

## PI5USB216E

### USB 2.0 Signal Conditioner, BC 1.2 CDP

## Description

The PI5USB216E 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-.

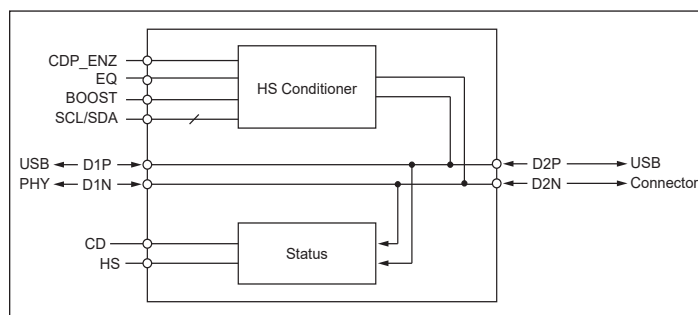
The PI5USB216E can be used in USB Host or Device application, far from USB PHY or far from connector application. Boost/Pre-emphasis and Receiver Equalization levels can be configured through pin or I2C mode depending on the channel conditions. Device Attach and High-Speed handshake success are also detected and reported.

The PI5USB216E 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)

- Servers, Storage Servers, JBOD, RBOD

## Functional Block Diagram



## Features

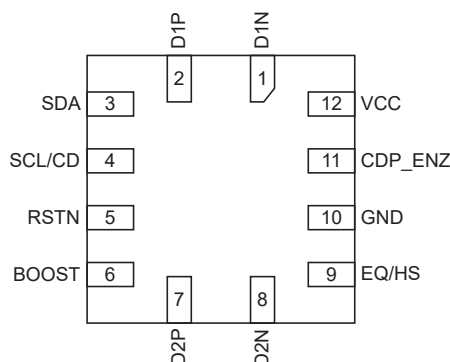
- Wide Supply Voltage Range: 2.3V to 5.5V
- USB Ports 5.5V Tolerance
- Low Power Consumption in Disconnect and Shutdown Mode
- Compatible with USB2.0, OTG 2.0 and BC 1.2
- Integrated BC 1.2 CDP Battery Charging Controller
- Host or Device Agnostic
- Boost/Pre-emphasis Level and Receiver Equalization 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 PI5USB216E
- ESD Performance: 2KV HBM, 1KV CDM
- Industrial Temperature Range: -40°C to 85°C
- 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)
- For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please [contact us](https://www.diodes.com/quality/product-definitions/) or your local Diodes representative.

<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.

## 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>500kΩ internal pulled high and 1.8MΩ internal pulled down.</p> <p><u>In I2C mode:</u><br/>           Bidirectional I2C data pin; Connected to a pull-up resistor<br/>           During power up, pulled up SDA and SCL/CD with Rpu (&lt;10kΩ) to enter I2C mode<br/>           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<br/>           During power up, pulled up SDA and SCL/CD with Rpu (&lt;10kΩ) to enter I2C mode<br/>           OR floating to enter Pin mode (500kΩ pull-down during RSTN rising)</p> <p><u>In Pin mode:</u><br/>           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.<br/>           Low – Device is at RESET and in shutdown, and<br/>           High – Normal operation.</p> <p>500kΩ internal pulled high and 1.8MΩ internal pulled down.<br/>           Recommend 0.1-uF external capacitor to GND to ensure clean power on reset if not driven.</p> <p>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.<br/>           Select via external pull down resistor.<br/>           Sampled upon de-assertion of RSTN. Does not recognize real time adjustments.</p>                                                                                                                                                                                                                                                               |
| 7, 8       | D2P, D2N | I/O  | USB High speed port                                                                                                                                                                                                                                                                                                                                                                                                                                     |

**PI5USB216E**

| 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><br/>           At reset: 3-level input signal EQ. Receiver Equalization selection.<br/>           High Equalization (pin is pulled high)<br/>           Medium Equalization (pin is left floating)<br/>           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:<br/>           1. Detection of USB-IF High Speed test fixture from an unconnected state followed by transmission of USB TEST_PACKET pattern.<br/>           2. Detection of High Speed a successful High Speed handshake</p> |
| 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_LS</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 | V <sub>CC</sub> = 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 = V <sub>CC</sub>                 | -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 = V <sub>CC</sub>                   | -5   |      | 5    | uA    |
| I <sub>IL</sub>     | Low-level input current                                                    | VEQ = 0V                                | -5   |      | 5    | uA    |

