



# Overvoltage Protection Controllers with Reverse Polarity Protection

## General Description

The MAX4864L/MAX4865L/MAX4866L/MAX4867 overvoltage protection controllers protect low-voltage systems against high-voltage faults up to +28V, and negative voltages down to -28V. These devices drive a low-cost complementary MOSFET. If the input voltage exceeds the overvoltage threshold, these devices turn off the n-channel MOSFET to prevent damage to the protected components. If the input voltage drops below ground, the devices turn off the p-channel MOSFET to prevent damage to the protected components. An internal charge pump eliminates the need for external capacitors and drives the MOSFET GATEN for a simple, robust solution.

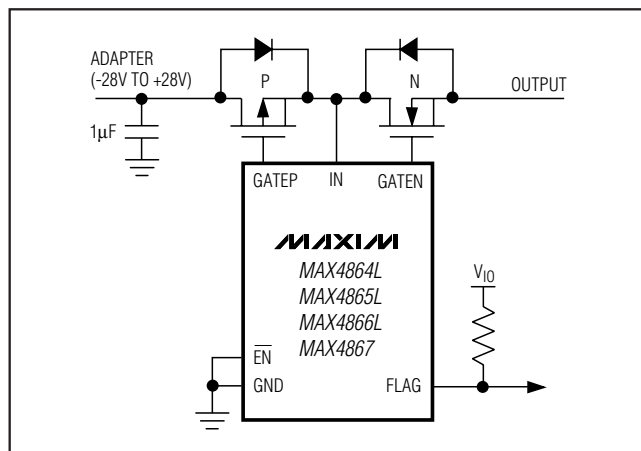
The overvoltage thresholds are preset to +7.4V (MAX4864L), +6.35V (MAX4865L), +5.8V (MAX4866L), and +4.65V (MAX4867). When the input voltage drops below the undervoltage lockout (UVLO) threshold, the devices enter a low-current standby mode (8.5 $\mu$ A). Also in shutdown ( $\overline{\text{EN}}$  set to logic-high), the current is reduced further (0.4 $\mu$ A). The MAX4864L/MAX4865L/MAX4866L have a +2.85V UVLO threshold, and the MAX4867 has a +2.5V UVLO threshold.

In addition, a  $\pm 15$ kV ESD protection is provided to the input when bypassed with a 1 $\mu$ F capacitor to ground. All devices are offered in a small 6-pin SOT23 and a 6-pin, 2mm x 2mm  $\mu$ DFN package, and are specified for operation over the -40°C to +85°C temperature range.

## Applications

Cell Phones                      PDAs and Palmtop Devices  
Digital Still Cameras        MP3 Players

## Typical Operating Circuit



## Features

- ◆ Overvoltage Protection Up to +28V
- ◆ Reverse Polarity Protection Down to -28V
- ◆ Preset Overvoltage (OV) Trip Level (7.4V, 6.35V, 5.8V, 4.65V)
- ◆ Drive Low-Cost Complementary MOSFET
- ◆ Internal 50ms Startup Delay
- ◆ Internal Charge Pump
- ◆ 8.5 $\mu$ A Standby Current (In UVLO Mode)
- ◆ 0.4 $\mu$ A Shutdown Current
- ◆ Overvoltage Fault FLAG Indicator
- ◆ 6-Pin (2mm x 2mm)  $\mu$ DFN and 6-Pin SOT23 Packages

## Ordering Information

PART	PIN-PACKAGE	OV TRIP LEVEL (V)	TOP MARK
MAX4864LEUT-T	6 SOT23-6	7.40	ABVO
MAX4864LELT	6 $\mu$ DFN	7.40	AAE
MAX4865LEUT-T	6 SOT23-6	6.35	ABVP
MAX4865LELT	6 $\mu$ DFN	6.35	AAF
MAX4866LEUT-T	6 SOT23-6	5.80	ABVQ
MAX4866LELT	6 $\mu$ DFN	5.80	AAG
MAX4867EUT-T	6 SOT23-6	4.65	ABVN
MAX4867ELT	6 $\mu$ DFN	4.65	AAD

**Note:** All devices are specified over the -40°C to +85°C operating temperature range.  
T = Tape and reel.

Functional Diagram appears at end of data sheet.

MAX4864L/MAX4865L/MAX4866L/MAX4867

# Overvoltage Protection Controllers with Reverse Polarity Protection

## ABSOLUTE MAXIMUM RATINGS

IN to GND	-0.3V to +30V
GATEN, GATEP to GND	-0.3V to +12V
IN to GATEP	-0.3V to +20V
FLAG, $\overline{\text{EN}}$ to GND	-0.3V to +6V
Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )	
6-Pin $\mu\text{DFN}$ (2mm x 2mm) (derate 2.1mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ )	168mW
6-Pin SOT23 (derate 8.7mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ )	696mW

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
Soldering Temperature (reflow)	+240°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

