

PI5USB216EQ

## USB 2.0 Signal Conditioner, BC 1.2 CDP

### Description

The PI5USB216EQ is an USB2.0 Signal conditioner to boost the signals and insert pre-emphasis to compensate the ISI signal loss in the channels before and after the conditioner. Patent-pending Design to maintain stable common mode with symmetrical Boost/Pre-emphasis on D+/D-.

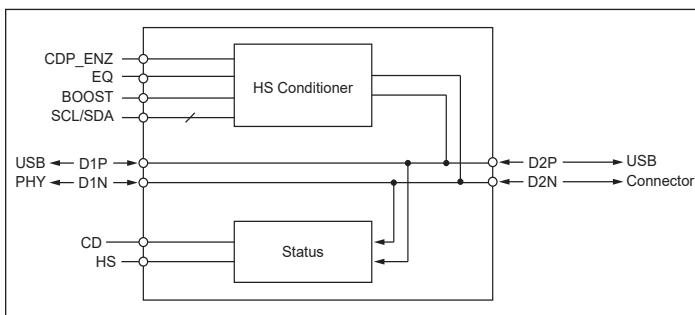
The PI5USB216EQ can be used in USB Host or Device application, far from USB PHY or far from connector application. Boost/Pre-emphasis and Receiver Equalization levels can be configured through pin or I2C mode depending on the channel conditions. Device Attach and High-Speed handshake success are also detected and reported.

The PI5USB216EQ is compatible with the USB On-The-Go (OTG) and battery charging (BC 1.2) protocols. The Integrated BC 1.2 battery charging controller can be enabled via a control pin.

### Application(s)

- Automotive Infotainment and Clusters
- Automotive Head Units
- Active Cables, Cable Extenders, Backplanes

### Functional Block Diagram



### Features

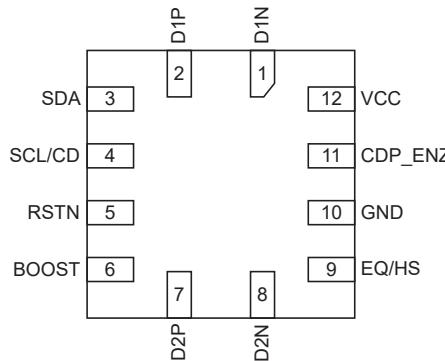
- AEC-Q100 Qualified for Automotive Applications
  - Device Temperature Grade 2: -40°C to 105°C
- Wide Supply Voltage Range: 2.3V to 5.5V
- USB Ports 5.5V Tolerance
- Low Power Consumption in Disconnect and Shutdown Mode
- Compatible with USB2.0, OTG 2.0 and BC 1.2
- Integrated BC 1.2 CDP Battery Charging Controller
- Host or Device Agnostic
- Boost/Pre-emphasis Level and Receiver Equalization Programming through Pin Mode or I2C Mode
- Symmetrical Boost/Pre-emphasis on D+/D- to Maintain Stable Common Mode
- Device Attach and High-Speed Detections
- Supports up to 5m Cable Length
- Supports up to 10m Cable Length with Two PI5USB216EQ
- ESD Performance: 2KV HBM, 1KV CDM
- Packaging (Pb-free & Green):
  - 12-contact, X2QFN (XUA)
- Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)
- Halogen and Antimony Free. "Green" Device (Note 3)
- The PI5USB216EQ is suitable for automotive applications requiring specific change control; this part is AEC-Q100 qualified, PPAP capable, and manufactured in IATF 16949 certified facilities.

<https://www.diodes.com/quality/product-definitions/>

#### Notes:

- No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
- See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
- Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
- Automotive products are AEC-Q100 qualified and are PPAP capable. Refer to <https://www.diodes.com/quality/>.

