



## MAX14653/MAX14654/ MAX14655/MAX14717

## High-Current Overvoltage Protectors with Adjustable OVLO

### General Description

The MAX14653/MAX14654/MAX14655/MAX14717 overvoltage protection devices feature a low  $38\text{m}\Omega$  (typ)  $R_{\text{ON}}$  internal FET and protect low-voltage systems against voltage faults up to  $+28\text{V}_{\text{DC}}$ . An internal clamp also protects the devices from surges up to  $+80\text{V}$ . When the input voltage exceeds the overvoltage threshold, the internal FET is turned off to prevent damage to the protected downstream components.

The overvoltage protection threshold can be adjusted with optional external resistors to any voltage between  $4\text{V}$  and  $20\text{V}$ . With the OVLO input set below the external OVLO select voltage, the MAX14653/MAX14654/MAX14655/MAX14717 automatically choose the accurate internal trip thresholds. The internal overvoltage thresholds (OVLO) are preset to  $15.5\text{V}$  typical (MAX14653),  $6.8\text{V}$  typical (MAX14654/MAX14717), or  $5.825\text{V}$  typical (MAX14655). The devices feature an open-drain  $\overline{\text{ACOK}}$  output indicating a stable supply between minimum supply voltage and  $V_{\text{OVLO}}$ . The MAX14653/MAX14654/MAX14655/MAX14717 are also protected against overcurrent events by an internal thermal shutdown.

The MAX14653/MAX14654/MAX14655/MAX14717 are offered in a small 12-bump WLP package and operate over the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  extended temperature range.

### Applications

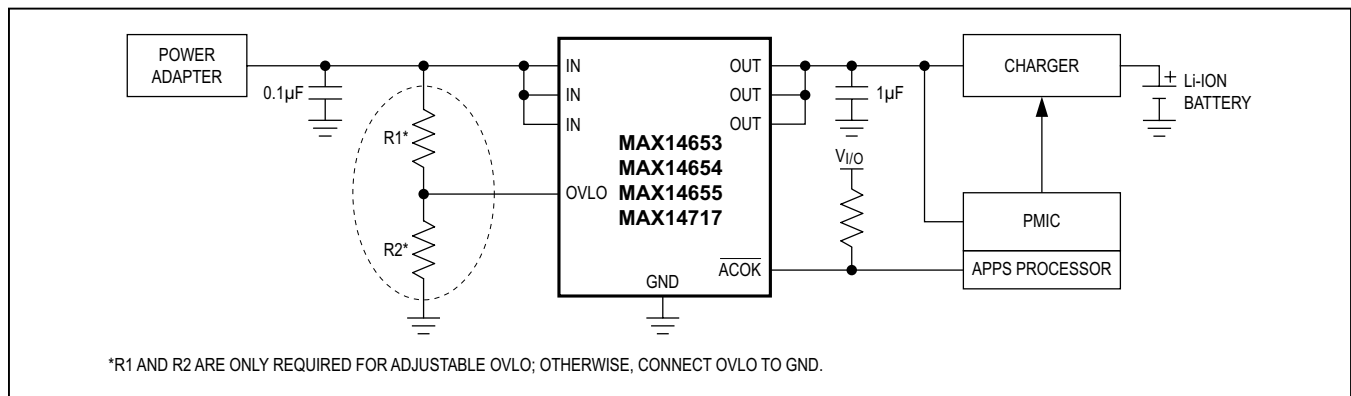
- Smartphones
- Tablet PCs
- Mobile Internet Devices

### Benefits and Features

- Protect High-Power Portable Devices
  - Wide Operating Input Voltage Protection from  $+2.5\text{V}$  to  $+28\text{V}$
  - Integrated  $38\text{m}\Omega$  (typ) n-Channel MOSFET Switch
- Flexible Overvoltage Protection Design
  - Adjustable Overvoltage Protection Trip Level
  - Wide Adjustable OVLO Threshold Range from  $+4\text{V}$  to  $+20\text{V}$
  - Preset Internal Accurate OVLO Thresholds:
    - $15.5\text{V} \pm 3.3\%$  (MAX14653)
    - $6.8\text{V} \pm 2.9\%$  (MAX14654/MAX14717)
    - $5.825\text{V} \pm 3\%$  (MAX14655)
- Additional Protection Features Increase System Reliability
  - Surge Immunity to  $+80\text{V}$
  - Soft-Start to Minimize In-Rush Current
  - Internal  $15\text{ms}$  Startup Debounce
  - Thermal-Shutdown Protection
- Minimize PCB Area
  - 12-Bump WLP ( $1.29\text{mm} \times 1.83\text{mm}$ ) Package
- $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  Operating Temperature Range

**Ordering Information** appears at end of data sheet.

### Typical Application Circuit



## Absolute Maximum Ratings

(All voltages referenced to GND.)

