



## LM4040/LM4041

### Precision Micropower Shunt Voltage Reference

#### General Description

Ideal for space critical applications, the LM4040 and LM4041 precision voltage references are available in the subminiature (3mm × 1.3mm) SOT-23 surface-mount package.

The LM4040 is available in fixed reverse breakdown voltages of 2.500V, 4.096V, and 5.000V. The LM4041 is available with a fixed 1.225V or an adjustable reverse breakdown voltage.

The minimum operating current ranges from 60μA for the LM4041-1.2 to 74μA for the LM4040-5.0. LM4040 versions have a maximum operating current of 15mA. LM4041 versions have a maximum operating current of 12mA.

The LM4040 and LM4041 have bandgap reference temperature drift curvature correction and low dynamic impedance, ensuring stable reverse breakdown voltage accuracy over a wide range of operating temperatures and currents.

Datasheets and support documentation are available on Micrel's web site at: [www.micrel.com](http://www.micrel.com).

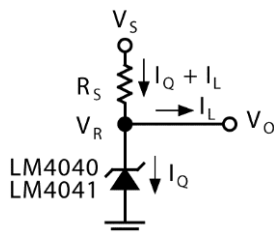
#### Features

- Small SOT-23 package
- No output capacitor required
- Tolerates capacitive loads
- Fixed reverse breakdown voltages of 1.225, 2.500V, 4.096V, and 5.000V
- Adjustable reverse breakdown version
- Contact Micrel for parts with extended temperature range.

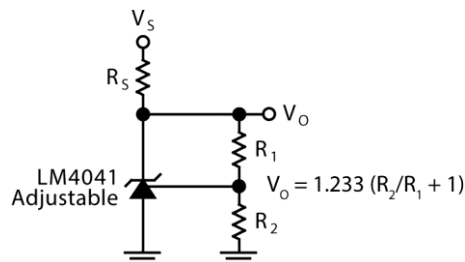
#### Applications

- Battery-powered equipment
- Data acquisition systems
- Instrumentation
- Process control
- Energy management
- Product testing
- Automotive electronics
- Precision audio components

#### Typical Application



LM4040, LM4041 Fixed Shunt Regulator Application

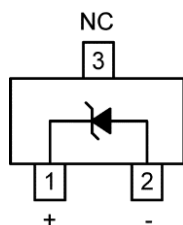


LM4041 Adjustable Shunt Regulator Application

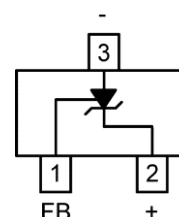
## Ordering Information

Part Number	Marking	Voltage	Accuracy, Temp. Coefficient	Package
LM4040CYM3-2.5	Y2C	2.500V	$\pm 0.5\%$ , 100ppm/°C	3-Pin SOT-23
LM4040DYM3-2.5	Y2D	2.500V	$\pm 1.0\%$ , 150ppm/°C	3-Pin SOT-23
LM4040CYM3-4.1	Y4C	4.096V	$\pm 0.5\%$ , 100ppm/°C	3-Pin SOT-23
LM4040DYM3-4.1	Y4D	4.096V	$\pm 1.0\%$ , 150ppm/°C	3-Pin SOT-23
LM4040CYM3-5.0	Y5C	5.000V	$\pm 0.5\%$ , 100ppm/°C	3-Pin SOT-23
LM4040DYM3-5.0	Y5D	5.000V	$\pm 1.0\%$ , 150ppm/°C	3-Pin SOT-23
LM4041CYM3-1.2	Y1C	1.225V	$\pm 0.5\%$ , 100ppm/°C	3-Pin SOT-23
LM4041DYM3-1.2	Y1D	1.225V	$\pm 1.0\%$ , 150ppm/°C	3-Pin SOT-23
LM4041CYM3-ADJ	YAC	1.24V to 10V	$\pm 0.5\%$ , 100ppm/°C	3-Pin SOT-23
LM4041DYM3-ADJ	YAD	1.24V to 10V	$\pm 1.0\%$ , 150ppm/°C	3-Pin SOT-23

## Pin Configuration



**SOT-23 (M3)  
Fixed Version**



**SOT-23 (M3)  
Adjustable Version**

## Pin Description

Pin Number Fixed	Pin Number Adjustable	Pin Name	Pin Function
1	2	+	Cathode, connect to positive voltage.
-	1	FB	Feedback, connect to a resistive divider network to set the output voltage.
2	3	-	Anode, connect to negative voltage.
3	-	NC	Not internally connected. This pin must be left floating or connected to – (Pin 2).