## Pin Configuration



## Pin Description

Pin Number	Pin Name	Type	Description
1, 2	D1N, D1P	I/O	USB High speed port
3	SDA	I/O	<p>500k<math>\Omega</math> internal pulled high and 1.8M<math>\Omega</math> internal pulled down.  <u>In I2C mode:</u>            Bidirectional I2C data pin; Connected to a pull-up resistor            During power up, pulled up SDA and SCL/CD with Rpu (&lt;10k<math>\Omega</math>) to enter I2C mode            OR floating to enter Pin mode</p> <p><u>In Pin mode:</u> Do not connect</p>
4	SCL/CD	I/O	<p><u>In I2C mode:</u> I2C Clock pin            During power up, pulled up SDA and SCL/CD with Rpu (&lt;10k<math>\Omega</math>) to enter I2C mode            OR floating to enter Pin mode (500k<math>\Omega</math> pull-down during RSTN rising)</p> <p><u>In Pin mode:</u>            Output CD, Flag indicating that a USB device is attached. Asserted from an unconnected state upon detection of DP or DM pull up resistor. De-asserted upon detection of disconnect.</p>
5	RSTN	I	<p>Device disable/enable.            Low – Device is at RESET and in shutdown, and            High – Normal operation.            500k<math>\Omega</math> internal pulled high and 1.8M<math>\Omega</math> internal pulled down.            Recommend 0.1-uF external capacitor to GND to ensure clean power on reset if not driven.            If the pin is driven, it must be held low until the supply voltage for the device reaches within specifications.</p>
6	BOOST	I	<p>USB High Speed Boost selection.            Select via external pull down resistor.            Sampled upon de-assertion of RSTN. Does not recognize real time adjustments.</p>
7, 8	D2P, D2N	I/O	USB High speed port

Pin Number	Pin Name	Type	Description
9	EQ/HS	I/O	<p><u>In I2C mode:</u> No function</p> <p><u>In Pin mode:</u>  At reset: 3-level input signal EQ. Receiver Equalization selection.  High Equalization (pin is pulled high)  Medium Equalization (pin is left floating)  Low Equalization (pin is pulled low)</p> <p>After Reset: Output signal HS. Flag indicating that channel is in High Speed mode.</p> <p>Asserted upon:</p> <ol style="list-style-type: none"> <li>1. Detection of USB-IF High Speed test fixture from an unconnected state followed by transmission of USB TEST_PACKET pattern.</li> <li>2. Detection of High Speed a successful High Speed handshake</li> </ol>
10	GND	Power	Ground
11	CDP_ENZ	I	Set CDP_ENZ is low to enable BC 1.2 CDP controller. Internal pullup 500kΩ
12	VCC	Power	Supply Power

## Maximum Ratings

(Above which useful life may be impaired. For user guidelines, not tested.)

Storage Temperature .....	-55°C to +125°C
Supply Voltage .....	-0.5V to +6.0V
USB IO Voltage .....	-0.5V to +6.0V
Control Input Voltage .....	-0.5V to +6.0V
Output Current .....	10mA
ESD: HBM Mode .....	2000V

**Note:**

Stresses greater than those listed under MAXIMUM RATINGS may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

## Recommended Operating Conditions

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Units
V <sub>CC</sub>	Supply Voltage		2.3		5.5	V
T <sub>A</sub>	Ambient Temperature		-40		85	°C

