# TND6001/D

# New EMI Challenges Facing OEMs as They Incorporate High Speed Serial Interfaces into Streamlined Smartphone Designs

**ON Semiconductor®**

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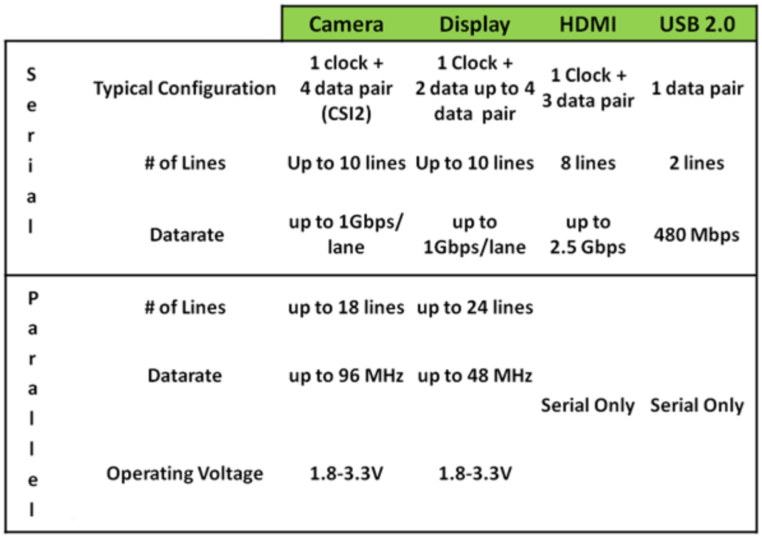
## TECHNICAL NOTE

Smartphones represent the fastest growing segment of the cell phone market, with 302 million units shipped in 2010, representing a year-over-year growth rate of 74% according to figures from IDC [1]. The expansion of this segment is expected to continue, as handset manufacturers segment the market based upon operating systems, applications and feature sets. A study conducted by Portio Research predicts that smartphones will constitute approximately 40% of total cell phone handset shipments by the year 2015 [2], with traditional brands being joined by new entrants into the market looking for a piece of the action.

Handset customers are demanding increased download speeds and enhanced audio quality, in form factors that fit comfortably in a pocket or purse. They desire one device which has applications and interfaces capable of supporting increasingly bandwidth-intensive functionality, with high resolution cameras (typically with 8 Megapixels or more), higher quality displays (including 3D capabilities), ports to connect the handset to larger format displays, and the means to drive high definition video, through MHL (Mobile High-Definition Link) or HDMI® (High Definition Multimedia Interface) all being incorporated.



| | | Camera | Display | HDMI | USB 2.0 |
|---|---|---|---|---|---|
| Serial | Typical Configuration | 1 clock +<br>4 data pair<br>(CSI2) | 1 Clock +<br>2 data up to 4<br>data pair | 1 Clock +<br>3 data pair | 1 data pair |
| | # of Lines | Up to 10 lines | Up to 10 lines | 8 lines | 2 lines |
| | Datarate | up to 1Gbps/ lane | up to 1Gbps/lane | up to 2.5 Gbps | 480 Mbps |
| Parallel | # of Lines | up to 18 lines | up to 24 lines | Serial Only | Serial Only |
| | Datarate | up to 96 MHz | up to 48 MHz | | |
| | Operating Voltage | 1.8-3.3V | 1.8-3.3V | | |

**Figure 1. Comparison of Parallel and Serial Configurations**

(Actual speeds dependent upon cable lengths, wire thickness, and interface configuration)

Interfaces which connect the display, camera, and data port I/Os in smartphone handsets are leading to increased proliferation of differential signaling across new serial interface standards within the handset space, such as MIPI® (Mobile Industry Processor Interface) and USB (Universal Serial Bus), as well as the aforementioned HDMI and MHL. These differential signaling standards allow the transfer of data at much greater rates than the legacy parallel interfaces, and can be implemented over fewer lines while running at lower voltages.