**Absolute Maximum Ratings<sup>(1)</sup>**

Reverse Current .....	20mA
Forward Current .....	10mA
Maximum Output Voltage (LM4041-ADJ) .....	15V
Lead Temperature	
Vapor phase (60s) .....	215°C
Infrared (15s) .....	220°C
Power Dissipation ( $T_A = 25^\circ\text{C}$ ) <sup>(3)</sup> .....	306mW
Storage Temperature ( $T_s$ ) .....	-65°C to +150°C
ESD Susceptibility	
Human Body Model <sup>(4)</sup> .....	2kV
Machine Model <sup>(4)</sup> .....	200V

**Operating Ratings<sup>(2)</sup>**

Operating Temperature Range ( $T_A$ ) .....	-40°C to +85°C
Reverse Current	
LM4040-2.5 .....	60μA to 15mA
LM4040-4.1 .....	68μA to 15mA
LM4040-5.0 .....	74μA to 15mA
LM4041-1.2 .....	60μA to 12mA
LM4041-ADJ .....	60μA to 12mA
Output Voltage Range	
LM4041-ADJ .....	1.24V to 10V
Thermal Resistance	
3-Pin SOT-23 ( $\Theta_{JA}$ ) .....	326°C/W

**LM4040-2.5 Electrical Characteristics<sup>(5)</sup>**

$T_A$  = Operating Temperature Range, **bold** values indicate  $T_A = T_J = -40^\circ\text{C}$  to  $+85^\circ\text{C}$ , unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040C</b>						
$V_R$	Reverse Breakdown Voltage	$I_R = 100\mu\text{A}$		2.500		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±12	mV
					<b>±29</b>	mV
$I_{RMIN}$	Minimum Operating Current			45	60	μA
					<b>65</b>	μA
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	$I_R = 10\text{mA}$		±20		ppm/°C
		$I_R = 1\text{mA}$		±15	<b>±100</b>	ppm/°C
		$I_R = 100\mu\text{A}$		±15		ppm/°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	mV
					<b>1.0</b>	mV
		$1\text{mA} \leq I_R \leq 15\text{mA}$		2.5	6.0	mV
					<b>8.0</b>	mV
$Z_R$	Reverse Dynamic Impedance	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$		0.3	0.9	Ω
$e_N$	Wideband Noise	$I_R = 100\mu\text{A}$ , $10\text{Hz} \leq f \leq 10\text{kHz}$		35		μV <sub>RMS</sub>
$\Delta V_R$	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

**Notes:**

- Exceeding the absolute maximum ratings may damage the device.
- The device is not guaranteed to function outside its operating ratings.
- 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 and LM4041,  $T_{JMAX} = 125^\circ\text{C}$  and the typical thermal resistance, when board-mounted, is 326°C/W for the SOT-23 package.
- Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF. The machine model is a 200pF capacitor discharged directly into each pin.
- Specification for packaged product only.
- The boldface (overtemperature) limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance  $\pm[(\Delta V_R/\Delta T)(65^\circ\text{C})(V_R)]$ .  $\Delta V_R/\Delta T$  is the  $V_R$  temperature coefficient, 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 overtemperature tolerance for the different grades follows:
  - C-grade:  $\pm 1.15\% = \pm 0.5\% \pm 100\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$
  - D-grade:  $\pm 1.98\% = \pm 1.0\% \pm 150\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$
 Example: The C-grade LM4040-2.5 has an overtemperature Reverse Breakdown Voltage tolerance of  $\pm 2.5 \times 1.15\% = \pm 29\text{mV}$ .

## LM4040-2.5 Electrical Characteristics<sup>(5)</sup> (Continued)

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040D</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		2.500		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±25	mV
					<b>±49</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			45	65	μA
					<b>70</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±20		ppm/°C
		I <sub>R</sub> = 1mA		±15	<b>±150</b>	ppm/°C
		I <sub>R</sub> = 100μA		±15		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.3	1.0	mV
					<b>1.2</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		2.5	8.0	mV
					<b>10.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.3	1.1	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		35		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4040-4.1 Electrical Characteristics<sup>(5)</sup>

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040C</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		4.096		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±20	mV
					<b>±47</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			50	68	μA
					<b>73</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±30		ppm/°C
		I <sub>R</sub> = 1mA		±20	<b>±100</b>	ppm/°C
		I <sub>R</sub> = 100μA		±20		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.5	0.9	mV
					<b>1.2</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		3.0	7.0	mV
					<b>10.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.5	1.0	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		80		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4040-4.1 Electrical Characteristics<sup>(5)</sup> (Continued)

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040D</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		4.096		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±41	mV
					<b>±81</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			50	73	μA
					<b>78</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±30		ppm/°C
		I <sub>R</sub> = 1mA		±20	<b>±150</b>	ppm/°C
		I <sub>R</sub> = 100μA		±20		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.5	1.2	mV
					<b>1.5</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		3.0	9.0	mV
					<b>13.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.5	1.3	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		80		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4040-5.0 Electrical Characteristics<sup>(5)</sup>

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040C</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		5.000		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±25	mV
					<b>±58</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			54	74	μA
					<b>80</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±30		ppm/°C
		I <sub>R</sub> = 1mA		±20	<b>±100</b>	ppm/°C
		I <sub>R</sub> = 100μA		±20		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.5	1.0	mV
					<b>1.4</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		3.5	8.0	mV
					<b>12.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.5	1.1	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		80		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4040-5.0 Electrical Characteristics<sup>(5)</sup> (Continued)

