

# MAX34565

## 12V Hot-Plug Switch in TDFN Package

### General Description

The MAX34565 is a hot-plug controller for 12V power rails. It is a completely integrated solution including the required power-pass MOSFET device for 12V supplies. During hot-plug, the device controls the supply output voltage ramp (dV/dt) and limits the current at a user-controlled level. The device also limits the output voltage to protect downstream devices from overvoltage events. The MAX34565 is offered in a latching version.

### Applications

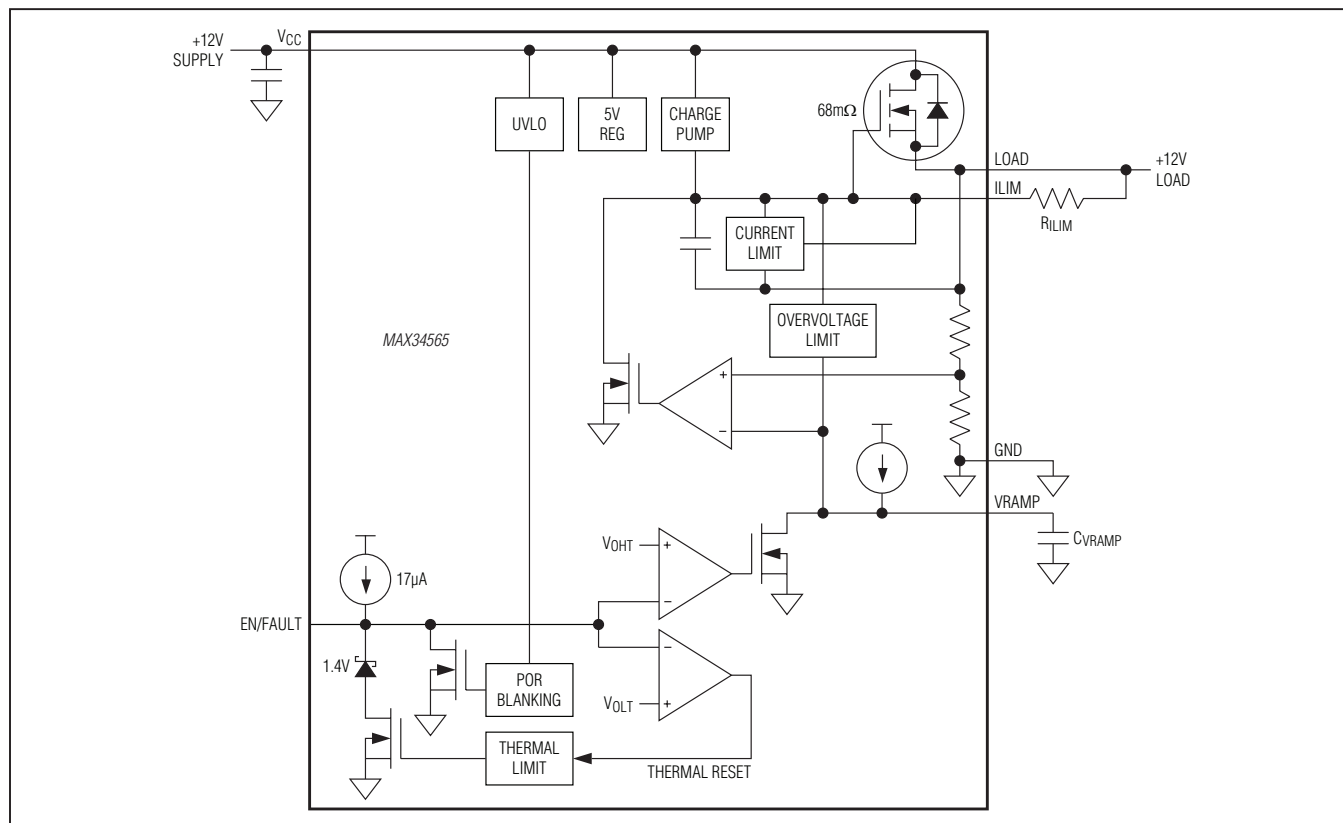
|                  |                  |
|------------------|------------------|
| RAID/Hard Drives | PCI/PCI Express® |
| Servers          | InfiniBand™/SM   |
| Switches/Routers | Base Stations    |

### Features

- ◆ Completely Integrated Hot-Plug Functionality for 12V Power Rails
- ◆ On-Board Power MOSFET
- ◆ No High Power R<sub>SENSE</sub> Resistor Needed
- ◆ Adjustable Current Limit
- ◆ Adjustable Output Voltage Slew Rate
- ◆ Thermal Fault Indication
- ◆ Output Overvoltage Limiting
- ◆ On-Board Thermal Protection
- ◆ On-Board Charge Pump
- ◆ Latchoff Version

