Technical White Paper

Multiplexing FPD-Link Serializer Deserializer (SerDes)

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ABSTRACT

With the growing focus on technological advancement and autonomy in the automotive industry, high-resolution, uncompressed data channels are increasingly in demand for cameras, radar, LIDAR, ultrasound, and display applications. The FPD-Link SerDes family of products supports the delivery of high-resolution signals and streamlines designs within advanced driver assistance systems (ADAS) and infotainment displays. For certain applications multiplexing with FPD-Link SerDes can facilitate the addition of more sensor modules in a system. Multiplexing provides a simple solution to switch between different sensor modules without degrading the signal integrity of FPD-Link SerDes.

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1 Market Need

As a whole, the automotive industry is seeing a trend towards more advanced systems that assist drivers, reduce vehicular accidents, and improve passengers' overall experience. These driver assistance systems incorporate environmental sensing, as well as driver and in-cabin monitoring to create functionally safe systems. The successful implementation of these designs necessitates an increase in the number of camera modules, and a matching increase in communication channels needed for these sensors.

FPD-Link SerDes provides a method of high resolution, uncompressed data transfer enabling high-speed, high-performance video and sensor interfaces. Quad- and dual-channel FPD-Link SerDes modules are available for multi-camera applications. In some cases however, an odd number of cameras is not easily supported by these even-channeled deserializers. In these cases one method for the addition of a third or fifth camera module to a dual- or quad-camera system is with the use of multiplexing. Multiplexing FPD-Link can be used specifically for multi-camera systems where using two or more cameras in the application are mutually exclusive in use, as illustrated by Figure 1-1. Multiplexing also reduces the number of CSI-2 ports needed on the central processor, freeing up important IOs for other use cases through the vehicle. This configuration can contribute to a reduction in the cost and size of the system and overall space efficiency.

Figure 1-1 illustrates two mutually-exclusive cameras in a single ADAS system.

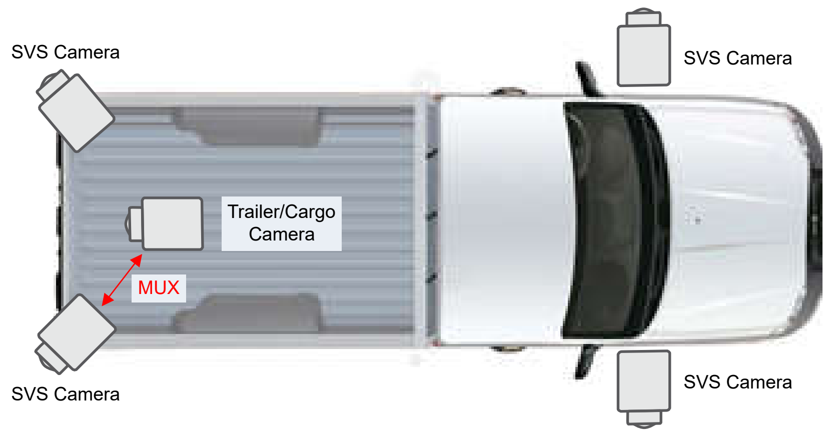


Figure 1-1. Automotive Application of Multiplexing FPD-Link SerDes

2 Multiplexing FPD-Link Scheme

For high-speed, high-resolution multiplexing applications, considering the impact on channel scattering parameters and link margin between the SER and DES is important to determine how the transmission channel is affected. This characterization was done using the setup shown in Figure 2-1.

The multiplexer intercepts the FPD-Link SerDes transmission channel on the deserializer side of the power over coax (PoC) connection. This allows for the DC component of the PoC connection to be removed prior to being fed into the multiplexer. The component then connects directly to the FPD-Link III RX Port 3 pins (RIN3+ and RIN3–). Switch the multiplexer according to the protocol described in Section 4, Implementation of Switching Protocol for proper function.

