PTN3222DUK

1-port eUSB2 to USB2 redriver

Rev. 1.1 — 1 December 2023 **Product data sheet**

1 General description

PTN3222 is a 1-port eUSB2 to USB2 redriver IC that performs translation between eUSB2 and USB2 signaling schemes. It is meant to be used in systems that have eUSB2 interface on one side and USB2 interface on the other side. It supports host repeater, device repeater or dual role repeater function.

PTN3222 implements Repeater mode (eUSB2 to USB2 redriver) and it supports Link Power management features. PTN3222 is targeted to be USB2 compliant and eUSB2 conformant. It supports all three speeds/data rates: Low Speed (1.5 Mbps), Full Speed (12 Mbps) and High Speed (480 Mbps).

PTN3222 provides a target I^2C register interface to initialize the required functionality and features as per the platform application need. The I^2C target address is selectable using a quaternary input pin (that selects one of the four addresses).

It is powered by two power supplies (VDD3V3, VDD1V8) and is available in a WLCSP12 package (1.55 mm x 1.18 mm x 0.455 mm body, 0.35 mm pitch).

2 Features and benefits

- 1-port eUSB2 to USB2 redriver functionality
- Conforms to USB2 specification along with relevant ECNs
- Conforms to eUSB2 specification v1.1
- Supports host only repeater, device only repeater and dual mode repeater role
- Supports all USB2.0 data rates
  - Low speed operation (1.5 Mbps)
  - Full speed operation (12 Mbps)
  - High speed operation (480 Mbps)
- Supports RAP accesses for a select set of register accesses
- Integrated and selectable pullup and pulldown resistors on both eUSB2 and USB2 ends
- Signal Integrity (SI) configurability
  - eUSB2 – Tx de-emphasis, Rx equalization, Rx squelch threshold, Tx output swing
  - USB2 – HS disconnect detection threshold, Rx squelch threshold, Rx termination, Rx equalization, Tx de-emphasis, Tx slew rate, Tx output swing
- Supports BC1.2 power provider CDP configuration capability in host mode
- Low current consumption
  - Supports eUSB2 and USB2 power management
  - Implements Deep standby mode for lowest power consumption
- Robustness features
  - USB2 data pins tolerate 5.5 V (DC) for 24 hours
  - USB2 data pins withstand short to GND for 24 hours
  - USB2 data pins withstand collision on DP/DN pins due to faulty USB devices
- GPIOs and high speed data pins are backpower safe
- I^2C target interface supports standard mode, fast mode and fast mode plus
- Power supplies - VDD3V3, VDD1V8

- ESD HBM 2 kV CDM 500 V
- Operating ambient temperature range -40 °C to +85 °C
- Available in WLCSP12 package

3 Applications

- eUSB2 to USB2 repeater function in platforms (e.g. hosts, devices, hubs, routers, protocol bridges, etc.) with Standard A/ Standard B/ Micro-B/USB Type-C connector scenarios
  - Host only repeater
  - Device only repeater
  - Dual role repeater (as determined dynamically in the application)

4 Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
PTN3222DUK	WLCSP12	WLCSP12, wafer level chip scale package, 12 terminals, 0.35 mm pitch, 1.55 mm x 1.18 mm x 0.455 mm body (backside coating included)	SOT2063-1

4.1 Ordering options

Table 2. Ordering options

Type number	Orderable part number	Package	Packing method	Minimum order quantity	Temperature
PTN3222DUK	PTN3222DUKZ	WLCSP12	Reel dry pack, SMD, 13" Q1 standard product orientation	8000	T_{amb} = -40 °C to 85 °C

4.2 Top side marking

Table 3. Top side marking

Line number	Character	Content	Remarks
Line A	1	Pin 1 dot	Pin 1 indication
	2-3	Product life cycle	Product status: • "2D": Production silicon
Line B	1-3	Production information	Lot ID
Line C	1-2	Production information	Lot ID
	3	Production information	Wafer number (0-9, A-R excluding I,O, Q)

5 Functional diagram

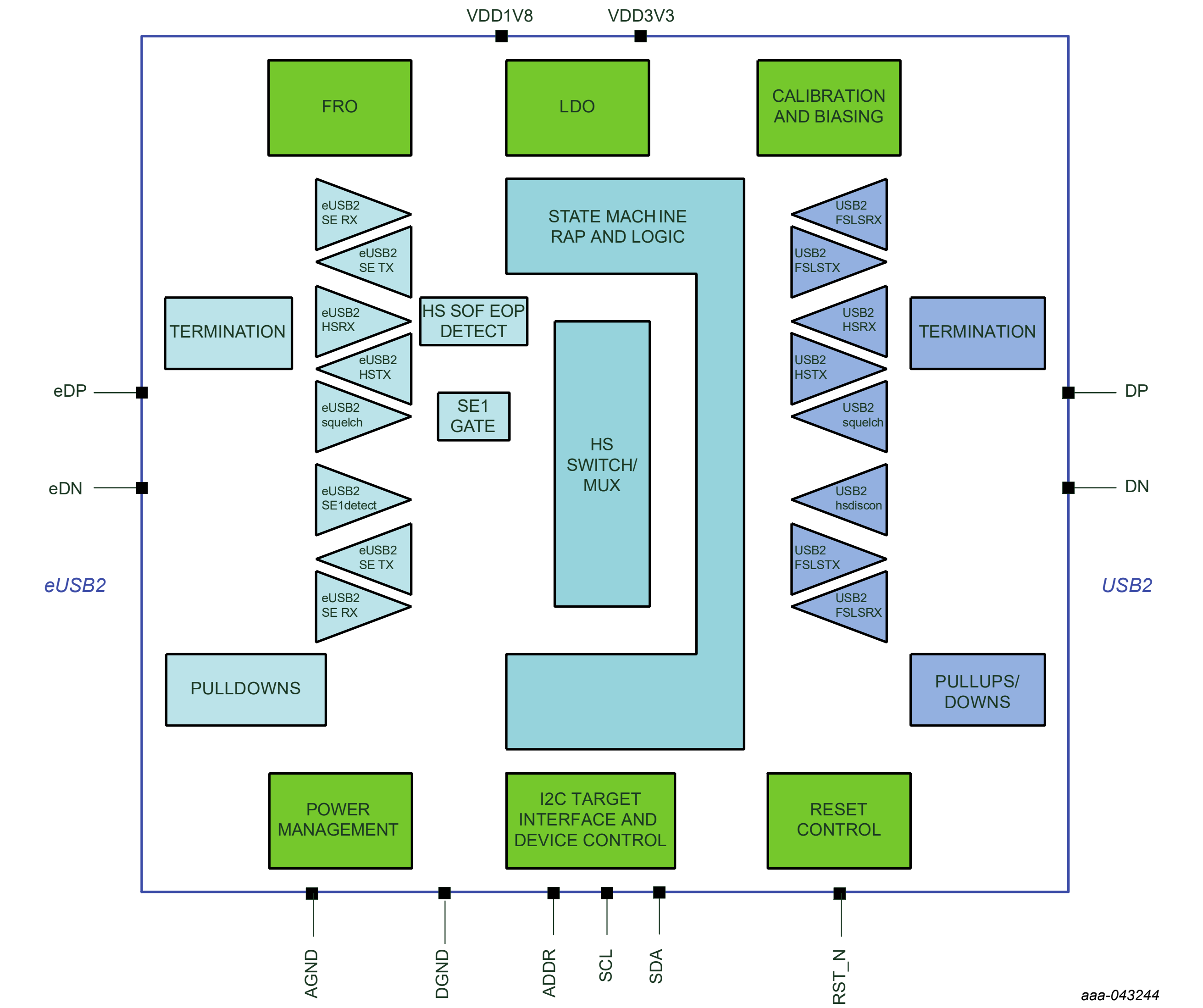


Figure 1. Functional block diagram

6 Pinning information

6.1 Pinning

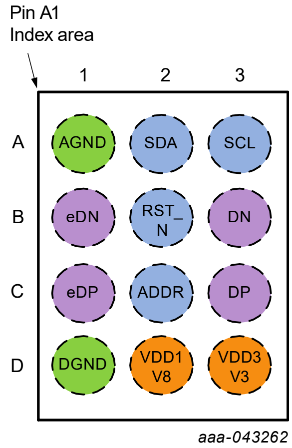


Figure 2. PTN3222 WLCSP pinning (transparent top view)

6.2 Pin description

Table 4. Pin description

WLCSP Pin	Symbol	Direction	Pad power domain	Type	Description
D1	DGND	OUT		Power	Digital ground. This pin is connected to low noise ground plane and avoids long PCB traces
D2	VDD1V8	IN		Power	1.8 V power supply. 0.47 µF and 33 pF decoupling capacitors are placed on this pin on the PCB
D3	VDD3V3	IN		Power	3.3 V power supply. 0.47 µF and 33 pF decoupling capacitors are placed on this pin on the PCB
C1	eDP	IO	VDD1V8	Analog input/output	Positive terminal of eUSB2 analog transceiver interface
C2	ADDR	IN	VDD1V8	Analog input	Quaternary pin for I^2C target address selection (sampled once after POR and when power supplies are stable and valid). The external pullup resistor shall be placed close enough to the decoupling capacitors of VDD1V8
C3	DP	IO	VDD1V8, VDD3V3	Analog input/output	Positive terminal of USB2 analog transceiver interface DP pin has an internal 2 MΩ pulldown resistor enabled under all situations
B1	eDN	IO	VDD1V8	Analog input/output	Negative terminal of eUSB2 analog transceiver interface
B2	RST_N	IN	VDD1V8	Digital input	This is an Active Low input pin. When RST_N is LOW, PTN3222's DP and DN pins are put to Hi-Z condition and redriver is placed in Deep standby state. When RST_N is HIGH, the redriver is put into repeater mode
B3	DN	IO	VDD1V8, VDD3V3	Analog input/output	Negative terminal of USB2 analog transceiver interface DN pin has an internal 2 MΩ pulldown resistor enabled under all situations
A1	AGND	OUT		Power	Analog low noise ground. This pin should connect to PCB ground plane, avoid long PCB traces and not be routed near noisy circuits
A2	SDA	IO	VDD1V8	Digital input/output	I^2C data input/output. There is no internal pull up resistor, and an external pull up resistor to I^2C pullup voltage must be used on the PCB
A3	SCL	I	VDD1V8	Digital input	I^2C clock input. There is no internal pull up resistor, and an external pull up resistor to I^2C pullup voltage must be used on the PCB

7 Functional description

PTN3222 consists of the following major functions:

- eUSB2 repeater
- BC1.2 support
- I^2C interface
- Reset schemes

7.1 Reset

PTN3222 supports the following reset schemes:

- POR
- Software reset

When in reset, PTN3222's SCL and SDA IO pins are in high impedance state to prevent the I^2C bus from being altered or corrupted in any way.

The RST_N pin is used to put USB DP/DN IO circuitry is put into Hi-Z condition and USB2 pins are pulled down with 2 MΩ resistors. The redriver is also placed in Deep standby condition. The I^2C configuration registers are retained except for Link control, Device status and RAP signature registers. As long as the system asserts this pin low, the IC is held in this state. When RST_N is HIGH, then the redriver is put into repeater mode.

7.2 Operating modes

PTN3222 has several operating modes: a specific operating mode is selected depending on repeater configuration, link and connection status. Table 5 below gives a high level overview of the major building blocks that are kept powered in different modes.

Table 5. Status of design blocks in different power modes

Power Mode	I^2C interface	FS/LS front ends	HS Front ends
OFF	OFF	OFF	OFF
Deep standby	ON	OFF	OFF
Connect Detect (Detached condition)	ON	ON (SE detector only)	OFF
L1 sleep	ON	ON (SE detector only)	HS OFF; only SE detector is ON
L2 suspend	ON	ON (SE detector only)	HS OFF; only SE detector is ON
Active LS/FS	ON	ON	OFF
Active HS	ON	OFF	ON

7.3 eUSB2 repeater

This subsystem includes eUSB2 analog front end circuitry, repeater state machine, USB2 analog front end circuitry and the associated power management circuits. The USB2 DP/DN pin have internal 2 MΩ pulldown resistors enabled under all situations.

PTN3222 is designed to function as a host repeater or a peripheral repeater. Figure 3 illustrates the role transition and associated arcs that enable role change.

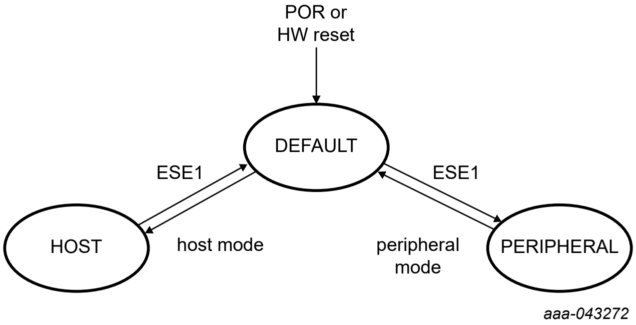


Figure 3. PTN3222 role transition

Figure 4 illustrates the eUSB2 Host repeater usage in a typical Host platform application.

On one side, the repeater interfaces with USB2 peripheral (that is either plugged in directly or via cable/channel topology) and on the system side, it interfaces with host controller w/eUSB2 PHY.

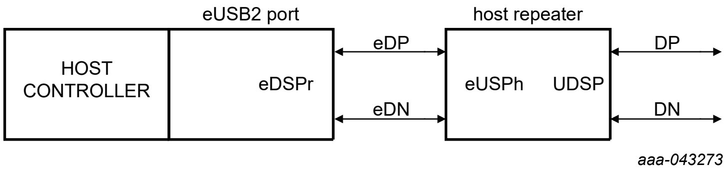


Figure 4. PTN3222 as eUSB2 Host repeater

Figure 5 illustrates the eUSB2 Device repeater usage in a typical peripheral environment.

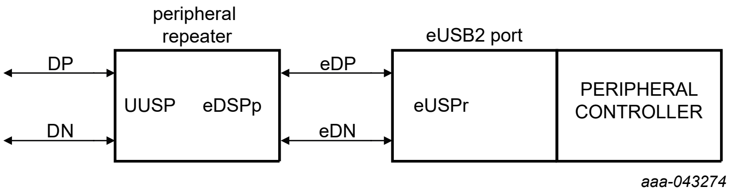


Figure 5. PTN3222 as eUSB2 Peripheral repeater

PTN3222 implements aggressive power management to optimize on overall power consumption under the various operating modes. It supports USB Link Power Management and supports L1 and L2 power states. In addition, it implements specific features required by [4].

