



National Semiconductor

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## LM4040 Precision Micropower Shunt Voltage Reference

### LM4040

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#### General Description

Ideal for space critical applications, the LM4040 precision voltage reference is available in the sub-miniature (3 mm x 1.3 mm) SOT-23 surface-mount package. The LM4040's advanced design eliminates the need for an external stabilizing capacitor while ensuring stability with any capacitive load, thus making the LM4040 easy to use. Further reducing design effort is the availability of several fixed reverse breakdown voltages: 2.500V, 4.096V, 5.000V, 8.192V, and 10.000V. The minimum operating current increases from 60  $\mu$ A for the LM4040-2.5 to 100  $\mu$ A for the LM4040-10.0. All versions have a maximum operating current of 15 mA.

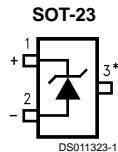
The LM4040 utilizes fuse and zener-zap reverse breakdown voltage trim during wafer sort to ensure that the prime parts have an accuracy of better than  $\pm 0.1\%$  (A grade) at 25°C. Bandgap reference temperature drift curvature correction and low dynamic impedance ensure stable reverse breakdown voltage accuracy over a wide range of operating temperatures and currents.

Also available is the LM4041 with two reverse breakdown voltage versions: adjustable and 1.2V. Please see the LM4041 data sheet.

#### Features

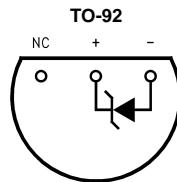
- Small packages: SOT-23, TO-92
- No output capacitor required

#### Connection Diagrams



\*This pin must be left floating or connected to pin 2.

**Top View**  
See NS Package Number M03B  
(JEDEC Registration TO-236AB)



**Bottom View**  
See NS Package Number Z03A

## Ordering Information

### Industrial Temperature Range (-40 °C to +85 °C)

Reverse Breakdown Voltage Tolerance at 25°C and Average Reverse Breakdown Voltage Temperature Coefficient	Package	
	M3 (SOT-23)	Z (TO-92)
±0.1%, 100 ppm/°C max (A grade)	LM4040AIM3-2.5, LM4040AIM3-4.1, LM4040AIM3-5.0, LM4040AIM3-8.2, LM4040AIM3-10.0  See NS Package Number M03B	LM4040AIZ-2.5, LM4040AIZ-4.1, LM4040AIZ-5.0, LM4040AIZ-8.2, LM4040AIZ-10.0  See NS Package Number Z03A
±0.2%, 100 ppm/°C max (B grade)	LM4040BIM3-2.5, LM4040BIM3-4.1, LM4040BIM3-5.0, LM4040BIM3-8.2, LM4040BIM3-10.0  See NS Package Number M03B	LM4040BIZ-2.5, LM4040BIZ-4.1, LM4040BIZ-5.0, LM4040BIZ-8.2, LM4040BIZ-10.0  See NS Package Number Z03A
±0.5%, 100 ppm/°C max (C grade)	LM4040CIM3-2.5, LM4040CIM3-4.1, LM4040CIM3-5.0, LM4040CIM3-8.2, LM4040CIM3-10.0  See NS Package Number M03B	LM4040CIZ-2.5, LM4040CIZ-4.1, LM4040CIZ-5.0, LM4040CIZ-8.2, LM4040CIZ-10.0  See NS Package Number Z03A
±1.0%, 150 ppm/°C max (D grade)	LM4040DIM3-2.5, LM4040DIM3-4.1, LM4040DIM3-5.0, LM4040DIM3-8.2, LM4040DIM3-10.0  See NS Package Number M03B	LM4040DIZ-2.5, LM4040DIZ-4.1, LM4040DIZ-5.0, LM4040DIZ-10.0,  See NS Package Number Z03A
±2.0%, 150 ppm/°C max (E grade)	LM4040EIM3-2.5  See NS Package Number M03B	LM4040EIZ-2.5  See NS Package Number Z03A

## Ordering Information (Continued)

### Extended Temperature Range (-40 °C to +125 °C)

Reverse Breakdown Voltage Tolerance at 25 °C and Average Reverse Breakdown Voltage Temperature Coefficient	Package
	M3 (SOT-23) See NS Package Number M03B
±0.5%, 100 ppm/°C max (C grade)	LM4040CEM3-2.5, LM4040CEM3-5.0
±1.0%, 150 ppm/°C max (D grade)	LM4040DEM3-2.5, LM4040DEM3-5.0
±2.0%, 150 ppm/°C max (E grade)	LM4040EEM3-2.5

## SOT-23 Package Marking Information

Only three fields of marking are possible on the SOT-23's small surface. This table gives the meaning of the three fields.