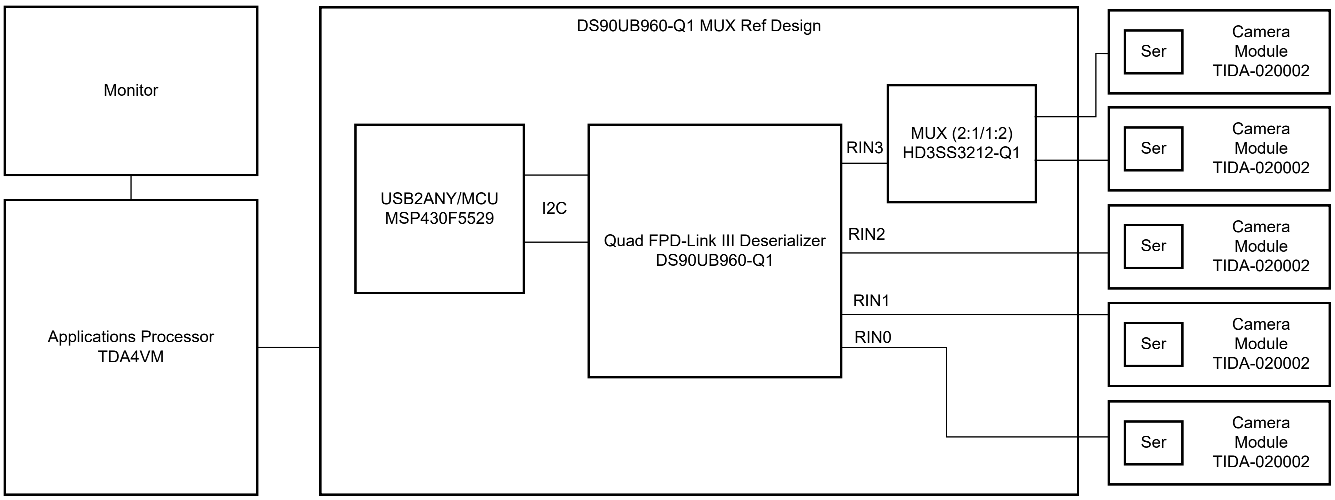


Figure 2-1. Multiplexing Testing Scheme

3 Multiplexing Execution and Setup

The setup for multiplexing with the previously-mentioned *FPD-Link* is executed as follows. A DS90UB960-Q1 EVM was modified with multiplexing capabilities on one out of four channels using a high-speed, bidirectional multiplexer, HD3SS3212-Q1. DS90UB960-Q1 is a quad 2MP camera hub FPD-Link III deserializer device with dual CSI-2 output ports. HD3SS3212-Q1 is a two-channel differential 2:1 and 1:2 multiplexing and demultiplexing device that operates at up to 10Gbps. A single mini-FAKRA connector was added in addition to the quad FAKRA connector for the additional fifth camera input. For implementing the multi-camera application in Vision Apps, five TIDA-02002 modules using an IMX390 imager were used in conjunction with this board. Figure 3-1 and Figure 3-2 show the layout for this board.

