Design Guide: TIDEP-01014
Reference Design to Demonstrate CAN FD Communication on Hercules™ Microcontroller

Description

This reference design showcases Controller Area Network, Flexible Data-rate communication (CAN FD) on Hercules TMS570 Microcontrollers using the TCAN4550 CAN FD Controller. The interface between the TMS570 and the TCAN parts is done through a Serial Peripheral Interface (SPI). This example can be used to implement CAN FD communication on any microcontroller that does not natively support CAN FD.

Resources

TIDEP-01014	Design Folder
TMS570LS1224	Product Folder
TCAN4550-Q1	Product Folder
LAUNCHXL2-TMS57012	Tool Folder
TCAN4550 BoosterPack™	Tool Folder

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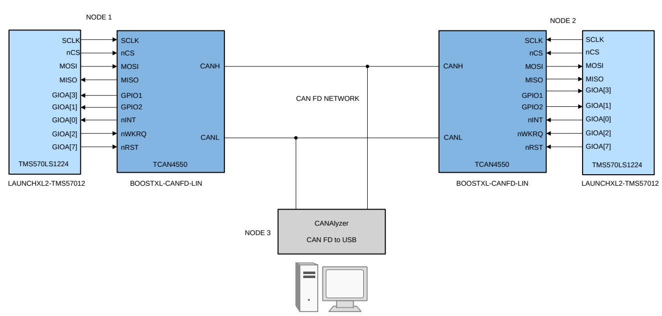
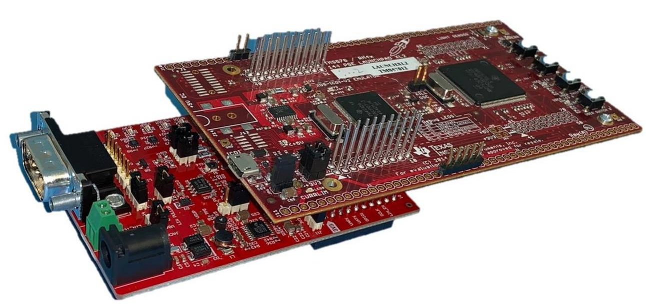
Features

- Demonstrates CAN FD communication on TMS570 microcontroller
- TCAN4550 connected to TMS570LS1224 to emulate CAN FD node
- Demonstration application implements communication between two such nodes in a CAN FD network
- Monitor CAN FD traffic on a PC using a CAN FD-to-USB adapter
- Implementation done using available development boards

Applications

- Automotive
  - Battery management system (BMS)
  - Inverter and motor control





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1 System Description

The Controller Area Network (CAN) bus protocol was created in 1986. The protocol's version 2.0 is used in a wide variety of applications, including automotive, industrial, and medical. The CAN 2.0 protocol offers several advantages such as reliability, cost effectiveness, engineering expertise and the availability of tools and components. CAN Flexible Data (FD) rate builds on the existing benefits of CAN 2.0 technology, allowing system designers to leverage all CAN 2.0 benefits while also taking advantage of CAN FD's increased data rate and flexible data field length. The 1Mbps network speed limit of CAN is starting to get squeezed by the demands of modern technology. A rise in vehicle functionality is driving an explosion in data that is using up all available communication bandwidth. Moreover, CAN 2.0 defines each message to carry exactly 8 bytes of data, thereby limiting available bandwidth for nodes that have much more data to share. CAN FD resolves these issues, effectively creating a CAN protocol for the future. It has been incorporated into the international standard for the CAN bus protocol, ISO11898 in its 2015 update.

This design guide showcases CAN FD communication on Hercules TMS570 Microcontrollers (MCUs). TMS570 MCUs do not natively support a CAN FD interface, only the classic CAN or CAN 2.0 interface. This reference design uses a CAN FD controller from TI, TCAN4550, which integrates a CAN FD transceiver and interfaces to a TMS570 MCU using the SPI interface. The CAN FD processor inside TCAN4550 meets the specifications of the ISO11898-1: 2015 standard and the CAN transceiver meets the specifications for High-Speed CAN Physical Layer standard ISO11898-2: 2016.

A CAN FD network is created using two such (TMS570 and TCAN4550) nodes. Communication between these two nodes can be monitored on a PC using a CAN FD to USB adapter.