**Ordering Information** appears at end of data sheet.

### Functional Diagram



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For related parts and recommended products to use with this part, refer to: [www.maxim-ic.com/MAX34565.related](http://www.maxim-ic.com/MAX34565.related)

**For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim's website at [www.maxim-ic.com](http://www.maxim-ic.com).**

## 12V Hot-Plug Switch in TDFN Package

### ABSOLUTE MAXIMUM RATINGS

(All voltages relative to GND.)

Voltage Range on  $V_{CC}$

Continuous.....-0.3V to +18V

1ms .....-0.3V to +22V

Voltage Range on  $I_{LIM}$ ,  $V_{RAMP}$  .....-0.3V to ( $V_{CC} + 0.3V$ ),  
not to exceed +18V

Voltage on EN/FAULT .....-0.3V to +6V

12V Drain Current ( $T_A = +25^\circ\text{C}$ , 0.5sq in. pad) .. 3.6A (continuous)

Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )

TDFN (derate at 24.4mW/ $^\circ\text{C}$  above  $+70^\circ\text{C}$ )..... 1951.2mW

Operating Junction Temperature.....  $-40^\circ\text{C}$  to  $+150^\circ\text{C}$

Storage Temperature Range .....  $-55^\circ\text{C}$  to  $+150^\circ\text{C}$

Lead Temperature (soldering, 10s) .....  $+300^\circ\text{C}$

Soldering Temperature (reflow) .....  $+260^\circ\text{C}$

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.

### RECOMMENDED OPERATING CONDITIONS

( $T_J = -40^\circ\text{C}$  to  $+150^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                          | SYMBOL     | CONDITIONS   | MIN | TYP | MAX  | UNITS    |
|------------------------------------|------------|--------------|-----|-----|------|----------|
| $V_{CC}$ Voltage                   | $V_{CC}$   | (Notes 1, 2) | 9   | 12  | 13.2 | V        |
| $R_{ILIM}$ Value                   | $R_{ILIM}$ |              | 12  |     | 30   | $\Omega$ |
| EN/FAULT Low Level (LOAD Disabled) | $V_{OLT}$  |              |     |     | 0.80 | V        |
| EN/FAULT High Level (LOAD Enabled) | $V_{OHT}$  |              | 3.3 |     |      | V        |

### ELECTRICAL CHARACTERISTICS

( $V_{CC} = 12V$ ,  $T_J = +25^\circ\text{C}$ , unless otherwise noted.)

| PARAMETER                                           | SYMBOL      | CONDITIONS                       | MIN  | TYP  | MAX  | UNITS            |
|-----------------------------------------------------|-------------|----------------------------------|------|------|------|------------------|
| Supply Current                                      | $I_{CC}$    | (Note 3)                         |      | 1.6  | 2.25 | mA               |
| UVLO Rising                                         | $V_{UR}$    |                                  | 7.5  | 8.0  | 8.5  | V                |
| UVLO Falling                                        | $V_{UF}$    |                                  | 6.5  | 7.0  | 7.5  | V                |
| UVLO Hysteresis                                     | $V_{UH}$    |                                  |      | 1    |      | V                |
| On-Resistance                                       | $R_{ON}$    |                                  |      | 68   | 88   | m $\Omega$       |
| MOSFET Output Capacitance                           | $C_{OUT}$   |                                  |      | 400  |      | pF               |
| Shutdown Junction Temperature                       | $T_{SHDN}$  | (Note 4)                         | +140 | +155 | +175 | $^\circ\text{C}$ |
| Thermal Hysteresis                                  | $T_{HYS}$   |                                  |      | 40   |      | $^\circ\text{C}$ |
| Overvoltage Clamp                                   | $V_{OVC}$   |                                  | 13.5 | 15   | 16.5 | V                |
| Power-On Short-Circuit Current Limit (Kelvin Sense) | $I_{SCL}$   | $R_{ILIM} = 15.4\Omega$ (Note 4) | 2.75 | 3.44 | 4.25 | A                |
|                                                     |             | $R_{ILIM} = 24.9\Omega$          |      | 2.1  |      | A                |
| Operating Overload Current Limit (Kelvin Sense)     | $I_{OVL}$   | $R_{ILIM} = 15.4\Omega$          |      | 4.6  |      | A                |
|                                                     |             | $R_{ILIM} = 24.9\Omega$          |      | 3.5  |      | A                |
| VRAMP Time (0V to 12V)                              | $t_{VRAMP}$ | $C_{VRAMP} = 270\text{pF}$       |      | 7    |      | ms               |
|                                                     |             | $C_{VRAMP} = 470\text{pF}$       |      | 12   |      | ms               |
|                                                     |             | $C_{VRAMP} = 1000\text{pF}$      |      | 25   |      | ms               |