**PI5USB216E**

| 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> | I2C 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 PI5USB216E 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. PI5USB216E 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 PI5USB216E 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 PI5USB216E, and pre-emphasis compensates the high frequency loss due to the low-pass long channel after PI5USB216E. 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 (<160Ω)    | 0000                   | Lowest                   |
| Setting 1 (~1.8kΩ)   | 0101                   | Lower Mid                |
| Setting 2 (~3.6kΩ)   | 1010                   | Higher Mid               |
| Setting 3 (>7.5kΩ)   | 1111                   | Highest                  |

### Receiver Equalization

The EQ pin of PI5USB216E 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 PI5USB216E can serve USB BC 1.2 host charging controller functionality if the host itself does not provide. When CDP\_ENZ is low, the PI5USB216E 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  |

**PI5USB216E**

## I2C Mode

PI5USB216E 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                         | Boost/Pre-emphasis Level                               |       |                                                 |       | Receiver Sensitivity Level              |       |       |
|         |           |      |             | 00 (Lowest)<br>01<br>10<br>11 (Highest)             | Coarse<br>00 (Lowest)<br>01<br>10<br>11 (Highest)      |       | Fine<br>00 (Lowest)<br>01<br>10<br>11 (Highest) |       | 00 (Lowest)<br>01<br>10<br>11 (Highest) |       |       |
|         |           |      |             | Default value set by EQ pin sampling during startup | Default value set by BOOST pin sampling during startup |       |                                                 |       | Default value is 00                     |       |       |
|         |           |      |             |                                                     |                                                        |       |                                                 |       |                                         |       |       |
| 02h     | Device ID | R    | 10110000b   | Device ID: 10110                                    |                                                        |       |                                                 |       | Revision: 000                           |       |       |

## Device Functional Modes

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

PI5USB216E automatically detects a LS/FS connection and does not enable signal compensation. In pin mode, CD pin is asserted high.

### High Speed (HS) Mode

PI5USB216E 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

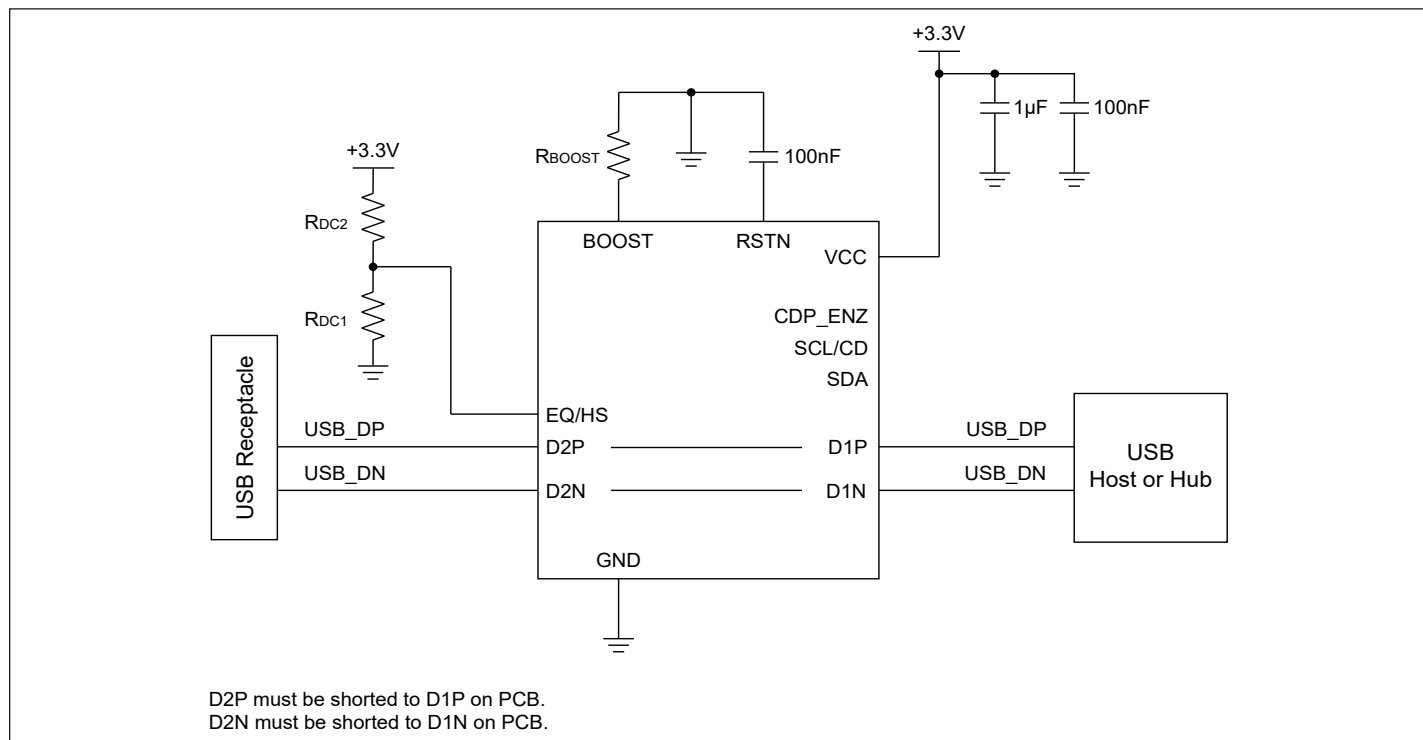
PI5USB216E does not enable signal compensation for OTG or B.C.1.2 signals. In pin mode, CD pin is asserted low.

