National Semiconductor

April 1998

LM9140
Precision Micropower Shunt Voltage Reference

General Description

The LM9140's reverse breakdown voltage temperature coefficients of ±25 ppm/˚C are ideal for precision applications. The LM9140's advanced design eliminates the need for an external stabilizing capacitor while ensuring stability with any capacitive load, thus making the LM9140 easy to use. Further reducing design effort is the availability of several fixed reverse breakdown voltages: 2.500V, 4.096V, 5.000V, and 10.000V. The minimum operating current increases from 60 µA for the LM9140-2.5 to 100 µA for the LM9140-10.0. All versions have a maximum operating current of 15 mA.

The LM9140 utilizes fuse and zener-zap reverse breakdown voltage trim during wafer sort to ensure that the prime parts have an accuracy of better than ±0.5% (B grade) at 25˚C. Bandgap reference temperature drift curvature correction and low dynamic impedance ensure stable reverse breakdown voltage accuracy over a wide range of operating temperatures and currents.

Features

- Guaranteed temperature coefficient of ±25 ppm/˚C
- Reverse breakdown voltage tolerance of ±0.5%
- Small package: TO-92
- No output capacitor required
- Tolerates capacitive loads
- Fixed reverse breakdown voltages of 2.500V, 4.096V, 5.000V, and 10.000V

Key Specifications

(LM9140-2.5)

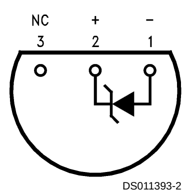
- Temperature coefficient: ±25 ppm/˚C (max)
- Output voltage tolerance: ±0.5% (max)
- Low output noise (10 Hz to 10 kHz): 35 μV_{rms} (typ)
- Wide operating current range: 60 µA to 15 mA
- Industrial temperature range: −40˚C to +85˚C

Applications

- Portable, Battery-Powered Equipment
- Data Acquisition Systems
- Instrumentation
- Process Control
- Energy Management
- Product Testing
- Automotive
- Precision Audio Components

Connection Diagram

TO-92



Bottom View
See NS Package Number Z03A

Ordering Information

Reverse Breakdown Voltage Tolerance at 25˚C and Average Reverse Breakdown Voltage Temperature Coefficient	Z (TO-92)
0.5%, 25 ppm/˚C max	LM9140BYZ-2.5, LM9140BYZ-4.1, LM9140BYZ-5.0, LM9140BYZ-10.0

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Reverse Current	20 mA
Forward Current	10 mA
Power Dissipation (T_A = 25˚C) (Note 2)	
Z Package	550 mW
Storage Temperature	−65˚C to +150˚C
Lead Temperature	
Z Package	
Soldering (10 seconds)	+260˚C
ESD Susceptibility	
Human Boddy Mode (Note 3)	2 kV
Machine Model (Note 3)	200V

Operating Ratings (Notes 1, 2)

Temperature Range	
(T_{min} ≤ T_A ≤ T_{max})	−40˚C ≤ T_A ≤ +85˚C
Reverse Current	
LM9140-2.5	60 µA to 15 mA
LM9140-4.1	68 µA to 15 mA
LM9140-5.0	74 µA to 15 mA
LM9140-10.0	100 µA to 15 mA

LM9140BYZ-2.5

Electrical Characteristics

Boldface limits apply for T_A = T_J = T_{MIN} to T_{MAX}; all other limits T_A = T_J = 25˚C

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
V_R	Reverse Breakdown Voltage	I_R = 100 µA	2.500		V
	Reverse Breakdown Voltage Tolerance (Note 6)	I_R = 100 µA		±12.5 **±16.6**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		45	 60 **65**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 7)	I_R = 10 mA I_R = 1 mA I_R = 100 µA	±10 ±10 ±10	 **±25** 	ppm/˚C ppm/˚C (max) ppm/˚C
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	I_{RMIN} ≤ I_R ≤ 1 mA	0.3	 0.8 **1.0**	mV mV (max) mV (max)
		1 mA ≤ I_R ≤ 15 mA	2.5	 6.0 **8.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R	0.3	 0.8	Ω Ω (max)
e_N	Wideband Noise	I_R = 100 µA 10 Hz ≤ f ≤ 10 kHz	35		μV_{rms}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000 hrs T = 25˚C ±0.1˚C I_R = 100 µA	120		ppm

