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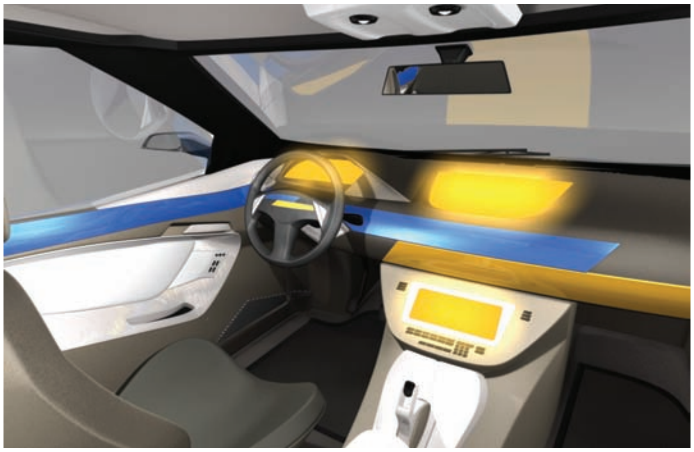
# Circuit Protection Considerations for Automotive Information Busses

New passenger cars, trucks, buses, trains and even motorcycles have become mobile networks, connecting a wide variety of features and functions, including embedded controls, mobile media, and wireless options. Applications such as infotainment, telematics, safety, and control require the use of several established networking standards such as LIN, CAN, MOST, IDB-1394, FlexRay, *byteflight*, Bluetooth for embedded control, and others.

Networking applications are physically connected through the wiring harness. Most of the embedded controllers, embedded or pluggable multimedia, and wireless networked functions are powered via the vehicle battery directly, or through the ignition switch. This growing array of sensitive automotive electronics is susceptible to disturbances generated by the electrical system itself, by human interaction, or by load dump pulses.

Figure 1 illustrates the most common power rail transients, which may vary from severe low level-high energy, to very high level-low energy transients. Transients on the supply rail are of particular concern in meeting ISO7637-2 and ISO10605 standards.

Load-dump and jump start generate the most energetic transients. The 6V crank transient is generated when the car is started, causing the power voltage to drop to 6V. Load-dump is a result of the discharged battery being disconnected from the



alternator while the alternator is generating charging current.

The +100/-150V spikes are a result of the ignition process used to ignite the gasoline mixture. The frequency of these spikes depends on the number of cylinders and the engine's rotation speed.

The temporary application of an overvoltage in excess of the battery voltage causes the 24V jump start transient. The reverse battery transient is caused by inadvertent battery inversion.

Figure 2 shows that transients generated on data lines are mainly ESD surges. Although these surges are low energy, they can generate a very strong electromagnetic field.

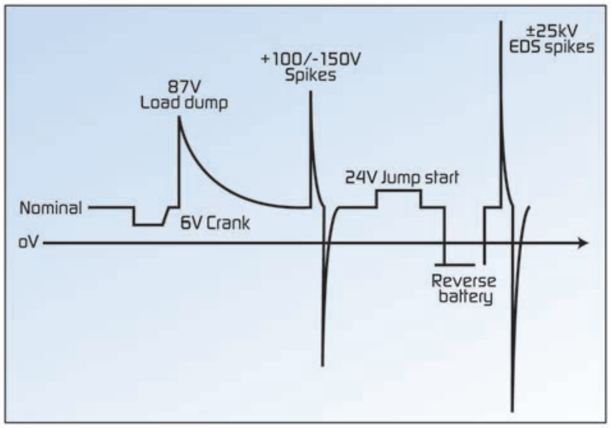



Figure 1. Typical surges on automotive power rail.

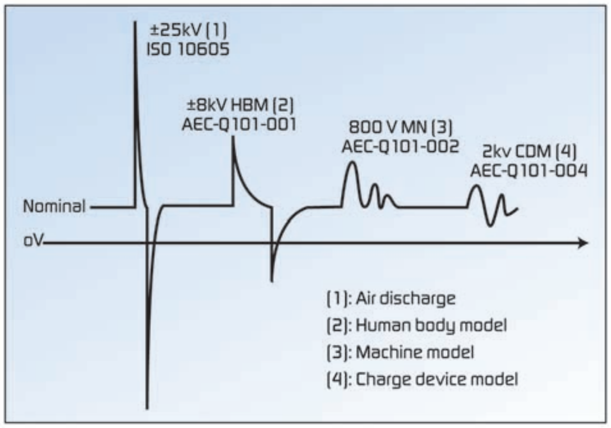



Figure 2. Typical ESD surges on data lines.