## DC Electrical Characteristics

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Units
<b>Power</b>						
I <sub>ACTIVE</sub>	High-speed (HS) active current	USB channel in HS mode with traffic		22	30	mA
I <sub>IDLE</sub>	High-speed idle current	USB channel in HS mode without traffic		14	22	mA
I <sub>SUSPE</sub>	High-speed suspend current	USB channel in HS Suspend mode		0.55	1.5	mA
I <sub>FS_L5</sub>	Full/Low speed current	USB channel in FS/LS mode		0.6	1.5	mA
I <sub>DISC</sub>	Disconnect current	No USB attachment		0.7	1.5	mA
I <sub>RSTN</sub>	Disable current	RSTB = 0V		13	80	μA
I <sub>LKG_FS</sub>	Pin fail-safe leakage current for SDA, SCL/CD, DxP/N, RSTN, EQ/HS, CDP_ENZ	VCC = 0V, Tested Pin = 5.5V			40	μA
<b>RSTN</b>						
V <sub>IH</sub>	High-level input voltage		1.05		5.5	V
V <sub>IL</sub>	Low-level input voltage		0		0.4	V
I <sub>IH</sub>	High-level input current	VRSTN = VCC	-15		15	μA
I <sub>IL</sub>	Low-level input current	VRSTN = 0V	-20		20	μA
<b>EQ</b>						
V <sub>IH</sub>	High-level input voltage		1.6			V
V <sub>IF</sub>	Floating-level input voltage		1.0		1.5	V
V <sub>IL</sub>	Low-level input voltage				0.8	V
I <sub>IH</sub>	High-level input current	VEQ = VCC	-5		5	uA
I <sub>IL</sub>	Low-level input current	VEQ = 0V	-5		5	uA

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Units
<b>CDP_ENZ</b>						
V <sub>IH</sub>	High-level input voltage		1.05		5.5	V
V <sub>IL</sub>	Low-level input voltage		0		0.4	V
I <sub>IH</sub>	High-level input current	V <sub>CDP_ENZ</sub> = V <sub>CC</sub>	-5		5	uA
I <sub>IL</sub>	Low-level input current	V <sub>CDP_ENZ</sub> = GND	-20		20	uA
<b>BOOST</b>						
R <sub>BOOST</sub>	Setting 0				160	Ω
	Setting 1		1.5		2	kΩ
	Setting 2		3.4		3.96	kΩ
	Setting 3		7.5			kΩ
<b>CD, HS</b>						
V <sub>OH</sub>	High-level output voltage	I <sub>out</sub> = 50uA, V <sub>CC</sub> > 3.0V	2.5			V
		I <sub>out</sub> = 25uA, V <sub>CC</sub> = 2.3V	1.8			
V <sub>OL</sub>	Low-level output voltage	I <sub>out</sub> = 50uA			0.4	V
<b>SCL, SDA</b>						
C <sub>I2CBUS</sub>	I <sub>2</sub> C Bus capacitance		4		150	pF
V <sub>IH</sub>	SDA and SCL input high level voltage		1.05		5.5	V
V <sub>IL</sub>	SDA and SCL input low level voltage		0		0.3	V
I <sub>SDAO</sub>	SDA low level output current	SDA = 0.4V	1.5			mA
f <sub>SCL</sub>	SCL clock frequency				1000	KHz
<b>DxP, DxM</b>						
C <sub>IO</sub>	Capacitance to GND	240MHz, Device off		2.4		pF

## Switching Characteristics

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Units
F <sub>BR</sub>	DxP/M bit rate				480.24	Mbps
t <sub>RISE</sub>	DxP/M rise time	10% - 90%; V <sub>CC</sub> = 5.5V; Max BOOST	100			ps
t <sub>FALL</sub>	DxP/M fall time	90% - 10%; V <sub>CC</sub> = 5.5V; Max BOOST	100			ps
t <sub>RSTN_PW</sub>	Minimum width to detect a valid RSTN signal assert when the pin is actively driven		20			μs
t <sub>STABLE</sub>	V <sub>CC</sub> stable before RSTN de-assertion		100			μs
t <sub>VCC_RAMP</sub>	V <sub>CC</sub> ramp time		0.2		100	ms

## Detail Description

### Overview

The PI5USB216EQ is an USB2.0 High-Speed (HS) Signal conditioner to boost the signals and insert pre-emphasis to compensate the ISI signal loss in the channels before and after. PI5USB216EQ will not alter the signals of USB Low Speed (LS), Full Speed (FS), On-The-Go (OTG) and Battery Charging (BC), while HS signals are compensated. Boost/Pre-emphasis level and Receiver Equalization can be programmed by I2C or pin mode.