1.1 Key System Specifications

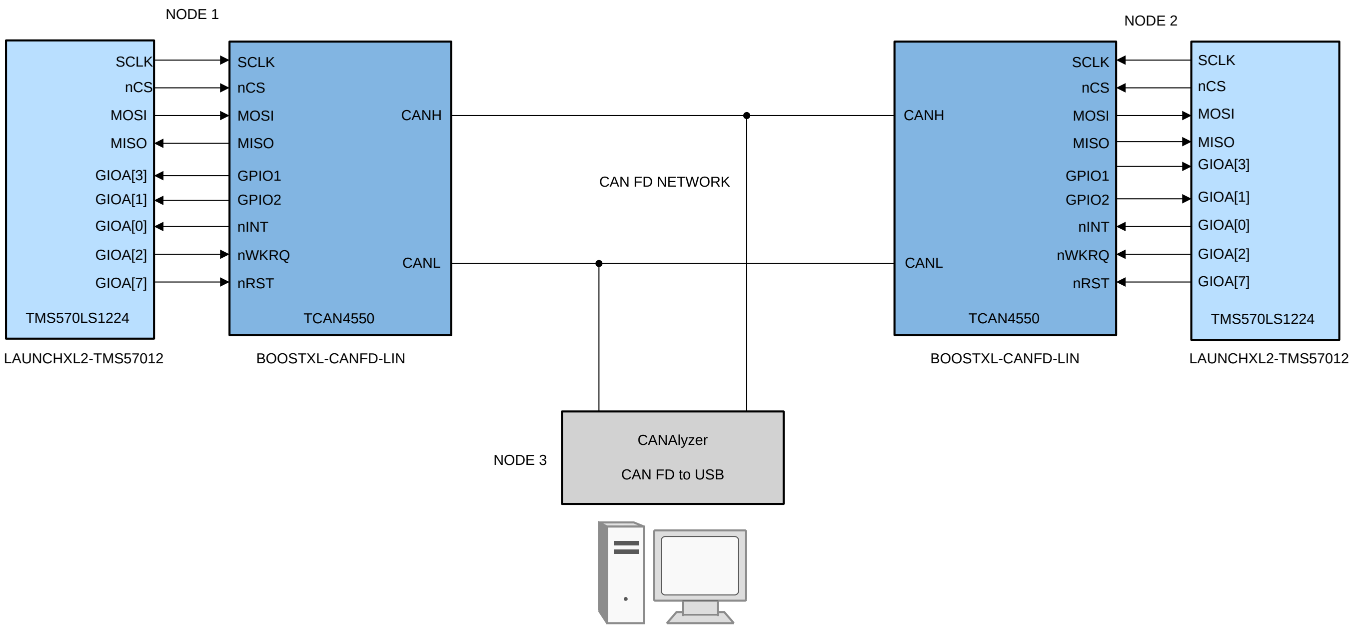
Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
SPI interface signals between TMS570 and TCAN4550	4-pin standard interface including: nCS, SCLK, SIMO, SOMI	4-pin SPI mode with chip select
SPI interface clock frequency	Maximum 18MHz	SPICLK max frequency
SPI interface character length	8 bits	1-byte character length

2 System Overview

2.1 Block Diagram

Figure 1. TIDEP-01014 Block Diagram



As shown in Section 2.1, this reference design is implemented using two sets of LAUNCHXL2-TMS57012 LaunchPad and BOOSTXL-CANFD-LIN Boosterpack. These combinations are connected to form a CAN FD network with two nodes. A third node is added by connecting a PCAN CAN FD to USB protocol converter. This allows a user to monitor the CAN FD communication on the network.

2.2 Design Considerations

The software development for this reference design is created using TI's HALCoGen (Hardware Abstraction Layer Code Generator) for Hercules Microcontrollers (MCUs). HALCoGen provides a graphical user interface (GUI) that enables generation of a fundamental software platform for developing embedded applications on Hercules MCUs. It can be used to generate all the C and assembly source code files required for this reference design.

A second software component in this reference design is the driver for interfacing to the TCAN4550 CAN FD controller. This driver was developed for another TI MCU, and was ported over to the Hercules MCU for this reference design.

The HALCoGen files as well as the TCAN4550 driver are included as part of the software download associated with this design guide.

