

# LM4312 Mobile Pixel Link Two (MPL-2), RGB Display Differential Interface Serializer with Optional Dithering and Look Up Table

Check for Samples: [LM4312](#)

## FEATURES

- RGB Display Interface to >640 x 480 (VGA) Resolution
- 24 or 18-bit RGB Transport
- 24-to-18-bit RGB Dithering Option
- Look Up Table Option for Independent Color Correction Option
- Robust MPL-2 Differential SLVS Interface
- SPI Interface for Configuration / Control and LUT Options
- Low Power Consumption & SLEEP State
- Auto Power Down on STOP PCLK
- Automatically Generates Frame Sequence Bits for Resync upon Data or Clock Error
- Odd Parity Generation

## SYSTEM BENEFITS

- Dithered Data Reduction
- Independent RGB Color Correction
- 24-bit Color Input
- Small Robust Interface
- Low Power & Low EMI

## DESCRIPTION

The LM4312 is a MPL-2 Serializer (SER) that accepts a 24- or 18-bit RGB interface and serializes this wide bus to 3 differential signals. The optional Dithering feature can reduce 24-bit RGB to 18-bit RGB. The optional Look Up Table (Three X 256 X 8 bit RAM) is provided for independent color correction. 18-bit Bufferless displays from QVGA (320 x 240) up to >VGA (640 x 480) pixels are supported.

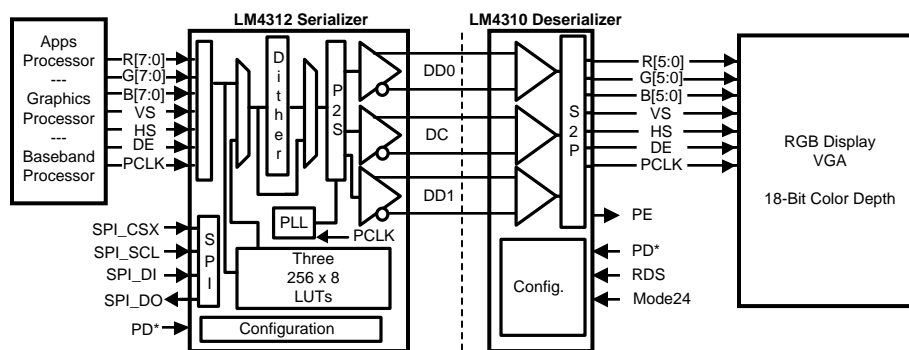
The interconnect is reduced from 28 LVCMOS signals (RGB888+V+H+DE+PCLK) to only 3 active differential signals (DD0P/M, DCP/M, DD1P/M) with the LM4312 Serializer and companion LM4310 Deserializer easing flex interconnect design, size constraints and cost.

The LM4312 SER resides by the application, graphics or baseband processor and translates the wide parallel video bus from LVCMOS levels to serial MPL-2 levels for transmission over a flex cable and PCB traces to the DES located in the display module.

When in Power\_Down, the SER is put to sleep and draws less than 10µA. The SER can be powered down by stopping the PCLK or by asserting its PD\* input pin.

The LM4312 implements the physical layer of the MPL-2 Interface and features robust common-mode noise rejection.

## Typical Application Diagram - Bridge Chips - 24-bit to 18-bit RGB



[Supply, all Configuration pins, and bypass caps. and grounding not shown]



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### Pin Descriptions

| Pin Name                                    | No. of Pins | I/O, Type <sup>(1)</sup> | Description<br>RGB Serializer   |
|---|-------------|--------------------------|---|
| <b>MPL-2 SERIAL BUS PINS</b>                |             |                          |   |
| DD0P, DD0M,<br>DD1P, DD1M                   | 4           | O, MPL-2                 | MPL-2 Differential Data Line Driver True (Plus) and Compliment (Minus) Outputs Channel 0 and 1  |
| DCP, DCM                                    | 2           | O, MPL-2                 | MPL-2 Differential Clock Line Driver True (Plus) and Compliment (Minus) Outputs   |
| <b>SPI INTERFACE and CONFIGURATION PINS</b> |             |                          |   |
| SPI_CSX                                     | 1           | I,<br>LVCMOS             | SPI_Chip Select Input<br>SPI port is enabled when: SPI_CSX is Low, PD* is High.   |
| SPI_SCL                                     | 1           | I,<br>LVCMOS             | SPI_Clock Input   |
| SPI_DI                                      | 1           | I,<br>LVCMOS             | SPI Data Input  |
| SPI_DO                                      | 1           | O,<br>LVCMOS             | SPI Data Output   |
| PD*   | 1           | I,<br>LVCMOS             | Power Down Mode Input<br>PD* = Low, SER is in SLEEP Mode,<br>SPI Registers are RESET, LUT Data is retained.<br>PD* = High and PCLK = Stopped, SER is in SLEEP Mode,<br>SPI Register settings are retained and LUT data is retained.<br>PD* = High, Device is enabled. |
| RES1  | 1           | I,<br>LVCMOS             | <b>Tie High</b>   |
| TM  | 1           | I<br>LVCMOS              | <b>Tie Low</b><br>H = Test Mode (Reserved)  |
| <b>VIDEO INTERFACE PINS</b>                 |             |                          |   |
| PCLK  | 1           | I,<br>LVCMOS             | Pixel Clock Input<br>Video Signals are latched on the <b>RISING</b> edge.   |
| R[7:0]<br>G[7:0]<br>B[7:0]                  | 24          | I,<br>LVCMOS             | RGB Data Bus Inputs – Bit 7 is the MSB.<br>24-bit Mode - use RGB[7:0]<br>18-bit Mode - use RGB[7:2], tie off RGB[1:0] to GND, do not float.   |
| VS  | 1           | I,<br>LVCMOS             | Vertical Sync. Input<br><b>This signal is used as a frame start for the Dither block and is required when Dither option is selected.</b><br>The VS signal is serialized unmodified.   |
| HS  | 1           | I,<br>LVCMOS             | Horizontal Sync. Input  |
| DE  | 1           | I,<br>LVCMOS             | Data Enable Input   |
| <b>POWER/GROUND PINS</b>                    |             |                          |   |
| V <sub>DD</sub>                             | 7           | Power Supply             | Power Supply Pins. All VDD pins must be connect to power supply.<br>1.6V to 2.0V  |
| V <sub>SS</sub>                             | 1           | Ground                   | Ground Pin<br>DAP pad must be connected to Ground.  |

(1) **Note:** I = Input, O = Output, IO = Input/Output. **Do not float unused input pins.**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

**ABSOLUTE MAXIMUM RATINGS** <sup>(1)(2)</sup>

|  |                                 |                              |
|--|---------------------------------|------------------------------|
| Supply Voltage ( $V_{DD}$ )                        |                                 | -0.3V to +2.2V               |
| LVC MOS Input/Output Voltage                       |                                 | -0.3V to ( $V_{DD} + 0.3V$ ) |
| MPL-2 Output Voltage                               |                                 | -0.3V to $V_{DD}$            |
| Junction Temperature                               |                                 | +150°C                       |
| Storage Temperature                                |                                 | -65°C to +150°C              |
| ESD Ratings:                                       | HBM, 1.5 k $\Omega$ , 100 pF    | $\geq \pm 2$ kV              |
|  | EIAJ, 0 $\Omega$ , 200 pF       | $\geq \pm 200$ V             |
| Maximum Package Power Dissipation Capacity at 25°C | X2QFN Package                   | 2.25 W                       |
|  | Derate X2QFN Package above 25°C | 22.57 mW/°C                  |

- (1) "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be specified. They are not meant to imply that the device should be operated at these limits. The tables of "Electrical Characteristics" specify conditions for device operation.
- (2) If Military/Aerospace specified devices are required, please contact the TI Sales Office/ Distributors for availability and specifications.

**RECOMMENDED OPERATING CONDITIONS**

|                            |                      | Min | Typ | Max | Units |
|----------------------------|----------------------|-----|-----|-----|-------|
| Supply Voltage             | $V_{DD}$ to $V_{SS}$ | 1.6 | 1.8 | 2.0 | V     |
| Pixel Clock Frequency (6X) |                      | 5   |     | 30  | MHz   |
| Pixel Clock Frequency (8X) |                      | 5   |     | 30  | MHz   |
| DC Frequency               |                      | 30  |     | 240 | MHz   |
| Ambient Temperature        |                      | -40 | 25  | 85  | °C    |

