19-1153; Rev 0; 10/96

MAXIM

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

General Description

The MAX894L/MAX895L smart, dual, 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 temperature.

The MAX894L/MAX895L's maximum current limits are 500mA and 250mA, respectively. The current limit through the switches is programmed with resistors from SET A/SET B to ground. When the switches are on, the quiescent supply current is a low 16µA. When the switches are off, the supply current decreases to 0.1µA.

The MAX894L/MAX895L are available in an 8-pin SO package.

Applications

PCMCIA Slots

Access Bus Slots

Portable Equipment

Features

- **+2.7V to +5.5V Input Range**
- **Programmable Current Limits**
- **Low Supply Current:**
  16µA I_Q at V_{IN} = 3.3V
  0.1µA with Switch Off
- **Thermal Shutdown**

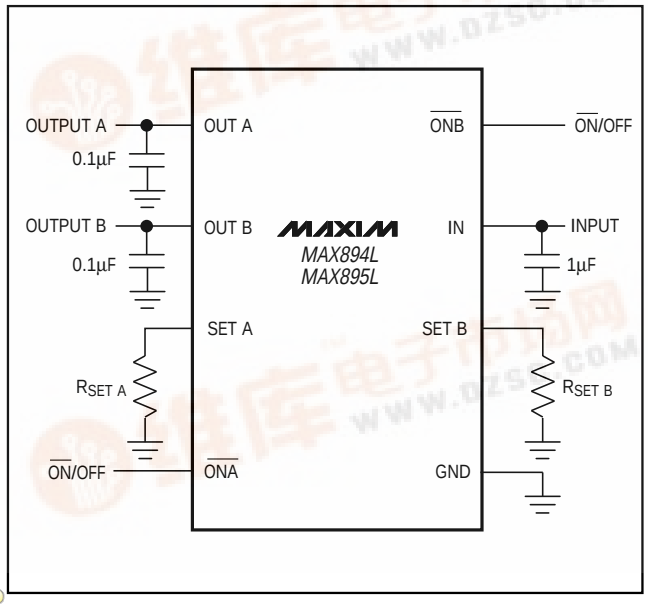
Ordering Information

PART*	TEMP. RANGE	PIN-PACKAGE	CURRENT LIMIT
MAX894LC/D	0°C to +70°C	Dice**	500mA
MAX894LESA	-40°C to +85°C	8 SO	500mA
MAX895LC/D	0°C to +70°C	Dice**	250mA
MAX895LESA	-40°C to +85°C	8 SO	250mA

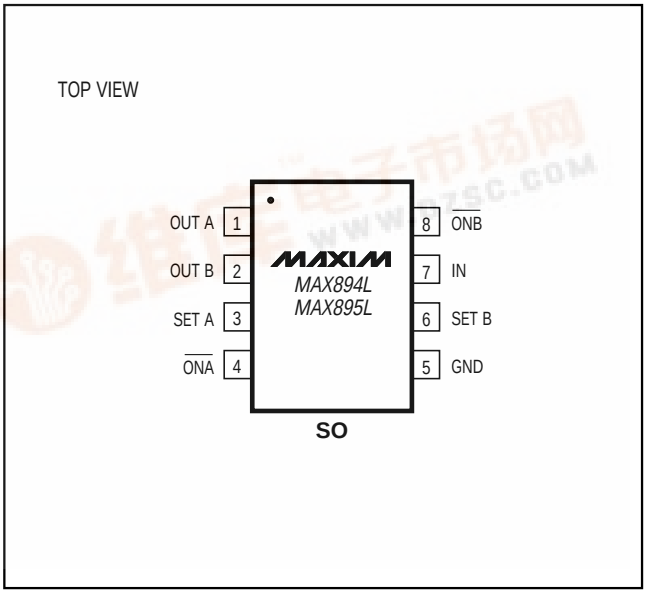
*To order these units in tape and reel, add (-T) to the end of the part number.

