LT3960 I²C to CAN-Physical Transceiver in A²B Communications

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Introduction

This application note describes the integration of the LT3960 I²C extender in Automotive Audio Bus (A²B) ® systems. It serves as a guide for prototyping systems that require an extension of clean I²C data to various targets.

EVAL-LT3960-AZ I²C to CAN-Physical Transceiver

The LT3960 transceiver is a robust high-speed transceiver that extends a single-controller I²C bus through a harsh or noisy environment at up to 400 kb/s using the CAN-physical layer.

One LT3960 transceiver sits near the I²C controller creating SCL and SDA equivalent differential buses (I²CAN) on two twisted pair connections. At the other end of the twisted pairs, a second LT3960 transceiver recreates the I²C bus locally for any target I²C devices. The SDA and SCL data lines are converted to differential signals and are shared between devices connected to the bus. This configuration permits the physical separation of the I²C controller and target [2].

Automotive Audio Bus (A²B)

The Automotive Audio Bus is a high bandwidth, bidirectional, digital audio bus capable of transporting I²S/TDM/PDM data and I²C control information, along with clock and power. A²B signals are routed using a single, two wire UTP cable. The A²B system can be used as its own network with embedded sub-networks, or as an endpoint transport bus used in combination with other, longer distance protocols. The clock is synchronous on all nodes in a single A²B network. Microphone and serial audio data are received on each node in the system simultaneously.

I²C Extenders in A²B Systems

Two primary use cases employ I²C extenders in A²B systems. Automotive head units may employ A²B nodes and I²C extenders in parallel. Figure 1 effectively shows how to extend the I²C control data from a single I²C controller (host processor) to both the A²B main node and separate I²C targets (use case 1). Figure 2 shows how the LT3960 device can extend I²C signals from a subordinate node along the A²B bus to external peripheral devices (use case 2).

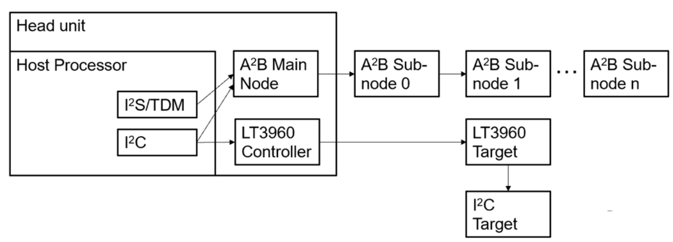


Figure 1. Use Case 1

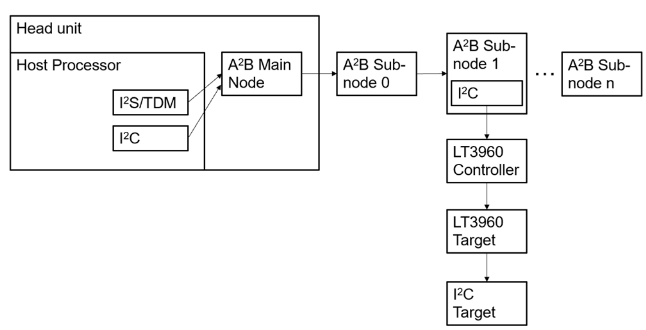


Figure 2. Use Case 2

Features

The EVAL-LT3960-AZ evaluation board and EVAL-AD2428WB1BZ A^2B evaluation board have the following features.

EVAL-LT3960-AZ Board

- Two I^2C to CAN-Physical transceivers
- Test Points for digital signals and analog inputs
- Protected from overvoltage line faults to ±40V
- Up to 400kbps I^2C communications
- 4 V to 60 V power supply range with internal 3.3 V
- Regulator
- 3.3 V or 5 V bus voltage
- Extended common mode range (±36V)
- ±8kV HBM ESD on CAN pins, ±2 kV HBM ESD on all other pins
- Current limited drivers with thermal shutdown
- Power-up/down glitch free driver outputs
- Low current shutdown mode
- Transmit data dominant timeout function
- E- and J-Grades available
- Available in a 10 lead MSOP package