Part Marking	Field Definition
R2A	First Field: R = Reference
R4A	Second Field: 2 = 2.500V Voltage Option
R5A	4 = 4.096V Voltage Option
R8A	5 = 5.000V Voltage Option
R0A	8 = 8.192V Voltage Option
R2B	0 = 10.000V Voltage Option
R4B	Third Field: R2C
R5B	A-E = Initial Reverse Breakdown Voltage or Reference Voltage Tolerance
R8B	A = ±0.1%, B = ±0.2%, C = +0.5%, D = ±1.0%, E = ±2.0%
R0B	R0C
R2D	R2E
R4D	
R5D	
R8D	
R0D	
R2E	

## 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 ( $T_A = 25^\circ\text{C}$ ) (Note 2)	
M3 Package	306 mW
Z Package	550 mW
Storage Temperature	-65°C to +150°C
Lead Temperature	
M3 Package	
Vapor phase (60 seconds)	+215°C
Infrared (15 seconds)	+220°C
Z Package	
Soldering (10 seconds)	+260°C
ESD Susceptibility	

Human Body Model (Note 3)

2 kV

200V

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

## Operating Ratings (Notes 1, 2)

Temperature Range	$(T_{\min} \leq T_A \leq T_{\max})$
Industrial Temperature Range	-40°C $\leq T_A \leq +85^\circ\text{C}$
Extended Temperature Range	-40°C $\leq T_A \leq +125^\circ\text{C}$
Reverse Current	
LM4040-2.5	60 $\mu\text{A}$ to 15 mA
LM4040-4.1	68 $\mu\text{A}$ to 15 mA
LM4040-5.0	74 $\mu\text{A}$ to 15 mA
LM4040-8.2	91 $\mu\text{A}$ to 15 mA
LM4040-10.0	100 $\mu\text{A}$ to 15 mA

## LM4040-2.5

### Electrical Characteristics (Industrial Temperature Range)

**Boldface** limits apply for  $T_A = T_J = T_{\min}$  to  $T_{\max}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A and B designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.1\%$  and  $\pm 0.2\%$ , respectively.

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040AIM3 LM4040AIZ Limits (Note 5)	LM4040BIM3 LM4040BIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	2.500			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		$\pm 2.5$ <b><math>\pm 19</math></b>	$\pm 5.0$ <b><math>\pm 21</math></b>	mV (max) mV (max)
$I_{R\min}$	Minimum Operating Current		45	60 <b>65</b>	60 <b>65</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R / \Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 20$ $\pm 15$ $\pm 15$	<b><math>\pm 100</math></b>	<b><math>\pm 100</math></b>	ppm/°C ppm/°C (max) ppm/°C
	Reverse Breakdown Voltage Change with Operating Current Change	$I_{R\min} \leq I_R \leq 1 \text{ mA}$	0.3	0.8 <b>1.0</b>	0.8 <b>1.0</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	2.5	6.0 <b>8.0</b>	6.0 <b>8.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.3	0.8	0.8	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	35			$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

## LM4040-2.5

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ C$ . The grades C, D and E designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$ ,  $\pm 1.0\%$  and  $\pm 2.0\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CIM3 LM4040CIZ Limits (Note 5)	LM4040DIM3 LM4040DIZ Limits (Note 5)	LM4040EIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu A$	2.500				V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu A$		<b><math>\pm 12</math></b> <b><math>\pm 29</math></b>	<b><math>\pm 25</math></b> <b><math>\pm 49</math></b>	<b><math>\pm 50</math></b> <b><math>\pm 74</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		45	60 <b>65</b>	65 <b>70</b>	65 <b>70</b>	$\mu A$ $\mu A$ (max) $\mu A$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu A$	$\pm 20$ $\pm 15$ $\pm 15$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ C$ ppm/ $^\circ C$ (max) ppm/ $^\circ C$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.4	0.8 <b>1.0</b>	1.0 <b>1.2</b>	1.0 <b>1.2</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	2.5	6.0 <b>8.0</b>	8.0 <b>10.0</b>	8.0 <b>10.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ $I_{AC} = 0.1 I_R$	0.3	0.9	1.1	1.1	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu A$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	35				$\mu V_{rms}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ C \pm 0.1^\circ C$ $I_R = 100 \mu A$	120				ppm

## LM4040-2.5

### Electrical Characteristics (Extended Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ;** all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades C, D and E designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5$

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CEM3 Limits (Note 5)	LM4040DEM3 Limits (Note 5)	LM4040EEM3 Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	2.500				V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		$\pm 12$ <b><math>\pm 38</math></b>	$\pm 25$ <b><math>\pm 63</math></b>	$\pm 50$ <b><math>\pm 88</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		45	60 <b>68</b>	60 <b>73</b>	60 <b>73</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 20$ $\pm 15$ $\pm 15$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.3	0.8	1.0	1.0	mV
				<b>1.0</b>	<b>1.2</b>	<b>1.2</b>	mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.3	0.9	1.1	1.1	$\Omega$ $\Omega$ (max)
							$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120				ppm

### LM4040-4.1

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ .** The grades A and B designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.1\%$  and  $\pm 0.2\%$ , respectively.

