19-4814; Rev 0; 7/09

# 250mA to 1.5A, Adjustable Current-Limit Switches



## General Description

The MAX14523A/MAX14523AL/MAX14523B/MAX14523C programmable current-limit switches feature internal current limiting to prevent damage to host devices due to faulty load conditions. These current-limit switches feature a low 70mΩ on-resistance and operate from a +1.7V to +5.5V input voltage range. The current limit is adjustable from 250mA to 1.5A, making these devices ideal for SDIO (secure digital input/output) and other load-switching applications.

Each device in the family handles an overcurrent event differently depending on the option selected. The MAX14523A/MAX14523AL go into an autoretry mode, the MAX14523B latches off the switch, and the MAX14523C features a continuous current-limit mode. Additional safety features include thermal shutdown to prevent overheating and reverse-current blocking to prevent current from being driven back into the source.

The MAX14523A/MAX14523AL/MAX14523B/MAX14523C are available in a tiny 8-pin, 3mm x 3mm, TDFN package and operate over the -40°C to +125°C automotive temperature range.

## Applications

SDIO Ports

USB Ports

Notebook VGA Ports

GPS

Cell Phones

MP3 Players

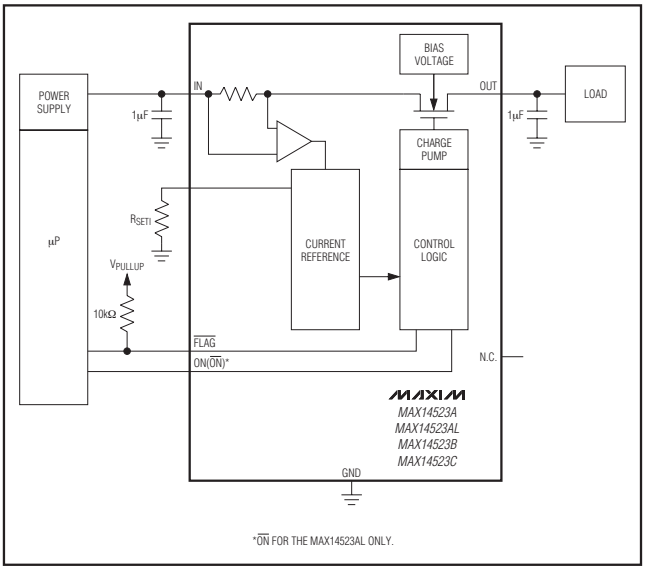
UTCA/ATCA Platforms

***Pin Configuration appears at end of data sheet.***

## Features

- **Accurate (±10%) Overload Current Limit**
- **Adjustable Current-Limit Threshold**
- **Low-Dropout Voltage (70mV at 1A Load Current)**
- **Short-Circuit Protection**
- **Thermal-Shutdown Protection**
- **Reverse-Current Protection**
- **170µA (typ) Supply Current**
- **Shutdown Reverse Current, 0.6µA (max)**
- **+1.7V to +5.5V Supply Voltage Range**
- **Tiny 8-Pin, 3mm x 3mm, TDFN Package**

## Typical Operating Circuit




## Ordering Information/Selector Guide

| PART | PIN-PACKAGE | TOP MARK | ON POLARTIY | OVERCURRENT RESPONSE |
|---|---|---|---|---|
| **MAX14523A**ATA+ | 8 TDFN-EP* | BLO | Active-High | Autoretry |
| **MAX14523AL**ATA+** | 8 TDFN-EP* | BLP | Active-Low | Autoretry |
| **MAX14523B**ATA+ | 8 TDFN-EP* | BLQ | Active-High | Latch-Off |
| **MAX14523C**ATA+ | 8 TDFN-EP* | BLS | Active-High | Continuous |

***Note:*** *All devices are specified over the -40°C to +125°C operating temperature range.*
*+Denotes a lead(Pb)-free package/RoHs-compliant package.*
**EP = Exposed pad.*
***Future product—contact factory for availability.*

# 250mA to 1.5A, Adjustable Current-Limit Switches

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)
IN, ON, $\overline{ON}$, $\overline{FLAG}$, OUT, and SETI to GND .....-0.3V to +6V
Current into Any Pin (Except IN, OUT).....20mA
Out Short Circuit to GND.....Internally Limited
Continuous Power Dissipation ($T_A$ = +70°C) for multilayer board:
8-Pin TDFN (derate 24.4mW/°C above +70°C) .....1952mW
Junction-to-Case Thermal Resistance ($\theta_{JC}$)
(Note 1) .....8.0°C/W
Junction-to-Ambient Thermal Resistance ($\theta_{JA}$)
(Note 1) .....41.0°C/W
Operating Temperature Range .....-40°C to +125°C
Junction Temperature.....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