EVAL-AD2428WB1BZ A^2B Evaluation Board

- Bus-powered A^2B® subordinate transceiver (AD2428W)
- Stereo audio codec/SigmaDSP® (ADAU1761)
- Two stereo MEMS microphones
- EEPROM
- LED and push-button on GPIO/IRQ
- Test points for digital signals and analog inputs

Equipment Needed

- A^2B main node (EVAL-AD2428WD1BZ)
- EVAL-ADUSB2EBZ USB interface
- Bus-powered A^2B subordinate node (AD2428WB1BZ)
- Additional A^2B subordinate nodes (optional)
    - EVAL-AD2428WG1BZ
    - EVAL-AD2428WC1BZ
- 1.8 m twisted-pair cables (CAT5e-Rated, with DuraClik™ Connectors)
- Jumper wires
- Power supply

Documents Needed

- EVAL-AD2428WB1BZ A^2B Evaluation Board User Guide (EE-419) [1]
- EVAL-LT3960-AZ I^2C to CAN-Physical Transceiver User Guide [2]
- LT3960 I^2C to CAN-Physical Transceiver Data Sheet [3]
- Demo Manual DC2686A [4]

Software Needed

- SigmaStudio® rev. 4.5 or later
- A^2B software release 19.4.0 or later

System Specifications

The EVAL-LT3960-AZ evaluation circuit consists of two LT3960 I^2C to CAN-physical transceivers that can be configured either in controller or target mode using selectable jumpers, JP1 and JP3. The board is designed to be easily snapped apart at the center, separating the two circuitries.

One LT3960 device connects to the I^2C controller (e.g. host processor). The second LT3960 device connects to the first LT3960 device through two twisted pairs and regenerates a clean I^2C bus locally for one or more I^2C target devices. The LT3960 devices transmit the clock signal in only one direction, from controller to target. However, bidirectional communication of the data signal is permitted [2].

Refer to the LT3960 data sheet and user guide to review the complete description of the parts, their operation, and application information.

Operation

Each transceiver consists of a transmitter and receiver, capable of quickly converting a single-ended I^2C dominant signal into a differential dominant signal, and vice versa. The transmitter is a current-regulated differential driver that generates a differential voltage between the CANxH and CANxL pins. The voltage is determined by the drive current and the equivalent resistive load on the CANx bus. The receiver is a CAN compatible differential receiver with a wide common-mode range of ±25V or ±36V, depending on V_{CC} voltage.

Bidirectional communication is supported on the data channel (SDA and CANSDA) regardless of the mode of operation. Communication on the clock channel (SCL and CANSCL) is unidirectional, with the direction determined by the selected mode of operation. In target mode, an LT3960 device only communicates clock signals from the CANSCL bus to the SCL bus. In controller mode, an LT3960 device only communicates clock signals from the SCL bus to the CANSCL bus. Regardless of the number of LT3960 devices tied to a I^2CAN bus in a given application, exactly one will operate in controller mode, driving the clock signal to the I^2CAN bus and, ultimately, to all I^2C target devices. The LT3960 device does not support multi-controller I^2C systems [3].

Pin Functions

CANSDAL (Pin 1): low level CAN bus line. Carries the I^2C data bus.

CANSDAH (Pin 2): high level CAN bus line. Carries the I^2C data bus.

CANSCLH (Pin 4): high level CAN bus line. Carries the I^2C clock bus.

CANSCLL (Pin 5): low level CAN bus line. Carries the I^2C clock bus.

GND (Pin 3 and exposed pad): ground. Solder the exposed pad and pin directly to the ground plane.

V_{IN} (Pin 6): input voltage supply. This pin is the power supply input to the LDO. It must be locally bypassed with a 1 µF filter capacitor to GND as close to the pin as possible. If the LDO function is unused, tie V_{IN} to V_{CC}.

EN/MODE (Pin 7): MODE/shutdown pin. Tie above 2 V to select controller mode, float pin to select target mode, or pull this pin to ground for low power shutdown mode.

V_{CC} (Pin 8): low dropout regulator output and device power supply input. Bypass this pin with a 2.2 µF or greater capacitor to ground. Any bypass capacitors must be located as close to the pin as possible.

