

General Description

The MAX1607 is a current-limited $60m\Omega$ switch with built-in fault blanking. Its accurate, preset 0.7A to 1.0A current limit makes it ideal for USB applications. Its low quiescent supply current (14µA) and standby current (1µA) conserve battery power in portable applications. The MAX1607 operates with inputs from +2.7V to +5.5V, making it ideal for both 3V and 5V systems.

An overcurrent signal (OC) notifies the microprocessor that the internal current limit has been reached. A 10ms overcurrent-blanking feature allows momentary faults (such as those caused when hot-swapping into a capacitive load) to be ignored, thus preventing false alarms to the host system. This blanking also prevents an OC signal from being issued when the device is powering up.

The MAX1607 has several safety features to ensure that the USB port is protected. Built-in thermal-overload protection limits power dissipation and junction temperature. The device also has accurate internal currentlimiting circuitry to protect the input supply against overload.

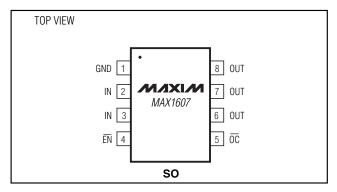
The MAX1607 is a pin-compatible upgrade to Texas Instruments' TPS2014, TPS2015, and TPS2041 for USB applications. The same die is available in a space-saving 10-pin µMAX package (MAX1693) and can be used for next-generation designs. The MAX1694 is similar to the MAX1693, but it has a built-in latch that turns off the power switch in case of a long-term short-circuit condition.

Applications

Notebook Computers **USB** Ports **USB Hubs**

Docking Stations

Pin Configuration



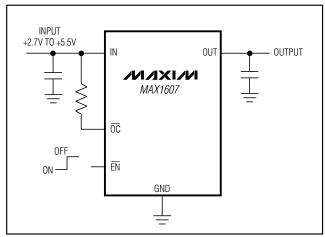
Features

- ♦ Pin Compatible with TPS2014, TPS2015, and **TPS2041**
- **♦** Accurate Current Limit (0.7A min, 1.0A max)
- ♦ Guaranteed 0.75A Short-Circuit Protection
- ♦ 10ms Internal OC Blanking Timeout
- ♦ No Overcurrent (OC) Signal During Power-Up
- ♦ 125mΩ max High-Side MOSFET
- ♦ 500mA Continuous Current
- ♦ Short-Circuit and Thermal Protection with **Overcurrent Logic Output**
- ♦ 1ms Start-Up Time
- ♦ Undervoltage Lockout
- ♦ 14µA Quiescent Supply Current
- ♦ 1µA max Standby Supply Current
- ♦ +2.7V to +5.5V Supply Range
- ♦ UL Approved #E211935

Ordering Information

PART	TEMP. RANGE	PIN-PACKAGE
MAX1607ESA	-40°C to +85°C	8 SO

Typical Operating Circuit



MIXIM

Maxim Integrated Products 1

For price, delivery, and to place orders, please contact Maxim Distribution at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

ABSOLUTE MAXIMUM RATINGS

IN, EN, OC to GND		Continuous Power Dissipation ($T_A = +70^{\circ}C$)
OUT to GND	0.3V to (V _{IN} + 0.3V)	8-Pin SO (derate 5.88mW/°C above +70°C)471mW
Maximum Switch Current	1.2A (internally limited)	Operating Temperature Range (extended)40°C to +85°C
OUT Short-Circuit to GND	Continuous	Storage Temperature Range65°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

 $(V_{IN} = +5V, T_A = 0^{\circ}C \text{ to } +85^{\circ}C, \text{ unless otherwise noted. Typical values are at } T_A = +25^{\circ}C.)$

