



Restrictions    Public Document  
Abstract        This application notes discusses three commonly encountered high speed CAN physical layer problems - bus termination, signal levels, and ground.

**Table of Contents**

1	Overview .....	1
1.1	CAN Implementations .....	1
2	Common High-Speed CAN Bus Physical Problems.....	2
2.1	Bus Termination .....	2
2.1.1	Termination Resistor Location.....	3
2.1.2	Checking Termination Resistance.....	4
2.1.3	Tool-Related Termination Problems.....	4
2.2	CAN Bus DC and AC Voltages .....	5
2.2.1	CAN Controller Logic Reference .....	5
2.2.2	Checking the CAN_H Signal Line.....	5
2.2.3	Checking the CAN_L Signal Line .....	6
2.2.4	Checking the CAN Signal Waveforms.....	6
2.3	CAN Bus Ground.....	8
2.3.1	The Ground Requirement.....	8
2.3.2	Checking the Ground.....	8
2.3.3	Ground Shifts.....	9
3	Contacts.....	10

**1 Overview**

Determining the exact cause of a CAN problem is not at all simple.

Is the problem in hardware or software? Is the problem on the circuit board or on the CAN network wiring? Sometimes the problem may not be at the module level - perhaps the cause is up at the system level.

This application note discusses methods used to investigate several of the more common CAN Physical Layer problems typically encountered when debugging high-speed CAN.

**1.1 CAN Implementations**

As shown in Figure 1, each CAN-based module design requires three key items to implement CAN - software, a CAN Controller, and a Physical Layer – and if problems arise, the effort to isolate the problem will focus on these three areas.

The developer trying to get CAN up and running for the very first time may have problems in more than one area. In this case, it may be more appropriate to focus on the CAN Controller first.

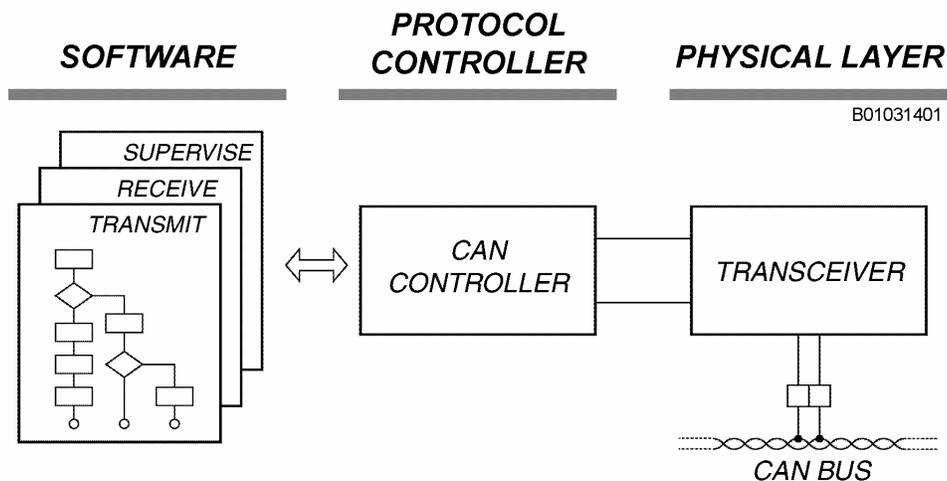


Figure 1 – Three Main Focus Areas when Debugging CAN

Based on reported experiences, if a working module is not functioning now or has been demonstrating intermittent operation, in most cases the problem is probably in the Physical Layer area.

## 2 Common High-Speed CAN Bus Physical Problems

In order of occurrence, the more prevalent high-speed CAN bus physical layer problems are as follows:

- Incorrect bus termination
- Incorrect CAN bus DC and AC voltages
- Poor grounding

Let's look at these problems now in more detail to understand how to solve them.

### 2.1 Bus Termination

Bus termination is an integral component of high speed CAN networks, but if implemented incorrectly becomes a common source of CAN Error Frames.

Bus Termination is used to prevent high-speed communication signals from being reflected back into the cable (somewhat like an echo in a canyon) and causing electrical interference. Unless restricted to a few inches in overall length, a high-speed CAN network requires bus termination. Otherwise, the signal reflections will change good CAN signal waveforms to bad – resulting in error frames or no communication at all.

