

**USB Charging Port Controller and Detection Power Switch**

**Features**

- ➔ Supports CDP/DCP Modes per USB Battery Charging Specification 1.2
- ➔ Supports Shorted Mode per Chinese Telecommunication Industry Standard YD/T1591-2009
- ➔ Supports non-BC1.2 Charging Modes by Automatic Selection
  - Divider-1A mode
  - Divider-2A mode
  - DCP-1.2V mode
- ➔ Supports Sleep-Mode Charging and Mouse/Keyboard Wake up
- ➔ Automatic SDP/CDP Switching for Devices that do not request for the CDP Ports
- ➔ Load Detection for Power Supply Control in S4/S5 Charging and Port Power Management in all Charge Modes
- ➔ Compatible with USB 2.0/3.0 Power Switch requirements
- ➔ Integrated 73-mΩ (Typ.) High-Side MOSFET
- ➔ Adjustable Current-Limit up to 3A(Typ.)
- ➔ Operating Range:4.5V to 5.5V
- ➔ Max Device Current
  - 2μA at Device Disabled
  - 270μA at Device Enabled
- ➔ Device Package: TQFN 3.0x3.0-16ZH

**Description**

The PI5USB2544 is a USB charging port controller and power switch with an integrated USB 2.0 high-speed data line (D+/D-) switch. PI5USB2544 provides the electrical signatures on D+/D- to support charging schemes listed under device feature section. This series is compatible with both popular BC1.2 compliant and non-BC1.2 compliant devices.

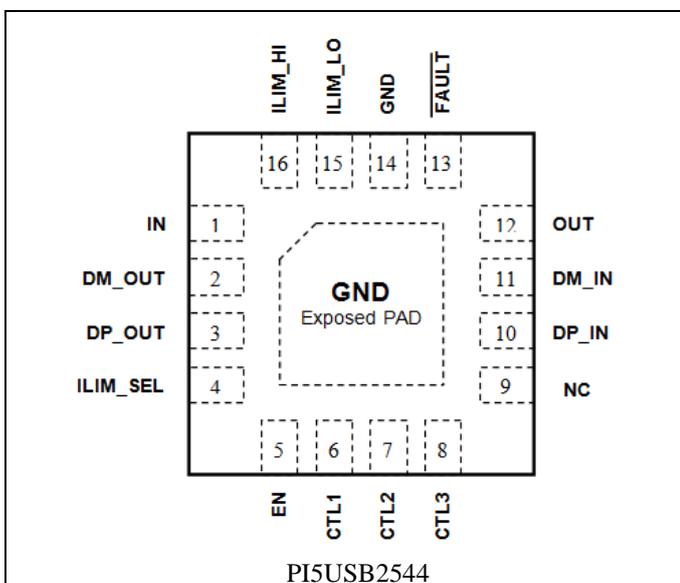
System wake up (from S3) with a mouse/keyboard (both low speed and full speed) is fully supported in the PI5USB2544.

The PI5USB2544 series 73-mΩ power-distribution switch is intended for applications where heavy capacitive loads and short-circuits are likely to be encountered. Two programmable current thresholds provide flexibility for setting current limits and load detect thresholds.

**Applications**

- ➔ USB Ports (Host and Hubs)
- ➔ Notebook and Desktop PCs
- ➔ Universal Wall Charging Adapters

**Pin Configuration (TQFN-16, ZH)**



## Pin Description

Pin #	Name	Type	Description
1	IN	P	Input voltage and supply voltage; connect 0.1 $\mu$ F or greater ceramic capacitor from IN to GND as close to the device as possible
2	DM_OUT	I/O	D- Data line to USB host controller.
3	DP_OUT	I/O	D+ data line to USB host controller.
4	ILIM_SEL	I	Logic-level input signal used to control the charging mode, current limit threshold, and load detection, see the control truth table. Can be tied directly to IN or GND without pull-up or pull-down resistor.
5	EN	I	Logic-level input for turning the power switch and the signal switches on/off, logic low turns off the signal and power switches and holds OUT in discharger. Can be tied directly to IN or GND without pull-up or pull-down resistor.
6	CTL1	I	Logic-level inputs used to control the charging mode and signal switches; see the control truth table. Can be tied directly to IN or GND without pull-up or pull-down resistor.
7	CTL2	I	
8	CTL3	I	
9	NC	--	Connect to GND or leave open.
10	DP_IN	I/O	D+ data line to downstream connector
11	DM_IN	I/O	D- data line to downstream connector.
12	OUT	P	Power-switch output
13	$\overline{\text{FAULT}}$	O	Active-low open-drain output, asserted when over-temperature or current limit conditions
14	GND	G	Ground connection
15	ILIM_LO	I	External resistor connection used to set the low current-limit threshold and the load detection current threshold. A resistor to ILIM_LO is optional; see Current-Limit Settings.
16	ILIM_HI	I	External resistor connection used to set the high current-limit threshold.
NA	Exposed PAD	G	Internally connected to GND. Thermal pad to heat-sink the part to the circuit board.

\* I = Input; O = Output; P = Power; G = Ground

## Maximum Ratings

All Input (except IN to OUT, and DP_IN, DM_IN, DP_OUT, DM_OUT)	.....-0.3V to +6.0V
IN to OUT	.....-6.0V to +6.0V
DP_IN, DM_IN, DP_OUT, DM_OUT	.....-0.3V to IN+0.3 or +5.7V
Input clamp current (DP_IN, DM_IN, DP_OUT, DM_OUT)	.....±20mA
Continuous current in SDP or CDP mode	
(DP_IN to DP_OUT or DM_IN to DM_OUT)	.....±100mA
Continuous current in BC1.2 DCP mode (DP_IN to DM_IN)	.....±50mA
Continuous output current (OUT)	.....Internally limited
Continuous output sink current (/FAULT)	.....25mA
Continuous output source current (ILIM_LO, ILIM_HI)	.....internally limited
ESD: HBM Mode (All pins)	.....2kV
CDM Mode (All pins)	.....500V
HBM (USB connector pins: DP_IN, DM_IN, OUT to GND)	.....6kV

**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	Parameter	Min.	Typ.	Max.	Unit
V <sub>IN</sub>	Input Voltage, IN	4.5	-	5.5	V
	Input Voltage, logic-level EN, CTL1, CTL2, CTL3, ILIM_SEL inputs	0	-	5.5	V
	Input Voltage, data line inputs, DP_IN, DM_IN, DP_OUT, DM_OUT	0	-	V <sub>IN</sub>	V
V <sub>IH</sub>	High-level input voltage, EN, CTL1, CTL2, CTL3, ILIM_SEL	1.8	-	-	V
V <sub>IL</sub>	Low-level input voltage, EN, CTL1, CTL2, CTL3, ILIM_SEL	-	-	0.8	V
	Continuous current data line inputs, SDP or CDP mode, DP_IN to DP_OUT or DM_IN to DM_OUT	-	-	±30	mA
	Continuous current data line inputs, BC1.2 DCP mode, DP_IN to DM_IN	-	-	±15	mA
I <sub>OUT</sub>	Continuous output current, OUT	0	-	2.5	A
	Continuous output sink current, /FAULT	0	-	10	mA
R <sub>ILIM,XX</sub>	Current-limit set resistor	16.9	-	750	kΩ
T <sub>A</sub>	Ambient Temperature Range	-40	-	85	°C
T <sub>J</sub>	Operating Virtual Junction Temperature Range	-40	-	125	°C

## Electrical Characteristics

$4.5V \leq V_{IN} \leq 5.5V$ ,  $T_J = -40^\circ C$  to  $+125^\circ C$ ,  $V_{EN} = V_{IN}$ ,  $V_{ILIM\_SEL} = V_{IN}$ ,  $V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$ ,  $R_{FAULT} = 10k\Omega$ ,  $R_{ILIM\_HI} = 20k\Omega$ ,  $R_{ILIM\_LO} = 80.6k\Omega$ ,  
 Positive currents are into pins. Typical values are at  $25^\circ C$ . All voltages are with respect to GND. unless otherwise specified.

