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WHITE PAPER

Ethernet Termination in AUTOMOTIVE APPLICATIONS

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Carbon Film MELF Resistors | White Paper

Enabling Automotive Ethernet by Using Common Mode Termination Resistors With Long Term Stability

By Wolf Maibom

INTRODUCTION

Termination resistors are used for common mode impedance matching within a vast number of ethernet applications. Depending on the data transmission rate, they vary in resistance value and allowed tolerance. For automotive ethernet applications, the Open Alliance standards specify, among other requirements, a power rating of 400 mW and also the ESD pulse stability of the termination resistors:

100BaseT: a maximum resistance change of 1 % after 6 kV contact ESD tests according to IEC 61000-4-2 is specified

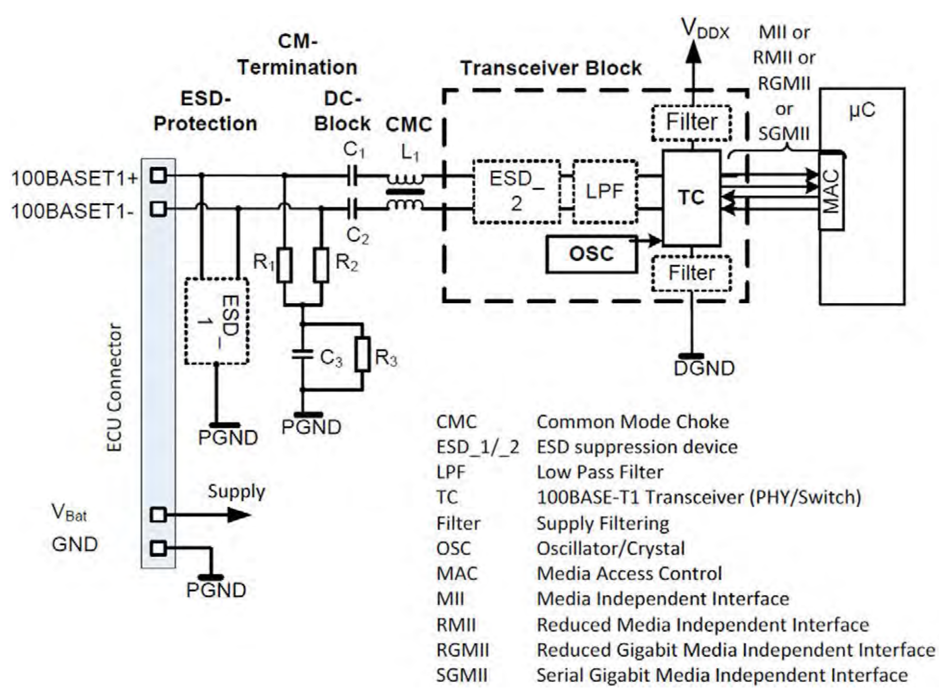
1000BaseT: a maximum resistance change of 0.5 % after 6 kV contact ESD tests according to IEC 61000-4-2 is specified

This white paper explains in more detail why such additional ESD requirements are necessary for the termination resistors in this application and how to prepare for them.

Resistor manufacturers provide the maximum initial delivery tolerance of the resistance value for that specific resistor within the product's datasheet. Additional resistance changes are specified in the datasheet, which apply under certain circumstances, e.g. resistance changes due to rapid change of temperature or high temperature exposure. Not all vendors specify the additional resistance changes to be added in case ESD events occur. In this context, the required tolerance level by the Open Alliance specification includes the sum of the initial delivery tolerance plus the additional resistance change caused by ESD events.

AUTOMOTIVE ETHERNET COMMON MODE TERMINATION

The circuit diagram of an automotive ethernet common mode termination is shown below.



