TMDSFSIADAPEVM FSI Adapter Board User's Guide

This document is provided with the FSI Adapter Board (TMDSFSIADAPEVM) customer evaluation module. This user's guide provides details on the setup and hardware implementation of the adapter board.

NOTE: Follow the general ESD precautionary measures when operating this EVM.

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1 Introduction

The FSI (Fast Serial Interface) Adapter Board is hardware that helps in understanding the functionality of the FSI peripheral and evaluate it in different system use cases, such as industrial drives, servo, or sensing network topologies. The FSI adapter board supports several on-board reference solutions, relating to isolated power biasing, digital isolation, and transceivers (high-speed LVDS and medium speed RS485). They are integrated into one adapter to experiment with the FSI serial port in an on-board or board-to-board system. See the C2000 Peripherals Reference Guide for C2000™ device families that have the FSI peripheral included.

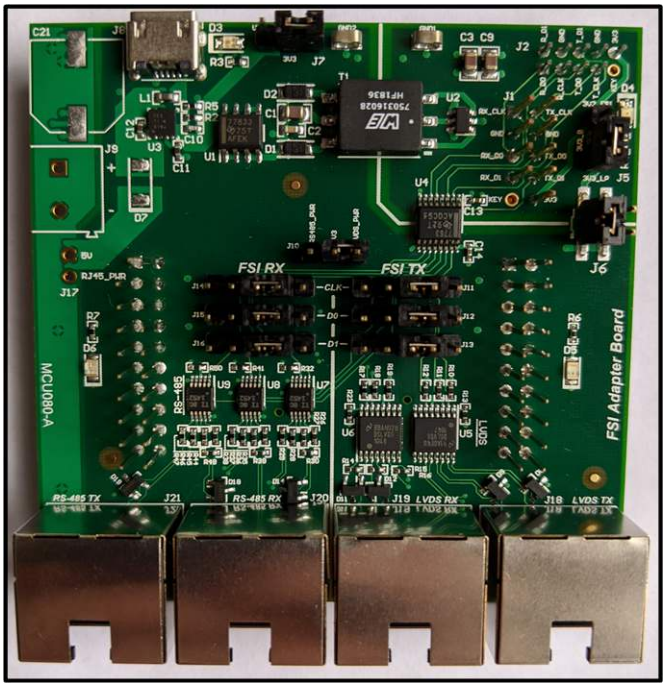


Figure 1. FSI Adapter Board

WARNING

The FSI adapter board has several isolated GND sections. The primary ground plane, labeled GND1, and the secondary ground plane, labeled GND2, are separated by an isolation boundary. Use extra precaution when powering the separate power sections and use isolated power supplies. Alternatively, only power the primary side (1) and take advantage of the built-in isolated power to source the secondary side (2).

FSI is a unique peripheral designed to transfer serial data up to 50 MHz, using one clock line and one or two data lines. Because the peripheral is capable of transmitting and receiving data on both edges of a clock pulse, it can offer a throughput of 100 Mbps or 200 Mbps, depending on the number of data lines used. The data transfer is based on a defined packet, frame, or structure, which includes a preamble, CRC byte, postamble, and more. Refer to the device-specific Technical Reference Manual (TRM) for the full feature set of the FSI peripheral and the device-specific data sheet for timing and electrical specifications.

The FSI peripheral is suited to transfer data across an isolation barrier using digital isolators. This is a typical use case when an MCU controls a power stage which operates on high voltages. Motor control and digital power applications have a number of system topologies which have components that must communicate with each other, but operate on the hot (high voltage) or cold (low voltage) sides of a control system. While the application depends on the partitioning of the hot and cold planes, this peripheral can also extend to broader use with or without isolation using LVDS, RS485, and CMOS transceivers.

The FSI adapter board is designed to work directly with existing C2000 evaluation modules, such as the low-cost LaunchPad as a pluggable adapter or within the control card eco-system. The adapter board only works with select evaluation modules that include a C2000 device with the FSI peripheral.

This document covers the kit contents and hardware details, with explanations of the functions and locations of various connectors and devices present on the board. It also includes a list of available C2000 software examples to assist with evaluating FSI and the adapter board.

2 Hardware Overview

2.1 Kit Contents

The FSI Adapter Board kit contains these items:

- FSI Adapter PCB Board
- CAT5 T568B patch cable, 1 ft.
- 10 pin 2.00 mm IDC Ribbon Cable

2.2 Features

The FSI Adapter Board has these features:

- Two FSI receptacle connectors - 2.54 mm (LaunchPad) and 2 mm (controlCARD) 2×5 male/female headers
- 3.3-V to 3.3-V Isolated Power - SN6505
- Digital Isolation - ISO7763
- High-speed LVDS transceivers - DSLVDS1047/48
  - Intended for point-to-point communications. LVDS TX drivers with multi-drop support should be used for one-to-many communications.
- Medium-speed RS485 transceivers - THVD1452
- ESD protection diodes
- 20-pin LaunchPad Boosterpack Headers
  - Primarily for mechanical purposes
- Two pairs of Cat5 capable RJ45 connectors - RX/TX
  - LVDS channel
  - RS485 channel
- Supports full-duplex FSI communications
- 5-V to 3.3-V USB power input to provide isolated bias to LVDS/RS485 transceivers (optional)
- FSI signal selection jumper matrix routing ISO7763 signals to and from LVDS or RS485 transceivers
- Power selection for LVDS or RS485 circuitry

NOTE: The LaunchPad and controlCARD are development boards for evaluating the C2000 MCU product line.

Figure 2 shows the major functional blocks of the FSI Adapter Board.