( $V_{\text{IN}} = +5\text{V}$  (MAX4864L/MAX4865L/MAX4866L),  $V_{\text{IN}} = +4\text{V}$  (MAX4867),  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $C_{\text{GATEN}} = 500\text{pF}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS			MIN	TYP	MAX	UNITS
Input Voltage Range	$V_{\text{IN}}$				1.2		28.0	V
Overvoltage Trip Level	OVLO	$V_{\text{IN}}$ rising	MAX4864L	7.0	7.4	7.8	V	
			MAX4865L	5.95	6.35	6.75		
			MAX4866L	5.45	5.8	6.15		
			MAX4867	4.35	4.65	4.95		
Overvoltage Lockout Hysteresis			MAX4864L	75			mV	
			MAX4865L	65				
			MAX4866L	55				
			MAX4867	50				
Undervoltage Lockout Threshold	UVLO	$V_{\text{IN}}$ falling	MAX4864L/MAX4865L/MAX4866L	2.65	2.85	3.05	V	
			MAX4867	2.3	2.5	2.7		
Undervoltage Lockout Hysteresis			MAX4864L/MAX4865L/MAX4866L	44			mV	
			MAX4867	25				
IN Supply Current	$I_{\text{IN}}$	$\overline{\text{EN}} = \text{GND}$	MAX4864L/MAX4865L/MAX4866L	77	120		$\mu\text{A}$	
			MAX4867	68	110			
UVLO Supply Current	$I_{\text{UVLO}}$	$\overline{\text{EN}} = \text{GND}$	MAX4864L/MAX4865L/MAX4866L, $V_{\text{IN}} = +2.6\text{V}$	8.5	22		$\mu\text{A}$	
			MAX4867, $V_{\text{IN}} = +2.2\text{V}$	8	18			
Shutdown Supply Current	$I_{\text{SHD}}$	$\overline{\text{EN}} = 1.6\text{V}$	MAX4864L/MAX4865L/MAX4866L, $V_{\text{IN}} = 3.6\text{V}$	0.4	2		$\mu\text{A}$	
			MAX4867, $V_{\text{IN}} = 3.6\text{V}$	0.4	2			
GATEN Voltage	$V_{\text{GATEN}}$	1 $\mu\text{A}$ load	MAX4864L/MAX4865L/MAX4866L	9	9.83	10	V	
			MAX4867	7.5	7.85	8.0		
GATEN Pulldown Current	$I_{\text{PD}}$	$V_{\text{IN}} > \text{OVLO}$ , $V_{\text{GATEN}} = +5.5\text{V}$			12	32	65	mA
GATEP Clamp Voltage	$V_{\text{CLAMP}}$				13.5	16.5	19.5	V
GATEP Pulldown Resistor	$R_{\text{GATEP}}$				32	48	64	k $\Omega$
FLAG Output-Low Voltage	$V_{\text{OL}}$	$I_{\text{SINK}} = 1\text{mA}$			0.4			V
FLAG Leakage Current		$V_{\text{FLAG}} = +5.5\text{V}$			1			$\mu\text{A}$
$\overline{\text{EN}}$ Input-High Voltage	$V_{\text{IH}}$				1.5			V
$\overline{\text{EN}}$ Input-Low Voltage	$V_{\text{IL}}$				0.4			V

# Overvoltage Protection Controllers with Reverse Polarity Protection

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{IN} = +5V$  (MAX4864L/MAX4865L/MAX4866L),  $V_{IN} = +4V$  (MAX4867),  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ ,  $C_{GATEN} = 500\text{pF}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$\overline{\text{EN}}$ Input Leakage Current	$I_{\text{LKG}}$	$\overline{\text{EN}} = \text{GND}$ or $+5.5\text{V}$			1	$\mu\text{A}$
<b>TIMING</b>						
Startup Delay	$t_{\text{START}}$	$V_{IN} > \text{UVLO}$ to $V_{\text{GATEN}} > 0.3\text{V}$ , Figure 1	20	50	80	ms
FLAG Blanking Time	$t_{\text{BLANK}}$	$V_{\text{GATEN}} > 0.3\text{V}$ to $V_{\text{FLAG}} < 0.3\text{V}$ , Figure 1	20	50	80	ms
GATEN Turn-On Time	$t_{\text{GON}}$	$C_{\text{GATEN}} = 500\text{pF}$ , $V_{\text{GATEN}} = 0.3\text{V}$ to $+8\text{V}$ (MAX4864L/MAX4865L/MAX4866L) $V_{\text{GATEN}} = 0.3\text{V}$ to $+7\text{V}$ (MAX4867), Figure 1		10		ms
GATEN Turn-Off Time	$t_{\text{GOFF}}$	$V_{IN}$ rising at $3\text{V}/\mu\text{s}$ from $+5\text{V}$ to $+8\text{V}$ (MAX4864L/MAX4865L/MAX4866L), or from $+4\text{V}$ to $+7\text{V}$ (MAX4867) $V_{\text{GATEN}} = 0.3\text{V}$ , $C_{\text{GATEN}} = 500\text{pF}$ , Figure 2		7	20	$\mu\text{s}$
FLAG Assertion Delay	$t_{\text{FLAG}}$	$V_{IN}$ rising at $3\text{V}/\mu\text{s}$ from $5\text{V}$ to $8\text{V}$ (MAX4864L/MAX4865L/MAX4866L), or from $+4\text{V}$ to $+7\text{V}$ (MAX4867), $V_{\text{FLAG}} = 0.3\text{V}$ , Figure 2		3.5		$\mu\text{s}$
Initial Overvoltage Fault Delay	$t_{\text{OVP}}$	$V_{IN}$ rising at $3\text{V}/\mu\text{s}$ from $0\text{V}$ to $+9\text{V}$ , time from $V_{IN} = 5\text{V}$ to $I_{\text{GATEN}} = 80\%$ of $I_{\text{PD}}$ (GATEN pulldown current), Figure 3		1.5		$\mu\text{s}$
Disable Time	$t_{\text{DIS}}$	$\overline{\text{VEN}} = +2.4\text{V}$ , $V_{\text{GATEN}} = 0.3\text{V}$ , Figure 4		2		$\mu\text{s}$