IN (Note 1)	-0.3V to +29V
OUT	-0.3V to $V_{IN} + 0.3V$
OVLO	-0.3V to +24V
ACOK	-0.3V to +6V
Continuous IN, OUT Current	4.5A

(Note: Continuous current limited by thermal design.)

Peak IN, OUT Current (10ms)	8A
Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ )	
WLP (derate 13.7mW/°C above +70°C)	1096mW
Operating Temperature Range	-40°C to +85°C
Junction Temperature	+150°C
Storage Temperature Range	-65°C to +150°C
Soldering Temperature (reflow)	+260°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.

## Package Thermal Characteristics (Note 2)

WLP

Junction-to-Ambient Thermal Resistance ( $\theta_{JA}$ ) ..... 73°C/W

**Note 1:** Survives burst pulse up to 80V with 2Ω series resistance.

**Note 2:** Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to [www.maximintegrated.com/thermal-tutorial](http://www.maximintegrated.com/thermal-tutorial).

## Electrical Characteristics

( $V_{IN} = +2.5V$  to +28V,  $C_{IN} = 0.1\mu\text{F}$ ,  $T_A = -40^\circ\text{C}$  to +85°C, unless otherwise noted. Typical values are at  $V_{IN} = +5.0V$ ,  $I_{IN} \leq 3A$ , and  $T_A = +25^\circ\text{C}$ .) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Input Voltage Range	$V_{IN}$		2.5		28	V	
Input Clamp Voltage	$V_{IN\_CLAMP}$	$I_{IN} = 10\text{mA}$ , $T_A = +25^\circ\text{C}$		33		V	
Input Supply Current	$I_{IN}$	$V_{IN} = 5V$		70	120	μA	
OVLO Supply Current	$I_{IN\_Q}$	$V_{OVLO} = 3V$ , $V_{IN} = 5V$ , $V_{OUT} = 0V$		63	120	μA	
Internal Overvoltage Trip Level	$V_{IN\_OVLO}$	$V_{IN}$ rising	MAX14653	15	15.5	16	V
			MAX14654/ MAX14717	6.6	6.8	7.0	
			MAX14655	5.65	5.825	6.00	
		$V_{IN}$ falling	MAX14653	14.5			
			MAX14654/ MAX14717	6.5			
			MAX14655	5.55			
OVLO Set Threshold	$V_{OVLO\_TH}$	MAX14653	1.22	1.26	1.30	V	
		MAX14654, MAX14655, MAX14717	1.18	1.22	1.26		
Adjustable OVLO Threshold Range			4		20	V	
External OVLO Select Threshold	$V_{OVLO\_SELECT}$		0.2		0.3	V	
Switch On-Resistance	$R_{ON}$	$V_{IN} = 5V$ , $I_{OUT} = 1A$ , $T_A = +25^\circ\text{C}$		38	53	mΩ	
OUT Load Capacitance	$C_{OUT}$	$V_{IN} = 5V$			1000	μF	
OVLO Input Leakage Current	$I_{OVLO}$	$V_{OVLO} = V_{OVLO\_TH}$	-100		100	nA	

