Industrial Automation using the CAN Bus Platform White Paper

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Texas Instruments

Contents

Introduction

This white paper describes the design of a demonstration system that shows the operation of several subsystems emulating automotive and industrial applications across the CAN bus. The platform shows these subsystems operation as the bus loading is varied, demonstrating the robustness of the multi-master CAN bus. The platform highlights:

- Interoperability of 5V and 3.3V CAN bus transceivers
- Multi-master operation of the CAN bus
- Bus arbitration operation
- Performance with injected error conditions.

This paper describes the features and design of the platform that allow these items to be highlighted.

CAN Bus Overview

The Controller Area Network (CAN) bus is a multi-master message broadcast system that is suitable for systems where data contained in short messages are needed to be received at multiple locations simultaneously. Because messages are sent to all the nodes in a system, CAN is especially suited to systems where consistency in the received messages at all the receiving nodes is needed. Provisions are included in the protocol to reject messages if any destination node detects an error. In this case, all nodes are notified of the rejection, ensuring the data consistency across the network.

Messages are sent to all nodes, but their "message identifiers" indicate whether each node should act on the message. However, all nodes participate in indicating whether the message was sent correctly, increasing the reliability of the bus.

Reference 1 describes the CAN bus and protocol in detail.

System Design

System Requirements Overview

The demonstration platform was meant to show how several subsystems, chosen to resemble typical industrial or automotive subsystems, could be controlled via a CAN bus. The subsystems were spread across three electronics boards.

Since many DSPs and microprocessors are migrating to 3.3V operation, we wanted to incorporate TI's 3.3V CAN transceivers into the platform, showing how they interoperate with standard 5V CAN transceivers. Because of this, this platform includes both 3.3V and 5V CAN transceivers.

There are many processors that include integrated CAN controllers. For this demonstration, we have chosen three processors that span the low-end control (TMS320LF2406A), high-end control (TMS320F2810), and general microprocessor (TMS470R1VF338 – an ARM7 processor) markets.

