19-2664; Rev 1; 4/03

MAXIM

50mA/100mA Current-Limit Switches

General Description

The MAX4785–MAX4788 family of switches feature internal current limiting to prevent host devices from being damaged due to faulty load conditions. These analog switches have a low 0.7Ω on-resistance and operate from a 2.3V to 5.5V input voltage range. They are available with guaranteed 50mA and 100mA current limits, making them ideal for load-switching applications.

When the switch is on and a load is connected to the port, a guaranteed blanking time of 14ms ensures that the transient voltages settle down. If after this blanking time the load current is greater than the current limit, the MAX4785 and MAX4787 enter a latch-off state where the switch is turned off and $\overline{FLAG}$ is issued to the microprocessor. The switch can be turned on again by cycling the power or the ON pin.

The MAX4786 and MAX4788 have an autoretry feature where the switch turns off after the blanking time and then continuously checks to see if the overload condition is present. The switch remains on after the overload condition disappears.

The MAX4785 and MAX4787 are available in a tiny space-saving 4-pin or 5-pin SC70 package. The MAX4786 and MAX4788 are available only in the 4-pin SC70 package. For higher current current-limiting switches, refer to the MAX4789–MAX4794 and MAX1693 data sheets.

Applications

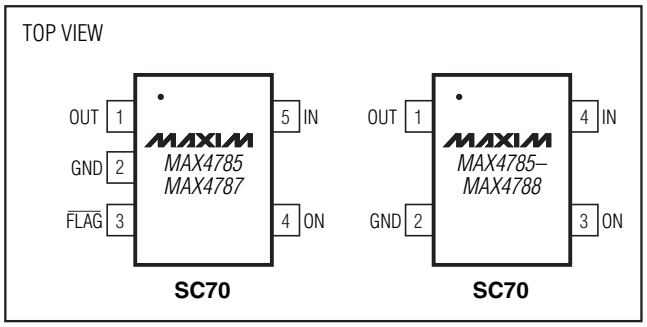
PDAs and Palmtop Devices

Cell Phones

GPS Systems

Hand-Held Devices

Pin Configurations



Features

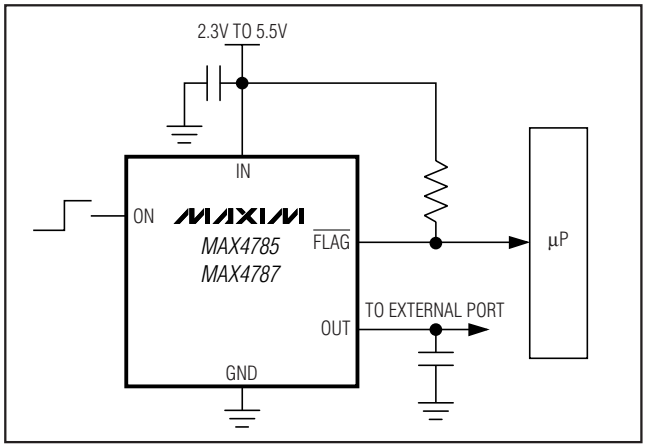
- **Guaranteed Current Limit: 50mA, 100mA**
- **Thermal-Shutdown Protection**
- **Reverse-Current Protection**
- **0.7Ω On-Resistance**
- **14ms Guaranteed Blanking Time**
- **$\overline{FLAG}$ Function (MAX4785/MAX4787)**
- **65µA Supply Current**
- **8µA Latch-Off Current (MAX4785/MAX4787)**
- **0.01µA Shutdown Current**
- **2.3V to 5.5V Supply Range**
- **Undervoltage Lockout**
- **Fast Current-Limit Response Time**
- **Tiny SC70 Package**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX4785EXS-T	-40°C to +85°C	4 SC70-4	AGE
MAX4785EXK-T	-40°C to +85°C	5 SC70-5	ADL
MAX4786EXS-T	-40°C to +85°C	4 SC70-4	AGF
MAX4787EXS-T	-40°C to +85°C	4 SC70-4	AGG
MAX4787EXK-T	-40°C to +85°C	5 SC70-5	AND
MAX4788EXS-T	-40°C to +85°C	4 SC70-4	AGH

Selector Guide appears at end of data sheet.