LM9140BYZ-4.1

Electrical Characteristics

Boldface limits apply for T_A = T_J = T_{MIN} to T_{MAX}; all other limits T_A = T_J = 25˚C

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
V_R	Reverse Breakdown Voltage	I_R = 100 µA	4.096		V
	Reverse Breakdown Voltage Tolerance (Note 6)	I_R = 100 µA		±20.5 **±27.1**	mV (max) mV (max)

Electrical Characteristics (Continued)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
I_{RMIN}	Minimum Operating Current		50		µA
				68	µA (max)
				73	µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 7)	I_R = 10 mA	±10		ppm/°C
		I_R = 1 mA	±10	**±25**	ppm/°C (max)
		I_R = 100 µA	±10		ppm/°C
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R \le$ 1 mA	0.5		mV
				0.9	mV (max)
				1.2	mV (max)
		1 mA ≤ I_R ≤ 15 mA	3.0		mV
				7.0	mV (max)
				10.0	mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1 mA, f = 120 Hz, $I_{AC} = 0.1\ I_R$	0.5		Ω
				1.0	Ω(max)
e_N	Wideband Noise	I_R = 100 µA, 10 Hz ≤ f ≤ 10 kHz	80		$µV_{rms}$
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000 hrs, T = 25°C ±0.1°C, I_R = 100 µA	120		ppm

LM9140BYZ-5.0 Electrical Characteristics

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
V_R	Reverse Breakdown Voltage	I_R = 100 µA	5.000		V
	Reverse Breakdown Voltage Tolerance (Note 6)	I_R = 100 µA		±25.0	mV (max)
				±33.1	mV (max)
I_{RMIN}	Minimum Operating Current		55		µA
				74	µA (max)
				80	µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 7)	I_R = 10 mA	±10		ppm/°C
		I_R = 1 mA	±10	**±25**	ppm/°C (max)
		I_R = 100 µA	±10		ppm/°C
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R \le$ 1 mA	0.5		mV
				1.0	mV (max)
				1.4	mV (max)
		1 mA ≤ I_R ≤ 15 mA	3.5		mV
				8.0	mV (max)
				12.0	mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1 mA, f = 120 Hz, $I_{AC} = 0.1\ I_R$	0.5		Ω
				1.1	Ω(max)
e_N	Wideband Noise	I_R = 100 µA, 10 Hz ≤ f ≤ 10 kHz	80		$µV_{rms}$

Electrical Characteristics (Continued)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25˚C$

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000 hrs T = 25˚C ±0.1˚C I_R = 100 µA	120		ppm

LM9140BYZ-10.0

Electrical Characteristics

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25˚C$

Symbol	Parameter	Conditions	Typical (Note 4)	Limits (Note 5)	Units (Limit)
V_R	Reverse Breakdown Voltage	I_R = 150 µA	10.00		V
	Reverse Breakdown Voltage Tolerance (Note 6)	I_R = 100 µA		±50.0 **±66.3**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		75	 100 **103**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 7)	I_R = 10 mA I_R = 1 mA I_R = 150 µA	±10 ±10 ±10	 **±25** 	ppm/˚C ppm/˚C (max) ppm/˚C
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R \le$ 1 mA	0.8	 1.6 **3.5**	mV mV (max) mV (max)
		1 mA ≤ I_R ≤ 15 mA	8.0	 12.0 **23.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1 mA, f = 120 Hz, I_{AC} = 0.1 I_R	0.7	 1.7	Ω Ω(max)
e_N	Wideband Noise	I_R = 150 µA 10 Hz ≤ f ≤ 10 kHz	180		$µV_{rms}$
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000 hrs T = 25˚C ±0.1˚C I_R = 150 µA	120		ppm

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.