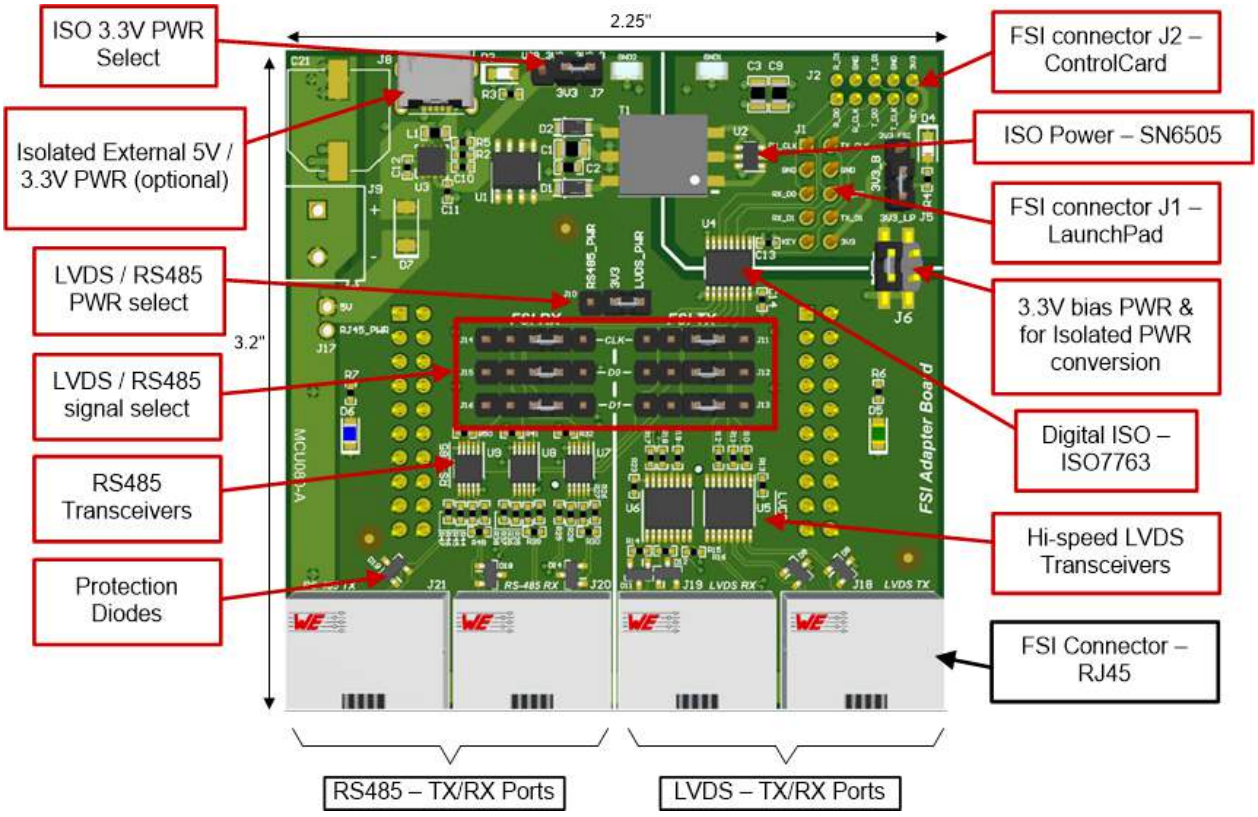


Figure 2. FSI Adapter Board - Front Side Hardware

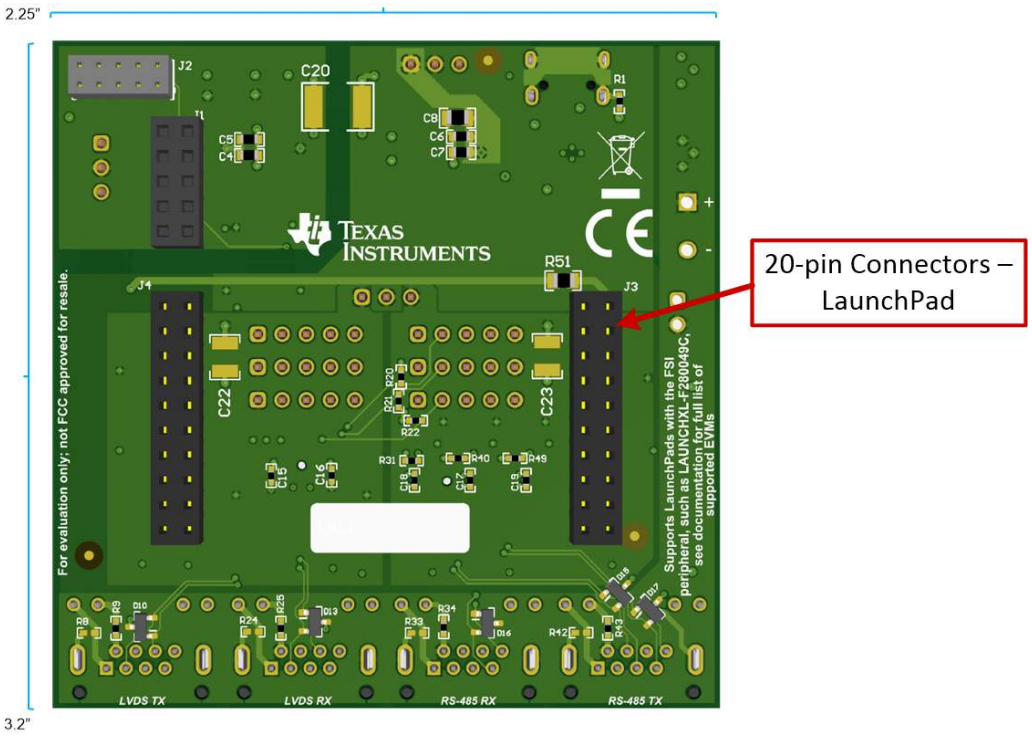


Figure 3. FSI Adapter Board - Back Side Hardware

2.3 Hardware Reference Summary

A summary of the various hardware connections available on the FSI Adapter Board are provided in the following tables:

Table 1. Hardware References

Connectors	
J1	LaunchPad FSI header/conector
J2	controlCARD FSI header/connector
J3/J4	20-pin LaunchPad BoosterPack headers/connectors
J5	Primary side PWR selection header
J6	LaunchPad 3.3-V primary side PWR header - connects 3.3 V from J3 pin to primary side
J7	Secondary side PWR selection header
J8	5-V micro-USB PWR connector
J9	DNP - Not supported in current revision
J10	Differential transceiver PWR selection header
J11	FSI TX CLK signal selection header
J12	FSI TX D0 signal selection header
J13	FSI TX D1 signal selection header
J14	FSI RX CLK signal selection header
J15	FSI RX D0 signal selection header
J16	FSI RX D1 signal selection header
J17	DNP - Not supported in current revision
J18	RJ45 (CAT5) connector - LVDS FSI TX
J19	RJ45 (CAT5) connector - LVDS FSI RX
J20	RJ45 (CAT5) connector - RS485 FSI RX
J21	RJ45 (CAT5) connector - RS485 FSI TX

LEDs	
D3	Turns on when 5-V USB is plugged into J9
D4	Turns on when primary side of board is powered
D5	Turns on when LVDS transceivers are powered
D6	Turns on when RS485 transceivers are powered

3 Using the FSI Adapter Board

The following sections describe how to use the FSI Adapter Board.

3.1 Connecting to a LaunchPad

To interface with a LaunchPad development board, plug the 20-pin connectors J3 and J4 of the FSI Adapter Board onto the top headers of the LaunchPad. In doing this, the FSI connector on the LaunchPad should also be connected to FSI connector J1 of the Adapter Board, as shown in Figure 4.

