Protecting automotive buses from transient-voltage damage

As silicon geometries shrink allowing more functionality to be squeezed into smaller spaces, oxide layers have become thinner and die areas reduced. As a result, individual ICs such as network transceivers are more vulnerable to ElectroStatic Discharge (ESD) strikes, the sudden flow of electricity between two electrically-charged objects caused by contact, an electrical short, or a dielectric breakdown. These events can have peak voltages up to 30 kV, so reliance on embedded chip ESD structures to provide system protection is a luxury no longer available. That external protection is needed is, as Thomas Jefferson eloquently put it, *a self-evident truth.*

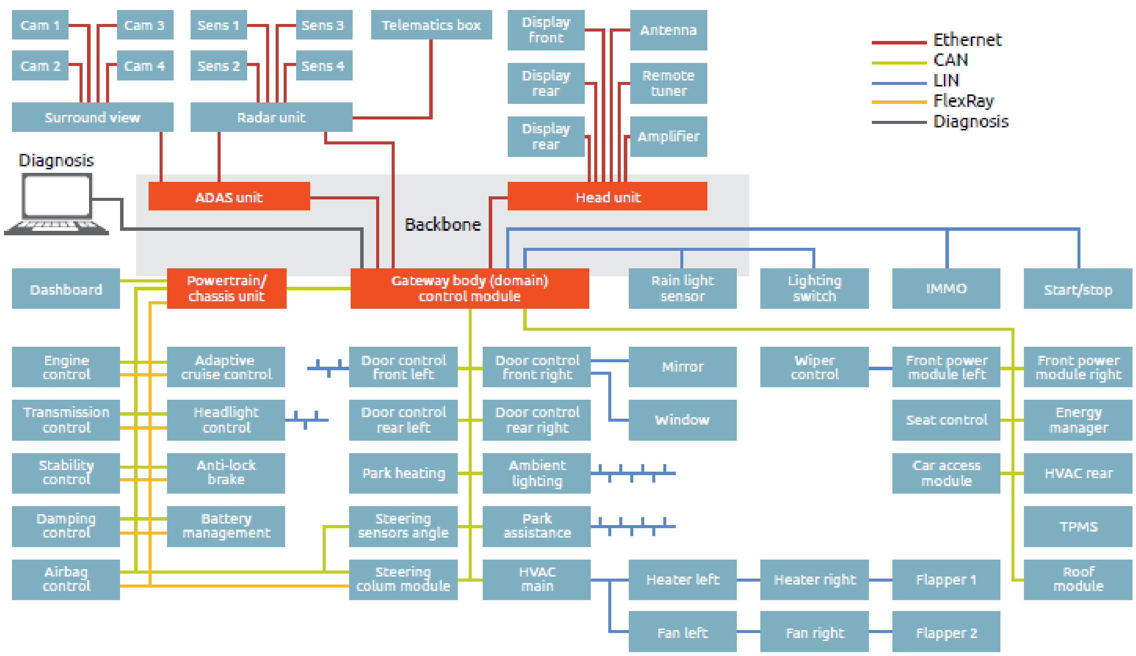
Transient voltages can cause unprotected devices to exceed their maximum ratings. When the energy potential of an ESD pulse is suddenly discharged into an unprotected device the resulting damage could render the device immediately inoperable, or it could lead to a failure at a later time during operation. At the very least it will substantially diminish electrical performance.

While sensitive electrical devices can be adversely affected by energy either coupled or radiated from electrostatic discharges, the need for ESD protection in today's vehicles is not simply limited to individual ICs. As the number of automotive ECUs (Electronic Control Units) grows, complex automotive networks or In-Vehicle Networks (IVNs) are needed to exchange all the connected car's data as it flows back and forth. These electronic subsystems are also susceptible to disturbances that can be generated by the electrical system itself, by human interaction, or even by load dump pulses. This introduces new and different ESD immunity challenges for engineers.

Fortunately, these vulnerable automotive networks can be effectively safeguarded to meet even the most stringent ESD immunity and signal integrity requirements. As new automotive networks and pertinent standards have been introduced, Nexperia's protection technologies have evolved with these trends – offering the highest level of protection in the industry's smallest packages.