SCL (Pin 9): clock input or output pin for the I^2C serial port. When EN/MODE is 2 V or above, the SCL pin is an input for the controller clock. When EN/MODE is floating, the SCL pin is an output for data received on the CANSCLH/L pins.

SDA (Pin 10): data input and output pin for the I^2C serial port.

Setup

Setup includes instructions for A^{2}B system configuration and integration of the EVAL-LT3960-AZ evaluation board.

A^{2}B System Configuration

The A^{2}B test configuration consists of three nodes with EVAL-AD2428WD1BZ as the main node and two EVAL-AD2428WB1BZ nodes as bus-powered subordinate nodes 0 and 1. Cables of length 1.8 m connect each A^{2}B node for a total system length of 3.6 m. The jumper wires utilized between the CAN buses and I^{2}C buses are 18 cm long. Reference the EVAL-AD2428WB1BZ A^{2}B evaluation board user guide (EE-419) for tips on how to set up and discover A^{2}B systems [1]. Figure 3 shows the A^{2}B system schematic in SigmaStudio.

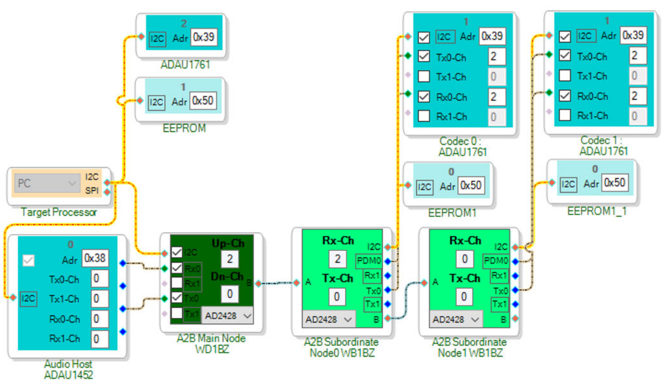


Figure 3. A^{2}B System in SigmaStudio

Getting Started with the EVAL-LT3960-AZ Evaluation Board

Complete the following steps to bring up the evaluation board with the A^{2}B system.

1) Use two twisted pairs of small wires to connect CANSCLL1 - CANSCLL2, CANSCLH1- CANSCLH2, CANSDAH1 - CANSDAH2, and CANSDAL1 - CANSDAL2. The GND connection is optional.
2) Use jumper cables to connect SCL and SDA lines from the I^{2}C controller to the respective pins on the LT3960 devices.
    a. Use case 1: Host processor as the I^{2}C controller. Connect the I^{2}C signals from the EVAL-ADUSB2EBZ USBi I^{2}C programmer to the LT3960 device to extend control data to external targets.
    b. Use case 2: Subordinate node as the I^{2}C controller. Connect the I^{2}C signals from an EVAL-AD2428WB1BZ sub node to the LT3960 device to extend I^{2}C data from A^{2}B subordinate node to external peripheral devices.
3) For the LT3960 device connected to the I^{2}C controller, use the jumper header to connect the pair of pins along the top row of the selectable header JP1 or JP3 to enable controller mode.
4) For the LT3960 device connected to the I^{2}C target, use the jumper header to connect the pair of pins along the middle row of selectable header JP 1 or JP3 to enable target mode.
5) Use the provided 2-pin jumper header to connect the middle and bottom pins of JP2 and JP4, which shorts V_{CC} to V_{IN} ($V_{IN} = V_{CC}$) and bypasses the integrated LDO.
6) Connect a 3.3 or 5 V supply to $V_{IN1,2}$ on both I^{2}C LT3960 devices via alligator clips.
7) Connect ground to $GND_{1,2}$ on both I^{2}C LT3960 devices via alligator clips.
8) Make any other necessary connections to the target I^{2}C device (e.g. V_{in} and GND).

Figure 4 shows the I^{2}CAN bus link between two LT3960 devices in more detail. Refer to the LT3960 I ^{2}C to CAN-Physical transceiver data sheet if more information is needed [3].

