19-1450; Rev 0; 7/99

# 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

MAX893L

## General Description

The MAX893L smart, low-voltage, P-channel, MOSFET power switch is intended for high-side load-switching applications. This switch operates with inputs from +2.7V to +5.5V, making it ideal for both +3V and +5V systems. Internal current-limiting circuitry protects the input supply against overload. Thermal overload protection limits power dissipation and junction temperature.

The MAX893L's maximum programmed current limit is 1.2A. The typical short-circuit current is 1.5 times the programmed current; therefore, a 1.2A programmed limit will result in a 1.8A short-circuit current limit. The current limit through the switch is programmed with a resistor from SET to ground. The quiescent supply current is a low 13µA. When the switch is off, the supply current decreases to 0.1µA.

The MAX893L is available in an 8-pin SO package.

## Features

- **+2.7V to +5.5V Input Range**
- **Programmable Current Limit**
  - **0.2A to 1.2A Range**
  - **±20% Accuracy**
- **1.2A Continuous Load Current**
- **1.8A Short-Circuit Current**
- **Low Quiescent Current**
  - **13µA at $V_{IN}$ = 3.3V**
  - **0.1µA with Switch Off**
- **Thermal Shutdown**
- **$\overline{\text{FAULT}}$ Indicator Output**
- **0.07Ω On-Resistance**

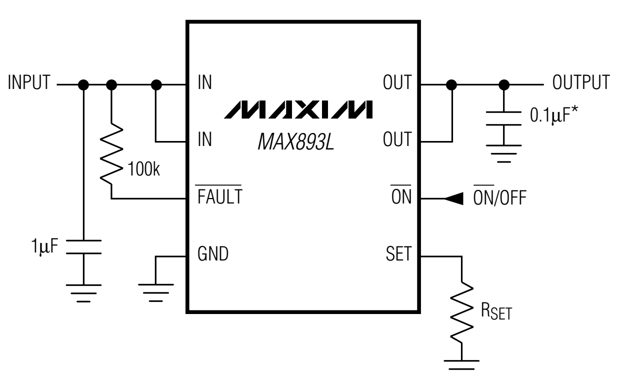
## Applications

USB Ports
USB Hubs
PCMCIA Slots
Access Bus Slots
Portable Equipment

## Ordering Information

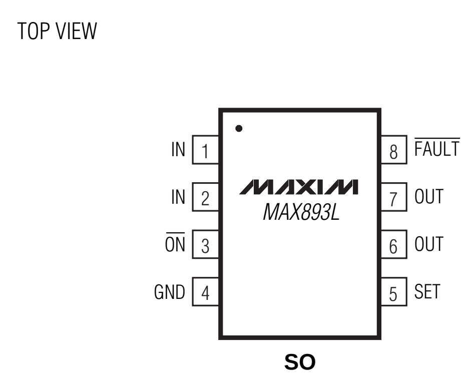
| PART | TEMP. RANGE | PIN-PACKAGE |
|---|---|---|
| MAX893LESA | -40°C to +85°C | 8 SO |

## Typical Operating Circuit




*USB SPECIFICATIONS REQUIRE HIGHER CAPACITANCE.

## Pin Configuration



# 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

## ABSOLUTE MAXIMUM RATINGS

IN to GND ..............................................................-0.3V to +6V
$\overline{ON}$, $\overline{FAULT}$ to GND ................................................-0.3V to +6V
SET, OUT to GND ..................................... -0.3V to ($V_{IN}$ + 0.3V)
Maximum Continuous Short-Circuit Switch Current .............2.0A
Continuous Power Dissipation ($T_A$ = +70°C)
SO (derate 5.88mW/°C above +70°C) .........................471mW

Operating Temperature Range
MAX893LESA ..................................................-40°C to +85°C
Storage Temperature Range ........................... -65°C to +150°C
Lead Temperature (soldering, 10sec) .............................+300°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.*