**Note 1:** All parts are 100% tested at  $+25^\circ\text{C}$ . Electrical limits across the full temperature range are guaranteed by design and correlation.

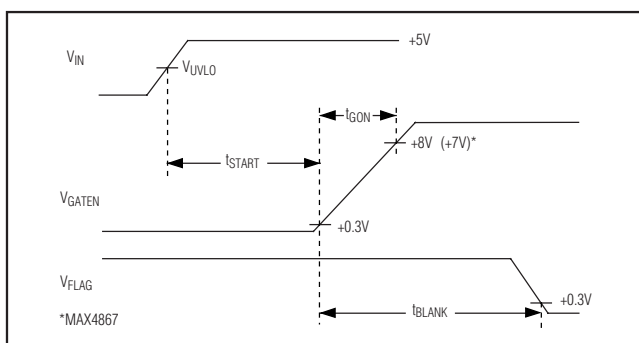


Figure 1. Startup Timing Diagram

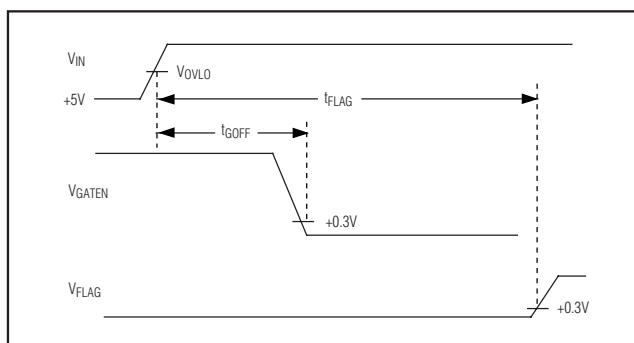


Figure 2. Shutdown Timing Diagram

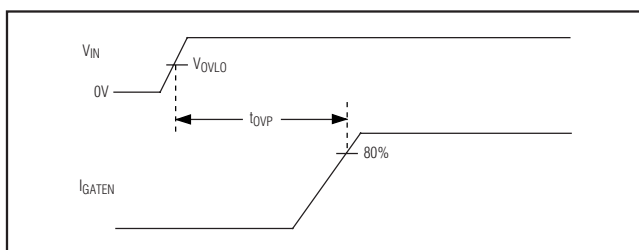


Figure 3. Power-Up Overvoltage Timing Diagram

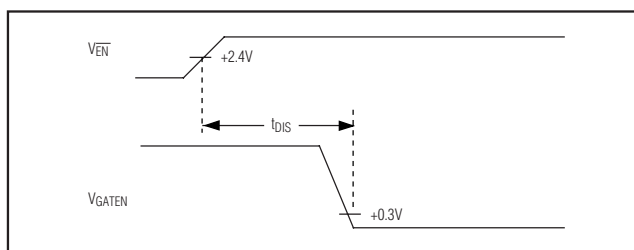


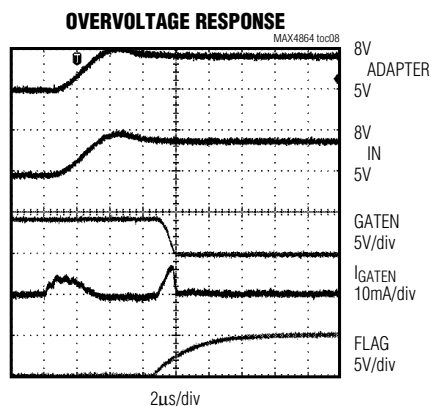
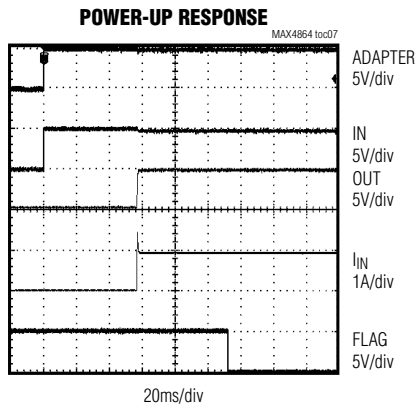
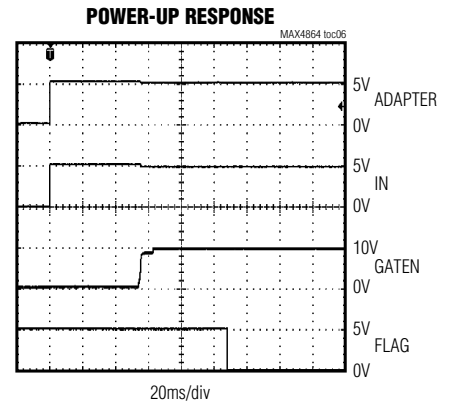
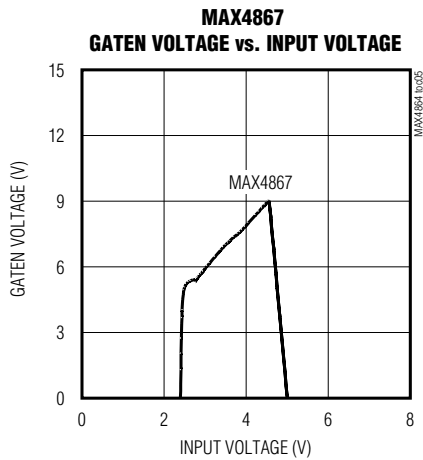
