19-1223; Rev 0; 4/97

MAXIM

Current-Limited, High-Side P-Channel Switches with Thermal Shutdown

General Description

The MAX891L/MAX892L smart, low-voltage, P-channel, MOSFET power switches are intended for high-side load-switching applications. These switches operate with inputs from 2.7V to 5.5V, making them 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 temperatures.

The MAX891L/MAX892L's maximum current limits are 500mA and 250mA, respectively. The current limit through the switch is programmed with a resistor from SET to ground. When the switch is on, the quiescent supply current is a low 13µA. When the switch is off, the quiescent current decreases to 0.1µA.

The MAX891L/MAX892L are available in 8-pin µMAX packages.

Applications

PCMCIA Slots

Access Bus Slots

Portable Equipment

Features

- **Ultra-Small µMAX Package—Only 1.11mm High**
- **2.7V to 5.5V Input Range**
- **Programmable Current Limit**
- **Low 13µA Quiescent Current at V_{IN} = 3.3V, 0.1µA Switch Off**
- **Thermal Shutdown**
- **$\overline{FAULT}$ Indicator Output**
- **On-Resistances:**
  0.12Ω (MAX891L)
  0.25Ω (MAX892L)

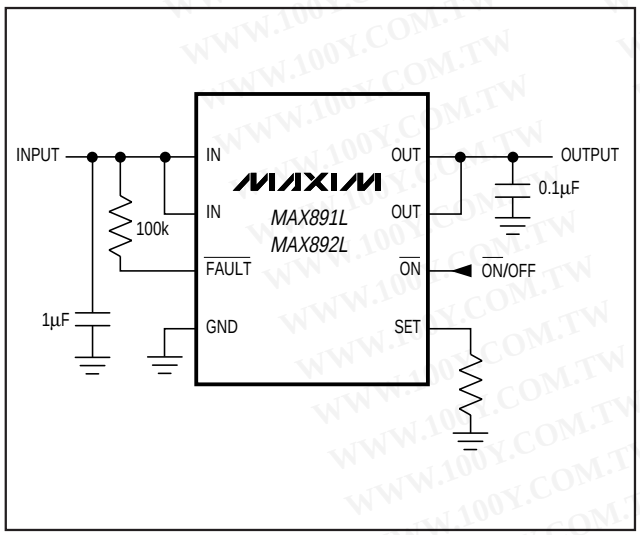
Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE	CURRENT LIMIT
MAX891LC/D	0°C to +70°C	Dice**	500mA
MAX891LEUA*	-40°C to +85°C	8 µMAX	500mA
MAX892LC/D	0°C to +70°C	Dice**	250mA
MAX892LEUA*	-40°C to +85°C	8 µMAX	250mA

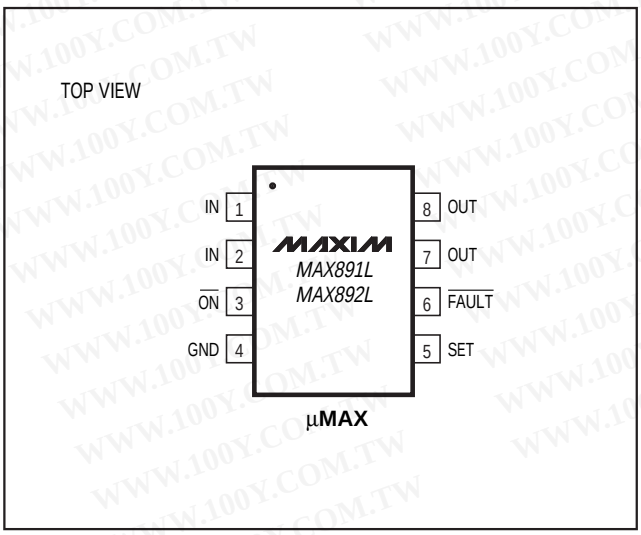
** To order these units in tape and reel, add (-T) to the end of the part number.*

*** Dice are tested at T_A = +25°C.*

Typical Operating Circuit



Pin Configuration



Current-Limited, High-Side P-Channel Switches 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 Switch Current
MAX891L 0.75A
MAX892L 0.375A