### Shutdown Mode

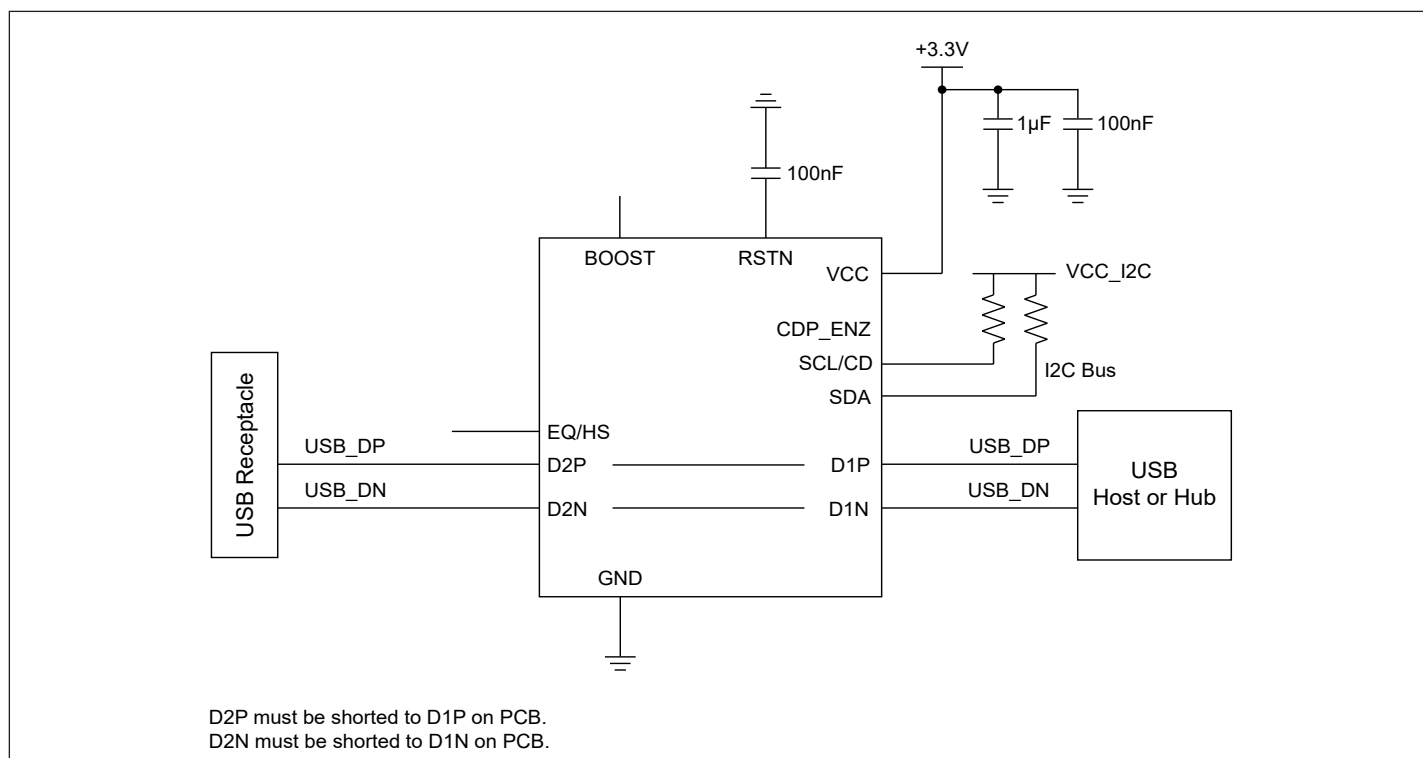
PI5USB216E is disabled when its RSTN pin is asserted low. In shutdown mode the USB channel is still fully operational, but there is neither signal compensation nor any indication from the CD or HS pin as to the status of the channel.