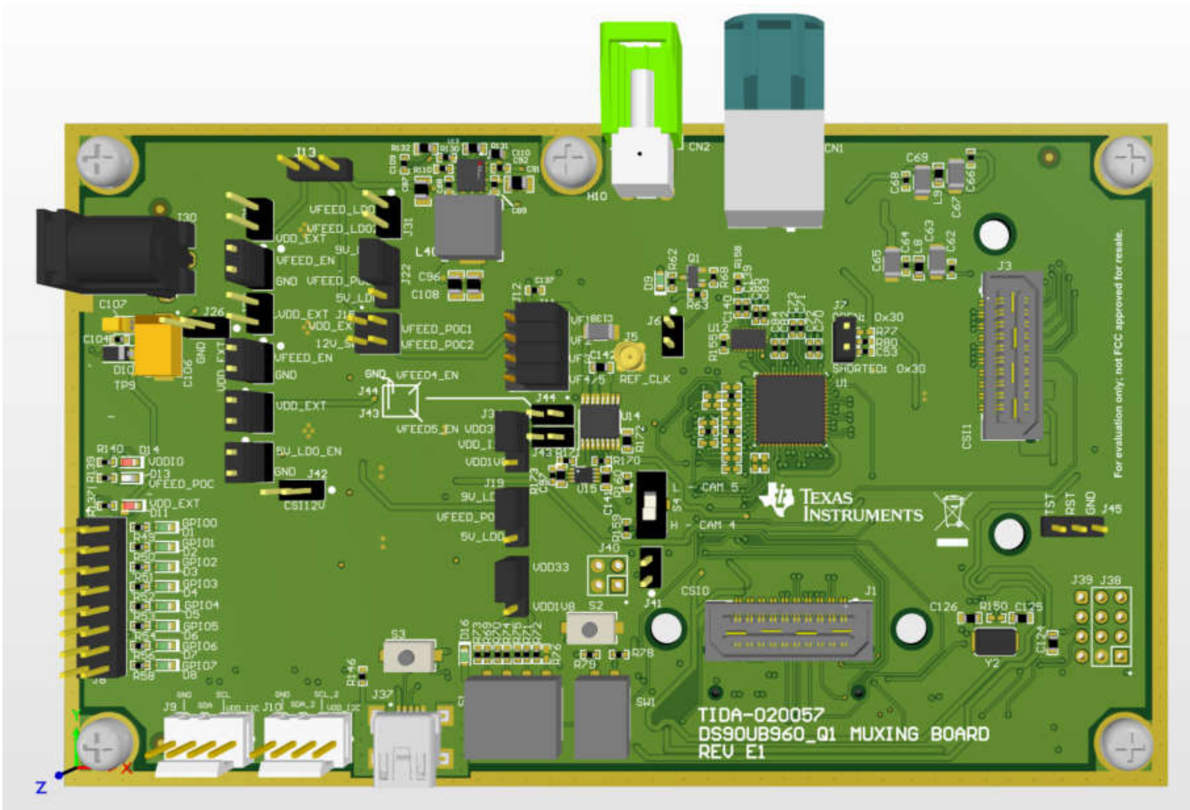


Figure 3-1. Multiplexing Board Layout - Top View

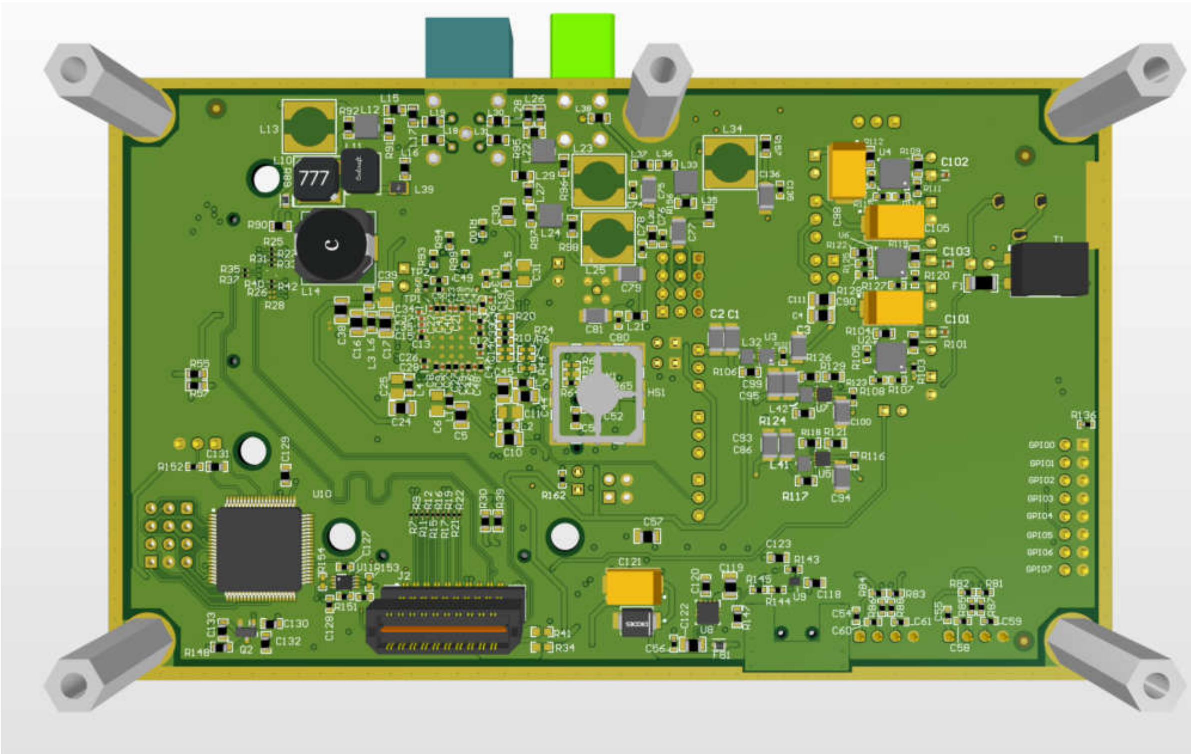


Figure 3-2. Multiplexing Board Layout - Bottom

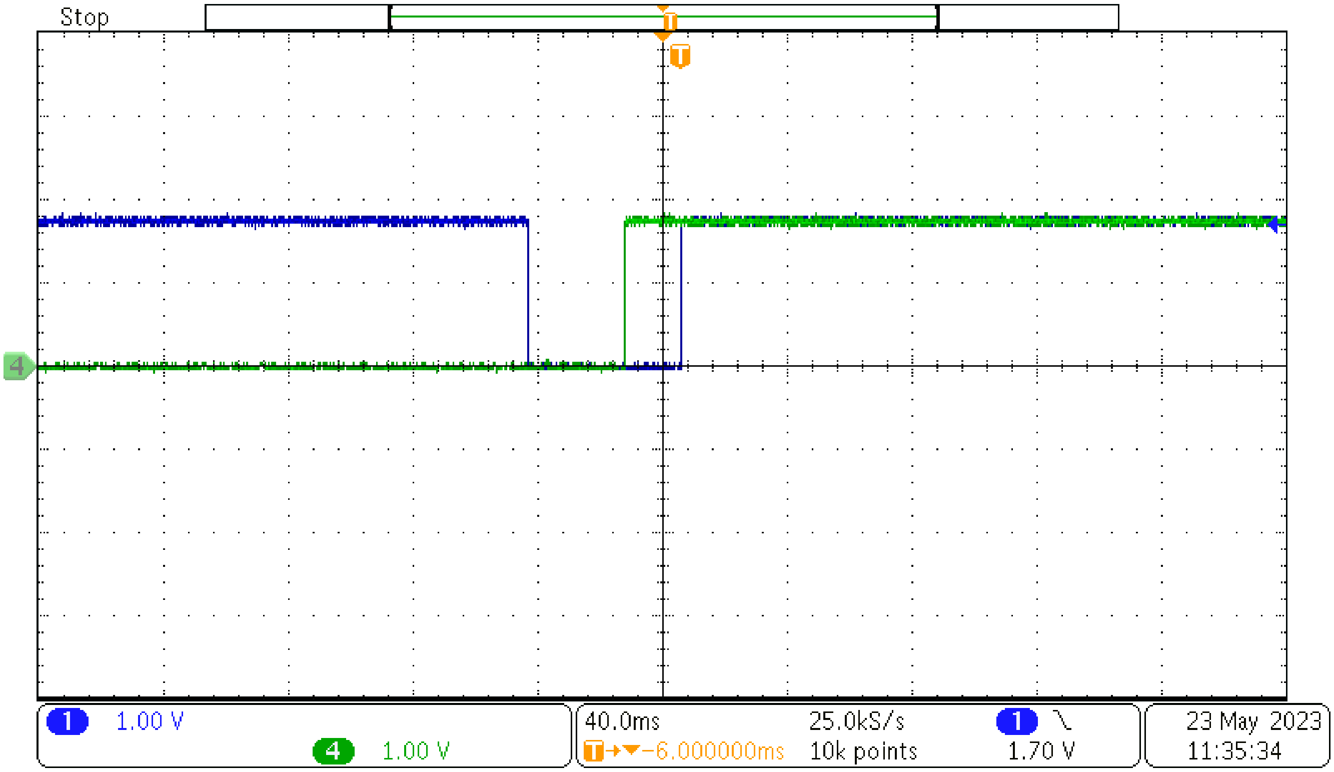
The MUX board has a SAMTEC CSI-2 connector that interfaces with a TDA4VM (J721EXSOMG01EVM) SOM board mounted on the J721EXCPXEVM common processor board for Jacinto 7 processors. The interface with the TDA4VM allows for camera output to be seen on a connected monitor. To switch between cameras, switching protocol functionality must be added to the TDA4 in the Software Development Kit (SDK).