Bus termination is typically accomplished by physically placing two termination resistors at the far ends of the CAN bus, as shown in Figure 2. Each resistor, typically 120 ohms, is connected between the CAN\_L and CAN\_H signal lines.

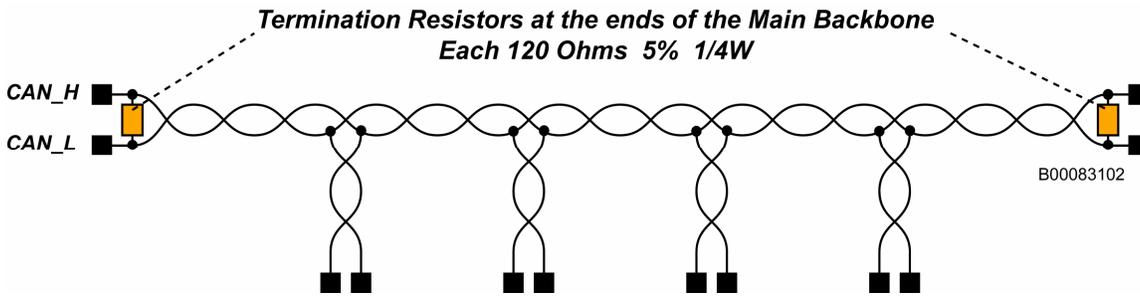


Figure 2 – Termination Resistors and Their Locations

### 2.1.1 Termination Resistor Location

At the system level, the location of the bus termination resistors is usually specified by the manufacturer of the distributed product. Prime placement locations for bus termination resistance include inside individual CAN modules or within the wiring harness itself.

However, during development at the module level, it is typically necessary to add sufficient termination resistance to the development environment so testing can be conducted. If the module already includes termination resistance internally only a single termination resistor will be required. However, in most cases the module does not include termination, so this will require two termination resistors, carefully placed at the far ends of the testing cable.

As changes are made during the design process it is possible to place these resistors in the wrong location, as shown in Figure 3.

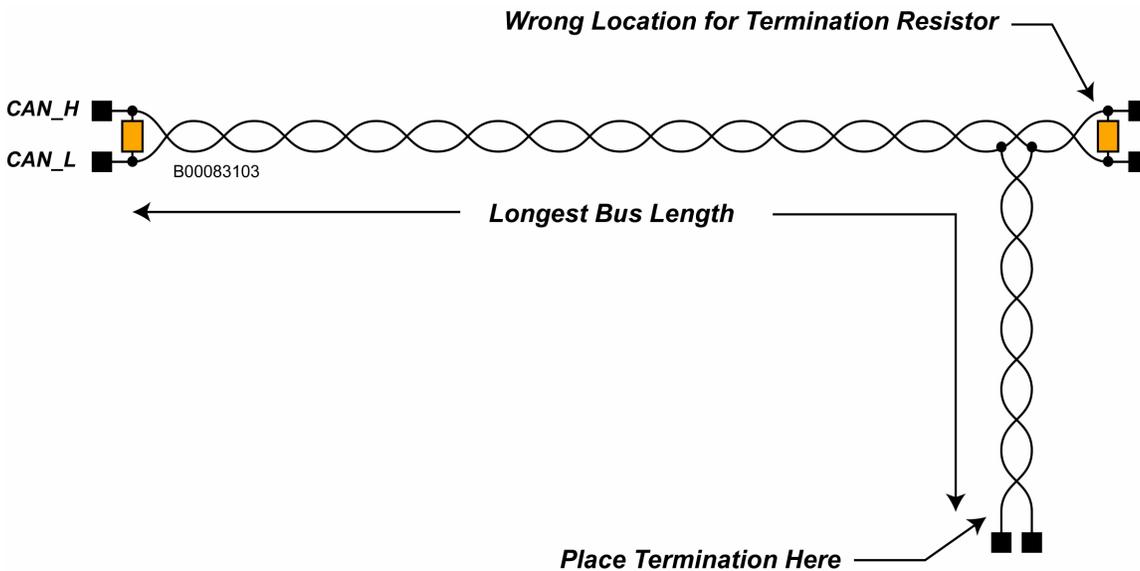


Figure 3 – Incorrect Termination Location

Both insufficient termination resistance and inappropriate termination resistance locations may cause Error Frames.

