

MAX14578E/MAX14578AE

USB Battery Charger Detectors

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. 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 12-bump, 0.4mm pitch, 1.3mm x 1.68mm WLP and 16-pin TQFN packages and operate over the -40°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
- ◆ 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 6100-4-2 Contact Discharge

Applications

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

Ordering Information/Selector Guide

| PART | I ² C | $\overline{\text{EN}}$ | LDO | TEMP RANGE | PIN-PACKAGE | TOP MARK |
|------------------|------------------|------------------------|-----|--|-------------|----------|
| MAX14578EWC+T | Yes | No | No | -40°C to $+85^{\circ}\text{C}$ | 12 WLP | +ABW |
| MAX14578AECWC+T | No | Yes | Yes | -40°C to $+85^{\circ}\text{C}$ | 12 WLP | +ABX |
| MAX14578EETE+T | Yes | No | No | -40°C to $+85^{\circ}\text{C}$ | 16 TQFN | AJA |
| MAX14578AEEETE+T | No | Yes | Yes | -40°C to $+85^{\circ}\text{C}$ | 16 TQFN | AJB |

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

*EP = Exposed Pad

T = Tape and reel.

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ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)

BAT, INT, SDA, SCL, CE0, CE1, CE2, EN -0.3V to +6.0V
 LOUT -0.3V to (VB + 0.3V, 6V) (min)
 VB -0.3V to +30V
 Switch Disabled or CP_ENA = 1 (Note 1)
 CD+, CD- -2.1V to (VSWPOS + 0.3V)
 TD+, TD- -0.3V to (VSWPOS + 0.3V)
 Switch Enabled or CP_ENA = 0 (Note 2)
 CD+, CD-, TD+, TD- -0.3V to (VCCINT + 0.3V)

Continuous Current into LOUT ±150mA
 Continuous Current into Any Other Terminal ±50mA
 Continuous Power Dissipation (TA = +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: VSWPOS = (VCCINT or 3.3V) (min)

Note 2: VCCINT = (VBAT, [(VB 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

Junction-to-Ambient Thermal Resistance (θ_{JA}) 73°C/W

TQFN

Junction-to-Ambient Thermal Resistance (θ_{JA}) 48°C/W

Junction-to-Case Thermal Resistance (θ_{JC}) 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.maximintegrated.com/thermal-tutorial.

ELECTRICAL CHARACTERISTICS

(VBAT = +2.8V to +5.5V, VB = +3.5V to +5.5V, TA = -40°C to +85°C, unless otherwise noted. Typical values are at VBAT = +3.6V, VB = +5.0V, TA = +25°C.) (Note 4)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|------------------------------------|----------|----------------------|-------|-------|-------|-------|
| DC CHARACTERISTICS | | | | | | |
| Supply Voltage Range | VBAT | | 2.8 | | 5.5 | V |
| | VB | | 3.5 | | 28 | |
| Internal Positive Switch Regulator | VSWPOS | | 3.25 | 3.4 | 3.6 | V |
| Internal Negative Switch Regulator | VSWNEG | | -2.06 | -1.90 | -1.76 | V |
| VBAT UVLO | VBATUVLO | VBAT = 4.2V, VB = 0V | 0.90 | 1.65 | 2.45 | V |
| VBUS UVLO | VBUSUVLO | VBAT = 0V, VB = 5.5V | 1.0 | 1.33 | 3.30 | V |

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ELECTRICAL CHARACTERISTICS (continued)

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

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS | |
|---|--|---|--|------|------|-------|----|
| BAT Supply Current | I _{BAT} | MAX14578E | V _{BAT} = +3.6V, V _B = 0V, CP_ENA = 0, USBSWC = 0 | | 1 | 2.5 | μA |
| | | MAX14578E | V _{BAT} = +4.2V, V _B = 0V, CP_ENA = 1, USBSWC = 1, V _{SDA} = V _{SCL} = 1.8V | | 34.5 | 59 | |
| | | MAX14578AE | V _{BAT} = +3.6V, V _B < V _{BRAW} , V _{EN} = +3.6V | | 1 | 2.5 | |
| | | MAX14578AE | V _{BAT} = +4.2V, V _B = 0V, V _{EN} = 0V | | 1.3 | 30 | |
| | | MAX14578AE | Supply current increase when V _{EN} = 1.6V, V _{BAT} = +4.2V | | 1.3 | 3.5 | |
| V _B Supply Current | I _{VB} | MAX14578E | V _B = +5.5V, CP_ENA = 0, USBSWC = 0 | | 87 | 140 | μA |
| | | MAX14578AE | V _B = +5.5V, V _{EN} = 0V | | 190 | 295 | μA |
| | | | V _B = +5.0V, V _{EN} = 0V | | 4.1 | | mA |
| | | | V _B = +5.5V, V _{EN} = +5.5V | | 75 | 125 | μA |
| LOUT (LDO OUT) (MAX14578AE ONLY) | | | | | | | |
| LOUT Current Limit | I _{LOUT} | | | 95 | | mA | |
| LOUT Voltage | V _{LOUT} | I _{LOUT} = 10mA, V _B = 5.0V | 4.87 | 4.94 | | V | |
| | | I _{LOUT} = 0mA, V _B = 6.0V | 4.0 | 5.3 | 5.5 | | |
| LOUT Debounce Time | t _{LOUT_DEB} | V _B = 5.0V to V _{LOUT} = 4.5V | | 20 | | ms | |
| LOUT Turn-On Time | | | | 100 | | μs | |
| Thermal Shutdown | | | | +141 | | °C | |
| Thermal Shutdown Hysteresis | | | | 20 | | °C | |
| CHARGER DETECTION | | | | | | | |
| V _{DP_SRC} Voltage | V _{DP_SRC} | | 0.5 | | 0.7 | V | |
| V _{DAT_REF} Voltage | V _{DAT_REF} | | 0.25 | | 0.4 | V | |
| V _{LGC} Voltage | V _{LGC} | | 0.8 | | 2.0 | V | |
| I _{DP_SRC} Current | I _{DP_SRC} | | 6.6 | | 11 | μA | |
| CD+ and CD- Sink Current | I _{CD+_SINK} I _{CD-_SINK} | | 50 | | 150 | μA | |
| R _{CD} Resistance | R _{CD} | | 200 | 330 | 500 | kΩ | |
| TD+ Pulldown Resistor | RTD+_DWN | | 15 | 20 | 25 | kΩ | |

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ELECTRICAL CHARACTERISTICS (continued)

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

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|-------------------------------------|---|--------------------|------|---------------------|-------|
| TD- Pulldown Resistor | R _{TD-DWN} | | 14.25 | | 24.8 | kΩ |
| Charger Detection Weak Sink | I _{WEAK} | | | | 0.18 | μA |
| V _{BUS25} Ratio | V _{BUS25} | Reference ratio for special charger as a percentage of V _{BUS} voltage, V _B = 5V | 24 | 26 | 29 | % |
| V _{BUS47} Ratio | V _{BUS47} | Reference ratio for special charger as a percentage of V _{BUS} voltage, V _B = 5V | 44 | 47 | 50 | % |
| V _{BUS60} Ratio | V _{BUS60} | | 57.5 | 60.3 | 63.5 | % |
| DCD M Time | t _{MDEB} | All comparators | 20 | 30 | 40 | ms |
| DCD C Time | t _{CDEB} | All comparators | | | 5 | ms |
| DCD Timer | | | | 2 | | s |
| Charger-Detect Source Time | t _{DP_SRC_ON} | DCHK = 0 | | 40 | | ms |
| | | DCHK = 1 | | 625 | | |
| Charger-Detect-Type Detection Time | t _{DP_RES_ON} | | 120 | | | ms |
| Charger-Detect Delay Time | t _{DP_SRC_HICRNT} | | 40 | | 80 | ms |
| V _B Attach to CE1 and CE2 Output Time | t _{VBSW} | 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 | V _{VBRAW} | | 1.7 | 2.6 | 3.5 | V |
| V _B -Detect Threshold | V _{VBDET} | | 3.2 | 3.5 | 3.3 | V |
| V _B -Detect Threshold Hysteresis | V _{VBDET_HYS} | | 38 | 50 | | mV |
| USB ANALOG SWITCHES (CD-, CD+) | | | | | | |
| 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 _{ONUSB} | V _{BAT} = +3.0V, I _{CD+} = I _{CD-} = 10mA, V _{CD+} , V _{CD-} = 0 to +3.0V | | 3.3 | 6 | Ω |
| On-Resistance Match Between Channels | ΔR _{ONUSB} | V _{BAT} = +3.0V, I _{CD+} = I _{CD-} = 10mA, V _{CD+} , V _{CD-} = +400mV | | | 0.5 | Ω |
| On-Resistance Flatness | R _{FLATUSB} | V _{BAT} = +3.0V, I _{CD+} = I _{CD-} = 10mA, V _{CD+} , V _{CD-} = 0 to +3.3V | | 0.06 | 0.26 | Ω |
| Off-Leakage Current | I _{LUSB(OFF)} | 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 _{LUSB(ON)} | V _{BAT} = 4.2V, switch closed, V _{CD+} or V _{CD-} = +0.3V or +2.5V | -360 | | +360 | nA |
| DIGITAL SIGNALS (INT, SCL, SDA, EN, CE0, CE1, CE2) | | | | | | |
| Input Logic-High | V _{IH} | | 1.4 | | | V |
| Input Leakage Current | I _{INLEAK} | | -1 | | +1 | μA |
| Input Logic-Low | V _{IL} | | | | 0.4 | V |