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 3V, **$T_A$ = 0°C to +85°C**, unless otherwise noted. Typical values are at $T_A$ = +25°C.)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Operating Voltage | | 2.7 | | 5.5 | V |
| Quiescent Current | $V_{IN}$ = 5V, $\overline{ON}$ = GND, $I_{OUT}$ = 0 | | 13 | 20 | µA |
| Off-Supply Current | $\overline{ON}$ = IN, $V_{IN}$ = $V_{OUT}$ = 5.5V | | 0.03 | 1 | µA |
| Off-Switch Current | $\overline{ON}$ = IN, $V_{IN}$ = 5.5V, $V_{OUT}$ = 0 | | 0.04 | 15 | µA |
| Undervoltage Lockout | Rising edge, 1% hysteresis | 2.0 | 2.4 | 2.6 | V |
| On-Resistance | $V_{IN}$ = 4.5V | | 70 | 125 | mΩ |
| | $V_{IN}$ = 3.0V | | 88 | 160 | |
| Current-Limit-Amplifier Threshold | $V_{SET}$ required to turn the switch off (Note 1) | 1.178 | 1.240 | 1.302 | V |
| Maximum Programmable Continuous Output Current Limit | | | 1.2 | | A |
| Short-Circuit Current | | | 1.8 | | A |
| $I_{OUT}$ to $I_{SET}$ Current Ratio | $I_{OUT}$ = 500mA, $V_{OUT}$ > 1.6V | 920 | 1080 | 1250 | A/A |
| $\overline{ON}$ Input Voltage Low | $V_{IN}$ = 2.7V to 5.5V | | | 0.8 | V |
| $\overline{ON}$ Input Voltage High | $V_{IN}$ = 2.7V to 3.6V | 2.0 | | | V |
| | $V_{IN}$ = 4.5V to 5.5V | 2.4 | | | |
| $\overline{ON}$ Input Leakage Current | $V_{\overline{ON}}$ = 5.5V | | 0.01 | 1 | µA |
| $I_{SET}$ Bias Current | $V_{SET}$ = 1.24V, $I_{OUT}$ = 0; $V_{IN}$ = $V_{OUT}$ | | 0.5 | 3 | µA |
| $\overline{FAULT}$ Logic Output Voltage Low | $I_{SINK}$ = 1mA, $V_{SET}$ = 1.4V | | | 0.4 | V |
| $\overline{FAULT}$ Logic Output High Leakage Current | $V_{\overline{FAULT}}$ = 5.5V, $V_{SET}$ = 1V | | 0.05 | 1 | µA |
| Slow Current-Loop Response Time | 20% current overdrive, $V_{IN}$ = 5V | | 5 | | µs |
| Fast Current-Loop Response Time | | | 2 | | µs |
| Turn-On Time | $V_{IN}$ = 5V, $I_{OUT}$ = 500mA | | 80 | 200 | µs |
| | $V_{IN}$ = 3V, $I_{OUT}$ = 500mA | | 115 | | |
| Turn-Off Time | $V_{IN}$ = 5V, $I_{OUT}$ = 500mA | 2 | 4 | | µs |

## ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 3V, **$T_A$ = -40°C to +85°C**, unless otherwise noted.) (Note 2)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| Operating Voltage | | 3.0 | | 5.5 | V |
| Quiescent Current | $V_{IN}$ = 5V, $\overline{ON}$ = GND, $I_{OUT}$ = 0 | | | 30 | µA |
| Off-Supply Current | $\overline{ON}$ = IN, $V_{IN}$ = $V_{OUT}$ = 5.5V | | | 2.2 | µA |
| Off-Switch Current | $\overline{ON}$ = IN, $V_{IN}$ = 5.5V, $V_{OUT}$ = 0 | | | 15 | µA |
| Undervoltage Lockout | Rising edge, 1% hysteresis | 2.0 | | 2.9 | V |
| On-Resistance | $V_{IN}$ = 4.5V | | | 125 | mΩ |
| | $V_{IN}$ = 3.0V | | | 160 | |
| Current-Limit-Amplifier Threshold | $V_{SET}$ required to turn the switch off (Note 1) | 1.14 | | 1.34 | V |
| $I_{OUT}$ to $I_{SET}$ Current Ratio | $I_{OUT}$ = 500mA, $V_{OUT}$ > 1.6V | 865 | | 1300 | A/A |
| $\overline{FAULT}$ Logic Output Voltage Low | $I_{SINK}$ = 1mA, $V_{SET}$ = 1.4V | | | 0.4 | V |
| Turn-On Time | $V_{IN}$ = 5V, $I_{OUT}$ = 500mA | | | 200 | µs |
| Turn-Off Time | $V_{IN}$ = 5V, $I_{OUT}$ = 500mA | 1 | | 20 | µs |