**Note 1:** 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-turorial**.

*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.*

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = +1.7V to +5.5V, $R_{SETI}$ = 94.2kΩ, $C_{IN}$ = $C_{OUT}$ = 1µF, and $T_A$ = $T_J$ = -40°C to +125°C, unless otherwise noted. Typical values are at $V_{IN}$ = +3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **SUPPLY OPERATION** | | | | | | |
| Operating Voltage | $V_{IN}$ | | 1.7 | | 5.5 | V |
| Quiescent Current | $I_Q$ | $I_{OUT}$ = 0A, switch on, $V_{IN}$ = 3.3V | | 170 | 300 | µA |
| Latchoff Current | $I_{LATCH}$ | $V_{IN}$ = 3.3V, $I_{OUT}$ = 0A , after an overcurrent fault (MAX14523B) | | 10 | 20 | µA |
| Shutdown Forward Current | $I_{SHDN}$ | $V_{ON}$ = 0V, $V_{\overline{ON}}$ = $V_{IN}$, $V_{IN}$ = 5.5V, $V_{OUT}$ = 0V | | 0.5 | 7 | µA |
| Shutdown Reverse Current | $I_{RSHDN}$ | $V_{ON}$ = 0V, $V_{\overline{ON}}$ = $V_{IN}$, $V_{IN}$ = 1.7V, $V_{OUT}$ = 5.5V (current into OUT) | | 0.01 | 0.6 | µA |
| **INTERNAL FET** | | | | | | |
| Switch-On Resistance | $R_{ON}$ | $V_{IN}$ = 3.3V, $I_{OUT}$ lower than $I_{LIM}$ | | 70 | 130 | mΩ |
| Forward-Current Limit | $I_{LIM}$ | $R_{SETI}$ = 91.78kΩ, $V_{IN}$ - $V_{OUT}$ = 1V | 1350 | 1500 | 1650 | mA |
| | | $R_{SETI}$ = 563.12kΩ, $V_{IN}$ - $V_{OUT}$ = 1V | 225 | 250 | 275 | |
| ($R_{SETI}$ +2.48kΩ) × $I_{LIM}$ Product | | $I_{LIM}$ = 250mA to 1500mA, $V_{IN}$ - $V_{OUT}$ = 1V | 127.2 | 141.4 | 155.5 | kV |
| Reverse Blocking Current | | $V_{OUT}$ > $V_{IN}$ + 140mV, after reverse-current-limit shutdown | | | 2 | µA |
| Reverse Blocking Threshold | $V_{OUT}$ - $V_{IN}$ | $V_{OUT}$ - $V_{IN}$ = 300mV, OUT falling until switch turns on | 40 | 95 | 140 | mV |
| $\overline{FLAG}$ Assertion Drop Voltage Threshold | $V_{FA}$ | Increase ($V_{IN}$ - $V_{OUT}$) drop until $\overline{FLAG}$ asserts, $I_{OUT}$ limiting, $V_{IN}$ = 3.3V | | 350 | | mV |
| **ON, $\overline{ON}$ INPUT** | | | | | | |
| ON, $\overline{ON}$ Input Leakage | $I_{LEAK}$ | $V_{ON}$, $V_{\overline{ON}}$ = $V_{IN}$ or $V_{GND}$ | -1 | | +1 | µA |
| ON, $\overline{ON}$ Input Logic-High Voltage | $V_{IH}$ | | 1.6 | | | V |
| ON, $\overline{ON}$ Input Logic-Low Voltage | $V_{IL}$ | | | | 0.4 | V |

## ELECTRICAL CHARACTERISTICS (continued)

($V_{IN}$ = +1.7V to +5.5V, $R_{SETI}$ = 94.2kΩ, $C_{IN}$ = $C_{OUT}$ = 1µF, and $T_A$ = $T_J$ = -40°C to +125°C, unless otherwise noted. Typical values are at $V_{IN}$ = +3.3V, $T_A$ = +25°C.) (Note 2)

| PARAMETER | SYMBOL | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|
| **$\overline{FLAG}$ OUTPUT** | | | | | | |
| $\overline{FLAG}$ Output Logic-Low Voltage | | $I_{SINK}$ = 1mA | | | 0.4 | V |
| $\overline{FLAG}$ Output Leakage Current | | $V_{IN}$ = $V_{\overline{FLAG}}$ = 5.5V, $\overline{FLAG}$ deasserted | | | 1 | µA |
| **DYNAMIC** | | | | | | |
| Turn-On Time | $t_{SS}$ | Time from ENABLE signal to $V_{OUT}$ = 90% of $V_{IN}$ = 3.3V, Figure 1 | | 1 | | ms |
| Turn-Off Time | $t_{OFF}$ | Time from DISABLE signal to $V_{OUT}$ = 10% of $V_{IN}$ = 3.3V, $R_L$ = 20Ω, Figure 1 | | 250 | | µs |
| Current-Limit Reaction Time | $t_{LIM}$ | $V_{IN}$ = 3.3V, $R_{SETI}$ = 91.78kΩ to 563.12kΩ, output high and then short-circuit applied | | 3 | | µs |
| Blanking Time | $t_{BLANK}$ | (Note 3) | 10 | 14.5 | 25 | ms |
| Retry Time | $t_{RETRY}$ | MAX14523A/MAX14523AL (Note 3) | 320 | | 875 | ms |
| **THERMAL PROTECTION** | | | | | | |
| Thermal Shutdown | | Low-to-high | | +170 | | °C |
| Thermal Shutdown Hysteresis | | | | 15 | | °C |

**Note 2:** All devices are 100% tested at 125°C. Electrical limits across the full temperature range are guaranteed by design and correlation.

**Note 3:** Blanking time and retry time are generated by the same oscillator. Therefore, the ratio of $\frac{t_{RETRY}}{t_{BLANK}}$ is a constant value of 32. See Figures 2 and 3.