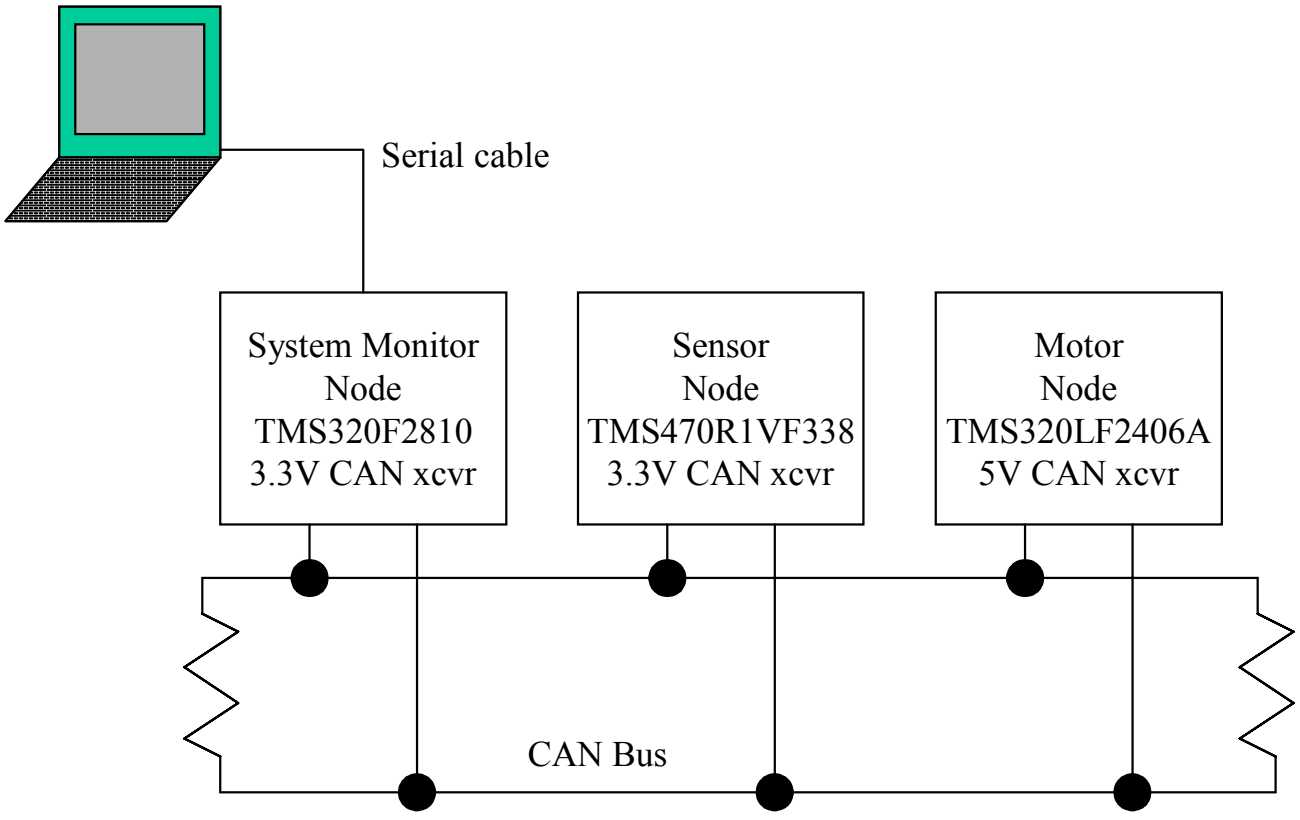

Figure 1. CAN Platform Boards

We also wanted to show the bus arbitration behavior of the bus (that is, how it reacts when more than one node needs to transmit to the bus at a time), leading us to add traffic generators to stress the bus.

These subsystems were included in the demonstration.

- Fan/temperature control.
  This system was meant to model an industrial control application, where the temperature set point would be communicated to a temperature control system that would use a fan to control to a target temperature. This might emulate, say, an HVAC system or, in general, any subsystem where the control would happen locally at a node based on a commanded set-point from another node on the CAN bus.
- Motor control
  This system is meant to emulate the popular industrial application of motor control. Here the motor speed and/or position is commanded from a remote node on the CAN bus while the actual motor control is performed locally at one of the nodes.
- CAN bus corrupter
  This subsystem allows various impairments to be injected onto the CAN bus to show how the bus detects errors and also how the bus can recover from the errors with no failures as the errors are removed.
- Bus loading factor control
  This subsystem generates additional CAN bus traffic. There are two traffic generators. The first is additional traffic with rate determined by the speed of the motor. The second is a traffic generator that is purely micro-controller based. The intent is to load the bus with additional traffic that would cause bus arbitration to occur and show the robustness of the CAN bus to heavy bus loading. Under heavy bus loading, lower priority packets are delayed as higher priority packets use the bus. We have configured the platform to give an audible indication when a low priority packet has been delayed.

Figure 2 shows the various sub-systems and how they're distributed across the three nodes.