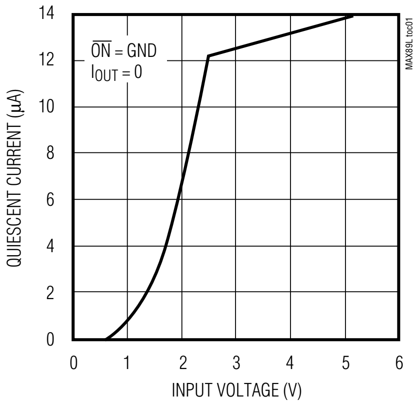
**Note 1:** Tested with $I_{OUT}$ = 100mA and $V_{SET}$ raised until $V_{IN}$ - $V_{OUT}$ ≥ 0.8V.
**Note 2:** Specifications to -40°C are guaranteed by design, not production tested.

# 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

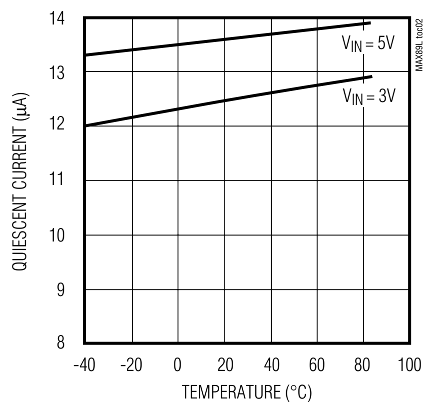
## Typical Operating Characteristics

($T_A$ = +25°C, unless otherwise noted.)