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Unit
<b>Power Switch</b>						
$R_{DS(on)}$	On Resistance <sup>(1)</sup>	$T_J = 25^\circ C$ , $I_{OUT} = 2A$		73	84	m $\Omega$
		$-40^\circ C \leq T_J \leq 85^\circ C$ , $I_{OUT} = 2A$		73	105	
		$-40^\circ C \leq T_J \leq 125^\circ C$ , $I_{OUT} = 2A$		73	120	
$t_r$	OUT voltage rise time	$V_{IN} = 5V$ , $C_L = 1\mu F$ , $R_L = 100\Omega$	0.7	1.0	1.60	ms
$t_f$	OUT voltage fall time		0.2	0.35	0.5	
$t_{on}$	OUT voltage turn-on time	$V_{IN} = 5V$ , $C_L = 1\mu F$ , $R_L = 100\Omega$		2.7	4	ms
$t_{off}$	OUT voltage turn-off time			1.7	3	
$I_{REV}$	Reverse leakage current	$V_{OUT} = 5.5V$ , $V_{IN} = V_{EN} = 0V$ , $-40^\circ C \leq T_J \leq 85^\circ C$ , Measure $I_{OUT}$			2	$\mu A$
<b>Discharge</b>						
$R_{DCHG}$	OUT discharge resistance	$V_{OUT} = 4V$ , $V_{EN} = 0V$	400	500	630	$\Omega$
$t_{DCHG}$	OUT discharge hold time	Time $V_{OUT} < 0.7V$	1.30	2.0	2.9	s
<b>EN, ILIM_SEL, CTL1, CTL2, CTL3, inputs</b>						
	Input pin rising logic threshold voltage	-	1	1.35	1.70	V
	Input pin falling logic threshold voltage	-	0.85	1.15	1.45	V
	Hysteresis <sup>(2)</sup>	-	-	200	-	mV
	Input current	Pin voltage = 0V to 5.5V	-0.5	-	0.5	$\mu A$

(1) Pulse-testing techniques maintain junction temperature close to ambient temperature; Thermal effects must be taken into account separately

(2) These parameters are provided for reference only and do not constitute part of Pericom's published device specifications for purposes of Pericom's product warranty

## Electrical Characteristics

4.5V ≤ V<sub>IN</sub> ≤ 5.5V, T<sub>J</sub> = -40°C to +125°C, V<sub>EN</sub> = V<sub>IN</sub>, V<sub>ILIM\_SEL</sub> = V<sub>IN</sub>, V<sub>CTL1</sub> = V<sub>CTL2</sub> = V<sub>CTL3</sub> = V<sub>IN</sub>, R<sub>FAULT</sub> = 10kΩ, R<sub>ILIM\_HI</sub> = 20kΩ, R<sub>ILIM\_LO</sub> = 80.6kΩ, Positive currents are into pins. Typical values are at 25°C. All voltages are with respect to GND, unless otherwise specified.

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Unit
<b>ILIM_SEL Current Limit</b>						
I <sub>OS</sub>	OUT Current-limit <sup>(2)</sup>	V <sub>ILIM_SEL</sub> = 0 V R <sub>ILIM_LO</sub> = 210kΩ	205	240	275	mA
		V <sub>ILIM_SEL</sub> = 0 V R <sub>ILIM_LO</sub> = 80.6kΩ	575	625	680	
		V <sub>ILIM_SEL</sub> = 0 V R <sub>ILIM_LO</sub> = 22.1kΩ	2120	2275	2430	
		V <sub>ILIM_SEL</sub> = V <sub>IN</sub> R <sub>ILIM_HI</sub> = 20kΩ	2340	2510	2685	
		V <sub>ILIM_SEL</sub> = V <sub>IN</sub> R <sub>ILIM_HI</sub> = 16.9kΩ	2770	2970	3170	
t <sub>IOS</sub>	Response time to OUT short circuit <sup>(1)</sup>	V <sub>IN</sub> = 5.0V, R = 0.1Ω, lead length = 2"	-	1.5	-	μs
<b>Supply Current</b>						
I <sub>IN_OFF</sub>	Disabled IN supply current	V <sub>EN</sub> = 0V, V <sub>OUT</sub> = 0V, T <sub>J</sub> = -40°C to +125°C	-	0.1	2	μA
I <sub>IN_ON</sub>	Enable IN supply current	V <sub>CTL1</sub> = V <sub>CTL2</sub> = V <sub>IN</sub> , V <sub>CTL3</sub> = 0V V <sub>ILIM_SEL</sub> = 0V	-	165	220	
		V <sub>CTL1</sub> = V <sub>CTL2</sub> = V <sub>CTL3</sub> = V <sub>IN</sub> , V <sub>ILIM_SEL</sub> = 0V	-	175	230	
		V <sub>CTL1</sub> = V <sub>CTL2</sub> = V <sub>IN</sub> , V <sub>CTL3</sub> = 0V, V <sub>ILIM_SEL</sub> = V <sub>IN</sub>	-	185	240	
		V <sub>CTL1</sub> = V <sub>CTL2</sub> = V <sub>CTL3</sub> = V <sub>IN</sub> , V <sub>ILIM_SEL</sub> = V <sub>IN</sub>	-	195	250	
		V <sub>CTL1</sub> = 0V, V <sub>CTL2</sub> = V <sub>CTL3</sub> = V <sub>IN</sub> , V <sub>ILIM_SEL</sub> = 0V	-	215	270	
		V <sub>CTL1</sub> = 0V, V <sub>CTL2</sub> = V <sub>CTL3</sub> = V <sub>IN</sub> , V <sub>ILIM_SEL</sub> = V <sub>IN</sub>	-	240	290	
<b>Undervoltage Lockout</b>						
V <sub>UVLO</sub>	IN rising UVLO threshold voltage	-	3.9	4.1	4.3	V
	Hysteresis <sup>(1)</sup>	-	-	100	-	mV
<b>/FAULT</b>						
V <sub>OL</sub>	Output low voltage	I <sub>FAULT</sub> = 1mA	-	-	100	mV
I <sub>OFF</sub>	Off-state leakage current	V <sub>FAULT</sub> = 5.5V	-	-	1	μA
T <sub>D</sub>	Over current /FAULT rising and falling deglitch	-	5	8.2	12	ms
<b>Thermal Shutdown</b>						
OTSD	Thermal shutdown threshold	-	-	170	-	°C
	Hysteresis <sup>(1)</sup>	-	-	20	-	

**Note:**

- (1) These parameters are provided for reference only and do not constitute part of Pericom's published device specifications for purposes of Pericom's product warranty
- (2) Pulse-testing techniques maintain junction temperature close to ambient temperature; current limit value tested at 80% output voltage. Thermal effects must be taken into account separately.

## Electrical Characteristics, High-bandwidth Switch

$4.5V \leq V_{IN} \leq 5.5V$ ,  $T_J = -40^\circ C$  to  $+125^\circ C$ ,  $V_{EN} = V_{IN}$ ,  $V_{ILIM\_SEL} = V_{IN}$ ,  $V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$ ,  $R_{FAULT} = 10k\Omega$ ,  $R_{ILIM\_HI} = 20k\Omega$ ,  $R_{ILIM\_LO} = 80.6k\Omega$ , Positive currents are into pins. Typical values are at  $25^\circ C$ . All voltages are with respect to GND, unless otherwise specified.

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Unit
<b>HIGH_BANDWIDTH ANALOG SWITCH</b>						
	DP/DM switch on resistance	$V_{DP/DM\_OUT} = 0V$ , $I_{DP/DM\_IN} = 30mA$	-	2	4	$\Omega$
		$V_{DP/DM\_OUT} = 2.4V$ , $I_{DP/DM\_IN} = -15mA$	-	3	6	$\Omega$
	Switch resistance mismatch between DP/DM channels	$V_{DP/DM\_OUT} = 0V$ , $I_{DP/DM\_IN} = 30mA$	-	0.05	0.15	$\Omega$
		$V_{DP/DM\_OUT} = 2.4V$ , $I_{DP/DM\_IN} = -15mA$	-	0.05	0.15	$\Omega$
	DP/DM switch off-state capacitance <sup>(1)</sup>	$V_{EN} = 0V$ , $V_{DP/DM\_IN} = 0.3V$ , $V_{ac} = 0.6V_{PK-PK}$ , $f = 1MHz$	-	4.5	-	pF
	DP/DM switch on-state capacitance <sup>(2)</sup>	$V_{DP/DM\_IN} = 0.3V$ , $V_{ac} = 0.6V_{PK-PK}$ , $f = 1MHz$	-	5.4	6.2	pF
$O_{IRR}$	Off-state isolation <sup>(3)</sup>	$V_{EN} = 0V$ , $f = 250MHz$	-	33	-	dB
$X_{TALK}$	Off-state cross channel isolation <sup>(3)</sup>	$f = 250MHz$	-	52	-	dB
$I_{OFF}$	Off-state leakage current	$V_{EN} = 0V$ , $V_{DP/DM\_IN} = 3.6V$ , $V_{DP/DM\_OUT} = 0V$ , measure $I_{DP/DM\_OUT}$	-	0.1	1.5	$\mu A$
BW	Bandwidth(-3dB) <sup>(3)</sup>	$R_L = 50\Omega$	-	2.0	-	GHz
$t_{pd}$	Propagation delay <sup>(3)</sup>	-	-	0.25	-	ns
$t_{SK}$	Skew between opposite transitions of the same port( $t_{PHL} - t_{PLH}$ )	-	-	0.1	0.2	ns

**Note:**

- (1) The resistance in series with the parasitic capacitance to GND is typically 250  $\Omega$ .
- (2) The resistance in series with the parasitic capacitance to GND is typically 150  $\Omega$ .
- (3) These parameters are provided for reference only and do not constitute part of Pericom's published device specifications for purposes of Pericom's product warranty.