Typical Operating Circuit



For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

50mA/100mA Current-Limit Switches

ABSOLUTE MAXIMUM RATINGS

IN, ON, $\overline{FLAG}$, OUT to GND .....-0.3V to +6V
OUT Short Circuit to GND .....Internally Limited
Continuous Power Dissipation (T_A = +70°C)
4-Pin SC70 (derate 3.1mW/°C above +70°C) 245mW
5-Pin SC70 (derate 3.1mW/°C above +70°C) 247mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+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} = 2.3V to 5.5V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{IN} = 3.3V, T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Operating Voltage	V_{IN}			2.3		5.5	V
Quiescent Current	I_Q	V_{ON} = V_{IN}, I_{OUT} = 0, switch on	V_{IN} = 2.3V to 5.0V		65	100	µA
			V_{IN} = 5.0V to 5.5V			120	
Latch-Off Current (Note 2)	I_{LATCH}	V_{ON} = V_{IN}, after an overcurrent fault (MAX4785/MAX4787)			8	15	µA
Shutdown Current	I_{SHDN}	V_{ON} = 0V			0.01	1	µA
Forward Current Limit	I_{FWD}	MAX4785/MAX4786		50		120	mA
		MAX4787/MAX4788		100		240	
Reverse Current Limit	I_{REV}	MAX4785/MAX4786				120	mA
		MAX4787/MAX4788				240	
ON Input Leakage		V_{ON} = V_{IN} or GND		-1		+1	µA
Off Switch Leakage		V_{ON} = 0V, V_{OUT} = 0V			0.01	1	µA
Undervoltage Lockout	UVLO	Rising edge		1.8		2.2	V
Undervoltage Lockout Hysteresis					100		mV
On-Resistance	R_{ON}	T_A = +25°C, I_{OUT} = 20mA			0.7	1	Ω
		T_A = -40°C to +85°C, I_{OUT} = 20mA				1.3	
ON Input Logic High Voltage	V_{IH}			2.0			V
ON Input Logic Low Voltage	V_{IL}					0.8	V
$\overline{FLAG}$ Output Logic Low Voltage		I_{SINK} = 1mA (MAX4785/MAX4787)				0.4	V
$\overline{FLAG}$ Output High Leakage Current		V_{IN} = $V_{\overline{FLAG}}$ = 5.5V (MAX4785/MAX4787)				1	µA
Thermal Shutdown					150		°C
Thermal-Shutdown Hysteresis					15		°C
DYNAMIC							
Turn-On Time (Note 3)		ON from low to high; I_{OUT} = 10mA, C_L = 0.1µF			50		µs
Turn-Off Time (Note 3)		ON from high to low; I_{OUT} = 10mA, C_L = 0.1µF			30		ns

ELECTRICAL CHARACTERISTICS (continued)

(V_{IN} = 2.3V to 5.5V, T_A = -40°C to +85°C, unless otherwise noted. Typical values are at V_{IN} = 3.3V, T_A = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Blanking Time	t_{BLANK}	Overcurrent fault, Figures 2, 3	14		60	ms
Short-Circuit Current-Limit Response Time		V_{ON} = V_{IN} = 3.3V, short circuit applied to OUT		5		µs
Retry Time (Note 4)	t_{RETRY}	MAX4786/MAX4788: overcurrent fault, Figure 2	98		420	ms

Note 1: All parts are 100% tested at +25°C. Limits across the full temperature range are guaranteed by design and correlation.

Note 2: Latch-off current does not include the current flowing into $\overline{FLAG}$.

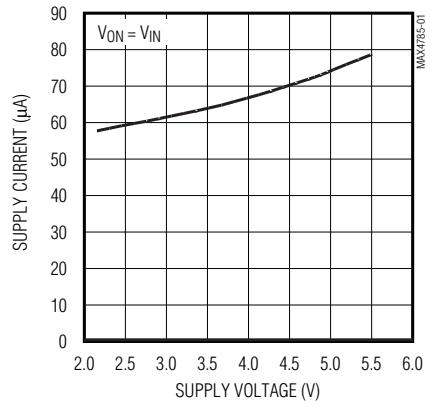
Note 3: The on-time is defined as the time taken for the current through the switch to go from 0mA to full load. The off-time is defined as the time taken for the current through the switch to go from full load to 0mA.

Note 4: Retry time is typically 7x the blanking time.

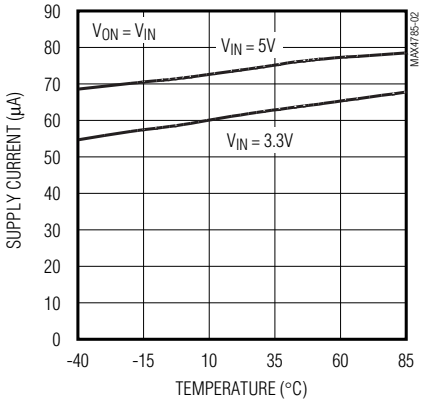
Typical Operating Characteristics

(V_{IN} = 3.3V, T_A = +25°C, unless otherwise noted.)