Automotive Networks – protocols and ESD requirements

Safety, powertrain, control, infotainment and telematics all require the use of established network standards. However different applications come with different data rate and signal integrity requirements. This is often linked to whether they are real-time safety critical systems or not. Let's look at some popular protocols, as highlighted in Figure 1, as well as their ESD requirements:



In-Vehicle Networks

Controller Area Network (CAN) bus systems are used for driver assistance along with body control modules like antilock braking system (ABS), engine management system or power control. CAN bus transceivers are tolerant of power bus supply voltages of up to ±80 V_{DC}. However, load-dump surges can generate higher transients and may damage the part. The IEC standard 61000-4 (more on standards in the next section) defines the differences among the common voltage-transient threats to a CAN network beyond ESD events. Standardized testing is presented in IEC 61000-4-4 and IEC 61000-4-5. Nexperia offers a range of CAN ESD solutions for your application as well as devices to protect two automotive CAN bus lines, and they can be used with high-speed and fault-tolerant CAN buses.

LIN (Local Interconnect Network) typically connects to motors, switches and actuators
In the vehicle, such as automatic door locks or windows-lifters. LIN handles voltage from –27 V to 45 V (Short to Battery or Ground). The LIN bus specification requires that the network resume normal operation in the event that the LIN bus line is shorted to either positive battery or ground. ESD surge resistance requirements on the physical layer must be compliant with a minimum discharge voltage level of ± 2 kV according to IEC61000-4-2 (again, more on this shortly). However, a level up to ±8 kV may be seen at the connectors of the ECU. Here,

Nexperia offers single or dual automotive LIN bus line ESD solutions featuring an asymmetrical internal diode configuration, ensuring optimized electromagnetic immunity for the protected LIN ECU.

FlexRay has a fault-tolerant dual-channel architecture well-suited to electronic systems where safety is paramount, such as for X-by-wire applications such as brake-by-wire and steer-by-wire. Data rates are approximately 10 Mb/s and FlexRay features time- and event-triggered behavior. Designed specifically for FlexRay data lines, Nexperia devices provide a surge capability of up to 200 W per line for an 8/20 µs pulse.

High-bandwidth and multimedia buses

High-bandwidth multimedia bus systems and infotainment networks may not handle real-time or safety-critical data, here the primary challenge is data volume. While they are based on existing consumer or computing protocols such as Ethernet, USB or HDMI connectivity, these networks must still meet more stringent automotive requirements. So the normal 5 V breakdown ESD devices used in consumer devices are not be suitable here.

The Ethernet bus brings the advantage of reduced cabling costs and is better suited for high-bandwidth applications over conventional In-Vehicle Networks such LIN, CAN and FlexRay. Ethernet interfaces will need robust, low-clamping transient protection solutions to adequately safeguard Ethernet silicon. 100 Mbps Ethernet with unshielded cables will make it easier to connect advanced driver-assistance systems (ADAS) such as cameras as well as high data rate multimedia connectivity.

USB 2.0 is a common interface in head units and car radios. It is also used to charge portable devices, connect media players and for firmware updates. It will likely soon be replaced by USB Type-C, the latest USB connection standard to hit the consumer market and is already beginning to appear in cars. Features include a simple symmetrical or reversible connector with high-speed data transfer and fast charging capabilities.

HDMI 1.4 is capable of delivering true HD video to an automotive seatback or dashboard display from a connected personal media player. It supports transfer rates of 3.4 Gbit/s while the newer HDMI 2.0 standard supports rates of up to 6 Gbit/s.