Though the move to high speed serial interfaces both supports the data rates (see Figure 1) and adheres to the space constraints being set for modern smartphone design, there are other issues that need to be considered. The objective of this paper is to describe how new advances in semiconductor technology will be able to better address these issues.

**January, 2014 − Rev. 1**

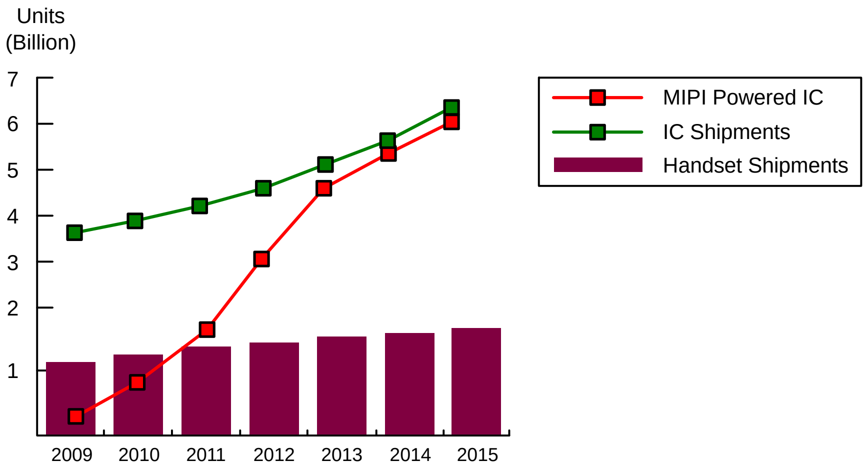


**Figure 2. Comparison of Handset Shipments and Related IC Shipments [Source: ABI Research]**

### High Speed Serial Interfaces

The differential signaling utilized in high speed serial I/Os permits faster clocking speeds, which enables higher resolution cameras and displays to be incorporated into cell phone handsets and thus greatly enhances the user experience. In addition, the lower operating voltages these interfaces require translates into to less power consumption and thereby extends the battery life of the handset, which is of benefit to all smartphone consumers. However, it introduces a level of complexity in design, and challenges of protecting against electrostatic discharge (ESD) events and creates a smartphone ecosystem rich in potential electromagnetic interference (EMI) challenges. It is important to note that many of the new entrants into the smartphone market are well familiar with differential signaling, as they serve other consumer electronics markets where it has become an interface standard, such as LVDS (Low Voltage Differential Signaling) in the laptop and computer market. This has the potential to leave established handset brands at a disadvantage.

### Differential Signaling

Differential signaling has become the de facto standard for high speed serial interfaces. It provides higher noise rejection when compared to the same interface using single ended signals. Figure 3 describes the basic benefits of differential signaling by showing the receiver as a basic differential amplifier. Since differential signals are 180 degrees out of phase, they will add at the output of the amplifier after the inverted signal is subtracted (inverted) by the differential amplifier (as shown in the diagram on the left).

The diagram on the right shows identical signals as the input to the differential amplifier. These are called common mode signals since the signal is common to both inputs of the receiver. This type of signal could be caused by radio frequency (RF) interference from the power amplifier in a cell phone getting coupled on to data lines either through radiation directly to the lines or from ground coupling. The differential amplifier will provide cancellation to common mode signals as is shown.

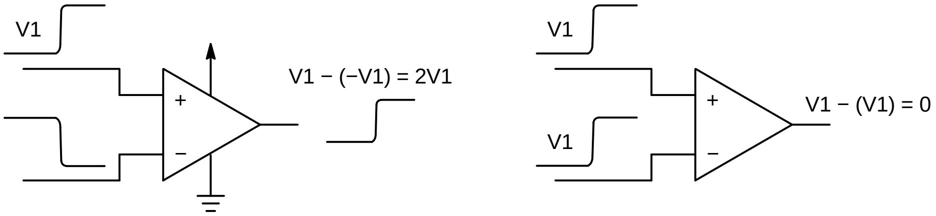


**Figure 3. Differential Signaling**

A passive common filter provides similar common and differential mode properties through transformer action in the coupled inductors of the device. This is shown in Figure 4. On the left, the input current waveforms are again 180° out of phase for differential signaling. This current is in phase with the induced currents in the other coil so will be attenuated only by the series resistance of the coils. The diagram to the right shows common mode or in phase current waveforms as inputs to the coupled inductors of the device.

