User's Guide
SPRUII1–November 2017

Fusion Application Board

This document provides detailed information about various video-input options, user configuration details, and GPIO selection, to make more effective use and yield the targeted benefits of the Fusion application board, from the user's point of view.

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1 Introduction

The Fusion application board allows up to eight, high-speed, data sources, such as megapixel imagers and RADAR and LIDAR sensors, to be combined into two digital MIPI CSI-2 output ports, which are then connected to a TDA2Px or similar system-on-chip (SoC) evaluation module (EVM), with stand-alone operation (see Figure 1). Each sensor source connects to one of the hubs through a single coax cable or twisted pair (HSD). Two DS90UB960 FPD-Link III hubs are on the board. Each DS90UB960 device outputs four, high-speed, data inputs on only one CSI-2 LVDS interface. This greatly simplifies the system by combining eight sensor inputs into two outputs. These outputs are available on an external connector that attaches to a TDA2Px EVM or a similar SoC/processor. Because the Fusion application board supports multiple video inputs and multiplexing options, it is a well suited solution for Advanced Driver Assistance Systems (ADAS) development activity.

The Fusion application board EVM consists of the following:

- PCB application board:
  - Accepts eight, high-speed data inputs over FPD-Link III
  - Uses two DS90UB960-Q1 devices for CSI-2 output to directly connect to CSI-2 video ports on TDA2Px, TDA2Ex, and TDA3x EVMs
  - Provides a wide-range supply voltage for Power over Coax (PoC: 4 to 14 V)
- FPD-Link III DS90UB960-Q1: Supports eight, high-speed, data inputs with only two outputs, for surround and stereoscopic view and ease of design
- Stand-alone operation:
  - Board power can come directly from a car battery (3.8 V to 65 V) or power source
  - Onboard MSP430F2272-Q1 device for stand-alone operation
  - Provides up to four 8 W and four 1.5 W PoC to each of the FPD-Link III inputs

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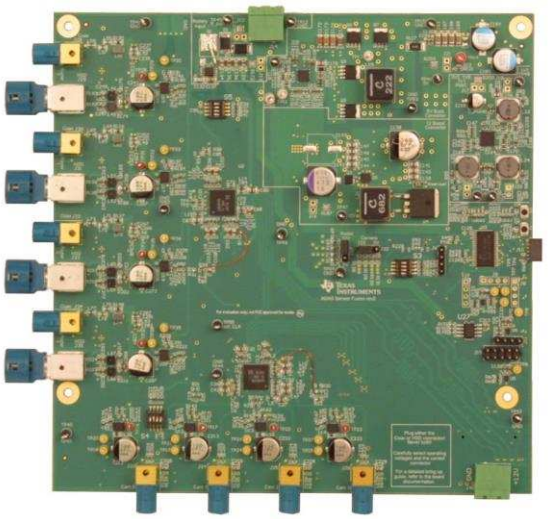
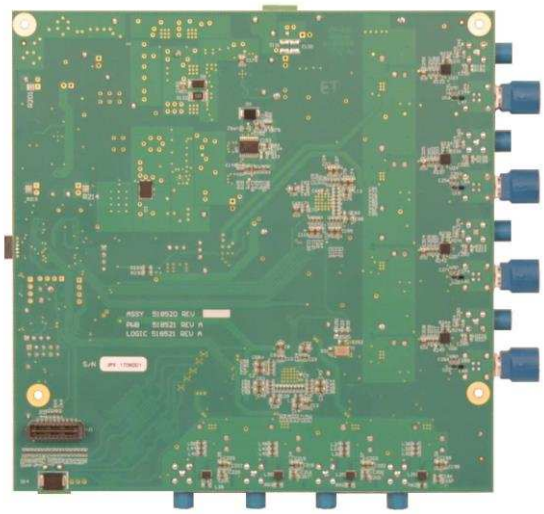
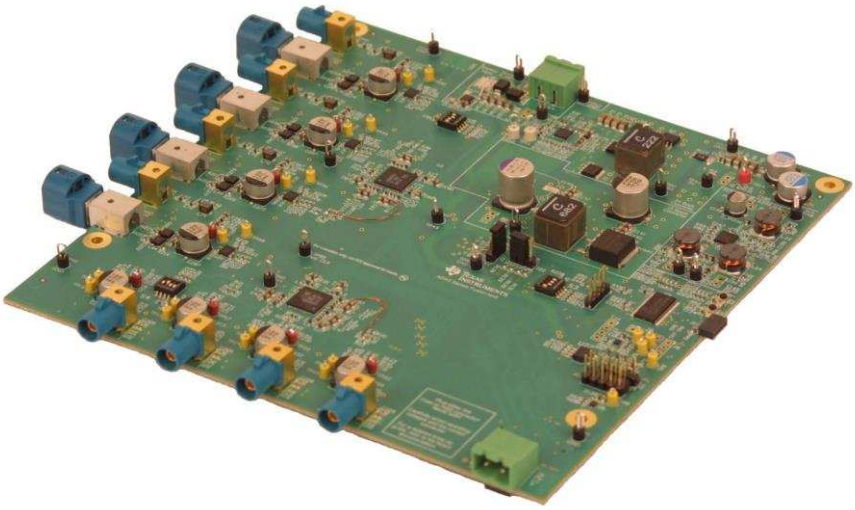
Use this board with the TDA2Px CPU EVM to enable a complete system solution.



Fusion Application Board (Top View)



Fusion Application Board (Bottom View)



Fusion Application Board (Isotropic View)

Figure 1. Fusion Application Board

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2 Overview

2.1 Fusion Application Board

Figure 2 shows the functional block diagram of the Fusion application board.