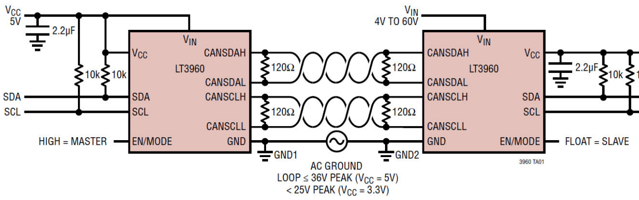


Figure 4. I²CAN Bus Link [3]

Supply Voltage

An LT3960 device operating with a V_{CC} at 5V may share an I²CAN bus with an LT3960 device operating with V_{CC} at 3.3V. However, the fluctuation in common mode voltage between 1.95V (when an LT3960 device with V_{CC} = 3.3V is dominant) and 2.5V (when an LT3960 device with V_{CC} = 5V is dominant) may increase electromagnetic emissions [3].

Alternatively, if V_{IN} ranges from 4 to 60 V such that V_{CC} is internally regulated from V_{IN} ($V_{CC} \neq V_{IN}$), use the provided 2-pin jumper header to connect the top and middle pins of JP2 and JP4. The LDO regulates the input from the V_{IN} pin to 3.3 on the V_{CC} pin. Ensure that the proper bypass capacitors and resistors are used with respect to V_{CC} and EN/MODE pins as per the LT3960 data sheet. Figure 5 shows the recommended controller mode configuration.

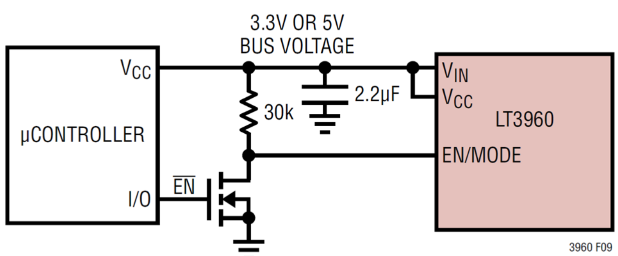


Figure 5. Recommended Controller Mode Setup

Controller and Target Mode Configurations

After completing the step-by-step connectivity guide, EN/MODE pins are tested to ensure the proper modes are selected. Independently probing the EN/MODE pin on the LT3960 device connected to I²C controller yields a voltage above the 2.0 V required to operate in controller mode. Probing the EN/MODE pin on the LT3960 device connected to I²C target yields a voltage within the recommended range of 0.7 and 2.0 V required to enable the LDO and set the transceiver in target mode.

Connecting the middle pins of the JP1/JP3 header is equivalent to leaving the EN/MODE pin floating. When left floating, the EN/MODE pin will pull up to approximately 1.2V if the V_{IN} pin is powered above 2V, setting the LT3960 device in target mode.

Results

Two use cases are considered for extending I²C data from the host processor with the EVAL-LT3960-AZ evaluation board.

Use Case 1: Extending I²C Data from Host Processor

The LT3960 device is used to extend I²C data from the host processor to both the A²B system and an external target device (e.g. Arduino Uno®) as outlined in use case 1 in Figure 1. All captures are taken during A²B bus discovery. Figure 6 shows the capture of I²C signals on target board using LT3960 transceivers.

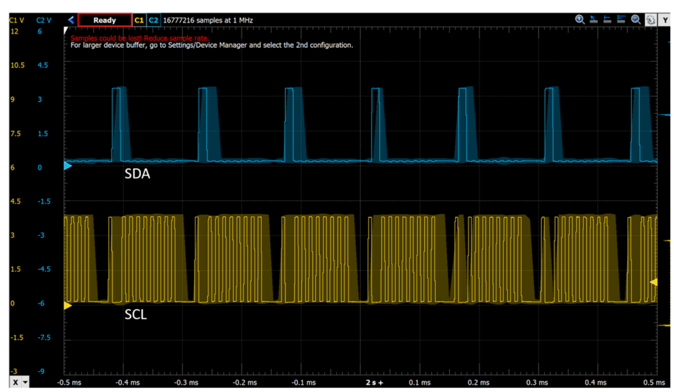


Figure 6. I²C Signals with LT3960 Transceivers

The I²C extender delivers clean SDA and SCL signals to the I²C target board.

Figure 7 shows the capture of I²C signals on target board without using LT3960 transceivers.

