



# USB Battery Charger Detectors

MAX14578E/MAX14578AE

## General Description

The MAX14578E/MAX14578AE are USB charger detectors compliant with USB Battery Charging Revision 1.1. The USB charger-detection circuitry detects USB standard downstream ports (SDPs), USB charging downstream ports (CDPs), or dedicated charger ports (DCPs), and controls an external lithium-ion (Li+) battery charger.

The devices implement USB Battery Charging Revision 1.1-compliant detection logic including data contact detection, D+/D- short detection, charging downstream port identification, and optional USB dead-battery charging support. Dead-battery charging support features a 45-minute (max) charge timer and weak battery voltage monitor controlled by I<sup>2</sup>C communication (MAX14578E only.) The MAX14578AE features an enable ( $\overline{\text{EN}}$ ) input and an LDO output.

In addition, the internal USB switch is compliant to Hi-Speed USB, full-speed USB, and low-speed USB signals. The devices feature low on-resistance, low on-resistance flatness, and very low capacitance. The devices also feature high-ESD protection up to  $\pm 15\text{kV}$  Human Body Model on the CD+ and CD- pins.

In addition, the MAX14578E/MAX14578AE feature Apple and Sony charger detection that allows identification of resistor-divider networks on D+/D-.

The MAX14578E/MAX14578AE are available in both a 12-bump, 0.4mm pitch, 1.3mm x 1.68mm WLP package and 16-pin TQFN package, and operate over the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  extended temperature range.

## Features

- ◆ Compliant to USB Battery Charging Revision 1.1
- ◆ Data Contact Detection for Foolproof Connector Insertion Detection
- ◆ USB Dead-Battery Charging Support
- ◆ Charging Downstream Detection
- ◆ Apple/Sony Charger Detection
- ◆ Dedicated Charger Detection
- ◆ China YD/T1591-Compliant Charger Detection
- ◆ Internal Switches Isolate the USB Transceiver During the Charger Detection Process
- ◆ VBUS Connection Capable of 28V
- ◆ Device Status Change Interrupt
- ◆ Low Supply Current
- ◆ High-ESD Protection on CD+ and CD-
  - $\pm 15\text{kV}$  Human Body Model
  - $\pm 8\text{kV}$  IEC 61000-4-2 Contact Discharge

## Applications

DSC and Camcorder  
Media Players  
Cell Phones  
e-Book Readers  
Mobile Internet Devices (MIDs)

## Ordering Information/Selector Guide

PART	I <sup>2</sup> C	$\overline{\text{EN}}$	LDO	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX14578EEWC+T	Yes	No	No	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	12 WLP	+ABW
MAX14578EETE+T	Yes	No	No	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	16 TQFN-EP*	AJA
MAX14578AEWC+T	No	Yes	Yes	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	12 WLP	+ABX
MAX14578AEETE+T	No	Yes	Yes	$-40^{\circ}\text{C}$ to $+85^{\circ}\text{C}$	16 TQFN-EP*	AJB

+Denotes a lead(Pb)-free/RoHS-compliant package.

\*EP = Exposed Pad.

T = Tape and reel.

# USB Battery Charger Detectors

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)

BAT, $\overline{\text{INT}}$ , SDA, SCL, CE0, CE1, CE2, $\overline{\text{EN}}$ .....	-0.3V to +6.0V
LOUT .....	-0.3V to (V <sub>B</sub> + 0.3V, 6V) (min)
V <sub>B</sub> .....	-0.3V to +30V
Switch Disabled or CP_ENA = 1 (Note 1)	
CD+, CD- .....	-2.1V to (V <sub>SWPOS</sub> + 0.3V)
TD+, TD- .....	-0.3V to (V <sub>SWPOS</sub> + 0.3V)
Switch Enabled or CP_ENA = 0 (Note 2)	
CD+, CD-, TD+, TD- .....	-0.3V to (V <sub>VCCINT</sub> + 0.3V)

Continuous Current into LOUT .....	±150mA
Continuous Current into Any Other Terminal .....	±50mA
Continuous Power Dissipation (T <sub>A</sub> = +70°C)	
WLP (derate 13.7mW/°C above +70°C) .....	1096mW
TQFN (derate 20.8mW/°C above +70°C) .....	1667mW
Operating Temperature Range .....	-40°C to +85°C
Junction Temperature .....	+150°C
Storage Temperature Range .....	-65°C to +150°C
Soldering Temperature (reflow) .....	+260°C

**Note 1:** V<sub>SWPOS</sub> = (V<sub>VCCINT</sub> or 3.3V) (min)

**Note 2:** V<sub>VCCINT</sub> = (V<sub>BAT</sub>, [(V<sub>B</sub> or 4.2V) (min)]) (max)

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 other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## PACKAGE THERMAL CHARACTERISTICS (Note 3)

WLP	TQFN
Junction-to-Ambient Thermal Resistance (θ <sub>JA</sub> ) .....	73°C/W
Junction-to-Ambient Thermal Resistance (θ <sub>JA</sub> ) .....	48°C/W
Junction-to-Case Thermal Resistance (θ <sub>JC</sub> ) .....	10°C/W

**Note 3:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

## ELECTRICAL CHARACTERISTICS

(V<sub>BAT</sub> = +2.8V to +5.5V, V<sub>B</sub> = +3.5V to +5.5V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at V<sub>BAT</sub> = +3.6V, V<sub>B</sub> = +5.0V, T<sub>A</sub> = +25°C.) (Note 4)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
<b>DC CHARACTERISTICS</b>						
Supply Voltage Range	V <sub>BAT</sub>		2.8		5.5	V
	V <sub>B</sub>		3.5		28	
Internal Positive Switch Regulator	V <sub>SWPOS</sub>		3.25	3.4	3.6	V
Internal Negative Switch Regulator	V <sub>SWNEG</sub>		-2.06	-1.90	-1.76	V
V <sub>BAT</sub> UVLO	V <sub>BATUVLO</sub>	V <sub>BAT</sub> = 4.2V, V <sub>B</sub> = 0V	0.90	1.65	2.45	V
V <sub>BUS</sub> UVLO	V <sub>BUSUVLO</sub>	V <sub>BAT</sub> = 0V, V <sub>B</sub> = 5.5V	1.0	1.33	3.30	V

# USB Battery Charger Detectors

MAX14578E/MAX14578AE

## ELECTRICAL CHARACTERISTICS (continued)

(V<sub>BAT</sub> = +2.8V to +5.5V, V<sub>B</sub> = +3.5V to +5.5V, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at V<sub>BAT</sub> = +3.6V, V<sub>B</sub> = +5.0V, T<sub>A</sub> = +25°C.) (Note 4)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
BAT Supply Current	IBAT	MAX14578E	V <sub>BAT</sub> = +3.6V, V <sub>B</sub> = 0V, CP_ENA = 0, USBSWC = 0		1	2.5	μA
			V <sub>BAT</sub> = +4.2V, V <sub>B</sub> = 0V, CP_ENA = 1, USBSWC = 1, V <sub>SDA</sub> = V <sub>SCL</sub> = 1.8V		34.5	59	
		MAX14578AE	V <sub>BAT</sub> = +3.6V, V <sub>B</sub> < V <sub>BRAW</sub> , V <sub>EN</sub> = +3.6V		1	2.5	
			V <sub>BAT</sub> = +4.2V, V <sub>B</sub> = 0V, V <sub>EN</sub> = 0V		1.3	30	
			Supply current increase when V <sub>EN</sub> = 1.6V, V <sub>BAT</sub> = +4.2V		1.3	3.5	
V <sub>B</sub> Supply Current	I <sub>VB</sub>	MAX14578E	V <sub>B</sub> = +5.5V, CP_ENA = 0, USBSWC = 0		87	140	μA
		MAX14578AE	V <sub>B</sub> = +5.5V, V <sub>EN</sub> = 0V		190	2.95	
			V <sub>B</sub> = +5.5V, V <sub>EN</sub> = +5.5V		75	125	
<b>LOUT (LDO OUT) (MAX14578AE ONLY)</b>							
LOUT Current Limit	I <sub>LOUT</sub>				95		mA
LOUT Voltage	V <sub>LOUT</sub>	I <sub>LOUT</sub> = 10mA, V <sub>B</sub> = 5.0V		4.87	4.94		V
		I <sub>LOUT</sub> = 0mA, V <sub>B</sub> = 6.0V		4.0	5.3	5.5	
LOUT Debounce Time	t <sub>LOUT_DEB</sub>	V <sub>B</sub> = 5.0V to V <sub>LOUT</sub> = 4.5V			20		ms
LOUT Turn-On Time					100		μs
Thermal Shutdown					+141		°C
Thermal Shutdown Hysteresis					20		°C
<b>CHARGER DETECTION</b>							
VDP_SRC Voltage	VDP_SRC			0.5		0.7	V
V <sub>DATA</sub> _REF Voltage	V <sub>DATA</sub> _REF			0.25		0.4	V
V <sub>LGC</sub> Voltage	V <sub>LGC</sub>			0.8		2.0	V
I <sub>DP</sub> _SRC Current	I <sub>DP</sub> _SRC			6.6		11	μA
CD+ and CD- Sink Current	I <sub>CD+</sub> _SINK I <sub>CD-</sub> _SINK			50		150	μA
R <sub>CD</sub> Resistance	R <sub>CD</sub>			200	330	500	kΩ
TD+ Pulldown Resistor	R <sub>TD+</sub> _DWN			15	20	25	kΩ
TD- Pulldown Resistor	R <sub>TD-</sub> _DWN			14.25		24.8	kΩ
Charger Detection Weak Sink	I <sub>WEAK</sub>					0.18	μA