4 Implementation of Switching Protocol

Prior to switching, disable the deserializer output to prevent the system from entering an error handling or fail-safe mode. Switching between cameras while data is actively being transmitted is not recommended. Implement the following protocol when multiplexing between channels.

```
Analog LaunchPad Program
# Digital reset at initialization
        board.WriteI2C(desAddr,0x01,0x01)

# Enable CSI-2 output and forwarding (steps below)
        board.WriteI2C(desAddr,0x32,0x01) # Select CSI-2 port 0
        board.WriteI2C(desAddr,0x33,0x03) # Enable CSI-2 output with continuous clock mode
        board.WriteI2C(desAddr,0x20,0x00) # Forward all CSI-2 to port 0

# Before switching the MUX, disable the associated port and forwarding
        board.WriteI2C(desAddr,0x20,0xF0) # Disable forwarding
        board.WriteI2C(desAddr,0x0C,0x00) # Disable the RX port receiver

# After switching the MUX, restart the forwarding and the port receiver.
        board.WriteI2C(desAddr,0x0C,0x0F) # Enable the RX port receiver
        time.sleep(0.1) # Allow time for the port to re-lock
        board.WriteI2C(desAddr,0x20,0x00) # Enable forwarding

# The switching protocol above disables forwarding for all channels. Depending on the application,
deactivating only the multiplexed channel is sufficient.

For Example:
        # Disable forwarding of RX Port 2
        board.WriteI2C(desAddr, 0x20, 0x40)

        # Disable Port 2 Receiver
        board.WriteI2C(desAddr, 0x0C, 0x0B)
```

Figure 4-1 demonstrates the switching time from when the MUX is switched and the link is re-established. The initialization time of the Imager via I2C also needs to be accounted for in addition to the time it takes to re-establish the link, and once initialization of the camera is complete, the output is seen at the processor.



Blue: Link Status, Green: Multiplexer switch on or off

Figure 4-1. Link Status During MUXing

5 Assessing Impact on Signal Integrity

Introducing an additional component such as a multiplexer into the signal path can impact the signal integrity and performance of the system, and this impact needs to be measured and quantified.

Scattering-parameters, or S-parameters, provide a framework for describing networks based on the ratio of incident and reflected microwaves. These S-parameters are useful for characterizing linear, high-frequency circuits. S-parameter analysis provides information about return loss and insertion loss specifically to compare the signal integrity of FPD-Link SerDes with and without a multiplexer.

Return loss is the ratio of the reflected signal to the launched signal. Insertion loss is a measure of the transmitted signal attenuation. Higher return loss and lower insertion loss translates to higher signal integrity.

Figure 5-1 shows the reconfiguration of the signal path with the addition of the multiplexer.