Note 2: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{Jmax} (maximum junction temperature), θ_{JA} (junction to ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is $PD_{MAX} = (T_{Jmax} - T_A)/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM9140, T_{Jmax} = 125˚C, and the typcial thermal resistance (θ_{JA}), when board mounted, is 170˚C/W with 0.125" lead length for the TO-92 package.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. The machine mode is a 200 pF capacitor discharged directly into each pin.

Note 4: Typicals are at T_J = 25˚C and represent most likely parametric norm.

Note 5: Limits are 100% production tested at 25˚C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate National's AOQL.

Note 6: The boldface (over-temperature) limit for Reverse Breakdown Voltage Tolerance is defined as a room termperature Reverse Breakdown Voltage Tolerance ± [$\Delta V_R/\Delta T$) (65˚C) (V_R)]. $\Delta V_R/\Delta T$ is the V_R temperature coefficent, 65˚C is the temperature range from −40˚C to the reference point of 25˚C, and V_R is the reverse breakdown voltage. The total over-temperature tolerence for the different grades is shown below:

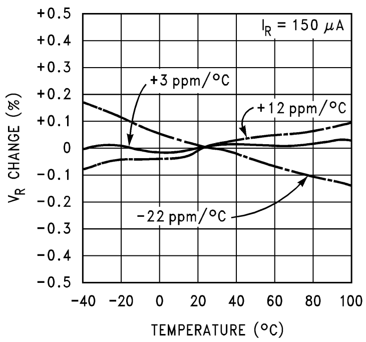
B-grade: ±0.66% = ±0.5% ±25 ppm/˚C x 65˚C

Therefore, as an example, the B-grade LM9140-2.5 has an over-temperature Reverse Breakdown Voltage tolerance of ±2.5V x 0.66% = ±16.6 mV.

Note 7: The average temperature coefficient is defined as the maximum deviation of reference voltage at all measured temperatures between the operating T_{MAX} and T_{MIN}, divided by $T_{MAX} - T_{MIN}$. The measured temperatures are −55˚C, −40˚C, 0˚C, 25˚C, 70˚C, 85˚C and 125˚C.

Typical Performance Characteristics

Temperature Drift for Different Average Temperature Coefficient



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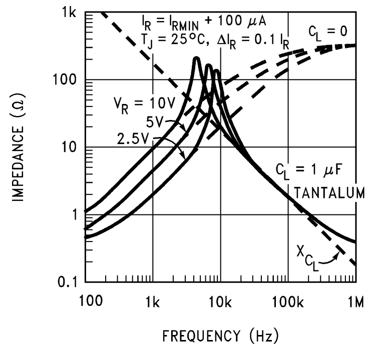
Output Impedance vs Frequency



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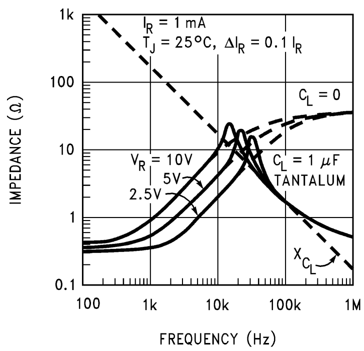
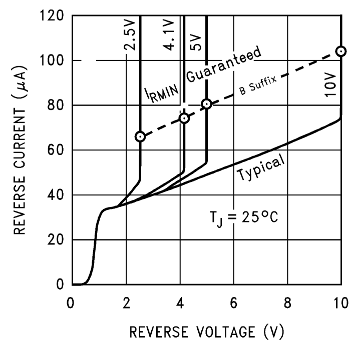
Output Impedance vs Frequency