# USB Battery Charger Detectors

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{BAT} = +2.8V$  to  $+5.5V$ ,  $V_B = +3.5V$  to  $+5.5V$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $V_{BAT} = +3.6V$ ,  $V_B = +5.0V$ ,  $T_A = +25^\circ C$ .) (Note 4)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
VBUS25 Ratio	VBUS25	Reference ratio for special charger as a percentage of $V_{BUS}$ voltage, $V_B = 5V$	24	26	29	%
VBUS47 Ratio	VBUS47	Reference ratio for special charger as a percentage of $V_{BUS}$ voltage, $V_B = 5V$	44	47	50	%
VBUS60 Ratio	VBUS60		57.5	60.3	63.5	%
DCD M Time	tMDEB	All comparators	20	30	40	ms
DCD C Time	tCDEB	All comparators			5	ms
DCD Timer				2		s
Charger-Detect Source Time	tDP_SRC_ON	DCHK = 0		40		ms
		DCHK = 1		625		
Charger-Detect-Type Detection Time	tDP_RES_ON		120			ms
Charger-Detect Delay Time	tDP_SRC_HICRNT		40		80	ms
$V_B$ Attach to CE1 and CE2 Output Time	tVBSW	From $V_B > V_{VBDET}$ or CHG_TYP_M = 1 (DCHK = 0) to CE1 and/or CE2 change			520	ms
		From $V_B > V_{VBDET}$ or CHG_TYP_M = 1 (DCHK = 1) to CE1 and/or CE2 change			1450	
$V_B$ Raw-Detect Threshold	VVBRAW		1.7	2.6	3.5	V
$V_B$ -Detect Threshold	VVBDET		3.2	3.5	3.3	V
$V_B$ -Detect Threshold Hysteresis	VVBDET_HYS		38	50		mV
<b>USB ANALOG SWITCHES (CD-, CD+)</b>						
Analog-Signal Range	$V_{DN2}$ , $V_{DP2}$	CP_ENA = 0 (MAX14578E)	0		$V_{VCCINT}$	V
		CP_ENA = 1	$V_{SWNEG}$		$V_{SWPOS}$	
On-Resistance	R <sub>ONUSB</sub>	$V_{BAT} = +3.0V$ , $I_{CD+} = I_{CD-} = 10mA$ , $V_{CD+}$ , $V_{CD-} = 0$ to $+3.0V$		3.3	6	$\Omega$
On-Resistance Match Between Channels	$\Delta R_{ONUSB}$	$V_{BAT} = +3.0V$ , $I_{CD+} = I_{CD-} = 10mA$ , $V_{CD+}$ , $V_{CD-} = +400mV$			0.5	$\Omega$
On-Resistance Flatness	R <sub>FLATUSB</sub>	$V_{BAT} = +3.0V$ , $I_{CD+} = I_{CD-} = 10mA$ , $V_{CD+}$ , $V_{CD-} = 0$ to $+3.3V$		0.06	0.26	$\Omega$
Off-Leakage Current	I <sub>LUSB(OFF)</sub>	$V_{BAT} = 4.2V$ , switch open, $V_{CD+} = V_{CD-} = +0.3V$ or $+2.5V$ ; $V_{TD+}$ or $V_{TD-} = +2.5V$ or $+0.3V$	-360		+360	nA
On-Leakage Current	I <sub>LUSB(ON)</sub>	$V_{BAT} = 4.2V$ , switch closed, $V_{CD+}$ or $V_{CD-} = +0.3V$ or $+2.5V$	-360		+360	nA
<b>DIGITAL SIGNALS (<math>\overline{INT}</math>, SCL, SDA, <math>\overline{EN}</math>, CE0, CE1, CE2)</b>						
Input Logic-High	$V_{IH}$		1.4			V
Input Logic-Low	$V_{IL}$				0.4	V
Input Leakage Current	I <sub>INLEAK</sub>		-1		+1	$\mu A$
Open-Drain Low	V <sub>ODOL</sub>	I <sub>SINK</sub> = 1mA			0.4	V

# USB Battery Charger Detectors

MAX14578E/MAX14578AE

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{BAT} = +2.8V$  to  $+5.5V$ ,  $V_B = +3.5V$  to  $+5.5V$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $V_{BAT} = +3.6V$ ,  $V_B = +5.0V$ ,  $T_A = +25^\circ C$ .) (Note 4)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Output Logic-High	$V_{OH}$	$I_{SOURCE} = 1mA$	$V_{IO} - 0.2$			V
Output Logic-Low	$V_{OL}$	$I_{SINK} = 1mA$			0.2	V
<b>DYNAMIC (Note 5)</b>						
Charge-Pump Delay Time	$t_{CP}$	CP_ENA from 0 to 1 until switch on			1	ms
Analog-Switch Turn-On Time	$t_{ON}$	MAX14578E, I <sup>2</sup> C STOP to switch on, $R_L = 50\Omega$		0.1	1	ms
Analog-Switch Turn-Off Time	$t_{OFF}$	MAX14578E, I <sup>2</sup> C STOP to switch off, $R_L = 50\Omega$		0.1	1	ms
Break-Before-Make Delay Time	$t_{BBM}$	$R_L = 50\Omega$ , $T_A = +25^\circ C$	> 0			$\mu s$
Off-Capacitance	$C_{OFF}$	TD-, TD+, applied voltage is 0.5VP-P, DC bias = 0V, f = 240MHz; CD-, CD+ not connected to TD-, TD+		2		pF
On-Capacitance	$C_{ON}$	TD-, TD+, applied voltage is 0.5VP-P, DC bias = 0V, f = 240MHz; CD-, CD+ connected to TD-, TD+; $R_L = 50\Omega$		4.5		pF
-3dB Bandwidth	BW	$V_{CD\_} = 0.5VP-P$		1000		MHz
Off-Isolation	$V_{ISO}$	$R_L = 50\Omega$ , f = 20kHz, $V_{CD\_} = 0.5VP-P$		-60		dB
<b>I<sup>2</sup>C TIMING SPECIFICATIONS</b>						
I <sup>2</sup> C Max Clock	$f_{I2CCLK}$			400		kHz
Bus Free Time Between STOP and START Conditions	$t_{BUF}$		1.3			$\mu s$
START Condition Setup Time			0.6			$\mu s$
Repeat START Condition Setup Time	$t_{SU:STA}$	90% to 90%	0.6			$\mu s$
START Condition Hold Time	$t_{HD:STA}$	10% of SDA to 90% of SCL	0.6			$\mu s$
STOP Condition Setup Time	$t_{SU:STO}$	90% of SCL to 10% of SDA	0.6			$\mu s$
Clock Low Period	$t_{LOW}$	10% to 10%	1.3			$\mu s$
Clock High Period	$t_{HIGH}$	90% to 90%	0.6			$\mu s$
Data Valid to SCL Rise Time	$t_{SU:DAT}$	Write setup time	100			ns
Data Hold Time to SCL Fall	$t_{HD:DAT}$	Write hold time			0	ns
<b>ESD PROTECTION</b>						
CD+, CD-		Human Body Model		$\pm 15$		kV
		IEC 61000-4-2 Contact Discharge		$\pm 8$		

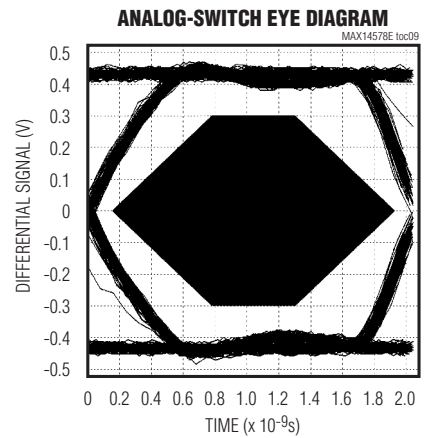
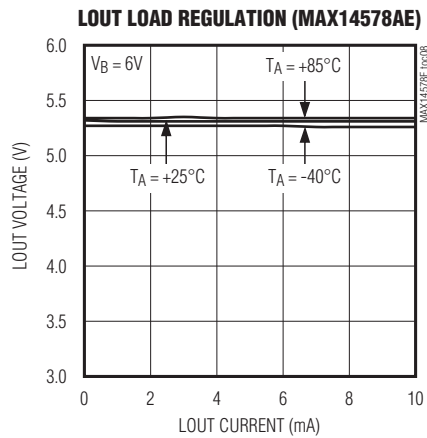
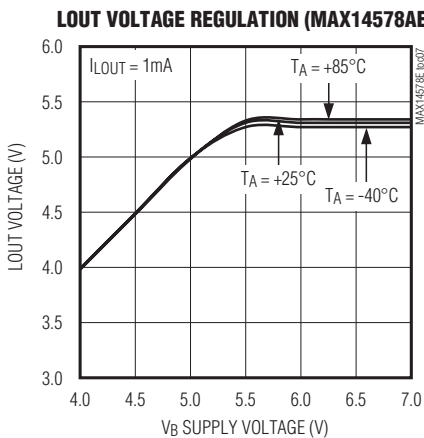
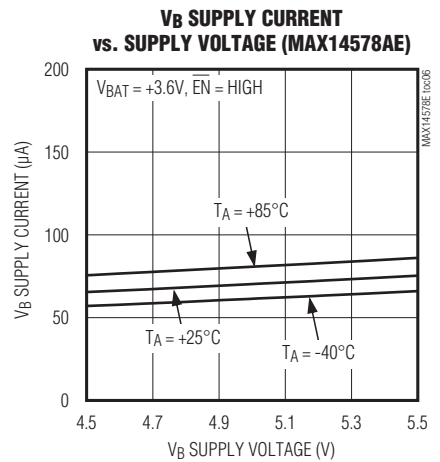
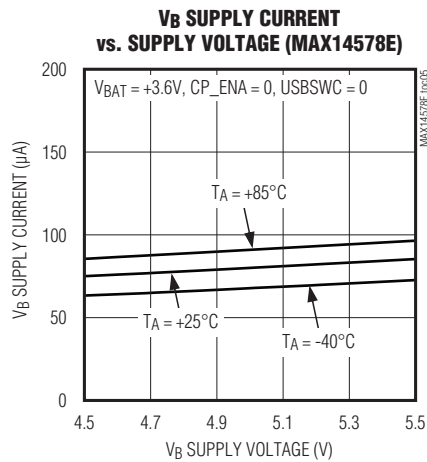
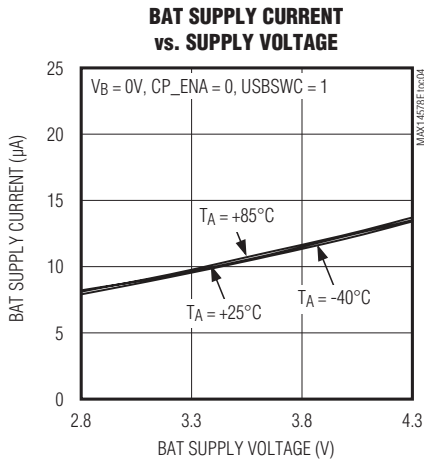
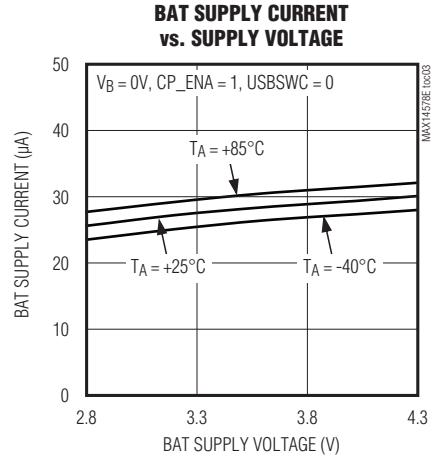
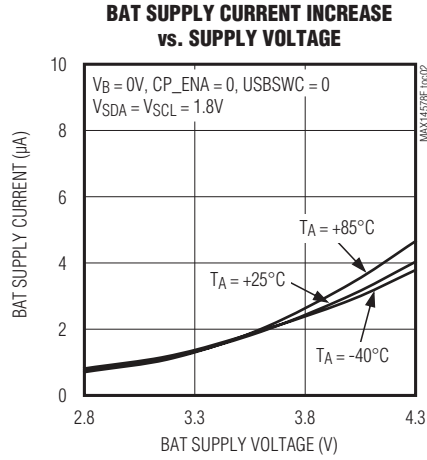
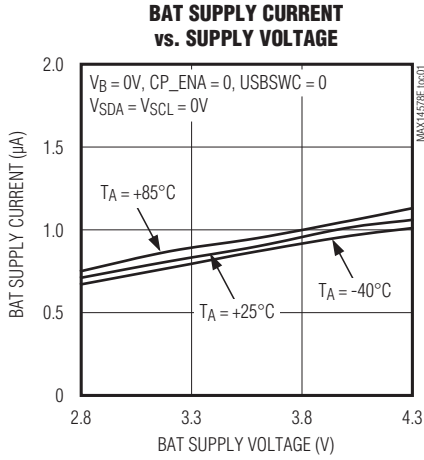
**Note 4:** All units are 100% production tested at  $T_A = +25^\circ C$ . Limits over the operating temperature range are guaranteed by design and not production tested.

