

SNx5DPHY440SS MIPI® CSI-2/DSI DPHY Retimer

1 Features

- MIPI® DPHY 1.1 specification compliant
- Enables low-cost cable solutions
- Supports up to 4 lanes at 1.5Gbps
 - CSI-2/DSI clock rates from 100MHz to 750MHz
- Sub mW Power in shutdown state
- MIPI® DSI bidirectional LP mode supported
- Supports for both ULPS and LP power states
- Adjustable output voltage swing
- Selectable TX pre-emphasis levels
- Adjustable RX EQ to compensate for ISI loss
- Configurable edge rate control
- Dynamic data and clock skew compensation
- ESD HBM protection: 3kV
- Industrial temperature range: -40°C to 85°C (SN65DPHY440SS)
- Commercial temperature range: 0°C to 70°C (SN75DPHY440SS)
- Available in single 1.8V supply

2 Applications

- Notebook PCs
- Clam shells
- Tablets
- Cameras

3 Description

The DPHY440 is a 1-lane to 4-lane and clock MIPI® DPHY retimer that regenerates the DPHY signaling. The device complies with MIPI® DPHY 1.1 standard and can be used in either a MIPI® CSI-2 or MIPI® DSI application at data rates of up to 1.5Gbps.

The device compensates for PCB, connector, and cable related frequency loss and switching related loss to provide the optimum electrical performance from a CSI-2/DSI source to sink. The DPHY440 DPHY inputs feature configurable equalizers.

The output pins automatically compensate for uneven skew between clock and data lanes received on the inputs ports of the device. The DPHY440 output voltage swing and edge rate can be adjusted by changing the state of the VSADJ_CFG0 pin and ERC pin, respectively.

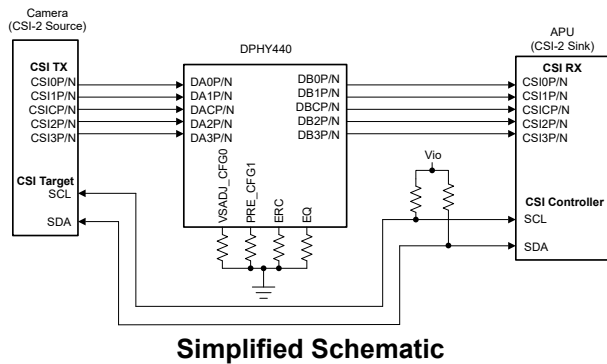
The DPHY440 is optimized for mobile applications, and contains activity detection circuitry on the DPHY Link interface that can transition into a lower power mode when in ULPS and LP states.

The SN65DPHY440SS is characterized for an industrial temperature range from -40°C to 85°C while SN75DPHY440SS is characterized for commercial temperature range from 0°C to 70°C.

Package Information

| PART NUMBER | PACKAGE (1) | PACKAGE SIZE (2) |
|---------------|-------------|------------------|
| SN65DPHY440SS | (WQFN, 28) | 5.5mm × 3.5mm |
| SN75DPHY440SS | | |

- (1) For all available packages, see [Section 10](#).
- (2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Application



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4 Pin Configuration and Functions

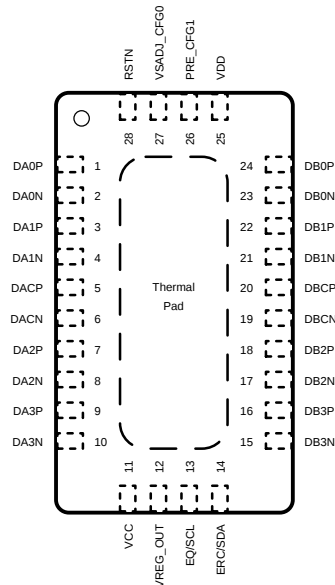


Figure 4-1. RHR Package 28 Pin (WQFN) Top View

Table 4-1. Pin Functions

| PIN | | I/O | INTERNAL PULLUP/PULLDOWN | DESCRIPTION |
|----------|-----|-------------------------------------|--------------------------|--|
| NAME | NO. | | | |
| DA0P | 1 | 100-Ω Differential Input | | CSI-2/DSI Lane 0 Differential positive Input. Supports DSI LP Backchannel. If unused, this pin should be tied to GND. |
| DA0N | 2 | | | CSI-2/DSI Lane 0 Differential negative Input. Supports DSI LP Backchannel. If unused, this pin should be tied to GND. |
| DA1P | 3 | 100-Ω Differential Input (Failsafe) | | CSI-2/DSI Lane 1 Differential positive Input. If unused, this pin should be tied to GND. |
| DA1N | 4 | | | CSI-2/DSI Lane 1 Differential negative input. If unused, this pin should be tied to GND. |
| DACP | 5 | 100-Ω Differential Input (Failsafe) | | CSI-2/DSI Differential Clock positive Input |
| DACN | 6 | | | CSI-2/DSI Differential Clock negative Input |
| DA2P | 7 | 100-Ω Differential Input (Failsafe) | | CSI-2/DSI Lane 2 Differential positive Input. If unused, this pin should be tied to GND. |
| DA2N | 8 | | | CSI-2/DSI Lane 2 Differential negative Input. If unused, this pin should be tied to GND. |
| DA3P | 9 | 100-Ω Differential Input (Failsafe) | | CSI-2/DSI Lane 3 Differential positive Input. If unused, this pin should be tied to GND. |
| DA3N | 10 | | | CSI-2/DSI Lane 3 Differential negative Input. If unused, this pin should be tied to GND. |
| VCC | 11 | Power | | 1.8V (±10%) Supply. |
| VREG_OUT | 12 | Power | | 1.2 V Regulator Output. Requires a 0.1 μF capacitor to GND. |
| EQ/SCL | 13 | I/O (3-level) | PU (100K) PD (100K) | RX Equalization Select. Pin state sampled on rising edge of RSTN. This pin also functions as I ² C SCL pin. V _{IL} = 0 dB V _{IM} = 2.5 dB V _{IH} = 5 dB |
| ERC/SDA | 14 | I/O (3-level) | PU (100K) PD (100K) | Edge Rate Control for DB[4:0]P/N High speed transmitter rise and fall time. Pin state sampled on rising edge of RSTN. This pin also functions as I ² C SDA pin. V _{IL} = 200 ps typical V _{IM} = 150 ps typical V _{IH} = 250 ps typical |

Table 4-1. Pin Functions (continued)

| PIN | | I/O | INTERNAL PULLUP/PULLDOWN | DESCRIPTION |
|------------|-------------|---------------------------------|-----------------------------|--|
| NAME | NO. | | | |
| DB3N | 15 | 100-Ω Differential Output | | CSI-2/DSI Lane 3 Differential negative Output. If unused, this pin should be left unconnected. |
| DB3P | 16 | | | CSI-2/DSI Lane 3 Differential positive Output. If unused, this pin should be left unconnected. |
| DB2N | 17 | 100-Ω Differential Output | | CSI-2/DSI Lane 2 Differential negative Output. If unused, this pin should be left unconnected. |
| DB2P | 18 | | | CSI-2/DSI Lane 2 Differential positive Output. If unused, this pin should be left unconnected. |
| DBCN | 19 | 100-Ω Differential Output | | CSI-2/DSI Differential Clock negative Output |
| DBCP | 20 | | | CSI-2/DSI Differential Clock positive Output |
| DB1N | 21 | 100-Ω Differential Output | | CSI-2/DSI Lane 1 Differential negative Output. If unused, this pin should be left unconnected. |
| DB1P | 22 | | | CSI-2/DSI Lane 1 Differential positive Output. If unused, this pin should be left unconnected. |
| DB0N | 23 | 100-Ω Differential Output | | CSI-2/DSI Lane 0 Differential negative Output. Supports DSI LP Back channel. If unused, this pin should be left unconnected. |
| DB0P | 24 | | | CSI-2/DSI Lane 0 Differential positive Output. Supports DSI LP Back channel. If unused, this pin should be left unconnected. |
| VDD | 25 | Power | | This pin must be connected to the VREG_OUT pin through at least a 10-mil trace and a 0.1 μF capacitor to ground. |
| PRE_CFG1 | 26 | I/O (3-level) | PU (100K) PD (100K) | Controls DPHY TX HS pre-emphasis level and the LP TX rise and fall times. Pin state is sampled on the rising edge of RSTN. V _{IL} = 0 dB V _{IM} = 0 dB V _{IH} = 2.5 dB |
| VSADJ_CFG0 | 27 | I (3-level) | PU (100K) PD (100K) | Controls output voltage swing for DB HS transmitters and the LP TX rise and fall times. Pin state is sampled on the rising edge of RSTN. Refer to Table 6-3 for details on voltage swing settings based on this pin and PRE_CFG1 sampled state. V _{IL} = 200 mV or 220 mV based on PRE_CFG1 sampled state. V _{IM} = 200 mV typical V _{IH} = 220 mV typical |
| RSTN | 28 | I | PU (300K) | Reset, active low. When low, all internal CSR are reset to default and DPHY440 is placed in low power state. |
| GND | Thermal pad | GND | | Ground. |

5 Specifications

5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) ⁽¹⁾

| | | MIN | MAX | UNIT |
|--|------------------------------------|------|-------|------|
| Supply voltage range | V _{CC} | -0.3 | 2.175 | V |
| Voltage range | DPHY Lane I/O Differential Voltage | -0.3 | 1.4 | V |
| | RSTN | -0.3 | 2.175 | V |
| | All other terminals | -0.3 | 2.175 | V |
| Maximum junction temperature, T _J | | | 105 | °C |
| Storage temperature, T _{stg} | | -65 | 150 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

5.2 ESD Ratings

| | | VALUE | UNIT |
|--|--|-------|------|
| V _(ESD) Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | ±3000 | V |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | ±1000 | |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

| | | MIN | NOM | MAX | UNIT |
|-----------------|--|------|-----|------|------|
| V _{CC} | Supply voltage | 1.62 | 1.8 | 1.98 | V |
| T _A | Operating free-air temperature [SN65DPHY440SS] | -40 | | 85 | °C |
| | Operating free-air temperature [SN75DPHY440SS] | 0 | | 70 | |

5.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | SNx5DPHY440SS | UNIT |
|-------------------------------|--|---------------|------|
| | | RHR (WQFN) | |
| | | 12 PINS | |
| R _{θJA} | Junction-to-ambient thermal resistance | 42.1 | °C/W |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 32.3 | °C/W |
| R _{θJB} | Junction-to-board thermal resistance | 12.8 | °C/W |
| ψ _{JT} | Junction-to-top characterization parameter | 0.5 | °C/W |
| ψ _{JB} | Junction-to-board characterization parameter | 12.6 | °C/W |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 5.2 | °C/W |

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

5.5 Electrical Characteristics, Power Supply

over operating free-air temperature range (unless otherwise noted)

| | | | MIN | NOM | MAX | UNIT |
|-------------|--|--|-----|------|-----|------|
| PACTIVE1_SS | Power under normal operation for 4 data lanes + clock. | DPHY Lanes at 1 Gbps; V _{CC} supply stable, V _{CC} = 1.8 V; | | 150 | | mW |
| PACTIVE2_SS | Power under normal operation for 2 data lanes + clock. | DPHY Lanes 1 Gbps; V _{CC} supply stable, V _{CC} = 1.8 V; | | 115 | | mW |
| PLP11_SS | LP11 Power | All DPHY lanes in LP11; V _{CC} supply stable; V _{CC} = 1.8 V; | | 14 | | mW |
| PRSTN_SS | RSTN Power | RSTN held in asserted state (low); V _{CC} supply stable; V _{CC} = 1.8 V; | | 0.75 | | mW |