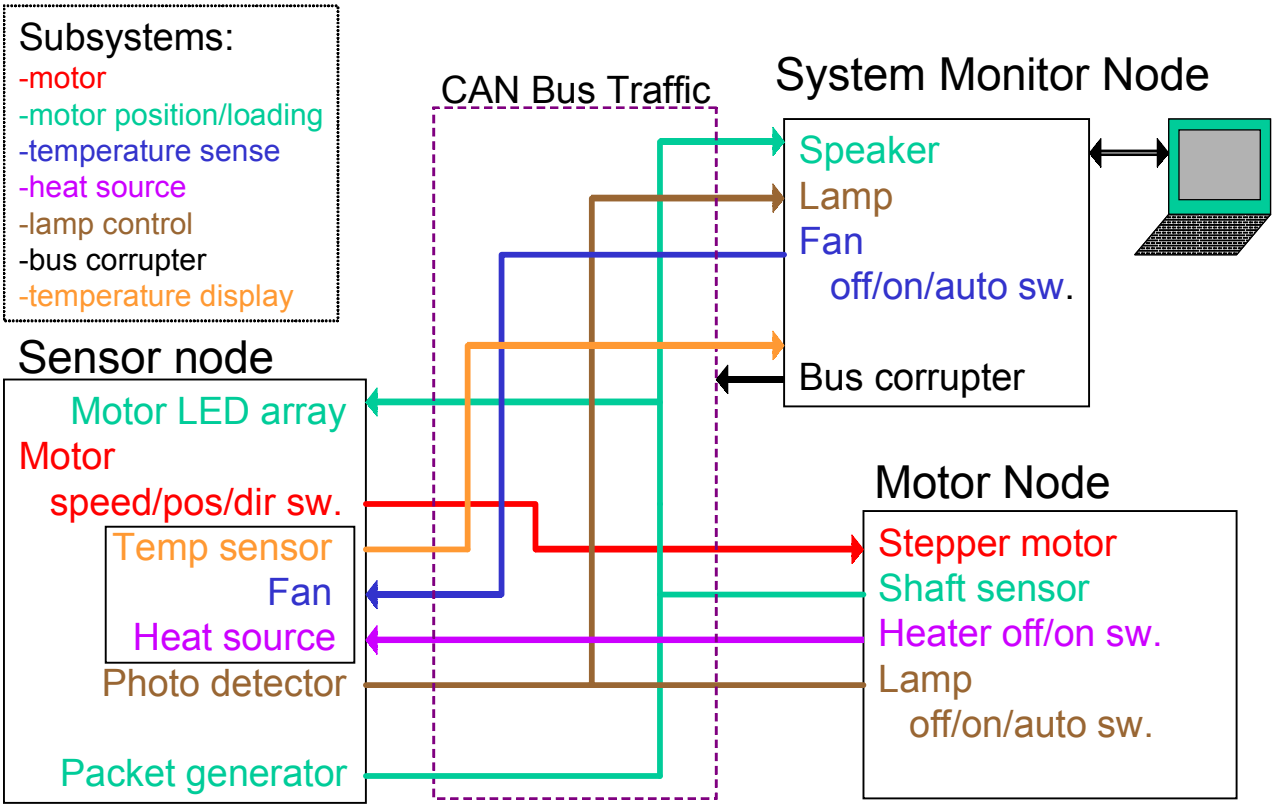

Figure 2. Platform Subsystems

Communication across the Bus

Communication between the processors along the CAN bus is handled by specialized CAN controllers included as part of each of the processor devices. These controllers support version 2.0B of the CAN protocol. While the hardware is similar between the three processors, there are differences between the controllers available, summarized in Table 1.

Processor	Type(s) of CAN controller(s)	Number of mailboxes
TMS320F2810	eCAN	32
TMS320LF2406A	SCC	6
TMS470R1VF338	SCC/HECC	16(SCC)/32(HECC)

Notes. SCC=standard CAN controller; HECC=high-end CAN controller; eCAN=enhanced CAN controller

Messages are passed from processor to processor through "mailboxes." These mailboxes are configured to either receive or transmit messages containing certain message identifiers. When a message is sent, each processor's controller participates in validating that the message has been sent correctly. Then, if the message identifier matches a mailbox's message identifier, the message is stored for processing. If there is no match, the message is discarded.

Specific message identifiers and mailbox assignments are detailed in the "Industrial Automation using CAN Bus Software Architecture" manual. Detailed information on the

implementation of the CAN controller software on the C24x and C28x platforms can be found in References 4 and 5.

3.3V and 5V Interoperability

The CAN physical layer described in ISO 11898 is fundamentally a 5-volt system (Reference 2) that biases the signal lines to 2.5V. It would seem natural to use a 5-volt part for a CAN transceiver, and this is what has traditionally been done.

Most electronics systems, though, are migrating to 3.3V or lower operation. An ideal CAN transceiver would allow operation using a 3.3V power supply. TI has a family of CAN transceivers (SN65HVD23x) that allow operation on a traditional 5-volt CAN bus that themselves run on 3.3V. Reference 3 describes testing that was done showing the compatibility of the SN65HVD230 with a standard 5V CAN bus.

This platform uses a mix of 5-volt and 3.3-volt CAN transceivers to show the interoperability of these two types of devices.

Features to Assist Demonstration and Evaluation

Some features that have been added to the demonstration platform to assist in the evaluation of the CAN bus function. These features are described here.

The F2810 contains an SCI interface that can be easily tied to a PC's UART through a level translator (e.g., the SN75LV4737A). A command interface has been developed that allows the bus operation to be monitored and controlled from a program on the host PC. Using this program, control messages to other nodes can be sent, and the status of the CAN bus can be monitored.

Several LED's have been placed on the board to indicate when the CAN bus is active, when commands are being received from the PC, and so forth. These LED's are described in the "Industrial Automation using CAN Bus Platform Getting Started Guide."

Bus Loading and Corruption

This section of the paper describes the circuitry used to load the bus with traffic and the circuitry used to inject error conditions onto the bus.