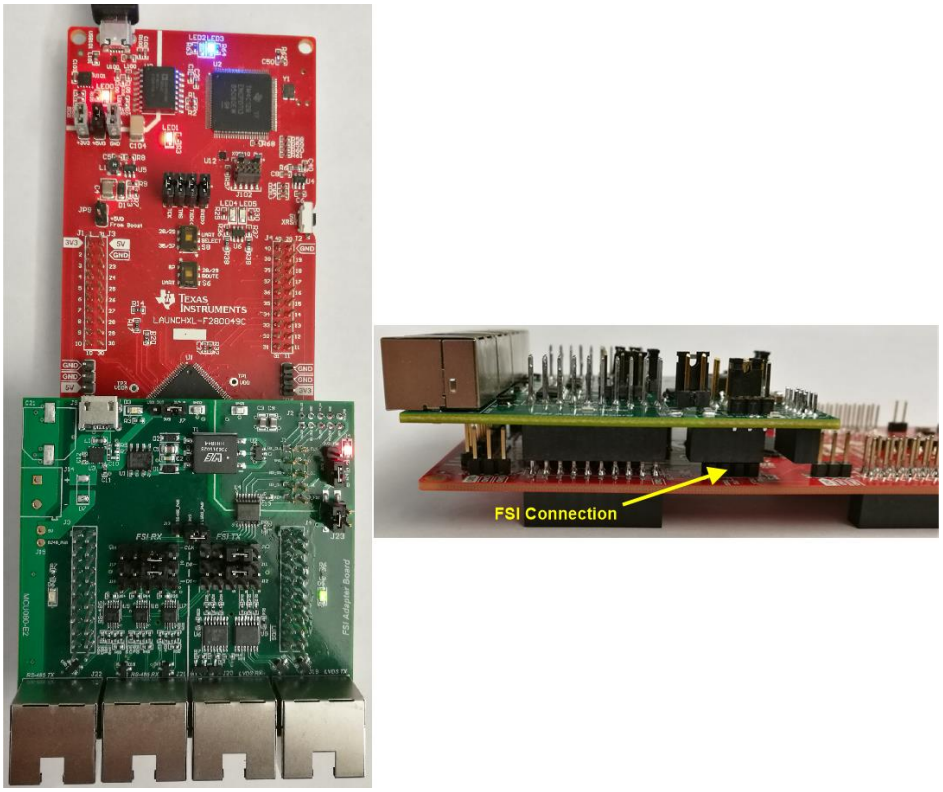
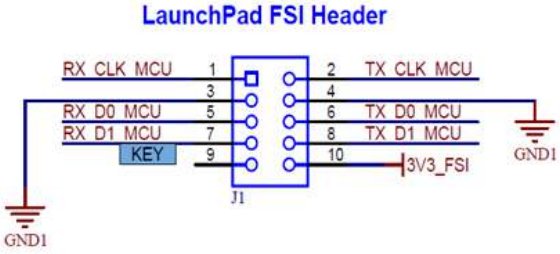


Figure 4. LaunchPad Setup

The 20-pin connectors J3 and J4 are primarily used for mechanical support when interfacing the adapter board with a LaunchPad. All of the LaunchPad connector pins are unused, except for the 3.3-V power pin. The through-hole pins can be used if access to the LaunchPad pins are needed or if additional boosterpacks are to be stacked.

NOTE: If the ground pins on the 20-pin headers are used, they will correspond to GND1.

Connecting the FSI Adapter Board to a LaunchPad as described above completes the connection of the FSI signals from the C2000 Microcontroller to the rest of the board through the J1 connector. The J1 LaunchPad FSI connector signal layout is shown in Figure 5.



RX_CLK	TX_CLK
GND	GND
RX_D0	TX_D0
RX_D1	TX_D1
KEY	3V3

Figure 5. J1 LaunchPad FSI Connector Signals

NOTE: The FSI connector on revision 'A' of the LAUNCHXL-F280049C is an 8-pin connector which does not support TX/RX D1 FSI signals or 3.3-V power. See Section 3.3 for information on supplying power to the FSI Adapter Board.

3.2 Connecting to a controlCARD

To interface with a controlCARD, connect FSI connector J2 on the Adapter Board to the FSI connector on the respective controlCARD. See the specific controlCARD schematic or User's Guide for the FSI connector's identifier. This connection can be best accomplished using a 10-pin ribbon cable (not included), such as the one shown in Figure 6.

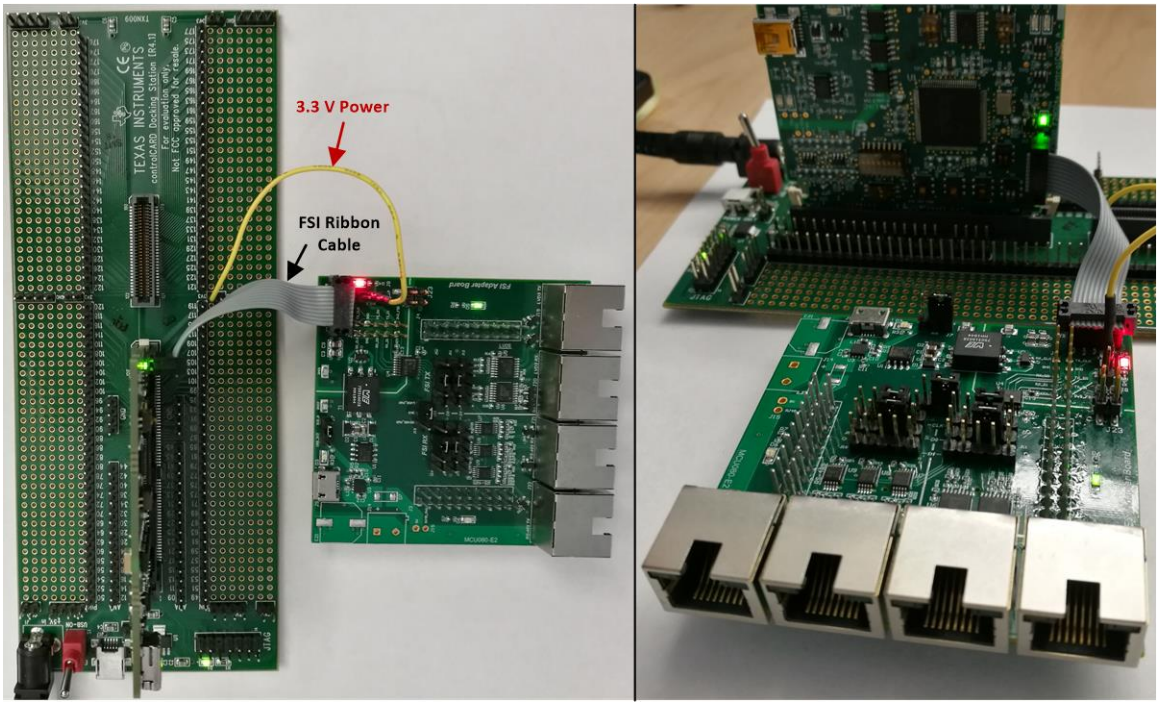
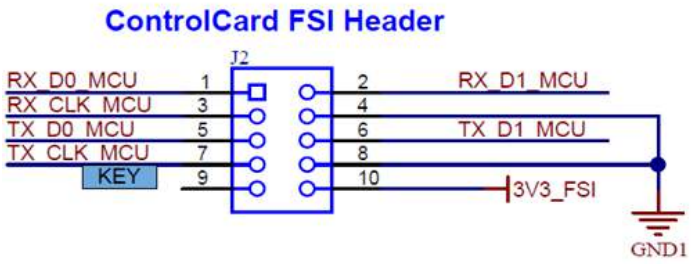


Figure 6. controlCARD Setup

Connecting the FSI Adapter Board to a controlCARD as described above completes the connection of the FSI signals from the C2000 Microcontroller to the rest of the board through the J2 connector. The J2 controlCARD FSI connector signal layout is shown in Figure 7.



RX_D0	RX_D1
RX_CLK	GND
TX_D0	TX_D1
TX_CLK	GND
KEY	3V3

Figure 7. J2 controlCARD FSI Header Signals

NOTE: The FSI connectors on revision 'B' of the TMDSCNCD280049C and revision 'E2' of the TMDSCNCD28388D are 8-pin connectors which do not support TX/RX D1 FSI signals or 3.3-V power. See Section 3.3 for information on supplying power to the FSI Adapter Board.