**Note 5:** Guaranteed by design; not production tested.

# USB Battery Charger Detectors

## Typical Operating Characteristics

(VBAT = +4.2V, VB = +5.0V, CBAT = 1μF, CVB = 1μF, unless otherwise noted.)

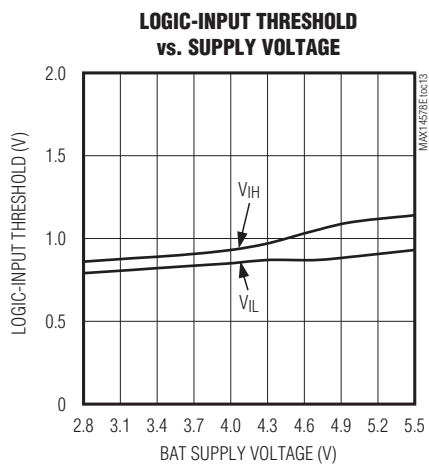
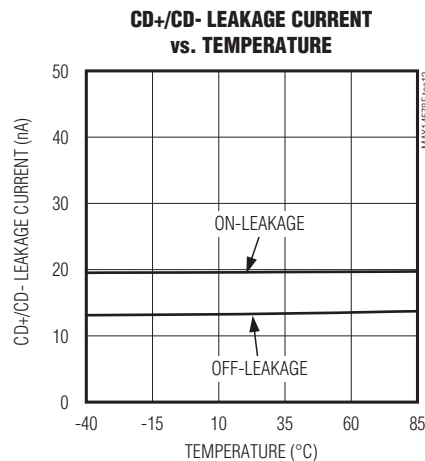
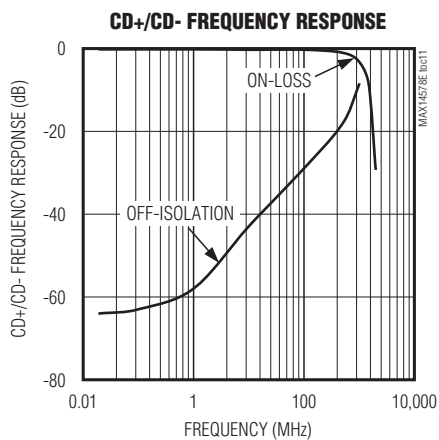
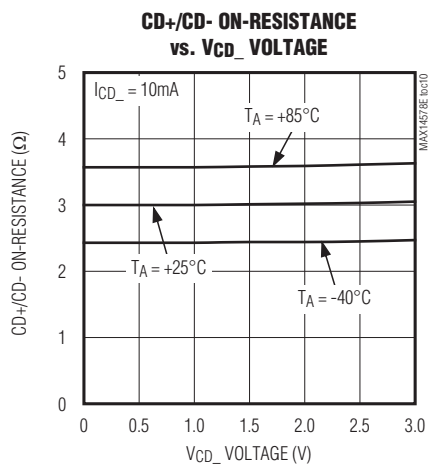


# USB Battery Charger Detectors

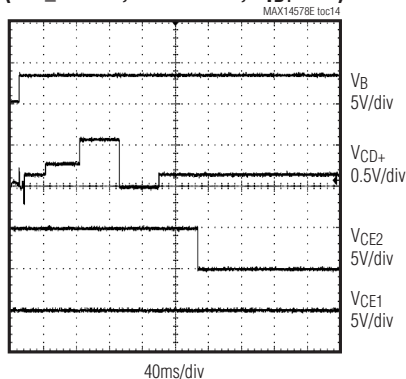
MAX14578E/MAX14578AE

## Typical Operating Characteristics (continued)

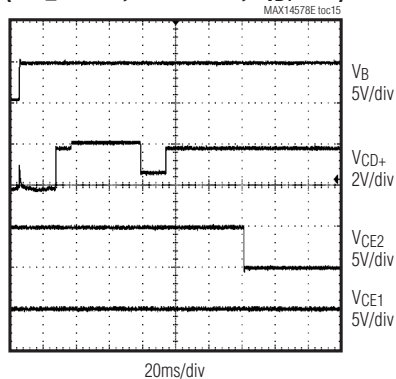
( $V_{BAT} = +4.2V$ ,  $V_B = +5.0V$ ,  $C_{BAT} = 1\mu F$ ,  $C_{VB} = 1\mu F$ , unless otherwise noted.)



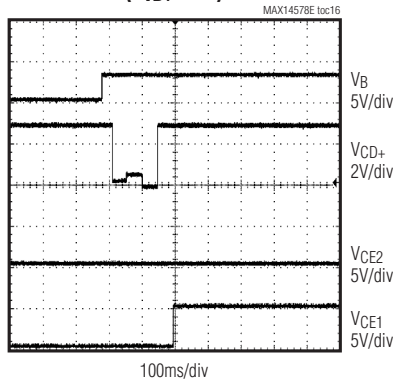
**CE\_ vs.  $V_{BUS}$  CONNECTION (MAX14578E)**  
**USB CHARGING DOWNSTREAM PORT, USB COMPLIANT**  
**( $USB\_CPL = 1$ ,  $USBSWC = 0$ ,  $V_{TD+} = 3V$ )**



**CE\_ vs.  $V_{BUS}$  CONNECTION (MAX14578E)**  
**APPLE 1A CHARGER, USB COMPLIANT**  
**( $USB\_CPL = 1$ ,  $USBSWC = 0$ ,  $V_{TD+} = 3V$ )**

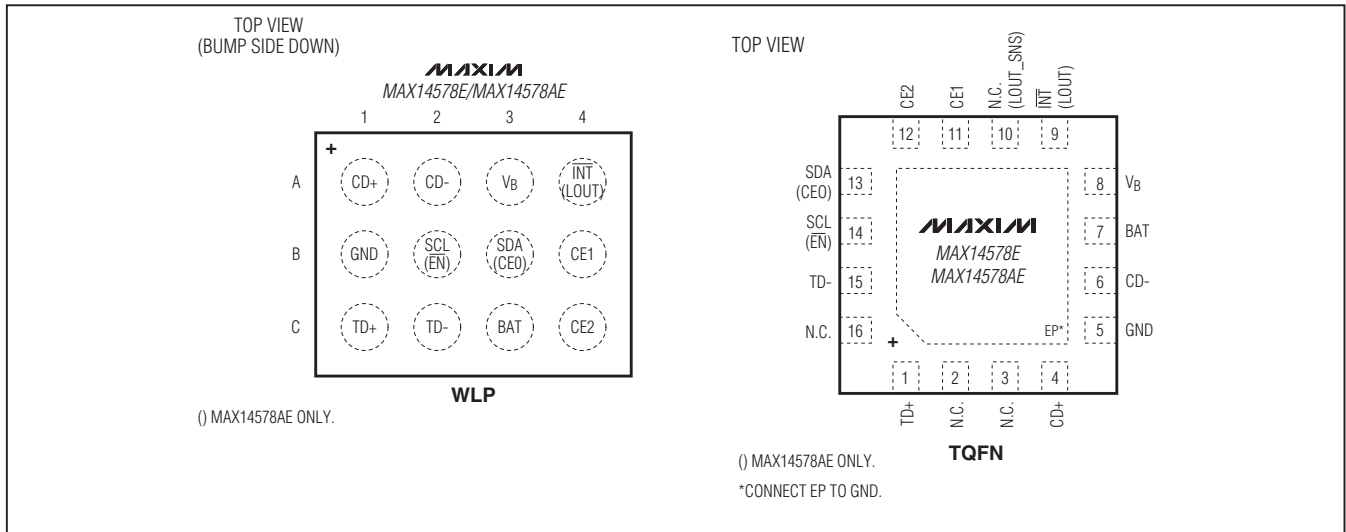


**CE\_ vs.  $V_{BUS}$  CONNECTION (MAX14578AE)**  
**USB CHARGING DOWNSTREAM PORT**  
**( $V_{TD+} = 3V$ )**



# USB Battery Charger Detectors

## Pin/Bump Configurations



## Pin/Bump Description

PIN				NAME	FUNCTION
MAX14578E		MAX14578AE			
TQFN-EP	WLP	TQFN-EP	WLP		
1	C1	1	C1	TD+	USB Transceiver D+ Connection
2, 3, 10, 16	—	2, 3, 16	—	N.C.	No Connection. Not internally connected.
4	A1	4	A1	CD+	USB Connector D+ Connection
5	B1	5	B1	GND	Ground
6	A2	6	A2	CD-	USB Connector D- Connection
7	C3	7	C3	BAT	Battery Connection Input. Connect a 1µF capacitor as close as possible between BAT and GND.
8	A3	8	A3	V <sub>B</sub>	USB Connector V <sub>BUS</sub> Connection. Connect a 1µF capacitor as close as possible between V <sub>B</sub> and GND for ±15kV ESD protection.
9	A4	—	—	INT	Active-Low Interrupt Request, Open-Drain Output
—	—	9	A4	LOUT	+5.3V USB Transceiver V <sub>BUS</sub> Power Output. Connect a 1µF capacitor as close as possible between LOUT and GND.
—	—	10	—	LOUT_SNS	Connect Externally to LOUT (MAX14578AE, TQFN Only)
11	B4	11	B4	CE1	Charger-Enable Control 1, Open-Drain Output
12	C4	12	C4	CE2	Charger-Enable Control 2, Open-Drain Output
13	B3	—	—	SDA	I <sup>2</sup> C Serial-Data Input/Output. Connect SDA to an external pullup resistor.
—	—	13	B3	CE0	Charger-Enable Control 0, Open-Drain Output
—	—	14	B2	EN	Active-Low Enable Input. Drive EN low to enable the charger ID detection and close the USB switches after charger detection is complete.