## Electrical Characteristics, Charging Controller

$4.5V \leq V_{IN} \leq 5.5V$ ;  $T_J = -40^\circ C$  to  $+125^\circ C$ ;  $V_{EN} = V_{IN}$ ,  $V_{ILIM\_SEL} = V_{IN}$ ,  $V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$ ,  $R_{FAULT} = 10k\Omega$ ,  $R_{ILIM\_HI} = 20k\Omega$ ,  $R_{ILIM\_LO} = 80.6k\Omega$ ,  
 Positive currents are into pins. Typical values are at  $25^\circ C$ . All voltages are with respect to GND, unless otherwise specified.

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Unit
<b>SHORTED MODE (BC1.2 DCP)</b>						
	DP_IN/DM_IN shorting resistance	$V_{CTL1} = V_{IN}$ ; $V_{CTL2} = V_{CTL3} = 0V$	-	125	200	$\Omega$
<b>DCP-1.2V MODE</b>						
	DP_IN/DM_IN output voltage	$V_{CTL1} = 0V$ ; $V_{CTL2} = V_{CTL3} = V_{IN}$ , Apply 3V on DP_IN for 0.5s and measure the D+/D- voltage within the 2s	1.19	1.25	1.31	V
	DP_IN/DM_IN output impedance		60	75	94	k $\Omega$
<b>DIVIDER-1A MODE</b>						
	DP_IN Divider-1A output voltage	$V_{CTL1} = 0V$ ; $V_{CTL2} = V_{CTL3} = V_{IN}$ ,	1.9	2.0	2.1	V
	DM_IN Divider-1A output voltage		2.57	2.7	2.84	V
	DP_IN/DM_IN output impedance		7.5	10.5	16	k $\Omega$
<b>DIVIDER-2A MODE</b>						
	DP_IN Divider-2A output voltage	$V_{CTL1} = 0V$ ; $V_{CTL2} = V_{CTL3} = V_{IN}$ ; $I_{OUT} = 1A$	2.57	2.7	2.84	V
	DM_IN Divider-2A output voltage		1.9	2.0	2.1	V
	DP_IN/DM_IN output impedance		7.5	10.5	16	k $\Omega$
<b>CHARGING DOWNSTREAM PORT</b>						
$V_{DM\_SRC}$	DP_IN CDP output voltage	$V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$ , $V_{IN} = 0.6V$ , $-250\mu A \leq I_{DM\_IN} \leq 0\mu A$	0.5	0.6	0.7	V
$V_{DAT\_REF}$	DP_IN rising lower window threshold for $V_{DM\_SRC}$ activation	$V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$	0.25	-	0.4	V
	Hysteresis <sup>(1)</sup>		-	50	-	mV
$V_{LGC\_REF}$	DP_IN rising upper window threshold for $V_{DM\_SRC}$ de-activation		0.8	-	1.5	V
	Hysteresis <sup>(1)</sup>		-	100	-	mV
<b>LOAD DETECT- NON POWER WAKE</b>						
$I_{LD}$	$I_{OUT}$ rising load detect current threshold	$V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$	550	650	765	mA
	Hysteresis <sup>(1)</sup>		-	50	-	mA
$t_{LD\_SET}$	Load detect set time		140	200	275	ms
	Load detect reset time		1.9	3	4.2	s

**Note:**  
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## Electrical Characteristics, Charging Controller

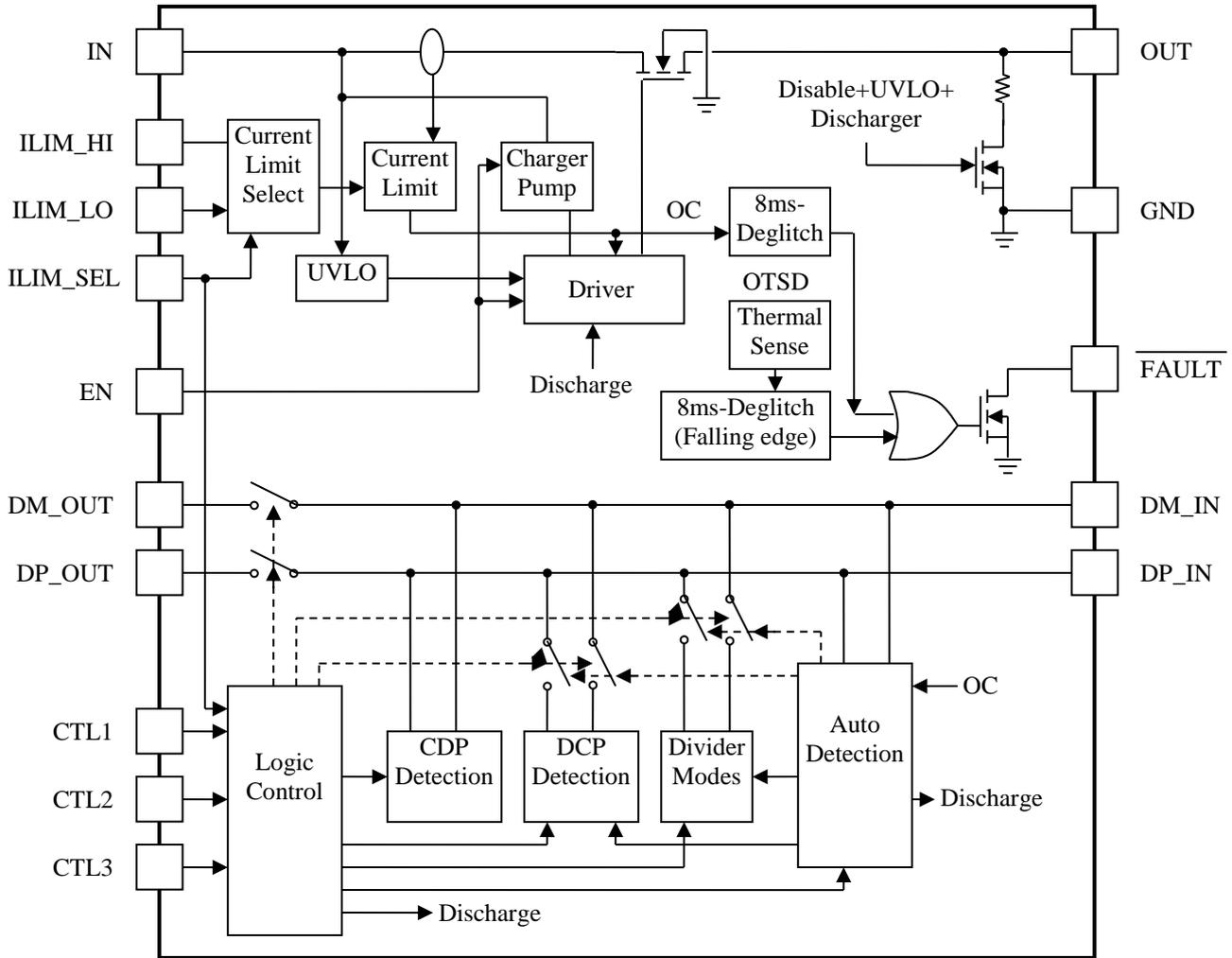
$4.5V \leq V_{IN} \leq 5.5V$ ;  $T_J = -40^\circ C$  to  $+125^\circ C$ ;  $V_{EN} = V_{IN}$ ,  $V_{ILIM\_SEL} = V_{IN}$ ,  $V_{CTL1} = V_{CTL2} = V_{CTL3} = V_{IN}$ ,  $R_{/FAULT} = R_{/STATUS} = 10k\Omega$ ,  $R_{ILIM\_HI} = 20k\Omega$ ,  $R_{ILIM\_LO} = 80.6k\Omega$ , Positive currents are into pins. Typical values are at  $25^\circ C$ . All voltages are with respect to GND, unless otherwise specified.