**ELECTRICAL CHARACTERISTICS**

 Over recommended operating supply and temperature ranges unless otherwise specified. <sup>(1)(2)</sup>

| Symbol                                  | Parameter                                | Conditions   |                    | Min              | Typ          | Max          | Units    |    |
|---|--|--|--------------------|------------------|--------------|--------------|----------|----|
| <b>MPL-2</b>                            |  |  |                    |                  |              |              |          |    |
| $V_{OD}$                                | Differential Output Voltage              | 100 $\Omega$ Load  | See <sup>(3)</sup> | $V_{OD}$ setting | 95           | 150          | 211      | mV |
|   |  |  |                    | $V_{OD}$ setting | 140          | 200          | 270      |    |
| $\Delta V_{OD}$                         | Delta Differential Output Voltage        | Match of Differential Output Voltage magnitude between logic states. | See <sup>(3)</sup> | $V_{OD} = 150$   |              | 0            | 10       | mV |
|   |  |  |                    | $V_{OD} = 200$   |              | 0            | 10       |    |
| $V_{OS}$                                | Differential Driver Offset Voltage       | 100 $\Omega$ Load  | See <sup>(3)</sup> | $V_{OD} = 150$   | 112          | 150          | 188      | mV |
|   |  |  |                    | $V_{OD} = 200$   | 150          | 200          | 250      |    |
| $\Delta V_{OS}$                         | Differential Driver Offset Voltage Match | Match of Driver Offset Voltage magnitude between logic states.       | See <sup>(3)</sup> | $V_{OD} = 150$   |              | 0            | 5        | mV |
|   |  |  |                    | $V_{OD} = 200$   |              | 0            | 5        |    |
| $R_{OUT}$                               | Driver Output Impedance                  |  |                    |                  | 50           |              | $\Omega$ |    |
| <b>LVC MOS (1.6V to 2.0V Operation)</b> |  |  |                    |                  |              |              |          |    |
| $V_{IH}$                                | Input Voltage High Level                 |  |                    | 0.7 $V_{DD}$     |              | $V_{DD}$     | V        |    |
| $V_{IL}$                                | Input Voltage Low Level                  |  |                    | GND              |              | 0.3 $V_{DD}$ | V        |    |
| $V_{HY}$                                | Input Hysteresis                         |  |                    |                  | 100          |              | mV       |    |
| $I_{IN}$                                | Input Current                            |  |                    | -1               | 0            | +1           | $\mu$ A  |    |
| $V_{OH}$                                | Output Voltage High Level                | SPI_DO   |                    | $I_{OH} = -1$ mA | 0.8 $V_{DD}$ | $V_{DD}$     | V        |    |
| $V_{OL}$                                | Output Voltage Low Level                 |  |                    | $I_{OL} = 1$ mA  | $V_{SS}$     | 0.2 $V_{DD}$ | V        |    |

- (1) Typical values are given for  $V_{DD} = 1.8V$  and  $T_A = 25^\circ C$ .
- (2) Current into a device pin is defined as positive. Current out of device pins is defined as negative. Voltages are referenced to Ground unless otherwise specified.
- (3) Specification is ensured by design or characterization

## ELECTRICAL CHARACTERISTICS (continued)

Over recommended operating supply and temperature ranges unless otherwise specified.<sup>(1)(2)</sup>

| Symbol   | Parameter   | Conditions  | Min            | Typ | Max | Units |
|--|---|---|----------------|-----|-----|-------|
| <b>SUPPLY CURRENT</b>                                    |   |   |                |     |     |       |
| $I_{DD}$   | Total Supply Current - RGB24 Mode. <sup>(4)</sup> | DC = 240 MHz, Checker Board, LUT Enable, Dither Disable. <sup>(5)</sup> | $V_{OD} = 150$ | 20  | 33  | mA    |
|  |   |   | $V_{OD} = 200$ | 22  |     |       |
|  |   | DC = 160 MHz, Checker Board, LUT Enable, Dither Disable                 | $V_{OD} = 150$ | 15  | mA  |       |
|  |   |   | $V_{OD} = 200$ | 17  |     |       |
|  | Total Supply Current - RGB18 Mode.                | DC = 180 MHz, Checker Board, LUT Enable, Dither Disable.                | $V_{OD} = 150$ | 17  | mA  |       |
|  |   |   | $V_{OD} = 200$ | 19  |     |       |
| DC = 120 MHz, Checker Board, LUT Enable, Dither Disable. |   | $V_{OD} = 150$  | 13             | mA  |     |       |
|  |   | $V_{OD} = 200$  | 15             |     |     |       |
| $I_{DDZ}$  | Supply Current—Disable Power Down Modes           | PD* = L   | Ta = 25°C      | 1   | 10  | μA    |
|  |   | Stop Clock: PD* = H and PCLK = L or H                                   |                | 1   | 10  | μA    |
| PD   | Power Dissipation                                 | $V_{OD} = 200$ mV, $V_{DD} = 1.8$ V                                     |                | 27  |     | mW    |

(4) For  $I_{DD}$  tests - input signal conditions are: (swing, edge, freq, DE = H, VS = L, HS = L, RGB Checkerboard Pattern: AAAAAA-555555)

(5) Total Supply Current Conditions: SER  $C_L = 15$  pF, TYP  $V_{DD} = 1.8$ V.

## SWITCHING CHARACTERISTICS

Over recommended operating supply and temperature ranges unless otherwise specified.<sup>(1)</sup>

| Symbol                         | Parameter                           | Conditions  | Min | Typ                | Max | Units       |
|--------------------------------|-------------------------------------|---|-----|--------------------|-----|-------------|
| <b>PARALLEL BUS TIMING</b>     |                                     |   |     |                    |     |             |
| $t_{SET}$                      | Set Up Time                         | SER Inputs: RGB, VS, HS, DE to PCLK<br><a href="#">Figure 1</a>               | 5   |                    |     | ns          |
| $t_{HOLD}$                     | Hold Time                           | SER Inputs: PCLK to RGB, VS, HS, DE<br><a href="#">Figure 1</a>               | 5   |                    |     | ns          |
| <b>MPL-2 SERIAL BUS TIMING</b> |                                     |   |     |                    |     |             |
| $t_{DVBC}$                     | Serial Data Valid before Clock Edge | SER Data Pulse Width <a href="#">Figure 2</a> , <sup>(2)</sup> <sup>(3)</sup> | 0.3 |                    | 0.7 | UI          |
| $t_{DVAC}$                     | Serial Data Valid after Clock Edge  |   | 0.3 |                    | 0.7 | UI          |
| $t_T$                          | Transition Time                     | See <sup>(4)</sup>  |     | 300                |     | ps          |
| <b>POWER UP TIMING</b>         |                                     |   |     |                    |     |             |
| $t_{PLL}$                      | PLL Lock Time                       |   |     | 1024               |     | PCLK cycles |
| $t_{PZclk}$                    | Enable Time - Clock Start           | PCLK to DC <sub>OUT</sub> <a href="#">Figure 4</a> , <a href="#">Figure 8</a> |     | See <sup>(5)</sup> |     |             |
| <b>MPL-2 POWER OFF TIMING</b>  |                                     |   |     |                    |     |             |
| $t_{PAZ}$                      | Disable Time to Power Down          | See <sup>(6)</sup>  |     |                    | 15  | ms          |
| $t_{PXZclk}$                   | Disable Time - Clock Stop           | PCLK to DC <sub>OUT</sub> <a href="#">Figure 3</a> <sup>(7)</sup>             |     | 2                  |     | PCLK cycles |
| <b>SPI INTERFACE</b>           |                                     |   |     |                    |     |             |
| $t_{ACC}$                      | SPI Data Active (SPI_DO)            | See <a href="#">Figure 15</a>   | 0   |                    | 50  | ns          |
| $t_{OHR}$                      | SPI Data Tri-State (SPI_DO)         | See <a href="#">Figure 15</a> <sup>(3)</sup>                                  | 0   |                    | 50  | ns          |

(1) Typical values are given for  $V_{DD} = 1.8$ V and  $T_A = 25^\circ\text{C}$ .

(2) 1 UI is the serial data DD pulse width = 1 / 12xPCLK (18-bit mode), 1 UI is the serial data DD pulse width = 1 / 16xPCLK (24-bit mode)

(3) Specification is ensured by design or characterization

(4) MPL-2 serial link transition time is measured from 20% to 80 %.

(5) Enable Time is a complete MPL-2 start up  $t_1+t_2+t_3$ . See also [Figure 8](#).

(6) Specified functionally by the  $I_{DDZ}$  parameter. See also [Figure 9](#).

(7) This is the minimum time that the PCLK needs to be held off for in order for the device to be reset. Once PCLK is reapplied, a PLL Lock is required and start up sequence before video data is serialized.

## RECOMMENDED INPUT TIMING REQUIREMENTS (PCLK AND SPI)

Over recommended operating supply and temperature ranges unless otherwise specified. <sup>(1)</sup>

| Symbol                    | Parameter                | Conditions             | Min | Typ | Max  | Units       |
|---------------------------|--------------------------|------------------------|-----|-----|------|-------------|
| <b>PIXEL CLOCK (PCLK)</b> |                          |                        |     |     |      |             |
| f <sub>PCLK</sub>         | Pixel Clock Frequency    | 18-bit RGB Mode (6X)   | 5   |     | 30   | MHz         |
|                           |                          | 24-bit RGB Mode (8X)   | 5   |     | 30   | MHz         |
| PCLK <sub>DC</sub>        | Pixel Clock Duty Cycle   |                        | 30  | 50  | 70   | %           |
| t <sub>T</sub>            | Input Transition Time    | See <sup>(2)(3)</sup>  | 2   | >2  |      | ns          |
| t <sub>STOPpclk</sub>     | Clock Stop Gap           | See <sup>(4) (3)</sup> | 4   | 2   |      | PCLK cycles |
| <b>SPI INTERFACE</b>      |                          |                        |     |     |      |             |
| f <sub>SCLw</sub>         | SPI_SCL Frequency        | WRITE                  |     |     | 10   | MHz         |
| f <sub>SCLr</sub>         |                          | READ                   |     |     | 6.67 | MHz         |
| t <sub>s0</sub>           | SPI_CSX Set Time         | See Figure 14          | 60  |     |      | ns          |
| t <sub>s1</sub>           | SI Set Time              |                        | 30  |     |      | ns          |
| t <sub>h1</sub>           | SI Hold Time             |                        | 30  |     |      | ns          |
| t <sub>w1h</sub>          | SPI_SCL Pulse Width High | WRITE                  | 35  |     |      | ns          |
|                           |                          | READ                   | 60  |     |      | ns          |
| t <sub>w1l</sub>          | SPI_SCL Pulse Width Low  | WRITE                  | 35  |     |      | ns          |
|                           |                          | READ                   | 60  |     |      | ns          |
| t <sub>r</sub>            | SPI_SCL Rise Time        | See Figure 14          |     | 5   |      | ns          |
| t <sub>f</sub>            | SPI_SCL Fall Time        |                        |     | 5   |      | ns          |
| t <sub>0H</sub>           | SI Hold Time             |                        | 30  |     |      | ns          |
| t <sub>h0</sub>           | SPI_CSX Hold Time        |                        | 65  |     |      | ns          |
| t <sub>w2</sub>           | SPI_CSX OFF Time         |                        | 100 |     |      | ns          |

(1) Typical values are given for V<sub>DD</sub> = 1.8V and T<sub>A</sub> = 25°C.