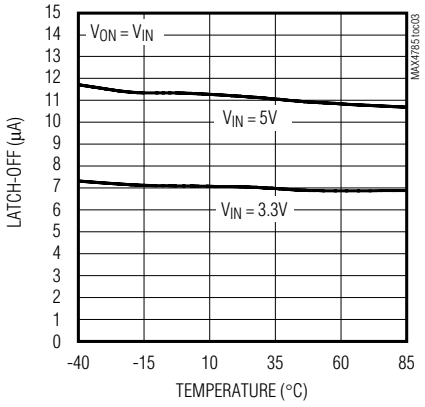
QUIESCENT SUPPLY CURRENT vs. SUPPLY VOLTAGE



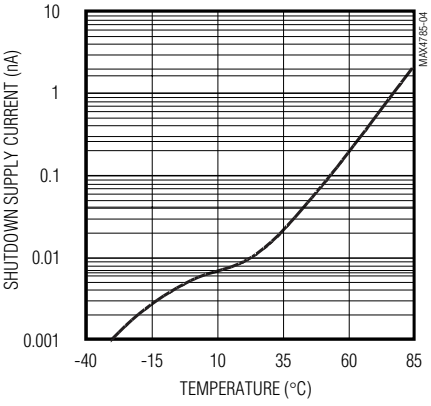
SUPPLY CURRENT vs. TEMPERATURE



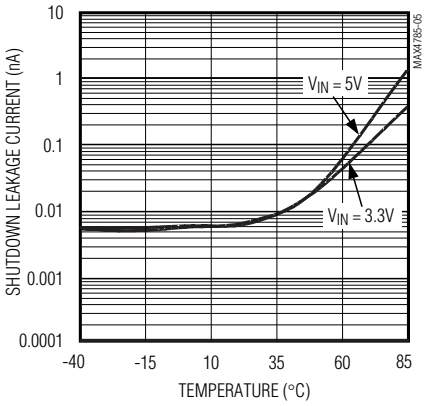
LATCH-OFF CURRENT vs. TEMPERATURE



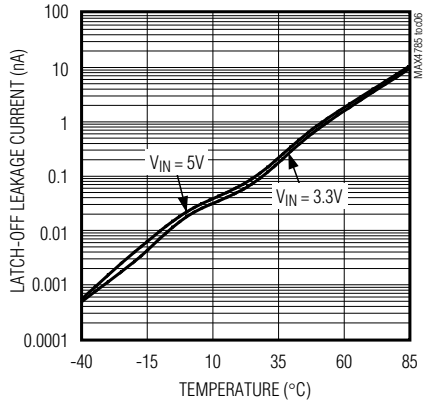
SHUTDOWN SUPPLY CURRENT vs. TEMPERATURE



SHUTDOWN LEAKAGE CURRENT vs. TEMPERATURE



LATCH-OFF LEAKAGE CURRENT vs. TEMPERATURE

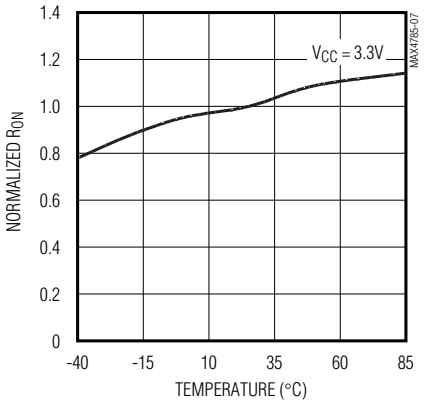


50mA/100mA Current-Limit Switches

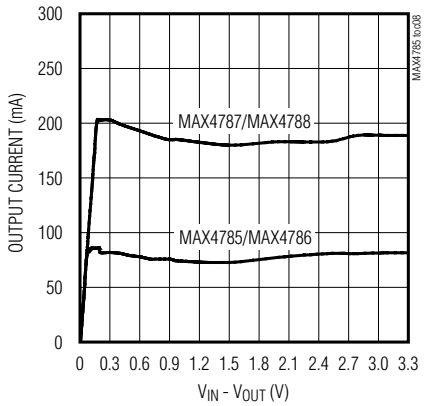
Typical Operating Characteristics (continued)

(V_{IN} = 3.3V, T_A = +25°C, unless otherwise noted.)