5.6 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|---|--|--|---------------------|-----------------------|------|-----|
| Standard IO (RSTN, ERC, EQ, CFG[1:0]) | | | | | | |
| V _{IL} | Low-level control signal input voltage | | | 0.2 x V _{CC} | V | |
| V _{IM} | Mid-level control signal input voltage | | V _{CC} / 2 | | V | |
| V _{IH} | High-level control signal input voltage | 0.8 x V _{CC} | | | V | |
| V _F | Floating Voltage | V _{IN} = High Impedance | V _{CC} / 2 | | V | |
| V _{OL} | Low level output voltage (open-drain). ERC (SDA) only | At I _{OL} max. | | 0.2 x V _{CC} | V | |
| I _{OL} | Low Level Output Current | | | 3 | mA | |
| I _{IH} | High level input current | | | ±36 | µA | |
| I _{IL} | Low level input current | | | ±36 | µA | |
| R _{PU} | Internal pull-up resistance | | 100 | | kΩ | |
| R _{PD} | Internal pull-down resistance | | 100 | | kΩ | |
| R _(RSTN) | RSTN control input pullup resistor | | 300 | | kΩ | |
| MIPI Input Leakage (DA1P/N, DA2P/N, DA3P/N, DACP/N) | | | | | | |
| I _{lkg} | Input failsafe leakage current | V _{CC} = 0 V; V _{DD} = 0 V; MIPI DPHY pulled up to 1.35 V | -65 | | 65 | µAV |
| MIPI DPHY HS RECIEVER INTERFACE (DA0P/N, DA1P/N, DA2P/N, DA3P/N, DACP/N) | | | | | | |
| V _(CM-RX_DC) | Differential Input Common-mode voltage HS Receive mode | V _(CM-RX) = (V _{AxP} + V _{AxN})/2 | 70 | | 330 | mV |
| V _{ID} | HS Receiver input differential voltage | V _{ID} = V _{AxP} - V _{AxN} | 70 | | | mV |
| V _{IH(HS)} | Single-ended input high voltage | | | | 460 | mV |
| V _{IL(HS)} | Single-ended input low voltage | | -40 | | | mV |
| R _(DIFF-HS) | Differential input impedance | | 80 | 100 | 125 | Ω |
| V _(RXEQ0) | RX EQ gain when EQ/SCL pin ≤ V _{IL} | | | 0 | | dB |
| V _(RXEQ1) | RX EQ gain when EQ/SCL pin = V _{IM} | At 750 MHz | | 2.5 | | dB |
| V _(RXEQ2) | RX EQ gain when EQ/SCL pin ≥ V _{IH} | At 750 MHz | | 5 | | dB |
| MIPI DPHY LP Receiver Interface (DA0P/N, DA1P/N, DA2P/N, DA3P/N, DACP/N, DB0P/N) | | | | | | |
| V _(LPIH) | LP Logic 1 Input Voltage | | 880 | | | mV |
| V _(LPIL) | LP Logic 0 Input voltage | | | 550 | | mV |
| V _(HYST) | LP Input Hysteresis | | 25 | | | mV |
| MIPI DPHY HS Transmitter Interface (DB0P/N, DB1P/N, DB2P/N, DB3P/N, DBCP/N) | | | | | | |
| V _(CMTX) | HS Transmit static common-mode voltage | V _(CMTX) = (V _(BP) + V _(BN)) / 2 | 150 | 200 | 300 | mV |
| ΔV _(CMTX) (1,0) | VCMTX mismatch when output is Differential-1 or differential-0. | ΔV _(CMTX) (1,0) = (V _(CMTX) (1) - V _(CMTX) (0)) / 2 | | | 5 | mV |
| V _{OD(VD0)} | HS Transmit differential voltage for CFG0 = 2'b00 with TX pre-emphasis disabled or for non-transition bit when TX pre-emphasis is enabled. | V _{OD} = V _(DP) - V _(DN) | 140 | 180 | 220 | mV |

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------|---|---|-----|-----|-----|------|
| $ V_{OD(VD1)} $ | HS Transmit differential voltage for CFG0 = V_{IM} with TX pre-emphasis disabled or for non-transition bit when TX pre-emphasis is enabled. | $ V_{OD} = V_{(DP)} - V_{(DN)} $ CFG0 = V_{IM} | 160 | 200 | 250 | mV |
| $ V_{OD(VD2)} $ | HS Transmit differential voltage for CFG0 = V_{IH} with TX pre-emphasis disabled or for non-transition bit when pre-emphasis is enabled.. | $ V_{OD} = V_{(DP)} - V_{(DN)} $ CFG0 $\geq V_{IH}$ | 170 | 220 | 270 | mV |
| $ \Delta V_{OD} $ | V_{OD} mismatch when output is differential-1 or differential-0. | $\Delta V_{OD} = \Delta V_{O(D1)} - \Delta V_{O(D0)} $ | | | 14 | mV |
| $V_{OH(HS)}$ | HS Output high voltage for non-transition bit. | CFG0 $\geq V_{IH}$ HS Pre = 2.5 dB | | | 430 | mV |
| $V_{(PRE1)}$ | Pre-emphasis Level for HSTX_PRE = 2'b00.. Refer to Figure 5-3 | PRE = 20 x LOG ($V_{OD(TBX)} / V_{OD(VDX)}$) | | 1.5 | | dB |
| $V_{(PRE2)}$ | Pre-emphasis level for HSTX_PRE = 2'b1X. Refer to Figure 5-3 | PRE = 20 x LOG ($V_{OD(TBX)} / V_{OD(VDX)}$) | | 2.5 | | dB |

MIPI DPHY LP Transmitter Interface (DB0P/N, DB1P/N, DB2P/N, DB3P/N, DBCP/N, DA0P/N)

| | | | | | | |
|--------------|------------------------------------|--|-----|-----|-----|----------|
| $V_{(LPOH)}$ | LP Output High Level | | 1.1 | 1.2 | 1.3 | V |
| $V_{(LPOL)}$ | LP Output Low Level | | -50 | | 50 | mV |
| $V_{IH(CD)}$ | LP Logic 1 contention threshold | | 450 | | | mV |
| $V_{IL(CD)}$ | LP Logic 0 contention threshold | | | | 200 | mV |
| $Z_{O(LP)}$ | Output Impedance of LP transmitter | | 110 | | | Ω |

5.7 Timing Requirements

| | | MIN | NOM | MAX | UNIT |
|---|---|---|----------|----------|---------|
| I²C (ERC (SDA), EQ (SCL)) | | | | | |
| $t_{HD:STA}$ | Hold Time (repeated) START condition. After this period, the first clock pulse is generated | 4 | | | μ s |
| t_{LOW} | Low period of SCL clock | 4.7 | | | μ s |
| t_{HIGH} | High period of SCL clock | 4 | | | μ s |
| $t_{SU:STA}$ | Setup time for a repeated START condition | 4.7 | | | μ s |
| $t_{HD:DAT}$ | Data hold time | 5 | | | ns |
| $t_{SU:DAT}$ | Data setup time | 250 | | | ns |
| $t_{SU:STO}$ | Setup time for STOP condition | 4 | | | μ s |
| t_{BUF} | Bus free time between a STOP and START condition | 4.7 | | | μ s |
| f_{CLK} | I ² C clock frequency | 0 | | 100 | kHz |
| MIPI DPHY HS Interface | | | | | |
| t_{HSPD} | Propagation delay from DA to DB. | | 4 + 12ns | 4 + 40ns | UI |
| t_{DBC_DCYCLE} | DAC to DBC output duty cycle distortion percentage | 750 MHz clock with 50%-50% duty cycle at DAC input. | -5 | 5 | % |
| $t_{SKEW-TX-1G}$ | Data to Clock variation from 0.5UI. Refer to Figure 5-2 | Datarate \leq 1 Gbps | -0.1 | 0.1 | UI |
| $t_{SETUP-RX-1G}$ | Data to Clock setup time. Refer to Figure 5-2 | Datarate \leq 1 Gbps | 0.1 | | UI |
| $t_{HOLD-RX-1G}$ | Clock to data hold time. Refer to Figure 5-2 | Datarate \leq 1 Gbps | 0.1 | | UI |
| $t_{SKEW-TX-1P5G}$ | Data to Clock variation from 0.5UI. Refer to Figure 5-2 | Datarate $>$ 1 Gbps | -0.15 | 0.15 | UI |
| $t_{SETUP-RX-1P5G}$ | Data to Clock setup time. Refer to Figure 5-2 | Datarate $>$ 1 Gbps | 0.15 | | UI |
| $t_{HOLD-RX-1P5G}$ | Clock to data hold time. Refer to Figure 5-2 | Datarate $>$ 1 Gbps | 0.15 | | UI |

5.8 Switching Characteristics

over operating free-air temperature range (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP (1) | MAX | UNIT |
|--|---|--|---------|------|--------|
| I²C (ERC (SDA), EQ (SCL)) | | | | | |
| F _(SCL) | I ² C Clock Frequency | | | 100 | kHz |
| t _{F,I²C} | Fall time of both SDA and SCL signals | Load of 350 pF with 2-K pullup resistor. | | 300 | ns |
| t _{R,I²C} | Rise Time of both SDA and SCL signals | Measure at 30% - 70% | | 1000 | ns |
| DPHY LINK | | | | | |
| F _(BR) | Bit Rate | | | 1.5 | Gbps |
| F _(HSCLK) | HS Clock Input range | 100 | | 750 | MHz |
| F _(DESKEW) | Automatic Deskew range | 220 | | 750 | MHz |
| MIPI DPHY HS Receiver Interface (DA0P/N, DA1P/N, DA2P/N, DA3P/N, DACP/N) | | | | | |
| ΔV _(CMRX_HF) | Common-mode Interface beyond 450 MHz | | | 100 | mV |
| ΔV _(CMRX_LF) | Common-mode interference 50 MHz – 450 MHz | -50 | | 50 | mV |
| MIPI DPHY HS Transmitter Interface (DB0P/N, DB1P/N, DB2P/N, DB3P/N, DBCP/N) | | | | | |
| ΔV _(CMRX_HF) | Common-level variations above 450 MHz | | | 5 | mVrms |
| ΔV _(CMRX_LF) | Common-level variation between 50 MHz – 450 MHz. | | | 25 | mVpeak |
| t _R and t _F | 20% - 80% rise time and fall time | Datarate ≤ 1 Gbps | | 0.3 | UI |
| | | Datarate > 1 Gbps | | 0.35 | UI |
| | | | | 100 | ps |
| MIPI DPHY LP Receiver Interface (DA0P/N, DA1P/N, DA2P/N, DA3P/N, DACP/N, DB0P/N) | | | | | |
| e _{SPIKE} | Input Pulse rejection | | | 300 | V ps |
| t _{MIN(RX)} | Minimum pulse width response | 20 | | | ns |
| V _(INT) | Peak interference amplitude | | | 200 | mv |
| F _(INT) | Interference Frequency | 450 | | | Mhz |
| t _(LP-PULSE-RX) | Pulse Width of the XOR of DAxP and DAxN | First LP XOR clock pulse after Stop state or last pulse before Stop state. | | 42 | ns |
| | | All other pulses. | | 22 | ns |
| MIPI DPHY LP Transmitter Interface (DB0P/N, DB1P/N, DB2P/N, DB3P/N, DBCP/N, DA0P/N) | | | | | |
| t _{REOT} | 30% - 85% rise time and fall time | Measured at end of HS transmission. | | 35 | ns |
| t _(LP-PULSE-TX) | Pulse Width of the LP XOR clock | First LP XOR clock pulse after Stop state or last pulse before Stop state | | 40 | ns |
| | | All other pulses | | 20 | ns |
| t _(LP-PER-TX) | Period of the LP XOR clock | | | 90 | ns |
| δV/δtsr | Slew Rate at C _{LOAD} = 70 pF | | | 150 | mV/ns |
| | Slew Rate at C _{LOAD} = 0 pF Falling edge only | | | 30 | mV/ns |
| | Slew Rate at C _{LOAD} = 0 pF Rising edge only | | | 30 | mV/ns |
| C _{LOAD} | Load Capacitance | | | 70 | pF |

(1) (1) All typical values are at V_{CC} = 3.3 V, and T_A = 25°C.