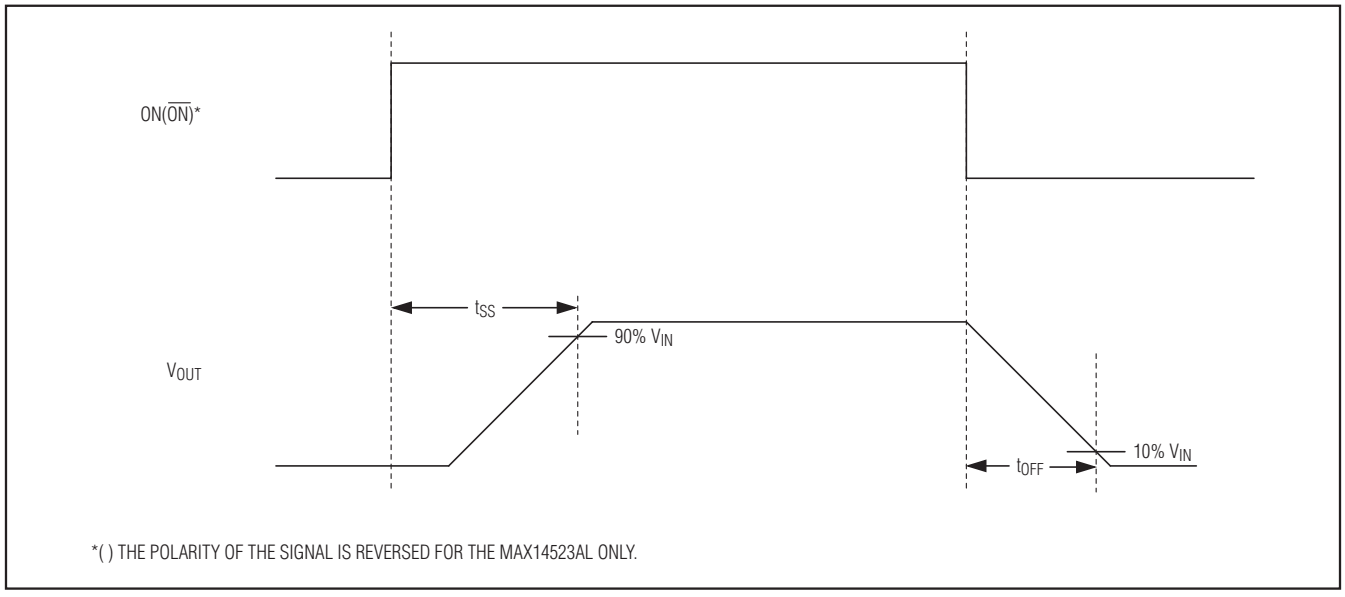



*Figure 1. Timing Diagram for Measuring Turn-On Time ($t_{SS}$) and Turn-Off Time ($t_{OFF}$)*