**Dice are tested at T_A = +25°C.

Typical Operating Circuit



Pin Configuration



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

ABSOLUTE MAXIMUM RATINGS

IN to GND .....-0.3V to 6V
$\overline{ONA}$, $\overline{ONB}$ to GND .....-0.3V to 6V
SET A, SET B, OUT A, OUT B to GND .....-0.3V to (V_{IN} + 0.3V)
Maximum Continuous Switch Current
MAX894L 0.75A
MAX895L 0.375A

Continuous Power Dissipation (T_A = +70°C)
SO (derate 5.88mW/°C above +70°C) 471mW
Operating Temperature Range
MAX89_LESA .....-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	CONDITION		MIN	TYP	MAX	UNITS
Operating Voltage			2.7		5.5	V
Quiescent Current	V_{IN} = 5V, $\overline{ONA}$ = $\overline{ONB}$ = GND, $I_{OUT\ A}$ = $I_{OUT\ B}$ = 0			18	30	µA
Off-Supply Current	$\overline{ONA}$ = $\overline{ONB}$ = IN, V_{IN} = $V_{OUT\ A}$ = $V_{OUT\ B}$ = 5.5V			0.03	1	µA
Off-Switch Current	$\overline{ONA}$ = $\overline{ONB}$ = IN, V_{IN} = 5.5V, $V_{OUT\ A}$ = $V_{OUT\ B}$ = 0			0.04	3	µA
Undervoltage Lockout	Rising edge, 1% hysteresis		2.0	2.4	2.6	V
On-Resistance	V_{IN} = 4.5V	MAX894L		120	225	mΩ
		MAX895L		250	420	
	V_{IN} = 3.0V	MAX894L		150	300	
		MAX895L		300	500	
Current-Limit-Amplifier Threshold	V_{SET} required to turn the switch off (Note 1)		1.178	1.240	1.302	V
Maximum Output Current	MAX894L			500		mA
	MAX895L			250		
I_{OUT} to I_{SET} Current Ratio	V_{OUT} = 1.6V to 2.8V	MAX894L, I_{OUT} = 250mA	945	1085	1270	A/A
		MAX895L, I_{OUT} = 125mA	910	1050	1235	
$\overline{ONA}$, $\overline{ONB}$ Input Low Voltage	V_{IN} = 2.7V to 5.5V				0.8	V
$\overline{ONA}$, $\overline{ONB}$ Input High Voltage	V_{IN} = 2.7V to 3.6V		2.0			V
	V_{IN} = 4.5V to 5.5V		2.4			
$\overline{ONA}$, $\overline{ONB}$ Input Leakage	$V_{\overline{ONA}}$ = $V_{\overline{ONB}}$ = 5.5V			0.01	1	µA
I_{SETA}, I_{SETB} Bias Current	$V_{SET\ A}$ = 1.24V, $\overline{ONA}$ = 0, $\overline{ONB}$ = V_{IN}, $I_{OUT\ A}$ = 0			0.5	3	µA
	$V_{SET\ B}$ = 1.24V, $\overline{ONB}$ = 0, $\overline{ONA}$ = V_{IN}, $I_{OUT\ B}$ = 0			0.5	3	
Slow-Current-Loop Response Time	20% current overdrive, V_{CC} = 5V			5		µs
Fast-Current-Loop Response Time				2		µs
Turn-On Time	V_{IN} = 5V, I_{OUT} = 250mA (MAX894L), 125mA (MAX895L)			100	200	µs
	V_{IN} = 3V, I_{OUT} = 250mA (MAX894L), 125mA (MAX895L)			150		
Turn-Off Time			0.8	1.2	20	µs

Note 1: Tested with I_{OUT} = 50mA for the MAX894L and 25mA for the MAX895L, and V_{SET} raised until V_{IN} - V_{OUT} ≥ 0.8V.

ELECTRICAL CHARACTERISTICS (Note 2)

(V_{IN} = 3V, **T_A = -40°C to +85°C,** unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	CONDITION		MIN	TYP	MAX	UNITS
Operating Voltage			3.0		5.5	V
Quiescent Current	V_{IN} = 5V, $\overline{ONA}$ = $\overline{ONB}$ = GND, $I_{OUT\ A}$ = $I_{OUT\ B}$ = 0				50	µA
Off-Supply Current	$\overline{ONA}$ = $\overline{ONB}$ = IN, V_{IN} = $V_{OUT\ A}$ = $V_{OUT\ B}$ = 5.5V				2.2	µA
Off-Switch Current	$\overline{ONA}$ = $\overline{ONB}$ = IN, V_{IN} = 5.5V, $V_{OUT\ A}$ = $V_{OUT\ B}$ = 0				8	µA
Undervoltage Lockout	Rising edge, 1% hysteresis		2.0		2.9	V
On-Resistance	V_{IN} = 4.5V	MAX894L			250	mΩ
		MAX895L			420	
	V_{IN} = 3.0V	MAX894L			300	
		MAX895L			500	
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	V_{SET} = 1.24V, V_{OUT} = 1.6V to 2.8V	MAX894L, I_{OUT} = 250mA	910		1360	A/A
		MAX895L, I_{OUT} = 125mA	880		1315	
Turn-On Time	V_{IN} = 5V				200	µs
Turn-Off Time			0.25		20	µs