Data lines may include media transfer lines, data busses, and sensor data lines; they are of particular concern for compliance with AEC-Q and ISO 10605 standards.

The ISO10605 ± 25kV ESD surge test is applied to a complete system and simulates the ESD effect of human body contact on electronic modules in their environment. The AEC-Q standards address device ruggedness, including the human body model, machine model and charge device model tests (AEC-Q200 relates to passive components while AEC-Q101 relates to discrete semiconductors).

Protecting the network and the connected components from damage caused by these types of overcurrent, overvoltage or over-temperature conditions can present complicated design challenges for both automakers and component suppliers.

Table 1 lists several networked applications and the Tyco Electronics devices that are frequently used to help prevent circuit damage.

| Application | Overcurrent Circuit Protection Devices | | | Overvoltage Circuit Protection Devices | | | Integrated Protection |
|---|---|---|---|---|---|---|---|
| | PolySwitch Device | Slow-Blow Fuse | Fast-Acting Fuse | MOV | MLV | PESD | PolyZen Device |
| Electronic Control Modules (ECUs) | X | X | X | X | X | X | |
| HVAC and Climate Control | X | X | X | X | | | |
| Telematics Powered Components | X | | | X | X | X | X |
| Infotainment Equipment | X | X | | | | X | X |

Table 1. Networked applications and typical circuit protection devices

## LIN Topology: Circuit Protection Considerations

With bus speeds up to 20kbps over a single wire operating at $12V_{DC}$, LIN (Local Interconnect Network) enables low-cost automotive networking and complements the existing portfolio of automotive multiplex networks.

Typical applications for LIN include switches, actuators (e.g., window lift and door lock modules); body control electronics for occupant comfort (e.g., door, steering wheel, seat and mirror modules); and motors and sensors (e.g., in climate control, lighting, rain sensors, smart wipers, intelligent alternators and switch panels).

The LIN bus topology utilizes a single master or ECU (Electronic Control Unit) and multiple nodes, as shown in Figure 3. Connecting application modules to the vehicle network makes them accessible for diagnostics and service.

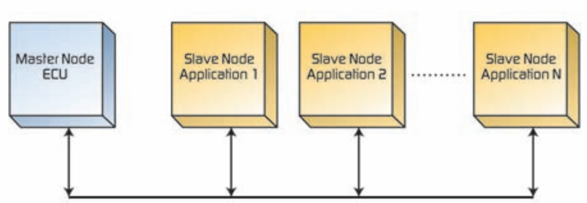



Figure 3. LIN bus topology is commonly used to connect switches, sensors and actuators to the vehicle network.

Unless otherwise indicated in the LIN specification, all voltages are referenced to the local ECU ground, and positive currents flow into the ECU. In case of an integrated resistor/diode network, no parasitic current paths must be formed between the bus line and the ECU-internal supply (VSUP). This would include the effect of any ESD surge suppression devices in the circuit.

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 with <26.5V or ground. ESD surge resistance requirements on the physical layer must be in compliance with a minimum discharge voltage level of ± 2 kV according to IEC61000-4-2. However, a level up to ± 8 kV may be seen at the connectors of the ECU.

Overcurrent protection is needed to limit excessive currents during a fault or overload condition. Circuit protection devices that help limit voltage spikes, or exposure to steady-state overvoltage conditions are also required.

The coordinated circuit protection schematic shown in Figure 4 illustrates how a resettable PolySwitch device on the power input helps protect the ECU and LIN node connectors from damage resulting from overcurrent conditions, and an MLV (multi-layer varistor) helps provide the high current-handling and energy-absorption overvoltage protection required for automotive networking applications.