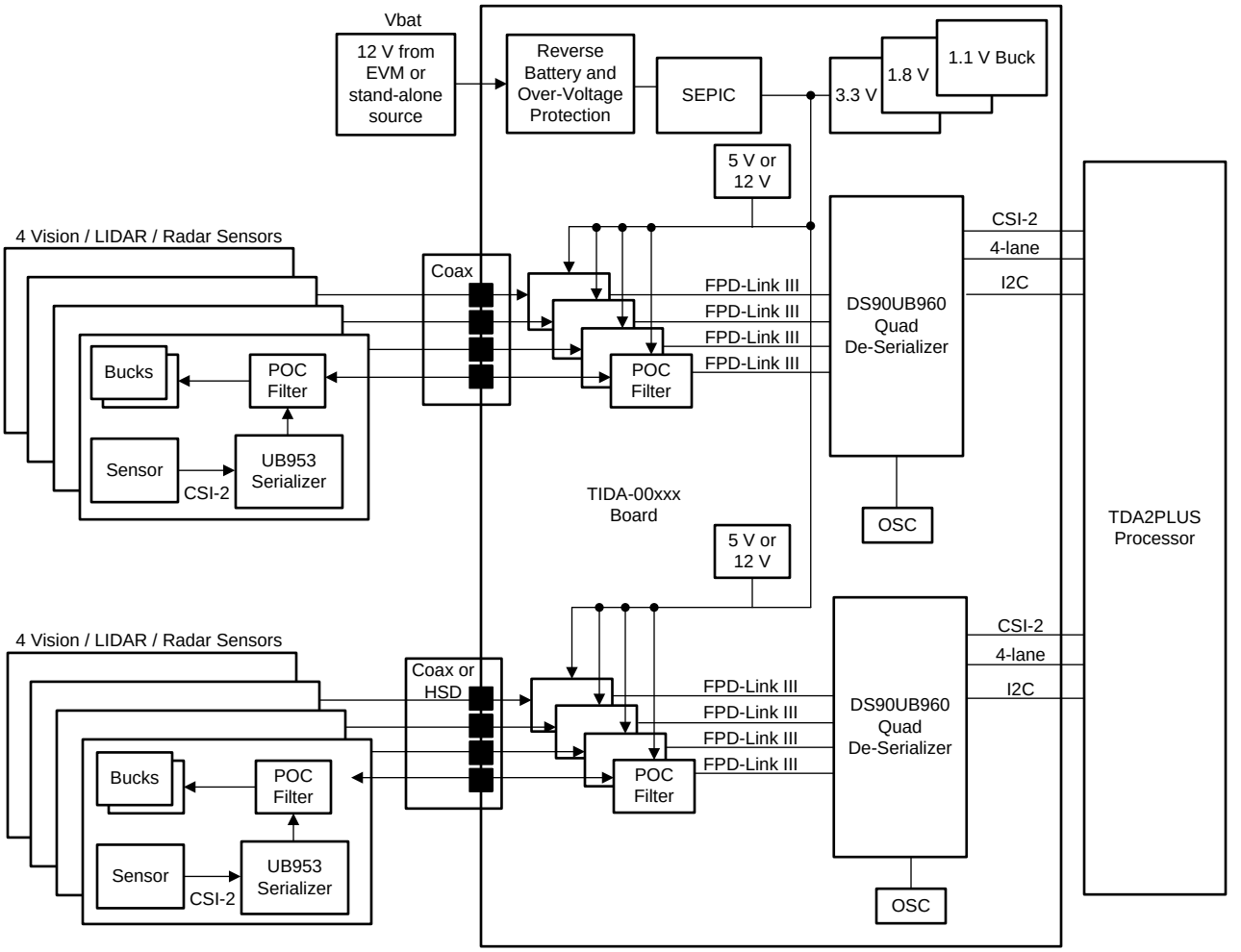

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Figure 2. Fusion Application Board Functional Block Diagram

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2.2 Fusion Board Features

The fusion board features follow:

- Power supply:
  - 12-V DC input from a power source or TDA2Px EVM
  - Optimized power management solution
  - Reverse voltage protection
  - eFuse protection, in case of failing sensors
  - Selectable 12 V or 5 V to camera/radar modules
- Printed circuit board (PCB):
  - Dimensions (W × D): 170 mm × 170 mm
  - Expansion connector to TDA2Px or similar device
- Memory: I^2C configuration EEPROM
- Coax/high-speed input:
  - Up to eight, high-speed, data inputs connected at once
  - Can support up to eight coax inputs, or four coax and four HSD inputs
  - Supports a variety of modules including multi-camera, RADAR, and LIDAR inputs
- DS90UB960-Q1 quad deserializer hub:
  - Two DS90UB960-Q1 devices, each with a four-channel deserializer with up to eight connected sensors
  - Reduce cabling with dual CSI-2 ports
  - Can be paired with DS90UB953-Q1 serializers
  - Flexible GPIOs for sensor synchronization and diagnostics
- MSP430F2272-Q1 device:
  - Hardware strapping allows the MSP430 device to be bypassed (not in circuit)
  - Can be used as a housekeeping and configuration microcontroller
  - Enables synchronization with the EVM upon power up
- PoC:
  - Selectable 12 V or 5 V for camera and radar modules
  - Sensor data, I^2C control, diagnostics, and power can all be transmitted up to 15 meters on a single, inexpensive, coax cable
  - Up to four 8 W and four 1.5 W PoC (sourced from external supply, J14)
- External interfaces:
  - 40-pin, CSI-2, LVDS connector to the TDA2Px EVM
  - 10-pin, Aardvark, I^2C connector
  - MSP430 programming header
  - Header pins to the external microcontroller

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3 Hardware

3.1 Hardware Architecture

Table 1 lists key specifications of the Fusion application board.

Table 1. Key Power Characteristics

Parameter		Comments	MIN	TYP	MAX	UNIT
System input						
V_{IN}	Supply Voltage	External supply (J14)	6	12	65	V
P_{TOTAL}	Total power consumption without sensors	At 12 V		TBD	TBD	W
P_{TOTAL}	Total power consumption with four camera sensors	At 12 V		TBD	TBD	W

3.1.1 Fusion Application Board With Component Identification

Figure 3 shows the major connectors and components on the top side of the board.