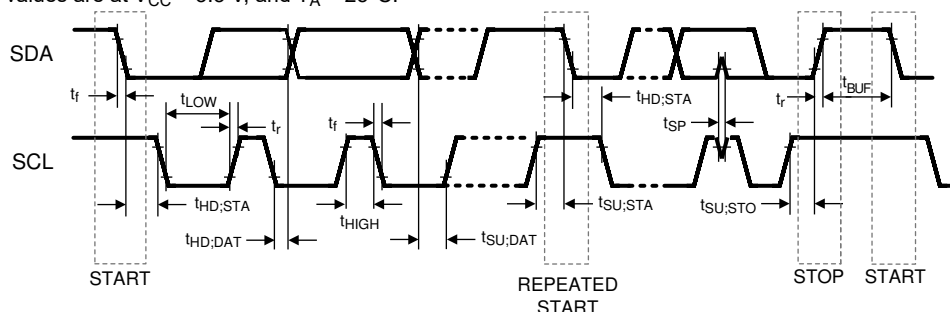


Figure 5-1. I²C Timing

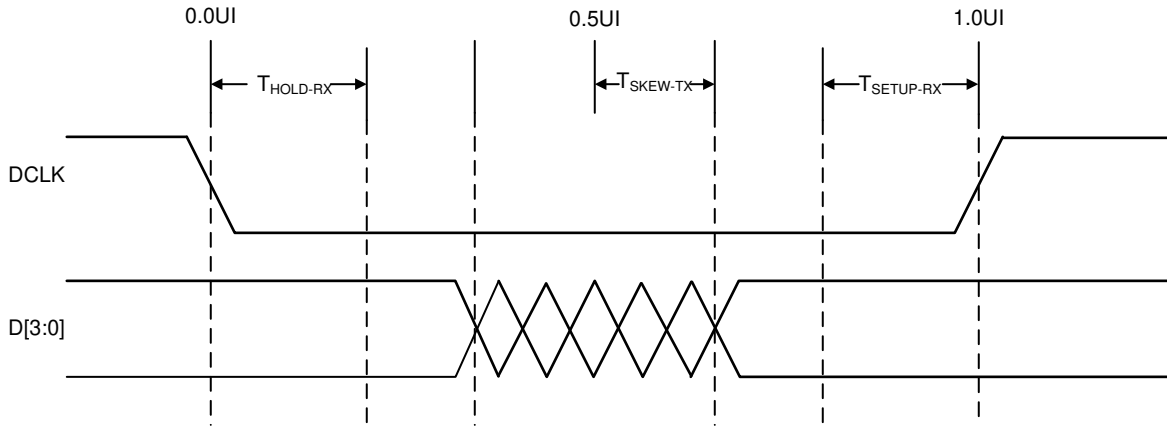


Figure 5-2. DPHY HS RX and TX Timing

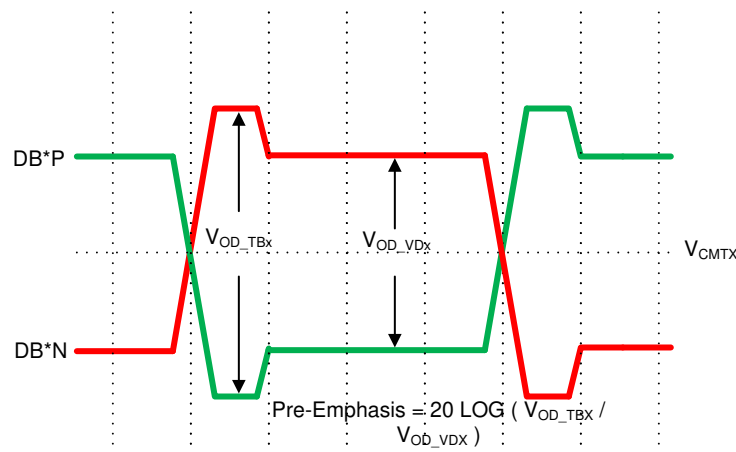
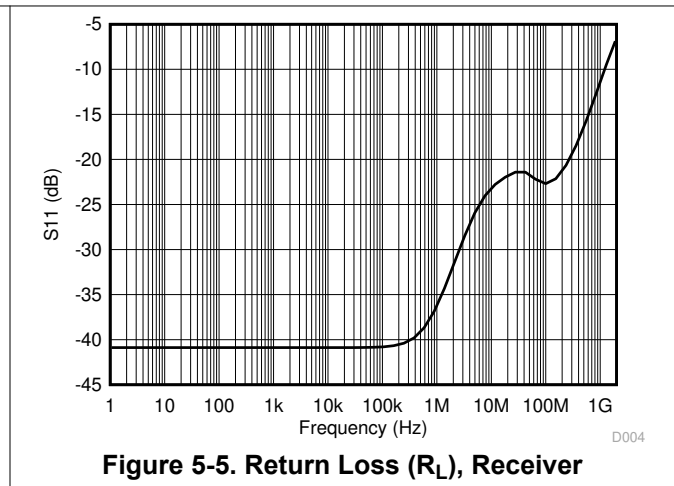
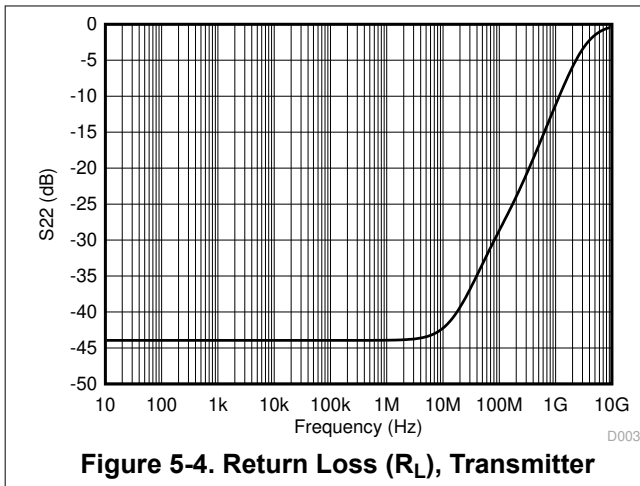


Figure 5-3. DPHY HS TX Pre-Emphasis

5.9 Typical Characteristics



6 Detailed Description

6.1 Overview

The DPHY440SS is a one to four lane and clock MIPI DPHY re-driver that regenerates the DPHY signaling. The device complies with MIPI DPHY 1.1 standard and can be used in either a MIPI CSI-2 or MIPI DSI application at datarates of up to 1.5 Gbps.

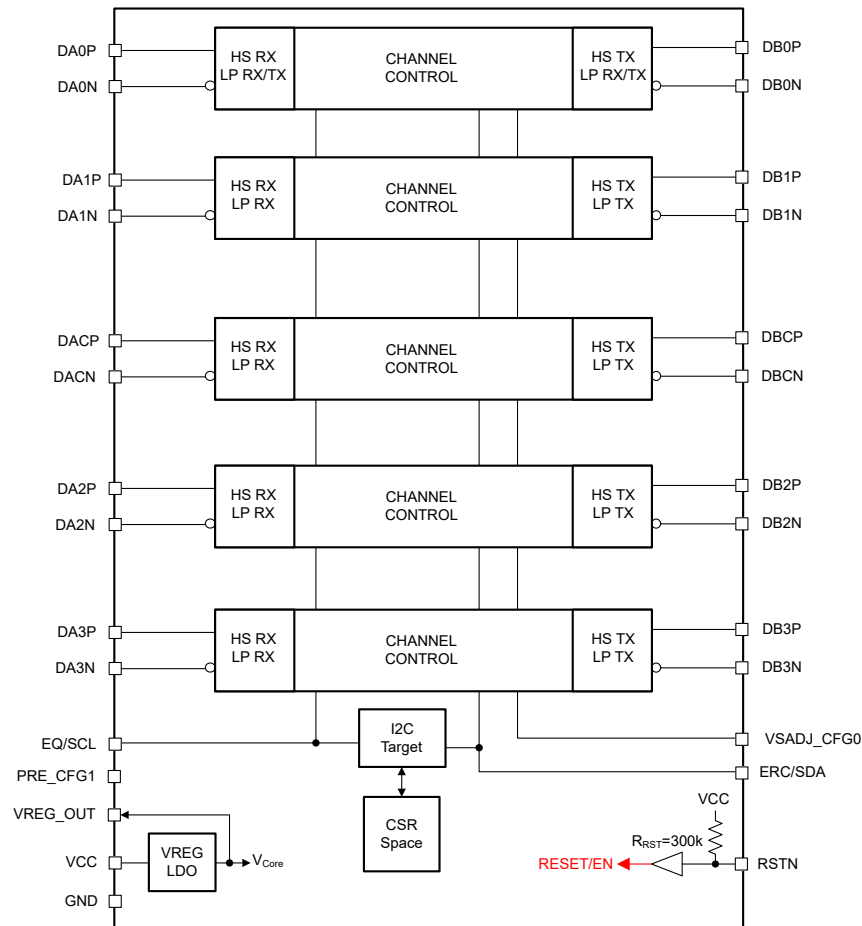
The device compensates for PCB, connector, and cable related frequency loss and switching related loss to provide the optimum electrical performance from a CSI2/DSI source to sink. The DPHY440 DPHY inputs feature configurable equalizers.

The output pins will automatically compensate for uneven skew between clock and data lanes. The DPHY440 output swing and edge rate can be adjusted by changing the state of the VSADJ_CFG0 pin and ERC pin respectively.

The DPHY440 is optimized for mobile applications, and contains activity detection circuitry on the DPHY Link interface that can transition into a lower power mode when in ULPS and LP states.

The device is characterized for an extended operational temperature range from -40°C to 85°C .

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 HS Receive Equalization

The DPHY440 supports three levels of receive equalization to compensate for ISI loss in the channel. These three levels are 0 dB, 2.5 dB, and 5 dB at 750MHz. The equalization level used by the DPHY440 is determined by the state of the EQ/SCL pin at the rising edge of RSTN. If necessary, the receiver equalization level can also be set through writing to the RXEQ register via the local I²C interface

Table 6-1. EQ/SCL Pin Functions

| EQ/SCL PIN | HS RX EQUALIZATION |
|---------------|---------------------------------------|
| $\leq V_{IL}$ | 0 dB |
| V_{IM} | 2.1 dB at 500 MHz / 2.5 dB at 750 MHz |
| $\geq V_{IH}$ | 4 dB at 500 MHz / 5 dB at 750 MHz |

6.3.2 HS TX Edge Rate Control

The DPHY440 supports control of the rise and fall time for the DB[3:0]P/N and DBCP/N High Speed (HS) transmitters. Depending on system operating datarate, the HS edge rate may need to be adjusted to help improve EMI performance. The HS edge rate setting is determined through the sampled state of ERC/SDA pin at the rising edge of RSTN. If necessary, the HS edge rate can be adjusted by writing to the HS_ERC register via the local I²C interface.

Table 6-2. 8.3.2 HS TX Edge Rate Control

| ERC/SDA PIN | HS RISE/FALL TIMES |
|---------------|--------------------|
| $\leq V_{IL}$ | 200 ps typical |
| V_{IM} | 150 ps typical |
| $\geq V_{IH}$ | 250 ps typical |

The DPHY440 also supports edge rate control for the LP interface. The adjustment of LP TX edge rate is determined by the state of the VSADJ_CFG0 and PRE_CFG1 pins as depicted in [Table 6-3](#), but can also be modified by changing LP_ERC register through the local I²C interface

6.3.3 TX Voltage Swing and Pre-Emphasis Control

In some applications, the DPHY440 may be placed at a location in the system where the channel from DPHY440 DB[3:0]P/N interface to the DPHY Sink (CSI-2 or DSI) is extremely long and the DPHY Sink does not have enough receive equalization to compensate for the ISI loss. In this application, the system architect may want to use the DPHY440 TX pre-emphasis feature to compensate for the lack of equalization at the DPHY sink. The DPHY440 provides two levels of pre-emphasis: 0 dB, and 2.5 dB. The TX pre-emphasis settings is determined through the sampled sate of PRE_CFG[1:0] pins at the rising edge of RSTN. If necessary, the TX pre-emphasis settings can be adjusted by writing to the HSTX_PRE register through the local I²C interface.

This feature must only be used when the HS pre-emphasis bit (transition bit) is attenuated by the channel. Enabling pre-emphasis in a system that has little channel loss (transition bit is not attenuated) may result in negative impact to system performance.