DS011393-5

Reverse Characteristics and Minimum Operating Current



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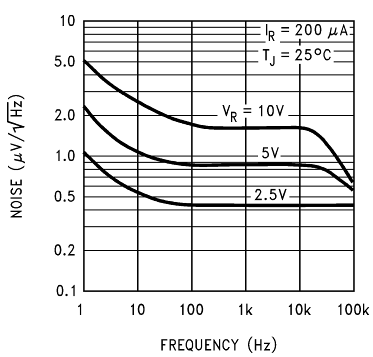
Noise Voltage vs Frequency



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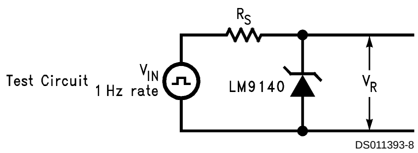
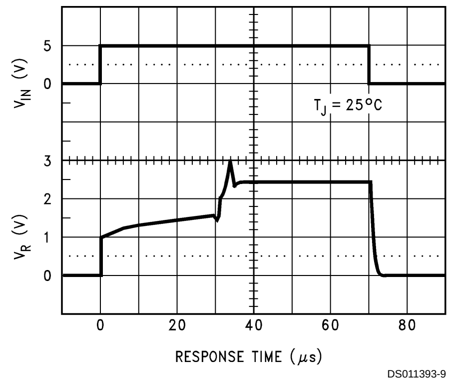
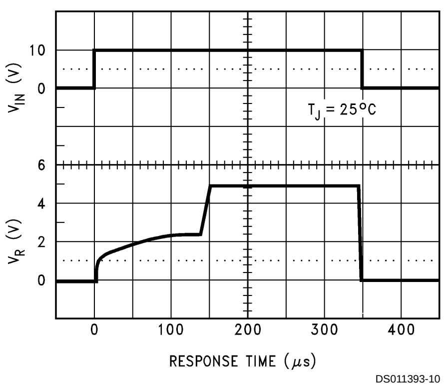
Start-Up Characteristics



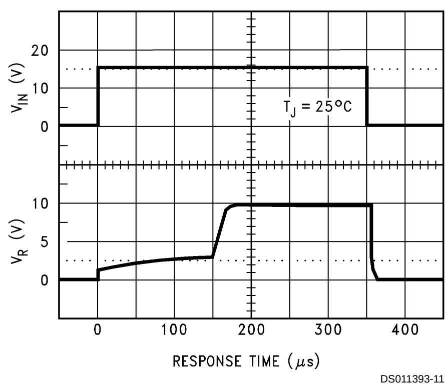
LM9140-2.5 R_S = 30k



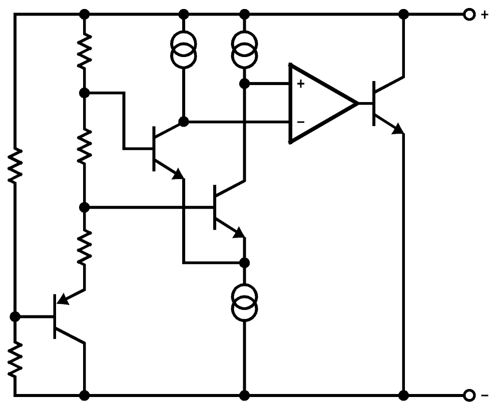
LM9140-5.0 R_S = 30k



LM9140-10.0 R_S = 30k



Functional Block Diagram



DS011393-12

Applications Information

The LM9140 is a precision micro-power curvature-corrected bandgap shunt voltage reference. The LM9140 has been designed for stable operation without the need of an external capacitor connected between the "+" pin and the "−" pin. If, however, a bypass capacitor is used, the LM9140 remains stable. Reducing design effort is the availability of several fixed reverse breakdown voltages: 2.500V, 4.096V, 5.000V, and 10.000V. The minimum operating current increases from 60 µA for the LM9140-2.5 to 100 µA for the LM9140-10.0. All versions have a maximum operating current of 15 mA.