## Application Diagram

### Pin Mode



### I2C Mode





**PI5USB216E**

## Part Marking

$\overline{\text{H}}$ V  
ZYW

HV: PI5USB216EXUAE

Z: Die Rev

Y: Date Code (Year)

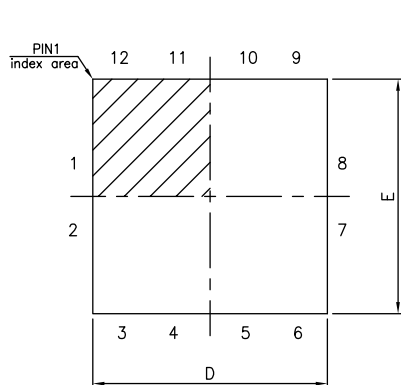
W: Date Code (Workweek)

Line above "H" denotes Pin 1 indicator, lead-free and Green.

**PI5USB216E**

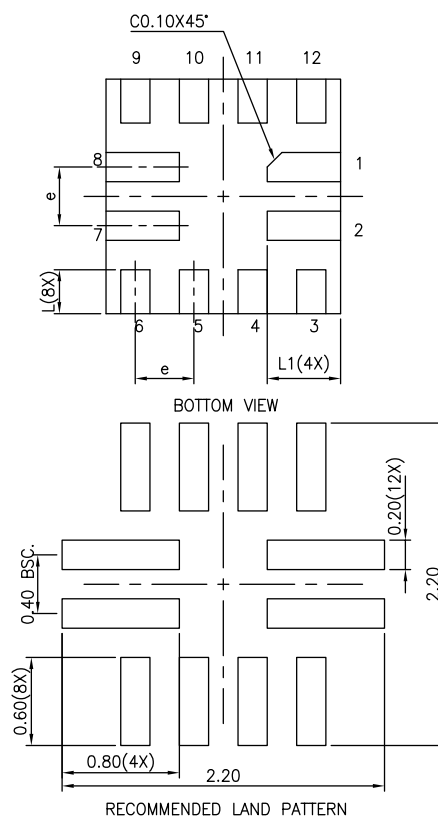
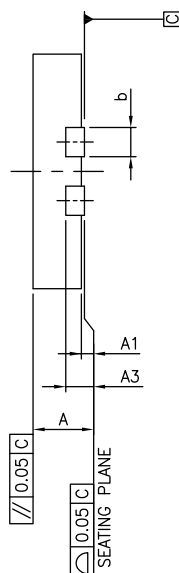
## Packaging Mechanical

### 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 :**

- ALL DIMENSIONS ARE IN mm. ANGLES IN DEGREES.
- REFER JEDEC MO-288
- 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/>

## Ordering Information

| Orderable Part Number | Package Code | Package Description |
|-----------------------|--------------|---------------------|
| PI5USB216EXUAEX       | XUA          | X2-QFN1616-12       |

**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.
- E = Pb-free and Green
- X suffix = Tape/Reel

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