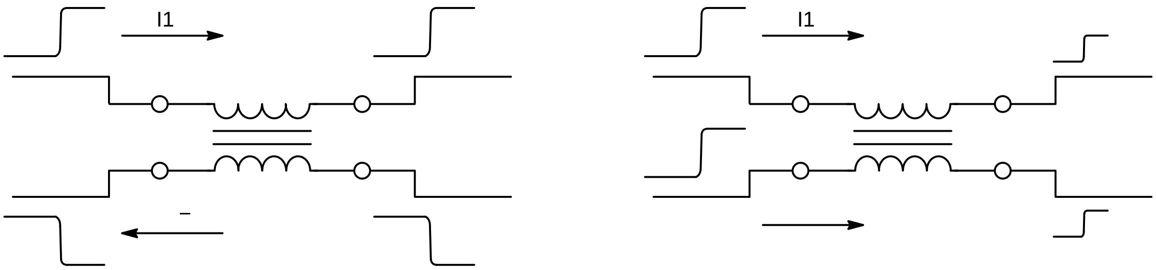


Figure 4. Common Mode Filtering (180° out of phase and in phase)

Data moving through wires on a rigid or flexible PCB creates electronic noise, which can interfere with the reception of signals from the cellular network, and interfere with the functionality of the smartphone itself. The movement data within a handset will create a certain degree of noise and this can potentially impact on critical handset functions (such as placing/receiving calls, viewing content on the display, taking pictures or video, or browsing the Internet). Having multiple data lines all situated within a very small space exacerbates interference within the system. Given that the smartphone era is thus resulting in handsets that are proving to be considerably noisier environments, steps need to be taken to counter the increased levels of interference arising, so that handset performance is in no way compromised and data errors can be avoided.

As already mentioned, of significant importance is the growing susceptibility of smartphone designs to ESD. Portable devices are by nature more vulnerable to ESD than stationary electronics products. With digital ICs geometries continuing to closely follow Moore’s Law, relying on semiconductor geometries that are becoming smaller and smaller with each generation, the circuits in which they are placed into are being put at greater risk of damage from ESD events.

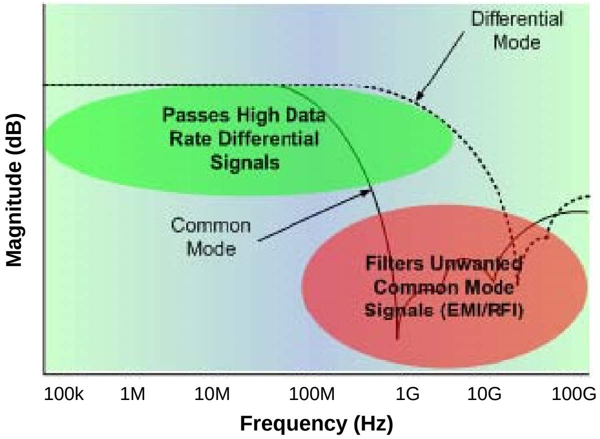


Figure 5. Common Mode Filtering

**Current Methodology for Suppressing EMI**

Passive filtering, using common mode filter (CMF) devices, permits high speed differential signals to pass through the filter without affecting data integrity (see Figure 5). Common mode noise, an artifact of differential signaling, gets attenuated, preventing this noise from interfering with the data and voice communication between the smartphone and the wireless network. Filtering common mode noise at cellular radio operating frequencies is especially important in a mobile handset because radiated field strength from common mode currents increases linearly with frequency [3]. Therefore, any transmission line in the handset that is susceptible to high frequency common mode noise can be a source of EMI if common mode noise is not properly filtered. This methodology enables a marked reduction in the effects of interference without having a major effect on the signal integrity – something that is vital if the particular smartphone model is to see widespread consumer adoption.