## 12V Hot-Plug Switch in TDFN Package

### ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = 12V$ ,  $T_J = +25^\circ C$ , unless otherwise noted.)

| PARAMETER                     | SYMBOL      | CONDITIONS | MIN  | TYP | MAX  | UNITS |
|-------------------------------|-------------|------------|------|-----|------|-------|
| EN/FAULT Fault Output Voltage | $V_{FAULT}$ |            | 0.82 |     | 1.95 | V     |

**Note 1:** All voltages are referenced to ground. Currents entering the device are specified positive, and currents exiting the device are negative.

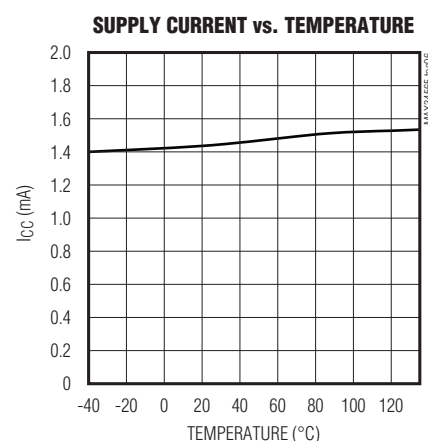
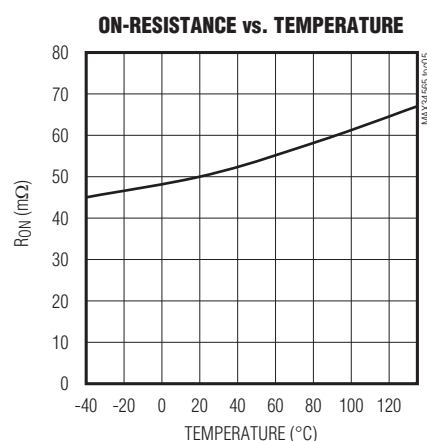
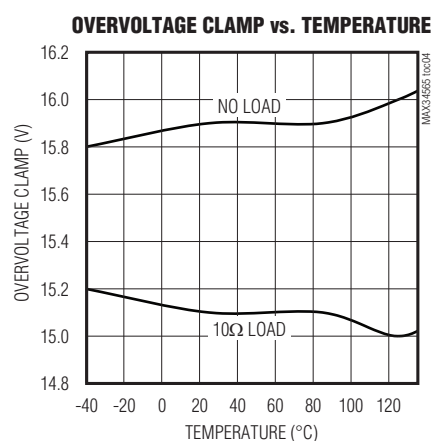
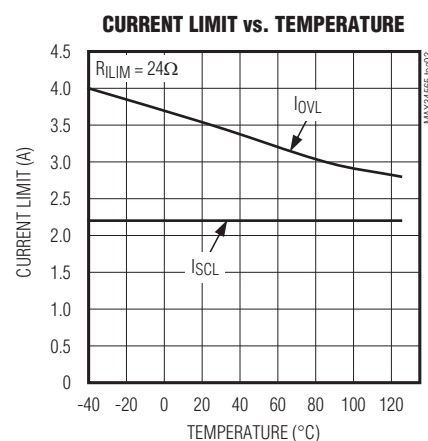
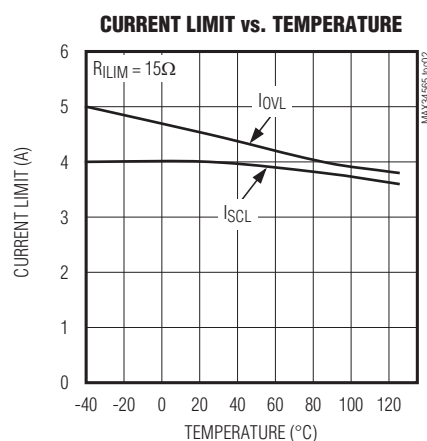
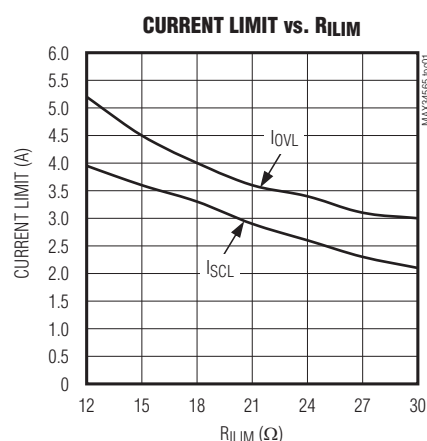
**Note 2:** This supply range guarantees that the LOAD voltage is not clamped by the overvoltage limit.