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ELECTRICAL CHARACTERISTICS (continued)

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

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---------------------|---|-----------------------|------|-----|-------|
| Open-Drain Low | V _{ODL} | I _{SINK} = 1mA | | | 0.4 | V |
| Output Logic-High | V _{OH} | I _{SOURCE} = 1mA | V _{IO} - 0.2 | | | V |
| Output Logic-Low | V _{OL} | I _{SINK} = 1mA | | | 0.2 | V |
| DYNAMIC (Note 5) | | | | | | |
| 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 ² C STOP to switch on, R _L = 50Ω | | 0.1 | 1 | ms |
| Analog-Switch Turn-Off Time | t _{OFF} | MAX14578E, I ² C STOP to switch off, R _L = 50Ω | | 0.1 | 1 | ms |
| Break-Before-Make Delay Time | t _{BBM} | R _L = 50Ω, T _A = +25°C | > 0 | | | μs |
| Off-Capacitance | C _{OFF} | TD-, TD+, applied voltage is 0.5V _{P-P} , DC bias = 0V, f = 240MHz; CD-, CD+ not connected to TD-, TD+ | | 2 | | pF |
| On-Capacitance | C _{ON} | TD-, TD+, applied voltage is 0.5V _{P-P} , DC bias = 0V, f = 240MHz; CD-, CD+ connected to TD-, TD+; R _L = 50Ω | | 4.5 | | pF |
| -3dB Bandwidth | BW | V _{CD-} = 0.5V _{P-P} | | 1000 | | MHz |
| Off-Isolation | V _{ISO} | R _L = 50Ω, f = 20kHz, V _{CD-} = 0.5V _{P-P} | | -60 | | dB |
| I²C TIMING SPECIFICATIONS | | | | | | |
| I ² C Max Clock | f _{I2CCLK} | | | 400 | | kHz |
| Bus Free Time Between STOP and START Conditions | t _{BUF} | | 1.3 | | | μs |
| START Condition Setup Time | | | 0.6 | | | μs |
| Repeat START Condition Setup Time | t _{SU:STA} | 90% to 90% | 0.6 | | | μs |
| START Condition Hold Time | t _{HD:STA} | 10% of SDA to 90% of SCL | 0.6 | | | μs |
| STOP Condition Setup Time | t _{SU:STO} | 90% of SCL to 10% of SDA | 0.6 | | | μs |
| Clock Low Period | t _{LOW} | 10% to 10% | 1.3 | | | μs |
| Clock High Period | t _{HIGH} | 90% to 90% | 0.6 | | | μs |
| 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 |
| ESD PROTECTION | | | | | | |
| CD+, CD- | | Human Body Model | | ±15 | | kV |
| | | IEC 61000-4-2 Contact Discharge | | ±8 | | |

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

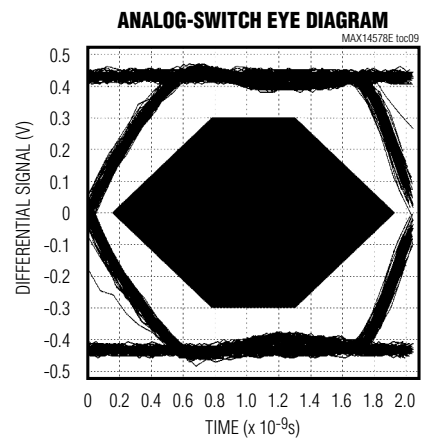
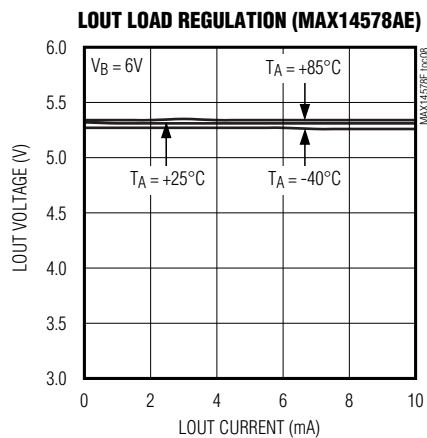
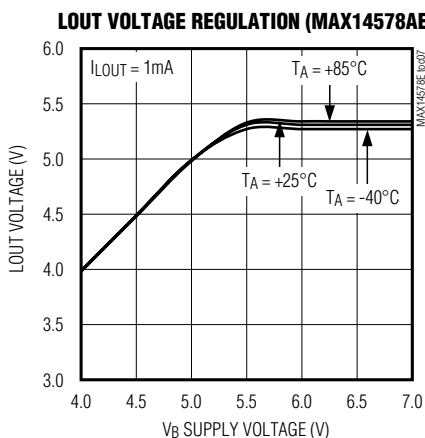
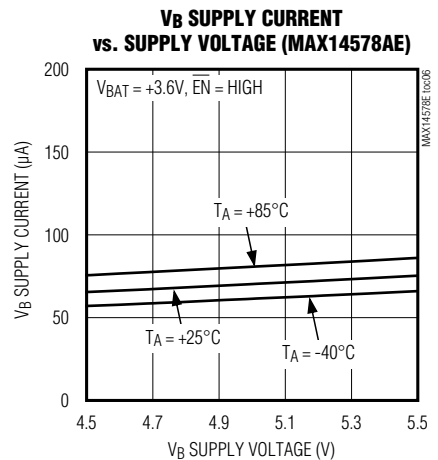
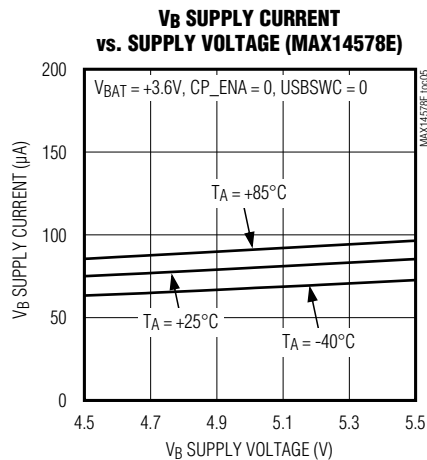
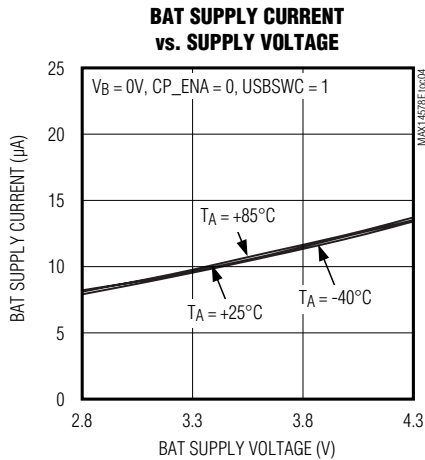
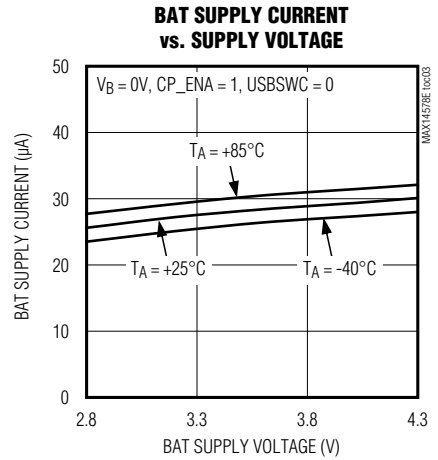
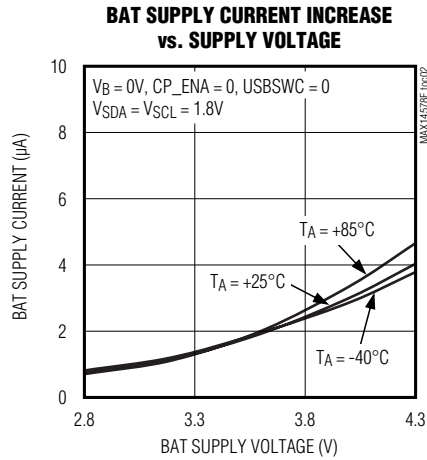
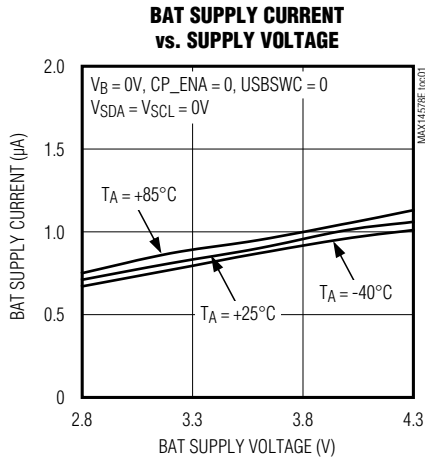
Note 5: Guaranteed by design; not production tested.