### 2.1.2 Checking Termination Resistance

It is easy to check the termination resistance with a digital volt meter (DVM). With power feeds to network ECUs off, connect the two leads of the DVM as shown in Figure 4. Set the meter to ohms and measure the resistance across the bus.

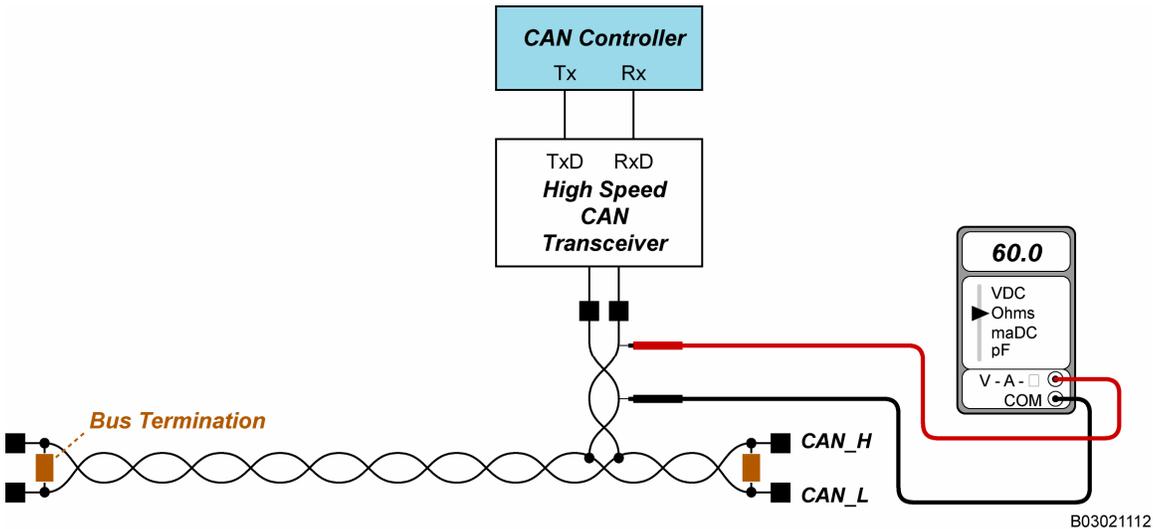


Figure 4 – Checking Termination Resistance

**Note:** It is a best practice to check the voltage of the bus prior to making a resistance measurement, so as to prevent damage the DVM

### 2.1.3 Tool-Related Termination Problems

Problems can also occur when connecting to CAN tools. Sometimes the addition of a tool connection will influence the maximum bus length and subsequently require relocating a termination resistor. To reduce the likelihood of this problem - try to make CAN tool connections near the middle of the test cabling, that is, between the module and a potential second module tester, as shown in Figure 5.