3.3 Powering the Board

The adapter board consists of two main GND planes separated by an isolation barrier, shown in Figure 8. The primary ground plane, GND1, is the same ground as the LaunchPad or controlCARD the board is connected to. The secondary ground plane, GND2, covers the LVDS and RS485 transceivers and the RJ45 connectors.

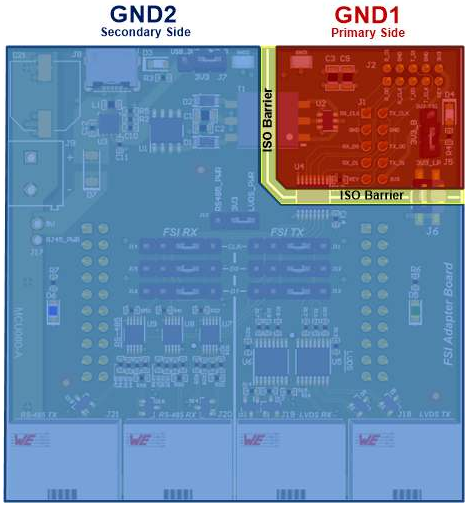
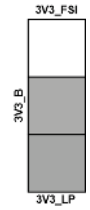
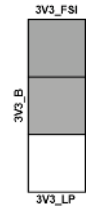
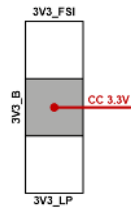
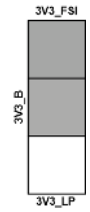


Figure 8. GND Planes

The primary side is powered by 3.3 V from a connected LaunchPad or controlCARD. The required external connections and jumper placements are explained in Table 2.

Table 2. Supplying Primary Side Power

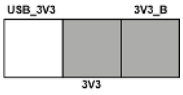
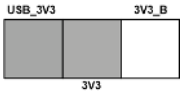
EVM	External Connections	Header ID	Jumper Configuration
LaunchPad	As described in Section 3.1	J6	Populate to cross isolation boundary and connect LaunchPad 3.3-V power to primary side
		J5	Populate bottom two pins: 
	As described in Section 3.1 and with 3.3-V power supported on the LaunchPad's FSI connector(1)	J5	Populate top two pins: 
controlCARD	Jump 3.3-V power from controlCARD HSEC base board to J8 header middle pin of the adapter board, as shown in Figure 6	J5	Jump 3.3 V to middle pin: 
	As described in Section 3.2 and with 3.3-V power supported on the controlCARD's FSI connector(2)	J5	Populate top two pins: 

(1) Not supported on all LaunchPad versions. See the specific LaunchPad User's Guide or schematic for 3.3V support on FSI connector.

(2) Not supported on all controlCARD versions. See the specific controlCARD User's Guide or schematic for 3.3V support on FSI connector.

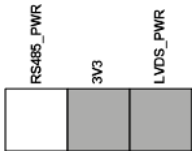
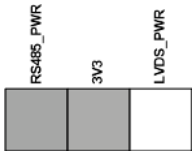
The secondary side is powered by 3.3 V from one of the sources described in Table 3.

Table 3. Supplying Secondary Side Power

Power Source	External Connections	Header ID	Jumper Configuration
Isolated DC/DC 3.3-V power from the primary side	LaunchPad or controlCARD connection with primary side being powered, as described in Table 2	J7	Populate the two right most pins: 
3.3-V Micro-USB power	5-V Micro-USB cable to J9		Populate the two left most pins: 

The LVDS or RS485 transceivers are powered off of the secondary side and require the jumper placement described in Table 4.

Table 4. Powering the Differential Transceivers

Transceiver	Header ID	Jumper Configuration
LVDS	J10	Populate the two right most pins: 
RS485		Populate the two left most pins: 

A visual representation of the different power domains of the adapter board is provided in the block diagram shown in Figure 9

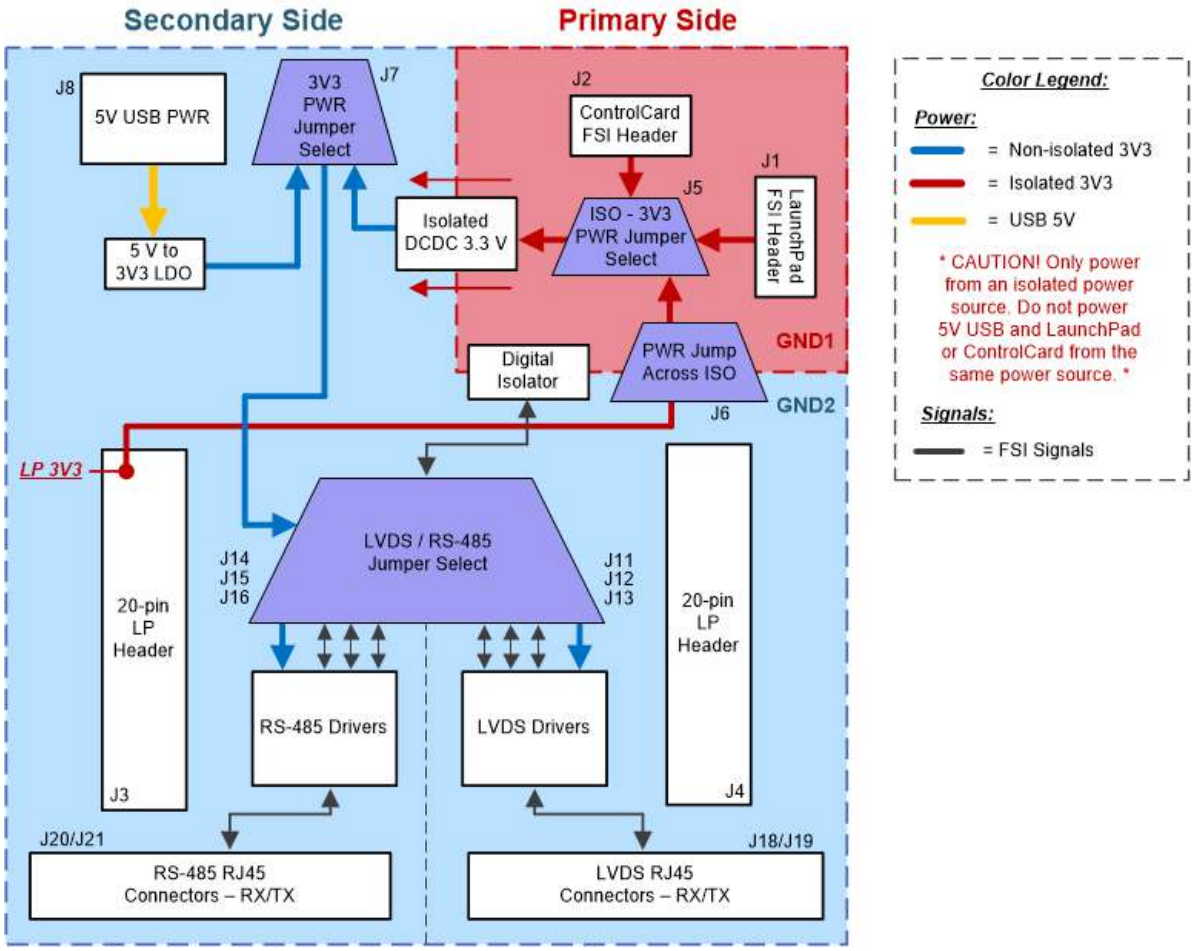


Figure 9. Power Domains Block Diagram

3.4 LVDS or RS485 Signal Selection

The FSI signals going to and coming from the J1 and J2 connectors make their way across the ISO7763 digital isolator. The LVDS / RS485 signal selection headers in the middle of the board are used to complete the single-ended FSI signal connections between the ISO7763 and LVDS / RS485 transceivers. Headers J11 to J13 are for the FSI TX signals and J14 to J16 are for the FSI RX signals. Table 5 describes the possible LVDS / RS485 signal selection jumper configurations.