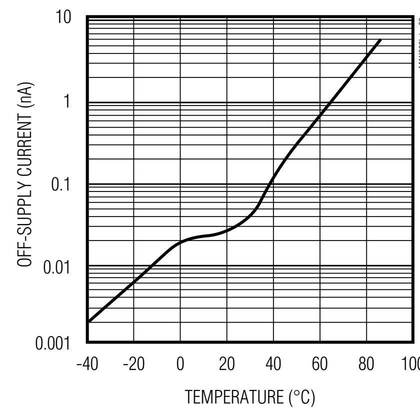
**QUIESCENT CURRENT vs. INPUT VOLTAGE**



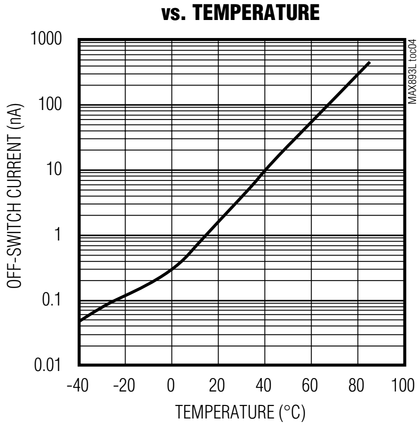

**QUIESCENT CURRENT vs. TEMPERATURE**



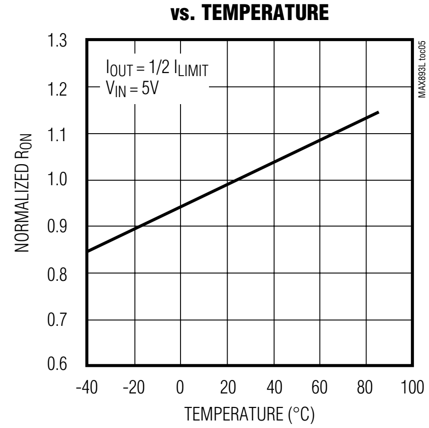

**OFF-SUPPLY CURRENT vs. TEMPERATURE**



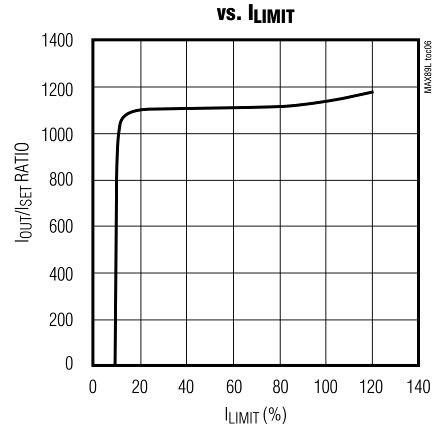

**OFF-SWITCH CURRENT vs. TEMPERATURE**



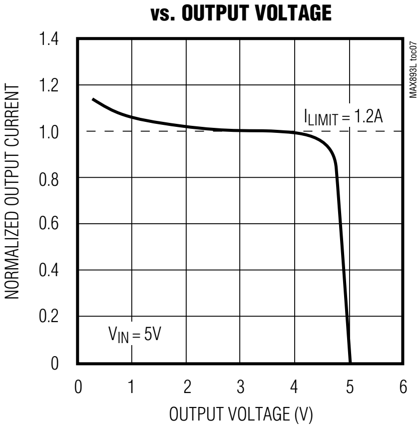

**NORMALIZED ON-RESISTANCE vs. TEMPERATURE**



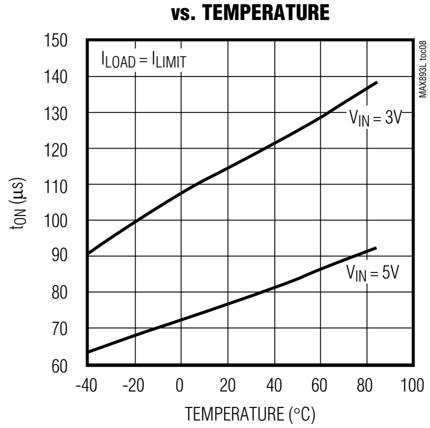

**IOUT/ISET RATIO vs. ILIMIT**



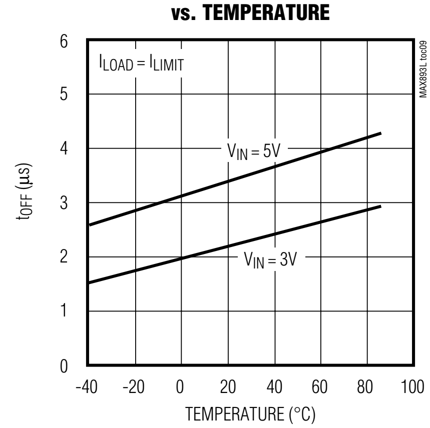

**NORMALIZED OUTPUT CURRENT vs. OUTPUT VOLTAGE**




**TURN-ON TIME vs. TEMPERATURE**



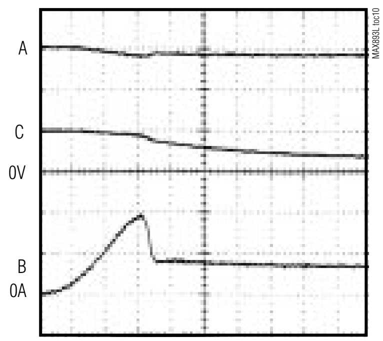

**TURN-OFF TIME vs. TEMPERATURE**



## Typical Operating Characteristics (continued)

($T_A$ = +25°C, unless otherwise noted.)

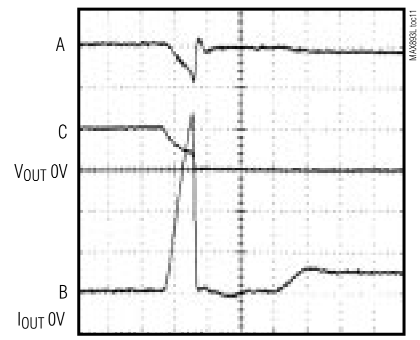
**OUTPUT OVERLOAD (SLOW-LOOP RESPONSE)**




2μs/div

$C_{IN}$ = 100μF, $C_{OUT}$ = 0.1μF
A: $V_{IN}$, 1V/div, AC-COUPLED
B: $I_{OUT}$, 1A/div
C: $V_{OUT}$, 5V/div

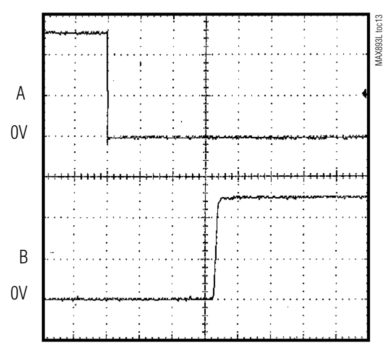
**OUTPUT SHORT CIRCUIT (FAST-LOOP RESPONSE)**




2μs/div

$C_{IN}$ = 100μF, $C_{OUT}$ = 0.1μF
A: $V_{IN}$, 1V/div, AC-COUPLED
B: $I_{OUT}$, 2A/div
C: $V_{OUT}$, 5V/div

