### 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  $\times$  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  $60\mu A$  for the LM4041-1.2 to  $74\mu A$  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: <a href="https://www.micrel.com">www.micrel.com</a>.

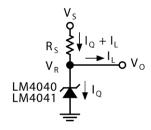
#### **Features**

- 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.

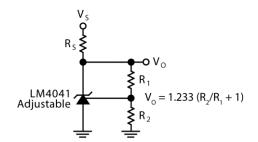
#### **Applications**

- · 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

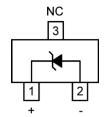
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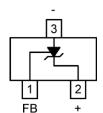
## **Ordering Information**

Part Number	Marking	Voltage	Accuracy, Temp. Coefficient	Package
LM4040CYM3-2.5	Y2C	2.500V	±0.5%, 100ppm/°C	3-Pin SOT-23
LM4040DYM3-2.5	Y2D	2.500V	±1.0%, 150ppm/°C	3-Pin SOT-23
LM4040CYM3-4.1	Y4C	4.096V	±0.5%, 100ppm/°C	3-Pin SOT-23
LM4040DYM3-4.1	Y4D	4.096V	±1.0%, 150ppm/°C	3-Pin SOT-23
LM4040CYM3-5.0	Y5C	5.000V	±0.5%, 100ppm/°C	3-Pin SOT-23
LM4040DYM3-5.0	Y5D	5.000V	±1.0%, 150ppm/°C	3-Pin SOT-23
LM4041CYM3-1.2	Y1C	1.225V	±0.5%, 100ppm/°C	3-Pin SOT-23
LM4041DYM3-1.2	Y1D	1.225V	±1.0%, 150ppm/°C	3-Pin SOT-23
LM4041CYM3-ADJ	YAC	1.24V to 10V	±0.5%, 100ppm/°C	3-Pin SOT-23
LM4041DYM3-ADJ	YAD	1.24V to 10V	±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.
ſ	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 $(T_A = 25^{\circ}C)^{(3)}$	306mW
Storage Temperature (Ts)	65°C to +150°C
ESD Susceptibility	
Human Body Model <sup>(4)</sup>	
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 (Θ <sub>14</sub> )	326°C/W

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

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040C						
	Reverse Breakdown Voltage			2.500		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±12	mV
	Tolerance <sup>(6)</sup>				±29	mV
	Minimum On anating Course			45	60	μA
I <sub>RMIN</sub>	Minimum Operating Current				65	μA
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±20		ppm/°C
$\Delta V_R/\Delta T$		I <sub>R</sub> = 1mA		±15	±100	ppm/°C
	Coefficient	I <sub>R</sub> = 100μA		±15	±12 ±29 45 60 65 ±20 ±15 ±100 ±15 0.3 0.8 1.0 2.5 6.0 8.0 0.3 0.9	ppm/°C
				0.3	0.8	mV
A) / /A I	Reverse Breakdown Voltage				1.0	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change	40 < 1 < 450		2.5	6.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			8.0	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	0.9	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		35		$\mu V_{RMS}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

#### Notes:

- 1. Exceeding the absolute maximum ratings may damage the device.
- The device is not guaranteed to function outside its operating ratings.
- 3. The maximum power dissipation must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub> (maximum junction temperature), Θ<sub>JA</sub> (junction to ambient thermal resistance), and TA (ambient temperature). The maximum allowable power dissipation at any temperature is PD<sub>MAX</sub> = (T<sub>JMAX</sub> T<sub>A</sub>)/ Θ<sub>JA</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4040 and LM4041, T<sub>JMAX</sub> = 125°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.
- 5. Specification for packaged product only.
- 6. The boldface (overtemperature) limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance ±[(ΔV<sub>R</sub>/ΔT)(65°C)(V<sub>R</sub>)]. ΔV<sub>R</sub>/ΔT is the V<sub>R</sub> temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V<sub>R</sub> is the reverse breakdown voltage. The total overtemperature tolerance for the different grades follows:
  - a. C-grade:  $\pm 1.15\% = \pm 0.5\% \pm 100$ ppm/°C × 65°C
  - b. D-grade:  $\pm 1.98\% = \pm 1.0\% \pm 150$ ppm/°C × 65°C

Example: The C-grade LM4040-2.5 has an overtemperature Reverse Breakdown Voltage tolerance of ±2.5 x 1.15% = ±29mV.

