ESD Protection for Communication Interfaces in Automobiles

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Introduction

The Motor Vehicle came into global use during early 20th century. Since then, it has evolved significantly, adopting a multitude of innovations, changes and modifications. Some of the key evolutionary changes include the replacement of mechanical systems with electro-mechanical and electronic systems covering subsystems / modules such as the power generator, power bank, cooling fan, wiper motor, power window, on-board computer, switch, lights and the starter motor. Modern cars feature sophisticated capabilities such as the backup camera, a full-featured infotainment system, smart-phone docks, high-speed data ports for multimedia consoles, LED mood lighting, GPS navigation and Bluetooth connectivity along with several other advanced features. These sub-systems need to communicate with each other.

The most common form of in-vehicle communication employs analog or digital signals transmitted via metallic conductors such as wires using point-to-point connectivity. Different communication protocols are used to structure communications on these cables; the most popular ones include LIN (Local Interconnect Network), CAN (Controller Area Network), LVDS (Low Voltage Differential Signaling), Flexray and MOST (Media Oriented System Transport). Regardless of the protocol used, a dramatic growth in the number of electronic and electrical sub-systems has led to a significant increase in the number of cables inside a car, adding to its weight, and also contributing to decreased fuel efficiency.

The electronic content in Automobiles continues to grow. New capabilities such as forward and rear collision detection and avoidance, autonomous and semi-autonomous driving, configurable instrumentation and autonomous parking assist are key drivers for this content growth. In a drive to reduce the cabling complexity and weight, vehicle manufacturers started exploring alternate ways of efficient electronic communication with fewer wires. Twisted pair Ethernet cable is a compelling format that has found recent, widespread acceptance. We explore this trend in this article and examine the techniques of suitably protecting this interface.

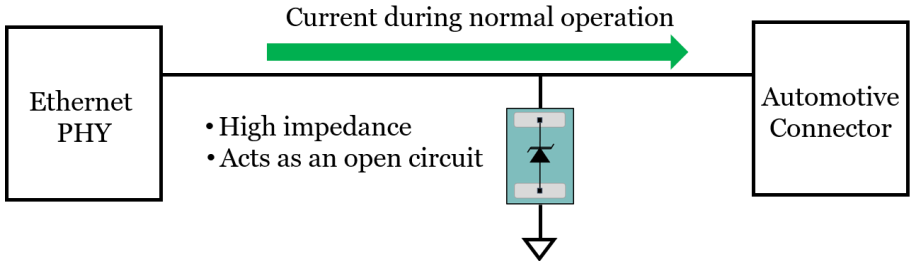
Twisted-Pair Ethernet Cable: A background

A joint study by Broadcom and Bosch showed that all inter vehicle communications can be effectively done via an Ethernet interface that employed a single twisted pair of wires connected to a central switch. The invented a new modified communication protocol called BroadR-Reach™ communication protocol operating at 100Mbps employing an unshielded twisted-pair. This was much faster than any other existing in-vehicle network protocols and worked seamlessly and effectively in high bandwidth applications. This has since been revised and adopted as an IEEE standard – the 100-Base-T1. This simplification of the interface to a single, twisted pair of

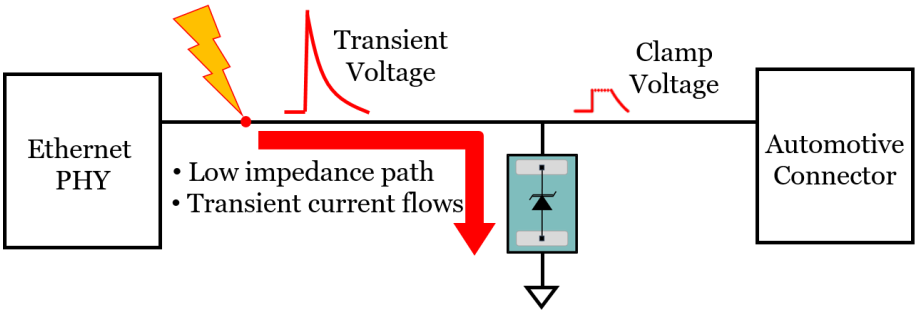
unshielded wires with universal applicability has led to significantly reduction of cable numbers and cabling weight.