Continuous Power Dissipation (T_A = +70°C)
µMAX (derate 4.1mW/°C above +70°C) 330mW
Operating Temperature Range
MAX891LEUA/MAX892LEUA .....-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} = 0mA			13	20	µA
Off-Supply Current	$\overline{ON}$ = IN, V_{IN} = V_{OUT} = 5.5V			0.02	1	µA
Off-Switch Current	$\overline{ON}$ = IN, V_{IN} = 5.5V, V_{OUT} = 0V			0.02	3	µA
Undervoltage Lockout	Rising edge, 1% hysteresis		2.0	2.3	2.6	V
On-Resistance	V_{IN} = 4.5V	MAX891L		120	225	mΩ
		MAX892L		250	420	
	V_{IN} = 3.0V	MAX891L		150	300	mΩ
		MAX892L		300	500	
Current-Limit-Amplifier Accuracy	V_{SET} required to turn the switch off (Note 1)		1.178	1.240	1.302	V
Maximum Output Current	MAX891L			500		mA
	MAX892L			250		
I_{OUT} to I_{SET} Current Ratio	V_{OUT} = 1.6V to 2.8V	MAX891L, I_{OUT} = 250mA	840	965	1130	A/A
		MAX892L, I_{OUT} = 125mA	840	965	1130	
$\overline{ON}$ Input Low Voltage	V_{IN} = 2.7V to 5.5V				0.8	V
$\overline{ON}$ Input High Voltage	V_{IN} = 2.7V to 3.6V		2.0			V
	V_{IN} = 4.5V to 5.5V		2.4			
$\overline{ON}$ Input Leakage	$V_{\overline{ON}}$ = 5.5V		-1	0.01	1	µA
I_{SET} Bias Current	V_{SET} = 1.24V, I_{OUT} = 0mA			0.5	3	µA
$\overline{FAULT}$ Logic Output Low Voltage	I_{SINK} = 1mA, V_{SET} = 1.4V				0.4	V
$\overline{FAULT}$ Logic Output High Leakage	$V_{\overline{FAULT}}$ = 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	I_{OUT} = 250mA (MAX891L), or 125mA (MAX892L)	V_{IN} = 5V		100	200	µs
		V_{IN} = 3V		150		
Turn-Off Time	V_{IN} = 5V		0.8	2	20	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} = 0mA				50	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} = 0V				8	µA
Undervoltage Lockout	Rising edge, 1% hysteresis		2.0		2.9	V
On-Resistance	V_{IN} = 4.5V	MAX891L			225	mΩ
		MAX892L			420	
	V_{IN} = 3.0V	MAX891L			300	mΩ
		MAX892L			500	
Current-Limit-Amplifier Accuracy	V_{SET} required to turn the switch off (Note 1)		1.14		1.34	V
I_{OUT} to I_{SET} Current Ratio	V_{OUT} = 1.6V to 2.8V	MAX891L, I_{OUT} = 250mA	805		1210	A/A
		MAX892L, I_{OUT} = 125mA	805		1210	
$\overline{FAULT}$ Logic Output Low Voltage	I_{SINK} = 1mA, V_{SET} = 1.4V				0.4	V
Turn-On Time	V_{IN} = 5V				200	µs
Turn-Off Time	V_{IN} = 5V		0.25		20	µs

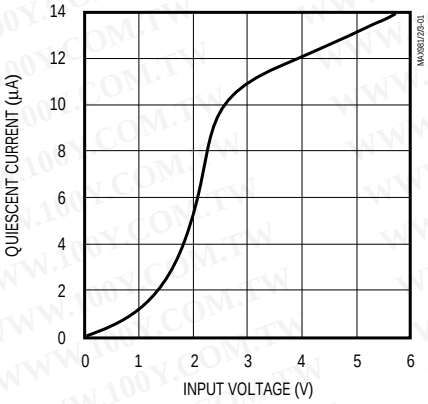
Note 1: Tested with I_{OUT} = 50mA for the MAX891L, 25mA for the MAX892L, and V_{SET} raised until V_{IN} - V_{OUT} ≥ 0.8V.
Note 2: Parameters to -40°C are guaranteed by design, not production tested.

