

# MAX6138

# 0.1%, 25ppm, SC70 Shunt Voltage Reference with Multiple Reverse Breakdown Voltages

## Absolute Maximum Ratings

Reverse Current (cathode to anode).....	20mA	Operating Temperature Range.....	-40°C to +85°C
Forward Current (anode to cathode).....	10mA	Storage Temperature Range.....	-65°C to +150°C
Continuous Power Dissipation (T <sub>A</sub> = +70°C)		Junction Temperature.....	+150°C
3-Pin SC70 (derate 2.17mW/°C above +70°C).....	174mW	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—MAX6138\_12 (1.2205V)

(I<sub>R</sub> = 100µA, T<sub>A</sub> = -40°C to +85°C, unless otherwise noted. Typical values are at T<sub>A</sub> = +25°C.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Reverse Breakdown Voltage (Note 2)	V <sub>R</sub>	T <sub>A</sub> = +25°C	MAX6138A (0.1%)	1.2193	1.2205	1.2217	V
			MAX6138B (0.2%)	1.2181	1.2205	1.2229	
			MAX6138C (0.5%)	1.2144	1.2205	1.2266	
Minimum Operating Current	I <sub>RMIN</sub>			45	60	µA	
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC			4	25	ppm/°C	
Reverse Breakdown Voltage Change with Operating Current Change	ΔV <sub>R</sub> /ΔI <sub>R</sub>	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.3	1.0	mV	
		1mA ≤ I <sub>R</sub> ≤ 12mA		2.5	8.0		
Reverse Dynamic Impedance (Note 3)	Z <sub>R</sub>	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.3	0.8	Ω	
Wideband Noise	e <sub>N</sub>	I <sub>R</sub> = 10µA, 10Hz ≤ f ≤ 10kHz		20		µV <sub>RMS</sub>	
Reverse Breakdown Voltage	ΔV <sub>R</sub>	t = 1000h		120		ppm	

# MAX6138

## 0.1%, 25ppm, SC70 Shunt Voltage Reference with Multiple Reverse Breakdown Voltages

### Electrical Characteristics—MAX6138\_21 (2.048V)

( $I_R = 100\mu\text{A}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ\text{C}$	MAX6138A (0.1%)	2.0460	2.0480	2.0500	V
			MAX6138B (0.2%)	2.0439	2.0480	2.0521	
			MAX6138C (0.5%)	2.0378	2.0480	2.0582	
Minimum Operating Current	$I_{RMIN}$			45	65		$\mu\text{A}$
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC				4	25	ppm/ $^\circ\text{C}$
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1\text{mA}$			0.3	1.0	mV
		$1\text{mA} \leq I_R \leq 15\text{mA}$			2.5	8.0	
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$			0.3	0.8	$\Omega$
Wideband Noise	$e_N$	$10\text{Hz} \leq f \leq 10\text{kHz}$			28		$\mu\text{V}_{RMS}$
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000\text{h}$			120		ppm

### Electrical Characteristics—MAX6138\_25 (2.5V)

( $I_R = 100\mu\text{A}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ\text{C}$	MAX6138A (0.1%)	2.4975	2.5000	2.5025	V
			MAX6138B (0.2%)	2.4950	2.5000	2.5050	
			MAX6138C (0.2%)	2.4875	2.5000	2.5125	
Minimum Operating Current	$I_{RMIN}$			45	65		$\mu\text{A}$
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC				4	25	ppm/ $^\circ\text{C}$
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1\text{mA}$			0.3	1.0	mV
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$1\text{mA} \leq I_R \leq 15\text{mA}$			2.5	8.0	mV
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$			0.3	0.8	$\Omega$
Wideband Noise	$e_N$	$10\text{Hz} \leq f \leq 10\text{kHz}$			35		$\mu\text{V}_{RMS}$
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000\text{h}$			120		ppm

# MAX6138

# 0.1%, 25ppm, SC70 Shunt Voltage Reference with Multiple Reverse Breakdown Voltages

## Electrical Characteristics—MAX6138\_30 (3.0V)

( $I_R = 100\mu A$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ C$	MAX6138A (0.1%)	2.9970	3.0000	3.0030	V
			MAX6138B (0.2%)	2.9940	3.0000	3.0060	
			MAX6138C (0.5%)	2.9850	3.0000	3.0150	
Minimum Operating Current	$I_{RMIN}$			45	65	$\mu A$	
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC			4	25	ppm/ $^\circ C$	
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1mA$		0.3	1.0	mV	
		$1mA \leq I_R \leq 15mA$		2.5	8.0		
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1mA$ , $f = 120Hz$ , $I_{AC} = 0.1I_R$		0.3	0.8	$\Omega$	
Wideband Noise	$e_N$	$10Hz \leq f \leq 10kHz$		45		$\mu V_{RMS}$	
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000h$		120		ppm	

