DS320PR410 Four-Channel Linear Redriver for PCIe™ 5.0, CXL 2.0

1 Features

- Four-channel linear redriver supporting PCIe™ 5.0, CXL 2.0, UPI 2.0 up to 32 Gbps
- Supports most ac coupled interfaces including DP, SAS, SATA, XFI
- CTLE boosts up to 22 dB at 16 GHz
- Ultra-low latency of 100 ps
- Low additive random jitter of 45 fs for PRBS data
- Excellent return loss of -10 dB at 16 GHz
- Single 3.3 V supply
- Internal voltage regulator provides immunity to supply noise
- Low active power of 160 mW / channel
- No heat sink required
- Pin-strap, SMBus or EEPROM programming
- Automatic receiver detection for PCIe use cases
- Protocol agnostic linear redriver allows seamless support for PCIe link training
- Support for x4, x8, x16, x24 bus width with one or multiple DS320PR410
- Temperature range of –40 °C to 85 °C
- 4 mm × 6 mm, 40 pin WQFN package

2 Applications

- Rack server, microserver, and tower server
- High performance computing
- Hardware accelerator
- Network attached storage
- Storage area network (SAN) and host bus adapter (HBA) card
- Network interface card (NIC)
- Desktop PC or motherboard
- Active cables

3 Description

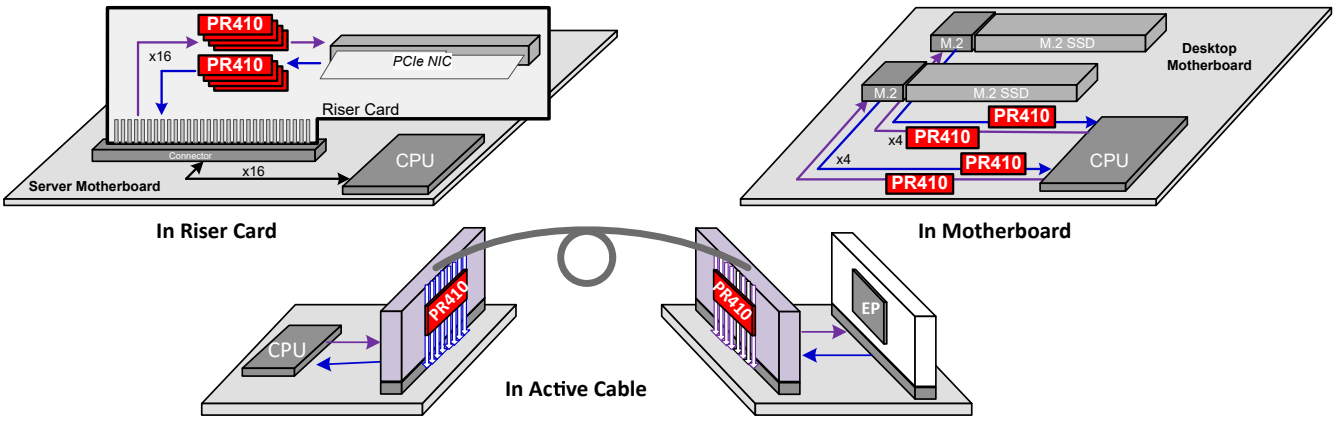
The DS320PR410 is a four-channel low-power high-performance linear repeater or redriver designed to support PCIe 5.0, CXL 2.0, UPI 2.0, and other interfaces up to 32 Gbps.

The DS320PR410 receivers deploy continuous time linear equalizers (CTLE) to provide a programmable high-frequency boost. The equalizer can open an input eye that is completely closed due to inter-symbol interference (ISI) induced by an interconnect medium, such as PCB traces. The CTLE receiver is followed by a linear output driver. The linear data-paths of DS320PR410 preserve transmit preset signal characteristics. The linear redriver becomes part of the passive channel that as a whole get link trained for best transmit and receive equalization settings. This transparency in the link training protocol results in best electrical link and lowest possible latency. Low channel-channel cross-talk, low additive jitter and excellent return loss makes the device almost a passive element in the link, but with its useful equalization.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
DS320PR410	RNQ (WQFN, 40)	6 mm × 4 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Applications

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Revision History

DATE	REVISION	NOTES
October 2023	*	Initial Release

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5 Pin Configuration and Functions

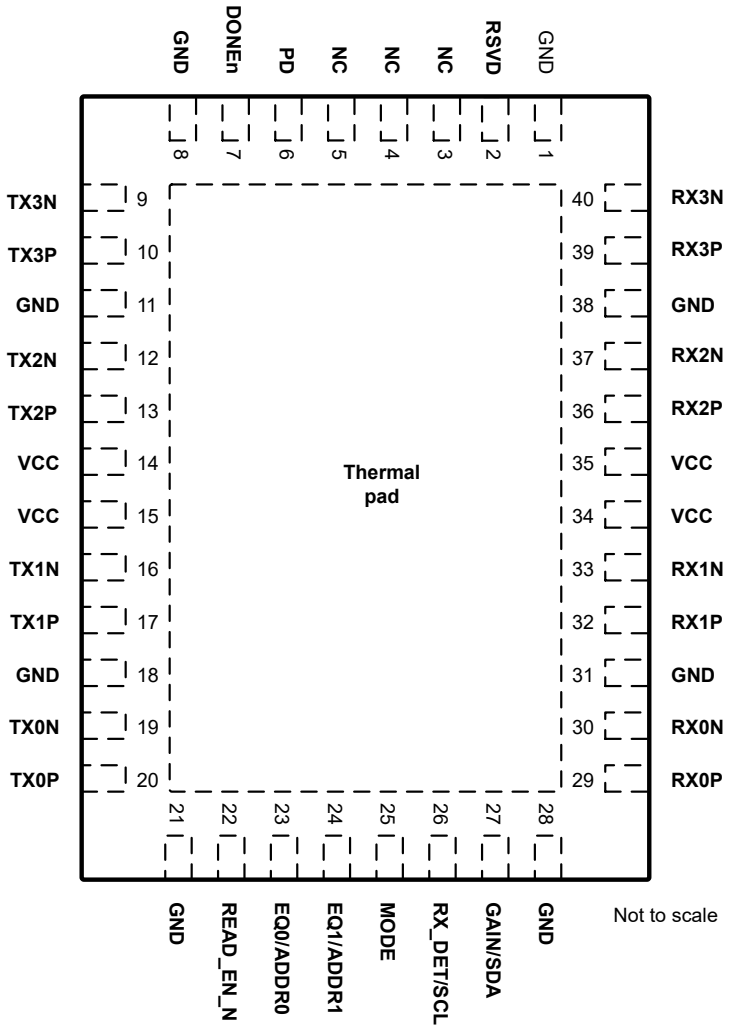


Figure 5-1. RNQ Package, 40-Pin WQFN (Top View)

Table 5-1. Pin Functions

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
DONEn	7	O, 3.3 V open drain	In **SMBus/I²C Primary mode**: Indicates the completion of a valid EEPROM register load operation. External pullup resistor such as 4.7 kΩ required for operation. High: External EEPROM load failed or incomplete Low: External EEPROM load successful and complete In **SMBus/I²C Secondary/Pin mode**: This output is High-Z. The pin can be left floating.

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Table 5-1. Pin Functions (continued)

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
MODE	25	I, 5-level	Sets device control configuration modes. 5-level IO pin as provided in Table 7-4. The pin can be exercised at device power up or in normal operation mode. L0: **Pin mode** – strap pins solely sets device control configuration settings. L1: **SMBus/I²C Primary mode** – device control configuration is read from external EEPROM. When the DS320PR410 has finished reading from the EEPROM successfully, it will drive the DONEn pin LOW. SMBus/I²C secondary operation is available in this mode before, during or after EEPROM reading. Note: during EEPROM reading if the external SMBus/I²C primary wants to access DS320PR410 registers it must support arbitration. L2: **SMBus/I²C Secondary mode** – an external controller with SMBus/I²C primary sets device control configuration settings. L3 and L4 (Float): RESERVED – TI internal test modes.
EQ0 / ADDR0	23	I, 5-level	In **Pin mode:** Sets receiver linear equalization (CTLE) boost for channels 0-3 as provided in Table 7-1. These pins are sampled at device power-up only. In **SMBus/I²C mode:** Sets SMBus / I²C secondary address as provided in Table 7-5. These pins are sampled at device power-up only. In this mode, equalization boost is configured by setting SMBus / I²C register bits.
EQ1 / ADDR1	24	I, 5-level	
GAIN / SDA	27	I, 5-level / I/O, 3.3 V LVCMOS, open drain	In **Pin mode:** Flat gain (DC and AC) from the input to the output of the device for channels 0-3. The pin is sampled at device power-up only. In **SMBus/I²C mode:** 3.3 V SMBus/I²C data. External 1 kΩ to 5 kΩ pullup resistor is required as per SMBus / I²C interface standard. In this mode, Flat gain is configured by setting SMBus / I²C register bits.
GND	1, 8, 11, 18, 21, 28, 31, 38, EP	P	Ground reference for the device. EP: the Exposed Pad at the bottom of the QFN package. It is used as the GND return for the device. The EP should be connected to one or more ground planes through the low resistance path. A via array provides a low impedance path to GND. The EP also improves thermal dissipation.
PD	6	I, 3.3 V LVCMOS	2-level logic controlling the operating state of the redriver. Active in all device control modes. The pin has internal 1-MΩ weak pull-down resistor. The pin triggers PCIe Rx detect state machine when toggled. High: power down for channels 0-3 Low: power up, normal operation for channels 0-3
READ_EN_N	22	I, 3.3 V LVCMOS	In **SMBus/I²C Primary mode**: After device power up, when the pin is low, the pin initiates the SMBus / I²C Primary mode EEPROM read function. When EEPROM read is complete (indicated by assertion of DONEn low), this pin can be held low for normal device operation. During the EEPROM load process the device's signal path is disabled. In **SMBus/I²C Secondary and Pin modes:** In these modes the pin is not used. The pin can be left floating. The pin has internal 1-MΩ weak pull-down resistor.
RSVD	2	—	Reserved use for TI. The pin must be left floating (NC).
RX_DET / SCL	26	I, 5-level / I/O, 3.3 V LVCMOS, open drain	In **Pin mode:** Sets receiver detect state machine options as provided in Table 7-3. The pin is sampled at device power-up only. In **SMBus/I²C mode:** 3.3V SMBus/I²C clock. External 1 kΩ to 5 kΩ pullup resistor is required as per SMBus / I²C interface standard. In this mode, receiver detect state machine is configured by setting SMBus / I²C register bits.
RX0N	30	I	Inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 0.
RX0P	29	I	Non-inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 0.
RX1N	33	I	Inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 1.

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Table 5-1. Pin Functions (continued)

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
RX1P	32	I	Non-inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 1.
RX2N	37	I	Inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 2.
RX2P	36	I	Non-inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 2.
RX3N	40	I	Inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 3.
RX3P	39	I	Non-inverting differential inputs to the equalizer. Integrated 50 Ω termination resistor from the pin to internal CM bias voltage. Channel 3.
TX0N	19	O	Inverting pin for 100 Ω differential driver output. Channel 0.
TX0P	20	O	Non-inverting pin for 100 Ω differential driver output. Channel 0.
TX1N	16	O	Inverting pin for 100 Ω differential driver output. Channel 1.
TX1P	17	O	Non-inverting pin for 100 Ω differential driver output. Channel 1.
TX2N	12	O	Inverting pin for 100 Ω differential driver output. Channel 2.
TX2P	13	O	Non-inverting pin for 100 Ω differential driver output. Channel 2.
TX3N	9	O	Inverting pin for 100 Ω differential driver output. Channel 3.
TX3P	10	O	Non-inverting pin for 100 Ω differential driver output. Channel 3.
VCC	14, 15, 34, 35	P	Power supply pins. VCC = 3.3 V ±10%. The VCC pins on this device should be connected through a low-resistance path to the board VCC plane. Install a decoupling capacitor to GND near each VCC pin.