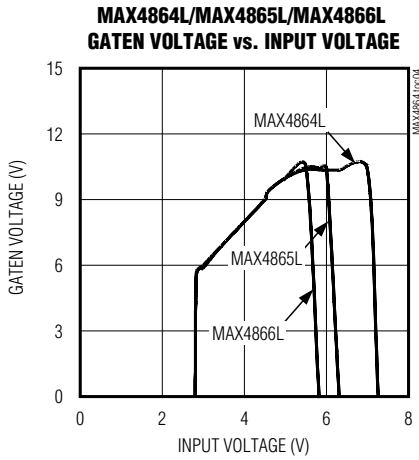
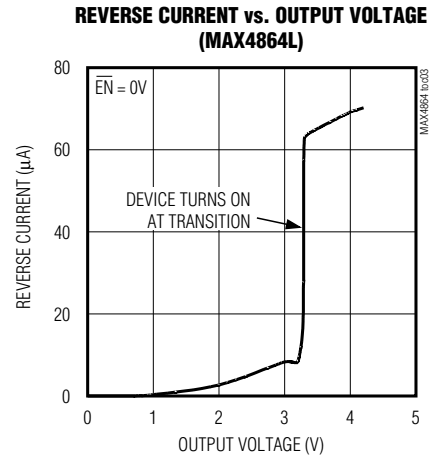
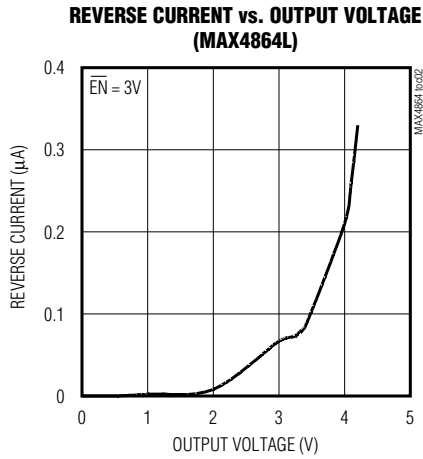
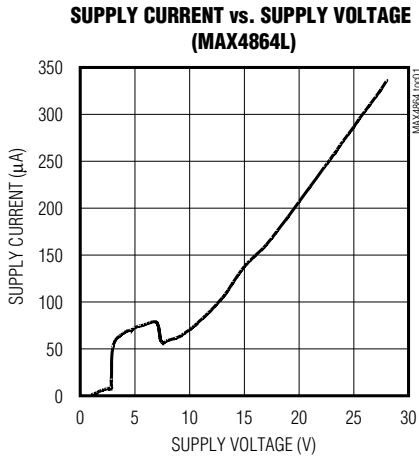
Figure 4. Disable Timing Diagram

MAX4864L/MAX4865L/MAX4866L/MAX4867

# Overvoltage Protection Controllers with Reverse Polarity Protection

## Typical Operating Characteristics

( $T_A = +25^\circ\text{C}$ , unless otherwise noted.)

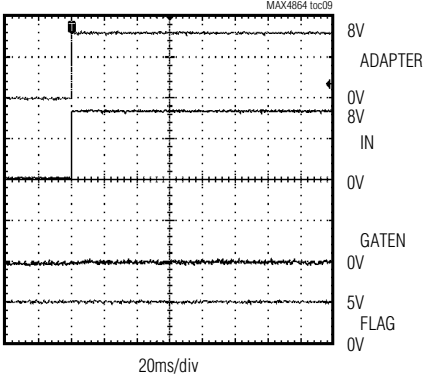


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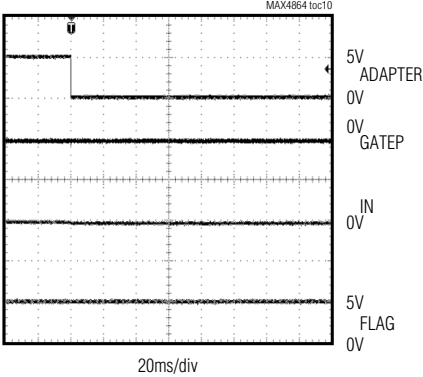
## Typical Operating Characteristics (continued)

(T<sub>A</sub> = +25°C, unless otherwise noted.)