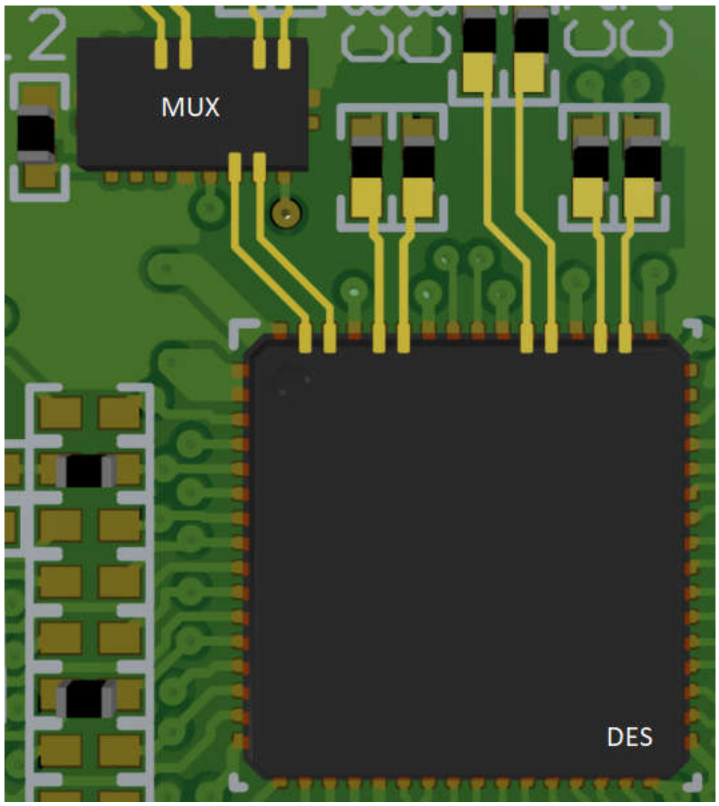


Figure 5-1. Multiplexer and Deserializer Configuration

5.1 Return Loss

The return loss for both non-multiplexed and multiplexed channels are within the required limits for stable operation as defined by Texas Instruments FPD-Link SerDes shown in red in Figure 5-2. In this test setup, the hardware used was a variation of the setup shown in Section 2, and this board variation had both CH3 and CH4 connected to a multiplexer. CH1 and CH2 were the non-multiplexed channels in this setup.

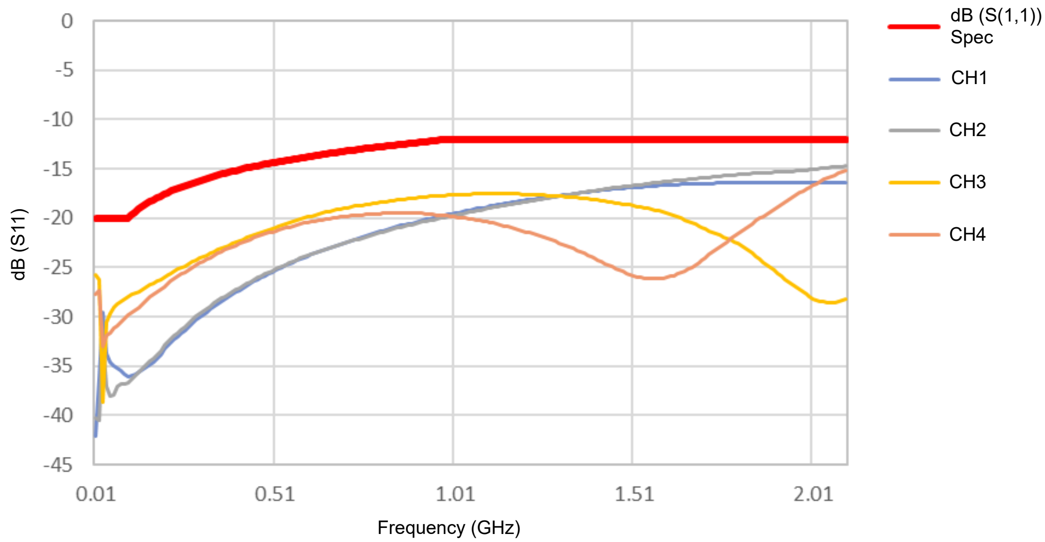


Figure 5-2. Channel Return Loss

5.2 Insertion Loss

The non-multiplexed configuration meets the requirements outlined by TI shown in red on Figure 5-3. However, the addition of the multiplexer increases the insertion loss by 0.4 dB, so the recommended PCB insertion loss is no longer met. The total channel insertion loss requirements between the serializer and deserializer are dependent on both the PCB and the cable assembly budget. As the insertion loss penalty for using a multiplexer is relatively small with regards to the overall cable budget guidance, the required insertion loss minimum value for the total channel can still be met by offsetting the cable loss budget by 0.4 dB. This measurement was taken using the same test setup described in Section 5.1, where CH3 and CH4 are connected to a multiplexer and CH1 and CH2 are non-multiplexed.