Symbol	Description	Test Conditions	Min.	Typ.	Max.	Unit
<b>LOAD DETECT- POWER WAKE</b>						
$I_{OS\_PW}$	Power wake short circuit current limit	$V_{CTL1} = V_{CTL2} = 0V$ , $V_{CTL3} = V_{IN}$	20	55	90	mA
	$I_{OUT}$ falling power wake reset current threshold		10	45	85	mA
	Reset current hysteresis <sup>(1)</sup>		-	5	-	mA
	Power wake reset time		10.7	15	20.6	s

- Note:**
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**Functional Description**

**PI5USB2544 Block Diagram**



## Details Description

The following overview references various industry standards. It is always recommended to consult the most up-to-date standard to ensure the most recent and accurate information. Rechargeable portable equipment requires an external power source to charge its batteries. USB ports are a convenient location for charging because of an available 5V power source. Universally accepted standards are required to make sure host and client-side devices operate together in a system to ensure power management requirements are met. Traditionally, host ports following the USB 2.0 specification must provide at least 500mA to downstream client-side devices. Because multiple USB devices can be attached to a single USB port through a bus-powered hub, it is the responsibility of the client-side device to negotiate its power allotment from the host to ensure the total current draw does not exceed 500mA. In general, each USB device is granted 100mA and may request more current in 100mA unit steps up to 500mA. The host may grant or deny based on the available current. A USB 3.0 host port not only provides higher data rate than USB 2.0 port but also raises the unit load from 100mA to 150mA. It is also required to provide a minimum current of 900mA to downstream client-side devices.

Additionally, the success of USB has made the mini-USB connector a popular choice for wall adapter cables. This allows a portable device to charge from both a wall adapter and USB port with only one connector. As USB charging has gained popularity, the 500mA minimum defined by USB 2.0 or 900mA for USB 3.0 has become insufficient for many handset and personal media players which need a higher charging rate. Wall adapters can provide much more current than 500mA/900mA. Several new standards have been introduced defining protocol handshaking methods that allow host and client devices to acknowledge and draw additional current beyond the 500mA/900mA minimum defined by USB 2.0/3.0 while still using a single micro-USB input connector. The PI5USB2544 supports four of the most common USB charging schemes found in popular hand-held media and cellular devices:

- USB Battery Charging Specification BC1.2
- Chinese Telecommunications Industry Standard YD/T 1591-2009
- Divider-1A and Divider-2A
- DCP-1.2V Mode

YD/T 1591-2009 is a subset of BC1.2 spec. supported by vast majority of devices that implement USB charging.

Divider-1A, Divider-2A and DCP-1.2V charging schemes are supported in devices from specific yet popular device makers.

BC1.2 lists three different port types as listed below:

- Standard Downstream Port (SDP)
- Charging Downstream Port (CDP)
- Dedicated Charging Port (DCP)

BC1.2 defines a charging port as a downstream facing USB port that provides power for charging portable equipment, under this definition CDP and DCP are defined as charging ports

Table 1 shows the differences between these ports.

**Table 1. Operation Modes**

Port Type	Support USB 2.0 Communication	Max. allowable current draw by portable device
SDP (USB 2.0)	Yes	0.5A
SDP (USB 3.0)	Yes	0.9A
CDP	Yes	1.5A
DCP	No	1.5A

## Standard Downstream Port (SDP) USB 2.0/USB 3.0

An SDP is a traditional USB port that follows USB 2.0/3.0 protocol and supplies a minimum of 500mA/900mA per port. USB 2.0/3.0 communications is supported, and the host controller must be active to allow charging. PI5USB2544 supports SDP mode in system power state S0 when system is completely powered ON and fully operational. For more details on control pin (CTL1, CTL2, CTL3 and ILIM\_SEL) settings to program this state please refer to device truth table.

## Charging Downstream Port (CDP)

A CDP is a USB port that follows USB BC1.2 and supplies a minimum of 1.5A per port. It provides power and meets USB 2.0 requirements for device enumeration. USB 2.0 communications is supported and the host controller must be active to allow charging. What separates a CDP from an SDP is the host-charge handshaking logic that identifies this port as a CDP. A CDP is identifiable by a compliant BC1.2 client device and allows for additional current draw by the client device.

The CDP hand-shaking process is done in two steps. During step one the portable equipment outputs a nominal 0.6V output on its D+ line and reads the voltage input on its D- line. The portable device concludes it is connected to an SDP if the voltage is less than the nominal data detect voltage of 0.3V. The portable device concludes that it is connected to a Charging Port if the D- voltage is greater than the nominal data detect voltage of 0.3V and optionally less than 0.8V.

The second step is necessary for portable equipment to determine if it is connected to CDP or DCP. The portable device outputs a nominal 0.6V output on its D- line and reads the voltage input on its D+ line. The portable device concludes it is connected to a CDP if the data line being read remains less than the nominal data detect voltage of 0.3V. The portable device concludes it is connected to a DCP if the data line being read is greater than the nominal data detect voltage of 0.3V.

PI5USB2544 supports CDP mode in system power state S0 when system is completely powered ON and fully operational. For more details on control pin (CTL1, CTL2, CTL3 and ILIM\_SEL) settings to program this state please refer to device truth table.

## Dedicated Charging Port (DCP)

A DCP only provides power but does not support data connection to an upstream port. As shown in following sections, a DCP is identified by the electrical characteristics of its data lines. The PI5USB2544 emulates DCP in two charging states, namely DCP Forced and DCP Auto as shown in Figure 4. In DCP Forced state the device will support one of the two DCP charging schemes, namely Divider-1A or DCP\_Shorted. In the DCP Auto state, the device charge detection state machine is activated to selectively implement charging schemes involved with the Shorted DCP mode, Divider-1A, Divider-2A and DCP-1.2V modes. Shorted DCP mode complies with BC1.2 and Chinese Telecommunications Industry Standard YD/T 1591-2009, while the Divider-1A, Divider-2A and DCP-1.2V modes are employed to charge devices that do not comply with BC1.2 DCP standard.

## DCP BC1.2 and YD/T 1591-2009

Both standards define that the D+ and D- data lines should be shorted together with a maximum series impedance of 200 Ω. This is shown as Figure 1.

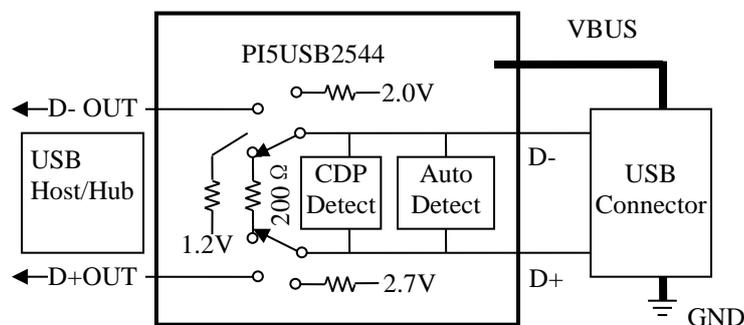
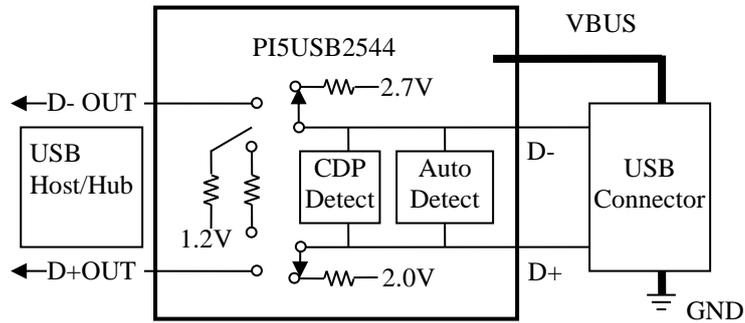


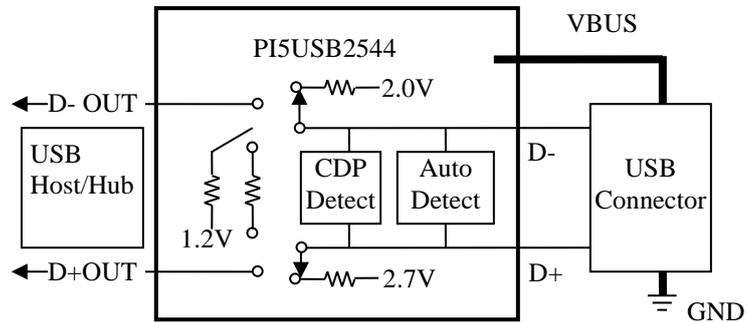
Figure 1, DCP mode

### Divider-1A and Divider-2A Charging Scheme

There are two charging schemes supported by PI5USB2544, Divider-1A and Divider-2A as shown below. In Divider-1A charging scheme the device applies 2.0V and 2.7V to D+ and D- data line respectively. This is reversed in Divider-2A mode.