(1) I = input, O = output, P = power

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6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
VCC_{ABSMAX}	Supply voltage (VCC)	–0.5	4.0	V
$VIO_{CMOS,ABSMAX}$	3.3 V LVCMOS and open drain I/O voltage	–0.5	4.0	V
$VIO_{5LVL,ABSMAX}$	5-level input I/O voltage	–0.5	2.75	V
$VIO_{HS-RX,ABSMAX}$	High-speed I/O voltage (RXnP, RXnN)	–0.5	3.2	V
$VIO_{HS-TX,ABSMAX}$	High-speed I/O voltage (TXnP, TXnN)	–0.5	2.75	V
$T_{J,ABSMAX}$	Junction temperature		150	°C
T_{stg}	Storage temperature range	–65	150	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute maximum ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If briefly operating outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not sustain damage, but it may not be fully functional. Operating the device in this manner may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2000	V
		Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002(2)	±500	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Pins listed as ±2 kV may actually have higher performance.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
VCC	Supply voltage, VCC to GND	DC plus AC power should not exceed these limits	3.0	3.3	3.6	V
N_{VCC}	Supply noise tolerance	DC to <50 Hz, sinusoidal[1]			250	mVpp
		50 Hz to 500 kHz, sinusoidal[1]			100	mVpp
		500 kHz to 2.5 MHz, sinusoidal[1]			33	mVpp
		Supply noise, >2.5 MHz, sinusoidal[1]			10	mVpp
$T_{RampVCC}$	VCC supply ramp time	From 0 V to 3.0 V	0.150		100	ms
T_A	Operating ambient temperature		-40		85	°C
T_J	Operating junction temperature	All device modes			125	°C
PW_{LVCMOS}	Minimum pulse width required for the device to detect a valid signal on LVCMOS inputs	PD and READ_EN_N	200			µs
VCC_{SMBUS}	SMBus/I²C SDA and SCL open drain termination voltage	Supply voltage for open drain pull-up resistor			3.6	V
F_{SMBus}	SMBus/I²C clock (SCL) frequency in SMBus secondary mode		10		400	kHz
VID_{LAUNCH}	Source differential launch amplitude		800		1200	mVpp
DR	Data rate		1		32	Gbps

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6.4 Thermal Information

THERMAL METRIC(1)		DS320PR410 RNQ, 40 Pins	UNIT
$R_{\theta JA\text{-}High\ K}$	Junction-to-ambient thermal resistance	30.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	20.8	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	11.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	0.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	11.4	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	3.8	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report.

6.5 DC Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power						
P_{ACT}	Device active power	4 channels active, EQ = 0-2		0.57	0.71	W
		4 channels active, EQ = 5-19		0.69	0.87	W
P_{RXDET}	Device power consumption while waiting for far end receiver terminations	All channels enabled but no far end receiver detected		89		mW
P_{STBY}	Device power consumption in standby power mode	All channels disabled (PD = H)		17	25	mW
Control IO						
V_{IH}	High level input voltage	SDA, SCL, PD, READ_EN_N pins	2.1			V
V_{IL}	Low level input voltage	SDA, SCL, PD, READ_EN_N pins			1.08	V
V_{OH}	High level output voltage	$R_{pull\text{-}up}$ = 4.7 kΩ (SDA, SCL, DONEn pins)	2.1			V
V_{OL}	Low level output voltage	I_{OL} = –4 mA (SDA, SCL, DONEn pins)			0.4	V
I_{IH}	Input high leakage current	V_{Input} = VCC, (SCL, SDA, PD, READ_EN_N pins)			10	µA
I_{IL}	Input low leakage current	V_{Input} = 0 V, (SCL, SDA, PD, READ_EN_N pins)	-10			µA
$I_{IH,FS}$	Input high leakage current for fail safe input pins	V_{Input} = 3.6 V, VCC = 0 V, (SCL, SDA, , PD, READ_EN_N pins)			200	µA
$C_{IN\text{-}CTRL}$	Input capacitance	SDA, SCL, PD, READ_EN_N pins		1.6		pF
5 Level IOs (MODE, GAIN, EQ0, EQ1, RX_DET pins)						
I_{IH_5L}	Input high leakage current, 5-level IOs	VIN = 2.5 V			10	µA
I_{IL_5L}	Input low leakage current for all 5-level IOs except MODE.	VIN = GND	-10			µA
$I_{IL_5L,MODE}$	Input low leakage current for MODE pin	VIN = GND	-200			µA
Receiver						
$V_{RX\text{-}DC\text{-}CM}$	RX DC common vode voltage	Device is in active or standby state		1.4		V
$Z_{RX\text{-}DC}$	Rx DC single-ended impedance			50		Ω
$Z_{RX\text{-}HIGH\text{-}IMP\text{-}DC\text{-}POS}$	DC input CM input impedance during Reset or power-down	Inputs are at $V_{RX\text{-}DC\text{-}CM}$ voltage	15			kΩ
Transmitter						

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6.5 DC Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$Z_{TX-DIFF-DC}$	DC differential Tx impedance	Impedance of Tx during active signaling, VID,diff = 1 Vpp		100		Ω
$V_{TX-DC-CM}$	Tx DC common mode voltage			1.0		V
$I_{TX-SHORT}$	Tx short circuit current	Total current the Tx can supply when shorted to GND		70		mA

6.6 High Speed Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Receiver						
$RL_{RX-DIFF}$	Input differential return loss	50 MHz to 1.25 GHz		-24		dB
		1.25 GHz to 2.5 GHz		-19		dB
		2.5 GHz to 4.0 GHz		-18		dB
		4.0 GHz to 8.0 GHz		-15		dB
		8.0 GHz to 16 GHz		-9		dB
RL_{RX-CM}	Input common-mode return loss	50 MHz to 2.5 GHz		-17		dB
		2.5 GHz to 8.0 GHz		-13		dB
		8.0 GHz to 16 GHz		-8		dB
XT_{RX}	Receiver-side pair-to-pair isolation; Port A or Port B	Minimum over 10 MHz to 16 GHz range		-50		dB
Transmitter						
$V_{TX-AC-CM-PP}$	Tx AC peak-to-peak common mode voltage	Measured with lowest EQ, GAIN = L4; PRBS-7, 32 Gbps, over at least 10^6 bits using a bandpass-Pass Filter from 30 Khz - 500 Mhz			50	mVpp
$V_{TX-CM-DC-ACTIVE-IDLE-DELTA}$	Absolute delta of DC common mode voltage during L0 and electrical idle	$V_{TX-CM-DC} = \lvert V_{OUTn+} + V_{OUTn-}\rvert/2$, measured by taking the absolute difference of $V_{TX-CM-DC}$ during PCIe state L0 and Electrical Idle	0		120	mV
$V_{TX-RCV-DETECT}$	Amount of voltage change allowed during receiver detection	Measured while Tx is sensing whether a low-impedance receiver is present. No load is connected to the driver output	0		600	mV
$RL_{TX-DIFF}$	Output differential return loss	50 MHz to 1.25 GHz		-24		dB
		1.25 GHz to 2.5 GHz		-21		dB
		2.5 GHz to 4.0 GHz		-19		dB
		4.0 GHz to 8.0 GHz		-16		dB
		8.0 Ghz to 16 Ghz		-14		dB
RL_{TX-CM}	Output common-mode return loss	50 MHz to 2.5 GHz		-15		dB
		2.5 GHz to 8.0 GHz		-12		dB
		8.0 GHz to 16 GHz		-11		dB
XT_{TX}	Transmit-side pair-to-pair isolation	Minimum over 10 MHz to 16 GHz range		-50		dB
Device Datapath						
$T_{PLHD/PHLD}$	Input-to-output latency (propagation delay) through a data channel	For either low-to-high or high-to-low transition.		100	130	ps
$L_{TX-SKEW}$	Lane-to-lane output skew	Between any two lanes within a single transmitter.			20	ps

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6.6 High Speed Electrical Characteristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$T_{RJ-DATA}$	Additive random jitter with data	Jitter through redriver minus the calibration trace. 32 Gbps PRBS15. 800 mVpp-diff input swing.		45		fs
$T_{RJ-INTRINSIC}$	Intrinsic additive random jitter with clock	Jitter through redriver minus the calibration trace. 16 Ghz CK. 800 mVpp-diff input swing.		35		fs
$JITTER_{TOTAL-DATA}$	Additive total jitter with data	Jitter through redriver minus the calibration trace. 32 Gbps PRBS15. 800 mVpp-diff input swing.		1.2		ps
$JITTER_{TOTAL-INTRINSIC}$	Intrinsic additive total jitter with clock	Jitter through redriver minus the calibration trace. 16 Ghz CK. 800 mVpp-diff input swing.		0.3		ps
FLAT-GAIN	Broadband DC and AC flat gain - input to output, measured at DC	Minimum EQ, GAIN = L0		-5.6		dB
		Minimum EQ, GAIN = L1		-3.8		dB
		Minimum EQ, GAIN = L2		-1.2		dB
		Minimum EQ, GAIN = L3		2.6		dB
		Minimum EQ, GAIN = L4 (Float)		0.6		dB
$EQ\text{-}MAX_{16G}$	EQ boost at max setting (EQ INDEX = 19)	AC gain at 16 GHz relative to gain at 100 MHz.		23		dB
$FLAT\text{-}GAIN_{VAR}$	Flat gain variation across PVT measured at DC	GAIN = L4, minimum EQ setting. Max-Min.	-2.5		1.5	dB
$EQ\text{-}GAIN_{VAR}$	EQ boost variation across PVT	At 16 Ghz. GAIN = L4, maximum EQ setting. Max-Min.	-3.0		4.0	dB
LINEARITY-DC	Output DC linearity	at GAIN = L4		1800		mVpp
LINEARITY-AC	Output AC linearity	at 16 Gbps, with GAIN = L4		1100		mVpp
		at 32 Gbps, with GAIN = L4		850		mVpp

6.7 SMBUS/I^{2}C Timing Charateristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Secondary Mode						
t_{SP}	Pulse width of spikes which must be suppressed by the input filter				50	ns
t_{HD-STA}	Hold time (repeated) START condition. After this period, the first clock pulse is generated		0.6			µs
t_{LOW}	LOW period of the SCL clock		1.3			µs
T_{HIGH}	HIGH period of the SCL clock		0.6			µs
t_{SU-STA}	Set-up time for a repeated START condition		0.6			µs
t_{HD-DAT}	Data hold time		0			µs
T_{SU-DAT}	Data setup time		0.1			µs
t_r	Rise time of both SDA and SCL signals	Pull-up resistor = 4.7 kΩ, Cb = 10 pF		120		ns
t_f	Fall time of both SDA and SCL signals	Pull-up resistor = 4.7 kΩ, Cb = 10 pF		2		ns
t_{SU-STO}	Set-up time for STOP condition		0.6			µs
t_{BUF}	Bus free time between a STOP and START condition		1.3			µs

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6.7 SMBUS/I²C Timing Charateristics (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{VD-DAT}	Data valid time				0.9	µs
t_{VD-ACK}	Data valid acknowledge time				0.9	µs
C_b	Capacitive load for each bus line				400	pF
Primary Mode						
f_{SCL-M}	SCL clock frequency			303		kHz
t_{LOW-M}	SCL low period			1.90		µs
T_{HIGH-M}	SCL high period			1.40		µs
$t_{SU-STA-M}$	Set-up time for a repeated START condition			2		µs
$t_{HD-STA-M}$	Hold time (repeated) START condition. After this period, the first clock pulse is generated			1.5		µs
$T_{SU-DAT-M}$	Data setup time			1.4		µs
$t_{HD-DAT-M}$	Data hold time			0.5		µs
t_{R-M}	Rise time of both SDA and SCL signals	Pull-up resistor = 4.7 kΩ, Cb = 10 pF		120		ns
T_{F-M}	Fall time of both SDA and SCL signals	Pull-up resistor = 4.7 kΩ, Cb = 10 pF		2		ns
$t_{SU-STO-M}$	Stop condition setup time			1.5		µs
EEPROM Timing						
T_{EEPROM}	EEPROM configuration load time	Time to assert DONEn after READ_EN_N has been asserted.		7.5		ms
T_{POR}	Time to first SMBus access	Power supply stable after initial ramp. Includes initial power-on reset time.		50		ms

6.8 Typical Characteristics

Figure 6-1 shows typical EQ gain curves versus frequency for different EQ settings. Figure 6-2 shows typical differential return loss for Rx and Tx pins.