**Note 3:** Supply current specified with no load on the LOAD pin.

**Note 4:** Guaranteed by design; not production tested.

### Typical Operating Characteristics

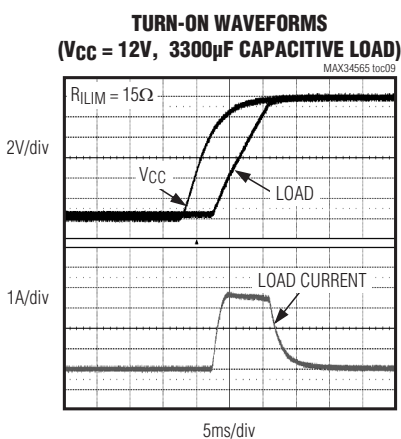
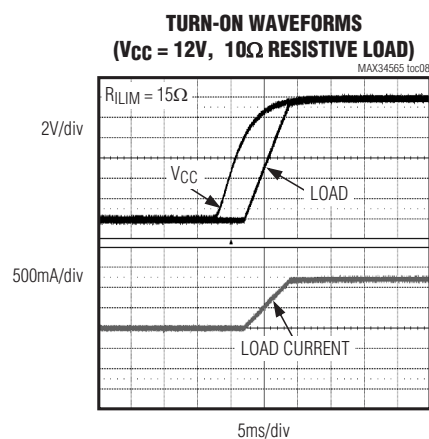
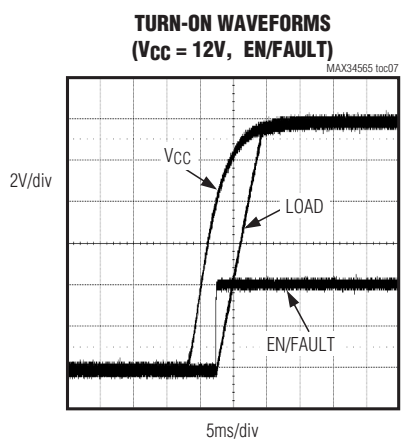
( $V_{CC} = 12V$ ,  $T_J = +25^\circ C$ , unless otherwise noted.)



## 12V Hot-Plug Switch in TDFN Package

### Typical Operating Characteristics (continued)

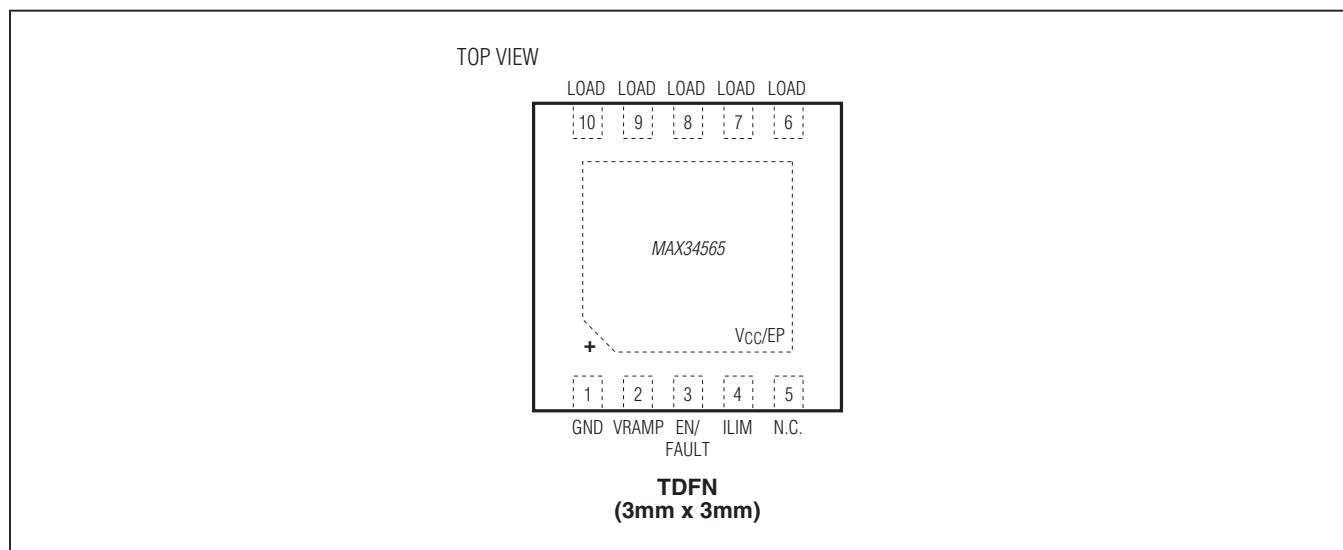
( $V_{CC} = 12V$ ,  $T_J = +25^\circ C$ , unless otherwise noted.)