2.2.1 Software Description

Figure 2. Software Description

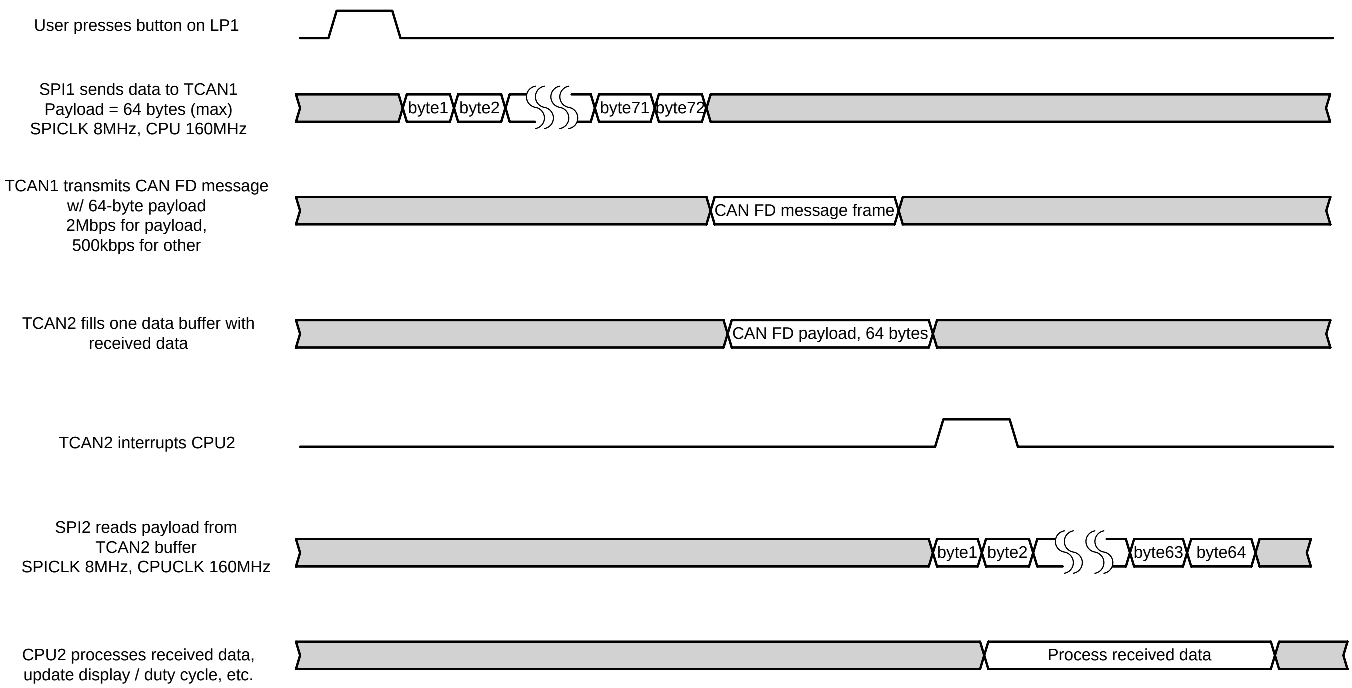


Figure 2 shows the software sequence followed in this design guide. Each of the two nodes in this CAN FD network have their own IDs which are used to identify the node for which a CAN FD message is intended. The software running on both the nodes is virtually identical in every other aspect.

The following steps are followed to demonstrate the CAN FD communication between the two nodes:

1. The LaunchPads LP1 and LP2 are both equipped with an optical intensity sensor that is connected to one of the ADC input channels. These inputs are being continuously sampled by the ADCs.
2. User presses "user button A" on the LaunchPad LP1. This triggers a SPI transfer from the LP1 to the TCAN4550 in combination 1 (TCAN1). This SPI transfer is comprised of 72 bytes, which includes a 64-byte payload and the header bytes for the CAN FD message frame.
3. Once the SPI transfer from LP1 to TCAN1 is completed, the TCAN1 transmits the CAN FD message frame on the network. This communication happens at 2Mbps for the message data payload and at 500Kbps for the message header. The header includes the identifier for TCAN2.
4. TCAN2 identifies the message on the network and fills up one data buffer with the received data. It generates an interrupt once this data reception is completed.
5. The application on LaunchPad2 (LP2) gets this interrupt and uses an SPI to transfer the 64-byte data payload from the TCAN2 buffer to RAM on LP2.
6. The application then processes this received data: displays received data on the serial terminal window, and updates PWM duty cycle.

2.3 Highlighted Products

The two main products used in this design guide include a TMS570LS1224 microcontroller and a TCAN4550 external CAN FD controller.

2.3.1 TMS570LS1224 16- and 32-bit RISC Flash Microcontroller

The TI Hercules™ TMS570LS12x family of microcontrollers provides the power of the ARM Cortex-R4F core coupled with highly integrated control and communication peripherals. This family is designed from the ground up for meeting the stringent diagnostic coverage requirements of applications requiring conformance to functional safety standards such as ISO26262 and IEC61508. The safety architecture includes dual CPUs in lockstep, CPU and memory BIST logic, ECC on both the flash and the data SRAM, parity on peripheral memories, and loopback capability on peripheral I/Os. The device features peripherals for real-time control-based applications, including two Next Generation High-End Timer (N2HET) timing coprocessors with up to 44 I/O terminals, seven Enhanced Pulse Width Modulator (ePWM) modules with up to 14 outputs, six Enhanced Capture (eCAP) modules, two Enhanced Quadrature Encoder Pulse (eQEP) modules, and two 12-bit Analog-to-Digital Converters (ADCs) supporting up to 24 inputs. The device has multiple communication interfaces: three multi-buffered serial peripheral interfaces (MibSPIs), two standard SPIs, one LIN, one SCI, three DCANs, and one I2C. The SPI and MibSPI interfaces can be used to connect external devices such as a TCAN4550 in case greater number of CAN ports are required, or if the device is required to connect to a CAN FD network.