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Typical Operating Characteristics

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

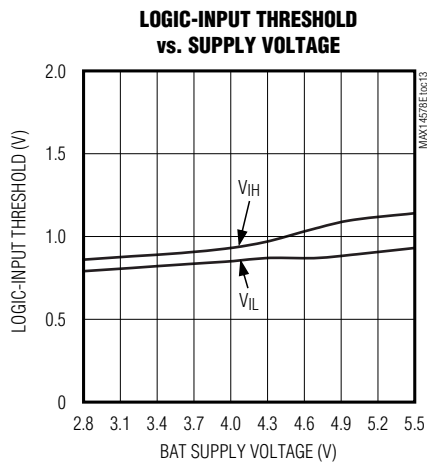
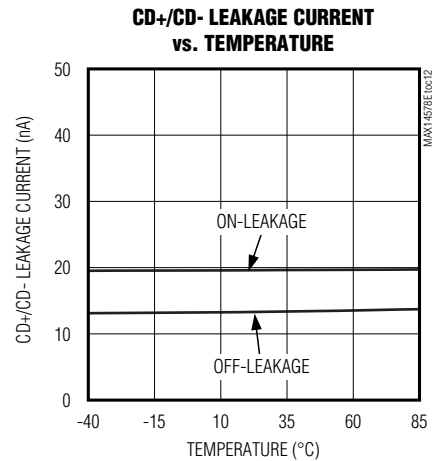
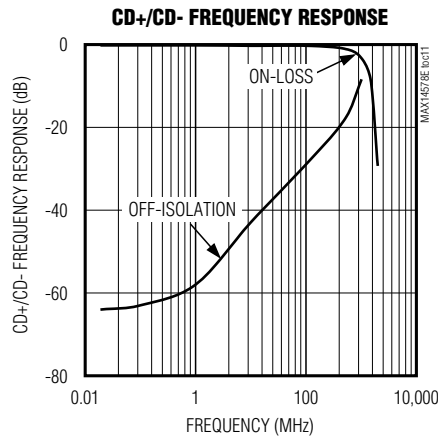
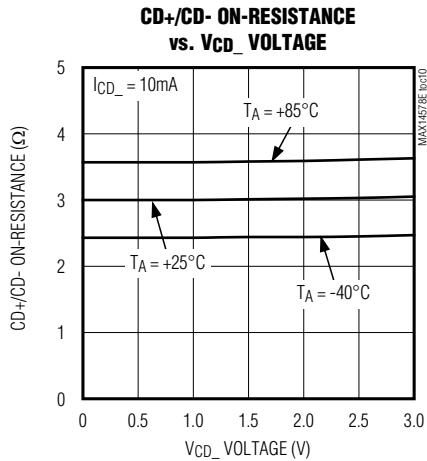


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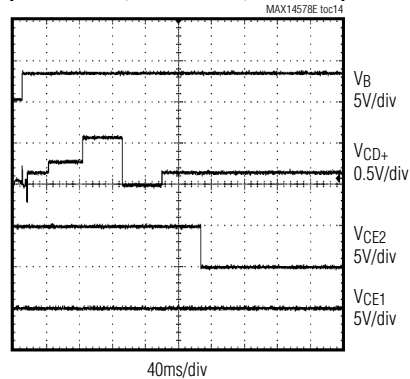
USB Battery Charger Detectors

Typical Operating Characteristics (continued)

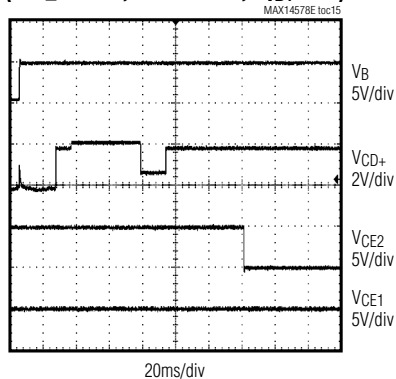
($V_{BAT} = +4.2V$, $V_B = +5.0V$, $C_{BAT} = 1\mu F$, $C_{VB} = 1\mu F$, unless otherwise noted.)



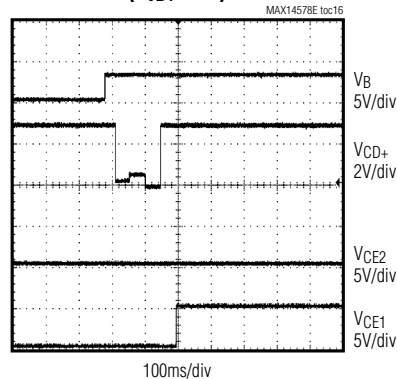
CE_ vs. V_{BUS} CONNECTION (MAX14578E)
USB CHARGING DOWNSTREAM PORT, USB COMPLIANT
($USB_CPL = 1$, $USBSWC = 0$, $V_{TD+} = 3V$)



CE_ vs. V_{BUS} CONNECTION (MAX14578E)
APPLE 1A CHARGER, USB COMPLIANT
($USB_CPL = 1$, $USBSWC = 0$, $V_{TD+} = 3V$)



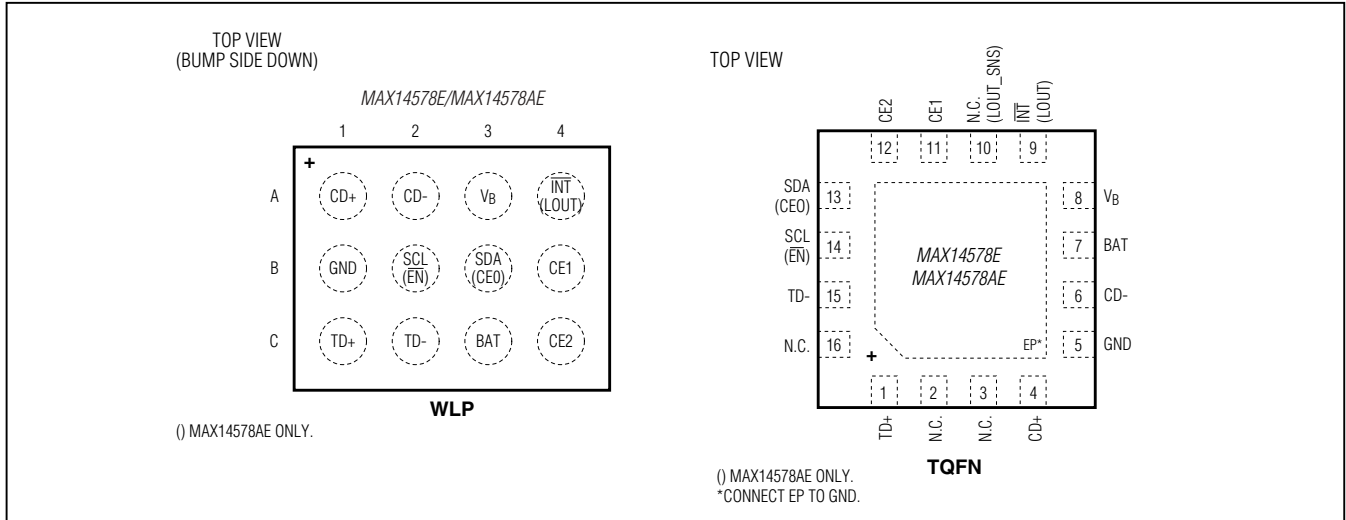
CE_ vs. V_{BUS} CONNECTION (MAX14578AE)
USB CHARGING DOWNSTREAM PORT
($V_{TD+} = 3V$)