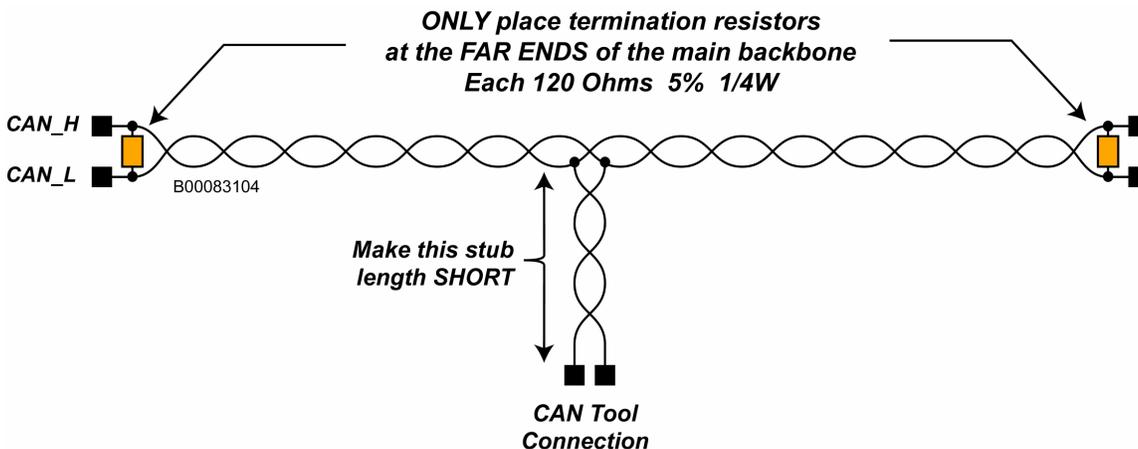


Figure 5 – CAN Tool Connections with Termination

## 2.2 CAN Bus DC and AC Voltages

CAN communication problems may result if the CAN bus signal levels are incorrect or when the CAN transceiver is not properly functioning. The following checks can be made to determine if a problem exists in this area.

To perform the following DC and AC voltage checks, make sure that the CAN transceiver circuitry is not connected to the CAN bus, any long wires, or any CAN analysis tool.

### 2.2.1 CAN Controller Logic Reference

Keep in mind that the logic reference used by the CAN Controller, shown in Figure 8, is as follows:

- logic level “0” is the dominant state
- logic level “1” is the recessive state

When not transmitting a message, the TX pin, an output, is left in the recessive state - logic level “1”.

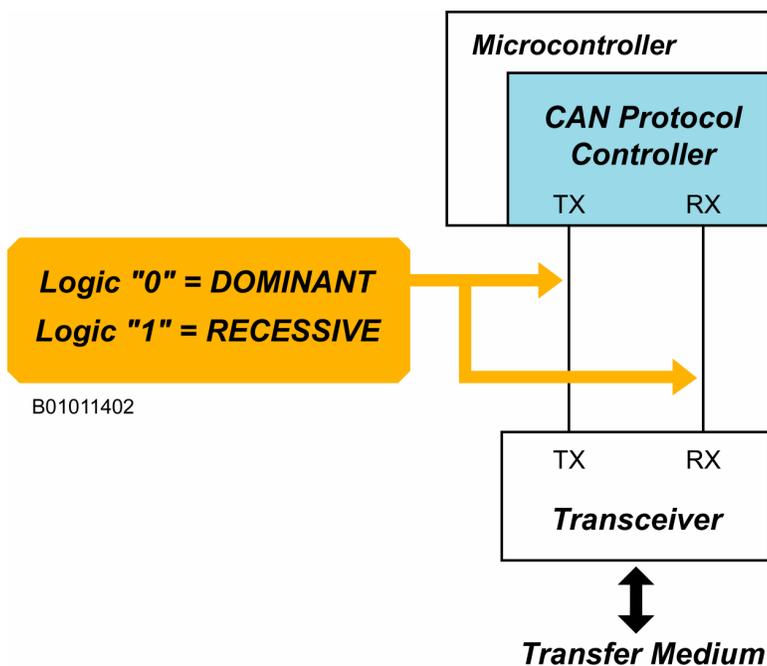


Figure 8 – CAN Controller Logic Reference

### 2.2.2 Checking the CAN\_H Signal Line

The voltage at CAN\_H should be half of the 5 volt logic level during time periods where no CAN message is being transmitted, or the CAN bus is otherwise at the “recessive” state.

If it is already known that the CAN Controller is not sending any messages in the test environment, then there may be no reason to disconnect it to make the following measurement.

Otherwise, to be sure the CAN Controller is not transmitting any messages, disconnect its TX pin from the transceiver and place the transceiver's TX input pin at logic level “1” (+5 volts) to force the transceiver to the “recessive” state.

Using an appropriate ground reference, connect the digital volt meter (DVM) to the CAN\_H signal line and measure the DC voltage as shown in Figure 6. It should measure close to 2.5 volts.