## Electrical Characteristics—MAX6138\_33 (3.3V)

( $I_R = 100\mu A$ ,  $T_A = -40^\circ C$  to  $+85^\circ C$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ C$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ C$	MAX6138A (0.1%)	3.2967	3.3000	3.3033	V
			MAX6138B (0.2%)	3.2934	3.3000	3.3066	
			MAX6138C (0.5%)	3.2835	3.3000	3.3165	
Minimum Operating Current	$I_{RMIN}$			45	67	$\mu A$	
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC			4	25	ppm/ $^\circ C$	
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1mA$		0.3	1.0	mV	
		$1mA \leq I_R \leq 15mA$			8.0		
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1mA$ , $f = 120Hz$ , $I_{AC} = 0.1I_R$		0.3	0.8	$\Omega$	
Wideband Noise	$e_N$	$10Hz \leq f \leq 10kHz$		50		$\mu V_{RMS}$	
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000h$		120		ppm	

# MAX6138

# 0.1%, 25ppm, SC70 Shunt Voltage Reference with Multiple Reverse Breakdown Voltages

## Electrical Characteristics—MAX6138\_41 (4.096V)

( $I_R = 100\mu\text{A}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ\text{C}$	MAX6138A (0.1%)	4.0919	4.0960	4.1001	V
			MAX6138B (0.2%)	4.0878	4.0960	4.1042	
			MAX6138C (0.5%)	4.0755	4.0960	4.1165	
Minimum Operating Current	$I_{RMIN}$			50	73	$\mu\text{A}$	
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC			4	25	ppm/ $^\circ\text{C}$	
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1\text{mA}$		0.5	1.2	mV	
		$1\text{mA} \leq I_R \leq 15\text{mA}$		3.0	10.0		
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$		0.5	1.0	$\Omega$	
Wideband Noise	$e_N$	$10\text{Hz} \leq f \leq 10\text{kHz}$		64		$\mu\text{V}_{RMS}$	
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000\text{h}$		120		ppm	

## Electrical Characteristics—MAX6138\_50 (5.0V)

( $I_R = 100\mu\text{A}$ ,  $T_A = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless otherwise noted. Typical values are at  $T_A = +25^\circ\text{C}$ .) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS	
Reverse Breakdown Voltage (Note 2)	$V_R$	$T_A = +25^\circ\text{C}$	MAX6138A (0.1%)	4.9950	5.0000	5.0050	V
			MAX6138B (0.2%)	4.9900	5.0000	5.0100	
			MAX6138C (0.5%)	4.9750	5.0000	5.0250	
Minimum Operating Current	$I_{RMIN}$			54	80	$\mu\text{A}$	
Reverse Voltage Temperature Coefficient (Notes 2, 3)	TC			4	25	ppm/ $^\circ\text{C}$	
Reverse Breakdown Voltage Change with Operating Current Change	$\Delta V_R/\Delta I_R$	$I_{RMIN} \leq I_R \leq 1\text{mA}$		0.5	1.4	mV	
		$1\text{mA} \leq I_R \leq 15\text{mA}$		3.5	12.0		
Reverse Dynamic Impedance (Note 3)	$Z_R$	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$		0.5	1.1	$\Omega$	
Wideband Noise	$e_N$	$10\text{Hz} \leq f \leq 10\text{kHz}$		80		$\mu\text{V}_{RMS}$	
Reverse Breakdown Voltage Long-Term Stability	$\Delta V_R$	$t = 1000\text{h}$		120		ppm	