### Electrical Characteristics (continued)

( $V_{IN} = +2.5V$  to  $+28V$ ,  $C_{IN} = 0.1\mu F$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $V_{IN} = +5.0V$ ,  $I_{IN} \leq 3A$ , and  $T_A = +25^\circ C$ .) (Note 3)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
IN Leakage Voltage by OVLO	$V_{IN\_LEAK}$	$V_{OVLO} = 20V$ , $V_{IN} =$ unconnected, $R_{OVLO} = 1M\Omega$			0.5	V
Thermal Shutdown				130		$^\circ C$
Thermal-Shutdown Hysteresis				20		$^\circ C$
<b>DIGITAL SIGNALS (ACOK)</b>						
ACOK Output Low Voltage	$V_{OL}$	$V_{I/O} = 3.3V$ , $I_{SINK} = 1mA$ , see the <i>Typical Application Circuit</i>			0.4	V
ACOK Leakage Current	$V_{ACOK\_LEAK}$	$V_{I/O} = 3.3V$ , ACOK deasserted, see the <i>Typical Application Circuit</i>	-1		+1	$\mu A$
<b>TIMING CHARACTERISTICS (Figure 1)</b>						
Debounce Time MAX14653/ MAX14654/MAX14655	$t_{DEB}$	Time from $2.5V < V_{IN} < V_{IN\_OVLO}$ to $V_{OUT} = 10\%$ of $V_{IN}$		15		ms
Debounce Time MAX14717	$t_{DEB}$	Time from $2.5V < V_{IN} < V_{IN\_OVLO}$ to $V_{OUT} = 10\%$ of $V_{IN}$		150		ms
Soft-Start Time MAX14653/ MAX14654/MAX14655	$t_{SS}$	$V_{OUT} = 10\%$ of $V_{IN}$ to soft-start off		30		ms
Soft-Start Time MAX14717	$t_{SS}$	$V_{OUT} = 10\%$ of $V_{IN}$ to soft-start off		165		ms
Switch Turn-On Time	$t_{ON}$	$V_{IN} = 5V$ , $R_L = 100\Omega$ , $C_{LOAD} = 100\mu F$ , $V_{OUT}$ from 10%, $V_{IN}$ to 90% $V_{IN}$		2		ms
Switch Turn-Off Time	$t_{OFF}$	$V_{IN} > V_{OVLO}$ to $V_{OUT} = 80\%$ of $V_{IN}$ , $R_L = 100\Omega$ , $V_{IN}$ rising at $2V/\mu s$		2		$\mu s$
<b>ESD PROTECTION</b>						
Human Body Model		All pins		$\pm 2$		kV
IEC 61000-4-2 Contact Discharge		IN pin		$\pm 8$		kV
IEC 61000-4-2 Air Gap Discharge		IN pin		$\pm 15$		kV

**Note 3:** All specifications are 100% production tested at  $T_A = +25^\circ C$ , unless otherwise noted. Specifications are over  $-40^\circ C$  to  $+85^\circ C$  and are guaranteed by design.