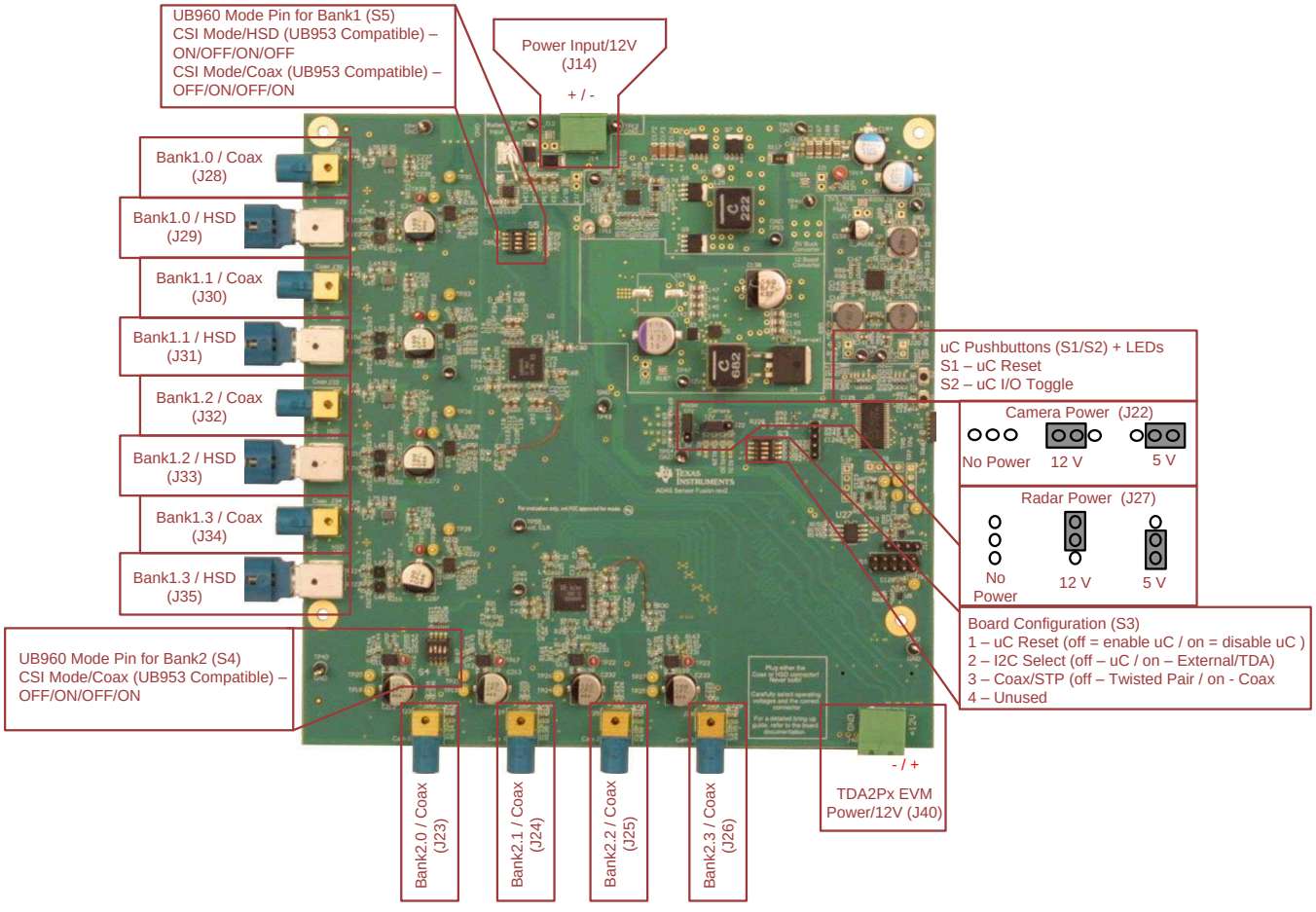

Figure 3. Board With Components Identifications

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The CSI-2 connector is placed on the bottom side of the board; this is the connector that makes an interface with the TDA2Px CPU board (see Figure 4). The Fusion board can also connect to J6Eco/Entry or other EVMs with a compatible cable, see Section 3.2.