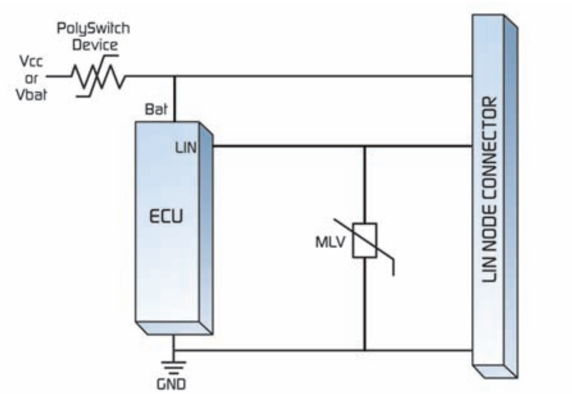



Figure 4. Coordinated circuit protection scheme for LIN bus application.

## CAN Topology: Circuit Protection Considerations

The CAN (Controller Area Network) specification is characterized by mid-range speed (up to 1 Mbps for high speed CAN). Single channel, dual wire and fault tolerant, the protocol is the most widely-used automotive bus architecture, but it is also found in many industrial applications.

CAN bus transceivers are tolerant of power bus supply voltages of up to +/-80$V_{DC}$. However, load-dump surges can generate higher transients than specified in the ISO-7637-2 specification (maximum of 86.5V) and may damage the transciever. Operating currents for transceivers may also vary, depending on the vendor.

Figure 5 shows how a resettable PolySwitch device and an MOV (Metal Oxide Varistor) can be used on the input power side to help protect against damage from surge current and voltage anomalies on the vehicle's power system bus. Two MLVs on the CAN transceivers I/O help provide lower capacitance shunt protection against Electromagnetic Emission (EME) from common-mode voltage steps.

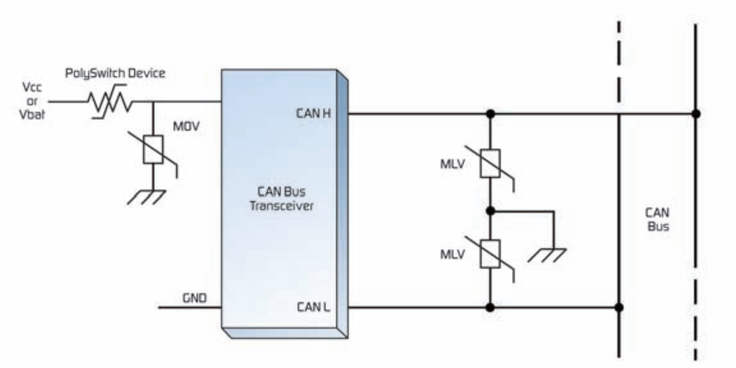



Figure 5. Coordinated protection solution for CAN bus transceivers.

Tyco Electronics' automotive-grade PolySwitch devices meet rigorous AEC-Q200 & SAE 2685 requirements and are available with a wide range of electrical characteristics and form factors to facilitate the most effective protection solution.

Like traditional fuses, PolySwitch devices limit the flow of dangerously high current during fault conditions. Unlike traditional fuses, they reset after the fault is cleared and power to the circuit is cycled. Another advantage is their relatively small form factor, which allows them to be mounted directly on the circuit board and located inside electronic modules, junction boxes, and power distribution centers.

Tyco Electronics' MOV devices may be installed in parallel with the equipment or components to be protected. In the event of an overvoltage condition, MOV devices switch rapidly from a high to a low impedance state, thus clamping the transient voltage across the components to a safe operating level. Under normal operating conditions, the overvoltage device appears as a high impedance device and should not affect normal system operation. The device's low leakage functionality also helps improve battery run-down rate.

## MOST Topology: Circuit Protection Considerations

MOST (Media-Oriented Systems Transport) enables video and audio functions and supports speeds of up to 40+Mbps over plastic fiber for both synchronous and asynchronous data transfer. MOST transceivers are found in devices that require high bandwidth for real time processing, such as DVD players, head sets, GPS devices, and voice control.

In effect, MOST is a network of nodes that are used to transport all of the various signals and data streams that occur in the vehicle's multimedia and infotainment systems.

The MOST standard supports a variety of physical interfaces, as shown in Figure 6. Within the MOST specification these applications are referred to as Functional Blocks or FBlocks. Each FBlock may contain several functions (e.g., a CD player may include functions such as play, stop, eject, and time played).