# MAX34565

## 12V Hot-Plug Switch in TDFN Package

### Pin Configuration



### Pin Description

| PIN | NAME        | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | GND         | Ground Connection                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 2   | VRAMP       | Voltage Ramp Control. A capacitor connected to this pin determines the voltage ramp of the LOAD output during turn-on according to the equation $t_{VRAMP} = 25E6 \times C_{VRAMP}$ for voltage ramp from 0 to 12V. This pin can be left open circuit for a minimum ramp time.                                                                                                                                                                                                  |
| 3   | EN/FAULT    | Enable/Fault. This pin is a multiple function digital input-output pin. When this pin is externally pulled low, the MOSFET is turned off. When this pin is left open or not externally driven, the internal pullup reference pulls the input high, and the MOSFET is allowed to turn on. Note: Do not use an external pullup on this pin. If the device experiences a thermal fault, this pin becomes an output that is pulled internally to a mid-level voltage, $V_{FAULT}$ . |
| 4   | ILIM        | Supply Current Limit Adjust. A resistor from this pin to LOAD determines the current limit for the pass connection.                                                                                                                                                                                                                                                                                                                                                             |
| 5   | N.C.        | No Connection. Do not connect any signal to this pin.                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 6   | LOAD        | Load Output. N-channel power MOSFET source connection.                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 7   |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 8   |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 9   |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| 10  |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| —   | $V_{CC}/EP$ | 12V Supply Input/Exposed Pad. Power-supply input and n-channel power MOSFET drain connection. Should be connected to a large trace or plane. The EP also acts as a heatsink, and can dissipate heat from the device.                                                                                                                                                                                                                                                            |

## 12V Hot-Plug Switch in TDFN Package

### Detailed Description

The MAX34565 is a self-contained hot-plug switch intended to be used on +12V power buses to limit through current and to control the power-up output-voltage ramp. The device begins to operate when  $V_{CC}$  exceeds the undervoltage lockout level,  $V_{UR}$ . At this level, the enable circuit and EN/FAULT pin become active. Once the device has been enabled by exceeding  $V_{OLT}$  on the EN/FAULT pin, a gate voltage is applied to the power MOSFET, allowing current to begin flowing from the  $V_{CC}$  pad to LOAD.

The device contains an on-board  $68m\Omega$  n-channel power MOSFET that is actively closed-loop controlled to ensure that an adjustable current limit is not exceeded. The maximum allowable current through the device is determined by an external resistor connected to the ILIM pin.

The device also contains the ability to control the power-up output-voltage ramp. A capacitor connected to the VRAMP pin sets the desired voltage ramp rate. The output voltage is unconditionally clamped to keep input overvoltage stresses from harming the load. The device has an on-board temperature sensor with hysteresis. If operating conditions cause the device to exceed an internal thermal limit, the device unconditionally shuts down and latches off while waiting for a power-on reset. In the event of thermal shutdown, the device drives the EN/FAULT pin to an intermediate voltage,  $V_{FAULT}$ .

### Undervoltage Lockout

When voltage is applied to  $V_{CC}$ , the undervoltage lockout rising limit,  $V_{UR}$ , must be exceeded before the MOSFET circuit is enabled. When the voltage on  $V_{CC}$  drops below  $V_{UF}$ , the current through the MOSFET is blocked. Note that to allow current to pass through to the LOAD pins,  $V_{CC}$  must exceed  $V_{UR}$  and the voltage on EN/FAULT must exceed  $V_{OHT}$ .