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

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040D						
	Reverse Breakdown Voltage			2.500		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±25	mV
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±49	mV
1	Minimum Operating Current			45	65	μA
I <sub>RMIN</sub>	Minimum Operating Current				70	μA
	Average Reverse Breakdown Voltage Temperature	$I_R = 10 \text{mA}$		±20		ppm/°C
$\Delta V_R/\Delta T$		$I_R = 1 \text{mA}$		±15	±150	ppm/°C
	Coefficient	I <sub>R</sub> = 100μA			ppm/°C	
		I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤1mA		0.3	1.0	mV
A\/ /AI	Reverse Breakdown Voltage				1.2	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current  Change	nange with Operating Current		2.5	8.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			10.0	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		$\mu V_{RMS}$
$\Delta V_R$	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>

 $T_A$  = Operating Temperature Range, **bold** values indicate  $T_A$  =  $T_J$  = -40°C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040C						
	Reverse Breakdown Voltage			4.096		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±20	mV
	Tolerance <sup>(6)</sup>				±47	mV
	Minimum Operating Current			50	68	μA
I <sub>RMIN</sub>	Minimum Operating Current				73	μA
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±30		ppm/°C
$\Delta V_R/\Delta T$		$I_R = 1 \text{mA}$		±20	±100	ppm/°C
	Coefficient	$I_R = 100 \mu A$		±20	<b>±100 ±20 ±20 0.5 0.9</b>	ppm/°C
		I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤1mA		0.5	0.9	mV
A)/ /AI	Reverse Breakdown Voltage				1.2	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change			3.0	7.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			10.0	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>
$\Delta V_R$	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)

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040D			•			•
	Reverse Breakdown Voltage			4.096		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±41	mV
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>				±81	mV
	Minimum Operating Current			50	73	μA
I <sub>RMIN</sub>	Minimum Operating Current				78	μA
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±30		ppm/°C
$\Delta V_R/\Delta T$		I <sub>R</sub> = 1mA		±20	±150	ppm/°C
	Coefficient	I <sub>R</sub> = 100μA			ppm/°C	
		I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤1mA		0.5	1.2	mV
A)/ /AI	Reverse Breakdown Voltage				1.5	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change			3.0	9.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			13.0	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		$\mu V_{RMS}$
$\Delta V_R$	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>

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040C			•			•
	Reverse Breakdown Voltage			5.000		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±25	mV
	Tolerance <sup>(6)</sup>				±58	mV
	Minimum On austing Course			54	74	μΑ
I <sub>RMIN</sub>	Minimum Operating Current				80	μΑ
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±30		ppm/°C
$\Delta V_R/\Delta T$		$I_R = 1mA$		±20	±100	ppm/°C
	Coefficient	$I_R = 100\mu A$		±20 ±100 ±20		ppm/°C
		I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤1mA		0.5	1.0	mV
A	Reverse Breakdown Voltage				1.4	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change			3.5	8.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			12.0	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>
$\Delta V_R$	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)

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4040D			•			
	Reverse Breakdown Voltage			5.000		V
$V_{R}$	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	$I_R = 100 \mu A$			±50	mV
	Tolerance <sup>(6)</sup>				±99	mV
	Minimum Operating Current			54	79	μA
I <sub>RMIN</sub>	Minimum Operating Current				85	μA
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±30		ppm/°C
$\Delta V_R/\Delta T$		$I_R = 1 \text{mA}$		±20	±150	ppm/°C
	Coefficient	$I_R = 100\mu A$		+		ppm/°C
				0.5	1.3	mV
A)/ /AI	Reverse Breakdown Voltage				1.8	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change	4-0 < 1 < 45-0		3.5	10.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			15.0	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}, f = 120 \text{Hz}, I_{AC} = 0.1 I_R$		0.5	1.5	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		80		μV <sub>RMS</sub>
$\Delta V_R$	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>

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4041C			•			•
	Reverse Breakdown Voltage			1.225		V
$V_{R}$	Reverse Breakdown Voltage	I <sub>R</sub> = 100μA			±6	mV
	Tolerance <sup>(6)</sup>				±14	mV
	Minimum Operating Comment			45	60	μΑ
I <sub>RMIN</sub>	Minimum Operating Current				65	μΑ
	Average Reverse Breakdown Voltage Temperature	I <sub>R</sub> = 10mA		±20		ppm/°C
$\Delta V_R/\Delta T$		I <sub>R</sub> = 1mA		±15	±100	ppm/°C
	Coefficient	$I_R = 100 \mu A$		±15		ppm/°C
		I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤1mA		0.7	1.5	mV
A)/ /AI	Reverse Breakdown Voltage				2.0	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change			4.0	6.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			8.0	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	$I_R = 100\mu A, 10Hz \le f \le 10kHz$		20		μV <sub>RMS</sub>
$\Delta V_R$	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  $T_A$  =  $T_J$  =  $-40^{\circ}$ C to +85°C, unless noted.