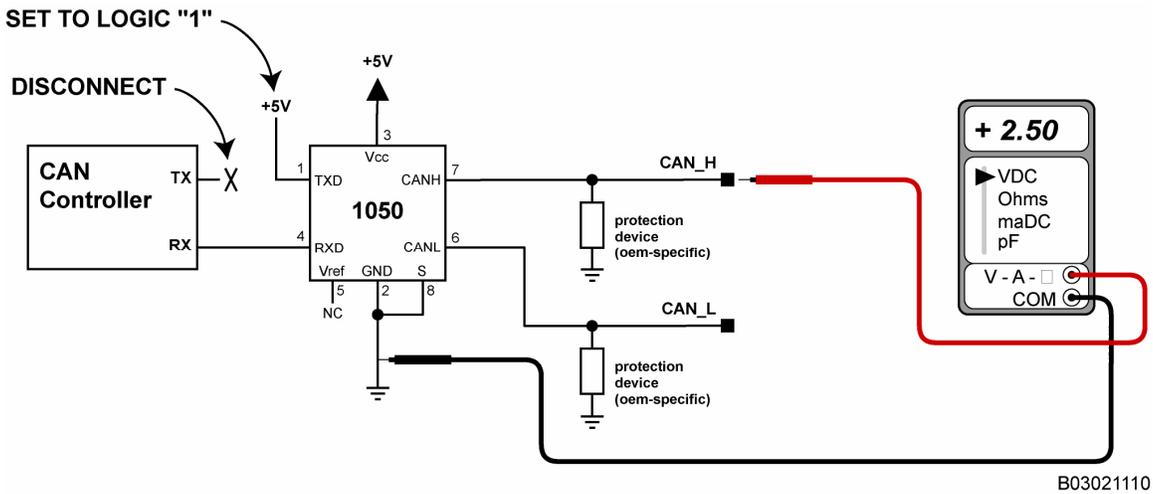


Figure 6 – CAN\_H DC Voltage Checks

### 2.2.3 Checking the CAN\_L Signal Line

The voltage at CAN\_L should be half of the 5 volt logic level during time periods where no CAN message is being transmitted, or the CAN bus is otherwise at the “recessive” state.

Connect the DVM to the CAN\_L signal line and measure the DC voltage using the same procedure as above, as shown in Figure 7. It should measure close to 2.5 volts.