Electro Static Discharge (ESD) Protection of Automotive Interfaces

Any new protocol requires new design and testing approaches. When designing a system to support high speed interface like Ethernet interface in a harsh automotive environment, it is imperative to make sure that there is sufficient ESD protection during transient events. ESD protection can be achieved by placing Transient Voltage Suppression (TVS) diodes on a data line to protect the interface during the fast rise time transient events like ESD in less than a nanosecond. TVS diodes protect data ports from ESD treats by arresting the system level ESD peak and diverting high currents away from the data port. They effectively clamp high voltage peaks (figure 1) and help avoid system damage. Under normal operating conditions, the TVS diode presents a high impedance to the protected circuit, so device appears as an open circuit and does not interfere with the rest of the circuit [Figure 1(a)]. During an ESD event, the voltage on the terminals of the protected transceiver can exceed safe operational limits. The TVS diode offers protection by getting triggered by the ESD event, and providing a low impedance path so that the transient current is diverted away from the transceiver circuit. The device limits the dangerous over-voltage at the transceiver to the clamping voltage of the TVS diode. At the conclusion of ESD event, the TVS diode reverts to a high impedance state. [Figure 1 (b)].



(a)



(b)

Figure 1.

TVS Diode Selection Criteria

As silicon data transceivers like Automotive Ethernets achieve faster data rates and incorporate process advancements, ESD protection becomes more challenging. Basically designers need to conceive of a TVS diode that can protect the automotive system during transient events while ensuring signal integrity by maintaining a low line-to-line capacitance. Now let us discuss why a lower value of line-to-line capacitance is required. We know that $i = C\frac{dv}{dt}$, where i is the instantaneous current flowing through the capacitor, C is the capacitance in Farads and dv/dt is the instantaneous rate of change of voltage in volts/second. When a small amount of voltage on the twisted pair data line changes, a small amount of current flows through the capacitor. However, we are talking about protecting a high speed data line like automotive Ethernet where the voltage changes much faster. In such scenarios, a huge current flows through the capacitor and thus the total current flow through the signal line reduces. This may eventually degrade the signal integrity of the data line. That's why for a higher speed interface like twisted pair Ethernet, the capacitance should be 3pF or less.

According to the IEC 61000-4-2 , a standard that is used for specifying system level ESD immunity, automotive manufacturers around the world need to incorporate ESD protection with at least a level 4 immunity (±8kV). Additionally, Semiconductors used for Automotive applications need to meet the qualifications requirements specified by AEC-Q100, which is an international standard of qualification for packaged integrated circuits used in the vehicle electronic circuits. Vehicle manufacturers look for conformance to these above standards when selecting protection devices to protect Ethernet interfaces.

ESD Protection Examples

ESD protection of Automotive Ethernet is typically done in two ways, PHY side protection and the connector side protection. We will discuss two different ways of PHY side protection. Figure 2 below shows an example of protecting a single-pair Automotive Ethernet PHY device with Semtech's RClamp0582BQ protection diode array. RClamp0582BQ is qualified to AEC-Q100, Grade 2 standard and is optimized for protection of two high-speed bi-directional data lines. It is mentioned previously in this article that a low capacitance is an essential requirement for protection of twisted-pair Ethernets. RClamp0582BQ has a maximum capacitance of 1.2pF.

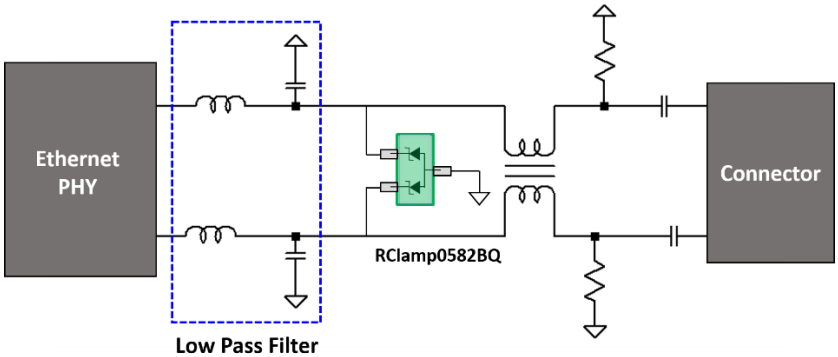


Figure 2.

Figure 3 below shows the clamping voltage waveform of RClamp0582BQ with +8kV contact discharge, as per the requirement of IEC 61000-4-2 standard. It shows clearly that RClamp0582BQ is able to clamp the voltage surge effectively at the peak ESD incident of +8kV voltage spike (Figure 6). The peak clamping voltage shown in Figure 3 is less than 120V. The RClamp0582BQ offers significantly superior ESD protection rated at ±25kV air and contact and exceeds the minimum system ESD standard protection of ±8kV.

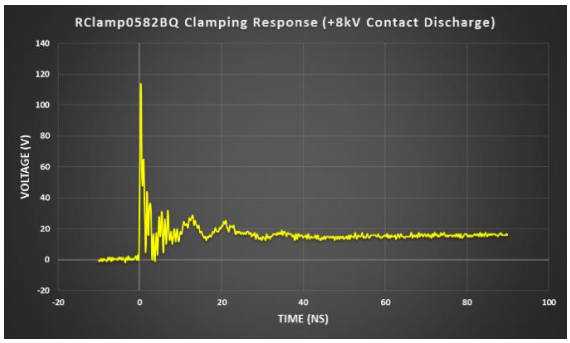


Figure 3.