2.3.2 TCAN4550 CAN FD Controller with Integrated Transceiver

The TCAN4550-Q1 is a CAN FD controller with an integrated CAN FD transceiver supporting data rates up to 5 Mbps. The CAN FD controller meets the specifications of the ISO11898-1:2015 high speed Controller Area Network (CAN) data link layer and meets the physical layer requirements of the ISO 11898–2 (2016) High Speed Controller Area Network (CAN) specification providing an interface between the CAN bus and the CAN protocol controller supporting both classical CAN and CAN FD up to 5 megabits per second (Mbps). The TCAN4550-Q1 provides CAN FD transceiver function: differential transmit capability to the bus and differential receive capability from the bus. The device includes many protection features providing device and CAN network robustness. The device can also wake up through remote wake up using CAN bus implementing the ISO11898-2:2016 Wake Up Pattern (WUP).

3 Hardware, Software, Testing Requirements, and Test Results

3.1 Required Hardware and Software

This reference design includes a LaunchPad for the TMS570LS1224 microcontroller and a BoosterPack for the TCAN4550 CAN FD controller. Combined together they form one node of a CAN FD network.

3.1.1 Hardware

3.1.1.1 TMS570LS1224 LaunchPad™

The Hercules™ TMS570LS12x LaunchPad™ Development Kit is an inexpensive evaluation platform designed to help you get started quickly in evaluating and developing with the Hercules microcontroller platform. The LaunchPad Development Kit is based on the IEC 61508 SIL 3 and ISO 26262 ASIL D capable TMS570LS1224, which is a lockstep ARM Cortex-R4F based MCU with integrated safety features. Hercules TMS570 MCUs can help reduce the development effort of ISO 26262 and IEC 61508 functional safety applications.

Figure 3. TMS57012x LaunchPad™

The LaunchPad features on-board emulation for programming and debugging, push buttons, LEDs and ambient light sensor, and two standard 40 pin BoosterPack expansion connectors (only one header is populated) to support a wide range of plug-in BoosterPack modules for added functionality such as displays, wireless sensors, and more.

The BoosterPack header highlighted in Figure 3 is used to connect the TCAN4550 BoosterPack for this reference design.

Main features of this LaunchPad:

- USB powered and capability for external 5 v supply
- On board USB XDS110 debug
- On board SCI to PC serial communication

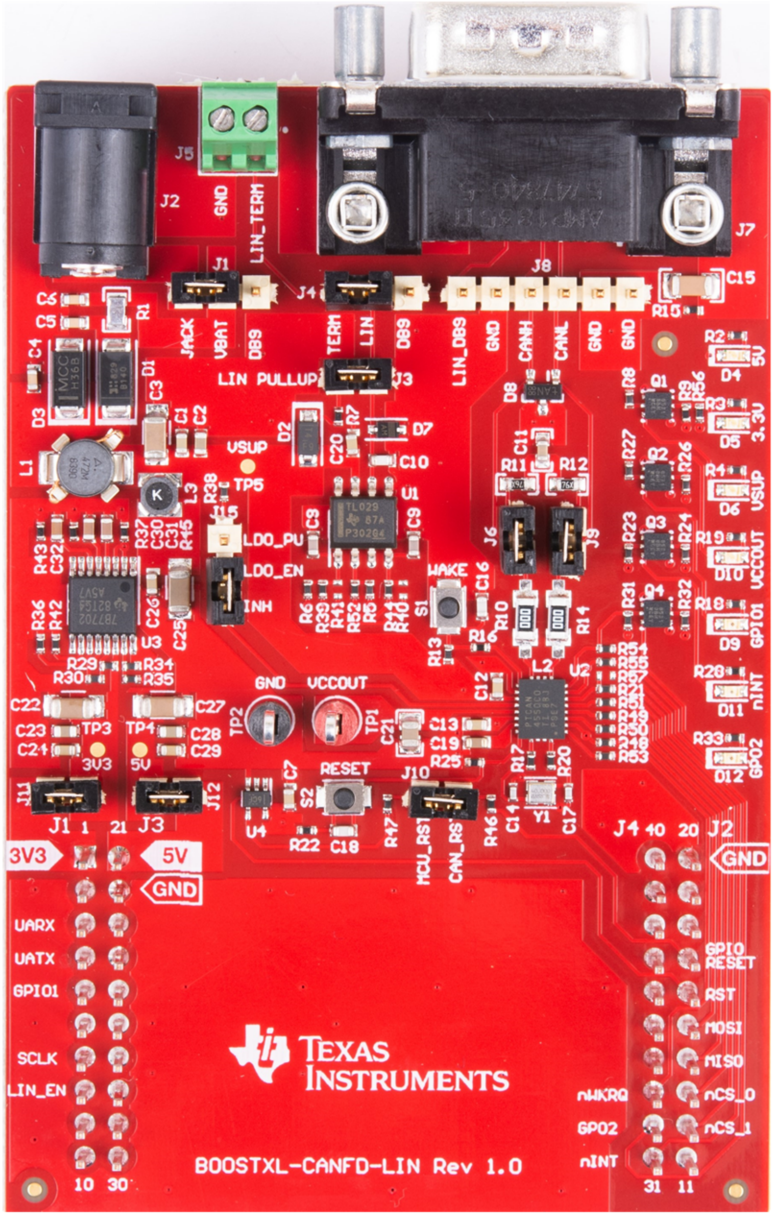
- User programmable push buttons, LEDs and ambient light intensity sensor
- Reset switches
- Two 40-pin BoosterPack XL Headers (only one populated)
- Footprint for expansion headers (not populated) to bring out all MCU Pins
- External high-speed emulation through 14-pin TI-JTAG header (not populated)