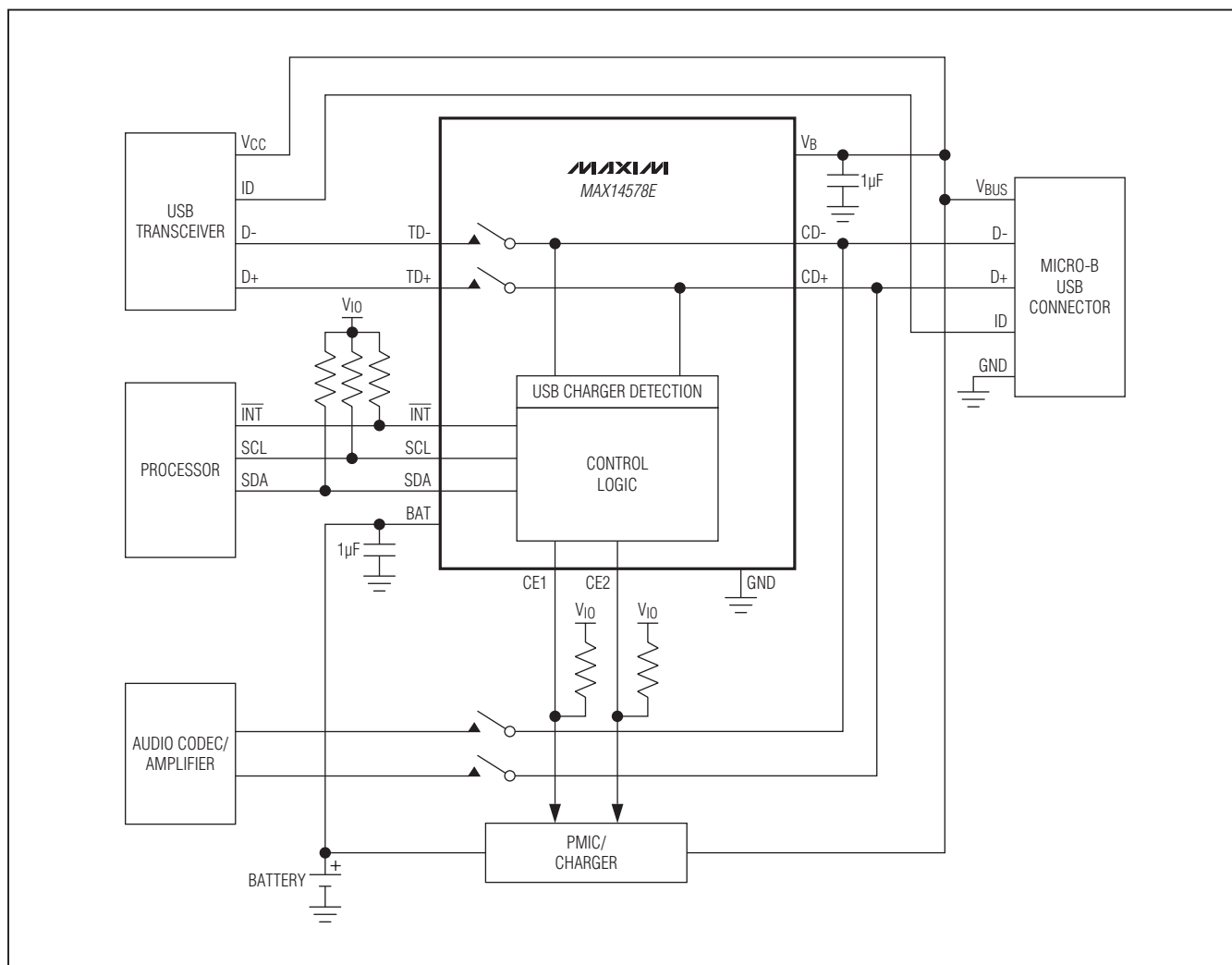


# USB Battery Charger Detectors

## Pin/Bump Description (continued)

PIN				NAME	FUNCTION
MAX14578E		MAX14578AE			
TQFN-EP	WLP	TQFN-EP	WLP		
14	B2	—	—	SCL	I <sup>2</sup> C Serial-Clock Input. Connect SCL to an external pullup resistor.
15	C2	15	C2	TD-	USB Transceiver D- Connection
—	—	—	—	EP	Exposed Pad (TQFN Only). EP is internally connected to GND. Connect to a large ground plane to maximize thermal performance. Not intended as an electrical connection point.

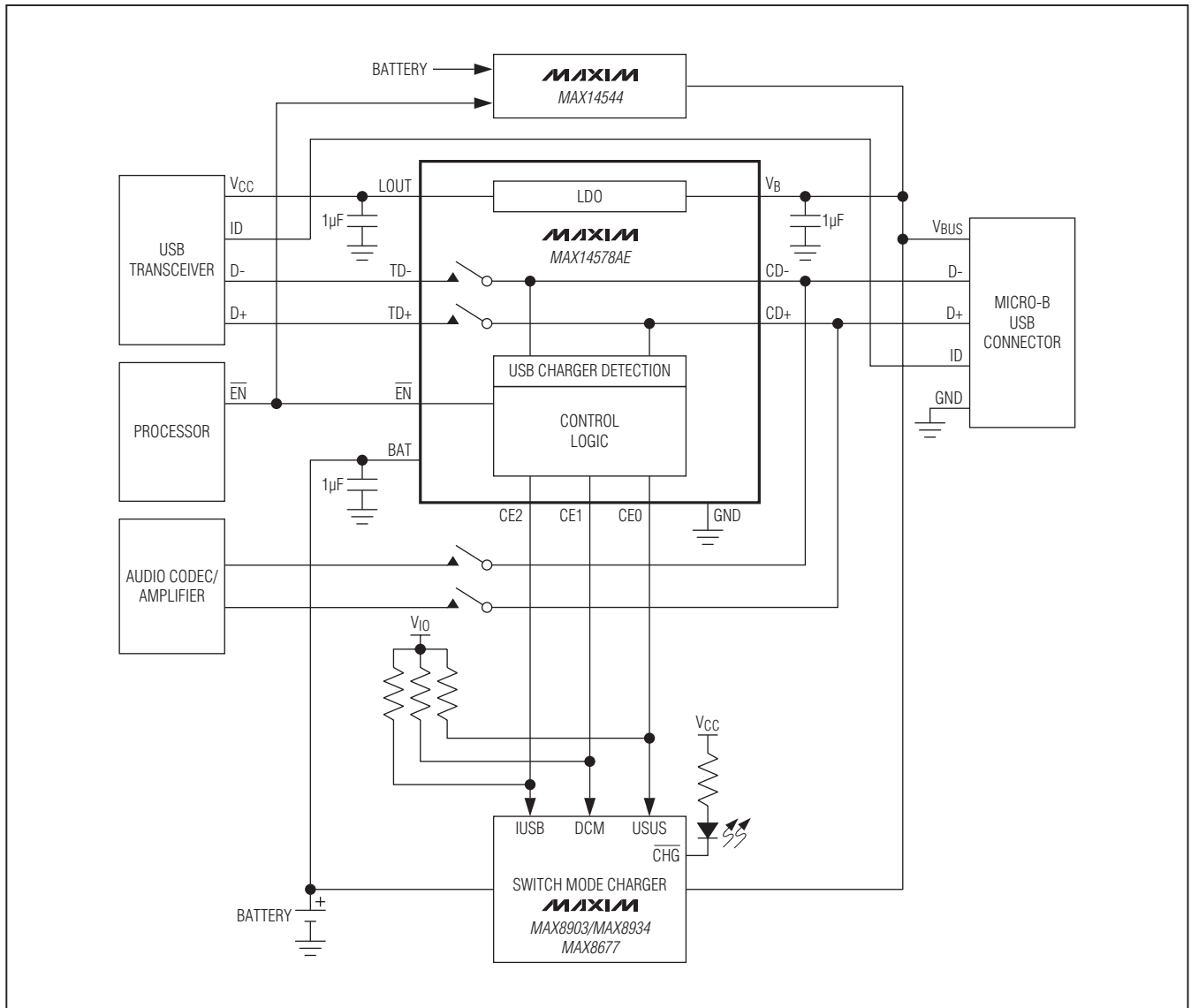
## MAX14578E Functional Diagram/Typical Application Circuit



MAX14578E/MAX14578AE

# USB Battery Charger Detectors

MAX14578AE Functional Diagram/Typical Application Circuit



# USB Battery Charger Detectors

MAX14578E/MAX14578AE

**Table 1. Register Map**

ADDRESS	NAME	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
0x00	DEVICE ID	VENDOR_ID				CHIP_REV			
0x01	CONTROL 1	INTPOL	INTEN	USBSWC	CP_ENA	LOW_POW	DCHK	CHG_TYP_M	USB_CHGDET
0x02	INTERRUPT	CHG_TYP			VBCOMP	DBCHG	DCD_T	CHGRUN	RFU
0x03	CONTROL 2	DCD_EN	DB_EXIT	DB_IDLE	SUS_LOW	CE_FRC	CE		
0x04	CONTROL 3	RFU	RFU	RFU	CDP_DET	USB_CPL	SFOUT_EN	SFOUTASRT	DCD_EXIT

**Table 2. Detailed Register Map**

FIELD NAME	READ/WRITE	BIT	DEFAULT	DESCRIPTION
<b>DEVICE ID (I<sup>2</sup>C ADDRESS = 0x00)</b>				
VENDOR_ID	Read Only	[7:4]	0010	Vendor Identification
CHIP_REV	Read Only	[3:0]	0001	Chip Revision
<b>CONTROL 1 (I<sup>2</sup>C ADDRESS = 0x01)</b>				
INTPOL	Read/Write	7	0	Interrupt Polarity 0 = Active low 1 = Active high
INTEN	Read/Write	6	0	Interrupt Enable. If interrupt is disabled, pending interrupts are not cleared and the INT pin deasserts. INTEN is a global setting to mask all interrupts. 0 = Interrupt disabled 1 = Interrupt enabled
USBSWC	Read/Write	5	0	Opens/Closes USB Switch 0 = Switch open 1 = Switch closed
CP_ENA	Read/Write	4	0	Charge-Pump Enable 0 = Charge pump disabled 1 = Charge pump enabled
LOW_POW	Read/Write	3	1	Low-Power Mode 0 = Low-power mode disabled; oscillator/bandgap always on 1 = Low-power mode enabled; oscillator/bandgap turned off under the following conditions: no VBUS, USBSWC = 0, and CP_ENA = 0
DCHK	Read/Write	2	0	Charger-Type Source-Detection Time 0 = DCHK, tDP_SRC_ON = 40ms 1 = DCHK, tDP_SRC_ON = 625ms
CHG_TYP_M	Read/Write	1	0	Charger-Type Manual-Detection Enable. Set CHG_TYP_M to 1 to force the internal logic to open the USB switches and perform a charger-type detection. After the detection state matching completes, this bit resets to 0. 0 = Charger detection disabled 1 = Force a manual charge detection