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4040D</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		5.000		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±50	mV
					<b>±99</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			54	79	μA
					<b>85</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±30		ppm/°C
		I <sub>R</sub> = 1mA		±20	<b>±150</b>	ppm/°C
		I <sub>R</sub> = 100μA		±20		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.5	1.3	mV
					<b>1.8</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		3.5	10.0	mV
					<b>15.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.5	1.5	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		80		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4041-1.2 Electrical Characteristics<sup>(5)</sup>

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4041C</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA		1.225		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±6	mV
					<b>±14</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			45	60	μA
					<b>65</b>	μA
ΔV <sub>R</sub> /ΔT	Average Reverse Breakdown Voltage Temperature Coefficient	I <sub>R</sub> = 10mA		±20		ppm/°C
		I <sub>R</sub> = 1mA		±15	<b>±100</b>	ppm/°C
		I <sub>R</sub> = 100μA		±15		ppm/°C
ΔV <sub>R</sub> /ΔI <sub>R</sub>	Reverse Breakdown Voltage Change with Operating Current Change	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA		0.7	1.5	mV
					<b>2.0</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA		4.0	6.0	mV
					<b>8.0</b>	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub>		0.5	1.5	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		20		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

## LM4041-1.2 Electrical Characteristics<sup>(5)</sup> (Continued)

$T_A$  = Operating Temperature Range, **bold** values indicate  $T_A = T_J = -40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ , unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4041D</b>						
$V_R$	Reverse Breakdown Voltage	$I_R = 100\mu\text{A}$		1.225		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				$\pm 12$	mV
					<b><math>\pm 24</math></b>	mV
$I_{RMIN}$	Minimum Operating Current			45	65	$\mu\text{A}$
					<b>70</b>	$\mu\text{A}$
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	$I_R = 10\text{mA}$		$\pm 20$		ppm/ $^{\circ}\text{C}$
		$I_R = 1\text{mA}$		$\pm 15$	<b><math>\pm 150</math></b>	ppm/ $^{\circ}\text{C}$
		$I_R = 100\mu\text{A}$		$\pm 15$		ppm/ $^{\circ}\text{C}$
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R \leq 1\text{mA}$		0.7	2.0	mV
					<b>2.5</b>	mV
		$1\text{mA} \leq I_R \leq 15\text{mA}$		2.5	8.0	mV
					<b>10.0</b>	mV
$Z_R$	Reverse Dynamic Impedance	$I_R = 1\text{mA}$ , $f = 120\text{Hz}$ , $I_{AC} = 0.1I_R$		0.5	2.0	$\Omega$
$e_N$	Wideband Noise	$I_R = 100\mu\text{A}$ , $10\text{Hz} \leq f \leq 10\text{kHz}$		20		$\mu\text{V}_{RMS}$
$\Delta V_R$	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

## LM4041-ADJ Electrical Characteristics<sup>(5)</sup>

T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4041C</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA, V <sub>OUT</sub> = 5V		1.233		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	I <sub>R</sub> = 100μA			±6.2	mV
					<b>±14</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			45	60	μA
					<b>65</b>	μA
ΔV <sub>REF</sub> / ΔI <sub>R</sub>	Reference Voltage Change with Operating Current	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA, V <sub>OUT</sub> ≥ 1.6V <sup>(7)</sup>		0.7	1.5	mV
					<b>2.0</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA, V <sub>OUT</sub> ≥ 1.6V <sup>(7)</sup>		2.0	4.0	mV
ΔV <sub>REF</sub> / ΔV <sub>O</sub>	Reference Voltage Change with Output Voltage Change	I <sub>R</sub> = 1mA		-1.55	-2.0	mV/V
					<b>-2.5</b>	mV/V
I <sub>FB</sub>	Feedback Current			60	100	nA
					<b>120</b>	nA
ΔV <sub>REF</sub> /ΔT	Average Reference Voltage Temperature Coefficient	V <sub>OUT</sub> = 5V, I <sub>R</sub> = 10mA		±20		ppm/°C
		V <sub>OUT</sub> = 5V, I <sub>R</sub> = 1mA		±15	<b>±100</b>	ppm/°C
		V <sub>OUT</sub> = 5V, I <sub>R</sub> = 100μA		±15		ppm/°C
Z <sub>OUT</sub>	Dynamic Output Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub> V <sub>OUT</sub> = V <sub>REF</sub>		0.3		Ω
		V <sub>OUT</sub> = 10V			2.0	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		20		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs, T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

**Note:**

7. When V<sub>OUT</sub> ≤ 1.6V, the LM4041-ADJ must operate at reduced I<sub>R</sub>. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the "Typical Performance Characteristics" section.