MAX14578E/MAX14578AE

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Bump Configuration



Bump Description

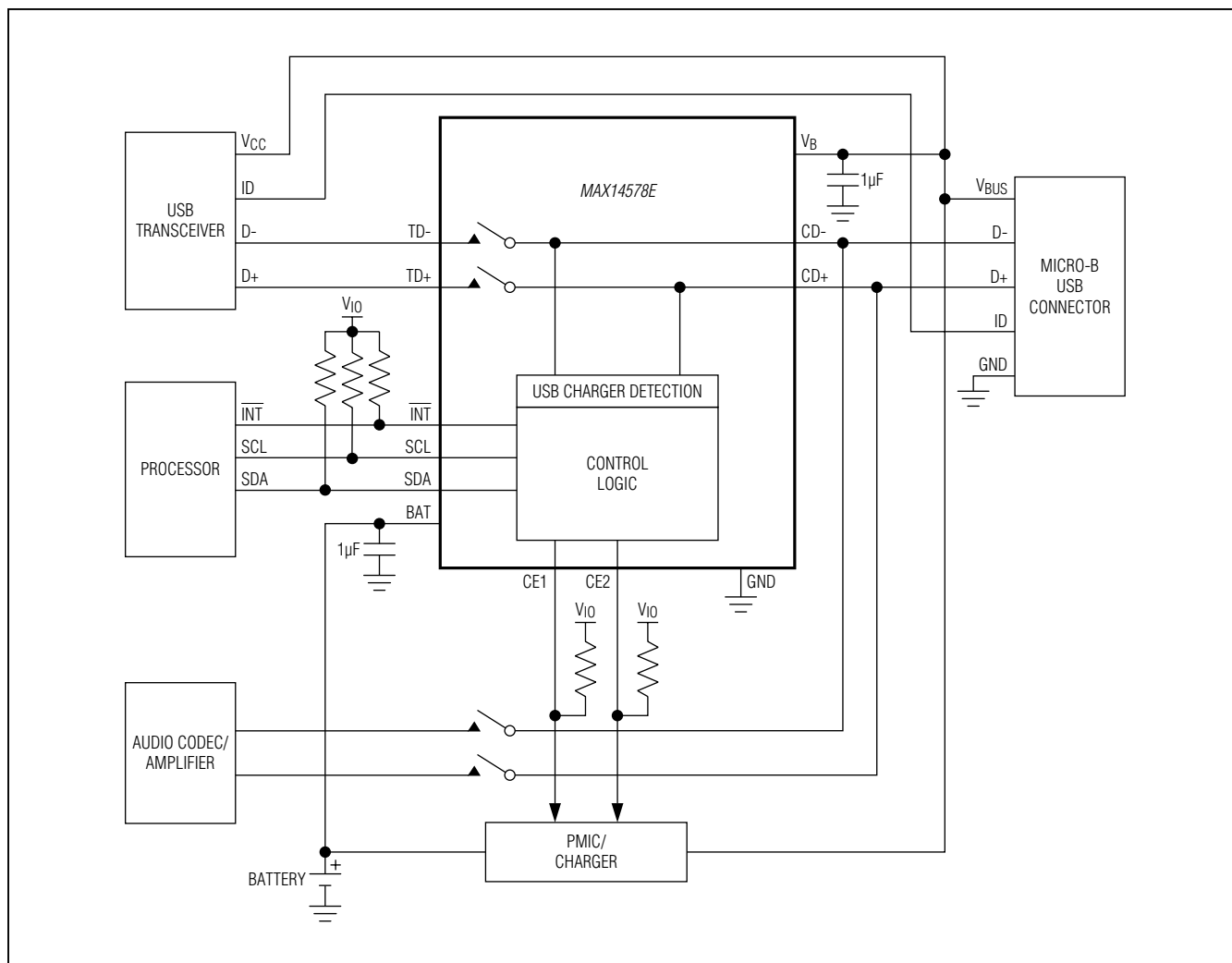
| PIN | | | | NAME | FUNCTION |
|--------------|-----|------------|-----|-------------------------|--|
| MAX14578E | | MAX14578AE | | | |
| TQFN-EP | WLP | TQFN-EP | WLP | | |
| 1 | C1 | 1 | C1 | TD+ | USB Transceiver D+ Connection |
| 2, 3, 10, 16 | — | 2, 3, 16 | — | N.C. | No Connection. Not internally 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 1 μ F capacitor as close as possible between BAT and GND. |
| 8 | A3 | 8 | A3 | VB | USB Connector VBUS Connection. Connect a 1 μ F capacitor as close as possible between VB and GND for \pm 15kV ESD protection. |
| 9 | A4 | — | — | $\overline{\text{INT}}$ | Active-Low Interrupt Request, Open-Drain Output |
| — | — | 9 | A4 | LOUT | +5.3V USB Transceiver VBUS Power Output. Connect a 1 μ F 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 ² C Serial-Data Input/Output. Connect SDA to an external pullup resistor. |
| — | — | 13 | B3 | CE0 | Charger-Enable Control 0, Open-Drain Output |
| — | — | 14 | B2 | $\overline{\text{EN}}$ | Active-Low Enable Input. Drive $\overline{\text{EN}}$ low to enable the charger ID detection and close the USB switches after charger detection is complete. |

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| PIN | | | | NAME | FUNCTION |
|-----------|-----|------------|-----|------|--|
| MAX14578E | | MAX14578AE | | | |
| TQFN-EP | WLP | TQFN-EP | WLP | | |
| 14 | B2 | — | — | SCL | I ² 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. |

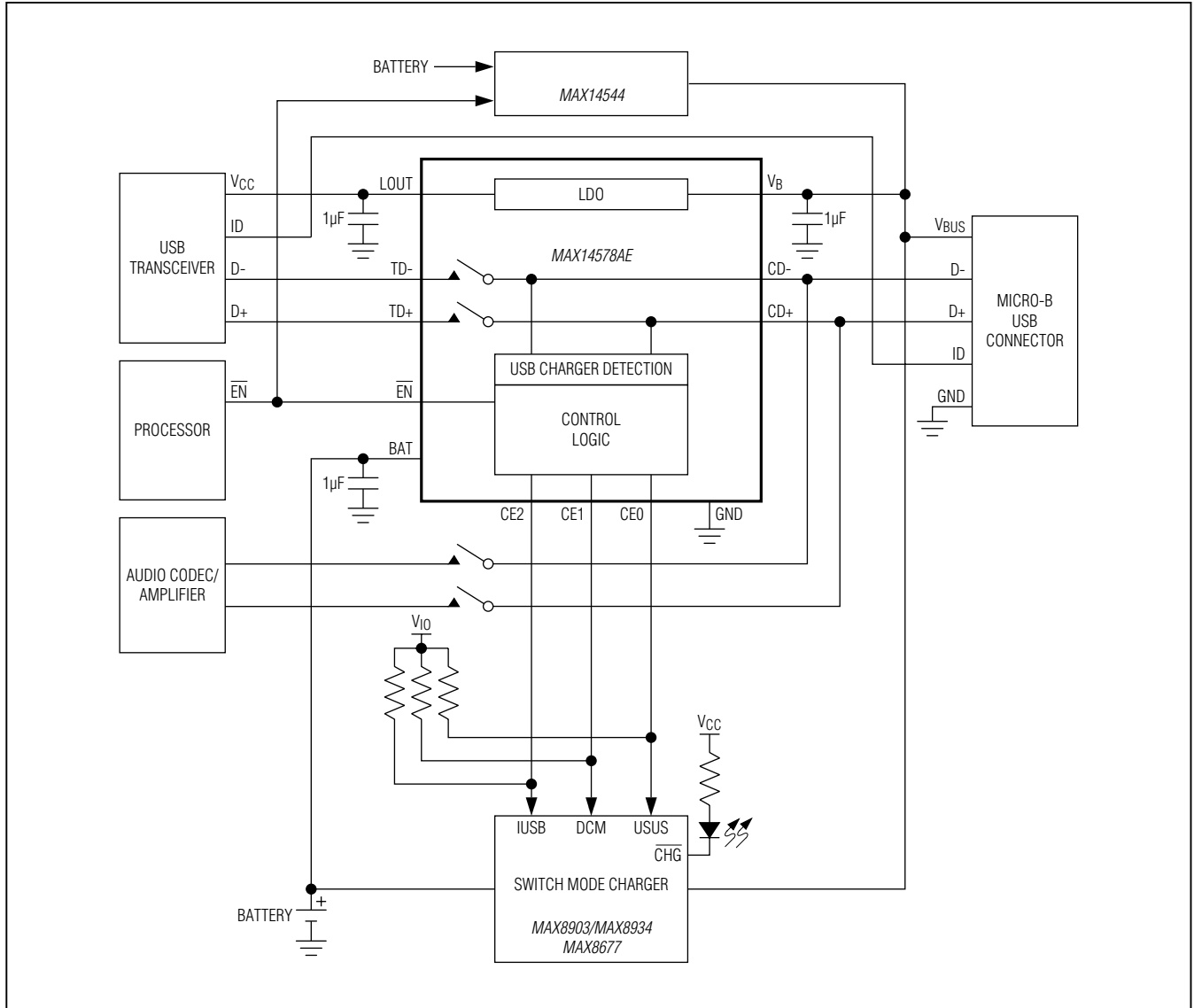
MAX14578E Functional Diagram/Typical Application Circuit