Another implementation option is to protect each data line by a single, physically separate, TVS diode as shown in Figure 4. This protection arrangement uses Semtech's RClamp0531TQ. The RClamp0531TQ is a bidirectional AEC-Q100 qualified TVS diode with a maximum capacitance of 0.8pF.

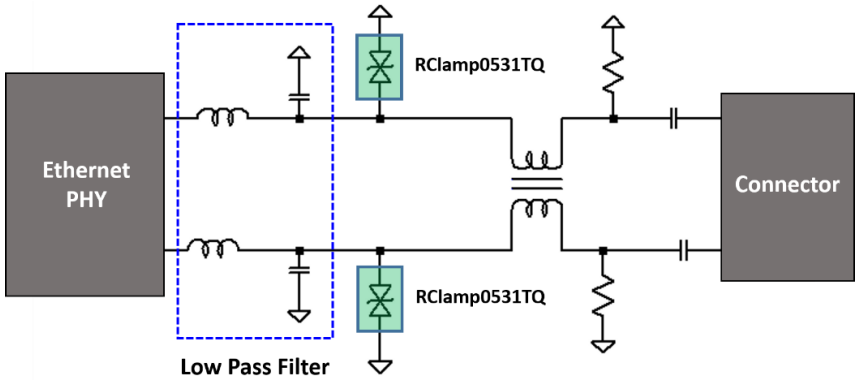


Figure 4.

Figure 5 below shows the ESD Clamping voltage of RClamp0531TQ per IEC61000-4-2 standard. It shows the positive clamping voltage at first peak of contact voltage waveform. The +8kV Contact Voltage Discharge according to IEC 61000-4-2 standard is shown in Figure 6 at right. When the +8kV contact discharge waveform reaches its peak at around 1.3kV shown by the red circle in Figure 6, the RClamp0531TQ is able to successfully clamp the voltage to 124.24V (Figure 5).

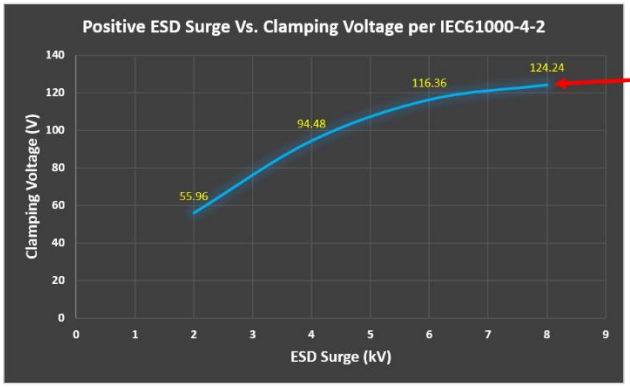


Figure 5.

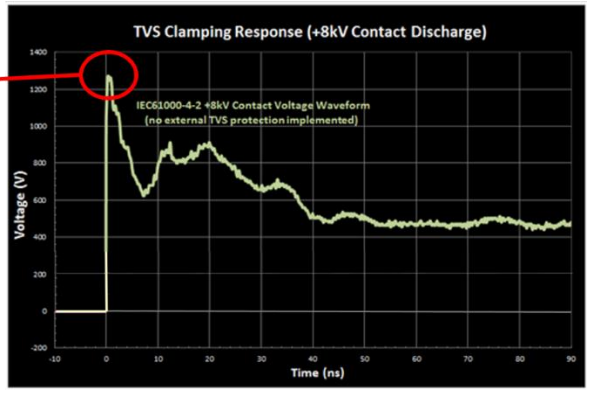


Figure 6.

Signal Integrity checks can be performed by reviewing the eye pattern of the signals on the twisted-pair Ethernet interface. However, it is quite easy to imagine that when the capacitance of the TVS protection part is quite small (1-2pF or less), the impedance of the interface changes only by a very small amount. Thus, the overall signal integrity remains intact for the high speed automotive Ethernet interface.

Conclusion

The trend in the automotive industry is to continue to add new and advanced electronic technologies. For the hundreds of electronic circuits in a vehicle, the twisted pair automotive Ethernet is becoming a popular choice due to its ability to enable faster communication and reduce vehicle's overall weight. In the harsh automotive environment, careful design and proper selection of TVS diodes is very important for safeguarding the high-speed data interfaces. For protection of automotive Ethernet, ultra-low capacitance with low voltage clamping capability is a must. Conformance to IEC61000-4-2 standard to level 4 along with completion of AEC-Q100 qualification are minimum criteria considered necessary for basic system design.

Sources:

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