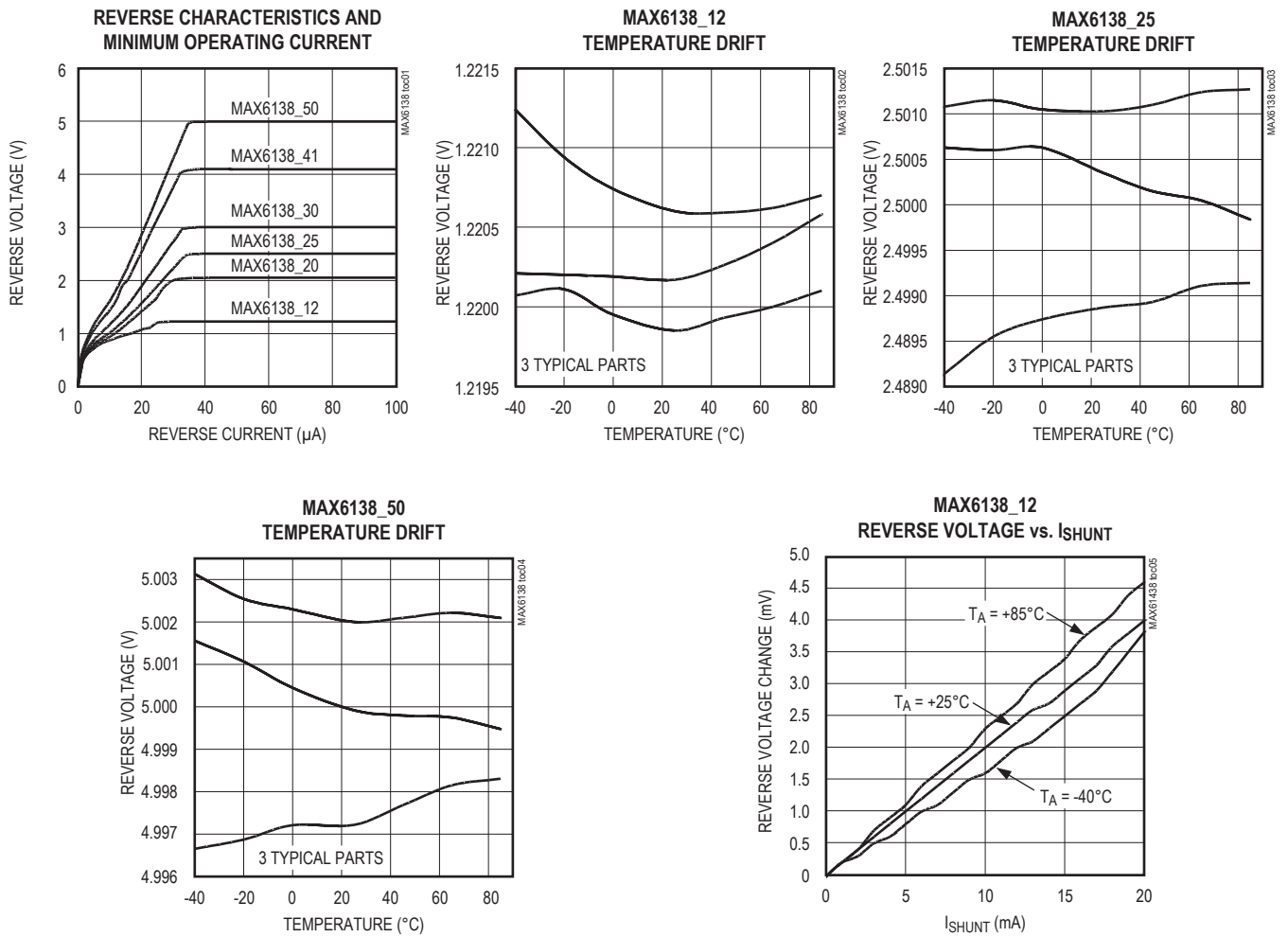
**Note 1:** All devices are 100% production tested at  $+25^\circ\text{C}$  and are guaranteed by correlation for  $T_A = T_{MAX}$  to  $T_{MIN}$ , as specified.

**Note 2:** TC is measured by the “box” method, i.e.  $(V_{MAX} - V_{MIN}) / (T_{MAX} - T_{MIN})$

**Note 3:** Guaranteed by design.

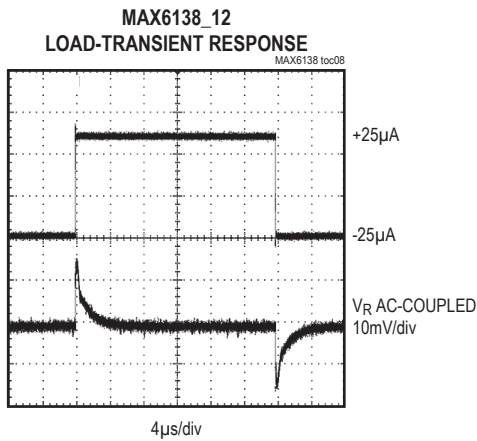
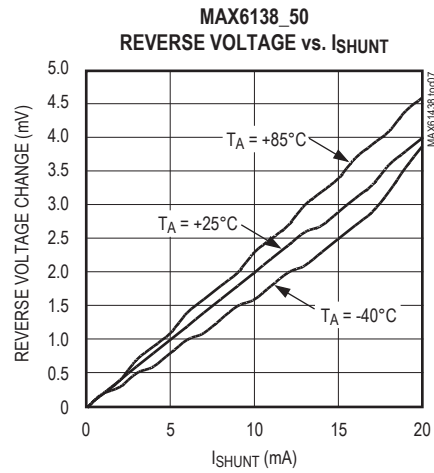
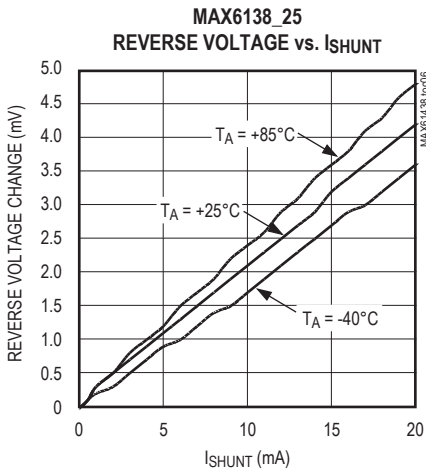
Typical Operating Characteristics