PTN3222 supports RAP – allowing customer facing registers only. The type of access is controlled via an I^2C register. There is no built-in arbitration support available if and when same register is being accessed through RAP commands and I^2C interface. The system application is expected not to issue simultaneous accesses, avoid register overwrites leading to incorrect behavior and response from PTN3222.

PTN3222 accepts RAP messages at any time even though host is expected to issue RAP messages only during initialization. In case, if the host would use RAP messages to read status register(s) or update any control register(s), PTN3222 does not inhibit or put limits on RAP messages as long as it is in the mode wherein customer I^2C registers are accessible.

PTN3222 supports Auto resume and asynchronous wake features as specified in [4]. Auto resume timeout of 20 ms (typ) has been implemented.

7.3.1 Over-Voltage Protection on USB2 DP/DN pins

PTN3222 implements Over Voltage Protection (OVP) circuitry, which activates whenever an OV condition occurs on USB2 DP/DN pins, PTN3222 operates autonomously without host software intervention. The following describes a possible sequence of steps that may occur due to OV event:

1. PTN3222 checks DP/DN pin(s) for over voltage condition that is higher than $V_{OVP,Th}$ (Low to High Threshold case) and it shuts down the USB2 analog IO as long as the event persists
2. PTN3222 enables USB2 analog IO path once the pin voltage falls below $V_{OVP,Th}$ (High to Low Threshold case)
3. The SoC host and eUSB2 redriver would lose communication with the USB2 entity since the analog path has been disabled
4. So, the SoC host may try the following options to reestablish the link
   a. issue CM.Reset in an attempt to issue a USB Bus Reset or,
   b. issue Port reset to the local redriver and also toggle VBUS to re-establish the connection and restart the data transport.

Note that option (a) may not be successful depending on the nature of the fault but is the fastest and least aggressive error recovery method. Use of Port Reset and toggling of VBUS are guaranteed to work, but comes with a downside of longer time duration to reestablish the link.

7.4 BC1.2 support

PTN3222 has a built-in support for enabling CDP (Charging Downstream Port) feature that allows a mobile device to detect and charge at higher current from the host platform. For the BC1.2 support, this IC implements a controlled voltage source that can be enabled on USB2 DN pin via an I^2C register bit. The host processor can enable this feature via I^2C during USB disconnect condition and the PTN3222 can autonomously disable this on a USB connect event and reset this I^2C configuration bit.

This feature is expected to be applied when in host repeater mode only. However, the PTN3222 does not inhibit enabling of this feature in device repeater mode.

7.5 I^2C operation

PTN3222 is an I^2C target only device, and it responds to I^2C commands in any operating mode as long as VDD3V3/VDD1V8 supplies are available. PTN3222 does not support clock stretching but it tolerates other I^2C targets performing clock stretching under the legal conditions defined by [1]. Also, it does not support I^2C General call address (and therefore does not issue an acknowledgement too), I^2C Software reset command nor 10-bit addressing. It acknowledges all 128 register offset addresses though there are certain undefined/ reserved locations as indicated in the register map.

Each I^2C operation involving writing to or reading from one or more consecutive registers is referred to as a transaction. Consecutive registers are defined as a series of incrementing register addresses, regardless of whether a given address has a definition in the register map.

A transaction may be a part of a series of transactions addressed to multiple different targets or to the same target repeatedly with different register address offsets, with each transaction separated by repeated-START conditions. PTN3222 does not inhibit other types of transactions as prescribed in I^2C specification.

Register address aliasing is not supported in PTN3222. When read or write transactions with multiple consecutive registers are performed, the register address rolls over to 0x00 once the maximum register offset of 0xFF is reached.

When an undefined or invalid register address is being addressed for read or write operation, PTN3222 acknowledges the I^2C transaction, but returns 0xFF for a read operation, or takes no action for a write operation.

7.5.1 I²C target address

PTN3222's 7-bit I²C target address is given in Table 6. Bits 3 and 4 can take one of the four possible values based on the quaternary address selection pin (ADDR).

Table 6. PTN3222 target address definition

ADDR pin configuration	Bit 7	Bit 6	Bit 5	ADDR		Bit 2	Bit 1	Bit 0
				Bit 4	Bit 3			
Connected to 1.8 V supply directly	1	0	0	0	0	1	1	R/W
Connected to 1.8 V supply via 56 kΩ (+/-10 %) pull up	1	0	0	0	1	1	1	R/W
Connected to 1.8 V supply via 200 kΩ (+/-10 %) pull up	1	0	0	1	0	1	1	R/W
Connected to GND directly	1	0	0	1	1	1	1	R/W

7.5.2 Example of writing one or more registers

PTN3222 recognizes the following procedure as a request to write to one or more registers:

1. I²C controller asserts START condition or repeated-START condition
2. Controller addresses PTN3222 target interface with R/W bit set as "Write"
3. Target acknowledges the request by asserting an ACK
4. Controller writes the desired starting register address
5. Target acknowledges the register address with ACK, even if register address is not part of the defined register map
6. Controller writes the data for that register address and the target updates the register value once all 8 bits of data have been written
7. Target acknowledges the data with an ACK
8. If the controller wishes to write to the next consecutive register address, it supplies another data byte, which the target ACKs. The controller can continue writing data bytes for consecutive registers. If the controller writes to more consecutive registers than what exists in the register map, the target discards the extra data bytes, but ACKs for each such write

When the controller has finished writing the desired register(s), it issues either a STOP condition or a repeated-START condition.

Figure 6 provides an illustrative example where the controller chooses to write to three consecutive registers starting with register "R".

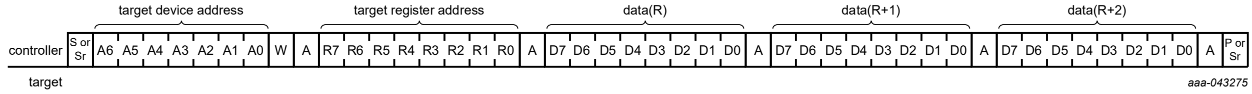


Figure 6. Writing one or more consecutive registers

7.5.3 Example of reading one or more registers

The target recognizes the following procedure as a request to read one or more registers:

1. Controller asserts START condition or repeated-START condition
2. Controller addresses PTN3222's target address with R/W bit set as "Write"
3. Target acknowledges the request by asserting ACK
4. Controller writes the desired starting register address

5. Target acknowledges the register address with ACK, even if the register address is not part of the defined register map
6. Controller issues a repeated-START condition
7. Controller addresses PTN3222's target address with R/W bit set as "Read"
8. In the following clock pulses, the target clocks out the value of the requested register
9. If controller wishes to read the next consecutive register, it issues an ACK and then provides another set of clock pulses, whereby the target supplies the value of the next register. As long as the controller continues to issue ACK and supply additional clock pulses, the target continues to supply the value of consecutive registers. If the controller attempts to read consecutive registers that do not exist in the defined register space, the target can return undefined data value of 0xFF.
10. When the controller does not wish to read additional consecutive registers, it supplies a NACK in response to the final register value it wishes to read and then issues a STOP or repeated-START condition.

Figure 7 provides an illustrative example where the controller chooses to read from two consecutive registers starting with register "R".

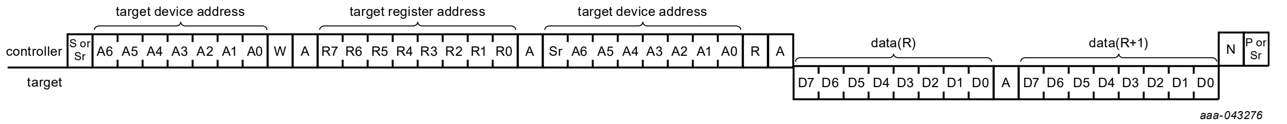


Figure 7. Reading one or more consecutive registers

8 System application

8.1 Use cases

PTN3222 is targeted to be used in various USB interface application cases. It interfaces to a host or device controller with eUSB2 PHY interface and on the other side, it interfaces directly to a connector/cable topology or another interface IC. Different connector configurations are possible: custom, USB Standard A/Standard B, USB Micro-B, USB Type-C, etc. For all use cases, it is not necessary for the host to initialize the I^2C registers after POR or reset event. On the contrary, PTN3222 functions without any I^2C configuration by relying on registers getting initialized after POR event.

A few use case illustrations are shown in Figure 8 through Figure 11; these figures do not capture all components (supply decoupling capacitors, ESD, CMF, etc.) in the channel topology.

1. Direct interface to connector
   This connectivity scheme is a straightforward topology and it may be relevant for generic IOT and certain computing applications. In certain applications, I^2C interface may not be connected and the repeater is expected to start operating after POR based on POR/default register settings.

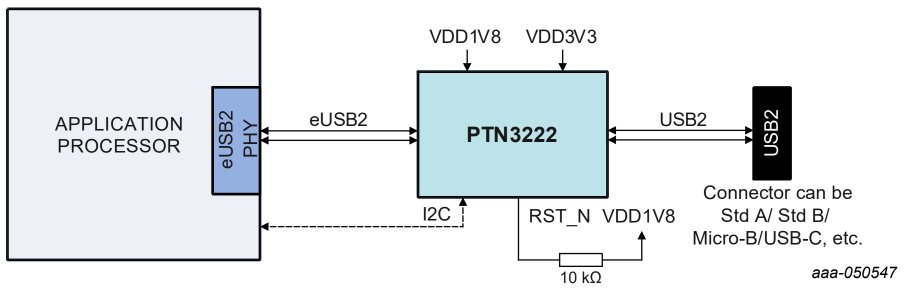


Figure 8. Use case 1 – Direct interfacing

2. Interface via USB protection IC

This connectivity scheme is relevant for applications where there is a risk/chance of high voltage appearing on the USB data pins (e.g. USB-C). In certain applications, I^2C interface may not be connected and the repeater is expected to start operating after POR based on POR/default register settings. Care must be taken to select suitable protection IC that has certain USB2 signal attenuation/Rdson. Also, the default power-up scenario must be analyzed.

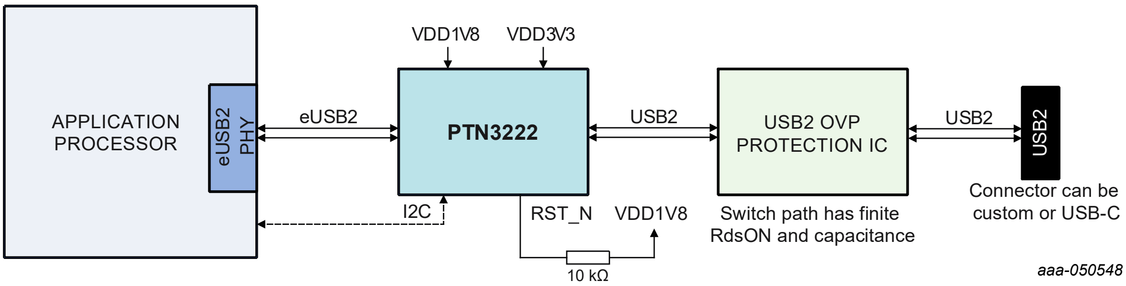


Figure 9. Use case 2 – Interfacing via Protection IC

3. Interface with parallel connection to PMIC
   This interfacing scheme is relevant for mobile applications (smartphone, tablets, etc.), where there is a high chance of system integrator using an interface PMIC to support various platform specific functions. Since there are two ICs connected to USB DP/DN data pins, the RST_N pin allows the system to put PTN3222's DP/DN IO circuitry to Hi-Z condition and connect 2 MΩ pulldown resistors on DP/DN pins so that the interface PMIC can use the DP/DN pins for other purpose(s).
   In certain applications, I^2C interface may not be connected and the repeater is expected to start operating after POR based on POR/default register settings

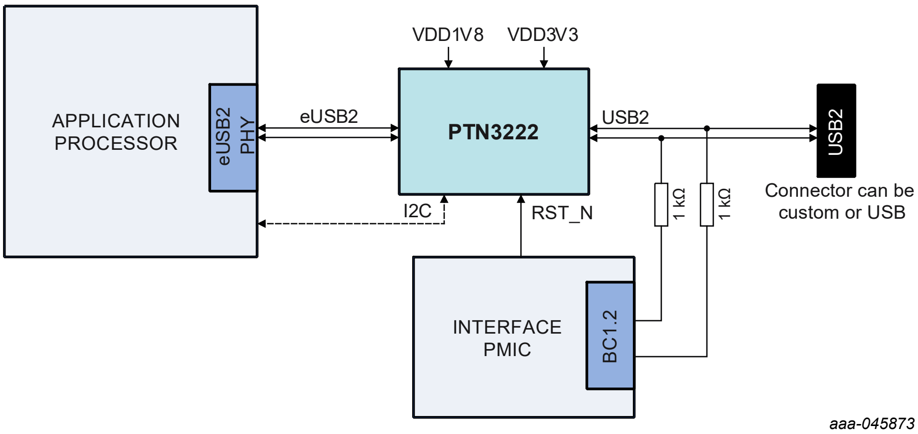


Figure 10. Use case 3 – Interface with parallel connection to PMIC

4. Interface to connector via passive signal switch
   This connectivity scheme provides the option to switch various debug and communication signals on to the same connector. In certain applications, I^2C interface may not be connected and the repeater is expected to start operating after POR based on POR/default register settings. The passive signal switch must be selected to ensure low signal attenuation and also the power-up scenario must be carefully analyzed. The RST_N pin shall be pulled up with 10 kΩ resistor externally either in the SoC or on the PCB.

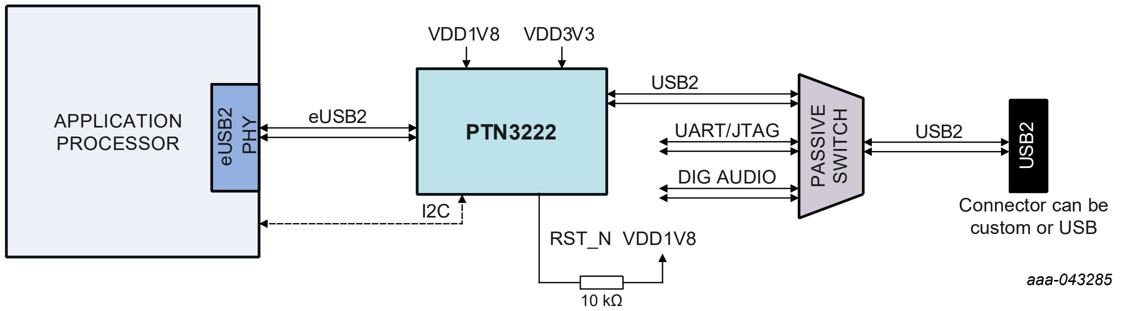


Figure 11. Use case 4 – Interfacing via passive switch

8.2 Power supply requirement

PTN3222 requires two power supplies (VDD3V3 and VDD1V8) to operate. It does not function until both supplies have ramped up and reached valid operating range. There is no specific power on or off sequencing requirement. In addition, the two supplies can follow different ramp-up and ramp down rates. The supply ramp limits are specified in Section 11.