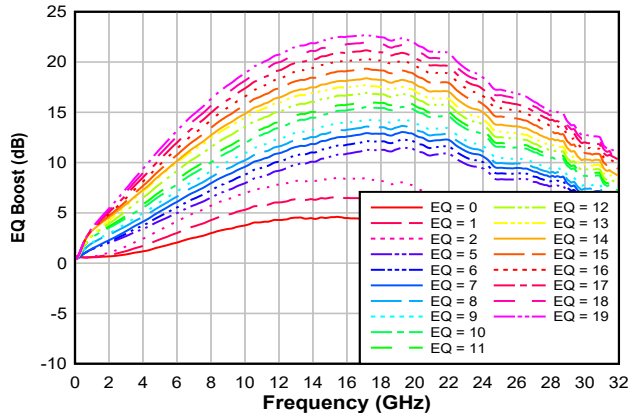


Figure 6-1. Typical EQ Boost vs Frequency

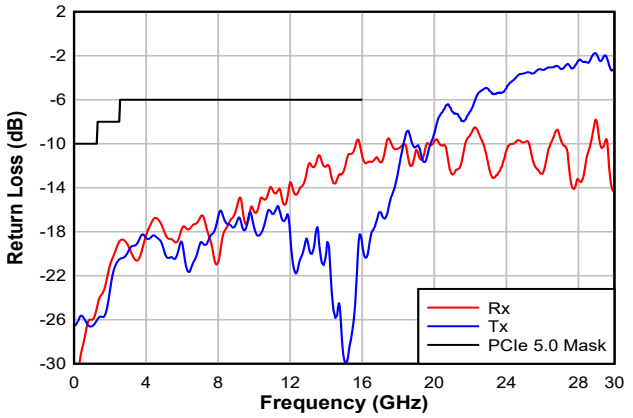


Figure 6-2. Typical Differential Return Loss

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6.9 Typical Jitter Characteristics

Figure 6-3 and Figure 6-4 show eye diagrams through calibration traces (no redriver) and through DS320PR410 and (equivalent) traces respectively for 16 Gbps, and Figure 6-5 and Figure 6-6 for 32 Gbps.

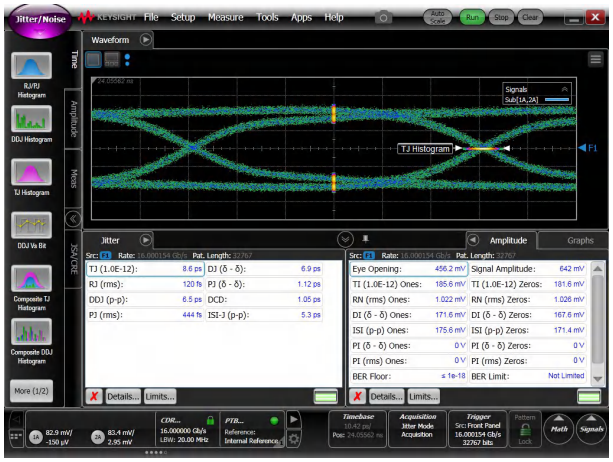


Figure 6-3. Through Baseline Calibration Trace (no redriver) Setup at 16 Gbps

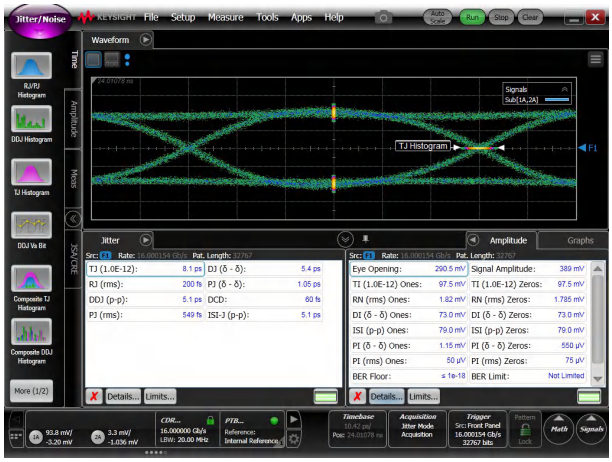


Figure 6-4. Through DS320PR410 and (equivalent) traces at 16 Gbps with EQ = 0 (3 dB)

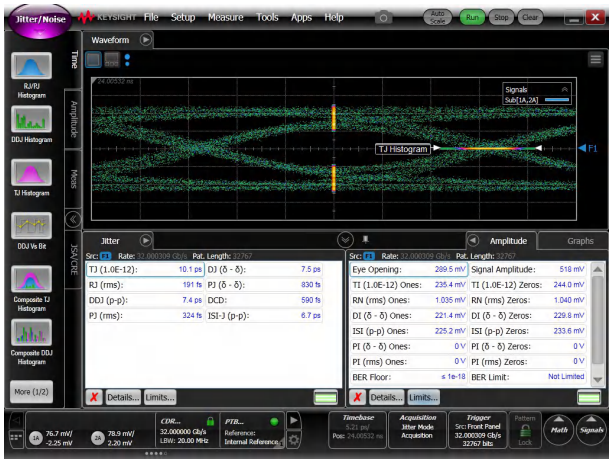


Figure 6-5. Through Baseline Calibration Trace (no redriver) Setup at 32 Gbps

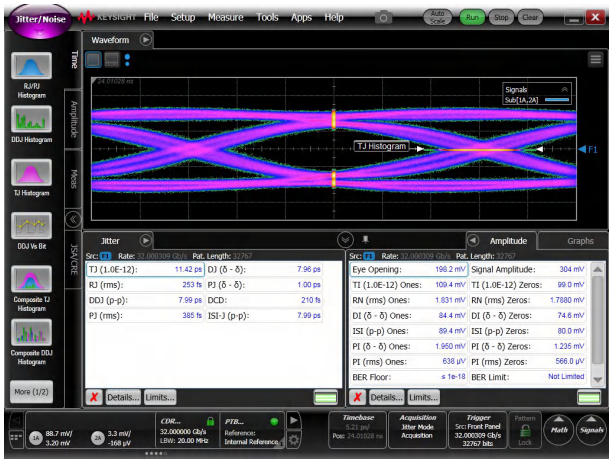


Figure 6-6. Through DS320PR410 and (equivalent) traces at 32 Gbps with EQ = 0 (4 dB)

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7 Detailed Description

7.1 Overview

The DS320PR410 is a four-channel multi-rate linear repeater with integrated signal conditioning. The device's signal channels operate independently from one another. Each channel includes a continuous-time linear equalizer (CTLE) and a linear output driver, which together compensate for a lossy transmission channel between the source transmitter and the final receiver. The linearity of the data path is specifically designed to preserve any transmit equalization while keeping receiver equalization effective.

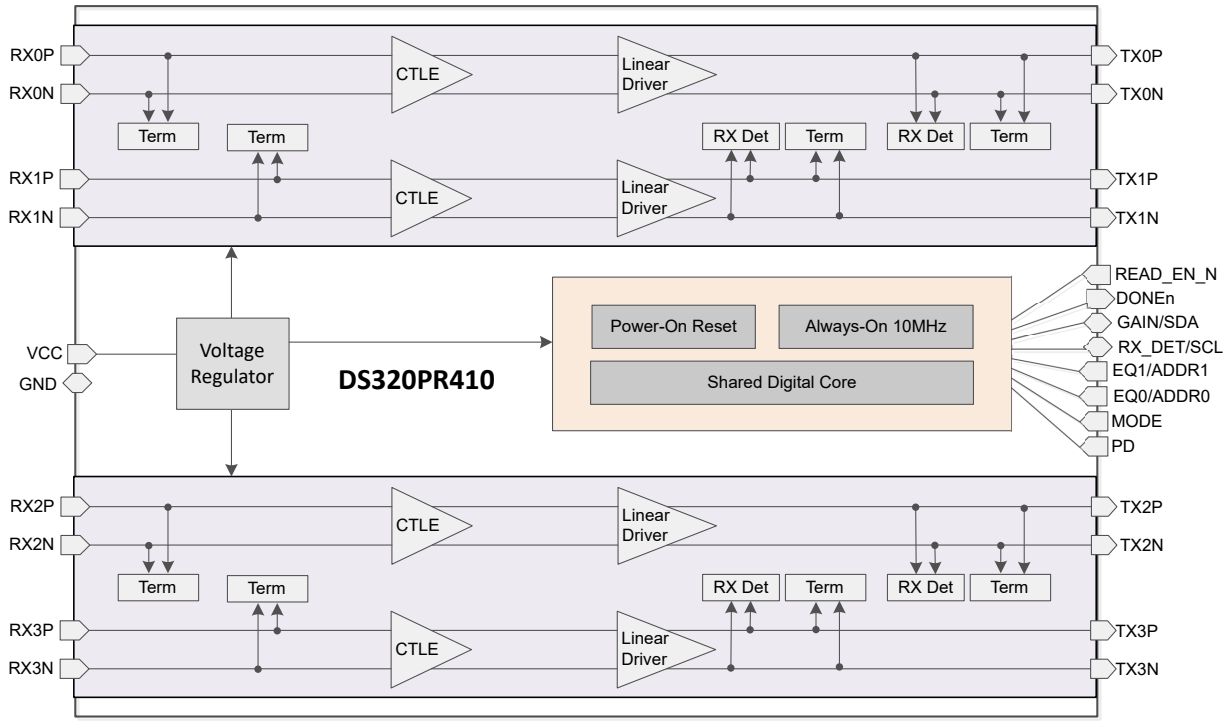
The DS320PR410 can be configured three different ways:

Pin mode – device control configuration is done solely by strap pins. Pin mode is expected to be good enough for many system implementation needs.