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040AIM3 LM4040AIZ Limits (Note 5)	LM4040BIM3 LM4040BIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	4.096			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		$\pm 4.1$ <b><math>\pm 31</math></b>	$\pm 8.2$ <b><math>\pm 35</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		50	68 <b>73</b>	68 <b>73</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 30$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 100</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$  $1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	0.5	0.9 <b>1.2</b>	0.9 <b>1.2</b>	mV mV (max) mV (max)
				3.0	7.0 <b>10.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.5	1.0	1.0	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	80			$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

### LM4040-4.1

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades C and D designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$  and  $\pm 1.0\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CIM3 LM4040CIZ Limits (Note 5)	LM4040DIM3 LM4040DIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	4.096			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		<b><math>\pm 20</math></b> <b><math>\pm 47</math></b>	<b><math>\pm 41</math></b> <b><math>\pm 81</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		50	68 <b>73</b>	73 <b>78</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R / \Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 30$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R / \Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.5	0.9 <b>1.2</b>	1.2 <b>1.5</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	3.0	7.0 <b>10.0</b>	9.0 <b>13.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.5	1.0	1.3	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	80			$\mu V_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

## LM4040-5.0

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ .** The grades A and B designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.1\%$  and  $\pm 0.2\%$ , respectively.

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040AIM3 LM4040AIZ Limits (Note 5)	LM4040BIM3 LM4040BIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	5.000			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		$\pm 5.0$ <b><math>\pm 38</math></b>	$\pm 10$ <b><math>\pm 43</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		54	74 <b>80</b>	74 <b>80</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 30$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 100</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$  $1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	0.5	1.0 <b>1.4</b>	1.0 <b>1.4</b>	mV mV (max) mV (max)
				3.5	8.0 <b>12.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.5	1.1	1.1	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	80			$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

## LM4040-5.0

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades C and D designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$  and  $\pm 1.0\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CIM3 LM4040CIZ Limits (Note 5)	LM4040DIM3 LM4040DIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	5.000			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		<b><math>\pm 25</math></b> <b><math>\pm 58</math></b>	<b><math>\pm 50</math></b> <b><math>\pm 99</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		54	74 <b>80</b>	79 <b>85</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R / \Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 30$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R / \Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.5	1.0 <b>1.4</b>	1.3 <b>1.8</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	3.5	8.0 <b>12.0</b>	10.0 <b>15.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.5	1.1	1.5	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	80			$\mu V_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

## LM4040-5.0

### Electrical Characteristics (Extended Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades C and D designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$  and  $\pm 1.0\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CEM3 Limits (Note 5)	LM4040DEM3 Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 100 \mu\text{A}$	5.000			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 100 \mu\text{A}$		<b><math>\pm 25</math></b> <b><math>\pm 75</math></b>	<b><math>\pm 50</math></b> <b><math>\pm 125</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		54	74 83	79 88	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 100 \mu\text{A}$	$\pm 30$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.5	1.0 1.4	1.0 1.8	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	3.5	8.0 12.0	8.0 15.0	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.5	1.1	1.1	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 100 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	80			$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 100 \mu\text{A}$	120			ppm

## LM4040-8.2

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A and B designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.1\%$  and  $\pm 0.2\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040AIM3 LM4040AIZ Limits (Note 5)	LM4040BIM3 LM4040BIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 150 \mu\text{A}$	8.192			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 150 \mu\text{A}$		$\pm 8.2$ <b><math>\pm 61</math></b>	$\pm 16$ <b><math>\pm 70</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		67	91 <b>95</b>	91 <b>95</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 150 \mu\text{A}$	$\pm 40$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 100</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.6	1.3 <b>2.5</b>	1.3 <b>2.5</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	7.0	10.0 <b>18.0</b>	10.0 <b>18.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.6	1.5	1.5	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 150 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	130			$\mu V_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 150 \mu\text{A}$	120			ppm

## LM4040-8.2

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ .** The grades C and D designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$  and  $\pm 1.0\%$ , respectively.