Signal integrity is also an issue. Ferrite and ceramics based solutions have rather shallow common mode noise attenuation curves, and do not strongly suppress noise from the cellular radio bands of interest, namely from 700 MHz to 2,500 MHz. Further, ferrite based common mode filters attenuate low frequency noise, but fly back at higher frequencies, permitting pollution in the cellular radio bands. Then there is mechanical robustness. Construction and package integrity of the ferrite and ceramic based solutions use ferrite or low temperature co-fired ceramics (LTCCs) as the substrate to create their coils. Larger ferrite and ceramics based solutions format construction devices have the best performance, but occupy the most board real estate. Smaller ferrite based solutions attenuate common mode noise less, and at lower frequencies, and fly back at the cellular radio bands. Finally some ceramic and ferrite based providers make no provision for ESD protection devices in their common mode filter arrays, or use a varistor-based approach which does not adequately protect the interface and the baseband or applications processors.

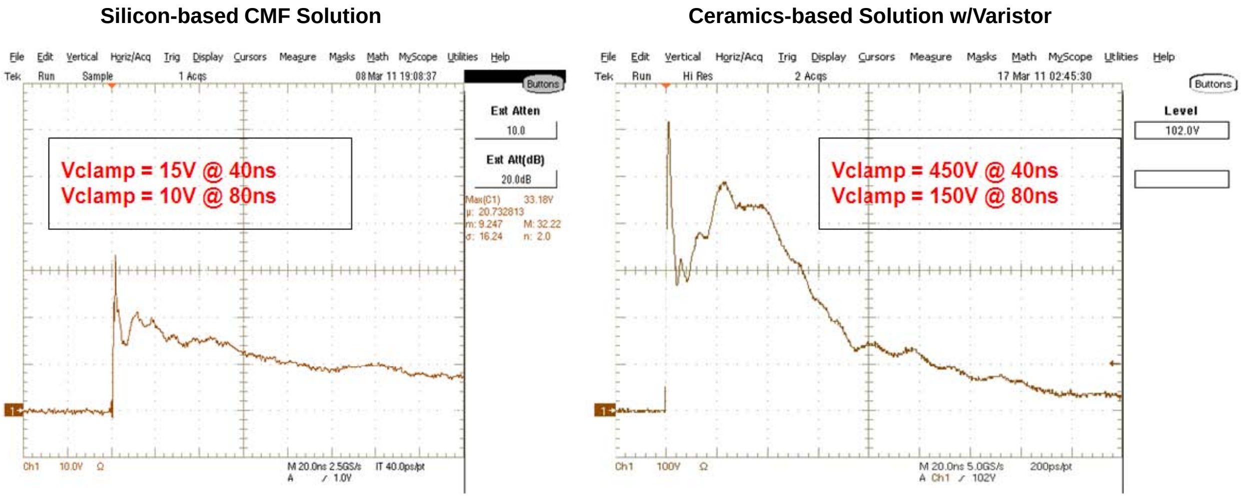


Figure 6. Comparison of ESD Clamping Capabilities of Ceramic and Silicon-based CMF Solutions

Differential signaling typically occurs in multiple pairs. There are four data lanes for HDMI signaling, which represent four pairs of common mode filters. MIPI differential signaling, camera serial interface (CSI) and display serial interface (DSI) require a minimum of two pairs for differential signaling (one pair for data, one pair for the clock signal for the data interface).

