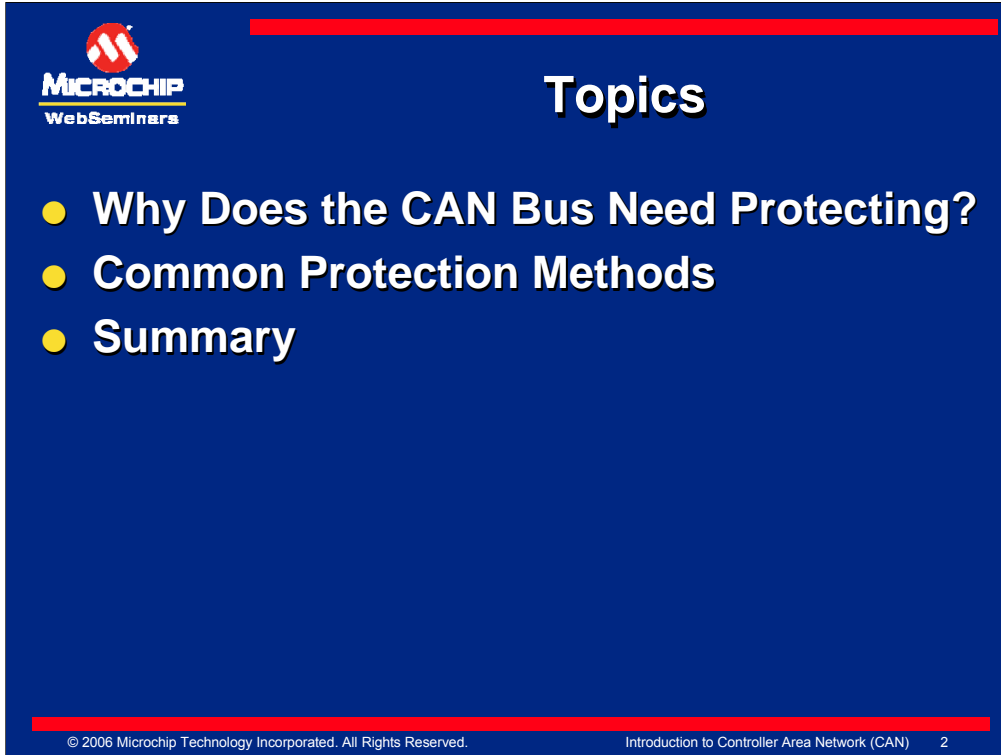




Hello, and welcome to the WebSeminar on the EMI and ESD protection for the CAN Bus. My name is Pat Richards. I am an Applications Engineer in the Analog and Interface Products Division. So let's get started.



The slide features a dark blue background with a red horizontal bar at the top. In the top left corner is the Microchip WebSeminar logo, which includes a red circular icon with a white stylized 'M' and the text 'MICROCHIP WebSeminar'. The word 'Topics' is displayed in a large, bold, white font in the upper right. Below it, a bulleted list of three topics is shown in yellow text. At the bottom, a red horizontal bar contains the copyright notice '© 2006 Microchip Technology Incorporated. All Rights Reserved.' on the left and 'Introduction to Controller Area Network (CAN) 2' on the right.

MICROCHIP
WebSeminar

Topics

- **Why Does the CAN Bus Need Protecting?**
- **Common Protection Methods**
- **Summary**

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Today we will be discussing protection methods for the Controller Area Network, or the CAN Bus. We will answer the question, "Why does the CAN Bus need extra protection?"

We will then identify some common protection methods, which include cabling, filters, common mode chokes, split termination, MOVs, TVSs and then we will finish with a brief summary.




MICROCHIP
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Topics

- **Why Does the CAN Bus Need Protecting?**
- Common Protection Methods
- Summary

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So, why does the CAN Bus need extra protection anyway? Doesn't the transceiver provide adequate protection?



Noisy, Harsh Environments

- CAN is used in automotive and industrial applications
- Nodes must survive high energy transients
 - Load dump
 - Inductive load switching
 - Relay noise
 - Ignition system noise
- And short circuit conditions

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CAN was originally developed for data communications in the automotive industry. The industry is a noisy, harsh environment.

CAN nodes are subject to high energy transients such as load dump, inductive load switching, relay noise, ignition switching, etc.

The most popular physical layer in CAN is specified by ISO 11898.