( $I_R = 100\mu A$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

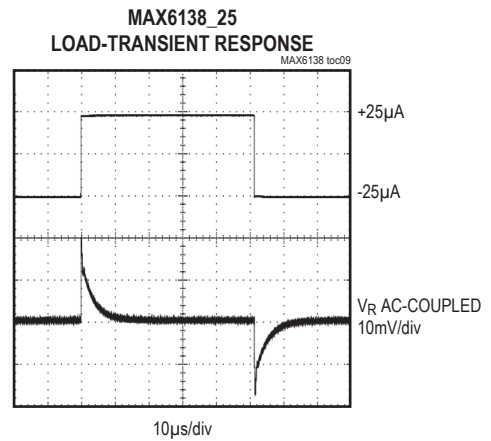


Typical Operating Characteristics (continued)

( $I_R = 100\mu A$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



$I_{SHUNT} = 100\mu A \pm 25A$   
 $R_L = 48k\Omega$



$I_{SHUNT} = 100\mu A$   
 $R_L = 100k\Omega$

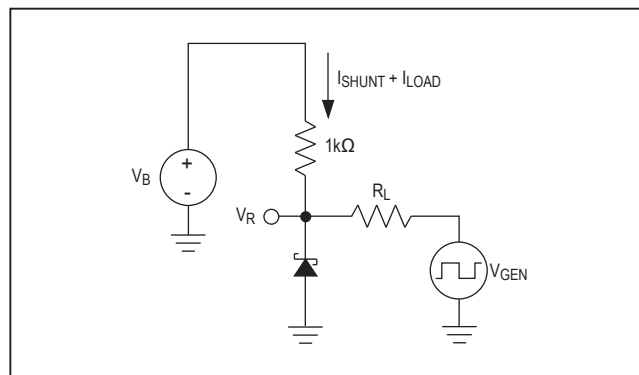


Figure 1. Load-Transient Circuit

Typical Operating Characteristics (continued)