MLVs are frequently used on the power bus for ESD protection in conjunction with a PolySwitch device for resettable overcurrent protection. Low-capacitance PESD devices or PESD arrays can be installed over the data lines for ESD protection.

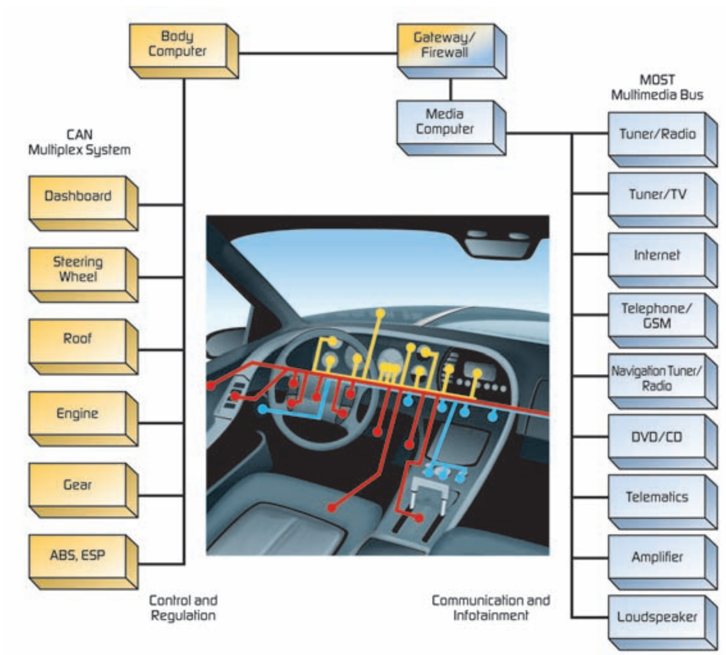



Figure 6. A wide range of applications are controlled and communicate via the MOST multimedia network

## IDB-1394 Topology: Circuit Protection Considerations

The IDB-1394 automotive architecture is divided into an embedded network and a Customer Convenience Port, or CCP, as shown in Figure 7. The specification defines an embedded plastic optical fiber (POF) vehicle network similar to the existing MOST specification. It is, however, more robust and easier to implement. Connected by the network are various electronic components such as DVD players, video displays, navigation systems, radio head units, and communications equipment.

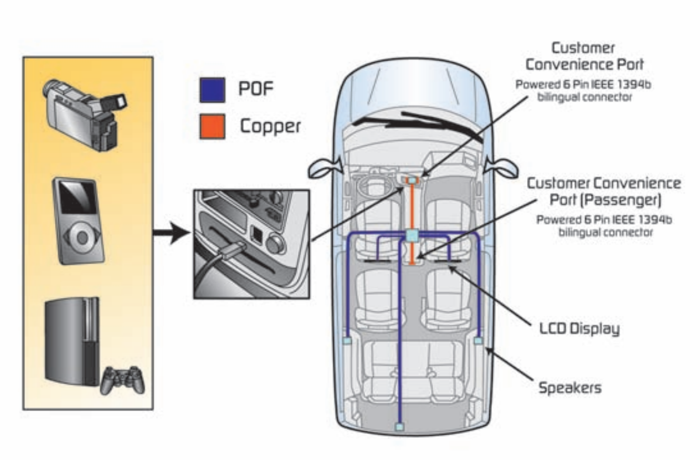



Figure 7. The IDB-1394 network includes a Customer Convenience Port (CCP) that lets passengers connect 1394-equipped devices to the network, with a cable that can be used in both the home and the vehicle.

The CCP port, which comprises an automotive grade 1394b physical layer and connector, lets users bring portable devices into the vehicle to access audio and video services over the IDB-1394 interface. The CCP uses a standard connector, and is specifically designed to provide power to the device. This power feature eliminates the need for extra batteries, a separate power cord, and customer concerns related to whether or not the device to be plugged in is already powered.