**POWER-UP OVERVOLTAGE RESPONSE**



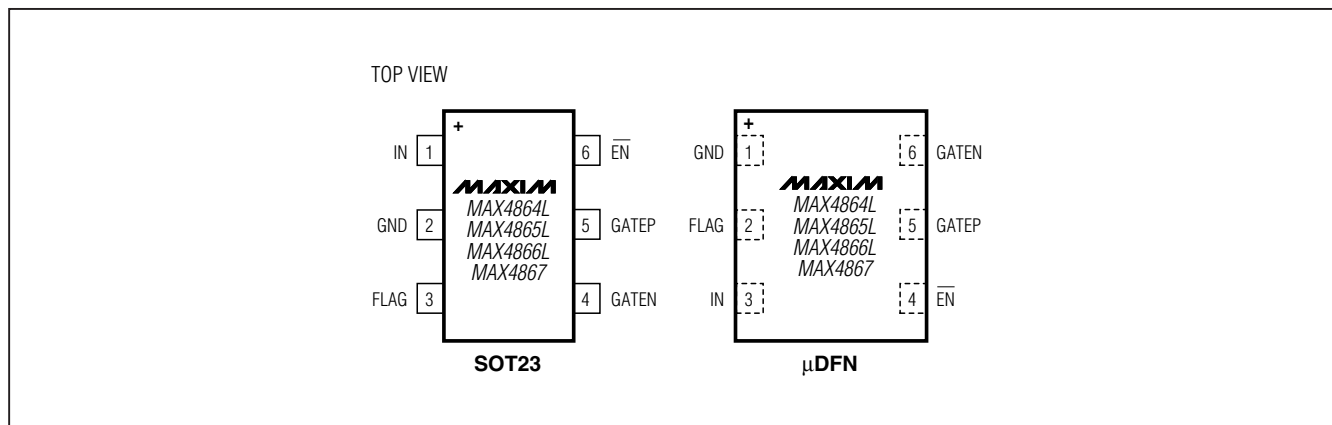
**NEGATIVE VOLTAGE RESPONSE**



MAX4864L/MAX4865L/MAX4866L/MAX4867

# Overvoltage Protection Controllers with Reverse Polarity Protection

## Pin Configuration



## Pin Description

PIN		NAME	FUNCTION
MAX4864LEUT/ MAX4865LEUT/ MAX4866LEUT/ MAX4867EUT	MAX4864LELT/ MAX4865LELT/ MAX4866LELT/ MAX4867ELT		
1	3	IN	Voltage Input. IN is both the power-supply input and the overvoltage sense input.
2	1	GND	Ground
3	2	FLAG	Fault-Indication Output. When $\overline{EN}$ goes high, FLAG becomes high-impedance. FLAG is asserted high during undervoltage lockout and overvoltage lockout conditions. FLAG is deasserted during normal operation. FLAG is an open-drain output.
4	6	GATEN	n-Channel MOSFET Gate-Drive Output. GATEN is the output of an on-chip charge pump. When $V_{UVLO} < V_{IN} < V_{OVLO}$ , GATEN is driven high to turn on the external n-channel MOSFET.
5	5	GATEP	p-Channel MOSFET Gate-Drive Output. GATEP is always on when input is above ground and off when input drops below ground.
6	4	$\overline{EN}$	Active-Low Enable Input. Connect to ground in normal operation. Drive $\overline{EN}$ high to disable device and enter shutdown mode.

# Overvoltage Protection Controllers with Reverse Polarity Protection

MAX4864L/MAX4865L/MAX4866L/MAX4867

## Detailed Description

The MAX4864L/MAX4865L/MAX4866L/MAX4867 provide up to +28V overvoltage and negative voltage protection for low voltage systems. When the input voltage exceeds the overvoltage trip level, the MAX4864L/MAX4865L/MAX4866L/MAX4867 turn off a low-cost external n-channel MOSFET to prevent damage to the protected components. The devices also drive an external p-channel MOSFET to protect against negative voltage inputs. An internal charge-pump (see the *Functional Diagram*), drives the MOSFET GATEN for a simple, robust solution. On power-up, the device waits for 50ms before driving GATEN high. The open-drain FLAG output is kept at a high impedance for an additional 50ms after GATEN goes high before deasserting. The FLAG output asserts high immediately to an overvoltage fault.

## Undervoltage Lockout (UVLO)

The MAX4864L/MAX4865L/MAX4866L have a fixed +2.85V typical UVLO level, and the MAX4867 has +2.5V UVLO level. When  $V_{IN}$  is less than the UVLO, the GATEN driver is held low and FLAG is asserted.

## Overvoltage Lockout (OVLO)

The MAX4864L has a +7.4V typical OVLO threshold; the MAX4865L has +6.35V typical OVLO threshold; the MAX4866L has a +5.8V typical OVLO threshold; and the MAX4867 has a +4.65V typical OVLO threshold. When  $V_{IN}$  is greater than OVLO, the GATEN driver is held low and FLAG is asserted.

## FLAG Output

The open-drain FLAG output is used to signal to the host system when there is a fault with the input voltage. On power-up, FLAG is held high for 50ms after GATEN turns on, before deasserting. FLAG asserts immediately to overvoltage and undervoltage faults. When the fault condition is removed, FLAG deasserts 50ms after GATEN turns on. Connect a pullup resistor from FLAG to the logic I/O voltage of the host system.