Refer to LAUNCHXL2-TMS57012 Hercules TMS570LS12x LaunchPad Development Kit for more information about this LaunchPad, and to order one.

3.1.1.2 TCAN4550 BoosterPack™

The TCAN4550 BoosterPack can be used to evaluate the TCAN4550 SPI to CAN FD controller and transceiver solution. The CAN bus signals are easily accessed through a DB9 connector or through header pins, and the digital host processor interface (SPI lines plus GPIOs) is accessible through a single dual-row header. Input clocks to the device can come from either an on-board crystal or from an external single-ended clock source.

Figure 4. TCAN4550 BoosterPack™



Main features of this BoosterPack:

- Provides access to CAN bus, SPI, clock, and all GPIO signals
- Clock input can be configured for on-board crystal or external clock source
- CAN bus termination can be enabled/disabled through jumpers
- Status LEDs indicate board power status and GPIO pin states

3.1.1.3 LaunchPad™to BoosterPack™ Signal Connections

The TCAN4550 BoosterPack is plugged onto the top of the TMS570LS12x LaunchPad using the one header that is populated, as shown in Figure 3.

This results in the following signal connections between the TCAN4550 CAN FD Controller and the TMS570LS1224 Microcontroller.

Table 2. TMS570LS1224 to TCAN4550 Connections

TMS570LS1224 SIGNAL NAME	TCAN4550 SIGNAL NAME	SIGNAL DESCRIPTION
SPI3_CLK	SCLK	Clock for serial interface, driven by master (TMS570)
SPI3_nCS2	nCS	Chip Select for serial interface, driven by master (TMS570)
SPI3_SIMO	SDI	Master Out Slave In for serial interface, driven by master (TMS570)
SPI3_SOMI	SDO	Master In Slave Out for serial interface, driven by slave (TCAN4550)
GIOA[0]	nINT	Active-low interrupt signal to host processor, driven by TCAN4550
GIOA[1]	GPO2	General-purpose output, driven by TCAN4550, functionality configurable through SPI
GIOA[2]	nWKRQ	Active-low wake request, driven by TCAN4550
GIOA[3]	CLKOUT/GPIO1	General-purpose Input / Output, functionality configurable through SPI
GIOA[7]	RST	Reset for TCAN4550, driven by TMS570

3.1.2 Software

All software for demonstrating CAN FD communication between these two CAN FD nodes can be downloaded from TIDEP-01014. There are two separate folders, one for each CAN FD node. The folders are labeled TMS570LS1224_TCAN4550_Demo_Node1 and TMS570LS1224_TCAN4550_Demo_Node2 for the two nodes. Both of the folders have self-contained sub-folders that include all of the source code and header files to build the two individual code projects. These projects first need to be imported from the Code Composer Studio and then build both of these projects to create the two separate .out files. These .out files then need to be programmed into the TMS570LS1224 parts on the LaunchPads. This programming can be done using Code Composer Studio or another tool such as Uniflash.