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units
LM4041D						
	Reverse Breakdown Voltage			1.225		V
$V_R$	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	$I_R = 100\mu A$			±12	mV
	Tolerance <sup>(6)</sup>				±24	mV
1	Minimum Operating Current			45	65	μA
I <sub>RMIN</sub>	Minimum Operating Current				70	μA
	Average Reverse Breakdown Voltage Temperature	$I_R = 10mA$		±20		ppm/°C
$\Delta V_R/\Delta T$		$I_R = 1 \text{mA}$		±15	±150	ppm/°C
	Coefficient	$I_R = 100\mu A$		±15 ±150 ±15 0.7 2.0		ppm/°C
		$I_{RMIN} \le I_R \le 1mA$		0.7	2.0	mV
A)/ /AI	Reverse Breakdown Voltage				2.5	mV
$\Delta V_R/\Delta I_R$	Change with Operating Current Change			2.5	8.0	mV
		1mA ≤ I <sub>R</sub> ≤ 15mA			10.0	mV
Z <sub>R</sub>	Reverse Dynamic Impedance	$I_R = 1 \text{ mA}, f = 120 \text{Hz}, I_{AC} = 0.1 I_R$		0.5	2.0	Ω
e <sub>N</sub>	Wideband Noise	I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz		20		$\mu V_{RMS}$
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm

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

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

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units				
LM4041C										
$V_{R}$	Reverse Breakdown Voltage	$I_R = 100 \mu A, V_{OUT} = 5 V$		1.233		V				
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	$I_R = 100\mu A$			±6.2	mV				
					±14	mV				
I <sub>RMIN</sub>	Minimum Operating Current			45	60	μΑ				
					65	μΑ				
$\Delta V_{REF}/$ $\Delta I_{R}$	Reference Voltage Change with Operating Current	$I_{RMIN} \le I_R \le 1 \text{mA}, V_{OUT} \ge 1.6 V^{(7)}$		0.7	1.5	mV				
					2.0	mV				
		1mA ≤ $I_R$ ≤ 15mA, $V_{OUT}$ ≥ 1.6 $V^{(7)}$		2.0	4.0	mV				
					6.0	mV				
$\Delta V_{REF}/\Delta V_{O}$	Reference Voltage Change with Output Voltage Change	$I_R = 1 \text{mA}$		-1.55	-2.0	mV/V				
					-2.5	mV/V				
I <sub>FB</sub>	Feedback Current			60	100	nA				
					120	nA				
$\Delta V_{REF}/\Delta T$	Average Reference Voltage Temperature Coefficient	$V_{OUT} = 5V$ , $I_R = 10$ mA		±20		ppm/°C				
		$V_{OUT} = 5V$ , $I_R = 1mA$		±15	±100	ppm/°C				
		$V_{OUT} = 5V, I_R = 100 \mu A$		±15		ppm/°C				
Z <sub>OUT</sub>	Dynamic Output Impedance	$I_R$ = 1mA, f = 120Hz, $I_{AC}$ = 0.1 $I_R$ $V_{OUT}$ = $V_{REF}$		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>				
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	$t = 1000 hrs, T = 25^{\circ}C \pm 0.1^{\circ}C, I_R = 100 \mu A$		120		ppm				

#### Note:

June 24, 2014 8 Revision 3.0

<sup>7.</sup> When  $V_{OUT} \le 1.6V$ , the LM4041-ADJ must operate at reduced  $I_R$ . 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.

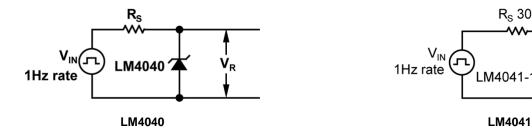
## LM4041-ADJ Electrical Characteristics<sup>(5)</sup>

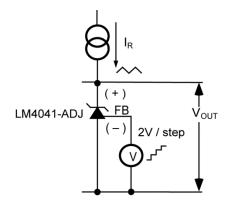
 $T_A$  = Operating Temperature Range, **bold** values indicate  $T_A$  =  $T_J$  =  $-40^{\circ}C$  to  $+85^{\circ}C$ , unless noted.