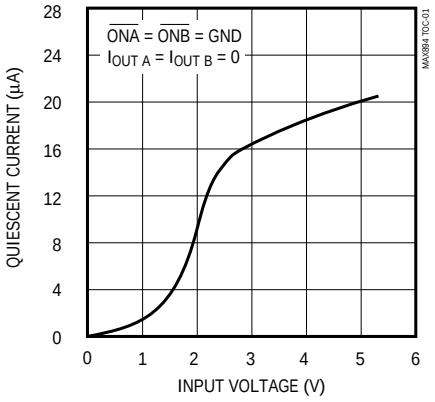
Note 2: Specifications to -40°C are guaranteed by design, not production tested.

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

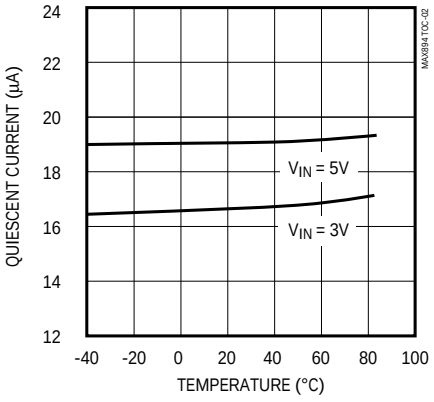
Typical Operating Characteristics

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

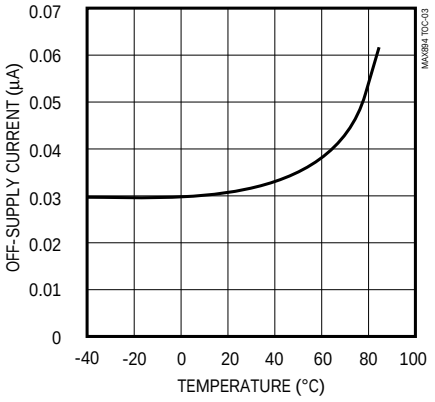
QUIESCENT CURRENT vs. INPUT VOLTAGE



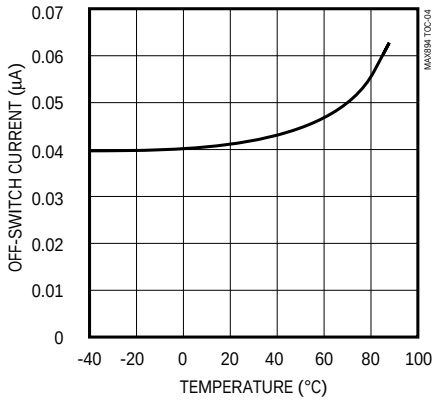
QUIESCENT CURRENT vs. TEMPERATURE



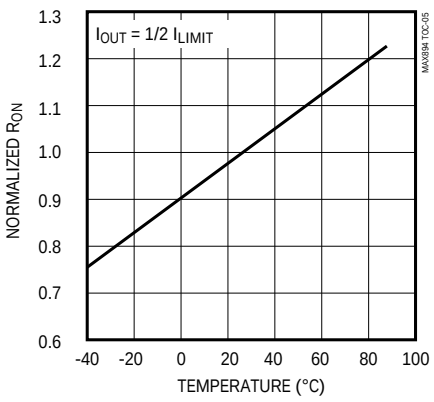
OFF-SUPPLY CURRENT vs. TEMPERATURE



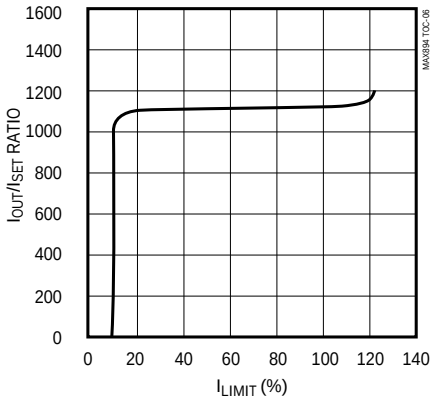
OFF-SWITCH CURRENT vs. TEMPERATURE



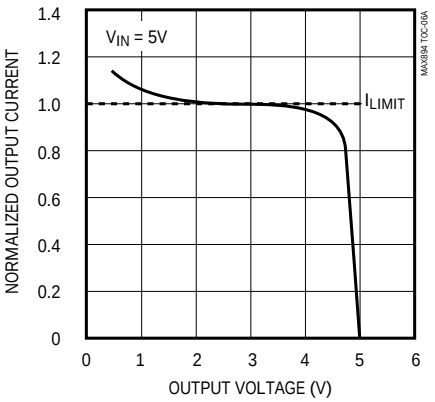