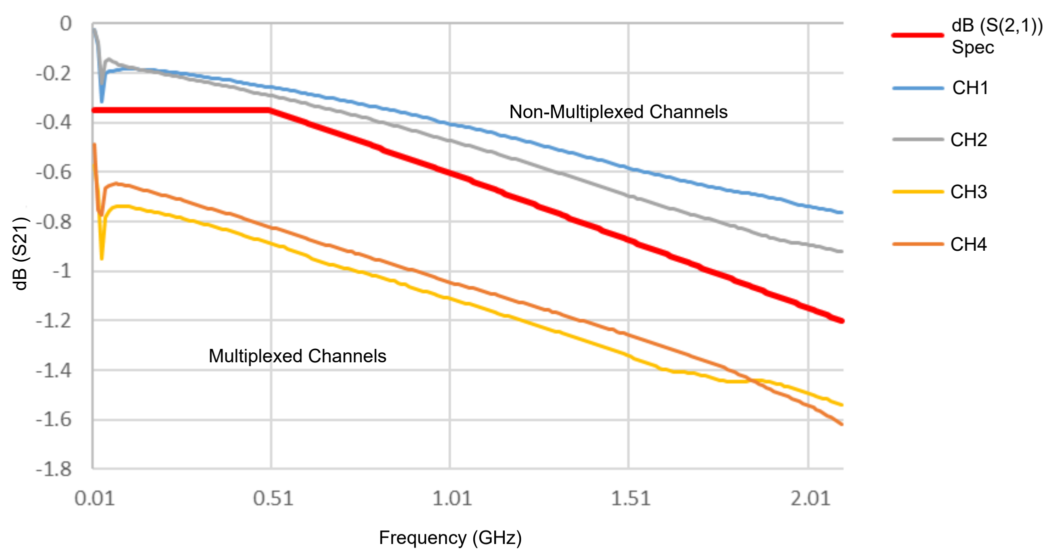


Figure 5-3. Channel Insertion Loss

6 Margin Analysis

The TI DS90UB960-Q1 deserializer includes multiple forms of automatic adaptations to improve link reliability. One such method is the use of automatically adjusted strobe positions, which controls where data is sampled in the signal eye. Different strobe positions can be the most effective in different circumstances depending on factors such as cable length, cable quality, and temperature. The Margin Analysis Program (MAP) checks for errors and lock at combinations of the strobe positions and EQ levels to analyze the margin in the system.

Manual strobe control is a useful tool for system evaluation, because the tool can be used to evaluate the condition of the eye with only an I2C connection. In general, this is done by creating a margin analysis plot where the status of the deserializer is monitored for each combination of EQ and strobe settings. These diagrams track lock status, parity errors, forward channel CRC errors, forward channel sequencing errors, and forward channel encoding errors over all EQ settings and strobe positions using the smaller base delay. The green squares indicate passing settings, in which the deserializer and serializer are locked with zero errors. EQ levels with at least four passing strobe positions are considered recommended EQ levels. In general, TI recommends having a margin of at least three EQ levels with four passing strobe positions, including a contiguous rectangle of passing states that measures two EQ levels by four strobe positions.

Both the non-multiplexed (Figure 6-1, Figure 6-2, Figure 6-3) and multiplexed (Figure 6-4) channels on the DS90UB960-Q1 MUX EVM have a passing margin analysis report as shown with the black rectangles. This demonstrates that the addition of the multiplexer does not significantly impact the overall channel signal integrity.

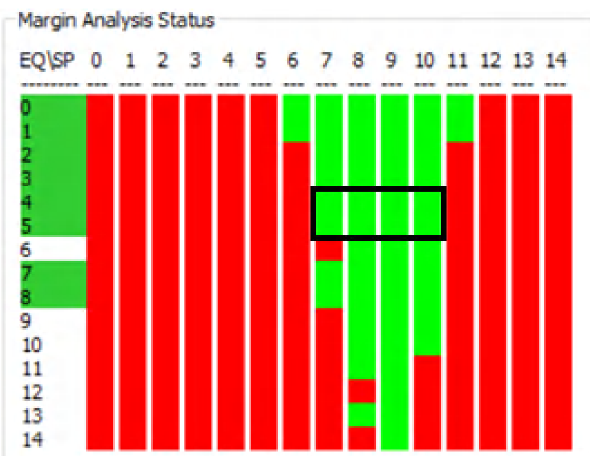


Figure 6-1. Margin Analysis Plot - RX PORT0 (CH1)