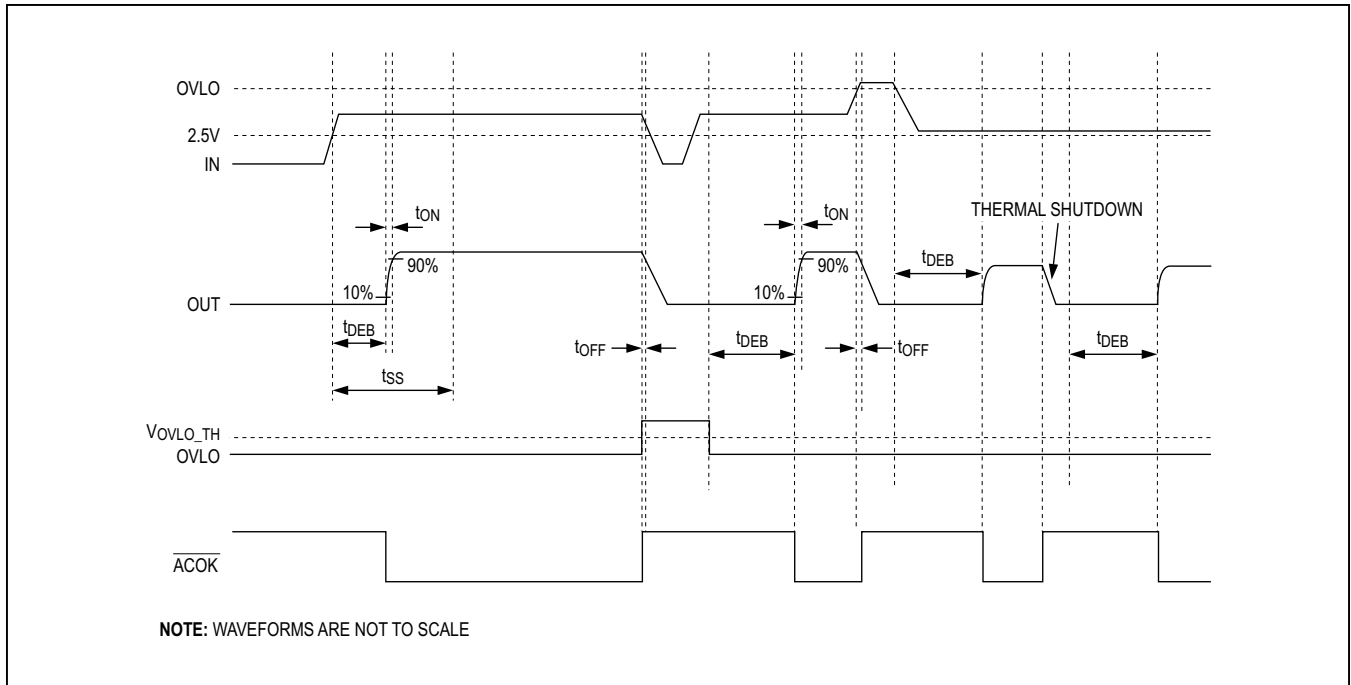
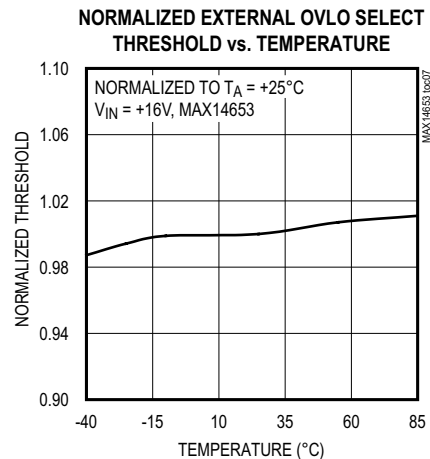
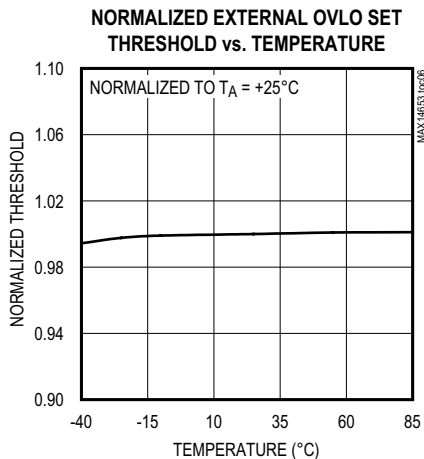
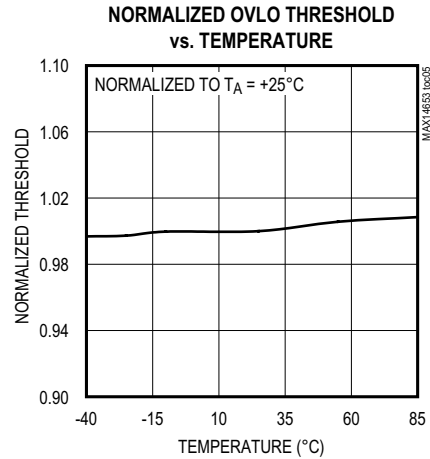
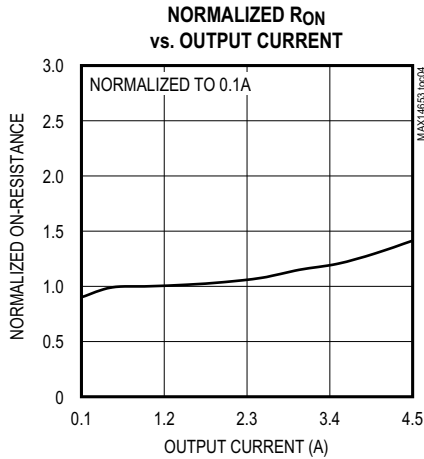
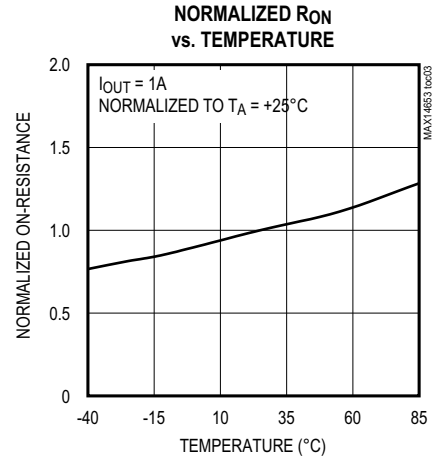
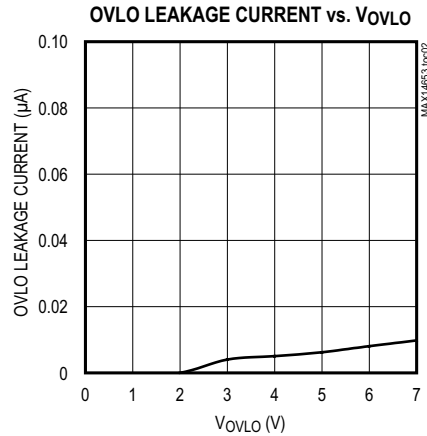
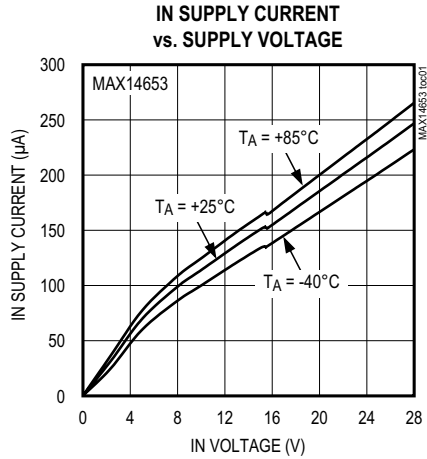