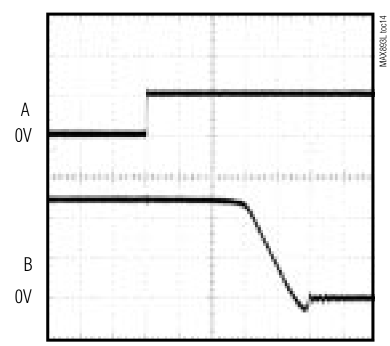
**SWITCH TURN-ON TIME**




20μs/div

$V_{IN}$ = 5V, $I_{OUT}$ = $I_{LIMIT/2}$
A: $V_{ON}$, 2V/div
B: $V_{OUT}$, 2V/div

**SWITCH TURN-OFF TIME**




1μs/div

$V_{IN}$ = 5V, $I_{OUT}$ = $I_{LIMIT/2}$
A: $V_{\overline{ON}}$, 2V/div
B: $V_{OUT}$, 2V/div

# 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

## Pin Description

| PIN | NAME | FUNCTION |
|---|---|---|
| 1, 2 | IN | Input. P-channel MOSFET source. Bypass IN with a 1µF capacitor to ground. |
| 3 | $\overline{ON}$ | Active-Low Switch On Input. A logic low turns the switch on. |
| 4 | GND | Ground |
| 5 | SET | Set Current-Limit Input. A resistor from SET to ground sets the current limit for the switch. $R_{SET} = 1.34 \cdot 10^3 / I_{LIMIT}$, where $I_{LIMIT}$ is the desired current limit in amperes. |
| 6, 7 | OUT | Switch Output. P-channel MOSFET drain. Bypass OUT with a 0.1µF capacitor to ground. |
| 8 | $\overline{FAULT}$ | Fault-Indicator Output. This open-drain output goes low when in current limit or when the die temperature exceeds +165°C. |

## Detailed Description

The MAX893L P-channel MOSFET power switch limits output current to a programmed level. When the output current is increased beyond the programmed current limit, or 1.2A ($I_{MAX}$), the current also increases through the replica switch ($I_{OUT}$ / 1080) and through $R_{SET}$ (Figure 1). The current-limit error amplifier compares the voltage across $R_{SET}$ to the internal 1.24V reference, and regulates the current to the programmed current limit ($I_{LIMIT}$).

This switch is not bidirectional; therefore, the input voltage must be higher than the output voltage.

### Setting the Current Limit

The MAX893L features internal current-limiting circuitry with a maximum programmable value ($I_{MAX}$) of 1.2A. For best performance, set the current limit ($I_{LIMIT}$) between 0.2A ≤ $I_{LIMIT}$ ≤ 1.2A. This current limit remains in effect throughout the input supply-voltage range.

Program the current limit with a resistor ($R_{SET}$) from SET to ground (Figure 2) as follows:

$$I_{SET} = I_{LIMIT} / 1080$$

$$R_{SET} = 1.24V / I_{SET} = 1.34 \cdot 10^3 / I_{LIMIT}$$

where $I_{LIMIT}$ is the desired current limit.

### Short-Circuit Protection

The MAX893L is a short-circuit protected switch. In the event of an output short circuit or a current overload condition, the current through the switch is limited by the internal current-limiting error amplifier to $1.5 \cdot I_{LIMIT}$. The short-circuit current is typically 1.8A for a programmed current limit of 1.2A. When the short-circuit condition is removed, the replica error amplifier will set the current limit back to $I_{LIMIT}$.

