, better have Plan B. Great words for sure, ad best to have that Plan B.

This year you will see some new organization for content within our unique reports. We went ahead with some specific and focused research and made some changes in format, sequence, and limited some content. These changes are designed to help streamline the reports and maintain the focus in reporting… Just so much going on, that it gets crowded a bit…

We hope you will appreciate the new format and streamlined content. As we try to keep the focus tight and limit the pages for print considerations, in so doing we must ensure we not compromise on quality of intelligence itself or our ability to communicate the information. As such, we welcome and ask for your feedback and comments, so please, be sure to talk with us or your local CS &A representatives before we close out the 2nd Half of the calendar year…

Thank you again for your continued support and for your business… It is both noted and appreciated.

M R Sherwood

Mark Sherwood
Founding Partner, Principal Associate
CS &A LLC