Table 6-3. HS Voltage Swing, HS Pre-Emphasis, LPTX Edge Rate Controls

| VSADJ_CFG0 | PRE_CFG1 | HS TX VOD | HS TX PRE-EMPHASIS | DB[3:0] LP TX RISE/FALL TIME |
|---------------|---------------|-----------|--------------------|------------------------------|
| $\leq V_{IL}$ | $\leq V_{IL}$ | 200 mV | 0 dB | 18 ns |
| V_{IM} | $\leq V_{IL}$ | 200 mV | 0 dB | 27 ns |
| $\geq V_{IH}$ | $\leq V_{IL}$ | 220 mV | 0 dB | 18 ns |
| $\leq V_{IL}$ | V_{IM} | 200 mV | 0 dB | 27 ns |
| V_{IM} | V_{IM} | 200 mV | 0 dB | 21 ns |
| $\geq V_{IH}$ | V_{IM} | 220 mV | 0 dB | 21 ns |
| $\leq V_{IL}$ | $\geq V_{IH}$ | 220 mV | 2.5 dB | 27 ns |
| V_{IM} | $\geq V_{IH}$ | 200 mV | 2.5 dB | 21 ns |
| $\geq V_{IH}$ | $\geq V_{IH}$ | 220 mV | 2.5 dB | 21 ns |

6.3.4 Dynamic De-skew

The DPHY440 implements a dynamic de-skew feature which will continuously de-skew the HS data received on the DA[3:0]P/N interface and provide a retimed version on the DB[3:0]P/N interface. The retimed version is centered within the DBCP/N clock.

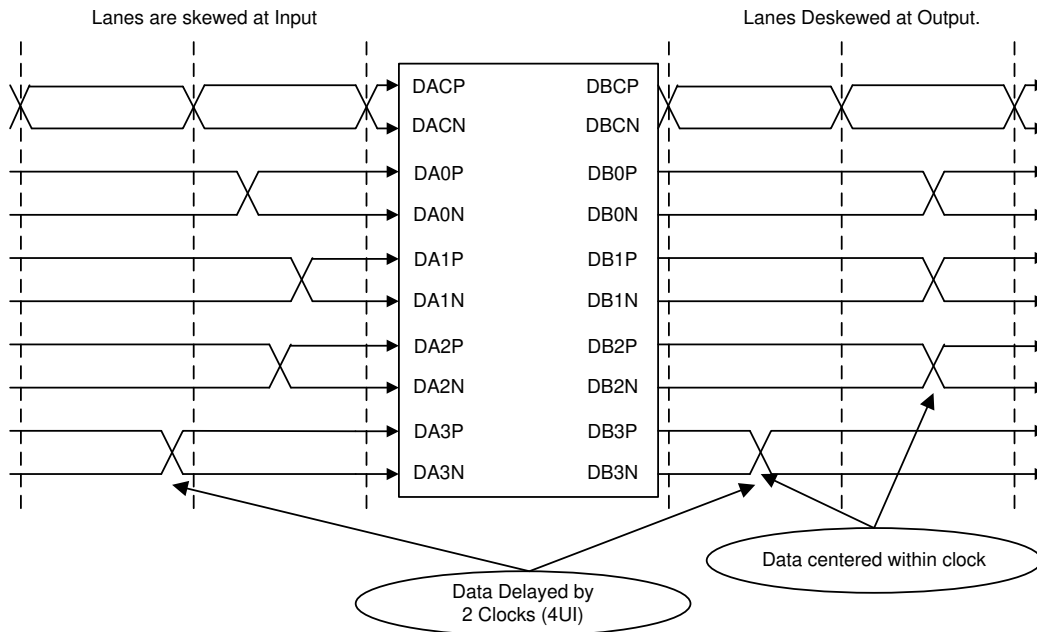


Figure 6-1. Dynamic De-skew

Note

The dynamic de-skew feature is only enabled in HS mode, and causes a 2 clock (4 UI) delay of data while data traverses from DA to DB.

6.4 Device Functional Modes

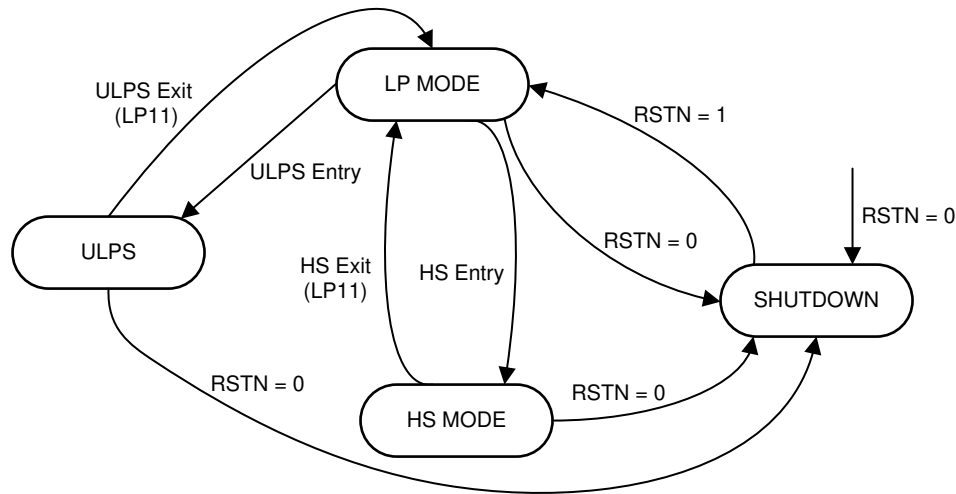


Figure 6-2. Functional Modes

6.4.1 Shutdown Mode

The DPHY440 can be placed into a low power consumption state by asserting the RSTN pin low while maintaining a stable V_{CC} and V_{DD} power supply. While in the Shutdown state, the DPHY440 drives DB[3:0]P/N and DBCP/N pins to the LP00 state. The DPHY440 ignores all activity on the DA[3:0]P/N and DACP/N pins while in Shutdown mode. The Shutdown mode is exited by deasserting the RSTN pin high. Upon exiting Shutdown mode, the DPHY440 enters LP Mode operation and pass what is received on the DA interface to the DB interface.

6.4.2 LP Mode

In this mode, the DPHY440 passes LP signals between DA[3:0]P/N and DB[3:0]P/N. The internal terminations for the HS receiver and HS transmitter are disabled when operating in this mode.

The MIPI DSI specification defines bidirectional communication between the host and peripheral. When a response is needed by the peripheral, the response is returned using LP signaling from DB0P/N to DA0P/N. The DPHY440 only supports this communication over lane 0 (DB0P/N to DA0P/N). The remaining lanes cannot be used for LP communications from peripheral to host (reverse direction).

6.4.3 ULPS Mode

The DPHY440 is continuously monitoring the DPHY LP protocol for entry into the ULPS state. Upon entry into the ULPS state, the DPHY440 keeps active the logic necessary for LP signaling (LP rx, LPtx, LP state machine, so forth). All logic needed for HS operation are disabled. This allows for a lower power state than can be achieved when in operating other LP power states.

Note

ULPS mode can only be entered from LP Mode.

6.4.4 HS Mode

The HS mode is entered when the required sequence of LP signals is detected by the LP state machine. In this mode, the internal termination for both the HS receiver and HS transmitter is enabled and the dynamic de-skew feature is enabled. The DPHY440 remains in this mode until a HS exit is detected by the LP state machine. Upon detecting the HS exit, the DPHY440 immediately transitions to [LP Mode](#).

6.5 Register Maps

The DPHY440 local I²C interface is enabled when RSTN is input high. Access to the CSR registers is supported during ultra-low power state (ULPS). The EQ/SCL and ERC/SDA terminals are used for I²C clock and I²C data respectively. The DPHY440 I²C interface conforms to the two-wire serial interface defined by the I²C Bus Specification, Version 2.1 (January 2000) and supports up to 100 kHz.

The device address byte is the first byte received following the START condition from the controller device. The 7 bit device address for DPHY440 is factory preset to 1101100.

Table 6-4. DPHY440 I²C Target Address Description

| Bit 7 (MSB) | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 (W/R) |
|---|-------|-------|-------|-------|-------|-------|-------------|
| 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0/1 |
| Address Cycle is 0xD8 (Write) and 0xD9 (Read) | | | | | | | |

The following procedure should be followed to write to the DPHY440 I²C registers:

1. The controller initiates a write operation by generating a start condition (S), followed by the DPHY440 7-bit address and a zero-value “W/R” bit to indicate a write cycle.
2. The DPHY440 acknowledges the address cycle.
3. The controller presents the sub-address (I²C register within DPHY440) to be written, consisting of one byte of data, MSB-first
4. The DPHY440 acknowledges the sub-address cycle.
5. The controller presents the first byte of data to be written to the I²C register.
6. The DPHY440 acknowledges the byte transfer.
7. The controller may continue presenting additional bytes of data to be written, with each byte transfer completing with an acknowledge from the DPHY440.
8. The controller terminates the write operation by generating a stop condition (P).

The following procedure should be followed to read the DPHY440 I²C registers:

1. The controller initiates a read operation by generating a start condition (S), followed by the DPHY440 7-bit address and a one-value “W/R” bit to indicate a read cycle
2. The DPHY440 acknowledges the address cycle.
3. The DPHY440 transmit the contents of the memory registers MSB-first starting at register 00h or last read sub-address+1. If a write to the DPHY440 I²C register occurred prior to the read, then the DPHY440 starts at the sub-address specified in the write.
4. The DPHY440 will wait for either an acknowledge (ACK) or a not-acknowledge (NACK) from the controller after each byte transfer; the I²C controller acknowledges reception of each data byte transfer.
5. If an ACK is received, the DPHY440 transmits the next byte of data.
6. The controller terminates the read operation by generating a stop condition (P).

The following procedure should be followed for setting a starting sub-address for I²C reads:

1. The controller initiates a write operation by generating a start condition (S), followed by the DPHY440 7-bit address and a zero-value “W/R” bit to indicate a write cycle.
2. The DPHY440 acknowledges the address cycle.
3. The controller presents the sub-address (I²C register within DPHY440) to be written, consisting of one byte of data, MSB-first.
4. The DPHY440 acknowledges the sub-address cycle.
5. The controller terminates the write operation by generating a stop condition (P).

Note

If no sub-addressing is included for the read procedure, and reads start at register offset 00h and continue byte by byte through the registers until the I²C controller terminates the read operation. If a I²C write occurred prior to the read, then the reads start at the sub-address specified by the write.

6.5.1 BIT Access Tag Conventions

A table of bit descriptions is typically included for each register description that indicates the bit field name, field description, and the field access tags. The field access tags are described in [Table 6-5](#).

Table 6-5. Tag Conventions

| ACCESS TAG | NAME | DEFINITION |
|------------|-----------|--|
| R | Read | The field may be read by software. |
| W | Write | The field may be written by software |
| S | Set | The field may be set by a write of one. Writes of zero to the field have no effect. |
| C | Clear | The field may be cleared by a write of one. Write of zero to the field have no effect. |
| U | Update | Hardware may autonomously update this field |
| N/A | No Access | Not accessible or not applicable |

6.5.2 Standard CSR Registers (address = 0x000 - 0x07)

Figure 6-3. Standard CSR Registers (0x000 - 0x07)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----------|---|---|---|---|---|---|---|
| DEVICE_ID | | | | | | | |
| R | R | R | R | R | R | R | R |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-6. Standard CSR Registers (0x000 - 0x07)

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|---|
| 7:0 | DEVICE_ID | R | 0 | For the DPHY440 these fields return a string of ASCII characters returning "DPHY100". Addresses 0x07 - 0x00 = {0x20, 0x30, 0x30, 0x31, 0x59, 0x48, 0x50, 0x44} |

6.5.3 Standard CSR Register (address = 0x08)

Figure 6-4. Standard CSR Register (0x08)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|------------|---|---|---|---|---|---|---|
| DEVICE_REV | | | | | | | |
| R | R | R | R | R | R | R | R |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-7. Standard CSR Register (0x08)

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|------------------|
| 7:0 | DEVICE_REV | R | 0 | Device revision. |

6.5.4 Standard CSR Register (address = 0x09)

Figure 6-5. Standard CSR Register(0x09)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|----|----|-----------|----|-----------|----|----|
| Reserved | | | RXEQ_CLK. | | RXEQ_DATA | | |
| R | RW | RW | RW | RW | RW | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-8. Standard CSR Register (0x09)