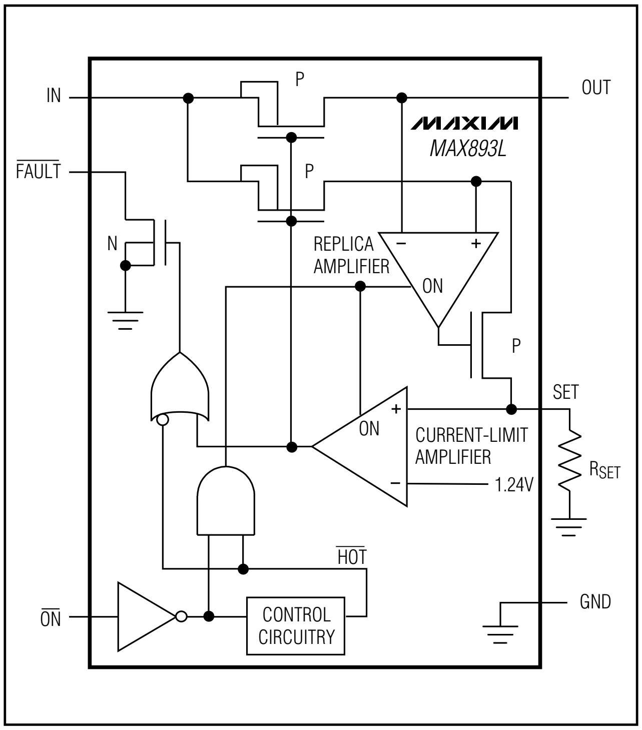



*Figure 1. Functional Diagram*

For a high $\Delta V_{DS}/\Delta t$ during an output short-circuit condition, the switch turns off and disconnects the input supply from the output. The current-limiting amplifier then slowly turns the switch on with the output current limited to $1.5 \cdot I_{LIMIT}$. When the short-circuit condition is removed, the current limit is set back to $I_{LIMIT}$. See Output Short-Circuit (Fast-Loop Response) and Output Overload (Slow-Loop Response) in the *Typical Operating Characteristics*.

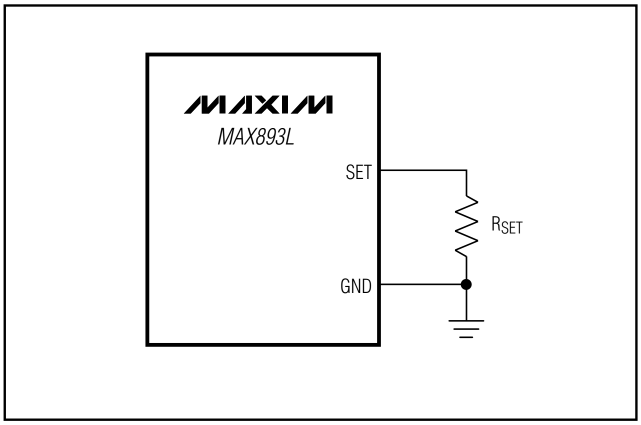



Figure 2. Setting the Current Limit

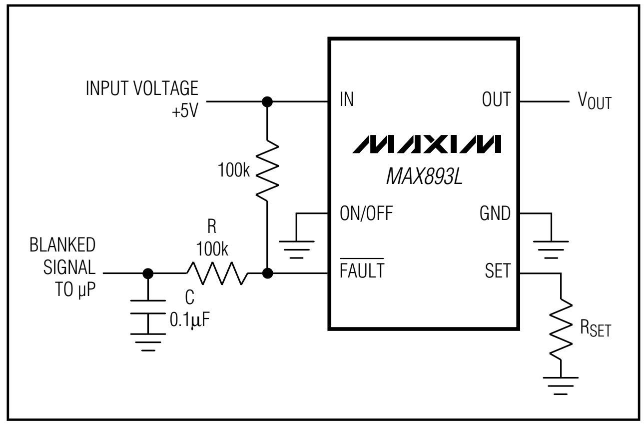



Figure 3. Fault-Blanking Circuit

### Thermal Shutdown

The MAX893L features thermal shutdown. The switch turns off when the junction temperature exceeds +165°C. Once the device cools by 10°C, the switch turns back on. If the fault condition is not removed, the switch will cycle on and off, resulting in a pulsed output.

### Fault Indicator

The MAX893L provides a fault output ($\overline{FAULT}$). This open-drain output goes low when in current limit or when the die temperature exceeds +165°C. A 100kΩ pull-up resistor from $\overline{FAULT}$ to IN provides a logic-control signal.

### Fault Blanking

During start-up in USB applications, the MAX893L charges the relatively large USB capacitance. This may activate an unwanted fault signal if the charging current exceeds the programmed current limit. To "blank out" this start-up fault signal, add a simple lowpass RC delay circuit as shown in Figure 3. This circuit provides a 10ms delay.

## Applications Information

### Input Capacitor

To limit the input voltage drop during momentary output short-circuit conditions, connect a capacitor no more than 5mm from IN to GND. A 1µF ceramic capacitor will be adequate for most applications; however, higher capacitor values will further reduce the voltage drop at the input.