### BOOST/PRE-EMPHASIS

The BOOST pin of PI5USB216EQ is used to configure the level of BOOST/PRE-EMPHASIS in pin mode and initialize the corresponding register in I2C mode. Amplitude boost compensates the amplitude loss due to the long channel before PI5USB216EQ, and pre-emphasis compensates the high frequency loss due to the low-pass long channel after PI5USB216EQ. The four settings can be selected by an external pulldown resistor at this pin and it will be sampled a short moment after RSTN rising.

BOOST Pin Connection	Register Default Value	Boost/Pre-Emphasis Level
Setting 0 (<160 Ω)	0000	Lowest
Setting 1 (~1.8 kΩ)	0101	Lower Mid
Setting 2 (~3.6 kΩ)	1010	Higher Mid
Setting 3 (>7.5 kΩ)	1111	Highest

### Receiver Equalization

The EQ pin of PI5USB216EQ is used to configure the level of Receiver Equalization in pin mode and initialize the corresponding register in I2C mode. The three settings can be selected by connecting the pin to VCC/Floating/GND during RSTN and it will be sampled a short moment after RSTN rising. After RSTN, the pin will function as an output for HS detection.

EQ Pin Connection	Register Default Value	Receiver Equalization Level
VCC	10	High
Floating	01	Mid
GND	00	Lowest

### BC 1.2 Charging Controller

The PI5USB216EQ can serve USB BC 1.2 host charging controller functionality if the host itself does not provide. When CDP\_ENZ is low, the PI5USB216EQ supports CDP charging downstream port functionality. CDP\_ENZ has an internal 500k pull up resistor when the pin is left open, CDP controller will be disable.

Pin 11 (CDP_ENZ)	CDP
High	Disable
Low	Enable

## I2C Mode

PI5USB216EQ supports 1MHz up-to-1.2V I2C for device configuration and status readback. This controller is enabled after SCL and SDA pins are sampled high shortly after de-assertion of RSTN. Otherwise, pin mode is enabled. In I2C mode, the registers can be accessed by I2C read/write transaction to 7-bit slave address 0x2C.

Address	Register	Type	Reset Value	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
00h	Reserved	RW	00000000b	Reserved							
01h	Control	RW	xx00xx00b	Receiver Equalization Level 00 (Lowest) 01 10 11 (Highest) Default value set by EQ pin sampling during startup	Boost/Pre-emphasis Level Coarse 00 (Lowest) 01 10 11 (Highest)	Fine 00 (Lowest) 01 10 11 (Highest)	Receiver Sensitivity Level 00 (Lowest) 01 10 11 (Highest)				
02h	Device ID	R	10110000b	Device ID: 10110			Default value is 00	Revision: 000			

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## Device Functional Modes

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### Low Speed (LS) Mode/Full Speed (FS) Mode

PI5USB216EQ automatically detects a LS/FS connection and does not enable signal compensation. In pin mode, CD pin is asserted high.

### High Speed (HS) Mode

PI5USB216EQ automatically detects a HS connection and will enable signal compensation. In pin mode, CD and HS pins are asserted high.