SMBus/I^{2}C Primary mode – device control configuration is read from external EEPROM. When the DS320PR410 has finished reading from the EEPROM successfully, it will drive the DONEn pin LOW. SMBus/I^{2}C secondary operation is available in this mode before, during, or after EEPROM reading. Note: during EEPROM reading, if the external SMBus/I^{2}C primary wants to access DS320PR410 registers, then it must support arbitration. The mode is preferred when software implementation is not desired.

SMBus/I^{2}C Secondary mode – provides most flexibility. Requires a SMBus/I^{2}C primary device to configure DS320PR410 though writing to its secondary address.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Linear Equalization

The DS320PR410 receivers feature a continuous-time linear equalizer (CTLE) that applies high-frequency boost and low-frequency attenuation to help equalize the frequency-dependent insertion loss effects of the passive channel. The receivers implement two stage linear equalizer for wide range of equalization capability. The equalizer stages also provide flexibility to make subtle modifications of mid-frequency boost for best EQ gain profile match with wide range of channel media characteristics. The EQ profile control feature is only available in SMBus/I^{2}C mode. In Pin mode, the settings are optimized for FR4 traces.

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Table 7-1 provides available equalization boost through EQ control pins or SMBus/I²C registers. In Pin Control mode EQ1 and EQ0 pins set equalization boost for channels 0-3. In I²C mode individual channels can be independently programmed for EQ boost.

Table 7-1. Equalization Control Settings

EQUALIZATION SETTING							TYPICAL EQ BOOST (dB)	
	Pin mode		SMBus/I²C Mode					
EQ INDEX	EQ1	EQ0	eq_stage1_3:0	eq_stage2_2:0	eq_profile_3:0	eq_stage1_bypass	at 8 GHz	at 16 GHz
0	L0	L0	0	0	0	1	3.0	4.5
1	L0	L1	1	0	0	1	4.0	6.5
2	L0	L2	3	0	0	1	5.5	8.5
5	L1	L0	0	0	1	0	6.5	11.0
6	L1	L1	1	0	1	0	7.0	12.0
7	L1	L2	2	0	1	0	8.0	12.5
8	L1	L3	3	0	3	0	8.5	13.0
9	L1	L4	4	0	3	0	9.0	14.0
10	L2	L0	5	1	7	0	10.0	15.0
11	L2	L1	6	1	7	0	10.5	15.5
12	L2	L2	8	1	7	0	11.5	16.5
13	L2	L3	10	1	7	0	12.5	17.5
14	L2	L4	10	2	15	0	13.0	18.0
15	L3	L0	11	3	15	0	13.5	19.0
16	L3	L1	12	4	15	0	14.0	20.0
17	L3	L2	13	5	15	0	15.0	21.0
18	L3	L3	14	6	15	0	15.5	22.0
19	L3	L4	15	7	15	0	16.0	22.5

7.3.2 Flat-Gain

The GAIN pin can be used to set the overall data-path flat gain (DC and AC) of the DS320PR410 when the device is in Pin mode. The pin GAIN sets the Flat-Gain for channels 0-3. In I²C mode each channel can be independently set. Table 7-2 provides flat gain control configuration settings. In the default recommendation for most systems will be GAIN = L4 (float) that provides flat gain of 0 dB.

The flat-gain and equalization of the DS320PR410 must be set such that the output signal swing at DC and high frequency does not exceed the DC and AC linearity ranges of the devices, respectively.

Table 7-2. Flat Gain Configuration Settings

Pin mode GAIN	I²C Modeflat_gain_2:0	Flat Gain
L0	0	-5.6 dB
L1	1	-3.8 dB
L2	3	-1.2 dB
L4 (float)	5	0.6 dB (default recommendation)
L3	7	+2.6 dB

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7.3.3 Receiver Detect State Machine

The DS320PR410 deploys an Rx detect state machine that governs the Rx detection cycle as defined in the PCI express specifications. At power up or after a manual PD toggle the redriver determines whether or not a valid PCI express termination is present at the far end receiver. The RX_DET pin of DS320PR410 provides additional flexibility for system designers to appropriately set the device in desired mode as provided in Table 7-3. If multiple DS320PR410 devices are used for a same PCI express link, then the PD pins from different devices can be shorted and driven together. For most applications the RX_DET pin can be left floating for default settings. In SMBus/I^{2}C mode each channel can be configured independently.

Table 7-3. Receiver Detect State Machine Settings

PD	RX_DET	Rx Impedance	COMMENTS
L	L0	Always 50 Ω	PCI Express Rx detection state machine is disabled. Recommended for non PCIe interface use case where the DS320PR410 is used as buffer with equalization.
L	L1	Pre Detect: Hi-Z Post Detect: 50 Ω.	Outputs polls until 3 consecutive valid detections
L	L2	Pre Detect: Hi-Z Post Detect: 50 Ω.	Outputs polls until 2 consecutive valid detections
L	L3	NA	Reserved
L	L4 (Float)	Pre Detect: Hi-Z Post Detect: 50 Ω.	Tx polls every ≅150 µs until valid termination is detected. Rx impedance held at Hi-Z until detection. Reset by asserting PD high for 200 µs then low.
H	X	Hi-Z	Reset Channels 0-3 signal path and set their Rx impedance to Hi-Z

In PCIe applications, the PD pin can be connected to PCIe sideband signals PERST# with inverted polarity or one or more appropriate PRSNTx# signals to achieve the desired RX detect functionality.

7.4 Device Functional Modes

7.4.1 Active PCIe Mode

In pin mode, the RX_DET = L1/L2/L4 sets the device in normal operation with PCIe state machine enabled. See RX Detect Control Registers in i^{2}c mode. In the active PCIe mode, the PD pin is driven low in a system (for example, by PCIE connector *PRSNTx#* or fundamental reset *PERST#* signal). In active PCIe mode, the DS320PR410 redrives and equalizes PCIe Rx or Tx signals to provide better signal integrity.

7.4.2 Active Buffer Mode

In pin mode, the RX_DET = L0 sets the device in normal operation with PCIe state machine disabled. For more information, see RX Detect Control Registers in I^{2}c mode. The active buffer mode is recommended for non-PCIe use cases, where the device is working as a buffer to provide linear equalization to improve signal integrity.

7.4.3 Standby Mode

The pin setting PD = H puts the device in standby mode. In this mode, the device is in standby mode conserving power.

7.5 Programming

7.5.1 Pin mode

The DS320PR410 can be fully configured through pin-strap pins. In this mode, the device uses 2-level and 5-level pins for device control and signal integrity optimum settings.

7.5.1.1 Five-Level Control Inputs

The DS320PR410 has five (EQ0, EQ1, GAIN, MODE, and RX_DET) 5-level input pins that are used to control the configuration of the device. These 5-level inputs use a resistor divider to help set the 5 valid levels and provide a wider range of control settings. External resistors must be of 10% tolerance or better. The EQ0, EQ1,

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GAIN, and RX_DET pins are sampled at power-up only. The MODE pin can be exercised at device power up or in normal operation mode.

Table 7-4. 5-level Control Pin Settings

LEVEL	SETTING
L0	1 kΩ to GND
L1	8.25 kΩ to GND
L2	24.9 kΩ to GND
L3	75 kΩ to GND
L4	F (Float)

7.5.2 SMBUS/I^{2}C Register Control Interface

If MODE = L2 (SMBus/I^{2}C Secondary control mode), then the DS320PR410 is configured through a standard I^{2}C or SMBus interface that may operate up to 400 kHz. The secondary address of the DS320PR410 is determined by the pin strap settings on the ADDR1 and ADDR0 pins. The sixteen possible secondary addresses for channels 0-3 are provided in Table 7-5. In SMBus/I^{2}C modes the SCL and SDA pins must be pulled up to a 3.3 V supply with a pull-up resistor. The value of the resistor depends on total bus capacitance. 4.7 kΩ is a good first approximation for a bus capacitance of 10 pF.

Table 7-5. SMBUS/I2C Secondary Address Settings

ADDR1	ADDR0	7-bit Secondary Address Channels 0-3
L0	L0	0x18
L0	L1	0x1A
L0	L2	0x1C
L0	L3	0x1E
L0	L4	Reserved
L1	L0	0x20
L1	L1	0x22
L1	L2	0x24
L1	L3	0x26
L1	L4	Reserved
L2	L0	0x28
L2	L1	0x2A
L2	L2	0x2C
L2	L3	0x2E
L2	L4	Reserved
L3	L0	0x30
L3	L1	0x32
L3	L2	0x34
L3	L3	0x36
L3	L4	Reserved

The DS320PR410 has two types of registers:

- **Shared Registers:** these registers can be accessed at any time and are used for device-level configuration, status read back, control, or to read back the device ID information.
- **Channel Registers:** these registers are used to control and configure specific features for each individual channel. All channels have the same register set and can be configured independent of each other or configured as a group through broadcast writes to Channels 0-3.

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Channel Registers Base Address	Channel 0-3 Access
0x00	Channel 0 registers
0x20	Channel 1 registers
0x40	Channel 2 registers
0x60	Channel 3 registers
0x80	Broadcast write channel 0-3 registers, read channel 0 registers
0xA0	Broadcast write channel 0-1 registers, read channel 0 registers
0xC0	Broadcast write channel 2-3 registers, read channel 2 registers
0xE0	Channel 0-3 share registers

7.5.2.1 Shared Registers

Table 7-6. General Registers (Offset = 0xE2)

Bit	Field	Type	Reset	Description
7	RESERVED	R	0x0	Reserved
6	rst_i2c_regs	R/W/SC	0x0	Device reset control: Reset all I^2C registers to default values (self-clearing).
5-1	RESERVED	R	0x0	Reserved
0	frc_eeprm_rd	R/W/SC	0x0	Override MODE and READ_EN_N status to force manual EEPROM configuration load.