(2) Maximum transition time is a function of clock rate and should be less than 30% of the clock period to preserve signal quality.

(3) Specification is ensured by design or characterization

(4) This is the minimum time that the PCLK needs to be held off for in order for the device to be reset. Once PCLK is reapplied, a PLL Lock is required and start up sequence before video data is serialized.

## TIMING DIAGRAMS

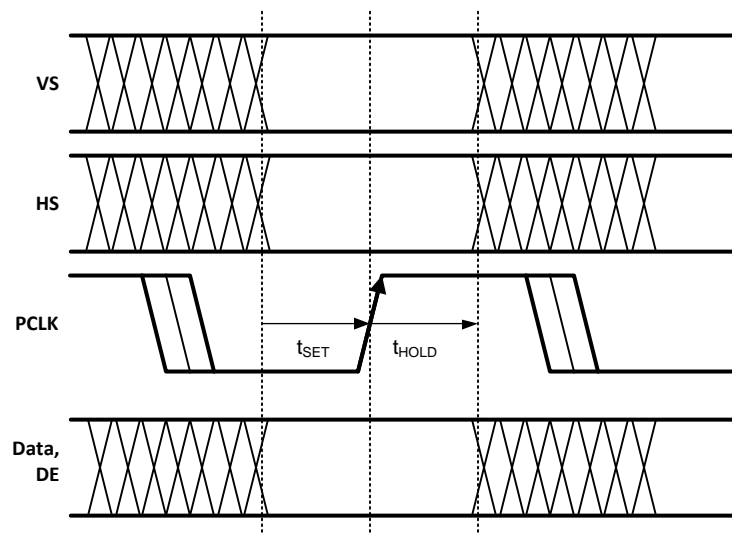


Figure 1. Input Timing for RGB Interface

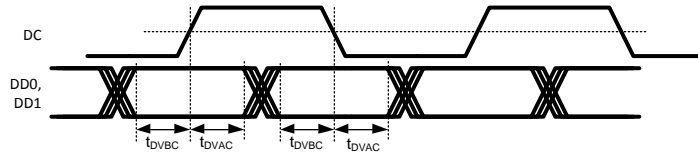


Figure 2. Serial Data Valid

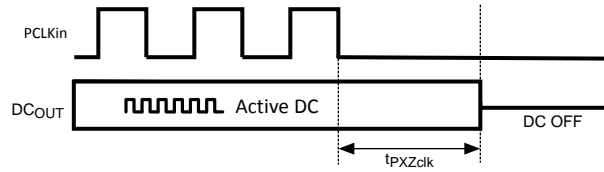


Figure 3. Stop Pixel Clock (PCLK) Power Down

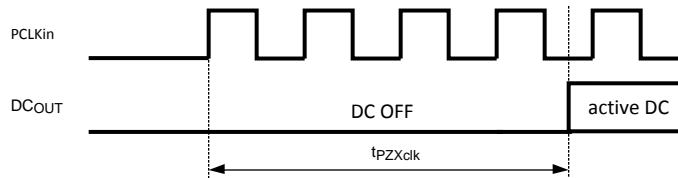


Figure 4. Stop Pixel Clock (PCLK) Power Up

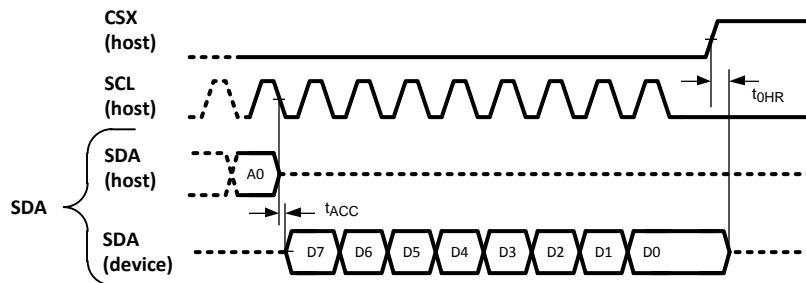


Figure 5. SPI Interface

PRODUCT PREVIEW

## FUNCTIONAL DESCRIPTION

The LM4312 is a Mobile Pixel Link two Serializer that serializes a 24-bit RGB plus three control signals (VS, HS, and DE) to two MPL-2 DD lines plus the serial clock DC line. 18-bit RGB, 24-bit RGB, or optionally 24-bit RGB data is dithered to 18 bits and then serialized and level translated to MPL-2 by the SER. An optional Look Up Table consisting of three 256 X 8-bit RAMs may also be used and is controlled via a 3 or 4-wire SPI interface. The LM4312 is compatible with the LM4310 Deserializer and also Display Drivers with integrated MPL-2 Deserializers.

Three link configurations are provided by the LM4312 SER. 24-bit RGB can be serialized onto the 2 DD + DC configuration using a 8X DC clock. 24-bit RGB can be dithered to 18-bit RGB and serialized onto the 2 DD + DC configuration using a 6X DC clock. Or 18-bit RGB can be serialized onto the 2 DD + DC configuration using a 6X DC clock. See [Table 1](#). The device's default configuration is for 18 bits input, Dither OFF, and 6X mode.

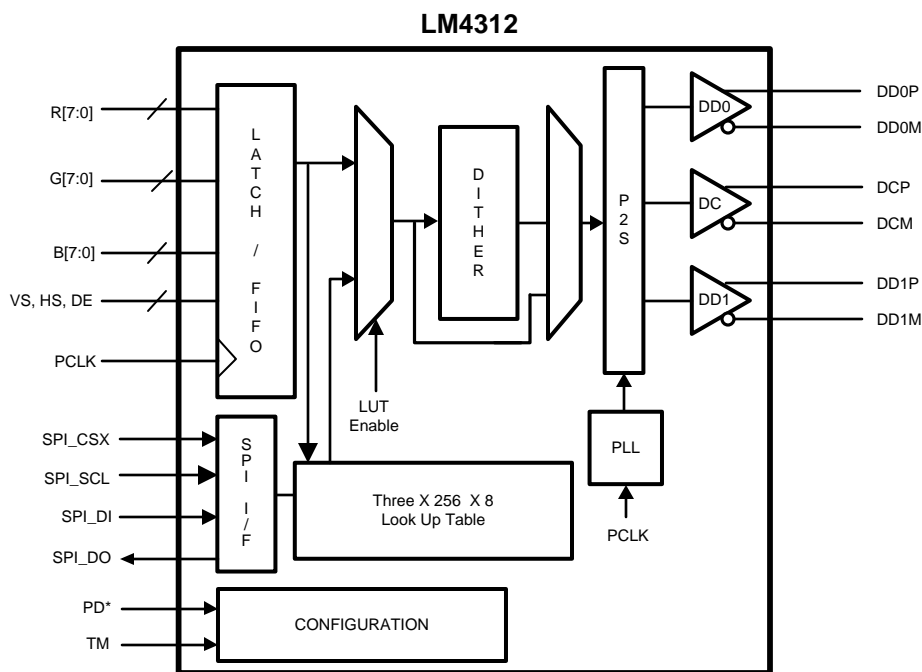


Figure 6. General LM4312 Block Diagram

Table 1. 2DD+DC MPL-2 Link Options

| Input      | Serial                               | Output     | Notes                    |
|------------|--------------------------------------|------------|--------------------------|
| 24-bit RGB | 2 DD + DC, <a href="#">Figure 10</a> | 24-bit RGB | Dither OFF, DC = 8X PCLK |
| 24-bit RGB | 2 DD + DC, <a href="#">Figure 11</a> | 18-bit RGB | Dither ON, DC = 6X PCLK  |
| 18-bit RGB | 2 DD + DC, <a href="#">Figure 11</a> | 18-bit RGB | Dither OFF, DC = 6X PCLK |

## BUS OVERVIEW

The LM4312 is a multi-lane MPL-2 Serializer that supports an 18-bit or 24-bit RGB source interface. The MPL-2 physical layer is purpose-built for robustness, low power and low EMI data transmission while requiring the fewest number of signal lines. No external line components are required, as termination is provided internal to the MPL-2 receiver. The differential interface conforms to the JEDEC SLVS (Scalable Low Voltage Signalling) Interface standard. A maximum raw throughput of >900 Mbps (2-lane raw) is possible with this chipset. The MPL-2 interface is designed for use with 80Ω to 100Ω differential lines. Lines may be microstrip or stripline construction.