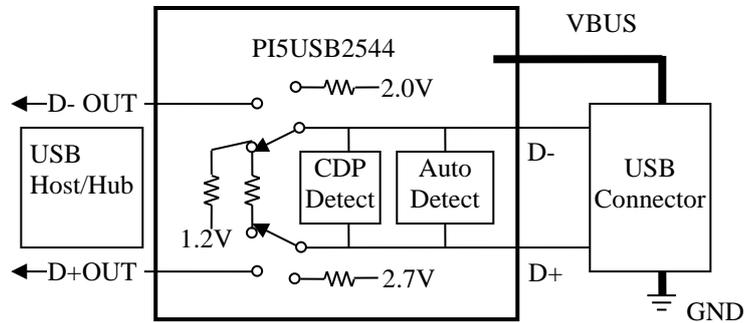
**Figure 2a, Divider-1A Charging Scheme**



**Figure 2b, Divider-2A Charging Scheme**

### DCP-1.2V Charging Scheme

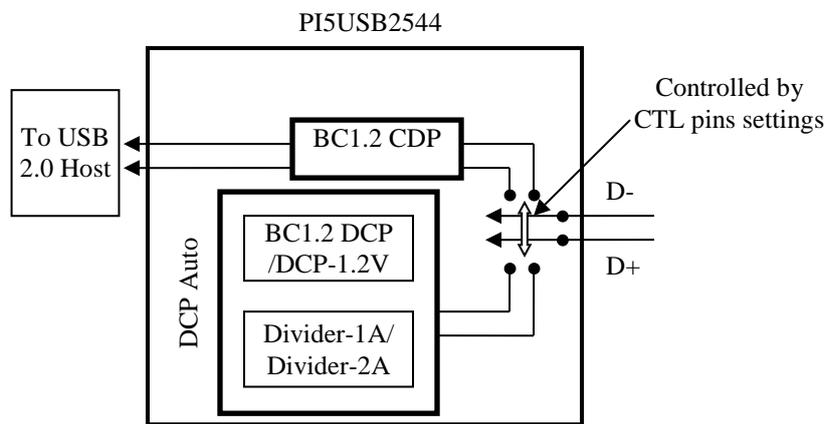
DCP-1.2V charging scheme is used by some handheld devices to enable fast charging at 2.0A. PI5USB2544 supports this scheme in the DCP-Auto mode before the device enters BC1.2 shorted mode. To simulate this charging scheme D+/D- lines are shorted and pulled-up to 1.2V for fixed duration then device moves to DCP shorted mode as defined in BC1.2 spec. This is shown as Figure 3.



**Figure 3, DCP-1.2V Charging Scheme**

### DCP Auto Mode

As mentioned above the PI5USB2544 integrates an auto-detect state machine that supports all the above DCP charging schemes. It starts in Divider-1A scheme, however if a BC1.2 or YD/T 1591-2009 compliant device is attached, the PI5USB2544 responds by discharging OUT, turning back on the power switch and operating in 1.2V mode briefly and then moving to BC1.2 DCP mode. It then stays in that mode until the device releases the data line, in which case it goes back to Divider-1A scheme. When a Divider-1A compliant device is attached the PI5USB2544 will stay in Divider-1A state. Also, the PI5USB2544 will automatically switch between the Divider-1A and Divider-2A schemes based on charging current drawn by the connected device. Initially the device will set the data lines to Divider-1A scheme. If charging current of the device >750mA is measured by the PI5USB2544, it switches to Divider-2A scheme and test to see if the peripheral device will still charge at a high current. If it does then it stays in Divider-2A charging scheme otherwise it will revert to Divider-1A scheme.



**Figure 4, DCP\_Auto Mode**

## DCP Forced Shorted / DCP Forced Divider-1A

In this mode the device is permanently set to one of the DCP schemes (BC1.2/ YD/T 1591-2009 or Divider-1A) as commanded by its control pin setting per device truth table.

## High-Bandwidth Data Line Switch

The PI5USB2544 passes the D+ and D- data lines through the device to enable monitoring and handshaking while supporting charging operation. A wide bandwidth signal switch is used, allowing data to pass through the device without corrupting signal integrity. The data line switches are turned on in any of CDP or SDP operating modes.

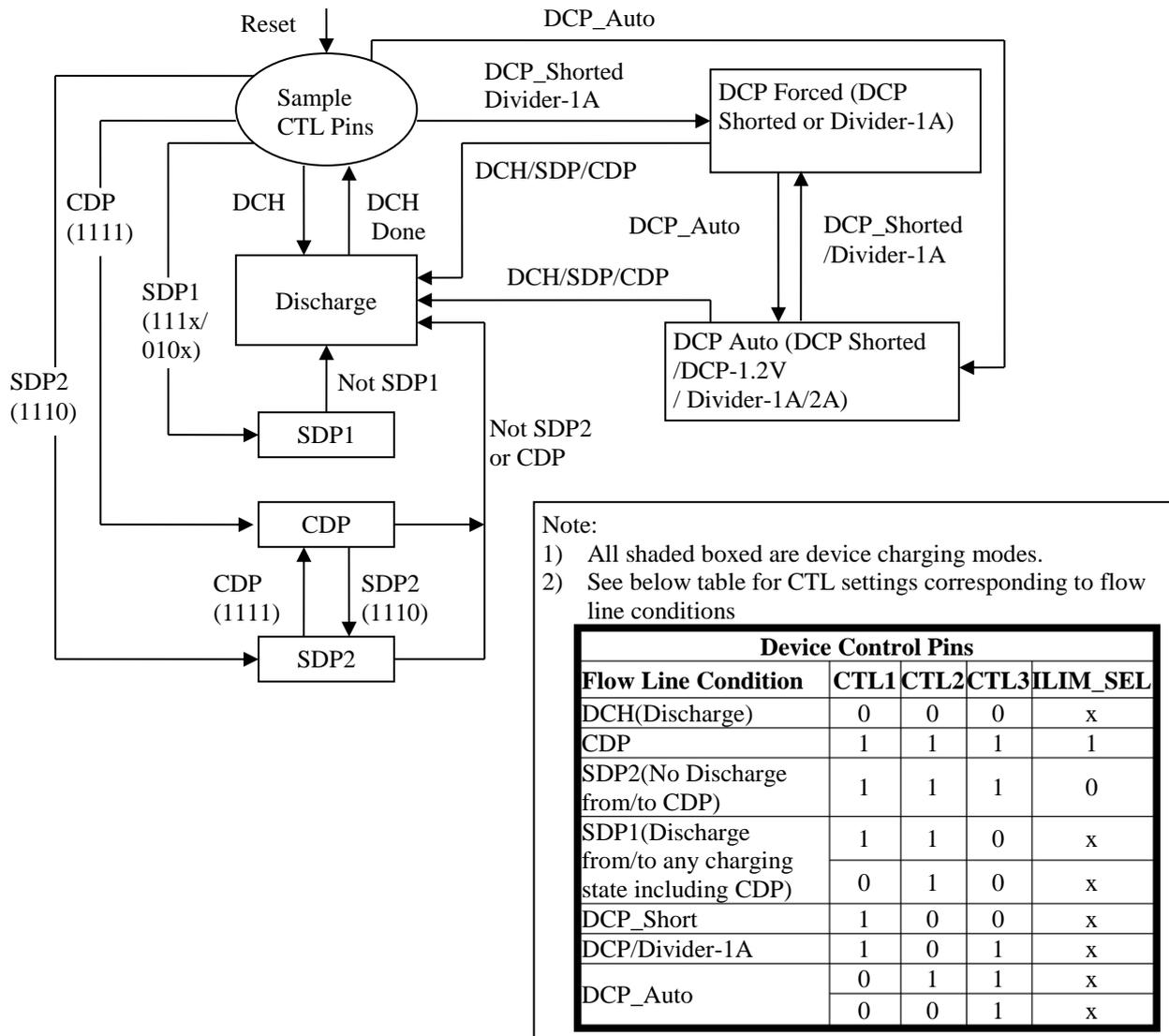
The EN input also needs to be at logic High for the data line switches to be enabled.

### NOTE:

1. Under CDP mode, the data switches are ON even while CDP handshaking is occurring.
2. The data line switches are OFF if EN or all CTL pins are held low, or if in DCP mode. They are not automatically turned off if the power switch (IN to OUT) is in current limit.
3. The data switches are for USB 2.0 differential pair only. In the case of a USB 3.0 host, the super speed differential pairs must be routed directly to the USB connector without passing through the PI5USB2544.
4. Data switches are OFF during OUT (VBUS) discharge

**Device Operation**

Please refer to the simplified device state diagram below. Power-on-reset (POR) holds device in initial state while output is held in discharge mode. Any POR event will take the device back to initial state. After POR clears, device goes to the next state depending on the CTL1, CTL2, CTL3 and ILIM\_SEL lines as shown Figure 5.