The 4.096V version allows single +5V 12-bit ADCs or DACs to operate with an LSB equal to 1 mV. For 12-bit ADCs or DACs that operate on supplies of 10V or greater, the 8.192V version gives 2 mV per LSB.

In a conventional shunt regulator application (*Figure 1*), an external series resistor (R_S) is connected between the supply voltage and the LM9140. R_S determines the current that flows through the load (I_L) and the LM9140 (I_Q). Since load current and supply voltage may vary, R_S should be small enough to supply at least the minimum acceptable I_Q to the LM9140 even when the supply voltage is at its minimum and the load current is at its maximum value. When the supply voltage is at its maximum and I_L is at its minimum, R_S should be large enough so that the current flowing through the LM9140 is less than 15 mA.

R_S is determined by the supply voltage, (V_S), the load and operating current, (I_L and I_Q), and the LM9140's reverse breakdown voltage, V_R.

$$R_S = \frac{V_S - V_R}{I_L + I_Q}$$

Typical Applications

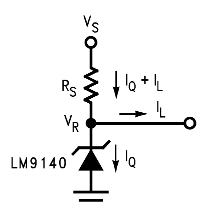


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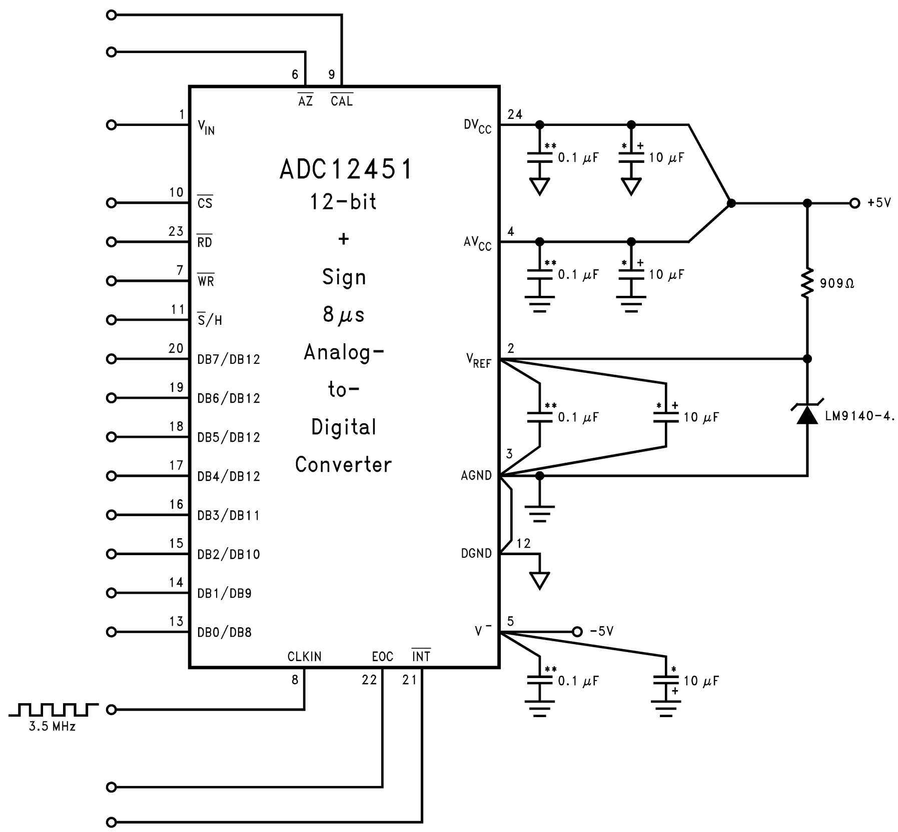
FIGURE 1. Shunt Regulator

Typical Applications (Continued)



*Tantalum

**Ceramic monolithic

FIGURE 2. LM9140-4.1's Nominal 4.096 breakdown voltage gives ADC12451 1 mV/LSB

Typical Applications (Continued)