Automotive ESD standards and testing

ESD solutions are required to pass emission and immunity tests and guarantee signal integrity. While many standards are designed to ensure that integrated circuits survive the assembly manufacturing process at the chip level, International Electrotechnical Commission IEC 61000-4-2 testing is for the protection of finished electronic products. An electrostatic discharge imunity test, IEC61000-4-2 defines a measurement setup that simulates everyday ESD strikes. The standard defines four levels of ESD robustness from 2 kV up to 8 kV. As a minimum automotive suppliers and OEMs require level 4 ESD immunity (±8 kV contact discharge, ±15 kV air discharge) which can see currents up to 30 A and capable if effectively melting silicon and conductor traces. However some carmakers impose their own specific ESD requirements which go beyond level 4. Figure 2 below shows the IEC 61000-4-2 ESD pulse waveform for the new PESD2IVN24-T in an SOT23 package.

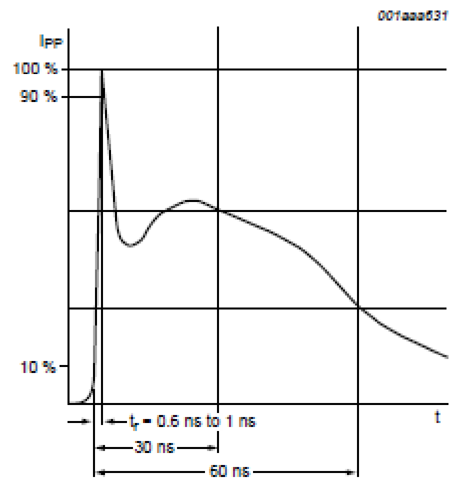


Fig. 2. ESD pulse waveform according to IEC 61000-4-2

The International Organization for Standardization released a newer standard based in part on IEC61000-4-2 and which describes vehicle-specific requirements. ISO 10605:2008 applies to all types of road vehicles regardless of the powertrain system (e.g. gasoline engine, diesel engine, electric motor). It describes ESD tests that are applicable to both automotive electronic modules and vehicles, specifying the electrostatic discharge (ESD) test methods necessary to evaluate electronic modules intended for vehicle use.

ISO10605:2008 applies to discharges in the following cases:

- ESD introduced in assembly and during servicing, where technicians working on electronic systems can inject ESD into ports not usually accessible by car occupants. A broken or exposed battery line connecting to an interface can cause potential damage to the ESD protection device, which needs to be able to withstand shorting of interfaces to the battery line.

- ESD caused by vehicle occupants - a charge can be built up as passengers move about the interior or as they get into or out of the vehicle. If they plug in a personal device to the car's sound system ESD can be injected into the system inputs. Examining how occupants affect ESD has assumed greater significance with the increase of vehicle electronic modules. Tests simulating the electrostatic discharge of humans, in common use by various industries, were looked at by the major standards organizations and it was determined that they were not fully applicable to the automotive environment. Consequently, ISO10605 tests tailored to the automotive environment were developed.

ISO10605 describes test procedures for evaluating both electronic modules on the bench and in complete vehicles. It also describes a test procedure that classifies the ESD sensitivity of modules with regard to packaging and handling.

The (IEC)61000-4-5 standard specifies that an ESD protection device has to be capable of withstanding a voltage pulse with a rise time of 8 µs and a fall time of 20 µs. The whole system must be tested consisting of both the protection device and the circuit to be protected.

Similarly, ISO 7637-2:2011 for road vehicles - "electrical disturbances from conduction and coupling" - specifies test methods and procedures to ensure the compatibility to conducted electrical transients of equipment installed on passenger cars and commercial vehicles fitted with 12 V or 24 V electrical systems. It describes bench tests for both the injection and measurement of transients. It is applicable to all types of road vehicles independent of the propulsion system.

Nexperia's IVN bus line protection solutions for high-speed network protection devices offer increased system robustness and are well-suited to automotive bus protection. For example, they operate at a low capacitance thus avoiding any unwanted circuit disturbances. ESD protection up to 30 kV is provided along with high peak pulse power (8/20 µs) performance. Other benefits include AEC-Q101 qualification, low clamping voltages to safeguard the latest SoCs (clamping voltage refers to the maximum amount of voltage that can pass a surge protector before it restricts further voltage from passing through) and reduced overall power consumption due to ultra-low leakage current. Nexperia also offers arrays that combine multi-line protection in a single device.