3.2 Testing and Results

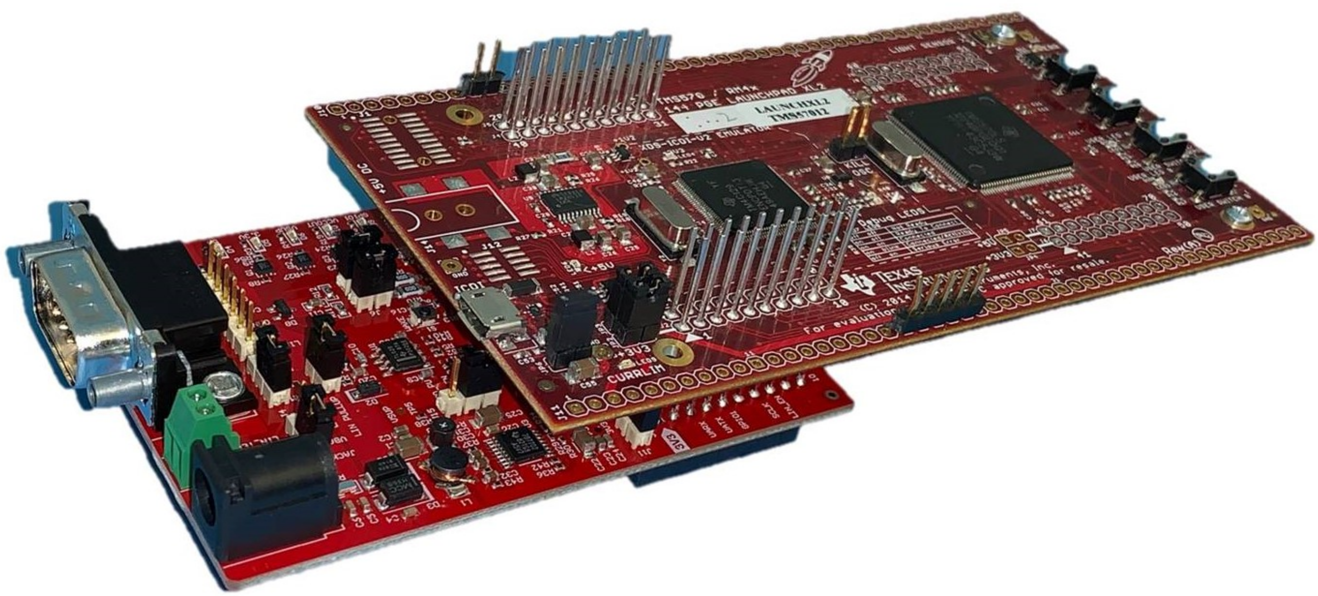
A CAN FD network is created by connecting two sets of TMS570LS1224 LaunchPad and TCAN4550 BoosterPack combinations. The included software is designed to demonstrate CAN FD communication between these two nodes when the user presses the button A on either LaunchPad.

3.2.1 Test Setup

CAN FD communication can be demonstrated using the following procedure:

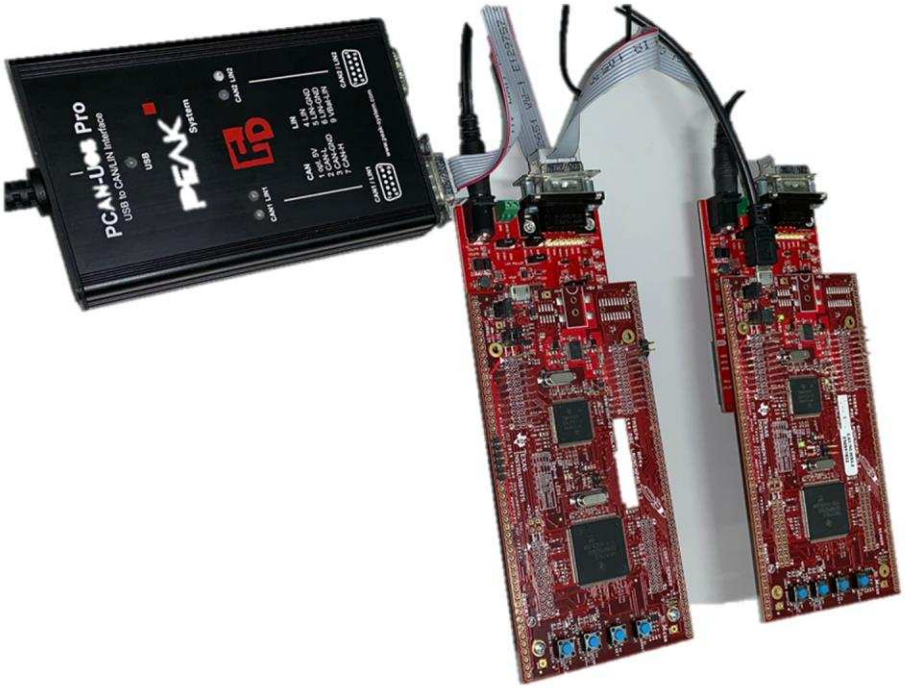
- Plug the TMS570LS12x LaunchPad on top of the TCAN4550 BoosterPack using the populated header on the LaunchPad. See Figure 5.