Table 5. LVDS and RS485 Signal Selection

Transceiver	Functional Description	Header ID	Jumper Configuration
LVDS	Isolated FSI CLK - TX	J11	
LVDS	Isolated FSI D0 - TX	J12	
LVDS	Isolated FSI D1 - TX	J13	
RS485	Isolated FSI CLK - TX	J11	
RS485	Isolated FSI D0 - TX	J12	
RS485	Isolated FSI D1 - TX	J13	
LVDS	Isolated FSI CLK - RX	J14	
LVDS	Isolated FSI D0 - RX	J15	
LVDS	Isolated FSI D1 - RX	J16	
RS485	Isolated FSI CLK - RX	J14	
RS485	Isolated FSI D0 - RX	J15	
RS485	Isolated FSI D1 - RX	J16	

3.5 RJ45 Connection

Differential signals going to and coming from the LVDS / RS485 transceivers are connected to RJ45 connectors J18 to J21 at the bottom of the board. Two of the RJ45 connectors are for LVDS transceiver use and two are for RS485 transceiver use, one for TX signals and one for RX signals in each case. Typical T568B CAT5 cables are used to connect the TX RJ45 to the RX RJ45 connectors, either between multiple adapter boards or the same board in a loopback fashion.

4 FSI Adapter Board Performance

The following sections discuss the performance of the FSI Adapter Board.

4.1 FSI Performance with CAT5 Cable Interface

Performance tests were completed to find the lengths of CAT5 cable that can effectively be used between the TX and RX RJ45 connectors of the adapter board when paired with a C2000 LaunchPad or controlCARD. An external loopback test was used to determine said CAT5 cable lengths, which consisted of a single C2000 device transmitting and receiving data words (0xAAAA) over FSI and then checking that the received data matches what was originally sent. A LAUNCHXL-F280049C was used as the C2000 device in these tests and the hardware setup can be seen in Figure 10.

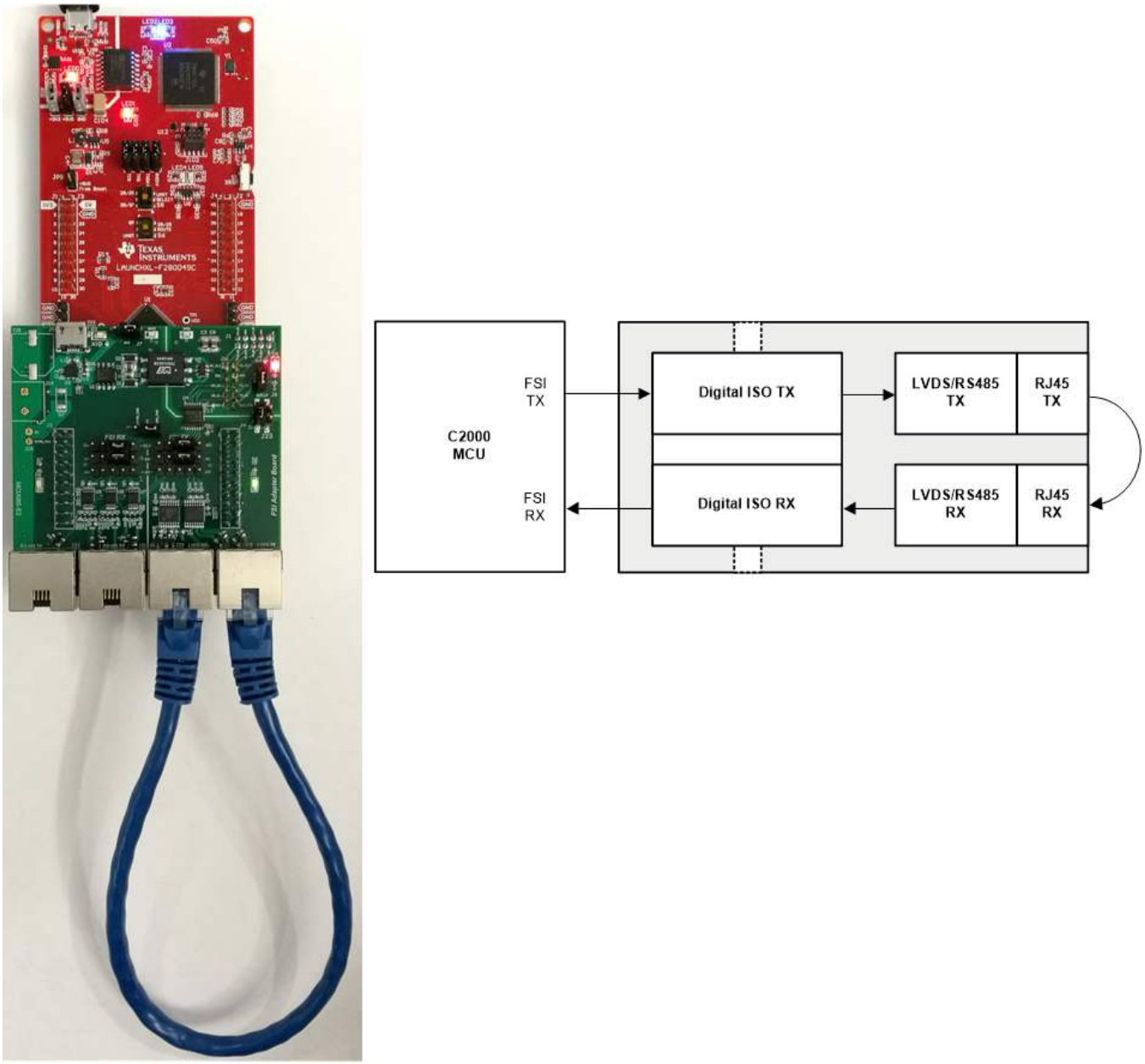


Figure 10. CAT5 External Loopback Hardware Setup

A cable length was found to be achievable to use if all data transmissions had no bit errors and if the clock and data signals at the FSI connector J1 and J2 met the FSI Timing Requirements listed in the respective C2000 device data sheet. See the FSIRX Timing Requirements within the specific device data sheet for compliance.

4.1.1 LVDS FSI CAT5 Performance

The LVDS performance results obtained from the tests described in Section 4.1 are provided below in Table 6. With the high-speed LVDS transceivers the maximum supported FSI clock speed is 50 MHz. The setup and hold times measured should be compared with those listed in the FSIRX Electrical Data and Timing section of the respective device data sheet for compliance.