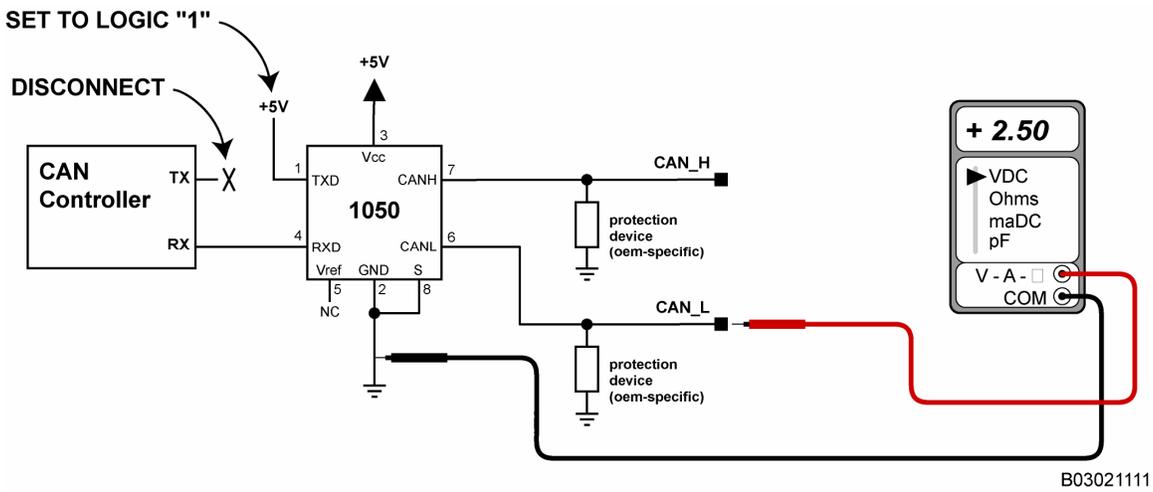
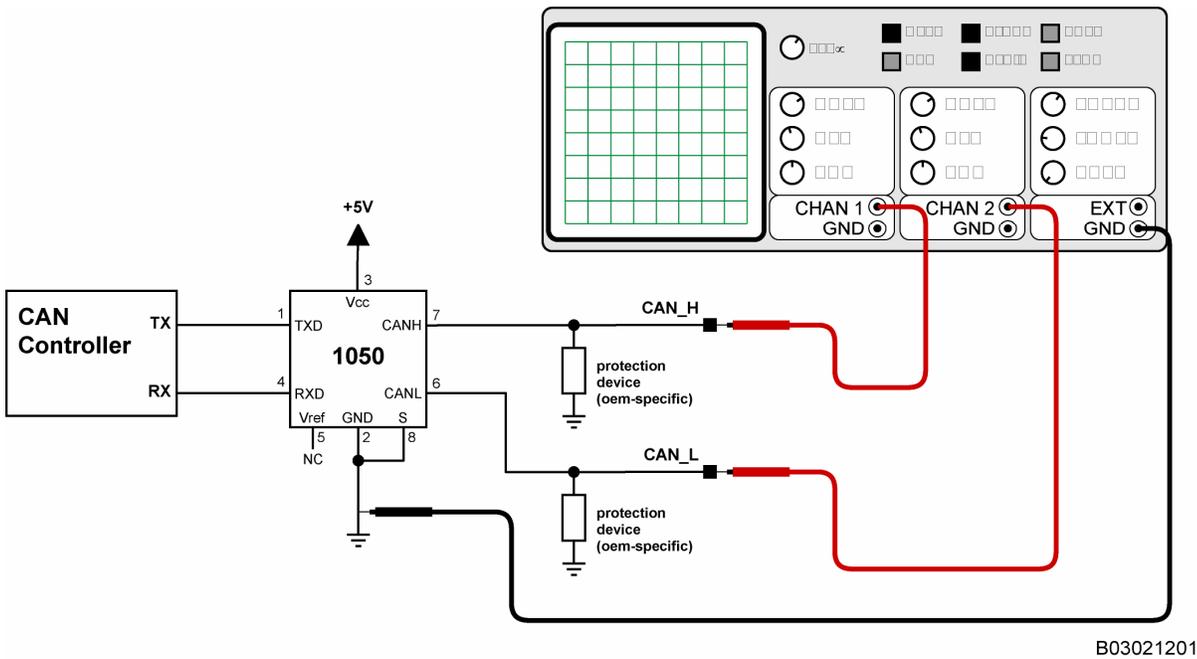


Figure 7 – CAN\_L DC Voltage Checks

### 2.2.4 Checking the CAN Signal Waveforms

Connecting a scope to CAN\_H and CAN\_L, as shown in Figure 9, will allow the CAN bus signal waveforms to be checked during CAN message transfers.

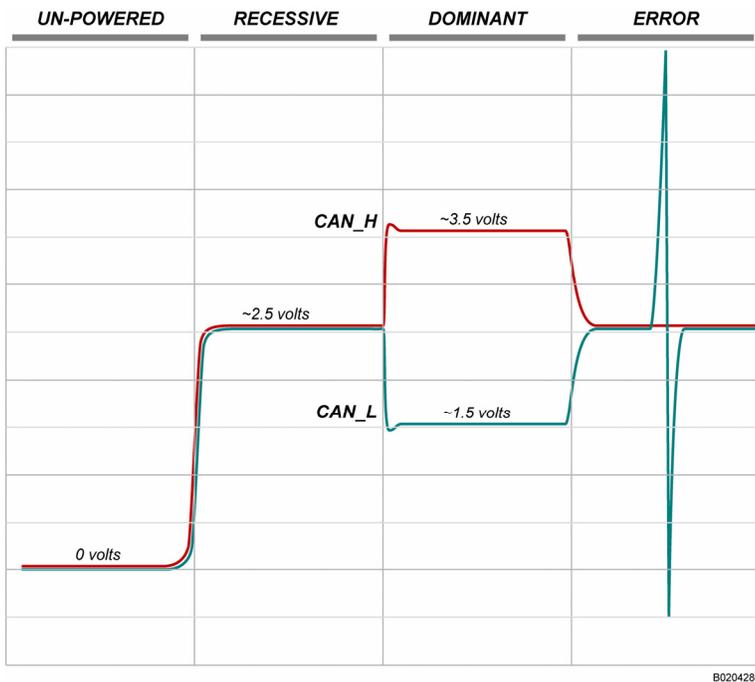


B03021201

Figure 9 – Scope Connections for Measuring CAN Bus Waveforms

Figure 10 shows a typical CAN signal seen during normal message transmission in the recessive and dominant columns. Beginning with both signal voltages at 2.5 volts, every dominant bit will shift the CAN\_H signal higher to approximately 3.5 volts and at the same time shift the CAN\_L signal down to 1.5 volts.