Figure 5. TMS570LS12x LaunchPad™ and TCAN4550 BoosterPack™ Combination



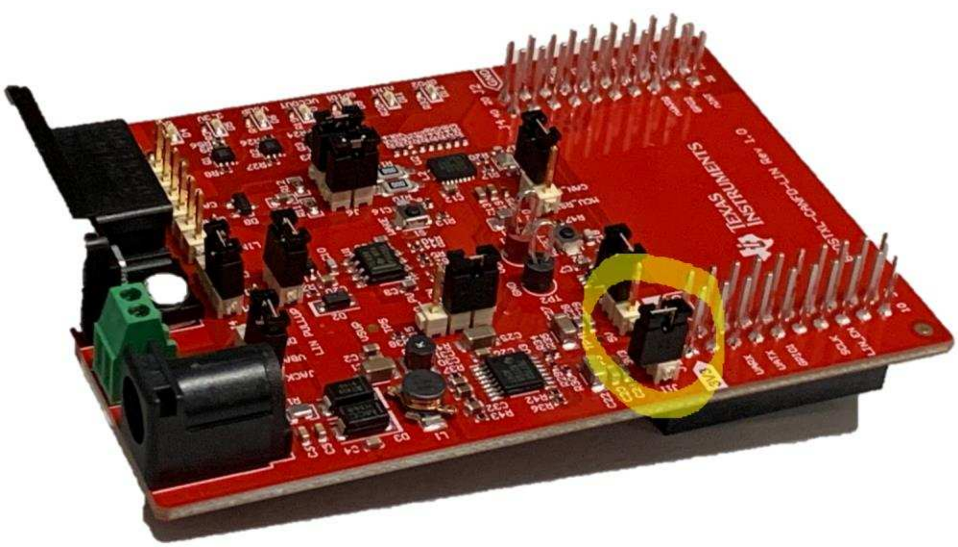
- Do the same process with the second set of LaunchPad and BoosterPack.
- Connect the two TCAN4550 BoosterPacks using a cable through the DB9 connectors on each BoosterPack.
- A computer can also be connected to the CAN FD network through a PEAK CAN FD to USB adaptor. This process allows a user to monitor the traffic on the CAN FD network. See Figure 6.

Figure 6. CAN FD Network with Three Nodes



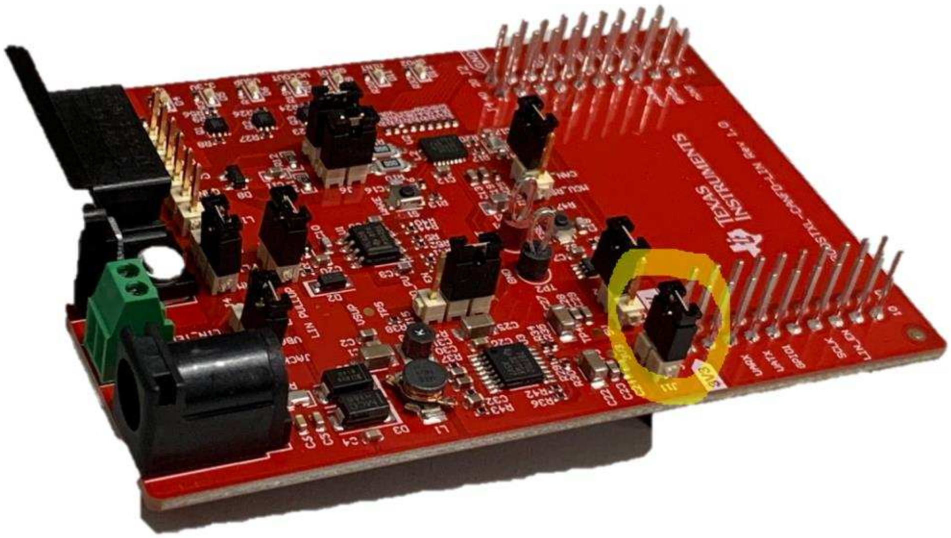
- Both the LaunchPad and BoosterPack on Node 1 need to be powered separately. Figure 7 shows the jumper settings required for this. The highlighted jumper allows 3.3 V and 5 V from the BoosterPack to be passed on to the LaunchPad. This jumper is not connected for Node1, since the LaunchPad in Node1 is separately powered from the PC USB port connection.