Ferrite or ceramics based solutions address the multiple pair problem by creating larger LTCC substrates and ganging multiple pairs of CMFs together. Growing the substrate addresses the need for ganged CMFs, but introduces concerns about mechanical robustness. Ferrite and LTCC substrates are brittle, and can undergo catastrophic damage by incidental drop, or through incidental flexing of the rigid or flexible PCBs during the customer experience with the smartphone. Cracks can appear in the ferrite or the LTCC substrates, damaging the core of the CMF structure, and rendering the components useless for EMI suppression or ESD protection. Comparable solutions with silicon based ESD protection require roughly 60% more board space per interface than a silicon-based CMF with ESD protection.

Legacy CMFs also exhibit performance issues over the commercial temperature range (particularly at +85°C). Ferrite cores saturate, resistances increase, and change filtering performance at elevated temperatures. In a smartphone, the internal temperatures can reach as high as +85°C while the power amplifier is in operation, and the wireless device is communicating over the cellular system.

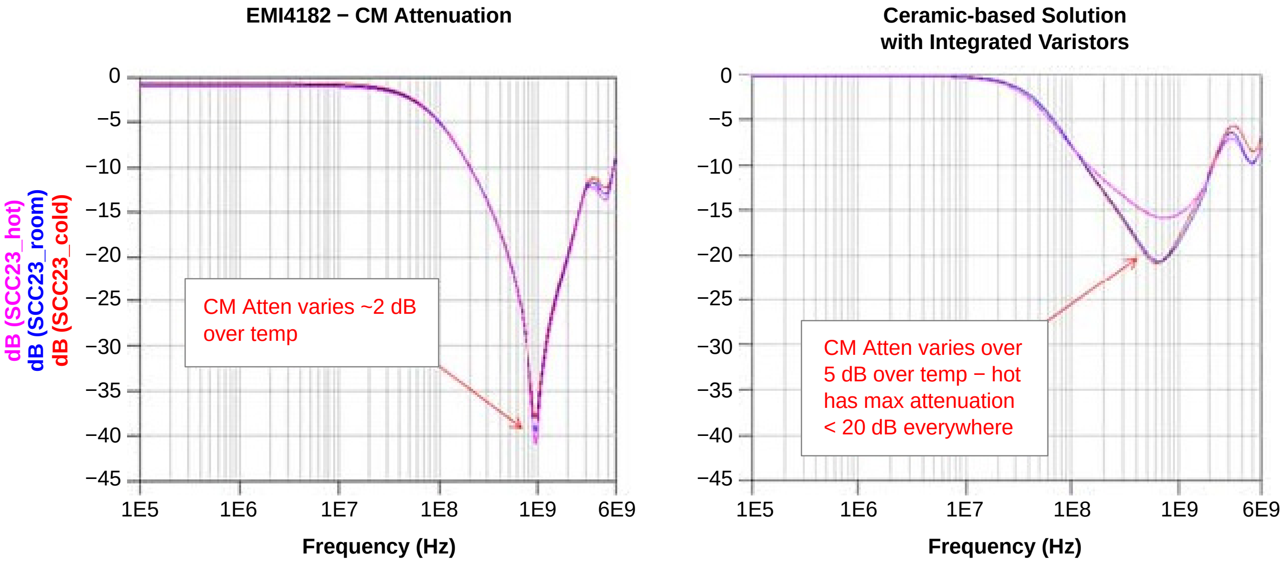


Figure 7. Comparison Common Mode Filter Performance for CMFs versus Ceramic Filters

Conventional CMFs are based on ferrite cores or ceramic substrates, are comparatively large in size, and by definition, are single in purpose. They address EMI suppression, but are not efficient from a space or cost savings standpoint, and do not adequately address ESD protection, a vital concern for smartphones using leading edge baseband and applications chipsets. The cost/performance, and board space/performance ratios of these devices are unattractive. Figure 8 shows the cost versus performance of different filtering solutions.