### SERIAL BUS TIMING

Data valid is relative to both edges of a RGB transaction as shown in Figure 7. Data valid is specified as: Data Valid before Clock, Data Valid after Clock, and Skew between data lines should be less than 500ps.

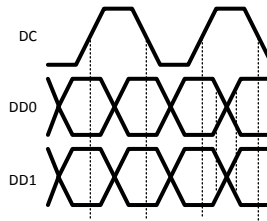


Figure 7. Dual Link Timing

### SERIAL BUS PHASES

There are three bus phases on the RGB MPL-2 serial bus. These are determined by the state of the DC and DD lines. The MPL-2 bus phases are shown in Table 2.

Table 2. Link Phases

| Name         | DC State | DDn State | Phase Description | Pre-Phase | Post-Phase |
|--------------|----------|-----------|-------------------|-----------|------------|
| OFF (O)      | GND      | GND       | Link is Off       | A, or LU  | LU         |
| LINK-UP (LU) | L        | L         | Start Up          | O         | A or O     |
| ACTIVE (A)   | A        | X         | Streaming Data    | LU        | O          |

### SERIAL BUS START UP TIMING

In the Serial Bus OFF phase, SER differential outputs are all driven to Ground.

When the SER is enabled, the differential outputs are driven to valid static High state until the SER PLL is locked. Then the DC becomes active and data is streamed to the DES.

Link-Up is shown in Figure 8. The DC and DDn signals are shown both as single-ended and differential waveforms.

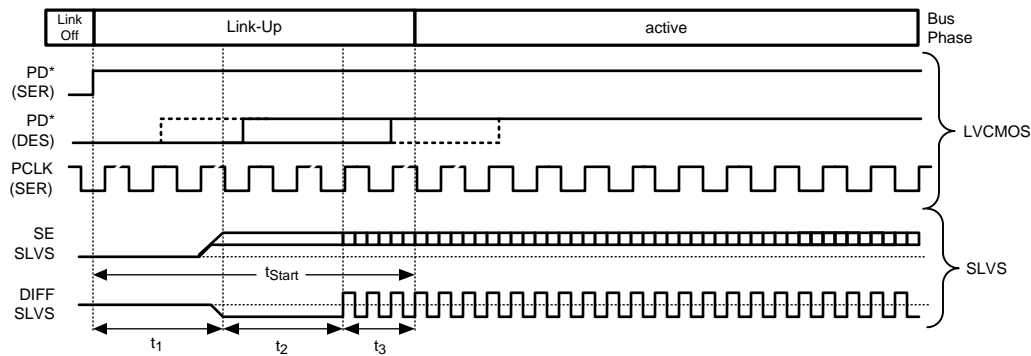


Figure 8. MPL-2 - LM4312 Link Up Timing

### OFF PHASE

In the Serial Bus OFF phase, SER differential outputs are all driven to Ground. Figure 9 shows the transition of the MPL-2 bus into the OFF phase.

PRODUCT PREVIEW



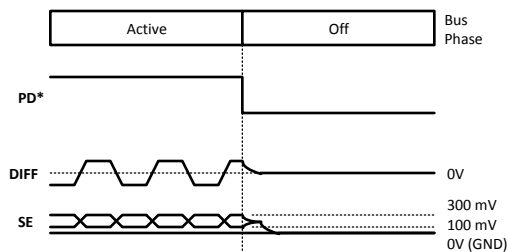


Figure 9. MPL-2 - LM4312 Link Off Timing

## RGB VIDEO INTERFACE

The LM4312 is transparent to data format and control signal polarity timing. Each PCLK, RGB inputs, HS, VS and DE are sampled on the **rising edge** of the PCLK. A PCLK by PCLK representation of these signals is duplicated on the opposite device after being transferred across the MPL-2 interface.

The LM4312 can accommodate a wide range of display formats. QVGA to >VGA can be supported within the 5MHz to 30 MHz PCLK input range.

Three operating modes of the link are possible (see Table 1).

The 24-bit RGB (R[7:0], G[7:0], B[7:0]) color information is serialized, followed by the control bits VS (VSYNC), HS (HSYNC), DE (Data Enable) and PE (Odd Parity) and Frame Sequence (F[1:0]) bits. The DC clock is 8X the PCLK, and 32 serial bits are sent per PCLK. The two additional Reserved (Low) bits are sent to complete the payload.

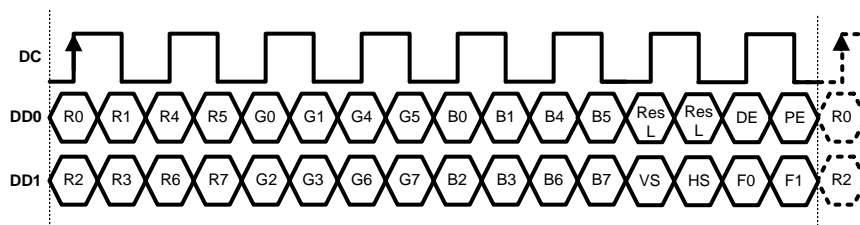


Figure 10. 24-bit RGB, 2 DD + DC Lane Serial Payload (8X)

When Dither option is enabled, the 24-bit RGB (R[7:0], G[7:0], B[7:0]) color information is Dithered to 18 bits, then serialized, followed by the control bits VS (VSYNC), HS (HSYNC), DE (Data Enable) and PE (Odd Parity) and Frame Sequence (F[1:0]) bits. The DC clock is 6X the PCLK, and 24 serial bits are sent per PCLK

With Dithering disabled, 18-bit RGB (R[7:2], G[7:2], B[7:2]) color information is serialized, followed by the control bits VS (VSYNC), HS (HSYNC), DE (Data Enable) and PE (Odd Parity) and Frame Sequence (F[1:0]) bits. Unused inputs (RGB[1:0]) must be tied off, do not float. The DC clock is 6X the PCLK, and 24 serial bits are sent per PCLK.

At a PCLK of 20.8 MHz, a 125 MHz DC clock is generated. The data lanes use both clock edges, thus 250 Mbps (raw) are sent per DD lane for a 500Mbps maximum throughput for the 2DD+DC configuration.

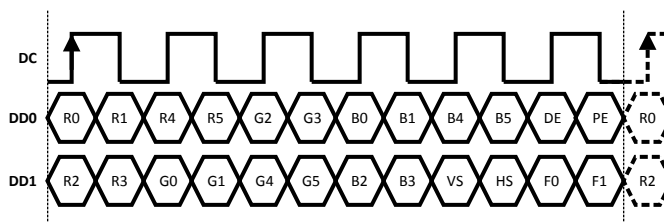


Figure 11. 24-bit dithered to 18-bit RGB / 18-bit RGB, 2 DD + DC Lane Serial Payload (6X)

## SERIAL PAYLOAD PARITY BIT

Odd Parity is calculated on the RGB bits, control (VS, HS, and DE) bits and F0, F1 bits and then sent from the SER to the DES via the serial PE bit. See DES Data sheets to determine how the parity bit is handled by the DES device.

## FRAME SEQUENCE — SYNC DETECT AND RECOVERY

If a data error or clock slip error occurs over the MPL-2 link, the RGB MPL-2 Deserializer can detect this condition and quickly recover from it. The method chosen is a data transparent method, and has very little overhead because it does not use a data expansion coding method. For the 18-bit RGB color transaction, it uses two bits that are already required in the 6 DC cycle transaction. Total overhead for each pixel is 3/24 or 12.5%, where the 3 bits are PE, F0 and F1.

The LM4312 MPL-2 RGB Serializer simply increments the two bit field F[1:0] on every pixel (MPL-2 frame) transmitted. Therefore every four MPL-2 frames, the pattern will repeat. It is very unlikely that this pattern would be found within the payload data, and if it were found, the probability that it would repeat for many frames becomes infinitely small. This code is used by the MPL-2 Deserializer to detect any frame alignment problems and quickly recover.

The RGB MPL-2 Deserializer, upon a normal power up sequence, uses the FS bits to obtain bit alignment. Once this is obtained, correct pixel data is recovered and driven to the display. If synchronization is lost for any reason, the DES searches for the incrementing pattern. Once found, it resynchronizes the output pixel data and timing signals. See MPL-2 DES Datasheet for details on how the specific DES handles the Frame Sequence.

## OPTIONAL DITHERING FEATURE

The LM4312 provides an optional Dithering mode. When selected, 24-bit RGB input data is internally dithered to 18-bits using a high-quality stochastic dithering process. This process has a "blue noise" characteristic that minimizes the visibility of the dither patterns. The resulting data stream of 18-bit data is then serialized and transmitted via MPL-2.

**The Dither circuitry requires the VS control signal for proper operation.** This signal is used to generate an internal signal that marks the start of the (video) frame. The serializer samples and sends the VS information unmodified.