Remember that when no messages are being sent (also called idle time) both CAN\_H and CAN\_L signal voltages remain at the mid supply level of approximately 2.5 volts.



B02042801

Figure 10 – CAN Bus High-Speed Waveforms

## 2.3 CAN Bus Ground

CAN communication problems may result if the CAN transceiver ground 'quality' is poor or the ground is missing. Ground problems can be a source of Error Frames and in more severe cases may cause damage in the CAN interface circuitry, the transceiver, or sometimes even in a CAN tool.

### 2.3.1 The Ground Requirement

All wire-based communications systems like RS232, RS485 or high-speed CAN require an adequate ground connection to function properly.

Unknowingly, the automotive industry, with its metal chassis ground, seems to have propagated the idea that high-speed CAN is only a two wire interface when in fact it is really a three wire interface:

- CAN\_H
- CAN\_L
- Ground

While many experimenters have successfully used CAN in laboratory conditions by using the local AC Ground as the third wire, such connections should not be relied on in all cases. Because there is no guarantee that the AC ground is properly wired, one should proceed with caution.

The random occurrence of large AC ground differential voltages may potentially damage a CAN transceiver and cause intermittent problems or complete loss of communication.

### 2.3.2 Checking the Ground

As shown in Figure 11, each ground should be investigated to determine whether there is a complete DC connection - do not rely on an AC ground!

The quality of the ground should be tested during system development, during module development, and whenever a CAN communication test system is changed.

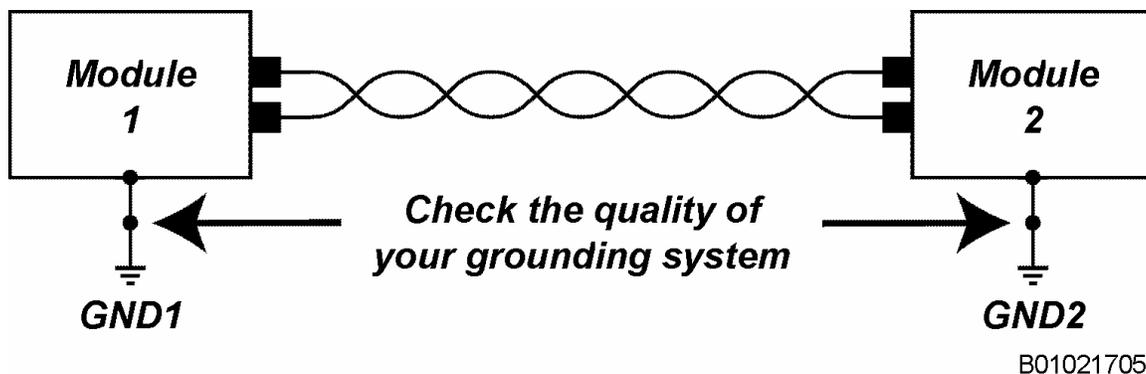


Figure 11 – Checking the Quality of the Ground

As shown in Figure 12, the ideal condition is to use a single common ground.