PTN3222 does not suffer from backpower issue (VDD node getting powered via a non-power pin).

The power supply decoupling capacitors shall be soldered close to power pins.

8.3 Ground requirement

PTN3222 has two ground pins, AGND and DGND.

Both pins provide connection to GND plane with low ground noise in the application PCB.

8.4 ESD requirements

PTN3222 supports 2 kV HBM and 500 V CDM on all pins. To achieve system level ESD protection (e.g. IEC61000-4-2 Level 4 8 kV contact discharge, 15 kV air discharge) on DP/DN pins, dedicated and matched ESD diodes shall be used near the connector. Matching of diodes is important to minimize DP/DN skew.

8.5 Application support

NXP can deliver PTN3222 customer support documentation and IBIS-AMI model for system level signal integrity simulation. The documentation includes Application note [6] and layout guidelines [7]. Please contact NXP support teams for further details.

9 Register set

The device is controlled and monitored by registers accessible via the I^{2}C bus. All registers can be accessed in standard mode or fast mode using single or sequential reads or writes. Register bit field types are defined in Table 7.

Table 7. Register type definitions

Access Type	Description
RW	Bit field can be read from and written to
RO	Bit field value can only be read

Table 7. Register type definitions*...continued*

Access Type	Description
WO	Bit field value is write only. Reading value has no meaning, and results in no action being taken
RAZ	Bit field contents are read as zero. Writes do not have any effect
R/W1, W0 Ignore	Bit field value is readable, and writing ‘b1 to each bit in the bit field sets value to ‘b1. Writing ‘b0 to a this bit field results in no action being taken

9.1 Register overview

Table 8 lists all the registers used for PTN3222. Default POR values of registers are also shown in this table.

Table 8. Register overview

Address	Register Name	Access	RESET		Default Value (Hex)	Information of individual bits							
			POR	Software Reset (or RST_N		7	6	5	4	3	2	1	0
0x00	RESERVED	RAZ			00								
0x01	RESET CONTROL	RW	•		00								Software Reset
0x02	LINK CONTROL 1	RW	•	•	00	Speed control		Role control			Operational mode		
0x03	LINK CONTROL 2	RW	•	•	00								Force ESE1
0x04	eUSB2 RX CONTROL	RW	•	•	20			eUSB2 HS Rx squelch detection threshold			eUSB2 HS Rx equalization		
0x05	eUSB2 TX CONTROL	RW	•	•	10			eUSB2 HS Tx output swing				eUSB2 HS Tx De-emphasis	
0x06	USB2 RX CONTROL	RW	•	•	40		USB2 Rx squelch detection threshold				USB2 HS Rx equalization		
0x07	USB2 TX CONTROL 1	RW	•	•	22			USB2 HS Tx De-emphasis bit duration			USB2 HS Tx De-emphasis		
0x08	USB2 TX CONTROL 2	RW	•	•	63		USB2 FS rise/fall time	USB2 HS rise/fall time			USB2 HS Tx output swing		
0x09	USB2 HS TER MINATION	RW	•	•	02						USB2 HS termination control		
0x0A	USB2 HS DIS CONNECT THR ESHOLD	RW	•	•	00							USB2 HS disconnect detection threshold	
0x0B - 0x0C	RESERVED	RO			XX								
0x0D	RAP_Signature	RW	•	•	00	RAP_Signature							
0x0E	VDX_ CONTROL	RW	•	•	00								VDx_ enable
0x0F	DEVICE STATUS	RO	•	•						Speed of operation status		Repeater status	
0x10	LINK STATUS	RO	•	•							Device and Link status		
0x11 - 0x12	RESERVED	RAZ			XX								
0x13	REVISION_ID	RO			A2	BASE = b'1010				METAL_= b'0010			
0x14	CHIP_ID_0	RO			22	CHIP_ID[7:0]=0x22							
0x15	CHIP_ID_1	RO			32	CHIP_ID[15:8]=0x32							
0x16	CHIP_ID_2	RO			01	b'0000						b'01	
	RESERVED	RO			XX	Reserved register space							

9.2 I²C registers and descriptions

9.2.1 Functional registers

The offset addresses with defined bit definitions are meant for functional registers, and can be accessed by the I²C controller at any time after POR. For normal operation, these registers are sufficient to setup the IC to known working conditions. Customers are advised not to write reserved values into the register bit fields. Read from the reserved bit field(s) need not match with what's written. Functional behavior is not guaranteed if such an operation is performed.

Table 9. Register 0x00 – Reserved

Register offset		Register Name		Register Description
0x00		RESERVED		
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:0	RSVD	RAZ	b'00000000	Reserved

Table 10. Register 0x01 – RESET CONTROL

Register offset		Register Name		Register Description
0x01		Reset Control		This register is meant to initiate reset of the chip via I^2C write
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:1	RSVD	RAZ	b'0000000	Reserved
0	Software Reset	R/W	b'0	This is a Self-clearing bit. The host writes ‘1’ to this bit to initiate software reset and this bit automatically clears to ‘0’. All R/W registers are reset to POR settings. Writing ‘0’ does not have any effect. Reads return ‘0’

Table 11. Register 0x02 – LINK CONTROL 1

Register offset		Register Name		Register Description
0x02		Link Control 1		This register is meant to force the repeater role and speed of operation to fixed settings
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:6	Speed control	RW	b'00	The bitfield determines the POR setting of USB2 speed: 00– Manage the speed via Auto negotiation 01– LS/FS only 10-11- Reserved
5:4	Role control	RW	b'00	Determines the redriver role 00 – Dual role Support both host and device eUSB2 Port Configuration negotiation. This is the expected normal operating setting managed via Host eUSB2 exchanges. 01 - Force Host role When bits are ‘01’, it forces the repeater into USB Host role irrespective of any configuration command getting received via eUSB2. But the repeater would acknowledge the configuration message from the host. 10- Force Device role When the bits are ‘10’, it forces the repeater into USB Device/Peripheral role irrespective of any configuration command getting received via eUSB2. But the repeater would acknowledge the configuration message from the host. 11- Reserved Forced host/device role setting is used in conjunction only with setting ‘2’ of Link Control 2[2:0] bits
3	RSVD	RAZ	b'0	Reserved

Table 11. Register 0x02 – LINK CONTROL 1*...continued*

Register offset		Register Name		Register Description
2:0	Operational Mode	RW	b'000	The bits set the operational mode of the repeater 0=Auto negotiation on the link (mode determined via control messages and link negotiation) 1= Deep standby mode (eUSB2 pins are pulled down, USB2 pins are held in weak pulldown condition and I^2C register contents are preserved) 2 - Connect.Detect state. Used for force the repeater into its Connect.Detect state (refer to eUSB specification). - This is acted upon only at the time the write occurs to this register. If an overriding condition is present, such as RST_N=0, then writing to this register with this setting is ignored, even when the overriding condition goes away Note that in this case Role Control field (in register 0x02) must have only a single bit set. Those bits are used to tell the repeater which role to jump into - This command places the repeater into the appropriate Connect.Detect state (based on specified role in Role Control). After the state transition occurs, the repeater automatically reacts from there as appropriate to the eUSB/USB2 bus conditions. 3 - Compliance Mode (HS L0 condition). This is equivalent to the reception of the Control Message CM.Test. It allows the system to force the repeater into HS.L0 state. The role is defined by the Role Control bits. Note that in this case, Role Control setting must have only a single bit set. If both or neither bit is set, then this command is ignored 4 to 7 - Reserved

Table 12. Register 0x03 – LINK CONTROL 2

Register offset		Register Name		Register Description
0x03		Link Control 2		This register programs specific feature of the repeater
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:1	RSVD	RAZ	b'0000000	Reserved
0	Force ESE1	RW	b'0	Bit to force Extended SE1 signaling 0 => No action 1 => Self Clearing bit. When written to 1, Repeater generates extended SE1 onto the eUSB pins. Normally, only the Host Repeater performs this action upon a HS disconnect detection. But this feature allows the system to force an extended SE1 as needed via I^2C interface

Table 13. Register 0x04 – eUSB2 RX CONTROL

Register offset		Register Name		Register Description
0x04		eUSB2 Rx Control		This register programs the eUSB2 Rx equalization and squelch detection threshold settings
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:6	RSVD	RAZ	b'00	Reserved
5:4	eUSB2 HS Rx Squelch detection threshold	RW	b'10	The bits determine the squelch detector (Low to High transition) threshold level for HS signaling on eUSB2 pins 00 = 50 mV 01 = 65 mV 10 = 85 mV 11 = 95 mV All settings are within +/-25 mV of nominal value mentioned above Squelch detector implements hysteresis of 10 mV to improve noise immunity.
3	RSVD	RAZ	b'0	Reserved
2:0	eUSB2 HS Rx equalization	RW	b'000	The bits determine the nominal eUSB2 receive equalization gain (@ 240 MHz) with respect to DC gain. All settings are within +/-1 dB of nominal value mentioned below 000 = 0 dB 001 = 1 dB 010 = 2 dB 011 = 3 dB 100 = 4 dB 101 to 111 = Reserved

Table 14. Register 0x05 – eUSB2 TX CONTROL

Register offset		Register Name		Register Description
0x05		eUSB2 Tx Control		This register configures the Transmit side settings – output signal swing and de-emphasis level on eUSB2 side
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:6	RSVD	RAZ	b'00	Reserved
5:4	eUSB2 HS Tx output swing	RW	b'01	The bits set the output signal swing for HS signaling on eUSB2 Tx side (when the interface is terminated) 00 = 180 mV 01 = 200 mV 10 = 220 mV 11 = 240 mV All settings are within +/-40 mV of nominal value mentioned above
3:2	RSVD	RAZ	b'00	Reserved
1:0	eUSB2 HS Tx De-emphasis	RW	b'00	The bits determine the Tx de-emphasis (nominal) level for HS signaling on eUSB2 pins. The de-emphasis duration is between 0.75 to 1 HS bit time. 00 = 0 dB 01 = 1 dB 10 = 2 dB

Table 14. Register 0x05 – eUSB2 TX CONTROL*...continued*

Register offset		Register Name		Register Description
				11 = 3 dB All settings other than ‘00’ are within +/-1 dB of nominal value mentioned below

Table 15. Register 0x06 – USB2 RX CONTROL

Register offset		Register Name		Register Description
0x06		USB2 Rx Control		The register programs the Rx equalization and squelch detection threshold levels on USB2 pins (applicable for HS signaling only)
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7	RSVD	RAZ	b'0	Reserved
6:4	USB2 HS Rx squelch detection threshold	RW	b'100	The 3 bits determine the squelch detector (low to high transition) threshold level for HS signaling at USB2 pins 000 = Reserved; not for use 001 = 65 mV 010 = 85 mV 011 = 95 mV 100 = 110 mV 101 = 125 mV 110 = 140 mV 111 = 155 mV All settings are within +/-25 mV of nominal value mentioned above Squelch detector implements hysteresis of 10 mV to improve noise immunity.
3	RSVD	RAZ	b'0	Reserved
2:0	USB2 HS Rx equalization	RW	b'000	The 3 bits determine the nominal USB2 receive equalization gain (@ 240 MHz) with respect to DC gain. All settings are within +/-1 dB of nominal value mentioned below 000 = 0 dB 001 = 1 dB 010 = 2 dB 011 = 3 dB 100 = 4 dB 101 to 111 = Reserved

Table 16. Register 0x07 – USB2 TX CONTROL 1

Register offset		Register Name		Register Description
0x07		USB2 Tx Control 1		This register configures the Transmit side settings – output signal swing and de-emphasis level on USB2 side
Bit	Bit Name	R/W	Reset	Description
7:6	RSVD	RAZ	b'00	Reserved
5:4	USB2 HS Tx De-emphasis bit duration	RW	b'10	The bits set the de-emphasis bit time (UI) for HS signaling on USB2 Tx side 00 = 0 01 = 0.5UI 10 = 0.8UI 11 = Reserved All settings are within +/-0.2UI of nominal value mentioned above
3	RSVD	RAZ	b'0	Reserved
2:0	USB2 HS Tx De-emphasis	RW	b'010	The bits determine the Tx de-emphasis (nominal) level for HS signaling on USB2 pins 000 = 0 dB 001 = 1 dB 010 = 2 dB 011 = 3 dB 100 = 4 dB 101 = 5 dB 110 = 6 dB All settings other than '000' are within +/-1 dB of nominal value mentioned above

PTN3222 implements de-emphasis feature for channel loss compensation of high frequency content of both eUSB2 and USB2 signals.

Figure 12 illustrates the difference between pre-emphasis and de-emphasis functions.

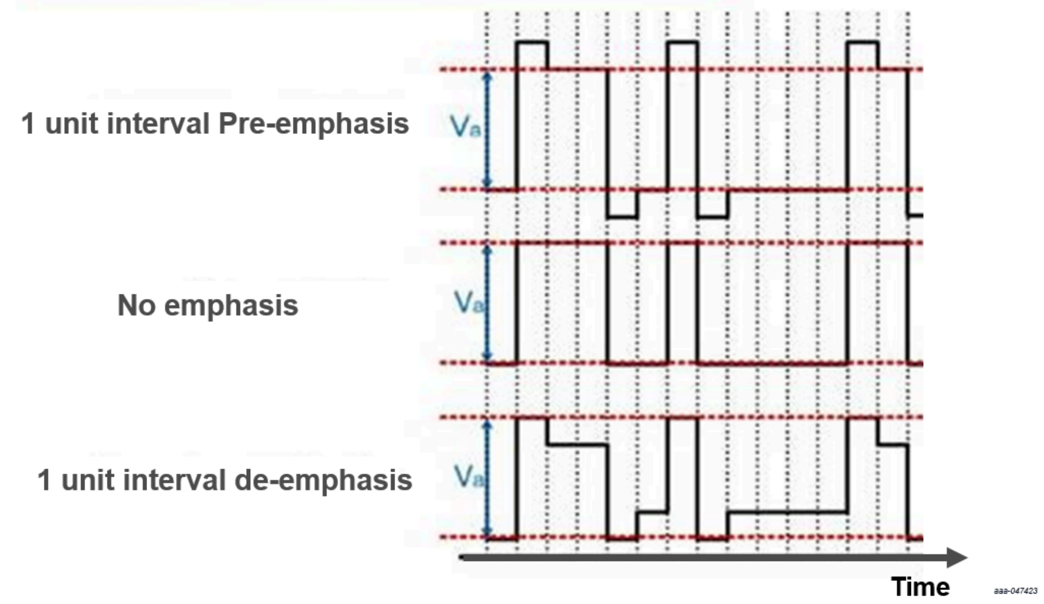


Figure 12. Difference between pre-emphasis and de-emphasis functions

With de-emphasis, when a steady pattern of 0s or 1s is being redriven, the transmit signal swing is reduced as per de-emphasis level and for an alternating pattern of 0s and 1s, the full signal swing is transmitted as per transmit signal swing level.