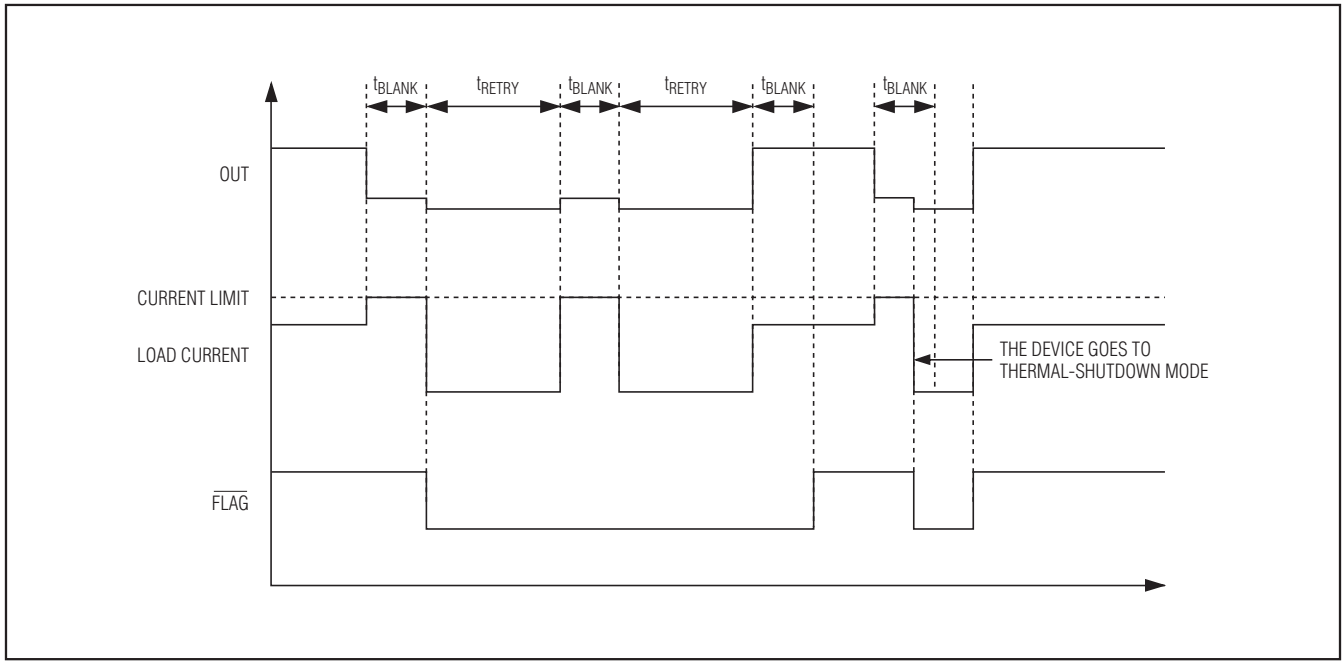



*Figure 2. Autoretry Fault Diagram*

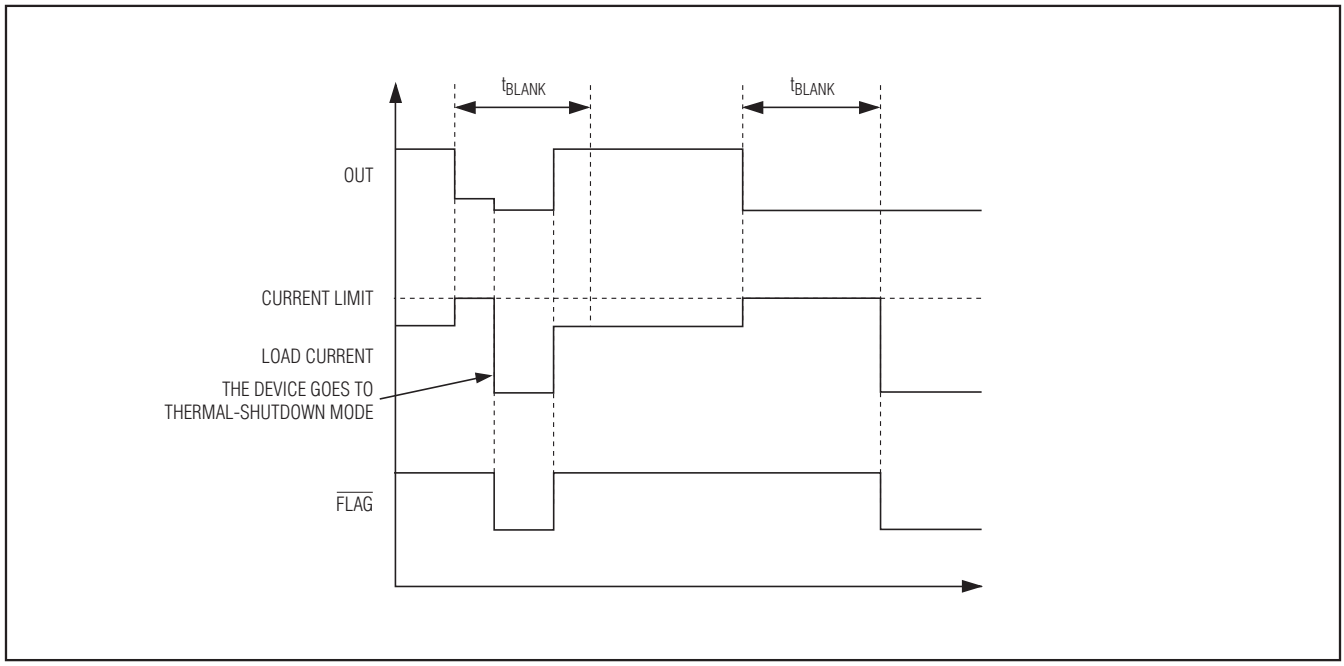
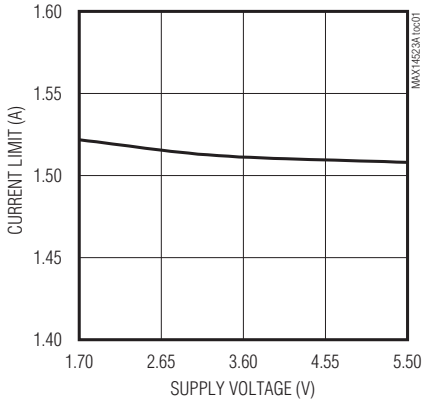



*Figure 3. Latchoff Fault Diagram*

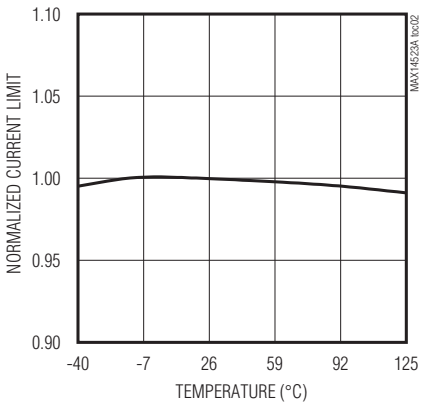
## Typical Operating Characteristics

($V_{IN}$ = +3.3V, $C_{IN}$ = 1µF, $C_{OUT}$ = 1µF, $R_{SETI}$ = 94.2kΩ, $T_A$ = +25°C, unless otherwise noted.)