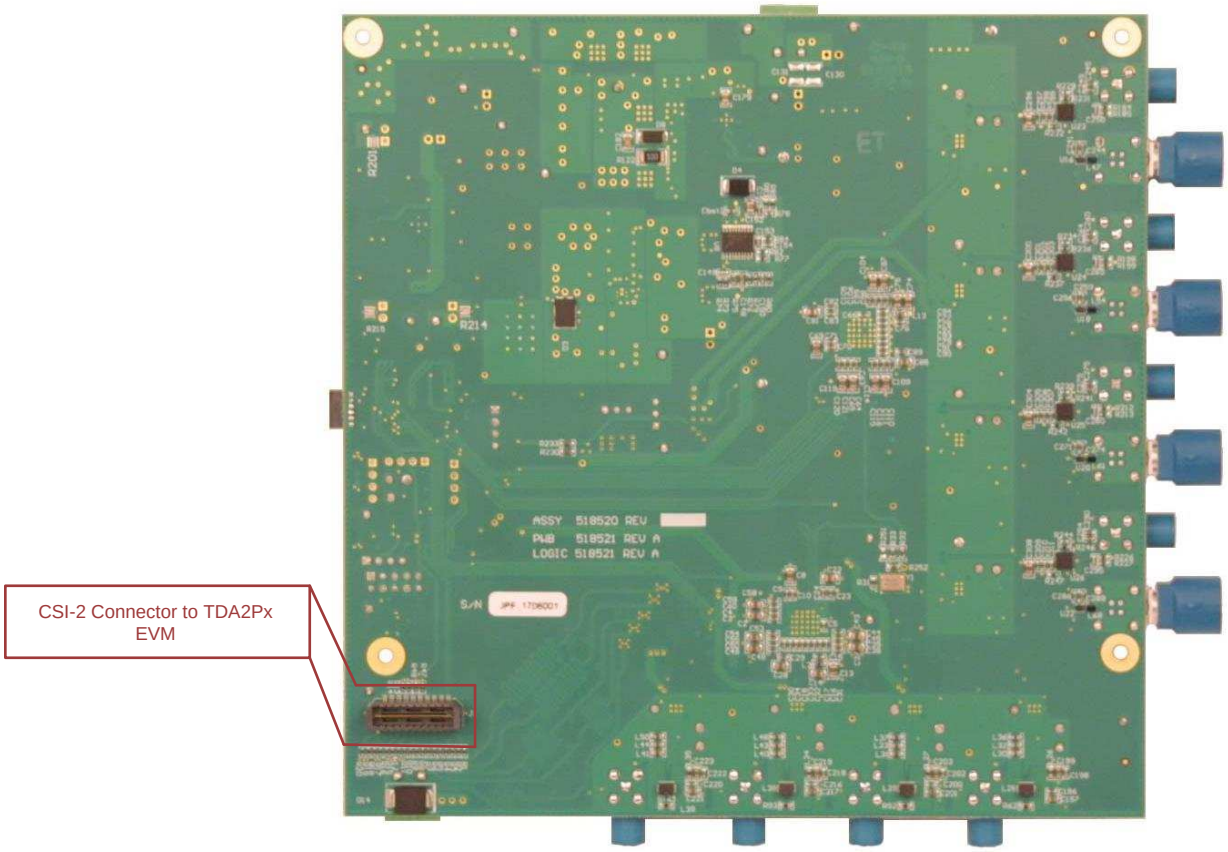

Figure 4. Bottom Side of Fusion Board With CSI-2 Connector

3.2 TDAx EVM Compatibility

The Fusion board is designed to match the size of various processor EVMs, such as the TDA2xEco or TDA2Px EVM. The TDA2Px processor is designed for automotive ADAS and self-driving car applications. The board size of the TDA3x EVM is larger than the EVMs previously mentioned, but the mounting holes are placed in the same position on all the boards, to maintain overall compatibility. The Fusion board can also connect to a J6Eco, J6Entry, or other EVMs with the same connector. An additional SAMTEC HQCD connector cable is needed to connect to the J6Eco or J6Entry. As a result, the connection between the board and the EVM must be in a fixed position too.

3.3 Fusion Power

The Fusion board can be operated as stand-alone, or connected and mounted to the TDA2Px EVM. There are two different power connectors:

- One for power from the TDA2Px EVM only (J40)
- One for a power source similar to a car battery, with circuitry to drop down the voltage for the Fusion board (J14)

The connector (J40) that is used for power when connected to the TDA2Px EVM has an included adapter in the Fusion box. The Fusion is powered specifically from the TDA2Px EVM. The 12-V power pins on the CSI-2 connector have been disconnected due to current limitations, hence the need for a separate power connector.

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There is also the stand-alone aspect of the Fusion board. The Fusion board can be used as stand-alone or connected to a TDA2 EVM such as J6Entry or J6Eco. However, for these use cases, there is a different power connector (J14) that must be used. The J14 connector is used and provides the circuitry to regulate input voltage from a separate power source. Pay special attention to the connector that is being used as improper use can damage the board.

3.4 DS90UB960 Modes

The Fusion board is equipped with two DS90UB960 deserializers. The DS90UB960 devices have multiple modes, however only two modes are used on the Fusion board: CSI mode (DS90UB953 compatible) and selecting between Coax and STP(HSD) connectors. The modes are selected by throwing the switches on the component. Table 10 lists the sequence of switches in step 4 of Section 5.

3.4.1 Power over Coax (PoC)

The DS90UB960 device supports PoC to power remote sensor systems. The power is delivered through the same Coax cable that transmits video data from the sensors. PoC is achieved through a network of filters that isolate the transmission line from the loading of the DC-DC regulator circuits and their connecting power traces on both sides.

J22 is named Camera and controls Bank2 voltages for the sensors. J27 is named Radar and controls the Bank1 voltages. On the Fusion board, there are two voltage options to choose from: 5 V and 12 V. Two separate jumpers select the voltage of choice: J27 and J22. There is also a switch (S3 position 3) for Bank1 to choose if Coax or HSD sensors are used. Regardless, the voltage selected is used for the HSD or Coax, and the method must be selected by the switch as just mentioned.

Table 2. DS90UB960 Pin Assignments

Pin	Name	Function	Description
DS90UB960 (U1)			
6	INTB_CAM	Interrupt output	Interrupt output for Bank2 sensors, goes to MSP430 P1.1
9	GPIO1_0	General purpose I/O	General input from the MSP430
10	GPIO1_1	General purpose I/O	General input from the MSP430
11	I2C_SDA	I^2C data input	I^2C data line from the host switch
12	I2C_SCL	I^2C clock input	I^2C clock line from the host switch
14	GPIO1_2	General purpose I/O	General input from the MSP430
15	GPIO1_3	General purpose I/O	General input from the MSP430
17	SYNC_CAMERA	Input	Sync Bank2 input from the CSI-2 connector
DS90UB960 (U2)			
6	INTB	Interrupt output	Interrupt output for Bank1 sensors, connects to MSP430 P1.0
9	GPIO0_0	General purpose I/O	General input from the MSP430
10	GPIO0_1	General purpose I/O	General input from the MSP430
11	I2C_SCL	I^2C data input	I^2C data line from the host switch
12	I2C_SDA	I^2C clock input	I^2C clock line from the host switch
14	GPIO0_2	General purpose I/O	General input from the MSP430
15	GPIO0_3	General purpose I/O	General input from the MSP430
17	SYNC_RADAR	Input	Sync Bank1 input from the CSI-2 connector

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3.5 I²C Addressing

3.5.1 Multiple Device Addressing (Aliasing)

Sensor fusion architectures, as for ADAS and self-driving applications, require multiple sensor modules in a single system. It is desirable for the sensors to be built alike, and therefore be fixed to the same physical I²C address. If these modules are all to be accessed on the same I²C bus, there must be a method of assigning each camera an alias that is used to address them. The FPD-Link parts provide the functionality to assign a slave ID (alias) to each camera. This allows the slave devices to be independently addressed. These physical slave addresses and their associated alias IDs are configured by programming the Slave ID and Slave Alias registers on the deserializer (DS90UB960-Q1).