Dithering parameters are controlled by two registers. When the dithering is bypassed, only RGB[7:2] is serialized and transmitted for 18-bit input RGB [5:0] (MSB aligned). Input RGB[1:0] should not be connected and the unused inputs should be tied low; do not float. **Dithering option is off by default.**

## OPTIONAL LOOK UP TABLE

The look up table is comprised of three 256 Byte SRAMs. It may be used for independent color correction. When the LM4312 is in the 24-bit RGB mode, the full 8-bits per color are used for addressing the 256 Bytes for each color. When the LM4312 is used in an 18-bit RGB mode and the LUT is desired, all 8-bits per color are still used for the LUT look-up. The 6 active bits from each color are used for addressing 64 locations in the LUT. The two LSBs of the 8-bit bus can be tied to 00, and every fourth location of the SRAM where the two LSBs equal 00, (addresses 0x00, 0x04, 0x08, 0x0c, etc.) will be used." Or, the two LSBs of the 8-bits can be tied to 01 and every fourth location of the SRAM where the low two bits equal 01 (addresses 0x01, 0x05, 0x09, 0x0d, etc.) will be used and so on. Selecting the two LSBs with GPIOs (0x0, 0x1, 0x2, and 0x3) allows for four different color correction tables to be accessed. The LUT is disabled by default and also after a device PD\* cycle. The PD\* cycle can be entered via the PD\* input pin directly, or by stopping the PCLK. When stop PCLK is used to disable the device, LUT data is retained. Before using the LUT, the SRAM must be loaded with its contents. If power is cycled to the device, the LUT must be loaded again.

To enable the LUT:

1. Select/Unlock the LM4312 SPI Interface - Write 0xFF to REG 0x16
2. Write the LUT contents to the SRAM using Writes or Page Writes
3. Enable the LUT - Write a 0x01 to REG 0x00
4. De-Select/Lock the LM4312 SPI interface - Write 0x00 to REG 0x16

When waking up the LM4312 from the power down mode (PD\*=L), the LUT needs to be enabled if it is desired, and the contents to the SRAM are still held and valid.

1. Select/Unlock the LM4312 SPI Interface - Write 0xFF to REG 0x16
2. Enable the LUT - Write a 0x01 to REG 0x00
3. Optional -select desired Level Select - if not using default value
4. De-Select/Lock the LM4312 SPI interface - Write 0x00 to REG 0x16

If power is cycled to the device, the LUT SRAMs must be loaded again.

## SPI INTERFACE

The Serial Peripheral Interface (SPI) allows control over various aspects of the LM4312, the Look Up Table operation, and access to the three 256 x 8-RAM blocks. Three SPI transactions are supported, which are: 16-bit WRITE, PAGE WRITE, and a 16-bit READ. The SPI interface is disabled when the device is in the sleep mode via the PD\* pin (PD\* = L). The SPI interface may be used when PD\* = H or when the device is in SLEEP via the PCLK stop feature. A device (SER) reset function is also available via the Configuration 3 register bit 1.

Due to the Select/Unlock – De-Select/Lock feature of the device the SPI interface may be shared with the display driver. Several connection configurations are possible. A couple examples are shown in [Figure 12](#) and [Figure 13](#). SPI\_DI and SPI\_DO may be tied together to form a bi-directional SDA line. If READs are not required, leave the SPI\_DO pin as a NC.

### 16-bit WRITE

The 16-bit WRITE is shown in [Figure 14](#). The SPI\_DI payload consists of a "0" (Write Command), seven address bits and eight data bits. The SPI\_CSX signal is driven Low, and 16-bits of DI (data input) are sent to the device. Data is latched on the rising edge of the SPI\_SCL. After each 16-bit WRITE, SPI\_CSX must return HIGH.

**Table 3. 16-bit WRITE – SPI**

| Bit | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7 | B6 | B5 | B4 | B3 | B2 | B1 | B0 |
|-----|-----|-----|-----|-----|-----|-----|----|----|----|----|----|----|----|----|----|----|
| DI  | 0   | A6  | A5  | A4  | A3  | A2  | A1 | A0 | D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |

### 16-bit READ

The 16-bit READ is shown in [Figure 15](#). The SPI\_DI payload consists of a "1" (Read Command), seven address bits. The SPI\_DO consists of eight data bits which are driven from the device. The SPI\_CSX signal is driven Low, and the host drives the first 8 bits of the DI ("1" and seven address bits), the device then drives the respective 8 bits of the data on the DO signal.

**Table 4. 16-bit READ – SPI**

| Bit | B15 | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7        | B6        | B5        | B4        | B3        | B2        | B1        | B0        |
|-----|-----|-----|-----|-----|-----|-----|----|----|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| DI  | 1   | A6  | A5  | A4  | A3  | A2  | A1 | A0 | Z         | Z         | Z         | Z         | Z         | Z         | Z         | Z         |
| DO  | Z   | Z   | Z   | Z   | Z   | Z   | Z  | Z  | <b>D7</b> | <b>D6</b> | <b>D5</b> | <b>D4</b> | <b>D3</b> | <b>D2</b> | <b>D1</b> | <b>D0</b> |

### PAGE WRITE

The PAGE WRITE is shown in [Figure 16](#). The SPI\_DI payload consists of a "0" (Write Command), seven address bits of the start address and then the consecutive data bytes. 256 bytes maximum can be sent. The SPI\_CSX signal is driven Low, and the host drives the SDA signal with a "0" (Write Command), the seven start address bits and the variable length data bytes. The Page Write is denoted by the SPI\_CSX signal staying low while the data bytes are streamed. Data is latched on the rising edge of the SPI\_SCL.

There are four SPI Interface signals: SPI\_CSX - SPI Chip Select, SPI\_SCL - SPI Clock, DI - SPI Data In and DO - SPI Data Out. SPI\_CSX, SPI\_SCL and SPI\_DI are inputs on the LM4312. SPI\_DO is the Data Output line for the READ\_DATA portion of a READ operation. READs are optional and are not required.

**Table 5. PAGE WRITE**

| Bit | B15             | B14 | B13 | B12 | B11 | B10 | B9 | B8 | B7                      | B6 | B5 | B4 | B3 | B2 | B1 | B0 |
|-----|-----------------|-----|-----|-----|-----|-----|----|----|-------------------------|----|----|----|----|----|----|----|
| DI  | 0               | A6  | A5  | A4  | A3  | A2  | A1 | A0 | D7                      | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|     | (start address) |     |     |     |     |     |    |    | (Data Byte 0)           |    |    |    |    |    |    |    |
| DI  | D7              | D6  | D5  | D4  | D3  | D2  | D1 | D0 | D7                      | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|     | (Data Byte 1)   |     |     |     |     |     |    |    | (Data Byte n, 256 max.) |    |    |    |    |    |    |    |

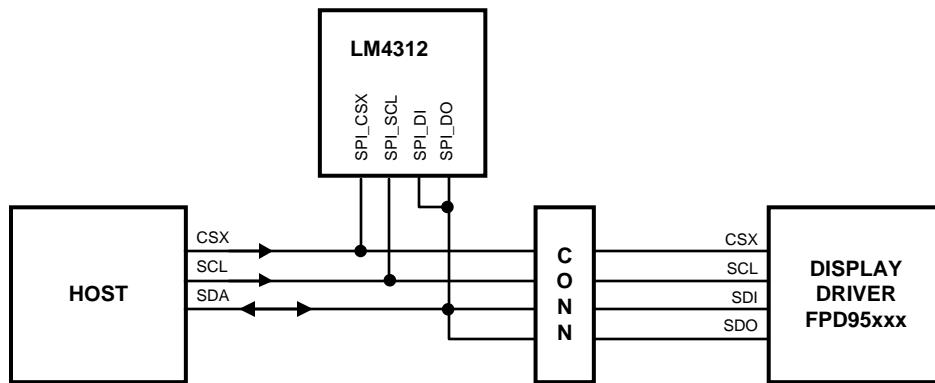


Figure 12. LM4312 WRITE & READ to 3-signal SPI HOST

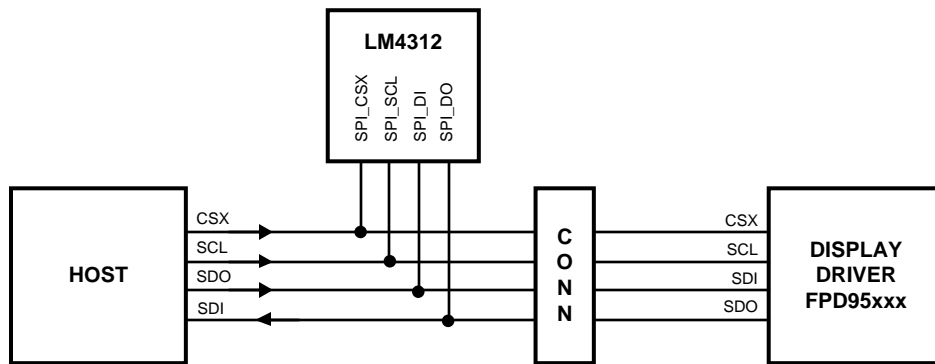


Figure 13. LM4312 WRITE & READ to 4-signal SPI HOST

Table 6. LM4312 SPI Registers

| Name                     | Address | Type <sup>(1)</sup> | Description  | Default |
|--------------------------|---------|---------------------|--|---------|
| Command                  | 0x00    | R/W                 | Bit 0 = LUT Enable<br>0'b = LUT Disabled, 1'b = LUT Enabled<br>Bit 4 = Special Register Access<br>0'b = SRA Locked, 1'b = SRA Unlocked<br>For access to Registers 0x08, 0x09, 0x0B, the Special Register Access bit must be unlocked. Must write all 8 bits. | 0x00    |
| Reserved, <sup>(2)</sup> | 0x01    | na                  | Reserved   |         |
| LUT Red RAM Address      | 0x02    | R/W                 | Red Address - This register contains the address for the next access to the Red LUT RAM. After every read or write access to the Red Data Register, this register auto-increments.   | 0x00    |
| LUT Red RAM Data         | 0x03    | R/W                 | Red Data   | 0xXX    |
| LUT Green RAM Address    | 0x04    | R/W                 | Green Address - This register contains the address for the next access to the Green LUT RAM. After every read or write access to the Green Data Register, this register auto-increments.   | 0x00    |
| LUT Green RAM Data       | 0x05    | R/W                 | Green Data   | 0xXX    |
| LUT Blue RAM Address     | 0x06    | R/W                 | Blue Address - This register contains the address for the next access to the Blue LUT RAM. After every read or write access to the Blue Data Register, this register auto-increments.  | 0x00    |
| LUT Blue RAM Data        | 0x07    | R/W                 | Blue Data  | 0xXX    |