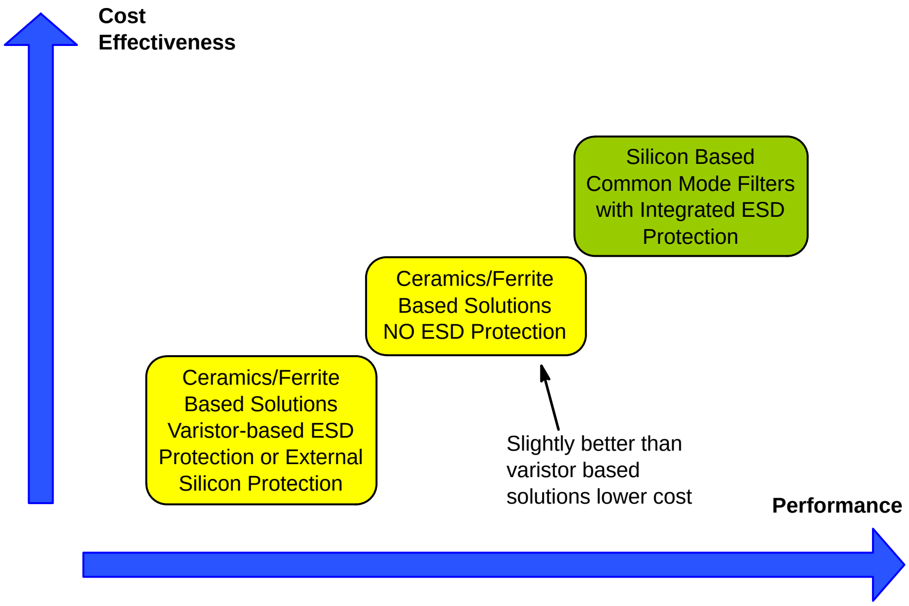


**Figure 8. The Cost Effectiveness and Performance of Different Filtering Solutions**

Varistors, included in some common mode filter arrays provide handset designers with what could best be described as false hope. They are known within the handset industry for not protecting well against ESD attack, and for passing relatively high levels on ESD spikes on to the chips that they are designated to protect. As a result they have fallen out of favor with design engineers who are knowledgeable about system survival in an ESD environment.

## An Integrated Approach to EMI/ESD

The specifying of conventional CMFs will prove to be a major hurdle if the evolution of smartphone is to continue, setting a limitation on the complexity of these products and the levels of functionality they can support. Innovative semiconductor technology is now being developed however to allow cell phone manufacturers to be able to realize the feature-rich smartphones they have set out in their product roadmaps. Creation of silicon-based filters, rather than ones using a combination of ceramic or ferrite materials, could hold the key to further progression in smartphone design. ON Semiconductor recognized at an early stage the transition from parallel to serial interfaces, driven by the adoption of MIPI as an interface standard for display and camera, and HDMI and variants of USB for external interfaces. In anticipation, the company embarked on a major development to introduce a product line for serial interfaces which would integrate silicon-based devices to provide suppression of EMI and ESD protection.

By applying knowledge gained while constructing copper over aluminum inductor process developed for ON Semiconductor’s low pass filter products, it has become possible to expand the process to create CMF coils embedded in a silicon substrate. These coil pairs are constructed of a base aluminum metal with copper deposited in subsequent semiconductor processes. This has proven to be an effective countermeasure to common mode noise, while having little impact on the differential signaling, permitting the differential signals to pass virtually unimpeded.

Individual dies, co-packaged with one another create a turnkey solution for smartphone design teams, featuring strong noise rejection, and robust, ESD protection. These mate to the most popular interfaces, including USB, MIPI, DSI and CSI, and HDMI. Future iterations will include building these common mode filter structures on a extremely low capacitance ESD protection structures, improving the integration and streamlining the manufacturing processes.