Table 6. LVDS FSI CAT5 Performance

CAT5 Cable Length (m)	FSI Frequency	Number of Data Lines	Throughput[1][2]	Typical RX Setup Time (ns)	Typical RX Hold Time (ns)
1	50 MHz	1	100 Mbps	4.4	4.2
5	50 MHz	1	100 Mbps	4.6	4.0
10	50 MHz	1	100 Mbps	4.1	4.1

(1) 200 Mbps throughput can be achieved if using two data line FSI. Only 100 Mbps throughput was tested in this case due to current hardware limitations.

(2) See the FSI peripheral section of the C2000 device TRM for FSI data frame protocol in order to calculate effective data throughput.

To provide an example of the measurements taken, waveforms for the 10m CAT5 cable length test are shown in Figure 11.

Figure 11. LVDS - FSIRX Setup and Hold Time Measurements

4.1.2 RS485 FSI CAT5 Performance

The RS485 performance results obtained from the tests described in Section 4.1 are provided below in Table 7. With the medium-speed RS485 transceivers the maximum supported FSI clock speed is 25 MHz. The setup and hold times measured should be compared with those listed in the FSIRX Electrical Data and Timing section of the respective device data sheet for compliance.

Table 7. RS485 FSI CAT5 Performance

CAT5 Cable Length (m)	FSI Frequency	Number of Data Lines	Throughput[1][2]	Typical RX Setup Time (ns)	Typical RX Hold Time (ns)
5	25 MHz	1	50 Mbps	8.0	8.8
10	25 MHz	1	50 Mbps	7.6	8.8
15	25 MHz	1	50 Mbps	8.2	8.6

(1) 100 Mbps throughput can be achieved if using two data line FSI. Only 50 Mbps throughput was tested in this case due to current hardware limitations.

(2) See the FSI peripheral section of the C2000 device TRM for FSI data frame protocol in order to calculate effective data throughput.

To provide an example of the measurements taken, waveforms for the 15m CAT5 cable length test are shown in Figure 12.

Figure 12. RS485 - FSIRX Setup and Hold Time Measurements

5 FSI Adapter Board Capabilities

The following sections discuss the capabilities of the FSI Adapter Board.

5.1 FSI Isolated No-transceiver Capability

The Adapter Board has the capability of testing FSI communication across an isolation boundary without the use of the LVDS and RS485 differential transceivers by jumping the FSI signals from the signal selection headers in the middle of the board. This is useful when wanting to evaluate FSI in an isolated design that only uses single-ended signals.

A loopback test similar to the one performed in Section 4.1 can be performed for the isolated no-transceiver case. The hardware test setup is shown in Figure 13.

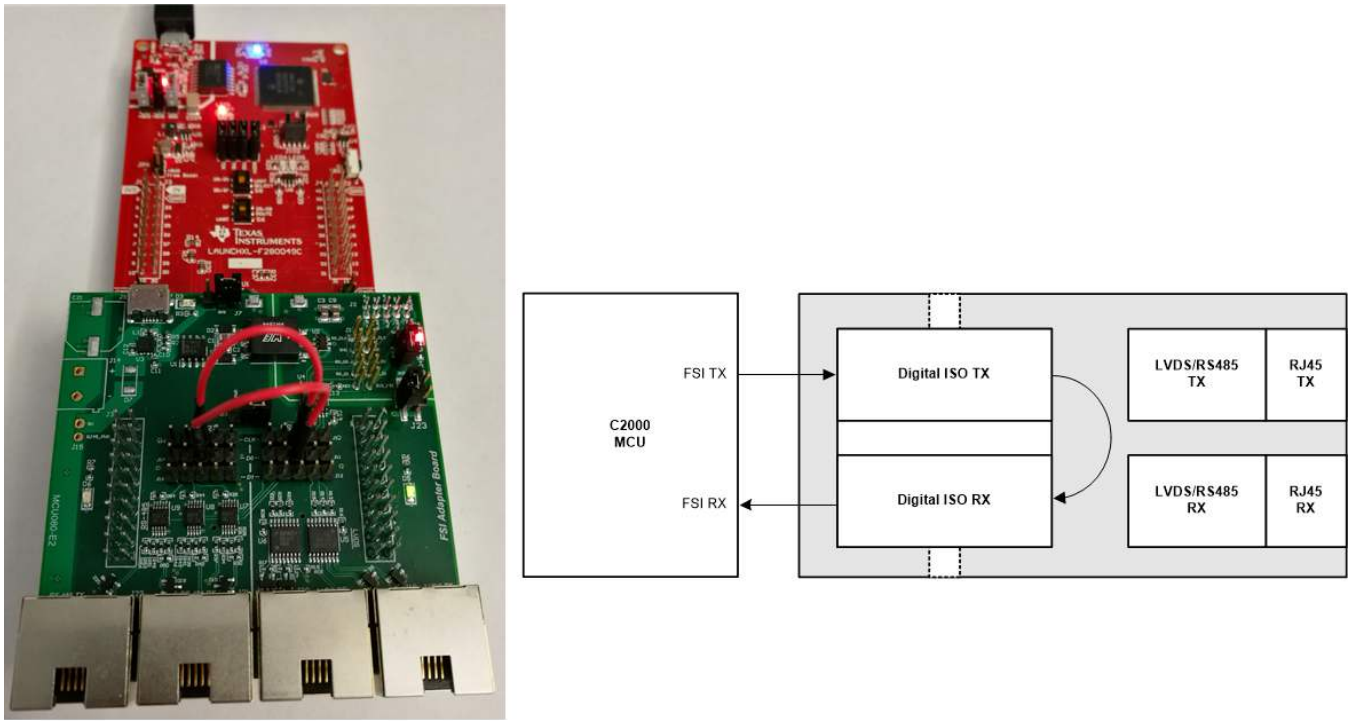


Figure 13. ISO No-Transceiver Loopback Hardware Setup

5.2 FSI Non-Isolated Differential Transceiver Capability

The Adapter board has the capability of testing FSI communication with the on-board LVDS/RS485 differential transceivers without crossing an isolation barrier by jumping the FSI signals from the signal selection headers in the middle of the board. This is useful when wanting to evaluate FSI in a board-to-board design that makes use of differential transceivers. The hardware implementation described is shown in Figure 14.