### Output Capacitor

Connect a 0.1µF capacitor from OUT to GND to prevent inductive parasitics from pulling OUT negative during turn-off.

### Layout and Thermal-Dissipation Considerations

To take full advantage of 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 to the device as possible (no more than 5mm).

Under normal operating conditions, the package can dissipate and channel heat away. Calculate the maximum power as follows:

$$P = (I_{LIMIT})^2 \cdot R_{ON}$$

where $R_{ON}$ is the on-resistance of the switch.

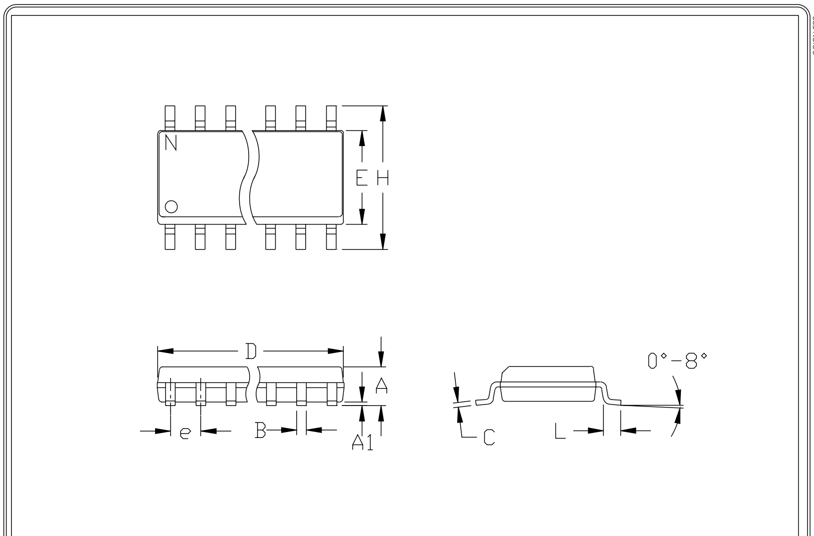
When the output is short circuited, the voltage drop across the switch equals the input supply. Hence, the power dissipated across the switch increases, as does the die temperature. If the fault condition is not removed, the thermal-shutdown protection circuitry turns the switch off until the die temperature falls by 10°C. A ground plane in contact with the device will help dissipate additional heat.

## Chip Information

TRANSISTOR COUNT: 340

# 1.2A, Current-Limited, High-Side P-Channel Switch with Thermal Shutdown

## Package Information




| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| | MIN | MAX | MIN | MAX |
| A | 0.053 | 0.069 | 1.35 | 1.75 |
| A1 | 0.004 | 0.010 | 0.10 | 0.25 |
| B | 0.014 | 0.019 | 0.35 | 0.49 |
| C | 0.007 | 0.010 | 0.19 | 0.25 |
| e | 0.050 | | 1.27 | |
| E | 0.150 | 0.157 | 3.80 | 4.00 |
| H | 0.228 | 0.244 | 5.80 | 6.20 |
| h | 0.010 | 0.020 | 0.25 | 0.50 |
| L | 0.016 | 0.050 | 0.40 | 1.27 |

| | INCHES | | MILLIMETERS | | | |
|---|---|---|---|---|---|---|
| | MIN | MAX | MIN | MAX | N | MS012 |
| D | 0.189 | 0.197 | 4.80 | 5.00 | 8 | A |
| D | 0.337 | 0.344 | 8.55 | 8.75 | 14 | B |
| D | 0.386 | 0.394 | 9.80 | 10.00 | 16 | C |

NOTES:
1. D&E DO NOT INCLUDE MOLD FLASH
2. MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .15mm (.006")
3. LEADS TO BE COPLANAR WITHIN .102mm (.004")
4. CONTROLLING DIMENSION: MILLIMETER
5. MEETS JEDEC MS012-XX AS SHOWN IN ABOVE TABLE
6. N = NUMBER OF PINS

MAXIM 120 SAN GABRIEL DR SUNNYVALE CA 94086 FAX (408) 737 7194 PROPRIETARY INFORMATION | TITLE: PACKAGE FAMILY OUTLINE: SOIC .150" | 1/1 | DOCUMENT CONTROL NUMBER: 21-0041 | REV: A