( $I_R = 100\mu A$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

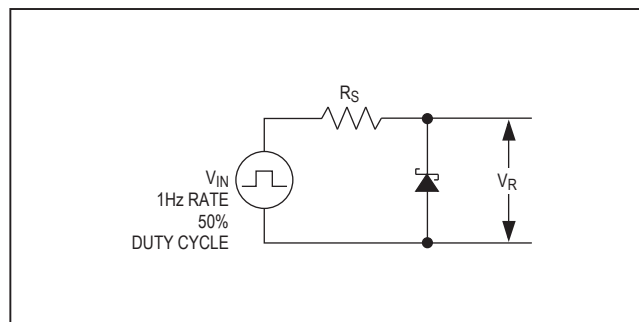
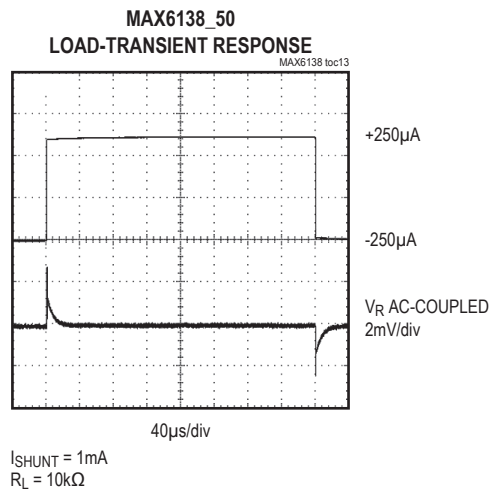
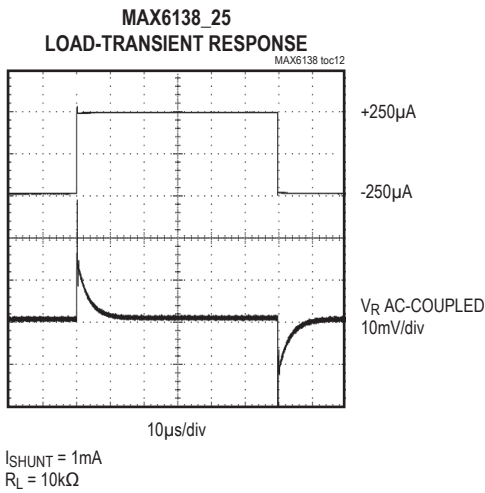
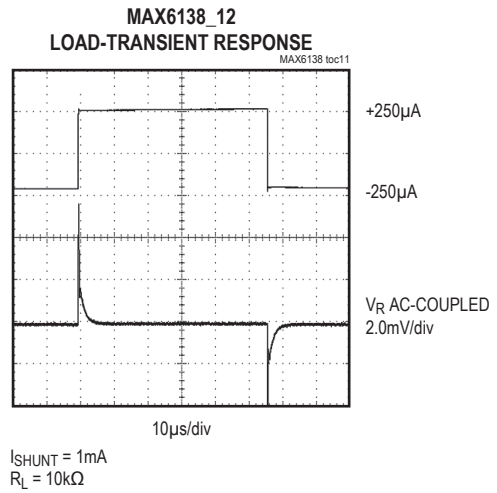
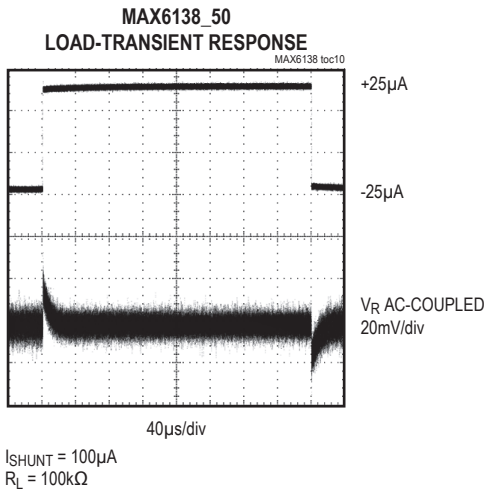
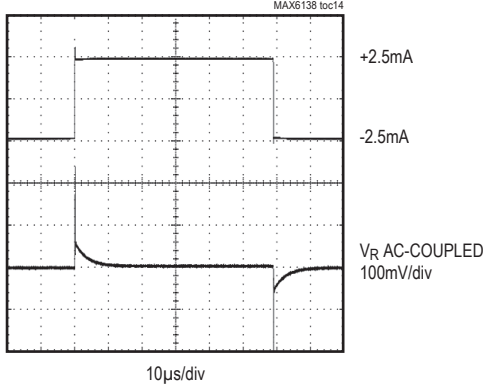


Figure 2. Startup Characteristics Test Circuit

Typical Operating Characteristics (continued)

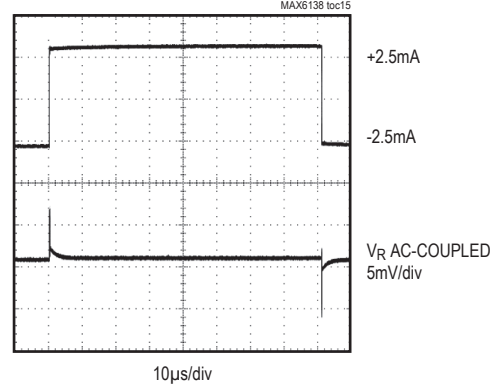
( $I_R = 100\mu A$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