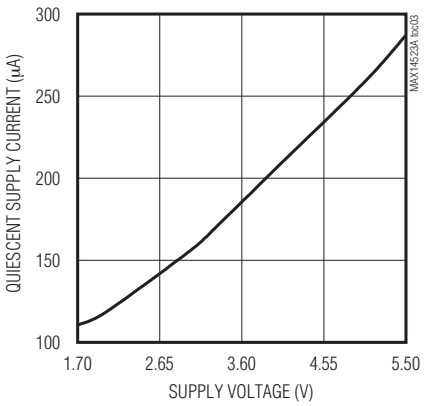
**CURRENT LIMIT vs. SUPPLY VOLTAGE**



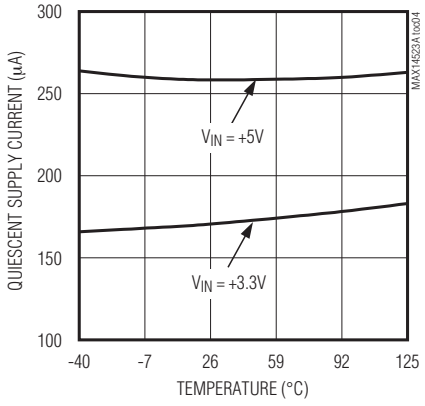

**NORMALIZED CURRENT LIMIT vs. TEMPERATURE**



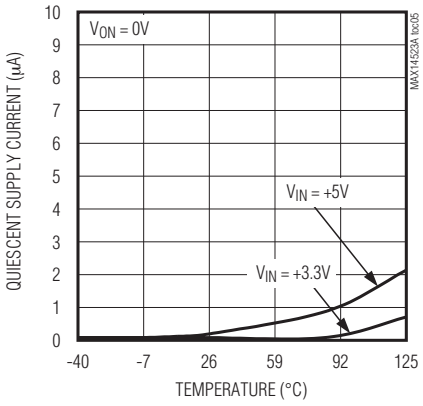

**QUIESCENT SUPPLY CURRENT vs. SUPPLY VOLTAGE**



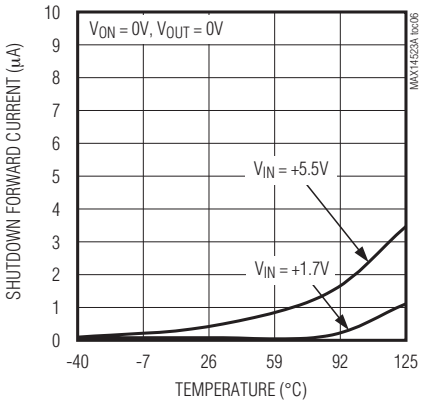

**QUIESCENT SUPPLY CURRENT vs. TEMPERATURE**




**SHUTDOWN SUPPLY CURRENT vs. TEMPERATURE**




**SHUTDOWN FORWARD CURRENT vs. TEMPERATURE**

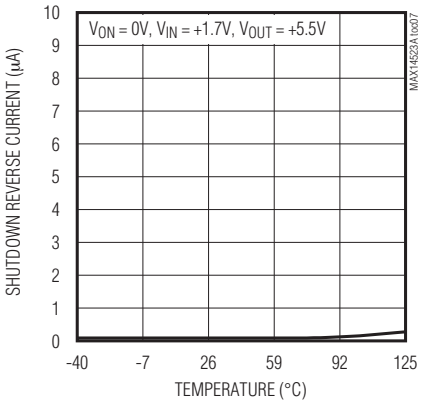


# 250mA to 1.5A, Adjustable Current-Limit Switches

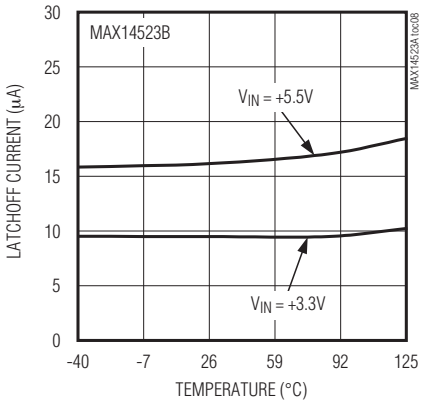
## Typical Operating Characteristics (continued)

($V_{IN}$ = +3.3V, $C_{IN}$ = 1µF, $C_{OUT}$ = 1µF, $R_{SETI}$ = 94.2kΩ, $T_A$ = +25°C, unless otherwise noted.)

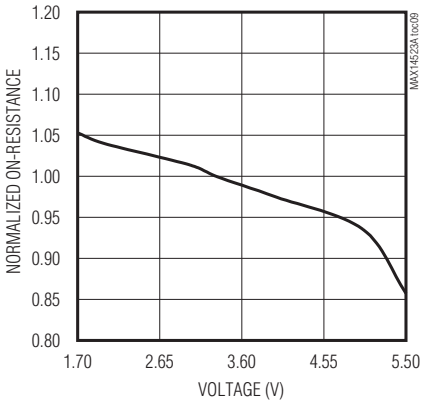
**SHUTDOWN REVERSE CURRENT vs. TEMPERATURE**