(1) If a WRITE is done to a reserved bits, data should be all 0's. If a READ is done to a reserved location, either 1's or 0's may be returned. Mask reserved data bits.

(2) DO NOT write to Reserved Registers.

Table 6. LM4312 SPI Registers (continued)

| Name                                 | Address   | Type <sup>(1)</sup> | Description  | Default |
|--------------------------------------|-----------|---------------------|--|---------|
| Dither Configuration1 <sup>(3)</sup> | 0x08      | R/W                 | Bit 0 - Dither Bypass<br>1'b = Bypass Dither, 0'b = Dither ON<br>Bit 1 - DE INV<br>1'b = Active Low DE, 0'b = Active High DE<br>Does not alter DE signal, dither block input only.<br>Bit 2 - VS INV<br>1'b = Active Low VS signal, 0'b = Active High VS signal.<br>Does not alter VS signal, dither block input only.<br>Bit 4 - Tempen0<br>1'b = Transposed Dither Pattern,<br>0'b = Even and odd frames use same dither pattern<br>Bit 5 - Tempen1<br>1'b = Temporal Dithering is Enabled, 0'b = Disabled<br>Bit 6 - Dith3 - Dither Amplitude<br>1'b = set to 3 bits, 0'b = set to 4 bits | 0x65    |
| Dither Configuration2 <sup>(3)</sup> | 0x09      | R/W                 | Dither Parameter<br><b>Reserved</b> , Default value recommended.   | 0x67    |
| <b>Reserved</b>                      | 0x0A      | na                  | <b>Reserved</b>  |         |
| Configuration 3, <sup>(3)</sup>      | 0x0B      | R/W                 | Bit 0 - Mode 24<br>1'b = 24-bit RGB Mode, 0'b = 18-bit RGB Mode<br>Bit 1 - SER_PD<br>1'b = RESET the SER, 0'b = normal mode<br>Bit[5:4] - Driver Level Select<br>00'b = VOD = 200mV<br>01'b = VOD = 150mV  | 0x00    |
| <b>Reserved</b> , <sup>(4)</sup>     | 0x0C-0x15 | na                  | <b>Reserved</b>  |         |
| Device Select (Unlock/Lock)          | 0x16      | R/W                 | 0xFF'h enables LM4312 SPI<br>All other values disables LM4312 SPI (0x00 to 0xFE)   | 0x00    |
| <b>Reserved</b> , <sup>(4)</sup>     | 0x17-0x7F | na                  | <b>Reserved</b>  |         |

(3) This register must be unlocked first through bit 4 of register 0. This register is currently a write only register, read is not supported.

(4) DO NOT write to Reserved Registers.

**SPI RESET BIT**

Configuration 3 register, bit 1 is a device RESET function. When this bit is set to a 1, the device is placed into reset. When this bit is a 0, the device is in normal mode and is controlled by the PCLK and PD\* signal pins.

**SPI Timing**

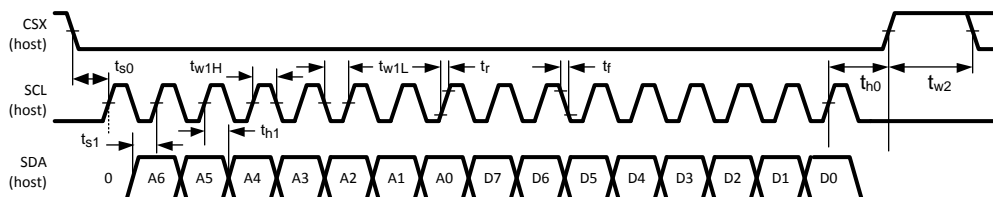


Figure 14. 16-bit SPI WRITE

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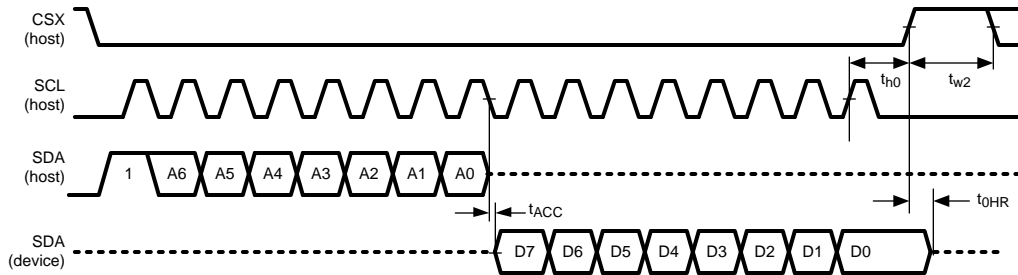


Figure 15. 16-bit SPI READ

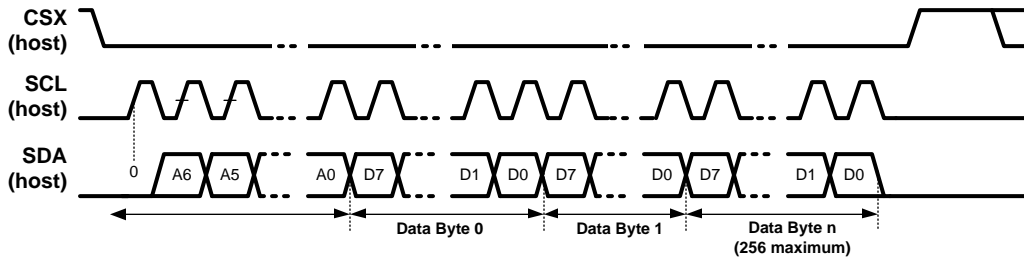


Figure 16. SPI Page Write

Figure 14, Figure 15, and Figure 16 show a 3-wire SPI Interface with the (LM4312) SPI\_DI and (LM4312) SPI\_DO pins tied together to form a bi-directional SPI data signal SDA. In the 16-bit READ, the SPI HOST drives the first 8 bits of the operation, and the SPI target (LM4312) drives the last 8 bits as shown in Figure 15.

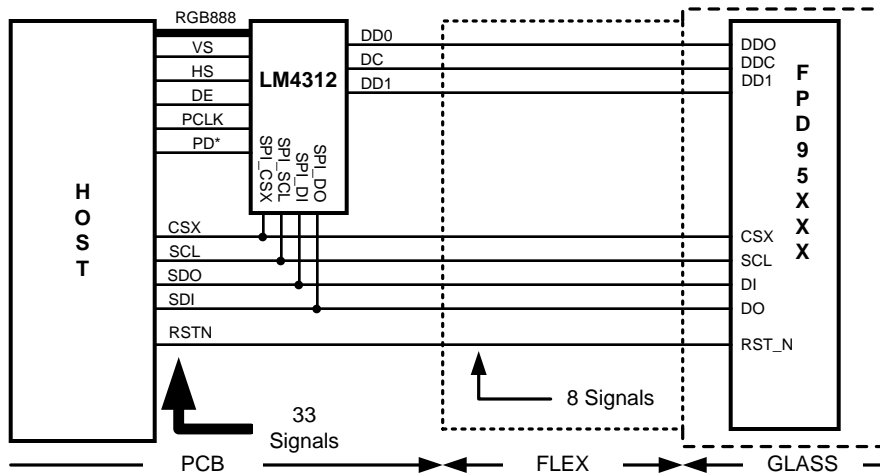


Figure 17. Typical Application Connection Diagram

In Figure 17, 33 host signals are reduced to only 7 or 8 signals. The reduced width interface to the display includes: 3 differential signals (DD0, DC, DD1), a Display Driver Reset signal (RSTN) and 3 or 4 wire SPI interface.

**LM4312 Operation**

**POWER SUPPLY & BYPASS RECOMMENDATION**

The  $V_{DD}$  power supply pins are intended to be connected together to the same plane.