On the other hand, with pre-emphasis function, the full signal amplitude is retained when a steady pattern of 0s or 1s is being redriven and for an alternating pattern of 0s and 1s, the transmit signal swing is boosted as per pre-emphasis level.

The de-emphasis settings map to specific output current drive level as illustrated in Table 17. The current drive level is with reference to 17.78 mA current considering 45 Ω terminations at both ends of the connection and 400 mV output swing level.

Table 17. De-emphasis level to USB2 Tx output swing level

USB2 Tx De-emphasis = 0.8UI (typical)															
USB2 Tx output swing Non-transition Voltage (mV)		Tx De-emphasis setting = 0		Tx De-emphasis setting = 1		Tx De-emphasis setting = 2		Tx De-emphasis setting = 3		Tx De-emphasis setting = 4		Tx De-emphasis setting = 5		Tx De-emphasis setting = 6	
		Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)	Transition level (mV)	Non-Transition level (mV)
Setting= 0	350	352	352	347	304	347	270	347	237	347	212	347	194	340	169
Setting= 1	400	399	399	394	344	394	309	390	267	390	239	390	219	385	190
Setting= 2	450	451	451	447	388	447	352	442	305	442	279	442	244	442	220
Setting= 3	500	498	498	492	434	492	390	487	337	487	305	487	269	487	244
Setting= 4	550	551	551	546	473	544	427	544	375	544	337	538	301	538	269
Setting= 5	600	600	600	595	520	595	469	595	416	584	366	584	330	580	295
Setting= 6	650	656	656	649	566	645	509	645	454	634	398	634	355	618	310
Setting= 7	700	703	703	702	613	692	537	680	474	680	423	675	372	675	344

Table 18. Register 0x08 – USB2 TX CONTROL 2

Register offset	Register Name			Register Description
0x08	USB2 Tx Control 2			This register configures the Transmit side settings – Tx output driver slew rate and output signal swing on USB2 side
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7	RSVD	RAZ	b'0	Reserved
6	USB2 FS rise/fall time	RW	b'1	This bit determines the FS Tx driver rise/fall time on USB2 pins 0 = 8 to 20 ns 1 = 4 to 10 ns Load conditions are as defined in USB standard
5:4	USB2 HS rise/fall time	RW	b'10	The 2 bits determine the Tx driver slew rate for HS signaling on USB2 pins. 00 = 500 to 900 ps 01 = 400 to 800 ps 10 = 300 to 700 ps 11 = Reserved Load conditions are as defined in USB standard
3	RSVD	RAZ	0	Reserved
2:0	Tx output signal swing	RW	b'011	The 3 bits determine the Tx output signal swing level for HS signaling on USB2 pins (when the interface is terminated) 000 = 350 mV 001 = 400 mV 010 = 450 mV 011 = 500 mV 100 = 550 mV 101 = 600 mV 110 = 650 mV 111 = 700 mV All settings are within +/-10% of nominal value mentioned above

Table 19. Register 0x09 – USB2 HS TERMINATION

Register offset	Register Name			Register Description
0x09	USB2 HS Termination control			This register sets the HS termination values on USB2 pins
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:3	RSVD	RAZ	b'00000	Reserved
2:0	USB2 HS Termination control	RW	b'010	The bits determine the HS termination on USB2 pins (differential impedance is specified here) 000 = 100 Ω differential 001 = 95 Ω differential 010 = 90 Ω differential 011 = 85 Ω differential 100 = 80 Ω differential 101 to 111 = Reserved All settings are within +/-10% of nominal value mentioned above

Table 20. Register 0x0A – USB2 HS DISCONNECT THRESHOLD

Register offset		Register Name		Register Description
0x0A		USB2 HS disconnect detection threshold		This register sets the HS disconnect threshold level on USB2 pins
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:2	RSVD	RAZ	b'000000	Reserved
1:0	HS Disconnect threshold level	RW	b'00	The bits determine the HS Disconnect detector threshold level on USB2 pins 00 = 575 mV 01 = 675 mV 10 = 775 mV 11 = 875 mV All settings are within ±50 mV of nominal value mentioned above The detector implements hysteresis of 30 mV to improve noise immunity.

Table 21. Register 0x0D – RAP Signature

Register offset		Register Name		Register Description
0x0D		RAP Signature		eUSB RAP Signature - Controls/limits RAP Command Access to the registers of the redriver.
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:0	RAP_Signature	RW	b'00000000	0x00 - No RAP Access to PTN3222 I^2C Registers 0x37 - RAP allowed read only access to Status, REVISION_ID, and Chip ID registers 0x92 - RAP allowed read only access to I^2C customer registers 0x21 - RAP allowed write/read access to I^2C customer registers All others - No RAP Access to registers

Table 22. Register 0x0E – VDX_CONTROL

Register offset		Register Name		Register Description
0x0E		VDX_CONTROL		PTN3222 can be used to indicate that the host system is a USB BC 1.2 CDP (Charging Downstream Port) to an USB peripheral. This involves activating a current source on USB DN pin (refer to USB BC 1.2 spec VDM_SRC definition).
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:1	RSVD	RAZ	b'00000000	Reserved
0	VDX_Ctrl	RW	b'0	VDX Control - Host Side Repeater Function 0 => Disable VDX_SRC 1 => Enable VDX_SRC The host shall enable VDX_SRC within 200 ms of a disconnect and PTN3222 VDX_SRC circuitry is automatically disabled upon detection of the next connection.

Table 23. Register 0x0F – DEVICE STATUS

Register offset	Register Name			Register Description
0x0F	Device Status			The register indicates the current state of repeater functionality. This register can only be read and writes don't have any effect
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:4	RSVD	RAZ		Reserved
3:2	Speed of operation	RO		This bit shows the current state of repeater speed of operation 00 = LS 01 = FS 10 = HS
1:0	Repeater role	RO		This bit shows the current role played by the repeater 00 = No role determined yet 01 = Device side repeater 10 = Host side repeater

Table 24. Register 0x10 – LINK STATUS

Register offset	Register Name			Register Description
0x10	Link Status			This status register reflects the current state of the repeater device and the link. This register can only be read and writes don't have any effect
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:3	RSVD	RAZ		Reserved
2:0	Device Link status	RO		The status bits reflect the device and link state 000 = Deep standby 001 = Connect detect 010 = L1 011 = L2 101 = Active HS (L0) 110 = Active HS (L0) forced due to USB2 compliance mode 111 = This setting represents transitioning condition between different states (e.g. Suspend to Resume to L0)

Table 25. Register 0x13 – REVISION_ID

Register offset	Register Name			Register Description
0x13	REVISION_ID			The REVISION ID register provides the silicon revision number. The Rev ID is a read only register whose value never changes.
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:4	BASE_STEP	RO	b'1010	Base layer version A0 stands for 1st version
3:0	METAL_STEP	RO	b'0010	Metal layer version 0 stands for A0 version, '01' for A1 version and '10' for A2 version

Table 26. Register 0x14 – CHIP_ID_0

Register offset		Register Name		Register Description
0x15		CHIP_ID_0		This ID register provides lower 8 bits of the 16-bit chip part number (3222). The ID register is a read-only register whose value never changes
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:0	CHIP_ID_0	RO	0x22	Lower 8-bit CHIP ID (0x22)

Table 27. Register 0x15 – CHIP_ID_1

Register offset		Register Name		Register Description
0x15		CHIP_ID_1		The ID register provides the upper 8 bits of the 16-bit chip part number (3222). The ID register is a read-only register whose value never changes
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:0	CHIP_ID_1	RO	0x32	Higher 8-bit CHIP ID (0x32)

Table 28. Register 0x16 – CHIP_ID_2

		Register Name		Register Description
0x16		CHIP_ID_2		The ID register provides the Configuration image information 4 bits and CHIP type (2 bits). The ID register is a read-only register whose value never changes
Bit	**Bit Name**	**R/W**	**Reset**	**Description**
7:4	Configuration	RO	b'0000	Fixed configuration
3:2	RSVD	RAZ		Reserved
1:0	CHIP Type	RO	b'01	CHIP type. 01 = Qualcomm configuration

10 Limiting values

Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability. Within these ratings, damage to the part must not occur, and all characteristics must still be met after the part is returned to recommended operating conditions.

Typical (Typ) values are based on typical PVT (nominal process, VDD3V = 3 V, VDD1V8 = 1.8 V, and 25 °C) and Min/Max values are based on all valid PVT ranges.

Table 29. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134); all voltage values are with respect to network ground terminal.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
VDD1V8	1V8 Supply voltage		Design	-0.5		2.4	V	LTC-VOL-PRIO1-001
VDD3V3	3V3 Supply voltage		Design	-0.5		4	V	LTC -VOL-PRIO1-002
V_I	Input voltage	SCL, SDA	Design	-0.5		2.4	V	LTC -VOL-PRIO1-003
		RST_N	Design	-0.5		2.4	V	LTC -VOL-PRIO1-004
		eDP, eDN	Design	-0.5		2.4	V	LTC -VOL-PRIO1-005
		DP, DN	Design	-0.5		5.5	V	LTC -VOL-PRIO1-006
		ADDR	Design	-0.5		2.4	V	LTC -VOL-PRIO1-007
T_{stg}	Storage temperature		Design	-60		+150	° C	LTC -TMP-PRIO1-008
V_{ESD}	Electrostatic discharge voltage	Human-Body Model [1]	Design	2			kV	LTC -VOL-PRIO1-008
		Charged-Device Model [2]	Design	500			V	LTC -VOL-PRIO1-009
$I_{LATCHUP}$	Latch-up current		Design	100			mA	LTC -CUR-PRIO1-012

[1] Human Body Model: ANSI/EOS/ESD-S5.1-1994, standard for ESD sensitivity testing, Human Body Model – Component level; Electrostatic Discharge Association, Rome, NY, USA.

[2] Charged Device Model: ANSI/EOS/ESD-S5.3-1-1999, standard for ESD sensitivity testing, Charged Device Model – Component level; Electrostatic Discharge Association, Rome, NY, USA.

11 Recommended operating conditions

Table 30. Operating conditions

Within these ratings, all characteristics in the following sections must be met unless noted otherwise. V_{PULLUP} is used to refer to I²C pullup voltage in the following sections. VDD1V8 refers to internal voltage reference used by PTN3222 for determining the logic levels of SCL/SDA pins.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
VDD3V3	3V3 Supply voltage		ATE	2.85	3	3.63	V	ROC-VOL-PRIO1-001
VDD1V8	1V8 Supply voltage		ATE	1.62	1.8	1.98	V	ROC-VOL-PRIO1-002
t_{VDD_rampup}	Supply voltage ramp-up time	Between 0V and VDD3V3min/VDD1 V8min	Bench	0.01		10	ms	ROC-TIM-PRIO1-003
VDD1V8	I²C interface pullup voltage	1.8 V voltage reference used for I²C pins (same as VDD1V8 supply)	ATE	VDD1V8 ,min	VDD1V8	VDD1V8 ,max	V	ROC-VOL-PRIO1-004
V_I	Input voltage	SCL, SDA	ATE	-0.3		1.98	V	ROC-VOL-PRIO1-006
		RST_N	ATE	-0.3		1.98	V	ROC-VOL-PRIO1-007
		eDP, eDN	ATE	-0.3		1.32	V	ROC-VOL-PRIO1-008
		DP, DN	ATE	-0.3		3.63	V	ROC-VOL-PRIO1-009
		ADDR	ATE	-0.3		1.98	V	ROC-VOL-PRIO1-010
T_{amb}	Ambient temperature	Operating in standing air environment – mobile/computing IOT market	Bench	-40		85	° C	ROC-TMP-PRIO1-011

Table 30. Operating conditions*...continued*

Within these ratings, all characteristics in the following sections must be met unless noted otherwise. V_{PULLUP} is used to refer to I^2C pullup voltage in the following sections. VDD1V8 refers to internal voltage reference used by PTN3222 for determining the logic levels of SCL/SDA pins.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
Tj [1]	Junction temperature	Captured mainly to ensure simulation is carried out in this temp corner		-40		125	° C	ROC-TMP-PRIO1-013

[1] PTN3222 is simulated for functionality up to junction temperature of 125 °C, but it is not guaranteed to meet the power/current consumption specifications.