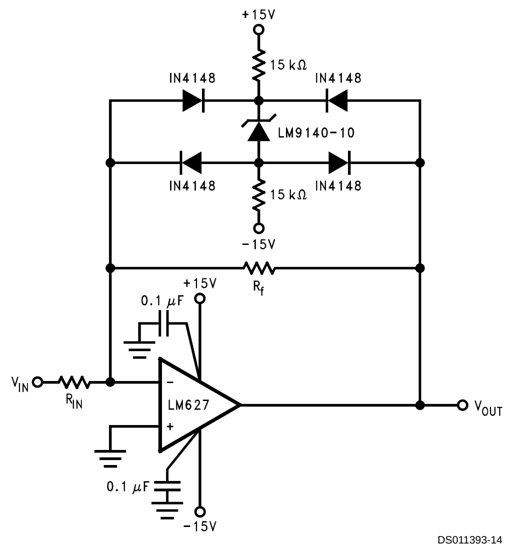


FIGURE 3. Bounded amplifier reduces saturation-induced delays and can prevent succeeding stage damage. Nominal clamping voltage is ±11.5V (LM9140's reverse breakdown voltage +2 diode V_F).

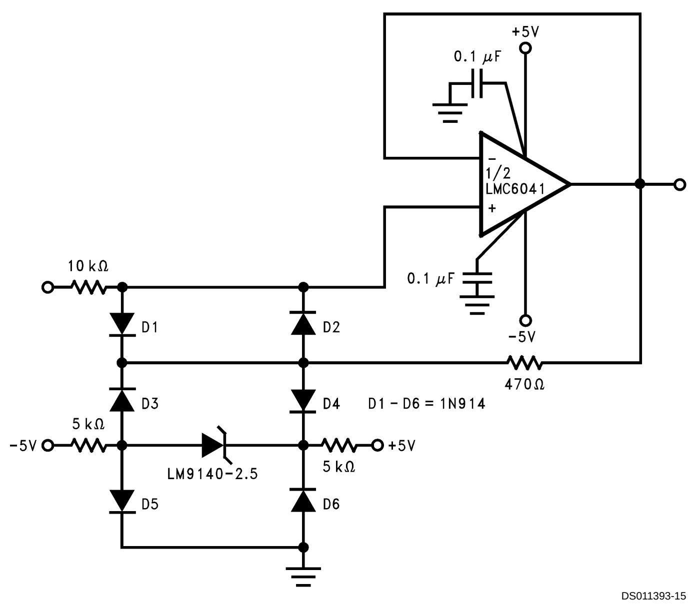


FIGURE 4. Protecting Op Amp input. The bounding voltage is ±4V with the LM9140-2.5 (LM9140's reverse breakdown voltage + 3 diode V_F).

Typical Applications (Continued)