Current-Limited, High-Side P-Channel Switches with Thermal Shutdown

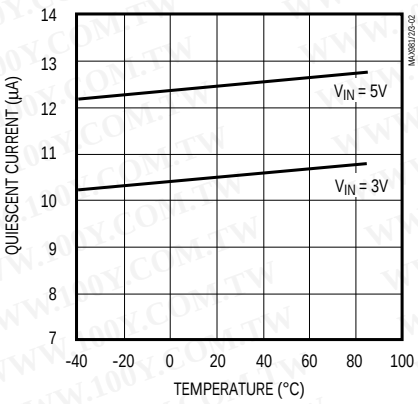
Typical Operating Characteristics

(Typical Operating Circuit, T_A = +25°C, unless otherwise noted.)

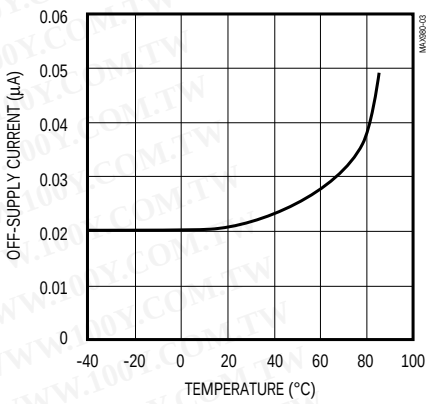
QUIESCENT CURRENT vs. INPUT VOLTAGE



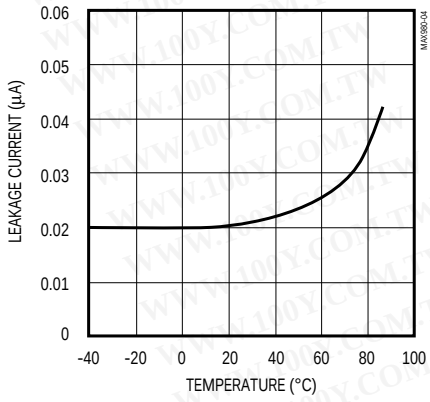
QUIESCENT CURRENT vs. TEMPERATURE



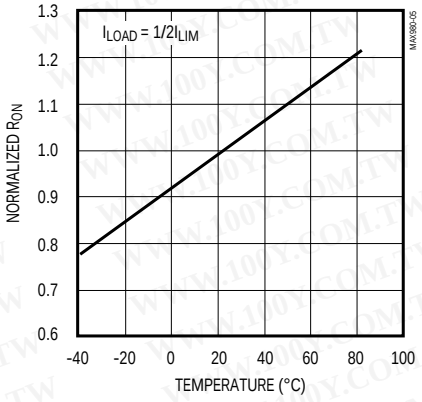
OFF-SUPPLY CURRENT vs. TEMPERATURE



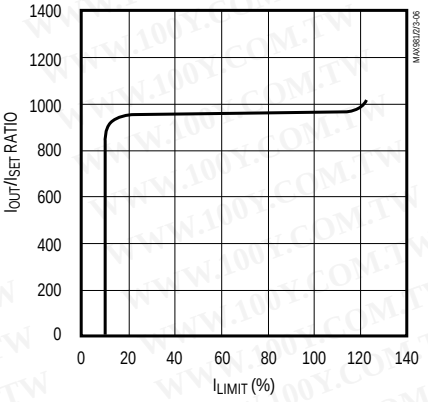
OFF-SWITCH LEAKAGE CURRENT vs. TEMPERATURE



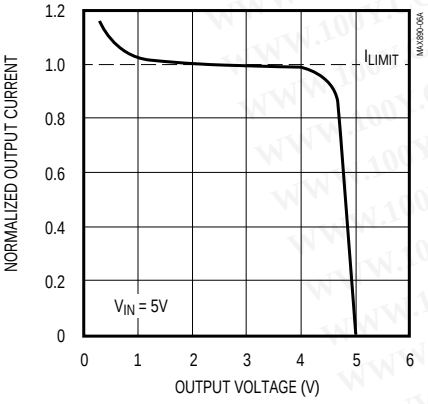
NORMALIZED ON-RESISTANCE vs. TEMPERATURE