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Bypass capacitors should be placed near the power supply pins of the device. Use high frequency ceramic (surface mount recommended) 0.1  $\mu\text{F}$  capacitors. A 2.2 to 4.7  $\mu\text{F}$  Tantalum capacitor is recommended near the SER for PLL bypass. Connect bypass capacitors with wide traces and use dual or larger via to reduce resistance and inductance of the feeds. Utilizing a thin spacing between power and ground planes will provide good high frequency bypass above the frequency range where most typical surface mount capacitors are less effective. To gain the maximum benefit from this, low inductance feed points are important. Also, adjacent signal layers can be filled to create additional capacitance. Minimize loops in the ground returns also for improved signal fidelity and lowest emissions.

### UNUSED INPUT PINS

Unused inputs **must** be tied to the proper input level — do not float.

### PHASE-LOCKED LOOP

A PLL is enabled to generate the serial link clock. The Phase-locked loop system generates the serial data clock at 6 or 8 of the input clock depending upon 18 or 24-bit RGB transport mode (set by SPI Register).

### SLEEP MODE & STOP CLOCK

The LM4312 (SER) can enter SLEEP (Low Power state) by two methods. The PD\* pin is one method, the other is by stopping the PCLK input (to a static level).

The PD\* Input pin may be controlled by the Host. When PD\* = High, the SER is enabled. When the PD\* = Low, the SER is in SLEEP Mode. Note that SPI Registers are reset to default values, and LUT data is retained.

When using the auto power down mode, the PD\* input needs to be held High. When the PCLK is held static, the SER will detect this condition and power down. When the PCLK is restarted, the SER powers up. See [Figure 3](#), [Figure 4](#), and [Figure 8](#). The stopping of the pixel clock should be done cleanly. The minimum clock stop gap should be at least 4 PCLK cycles wide. Floating of the PCLK input pin is not recommended. Consult the MPL-2 DES datasheet to determine requirements that the DES requires. When the SER is in SLEEP by the STOP CLOCK feature, SPI Register and LUT contents are retained.

If power is removed from the device, SPI Register and LUT contents are reset upon power up.

**Table 7. LM4312 Memory Status (LUT and SPI Registers)**

| Mode  | LUT                    | SPI Registers               |
|---|------------------------|-----------------------------|
| Power Cycle<br>VDDs = 0V                          | LUT contents are reset | Registers RESET to Defaults |
| Sleep State<br>PD* = L                            | LUT contents retained  | Registers RESET to Defaults |
| Sleep State<br>PD* = H and PCLK = static (H or L) | LUT contents retained  | Register contents retained  |

## Application Information

### SYSTEM BANDWIDTH CALCULATIONS

For a HVGA (320 X 480) application with the following assumptions: 60 Hz refresh rate, 10% blanking, RGB666, the following calculations can be made:

Calculate PCLK -  $320 \times 480 \times 1.1 \times 60 = 10.14 \text{ MHz PCLK}$

Calculate DC rate - since the application is 2 DD + DC and RGB666, PCLK X 6 is the DC rate or 60.83 MHz. Also check that this DC rate does not exceed the DC maximum rate for the chipset.

Calculate DD rate - MPL-2 uses both edges of the DC to send serialized data, thus data rate is 2X the DC rate, or 121.7 Mbps per DD lane in our example.

Calculate the application throughput - using 2 DD lanes, throughput is 2 X of the DD rate or 243.3 Mbps of raw band width.

For a VGA (640 X 480) application with the following assumptions: 60 Hz refresh rate, 35% blanking, RGB888, the following calculations can be made:



Calculate PCLK -  $640 \times 480 \times 1.35 \times 60 = 24.88 \text{ MHz PCLK}$

Calculate DC rate - since the application is 2 DD + DC and RGB888, PCLK X 8 is the DC rate or ~ 200 MHz.

Calculate DD rate - MPL-2 uses both edges of the DC to send serialized data, thus data rate is 2X the DC rate, or 400 Mbps per DD lane in our example.

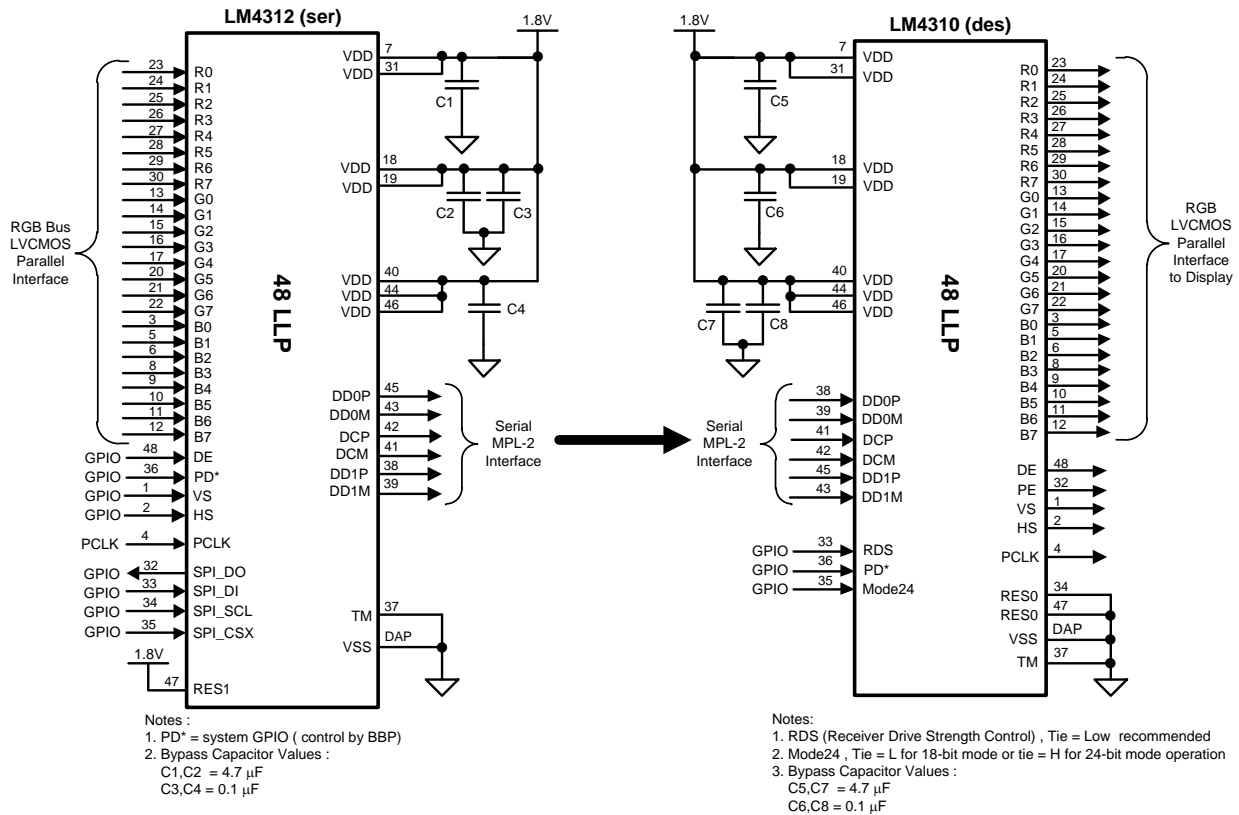
Calculate the application throughput - using 2 DD lanes, throughput is 2X of the DD rate or 800 Mbps of raw band width.

**SYSTEM CONSIDERATIONS**

**Typical VGA RGB888 Operation**

A Smart Display application is shown in Figure 18. The Serializer (SER) resides by the host (BBP) and connects to a Memory Interface. BBP Bus signals are connected as shown (PCLK, Data, DE, PD\*, VS, HS, and SPI signals). The device can be configured for 18-bit or 24-bit RGB interfaces. RGB signals are samples on the rising edge of the PCLK, and the serial data lines use both edge of the serial clock. The SER requires a pixel clock reference which is typically 25 MHz in a VGA application. This signal is used to generate the serial DC clock. The PCLK input is multiplied by the selected PLL multiplier to determine the serial clock rate. In the 25 MHz PCLK and 8X application, the DC rate will be 200 MHz. Due to the serial transmission scheme using both clock edges, the raw bandwidth is 400 Mbps per lane and device throughput is 800 Mbps. Dither and LUT options are OFF by default and can be turned ON by device SPI programming. The SER has a SLEEP mode to save power when the display is not active. The Sleep state is entered when the PD\* signal is driven Low. It is also entered if the PD\* signal is High and the PCLK input is stopped. When PCLK stop is used to place SER into Sleep mode, the SPI registers and the LUT content are retained. In the Sleep state, supply current into the SER is >1µA typical. Several configuration pins are also required to be set. For a SER, tie TM = L and RES1 = H. The DES recovers the serial signals and generates the parallel bus for the Display.

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**Figure 18. Typical VGA RGB888 Connection Diagram**



The DES VDD is set to be compatible with the Display(s) employed. Depending on application, the Mode24 and RDS may be tie to high, low or connected to BBP (GPIO) pins. The PD\* should be tied to PD\* pin on SER device. The other signals DE, VS, and HS signals are outputs only. The connection between the DES device and the display(s) should be done such that long stubs are avoided. The DES has user adjustable edge rate controls for the parallel bus outputs. This can be used to optimize the edge rate vs. the required VDD magnitude. This allows for using softer edges on the wide parallel data bus signals. The DES also provides a PE pin to flag any parity errors detected. This signal maybe routed back to the host for monitoring, or bought out to a test point. The DES supports 18-bit for 24-bit mode. These modes are obtained by setting the MODE24 pin to a logic Low for 18-bit mode or to logic High for 24-bit mode. The Sleep state of the display may be entered by driving the PD\* signal to a logic Low. This pin should be connected SED PD\* pin. Several configuration pins are also required to be set. For a DES, tie TM = L and RES0 = L.