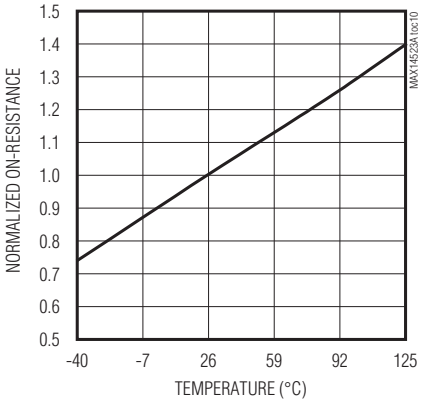

**LATCHOFF CURRENT vs. TEMPERATURE**



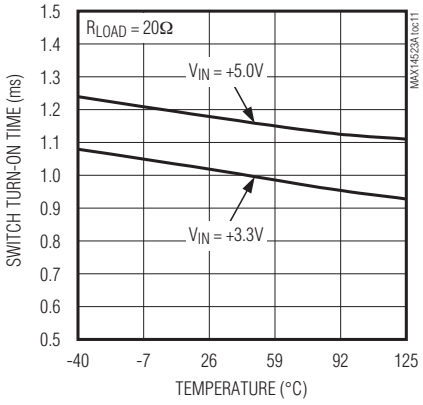

**NORMALIZED ON-RESISTANCE vs. SUPPLY VOLTAGE**



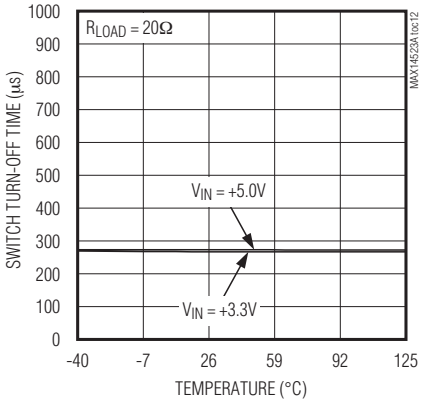

**NORMALIZED ON-RESISTANCE vs. SUPPLY TEMPERATURE**




**SWITCH TURN-ON TIME vs. SUPPLY TEMPERATURE**



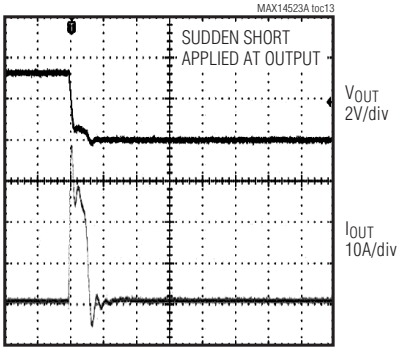

**SWITCH TURN-OFF TIME vs. SUPPLY TEMPERATURE**



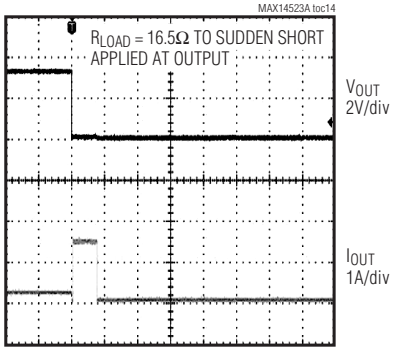
## Typical Operating Characteristics (continued)

($V_{IN}$ = +3.3V, $C_{IN}$ = 1µF, $C_{OUT}$ = 1µF, $R_{SETI}$ = 94.2kΩ, $T_A$ = +25°C, unless otherwise noted.)