Table 31. Thermal resistance

Symbol	Parameter	Conditions	Max	Unit	Unique identifier
$R_{th(j-a), CSP}$	Thermal resistance from junction to ambient [1]	JESD51-9	70	°C/W	THR-RES-PRIO1-001
$\Psi_{JT, CSP}$	Junction-to-Top of Package Thermal Characterization Parameter [2]	JESD51-9, 2s2p [3]	0.25	°C/W	THR-RES-PRIO1-002

[1] Determined in accordance to JEDEC JESD51-2A natural convection environment. Thermal resistance data in this report is solely for a thermal performance comparison of one package to another in a standard specified environment. It is not meant to predict the performance of a package in an application-specific environment.
[2] Thermal test board meets JEDEC specification for this package (JESD51-9)
[3] Junction-to-Case thermal resistance determined using an isothermal cold plate. Case is defined as the bottom of the packages

12 Characteristics

12.1 Device characteristics

Table 32. Device characteristics

Applicable across operating temperature and power supply ranges as mentioned under Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
$t_{Startup}$	Device start-up time	Time for device operation including I^2C accesses once both supply voltages are within recommended operating levels	Bench			1	ms	DEV-TIM-PRIO1-001
t_{SW_reset}	Time for software reset to complete	Supply voltages are valid	Bench			0.5	ms	DEV-TIM-PRIO1-002
t_{Cfg}	Device parameter (re)configuration time	Time for parameter (re)configuration values to take effect after I^2C programming (or RAP initialization)	Bench			0.5	ms	DEV-TIM-PRIO1-003
t_{DPSS_Exit}	Time duration that host has to wait before issuing further commands when PTN3222 is exiting deep standby		Bench			275	µs	DEV-TIM-PRIO1-033
t_{PD}	Pin to pin differential propagation delay between eUSB2 and USB2 pins	Parameter configured for maximum signal path latency for USB2 HS data	Bench			3	ns	DEV-TIM-PRIO1-004
$I_{supply,3V3}$	VDD3V3 Supply current	Deep standby	ATE			7	µA	DEV-CUR-PRIO1-005
		Connect Detect substate	ATE			10	µA	DEV-CUR-PRIO1-006
		L2 suspend	ATE			10	µA	DEV-CUR-PRIO1-007
		L1 sleep	ATE			10	µA	DEV-CUR-PRIO1-008
		Active LS/FS mode (w/10 pF load @ USB2 and 2.5 pF load @ eUSB2	ATE			6.5	mA	DEV-CUR-PRIO1-009
		Active HS mode (eUSB to USB direction); no de-emphasis; only Rx EQ enabled on eUSB2 / USB2 pins; 90 Ω termination on USB2 pins and 80 Ω on eUSB2 pins	ATE			8	mA	DEV-CUR-PRIO1-010
		Active HS mode (eUSB to USB direction) de-emphasis 3 dB on USB2; Rx EQ enabled on eUSB2 / USB2 pins; 85 Ω termination on USB2 side and 80 Ω termination on eUSB2 side	ATE			11	mA	DEV-CUR-PRIO1-011
		Active HS mode (USB to eUSB direction); no de-emphasis; only Rx EQ enabled on eUSB2 /	ATE			3	mA	DEV-CUR-PRIO1-037

Table 32. Device characteristics*...continued*

Applicable across operating temperature and power supply ranges as mentioned under Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
		USB2 pins; 90 Ω termination on USB2 pins and 80 Ω on eUSB2 pins						
		Active HS mode (USB to eUSB direction); de-emphasis 3 dB on USB2; Rx EQ enabled on eUSB2 /USB2 pins; 85 Ω termination on USB2 side and 80 Ω termination on eUSB2 side	ATE			4	mA	DEV-CUR-PRIO1-038
$I_{supply,1V8}$	VDD1V8 Supply current	Deep standby	ATE			50	µA	DEV-CUR-PRIO1-012
		Connect Detect substate	ATE			85	µA	DEV-CUR-PRIO1-013
		L2 suspend	ATE			85	µA	DEV-CUR-PRIO1-014
		L1 sleep	ATE			0.8	mA	DEV-CUR-PRIO1-015
		Active LS/FS mode (w/10 pF load @ USB2 and 2.5 pF load @ eUSB2	ATE			3.7	mA	DEV-CUR-PRIO1-016
		Active HS mode (eUSB to USB direction); no de-emphasis; only Rx EQ enabled on eUSB2 / USB2 pins; 90 Ω termination on USB2 side and 80 Ω on eUSB2 side, 400 mV USB2 output swing	ATE			47.5	mA	DEV-CUR-PRIO1-017
		Active HS mode (eUSB to USB direction); de-emphasis 3 dB on USB2; Rx EQ enabled on eUSB2 / USB2 pins; 85 Ω termination on USB2 pins and 80 Ω termination on eUSB2 pins	ATE			55	mA	DEV-CUR-PRIO1-018
		Active HS mode (USB to eUSB direction); no de-emphasis; only Rx EQ enabled on eUSB2 / USB2 pins; 90 Ω termination on USB2 side and 80 Ω on eUSB2 side, 400 mV USB2 output swing	ATE			28	mA	DEV-CUR-PRIO1-039
		Active HS mode (USB to eUSB direction); de-emphasis 3 dB on USB2; Rx EQ enabled on eUSB2 / USB2 pins; 85 Ω termination on USB2 pins and 80 Ω termination on eUSB2 pins	ATE			40	mA	DEV-CUR-PRIO1-040
$I_{backpower, 3V3}$	Back power current when VDD3V3 pin is shorted to GND	Current going into SCL pin when SCL is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-019
		Current going into SDA pin when SDA is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-020
		Current into RST_N pin when RST_N is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-021
$I_{backpower, 1V8}$	Back power current when VDD1V8 pin is shorted to GND	Current going into SCL pin when SCL is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-022
		Current going into SDA pin when SDA is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-023
		Current into RST_N pin when RST_N is tied to VDD1V8 max	ATE			1	µA	DEV-CUR-PRIO1-024
I_{INRUSH_3V3}	Inrush current when VDD3V3 ramp up from 0 V to final value		Bench			1	mA	DEV-CUR-PRIO1-031
I_{INRUSH_1V8}	Inrush current when VDD1V8 ramp up from 0 V to final value		Bench			1	mA	DEV-CUR-PRIO1-032

12.2 USB2 and eUSB2 characteristics

Table 33. USB2 and eUSB2 characteristics

Applicable across operating temperature and power supply ranges as Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
$V_{RX\_CM\_USB2}$	USB2 Rx common mode voltage		ATE	-100		500	mV	USB-VOL-PRIO1-001
$V_{IH\_LF\_USB2}$	USB2 Low/Full Speed High-level input voltage		ATE	2			V	USB-VOL-PRIO1-002
$V_{IL\_LF\_USB2}$	USB2 Low/Full Speed Low-level input voltage		ATE			0.8	V	USB-VOL-PRIO1-003
$V_{IHZ\_LF\_USB2}$	USB2 Low/Full speed Hi-Z input level		ATE	2.7		3.7	V	USB-VOL-PRIO1-004

Table 33. USB2 and eUSB2 characteristics*...continued*

Applicable across operating temperature and power supply ranges as Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
$V_{OL\_LF\_USB2}$	USB2 Low/Full speed Low-level output voltage		ATE			0.3	V	USB-VOL-PRIO1-005
$V_{OH\_LF\_USB2}$	USB2 Low/Full speed High-level output voltage		ATE	2.8		3.7	V	USB-VOL-PRIO1-006
$Z_{SO\_LF\_USB2}$	USB2 Transmit output series resistance		ATE	40.5		49.5	Ω	USB-RES-PRIO1-007
$V_{OP\_TX\_USB2}$	USB2 HS Tx output signal swing	Measured on DP/DN pin with no de-emphasis with 90 Ω (nominal) differential termination; I^2C register offset address 0x08 I^2C setting = 0	ATE	315	350	385	mV	USB-VOL-PRIO1-008
		I^2C setting = 1	Char	360	400	440	mV	USB-VOL-PRIO1-009
		I^2C setting = 2	Char	405	450	495	mV	USB-VOL-PRIO1-010
		I^2C setting = 3	ATE	450	500	550	mV	USB-VOL-PRIO1-011
		I^2C setting = 4	Char	495	550	610	mV	USB-VOL-PRIO1-012
		I^2C setting = 5	Char	540	600	660	mV	USB-VOL-PRIO1-013
		I^2C setting = 6	Char	585	650	715	mV	USB-VOL-PRIO1-014
		I^2C setting = 7	ATE	630	700	770	mV	USB-VOL-PRIO1-015
$G_{DE\_TX\_USB2}$	USB2 HS Tx output signal de-emphasis	Measurement on DP/DN pin @ 480 Mbps; with 90 Ω nominal differential termination; with 1 UI de-emphasis option; I^2C register offset address 0x07						
		I^2C setting = 1	Char	0	1	2	dB	USB-DB-PRIO1-017
		I^2C setting = 2	ATE	1	2	3	dB	USB-DB-PRIO1-018
		I^2C setting = 3	Char	2	3	4	dB	USB-DB-PRIO1-019
		I^2C setting = 4	Char	3	4	5	dB	USB-DB-PRIO1-020
		I^2C setting = 5	ATE	4	5	6	dB	USB-DB-PRIO1-021
		I^2C setting = 6	Char	5	6	7	dB	USB-DB-PRIO1-022
$t_{DE\_TX\_USB2}$	USB2 HS Tx output signal de-emphasis bit duration	Measurement on DP/DN pin @ 480 Mbps; with 90 Ω nominal differential termination; (UI ~2.08ns); I^2C register offset address 0x07						
		I^2C setting = 1	Char	0.3	0.5	0.7	UI	USB-TIM-PRIO1-024
		I^2C setting = 2	ATE	0.6	0.8	1	UI	USB-TIM-PRIO1-025
$t_{Rise\_TX\_HS\_USB2}$	USB2 HS Tx Rise/fall time	Measurement on DP/DN pin @ 480 Mbps (10 % to 90 % of final output level); with 90 Ω nominal differential termination and 10pF load capacitance; I^2C register offset address 0x08; I^2C setting = 0	Bench	500		900	ps	USB-TIM-PRIO1-026
		I^2C setting = 1	Bench	400		800	ps	USB-TIM-PRIO1-027
		I^2C setting = 2	Bench	300		700	ps	USB-TIM-PRIO1-028
$G_{EQ\_RX\_USB2}$	USB2 HS Rx input equalization	Measurement at 240 MHz with reference to DC to 1 MHz; I^2C register offset address 0x06 I^2C setting = 0	Bench	-1	0	1	dB	USB-DB-PRIO1-029
		I^2C setting = 1	Bench	0	1	2	dB	USB-DB-PRIO1-030
		I^2C setting = 2	Bench	1	2	3	dB	USB-DB-PRIO1-031
		I^2C setting = 3	Bench	2	3	4	dB	USB-DB-PRIO1-032
		I^2C setting = 4	Bench	3	4	5	dB	USB-DB-PRIO1-033
$R_{RCV\_DIF\_USB2}$	USB2 HS Rx differential receiver termination	Measured on DP/DN pin; I^2C register offset address 0x09 I^2C setting = 4	Char	72	80	88	Ω	USB-RES-PRIO1-034
		I^2C setting = 3	Char	75	85	95	Ω	USB-RES-PRIO1-035
		I^2C setting = 2	ATE	80	90	100	Ω	USB-RES-PRIO1-036
		I^2C setting = 1	Char	85	95	105	Ω	USB-RES-PRIO1-037
		I^2C setting = 0	ATE	90	100	110	Ω	USB-RES-PRIO1-038

Table 33. USB2 and eUSB2 characteristics*...continued*

Applicable across operating temperature and power supply ranges as Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
$V_{SQ\_RX\_USB2}$	USB2 HS Rx squelch detection threshold	Measured on DP/DN pin; with 90 Ω nominal differential termination; I^2C register offset address 0x06 I^2C setting = 0	ATE	25	50	75	mV	USB-VOL-PRIO1-039
		I^2C setting = 1	Char	40	65	90	mV	USB-VOL-PRIO1-040
		I^2C setting = 2	Char	60	85	110	mV	USB-VOL-PRIO1-041
		I^2C setting = 3	Char	70	95	120	mV	USB-VOL-PRIO1-042
		I^2C setting = 4	ATE	85	110	135	mV	USB-VOL-PRIO1-043
		I^2C setting = 5	ATE	100	125	150	mV	USB-VOL-PRIO1-044
		I^2C setting = 6	Char	115	140	165	mV	USB-VOL-PRIO1-045
		I^2C setting = 7	Char	130	155	180	mV	USB-VOL-PRIO1-046
$V_{DIS\_HS\_USB2}$	USB2 HS Rx disconnect detection threshold	Low to High amplitude transition measured on DP/DN pin under disconnect condition; I^2C register offset address 0x0A I^2C setting = 0	ATE	525	575	625	mV	USB-VOL-PRIO1-047
		I^2C setting = 1	Char	625	675	725	mV	USB-VOL-PRIO1-048
		I^2C setting = 2	Char	725	775	825	mV	USB-VOL-PRIO1-049
		I^2C setting = 3	ATE	825	875	925	mV	USB-VOL-PRIO1-050
$V_{RISE\_TX\_FS\_USB2}$	USB2 FS Tx Rise/Fall time control	Measured on DP/DN pin (10-90% of final voltage level); with 90 Ω nominal differential termination; I^2C register offset address 0x08 I^2C setting = 0	Bench	8		20	ns	USB-TIM-PRIO1-051
		I^2C setting = 1	Bench	4		10	ns	USB-TIM-PRIO1-052
	Total added jitter on USB2 HS	Measured on DP/DN pin with 90 Ω nominal differential termination with BER 1e-12 reference; PRBS HS input data payload with USB2 bit stuffing; clean input signal level 75 mV;	Bench		25	40	ps	USB-TIM-PRIO1-053
t_{JITTER_eUSB2}	Total added jitter on eUSB2 HS	Measured on eDP/eDN pin with 80 Ω nominal differential termination with BER 1e-12 reference; PRBS HS input data payload with USB2 bit stuffing; clean input signal level 100 mV;	Bench		25	40	ps	USB-TIM-PRIO1-088
$V_{RX\_CM\_eUSB2}$	eUSB2 HS Rx DC common mode voltage range		ATE	120		280	mV	USB-VOL-PRIO1-054
$C_{RX\_CM\_eUSB2}$	eUSB2 HS center tapped capacitance		Bench	15		50	pF	USB-CAP-PRIO1-055
$V_{RX\_DIF\_SENS\_eUSB2}$	eUSB2 HS Rx sensitivity		Bench	25	50		+/-mV	USB-VOL-PRIO1-056
$R_{RCV\_DIF\_eUSB2}$	eUSB2 HS Rx differential receiver termination	Measured on eDP/eDN pin;	ATE	72	80	88	Ω	USB-RES-PRIO1-057
$V_{OP\_TX\_eUSB2}$	eUSB2 HS Tx output signal swing	Measured on eDP/eDN pin with no de-emphasis with 80 Ω (nominal) differential termination; I^2C register offset address 0x05 I^2C setting = 0	Char	140	180	220	mV	USB-VOL-PRIO1-058
		I^2C setting = 1	ATE	160	200	240	mV	USB-VOL-PRIO1-059
		I^2C setting = 2	ATE	180	220	260	mV	USB-VOL-PRIO1-060
		I^2C setting = 3	Char	200	240	280	mV	USB-VOL-PRIO1-061
$GT_{X\_DE\_eUSB2}$	eUSB2 HS Tx de-emphasis as measured on eDP/eDN pin	Measurement at 240 MHz with reference to DC- 1 MHz; referenced to 200 mV (terminated) Tx signaling; I^2C register offset address 0x05						
		I^2C setting = 1	Char	0	1	2	dB	USB-DB-PRIO1-063
		I^2C setting = 2	Char	1	2	3	dB	USB-DB-PRIO1-064
		I^2C setting = 3	ATE	2	3	4	dB	USB-DB-PRIO1-065
$G_{RX\_EQ\_eUSB2}$	eUSB2 HS Rx equalization as measured on eDP/eDN pin	Measurement at 240 MHz with reference to DC- 1 MHz; I^2C register offset address 0x04 I^2C setting = 0	Bench	-1	0	1	dB	USB-DB-PRIO1-066
		I^2C setting = 1	Bench	0	1	2	dB	USB-DB-PRIO1-067
		I^2C setting = 2	Bench	1	2	3	dB	USB-DB-PRIO1-068
		I^2C setting = 3	Bench	2	3	4	dB	USB-DB-PRIO1-069