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
OPERATING CONDITION							
Input Voltage	VIN			2.7		5.5	V
POWER SWITCH							1
		T _A = +25°C	V _{IN} = 4.4V to 5.5V		60	90	
Switch Static Drain-Source On-State Resistance	R _{DS(ON)}	T _A = 0°C to +85°C	V _{IN} = 4.4V to 5.5V			125	mΩ
			V _{IN} = 3V		72	150	
Switch Turn-On Time	ton	I _{LOAD} = 400mA	I _{LOAD} = 400mA		80	200	μs
Switch Turn-Off Time	toff	I _{LOAD} = 400mA		3	6	20	μs
ENABLE INPUT (EN)	1	I		1			
TNI High Layed Innest Valtage	\/	$V_{IN} = 2.7V \text{ to } 3.6V$	/ to 3.6V 2.0			T .,	
EN High-Level Input Voltage	VIH	V _{IN} = 3.7V to 5.5V		2.4			- V
EN Low-Level Input Voltage	VIL	$V_{IN} = 2.7V \text{ to } 5.5V$				0.8	V
EN Input Current		VEN = VIN or GND		-1		1	μΑ
Start-Up Time		V _{IN} = 5V, C _{OUT} = 150μF from EN driven low to 50% full V _{OUT}			1		ms
CURRENT LIMIT							1
Overload Output Current	I _{LIMIT}	Force Vout to 4.5V	Force Vout to 4.5V		850	1000	mA
Short-Circuit Output Current	Isc	OUT shorted to GND			500	700	mA
SUPPLY CURRENT				"			
Supply Current, Low-Level Input		VEN = VIN = VOUT = 5.	5V		0.001	1	μΑ
Supply Current, High-Level	IQ	$V_{\overline{EN}} = GND, I_{OUT} = 0$	Timer not running		14	25	μΑ
Input			Timer running		35		
Supply Leakage Current		$V\overline{\text{EN}} = V_{\text{IN}} = 5.5V,$ $V_{\text{OUT}} = \text{GND}$	T _A = +25°C		0.01	2	μΑ
			$T_A = 0$ °C to +85°C			15	
UNDERVOLTAGE LOCKOUT	•						
Undervoltage Lockout	UVLO	Rising edge, 100mV h	ysteresis	2.0	2.4	2.6	V
OVERCURRENT (OC)	•						
OC Output Low Voltage	V _{OL}	I _{SINK} = 1mA, V _{IN} = 3V				0.4	V
OC Off-State Current		$V_{IN} = V_{\overline{OC}} = 5V$				1	μΑ
OC Blanking Timeout Period	t _{BL}	From overcurrent condition to OC assertion		7	10	13	ms
THERMAL SHUTDOWN	•			•			-
Thermal Shutdown Threshold					+165		°C

ELECTRICAL CHARACTERISTICS

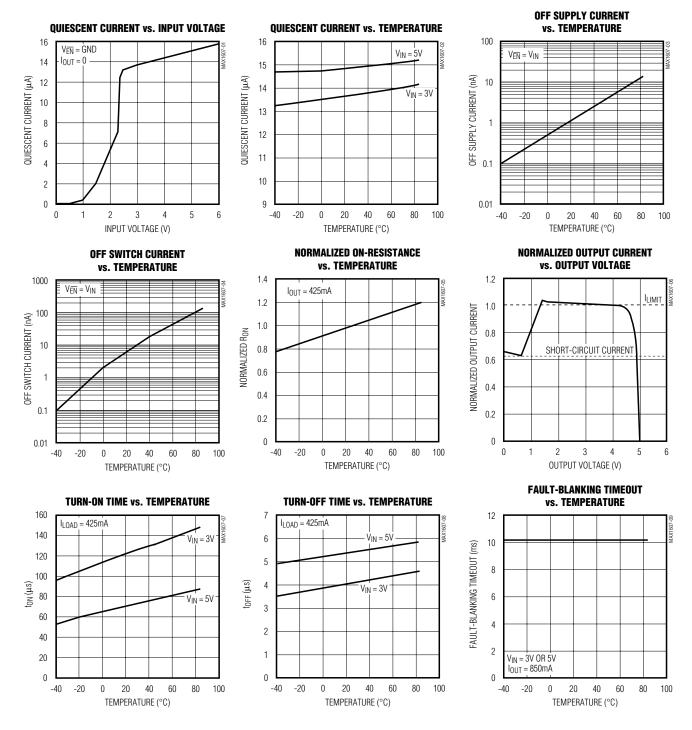
 $(V_{IN} = +5V, T_A = -40$ °C to +85°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
OPERATING CONDITION	l		'				
Input Voltage	VIN		3.0		5.5	V	
POWER SWITCH							
Switch Static Drain-Source	R _{DS(ON)}	V _{IN} = 4.4V to 5.5V			125	m0	
On-State Resistance		V _{IN} = 3V			150	mΩ	
Switch Turn-On Time	ton	I _{LOAD} = 400mA			200	μs	
Switch Turn-Off Time	toff	I _{LOAD} = 400mA	1		20	μs	
ENABLE INPUT (EN)							
EN High-Level Input Voltage	VIH	V _{IN} = 3.0V to 3.6V	2.0			V	
EN High-Level Input voltage	VIH	V _{IN} = 3.7V to 5.5V	2.4				
EN Low-Level Input Voltage	V _I L	V _{IN} = 3.0V to 5.5V			0.8	V	
EN Input Current		VEN = VIN or GND	-1		1	μΑ	
CURRENT LIMIT			•			•	
Overload Output Current	ILIMIT	Force V _{OUT} to 4.5V	640		1060	mA	
Short-Circuit Output Current	Isc	OUT shorted to GND			750	mA	
SUPPLY CURRENT			•			•	
Supply Current, Low-Level Input		$V_{\overline{\text{EN}}} = V_{\text{IN}} = V_{\text{OUT}} = 5.5V$			2	μΑ	
Supply Current, High-Level Input	IQ	$V_{\overline{EN}} = GND$, $I_{OUT} = 0$, timer not running			25	μΑ	
Supply Leakage Current		$V_{\overline{EN}} = V_{IN} = 5.5V, V_{OUT} = GND$			15	μΑ	
UNDERVOLTAGE LOCKOUT							
Undervoltage Lockout	UVLO	Rising edge, 100mV hysteresis	2.0		2.9	V	
OVERCURRENT (OC)	•		•			•	
OC Output Low Voltage VoL		ISINK = 1mA, V _{IN} = 3V			0.4	V	
OC Off-State Current		$V_{IN} = V_{\overline{OC}} = 5V$			1	μΑ	
OC Blanking Timeout Period	t _{BL}	From overcurrent condition to OC assertion	6		14	ms	