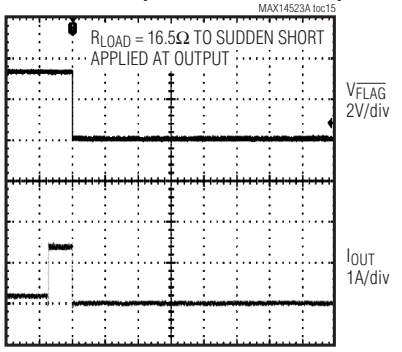
**CURRENT LIMIT RESPONSE**




**CURRENT LIMIT RESPONSE**




**FLAG RESPONSE (OVERLOAD CONDITION)**

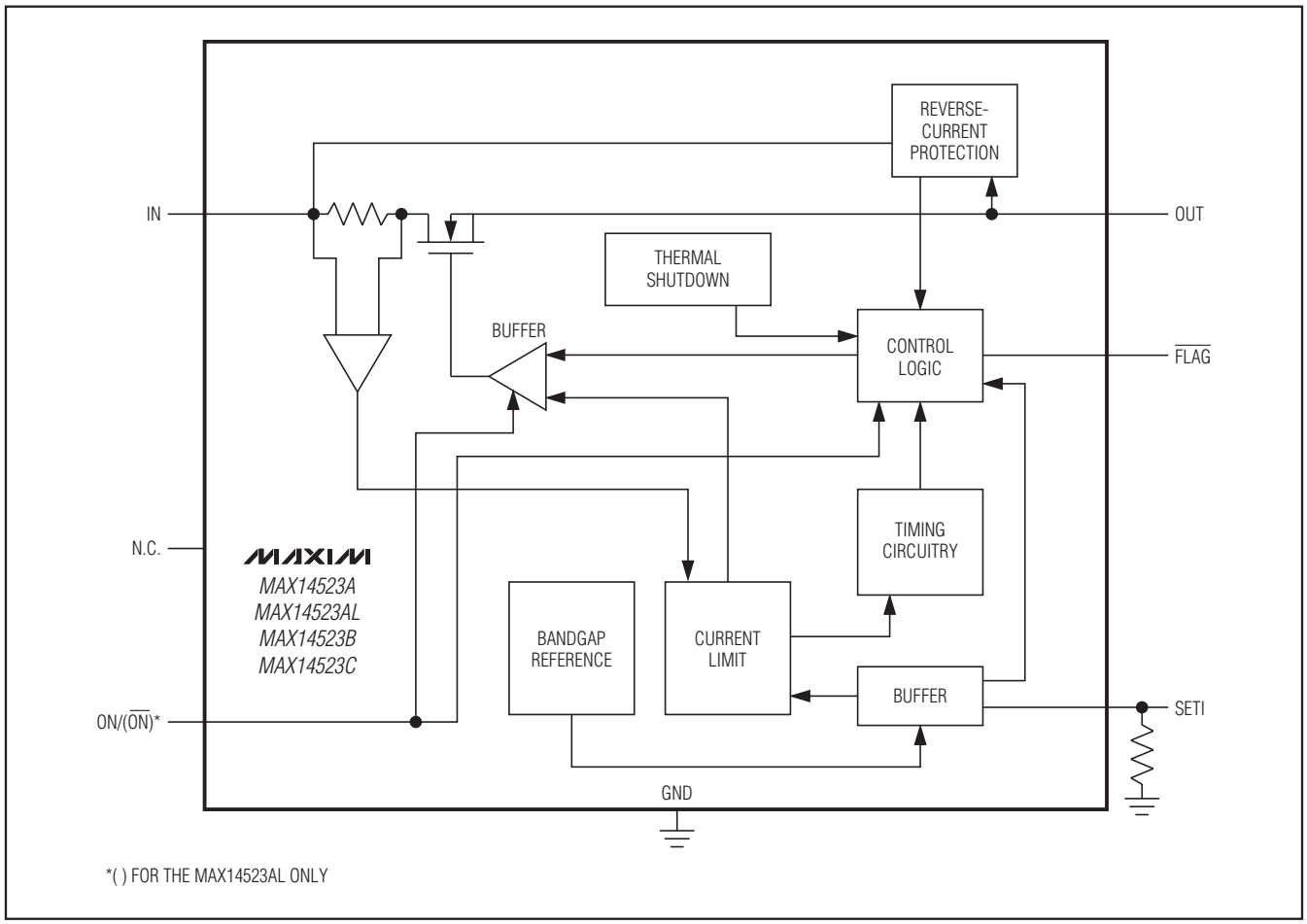



## Pin Description

| PIN | | NAME | FUNCTION |
|---|---|---|---|
| MAX14523AL | MAX14523A MAX14523B MAX14523C | | |
| 1, 6 | 1, 6 | N.C. | No Connection. Not internally connected. Connect N.C. to GND or leave unconnected. |
| 2 | 2 | $\overline{FLAG}$ | Open-Drain, Overload Indicator Output. $\overline{FLAG}$ goes low when the overload fault duration exceeds the blanking time, reverse current is detected, thermal shutdown mode is active, or SETI is connected to ground. |
| 3 | 3 | SETI | Overload-Current Limit Adjust. Connect a resistor from SETI to GND to program the overcurrent limit. If SETI is connected to GND the switch turns off and $\overline{FLAG}$ is asserted. If SETI is unconnected the current limit is at 0mA. Do not connect any capacitance larger than 20pF to SETI. |
| 4 | 4 | OUT | Switch Output. Bypass OUT with a 1µF capacitor to GND. |
| 5 | 5 | IN | Power Input. Bypass IN with a 1µF ceramic capacitor to GND. Use higher capacitance if necessary to prevent large load transients from pulling down the supply voltage. |
| 7 | — | $\overline{ON}$ | Active-Low, Switch-ON Input. Drive $\overline{ON}$ low to turn on the switch. |
| — | 7 | ON | Active-High, Switch-ON Input. Drive ON high to turn on the switch. |
| 8 | 8 | GND | Ground |
| — | — | EP | Exposed Pad. Internally connected to GND. For enhanced thermal dissipation, connect EP to a large copper ground plane. Do not use EP as the sole ground connection. |

# 250mA to 1.5A, Adjustable Current-Limit Switches

## Functional Diagram




## Detailed Description

The MAX14523A/MAX14523AL/MAX14523B/MAX14523C programmable current-limit switches operate from +1.7V to +5.5V and provide internal current limiting adjustable from 250mA to 1.5A. These devices feature a fixed blanking time, and a $\overline{FLAG}$ output that notifies the processor when a fault condition is present.

### Programmable Current Limit/Threshold

A resistor from SETI to GND sets the current limit/threshold for the switch (see the *Setting the Current Limit/Threshold* section). If the output current is limited at the current threshold value for a time equal to or longer than $t_{BLANK}$, the output flag asserts and the MAX14523A/MAX14523AL enter the autoretry mode, the MAX14523B latches off the switch, and the MAX14523C enters the continuous current-limit mode.

### Autoretry (MAX14523A/MAX14523AL)

When the forward current reaches the current threshold, the $t_{BLANK}$ timer begins counting (Figure 2). $\overline{FLAG}$ asserts if the overcurrent condition is present for $t_{BLANK}$ or longer. The timer resets if the overcurrent condition disappears before the blanking time ($t_{BLANK}$) has elapsed. A retry time delay ($t_{RETRY}$) starts immediately after the blanking time has elapsed. During that time, the switch latches off. At the end of $t_{RETRY}$, the switch turns on again. If the fault still exists, the cycle repeats. If the fault has been removed, the switch stays on. During this cycle, $\overline{FLAG}$ stays low. In autoretry, if the die temperature exceeds +170°C (typ) due to self heating, the MAX14523A/MAX14523AL go into thermal shutdown until the die temperature drops by approximately 15°C (see the *Thermal Shutdown* section.)

The autoretry feature saves system power in case of an overcurrent or short-circuit condition. During $t_{BLANK}$ time, when the switch is on, the supply current is held at the current limit. During time $t_{RETRY}$, when the switch is off, the current through the switch is zero. Thus, the average output current is much less than the programmed current limit. Calculate the average output current using the following equation:

$$I_{LOAD} = I_{LIM} [(t_{BLANK})/(t_{BLANK} + t_{RETRY})]$$

With a typical $t_{BLANK}$ = 17.5ms and typical $t_{RETRY}$ = 560ms, the duty cycle is 3%, resulting in a 97% power savings over the switch being on the entire time.

### Latchoff (MAX14523B)

When the forward current reaches the current threshold, the $t_{BLANK}$ timer begins counting (Figure 3). $\overline{FLAG}$ asserts if an overcurrent condition is present for greater than $t_{BLANK}$ time. The timer resets if the overcurrent condition disappears before $t_{BLANK}$ has elapsed. The switch turns off if the overcurrent condition continues beyond the blanking time. Reset the switch by either toggling the control logic (ON or $\overline{ON}$) or cycling the input voltage. If the die temperature exceeds +170°C (typ) due to self heating, the MAX14523B goes into thermal shutdown until the die temperature drops by approximately 15°C (see the *Thermal Shutdown* section).

### Continuous Current Limit (MAX14523C)

When the forward current reaches the forward-current threshold, the MAX14523C limits the output current to the programmed current limit. $\overline{FLAG}$ asserts if the current limit is present for $t_{BLANK}$ and deasserts when the overload condition is removed. In this mode, if die temperature exceeds +170°C (typ) due to self heating, the MAX14523C goes into thermal shutdown until the die temperature drops by approximately 15°C (see the *Thermal Shutdown* section).

## Table 1. Switch Truth Table

| MAX14523A MAX14523B MAX14523C | MAX14523AL | SWITCH STATUS |
|---|---|---|
| ON | $\overline{ON}$ | |
| 0 | 1 | Off |
| 1 | 0 | On |

### Switch-On/Off Control

The ON input for the MAX14523A/MAX14523B/MAX14523C and $\overline{ON}$ input for the MAX14523AL control the switch, see Table 1. Toggle ON for the MAX14523B to reset the fault condition once the short-circuit current is detected and the device shuts down.