Figure 7. I²C Signals without LT3960 Transceivers

Without integrating the LT3960 I²C to CAN-physical transceivers, the I²C data relayed to the target device is ridden with some noise. Though negligible here, further degradation of the I²C signal may result in errors or system or device failure.

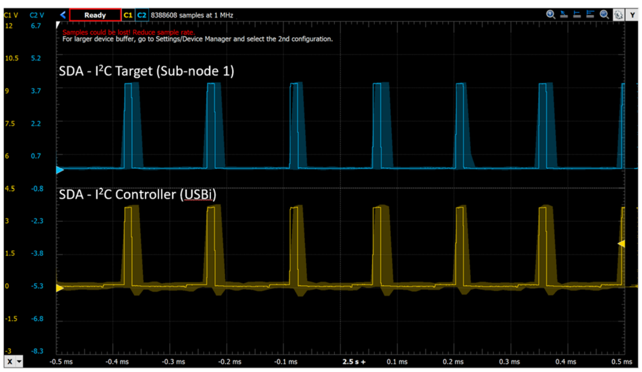


Figure 8. SDA Lines using LT3960 Transceivers

Figure 8 shows the capture of SDA lines on I²C controller and target using LT3960 transceivers. The SDA signal regenerated for the I²C target (blue) is slightly cleaner than the respective signal on the I²C controller (yellow).

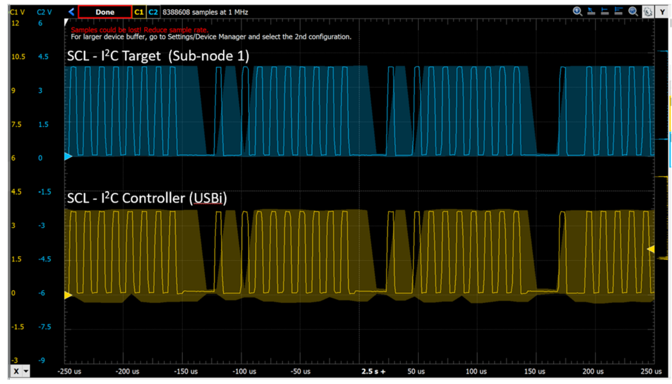


Figure 9. SCL lines using LT3960 transceivers

Figure 9 shows the capture of SCL lines on the I²C controller and target using LT3960 transceivers. The SCL signal regenerated for the I²C target (blue) is slightly cleaner than the respective signal on the I²C controller (yellow).

For systems that include more nodes or lengthier cables between nodes, I²C signals may experience more degradation.

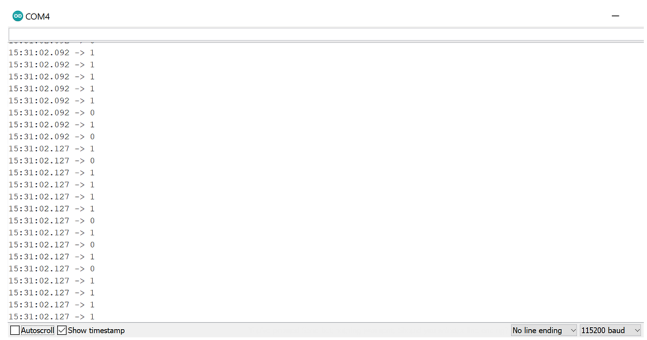


Figure 10. I²C Data

Figure 10 shows the Arduino Uno serial monitor displaying I²C data. The Arduino Uno acts as the I²C target, receiving the I²C data that is also passed from the host processor to the main A²B node.

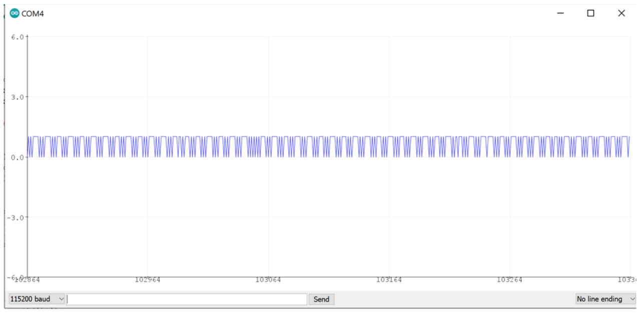


Figure 11. I²C Data

Insufficient baud rates on the Arduino Uno lead to inaccurate depictions of the I²C waveforms. However, Figure 11 demonstrates how data is successfully relayed from the host processor and captured by the Arduino Uno.