## USB Battery Charger Detectors

Table 2. Detailed Register Map (continued)

FIELD NAME	READ/WRITE	BIT	DEFAULT	DESCRIPTION
USB_CHGDET	Read/Write	0	1	Charger-Detection-Enable Start. Charger detection starts with any change in $V_B$ . 0 = Charger detection disabled 1 = Charger detection enabled
<b>INTERRUPT (I<sup>2</sup>C ADDRESS = 0x02)</b>				
CHG_TYP	Read Only	[7:5]	000	Output of USB Charger Detection 000 = Nothing attached 001 = USB cable attached 010 = Charging downstream port: current depends on USB operating speed 011 = Dedicated charger: current up to 1.8A 100 = Special charger: 500mA max 101 = Special charger: current up to 1A 110 = RFU 111 = Dead-battery charging: 100mA max
VBCOMP	Read Only	4	0	Output of $V_B$ Comparator. Changes in VBCOMP triggers interrupt. 0 = $V_B < V_{VBDET}$ 1 = $V_B \geq V_{VBDET}$
DBCHG	Read Only	3	0	Dead-Battery Charger Mode. If DBCHG = 1, the 45-minute timer is running. 0 = Not in dead-battery charge mode 1 = In dead-battery charge mode
DCD_T	Read Only	2	0	Data-Contact Detection (DCD) Time Wait. DCD_T generates an interrupt after a 0-to-1 transition. 0 = Data contact detection not running 1 = Data contact detection running for > 2s
CHGRUN	Read Only	1	0	Charger-Detection State Machine Running. For information only—no interrupt generated. 0 = Charger detection not running 1 = Charger detection running (DCD, dead battery, D+/D-short)
RFU	Read Only	0	0	Reserved
<b>CONTROL 2 (I<sup>2</sup>C ADDRESS = 0x03)</b>				
DCD_EN	Read/Write	7	1	DCD Enable. If DCD_EN = 1, D+/D- is tested for a short after DCD passes. If DCD_EN = 0, DCD is skipped and D+/D- short detection begins when $V_{BUS}$ is connected or CHG_TYP_M = 1. If DCD is stuck (DCD_T) = 1, setting DCD_EN = 0 bypasses DCD and D+/D- short detection begins. 0 = Disabled 1 = Enabled

# USB Battery Charger Detectors

MAX14578E/MAX14578AE

**Table 2. Detailed Register Map (continued)**

FIELD NAME	READ/WRITE	BIT	DEFAULT	DESCRIPTION
DB_EXIT	Read/Write	6	0	Exit Dead-Battery Charge Mode. If DBCHG = 1, setting DB_EXIT to 1 stops the 45-minute timer, sets DBCHG to 0, and leaves CHG_EN = 1. DB_EXIT is automatically reset to 0 if V <sub>BAT</sub> reaches the dead-battery threshold. 0 = Do not exit dead-battery mode 1 = Exit dead-battery mode
DB_IDLE	Read/Write	5	0	Dead-Battery Idle Mode. DB_IDLE = 1 in dead-battery mode to forces the USB switch to close. DB_IDLE is automatically reset when the USB switch is closed. 0 = Dead-battery mode off or test completed 1 = Dead-battery mode on or test still needed
SUS_LOW	Read/Write	4	0 (1)*	Suspend Mode Selection 0 = When the charger is disabled, CE1 = CE2 = 1 1 = When the charger is disabled, CE1 = CE2 = 0
CE_FRC	Read/Write	3	0	CE Outputs Force Enable 0 = CE outputs follow the charger-detection finite state machine (FSM) 1 = CE outputs follow the CE[2:0] register regardless of the result from the charger-detection FSM
CE	Read/Write	[2:0]	000	CE Outputs (CE2, CE1, CE0). If CE_FRC = 0, registers are set by the result of charger FSM. If CE_FRC = 1, registers are set by I <sup>2</sup> C command only.
<b>CONTROL 3 (I<sup>2</sup>C ADDRESS = 0x04)</b>				
RFU	Read/Write	[7:5]	000	Reserved
CDP_DET	Read/Write	4	0	0 = Normal detection 1 = Resistive detection
USB_CPL	Read/Write	3	1 (0)*	USB Compliance 0 = Device is not USB compliant 1 = Device is USB compliant
SFOUT_EN	Read/Write	2	0 (1)*	LOUT Enable 0 = LOUT off 1 = LOUT on as per SFOUTASRT
SFOUTASRT	Read/Write	1	1	LOUT Assert Timing 0 = LOUT asserts when the charger-detection FSM completes 1 = LOUT asserts after valid V <sub>BUS</sub> voltage detection
DCD_EXIT	Read/Write	0	1	Exit Charger-Type-Detection Routine After DCD_T is Set to 1 0 = Disabled 1 = Enabled

**Note:** CP\_ENA, DCHK, USB\_CHGDET, DCD\_EN, SUS\_LOW, CE\_FRC, CE, USB\_CPL, SFOUT\_EN, SFOUTASRT, and DCD\_EXIT can be configured to have different default values. Contact the factory for more information.

\*Default value for MAX14578AE only.

# USB Battery Charger Detectors

## Detailed Description

The MAX14578E/MAX14578AE are USB charger detectors compliant with USB Battery Charging Revision 1.1. The USB charger-detection circuitry detects USB standard downstream ports (SDPs), USB charging downstream ports (CDPs), or dedicated charger ports (DCPs), and controls an external lithium-ion (Li+) battery charger.

The MAX14578E features I<sup>2</sup>C communication, while the MAX14578AE features an  $\overline{\text{EN}}$  pin and an LDO output pin.

The internal USB switch is compliant to Hi-Speed USB, full-speed USB, and low-speed USB signals. Both devices feature low on-resistance, low on-resistance flatness, and very low capacitance.

### Input Sources and Routing

The typical Micro/Mini-USB connector has five signal lines: USB power, two USB signal lines (D-, D+), ID line, and ground. The USB power on the Micro/Mini-USB connector connects to V<sub>B</sub> on the MAX14578E/MAX14578AE. The two USB signal lines, D- and D+, connect to CD- and CD+.

### USB (CD-, CD+)

The MAX14578E/MAX14578AE support Hi-Speed (480Mbps), full-speed (12Mbps), and low-speed USB (1.5Mbps) signal levels. The USB channel is bidirectional and has low 3.3 $\Omega$  (typ) on-resistance and 4.5pF (typ) on-capacitance. The low on-resistance is stable as the analog input signals are swept from ground to V<sub>SWPOS</sub> for low signal distortion.

### LOUT LDO Output (MAX14578AE Only)

The LOUT LDO provides a 5.3V (typ) output, used to power a USB transceiver. Most USB transceivers are powered from a 3.3V or higher voltage that is difficult to derive from a Li+ battery. One solution is to power the transceivers from the USB V<sub>BUS</sub> power; however, V<sub>BUS</sub> can rise as high as +28V in a fault condition. The LOUT pin provides a voltage-limited supply that protects the USB transceiver from these high voltages. When V<sub>BUS</sub> rises above 9.0V (typ), the MAX14578AE detects an overvoltage fault and LOUT goes to 0V. Additionally,

LOUT features a 100mA (typ) current limit to protect the device in the event of a short circuit.

### Interrupts

The MAX14578E generates an interrupt for any change in VBCOMP, and when DBCHG or DCD\_T transitions from 0 to 1. The INTEN bit in the CONTROL 1 register (0x01) enables interrupt output. When INTEN is set to zero, all interrupts are masked but not cleared. A read to the INTERRUPT register (0x02) is required to clear interrupts.

### Detection Debounce

To avoid multiple interrupts at the insertion of an accessory and for added noise/disturbance protection, a 30ms (typ) debounce timer is present that requires an inserted or removed state hold for the debounce time before it sends an interrupt.

### Low-Power Modes

The MAX14578E has two I<sup>2</sup>C bits in the CONTROL 1 register (0x01) dedicated to low-power operation: LOW\_POW and CP\_ENA.

LOW\_POW sets low-power mode. In low-power mode, the internal oscillator is turned off under the following conditions: no V<sub>BUS</sub>, USBSWC = 0, and CP\_ENA = 0. When enabled, all switches are high impedance (note that no negative rail voltage can be applied).

CP\_ENA controls the charge pump required for proper operation of the analog switches. When set to disable, no negative rail voltage can be applied. A factory default sets CP\_ENA = 0 automatically.

### USB Charger Detection

The MAX14578E includes internal logic to detect if a valid USB charger is connected. When a valid V<sub>BUS</sub> voltage is applied to V<sub>B</sub> or when CHG\_TYP\_M in the CONTROL 1 register is set to 1, the MAX14578E/MAX14578AE begin the charger-type-detection sequence (see Figure 1). During the charger-type-detection sequence, the CD- and CD+ switches are open, and once the sequence completes, the switches return to their previous state. Figure 2 shows a timing diagram for an example charger-type-detection sequence.