**Figure 5, PI5USB2544 Charging States**

**Output Discharge**

To allow a charging port to renegotiate current with a portable device, PI5USB2544 uses the OUT discharge function. It proceeds by turning off the power switch while discharging OUT, then turning back on the power switch to reassert the OUT voltage. This discharge function is automatically applied as shown in device state diagram.

## Wake on USB Feature (Mouse/Keyboard Wake Feature)

### USB 2.0 Background Information

The PI5USB2544 data lines interface with USB 2.0 devices. USB 2.0 defines three types of devices according to data rate. These devices and their characteristics relevant to PI5USB2544 Wake on USB operation are shown below:

#### Low-speed USB devices

- 1.5 Mb/s
- Wired mice and keyboards are examples
- No devices that need battery charging
- All signaling performed at 2.0V and 0.8V hi/lo logic levels
- D- high to signal connect and when placed into suspend
- D- high when not transmitting data packets

#### Full-speed USB devices

- 12 Mb/s
- Wireless mice and keyboards are examples
- Legacy phones and music players are examples
- Some legacy devices that need battery charging
- All signaling performed at 2.0V and 0.8V hi/lo logic levels
- D+ high to signal connect and when placed into suspend
- D+ high when not transmitting data packets

#### High-speed USB devices

- 480 Mb/s
- Tablets, phones and music players are examples
- Many devices that need battery charging
- Connect and suspend signaling performed at 2.0V and 0.8V hi/lo logic levels
- Data packet signaling performed a logic levels below 0.8V
- D+ high to signal connect and when placed into suspend (same as a full-speed device)
- D+ and D- low when not transmitting data packets

## Wake On USB

Wake on USB is the ability of a wake configured USB device to wake a computer system from its S3 sleep state back to its S0 working state. Wake on USB requires the data lines to be connected to the system USB host before the system is placed into its S3 sleep state and remain continuously connected until they are used to wake the system.

The PI5USB2544 supports low and full speed HID (human interface device like mouse/key board) wake function. There are two scenarios under which wake on mouse are supported by the PI5USB2544. The specific CTL pin changes that the PI5USB2544 will override are shown below. The information is presented as CTL1, CTL2 and CTL3. The ILIM\_SEL pin plays no role

1. 111 (CDP/SDP2) to 011 (DCP-Auto)
2. 110/010 (SDP1) to 011 (DCP-Auto)

## USB Low-Speed / Full-Speed Device Recognition

PI5USB2544 is capable of detecting LS or FS device attachment when PI5USB2544 is in SDP or CDP mode. Per USB spec when no device is attached, the D+ and D- lines are near ground level. When a low speed compliant device is attached to the PI5USB2544 charging port, D- line will be pulled high in its idle state (mouse/keyboard not activated). However when a FS device is attached the opposite is true in its idle state, i.e. D+ is pulled high and D- remains at ground level.

PI5USB2544 monitors both D+ and D- lines while CTL pin settings are in CDP or SDP mode to detect LS or FS HID device attachment. To support HID sleep wake, PI5USB2544 must first determine that it is attached to a LS or FS device when system is in S0 power state. PI5USB2544 does this as described above. While supporting a LS HID wake is straight forward, supporting FS HID requires making a distinction between a FS and a HS device. This is because a high speed device will always present itself initially as a full speed device (by a 1.5K pull up resistor on D+). The negotiation for high speed then makes the distinction whereby the 1.5K pull up resistor gets removed.

PI5USB2544 handles the distinction between a FS and HS device at connect by memorizing if the D+ line goes low after connect. A HS device after connect will always undergo negotiation for HS which will require the 1.5K $\Omega$  resistor pull-up on D+ to be removed. To memorize a FS device, PI5USB2544 requires the device to remain connected for at least 11 sec while system is in S0 mode before placing it in sleep or S3 mode. If system is placed in sleep mode earlier than the 11 sec window, a FS device may not get recognized and hence could fail to wake system from S3. This requirement does not apply for LS device.

## No CTL Pin Timing Requirement after Wake Event and Transition from S3 to S0

There is no CTL pin timing requirement for the PI5USB2544 when the wake configured USB device wakes the system from S3 back to S0.

## Device Control Pins Truth Table

Device Control Pins Table lists all valid bias combinations for the four control pins CTL1, CTL2, CTL3 and ILIM\_SEL pins and their corresponding charging mode. It is important to note that the Device Control Pins Table *purposely* omits matching charging modes of the PI5USB2544 with global power states (S0-S5) as device is agnostic to system power states. The PI5USB2544 monitors its CTL inputs and will transition to whatever charging state it is commanded to go to (except when LS/FS HID device is detected). For example if sleep charging is desired when system is in standby or hibernate state then user must set PI5USB2544 control pins to correspond to DCP\_Auto charging mode per below table. When system is put back to operation mode then set control pins to correspond to SDP or CDP mode and so on.

## PI5USB2544 Device Control Pins Truth Table

CTL1	CTL2	CTL3	ILIM_SEL	MODE	Current Limit Setting	Comment
0	0	0	0	Discharge	NA	OUT held low
0	0	0	1	Discharge	NA	
0	x	1	x	DCP_Auto	ILIM_HI	Data lines disconnected
0	1	0	0	SDP1	ILIM_LO	Data lines connected
0	1	0	1	SDP1	ILIM_HI	
0	1	1	0	DCP_Auto	ILIM_HI	Data lines disconnected
0	1	1	1	DCP_Auto	ILIM_HI	Data lines disconnected
1	0	0	0	DCP_Shorted	ILIM_LO	Device forced to stay in DCP BC1.2 charging mode
1	0	0	1	DCP_Shorted	ILIM_HI	
1	0	1	0	Divider-1A	ILIM_LO	Device forced to stay in Divider-1A charging mode
1	0	1	1	Divider-1A	ILIM_HI	
1	1	0	0	SDP1	ILIM_LO	Data lines connected
1	1	0	1	SDP1	ILIM_HI	
1	1	1	0	SDP2 <sup>(1)</sup>	ILIM_LO	
1	1	1	1	CDP <sup>(1)</sup>	ILIM_HI	

**Note:**

(1) No OUT discharge when changing between 1111 and 1110.

Below tables can be used as an aid to program the PI5USB2544 per system states however not restricted to below settings only.

## PI5USB2544 Control Pin Setting Matched to System Power States

System Global Power State	Charging Mode	CTL1	CTL2	CTL3	ILIM_SEL	Current Limit Setting
S0	SDP1	1	1	0	1 or 0	ILIM_HI/ILIM_LO
S0	SDP2, no discharge to/from CDP	1	1	1	0	ILIM_LO
S0	CDP	1	1	1	1	ILIM_HI
S3/S4/S5	Auto mode	0	0	1	0	ILIM_HI
S3	Auto mode, keyboard/mouse wake up, no load detection	0	1	1	0	ILIM_HI
S3	SDP1, keyboard/mouse wake up	0	1	0	1 or 0	ILIM_HI/ILIM_LO

## CDP/SDP Auto Switch

PI5USB2544 is equipped with a CDP/SDP auto-switch feature to support some popular phones in the market that are not compliant to the BC1.2 specification, as they fail to establish data connection in CDP mode. These phones use primary detection (used to distinguish between an SDP and different types of Charging Ports) to only identify ports as SDP (data / no charge) or DCP (no data / charge). They do not recognize CDP (data /charge) ports. When connected to a CDP port, these phones classify the port as a DCP and will only charge. Since charging ports are configured as CDP when the computer is in S0, users do not get the expected data connection.

To remedy this problem PI5USB2544 employs a CDP/SDP Auto Switch scheme to ensure these BC1.2 non-compliant phones will establish data connection by following below steps:

- The PI5USB2544 will determine when a non-compliant phone has wrongly classified a CDP port as a DCP port and has not made a data connection
- The PI5USB2544 will then automatically do a OUT (VBUS) discharge and reconfigure the port as an SDP
- This allows the phone to discover it is now connected to an SDP and establish a data connection
- The PI5USB2544 will then switch automatically back to CDP without doing an OUT (VBUS) discharge
- The phone will continue to operate like it is connected to a SDP since OUT (VBUS) was not interrupted
- The port is now ready in CDP if a new device is attached

## Over-Current Protection

When an over-current condition is detected, the device maintains a constant output current and reduces the output voltage accordingly. Two possible overload conditions can occur. In the first condition, the output has been shorted before the device is enabled or before VIN has been applied. The PI5USB2544 the short and immediately switches into a constant-current output. In the second condition, a short or an overload occurs while the device is enabled. At the instant the overload occurs, high currents may flow for nominally one to two microseconds before the current-limit circuit can react. The device operates in constant-current mode after the current-limit circuit has responded. Complete shutdown occurs only if the fault is presented long enough to activate thermal limiting. The device will remain off until the junction temperature cools approximately 20°C and will then re-start. The device will continue to cycle on/off until the over-current condition is removed.