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CIM3 LM4040CIZ Limits (Note 5)	LM4040DIM3 LM4040DIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 150 \mu\text{A}$	8.192			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 150 \mu\text{A}$		<b><math>\pm 41</math></b> <b><math>\pm 94</math></b>	<b><math>\pm 82</math></b> <b><math>\pm 162</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		67	91 <b>95</b>	96 <b>100</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 150 \mu\text{A}$	$\pm 40$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$  $1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	0.6	1.3 <b>2.5</b>	1.7 <b>3.0</b>	mV mV (max) mV (max)
				7.0	10.0 <b>18.0</b>	15.0 <b>24.0</b>
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.6	1.5	1.9	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 150 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	130			$\mu\text{V}_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 150 \mu\text{A}$	120			ppm

## LM4040-10.0

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A and B designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.1\%$  and  $\pm 0.2\%$ , respectively.**

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040AIM3 LM4040AIZ Limits (Note 5)	LM4040BIM3 LM4040BIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 150 \mu\text{A}$	10.00			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 150 \mu\text{A}$		$\pm 10$ <b><math>\pm 75</math></b>	$\pm 20$ <b><math>\pm 85</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		75	100 <b>103</b>	100 <b>103</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 150 \mu\text{A}$	$\pm 40$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 100</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$	0.8	1.5 <b>3.5</b>	1.5 <b>3.5</b>	mV mV (max) mV (max)
		$1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	8.0	12.0 <b>23.0</b>	12.0 <b>23.0</b>	mV mV (max) mV (max)
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.7	1.7	1.7	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 150 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	180			$\mu V_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 150 \mu\text{A}$	120			ppm

## LM4040-10.0

### Electrical Characteristics (Industrial Temperature Range)

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ; all other limits  $T_A = T_J = 25^\circ\text{C}$ .** The grades C and D designate initial Reverse Breakdown Voltage tolerances of  $\pm 0.5\%$  and  $\pm 1.0\%$ , respectively.

Symbol	Parameter	Conditions	Typical (Note 4)	LM4040CIM3 LM4040CIZ Limits (Note 5)	LM4040DIM3 LM4040DIZ Limits (Note 5)	Units (Limit)
$V_R$	Reverse Breakdown Voltage	$I_R = 150 \mu\text{A}$	10.00			V
	Reverse Breakdown Voltage Tolerance (Note 6)	$I_R = 150 \mu\text{A}$		$\pm 50$ <b><math>\pm 115</math></b>	$\pm 100$ <b><math>\pm 198</math></b>	mV (max) mV (max)
$I_{RMIN}$	Minimum Operating Current		75	100 <b>103</b>	110 <b>113</b>	$\mu\text{A}$ $\mu\text{A}$ (max) $\mu\text{A}$ (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient (Note 6)	$I_R = 10 \text{ mA}$ $I_R = 1 \text{ mA}$ $I_R = 150 \mu\text{A}$	$\pm 40$ $\pm 20$ $\pm 20$	<b><math>\pm 100</math></b>	<b><math>\pm 150</math></b>	ppm/ $^\circ\text{C}$ ppm/ $^\circ\text{C}$ (max) ppm/ $^\circ\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1 \text{ mA}$  $1 \text{ mA} \leq I_R \leq 15 \text{ mA}$	0.8	1.5 <b>3.5</b>	2.0 <b>4.0</b>	mV mV (max) mV (max)
				8.0	12.0 <b>23.0</b>	18.0 <b>29.0</b>
$Z_R$	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}$ , $f = 120 \text{ Hz}$ , $I_{AC} = 0.1 I_R$	0.7	1.7	2.3	$\Omega$ $\Omega$ (max)
$e_N$	Wideband Noise	$I_R = 150 \mu\text{A}$ $10 \text{ Hz} \leq f \leq 10 \text{ kHz}$	180			$\mu V_{\text{rms}}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 \text{ hrs}$ $T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ $I_R = 150 \mu\text{A}$	120			ppm

## Electrical Characteristics(Notes)

**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 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),  $\theta_{JA}$  (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 LM4040,  $T_{Jmax} = 125^\circ\text{C}$ , and the typical thermal resistance ( $\theta_{JA}$ ), when board mounted, is  $326^\circ\text{C}/\text{W}$  for the SOT-23 package, and  $180^\circ\text{C}/\text{W}$  with 0.4" lead length and  $170^\circ\text{C}/\text{W}$  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 model is a 200 pF capacitor discharged directly into each pin.

**Note 4:** Typicals are at  $T_J = 25^\circ\text{C}$  and represent most likely parametric norm.

**Note 5:** Limits are 100% production tested at  $25^\circ\text{C}$ . 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 the room temperature Reverse Breakdown Voltage Tolerance  $\pm[(\Delta V_R/\Delta T)(\max\Delta T)(V_R)]$ . Where,  $\Delta V_R/\Delta T$  is the  $V_R$  temperature coefficient,  $\max\Delta T$  is the maximum difference in temperature from the reference point of  $25^\circ\text{C}$  to  $T_{MIN}$  or  $T_{MAX}$ , and  $V_R$  is the reverse breakdown voltage. The total over-temperature tolerance for the different grades in the industrial temperature range where  $\max\Delta T = 65^\circ\text{C}$  is shown below:

A-grade:  $\pm 0.75\% = \pm 0.1\% \pm 100 \text{ ppm}/^\circ\text{C} \times 65^\circ\text{C}$

B-grade:  $\pm 0.85\% = \pm 0.2\% \pm 100 \text{ ppm}/^\circ\text{C} \times 65^\circ\text{C}$

C-grade:  $\pm 1.15\% = \pm 0.5\% \pm 100 \text{ ppm}/^\circ\text{C} \times 65^\circ\text{C}$

D-grade:  $\pm 1.98\% = \pm 1.0\% \pm 150 \text{ ppm}/^\circ\text{C} \times 65^\circ\text{C}$

E-grade:  $\pm 2.98\% = \pm 2.0\% \pm 150 \text{ ppm}/^\circ\text{C} \times 65^\circ\text{C}$

The total over-temperature tolerance for the different grades in the extended temperature range where  $\max\Delta T = 100^\circ\text{C}$  is shown below:

C-grade:  $\pm 1.5\% = \pm 0.5\% \pm 100 \text{ ppm}/^\circ\text{C} \times 100^\circ\text{C}$

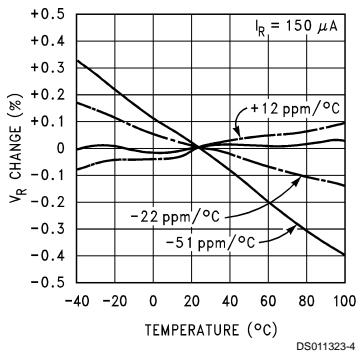
D-grade:  $\pm 2.5\% = \pm 1.0\% \pm 150 \text{ ppm}/^\circ\text{C} \times 100^\circ\text{C}$

E-grade:  $\pm 4.5\% = \pm 2.0\% \pm 150 \text{ ppm}/^\circ\text{C} \times 100^\circ\text{C}$

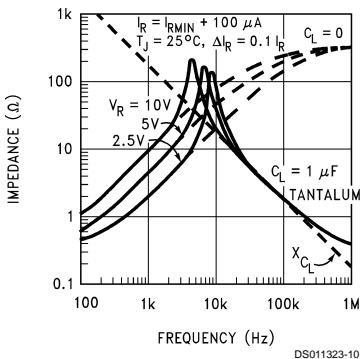
Therefore, as an example, the A-grade LM4040-2.5 has an over-temperature Reverse Breakdown Voltage tolerance of  $\pm 2.5V \times 0.75\% = \pm 19 \text{ mV}$ .

## Typical Performance Characteristics

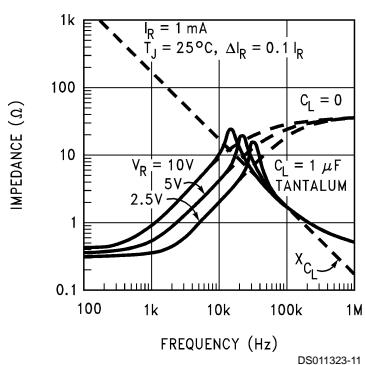
Temperature Drift for Different Average Temperature Coefficient