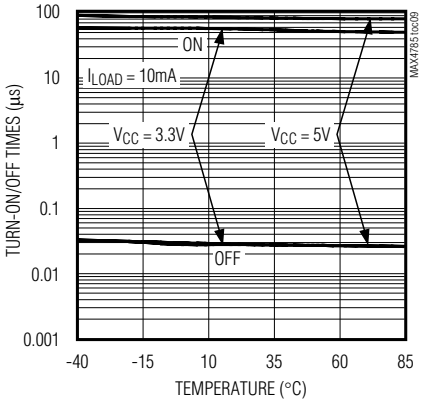
NORMALIZED ON-RESISTANCE vs. TEMPERATURE



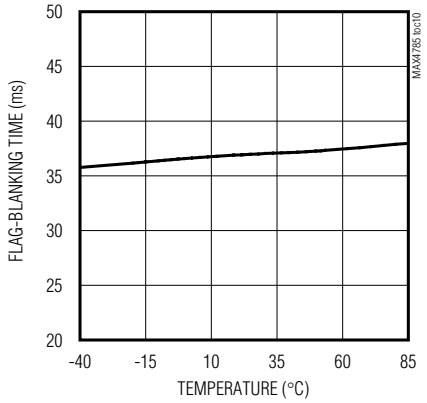
OUTPUT CURRENT vs. OUTPUT VOLTAGE



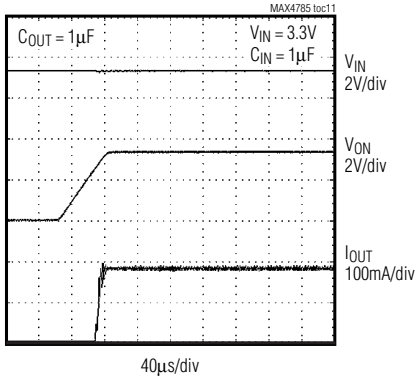
SWITCH TURN-ON/OFF TIMES vs. TEMPERATURE



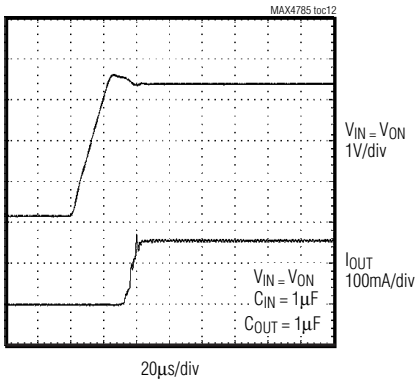
FLAG-BLANKING TIMEOUT vs. TEMPERATURE



CURRENT-LIMIT RESPONSE



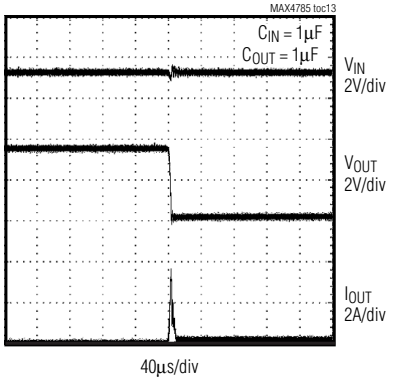
CURRENT-LIMIT RESPONSE



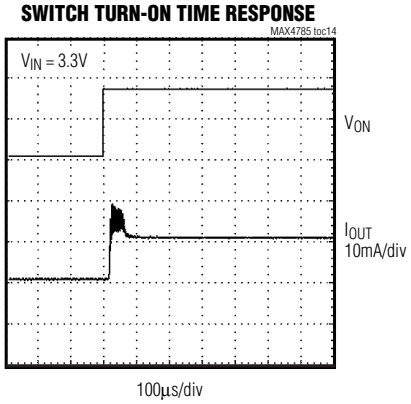
Typical Operating Characteristics (continued)

(V_{IN} = 3.3V, T_A = +25°C, unless otherwise noted.)

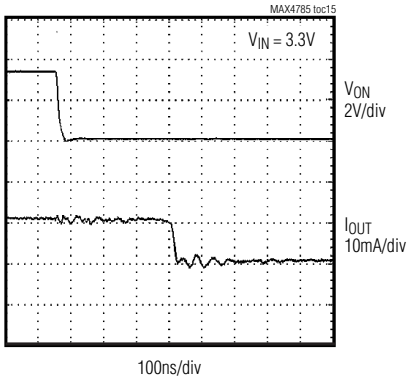
CURRENT-LIMIT RESPONSE (OUT SHORTED TO GND)



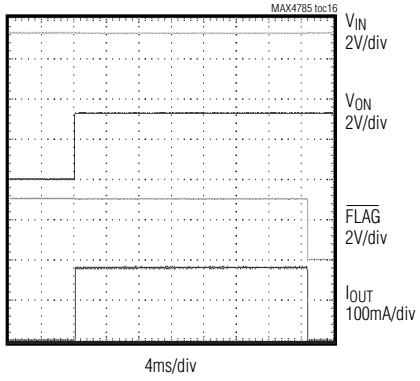
SWITCH TURN-ON TIME RESPONSE



SWITCH TURN-OFF TIME RESPONSE



FLAG-BLANKING RESPONSE



Pin Description

PIN		NAME	FUNCTION
SC70	SC70		
1	1	OUT	Switch Output. Bypass with a 0.1µF capacitor to ground.
2	2	GND	Ground
—	3	$\overline{FLAG}$	Fault Output. This open-drain output goes low when the device stays in forward or reverse current limit for more than the blanking time period. $\overline{FLAG}$ is high impedance when a fault is not present or when ON is low.
3	4	ON	Active-High Switch-On Input. A logic high turns the switch on.
4	5	IN	Input. Bypass with a 0.1µF ceramic capacitor to ground.