## Current-Limit Settings

The PI5USB2544 have two independent current limit settings that are each programmed externally with a resistor. The ILIM\_HI setting is programmed with R<sub>ILIM\_HI</sub> connected between ILIM\_HI and GND. The ILIM\_LO setting is programmed with R<sub>ILIM\_LO</sub> connected between ILIM\_LO and GND. Consult the Device Truth Table to see when each current limit is used. Both settings have the same relation between the current limit and the programming resistor. R<sub>ILIM\_LO</sub> is optional and the ILIM\_LO pin may be left unconnected if the ILIM\_SEL is always set high.

The following equation programs the typical current limit:

$$I_{OS\_TYP} \text{ (mA)} = 50250 / R_{LIM\_XX} \text{ (k}\Omega\text{)}$$

R<sub>LIM\_XX</sub> corresponds to either R<sub>LIM\_HI</sub> or R<sub>LIM\_LO</sub> as appropriate.

Many applications require that the current limit meet specific tolerance limits. When designing to these tolerance limits, both the tolerance of the PI5USB2544 current limit and the tolerance of the external programming resistor must be taken into account. The following equations approximate the PI5USB2544 minimum / maximum current limits to within a few mA and are appropriate for design purposes. These equations assume an ideal – no variation - external programming resistor. To take resistor tolerance into account, first determine the minimum /maximum resistor values based on its tolerance specifications and use these values in the equations. Because of the inverse relation between the current limit and the programming resistor, use the maximum resistor value in the I<sub>OS\_MIN</sub> equation and the minimum resistor value in the I<sub>OS\_MAX</sub> equation.

$$I_{OS\_MIN} \text{ (mA)} = 45271 / (R_{LIM\_XX} \text{ (k}\Omega\text{)})^{0.98437} - 30$$

$$I_{OS\_MAX} \text{ (mA)} = 55325 / (R_{LIM\_XX} \text{ (k}\Omega\text{)})^{1.0139} + 30$$

The traces routing the R<sub>ILIM\_XX</sub> resistors should be a sufficiently low resistance as to not affect the current-limit accuracy. The ground connection for the R<sub>ILIM\_XX</sub> resistors is also very important. The resistors need to reference back to the PI5USB2544 GND pin. Follow normal board layout practices to ensure that current flow from other parts of the board does not impact the ground potential between the resistors and the PI5USB2544 GND pin.

## /FAULT Response

The /FAULT open-drain output is asserted (active low) when an over-temperature or current limit condition. The output remains asserted until the fault condition is removed. The PI5USB2544 is designed to eliminate false /FAULT reporting by using an internal deglitch circuit for current limit conditions without the need for external circuitry. This ensures that /FAULT is not accidentally asserted due to normal operation such as starting into a heavy capacitive load. Over-temperature conditions are not deglitched and assert the /FAULT signal immediately.

## Undervoltage Lockout (UVLO)

The undervoltage lockout (UVLO) circuit disables the power switch until the input voltage reaches the UVLO turn on threshold. Built-in hysteresis prevents unwanted oscillations on the output due to input voltage drop from large current surges.

## Thermal Sense

The PI5USB2544 protects itself with thermal sensing circuit that monitor the operating temperature of the power distribution switch and disables operation if the temperature exceeds recommended operating conditions. The device operates in constant-current mode during an over-current condition, which increases the voltage drop across power switch. The power dissipation in the package is proportional to the voltage drop across the power switch, so the junction temperature rises during an over-current condition. The thermal sensor turns off the power switch when the die temperature exceeds 170°C regardless of whether the power switch is in current limit. Hysteresis is built into thermal sensor, and the switch turns on after the device has cooled by approximately 20°C. The switch continues to cycle off and on until the fault is removed. The open-drain false reporting output /FAULT is asserted (active low) when an over-temperature shutdown condition.

## Application Information

### Input and Output Capacitance

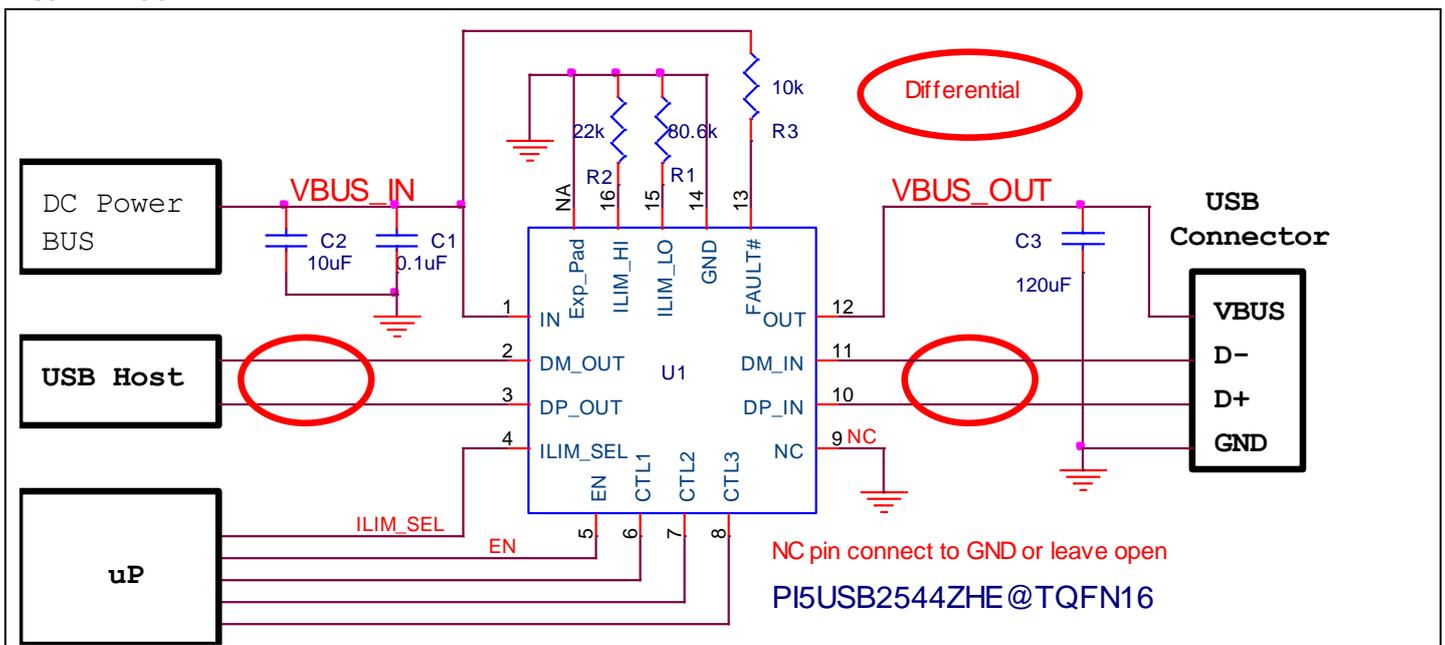
Input and output capacitance improves the performance of the device; the actual capacitance should be optimized for the particular application. For all applications, a 0.1uF or greater ceramic bypass capacitor between IN and GND is recommended as close to the device as possible for local noise decoupling. This precaution reduces ringing on the input due to power-supply transients. Additional input capacitance may be needed on the input to reduce voltage overshoot from exceeding the absolute-maximum voltage of the device during heavy transient conditions or output shorting. This is especially important during bench testing when long inductive cables are used to connect the evaluation board to the bench power supply. Normally suggested the distance between IC and DC supply is less than 15cm.

Output capacitance also needs to be close to IC as possible. When large transient currents are expected on the output, placing a high-value electrolytic capacitor on the output pin is recommended.