# USB Battery Charger Detectors

MAX14578E/MAX14578AE

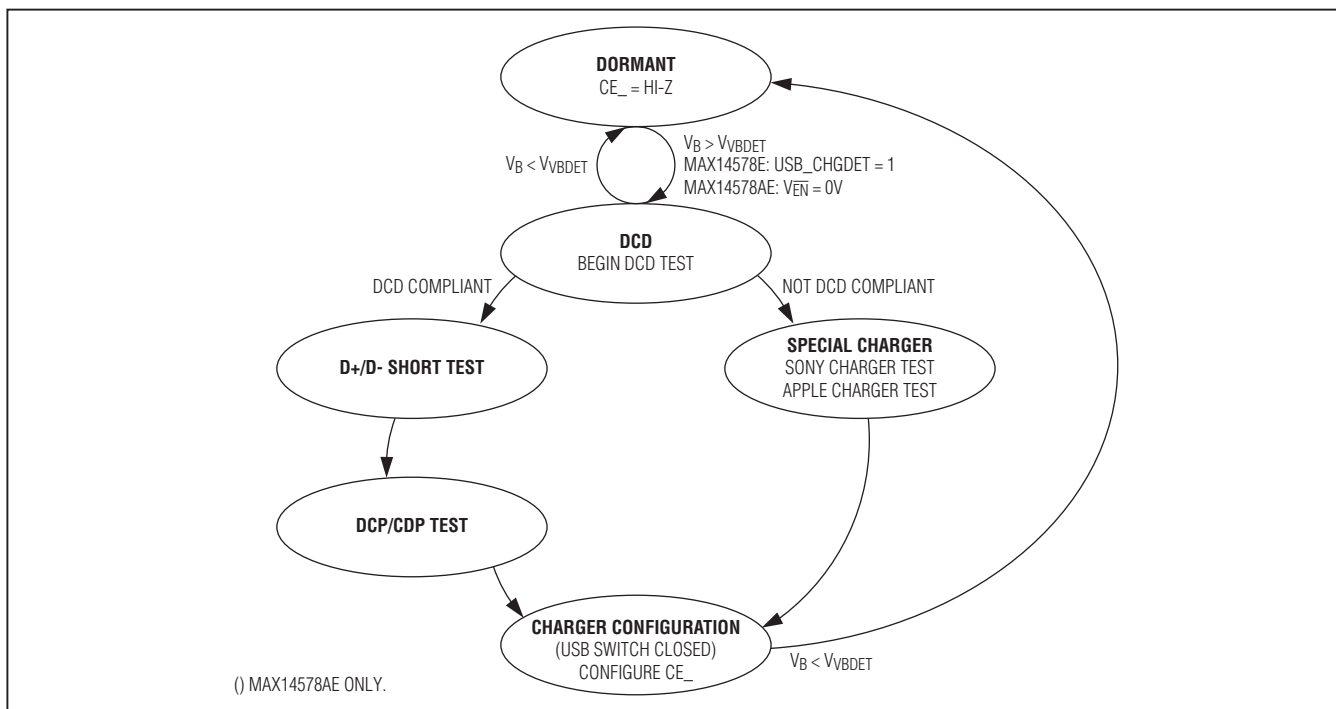


Figure 1. Charger-Type-Detection Sequence

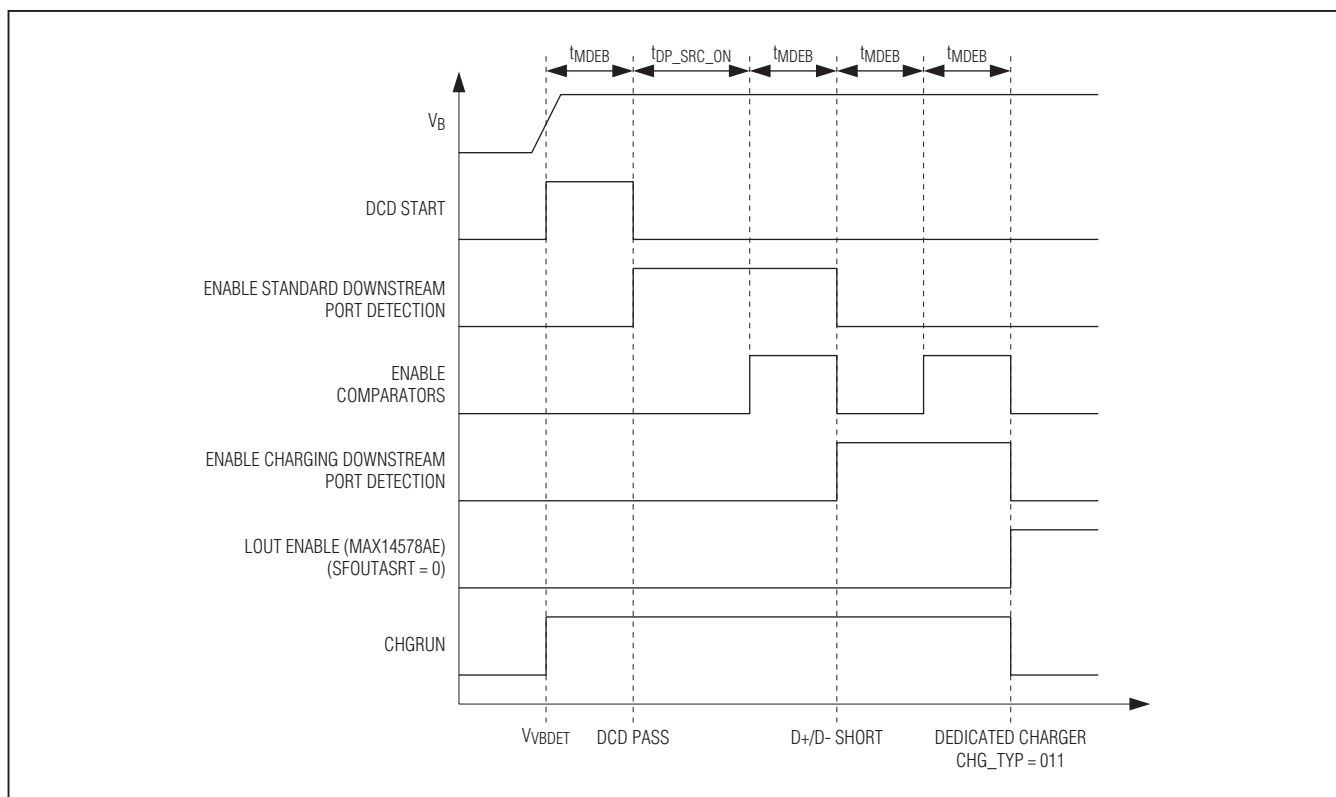


Figure 2. Charger-Detection Timing

# USB Battery Charger Detectors

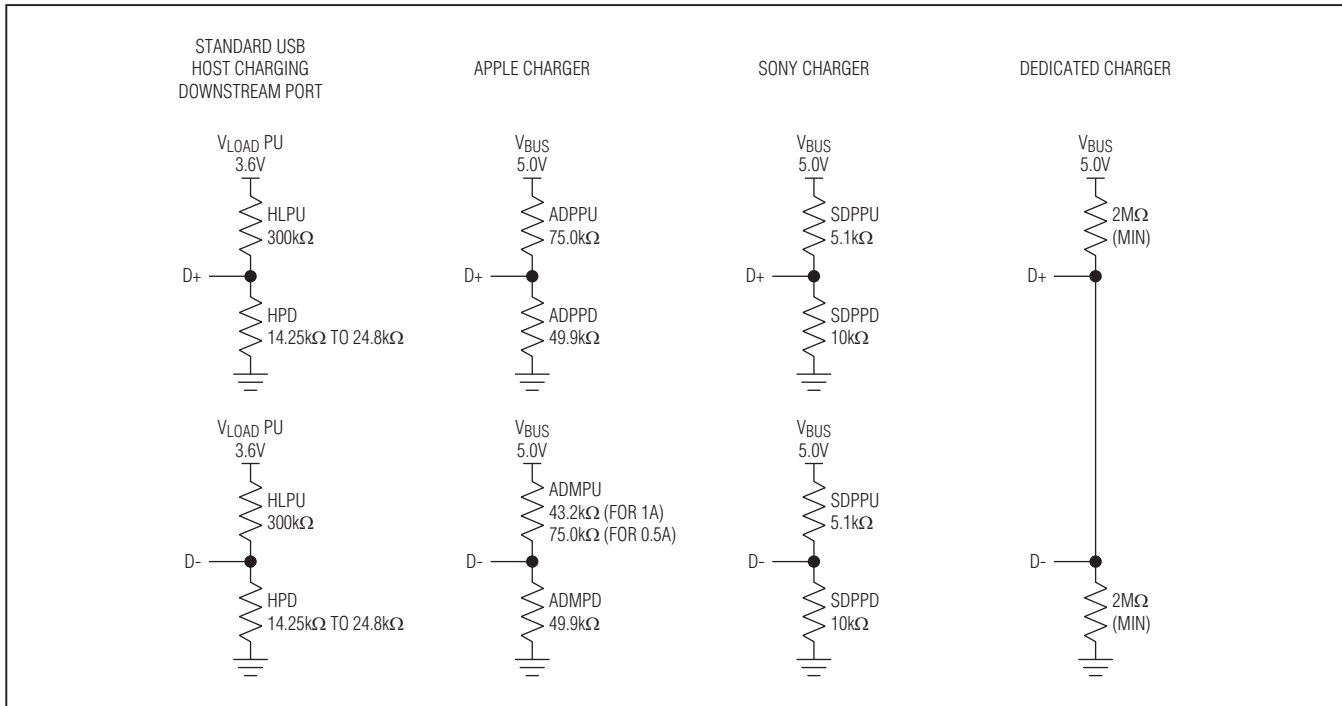


Figure 3. Standard USB Host/Charging Downstream Port, Apple Charger, Sony Charger, and Dedicated Charger

Figure 3 shows D+/D- terminations for a standard USB host/charging downstream port, an Apple charger, a Sony charger, and a dedicated charger.

### Charger-Enable Control Outputs

The MAX14578E/MAX14578AE feature digital open-drain outputs—CE0 (MAX14578AE only), CE1, and CE2—to control an external charger autonomously. See Table 3.

Table 3. Charger-Enable Control Outputs

SUS_LOW	EN	CHG_TYP	USB_CPL	CE2	CE1	CE0
0	1	X	X	1	1	1
1	1	X	X	0	0	1
0	0	000	X	1	1	1
1	0	000	X	0	0	1
0	0	110	X	1	1	1
1	0	110	X	0	0	1
X	0	001	0	1	0	0
0	0	001	1	1	1	1
1	0	001	1	0	0	1
X	0	010	X	0	1	0
X	0	011	X	0	1	0
X	0	100	X	1	0	0
X	0	101	X	0	1	0
X	0	111	X	0	0	0

Note: When CE\_FRC = 1, CE[2:0] are set by an I<sup>2</sup>C command.

X = Don't care.



# USB Battery Charger Detectors

MAX14578E/MAX14578AE

## I<sup>2</sup>C Serial Interface (MAX14578E)

### Serial Addressing

The MAX14578E operates as a slave device that sends and receives data through an I<sup>2</sup>C-compatible 2-wire interface. The interface uses a serial-data line (SDA) and a serial-clock line (SCL) to achieve bidirectional communication between master(s) and slave(s). A master (typically a microcontroller) initiates all data transfers to and from the MAX14578E and generates the SCL clock that synchronizes the data transfer. The SDA line operates as both an input and an open-drain output. A pullup resistor is required on SDA. The SCL line operates only as an input. A pullup resistor is required on SCL if there are multiple masters on the 2-wire interface, or if the master

in a single-master system has an open-drain SCL output. Each transmission consists of a START condition (Figure 4) sent by a master, followed by the MAX14578E 7-bit slave address plus a R/W bit, a register address byte, one or more data bytes, and finally a STOP condition.

### START and STOP Conditions

Both SCL and SDA remain high when the interface is not busy. A master signals the beginning of a transmission with a START (S) condition by transitioning SDA from high to low while SCL is high (see Figure 5). When the master has finished communicating with the slave, it issues a STOP (P) condition by transitioning SDA from low to high while SCL is high. The bus is then free for another transmission.