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|--|
| 7:4 | Reserved | R | 0 | Reserved |
| 3:2 | RXEQ_CLK | RW | 0 | This field selects the EQ level of the DACP/N. The value in this field will match the sampled state of EQ/SCL pin at the rising edge of RSTN. Software can change the value of this field at a later time. 00 – 0 dB (EQ/SCL pin = V _{IL}) 01 – 2.5 dB (EQ/SCL pin = V _{IM}) 10 – Reserved. 11 – 5 dB (EQ/SCL pin = V _{IH}) |
| 1:0 | RXEQ_DATA | RW | 0 | This field selects the EQ level of the DA[3:0]P/N . The value in this field will match the sampled state of EQ/SCL pin at the rising edge of RSTN. Software can change the value of this field at a later time. 00 – 0 dB. (EQ/SCL pin = V _{IL}) 01 – 2.5 dB (EQ/SCL pin = V _{IM}) 10 – Reserved. 11 – 5 dB. (EQ/SCL pin = V _{IH}) |

6.5.5 Standard CSR Register (address = 0x0A)

Figure 6-6. Standard CSR Register (0x0A)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|------------|----|------------|----|----------|---|---------|----|
| LPTXDA_ERC | | LPTXDB_ERC | | Reserved | | HSC_ERC | |
| RW | RW | RW | RW | R | R | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-9. Standard CSR Register (0x0A)

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|--|
| 7:6 | LPTXDA_ERC | RW | 0 | This field controls the edge rate of the DA0P/N LP transmitters. 00 – 18 ns at 70 pF (Default) 01 – 21 ns at 70 pF 10 – 15 ns at 70 pF 11 – 27 ns at 70 pF |
| 5:4 | LPTXDB_ERC | RW | 0 | This field controls the edge rate of the DB[3:0]P/N LP transmitters. The value in this field will be updated by hardware based on the state of the CFG[1:0] pin. Refer to Table 6-3 for settings based on sampled state of CFG[1:0] Software can change the value of this field at a later time. 00 – 18 ns at 70 pF 01 – 21 ns at 70 pF 10 – 15 ns at 70 pF 11 – 27 ns at 70 pF |
| 3:2 | Reserved | R | | Reserved |

Table 6-9. Standard CSR Register (0x0A) (continued)

| Bit | Field | Type | Reset | Description |
|-----|---------|------|-------|---|
| 1:0 | HSC_ERC | RW | 0 | This field controls the edge rate of the DBCP/N high speed transmitter. The value of this field will match the sampled state of the ERC pin. Software can change the value of this field at a later time. 00 – 200 ps at 1 Gbps. (ERC pin = V _{IL}) 01 – 150 ps at 1 Gbps. (ERC pin = V _{IM}) 10 – 250 ps at 1 Gbps. (ERC pin = V _{IH}) 11 – 300 ps at 1 Gbps |

6.5.6 Standard CSR Register (address = 0x0B)

Figure 6-7. Standard CSR Register (0x0B)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----------|----|-----------|----|-----------|----|-----------|----|
| HSDB3_ERC | | HSDB2_ERC | | RHSD1_ERC | | HSDB0_ERC | |
| RW | RW | RW | RW | RW | RW | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-10. Standard CSR Register (0x0B)

| Bit | Field | Type | Reset | Description |
|-----|-----------|------|-------|---|
| 7:6 | HSDB3_ERC | RW | 0 | This field controls the edge rate of the DB3P/N high speed transmitter. The value of this field will match the sampled state of the ERC pin. Software can change the value of this field at a later time. 00 – 200 ps at 1 Gbps. (ERC pin = V _{IL}) 01 – 150 ps at 1 Gbps. (ERC pin = V _{IM}) 10 – 250 ps at 1 Gbps. (ERC pin = V _{IH}) 11 – 300 ps at 1 Gbps |
| 5:4 | HSDB2_ERC | RW | 0 | This field controls the edge rate of the DB2P/N high speed transmitter. The value of this field will match the sampled state of the ERC pin. Software can change the value of this field at a later time. 00 – 200 ps at 1 Gbps. (ERC pin = V _{IL}) 01 – 150 ps at 1 Gbps. (ERC pin = V _{IM}) 10 – 250 ps at 1 Gbps. (ERC pin = V _{IH}) 11 – 300 ps at 1 Gbps |
| 3:2 | RHSD1_ERC | RW | 0 | This field controls the edge rate of the DB1P/N high speed transmitter. The value of this field will match the sampled state of the ERC pin. Software can change the value of this field at a later time. 00 – 200 ps at 1 Gbps. (ERC pin = V _{IL}) 01 – 150 ps at 1 Gbps. (ERC pin = V _{IM}) 10 – 250 ps at 1 Gbps. (ERC pin = V _{IH}) 11 – 300 ps at 1 Gbps |
| 1:0 | HSDB0_ERC | RW | 0 | This field controls the edge rate of the DB0P/N high speed transmitter. The value of this field will match the sampled state of the ERC pin. Software can change the value of this field at a later time. 00 – 200 ps at 1 Gbps. (ERC pin = V _{IL}) 01 – 150 ps at 1 Gbps. (ERC pin = V _{IM}) 10 – 250 ps at 1 Gbps. (ERC pin = V _{IH}) 11 – 300 ps at 1 Gbps |

6.5.7 Standard CSR Register (address = 0x0D)

Figure 6-8. Standard CSR Register (0x0D)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-----------|--------------|--------------|----------|--------------|--------------|---|---|
| Reserved. | CDB0N_STATUS | CDB0P_STATUS | Reserved | CDA0N_STATUS | CDA0P_STATUS | | |
| R | R | R | R | R | R | R | R |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-11. Standard CSR Register (0x0D)

| Bit | Field | Type | Reset | Description |
|-----|--------------|------|-------|--|
| 7:6 | Reserved. | R | | Reserved. |
| 5 | CDB0N_STATUS | R | 0 | 0 – Contention not detected on DB0N interface.(default) 1 – Contention detected on DB0N interface |
| 4 | CDB0P_STATUS | R | 0 | 0 – Contention not detected on DB0P interface.(default) 1 – Contention detected on DB0P interface |
| 3:2 | Reserved | R | | Reserved |
| 1 | CDA0N_STATUS | R | 0 | 0 – Contention not detected on DA0N interface.(default) 1 – Contention detected on DA0N interface |
| 0 | CDA0P_STATUS | R | 0 | 0 – Contention not detected on DA0P interface.(default) 1 – Contention detected on DA0P interface |

6.5.8 Standard CSR Register (address = 0x0E)

Figure 6-9. Standard CSR Register (0x0E)

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|----------|------------|----------|----------|---|---|----|----|
| Reserved | HSTX_VSADJ | Reserved | HSTX_PRE | | | | |
| R | R | RW | RW | R | R | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-12. Standard CSR Register (0x0E)

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|---|
| 7:6 | Reserved | R | | Reserved |
| 5:4 | HSTX_VSADJ | RWU | 0 | This field controls the HS TX voltage swing level. The value of this field will match the sampled state of the CFG[1:0] pins. Software can change the value of this field at a later time. 00 – 180 mV 01 – 200 mV (CFG0 = V _{IM} or (CFG0 = V _{IL} and !CFG1 = V _{IH})) 1X – 220mV (CFG0 = V _{IH} or (CFG0 = V _{IL} and CFG1 = V _{IH})) |
| 3:2 | Reserved | R | | Reserved |
| 1:0 | HSTX_PRE | RWU | 0 | This field controls the HS TX pre-emphasis level. The value of this field will match the sampled state of CFG1 pin. Software can change the value of this field at a later time. 00 – 1.5 dB 01 – 0 dB (CFG1 = V _{IM} or V _{IL}) 1X – 2.5 dB (CFG1 = V _{IH}) |

6.5.9 Standard CSR Register (address = 0x10) [reset = 0xFF]

Figure 6-10. Standard CSR Register (0x10)

| | | | | | | | |
|------------|----|----|----|----|----|----|----|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| LPTXDA_ERC | | | | | | | |
| RW | RW | RW | RW | RW | RW | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-13. Standard CSR Register (0x10)

| Bit | Field | Type | Reset | Description |
|-----|------------|------|-------|--|
| 7:0 | LPTXDA_ERC | RW | 0xFF | This field represents the lower 8-bits of the 16-bit BTA_TIMEOUT register. Timer is reset to default state when BTA request is detected and is stopped when BTA is acknowledged. If BTA is not acknowledged before this timer expires, then DPHY440 will terminate BTA operation. This counter operates on the LPTX clock. Defaults to 0xFF. |

6.5.10 Standard CSR Register (address = 0x11) [reset = 0xFF]

Figure 6-11. Standard CSR Register (0x11)

| | | | | | | | |
|----------------|----|----|----|----|----|----|----|
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BTA_TIMEOUT_HI | | | | | | | |
| RW | RW | RW | RW | RW | RW | RW | RW |

LEGEND: R/W = Read/Write; R = Read only; -n = value after reset

Table 6-14. Standard CSR Register (0x11)

| Bit | Field | Type | Reset | Description |
|-----|----------------|------|-------|--|
| 7:0 | BTA_TIMEOUT_HI | RW | 0xFF | This field represents the upper 8-bits of the 16-bit BTA_TIMEOUT register. Timer is reset to default state when BTA request is detected and is stopped when BTA is acknowledged. If BTA is not acknowledged before this timer expires, then DPHY440 will terminate BTA operation. This counter operates on the LPTX clock. Defaults to 0xFF. |

7 Application and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information,

The DPHY440 supports up to 4 DSI DPHY lanes and a clock lane. One of the four lanes is used for back channel communications between GPU and DSI panel. DPHY440's lane 0 is the only lane that supports the back channel. For this reason, DPHY440 lane 0 must always be connected to lane 0 of GPU and panel.

Other combinations, like 1 and 3 lane, examples are not shown, but are fully supported by the DPHY440. For all DSI implementations, the polarity must be maintained between the DSI Source and DSI Sink. The DPHY440 does not support polarity inversion.

7.2 Typical Application, CSI-2 Implementations

The DPHY440 supports 4 CSI-2 DPHY lanes plus a clock. Unlike DSI, CSI-2 does not have a back channel path. Because of this, there is no requirement on lane ordering. Because there is no lane ordering requirement, there are more combinations which can be implemented. All possible combinations are supported by the DPHY440. For all CSI-2 implementations, the polarity must be maintained between the CSI-2 Source and CSI-2 Sink. The DPHY440 does not support polarity inversion.