### Layout Design Guideline

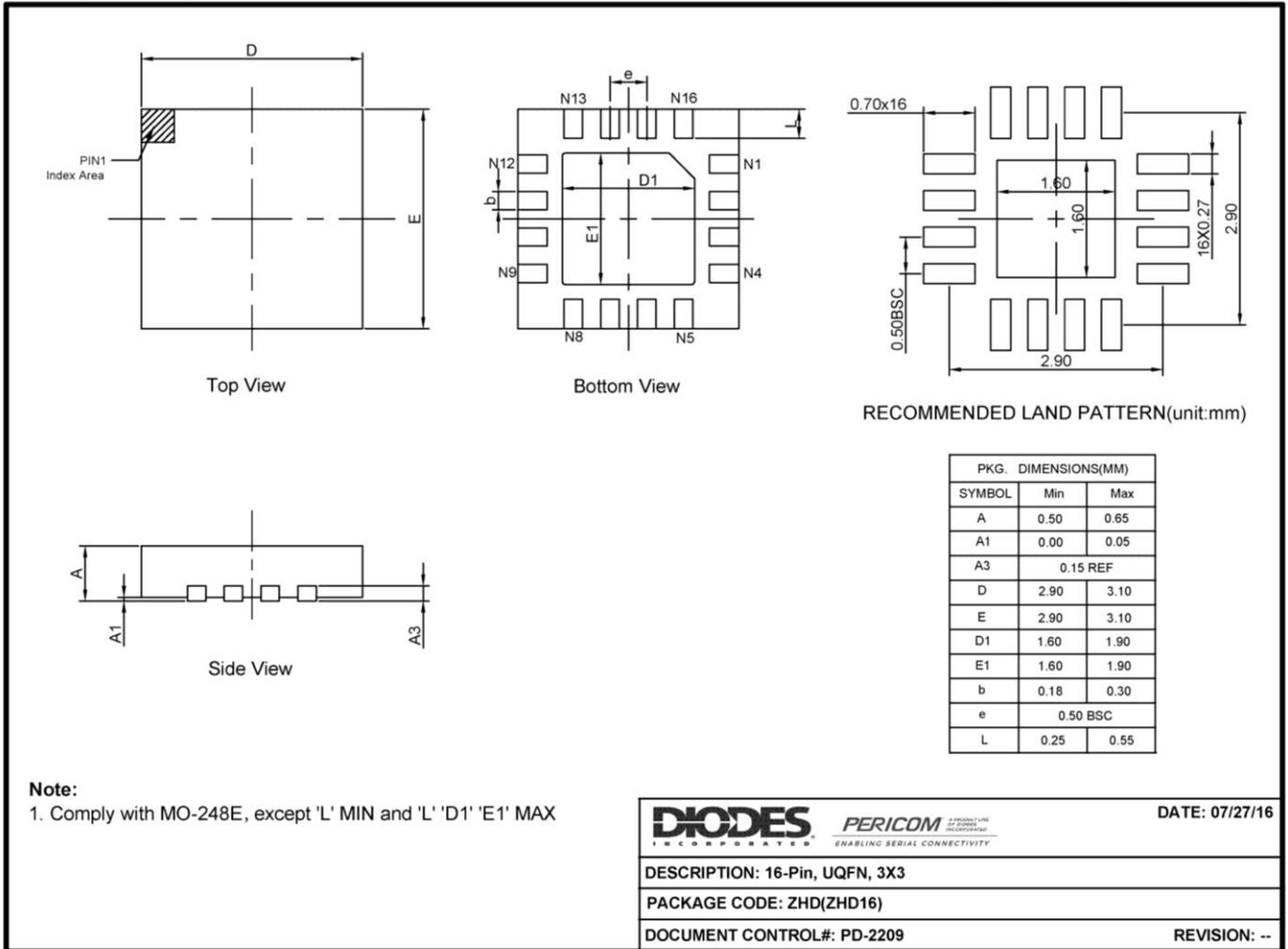
1. The PCB is suggested to use at least 4 layers
2. The high speed differential pair should maintain 90Ω
3. Do not route the high speed signal over any split plane
4. Minimized the number of vias and corners on the high speed trace for reducing the signal reflections and impedance changes
5. If it's necessary to turn 90°, use two 45° turns or an arc instead of making a single 90° turn. This can reduce reflections on the signal by minimizing impedance discontinuities.
6. The high speed trace should be routed symmetrically and parallelism (including the test points on the high speed trace). The non-parallelism trace will cause the impedance discontinuities and affect the signal quality
7. Avoid any unnecessary stubs on the differential pair. The stubs will introduce the signal reflections which affect the signal quality
8. Avoid routing the high speed differential pair under the crystal, oscillator, clock synthesizer, magnetic devices or ICs to cause the interference.
9. Avoid anti-etch on the GND plane

### Typical Application Circuit



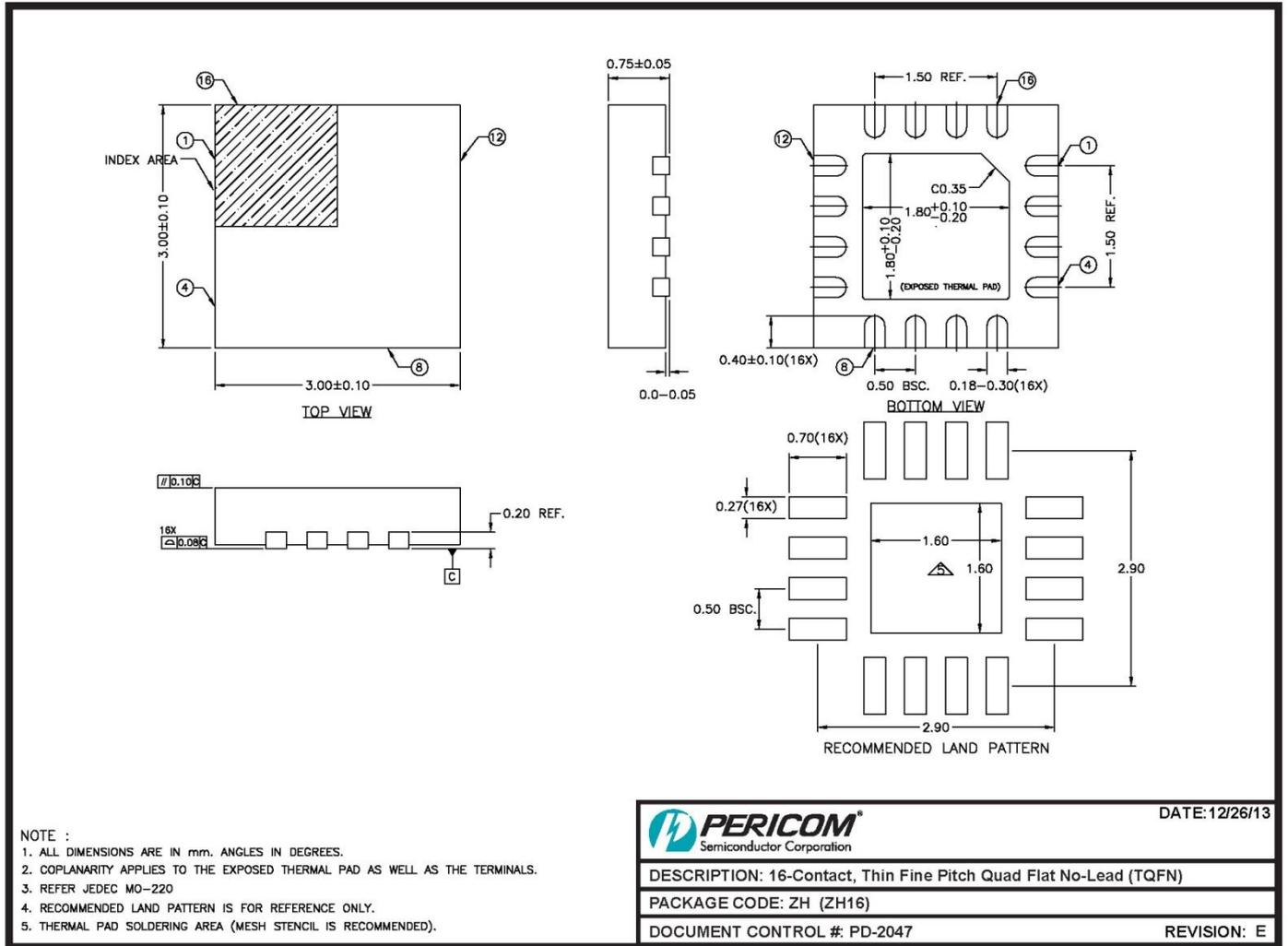
**Mechanical Information**

UGFN 3.0x3.0-16ZHD



16-0092

**TQFN 3.0x3.0-16ZH**



14-0244

For latest package info.

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**Ordering Information**

Part No.	Package Code	Package
PI5USB2544ZHDEX	ZHD	16-pin, 3.0x3.0 (UQFN)
PI5USB2544ZHEX	ZH	16-pin, 3.0x3.0 (TQFN)

**Notes:**

- Thermal characteristics can be found on the company web site at [www.diodes.com/design/support/packaging/](http://www.diodes.com/design/support/packaging/)
- E = Pb-free and Green
- X suffix = Tape/Reel

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