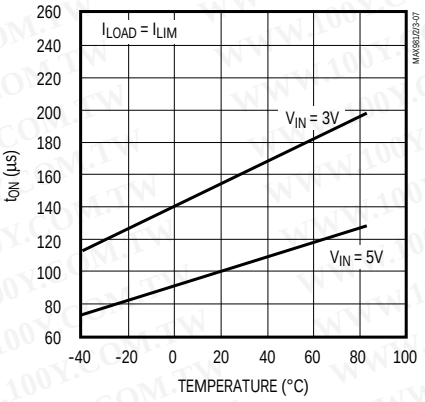
I_{OUT}/I_{SET} RATIO vs. I_{LIMIT}



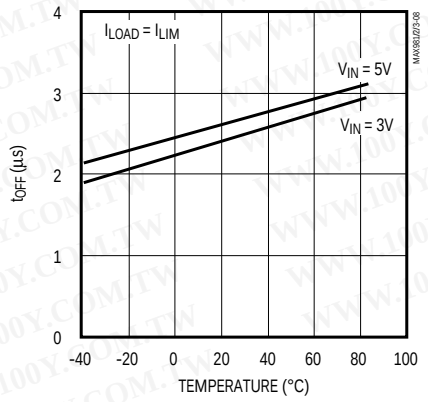
NORMALIZED OUTPUT CURRENT vs. OUTPUT VOLTAGE



TURN-ON TIME vs. TEMPERATURE



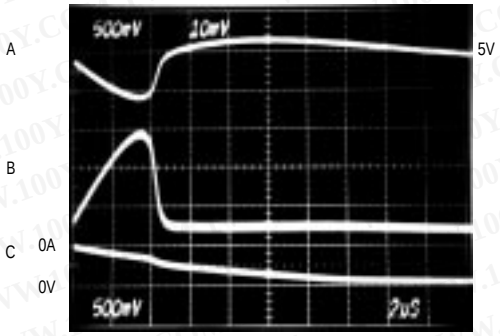
TURN-OFF TIME vs. TEMPERATURE



Typical Operating Characteristics (continued)

(Typical Operating Circuit, T_A = +25°C, unless otherwise noted.)

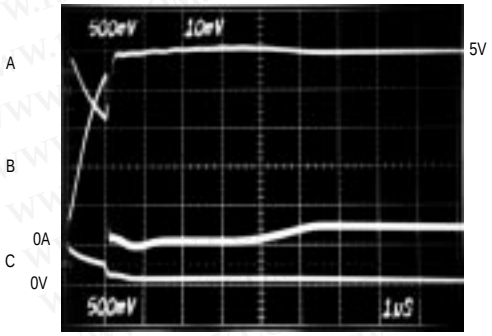
CURRENT-LIMIT RESPONSE
(MAX891L, R_L = 0.8Ω)



2µs/div

C_{IN} = 47µF, C_{OUT} = 0.1µF
A: V_{IN}, 500mV/div, AC COUPLED
B: I_{OUT}, 2A/div
C: V_{OUT}, 5V/div

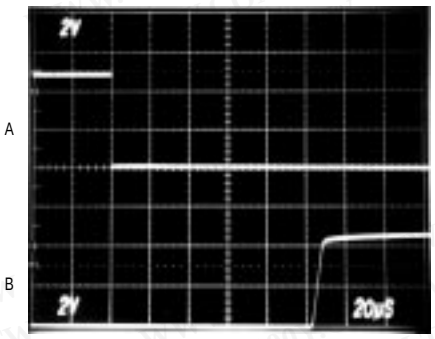
CURRENT-LIMIT RESPONSE
(MAX891L, R_L = 0.5Ω)



1µs/div

C_{IN} = 47µF, C_{OUT} = 0.1µF
A: V_{IN}, 500mV/div, AC COUPLED
B: I_{OUT}, 2A/div
C: V_{OUT}, 5V/div