Figure 7. BoosterPack1 Configuration



- Only the BoosterPack on Node 2 must be powered. The LaunchPad on Node 2 derives its power from the BoosterPack on Node 2. Figure 8 shows the jumper settings required for BoosterPack2. Note the difference in the highlighted jumper from that on BoosterPack1.

Figure 8. BoosterPack2 Configuration

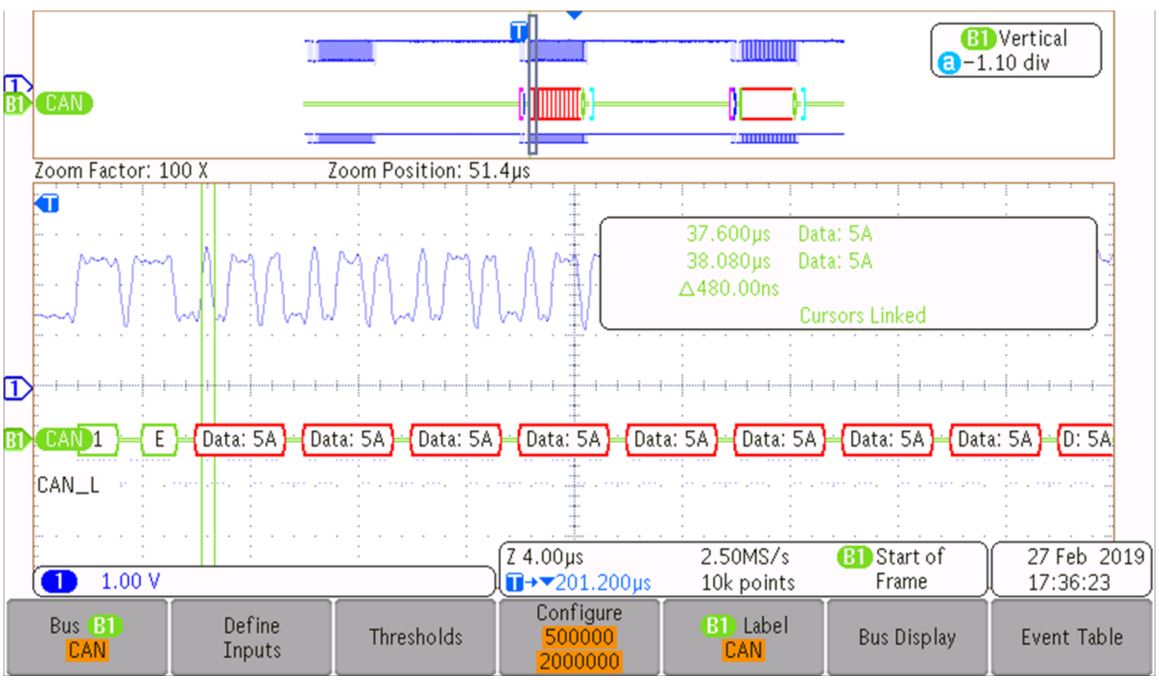


- User Switch A (S3) on either of the two nodes can be used to start the CAN FD communication. Pressing this button a second time stops the communication.
- The CAN FD data payload size is 64 bytes, which is the maximum size supported by the CAN FD communication protocol.
- The data payload transfer baud rate is 2Mbps, while the baud rate for the header fields is 500kbps.

3.2.2 Test Results

Figure 9 shows the communication between the two nodes.

Figure 9. Scope Shot: CAN FD Communication



The CAN FD communication can be established between two TMS570 MCUs using a TCAN4550 external CAN FD controller. The scope image also shows the 2Mbps baud rate achieved during the data payload transfer.

4 Design Files

All necessary design files are available for download from TIDEP-01014.

4.1 Schematics

To download the schematics, see the design files at TIDEP-01014.

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDEP-01014.

4.3 PCB Layout Prints

To download the layer plots, see the design files at TIDEP-01014.

4.4 Altium Project

To download the Altium Designer® project files, see the design files at TIDEP-01014.

4.5 Gerber Files

To download the Gerber files, see the design files at TIDEP-01014.

4.6 Assembly Drawings

To download the assembly drawings, see the design files at TIDEP-01014.

5 Software Files

Download the software files from TIDEP-01014.

6 Related Documentation

1. *TMS570LS12x4 16- and 32-BIT RISC Flash Microcontroller data sheet*
2. *TCAN4550-Q1 Automotive Control Area Network Flexible Data Rate (CAN FD) Controller with Integrated Transceiver data sheet*

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