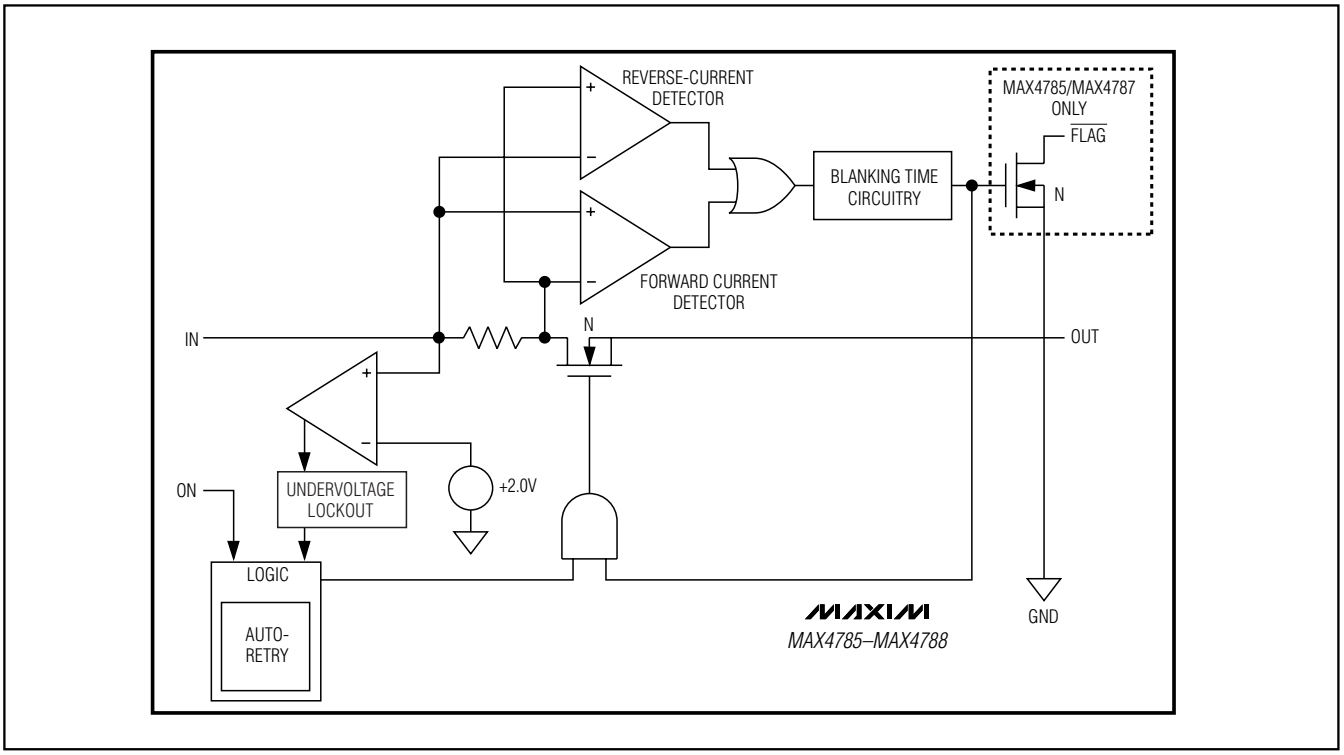


Figure 1. MAX4785–MAX4788 Functional Diagram

Detailed Description

The MAX4785–MAX4788 are forward/reverse current-limited switches that operate from a 2.3V to 5.5V input voltage range and guarantee a 50mA and 100mA minimum current-limit threshold for different options. The voltage drop across an internal sense resistor is compared to two reference voltages to indicate a forward or reverse current-limit fault. When the load current exceeds the preset current limit for greater than the fault-blanking time, the switch opens.

The MAX4786 and MAX4788 have an autoretry function that turns on the switch again after an internal retry time expires. If the faulty load condition is still present after the blanking time, the switch turns off again and the cycle is repeated. If the faulty load condition is not present, the switch remains on.

The MAX4785 and MAX4787 do not have the autoretry option and the switch remains in latch-off mode until the ON pin or the input power is cycled from high to low and then high again.

The undervoltage lockout (UVLO) circuit prevents erroneous switch operation when the input voltage goes too low during startup conditions.