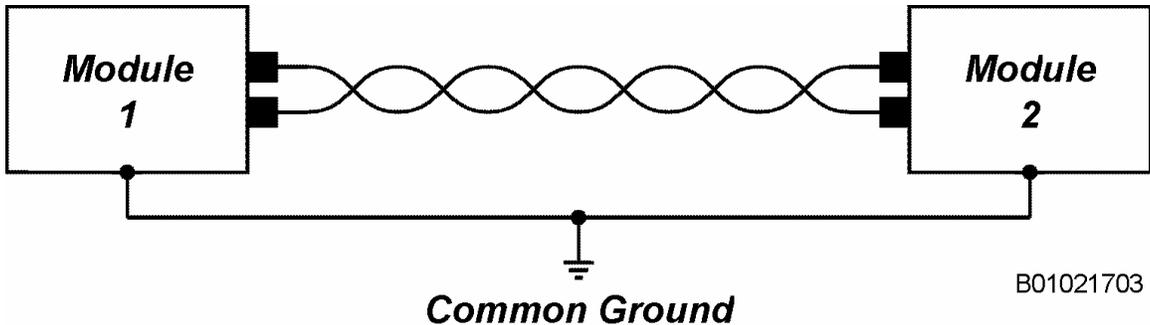


Figure 12 – Using a Common Ground

### 2.3.3 Ground Shifts

Although perfect grounds do not exist, near-perfect ones are good enough. Many CAN transceivers will function with ground differences or ground shifts up to a few volts.

While somewhat infrequent, ground shift problems occur more often in systems that use large amounts of current to control large loads. In the automotive environment, such modules might include audio amplifiers, window motor actuators, climate control fans, etc. Those load-controlling modules that use significant amounts of current may experience local ground shifting which may intermittently affect the quality of the CAN communication system. Early electric car experience demonstrated several communication difficulties when controlling the large motor loads.

As shown in Figure 13, if communication problems seem to coincide with the actuation of large current carrying loads, consider investigating the likelihood that ground shifting is occurring.

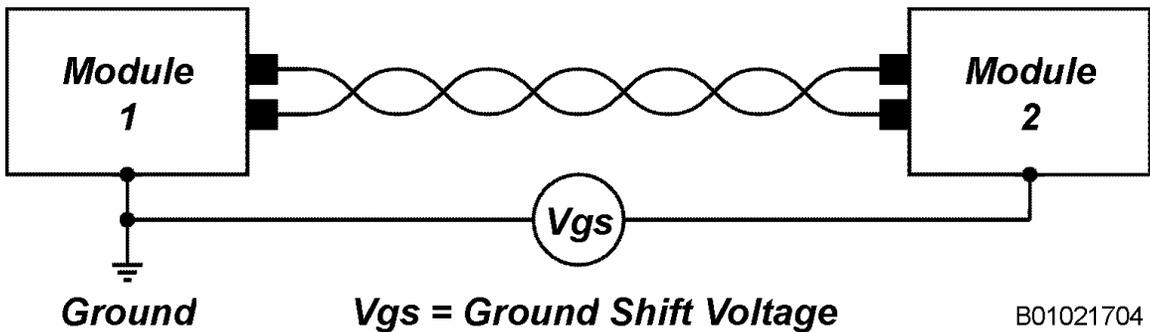


Figure 13 – Ground Shifting Affects Communications

### 3 Contacts

---

**Vector Informatik GmbH**  
Ingersheimer Straße 24  
70499 Stuttgart  
Germany  
Tel.: +49 711-80670-0  
Fax: +49 711-80670-111  
Email: [info@vector-informatik.de](mailto:info@vector-informatik.de)

**Vector CANTech, Inc.**  
39500 Orchard Hill Pl., Ste 550  
Novi, MI 48375  
Tel: (248) 449-9290  
Fax: (248) 449-9704  
Email: [info@vector-cantech.com](mailto:info@vector-cantech.com)

**VecScan AB**  
Lindholmospiren 5  
SE-417 56 Göteborg  
Sweden  
Tel: +46 (0) 31 764 76 00  
Fax: +46 (0) 31 764 76 19  
Email: [info@vecscan.com](mailto:info@vecscan.com)

**Vector France SAS**  
168 Boulevard Camélinat  
92240 Malakoff  
France  
Tel: +33 (0)1 42 31 40 00  
Fax: +33 (0)1 42 31 40 09  
Email: [information@vector-france.fr](mailto:information@vector-france.fr)

**Vector Japan Co. Ltd.**  
Seafort Square Center Bld. 18F  
2-3-12, Higashi-shinagawa,  
Shinagawa-ku  
Tokyo, 140-0002, Japan  
Tel: +81 03(5769)6970  
Fax: +81 03(5769)6975  
Email: [info@vector-japan.co.jp](mailto:info@vector-japan.co.jp)

---