### Enable/Fault Function (EN/FAULT)

The EN/FAULT pin can be used to control the output of the device and to indicate that a thermal fault has occurred. The voltage level of the EN/FAULT pin is compared to two internal sources: voltage on limit ( $V_{OHT}$ ) and voltage off limit ( $V_{OLT}$ ). When  $V_{CC}$  is above  $V_{UR}$  and the voltage level on EN/FAULT exceeds  $V_{OHT}$ , the voltage ramp circuit turns on, enabling the device's output. When the voltage on EN/FAULT is below  $V_{OLT}$ ,

the device's output is disabled. If the internal temperature of the device exceeds  $T_{SHDN}$ , a thermal fault occurs and the device drives EN/FAULT to  $V_{FAULT}$ . See Figure 1 for the EN/FAULT signal levels.

An open-drain device should be connected to the EN/FAULT pin for proper operation. Because the device pulls EN/FAULT to  $V_{FAULT}$  (a three-state condition) in the event of thermal shutdown, this pin should not be connected to an external pullup device. See Figure 2 for a typical application circuit.

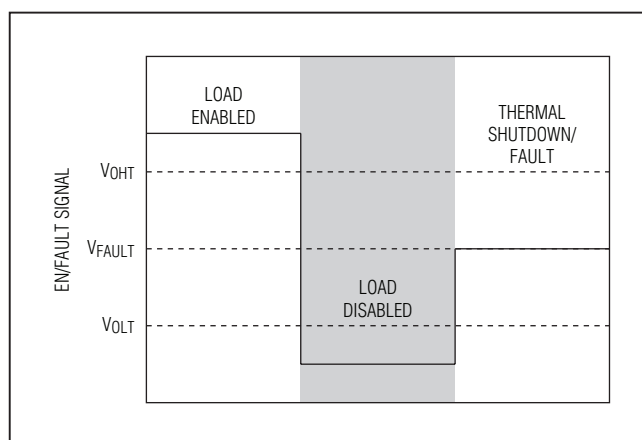


Figure 1. EN/FAULT Signal Levels

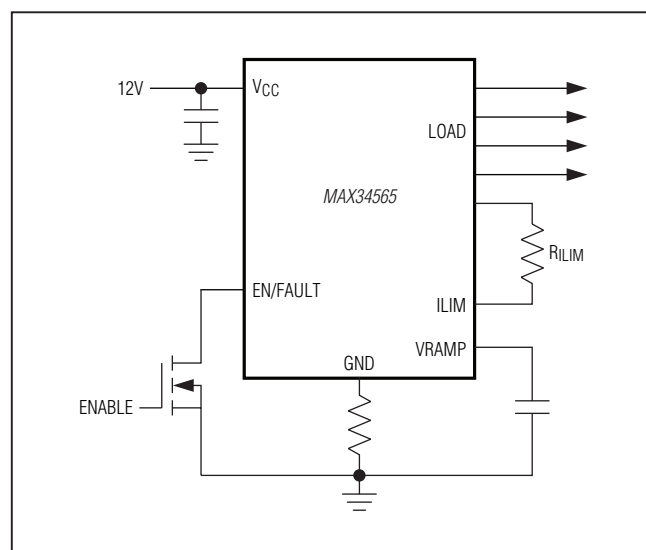


Figure 2. Typical Application Circuit

## 12V Hot-Plug Switch in TDFN Package

### Output-Voltage Ramp (VRAMP)

The voltage ramp circuit uses an operational amplifier to control the gate bias of the n-channel power MOSFET. When the voltage on EN/FAULT is below  $V_{OLT}$ , a FET is used to keep  $C_{VRAMP}$  discharged, which forces the output voltage to GND. Once the voltage on EN/FAULT is above  $V_{OHT}$ , an internal current source begins to charge the external capacitor,  $C_{VRAMP}$ , connected to the VRAMP pin. The amplifier controls the gate of the power MOSFET so that the LOAD output voltage divided by two tracks the rising voltage level of  $C_{VRAMP}$ . The output voltage continues to ramp until it reaches either the input  $V_{CC}$  level or the overvoltage clamp limits.

### Overvoltage Limit

The overvoltage-limiting clamp monitors the VRAMP voltage level compared to an internal voltage reference. When the voltage on VRAMP exceeds  $V_{OVC}/2$ , the gate voltage of the n-channel power MOSFET is reduced, limiting the voltage on LOAD to  $V_{OVC}$  even as  $V_{CC}$  increases. If the device is in overvoltage for an extended period of time, the device may overheat and enter thermal shutdown. This is caused by the power created by the voltage drop across the power MOSFET and the load current.