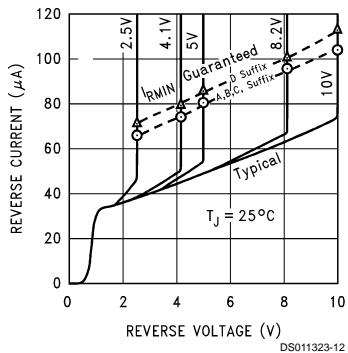
Output Impedance vs Frequency



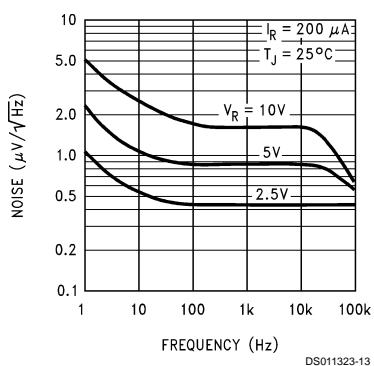
Output Impedance vs Frequency



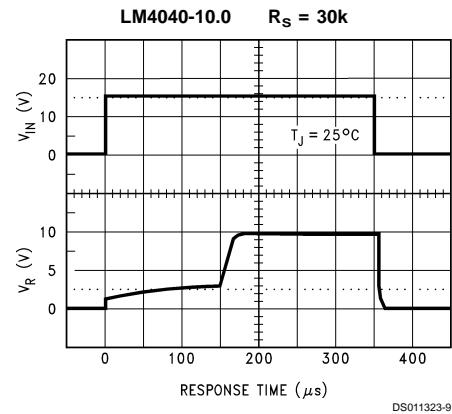
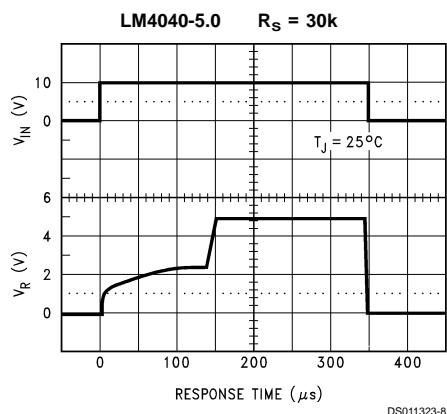
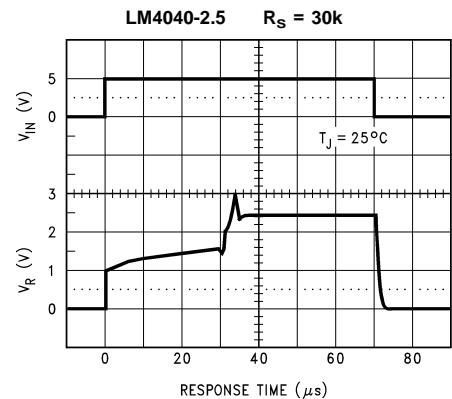
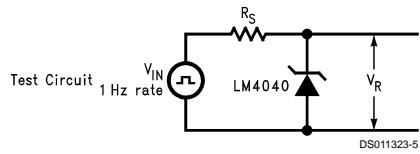
Reverse Characteristics and Minimum Operating Current



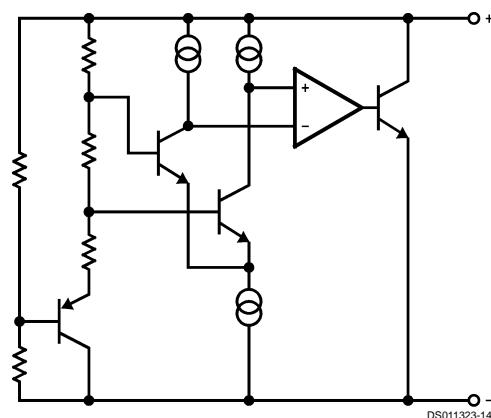
Noise Voltage vs Frequency



## Start-Up Characteristics



## Functional Block Diagram



## Applications Information

The LM4040 is a precision micro-power curvature-corrected bandgap shunt voltage reference. For space critical applications, the LM4040 is available in the sub-miniature SOT-23 surface-mount package. The LM4040 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 LM4040 remains stable. Reducing design effort is the availability of several fixed reverse breakdown voltages: 2.500V, 4.096V, 5.000V, 6.000, 8.192V, and 10.000V. The minimum operating current increases from 60  $\mu$ A for the LM4040-2.5 to 100  $\mu$ A for the LM4040-10.0. All versions have a maximum operating current of 15 mA.

LM4040s in the SOT-23 packages have a parasitic Schottky diode between pin 2 (-) and pin 3 (Die attach interface contact). Therefore, pin 3 of the SOT-23 package must be left floating or connected to pin 2.

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 LM4040.  $R_S$  determines the current that flows through the load ( $I_L$ ) and the LM4040 ( $I_Q$ ). 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

LM4040 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 LM4040 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 LM4040's reverse breakdown voltage,  $V_R$ .