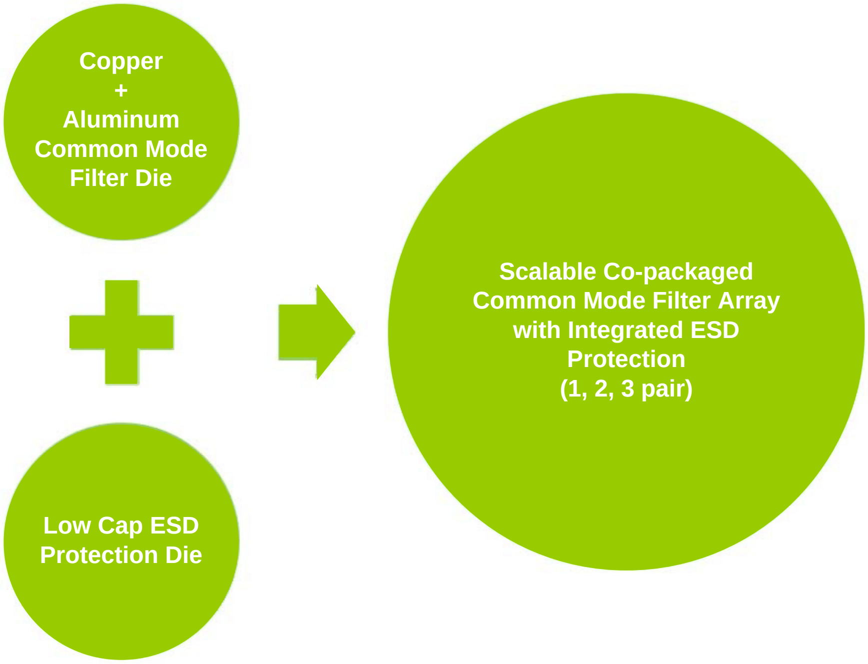
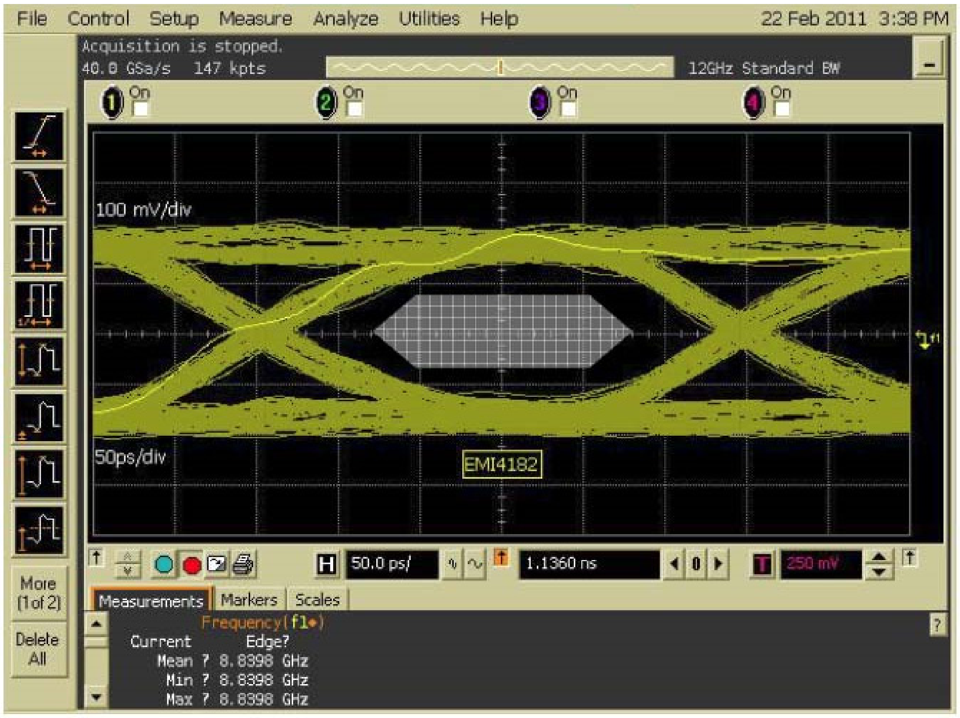


**Figure 9. Manufacturing Flow of Silicon-based Common Mode filter**

Implementation of the EMI filtering and ESD protection activities in a single device, as opposed to having discrete CMFs and transient voltage suppressor (TVS) diodes, has several major advantageous implications for smartphone design. It means that valuable board space can be saved, it lowers the bill-of-materials, it simplifies procurement, and finally it makes the assembly process easier as complex routing can be negated.