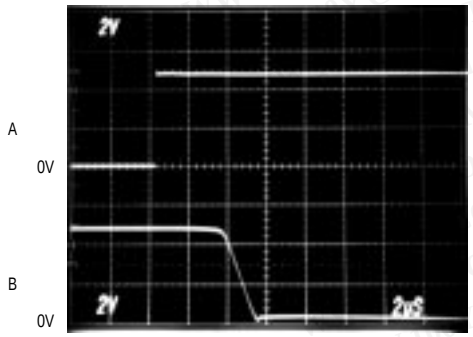
SWITCH TURN-ON TIME



20µs/div

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

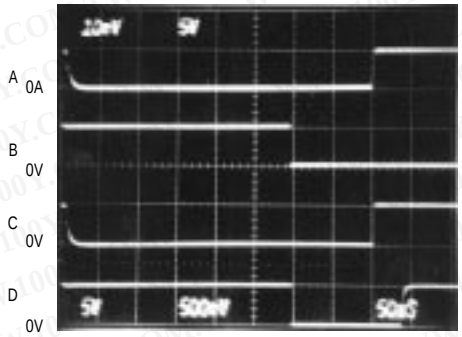
SWITCH TURN-OFF TIME



2µs/div

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

SWITCH TIMING CHARACTERISTICS



50µs/div

V_{IN} = 5V
A: I_{LOAD}, 0.1A/div
B: $V_{\overline{ON}}$, 5V/div
C: V_{OUT}, 5V/div
D: V_{FAULT}, 5V/div

Current-Limited, High-Side P-Channel Switches 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. See *Setting the Current Limit* section.
6	$\overline{FAULT}$	Fault-Indicator Output. This open-drain output goes low when in current limit or when the die temperature exceeds +135°C.
7, 8	OUT	Switch Output. P-channel MOSFET drain. Bypass OUT with a 0.1µF capacitor to ground.

Detailed Description

The MAX891L/MAX892L P-channel MOSFET power switches limit output current to a user-programmed level. When the output current is increased beyond the set current level, the current is also increased through the replica switch (I_{OUT}/965) 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 back to the lesser of the programmed current limit (I_{LIMIT}) or the maximum current limit (I_{MAX}).

These switches are not bidirectional; therefore, the input voltage must be higher than the output voltage.

Setting the Current Limit

The MAX891L/MAX892L feature internal current-limiting circuitry with maximum programmable values (I_{MAX}) of 500mA and 250mA, respectively. For best performance, set the current limit (I_{LIMIT}) between $0.2I_{MAX} \le I_{LIMIT} \le I_{MAX}$. 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:

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

$$R_{SET} = 1.240 / I_{SET}$$

where I_{LIMIT} is the desired current limit, and I_{RATIO} is the I_{OUT} to I_{SET} current ratio (965).

Short-Circuit Protection

The MAX891L/MAX892L are short-circuit-protected switches. In the event of an output short circuit or current-overload condition, the current through the switch is limited by the internal current-limiting error amplifier to 1.5 x I_{LIMIT}. When the fault condition is removed, the replica error amplifier sets the current limit back to I_{LIMIT}.

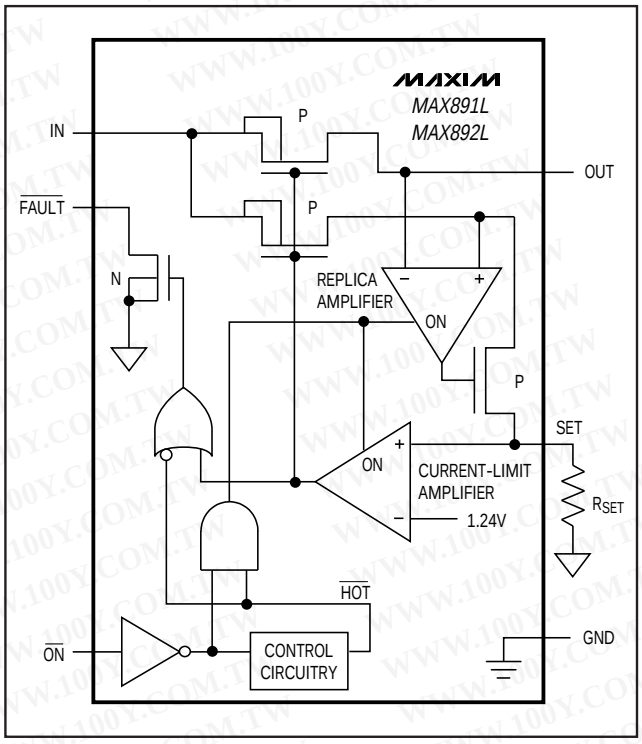


Figure 1. Functional Diagram

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 x I_{LIMIT}. When the fault condition is removed, the current limit is set back to I_{LIMIT}. Refer to the Current-Limit Response graphs in the *Typical Operating Characteristics*.