Reverse-Current Protection

The MAX4785–MAX4788 limit the reverse current (V_{OUT} to V_{IN}) from exceeding the maximum I_{REV} value. The switch is shut off and $\overline{FLAG}$ is asserted (MAX4785/MAX4787) if the reverse current-limit condition persists for more than the blanking time. This feature prevents excessive reverse currents from flowing through the device.

Switch-On/Off Control

Toggle ON high to enable the current-limited switches. The switches are continuously on, only if V_{IN} exceeds the UVLO threshold (typically 2V) and there is no fault. When a forward/reverse current fault is preset or the die exceeds the thermal-shutdown temperature of +150°C, OUT is internally disconnected from IN and the supply current decreases to 8µA (latch off). The switch is now operating in one of its off states. The switch off-state also occurs when driving ON low, thus reducing the supply current (shutdown) to 0.01µA. Table 1 illustrates the ON/OFF state of the MAX4785–MAX4788 current-limit switches.

Table 1. MAX4785–MAX4788 Switch Truth Table

ON	FAULT	SWITCH ON/OFF	SUPPLY CURRENT MODE
Low	X	OFF	Shutdown
High	Undervoltage lockout	OFF	Shutdown
High	Thermal	OFF immediately (t_{BLANK} period does not apply)	Latch off
High	Current limit	OFF after t_{BLANK} period has elapsed	Latch off
		ON during t_{BLANK} period, OFF during t_{RETRY} period for the MAX4786 and MAX4788; cycle repeats until fault is removed	See the *Autoretry* section

$\overline{FLAG}$ Indicator

The MAX4785 and MAX4787 feature a latched fault output, $\overline{FLAG}$. Whenever a fault is activated, it latches $\overline{FLAG}$ output low and also turns the switch off. $\overline{FLAG}$ is an open-drain output transistor and requires an external pullup resistor from $\overline{FLAG}$ to IN. During shutdown (ON is low), the pulldown on $\overline{FLAG}$ output is released in order to limit power dissipation. $\overline{FLAG}$ goes low when any of the following conditions occur:

- The die temperature exceeds the thermal-shutdown temperature limit of +150°C.
- The device is in current limit for more than the fault-blanking period.
- V_{IN} is below UVLO threshold.

Autoretry (MAX4786/MAX4788)

When the forward or reverse current-limit threshold is exceeded, t_{BLANK} timer begins counting (Figure 2). The timer resets if the overcurrent condition disappears before t_{BLANK} has elapsed. A retry time delay, t_{RETRY}, is started immediately after t_{BLANK} has elapsed and during that time, the switch is latched off. At the end of t_{RETRY}, the switch is turned on again. If the fault still exists, the cycle is repeated. If the fault has been removed, the switch stays on.

The autoretry feature saves system power in the case of an overcurrent or short-circuit condition. During t_{BLANK}, when the switch is on, the supply current is at the current limit. During t_{RETRY}, when the switch is off, the current through the switch is zero. Instead of observing the full load current, the switch sees the equivalent load current times duty cycle or $I_{SUPPLY} = I_{LOAD} \times t_{BLANK}/(t_{BLANK} + t_{RETRY})$. With a typical t_{BLANK} = 37ms and typical t_{RETRY} = 259ms, the duty cycle is 12%, which results in an 88% power savings over the switch being on the entire time. The duty cycle is consistent across the process and devices.

Latch Off (MAX4785/MAX4787)

When the forward or reverse current-limit threshold is exceeded, t_{BLANK} timer begins counting. The timer resets if the overcurrent condition disappears before t_{BLANK} has elapsed. The switch is shut off if the overcurrent condition continues up to the end of the blanking time. Reset the switch by either toggling ON (Figure 3a) or cycling the input voltage below UVLO, typically 2V (Figure 3b).

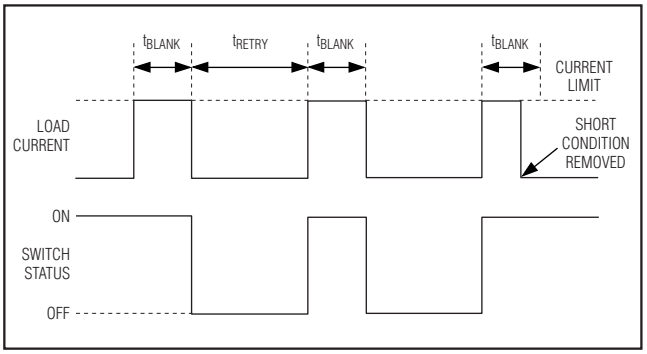


Figure 2. MAX4786/MAX4788 Autoretry Fault Blanking Diagram

Fault Blanking

The MAX4785–MAX4788 feature 14ms (min) fault blanking. Fault blanking allows current-limit faults, including momentary short-circuit faults that occur when hot swapping a capacitive load, and also ensures that no fault is issued during power-up. When a load transient causes the device to enter current limit, an internal counter starts. If the load-transient fault persists beyond the fault-blanking timeout, the MAX4785 and MAX4787s' $\overline{FLAG}$ asserts low. Load-transient faults less than t_{BLANK} do not cause a $\overline{FLAG}$ output assertion. Only current-limit faults are blanked.