MAX14578E/MAX14578AE

USB Battery Charger Detectors

MAX14578AE Functional Diagram/Typical Application Circuit



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USB Battery Charger Detectors

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 | RFU | DCD_T | CHGRUN | RFU |
| 0x03 | CONTROL 2 | RFU | RFU | 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 |
|--|------------|-------|---------|--|
| DEVICE ID (I²C ADDRESS = 0x00) | | | | |
| VENDOR_ID | Read Only | [7:4] | 0010 | Vendor Identification |
| CHIP_REV | Read Only | [3:0] | 0001 | Chip Revision |
| CONTROL 1 (I²C ADDRESS = 0x01) | | | | |
| 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 V _{BUS} , USBSWC = 0, and CP_ENA = 0 |
| DCHK | Read/Write | 2 | 0 | Charger-Type Source-Detection Time 0 = DCHK, t _{DP_SRC_ON} = 40ms 1 = DCHK, t _{DP_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 |

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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 |
| INTERRUPT (I²C ADDRESS = 0x02) | | | | |
| 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 |
| VBCOMP | Read Only | 4 | 0 | Output of V_B Comparator. Changes in VBCOMP triggers interrupt. 0 = $V_B < V_{VBDET}$ 1 = $V_B \geq V_{VBDET}$ |
| RFU | Read Only | 3 | 0 | |
| 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 |
| CONTROL 2 (I²C ADDRESS = 0x03) | | | | |
| 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 |

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USB Battery Charger Detectors

Table 2. Detailed Register Map (continued)

| FIELD NAME | READ/WRITE | BIT | DEFAULT | DESCRIPTION |
|--|------------|-------|---------|---|
| RFU | Read/Write | 6 | 0 | |
| RFU | Read/Write | 5 | 0 | |
| 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 ² C command only. |
| CONTROL 3 (I²C ADDRESS = 0x04) | | | | |
| 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 _{BUS} 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.

MAX14578E/MAX14578AE

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 I²C 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_B 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 Ω (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_{SWPOS} 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_{BUS} power; however, V_{BUS} 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_{BUS} 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 V_BCOMP, 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 I²C 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_{BUS}, 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_{BUS} voltage is applied to V_B 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.

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USB Battery Charger Detectors