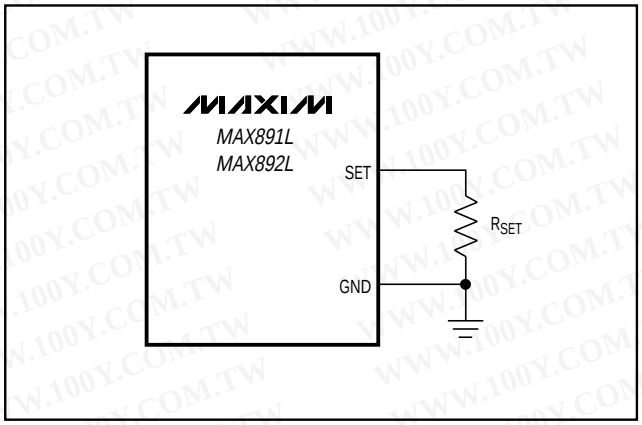


Figure 2. Setting the Current Limit

Thermal Shutdown

The MAX891L/MAX892L feature thermal shutdown. The switch turns off when the junction temperature exceeds +135°C. Once the device cools by 10°C, the switch turns back on. If the fault short-circuit condition is not removed, the switch will cycle on and off, resulting in a pulsed output.

Fault Indicator

The MAX891L/MAX892L provide a fault output ($\overline{FAULT}$). This open-drain output goes low when in current limit or when the die temperature exceeds +135°C. During start-up, $\overline{FAULT}$ is low until the switch is fully on and no over-current condition exists. A 100kΩ pull-up resistor from $\overline{FAULT}$ to IN provides a logic-control signal.

Applications Information

Input Capacitor

To limit input voltage drop during momentary output short-circuit conditions, connect a capacitor from IN to GND. A 1µF ceramic capacitor is adequate for most applications; however, higher capacitor values further reduce voltage drop at the input.

Output Capacitor

Connect a 0.1µF capacitor from OUT to GND. One function of this capacitor is to prevent inductive parasitics from pulling OUT negative during turn-off.

Layout and Thermal-Dissipation Consideration

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 as possible to the device (no more than 5mm).

Under normal operating conditions, the package dissipates and channels heat away. Calculate maximum power as follows:

$$P = I^2_{LIM} \times R_{ON}$$

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

When the output is short circuited, 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-overload-protection circuitry turns the switch off until the die temperature falls by 10°C. A ground plane in contact with the device helps dissipate additional heat.