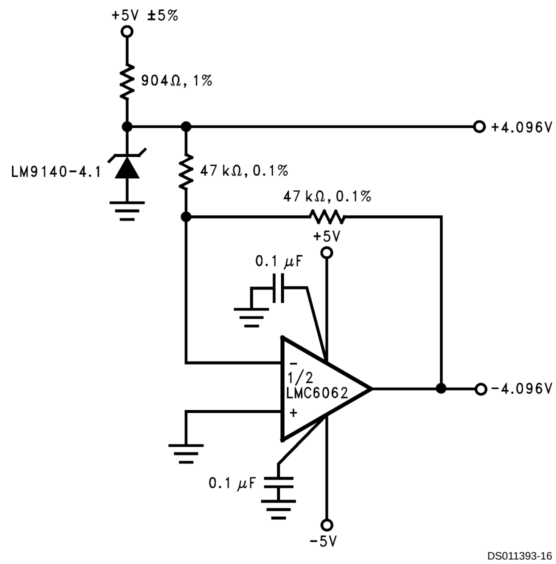
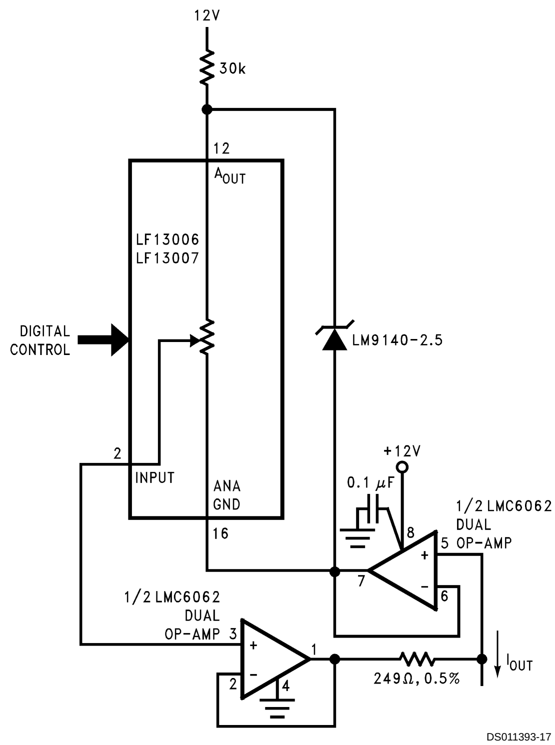


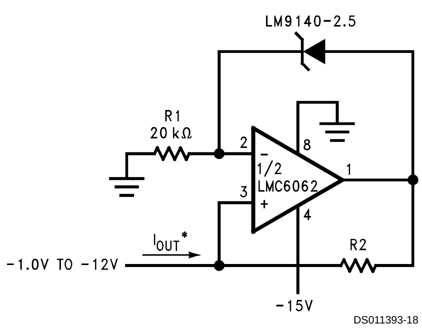
FIGURE 5. Precision ±4.096V Reference

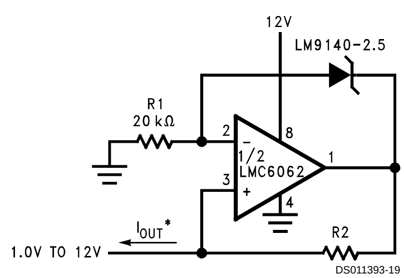
Typical Applications (Continued)



$$I_{OUT} = \frac{2.5V}{249\Omega}\left[\frac{1}{\text{gain set \#}}\right]$$

FIGURE 6. Programmable Current Source

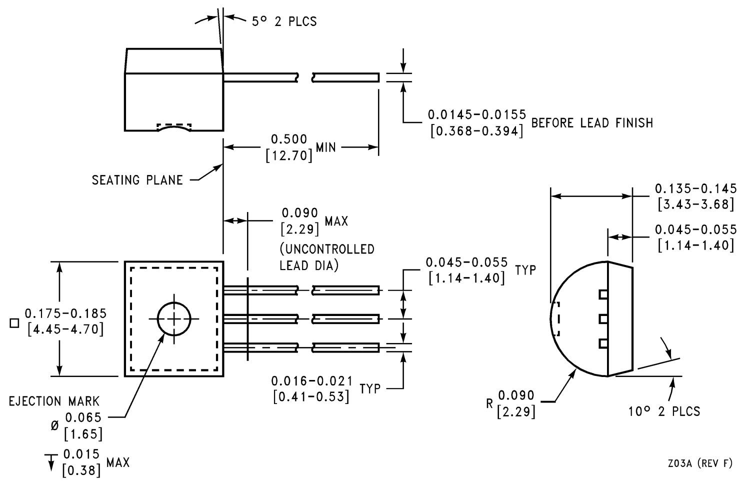




$$^*I_{OUT} = \frac{2.5V}{R2}$$

FIGURE 7. Precision 1 µA to 1 mA Current Sources

Physical Dimensions inches (millimeters) unless otherwise noted



TO-92 Package
NS Package Number Z03A

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