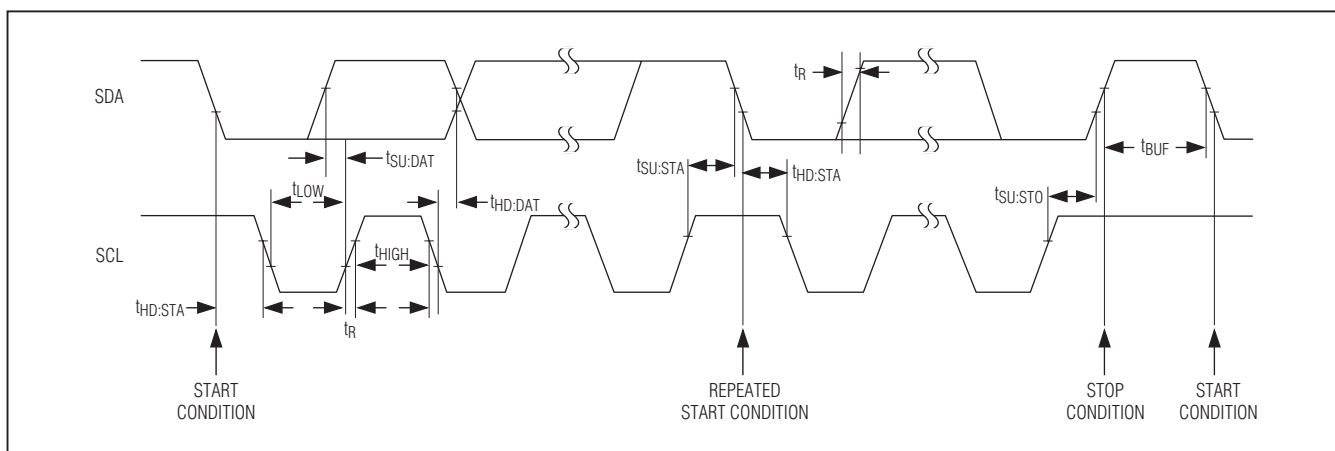


Figure 4. I<sup>2</sup>C Interface Timing Details

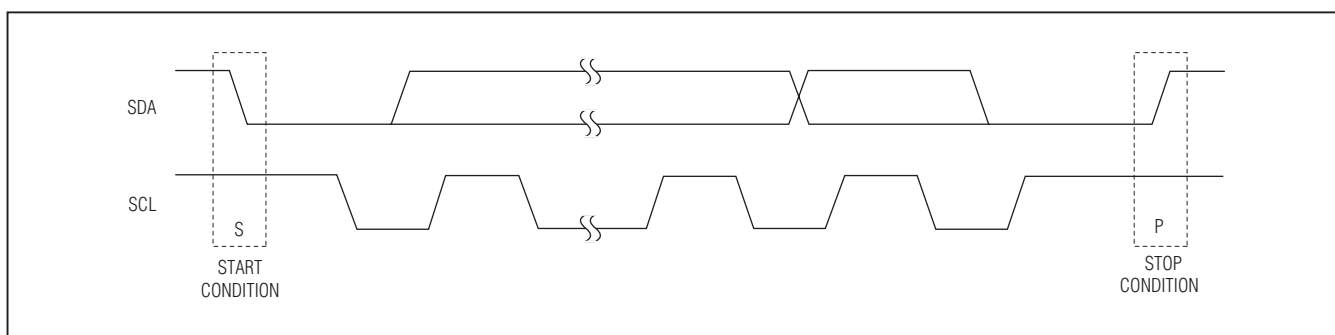


Figure 5. START and STOP Conditions

# USB Battery Charger Detectors

## Bit Transfer

One data bit is transferred during each clock pulse (Figure 6). The data on SDA must remain stable while SCL is high.

## Acknowledge

The acknowledge bit is a clocked 9th bit that the recipient uses to handshake receipt of each byte of data (Figure 7). Thus, each byte transferred effectively requires nine bits. The master generates the 9th clock pulse, and the recipient pulls down SDA during the acknowledge clock pulse. The SDA line is stable low during the high period of the clock pulse. When the master is transmitting to the MAX14578E, it generates the acknowledge bit because the MAX14578E is the

recipient. When the MAX14578E is transmitting to the master, the master generates the acknowledge bit because the master is the recipient.

## Slave Address

The MAX14578E has a 7-bit long slave address. The bit following a 7-bit slave address is the  $R/\bar{W}$  bit, which is low for a write command and high for a read command. The slave address is 01011001 for read commands and 01011000 for write commands. See Figure 8.

## Bus Reset

The MAX14578E resets the bus with the I<sup>2</sup>C START condition for reads. When the  $R/\bar{W}$  bit is set to 1, the MAX14578E transmits data to the master, thus the master is reading from the device.

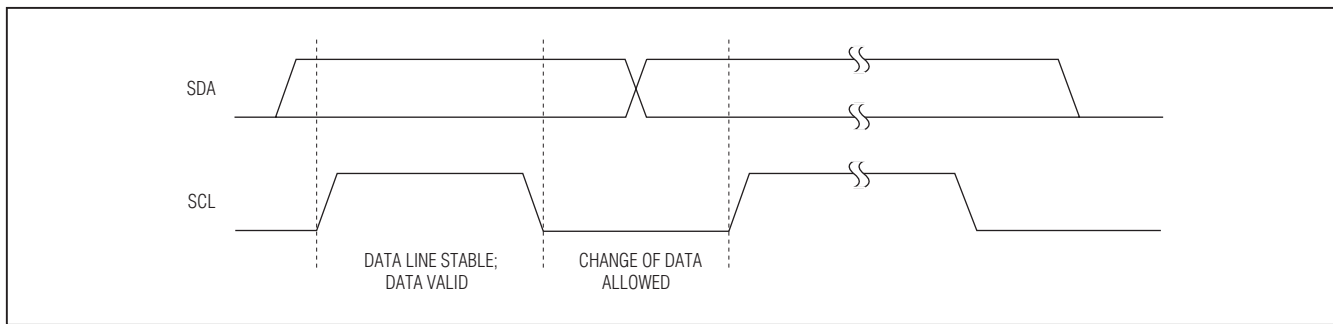


Figure 6. Bit Transfer

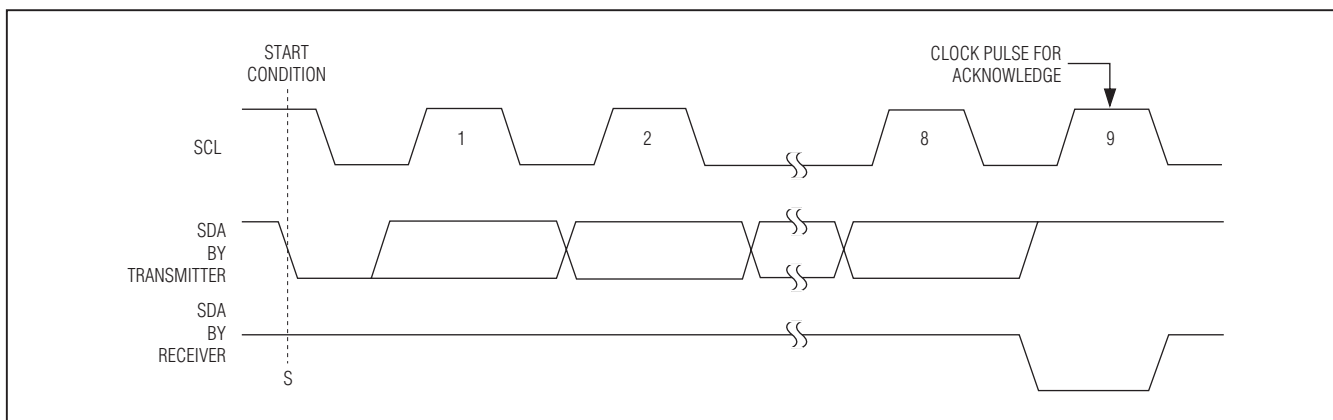


Figure 7. Acknowledge

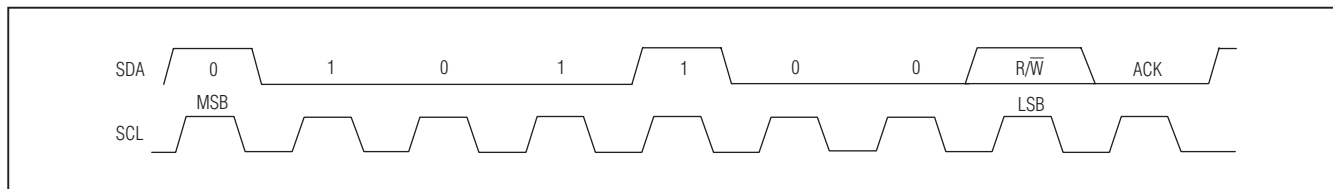


Figure 8. Slave Address

# USB Battery Charger Detectors

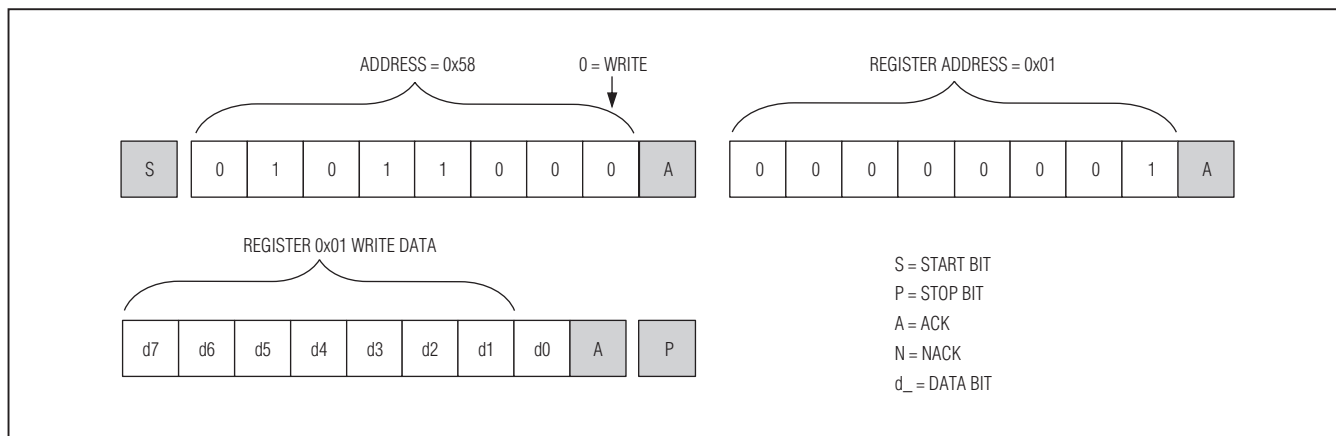


Figure 9. Format for I<sup>2</sup>C Write



Figure 10. Format for Writing to Multiple Registers

### Format for Writing

A write to the MAX14578E comprises the transmission of the slave address with the  $\overline{R/W}$  bit set to zero, followed by at least one byte of information. The first byte of information is the register address or command byte. The register address determines which register of the MAX14578E is to be written by the next byte, if received. If a STOP (P) condition is detected after the register address is received, the MAX14578E takes no further action beyond storing the register address (Figure 9). Any bytes received after the register address are data bytes. The first data byte goes into the register selected by the register address, and subsequent data bytes go into subsequent registers (Figure 10). If multiple data bytes are transmitted before a STOP condition, these

bytes are stored in subsequent registers because the register addresses autoincrements.