MAX6138\_12  
LOAD-TRANSIENT RESPONSE



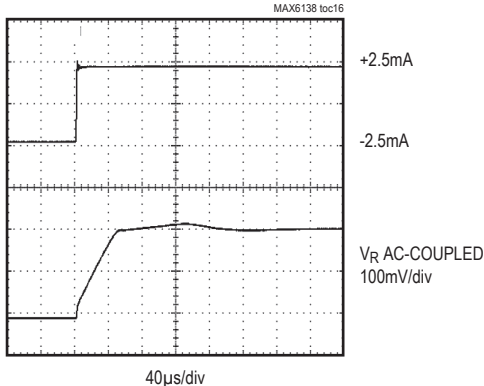
$I_{SHUNT} = 10mA$   
 $R_L = 1k\Omega$

MAX6138\_25  
LOAD-TRANSIENT RESPONSE



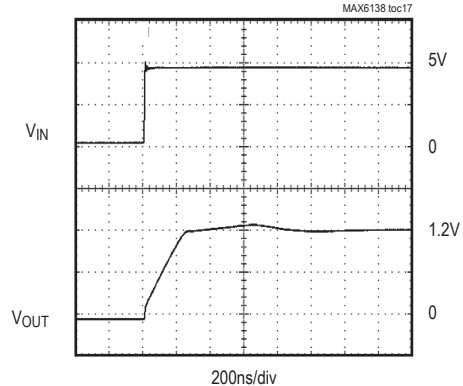
$I_{SHUNT} = 10mA$   
 $R_L = 1k\Omega$

MAX6138\_50  
LOAD-TRANSIENT RESPONSE



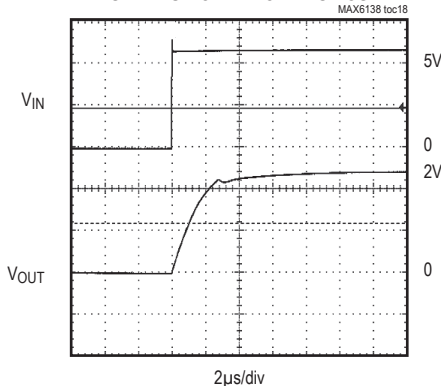
$I_{SHUNT} = 10mA$   
 $R_L = 1k\Omega$

MAX6138\_12  
STARTUP CHARACTERISTICS



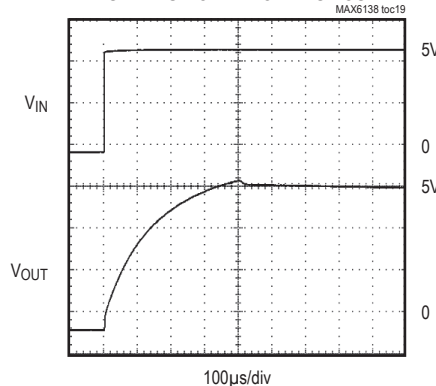
$I_{SHUNT} = 100\mu A$   
 $R_S = 30k\Omega$

MAX6138\_25  
STARTUP CHARACTERISTICS



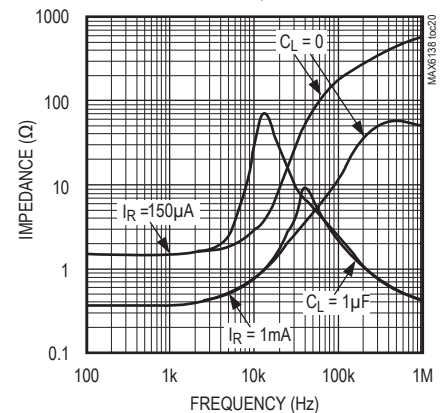
$I_{SHUNT} = 100\mu A$   
 $R_S = 30k\Omega$