## FLEX CIRCUIT RECOMMENDATIONS

The MPL-2 lines should generally run together to minimize any trace length differences (skew). For impedance control and also noise isolation (crosstalk), guard ground traces are recommended in between the signals. Commonly a Ground-Signal-Signal-Ground (GSSGSSG) layout is used. Locate fast edge rate and large swing signals further away to also minimize any coupling (unwanted crosstalk). In a stacked flex interconnect, crosstalk also needs to be taken into account in the above and below layers (vertical direction). To minimize any coupling locate MPL-2 traces next to a ground layer. Power rails also tend to generate less noise than LVCMOS so they are also good candidates for use as isolation and separation.

The interconnect from the SER to the DES may act like a transmission line. Thus impedance control and ground returns are an important part of system design. Impedance should be in the 80 to 100 Ohms for the differential pair.

## GROUNDING

The LM4312 offered in the 48 X2QFN package uses the center DAP Pad for the Ground connection. This pad **MUST** be connected to Ground for proper device operation.

## PCB RECOMMENDATIONS

General guidelines for the PCB design:

- Floor plan - locate MPL-2 SER near the connector to limit chance of cross talk to high speed serial signals.
- Route serial traces together, minimize the number of layer changes to reduce loading.
- Use ground lines as guards to minimize any noise coupling (specifies distance).
- Avoid parallel runs with fast edge, large LVCMOS swings.
- Also use a GSSG pinout in connectors (Board to Board or ZIF).
- DES device - follow similar guidelines.
- Bypass the device with MLC surface mount devices and thinly separated power and ground planes with low inductance feeds.
- High current returns should have a separate path with a width proportional to the amount of current carried to minimize any resulting IR effects.
- See AN-1187 ([SNOA401](#)) X2QFN Package Application Note for SMT Assembly Recommendations

Connection Diagram 48 X2QFN Package

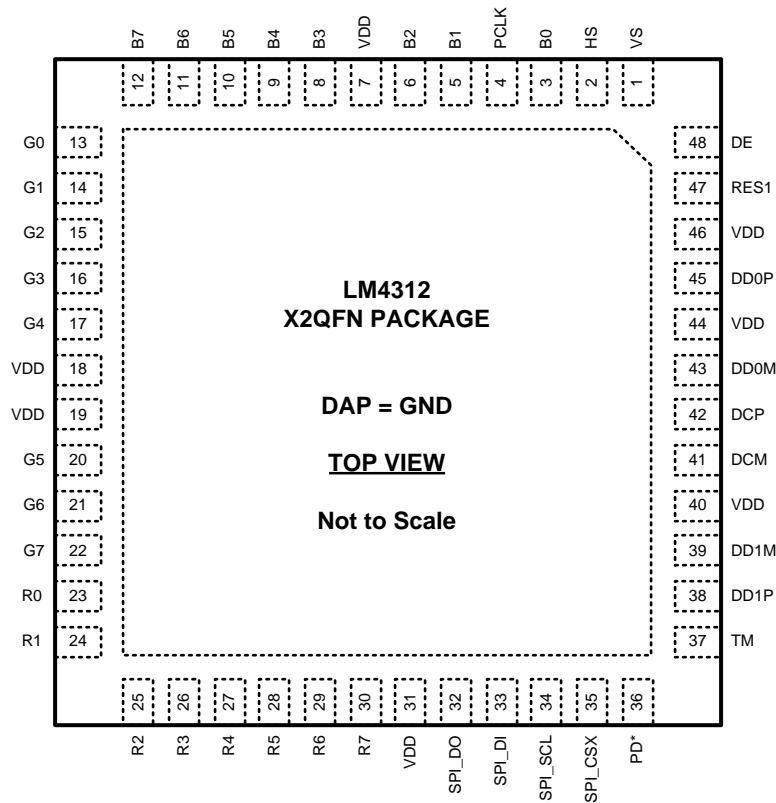


Figure 19. TOP VIEW  
(not to scale)

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## REVISION HISTORY

| Changes from Original (May 2013) to Revision A             | Page |
|--|------|
| • Changed layout of National Data Sheet to TI format ..... | 18   |

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**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2)         | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM4312SN/NOPB    | ACTIVE        | X2QFN        | NJS             | 48   | 250         | Green (RoHS & no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 4312SN                  | <a href="#">Samples</a> |
| LM4312SNX/NOPB   | ACTIVE        | X2QFN        | NJS             | 48   | 2500        | Green (RoHS & no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | -40 to 85    | 4312SN                  | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBsolete:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

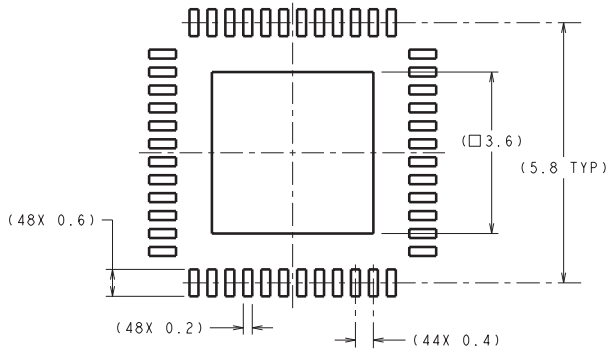
| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM4312SN/NOPB  | X2QFN        | NJS             | 48   | 250  | 178.0              | 16.4               | 6.3     | 6.3     | 1.5     | 12.0    | 16.0   | Q1            |
| LM4312SNX/NOPB | X2QFN        | NJS             | 48   | 2500 | 330.0              | 16.4               | 6.3     | 6.3     | 1.5     | 12.0    | 16.0   | Q1            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

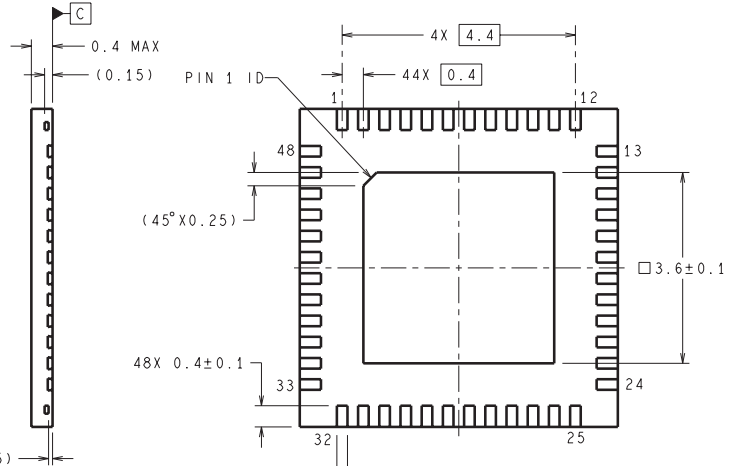
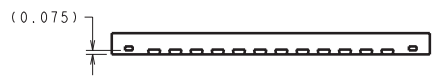
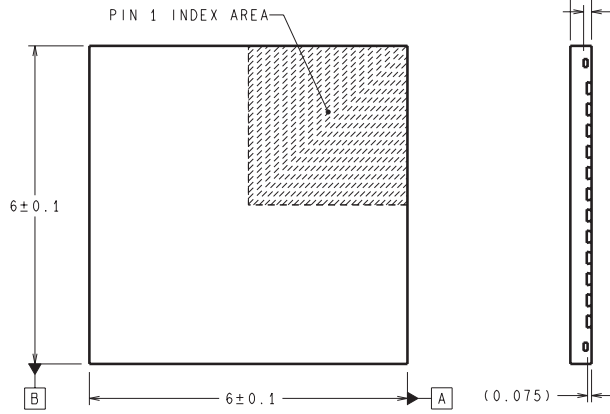
| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM4312SN/NOPB  | X2QFN        | NJS             | 48   | 250  | 213.0       | 191.0      | 55.0        |
| LM4312SNX/NOPB | X2QFN        | NJS             | 48   | 2500 | 367.0       | 367.0      | 38.0        |

NJS0048A



DIMENSIONS ARE IN MILLIMETERS  
DIMENSIONS IN ( ) FOR REFERENCE ONLY

RECOMMENDED LAND PATTERN



48X 0.2 ± 0.05  
⌀ 0.1 (M) C A (S) B (S)

SNF48A (Rev A)



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| DSP                          | <a href="http://dsp.ti.com">dsp.ti.com</a>   |
| Clocks and Timers            | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>                             |
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| Power Mgmt                   | <a href="http://power.ti.com">power.ti.com</a>                                       |
| Microcontrollers             | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a>                   |
| RFID                         | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>                                 |
| OMAP Applications Processors | <a href="http://www.ti.com/omap">www.ti.com/omap</a>                                 |
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|                               |  |
|-------------------------------|--|
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| Consumer Electronics          | <a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>                   |
| Energy and Lighting           | <a href="http://www.ti.com/energy">www.ti.com/energy</a>                                 |
| Industrial                    | <a href="http://www.ti.com/industrial">www.ti.com/industrial</a>                         |
| Medical                       | <a href="http://www.ti.com/medical">www.ti.com/medical</a>                               |
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