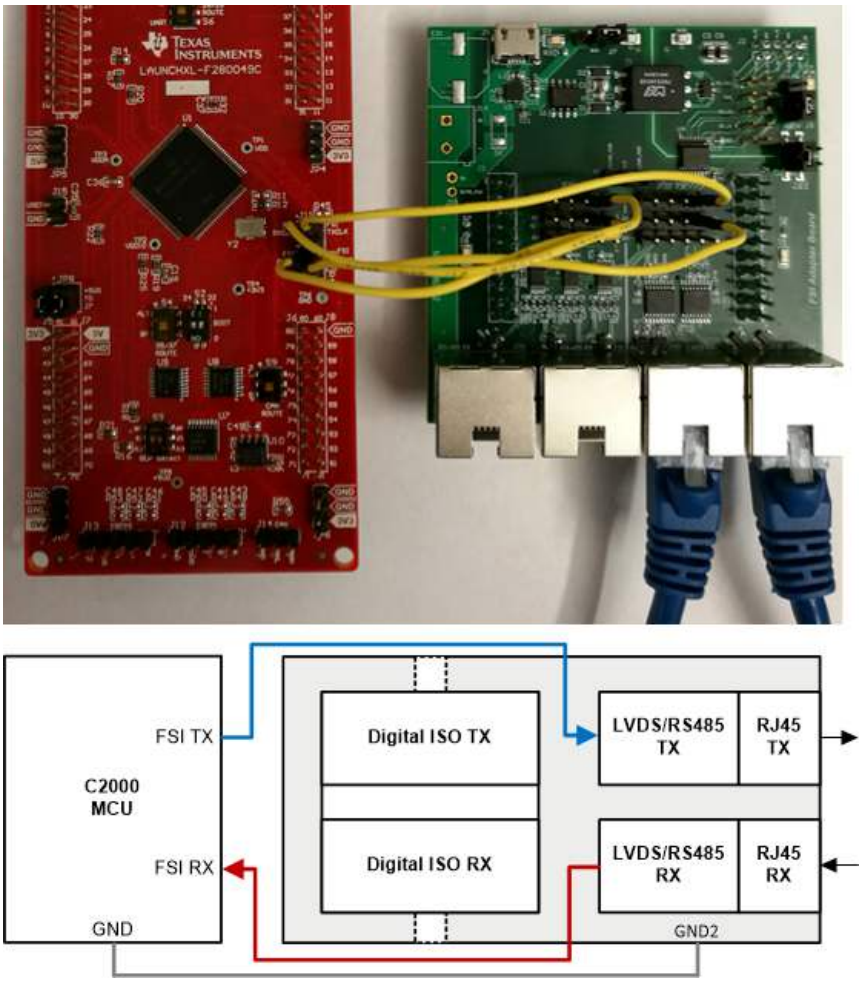


Figure 14. Non-Isolated Hardware Setup

NOTE: Only the secondary side of the Adapter Board must be powered for the implementation described in Section 5.2. Proper ground connections from the target device to GND2 should be made.

5.3 FSI RX Skew Compensation

The FSI receiver module has a skew adjustment block that enables programmable delay line control on each of the signal inputs: RXCLK, RXD0, and RXD1. Delay elements can be introduced on the individual FSI signals to adjust for any signal skew induced by device I/O selection, uneven trace/cable lengths, or from system level components, such as isolators, transceivers, and so forth. More information on the skew adjustment block can be found in the FSI section of the respective device Technical Reference Manual.

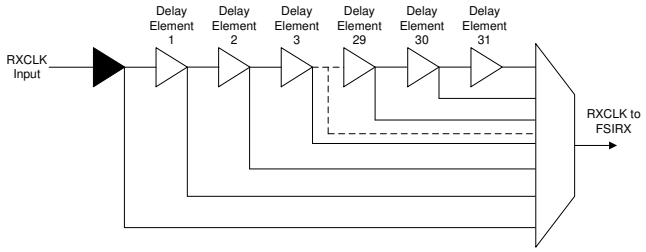


Figure 15. Delay Line Control Circuit

It is recommended to implement a calibration routine to configure the delay elements to their ideal values for each FSI RX module within a system design. More specific details on the FSI RX skew compensation capabilities, along with a supporting GUI and relevant software example documentation, can be found in the FSI Skew Compensation Application Report.

5.4 Example System Topologies

The FSI Adapter Board can be used to create a communication network topology within a system. A few system topology examples are described below. For more details on implementing system topologies, such as the ones described, see the Multi-device FSI Application Report.

A FSI daisy-chain topology block diagram is shown in Figure 16.

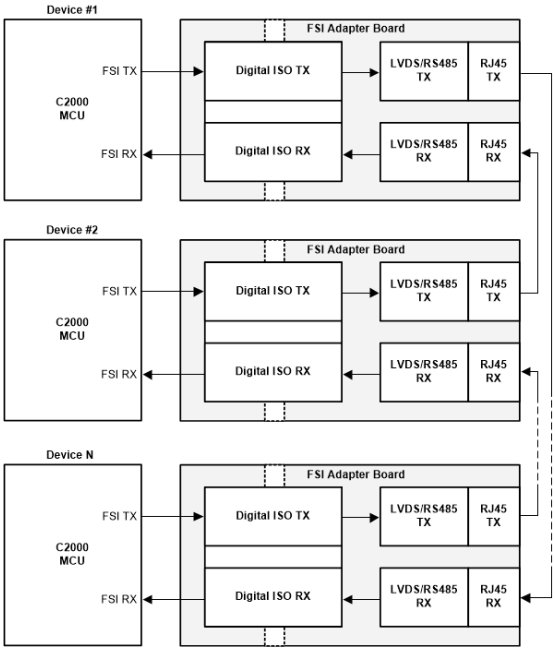


Figure 16. FSI Daisy-chain Block Diagram

A FSI star connection topology block diagram is shown in Figure 17. The topology diagram shown requires the host device to have more than one FSI RX module. For example, the F2838x device, which has eight FSI RX modules, could be used as the host device.

NOTE: For the LVDS case, TX drivers with multi-drop functionality should be used for one TX to multiple RX communications, such as the star topology demonstrated below.