Table 7-7. DEVICE_ID0 Register (Offset = 0xF0)

Bit	Field	Type	Reset	Description
7-4	RESERVED	R	0x0	Reserved
3	device_id0_3	R	0x0	Device ID0 [3:1]: 001
2	device_id0_2	R	0x1	see MSB
1	device_id0_1	R	0x1	see MSB
0	RESERVED	R	X	Reserved

Table 7-8. DEVICE_ID1 Register (Offset = 0xF1)

Bit	Field	Type	Reset	Description
7	device_id[7]	R	0x0	Device ID 0010 1001: DS320PR410
6	device_id[6]	R	0x0	see MSB
5	device_id[5]	R	0x1	see MSB
4	device_id[4]	R	0x0	see MSB
3	device_id[3]	R	0x1	see MSB
2	device_id[2]	R	0x0	see MSB
1	device_id[1]	R	0x0	see MSB
0	device_id[0]	R	0x0	see MSB

7.5.2.2 Channel Registers

Table 7-9. RX Detect Status Register (Channel Register Base + Offset = 0x00)

Bit	Field	Type	Reset	Description
7	rx_det_comp_p	R	0x0	Rx Detect positive data pin status: 0: Not detected 1: Detected – the value is latched

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Table 7-9. RX Detect Status Register (Channel Register Base + Offset = 0x00) (continued)

Bit	Field	Type	Reset	Description
6	rx_det_comp_n	R	0x0	Rx Detect negative data pin status: 0: Not detected 1: Detected – the value is latched
5-0	RESERVED	R	0x0	Reserved

Table 7-10. EQ Gain Control Register (Channel Register Base + Offset = 0x01)

Bit	Field	Type	Reset	Description
7	eq_stage1_bypass	R/W	0x0	Enable EQ stage 1 bypass: 0: Bypass disabled 1: Bypass enabled
6	eq_stage1_3	R/W	0x0	EQ Boost stage 1 control See Table 7-1 for details
5	eq_stage1_2	R/W	0x0	
4	eq_stage1_1	R/W	0x0	
3	eq_stage1_0	R/W	0x0	
2	eq_stage2_2	R/W	0x0	EQ Boost stage 2 control See Table 7-1 for details
1	eq_stage2_1	R/W	0x0	
0	eq_stage2_0	R/W	0x0	

Table 7-11. EQ Gain / Flat Gain Control Register (Channel Register Base + Offset = 0x03)

Bit	Field	Type	Reset	Description
7	RESERVED	R	0x0	Reserved
6	eq_profile_3	R/W	0x0	EQ mid-frequency boost profile See Table 7-1 for details
5	eq_profile_2	R/W	0x0	
4	eq_profile_1	R/W	0x0	
3	eq_profile_0	R/W	0x0	
2	flat_gain_2	R/W	0x1	Flat gain select: See Table 7-2 for details
1	flat_gain_1	R/W	0x0	
0	flat_gain_0	R/W	0x1	

Table 7-12. RX Detect Control Register (Channel Register Base + Offset = 0x04)

Bit	Field	Type	Reset	Description
7-3	RESERVED	R	0x0	Reserved
2	mr_rx_det_man	R/W	0x0	Manual override of rx_detect_p/n decision: 0: rx detect state machine is enabled 1: rx detect state machine is overridden – always valid RX termination detected
1	en_rx_det_count	R/W	0x0	Enable additional RX detect polling 0: Additional RX detect polling disabled 1: Additional RX detect polling enabled
0	sel_rx_det_count	R/W	0x0	Select number of valid RX detect polls – gated by en_rx_det_count = 1 0: Device transmitters poll until 2 consecutive valid detections 1: Device transmitters poll until 3 consecutive valid detections

Table 7-13. PD Override Register (Channel Register Base + Offset = 0x05)

Bit	Field	Type	Reset	Description
7	device_en_override	R/W	0x0	Enable power down overrides through SMBus/I^2C 0: Manual override disabled 1: Manual override enabled

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Table 7-13. PD Override Register (Channel Register Base + Offset = 0x05) (continued)

Bit	Field	Type	Reset	Description
6-0	device_en	R/W	0x1111111	Manual power down of redriver various blocks – gated by device_en_override = 1 1111111: All blocks are enabled 0000000: All blocks are disabled

Table 7-14. Bias Register (Channel Register Base + Offset = 0x06)

Bit	Field	Type	Reset	Description
5-3	Bias current	R/W	0x100	Control bias current Set 001 for best performance
7,6,2-0	Reserved	R/W	0x00000	Reserved

7.5.3 SMBus/I^{2}C Primary Mode Configuration (EEPROM Self Load)

The DS320PR410 can also be configured by reading from EEPROM. To enter into this mode, the MODE pin must be set to L1. The EEPROM load operation only happens once after the device's initial power-up. If the DS320PR410 is configured for SMBus Primary mode, then it will remain in the SMBus IDLE state until the READ_EN_N pin is asserted to LOW. After the READ_EN_N pin is driven LOW, the DS320PR410 becomes an SMBus primary and attempts to self-configure by reading the device settings stored in an external EEPROM (SMBus 8-bit address 0xA0). When the DS320PR410 has finished reading from the EEPROM successfully, it will drive the DONEn pin LOW. SMBus/I^{2}C secondary operation is available in this mode before, during, or after EEPROM reading. Note: during EEPROM reading, if the external SMBus/I^{2}C primary wants to access DS320PR410 registers, then it must support arbitration.

When designing a system for using the external EEPROM, the user must follow these specific guidelines:

- EEPROM size of 2 Kb (256 × 8-bit) is recommended.
- Set MODE = L1, configure for SMBus Primary mode.
- The external EEPROM device address byte must be 0xA0 and capable of 400 kHz operation at 3.3 V supply
- In SMBus/I^{2}C modes the SCL and SDA pins must be pulled up to a 3.3 V supply with a pull-up resistor. The value of the resistor depends on total bus capacitance. 4.7 kΩ is a good first approximation for a bus capacitance of 10 pF.

Figure 7-1 shows a use case with four DS320PR410 are cascaded to read from single EEPROM, but the user can cascade any number of DS320PR410 devices in a similar way. Tie the READ_EN_N pin of the first device low to automatically initiate EEPROM read at power up. Alternatively, the READ_EN_N pin of the first device can also be controlled by a micro-controller to initiate the EEPROM read manually. Leave the DONEn pin of the final device floating, or connect the pin to a micro-controller input to monitor the completion of the final EEPROM read.

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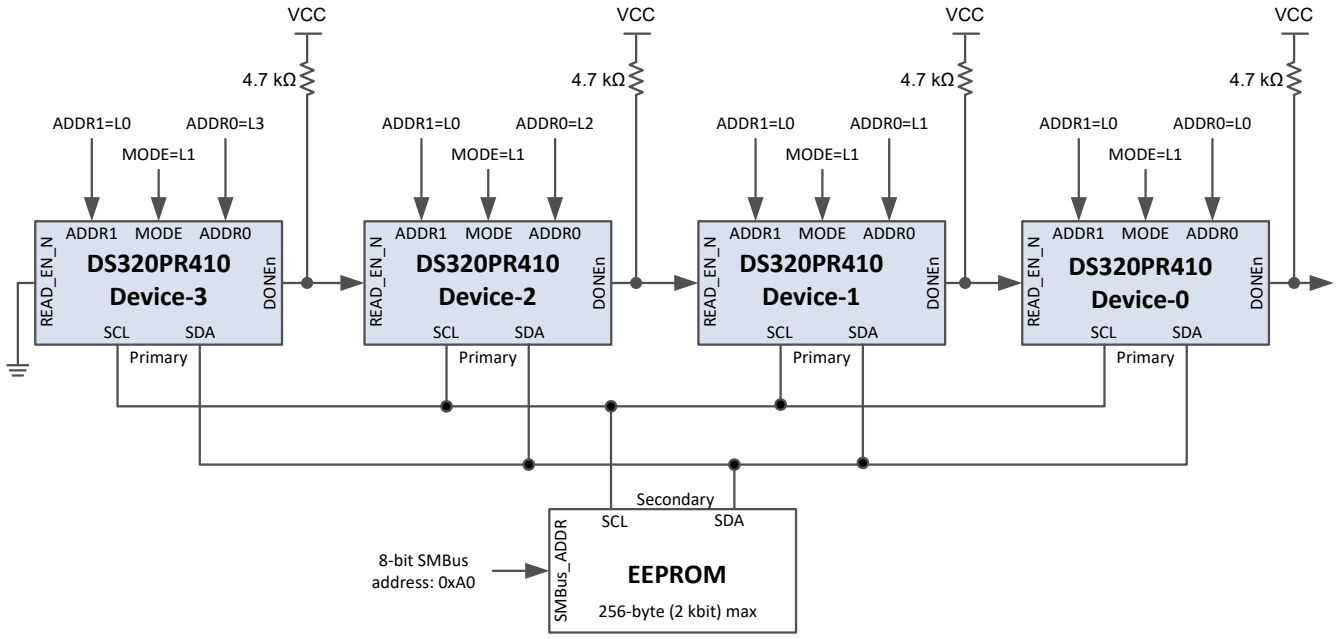


Figure 7-1. Daisy Chain Four DS320PR410 Devices to Read from Single EEPROM

8 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.

8.1 Application Information

The DS320PR410 is a high-speed linear redriver which extends the reach of differential channels impaired by loss from transmission media like PCBs and cables. It can be deployed in a variety of different systems. The following sections outline typical applications and their associated design considerations.

8.2 Typical Applications

The DS320PR410 is a PCI Express linear redriver that can also be configured as interface agnostic redriver by disabling its Rx detect feature. The device can be used in wide range of interfaces including:

- PCI Express 1.0, 2.0, 3.0, 4.0, and 5.0
- Ultra Path Interconnect (UPI) 1.0 and 2.0
- DisplayPort 2.0

The DS320PR410 is a protocol agnostic 4-channel linear redriver with PCIe receiver-detect capability. Its protocol agnostic nature allows it to be used in PCIe x4, x8, and x16 applications. Figure 8-1 shows how a number of DS320PR410 devices can be used to obtain signal conditioning for PCIe buses of varying widths.

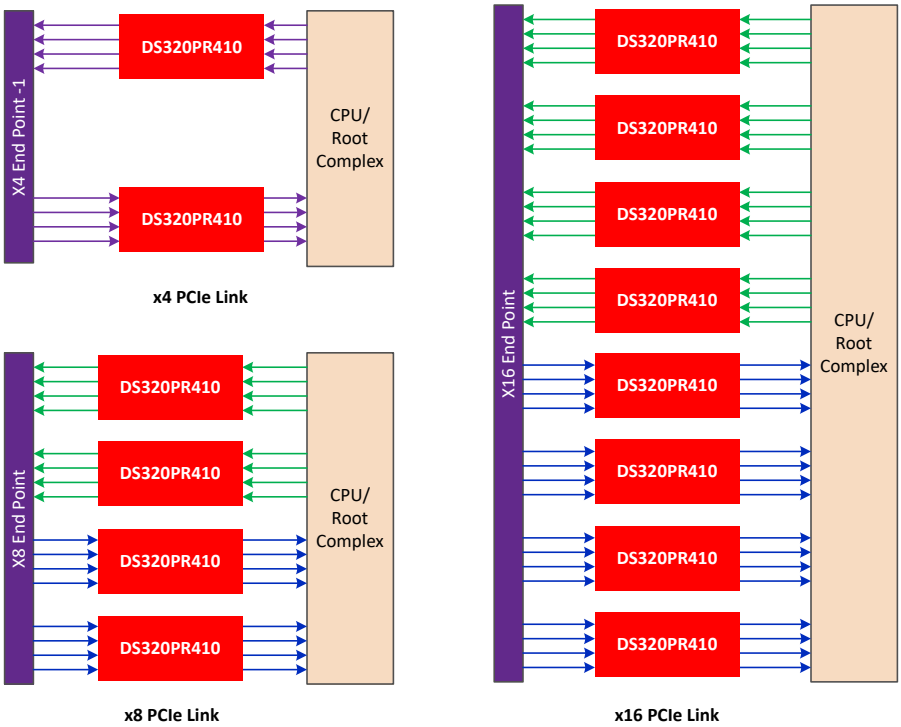


Figure 8-1. PCI Express x4, x8 and x16 Use Cases Using DS320PR410

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8.2.1 PCIe Reach Extension – x16 Lane Configuration

The DS320PR410 can be used in server or motherboard applications to boost transmit and receive signals to increase the reach of the host or root complex processor to PCI Express slots or connectors. The following sections outline detailed procedures and design requirements for a typical PCIe x16 lane configuration; however, the design recommendations can be used in any lane configuration.

8.2.1.1 Design Requirements

As with any high-speed design, there are many factors which influence the overall performance. The following list indicates critical areas for consideration during design.