Figure 1. Timing Diagram

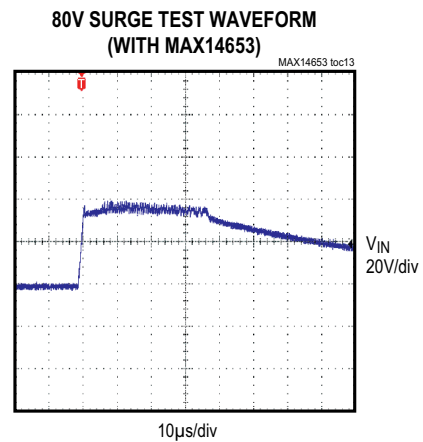
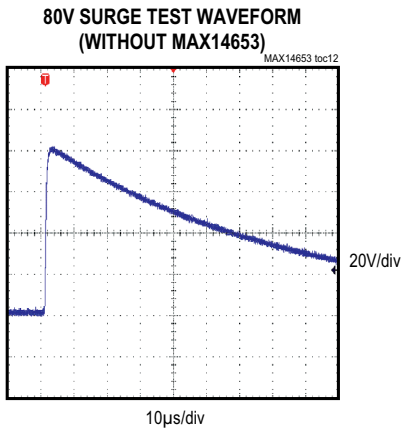
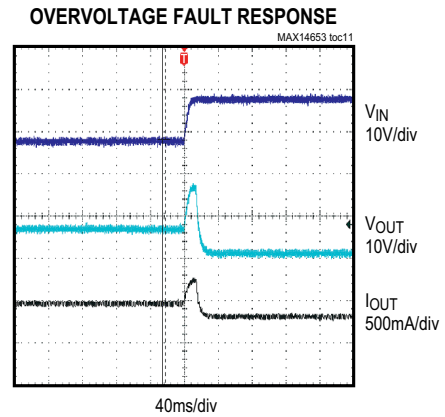
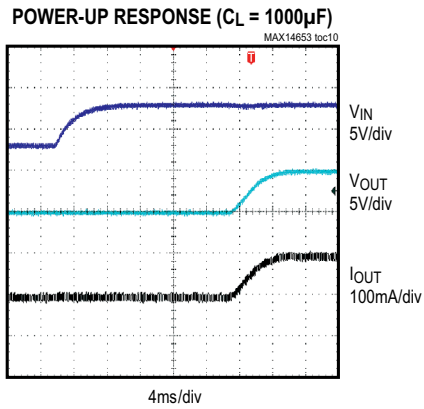
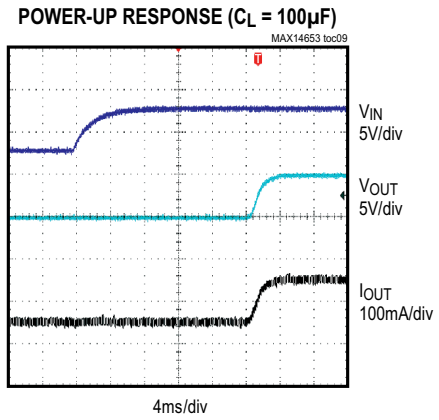
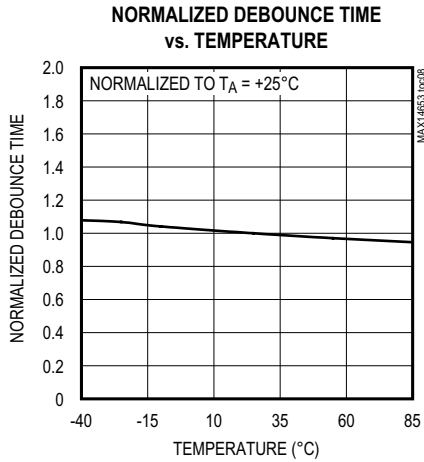
Typical Operating Characteristics