The ISO 11898 compatible transceivers do a good job of filtering out noise, which are coupled on the bus, and protecting the node from energy spikes and short circuit conditions. For example, the MCP2515 can withstand shorts of + or – 42 volts on the CAN bus and can withstand transient energy spikes of + or – 250 volts without damage to the node.

Additionally, the differential signaling inherent in CAN helps to filter out noise. However, in some systems the environment is harsh enough that extra protection and/or extra filtering is needed to protect the node and ensure clean communications.




Topics

- Why Does the CAN Bus Need Protecting?
- **Common Protection Methods**
- Summary

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The rest of the presentation we will look at some of the common protection methods for the CAN Bus.



Transceivers Provide Some Protection


- ISO 11898 requires:
 - Short circuit protection = -3.0V to +32V
 - Transient protection = -150V to +100V
- MCP2551 protection (bus pins)
 - Short circuit protection = $\pm 42V$
 - Transient protection = $\pm 250V$

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As mentioned earlier, ISO 11898 is by far the most popular physical layer for CAN. The spec requires that the transceiver be able to withstand short circuit conditions on the bus of -3 volts to +32 volts and transient energy surges of -150 volts to 100 volts. Compatible transceivers must meet these minimums.

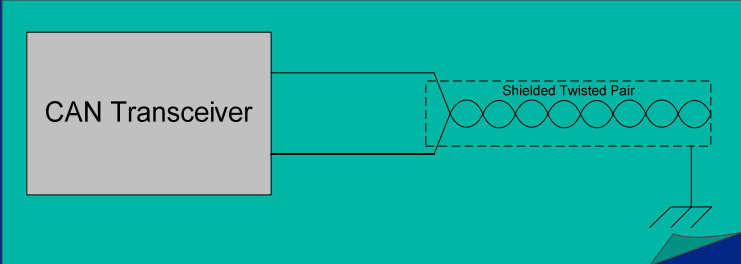
Microchip's MCP2551 exceeds the spec. On that device the short circuit protection is + or -42 volts and transient protection of + or -250 volts.

However, sometimes extra protection is still needed to further improve the robustness of the CAN system.



Shielded Twisted Pair Cable

- Shielded cable reduces radiated interference from introducing noise on the common mode voltage
- Twisted pair essentially equalizes the noise across both wires
 - Noise distributed equally is invisible to the differential bus




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Twisted pair wiring is a common method to reduce the effects of radiated emissions from external sources.

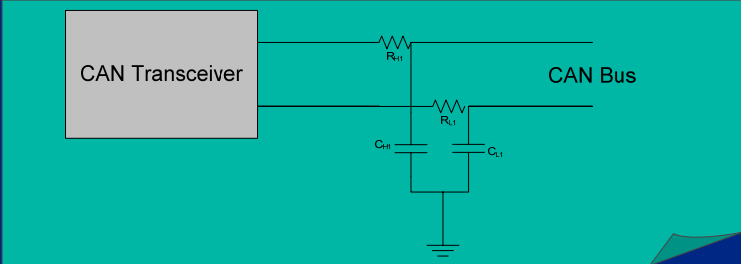
Shielded, twisted pair reduces the chance of noise coupling on the bus lines, and noise that does couple on the line is equally distributed to both wires and is effectively invisible to the differential signaling.

The twisted pair solution is basically a filter and does not provide any protection from high energy electrical disturbances.



Filters

- RC, LC, or Common Mode Choke
 - Will attenuate the magnitude of the noise on the CAN bus
 - May distort the signal
 - Does not provide voltage clamping



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The filters discussed here are used to reduce noise at the transceiver bus pins.

RC and LC are Low Pass filters. Common mode chokes attenuate the noise. It is very important for the components to match. Any mismatch will cause unbalanced filtering or attenuation between CANH and CANL pins which will result in distortion of the signal.

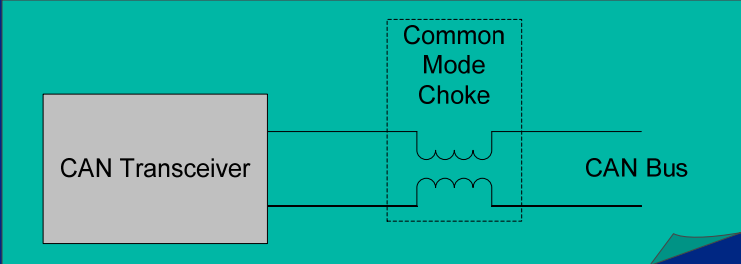
Additionally, these filter circuits do not provide any voltage clamping, they only filter.