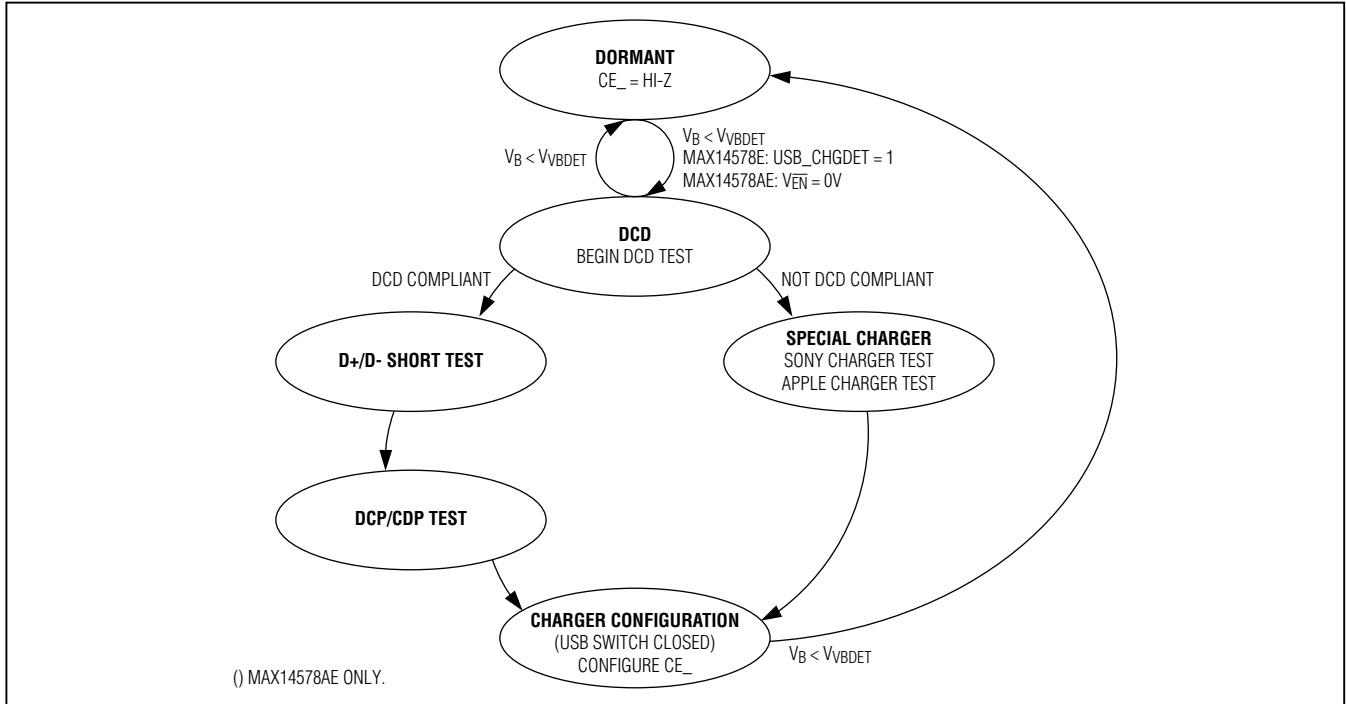


Figure 1. Charger-Type-Detection Sequence

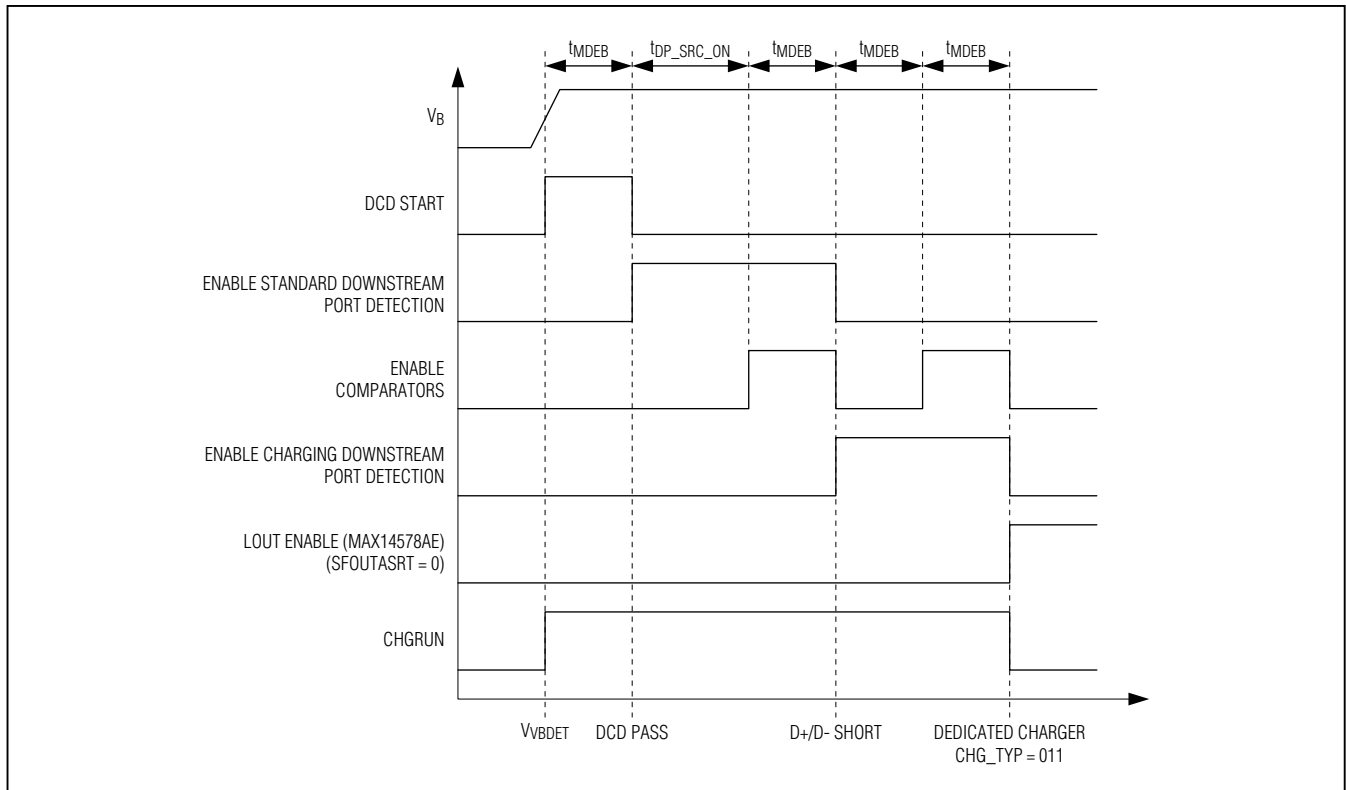


Figure 2. Charger-Detection Timing
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USB Battery Charger Detectors

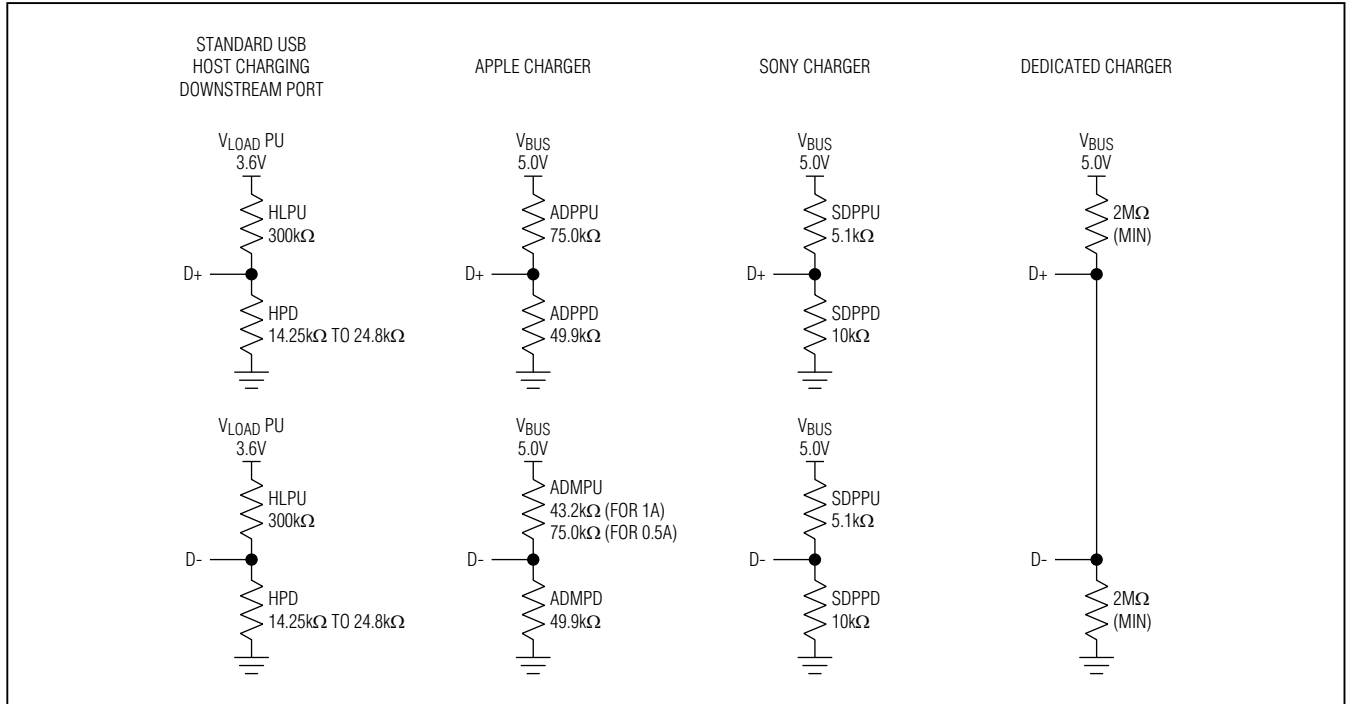


Figure 3. Standard USB Host/Charging Downstream Port, Apple Charger, Sony Charger, and Dedicated Charger

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 I²C command.

X = Don't care.

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USB Battery Charger Detectors

I²C Serial Interface (MAX14578E)

Serial Addressing

The MAX14578E operates as a slave device that sends and receives data through an I²C-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.