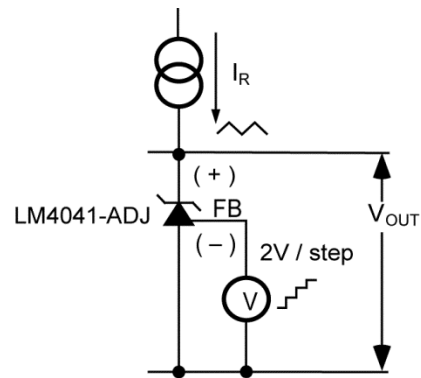
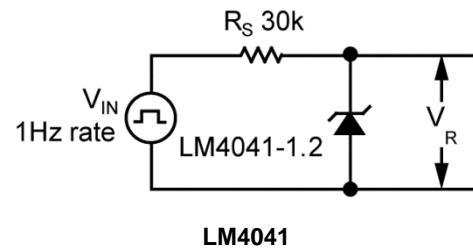
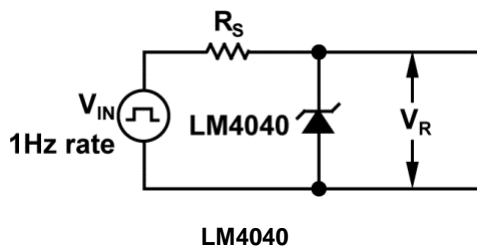


## LM4041-ADJ Electrical Characteristics<sup>(5)</sup>

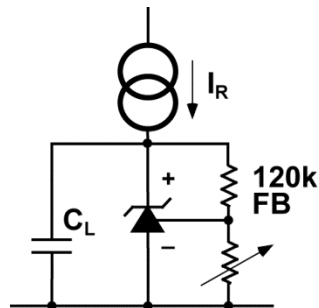
T<sub>A</sub> = Operating Temperature Range, **bold** values indicate T<sub>A</sub> = T<sub>J</sub> = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Units
<b>LM4041D</b>						
V <sub>R</sub>	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA, V <sub>OUT</sub> = 5V		1.233		V
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	I <sub>R</sub> = 100μA			±12	mV
					<b>±24</b>	mV
I <sub>RMIN</sub>	Minimum Operating Current			45	65	μA
					<b>70</b>	μA
ΔV <sub>REF</sub> / ΔI <sub>R</sub>	Reference Voltage Change with Operating Current	I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA, V <sub>OUT</sub> ≥ 1.6V <sup>(7)</sup>		0.7	2.0	mV
					<b>2.5</b>	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA, V <sub>OUT</sub> ≥ 1.6V <sup>(7)</sup>		2.0	6.0	mV
					<b>8.0</b>	mV
ΔV <sub>REF</sub> / ΔV <sub>O</sub>	Reference Voltage Change with Output Voltage Change	I <sub>R</sub> = 1mA		-1.55	-2.5	mV/V
					<b>-3.0</b>	mV/V
I <sub>FB</sub>	Feedback Current			60	150	nA
					<b>200</b>	nA
ΔV <sub>REF</sub> /ΔT	Average Reference Voltage Temperature Coefficient	V <sub>OUT</sub> = 5V, I <sub>R</sub> = 10mA		±20		ppm/°C
		V <sub>OUT</sub> = 5V, I <sub>R</sub> = 1mA		±15	<b>±150</b>	ppm/°C
		V <sub>OUT</sub> = 5V, I <sub>R</sub> = 100μA		±15		ppm/°C
Z <sub>OUT</sub>	Dynamic Output Impedance	I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub> V <sub>OUT</sub> = V <sub>REF</sub>		0.3		Ω
		V <sub>OUT</sub> = 10V			2.0	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		20		μV <sub>RMS</sub>
ΔV <sub>R</sub>	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs, T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

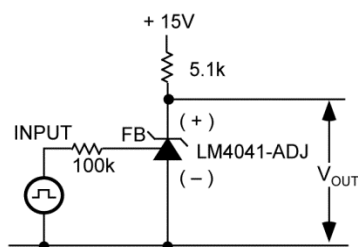
## Test Circuit



**Reverse Characteristics Test Circuit**



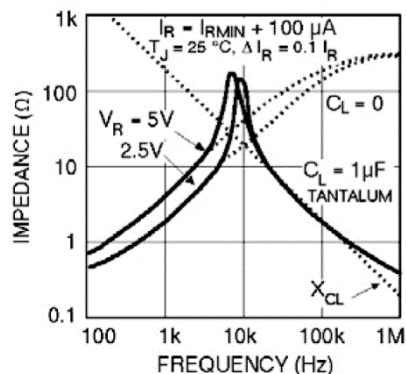
**Output Impedance vs. Frequency Test Circuit**