Note 1: Specifications to -40°C are guaranteed by design, not production tested.

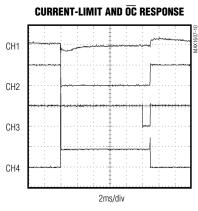
Typical Operating Characteristics

 $(V_{IN} = +5V, T_A = +25^{\circ}C, unless otherwise noted.)$



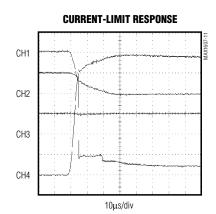
Typical Operating Characteristics (continued)

 $(V_{IN} = +5V, T_A = +25$ °C, unless otherwise noted.)



 $\begin{array}{l} CH1 = V_{IN}, 200mV/div, AC\text{-}COUPLED \\ CH2 = V_{OUT}, 5V/div \\ CH3 = V_{\overline{OC}}, 5V/div \\ \end{array}$

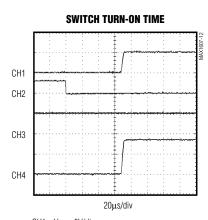
 $CH4 = I_{OUT}$, 500mA/div



 $CH1 = V_{IN}$, 200mV/div, AC-COUPLED

CH2 = V_{OUT}, 5V/div CH3 = $V_{\overline{0C}}$, 5V/div

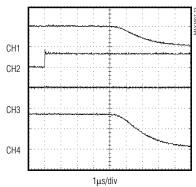
CH4 = I_{OUT}, 1A/div



 $\begin{array}{l} CH1 = V_{OUT}, \, 5V/div \\ CH2 = V_{\overline{EN}}, \, 5V/div \\ CH3 = V_{\overline{OC}}, \, 5V/div \end{array}$

 $CH4 = I_{OUT}$, 200mA/div

SWITCH TURN-OFF TIME

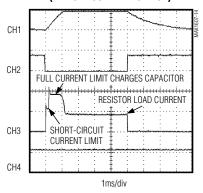


CH1 = V_{OUT}, 5V/div CH2 = V_{EN}, 5V/div

CH3 = $V_{\overline{0C}}$, 5V/div

 $CH4 = I_{OUT}$, 200mA/div

START-UP TIME (TYPICAL USB APPLICATION)



$$\begin{split} V_{IN} = 5V, \; R_L = 15\Omega, \; C_L = 150\mu F \\ CH1 = V_{OUT}, \; 5V/div \end{split}$$

 $CH2 = V_{EN}$, 5V/div

 $CH3 = I_{IN}$, 500mA/div

 $CH4 = V_{\overline{OC}}$, 5V/div

Pin Description

PIN	NAME	FUNCTION
1	GND	Ground
2, 3	IN	Input. P-channel MOSFET source—connect all IN pins together and bypass with a 1µF capacitor to ground.
4	ĒN	Active-Low Switch Enable Input. A logic low turns on the switch.
5	ŌC	Overcurrent-Indicator Output. This open-drain output goes low when the device is in thermal shutdown or undervoltage lockout, or during a sustained (>10ms) current-limit condition.
6, 7, 8	OUT	Switch Output. P-channel MOSFET drain—connect all OUT pins together and bypass with a 0.1µF capacitor to ground.

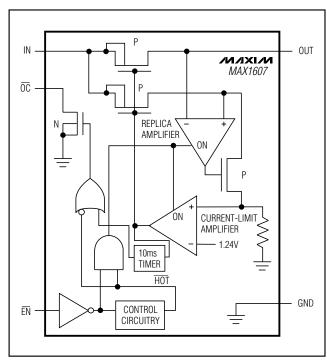


Figure 1. Functional Diagram

Detailed Description

The MAX1607 P-channel MOSFET power switch limits output current to 0.7A min and 1.0A max. When the output current is increased beyond the current limit (I_{LIMIT}), the current also increases through the replica switch (I_{OUT} / 6500). The current-limit error amplifier compares the voltage to the internal 1.24V reference and regulates the current back to the I_{LIMIT} (Figure 1).