### OTG Mode/B.C.1.2 Mode

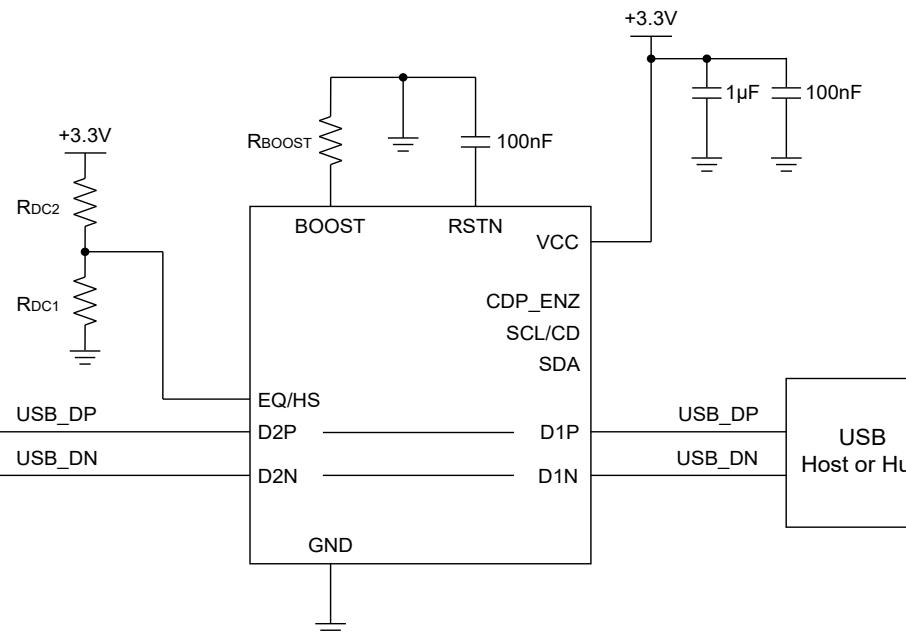
PI5USB216EQ does not enable signal compensation for OTG or B.C.1.2 signals. In pin mode, CD pin is asserted low.

### Shutdown Mode

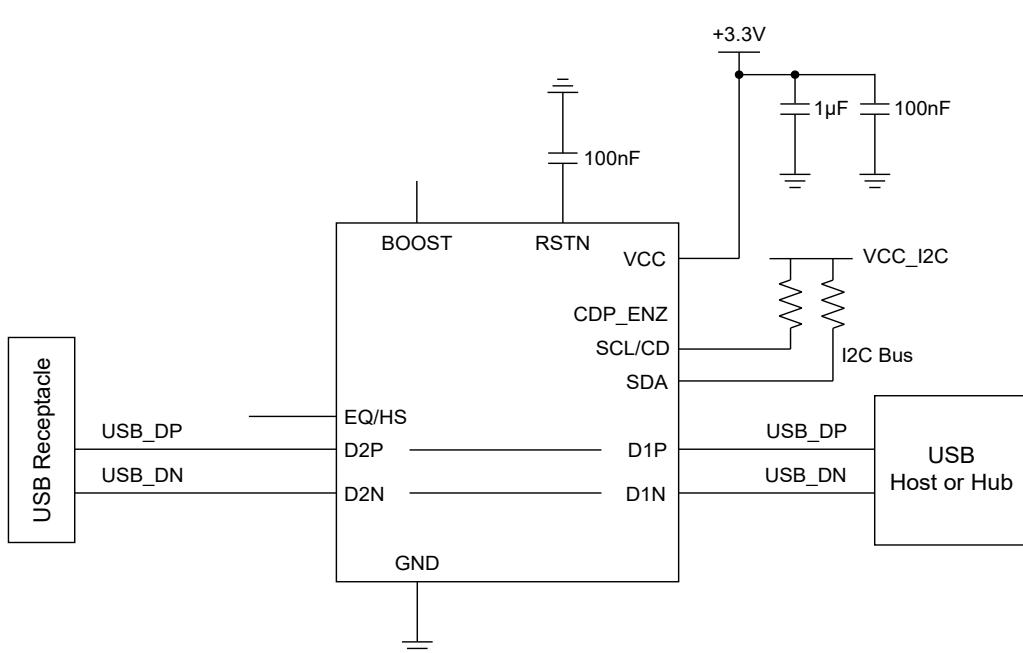
PI5USB216EQ is disabled when its RSTN pin is asserted low. In shutdown mode the USB channel is still fully operational, but there is neither signal compensation nor any indication from the CD or HS pin as to the status of the channel.