A thermal fault and input voltage drops below the UVLO threshold cause $\overline{FLAG}$ to assert immediately and do not wait for the blanking time.

Thermal Shutdown

The MAX4785–MAX4788 have a thermal shutdown feature to protect the devices from overheating. The switch turns off and $\overline{FLAG}$ goes low immediately (no fault blanking) when the junction temperature exceeds +150°C.

50mA/100mA Current-Limit Switches

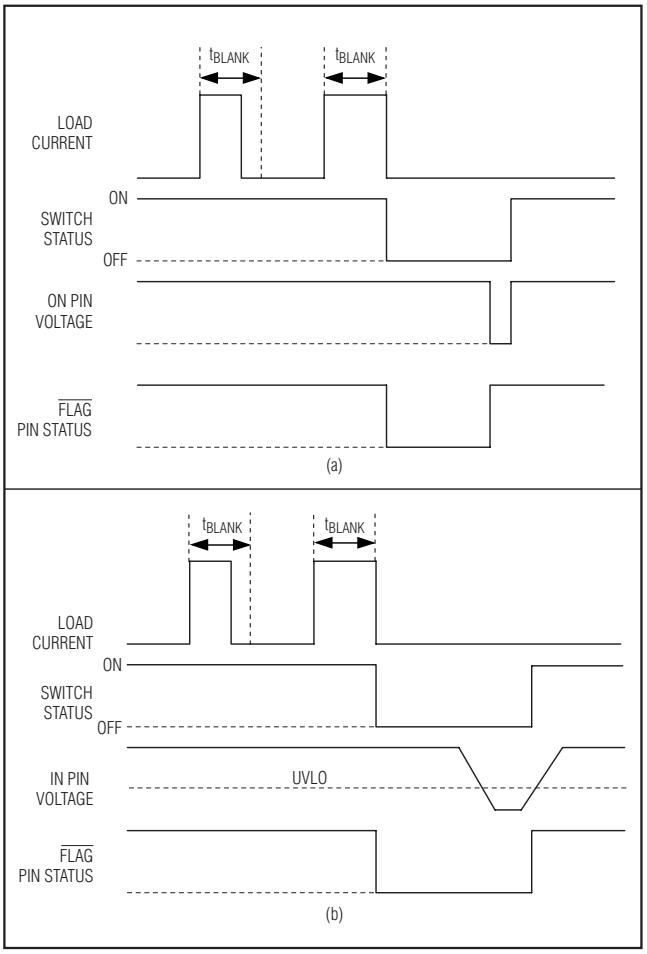


Figure 3. MAX4785/MAX4787 Latch Off Fault Blanking

The switches with autoretry feature turn back on when the device temperature drops approximately 15°C. The switches with latchoff feature require ON cycling.

Applications Information

Input Capacitor

To limit the input voltage drop during momentary output short-circuit conditions, connect a capacitor from IN to GND. A 0.1µF ceramic capacitor is adequate for most applications; however, higher capacitor values further reduce the voltage drop at the input and are recommended for lower voltage applications.

Output Capacitance

Connect a 0.1µF capacitor from OUT to GND. This capacitor helps prevent inductive parasitics from pulling OUT negative during turn-off, thus preventing the MAX4785–MAX4788 from tripping erroneously. If the load capacitance is too large, then current may not have enough time to charge the capacitance and the device assumes that there is a faulty load condition. The maximum capacitive load value that can be driven from OUT is obtained by the following formula:

$$C_{MAX} < \frac{I_{FWD_MIN} \times t_{BLANK_MIN}}{V_{IN}}$$

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 pins must be connected with 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:

$$P_{MAX} = \frac{V_{IN_MAX} \times I_{OUT_MAX} \times t_{BLANK}}{t_{RETRY} + t_{BLANK}} = 161mW$$

where V_{IN} = 5.5V, I_{OUT} = 240mA, t_{BLANK} = 14ms, and t_{RETRY} = 98ms.

Attention must be given to the MAX4785 and MAX4787 where the latch-off condition must be manually reset by toggling ON from high to low. If the latch-off time duration is not sufficiently high, it is possible for the device to reach the thermal-shutdown threshold and never be able to turn the device on until it cools down.