( $V_{IN} = +5.0V$ ,  $C_{IN} = 0.1\mu F$ ,  $C_{OUT} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

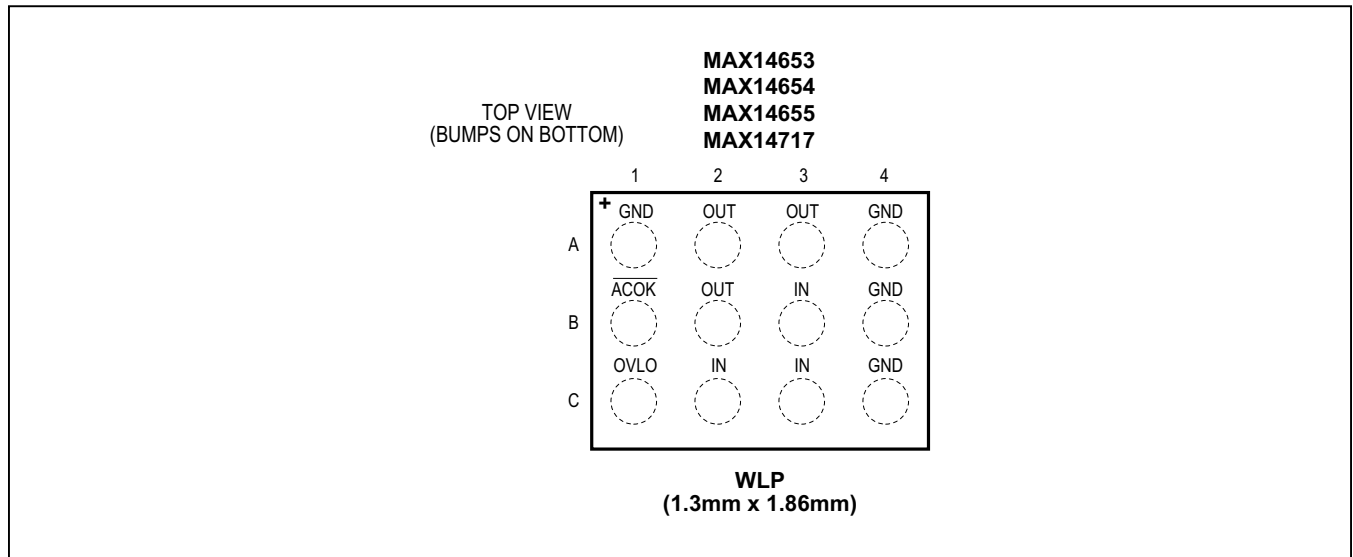


Typical Operating Characteristics (continued)

( $V_{IN} = +5.0V$ ,  $C_{IN} = 0.1\mu F$ ,  $C_{OUT} = 1\mu F$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