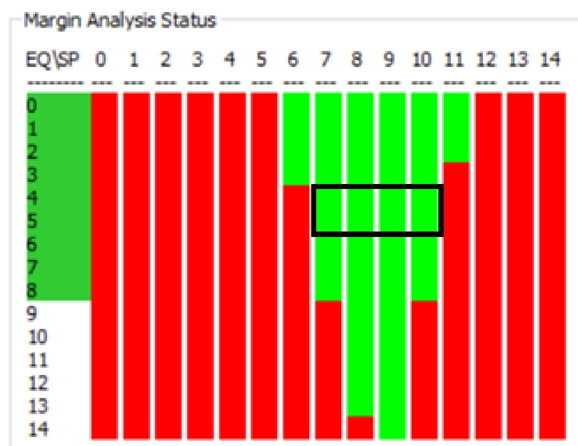


Figure 6-2. Margin Analysis Plot - RX PORT1 (CH2)

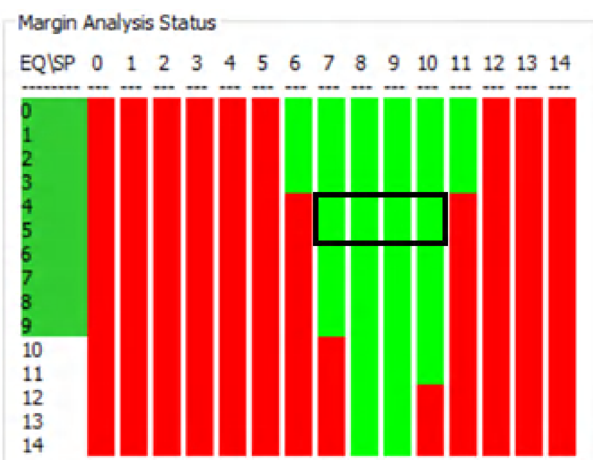


Figure 6-3. Margin Analysis Plot - RX PORT2 (CH3)

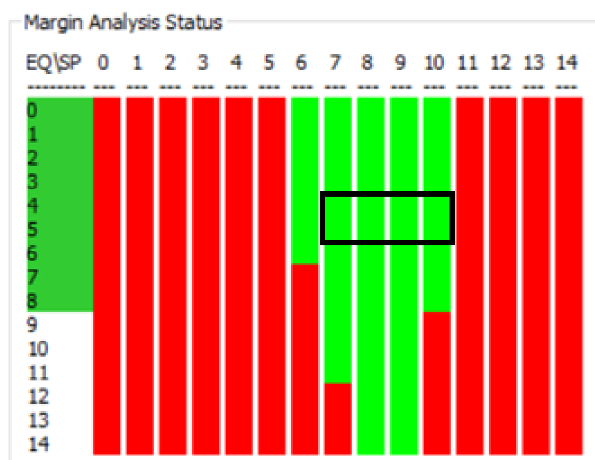


Figure 6-4. Margin Analysis Plot - MUX RX PORT3 (CH4)

7 Conclusion

Multiplexing FPD-Link is a viable answer for increasing the number of peripherals without necessarily increasing the number of deserializers. This method can provide a more space-efficient and simple implementation for systems with an odd number of mutually exclusive sensors. Additionally, multiplexing reduces the need for CSI-2 ports on the processor, a common limitation.

The multiplexing scheme does increase the insertion loss which can be offset according to user implementation with cabling choices. In terms of link margin and return loss, the multiplexed FPD-Link SerDes scheme is comparable to the non-multiplexed counterpart.

8 References

1. Texas Instruments, *DS90UB960-Q1 Quad 4.16-Gbps FPD-Link III Deserializer Hub With Dual MIPI CSI-2 Ports* data sheet
2. Texas Instruments, *HD3SS3212-Q1 Two-Channel Differential 2:1/1:2 USB3.2 Mux/Demux* data sheet
3. Texas Instruments, *Automotive 2.6-MP camera module reference design with POL PMIC, FPD-Link III, supervisor and POC* data sheet
4. Texas Instruments, *Automotive 2.6-MP Camera Module Reference Design With POL PMIC, FPD-Link III, Supervisor, and POC* design guide
5. Texas Instruments, *Margin Analysis Program (MAP) and strobe positions for DS90UB954-Q1 and DS90UB960-Q1* application note