## GATEN Driver

An on-chip charge pump is used to drive GATEN above IN, allowing the use of a low-cost n-channel MOSFET. The charge pump operates from the internal +5.5V regulator.

The actual GATEN output voltage tracks approximately two times  $V_{IN}$  until  $V_{IN}$  exceeds +5.5V, or the OVLO trip level is exceeded, whichever comes first. The MAX4864L has a +7.4V typical OVLO, therefore GATEN remains relatively constant at approximately +10.5V for  $+5.5V < V_{IN} < +7.4V$ . The MAX4866L has a +5.8V typical OVLO, but this can be as low as +5.5V. The GATEN

output voltage is a function of input voltage, as shown in the *Typical Operating Characteristics*.

## GATEP Driver

When the input voltage drops below ground, GATEP goes high turning the external p-channel MOSFET off. When the input voltage goes above ground, GATEP pulls low and turns on the p-channel MOSFET. An internal clamp protects the p-channel MOSFET by insuring that the GATEP-to-IN voltage does not exceed +16V when the input (IN) rises to +28V.

## Device Operation

The MAX4864L/MAX4865L/MAX4866L/MAX4867 have an on-board state machine to control device operation. A flowchart is shown in Figure 5. On initial power-up, if  $V_{IN} < UVLO$  or if  $V_{IN} > OVLO$ , GATEN is held at 0V and FLAG is high.

If  $UVLO < V_{IN} < OVLO$ , the device enters startup after a 50ms internal delay. The internal charge pump is enabled, and GATEN begins to be driven above  $V_{IN}$  by the internal charge pump. FLAG is held high during startup until the FLAG blanking period expires, typically 50ms after the GATEN starts going high. At this point, the device is in its on-state.

At any time if  $V_{IN}$  drops below UVLO, FLAG is driven high and GATEN is driven to ground.

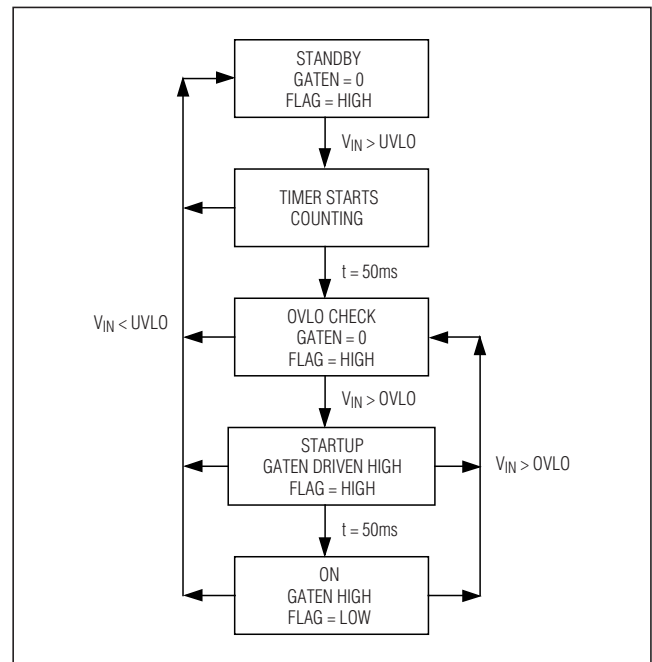


Figure 5. State Diagram

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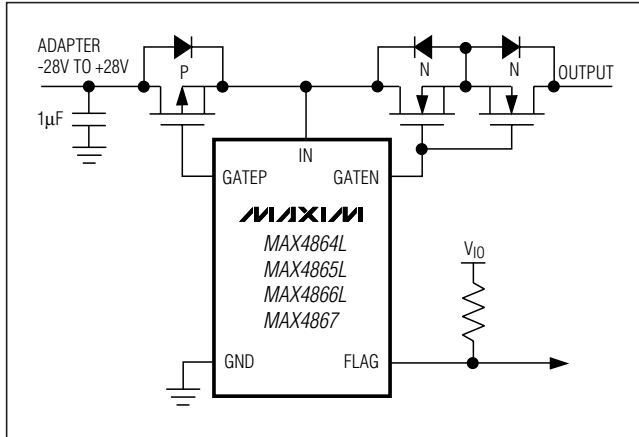


Figure 6. Back-to-Back External MOSFET Configuration

## Applications Information

### MOSFET Configuration

The MAX4864L/MAX4865L/MAX4866L/MAX4867 can be used with either a complementary MOSFET configuration as shown in the *Typical Operating Circuit*, or can be configured with a single p-channel MOSFET and back-to-back n-channel MOSFETs as shown in Figure 6.

The MAX4864L/MAX4865L/MAX4866L/MAX4867 can drive either a complementary MOSFET or a single p-channel MOSFET and back-to-back n-channel MOSFETs. The back-to-back configuration has almost zero reverse current when the adapter is not present or when the adapter voltage is below the UVLO threshold.

If reverse current leakage is not a concern, a single MOSFET can be used. This approach has half the loss of the back-to-back configuration when used with similar MOSFET types and is a lower cost solution. Note

that if the input is actually pulled low, the output will also be pulled low due to the parasitic body diode in the MOSFET. If this is a concern, then the back-to-back configuration should be used.