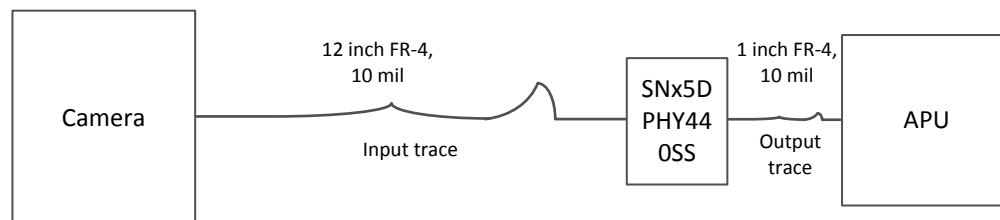


Figure 7-1. CSI-2 Example: Typical SNx5DPHY440SS Placement in the System

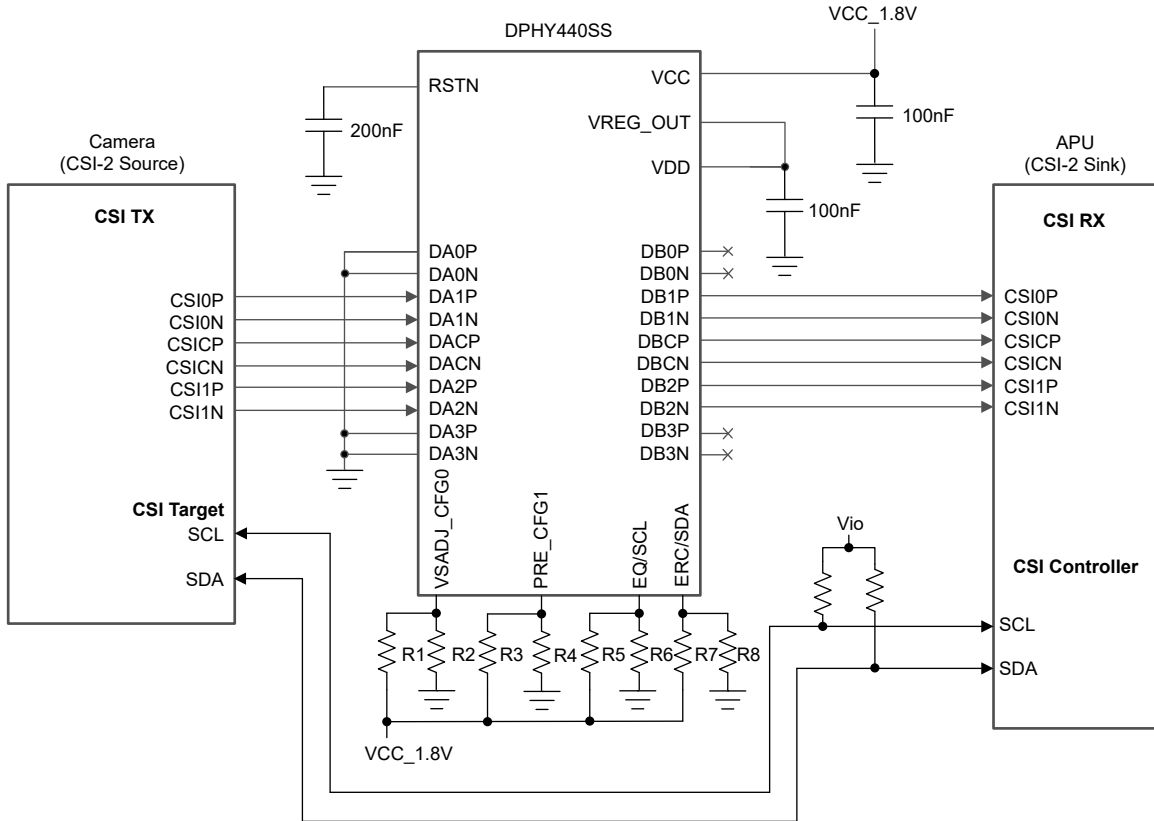


Figure 7-2. CSI-2 Two Lane Example

7.2.1 Design Requirements

Typically, in CSI-2 applications, the system trace length from the Camera (Source) to the DPHY440 device is different from that of the trace length from DPHY440 to the APU (Sink). Consequently, different pre-emphasis and equalization settings are required on the receiver and transmitter side of the device respectively.

For this design example, refer to Figure 7-1 and Figure 7-2. Shown is a CSI-2 system implementation in which the DPHY device is placed close to the Sink (APU). Here, the input trace length is about 12 inch while the output trace length is just 1 inch. The input signal characteristics assumed are shown in Table 7-1.

Table 7-1. Design Parameters

| PARAMETER | VALUE |
|----------------------------------|---------|
| Data Rate (200 Mbps to 1.5 Gbps) | 1 Gbps |
| Input trace length | 12 inch |
| Output trace length | 1 inch |
| Trace width | 10 mils |

7.2.2 Detailed Design Procedure

The typical example describes how to configure the VSADJ, PRE, EQ and ERC configuration pins of the DPHY440 device based on the board trace length between the Source (Camera) and DPHY440 and the DPHY440 and Sink (APU). Actual configuration settings might differ due to additional factors such as board layout, and connectors used in the signal path.

Though the data rate in this example is 1 Gbps, device is placed near to the Sink, with a short output trace of 1 inch. Consequently, the ERC pin can be configured to have a rise/fall time of 250 ps for the edge. Further, due to the short output trace, the PRE pin must be configured to a setting of 0 dB and the VSADJ to be 200 mV. The Application Curve in [Figure 7-6](#) shows the FR-4 loss characteristics of a 10 mil wide, 12 inch long trace. From this plot, the input signal trace suffers a loss of 1.5 dB at 500 MHz. Thus, the EQ setting can be either 0 dB or 2.5 dB. All the configuration settings and their corresponding inputs are tabulated in [Table 7-2](#).

Table 7-2. Configuration Pin Settings

| PIN | SETTING | INPUT VALUE |
|-------|----------------|----------------------|
| VSADJ | 200 mV | V_{IM} |
| PRE | 0 dB | V_{IM} |
| EQ | 0 dB or 2.5 dB | V_{IL} or V_{IM} |
| ERC | 250 ps | V_{IH} |

The configuration pins each have internal pull-up and pull-down resistors of 100 k Ω each. Thus, the recommendation is an external pull-up/pull-down resistors of about 10 k Ω each, to meet the requirement of the threshold levels for the V_{IL} and V_{IH} listed in the [Electrical Characteristics](#) table. The external resistors shown in [Figure 7-2](#) should be populated to produce corresponding configuration settings, according to the list given in [Table 7-3](#).

Table 7-3. Resistor Parameters

| RESISTOR NAME | VALUE |
|---------------|---|
| R1 | Leave unpopulated |
| R2 | Leave unpopulated |
| R3 | Leave unpopulated |
| R4 | Leave unpopulated |
| R5 | Leave unpopulated |
| R6 | 10 k Ω (EQ = 0 dB) or Leave unpopulated (EQ = 2.5 dB) |
| R7 | 10 k Ω |
| R8 | Leave unpopulated |

7.2.2.1 Reset Implementation

The DPHY440 RSTN input gives control over the device reset and to place the device into low power mode. It is critical to reset the digital logic of the DPHY440 after the V_{CC} supply is stable (that is, the power supply has reached the minimum recommended operating voltage). This is achieved by transitioning the RSTN input from a low level to a high level. A system may provide a control signal to the RSTN signal that transitions low to high after the power supply is (or supplies are) stable, or implement an external capacitor connected between RSTN and GND, to allow delaying the RSTN signal during power up. Both implementations are shown in Figure 7-3 and Figure 7-4.

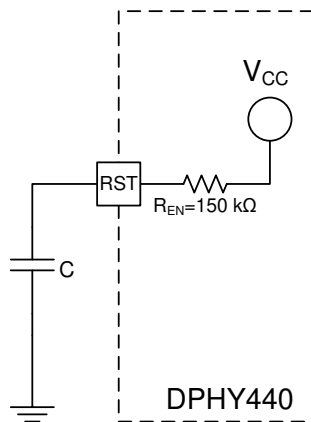


Figure 7-3. External Capacitor Controlled RSTN

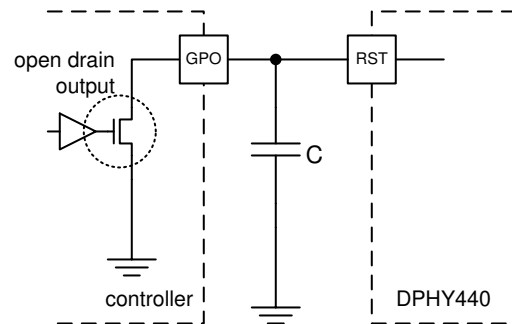


Figure 7-4. RSTN Input from Active Controller

When implementing the external capacitor, the size of the external capacitor depends on the power up ramp of the V_{CC} supply, where a slower ramp-up results in a larger value external capacitor.

Refer to the latest reference schematic for the DPHY440 device and/or consider approximately 200-nF capacitor as a reasonable first estimate for the size of the external capacitor.

When implementing an RSTN input from an active controller, it is recommended to use an open drain driver if the RSTN input is driven. This protects the RSTN input from damage of an input voltage greater than V_{CC}.

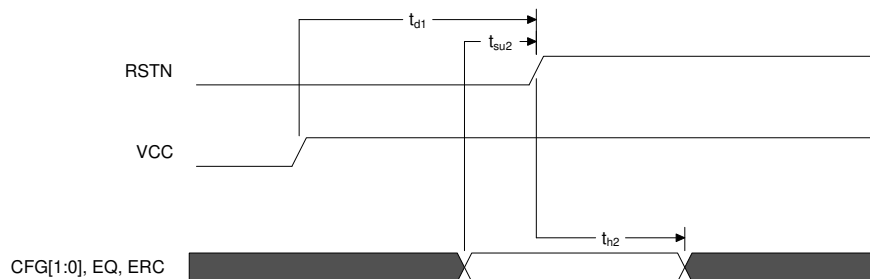


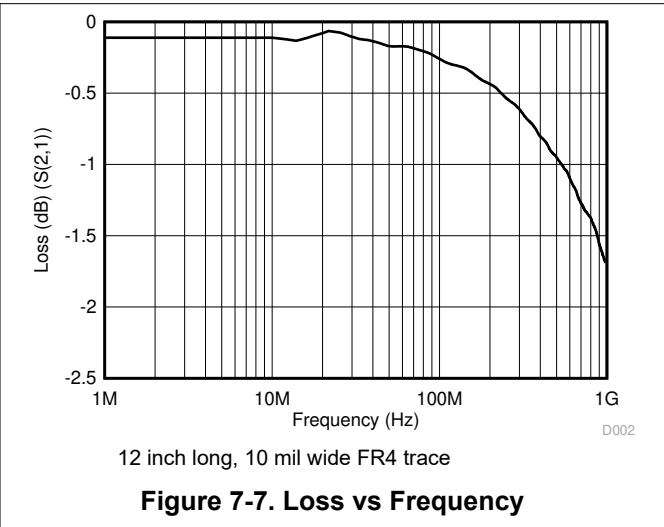
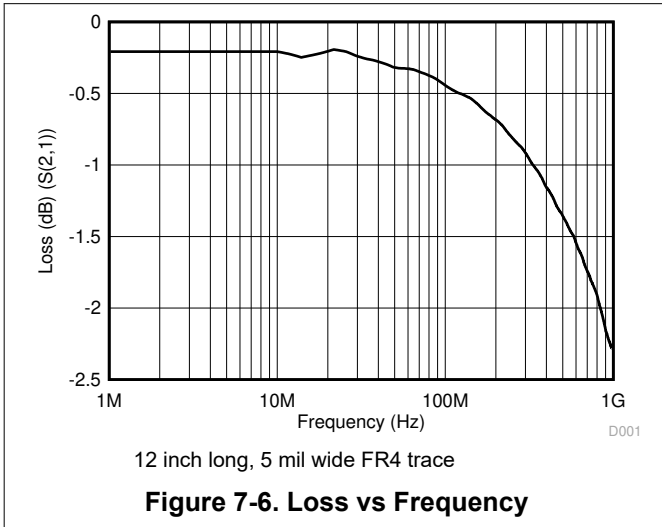
Figure 7-5. Power-Up Timing Requirements

Table 7-4. Timing Requirements

| | DESCRIPTION ⁽¹⁾ | MIN | MAX |
|-----------------------|---|--------|--------|
| t _{D1} | V _{CC} stable before deassertion of RSTN. | 100 μs | |
| t _{SU2} | Setup of VSADJ_CFG0, PRE_CFG1, EQ and ERC pin before deassertion of RSTN. | 0 | |
| t _{H2} | Hold of VSADJ_CFG0, PRE_CFG1, EQ and ERC pin after deassertion of RSTN. | 250 μs | |
| t _{VCC_RAMP} | V _{CC} supply ramp requirements | 0.2 ms | 100 ms |

(1) Unused DAXP/N pins shall be tied to GND.

7.2.3 Application Curves



7.3 Power Supply Recommendations

Texas Instruments recommends a 0.1- μ F capacitor on each power pin.

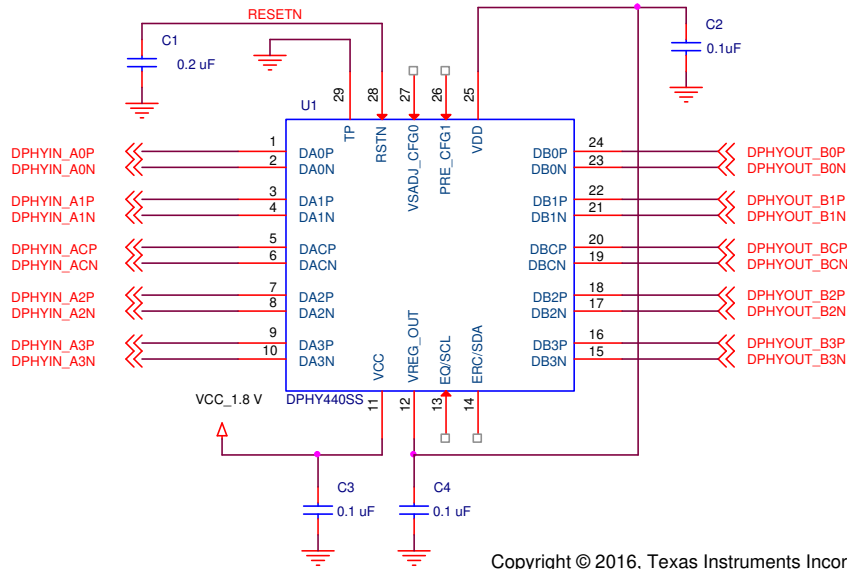


Figure 7-8. Supply Implementation

7.4 Layout

7.4.1 Layout Guidelines

- DAxP/N and DB*P/N pairs should be routed with controlled 100- Ω differential impedance ($\pm 15\%$) or 50- Ω single-ended impedance ($\pm 15\%$).
- Keep away from other high speed signals.
- Keep lengths to within 5 mils of each other.
- Length matching should be near the location of mismatch.
- Each pair should be separated at least by 3 times the signal trace width.
- The use of bends in differential traces should be kept to a minimum. When bends are used, the number of left and right bends should be as equal as possible and the angle of the bend should be ≥ 135 degrees. This will minimize any length mismatch causes by the bends and; therefore, minimize the impact bends have on EMI.
- Route all differential pairs on the same of layer.
- The number of VIAS should be kept to a minimum. It is recommended to keep the VIAS count to 2 or less.
- Keep traces on layers adjacent to ground plane.
- Do NOT route differential pairs over any plane split.
- Adding Test points will cause impedance discontinuity and will; therefore, negatively impact signal performance. If test points are used, they should be placed in series and symmetrically. They must not be placed in a manner that causes a stub on the differential pair.