The host microprocessor can now communicate with each imager by using its alias, even though the imagers in each camera are physically addressed identically. From the I²C host perspective, this will remap the address of each slave to its slave alias. For the Fusion board, multiple instances of the same sensor modules can be used.

Figure 5 shows how aliasing is performed even though all of the sensor modules are identical.

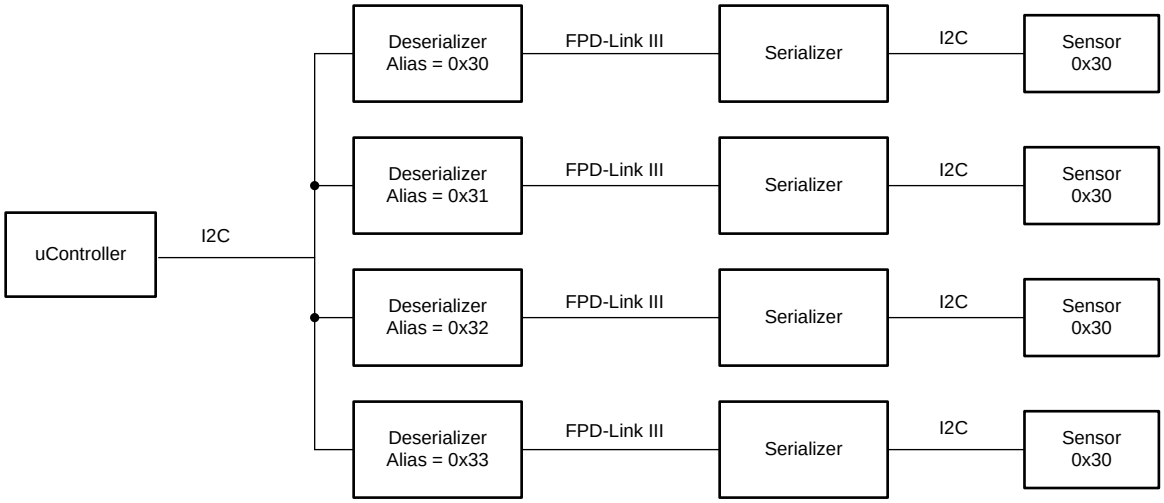

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Figure 5. Diagram of Aliasing Through Using the Deserializer

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3.5.2 I²C Bus Switches and Connections

There are three options for control and configuration of the DS90UB960-Q1 device, including the TDA2Px, MSP430, or an external microcontroller. Selection of what option controls is done through a combination of configuration switches and software. By default, the switch controls selection; however, there are several mechanisms to override the switch setting (MSP430 GPIO, TDA2Px GPIO, or header J6/J11). The external microcontroller (J6) has been broken out on the Fusion board to identify the I²C host in the system and to connect to an external microcontroller if applicable (see Figure 6).

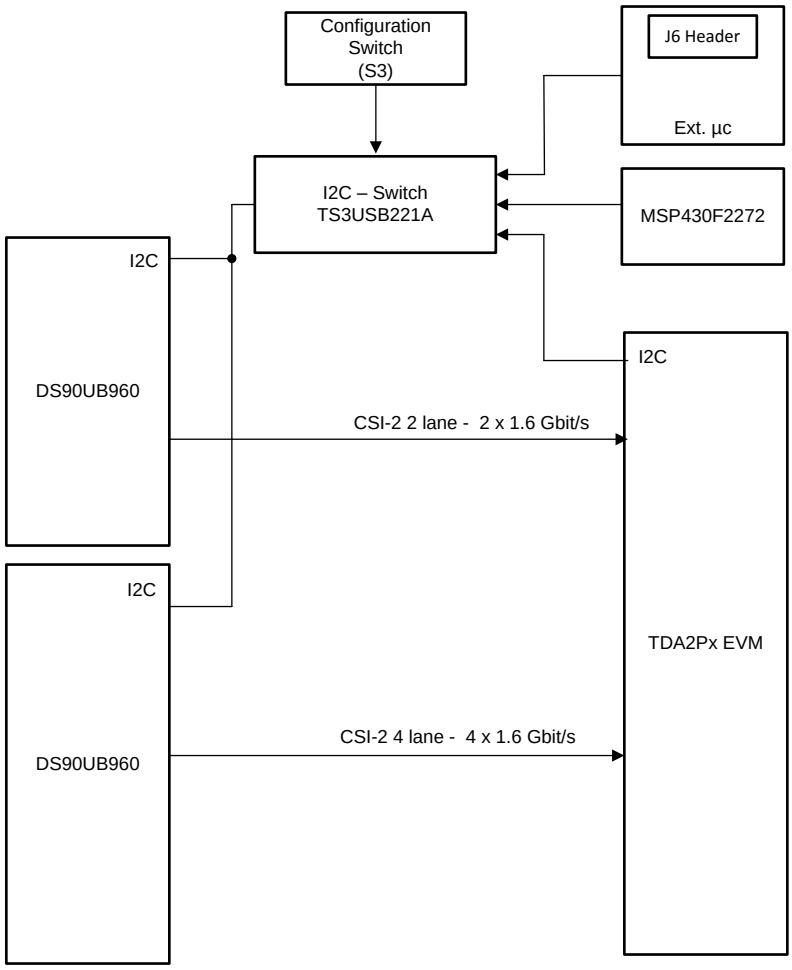

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Figure 6. Block Diagram of I²C Assignments

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When open, S3 position 2 selects I²C to the MSP430 microcontroller (see Table 3). When closed, S3 position 2 selects I²C to be used on the TDA2 EVM or external microcontroller.