### Current Limit

The load current is continuously monitored during the initial voltage ramping ( $I_{SCL}$ ) and during normal operation ( $I_{OVL}$ ). If the current exceeds the current limit that is set by the external resistance at ILIM, the gate voltage of the power MOSFET is decreased, reducing the output current to the set current limit. Current is limited by the device comparing the voltage difference between the LOAD and ILIM pins to an internal reference voltage. When the output power is initially ramping up, the current limit is  $I_{SCL}$ . Once the voltage ramping is complete, the current limit is  $I_{OVL}$ . The lower  $I_{SCL}$  current limit protects the source if there is a dead short on initial power-up. If the high current is maintained, the device will heat up and the internal temperature will eventually reach  $T_{SHDN}$ . The device act as a fuse and automatically disable the current flowing to the load when the temperature of the power MOSFET has exceeded the shutdown junction temperature,  $T_{SHDN}$ .

### Direct and Kelvin Current Sensing

The current limit circuit can be biased in one of two ways: direct sensing or Kelvin sensing. Using direct sensing, the sense resistor is connected between the ILIM pin and the LOAD pins (Figure 3). Because the bond wires of all five LOAD pins are in parallel, the on-resistance is slightly lower. Using Kelvin sensing, only one of the LOAD pins is connected to the ILIM pin through the sense resistor (Figure 4). Using this circuit, the voltage on the die is sensed, negating any impact of the bond wire resistance. Because four LOAD pins are connected in parallel, the on-resistance is slightly higher.

### Thermal Shutdown

The device enters a thermal shutdown state when the temperature of the power MOSFET reaches or exceeds  $T_{SHDN}$ , approximately  $+155^{\circ}\text{C}$ . When  $T_{SHDN}$  is exceeded, the thermal-limiting circuitry disables the device using the enable circuitry. The EN/FAULT pin is driven to  $V_{FAULT}$ . The device is offered in two different versions: an autoretry version and a latching version.

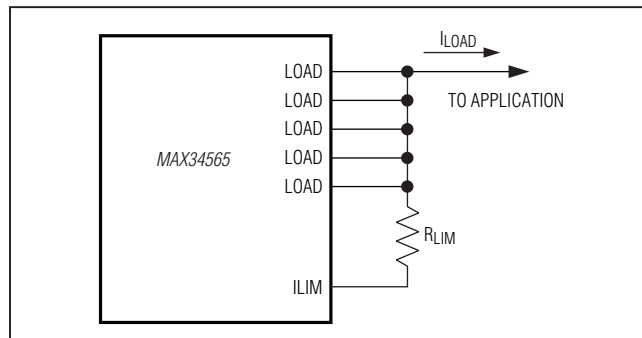


Figure 3. Direct Sensing Circuit

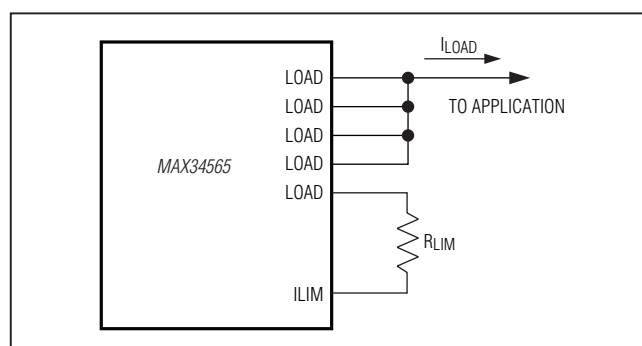


Figure 4. Kelvin Sensing Circuit

## 12V Hot-Plug Switch in TDFN Package

### Latchoff Version

Once the latchoff version has entered thermal shutdown, it does not attempt to turn back on. The only way to turn this device back on is to cycle the power to the device. When power is reapplied to the  $V_{CC}$  pad, the junction temperature needs to be less than  $T_{SHDN}$  for the device to be enabled.

### Applications Information

#### Exposed Pad ( $V_{CC}$ )

The exposed pad is the voltage supply pin for the device and should be connected to a large trace or plane. The exposed pad also acts as a heatsink, and can dissipate heat from the device.

#### Decoupling Capacitors

It is of utmost importance to properly bypass the device's supply pins. A decoupling capacitor absorbs the energy stored in the supply and board parasitic inductance when the FET is turned off, thereby reducing the magnitude of overshoot of  $V_{CC}$ . This can be accomplished by using a high-quality (low ESR, low ESL) ceramic capacitor soldered directly between the  $V_{CC}$  and GND connections. Any series resistance with this bypass capacitor lowers its effectiveness and is not recommended. A minimum 0.5 $\mu$ F ceramic capacitor is required (Figure 5). However, depending on the parasitic inductances present in the end application, a larger capacitor could be necessary.