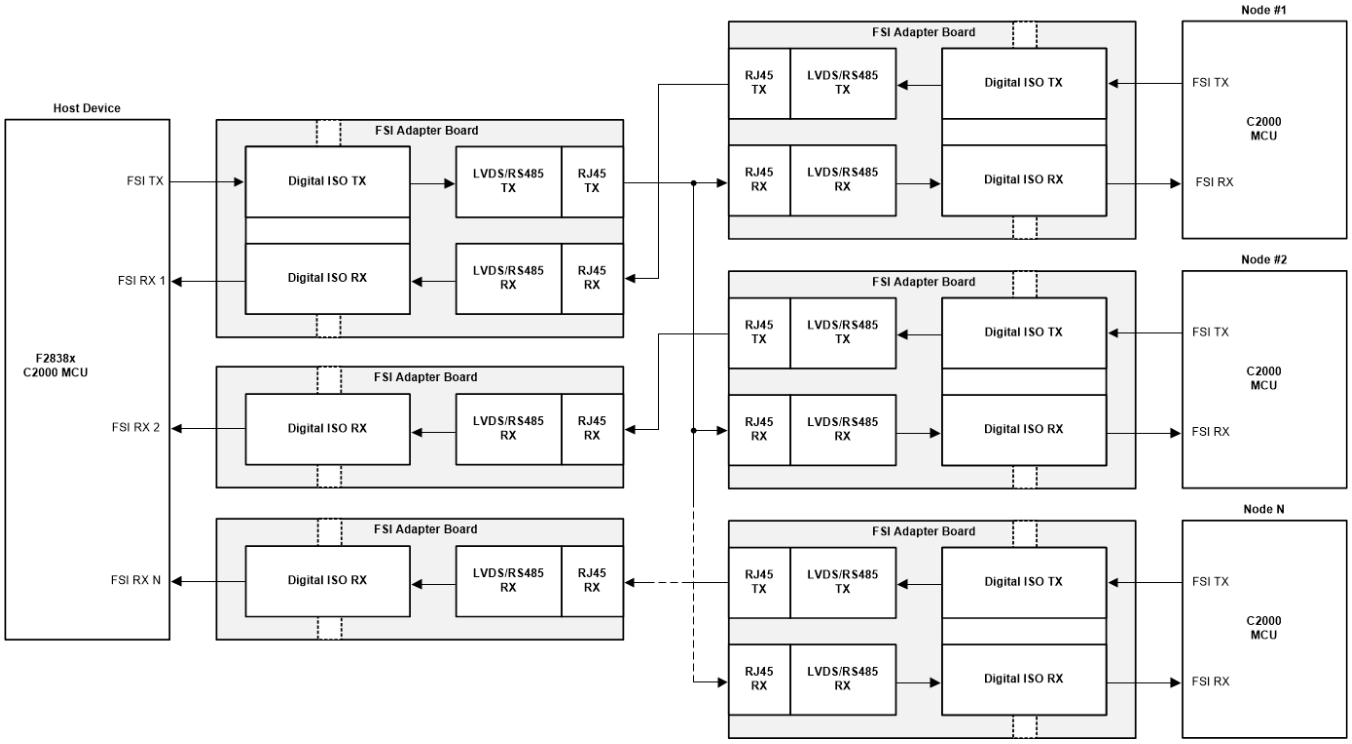


Figure 17. FSI Star Connection Block Diagram

A distributed multi-axis servo example system can be created using FSI Adapter Boards, C2000 MCUs, and motor drive devices. An example of this system in a daisy-chain topology can be seen in Figure 18. See the Distributed multi-axis servo drive over fast serial interface (FSI) reference design for an example of the implementation.

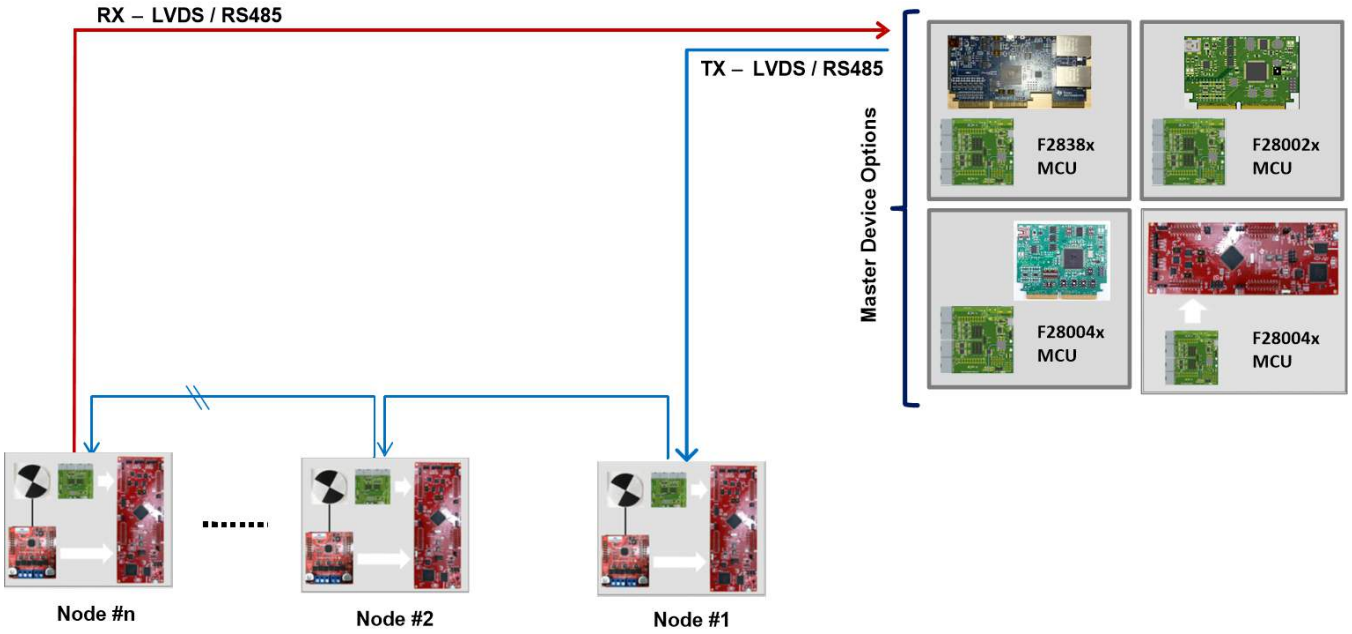


Figure 18. Distributed Multi-axis Servo Example

6 Evaluation Software

Supporting software to be run on a C2000 LaunchPad or controlCARD + FSI Adapter Board is found within the C2000WARE installation. See Table 8 for a list of relevant software examples available within c2000WARE.

Table 8. C2000WARE FSI Evaluation Software Examples

SW Example Name	Description
fsi_ex_loopback_cpucontrol	CPU controlled data frame transfers with internal and external loopback support and error checking
fsi_ex_loopback_clacontrol	FSI data transfer control (triggered) through CLA with internal and external loopback support and error checking
fsi_ex_loopback_dmacontrol	DMA controlled data frame transfers with internal and external loopback support and error checking
fsi_ex_loopback_epwmtrigger	FSI data frame transfer triggered by ePWM SOC with internal and external loopback support and error checking
fsi_ex_periodic_frame	FSI data frame transfers upon CPU Timer event with internal and external loopback support and error checking
fsi_ex_ext_p2pconnection_tx/rx	FSI Transmit in Point to Point Connection. Separate projects for TX and RX device
fsi_ex_delay_tap_measurement	FSI Receiver Skew Compensation Block - Element Delay Evaluation example(1)
fsi_ex_single_line_delay_select_tx/rx	FSI Skew Calibration Example in Single Data Line Mode. Separate projects for TX and RX device(1)
fsi_ex_dual_line_delay_select_tx/rx	FSI Skew Calibration Example in Dual Data Line Mode. Separate projects for TX and RX device(1)
fsi_ex_find_optimal_delay_device1/2	FSI Example to find Optimal Skew Compensation Setting For FSIRX. Separate projects for device 1 and 2(1)
fsi_ex_daisy_handshake_lead/node	FSI daisy-chain topology example. Separate projects for 'lead' and 'node' devices(2)
fsi_ex_star_broadcast	FSI star connection topology example. FSI communication using CPU control

(1) For more information on FSI skew compensation and relevant examples see FSI Skew Compensation Application Report
(2) For more information on the FSI daisy-chain and star topology examples see Multi-device FSI Application Report

Required software configurations for the examples listed above are described in Table 9.

Table 9. FSI Software Configurations

Relevant SW Examples	Usecase	SW Configuration
All Examples	If using a LaunchPad	Add _LAUNCHXL_F28xxxxx to Pre-defined Symbols(1)
	If using a controlCARD	Do **NOT** define _LAUNCHXL_F28xxxxx(1)
Loopback Examples	Enable External Loopback	Set EXTERNAL_FSI_ENABLE pre-processor directive equal to 1

(1) Defined symbol should match respective C2000 device.

7 FSI References

Other TI documents relevant to the FSI Adapter Board are described in Table 10.

Table 10. FSI Reference Documents

Document Name	Description
Multi-device FSI Application Report	Discusses how FSI can be used to communicate between multiple devices within a system.
FSI Skew Compensation Application Report	Provides details on the skew compensation functionality built into the FSI peripheral and how it can be utilized.
TMS320F28002x TRM	See FSI section in F28002x Technical Reference Manual
TMS320F28004x TRM	See FSI section in F28004x Technical Reference Manual
TMS320F2838x TRM	See FSI section in F2838x Technical Reference Manual
C2000 Peripherals Reference Guide	Provides an overview of all peripherals available on C2000 devices

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