Table 3. I²C Host Configurations

I²C Host	S3.1	S3.2	S3.3[1]	S3.4	J6.1	J6.1	J6.3	Details
TDA2Px EVM	On	On	Optional	N/A	Open	Open	Open	J1.20[2] must be set high to override the switch. Set from the TDA2Px EVM.
MSP430	Off	Off	Optional	N/A	Open	Open	Open	P2.7 on the MSP430 must be set low. P2.5 must be set high.
External microcontroller	On	On	Optional	N/A	Low	High	High	J6 and J11 or J15 external[3]. The external MCU overrides settings through J6.

(1) S3.3 is the switch that determines if coax or HSD will be used on Bank1. Functionality of the switch is in Table 7.
(2) J1.20 is on the CSI-2 connector. GPIO7_7 is the pin to be set high on the TDA2P EVM.
(3) The external microcontroller must connect to J6 and either J11 or J15, depending on the I²C connector from the external.

Table 4 lists the onboard I²C switch details.

Table 4. Onboard I²C Switches

Switch Name	Component Name	J6 Pin Number	Function
I2C_SW_SOC	U4	J6.1	Enables I²C communication with the EVM.
I2C_SW_EXTERNAL	U6	J6.2	Enables I²C communication with the external.
I2C_SW_UB960	U5	J6.3	Enables I²C communication with the DS90UB960 device.

- I2C_SW_SOC: Depending on when this switch is closed, the SoC can either initialize the board, or just control the sensors after board initialization is completed. Writing I²C commands into the DS90UB960 device during normal operation configures the external sensors. The DS90UB960 device passes the commands onto one of the sensors addressed. Routing of the commands takes place by use of the alias address scheme discussed earlier. When this switch is open, all SoC traffic is isolated from the board. This allows the local MSP430 or the external microcontroller to be the host.
- I2C_SW_External: When the switch is closed, it allows the external microcontroller to take over as the host of the I²C bus. If an external microcontroller is used, the MSP430 and SoC must avoid using the bus, per software configuration. When the switch is open, either the MSP430 or the SoC is the I²C host in the system.
- I2C_SW_UB960: When the I²C switch is closed, the main I²C bus on the DS90UB960 is connected to the main I²C bus on the board. This switch must be closed for all configurations to the DS90UB960 and all external sensors as well.

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3.6 EVM Interface

The TDA2Px EVM can be used as a host for I^2C on the Fusion board. There is a separate power connector (J40) that is used to power the Fusion board from the TDA2Px EVM. The I^2C bus that is used on the EVM is I^2C3 for SCL and SDA. The GPIO that controls whether the EVM will be the host is GPIO7_7 and is output only from the EVM. That GPIO can override the switch settings on the Fusion board. See Table 7 for correct switch settings to be deployed. If powered from the EVM, the total solution must not exceed 60 W. If so, TI recommends using the external supply connector for the Fusion board.

Table 5. Pin Associations on Fusion Board and TDA2Px EVM

CSI-2 Pin	Fusion Board	TDA2Px EVM	Function
2	I2C_SCL_SOC	I2C3_SCL	I^2C pin that must be initialized on the TDA2P EVM
4	I2C_SDA_SOC	I2C3_SDA	I^2C pin that must be initialized on the TDA2P EVM
18	SYNC_Bank2	GPIO7_9	Output from the DS90UB960 device to CSI2, determines if Bank2 sensors are to be synchronized
20	I2C_SW_SOC	GPIO7_7	Output that determines the TDA2P EVM is the host. Must be driven high.
22	SYNC_Bank1	GPIO7_10	Output from the DS90UB960 device to CSI2, determines if Bank1 sensors are to be synchronized

There is a SYNC input from the DS90UB960 device that is routed to the CSI-2 connector for both sensor banks on the Fusion board. The TDA2Px EVM can synchronize the sensors to be able to minimize the latency of the video streams coming in.

3.7 Sensor Connection

Two banks of connectors each support up to four sensors. One bank is coax only, the other is selectable between coax and HSD (see Figure 7).