Alternatives

The DC2686A demo circuit is another alternative to the EVAL-LT3960-AZ evaluation board. The user may opt for the board that better suits the intended functionalities.

DC2686A: LT3967 and LT3960 Demo Board

The demonstration circuit 2686A consists of the LT3967, a 1.3A 8-switch matrix LED dimmer, and two LT3960 I²C to CAN-physical transceivers. The LT3960 break-off board can be connected to the I²C controller and pass data over two twisted pair lines to the LT3960 transceiver on the main PCB or another LT3960 break-off board.

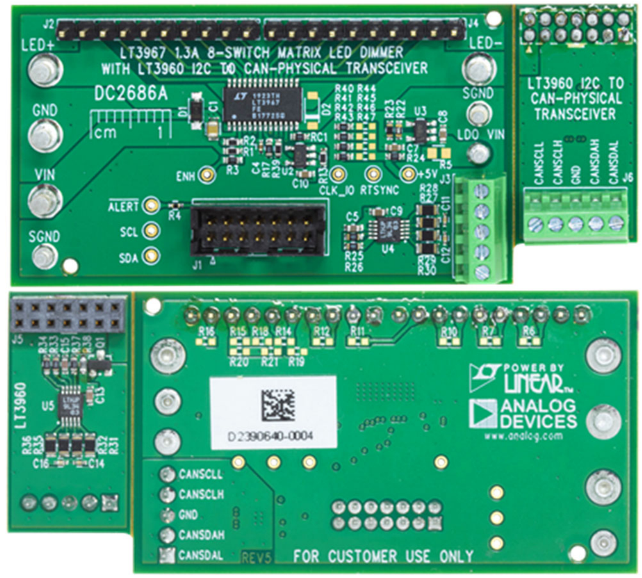


Figure 12. DC2686A Top and Bottom View

When using the LT3960 transceivers on DC2686, connections to the A²B nodes may appear slightly different. See Figure 12. Notably, the EN/MODE pin is designated as the GPIO pin on jumper J5 on demo circuit 2686A. Use cables to connect the SCL and SDA lines on jumper J5 to the I²C target or a controller of choice. Figure 13 zooms in on the LT3960 portion of the DC2686A demo circuit schematic. Refer to the DC2628A demo manual for more information on accessing I²C pins with respect to the LT3960 break-off board and main PCB [4].

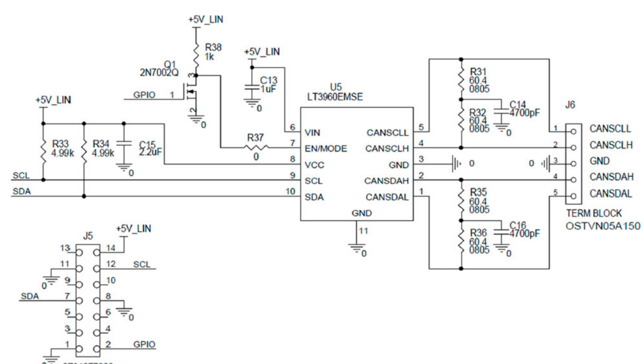


Figure 13. Schematic of DC2686A LT3960 Break-off Board

The EVAL-LT3960-AZ board offers more ease of use than DC2686A. V_{IN}, GND, EN/MODE, SCL and SDA pins are clearly labeled and functionally accessible. As shown in Figure 14, test points for SCL, SDA, and CANx signals allow for convenient access during setup and debug efforts.