### Reverse-Current Protection

The MAX14523A/MAX14523AL/MAX14523B/MAX14523C feature a reverse-current protection circuit that limits the backflow current to 2µA when the reverse-current protection circuitry has tripped. The switch turns off and $\overline{FLAG}$ asserts without waiting for $t_{BLANK}$ to elapse. The switch turns back on and $\overline{FLAG}$ deasserts when $V_{IN}$ - $V_{OUT}$ drops below the reverse-current threshold by 95mV (typ).

### FLAG Indicator

$\overline{FLAG}$ is an open-drain fault indicator output and requires an external pullup resistor to a DC supply. $\overline{FLAG}$ goes low when any of the following conditions occur:

- The blanking time has elapsed
- The reverse-current protection has tripped
- The die temperature exceeds +170°C
- SETI is connected to ground.

### Thermal Shutdown

Thermal-shutdown circuitry protects the devices from overheating. The switch turns off and $\overline{FLAG}$ goes low immediately when the junction temperature exceeds +170°C (typ). The switch turns on again after the device temperature drops by approximately 15°C (typ).

## Applications Information

### Setting the Current Limit/Threshold

A resistor from SETI to ground programs the current limit/threshold value for the MAX14523A/MAX14523AL/MAX14523B/MAX14523C. Table 2 lists various current limit/thresholds set by different resistor values at SETI. Leaving SETI unconnected selects a 0 current limit/threshold. Connecting SETI to ground asserts $\overline{FLAG}$.

Use the following formula to calculate the current limit:

$$R_{SETI}(k\Omega) = \frac{141400(V)}{I_{LIM}(mA)} - 2.48(k\Omega)$$

# 250mA to 1.5A, Adjustable Current-Limit Switches

### Table 2. Current Limit/Threshold vs. Resistor Values

| $R_{SETI}$ (kΩ) | TYPICAL CURRENT LIMIT/THRESHOLD (mA) |
|---|---|
| 91.78 | 1500 |
| 121 | 1145 |
| 221 | 632 |
| 301 | 466 |
| 422 | 333 |
| 563.12 | 250 |
| ∞ (Open) | 0 |

Do not use an $R_{SETI}$ value smaller than 91.78kΩ.

**Note:** Connecting any capacitance larger than 20pF to SETI can cause instability.

### IN Bypass Capacitor

Connect a minimum of 1µF capacitor from IN to GND to limit the input voltage drop during momentary output short-circuit conditions. Larger capacitor values further reduce the voltage undershoot at the input.

### OUT Bypass Capacitor

For stable operation over the full temperature range and over the full-programmable current-limit range, use a 1µF ceramic capacitor from OUT to ground.

Excessive output capacitance can cause a false overcurrent condition due to decreased dv/dt across the capacitor. Calculate the maximum capacitive load ($C_{MAX}$) value that can be connected to OUT using the following formula:

$$C_{MAX}(\mu F) = \frac{I_{LIM}(mA) \times t_{BLANK(MIN)}(ms)}{V_{IN}(V)}$$

For example, for $V_{IN}$ = 3.3V, $t_{BLANK}$ = 10ms, and $I_{LIM}$ = 300mA, $C_{MAX}$ equals 909µF.

### Layout and Thermal Dissipation

To optimize the switch response time to output short-circuit conditions, it is very important to keep all traces as short as possible to reduce the effect of undesirable parasitic inductance. Place input and output capacitors as close as possible to the device (no more than 5mm). IN and OUT must be connected with wide short traces to the power bus. During normal operation, the power dissipation is small and the package temperature change is minimal. If the output is continuously shorted to ground at the maximum supply voltage, the operation of the switches with the autoretry option does not cause problems because the total power dissipated during the short is scaled by the duty cycle:

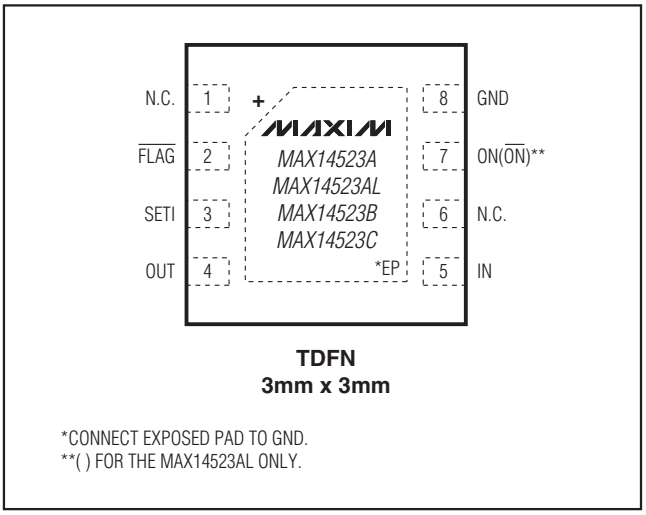
$$P_{(MAX)} = \frac{V_{IN(MAX)} \times I_{OUT(MAX)} \times t_{BLANK}}{t_{RETRY} + t_{BLANK}}$$

Attention must be given to the MAX14523C continuous current-limit version when the power dissipation during a fault condition can cause the device to reach the thermal shutdown threshold.

## Chip Information

PROCESS: BiCMOS

## Pin Configuration




**TDFN**
**3mm x 3mm**

*CONNECT EXPOSED PAD TO GND.
**( ) FOR THE MAX14523AL ONLY.

## Package Information

For the latest package outline information and land patterns, go to **www.maxim-ic.com/packages**.

| PACKAGE TYPE | PACKAGE CODE | DOCUMENT NO. |
|---|---|---|
| 8 TDFN-EP | T833+2 | 21-0137 |

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