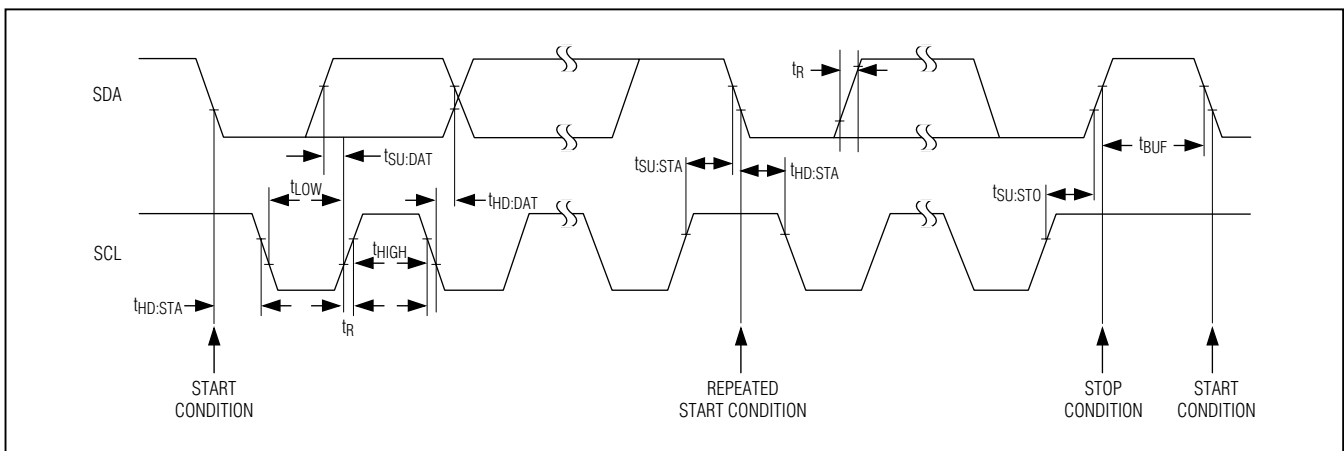


Figure 4. I²C Interface Timing Details

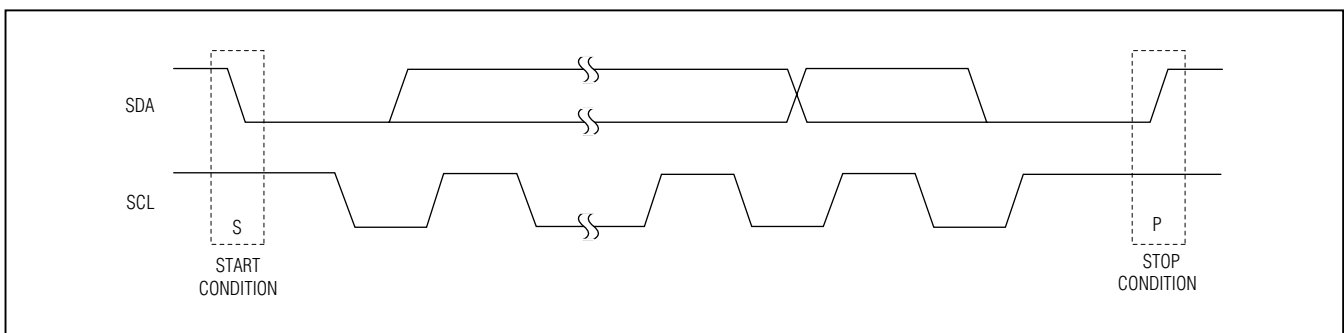


Figure 5. START and STOP Conditions

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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 I²C 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.

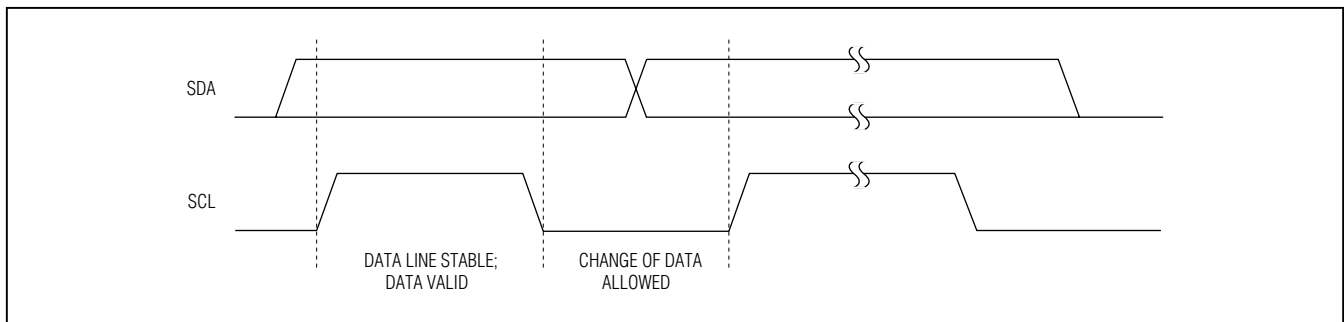


Figure 6. Bit Transfer

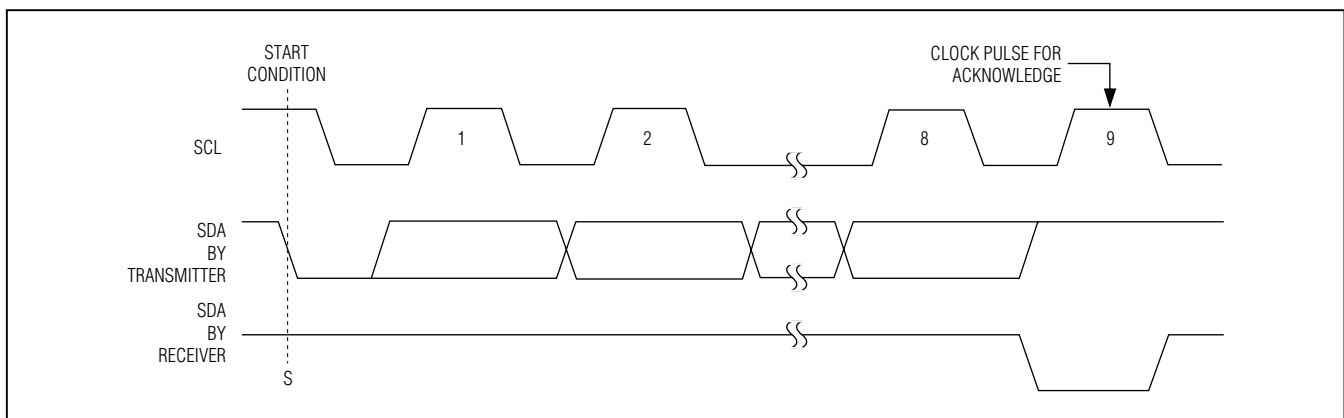


Figure 7. Acknowledge

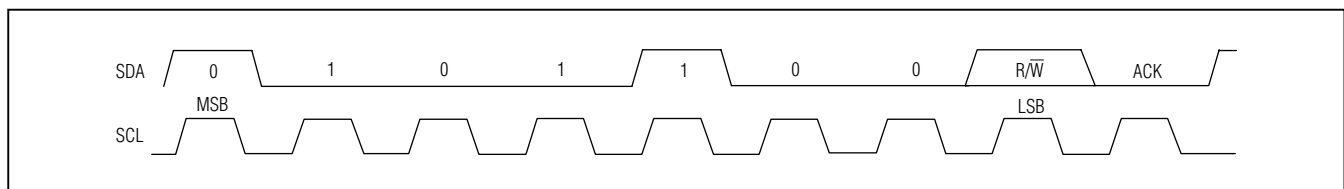


Figure 8. Slave Address

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USB Battery Charger Detectors

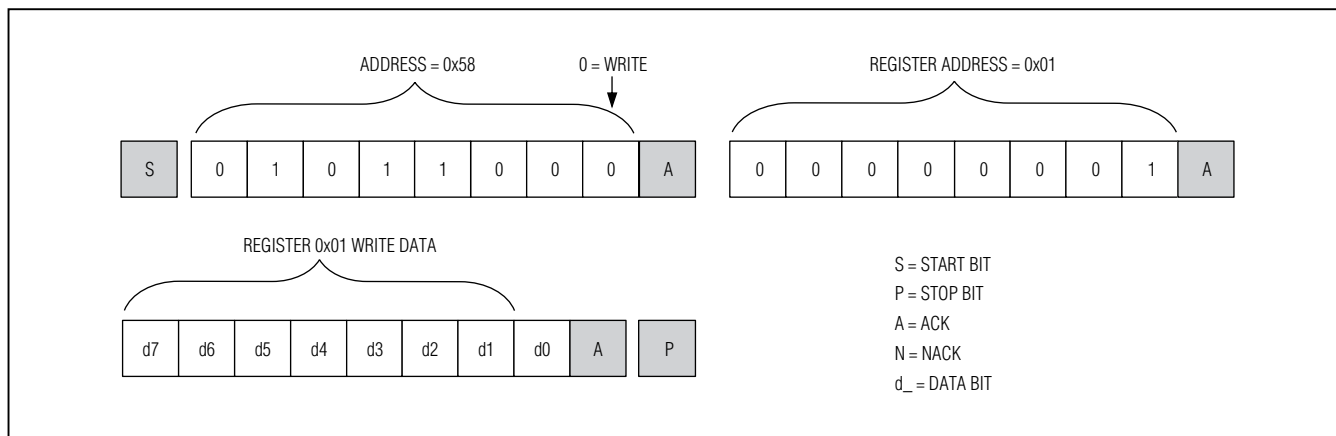


Figure 9. Format for I²C Write

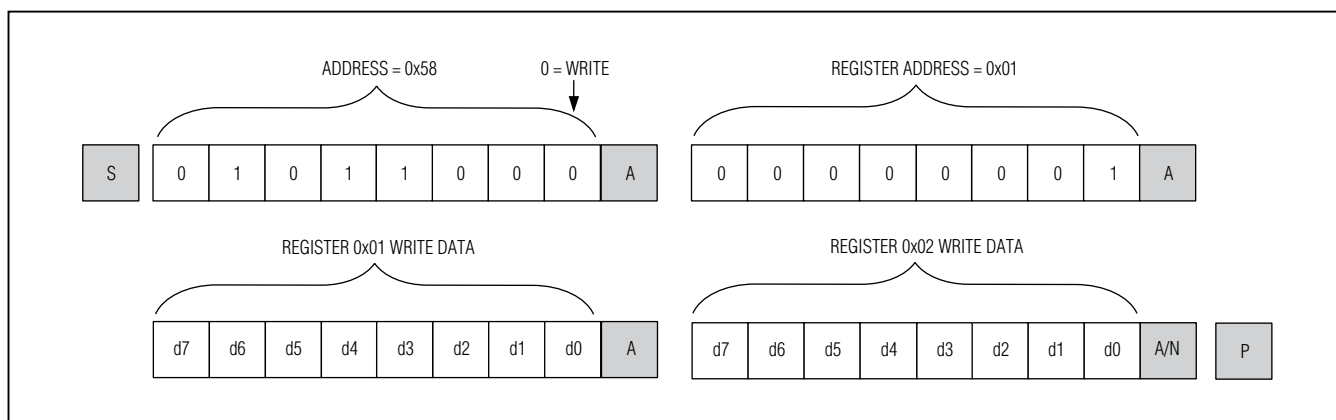


Figure 10. Format for Writing to Multiple Registers

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.