Symbol	Parameter	Condition	Min.	Тур.	Max.	Units				
LM4041D										
$V_{R}$	Reverse Breakdown Voltage	$I_R = 100 \mu A, V_{OUT} = 5V$		1.233		V				
	Reverse Breakdown Voltage Tolerance <sup>(6)</sup>	I <sub>R</sub> = 100μA			±12	mV				
					±24	mV				
I <sub>RMIN</sub>	Minimum Operating Current			45	65	μA				
					70	μA				
ΔV <sub>REF</sub> / ΔI <sub>R</sub>	Reference Voltage Change with Operating Current	$I_{RMIN} \le I_R \le 1 \text{mA}, V_{OUT} \ge 1.6 V^{(7)}$		0.7	2.0	mV				
					2.5	mV				
		$1 \text{mA} \le I_R \le 15 \text{mA}, V_{\text{OUT}} \ge 1.6 V^{(7)}$		2.0	6.0	mV				
					8.0	mV				
$\Delta V_{REF}/\Delta V_{O}$	Reference Voltage Change with Output Voltage Change	I <sub>R</sub> = 1mA		-1.55	-2.5	mV/V				
					-3.0	mV/V				
I <sub>FB</sub>	Feedback Current			60	150	nA				
					200	nA				
$\Delta V_{REF}/\Delta T$	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	±150	ppm/°C				
		V <sub>OUT</sub> = 5V, I <sub>R</sub> = 100μA		±15		ppm/°C				
Z <sub>OUT</sub>	Dynamic Output Impedance	$I_R$ = 1mA, f = 120Hz, $I_{AC}$ = 0.1 $I_R$ $V_{OUT}$ = $V_{REF}$		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>				
$\Delta V_R$	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs, T = 25°C ±0.1°C, I <sub>R</sub> = 100μA		120		ppm				

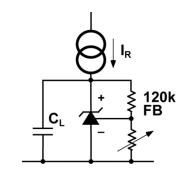
 $R_{S}$  30k

### **Test Circuit**

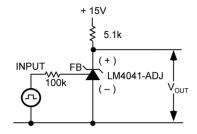




**Reverse Characteristics Test Circuit** 

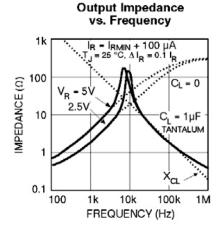


**Output Impedance vs. Frequency Test Circuit** 

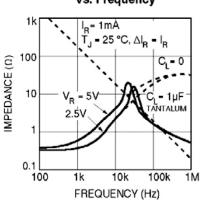


**Large Signal Response Test Circuit** 

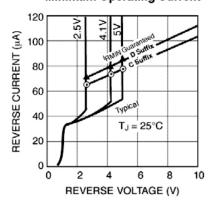
### **LM4040 Typical Characteristics**



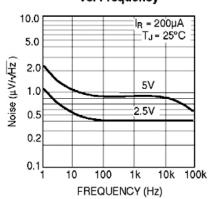
Output Impedance vs. Frequency



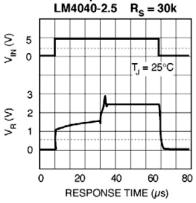
Reverse Characteristics and Minimum Operating Current



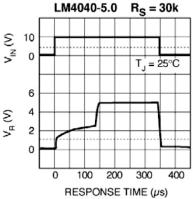
Noise Voltage vs. Frequency



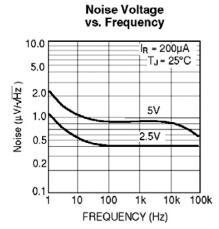
Start-up Characteristics LM4040-2.5 R<sub>o</sub> = 30k



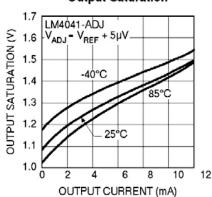
Start-up Characteristics



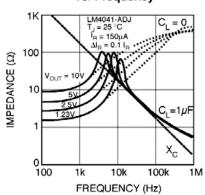
### **LM4041 Typical Characteristics**



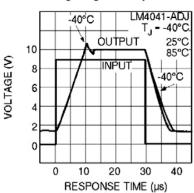
**Output Saturation** 



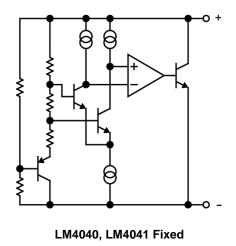
Output Impedence vs. Frequency \*

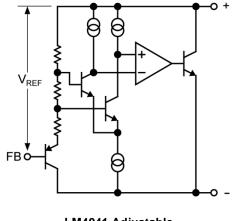


#### Large Signal Response ‡



## **Functional Diagrams**





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 ( $R_{\rm S}$ ) is connected between the supply voltage and the LM4040-x.x or LM4041-1.2 reference. RS determines the current that flows through the load ( $I_L$ ) and the reference ( $I_Q$ ). Because load current and supply voltage may vary,  $R_{\rm S}$  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,  $R_{\rm S}$  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 ( $V_R$ ):

$$R_S = (V_S - V_R) / (I_L + I_Q)$$
 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:

$$V_0 = V_{REF} [(R2/R1) + 1]$$
 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:

$$V_{REF} = V_O (\Delta V_{REF}/\Delta V_O) + V_Y$$
 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 –1.3mV/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 mV/V and  $V_Y=1.248V.$ 