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

Continuous Short-Circuit Protection

The MAX1607 is a short-circuit-protected switch. In the event of an output short-circuit condition, the current through the switch is foldback-current-limited to 500mA continuous.

Thermal Shutdown

The MAX1607 has a thermal shutdown feature. The switch turns off and the \overline{OC} output goes low immediately (no overcurrent blanking) when the junction temperature exceeds +165°C. When the MAX1607 cools 20°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.

OC Indicator

The MAX1607 provides an overcurrent output (\overline{OC}) . A $100k\Omega$ pull-up resistor from \overline{OC} to IN provides a logic control signal. This open-drain output goes low when any of the following conditions occur:

- The input voltage is below the 2.4V undervoltagelockout (UVLO) threshold.
- The die temperature exceeds the thermal shutdown temperature limit of +165°C.
- The device is in current limit for greater than 10ms.

OC Blanking

The MAX1607 features 10ms overcurrent blanking. Blanking allows brief current-limit faults, including momentary short-circuit faults that occur when hotswapping a capacitive load, and also ensures that no \overline{OC} is issued during power-up. When a load transient causes the device to enter current limit, an internal counter starts. If the load fault persists beyond the 10ms overcurrent-blanking timeout, the \overline{OC} output asserts low. Ensure that the MAX1607 input is adequately bypassed to prevent input glitches from triggering spurious \overline{OC} outputs. Input voltage glitches less

than 150mV will not cause a spurious \overline{OC} output. Load-transient faults less than 10ms (typ) will not cause an \overline{OC} output assertion.

Only current-limit faults are blanked. Die overtemperature faults and input voltage droops below the UVLO threshold will cause an immediate \overline{OC} output.

Applications Information

Input Capacitor

To limit the input voltage drop during momentary output short-circuit conditions, connect a capacitor from IN to GND. A $1\mu F$ ceramic capacitor will be adequate for most applications; however, higher capacitor values will further reduce the voltage drop at the input (Figure 2).

Output Capacitor

Connect a $0.1\mu F$ capacitor from OUT to GND. This capacitor helps to prevent inductive parasitics from pulling OUT negative during turn-off.

Layout and Thermal Dissipation

Important: Optimize the switch response time to output short-circuit conditions by keeping 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 away). All IN and OUT pins must be connected with short traces to the power bus. Wide power-bus planes will provide superior heat dissipation through the MAX1607's IN and OUT pins.

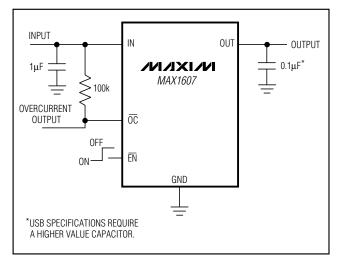


Figure 2. Typical Application Circuit

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

$$P = (I_{LIMIT})^2 \times RON$$

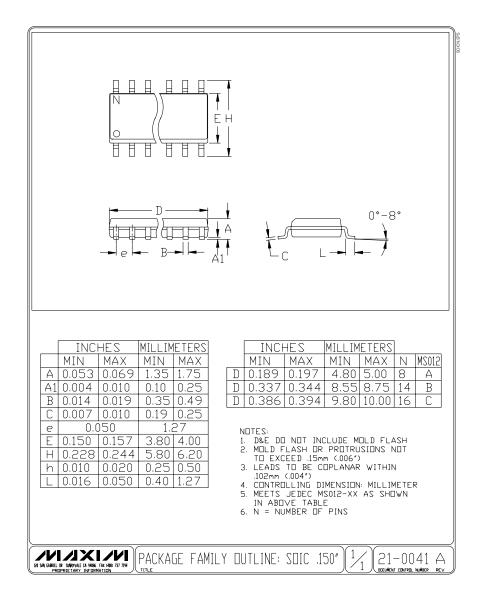
where I_{LIMIT} is the preset current limit (1.0A max) and R_{ON} is the on-resistance of the switch (125m Ω max).

When the output is short circuited, foldback-current limiting activates and the voltage drop across the switch equals the input supply. The power dissipated across the switch increases, as does the die temperature. If the fault condition is not removed, the thermal-overload-protection circuitry activates (see *Thermal Shutdown* section). Wide power-bus planes connected to IN and OUT and a ground plane in contact with the device will help dissipate additional heat.

Chip Information

TRANSISTOR COUNT: 715

Package Information



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.