Open Alliance Interface Circuitry / Schematic for 100BASE-T1 Automotive Ethernet

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System-level ESD protection of more sophisticated functions can be implemented within the ethernet PHY / transceiver block (ESD_2 in the above schematic). Alternatively, it can be added as an external component (ESD_1). Although the common mode termination resistors R_1 and R_2 will not protect against them, their resistance value may be affected by ESD events.

The Open Alliance specification requires common mode termination resistors to have a resistance value of 1000 Ω. Only if the resistance value measured after the ESD event is within the required tolerance range is a resistor compliant with the Open Alliance specification. As a result, for 1000BaseT transmission speeds, the resistor values of R_1 and R_2 need to stay within the range from 995 Ω to 1005 Ω after ESD events.

To understand the Open Alliance requirements on long term stability for those resistors, it is important to differentiate system-level from chip-level ESD requirements.

SYSTEM LEVEL ESD PROTECTION VS. CHIP LEVEL ESD PROTECTION

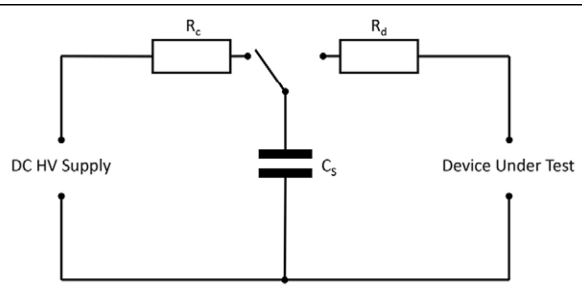
Different standards describe ESD protection levels and define test methods for components or applications.

Chip-level ESD events may occur during handling and manufacturing of the components and applications, due, for instance, to the static charging of working staff within the manufacturing process. However, those ESD events occur within a controlled environment, such as factories in which protective gloves and shoes are worn.

The most used standard to define chip-level ESD robustness is the human body model as described in JESD22-A-J114F or IEC 61340-3-1, which is similar to MIL-STD-883 or AEC-Q200.

System-level ESD protection is required to protect the final product against ESD events triggered by the end user. By walking with synthetic shoes on a synthetic floor, charges can be built up that may flash over to the next electrical device that is touched. Hence, mobile phones or laptops are protected by system-level ESD protection components to discharge the applied energy to ground. As these system-level ESD events occur in uncontrolled environments, protecting against them is even more demanding than protecting against chip-level ESD events.

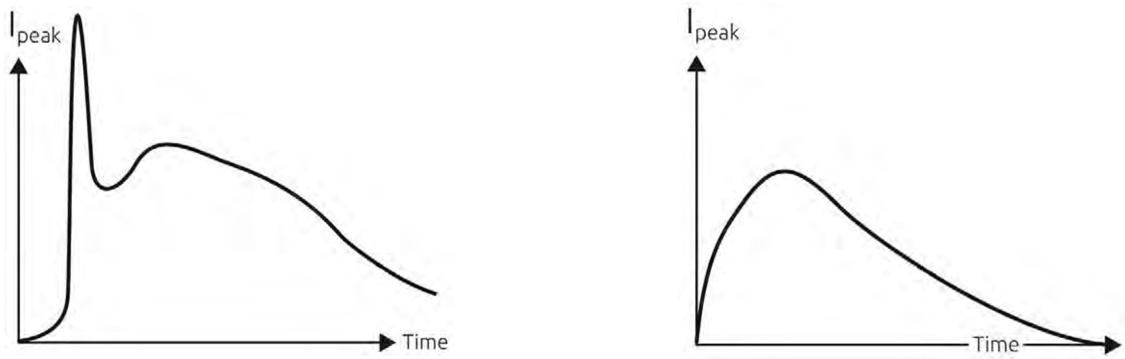
The standard IEC 61000-4-2 defines the system-level ESD requirements and test methods. The following test methods are described within the referring standards:

TEST CIRCUIT DESCRIPTION OF SYSTEM-LEVEL AND CHIP-LEVEL ESD PROTECTION STANDARDS				
TEST CIRCUIT	TEST MODEL	CHARGE CAPACITANCE, C_S	CHARGE RESISTOR, R_c	DISCHARGE RESISTOR, R_d
	IEC 61000-4-2 system level	150 pF	50 MΩ to 100 MΩ	330 Ω
	IEC 61340-3-1 chip level	100 pF	1 MΩ	1500 Ω
	AEC-Q200 chip level	150 pF	100 MΩ	2000 Ω

The different specifications of the test network, due to the different definition of the discharge resistor R_d, expose the device under test to different amounts of current, power, or energy:

COMPARISON OF SYSTEM-LEVEL AND-CHIP LEVEL ESD PROTECTION							
TEST MODEL	ESD LEVEL	RISE TIME	PULSE LENGTH	PEAK CURRENT	PEAK POWER	AVERAGE POWER	PULSE ENERGY
IEC 61000-4-2 system level	8 kV contact	1 ns	Not specified (> 100 ns)	~ 30 A at 8 kV (1 ns) ~ 16 A at 8 kV (30 ns)	~ 3000 W (30 A, 100 V)	~ 160 W (16 A, 10 V)	~ 16 μJ
IEC 61340-3-1 chip level	8 kV contact	10 ns	Not specified (> 400 ns)	~ 6 A at 8 kV (10 ns) ~ 2.2 A at 8 kV (1600 ns)	~ 120 W (6 A, 20 V)	~ 22 W (2.2 A, 10 V)	~ 8.8 μJ

Enabling Automotive Ethernet by Using Common Mode Termination Resistors With Long Term Stability



IEC 61000-4-2 IEC 61340-3-1

Pulse shapes

TESTING THE LONG TERM ESD STABILITY OF RESISTORS

The test methods for system-level ESD testing are described within IEC 61000-4-2.

If small components like resistors with footprint sizes of 1206 and smaller are stressed with strong ESD pulses, the energy applied by the pulse may flash over from terminal to terminal (or in the case of MELF resistors, from cap to cap) due to the relatively good conductivity of normal air.

Such flashovers are not critical within the automotive ethernet application, as additional ESD protection elements will protect the transceiver unit. During ESD tests for resistors, however, they must be prohibited to assure that the energy applied by the ESD pulse is conducted through the resistive element. Only by prohibiting those flashovers can it be proven that the resistor will not degrade over a car's lifetime because of ESD events.

Larger resistors will have a larger resistive layer to dissipate the energy from ESD pulses. For that reason, larger resistors are more stable against pulses like ESD events. Due to the trend for miniaturization, termination resistors for automotive ethernet are built up in 1206 or even 0805 footprint sizes. The resistive layer of commodity resistors in these small sizes may even be destroyed by system-level ESD pulses of only 2 kV.

At Vishay, a customized ESD test PCB was used to test the automotive ethernet common mode termination resistors. The PCB is milled out below the devices under test to ensure a full encapsulation of the resistors with epoxy resin. Using this customized PCB, no more flashovers could be observed, even at 15 kV contact ESD pulses in accordance with IEC 61000-4-2. Thus, the energy from the ESD strikes is forced through the resistive layer of the components.

Customized ESD test PCBs: resistors fully encapsulated with epoxy resin

The long term stability of the resistors can afterwards be measured by verifying their resistance value. For 100BaseT with an allowed resistance change after ESD events of 1 %, their resistance value must stay in the range of 990 Ω to 1010 Ω according to the Open Alliance specification. For 1000BaseT the range is specified with 995 Ω to 1005 Ω by this specification.