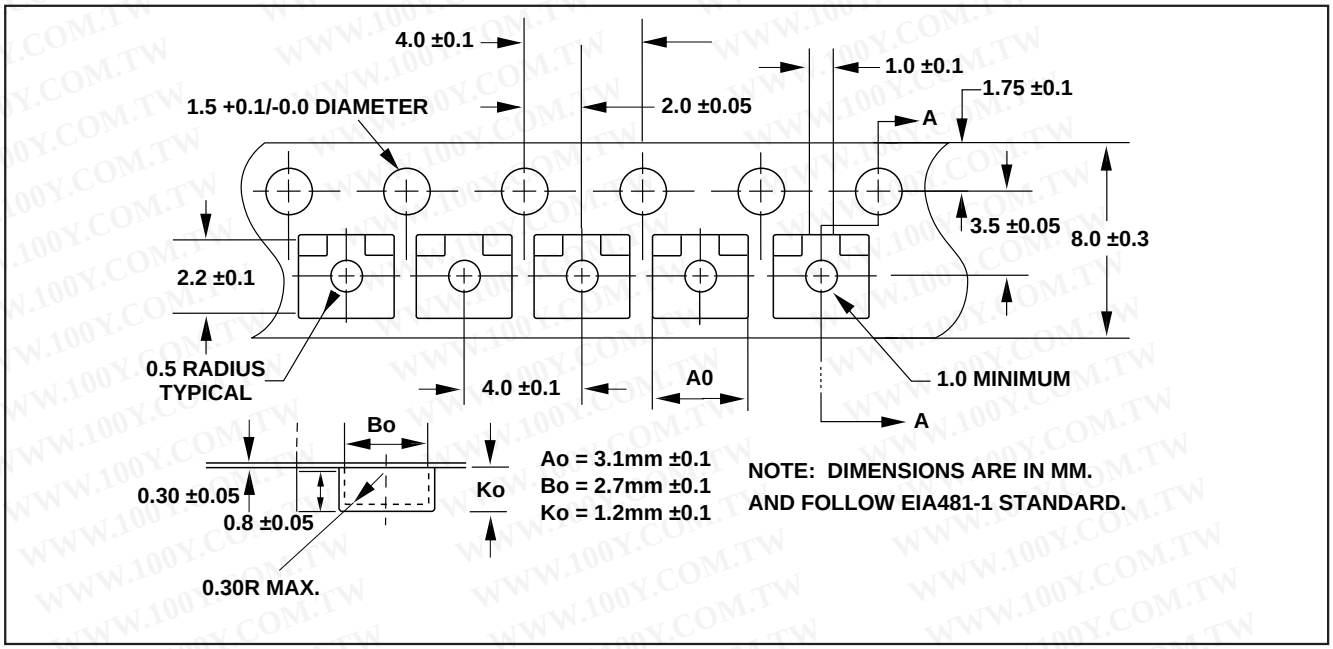
Chip Information

TRANSISTOR COUNT: 396

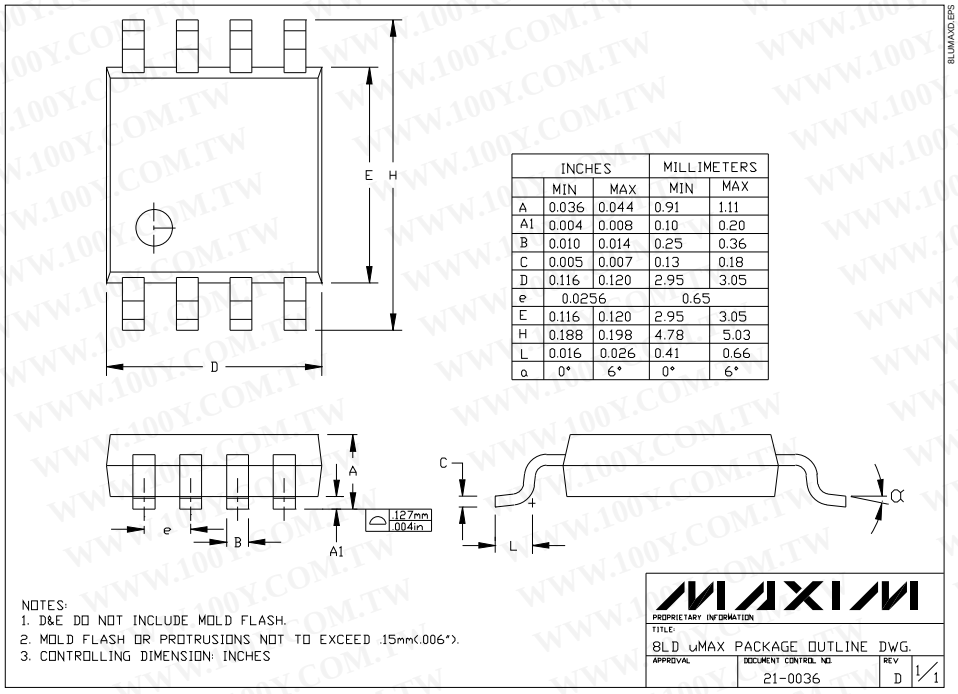
SUBSTRATE CONNECTED TO GND

Current-Limited, High-Side P-Channel Switches with Thermal Shutdown

Tape-and-Reel Information



Package Information



	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.036	0.044	0.91	1.11
A1	0.004	0.008	0.10	0.20
B	0.010	0.014	0.25	0.36
C	0.005	0.007	0.13	0.18
D	0.116	0.120	2.95	3.05
e	0.0256		0.65	
E	0.116	0.120	2.95	3.05
H	0.188	0.198	4.78	5.03
L	0.016	0.026	0.41	0.66
α	0°	6°	0°	6°