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USB Battery Charger Detectors

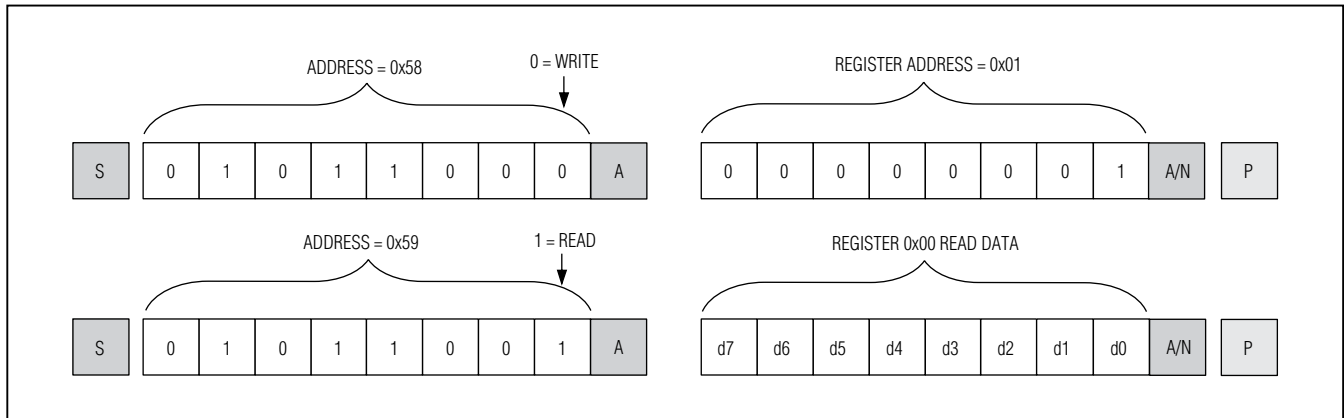


Figure 11. Format for Reads (Repeated START)

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_B and BAT with 1μF ceramic capacitors to GND as close as possible to the device.

Choosing I²C Pullup Resistors

I²C 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. I²C 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 *I²C 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.

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USB Battery Charger Detectors

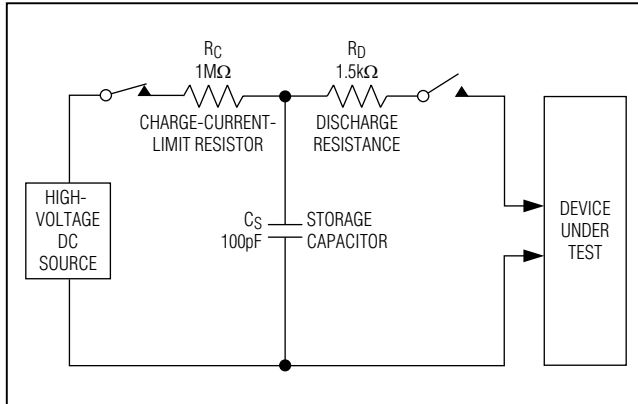


Figure 12. Human Body ESD Test Model

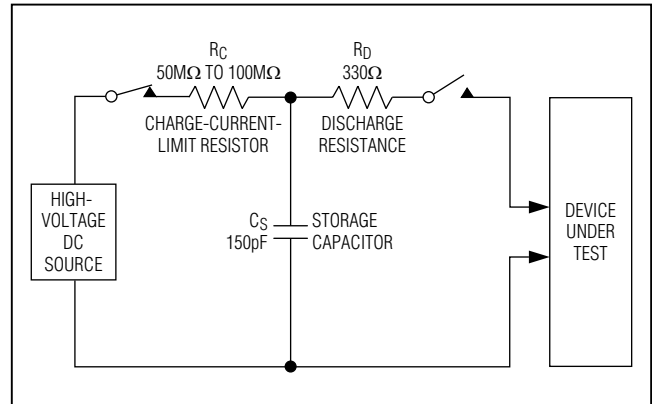


Figure 14. IEC 61000-4-2 ESD Test Model

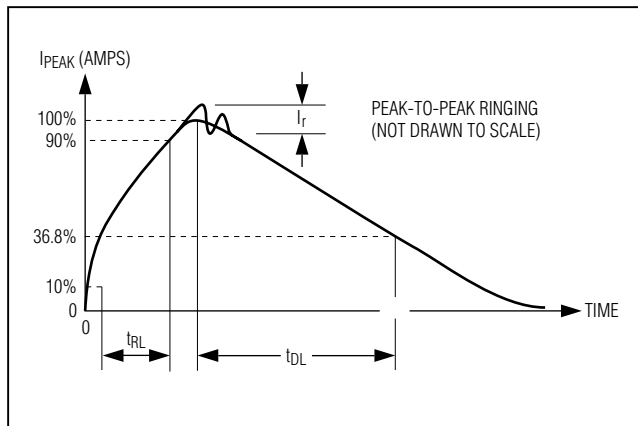


Figure 13. Human Body Current Waveform

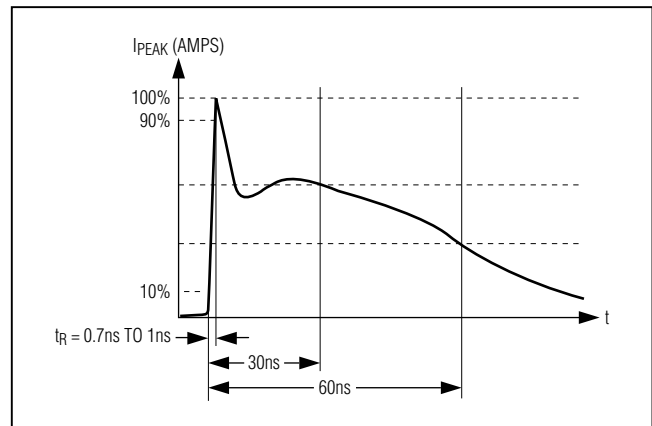


Figure 15. IEC 61000-4-2 ESD Generator Current Waveform

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 100pF 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 MAX4895E assists 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.

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USB Battery Charger Detectors

Chip Information

PROCESS: BiCMOS

Package Information

For the latest package outline information and land patterns (footprints), go to www.maximintegrated.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 | 21-0449 | Refer to Application Note 1891 |
| 16 TQFN | T1633+5 | 21-0136 | 90-0032 |

MAX14578E/MAX14578AE

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 MAX14578E <i>Functional Diagram/Typical Operating Circuit</i> , and corrected default values for MAX14578AE in Table 2 | 1, 2, 8, 9, 13, 22 |
| 2 | 9/12 | Updated Package Thermal Characteristics section and VB supply current parameter for the MAX14578A | 2, 3 |
| 3 | 8/13 | Removed USB dead-battery charging information | 1, 11, 12, 13 |
| 4 | 5/14 | Corrected typo in <i>Ordering Information/Selector Guide</i> that created double entry. | 1 |



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[DS2710G+T&R](#) [MAX17040G+T](#) [MAX14525ETA+T](#) [MP2615GQ-P](#) [MAX14578EEWC+T](#) [LC05132C01NMTTGTG](#) [MAX8971EWP+T](#)
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[DS2782G+T&R](#) [MAX1908ETI+T](#) [ISL95522IRZ](#) [ISL95522HRZ](#) [ARD00558](#) [NCP4371AAEDR2G](#) [BD8665GW-E2](#) [MAX8934EETI+T](#)