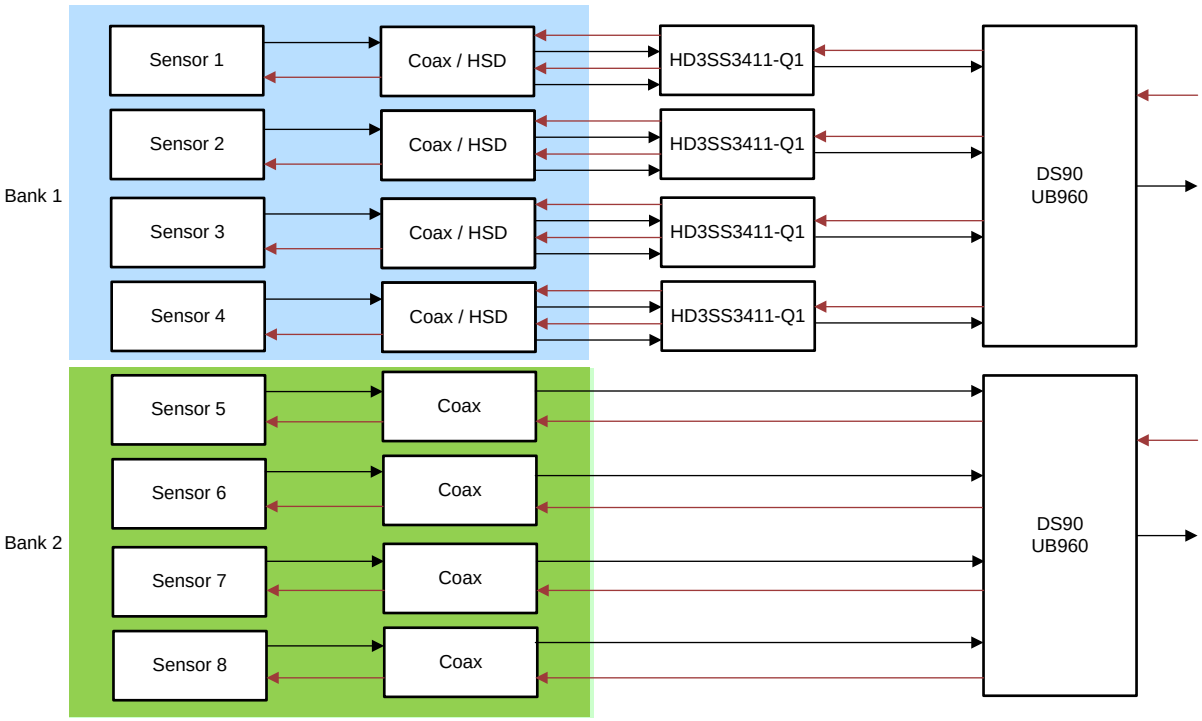

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Figure 7. Coaxial and HSD Connectors Diagram

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The coax cable can transmit both data and power over the same wire. However, the coax has limited power transfer capability. The HSD connection has separate data and power lines allowing more energy for power hungry sensors. To select between the HSD and Coax cable, switch S3 position 2 must be set. ON selects the coaxial cable. OFF selects the HSD twisted pair. For Bank1, all sensors must be configured for either coax or HSD (no mixing of the sensors). See Figure 3 for the location of the switch set (S3).

3.8 MSP430™ Microcontroller

The MSP430™ device is included to provide stand-alone functionality for control and configuration of the DS90UB960 devices. When used with a TDA2Px EVM, MSP430 use is optional. The MSP430 can be enabled or disabled by an onboard switch. Switch S3 position 1, set to the ON position disables the MSP430 (by holding in RESET). When in the off position, MSP430 is enabled.

Table 6 lists the connections of the MSP430 on the Fusion board. Notice P3.0 is a spare optional switch (S2) that can be used as a GPIO. Port 4 offers eight GPIO pins. The first four GPIOs are routed to the second deserializer, U2. The last four GPIOs are routed to the first deserializer, U1.

Table 6. Connection of MSP430™ Pins

Pin	Name	Function	Description
Port 1			
P1.0	INTB_RADAR	Interrupt input	Interrupt output – deserializer U2
P1.1	INTB_CAM	Interrupt input	Interrupt output – deserializer U1
Port 2			
P2.0	Spare4_UC	GPIO (output)	D15, green LED
P2.1	Spare5_UC	GPIO (output)	D16, yellow LED
P2.2	Spare6_UC	GPIO (output)	D17, orange LED
P2.3	Spare7_UC	GPIO (output)	D18, green LED
P2.4	Spare8_UC	GPIO (output)	D19, green LED
P2.5	I2C_SW_SOC	GPIO (output)	Enable I^2C bus to the TDA2Px EVM
P2.6	I2C_SW_UB960	GPIO (output)	Enable I^2C bus to the two DS90UB960s
P2.7	I2C_SW_EXTERNAL	GPIO (output)	Enable I^2C bus to the external option
Port 3			
P3.0	S2 (spare_switch)	GPIO (input)	Optional switch
P3.1	I2C_SDA_UC	I^2C data	I^2C data line
P3.2	I2C_SCL_UC	I^2C clock	I^2C clock line
P3.3	PDB_UB960_cam	GPIO (output)	Deserializer U1 wakeup
P3.4	PDB_UB960_radar	GPIO (output)	Deserializer U2 wakeup
P3.5	SPARE1_UC	GPIO (output)	D11, yellow LED
P3.6	SPARE2_UC	GPIO (output)	D12, orange LED
P3.7	SPARE3_UC	GPIO (output)	D13, green LED
Port 4			
P4.0	GPIO0_0	GPIO (output)	GPIO 0 - Deserializer U2
P4.1	GPIO0_1	GPIO (output)	GPIO 1 - Deserializer U2
P4.2	GPIO0_2	GPIO (output)	GPIO 2 - Deserializer U2
P4.3	GPIO0_3	GPIO (output)	GPIO 3 - Deserializer U2
P4.4	GPIO1_0	GPIO (output)	GPIO 0 - Deserializer U1
P4.5	GPIO1_1	GPIO (output)	GPIO 1 - Deserializer U1
P4.6	GPIO1_2	GPIO (output)	GPIO 2 - Deserializer U1
P4.7	GPIO1_3	GPIO (output)	GPIO 3 - Deserializer U1

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A push button, S1, on the Fusion board resets the MSP430. When pushed, the microcontroller is reset. With the Fusion board, the MSP430, TDA2Px, or an external microcontroller can be used to initialize components.

- S2 is a spare, optional, GPIO pushbutton that can be configured on the MSP430.
- J10 is used to program the MSP430 through the connector.

3.9 Configuration Options

3.9.1 Dipswitch (S3)

Table 7 lists the possible configurations.

Table 7. Possible Fusion Configurations

Switch	Mode	Off (Open)	On (Closed)
1	MSP430 active	Enabled	Hold in reset, disable
2	I^2C select	MSP430	External and TDA2 EVM
3	Coax and HSD	Twisted pair and HSD	Coax
4	Unused	N/A	N/A

- Switch 1 controls the MSP430 device on the board. If the switch is off, then the MSP430 is active and can initialize the board. If the switch is on, the MSP430 is held in reset so that it cannot be used. In other words, it is disabled to allow for a boot up from another device such as the TDA2Px EVM.
- As previously mentioned, three hosts can be used for I^2C on the Fusion board. Switch 2 controls the host selection between the MSP430 (off), or the SoC/External on the EVM (on). If an external microcontroller is going to be used, see Section 3.1.1.
- The group of connectors (J28 to J35) that can be coax or HSD have a switch that must be thrown to activate the connection to be used. Switch 3 is used to toggle coax (on) or HSD (off). There cannot be a combination of coax and HSD on these connectors.
- Switch 4 is unused, there is no functionality.