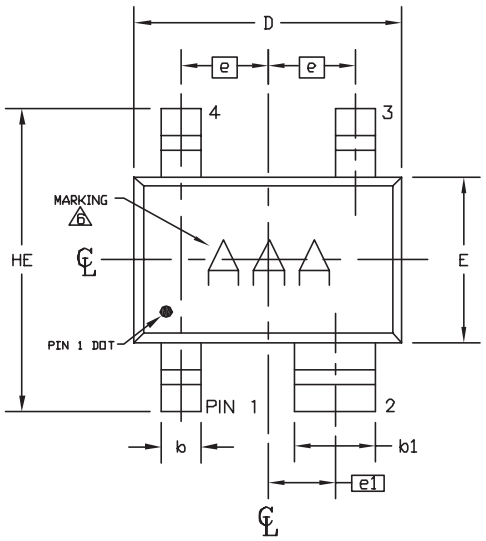
Selector Guide

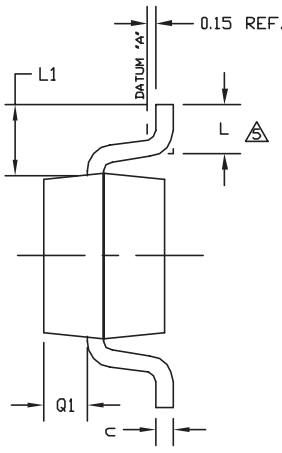
PART	CURRENT LIMIT (mA)	FLAG FUNCTION	AUTO-RETRY
MAX4785EXS	50	No	No
MAX4785EXK	50	Yes	No
MAX4786EXS	50	No	Yes
MAX4787EXS	100	No	No
MAX4787EXK	100	Yes	No
MAX4788EXS	100	No	Yes

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

SC70, 4L.EPS





COMMON DIMENSIONS		
SYMBOL	MIN	MAX
A	0.80	1.10
A1	0.00	0.10
A2	0.80	1.00
b	0.15	0.40
b1	0.55	0.70
c	0.10	0.18
D	1.80	2.25
e	0.65 BSC.	
e1	0.50 BSC.	
E	1.15	1.35
HE	1.80	2.40
L	0.10	0.40
L1	0.425 TYP.	
Q1	0.10	0.40

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. COPLANARITY 4 MILS. MAX.
5. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM "A" AND LEAD SURFACE.
6. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
7. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e" AND "e1", ±0.05.

-DRAWING NOT TO SCALE-

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 4L SC70

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0098	C	1/1

Chip Information

TRANSISTOR COUNT: 1659

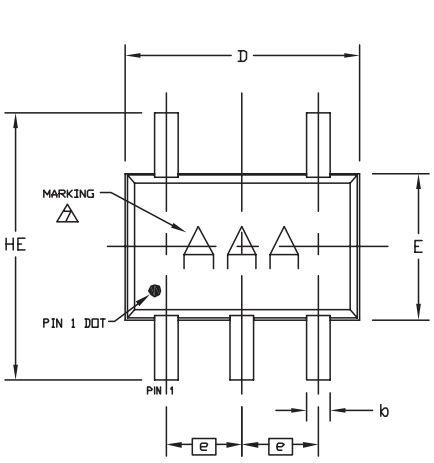
PROCESS: BiCMOS

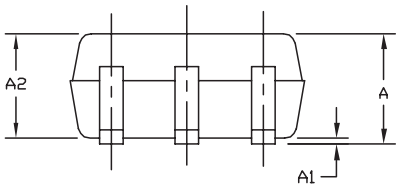
50mA/100mA Current-Limit Switches

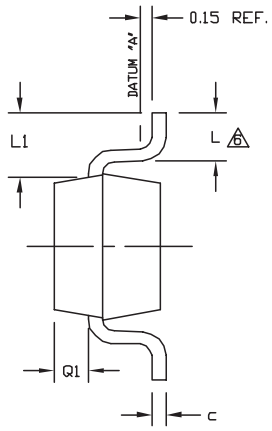
Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

SC70, 5L.EPS







COMMON DIMENSIONS		
SYMBOL	MIN	MAX
A	0.80	1.10
A1	0.00	0.10
A2	0.80	1.00
b	0.15	0.30
c	0.10	0.18
D	1.80	2.20
e	0.65 BSC.	
E	1.15	1.35
HE	1.80	2.40
L	0.10	0.40
L1	0.425 TYP.	
Q1	0.10	0.40

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS ARE INCLUSIVE OF PLATING.
3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.
4. COMPLY TO EIAJ SC70 EXCEPT FOR PIN COUNT AND DIMENSION "b".
5. COPLANARITY 4 MILS. MAX.
6. FOOT LENGTH MEASURED AT INTERCEPT POINT BETWEEN DATUM "A" AND LEAD SURFACE.
7. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
8. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.

DALLAS SEMICONDUCTOR MAXIM

TITLE: PACKAGE OUTLINE, 5L SC70			
APPROVAL	DOCUMENT CONTROL NO. 21-0076	REV. C	1/1

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