#### Current Limiting Resistor

A small resistor (2 $\Omega$  to 10 $\Omega$ ) in series with the GND pin of the device limits current flow during momentary reverse avalanche break down, and consequently limits total parasitic charge injected into the device (Figure 5). If this method is used, it is imperative that the bypass capacitor be directly across chip  $V_{CC}$  and ground connections, though not through this resistor.

#### LOAD and ILIM Connections

Small parasitic resistances in the bond wires of the LOAD pins and in the traces connected to the LOAD pins can result in a voltage offset while current is flowing. Since the voltage drop across  $R_{ILIM}$  is used to set the  $I_{SCL}$  and  $I_{OVL}$  limits, this induced offset can increase the value of  $I_{SCL}$  and  $I_{OVL}$  from the specified values for any given

$R_{ILIM}$ . To greatly reduce this offset, it is recommended that one of the LOAD pins have a dedicated connection to ILIM through  $R_{ILIM}$ , and not be used to pass the LOAD current,  $I_{LOAD}$  (Figure 6). This would leave four LOAD pins to pass  $I_{LOAD}$ , which should be sufficient. Because there is only a small amount of current passed from this lone LOAD pin to ILIM, there is a negligible voltage offset applied to the internal comparator. This method is the best way to attain an accurate current limit for  $I_{LOAD}$ .

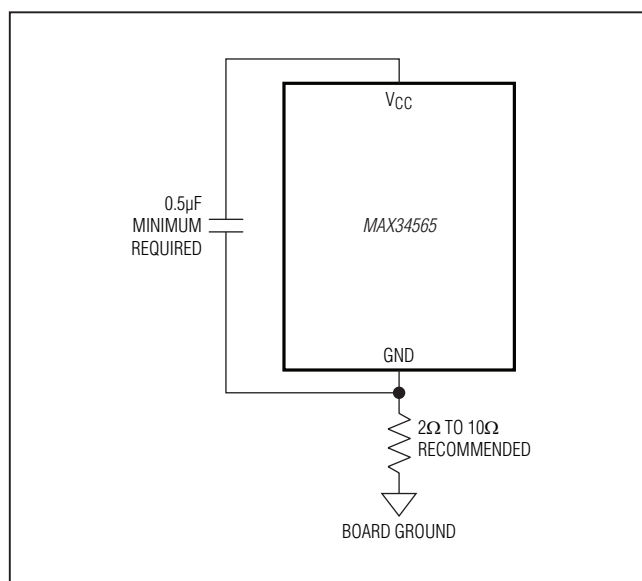


Figure 5. Power Conditioning Circuit

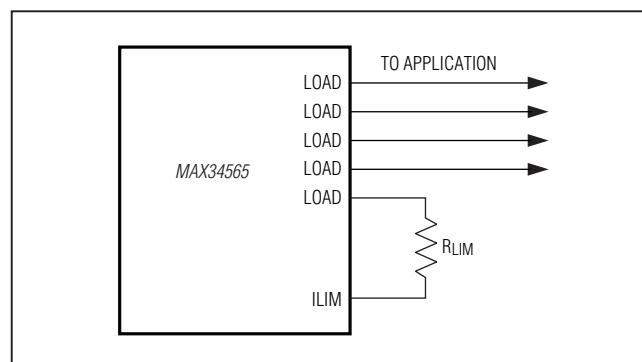


Figure 6. LOAD and ILIM Connections

## 12V Hot-Plug Switch in TDFN Package

### Ordering Information

| PART          | TEMP RANGE      | THERMAL SHUTDOWN | PIN-PACKAGE |
|---------------|-----------------|------------------|-------------|
| MAX34565ETB+  | -40°C to +150°C | Latchoff         | 10 TDFN-EP* |
| MAX34565ETB+T | -40°C to +150°C | Latchoff         | 10 TDFN-EP* |

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

T = Tape and reel.

\*EP = Exposed pad.

### 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.        |
|--------------|--------------|-------------------------|-------------------------|
| 10 TDFN-EP   | T1033+2      | <a href="#">21-0137</a> | <a href="#">90-0061</a> |

**MAX34565**

## **12V Hot-Plug Switch in TDFN Package**

### ***Revision History***

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION     | PAGES<br>CHANGED |
|--------------------|------------------|-----------------|------------------|
| 0                  | 12/11            | Initial release | —                |

*Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time. The parametric values (min and max limits) shown in the Electrical Characteristics table are guaranteed. Other parametric values quoted in this data sheet are provided for guidance.*

**Maxim Integrated Products, Inc. 160 Rio Robles, San Jose, CA 95134 USA 1-408-601-1000 \_\_\_\_\_ 10**