- Use 85 Ω impedance traces when interfacing with PCIe CEM connectors. Length matching on the P and N traces should be done on the single-end segments of the differential pair.
- Use a uniform trace width and trace spacing for differential pairs.
- Place AC-coupling capacitors near the receiver end of each channel segment to minimize reflections.
- For PCIe Gen 3.0, 4.0, and 5.0, AC-coupling capacitors of 220 nF are recommended. Set the maximum body size to 0402 and add a cutout void on the GND plane below the landing pad of the capacitor to reduce parasitic capacitance to GND.
- Back-drill connector vias and signal vias to minimize stub length.
- Use reference plane vias for a low inductance path for the return current.

8.2.1.2 Detailed Design Procedure

In PCIe Gen 3.0, 4.0, and 5.0 applications, the specification requires Rx-Tx (of root-complex and endpoint) link training to establish and optimize signal conditioning settings at 8 Gbps, 16 Gbps, and 32 Gbps, respectively. In link training, the Rx partner requests a series of FIR – preshoot and de-emphasis coefficients (10 Presets) from the Tx partner. The Rx partner includes 7-levels of CTLE followed by a single tap DFE. The link training would pre-condition the signal, with an equalized link between the root-complex and endpoint resulting an optimized link. Note that there is no link training in PCIe Gen 1.0 (2.5 Gbps) or PCIe Gen 2.0 (5.0 Gbps) applications.

For operation in Gen 3.0, 4.0, and 5.0 links, the DS320PR410 is designed with linear data-path to pass the Tx Preset signaling (by root complex and end point) onto the Rx (of root complex and end point) for the PCIe Gen 3.0, 4.0, or 5.0 link to train and optimize the equalization settings. The linear redriver DS320PR410 helps extend the PCB trace reach distance by boosting the attenuated signals with its equalization, which allows the user to recover the signal by the downstream Rx more easily. The device must be placed in between the Tx and Rx (of root complex and end point) in such a way that both Rx and Tx signal swing stays within the linearity range of the device. Adjustments to the DS320PR410 EQ setting should be performed based on the channel loss to optimize the eye opening in the Rx partner. The available EQ gain settings are provided in Table 7-1. For most PCIe systems, the default flat gain setting 0 dB (GAIN = floating) would be sufficient. However, a flat gain attenuation can be utilized to apply extra equalization when needed to keep the data-path linear.

The DS320PR410 can be optimized for a given system utilizing its three configuration modes – Pin mode, SMBus/I^2C Primary mode, and SMBus/I^2C Secondary mode. In SMBus/I^2C modes the SCL and SDA pins must be pulled up to a 3.3 V supply with a pull-up resistor. The value of the resistor depends on total bus capacitance. 4.7 kΩ is a good first approximation for a bus capacitance of 10 pF.

In PCIe applications PD pin can be connected to PCIe sideband signals PERST# with inverted polarity or one or more appropriate PRSNTx# signals to achieve desired RX detect functionality.

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Figure 8-2 shows a simplified schematic for x16 lane configuration in Pin mode.

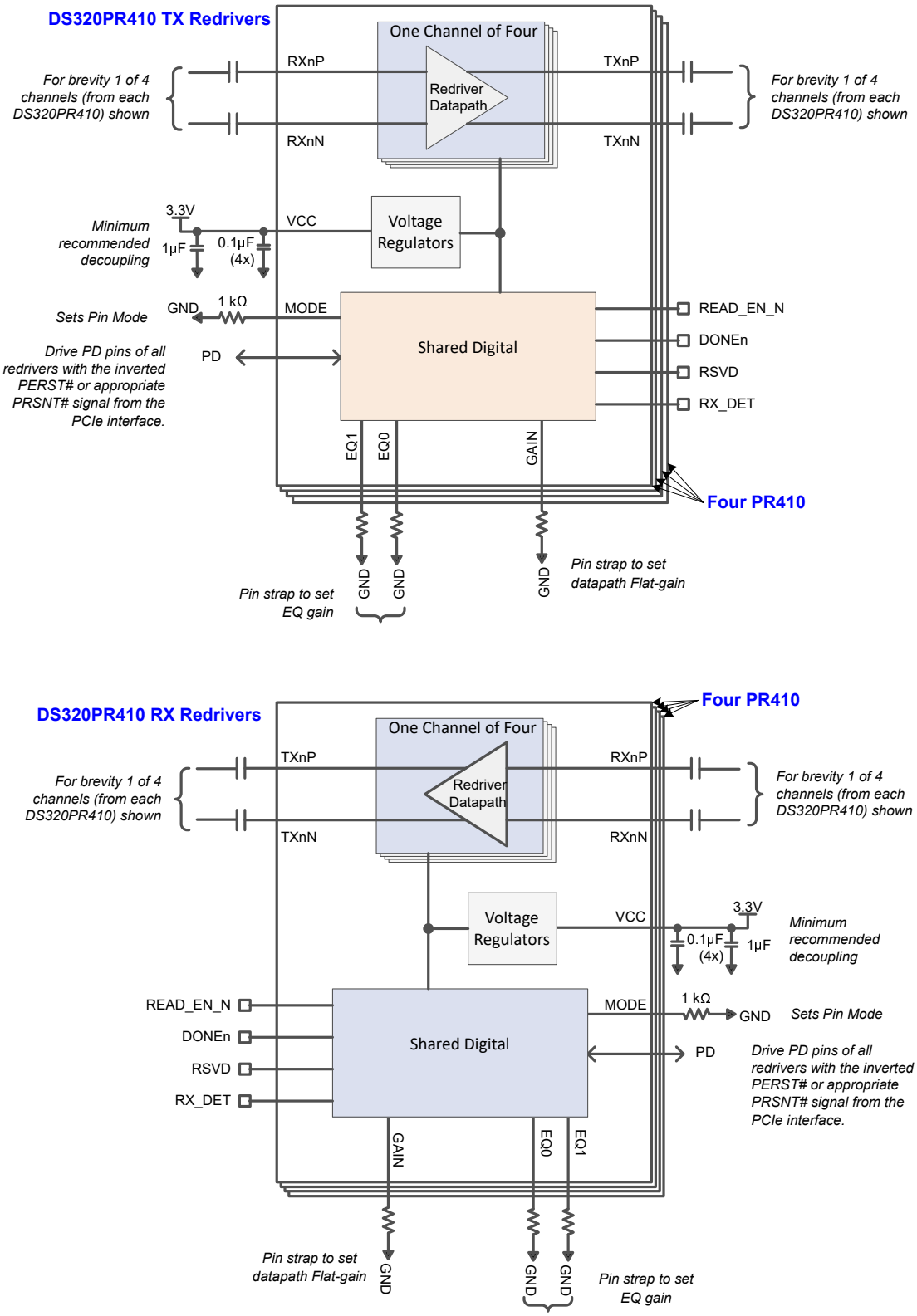


Figure 8-2. Simplified Schematic for PCIe x16 Lane Configuration in Pin mode

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8.2.1.3 Application Curves

The DS320PR410 is a linear redriver that can be used to extend channel reach of a PCIe link. Normally, PCIe-compliant Tx and Rx are equipped with signal-conditioning functions and can handle channel losses of up to 36 dB at 16 GHz. With the DS320PR410, the total channel loss between a PCIe root complex and an end point can be extended up to 58 dB at 16 GHz.

To demonstrate the reach extension capability of the DS320PR410, two comparative setups are constructed. In first setup as shown in Figure 8-3 there is no redriver in the PCIe 5.0 link. Figure 8-4 shows eye diagram at the end of the link using SigTest. In second setup as shown in Figure 8-5, the DS320PR410 is inserted in the middle to extend link reach. Figure 8-6 shows SigTest eye diagram.

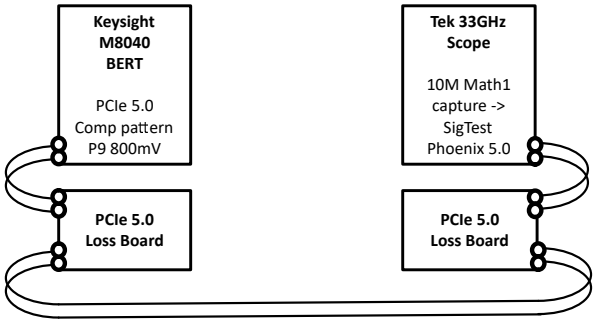


Figure 8-3. PCIe 5.0 Link Baseline Setup Without Redriver the Link Elements

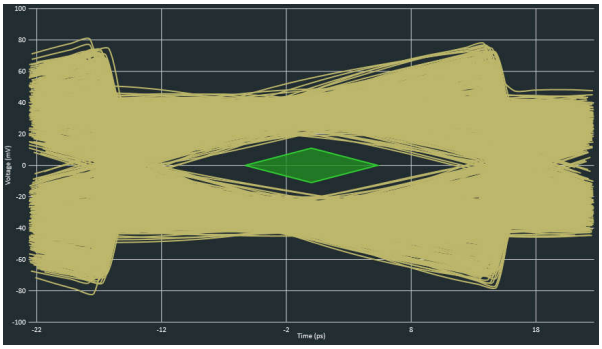


Figure 8-4. PCIe 5.0 link Baseline Setup Without Redriver Eye Diagram Using SigTest

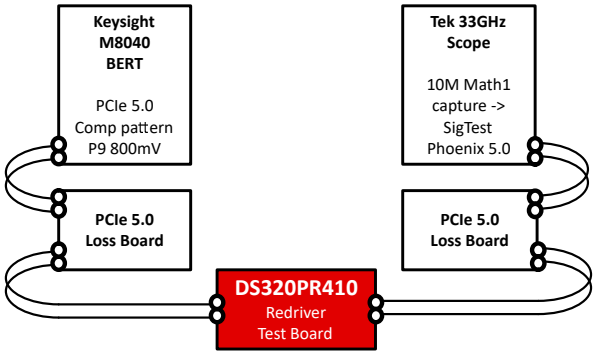


Figure 8-5. PCIe 5.0 Link Setup with the DS320PR410 the Link Elements

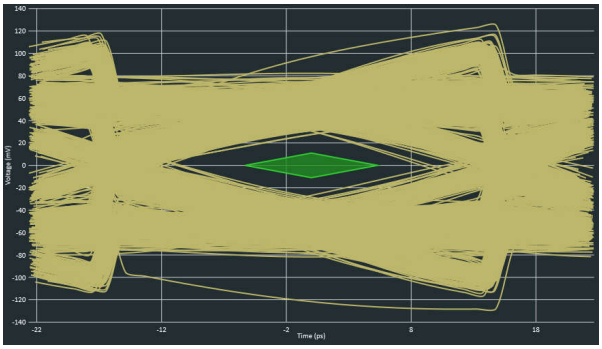


Figure 8-6. PCIe 5.0 Link Setup with the DS320PR410 Eye Diagram Using SigTest

Table 8-1 provides the PCIe 5.0 links without and with the DS320PR410 that shows that redriver is capable of ≅22 dB reach extension at PCIe 5.0 speed. Note: actual reach extension depends on various signal integrity factors. It is recommended to run signal integrity simulations with all the components in the link to get more accurate guidance.