NORMALIZED ON-RESISTANCE vs. TEMPERATURE



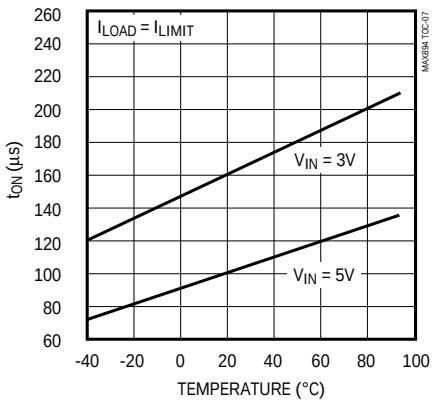
IOUT/ISET vs. ILIMIT



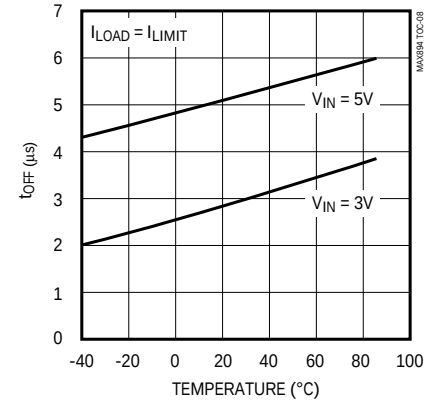
NORMALIZED OUTPUT CURRENT vs. OUTPUT VOLTAGE



TURN-ON TIME vs. TEMPERATURE



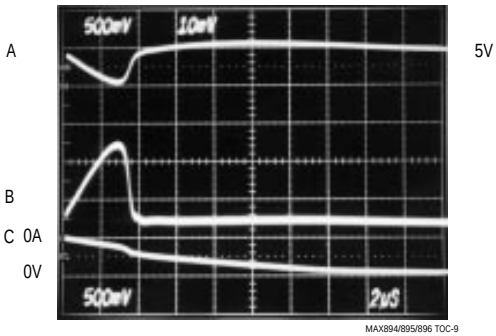
TURN-OFF TIME vs. TEMPERATURE



Typical Operating Characteristics (continued)

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

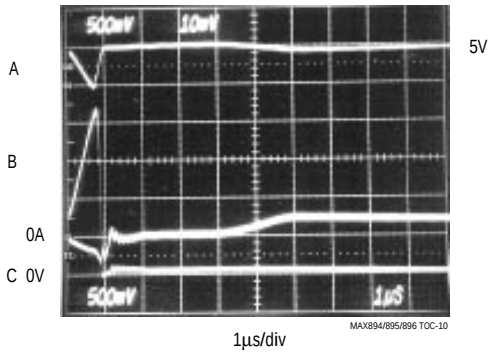
CURRENT-LIMIT RESPONSE (MAX894L, R_L = 1Ω)



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

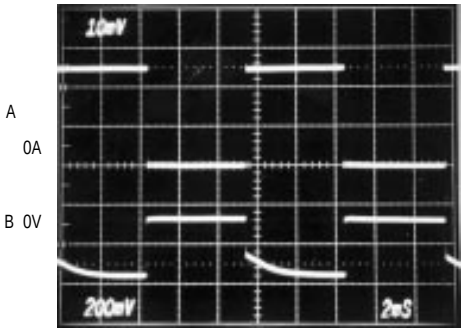
CURRENT-LIMIT RESPONSE (MAX894L, R_L = 0.7Ω)