IDB-1394 is designed for high-speed multimedia applications at bus speeds up to 800Mbps and specifies resettable overcurrent protection on powered ports.  As shown in Figure 8, a PolySwitch device can be used to help limit the flow of dangerously high current during fault conditions. An MLV can be installed on the power bus to help prevent damage caused by ESD surges and overvoltage transients. Low-capacitance PESD devices or PESD arrays can also be installed on the data lines to help provide ESD protection.

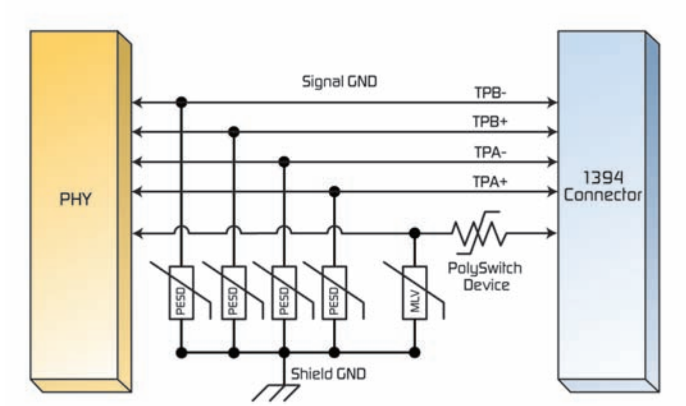



Figure 8. Coordinated overcurrent/overvoltage protection scheme for IDB 1394 application.

## FlexRay Topology: Circuit Protection Considerations

The FlexRay protocol is intended for X-by-wire applications, such as brake-by-wire and steer-by-wire. This wire-based network approach supports both synchronous and asynchronous data transfers with a data rate of approximately 10 Mb/s and features time- and event-triggered behavior, redundancy and fault-tolerance.

This architecture supports from 2 up to 64 nodes in a "cluster," with its functionality residing in two types of processors – ECUs and "active stars." The FlexRay communication is implemented between the ECU via a common bus or a star connection. The bus inputs of FlexRay components must be protected against short circuit conditions between a bus line and system supply voltage or ground potential.

Figure 9 illustrates a coordinated overcurrent/overvoltage protection scheme for ECUs. This scheme utilizes a PolySwitch device for overcurrent protection and two MLVs to help provide both ESD and transient overvoltage clamping suppression in a convenient surface-mount form factor.

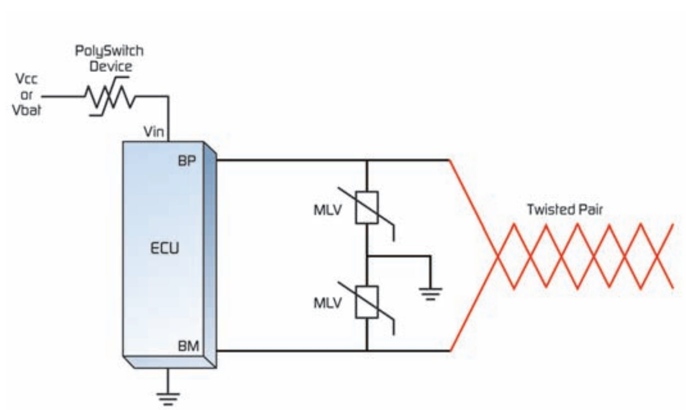



Figure 9. Coordinated overcurrent/overvoltage circuit protection solution for FlexRay components.

## *byteflight* Topology: Circuit Protection Considerations

The *byteflight* protocol is an automotive databus that was developed to provide a safety-critical, fault-tolerant means of electronic communication between automotive components. *byteflight* runs at 10Mbps over 2-wire or 3-wire plastic optical fibers (POF) in a bus, star or cluster configuration. The use of POF in this system architecture allows for functions to be electrically isolated on the data side. However, the nodes still receive power from the vehicle's power bus and are subject to electromagnetic interference.

Components that make up the network, such as the microprocessor, *byteflight* controller, and optical transceivers, are susceptible to damage caused by spikes on the power supply and reverse voltages. Integrated circuits (ICs) may incorporate ESD protection, but are usually limited to 2kV or less. As shown in Figure 10, PolySwitch devices and MLVs can help protect these modules against damage caused by high-energy overvoltage and overcurrent transients.