Table 8-1. PCIe 5.0 Reach Extension Using the DS320PR410

Setup	Pre Channel Loss	Post Channel Loss	Total Loss	Eye at BER 1E-12	SigTest Pass?
Baseline – no DUT	—	—	≅36 dB	13 ps, 28 mV	Pass
With DUT (DS320PR410)	≅29 dB	≅29 dB	≅58 dB	13 ps, 35 mV	Pass

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8.3 Power Supply Recommendations

Follow these general guidelines when designing the power supply:

1. Design the power supply so that it provides the DC voltage, AC noise, and start-up ramp time outlined in the *Recommended Operating Conditions* section.
2. The DS320PR410 does not require any special power supply filtering, such as ferrite beads, provided that the recommended operating conditions are met. Only standard supply decoupling is required. Typical supply decoupling consists of a 0.1 µF capacitor per VCC pin, one 1.0 µF bulk capacitor per device, and one 10 µF bulk capacitor per power bus that delivers power to one or more DS320PR410 devices. The local decoupling (0.1 µF) capacitors must be connected as close to the VCC pins as possible and with minimal path to the DS320PR410 ground pad.

8.4 Layout

8.4.1 Layout Guidelines

The following guidelines should be followed when designing the layout:

1. Place the decoupling capacitors as close to the VCC pins as possible. Placing the decoupling capacitors directly underneath the device is recommended if the board design permits.
2. High-speed differential signals TXnP/TXnN and RXnP/RXnN should be tightly coupled, skew matched, and impedance controlled.
3. Avoid vias on the high-speed differential signals when possible. When vias must be used, take care to minimize the via stub, either by transitioning through most or all layers or by back drilling.
4. GND relief can be used (but is not required) beneath the high-speed differential signal pads to improve signal integrity by counteracting the pad capacitance.
5. Place GND vias directly beneath the device connecting the GND plane attached to the device to the GND planes on other layers. This has the added benefit of improving thermal conductivity from the device to the board.

8.4.2 Layout Example

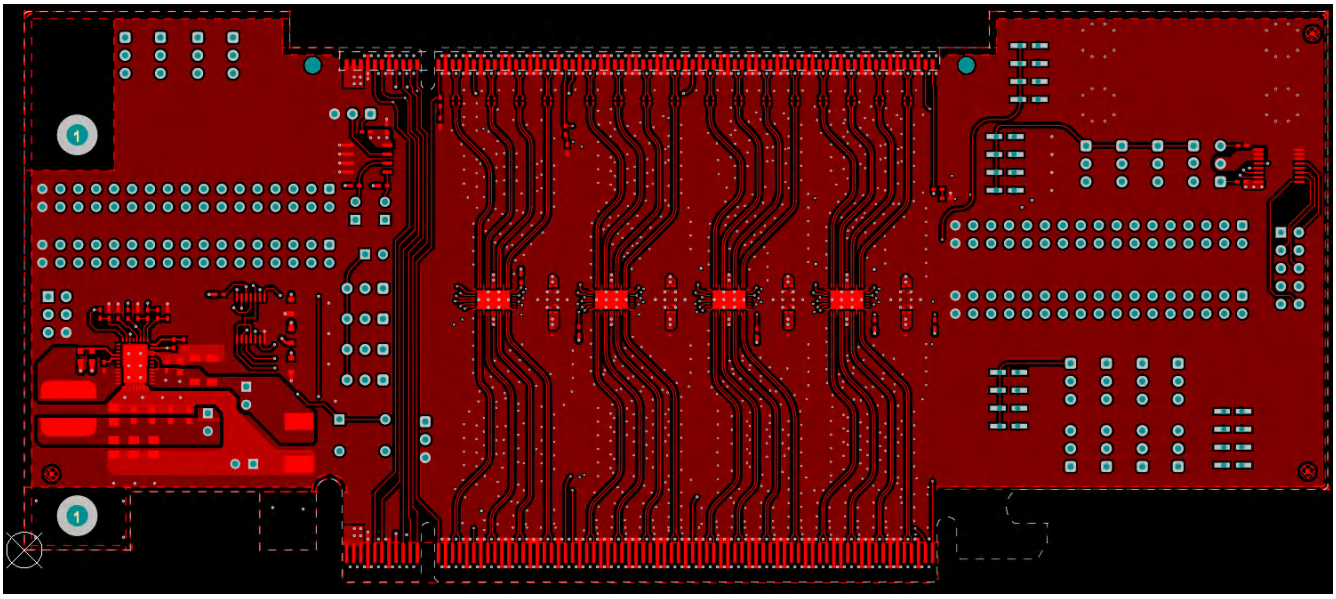


Figure 8-7. Layout Example: TI PCIe 5.0 Riser Card Using DS320PR410 With CEM Connectors - Top Layer

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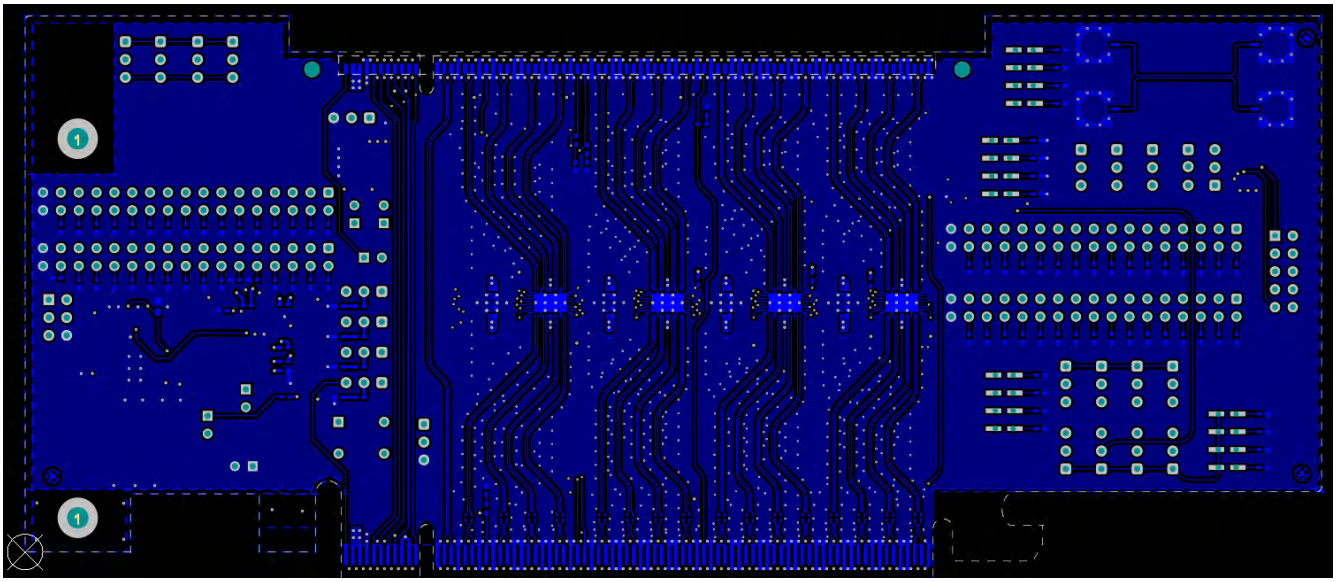


Figure 8-8. Layout Example: TI PCIe 5.0 Riser Card Using DS320PR410 With CEM Connectors - Bottom Layer

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9 Device and Documentation Support

9.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Subscribe to updates* 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.

9.2 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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9.4 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.

9.5 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

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.

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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)
DS320PR410RNQR	Active	Production	WQFN (RNQ) | 40	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5PR4
DS320PR410RNQR.B	Active	Production	WQFN (RNQ) | 40	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5PR4
DS320PR410RNQT	Active	Production	WQFN (RNQ) | 40	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5PR4
DS320PR410RNQT.B	Active	Production	WQFN (RNQ) | 40	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	5PR4

(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.

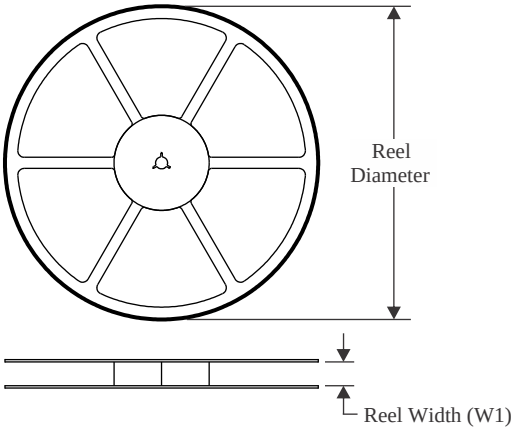
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

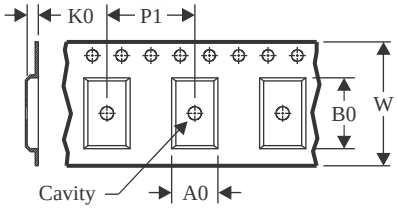
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

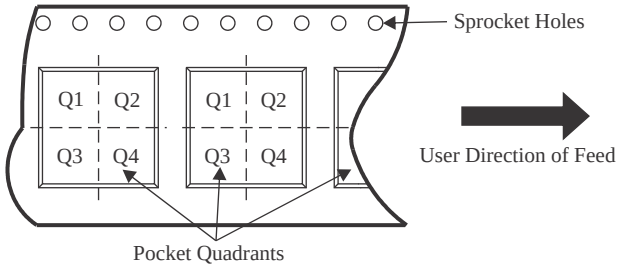


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

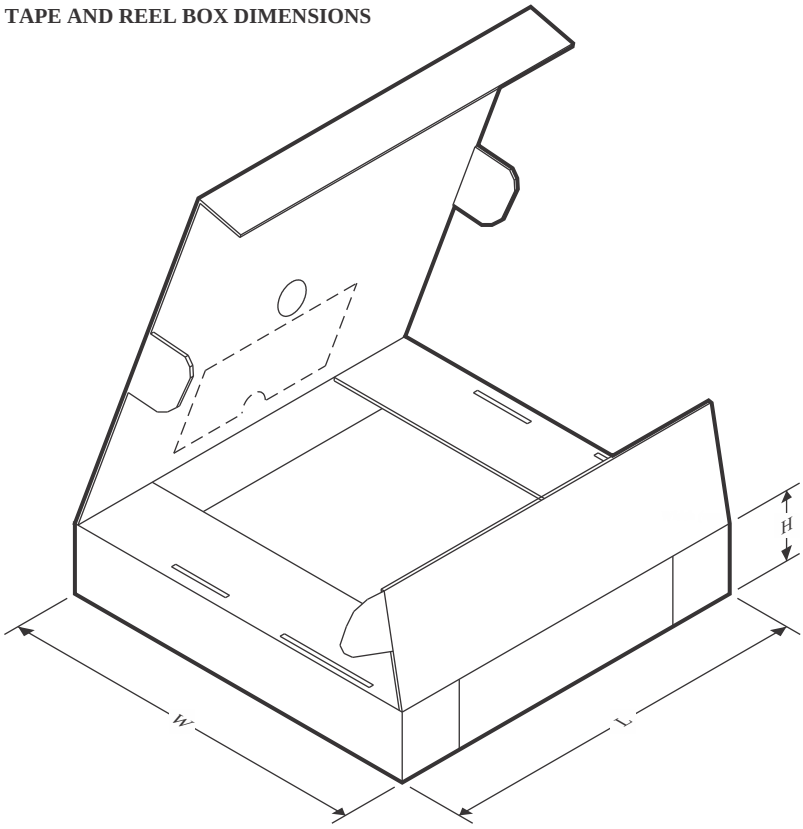
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
DS320PR410RNQR	WQFN	RNQ	40	3000	330.0	12.4	4.3	6.3	1.1	8.0	12.0	Q2
DS320PR410RNQT	WQFN	RNQ	40	250	180.0	12.4	4.3	6.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