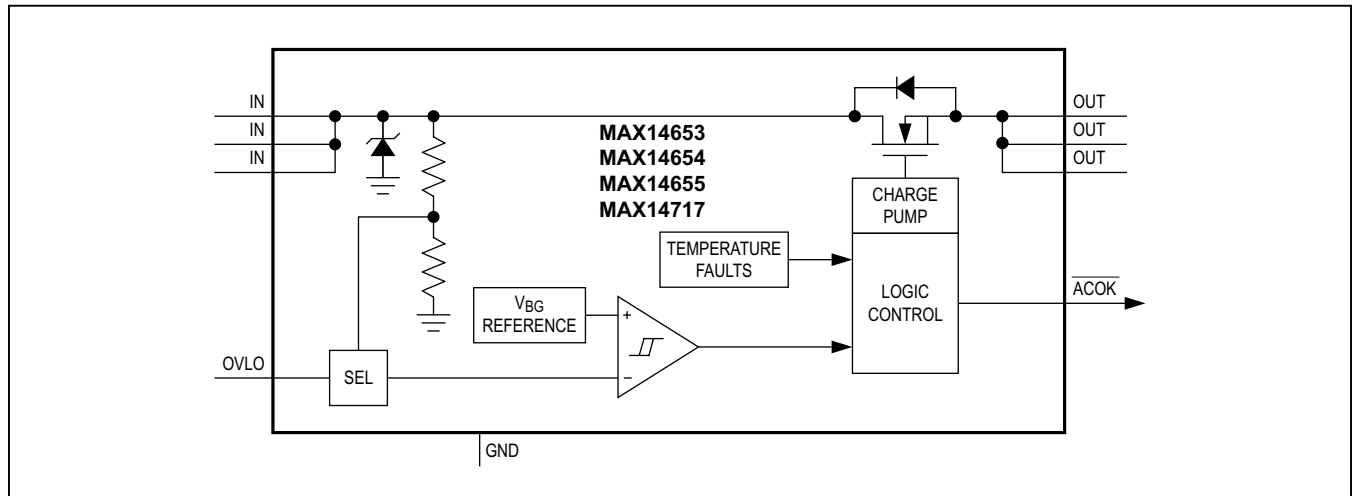
## Pin Configuration



## Pin Description

PIN	NAME	FUNCTION
A1, A4, B4, C4	GND	Ground. Connect GND pins together for proper operation.
A2, A3, B2,	OUT	Output Voltage. Output of internal switch. Connect OUT pins together for proper operation.
B1	ACOK	Open-Drain Flag Output. ACOK is driven low after input voltage is stable between minimum $V_{IN}$ and $V_{OVLO}$ after debounce. Connect a pullup resistor from ACOK to the logic I/O voltage of the host system. ACOK is high impedance after thermal shutdown.
B3, C2, C3	IN	Voltage Input. Bypass IN with a 0.1 $\mu$ F ceramic capacitor as close as possible to the device. Connect IN pins together for proper operation.
C1	OVLO	External OVLO Adjustment. Connect OVLO to GND when using the internal threshold. Connect a resistor-divider to OVLO to set a different OVLO threshold; this external resistor-divider is completely independent of the internal threshold.

## Functional Diagram



## Detailed Description

The MAX14653/MAX14654/MAX14655/MAX14717 overvoltage protection devices feature a low on-resistance ( $R_{ON}$ ) internal FET and protect low-voltage systems against voltage faults up to  $+28V_{DC}$ . An internal clamp also protects the devices from surges up to  $+80V$ . If the input voltage exceeds the overvoltage threshold, the internal FET is turned off to prevent damage to the protected components. The 15ms debounce time built into the device prevents false turn-on of the internal FET during startup.

### Device Operation

The devices contain timing logic that controls the turn-on of the internal FET. The internal charge pump is enabled when  $V_{IN} < V_{IN\_OVLO}$  if internal trip thresholds are used or when  $V_{IN} < \overline{V}_{OVLO\_TH}$  if external trip thresholds are used. The charge-pump startup, which occurs after a 15ms debounce delay, turns the internal FET on (see the *Functional Diagram*). After the debounce time, soft-start limits the FET inrush current for 30ms (typ). At any time, if  $V_{IN}$  rises above  $V_{OVLO\_THRESH}$ , OUT is disconnected from IN.

## Internal Switch

The MAX14653/MAX14654/MAX14655/MAX14717 incorporate an internal FET with a  $38m\Omega$  (typ)  $R_{ON}$ . The FET is internally driven by a charge pump that generates a necessary gate voltage above IN.

### Overvoltage Lockout (OVLO)

The MAX14653 has a 15.5V (typ) overvoltage threshold (OVLO). The MAX14654/MAX14717 and MAX14655 have 6.8V and 5.825V (typ) OVLO thresholds, respectively.

### Thermal Shutdown Protection

The MAX14653/MAX14654/MAX14655/MAX14717 feature thermal shutdown circuitry. The internal FET turns off when the junction temperature exceeds  $+130^{\circ}C$  (typ). The device exits thermal shutdown once the junction temperature cools by  $20^{\circ}C$  (typ).

### ACOK Output

An open-drain  $\overline{ACOK}$  output gives the MAX14653/MAX14654/MAX14655/MAX14717 the ability to communicate a stable power source to the host system.  $\overline{ACOK}$  is driven low after input voltage is stable between minimum  $V_{IN}$  and  $\overline{V}_{OVLO}$  after debounce. Connect a pullup resistor from  $\overline{ACOK}$  to the logic I/O voltage of the host system.  $\overline{ACOK}$  is high impedance after thermal shutdown.

## Applications Information

### IN Bypass Capacitor

For most applications, bypass IN to GND with a 0.1µF ceramic capacitor as close as possible to the device. If the power source has significant inductance due to long lead length, the device clamps the overshoot due to LC tank circuit.