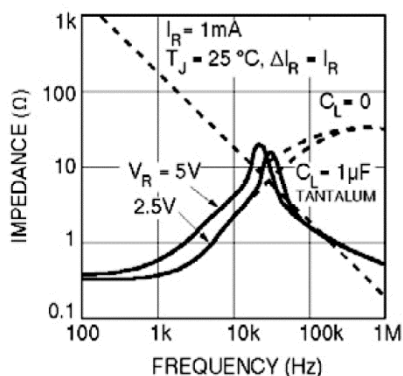
**Large Signal Response Test Circuit**

## LM4040 Typical Characteristics

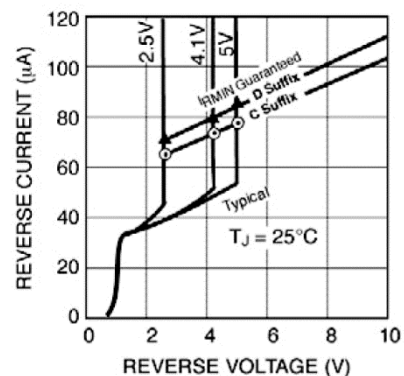
**Output Impedance  
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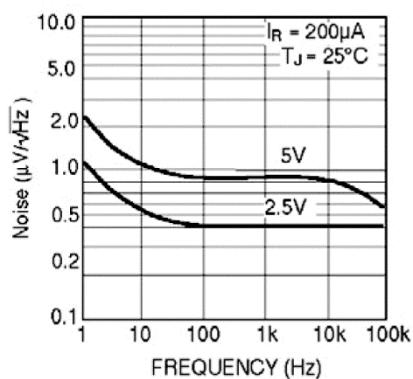
**Output Impedance  
vs. Frequency**



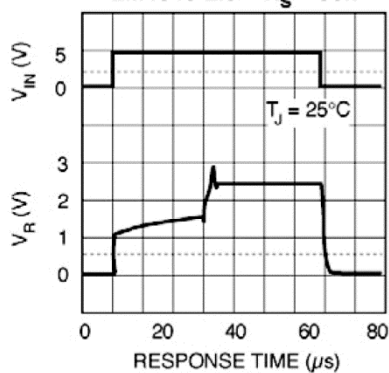
**Reverse Characteristics and  
Minimum Operating Current**