Having ESD protection built into the CMF substrate does not appreciably degrade signal integrity levels, and provides protection against repeated ESD events. As well as having much smaller footprints and attaining equivalent performance metrics to conventional coil-based CMFs (with common mode rejection of 15 dB at 500 MHz and 3 GHz cut off frequency [4]), these more integrated devices offer noise suppression over a far greater range of frequencies. Key features of these silicon-based CMFs include broadband attenuation across all smartphone communication frequencies. Designers can expect common mode attenuation of −25 dB starting at 700 MHz, an important frequency for LTE and 4G communication.

Its fast acting ESD protection safeguards against virulent ±15 kV contact strikes is superior to varistor-based products, which react much more slowly, due in part to the differences in construction. The slower response time of varistors translates to subjecting the interface to higher levels of voltage, and potentially damaging the products that the ESD devices were intended to protect. Silicon-based products can suppress 15 times more effectively than varistor-based solutions in an ESD testing environment. Ganged in 0.5 mm pitch plastic packages, they are pinout compatible and mate to the most popular interface standards. They can pass signals supporting HDMI 1080p 24 bit full color, without perturbing the signals.



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Acquisition is stopped.
40.0 GSa/s   147 kpts                12GHz Standard BW
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        Frequency(f1•)
Current      Edge?
   Mean ? 8.8398 GHz
    Min ? 8.8398 GHz
    Max ? 8.8398 GHz
```

**Figure 10. Signal Integrity Demonstration of Si CMF in HDMI 1.4 Environment**

**Table 1. ON SEMICONDUCTOR’S SI CMF PRODUCT PORTFOLIO**

| Device | MIPI Camera Interface | MIPI Display Interface | HDMI Source Interface | USB 2.0 Interface |
|---|---|---|---|---|
| EMI4182 | 1 Data Pair,<br>1 Clock Pair,<br>(Low Res) | 1 Data Pair,<br>1 Clock Pair,<br>(Low Res) | 2 EMI4182<br>Address<br>8 TMDS | N/A |
| EMI4183 | 2 Data Pair,<br>1 Clock Pair,<br>(High Res) | 2 Data Pair,<br>1 Clock Pair,<br>(High Res) | N/A | N/A |
| EMI2121 | N/A | N/A | N/A | 1 Pair<br>Addresses<br>D+, D− |

In conclusion, the rising popularity of bandwidth-intensive applications and the employment of larger, higher resolution displays in modern cell phone handsets are causing difficulties in terms of data transfer. To satisfy this using the current approach would result in an increase in the number parallel data lines, however space constraints make it impossible. Consumers still expect sleek, attractive handsets that are lightweight and have the small form factors to which they have grown accustomed. This is driving the move from parallel to serialized data lines, but is in turn setting very difficult challenges for design engineering teams when it comes to tacking EMI.

The advent of highly integrated ICs which combine common mode filtering and ESD protection have the potential to dramatically change the cell phone industry. This development offers deeper attenuation curves in the handset frequencies than either ferrite or ceramic based products, across the wireless frequency spectrum. It will facilitate the high bandwidth connectivity that smartphone designs need, while improving system reliability, reducing the part count and lowering costs.

## REFERENCES

[1] Worldwide Quarterly Mobile Phone Tracker, IDC, February 2011.
[2] Smartphone Futures 2011−2015, Portio Research, December 2010.
[3] Signal Integrity – Simplified, by E. Bogatin, Prentice Hall, 2004.
[4] ON Semiconductor EMI4182 datasheet, 2011.

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