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

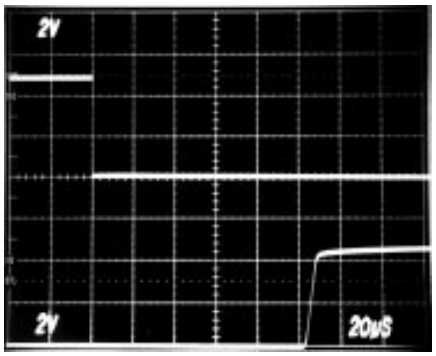
LOAD-TRANSIENT RESPONSE (MAX894L)



2ms/div

V_{IN} = 5V
A: I_{OUT} = 0 to 500mA, 0.2A/div
B: V_{OUT} RIPPLE, 200mV/div, AC COUPLED

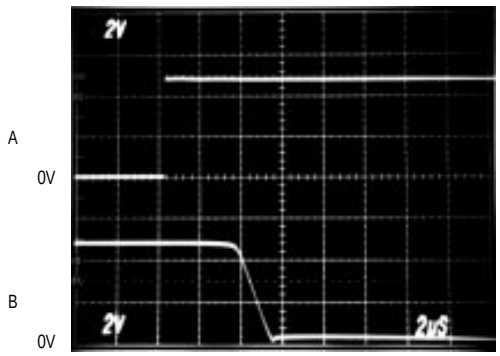
SWITCH TURN-ON TIME



20µs/div

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

SWITCH TURN-OFF TIME



2µs/div

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

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

Pin Description

PIN	NAME	FUNCTION
1	OUT A	Switch A Output. P-channel MOSFET drain. Bypass OUT A with a 0.1µF capacitor to ground.
2	OUT B	Switch B Output. P-channel MOSFET drain. Bypass OUT B with a 0.1µF capacitor to ground.
3	SET A	Set Current-Limit Input. A resistor from SET A to ground sets the current limit for switch A. See *Setting the Current Limit* section.
4	$\overline{ONA}$	Active-Low Switch A On Input. A logic low turns switch A on.
5	GND	Ground
6	SET B	Set Current-Limit Input. A resistor from SET B to ground sets the current limit for switch B. See *Setting the Current Limit* section.
7	IN	Input, Switches A and B. P-channel MOSFET source. Bypass IN with a 1µF capacitor to ground.
8	$\overline{ONB}$	Active-Low Switch B On Input. A logic low turns switch B on.