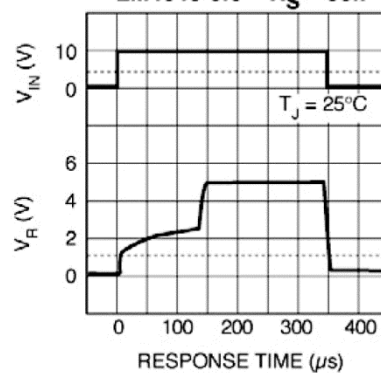
**Noise Voltage  
vs. Frequency**



**Start-up Characteristics  
LM4040-2.5  $R_S = 30k$**

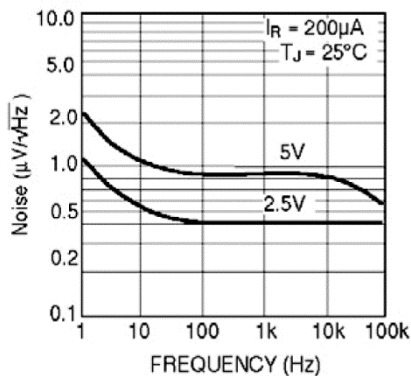


**Start-up Characteristics  
LM4040-5.0  $R_S = 30k$**

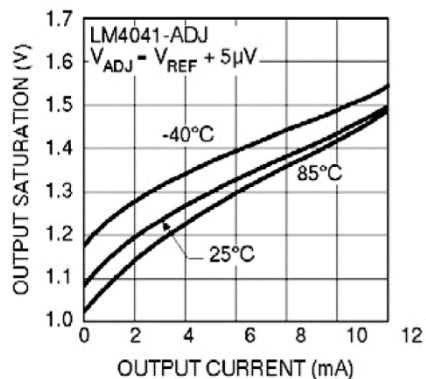


## LM4041 Typical Characteristics

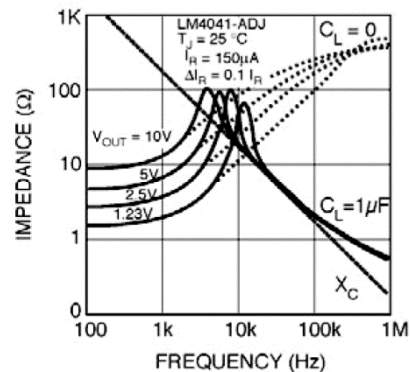
**Noise Voltage  
vs. Frequency**



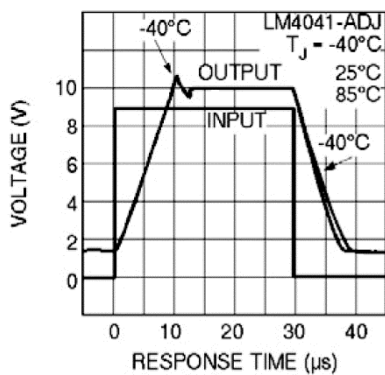
**Output Saturation**



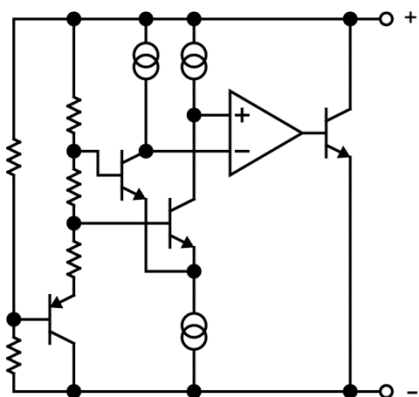
**Output Impedance  
vs. Frequency \***



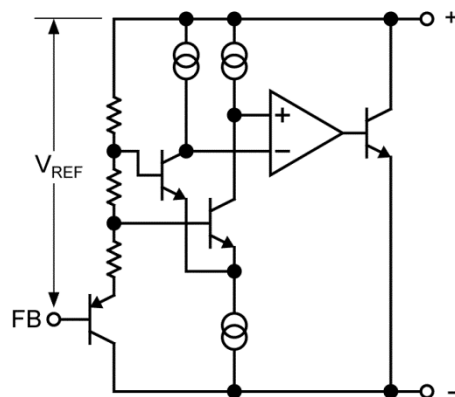
**Large Signal Response ‡**



## Functional Diagrams



LM4040, LM4041 Fixed



LM4041 Adjustable

## Applications Information

The stable operation of the LM4040 and LM4041 references requires an external capacitor greater than 10nF connected between the (+) and (–) pins. Bypass capacitors with values between 100pF and 10nF have been found to cause the devices to exhibit instabilities.

### Schottky Diode

LM4040-x.x and LM4041-1.2 in the SOT-23 package have a parasitic Schottky diode between pin 2 (–) and pin 3 (die attach interface connect). Pin 3 of the SOT-23 package must float or be connected to pin 2. The LM4041-ADJs use pin 3 as the (–) output.

### Conventional Shunt Regulator

In a conventional shunt regulator application (see Figure 1), an external series resistor ( $R_S$ ) is connected between the supply voltage and the LM4040-x.x or LM4041-1.2 reference.  $R_S$  determines the current that flows through the load ( $I_L$ ) and the reference ( $I_Q$ ). Because load current and supply voltage may vary,  $R_S$  should be small enough to supply at least the minimum acceptable  $I_Q$  to the reference 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-x.x is less than 15mA, and the current flowing through the LM4041-1.2 or LM4041-ADJ is less than 12mA.

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

$$R_S = (V_S - V_R) / (I_L + I_Q) \quad \text{Eq. 1}$$

### Adjustable Regulator

The LM4041-ADJ's output voltage can be adjusted to any value in the range of 1.24V through 10V. It is a function of the internal reference voltage ( $V_{REF}$ ) and the ratio of the external feedback resistors as shown in Figure 2. The output is found using the following equation:

$$V_O = V_{REF} [(R_2/R_1) + 1] \quad \text{Eq. 2}$$

where  $V_O$  is the desired output voltage. The actual value of the internal  $V_{REF}$  is a function of  $V_O$ . The corrected  $V_{REF}$  is determined by:

$$V_{REF} = V_O (\Delta V_{REF}/\Delta V_O) + V_Y \quad \text{Eq. 3}$$

where  $V_O$  is the desired output voltage.  $\Delta V_{REF}/\Delta V_O$  is found in the Electrical Characteristics section and is typically  $-1.3\text{mV/V}$  and  $V_Y$  is equal to 1.233V. Replace the value of  $V_{REF}$  in Equation 2 with the value  $V_{REF}$  found using Equation 3.

Note that actual output voltage can deviate from that predicted using the typical  $\Delta V_{REF}/\Delta V_O$  in Equation 3; for C-grade parts, the worst-case  $\Delta V_{REF}/\Delta V_O$  is  $-2.5\text{mV/V}$  and  $V_Y = 1.248\text{V}$ .

The following example shows the difference in output voltage resulting from the typical and worst case values of  $\Delta V_{REF}/\Delta V_O$ .

Let  $V_O = +9\text{V}$ . Using the typical values of  $\Delta V_{REF}/\Delta V_O$ ,  $V_{REF}$  is 1.223V. Choosing a value of  $R_1 = 10\text{k}\Omega$ ,  $R_2 = 63.272\text{k}\Omega$ . Using the worst case  $\Delta V_{REF}/\Delta V_O$  for the C-grade and D-grade parts, the output voltage is actually 8.965V and 8.946V respectively. This results in possible errors as large as 0.39% for the C-grade parts and 0.59% for the D-grade parts. Once again, resistor values found using the typical value of  $\Delta V_{REF}/\Delta V_O$  will work in most cases, requiring no further adjustment.