### Format for Reading

The MAX14578E is read using the internally stored register address as an address pointer, the same way the stored register address is used as an address pointer for a write. The pointer autoincrements after each data byte is read using the same rules as for a write. Thus, a read is initiated by first configuring the register address by performing a write (Figure 11). The master can now read consecutive bytes from the MAX14578E, with the first data byte being read from the register address pointed by the previously written register address. Once the master sends a NACK, the MAX14578E stops sending valid data.

# USB Battery Charger Detectors

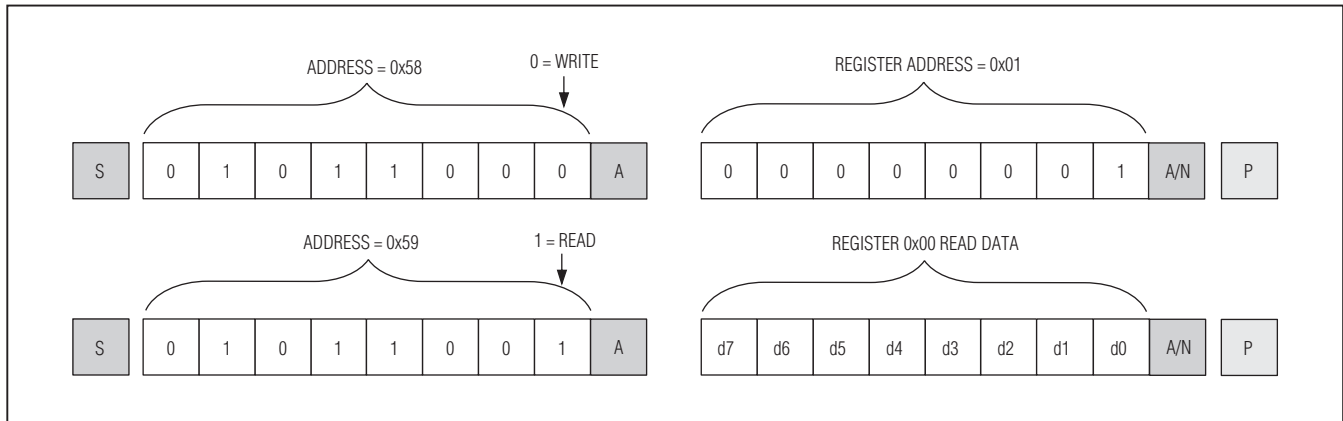


Figure 11. Format for Reads (Repeated START)

Table 4. CE\_ Outputs for Different Charger Control

	CE_ OUTPUTS	OFF	100mA	500mA	ISET	MAX8606, MAX8856	MAX8814, MAX8845
SUS_LOW = 0	(CE0)	1	0	0	0	—	EN
	CE1	1	0	0	1	EN1	—
	CE2	1	0	1	0	EN2	—
SUS_LOW = 1	CE_ OUTPUTS	OFF	100mA	500mA	ISET	MAX8934, MAX8677	MAX8903
	(CE0)	1	0	0	0	USUS	USUS
	CE1	0	0	0	1	PEN1	DCM
	CE2	0	0	1	0	PEN2	IUSB

() MAX14578AE only.

## Applications Information

### Charger Control

The MAX14578E charger-enable control outputs are ideal for autonomous external charger control. Table 4 shows example connections for various Maxim chargers.

### Hi-Speed USB

Hi-Speed USB requires careful PCB layout with 45Ω single-ended/90Ω differential controlled-impedance matched traces of equal lengths.

### Power-Supply Bypassing

Bypass V<sub>B</sub> and BAT with 1μF ceramic capacitors to GND as close as possible to the device.

### Choosing I<sup>2</sup>C Pullup Resistors

I<sup>2</sup>C requires pullup resistors to provide a logic-high level to data and clock lines. There are trade-offs between power dissipation and speed, and a compromise must

be made in choosing pullup resistor values. Every device connected to the bus introduces some capacitance even when device is not in operation. I<sup>2</sup>C specifies 300ns rise times to go from low to high (30% to 70%) for fast-mode, which is defined for a clock frequency up to 400kHz (see the *I<sup>2</sup>C Serial Interface (MAX14578E)* section for details).

To meet the rise time requirement, choose pullup resistors so that  $t_R = 0.85 \times R_{PULLUP} \times C_{BUS} < 300ns$ . If the transition time becomes too slow, the setup and hold times may not be met and waveforms may not be recognized.

### Extended ESD Protection

ESD-protection structures are incorporated on all pins to protect against electrostatic discharges up to ±2kV (Human Body Model) encountered during handling and assembly. The CD- and CD+ pins are further protected against ESD up to ±15kV (Human Body Model) and ±8kV IEC 61000-4-2 Contact Discharge without damage.

# USB Battery Charger Detectors

MAX14578E/MAX14578AE

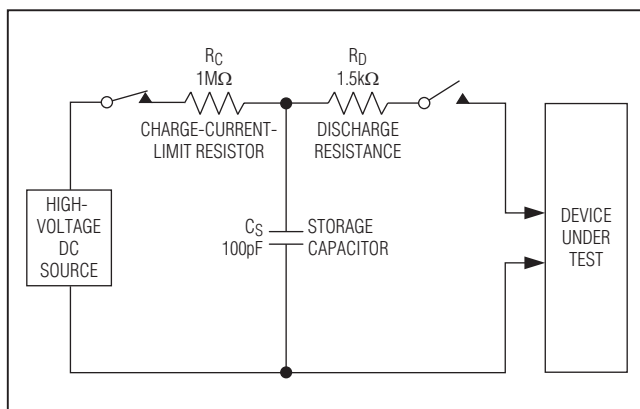


Figure 12. Human Body ESD Test Model

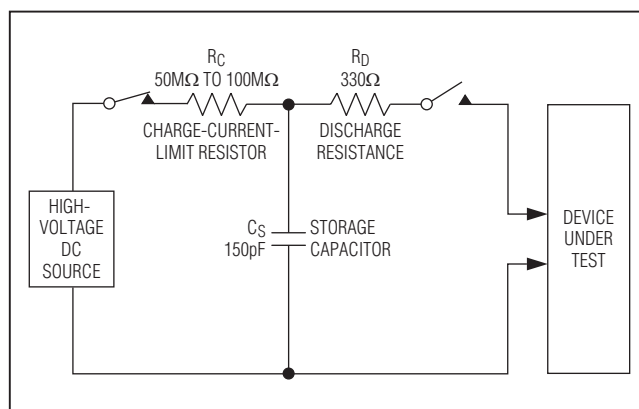


Figure 14. IEC 61000-4-2 ESD Test Model

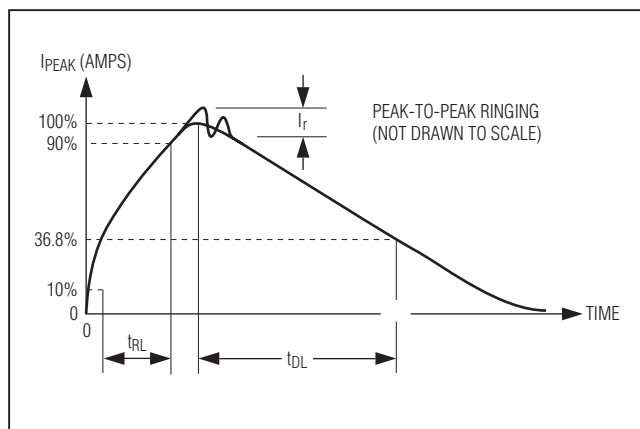


Figure 13. Human Body Current Waveform

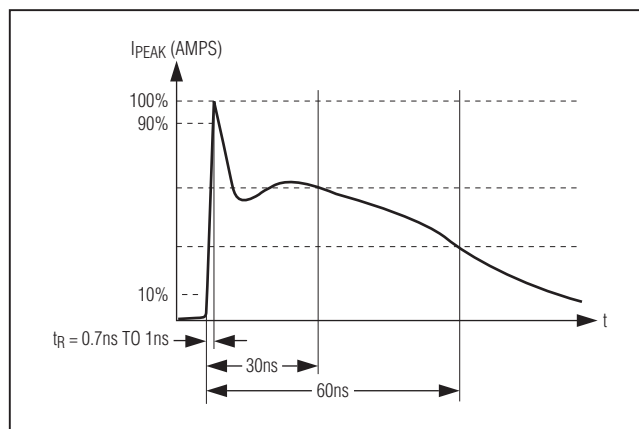


Figure 15. IEC 61000-4-2 ESD Generator Current Waveform

The  $V_B$  input withstands up to  $\pm 15\text{kV}$  (HBM) if bypassed with a  $1\mu\text{F}$  ceramic capacitor close to the pin. The ESD structures withstand high ESD both in normal operation and when the devices are powered down. After an ESD event, the MAX14578E/MAX14578AE continue to function without latchup.

### ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test setup, test methodology, and test results.

### Human Body Model

Figure 12 shows the Human Body Model, and Figure 13 shows the current waveform it generates when discharged into a low-impedance state. This model consists of a  $100\text{pF}$  capacitor charged to the ESD voltage of interest that is then discharged into the device through a  $1.5\text{k}\Omega$  resistor.

### IEC 61000-4-2

The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment. However, it does not specifically refer to integrated circuits. The MAX14578E/MAX14578AE assist in designing equipment to meet IEC 61000-4-2 without the need for additional ESD-protection components.

The major difference between tests done using the Human Body Model and IEC 61000-4-2 is higher peak current in IEC 61000-4-2, because series resistance is lower in the IEC 61000-4-2 model. Hence, the ESD withstand voltage measured to IEC 61000-4-2 is generally lower than that measured using the Human Body Model. Figure 14 shows the IEC 61000-4-2 model, and Figure 15 shows the current waveform for IEC 61000-4-2 ESD Contact Discharge test.

# USB Battery Charger Detectors

## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns (footprints), go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	OUTLINE NO.	LAND PATTERN NO.
12 WLP	W121A1+1	<a href="#">21-0449</a>	Refer to <a href="#">Application Note 1891</a>
16 TQFN	T1633+5	<a href="#">21-0136</a>	<a href="#">90-0032</a>

# USB Battery Charger Detectors

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	3/11	Initial release	—
1	2/12	Added TQFN package, corrected <i>MAX14578E Functional Diagram/Typical Operating Circuit</i> , and corrected default values for MAX14578AE in Table 2	1, 2, 8, 9, 13, 22

**MAX14578E/MAX14578AE**

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**Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600** \_\_\_\_\_ **23**