Also, the filter components are susceptible to high energy transients that can be damaged. We'll discuss how to protect these circuits later.



Common Mode Choke

- Increases Common Mode Rejection Ratio (CMRR) by:
 - Providing high impedance for common mode signals (bus in recessive state)
 - Providing low impedance for differential signals (bus in dominant state)




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Common mode chokes increase the Common Mode Rejection Ratio, or CMRR, by providing high impedance for the common mode signal, that is, when the bus is in a recessive state with no differential voltage between the CANH and CANL pins and providing low impedance for differential signals, that is, when the bus is dominant.

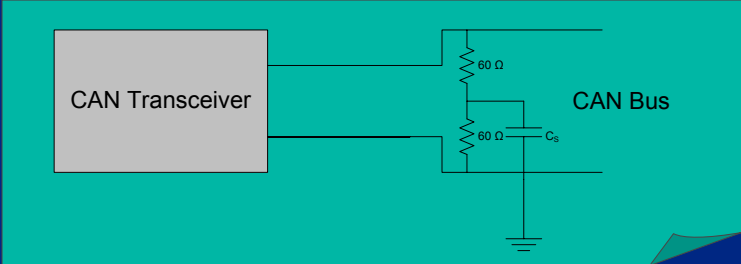
Chokes are common on CAN buses and can implement filtering on the common mode signal without adding a lot of distortion. That's because the coils are usually matched fairly well.

Like RC and LC filters, any mismatch in the inductance of the coils can cause distortion of the differential signals. Another thing to be aware of is that the inductance of the coils and the capacitance of the PCB could theoretically create a tank circuit and cause oscillations, although that is rare.



Split Termination Schemes

- Split termination effectively reduces emissions and improves immunity
- The 120 Ω resistor at each end of the bus is split into two 60 Ω resistors with a capacitor to ground
- Acts as a low pass filter




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Termination of an ISO 11898-2 bus consists of two 120 ohm resistors-- one placed at each end of the bus to eliminate reflections.

Splitting those single 120 ohm resistors into two 60 ohm resistors and installing a capacitor to ground between the two will create filtering at each end of the bus. Like the other filters discussed, this scheme does not provide any voltage clamping, only filtering.

So far, none of the circuits discussed provides protection from high energy transients or short circuits, they only provide noise filtering. It's still left up to the transceiver to provide this protection.

Next we will discuss a couple of solutions which will provide protection from high energy transients and short circuits.



Metal Oxide Varistor

- MOV devices are non-linear, voltage variable resistors
 - Avalanche diode effect as voltage increases past threshold
- Can have high leakage current (10 μ A and up)
- High shunt capacitance (45 pF and up)
 - Difficult to match capacitance

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Metal Oxide Varistors, or MOVs, are non-linear, voltage-variable resistors and provide clamping to protect against high energy transients and short circuits.


MOVs are very popular in protecting electronic circuits from transients in power lines but can also be used in communication lines such as CAN bus. They are very common in household surge protectors.

MOVs have a non-linear current voltage characteristic. They're connected from the power or data line in this case of the CAN bus to ground, and they have a very high resistance at low voltage and a very low resistance at high voltage, which is how the protection is implemented.

MOVs have a very fast turn-on time, in many cases less than 1 ns, meaning that they clamp very quickly. They have improved over the years and do not degrade when activated, the way the older MOVs used to.

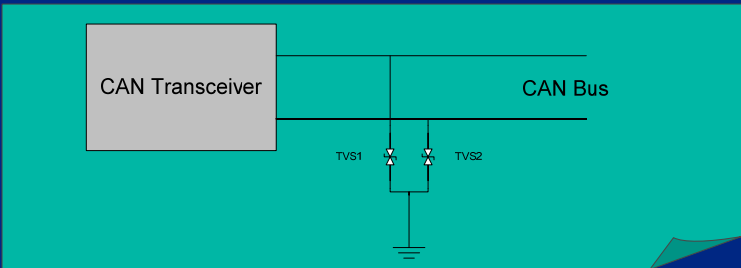
Some issues with MOVs on a differential CAN bus is that they can have high leakage current relative to TVS devices which will be discussed next.