## Typical Application Circuits

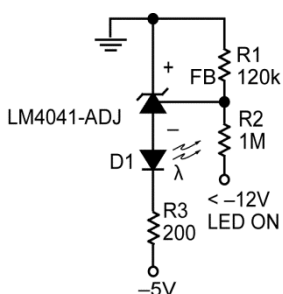


Figure 1. Voltage Level Detector

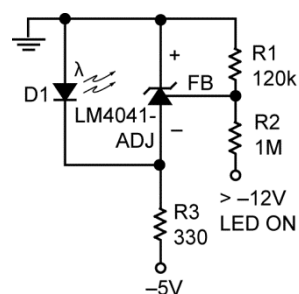
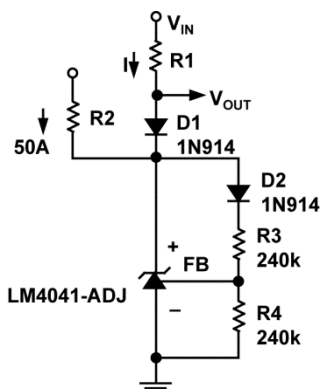
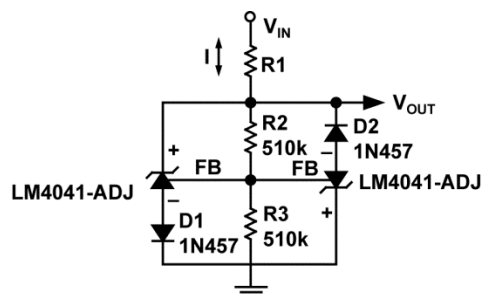
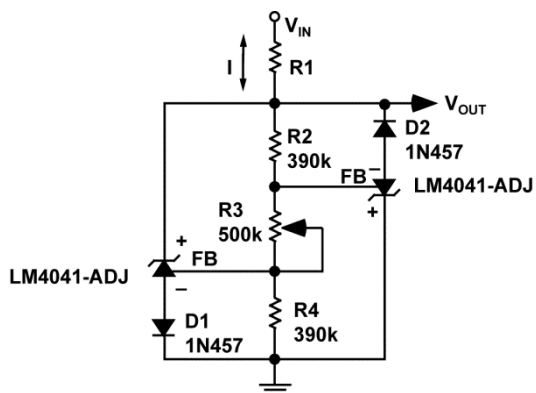
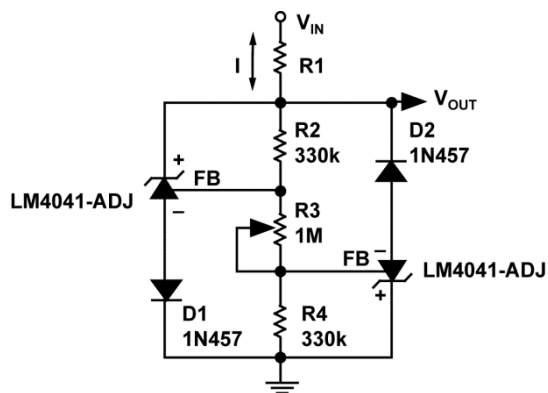


Figure 2. Voltage Level Detector

Figure 3. Fast Positive Clamp  
 $2.4V + \Delta V_{D1}$ Figure 4. Bidirectional Clamp  
 $\pm 2.4V$ Figure 5. Bidirectional Adjustable Clamp  
 $\pm 18V$  to  $\pm 2.4V$ Figure 6. Bidirectional Adjustable Clamp  
 $\pm 2.4V$  to  $\pm 6V$