Table 33. USB2 and eUSB2 characteristics*...continued*

Applicable across operating temperature and power supply ranges as Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
		I^2C setting = 4	Bench	3	4	5	dB	USB-DB-PRIO1-070
$V_{SQ\_RX\_eUSB2}$	eUSB2 HS Rx squelch threshold as measured on eDP/eDN pin	Measured on eDP/eDN pin; with 80 Ω nominal differential termination; I^2C register offset address 0x04 I^2C setting = 0	Char	25	50	75	mV	USB-VOL-PRIO1-071
		I^2C setting = 1	ATE	40	65	90	mV	USB-VOL-PRIO1-072
		I^2C setting = 2	ATE	60	85	110	mV	USB-VOL-PRIO1-073
		I^2C setting = 3	Char	70	95	120	mV	USB-VOL-PRIO1-074
$V_{CM\_RX\_AC\_eUSB2}$	eUSB2 HS RX AC common mode voltage	CM noise band (50 MHz to 480 MHz)	Bench			60	+/-m Vpeak	USB-VOL-PRIO1-075
$V_{OL\_LF\_eUSB2}$	eUSB2 LS/FS Low-level output voltage	(0.15 x internally derived 1.2 V reference from VDD1V8)	ATE			0.18	V	USB-VOL-PRIO1-076
$V_{OH\_LF\_eUSB2}$	eUSB2 LS/FS High-level output voltage	(0.85 x internally derived 1.2 V reference from VDD1V8)	ATE	1.02			V	USB-VOL-PRIO1-077
$V_{IL\_LF\_eUSB2}$	eUSB2 LS/FS Low-level input voltage	(0.35 x internally derived 1.2 V reference from VDD1V8)	ATE	-0.1		0.42	V	USB-VOL-PRIO1-078
$V_{IH\_LF\_eUSB2}$	eUSB2 LS/FS High-level input voltage	(0.65 x internally derived 1.2 V reference from VDD1V8)	ATE	0.78			V	USB-VOL-PRIO1-079
$V_{Hysteresis\_eUSB2}$	eUSB2 LS/FS Rx Hysteresis	(0.04 x internally derived 1.2 V reference from VDD1V8min)	Bench	32		130	mV	USB-VOL-PRIO1-080
$Z_{TXSRC\_LF\_eUSB2}$	eUSB2 LS/FS Transmit output impedance		ATE	28		60	Ω	USB-RES-PRIO1-081
$V_{CM\_TX\_AC\_USB2}$	USB2 HS TX AC common mode voltage (measured when 400mV USB2 HS Tx signaling level is selected and with 90Ohm termination) at USB2 pins	Measured spectral content from 800 MHz to 2 GHz frequency band	Bench			22	mVrms	USB-VOL-PRIO1-082
$V_{CM\_TX\_AC\_RF\_USB2}$	USB2 HS TX AC common mode voltage at specific harmonic frequency (measured when 400 mV USB2 HS Tx signaling level is selected and with 90 Ω termination) at USB2 pins; all dB level referenced to signal level at Nyquist frequency of 240 MHz	Freq = 720 MHz	Bench		-57	-49	dBV	USB-DB-PRIO1-083
		Freq = 960 MHz	Bench		-41	-35	dBV	USB-DB-PRIO1-084
		Freq = 1.2 GHz	Bench		-59	-51	dBV	USB-DB-PRIO1-085
		Freq = 1.44 GHz	Bench		-43	-38	dBV	USB-DB-PRIO1-086
tresponse	Response time to wake up and activate redriver data path for USB2 packet transmission		Bench			4	UI	USB-TIM-PRIO1-087
$V_{OVP,Th}$	VBUS Over voltage detector on DP and DN pins	Low to high transition	ATE	4.2	4.4	4.9	V	USB-VOL-PRIO1-089
		High to low transition	ATE	3.9	4.2	4.9	V	USB-VOL-PRIO1-090
V_{CRS}	USB2 LS cross-over voltage		ATE	1.3	-	2	V	USB-VOL-PRIO1-103

12.3 I^2C dynamic/static characteristics

Table 34. Standard mode I^2C characteristics

Applicable across operating temperature and power supply ranges as recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
f_{I2C}	I^2C clock frequency	Standard mode	ATE	0		100	kHz	STD-FRQ-PRIO1-001
R_{PULLUP}	I^2C interface pull up resistors on SCL/SDA lines	System Requirement		0.567	2.2	2.83	kΩ	STD-RES-PRIO1-002
V_{IH}	High level input voltage	Standard mode; 1.8 V	ATE	0.7 x VDD1V8			V	STD-VOL-PRIO1-003
V_{IL}	Low level input voltage	Standard mode; 1.8 V	ATE	-0.3		0.3 x VDD1V8	V	STD-VOL-PRIO1-004

Table 34. Standard mode I^2C characteristics*...continued*

Applicable across operating temperature and power supply ranges as recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
V_{hys}	Hysteresis of Schmitt trigger inputs	Standard mode: 1.8 V	Bench	0.05 x VDD1V8			V	STD-VOL-PRIO1-005
V_{OL}	Low level output voltage	Standard mode, 2mA sink current; VDD1V8 < 2 V	ATE	0		0.2 x VDD1V8	V	STD-VOL-PRIO1-006
I_{OL}	Low level output current	Standard mode, V_{OL} = 0.4 V;	ATE	3			mA	STD-CUR-PRIO1-007
I_{IL}	Low level input current	Standard mode, Pin voltage = $0.1V_{PULLUP}$ to $0.9V_{PULLUP,\ max}$	ATE	-10		10	uA	STD-CUR-PRIO1-008
C_I	Capacitance of I/O pins	Standard mode	Bench			10	pF	STD-CAP-PRIO1-009
$t_{HD,STA}$	Hold time (repeated-START) condition	Standard mode	ATE	4			us	STD-TIM-PRIO1-010
t_{LOW}	Low period of I^2C clock	Standard mode	ATE	4.7			us	STD-TIM-PRIO1-011
t_{HIGH}	High period of I^2C clock	Standard mode	ATE	4			us	STD-TIM-PRIO1-012
$t_{SU,STA}$	Setup time (REPEAT) START condition	Standard mode	ATE	4.7			us	STD-TIM-PRIO1-013
$t_{HD,\ DAT}$	Data hold time	Standard mode	ATE	0			us	STD-TIM-PRIO1-014
$t_{SU,\ DAT}$	Data setup time	Standard mode	ATE	250			ns	STD-TIM-PRIO1-015
$t_{SU,\ STO}$	Setup time for STOP condition	Standard mode	ATE	4			us	STD-TIM-PRIO1-016
t_{BUF}	Bus free time between STOP and START condition	Standard mode	ATE	4.7			us	STD-TIM-PRIO1-017
t_r	Rise time of SCL/SDA signals	Standard mode	Bench	20		1000	ns	STD-TIM-PRIO1-018
t_f	Fall time of SCL/SDA signals	Standard mode	Bench	20 x (VDD1V8 /5.5)		300	ns	STD-TIM-PRIO1-019
$t_{VD,DAT}$	Data valid time	Standard mode	ATE			3.45	us	STD-TIM-PRIO1-020
$t_{VD,ACK}$	Data valid acknowledge time	Standard mode	ATE			3.45	us	STD-TIM-PRIO1-021
t_{SP}	Pulse width of spikes that must be suppressed by input filter	Standard mode	ATE	0		50	ns	STD-TIM-PRIO1-022
V_{nL}	Noise margin at the LOW level	Standard mode, for each connected device (including hysteresis)	Bench	0.1 x VDD1V8			V	STD-VOL-PRIO1-023
V_{nH}	Noise margin at the HIGH level	Standard mode, for each connected device (including hysteresis)	Bench	0.2 x VDD1V8			V	STD-VOL-PRIO1-024
C_b	Capacitive load for each bus line	Standard mode, system requirement	System			400	pF	STD-CAP-PRIO1-025

Table 35. Fast mode I^2C characteristics

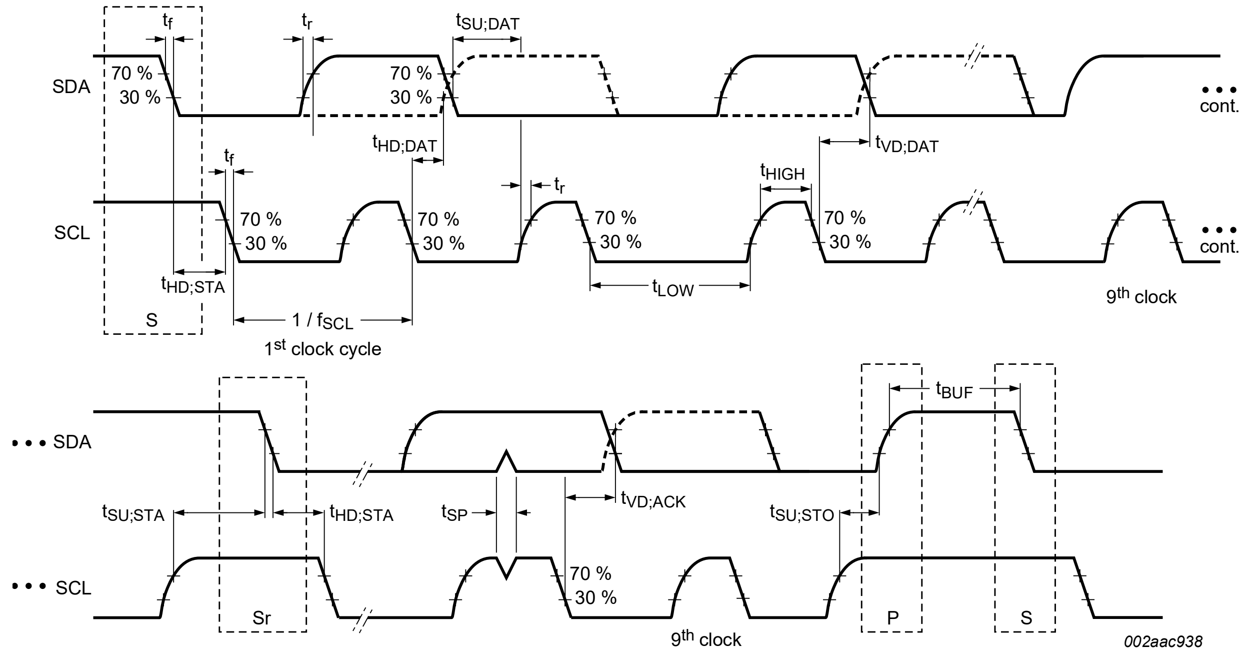
Applicable across operating temperature and power supply ranges as mentioned in Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
f_{I2C}	I^2C clock frequency	Fast mode	ATE	0		400	kHz	FST-FRQ-PRIO1-001
R_{PULLUP}	I^2C interface pull up resistors on SCL/SDA lines	System Requirement		0.567	2.2	2.83	kΩ	FST-RES-PRIO1-002
V_{IH}	High level input voltage	Fast mode; 1.8 V	ATE	0.7 x VDD1V8			V	FST-VOL-PRIO1-003
V_{IL}	Low level input voltage	Fast mode; 1.8 V	ATE	-0.3		0.3 x VDD1V8	V	FST-VOL-PRIO1-004
V_{hys}	Hysteresis of Schmitt trigger inputs	Fast mode; 1.8 V	Bench	0.05 x VDD1V8			V	FST-VOL-PRIO1-005
V_{OL}	Low level output voltage	Fast mode, 2mA sink current; VDD1V8 < 2 V	ATE	0		0.2 x VDD1V8	V	FST-VOL-PRIO1-006
I_{OL}	Low level output current	Fast mode, V_{OL} = 0.4 V;	ATE	3			mA	FST-CUR-PRIO1-007
I_{IL}	Low level input current	Fast mode, Pin voltage = $0.1V_{PULLUP}$ to $0.9V_{PULLUP,\ max}$	ATE	-10		10	uA	FST-CUR-PRIO1-008

Table 35. Fast mode I^{2}C characteristics...*continued*

Applicable across operating temperature and power supply ranges as mentioned in Recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
C_I	Capacitance of I/O pins	Fast mode	Bench			10	pF	FST-CAP-PRIO1-009
$t_{HD,STA}$	Hold time (repeated-START) condition	Fast mode	ATE	0.6			us	FST-TIM-PRIO1-010
t_{LOW}	Low period of I^{2}C clock	Fast mode	ATE	1.3			us	FST-TIM-PRIO1-011
t_{HIGH}	High period of I^{2}C clock	Fast mode	ATE	0.6			us	FST-TIM-PRIO1-012
$t_{SU,STA}$	Setup time (REPEAT) START condition	Fast mode	ATE	0.6			us	FST-TIM-PRIO1-013
$t_{HD, DAT}$	Data hold time	Fast mode	ATE	0			us	FST-TIM-PRIO1-014
$t_{SU, DAT}$	Data setup time	Fast mode	ATE	100			ns	FST-TIM-PRIO1-015
$t_{SU, STO}$	Setup time for STOP condition	Fast mode	ATE	0.6			us	FST-TIM-PRIO1-016
t_{BUF}	Bus free time between STOP and START condition	Fast mode	ATE	1.3			us	FST-TIM-PRIO1-017
t_r	Rise time of SCL/SDA signals	Fast mode	Bench	20		300	ns	FST-TIM-PRIO1-018
t_f	Fall time of SCL/SDA signals	Fast mode	Bench	20 x (VDD1V8 /5.5)		300	ns	FST-TIM-PRIO1-019
$t_{VD,DAT}$	Data valid time	Fast mode	ATE			0.9	us	FST-TIM-PRIO1-020
$t_{VD,ACK}$	Data valid acknowledge time	Fast mode	ATE			0.9	us	FST-TIM-PRIO1-021
t_{SP}	Pulse width of spikes that must be suppressed by input filter	Fast mode	ATE	0		50	ns	FST-TIM-PRIO1-022
V_{nL}	Noise margin at the LOW level	Fast mode, for each connected device (including hysteresis)	Bench	0.1 x VDD1V8			V	FST-VOL-PRIO1-023
V_{nH}	Noise margin at the HIGH level	Fast mode, for each connected device (including hysteresis)	Bench	0.2 x VDD1V8			V	FST-VOL-PRIO1-024
C_b	Capacitive load for each bus line	Fast mode, system requirement	System			400	pF	FST-CAP-PRIO1-025



$V_{IL} = 0.3V_{DD}$; $V_{IH} = 0.7V_{DD}$

Figure 13. Definition of timing for Fast/Standard mode devices on the I^{2}C bus

Table 36. Fast mode plus I^2C characteristics

Applicable across operating temperature and power supply ranges as recommended operating conditions unless otherwise noted. Typical values are specified at 25 °C unless otherwise noted.