3.9.2 Bank 1 Power (J27)

Connector J27 provides power to the other eight connectors depending on if coax (J28, J30, J32, and J34) or HSD (J29, J31, J33, and J35) has been chosen. See Figure 3 for the location and configuration of J27. If no sensors will be used on the connectors, then do not populate a jumper on J27 (see Figure 8).

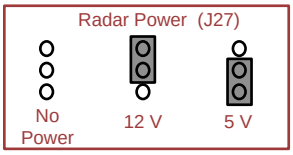

Figure 8. J27 Bank 1 Jumper Configurations

3.9.3 Bank 2 Power (J22)

Connector J22 provides power to the four, coax-only connectors (J23, J24, J25, and J26). See Figure 3 for the location and jumper configuration. J22 is capable of providing: no power, 12 V, and 5 V to the camera sensors. If no sensors will be used on the connectors, then do not populate a jumper on J22.

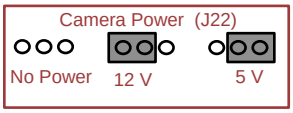

Figure 9. J22 Bank 2 Jumper Configurations

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3.10 Status LEDs

Table 8 lists the status LEDs of the Fusion board.

Table 8. Fusion Board Status LEDs

LED	Status
D5	Active 3.3-V rail
D6	Active 1.8-V rail
D7	Active 1.1-V rail
D10	5 V connected to 12-V boost
D11	Spare GPIO (output) on the MSP430
D12	Spare GPIO (output) on the MSP430
D13	Spare GPIO (output) on the MSP430
D14	Spare GPIO (output) on the MSP430
D15	Spare GPIO (output) on the MSP430
D16	Spare GPIO (output) on the MSP430
D17	Spare GPIO (output) on the MSP430
D18	Spare GPIO (output) on the MSP430
D19	Spare GPIO (output) on the MSP430

3.11 External Interfaces

If an external microcontroller will be used on the Fusion board, it can be connected through J11. The design also supports an Aardvark connector to interface with compatible tools. Switch S3 position 2 must be closed to allow the external microcontroller to take over control of the I^2C bus. The external microcontroller can override the GPIO on the MSP430 that turns on the USB switch. The header pin J6 breaks out to the external microcontroller, as well as J15 or J11. J15 is an Aardvark connector and J11 is a header pin. Both connect the I^2C bus of the external microcontroller to the USB switch and that is how the override can be initiated. The other optional I^2C hosts must be isolated before the external microcontroller can override. J6 pin 2 must be driven high by the external microcontroller to open the USB switch.

4 Image Sensor Module (Optional)

The Fusion board can be used with the image sensor module, EVMFUSIONCAM-V1-0. To power the image sensor module, the 12-V power jumper on the Fusion board must be selected so that there will be less current draw from the board. The module is powered through the coax cable.

4.1 OV2775 Image Sensor

The image sensor module has the OmniVision OV02775 high-definition image sensor used in automotive applications.

4.2 DS90UB953-Q1 Serializer

A DS90UB953 serializer is used on the image sensor module. The serializer is compatible with the DS90UB960 device on the Fusion board.

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5 Getting Started

5.1 Powering Up the Fusion Application Board

The Fusion board requires configuration before use. Perform the following configuration steps to avoid damage to the system components. The following configuration is for an eight-camera, surround-view system using the Fusion board and TDA2Px EVM. Power to the Fusion board is supplied by the TDA2Px EVM.

1. Ensure the board is not connected to any power source.
2. Ensure that the Fusion board has the appropriate hardware to mount onto the TDA2Px EVM to keep a sturdy connection. The CSI-2 connector from the TDA2Px EVM connects to the bottom side of the Fusion board to the CSI-2 connector.
3. Connect the Fusion board to the EVM.
4. Locate S3 on the board (see Figure 3). Table 9 lists the switch sequence for this startup application.

Table 9. Switch Configuration for TDA2Px EVM Operation

Switch	Switch Status
1	On
2	On
3	Optional, dependent on sensors
4	N/A

5. Locate S4 on the board (see Figure 3). This dip switch controls the deserializer mode for the four coax connectors (J23 to J26). Because these connectors are coax only, there is only one configuration the switches can be in.

Table 10. Bank2 Mode Selection for Deserialization

S4.3	S4.2	S4.1	S4.0	Mode
Off	On	Off	On	CSI Mode/Coax

6. Locate S5 on the board (see Figure 3). The dip switch controls the deserializer mode for the eight Radar/Coax connectors (J28 to J35). Ensure the decision to use all HSD or all coax for this bank has been made first, beacause there are two distinct modes depending on the connector. Table 11 lists the two modes and the positions of the switches.

Table 11. Bank1 Mode Selection for Deserialization

S5.3	S5.2	S5.1	S5.0	Mode
On	Off	On	Off	CSI Mode/HSD
Off	On	Off	On	CSI Mode/Coax

7. Set the jumper on J27 for the specified voltage of the sensors. See Figure 5 for the configuration.
8. Set the jumper on J22 for the specified voltage of the sensors. See Figure 6 for the configuration.
9. Connect the sensors with the chosen connectors.
10. Provide power to the board. The Fusion board can be powered from the TDA2Px EVM (J40). After powering the board, the status LEDs should illuminate, indicating operation, see Table 8 for indications.

After programming and setting the hardware correctly, the TDA2Px EVM starts to receive the data streams from the CSI-2 output ports if the Fusion board is connected.

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