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

Let  $V_O$  = +9V. Using the typical values of  $\Delta V_{REF}/\Delta V_O$ ,  $V_{REF}$  is 1.223V. Choosing a value of R1 = 10k $\Omega$ , R2 = 63.272k $\Omega$ . 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**

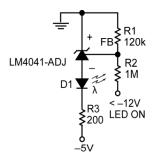


Figure 1. Voltage Level Detector

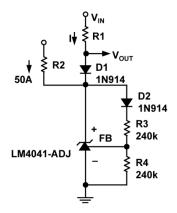


Figure 3. Fast Positive Clamp  $2.4V + \Delta V_{D1}$ 

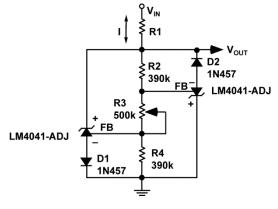


Figure 5. Bidirectional Adjustable Clamp ±18V to ±2.4V

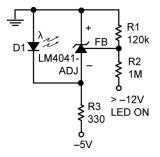


Figure 2. Voltage Level Detector

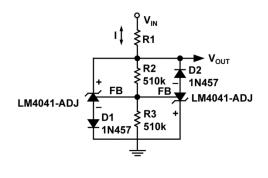


Figure 4. Bidirectional Clamp ±2.4V

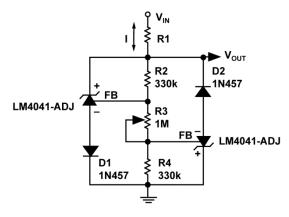
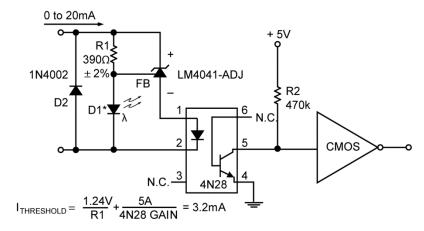


Figure 6. Bidirectional Adjustable Clamp ±2.4V to ±6V

### **Typical Application Circuits (Continued)**



 $^\star$  D1 can be any LED, V<sub>F</sub> = 1.5V to 2.2V at 3mA. D1 may act as an indicator. D1 will be on if I<sub>THRESHOLD</sub> falls below the threshold current, except with I = O.

**Figure 7. Floating Current Detector** 

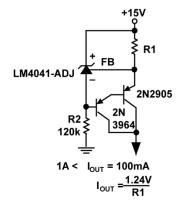
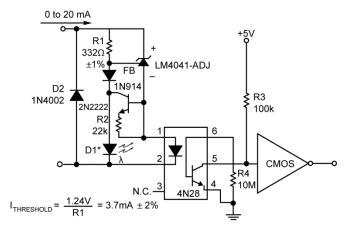


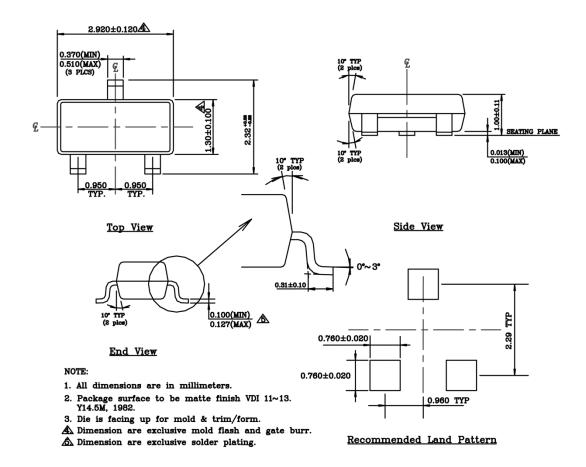
Figure 8. Current Source



 $^{\star}$  D1 can be any LED, V  $_{\rm F}$  = 1.5V to 2.2V at 3mA. D1 may act as an indicator. D1 will be on if I  $_{\rm THRESHOLD}$  falls below the threshold current, except with I = 0.

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 <a href="https://www.micrel.com">www.micrel.com</a>.

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