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

## Typical Applications

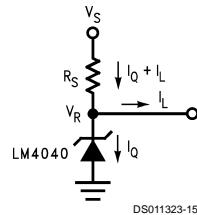


FIGURE 1. Shunt Regulator

## Typical Applications (Continued)

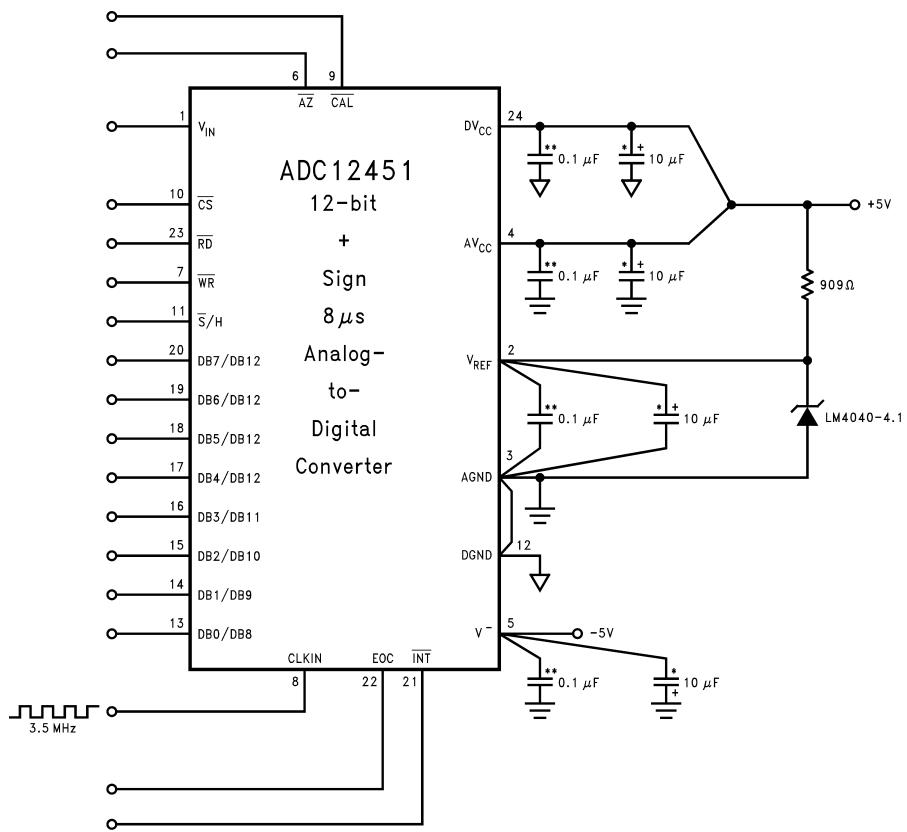
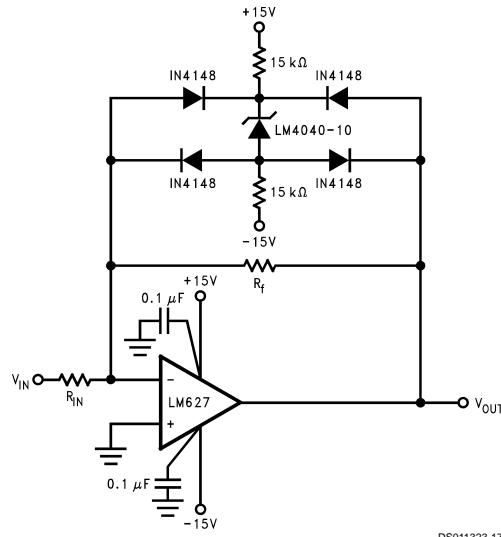


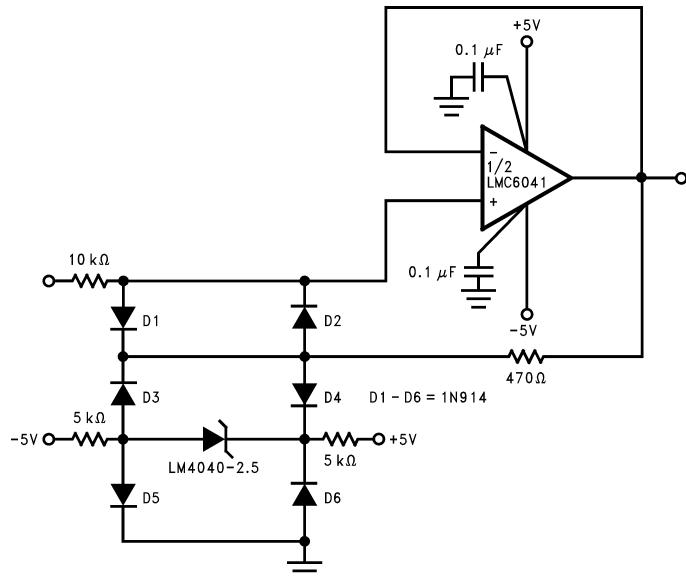
FIGURE 2. LM4040-4.1's Nominal 4.096 breakdown voltage gives ADC12451 1 mV/LSB

## Typical Applications (Continued)



DS011323-17

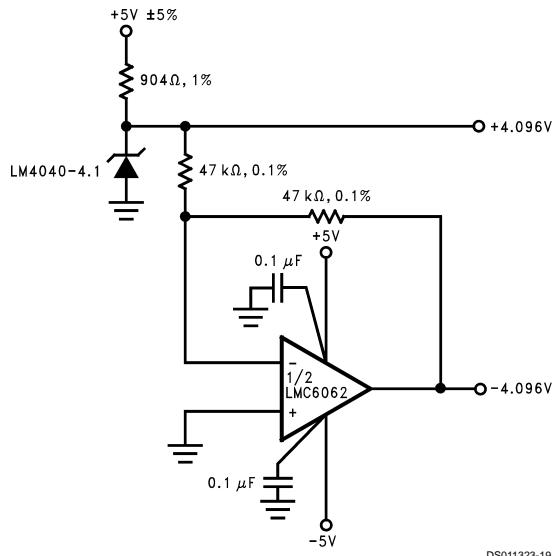
**FIGURE 3. Bounded amplifier reduces saturation-induced delays and can prevent succeeding stage damage. Nominal clamping voltage is  $\pm 11.5V$  (LM4040's reverse breakdown voltage +2 diode  $V_F$ ).**