### MOSFET Selection

The MAX4864L/MAX4865L/MAX4866L/MAX4867 are designed for use with a complementary MOSFET or single p-channel and dual back-to-back n-channel MOSFETs. In most situations, MOSFETs with  $R_{ON}$  specified for a  $V_{GS}$  of 4.5V work well. Also the  $V_{DS}$  should be +30V for the MOSFET to withstand the full +28V IN range of the MAX4864L/MAX4865L/MAX4866L/MAX4867. Table 1 shows a selection of MOSFETs which are appropriate for use with the MAX4864L/MAX4865L/MAX4866L/MAX4867.

### IN Bypass Considerations

For most applications, bypass ADAPTER to GND with a 1µF ceramic capacitor. If the power source has significant inductance due to long lead length, take care to prevent overshoots due to the LC tank circuit and provide protection if necessary to prevent exceeding the +30V absolute maximum rating on IN.

### ESD Test Conditions

ESD performance depends on a number of conditions. The MAX4864L/MAX4865L/MAX4866L/MAX4867 are specified for ±15kV typical ESD resistance on IN when ADAPTER is bypassed to ground with a 1µF ceramic capacitor.

### Human Body Model

Figure 7 shows the Human Body Model, and Figure 8 shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the device through a 1.5kΩ resistor.

Table 1. MOSFET Suggestions

PART	CONFIGURATION/ PACKAGE	$V_{GS}$ MAX (V)	$V_{DS}$ MAX (V)	$R_{ON}$ AT 4.5V (mΩ)	MANUFACTURER
Si5504DC	Complementary MOSFET/1206-8	±20	+30	143 (n-MOSFET)	Vishay Siliconix
			-30	290 (p-MOSFET)	
Si5902DC	Dual/1206-8	±20	+30	143 (n-MOSFET)	
Si1426DH	Single/µDFN-6	±20	+30	115 (n-MOSFET)	
Si5435DC	Single/1206-8	±20	-30	80 (p-MOSFET)	Fairchild Semiconductor
FDC6561AN	Dual/SSOT-6	±20	+30	145 (n-MOSFET)	
FDG315N	Single/µDFN-6	±20	+30	160 (n-MOSFET)	
FDC658P	Single/SSOT-6	±20	-30	75 (p-MOSFET)	
FDC654P	Single/SSOT-6	±20	-30	125 (p-MOSFET)	



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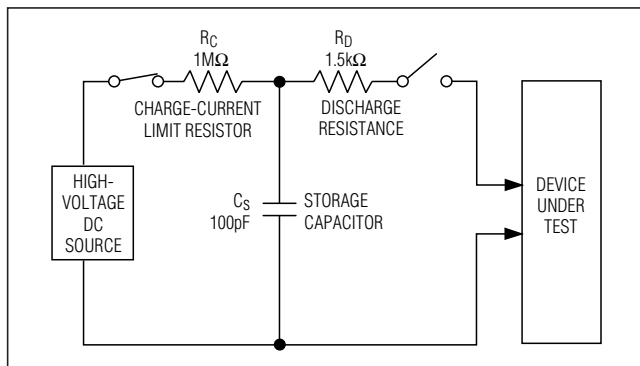