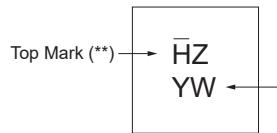
## Application Diagram

### Pin Mode



### I2C Mode



**PI5USB216EQ****Part Marking**

Y: Date Code (Year)

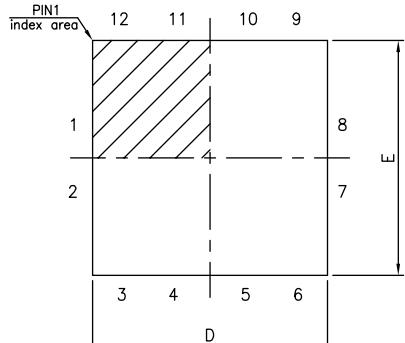
W: Date Code (Workweek)

Note: Date Code per MA-1251

Line above first character denotes Pin 1 indicator, Lead-free and Green

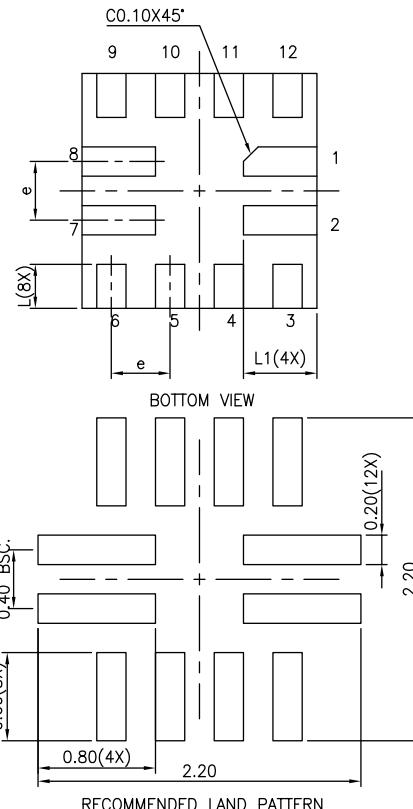
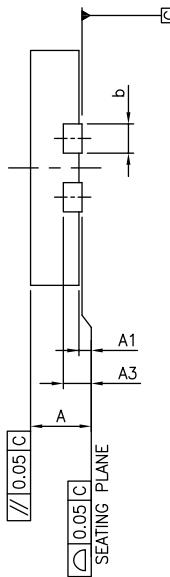
## Packaging Mechanical

### 12-X2QFN (XUA)



TOP VIEW

SYMBOLS	MIN.	NOM.	MAX.
A	0.30	0.35	0.40
A1	0.00	0.02	0.05
A3	0.127 REF.		
b	0.15	0.20	0.25
D	1.55	1.60	1.65
E	1.55	1.60	1.65
e	0.40 BSC		
L	0.25	0.30	0.35
L1	0.45	0.50	0.55



RECOMMENDED LAND PATTERN

NOTE :

1. ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
2. REFER JEDEC MO-288
3. RECOMMENDED LAND PATTERN IS FOR REFERENCE ONLY.



DATE: 04/21/22

DESCRIPTION: X2-QFN1616-12

PACKAGE CODE: XUA (XUA12)

DOCUMENT CONTROL #: PD-2167

REVISION: B

### For latest package info.

please check: <http://www.diodes.com/design/support/packaging/pericom-packaging/packaging-mechanicals-and-thermal-characteristics/>

## Mechanical Data

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish - Ni/Pd/Au Plated Leads. Solderable per MIL-STD-202, Method 208 ④
- Weight: 0.042 grams (Approximate)

**PI5USB216EQ**

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**Ordering Information**

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Orderable Part Number	Package Code	Package Description
PI5USB216EQ2XUAEX	XUA	X2-QFN1616-12

**Notes:**

1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See <https://www.diodes.com/quality/lead-free/> for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
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4. Q = Automotive Compliant
5. 2 = AEC-Q100 Grade Level
6. E = Pb-free and Green
7. X suffix = Tape/Reel

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