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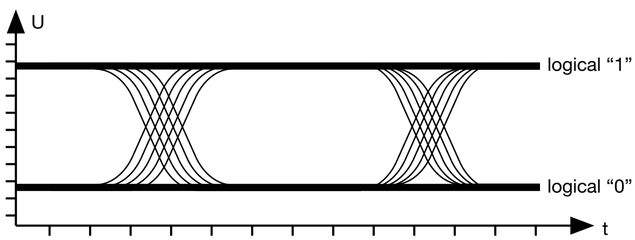
EFFECT OF AGING / EYE PATTERN CHANGES

To assure ethernet data transmission to applications like radar or lidar within a car, the Open Alliance specification requires the common mode termination resistors to keep their resistance value within the range of 995 Ω to 1005 Ω for 1 Gbit data transmission speed (respectively, between 990 Ω and 1010 Ω for 100 Mbit), even after 6 kV ESD contact system-level events in accordance with IEC 61000-4-2.

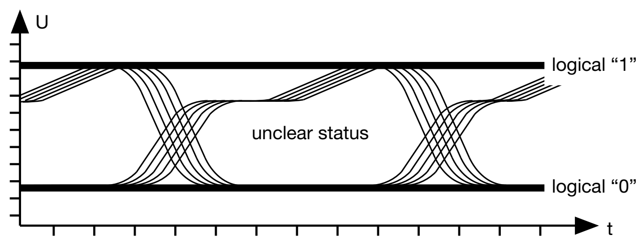
Accumulated system-level ESD events caused by car users may impact the resistance value of those termination resistors. If the deviation between both resistors connected to D+ and D- channels is too high, it will affect the data communication itself: logical levels may not easily be decoded anymore as logical “1” or “0”. In the worst case, such an impedance mismatch between D+ and D- will cause the application to fail.

The signal integrity can be visualized by using eye patterns. An eye pattern is an oscilloscope display in which a digital signal from a receiver is repetitively sampled and applied to the vertical input, while the data rate is used to trigger the horizontal sweep. The eye-height visualizes how “easy” a logical “1” can be separated from a logical “0”.

In the pictures below, an example of a typical eye pattern is compared to an example of a distorted eye pattern due to an impedance mismatch between the D+ and D- signals:



Typical eye pattern (low distortion, open eye)



Possible distortion from improper termination at D+ and D-

The common mode termination resistors used in such applications need to be chosen carefully to assure a long lifetime of the affected application. With its automotive ethernet common mode termination mini-MELF resistors [(1)], Vishay offers components that are tailor-made for these requirements. These resistors are offered with footprint size of 1206 and feature the right level of long term stability against system-level ESD pulses by using only one single component per data line. Tested at 8 kV contact system-level ESD in accordance with to IEC 61000-4-2, the change in resistance monitored for this product was less than 0.05 %.

Note

(1) To read the full specification of these components, please find the datasheet at www.vishay.com/doc?28954

SUMMARY

To assure correct operation over the full life span of applications such as radar or lidar, which are connected within a car via ethernet, the ESD requirements of the Open Alliance standard for common mode termination resistors must be met.

This requires (ESD-) pulse stable resistors with excellent long term stability.

The long term stability of most resistors is tested only on chip-level ESD, for instance, as required by AEC-Q200. But these components will normally not be exposed to the touch of the end user.

Commodity resistors in 1206 or even 0805 footprint sizes may even be destroyed by system-level ESD pulses of only 2 kV contact. ESD tests need to be carried out to assure the right level of long term stability.

Radar or lidar applications can sustain ESD events by end users. For that reason, only system-level ESD tests executed using the network defined by the IEC 61000-4-2 standard of at least 6 kV contact are accepted by the Automotive Ethernet Open Alliance specification for common mode termination resistors.

The initial tolerance level of the resistor, plus the resistance change from system-level ESD tests, must not exceed the overall tolerance requirement specified by the Open Alliance specification.

If resistors degrade through repeated ESD events, their resistance value may violate the requirements of the Open Alliance specification for automotive ethernet applications. As a result of the changed resistance value, the application using that ethernet interface may fail due to a too high bit error rate on that connection.

With the CMA02040X1001DB300, Vishay offers a tailor-made, single-component solution for this application in a 1206 footprint size.