Figure 7. Human Body ESD Test Model

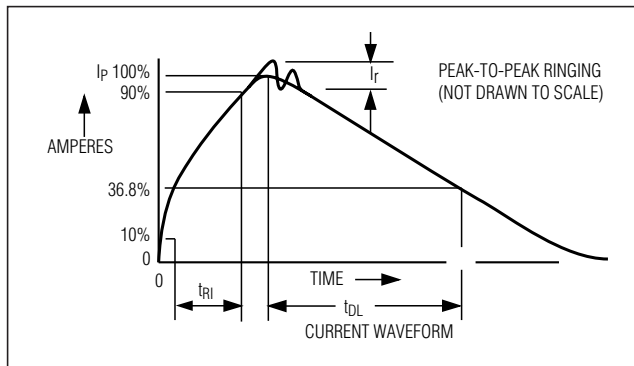


Figure 8. Human Body Current Waveform

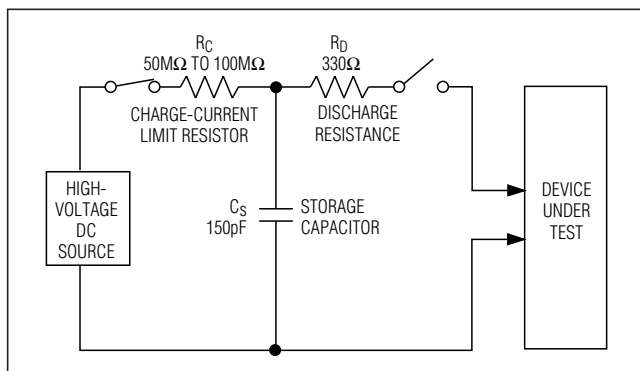


Figure 9. IEC 1000-4-2 ESD Test Model

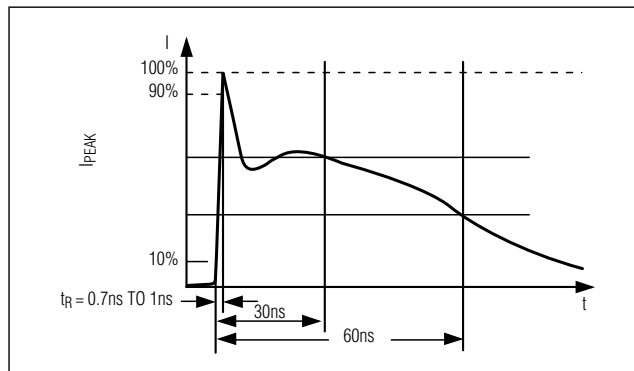


Figure 10. IEC 1000-4-2 ESD Generator Current Waveform

## IEC 1000-4-2

Since January 1996, all equipment manufactured and/or sold in the European Union has been required to meet the stringent IEC 1000-4-2 specification. The IEC 1000-4-2 standard covers ESD testing and performance of finished equipment. It does not specifically refer to ICs. The MAX4864L/MAX4865L/MAX4866L/MAX4867 help users design equipment that meets Level 3 of IEC 1000-4-2, without additional ESD-protection components.

The main difference between tests done using the Human Body Model and IEC 1000-4-2 is higher peak current in IEC 1000-4-2. Because series resistance is lower in the IEC 1000-4-2 ESD test model (Figure 9), the ESD-withstand voltage measured to this standard is gen-

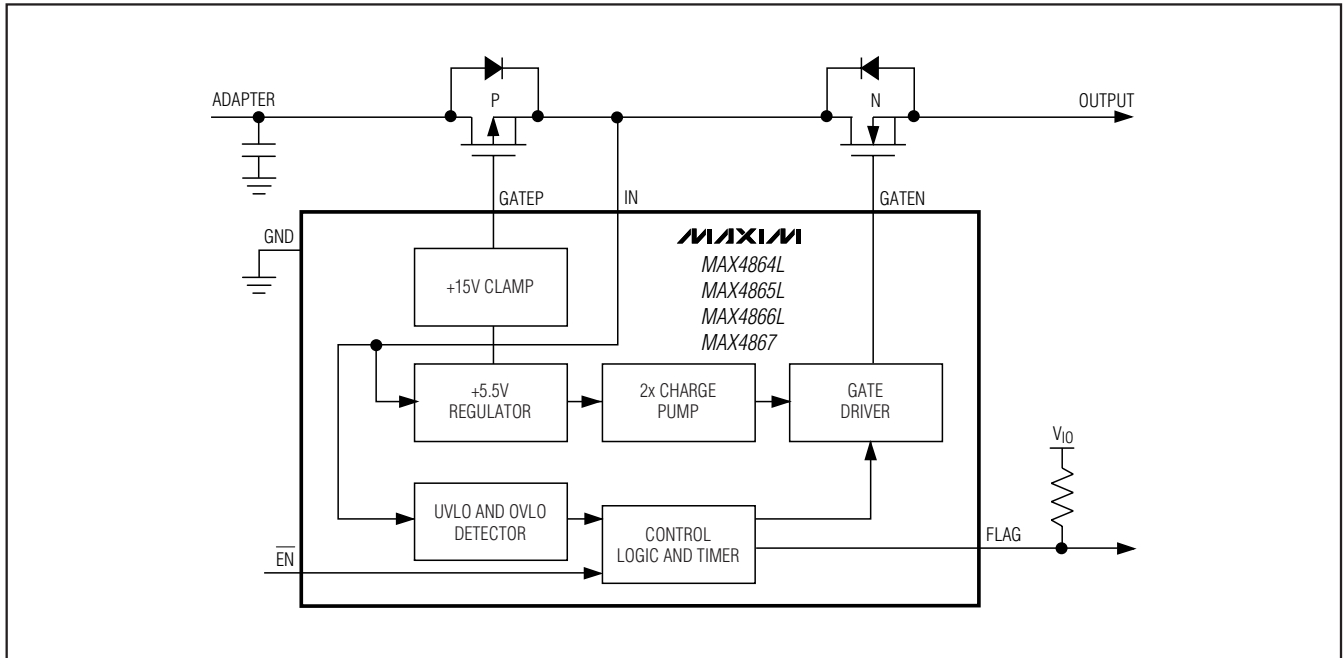
erally lower than that measured using the Human Body Model. Figure 10 shows the current waveform for the  $\pm 8\text{kV}$  IEC 1000-4-2 Level 4 ESD Contact Discharge test. The Air-Gap test involves approaching the device with a charger probe. The Contact Discharge method connects the probe to the device before the probe is energized.

## Chip Information

PROCESS: BiCMOS

# Overvoltage Protection Controllers with Reverse Polarity Protection

## Functional Diagram



## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages). Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

PACKAGE TYPE	PACKAGE CODE	DOCUMENT NO.
6 $\mu$ DFN	L622-1	<a href="#">21-0164</a>
6 SOT23	U6-1	<a href="#">21-0058</a>

# Overvoltage Protection Controllers with Reverse Polarity Protection

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
2	5/10	Deleted package codes from the <i>Ordering Information</i> table; updated the <i>Pin Configuration</i> , Figure 7, and Figure 9; deleted the transistor count from the <i>Chip Information</i> section	1, 6, 9, 10

MAX4864L/MAX4865L/MAX4866L/MAX4867

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