MAX6138\_50  
STARTUP CHARACTERISTICS



$I_{SHUNT} = 100\mu A$   
 $R_S = 16k\Omega$

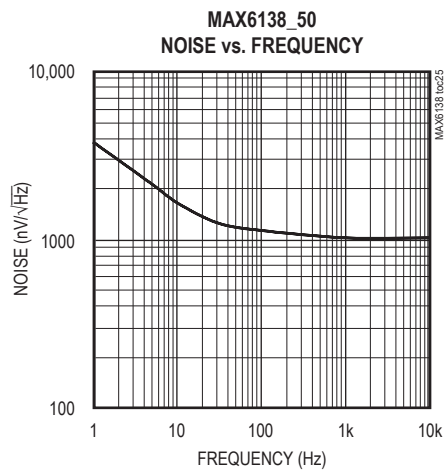
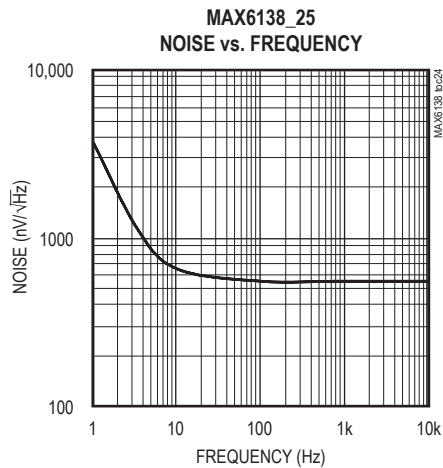
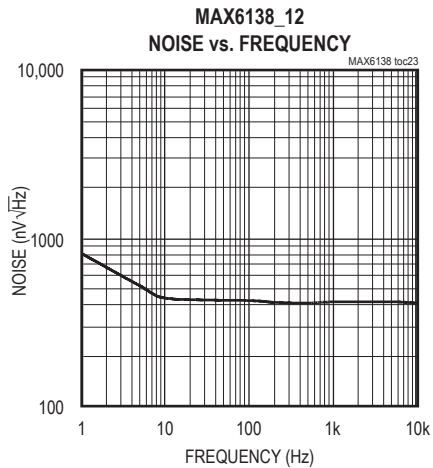
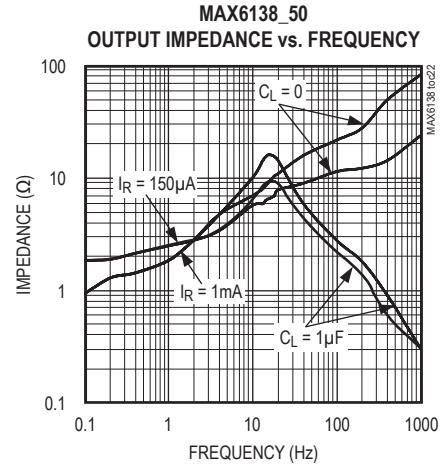
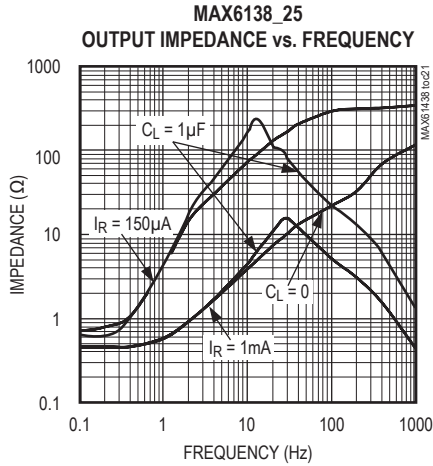
MAX6138\_12  
OUTPUT IMPEDANCE vs. FREQUENCY





Typical Operating Characteristics (continued)

( $I_R = 100\mu A$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pin Description

PIN	NAME	FUNCTION
1	+	Positive Terminal of the Shunt Reference
2	-	Negative Terminal of the Shunt Reference
3	N.C.	No Connection. Leave this pin unconnected or connect to Pin 2.

## Detailed Description

The MAX6138 shunt reference uses the bandgap principle to produce a stable, accurate voltage. The device behaves similarly to an ideal zener diode; a fixed voltage is maintained across its output terminals when biased with 60µA to 15mA of reverse current. The MAX6138 behaves similarly to a silicon diode when biased with forward currents up to 10mA.

Figure 3 shows a typical operating circuit. The MAX6138 is ideal for providing a stable reference from a high-voltage power supply.

## Applications Information

The MAX6138's internal pass transistor is used to maintain a constant output voltage ( $V_{SHUNT}$ ) by sinking the necessary amount of current across a source resistor. The source resistance ( $R_S$ ) is determined from the load current ( $I_{LOAD}$ ) range, supply voltage ( $V_S$ ) variations,  $V_{SHUNT}$ , and desired quiescent current.

Choose the value of  $R_S$  when  $V_S$  is at a minimum and  $I_{LOAD}$  is at a maximum. Maintain a minimum  $I_{SHUNT}$  of 60µA at all times. The  $R_S$  value should be large enough to keep  $I_{SHUNT}$  less than 15mA for proper regulation when  $V_S$  is maximum and  $I_{LOAD}$  is at a minimum. To prevent damage to the device,  $I_{SHUNT}$  should never exceed 20mA.

Therefore, the value of  $R_S$  is bounded by the following equation:

$$\frac{[V_{S(MIN)} - V_R] / [60\mu A + I_{LOAD(MAX)}]}{[V_{S(MAX)} - V_R] / [20mA + I_{LOAD(MIN)}]} > R_S >$$

Choosing a larger resistance minimizes the total power dissipation in the circuit by reducing the shunt current ( $P_{D(TOTAL)} = V_S \times I_{SHUNT}$ ). Provide a safety margin to incorporate the worst-case tolerance of the resistor used. Ensure that the resistor's power rating is adequate, using the following general power equation:

$$P_{DR} = I_{SHUNT} \times (V_{S(MAX)} - V_{SHUNT})$$

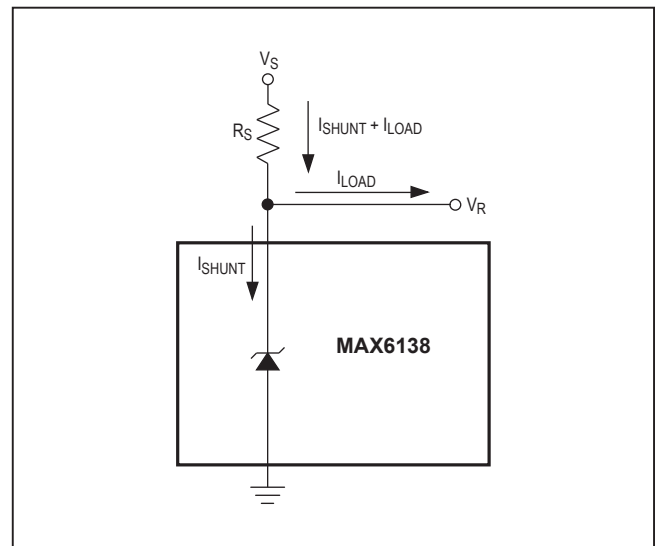


Figure 3. Typical Operating Circuit

## Output Capacitance

The MAX6138 does not require an external capacitor for operational stability and is stable for any output capacitance.

## Temperature Performance

The MAX6138 typically exhibits an output voltage temperature coefficient within  $\pm 4\text{ppm}/^\circ\text{C}$ . The polarity of the temperature coefficient may be different from one device to another; some may have positive coefficients, and others may have negative coefficients.

## Chip Information

TRANSISTOR COUNT: 70

PROCESS: BiCMOS

## Ordering Information

PART	OUTPUT VOLTAGE (V)	INITIAL ACCURACY (%)	TEMP RANGE	PIN-PACKAGE	TOP MARK
MAX6138AEXR12-T	1.2205	0.1	-40°C to +85°C	3 SC70-3	AEW
MAX6138BEXR12-T	1.2205	0.2	-40°C to +85°C	3 SC70-3	AEX
MAX6138CEXR12-T	1.2205	0.5	-40°C to +85°C	3 SC70-3	AEY
MAX6138AEXR21-T	2.0480	0.1	-40°C to +85°C	3 SC70-3	AFA
MAX6138BEXR21-T	2.0480	0.2	-40°C to +85°C	3 SC70-3	AFB
MAX6138CEXR21-T	2.0480	0.5	-40°C to +85°C	3 SC70-3	AFC
MAX6138AEXR25-T	2.5000	0.1	-40°C to +85°C	3 SC70-3	AFE
MAX6138BEXR25-T	2.5000	0.2	-40°C to +85°C	3 SC70-3	AFF
MAX6138CEXR25-T	2.5000	0.5	-40°C to +85°C	3 SC70-3	AFG
MAX6138AEXR30-T	3.0000	0.1	-40°C to +85°C	3 SC70-3	AFI
MAX6138BEXR30-T	3.0000	0.2	-40°C to +85°C	3 SC70-3	AFJ
MAX6138CEXR30-T	3.0000	0.5	-40°C to +85°C	3 SC70-3	AFK
MAX6138AEXR33-T	3.3000	0.1	-40°C to +85°C	3 SC70-3	ANG
MAX6138BEXR33-T	3.3000	0.2	-40°C to +85°C	3 SC70-3	ANH
MAX6138CEXR33-T	3.3000	0.5	-40°C to +85°C	3 SC70-3	ANI
MAX6138AEXR41-T	4.0960	0.1	-40°C to +85°C	3 SC70-3	AFM
MAX6138BEXR41-T	4.0960	0.2	-40°C to +85°C	3 SC70-3	AFN
MAX6138CEXR41-T	4.0960	0.5	-40°C to +85°C	3 SC70-3	AFO
MAX6138AEXR50-T	5.0000	0.1	-40°C to +85°C	3 SC70-3	AFQ
MAX6138BEXR50-T	5.0000	0.2	-40°C to +85°C	3 SC70-3	AFR
MAX6138CEXR50-T	5.0000	0.5	-40°C to +85°C	3 SC70-3	AFS

## 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.
3 SC70	X3+2	<a href="#">21-0075</a>	<a href="#">90-0208</a>

MAX6138

0.1%, 25ppm, SC70 Shunt Voltage Reference  
with Multiple Reverse Breakdown Voltages

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
3	12/19	Updated <i>Operating Temperature Range</i> in <i>Absolute Maximum Ratings</i>	2

For pricing, delivery, and ordering information, please visit Maxim Integrated's online storefront at <https://www.maximintegrated.com/en/storefront/storefront.html>.

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