7.4.2 Layout Example

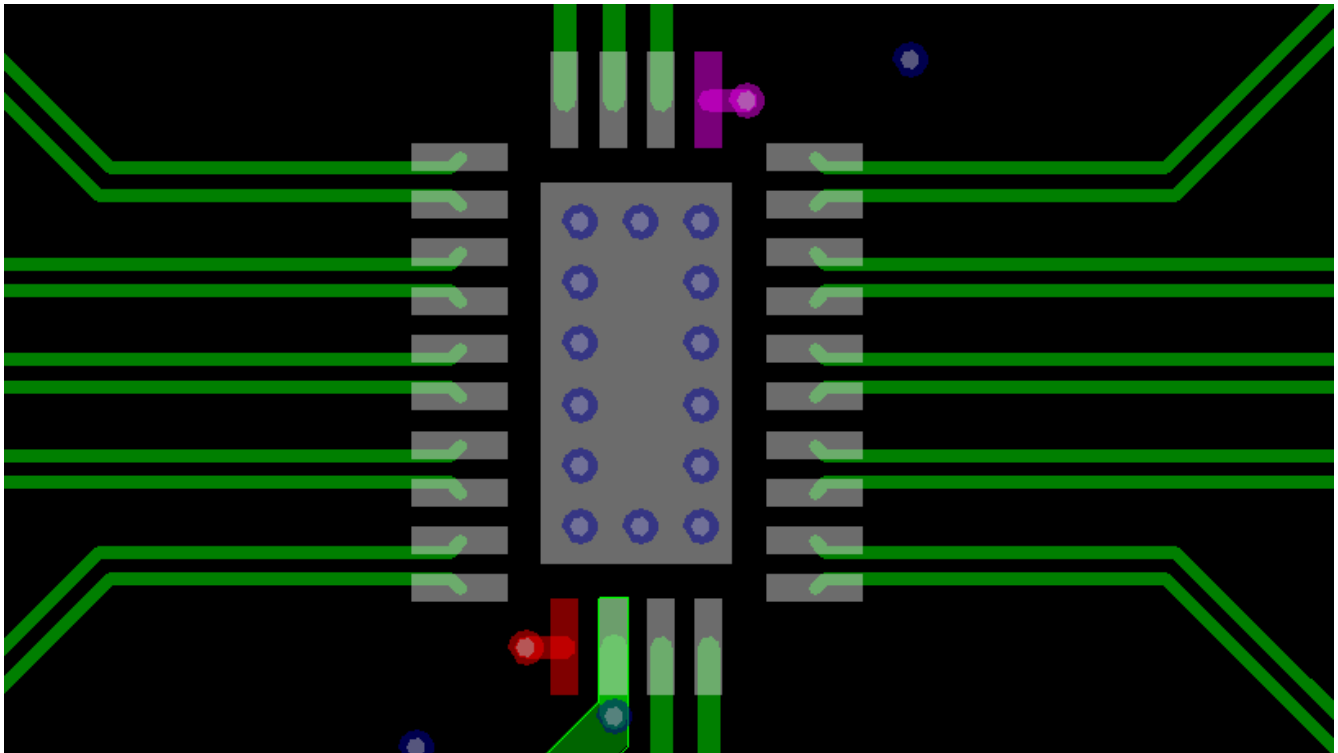


Figure 7-9. Example Layout

8 Device and Documentation Support

8.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.2 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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8.3 Trademarks

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8.4 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision C (August 2019) to Revision D (October 2024) | Page |
|---|------|
| • Updated the numbering format for tables, figures, and cross-references throughout the document..... | 1 |
| • Changed all instances of legacy terminology to controller and target where I ² C is mentioned..... | 1 |
| • Changed t _{HD;DAT} units from μs to ns in the <i>Timing Requirements</i> table..... | 7 |
| • Changed t _{SU;DAT} from 4μs minimum to 250ns minimum in the <i>Timing Requirements</i> table..... | 7 |
| • Added f _{CLK} parameter in the <i>Timing Requirements</i> table..... | 7 |

| Changes from Revision B (August 2017) to Revision C (August 2019) | Page |
|--|------|
| • Changed F _(BR) MAX value From: 1 Gbps To: 1.5 Gbps in the <i>Switching Characteristics</i> table..... | 8 |

| Changes from Revision A (April 2016) to Revision B (August 2017) | Page |
|--|------|
| • Changed <i>Feature</i> From: CSI-2/DSI Clock Rates From 100 MHz to 500 MHz To: CSI-2/DSI Clock Rates From 100 MHz to 750 MHz | 1 |
| • Changed text in the <i>Description</i> From: MIPI DSI application at datarates of up to 1 Gbps. To: MIPI DSI application at datarates of up to 1.5 Gbps..... | 1 |
| • Changed V _{IH} = 4 dB To: V _{IH} = 5 dB in the <i>Pin Functions</i> table..... | 3 |
| • Added a Test Condition of EQ is at 750 MHz to V _(RXEQ1) n the <i>Electrical Characteristics</i> table..... | 6 |
| • Changed V _(RXEQ2) TYP value From: 4 dB To: 5 dB in the <i>Electrical Characteristics</i> table | 6 |

| | |
|--|----|
| • Changed the MIPI DPHY HS Interface section in the <i>Timing Requirements</i> table..... | 7 |
| • Changed $F_{(HSCLK)}$ From 500 μ sMHz To: 750 MHz in the <i>Switching Characteristics</i> table..... | 8 |
| • Changed $F_{(DESKEW)}$ from 500 MHz To: 750 MHz. | 8 |
| • Changed t_R and t_F Datarate Test Conditions and values | 8 |
| • Changed text From: application at datarates of up to 1 Gbps To: application at datarates of up to 1.5 Gbps in the <i>Overview</i> section..... | 10 |
| • Changed Table 6-1 | 11 |
| • Changed 11 – 4 dB To: 11 – 5 dB for RXEQ_CLK in Table 6-8 | 16 |
| • Changed 11 – 4 dB To: 11 – 5 dB for RXEQ_DATA in Table 6-8 | 16 |
| • Changed From: Data Rate To: Data Rate (200 Mbps to 1.5 Gbps) in Table 7-1 | 21 |

Changes from Revision * (March 2016) to Revision A (April 2016)
Page

| | |
|---|----|
| • Changed <i>Features</i> From: 3-kV ESD HBM Protection To: 2-kV ESD HBM Protection..... | 1 |
| • Changed From: (approx. 100K) To: (100K) in the <i>Pin Functions</i> table for pins 13 and 14..... | 3 |
| • Changed From: (approx. 100K) To: (100K) in the <i>Pin Functions</i> table for pins 26, 27, and 28..... | 3 |
| • Changed <i>ESD Ratings</i> values. HBM From: \pm 2000 To: \pm 3000, and CDM Form: \pm 500 To: \pm 1000 | 5 |
| • Changed $V_{(RXEQ2)}$ TYP value From: 5 dB To: 4 dB in the <i>Electrical Characteristics</i> table | 6 |
| • Added MIN and MAX values to $ V_{OD(VD0)} $, $ V_{OD(VD1)} $, and $ V_{OD(VD2)} $ in the <i>Electrical Characteristics</i> table..... | 6 |
| • Deleted rows Z_{OS} and ΔZ_{OS} from the <i>Electrical Characteristics</i> table..... | 6 |
| • Updated the MIPI DPHY LP Transmitter Interface section of the <i>Switching Characteristics</i> table..... | 8 |
| • Changed 5 dB to 4 dB in <i>HS Receive Equalization</i> and Table 6-1 | 11 |
| • Changed 11 – 4 dB To: 11 – 5 dB in Table 6-8 | 16 |

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

| Orderable part number | Status (1) | Material type (2) | Package Pins | Package qty Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|-----------------------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| 65DPHY440SSRHRRG4 | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| 65DPHY440SSRHRRG4.A | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| SN65DPHY440SSRHRR | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| SN65DPHY440SSRHRR.A | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| SN65DPHY440SSRHRT | Active | Production | WQFN (RHR) 28 | 250 SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| SN65DPHY440SSRHRT.A | Active | Production | WQFN (RHR) 28 | 250 SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 85 | DPHY440 |
| SN75DPHY440SSRHRR | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | 0 to 70 | DPHY440 |
| SN75DPHY440SSRHRR.A | Active | Production | WQFN (RHR) 28 | 3000 LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | 0 to 70 | DPHY440 |
| SN75DPHY440SSRHRT | Active | Production | WQFN (RHR) 28 | 250 SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | 0 to 70 | DPHY440 |
| SN75DPHY440SSRHRT.A | Active | Production | WQFN (RHR) 28 | 250 SMALL T&R | Yes | NIPDAU | Level-1-260C-UNLIM | 0 to 70 | DPHY440 |

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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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 |
|-------------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| 65DPHY440SSRHRRG4 | WQFN | RHR | 28 | 3000 | 330.0 | 12.4 | 3.8 | 5.8 | 1.2 | 8.0 | 12.0 | Q1 |
| SN65DPHY440SSRHRR | WQFN | RHR | 28 | 3000 | 330.0 | 12.4 | 3.8 | 5.8 | 1.2 | 8.0 | 12.0 | Q1 |
| SN65DPHY440SSRHRT | WQFN | RHR | 28 | 250 | 180.0 | 12.4 | 3.8 | 5.8 | 1.2 | 8.0 | 12.0 | Q1 |
| SN75DPHY440SSRHRR | WQFN | RHR | 28 | 3000 | 330.0 | 12.4 | 3.8 | 5.8 | 1.2 | 8.0 | 12.0 | Q1 |
| SN75DPHY440SSRHRT | WQFN | RHR | 28 | 250 | 180.0 | 12.4 | 3.8 | 5.8 | 1.2 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|-------------------|--------------|-----------------|------|------|-------------|------------|-------------|
| 65DPHY440SSRHRRG4 | WQFN | RHR | 28 | 3000 | 346.0 | 346.0 | 33.0 |
| SN65DPHY440SSRHRR | WQFN | RHR | 28 | 3000 | 346.0 | 346.0 | 33.0 |
| SN65DPHY440SSRHRT | WQFN | RHR | 28 | 250 | 182.0 | 182.0 | 20.0 |
| SN75DPHY440SSRHRR | WQFN | RHR | 28 | 3000 | 346.0 | 346.0 | 33.0 |
| SN75DPHY440SSRHRT | WQFN | RHR | 28 | 250 | 182.0 | 182.0 | 20.0 |