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
f_{I2C}	I^2C clock frequency	Fast mode plus	ATE	0		1000	kHz	FMPLUS-FRQ-PRIO1-001
R_{PULLUP}	I^2C interface pull up resistors on SCL/ SDA lines	System Requirement		0.567	2.2	2.83	kΩ	FMPLUS-RES-PRIO1-002
V_{IH}	High level input voltage	Fast mode plus; 1.8 V	ATE	0.7 x VDD1V8			V	FMPLUS-VOL-PRIO1-003
V_{IL}	Low level input voltage	Fast mode plus; 1.8 V	ATE	-0.3		0.3 x VDD1V8	V	FMPLUS-VOL-PRIO1-004
V_{hys}	Hysteresis of Schmitt trigger inputs	Fast mode plus; 1.8 V	Bench	0.05 x VDD1V8			V	FMPLUS-VOL-PRIO1-005
V_{OL}	Low level output voltage	2mA sink current; VDD1V8 < 2 V	ATE	0		0.2 x VDD1V8	V	FMPLUS-VOL-PRIO1-006
I_{OL}	Low level output current	V_{OL} = 0.4 V; Fast mode plus	ATE	20			mA	FMPLUS-CUR-PRIO1-007
I_{IL}	Low level input current	Pin voltage = $0.1V_{PULLUP}$ to $0.9V_{PULLUP, max}$	ATE	-10		10	uA	FMPLUS-CUR-PRIO1-008
C_I	Capacitance of I/O pins		Bench			10	pF	FMPLUS-CAP-PRIO1-009
$t_{HD,STA}$	Hold time (repeated-START) condition	Fast mode plus	ATE	0.26			us	FMPLUS-TIM-PRIO1-010
t_{LOW}	Low period of I^2C clock	Fast mode plus	ATE	0.5			us	FMPLUS-TIM-PRIO1-011
t_{HIGH}	High period of I^2C clock	Fast mode plus	ATE	0.26			us	FMPLUS-TIM-PRIO1-012
$t_{SU,STA}$	Setup time (REPEAT) START condition	Fast mode plus	ATE	0.26			us	FMPLUS-TIM-PRIO1-013
$t_{HD, DAT}$	Data hold time		ATE	0			us	FMPLUS-TIM-PRIO1-014
$t_{SU, DAT}$	Data setup time	Fast mode plus	ATE	50			ns	FMPLUS-TIM-PRIO1-015
$t_{SU, STO}$	Setup time for STOP condition	Fast mode plus	ATE	0.26			us	FMPLUS-TIM-PRIO1-016
t_{BUF}	Bus free time between STOP and START condition	Fast mode plus	ATE	0.5			us	FMPLUS-TIM-PRIO1-017
t_r	Rise time of SCL/ SDA signals	Fast mode plus	Bench	0		120	ns	FMPLUS-TIM-PRIO1-018
t_f	Fall time of SCL/ SDA signals	Fast mode plus	Bench	20 x(VDD1 V8 /5.5)		120	ns	FMPLUS-TIM-PRIO1-019
$t_{VD,DAT}$	Data valid time	Fast mode plus	ATE			0.45	us	FMPLUS-TIM-PRIO1-020
$t_{VD,ACK}$	Data valid acknowledge time	Fast mode plus	ATE			0.45	us	FMPLUS-TIM-PRIO1-021
t_{SP}	Pulse width of spikes that must be suppressed by input filter		ATE	0		50	ns	FMPLUS-TIM-PRIO1-022
V_{nL}	Noise margin at the LOW level	Fast mode plus, for each connected device (including hysteresis)	Bench	0.1 x VDD1V8			V	FMPLUS-VOL-PRIO1-023
V_{nH}	Noise margin at the HIGH level	Fast mode plus, for each connected device (including hysteresis)	Bench	0.2 x VDD1V8			V	FMPLUS-VOL-PRIO1-024
C_b	Capacitive load for each bus line	System Requirement				400	pF	FMPLUS-CAP-PRIO1-025

12.4 ADDR pin characteristics

Table 37. ADDR characteristics

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
V_{IH1}	High level input voltage	Pin connected to VDD1V8	ATE	0.9 x VDD1V8		VDD1V8+0.3	V	QAT-VOL-PRIO1-001
V_{IH2}	High level input voltage	Rext = 56 kΩ (10 % resistor) pullup to VDD1V8	ATE	0.575 x VDD1V8		0.725 x VDD1V8	V	QAT-VOL-PRIO1-009
V_{IM}	High level input voltage	Rext = 200 kΩ (10 % resistor) pullup to VDD1V8	ATE	0.275 x VDD1V8		0.425 x VDD1V8	V	QAT-VOL-PRIO1-010
V_{IL}	Low level input voltage	Pin connected to GND	ATE			0.1 x VDD1V8	V	QAT-VOL-PRIO1-002
I_{bckcur}	Back current on pin when there is no power	VDD1V8=0 (no power supply to RST_N Input pad)	ATE			1	µA	QAT-CUR-PRIO1-003
I_{IL}	Pin Leakage current	Pin connected directly to GND	ATE			5	µA	QAT-CUR-PRIO1-004
Cpin	Pin capacitance		Bench			10	pF	QAT-CAP-PRIO1-007
Rpd	Internal pulldown resistor		ATE	86	105	122	kΩ	QAT-RES-PRIO1-008

12.5 RST_N pin characteristics

Table 38. RST_N characteristics

Symbol	Parameter	Condition	Spec guar by	Min	Typ	Max	Unit	Unique Identifier
V_{IH}	High level input voltage	1.8 V IO operation	ATE	1.2			V	BIN-VOL-PRIO1-001
V_{IL}	Low level input voltage	1.8 V IO operation	ATE			0.3	V	BIN-VOL-PRIO1-002
I_{bckcur}	Back current on pin when there is no power	VDD1V8=0 (no power supply to RST_N Input pad)	ATE			1	uA	BIN-CUR-PRIO1-003
I_{IL}	Pin Leakage current	Pin connected directly to GND	ATE			5	uA	BIN-CUR-PRIO1-004
$t_{RST\_N\_SP}$	Minimum De-glitch duration		Bench	200			ns	BIN-TIM-PRIO1-005
C_{pin}	Pin capacitance		Bench			10	pF	BIN-CAP-PRIO1-006

13 Package outline

13.1 SOT2063-1 (WLCSP12)

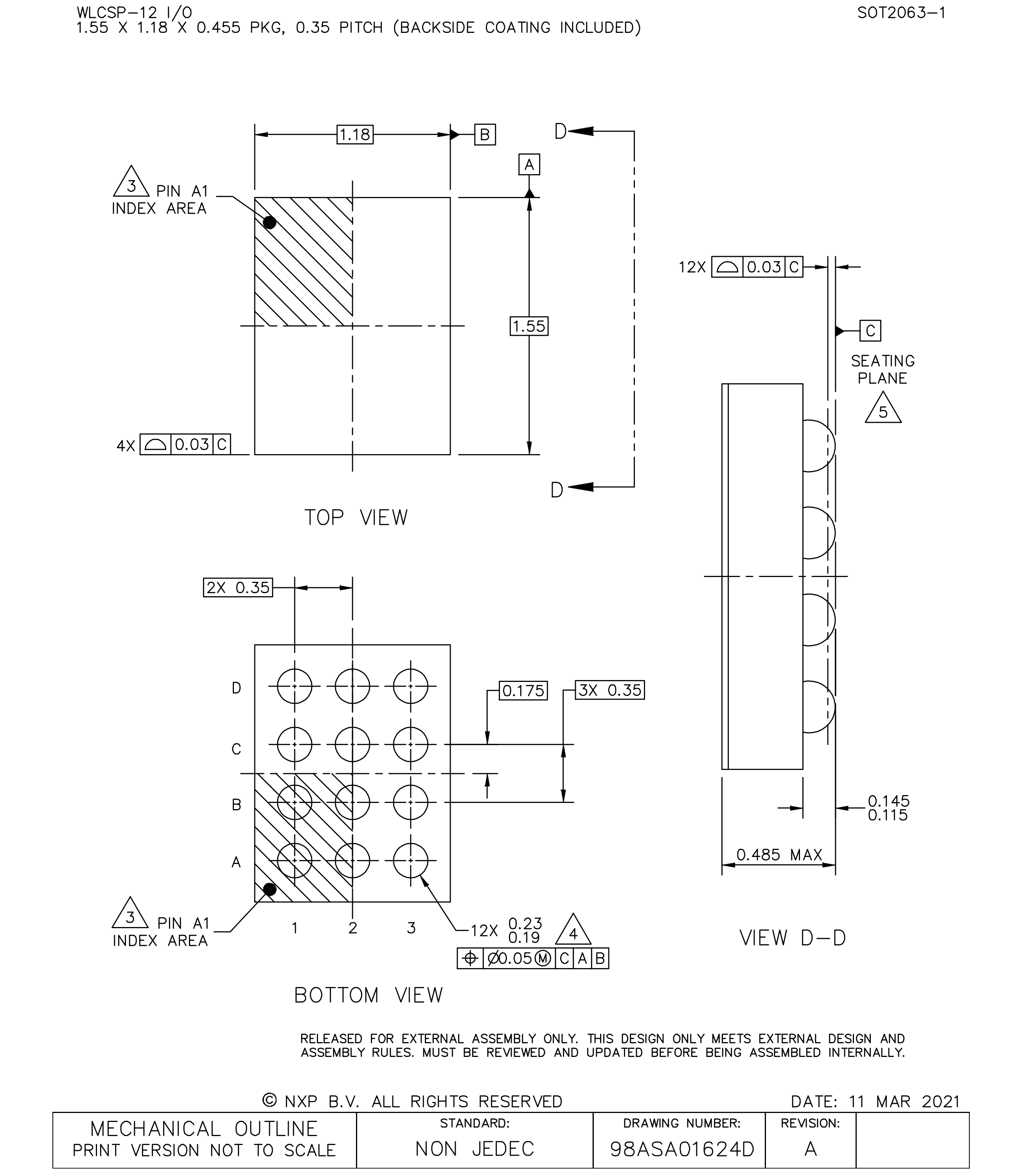
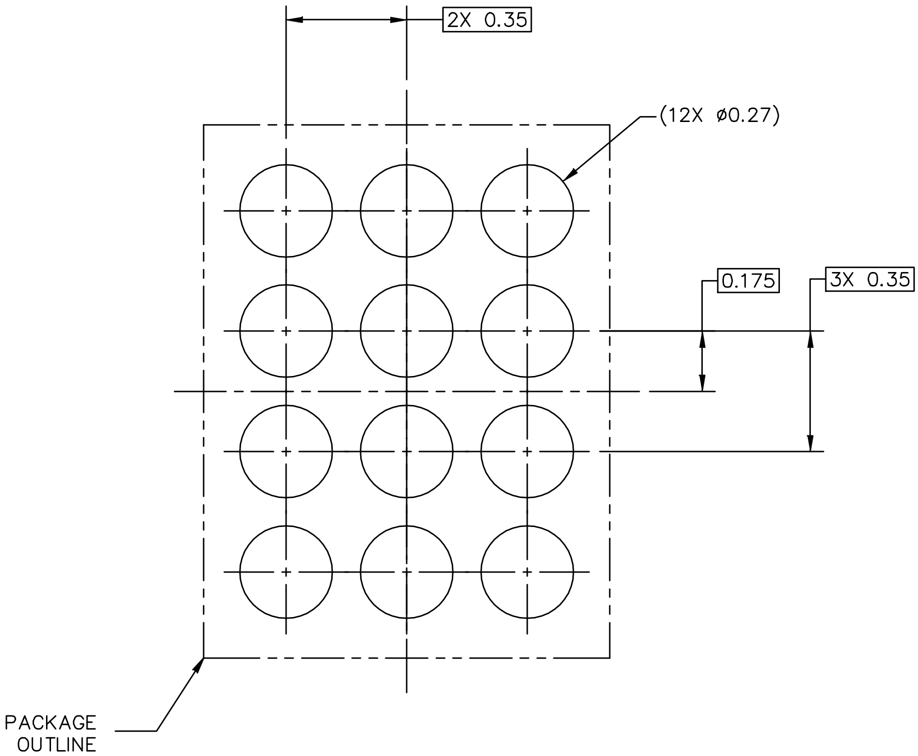


Figure 14. Package outline SOT2063-1 (WLCSP12) (1/5)

WLCSP–12 I/O
1.55 X 1.18 X 0.455 PKG, 0.35 PITCH (BACKSIDE COATING INCLUDED)

SOT2063–1



PCB DESIGN GUIDELINES – SOLDER MASK OPENING PATTERN

THIS SHEET SERVES ONLY AS A GUIDELINE TO HELP DEVELOP A USER SPECIFIC SOLUTION. DEVELOPMENT EFFORT WILL STILL BE REQUIRED BY END USERS TO OPTIMIZE PCB MOUNTING PROCESSES AND BOARD DESIGN IN ORDER TO MEET INDIVIDUAL/SPECIFIC REQUIREMENTS.