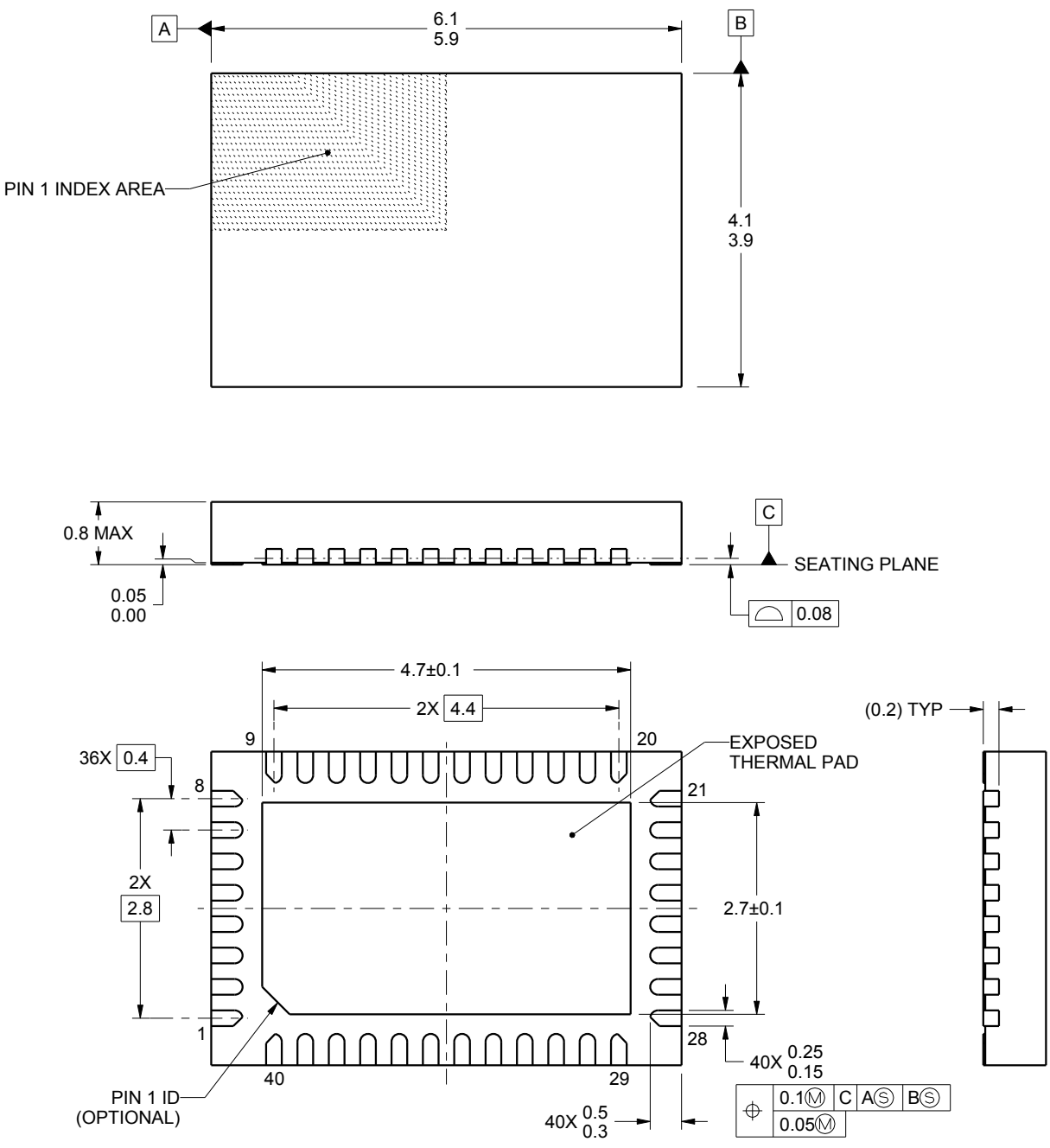
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
DS320PR410RNQR	WQFN	RNQ	40	3000	360.0	360.0	36.0
DS320PR410RNQT	WQFN	RNQ	40	250	210.0	185.0	35.0

PACKAGE OUTLINE

RNQ0040A

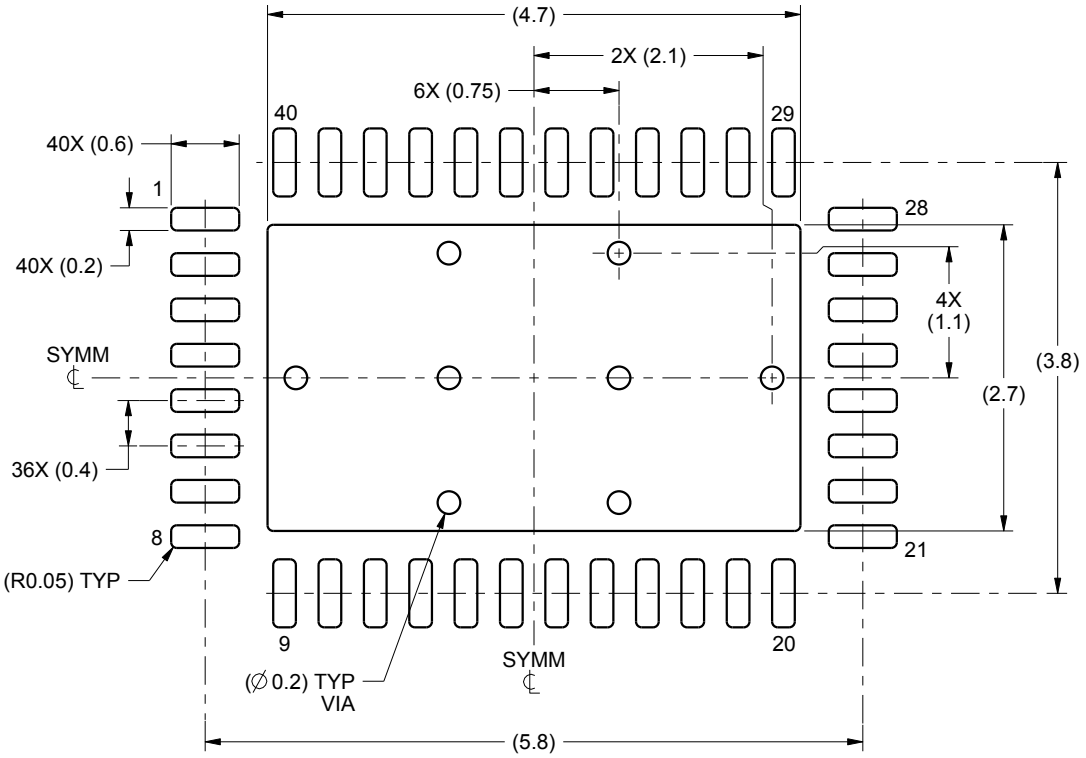
WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

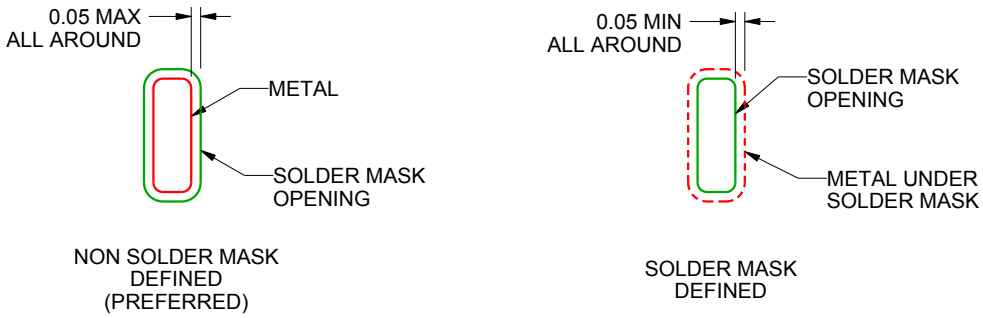


NOTES:

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.



LAND PATTERN EXAMPLE
SCALE:15X

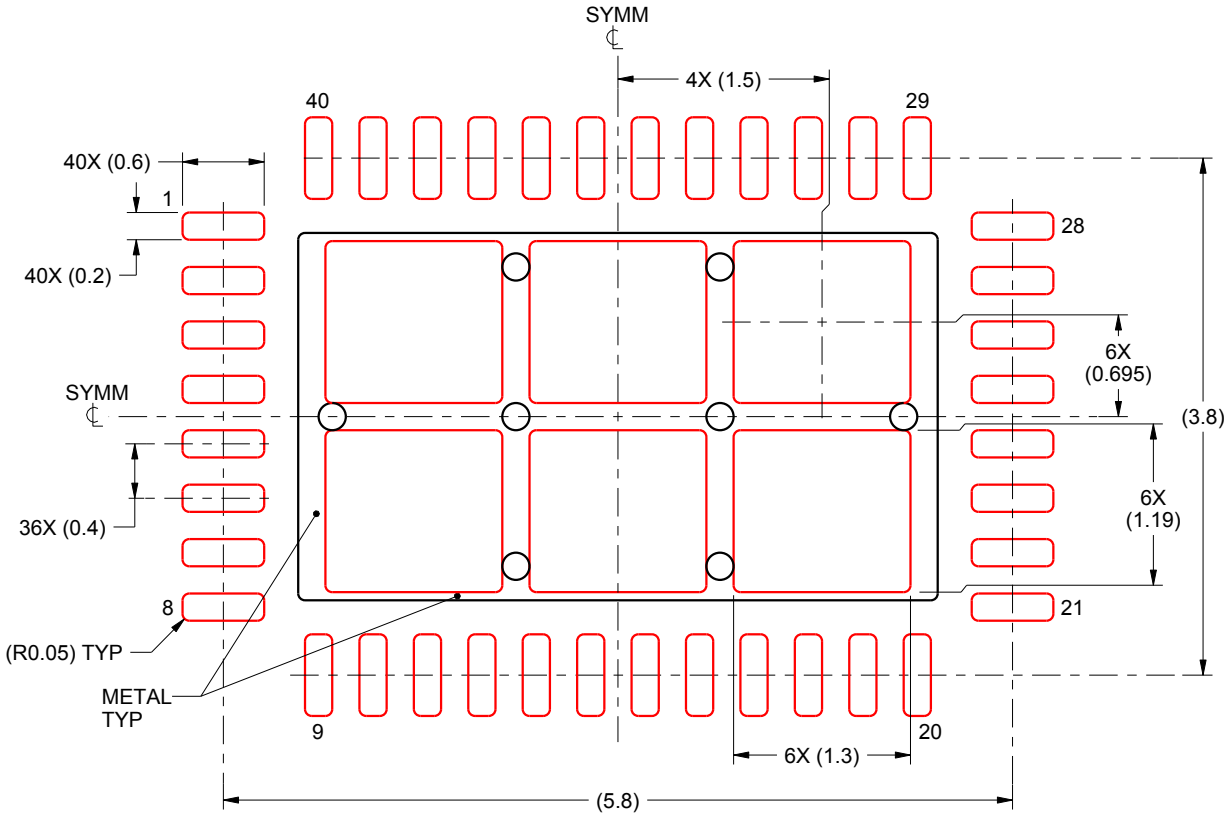


SOLDER MASK DETAILS

4222125/B 01/2016

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).



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD
73% PRINTED SOLDER COVERAGE BY AREA
SCALE:18X

4222125/B 01/2016

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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