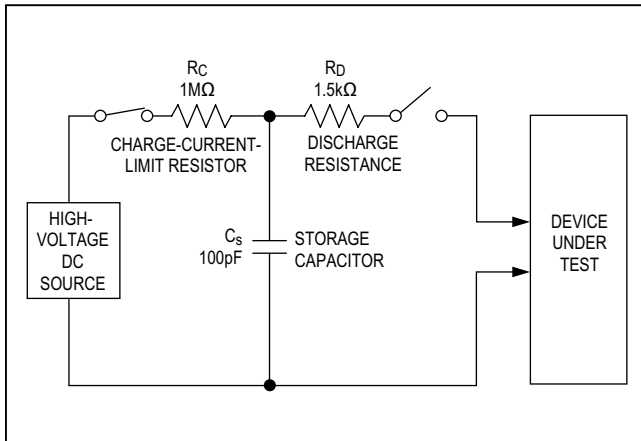


Figure 2a. Human Body ESD Test Model

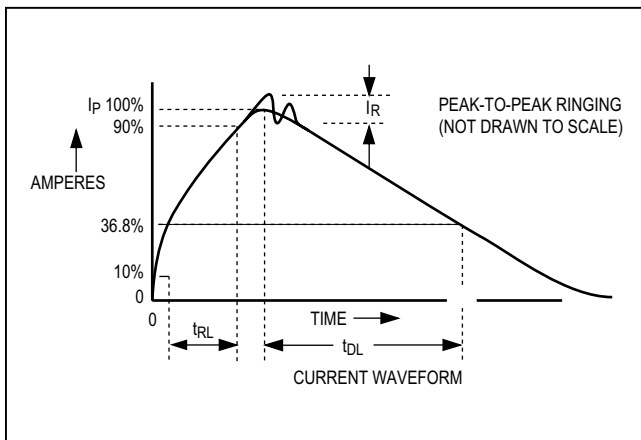


Figure 2b. Human Body Current Waveform

### OUT Output Capacitor

The slow turn-on time provides a soft-start function that allows the MAX14653/MAX14654/MAX14655/MAX14717 to charge an output capacitor up to 1000µF without turning off due to an overcurrent condition.

### External OVLO Adjustment Functionality

If OVLO is connected to ground, the internal OVLO comparator uses the internally set OVLO value.

If an external resistor-divider is connected to OVLO and  $V_{OVLO}$  exceeds the OVLO select voltage,  $V_{OVLO\_SELECT}$ , the internal OVLO comparator reads the IN fraction fixed by the external resistor divider.  $R_1 = 1M\Omega$  is a good starting value for minimum current consumption. Since  $V_{IN\_OVLO}$ ,  $V_{OVLO\_THRESH}$ , and  $R_1$  are known,  $R_2$  can be calculated from the following formula:

$$V_{IN\_OVLO} = V_{OVLO\_TH} \times \left[ 1 + \frac{R_1}{R_2} \right]$$

This external resistor-divider is completely independent from the internal resistor-divider.

### ESD Test Conditions

ESD performance depends on a number of conditions. The MAX14653/MAX14654/MAX14655/MAX14717 are specified for ±2kV HBM typical ESD on all pins, Contact and Air-Gap Discharge on pin IN. Contact Maxim for a reliability report that documents test setup, test methodology, and test results.

### HBM ESD Protection

Figure 2a shows the Human Body Model, while Figure 2b shows the current waveform it generates when discharged into 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.

MAX14653/MAX14654/  
MAX14655/MAX14717

## High-Current Overvoltage Protectors with Adjustable OVLO

### Ordering Information

PART	PIN- PACKAGE	TOP MARK	OVLO (V)
MAX14653EWC+T	12 WLP	ACS	15.5
MAX14654EWC+T	12 WLP	ACT	6.8
MAX14655EWC+T	12 WLP	ACU	5.825
MAX14717EWC+T	12 WLP	ADJ	6.8

**Note:** All devices are specified over the -40°C to +85°C temperature range.

+Denotes lead(Pb)-free/RoHS-compliant package.

T = Tape and reel.

### Chip Information

PROCESS: BICMOS

### Package Information

For the latest package outline information and land patterns (footprints), go to [www.maximintegrated.com/packages](http://www.maximintegrated.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	OUTLINE NO.	LAND PATTERN NO.
12 WLP	W121G1+1	<a href="#">21-0542</a>	Refer to <a href="#">Application Note 1891</a>

MAX14653/MAX14654/  
MAX14655/MAX14717

High-Current Overvoltage Protectors  
with Adjustable OVLO

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	1/13	Initial release	—
1	3/13	Removed future product asterisks for the MAX14653 and MAX14655	10
2	5/14	Added MAX14717	7

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at [www.maximintegrated.com](http://www.maximintegrated.com).

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