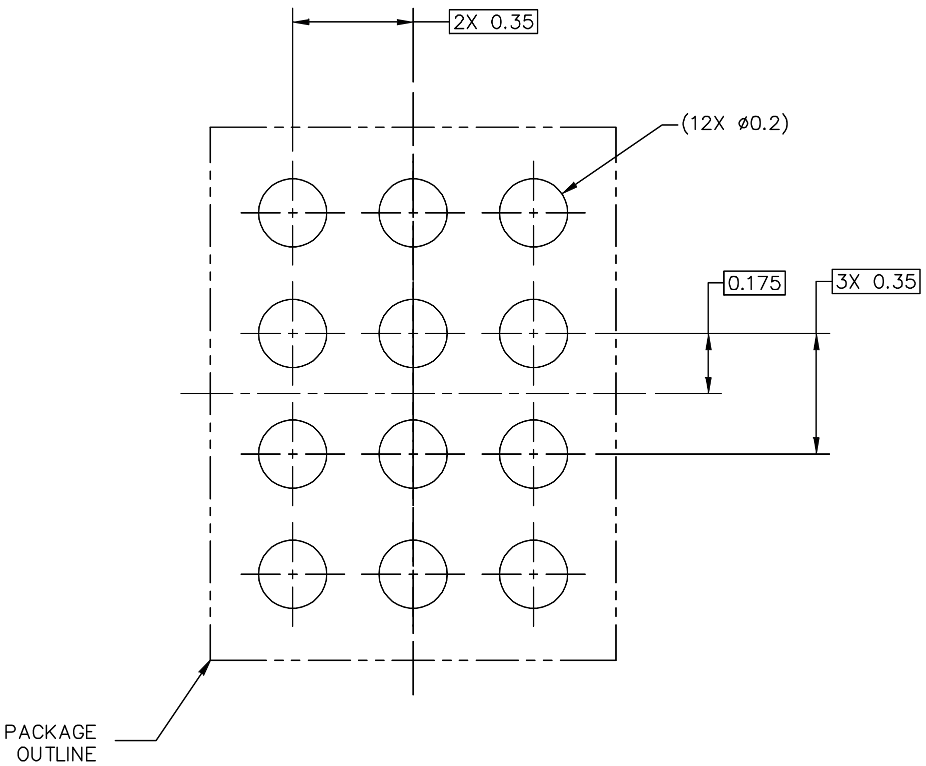
DATE: 11 MAR 2021

MECHANICAL OUTLINE PRINT VERSION NOT TO SCALE	STANDARD: NON JEDEC	DRAWING NUMBER: 98ASA01624D	REVISION: A	

Figure 15. Package outline SOT2063-1 (WLCSP12) (2/5)

WLCSP–12 I/O
1.55 X 1.18 X 0.455 PKG, 0.35 PITCH (BACKSIDE COATING INCLUDED)

SOT2063–1



PCB DESIGN GUIDELINES – I/O PADS AND SOLDERABLE AREA

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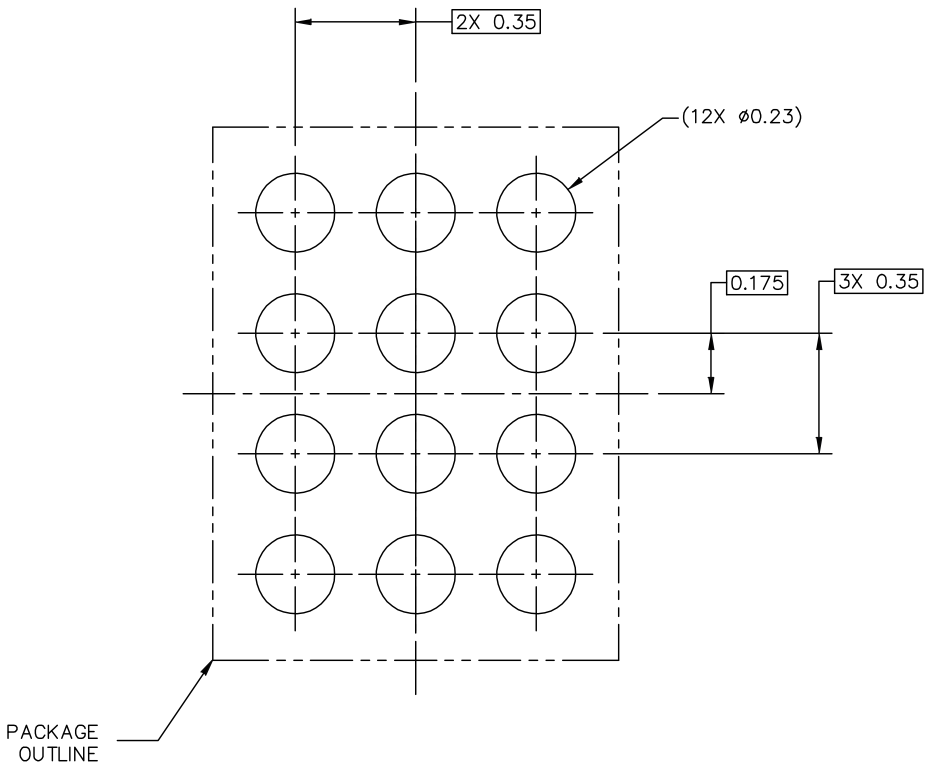
DATE: 11 MAR 2021

MECHANICAL OUTLINE PRINT VERSION NOT TO SCALE	STANDARD: NON JEDEC	DRAWING NUMBER: 98ASA01624D	REVISION: A	

Figure 16. Package outline SOT2063-1 (WLCSP12) (3/5)

WLCSP-12 I/O
1.55 X 1.18 X 0.455 PKG, 0.35 PITCH (BACKSIDE COATING INCLUDED)

SOT2063-1



RECOMMENDED STENCIL THICKNESS 0.08

PCB DESIGN GUIDELINES – SOLDER PASTE STENCIL

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DATE: 11 MAR 2021

MECHANICAL OUTLINE	STANDARD:	DRAWING NUMBER:	REVISION:	
PRINT VERSION NOT TO SCALE	NON JEDEC	98ASA01624D	A	

Figure 17. Package outline SOT2063-1 (WLCSP12) (4/5)

WLCSP-12 I/O
1.55 X 1.18 X 0.455 PKG, 0.35 PITCH (BACKSIDE COATING INCLUDED)

SOT2063-1

NOTES:

1. ALL DIMENSIONS IN MILLIMETERS.
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. PIN A1 FEATURE SHAPE, SIZE AND LOCATION MAY VARY.
4. MAXIMUM SOLDER BALL DIAMETER MEASURED PARALLEL TO DATUM C.
5. DATUM C, THE SEATING PLANE, IS DETERMINED BY THE SPHERICAL CROWNS OF THE SOLDER BALLS.
6. THIS PACKAGE HAS A BACK SIDE COATING THICKNESS OF 0.025.

DATE: 11 MAR 2021

MECHANICAL OUTLINE PRINT VERSION NOT TO SCALE	STANDARD: NON JEDEC	DRAWING NUMBER: 98ASA01624D	REVISION: A	

Figure 18. Package outline SOT2063-1 (WLCSP12) (5/5)

13.2 UBM stack-up information

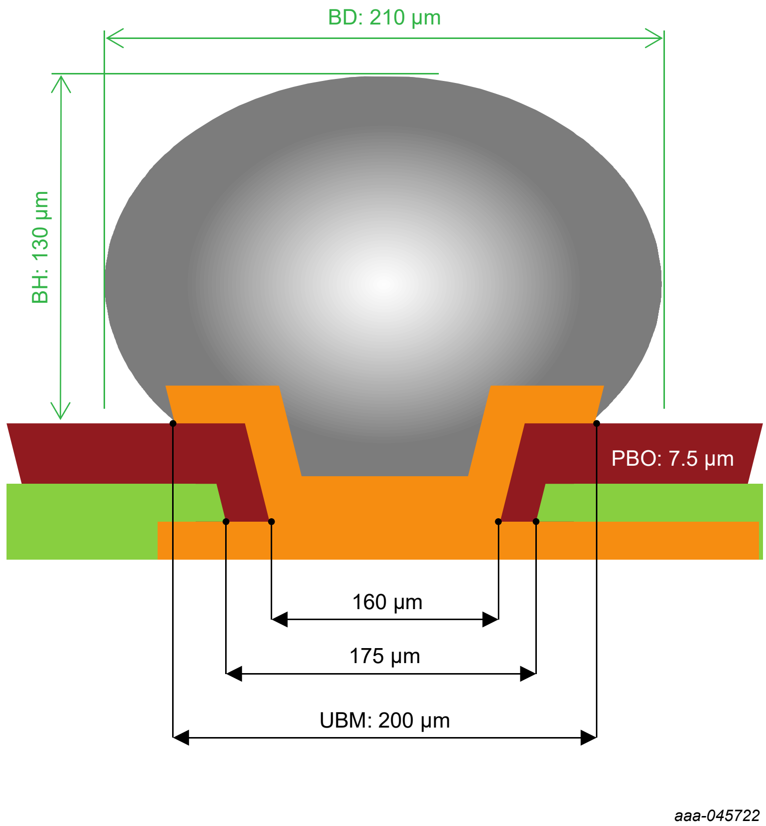


Figure 19. UBM stack-up

Table 39. UBM stack-up parameters

Parameter	Description (typical)
Package size	1.55mm x 1.18mm x 0.455mm
Ball matrix	4 x 3
Ball pitch	350um
Ball diameter (after reflow)	210um
Ball height (after reflow)	130um

14 Packing information

14.1 SOT2063-1 WLCSP12, wafer level chip scale package, 12 terminals, 0.35 mm pitch, 1.55 mm x 1.18 mm x 0.455 mm body (backside coating included)

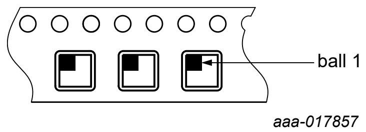
14.1.1 Dimensions and quantities

Table 40. Dimension and quantities

Reel dimensions d x w (mm) [1]	SPQ/PQ (pcs)	Reels per box
330 x 8	8000	1

[1] d = reel diameter; w = tape width

14.1.2 Product orientation



Ball 1 is in quadrant 1.

Figure 20. Product orientation in carrier tape

14.1.3 Carrier tape dimensions

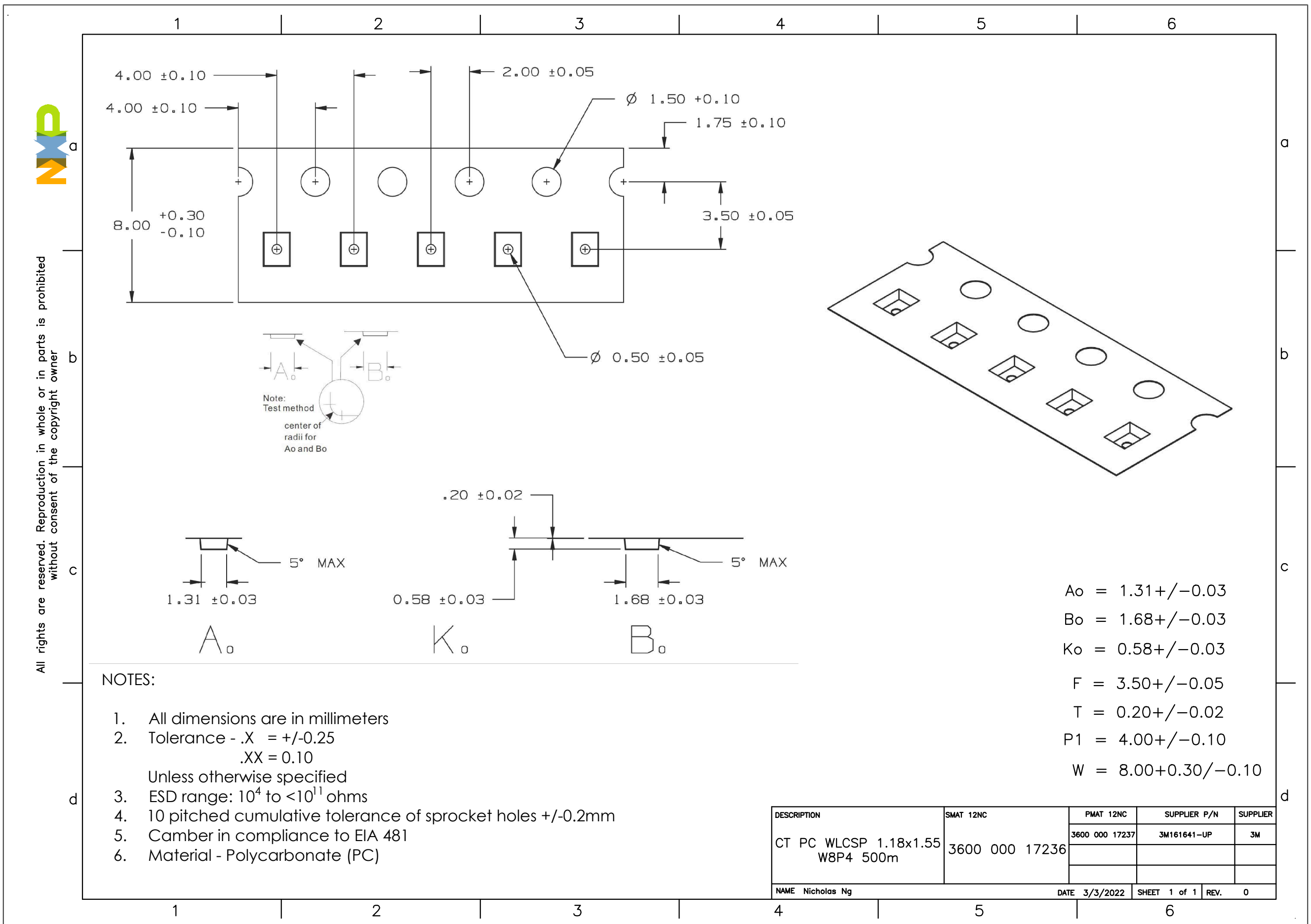


Figure 21. Carrier tape dimensions

15 Abbreviations

Table 41. Abbreviations

Acronym	Description
AFE	Analog Front End
CDM	Charged Device Model
HBM	Human Body Model
TX	Transmitter
RX	Receiver
eUSB	Embedded USB
LS	Low Speed mode of USB2 specification (1.5 Mbps)
FS	Full Speed mode of USB2 specification (12 Mbps)
HS	High Speed mode of USB2 specification (480 Mbps)
SE0	Single Ended Zero
SE1	Single Ended One
DSP	Downstream port
USP	Upstream port
SE	Single Ended
SI	Signal Integrity
EQ	Equalization
LPM	Link Power Management
ESE1	Extended SE1
SCM	Start of Control Message
CM	Control Message
RAP	Register Access Protocol
DRD	Dual Role Device
SOP	Start of Packet
EOP	End of Packet

16 References

[1]	UM10204	—	I^2C-bus specification and user manual, NXP Semiconductors
[2]	USB-IF organization document repository for eUSB2 specification	—	Embedded USB2 Physical Layer Supplement to USB Revision 2.0 specification, Revision 1.1, November 3, 2018
[3]	USB-IF organization document repository for USB2 specification	—	Universal Serial Bus Specification, Rev 2.0, April 27, 2000 and approved ECNs as per USB2.0 document package release (usb_20_20190524.zip)
[4]	Platform partner specification	—	Platform partner specification
[5]	USB BC1.2 specification	—	USB Battery Charging (BC1.2) specification from USB-IF
[6]	AN13637	—	PTN3222BUK Application note for handling abnormal pulses at the end of EOP, 2022
[7]	AN13462	—	PTN3222 Layout guidelines, 2022

17 Revision history

Revision history

Document ID	Release Date	Description
PTN3222DUK v1.1	1 December 2023	• Figure 8, Figure 9, and Figure 10: Corrected "eUSB2" to "USB2" in right hand side connector • Changed "PTN3222" to "PTN3222DUK" in document header; removed underscore in document ID
PTN3222_DUK v1.0	17 August 2022	• Initial version

Legal information

Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
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