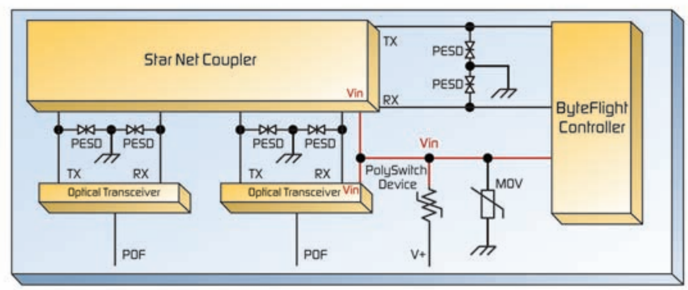



Figure 10. Coordinated overcurrent/overvoltage protection scheme for *byteflight* topology

## Bluetooth Topology: Circuit Protection Considerations

The Bluetooth standard, not originally envisioned for the automotive environment, has created new market opportunities for mobile electronic devices that can interact with the vehicle and its systems, such as cell phones, MP3 players and navigation equipment.

Protecting exposed communication interfaces from ESD and other voltage surges induced through the antenna and the instrument's wireless (RF) interface is a critical design issue. Figure 11 shows how a PolyZen integrated overcurrent/overvoltage device helps protect the power input to the Bluetooth module. MOVs or surface-mount MLVs are also used to help protect against voltage transients on the in-vehicle microphone and speaker interfaces. PESD devices can be used to help protect the antenna against ESD surges.

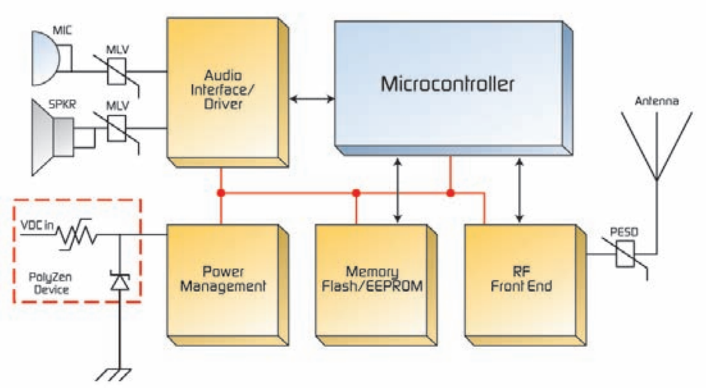



Figure 11. Typical circuit protection solution for Bluetooth modules

## Circuit Protection Devices for Automotive Designs

Tyco Electronics manufactures a broad range of overcurrent, overtemperature and overvoltage circuit protection devices that are qualified for and widely used in automotive designs. The company developed the PS400 test procedure to provide compliance with the AEC-Q200 standard when it is required. A copy of this document is available upon request.

**PolySwitch Device Benefits**

- Helps provide both overcurrent and overtemperature protection
- No frequency dependence up to 1MHz
- Resettable functionality allows for placement in inaccessible locations
- Wide range of electrical and physical sizes facilitate the most precise protection design
- Compatible with high-volume, automated insertion, electronic assembly processes
- Available for applications of up to 125°C

**Surface-Mount Fuse Benefits**

- High-current, small form-factor devices available in both fast- and slow-blow technologies
- Clean-blow characteristics contain the fusing event physically within the package
- Strong arc suppression characteristics and resistance to shock and vibration
- Available for applications of up to 125°C

**MOV and MLV Device Benefits**

- High current-handling and energy-absorption overvoltage protection
- MOVs available in a variety of diameters and in broad varistor-voltage ranges
- Low leakage functionality results in a lower battery run-down rate
- MLVs have small SMD packages and lower capacitance values

**PESD Device Benefits**

- Helps protect sensitive electronics against damage caused by ESD events and voltage transients
- Suitable for high-speed data transmission lines and radio-frequency data lines
- Extremely low capacitance, low trigger-voltage and fast response time in a very small SMD package
- Capable of withstanding numerous ESD strikes

**PolyZen Device Benefits**

- Helps protect sensitive automotive electronics from damage caused by inductive voltage spikes, voltage transients, incorrect power supplies and reverse bias
- Helps reduce design costs with single component placement and minimal heat sinking requirements
- Analog nature of trip events helps minimize upstream inductive spikes

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