Bus Loading

There are two mechanisms available to load the CAN bus with traffic. The first mechanism is a "flood packet" generator on the sensor node. The rate of packets flooding the bus is controlled through a pull-down menu item on the GUI interface on the laptop/PC. The appropriate flood rate depends on the bus data rate (1 Mbps, 500 kbps, 250 kbps, 125 kbps), selected by the DIP switches as described in the "Industrial Automation using CAN Bus Platform Getting Started Guide." The following table shows the theoretical maximum packet loading on the bus for each data rate as well as a recommended rate available on the GUI that loads the bus near its maximum capacity. The message length in bits is given by the formula:

$$L = SOF + MSGID + RTR + CTRL + (8 \bullet MSGLENGTH) + CRC + ACK + EOF + IFS + STUFF$$

where:

- *SOF* is the start of frame length, 1 bit
- *MSGID* is the message identifier length, 11 bits
- *RTR* is the remote transmission request bit length, 1 bit
- *CTRL* is the control field length, 6 bits, that includes the *IDE* (identifier extension bit), *r0* (reserved bit), and *DLC* (data length) fields.
- *MSGLENGTH* is the length of the message in bytes. Most of our messages are 6 bytes long, with one that is 8 bytes long. The calculations assume 6 bytes.
- *CRC* is the length of the cyclic redundancy code, 16 bits
- *ACK* is the length of the acknowledge bits (2 of these)
- *EOF* is the end of frame indicator length, 7 bits
- *IFS* is the minimum bus inter-frame space time between messages, 7 bits
- *STUFF* is the additional time in the message due to stuff bits. Transitions are forced on the bus after long strings of zeroes, and assuming the maximum number of stuff bits in the message and message identifier, (11+48)/5 bits.

Baud Rate (Mbps)	Data Field Length (Bytes)	Message Length (bits)	Message Time (μs)	Maximum messages per second	Recommended Rate on GUI
1	6	111	110	9090	7000
0.5	6	111	220	4545	3500
0.25	6	111	440	2272	1500
0.125	6	111	880	1136	500

The second mechanism can be used to push the bus loading over capacity. The rate that the motor spins determines the rate at which motor speed packets are loaded onto the bus. As the

motor speed is increased from zero, the bus becomes more heavily loaded. At some point, the low priority packets from the "flood packet" generator on the sensor node and the motor packets from the motor node are delayed to allow higher priority traffic onto the bus. The system monitor node checks for delayed messages and indicates a delayed message by clicking the speaker. So, a speaker click indicates that the bus arbitration is working, causing lower priority flood and motor position packets to be deferred in favor of higher priority packets.

Bus Corruption

The capability to inject error conditions on the bus is incorporated on the system monitor node, under control of the GUI interface. The bus corrupter is able to perform the following actions to the bus:

- Open the CAN_high line between the bus connectors and the CAN transceiver on the system monitor board
- Open the CAN_low line between the bus connectors and the CAN transceiver on the system monitor board
- Short the CAN_high line to 5V
- Short the CAN_low line to 5V
- Short the CAN_high line to ground
- Short the CAN_low line to ground
- Short the CAN_high and CAN_low lines together
- Remove termination between the CAN lines
- Install excessive termination between the CAN lines

Another error that can be created is:

- Unpower a CAN node (by unplugging one of the boards from power)

For most of these errors, the bus will cease to function (see the Performance Measurement section below). Some of these error conditions cause the bus error rate to be degraded. The effect of the error condition can be viewed using the statistics available on the GUI interface.

The requirement is that the CAN transceivers withstand these error conditions and return to the same error rate performance when the fault is removed. The data in the next section shows that TI's CAN transceivers meet this requirement.

Performance Measurements

This section provides a summary of the performance evaluation of the platform. Performance was measured by observing how communications between nodes was effected in each bus corruption mode for two different cable lengths. To test the effect of powered down node on the bus, the Motor Node was turned off. These tests were repeated for different baud rates on the CAN bus. Finally, a Philips PCA82C251 replaced the TI SN65HVD251 5V CAN transceiver and the tests run again. In no case did the TI CAN transceivers get damaged or show degraded performance after the corruption mode was removed. Also, TI's CAN transceivers performed equivalent to the Philips PCA82C251 CAN transceiver. The following tables show the results of those tests.