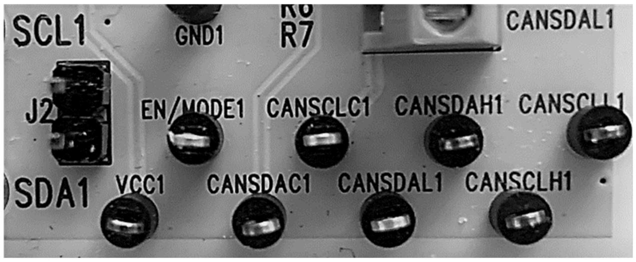


Figure 14. Test points on EVAL-LT3960-AZ

The EVAL-LT3960-AZ board is also a more cost-effective solution than the DC2686A board.

Debug

Failure to read the main A^2B node is a possible fault. A blue LED light appears on the USBi interface connected to the main node, indicating an error recognizing the I^2C address. In this case, attempt discovery with the SCL and SDA lines on the USBi interface disconnected from the LT3960 device. If the blue LED does not disappear, disconnect and reconnect the USB to the PC and/or power cycle the main node before reattempting discovery.

Ensure there is no daisy chaining between the LT3960 device and the I^2C target when attempting to discover and simultaneously capture I^2C waveforms. Discovery may prematurely terminate and therefore fail, resulting in an erroneous discovery waveform and incomplete collection of register configurations.

Probing I^2C signals directly on the USBi board (EVAL-ADUSB2EBZ) can also result in failure to identify the correct I^2C address and discover the A^2B bus, which can cause the SigmaStudio application to stop responding. Instead, as a workaround, probe I^2C test points on the LT3960 device as shown in Figure 15.

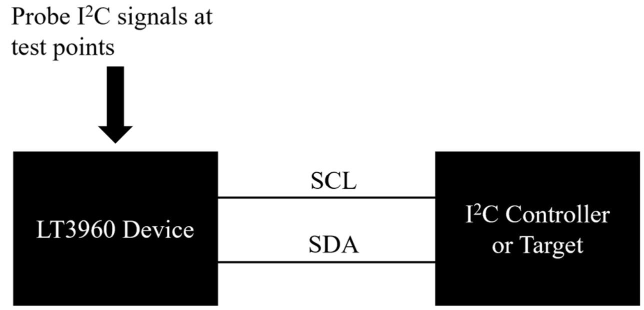
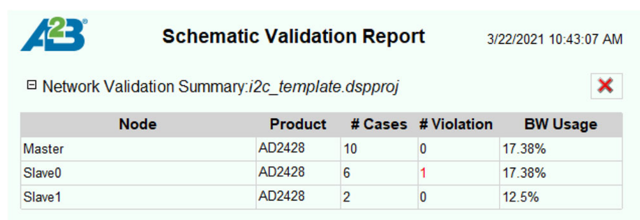


Figure 15. Recommended Probing Mechanism

Using A^2B version 19.3.1, following a failed discovery of the A^2B bus, a schematic validation report indicates violations at the node directly upstream of the subordinate node that serves as the I^2C target. See Figure 16 for an example of an A^2B schematic validation report. Ensure that A^2B versions 19.4.0 and later are loaded and the appropriate dynamic-link library (.dll) files are imported through the 'Add-Ins Browser' within the 'Tools' tab.


Schematic Validation Report 3/22/2021 10:43:07 AM

Network Validation Summary:*i2c_template.dspproj*

Node	Product	# Cases	# Violation	BW Usage
Master	AD2428	10	0	17.38%
Slave0	AD2428	6	1	17.38%
Slave1	AD2428	2	0	12.5%

Figure 16. A^2B Schematic Validation Report

References

[1] *EVAL-AD2428WB1BZ A²B Evaluation Board User Guide (EE-419)*. Rev 2, December 2020. Analog Devices, Inc.

[2] *Demo Manual EVAL-LT3960-AZ I^2C to CAN-Physical Transceiver.* March 2021. Analog Devices, Inc.

[3] *LT3960 I^2C to CAN-Physical Transceiver Data Sheet.* Rev A, February 2021. Analog Devices, Inc.

[4] *Demo Manual DC2686A: LT3967/LT3960 1.3A 8-Switch Matrix LED Dimmer with I^2C to CAN-Physical Layer Transceiver*. Rev 0, September 2020. Analog Devices, Inc.

Document History

Revision	Description
Rev 1 – June 22, 2021 by A. Dok	Initial Release