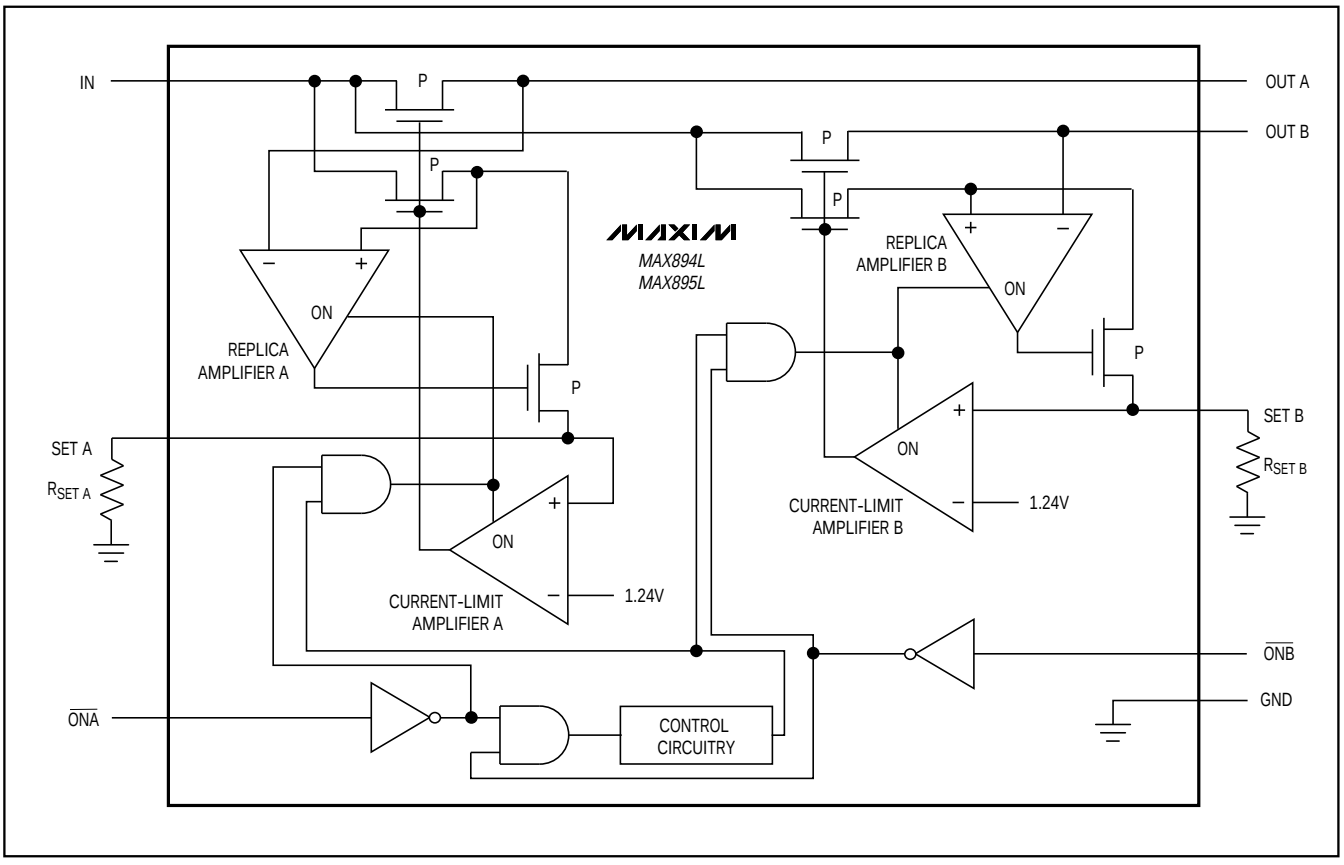


Figure 1. Functional Diagram

Detailed Description

The MAX894L/MAX895L 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 also increases through the replica switch (I_{OUT}/1050) (MAX895) 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 MAX894L/MAX895L 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 ($R_{SET\_}$) connected from SET_ to ground (Figure 2) as follows:

$$I_{SET} = I_{LIMIT} / I_{RATIO}$$
$$R_{SET} = 1.24V / I_{SET} = (1.24V \times I_{RATIO}) / I_{LIMIT}$$

where I_{LIMIT} is the desired current limit for either switch and I_{RATIO} is the I_{OUT} to I_{SET} current ratio (1085mA for the MAX894L and 1050mA for the MAX895L.

Short-Circuit Protection

The MAX894L/MAX895L are short-circuit-protected switches. In the event of an output short circuit or current-overload condition, the current through either 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}.

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_{SET}. When the fault condition is removed, the current limit is set back to I_{LIMIT}. Refer to Output Short-Circuit Fast-Loop Response and Output Short-Circuit Slow-Loop Response in the *Typical Operating Characteristics.*

Thermal Shutdown

The MAX894L/MAX895L 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 cycles on and off, resulting in a pulsed output.

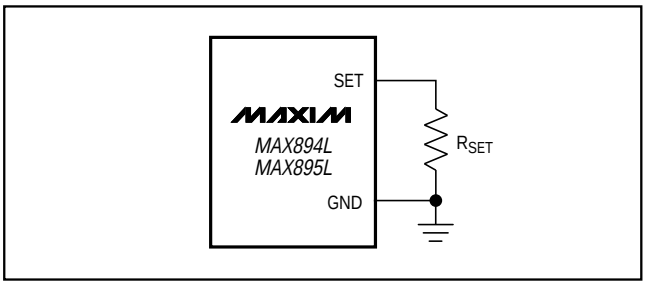


Figure 2. Setting the Current Limit

Applications Information

Input Capacitor

To limit input voltage drop during momentary output short-circuit conditions, place 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. This capacitor prevents 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, reducing 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 can dissipate and channel heat away. Calculate the maximum power as follows:

$$P = I^2_{LIMITA} \times R_{\overline{ONA}} + I^2_{LIMITB} \times R_{\overline{ONB}}$$

where $R_{\overline{ONA}}$ and $R_{\overline{ONB}}$ are the on-resistances of switches A and B, respectively.

When one or both outputs are 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-overload-protection circuitry turns the switch off until the die temperature falls by 10°C. A ground plane in contact with the device helps to further dissipate heat.

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

Chip Information

TRANSISTOR COUNT: 453

SUBSTRATE CONNECTED TO GND.

Tape-and-Reel Information