And the tradeoff for good performance can be a high shunt capacitance and the capacitance can be difficult to match between the two needed for CAN bus, one for each bus line. This can create distortions on the bus.



Transient Voltage Suppressor

- TVS devices are avalanche diodes
- Low leakage current (as low as 100 nA)
- Capacitance as low as 10 pF
- High integration

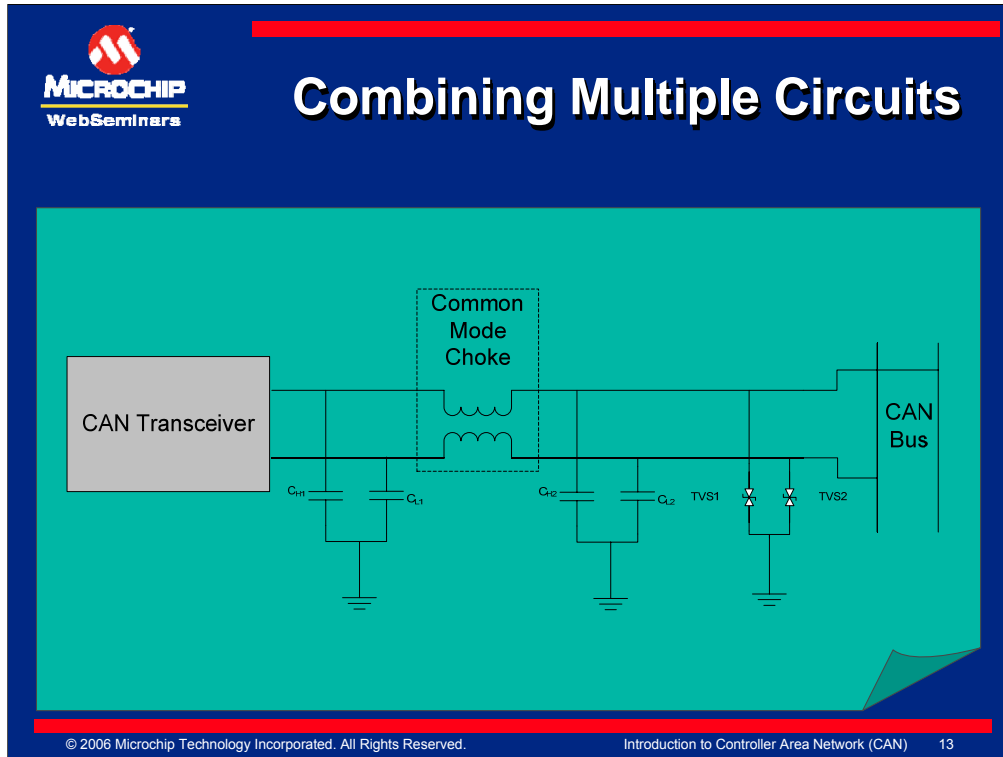


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Transient Voltage Suppressors, or TVS devices, operate as avalanche diodes which turn on high voltage to shunt voltages to safe levels for the transceiver.

Like MOVs, TVS devices have very fast turn-on times, typically less than 1ns. However, unlike MOVs, TVSs can have very low leakage current, as low as 100 nA. Also, capacitance is very low making TVS devices virtually transparent to the CAN system during normal operation.

TVSs are offered in pairs, i.e., mask capacitance, and have very small footprints making them ideal for CAN bus. Additionally, TVS devices can be combined with other diodes to create different protection schemes. However, these protection schemes are beyond the scope of this presentation and are not covered.



The best solution for filtering noise and protecting CAN nodes may be to combine the circuits. This slide shows one possible example. The TVS is placed so that it not only protects the transceiver, but also protects the filter components from high energy transients. A couple of things to keep in mind when using protection circuits for CAN. One thing is place the components as close as possible to the connector, and another one is to place the connector as close to the edge of the PCB as possible. This will lessen the chance of noise spreading on the PCB before it can be filtered or clamped.




Topics

- Why Does the CAN Bus Need Protecting?
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So in summary...



Summary

- Several options are available when adding extra protection circuits on the CAN bus
- In many cases, multiple protection schemes are used for maximum effectiveness with minimal tradeoffs

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Several options are available when adding extra protection circuits on the CAN bus.

In many cases, multiple protection schemes are used for maximum effectiveness with minimal tradeoffs.

This concludes the presentation.

Thank you.