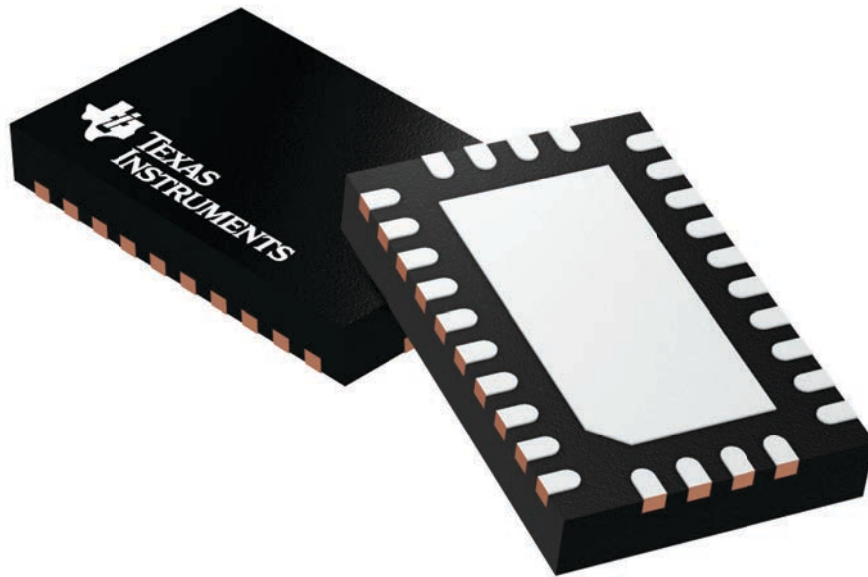
GENERIC PACKAGE VIEW

RHR 28

WQFN - 0.8 mm max height

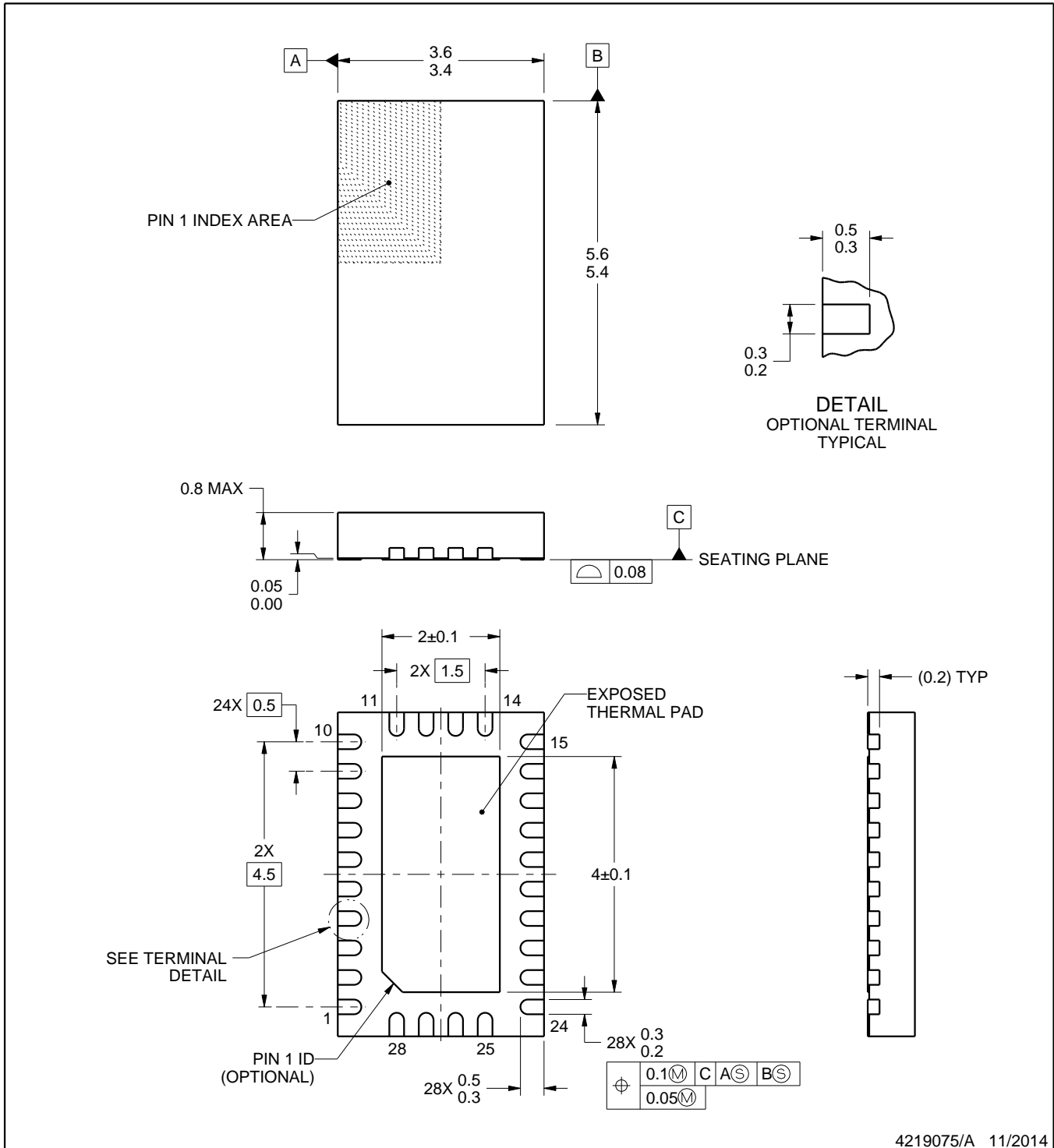
3.5 x 5.5, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

4210249/B



4219075/A 11/2014

NOTES:

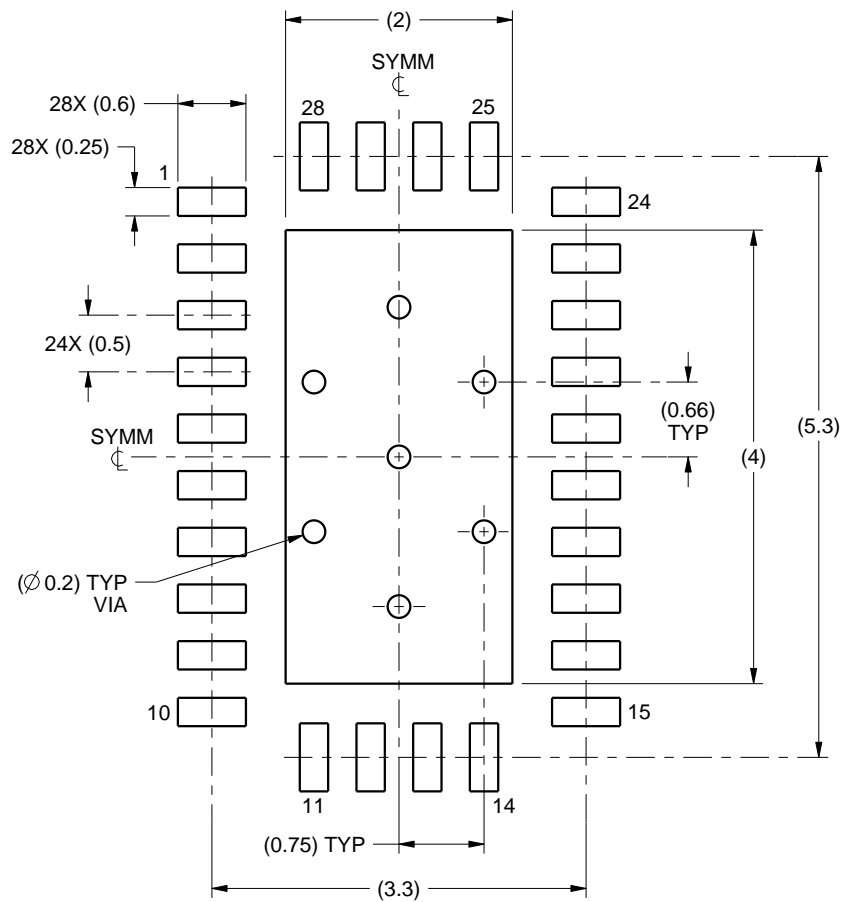
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

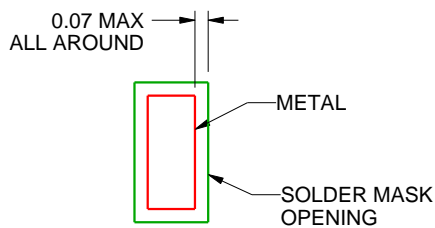
RHR0028A

WQFN - 0.8 mm max height

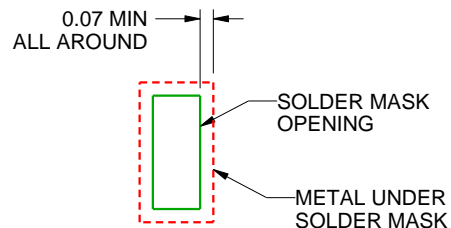
PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
SCALE:15X



NON SOLDER MASK
DEFINED
(PREFERRED)



SOLDER MASK
DEFINED

SOLDER MASK DETAILS

4219075/A 11/2014

NOTES: (continued)

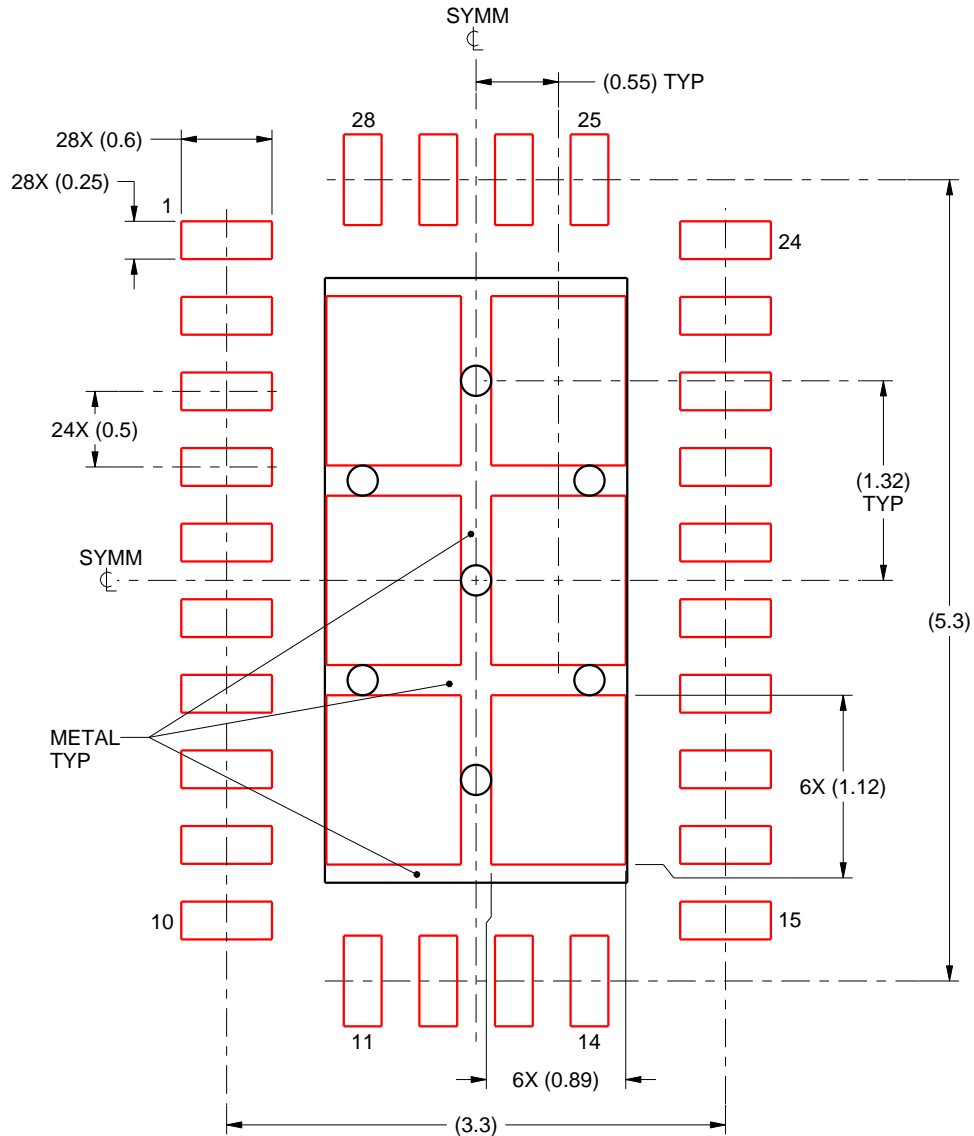
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).

EXAMPLE STENCIL DESIGN

RHR0028A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
75% PRINTED SOLDER COVERAGE BY AREA
SCALE:20X

4219075/A 11/2014

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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