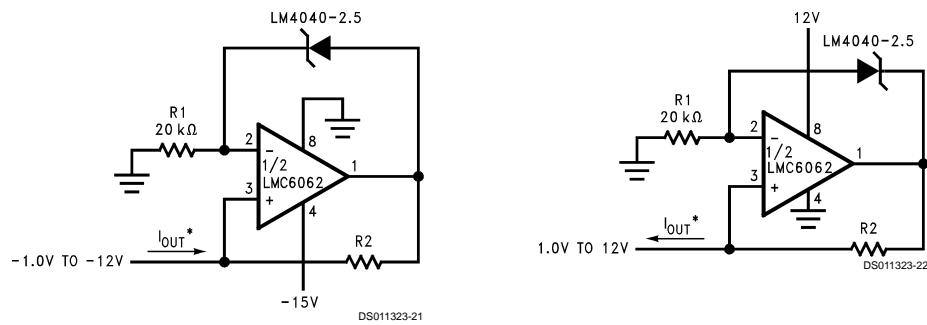
DS011323-18

**FIGURE 4. Protecting Op Amp input. The bounding voltage is  $\pm 4V$  with the LM4040-2.5 (LM4040's reverse breakdown voltage + 3 diode  $V_F$ ).**

## Typical Applications (Continued)



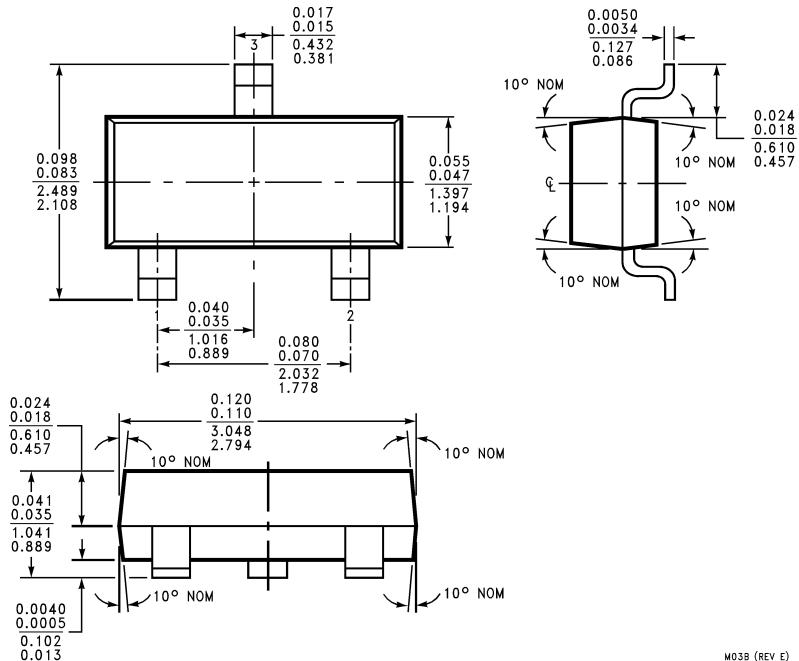
**FIGURE 5. Precision  $\pm 4.096\text{V}$  Reference**



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

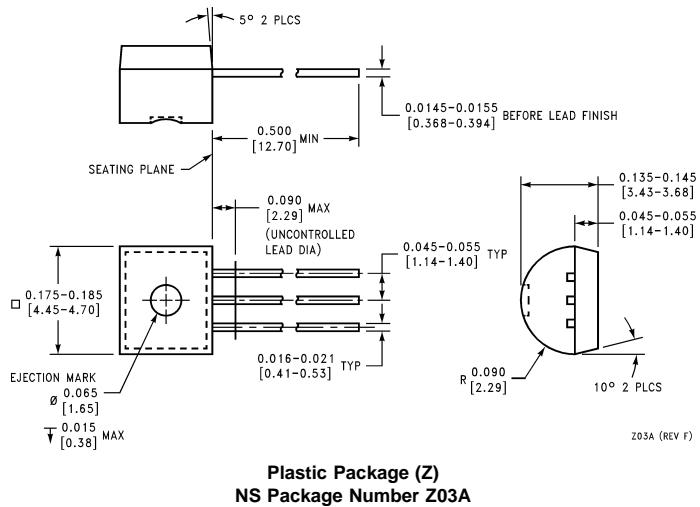
**FIGURE 6. Precision 1  $\mu$ A to 1 mA Current Sources**

## **Physical Dimensions** inches (millimeters) unless otherwise noted



**Plastic Surface Mount Package (M3)  
NS Package Number M03B  
(JEDEC Registration TO-236AB)**

## **Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)



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