40 Meter Cable (TI SN65HVD251)		**Messaging**		
Baud Rate	**Corruption Mode**	**SM to SN**	**SM to MN**	**SN to MN**
1Mbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
	Extra termination	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to Vcc	can send not rcvd	can send & rcvd	can rcvd not send
	CanL to Vcc	no messaging	no messaging	no messaging
	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send not rcvd	can send not rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd
500kbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
	Extra termination	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to Vcc	can send & rcvd	can send & rcvd	can send & rcvd
	CanL to Vcc	no messaging	no messaging	no messaging
	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send not rcvd	can send struggles to rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd
250kbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
	Extra termination	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to Vcc	can send & rcvd	can send & rcvd	can send & rcvd
	CanL to Vcc	no messaging	no messaging	no messaging
	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd
125kbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
	Extra termination	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to Vcc	can send & rcvd	can send & rcvd	can send & rcvd
	CanL to Vcc	no messaging	no messaging	no messaging
	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd

6 Meter Cable (TI SN65HVD251)		Messaging		
Baud Rate	**Corruption Mode**	**SM to SN**	**SM to MN**	**SN to MN**
1Mbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
	Extra termination	can send & rcvd	can send & rcvd	can send & rcvd
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	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send not rcvd	can send not rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
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40 Meter Cable (Philips PCA82C251)		Messaging		
Baud Rate	**Corruption Mode**	**SM to SN**	**SM to MN**	**SN to MN**
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	CanL to Gnd	can send & rcvd	can send & rcvd	can send & rcvd
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	CanL to Vcc	no messaging	no messaging	no messaging
	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd

6 Meter Cable (Phillips PCA82C251)		Messaging		
Baud Rate	**Corruption Mode**	**SM to SN**	**SM to MN**	**SN to MN**
1Mbps	No termination	can send & rcvd	can send & rcvd	can send & rcvd
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	CanH to Gnd	no messaging	no messaging	no messaging
	CanL to Gnd	can send & rcvd	can send & rcvd	can send & rcvd
	CanH to CanH	no messaging	no messaging	no messaging
	CanH open	no messaging	no messaging	can send & rcvd
	CanL open	no messaging	no messaging	can send & rcvd

Product Support

Support for the individual components in this design is provided through the product support structure of TI. Here are some sources for additional information that may be of interest.

Technical support contact information may be found at http://www.ti.com/corp/technical_support.htm, including telephone numbers and e-mail addresses for additional information on TI products. This page also has links to the DSP and analog knowledge bases.

There are also DSP discussion groups that may be helpful. See http://dspvillage.ti.com/docs/catalog/general/general.jhtml?templateId=5121&path=templatedata/cm/vilorphan/data/vil_discgroups.

Conclusions

This platform demonstrates these four key attributes of the CAN bus and CAN bus electronics available from TI.

- Interoperability of 5V and 3.3V CAN bus transceivers.
  By using a mix of 5V and 3.3V CAN bus transceivers, the interoperability in a standard 5V CAN bus system is shown.
- Multi-master operation of the CAN bus
  Messages are sourced from each of the three nodes and passed to any one of the two remaining nodes. No one node dominates the bus. Instead, bus operation is determined by the priority of the messages.
- Bus arbitration operation
  By loading the bus heavily with low priority packets, it is possible for higher priority packets to interfere with the timely delivery of the low priority packets. This platform shows this through an audio indication when a low priority packet is delayed due to higher priority traffic. This demonstrates that the bus arbitration works correctly, granting the bus to the higher priority packets.
- Performance with injected error conditions.
  The bus corrupter allows various error conditions to be injected onto the bus. In most cases, the bus was unable to operate with the injected error conditions. Most important is that the bus was able to recover from the injected error conditions when they were removed, and the bus operation was restored to its previous condition.

References

1. Texas Instruments, “Introduction to the Controller Area Network (CAN),” Application Report SLOA101, August 2002.
2. D. Marsh, “CANBus Networks Break into Mainstream Use,” EDN, Aug. 22, 2002, pp. 53-60.
3. Texas Instruments, “A System Evaluation of CAN Transceivers,” Application Report SLLA109, March 2002.
4. Texas Instruments, “Programming Examples for the 24x/240xA CAN,” Application Report SPRA890, January 2003.
5. Texas Instruments, “Programming Examples for the TMS320F281x ECAN,” Application Report SPRA876, January 2003.

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Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
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