## Typical Application Circuits (Continued)

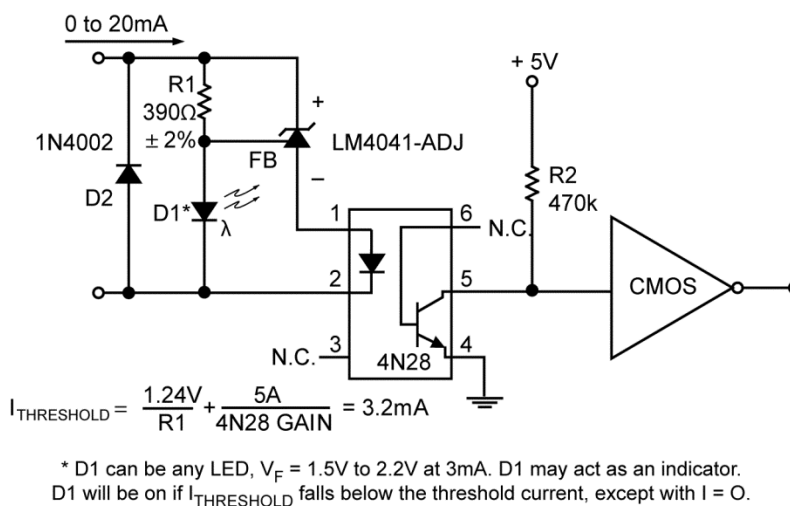


Figure 7. Floating Current Detector

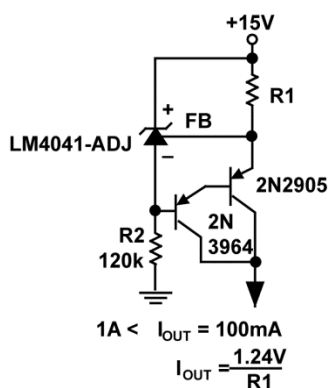


Figure 8. Current Source

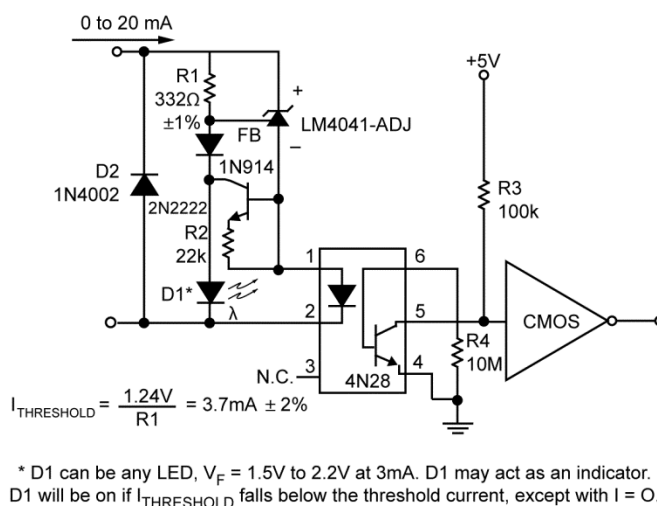
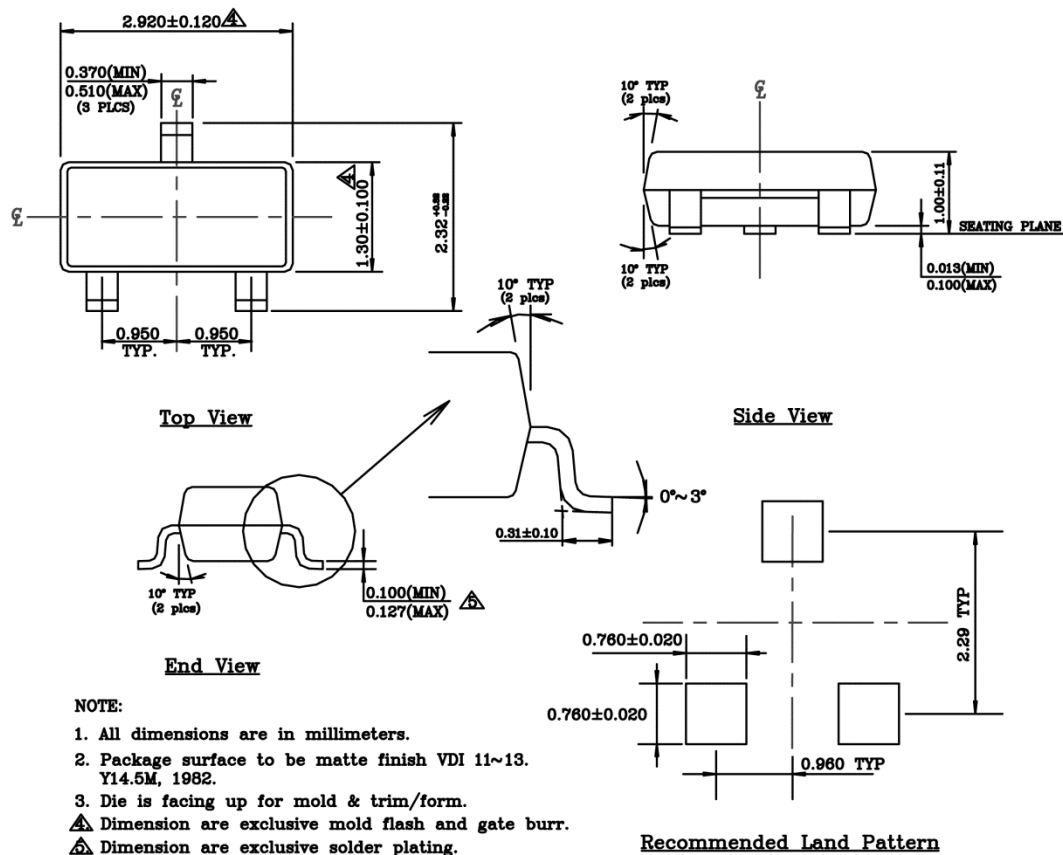


Figure 9. Precision Floating Current Detector



## Package Information<sup>(8)</sup>



### 3-Pin SOT-23 (M3)

#### Note:

8. Package information is correct as of the publication date. For updates and most current information, go to [www.micrel.com](http://www.micrel.com).

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