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 the 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.

Data sheets and support documentation can be found on Micrel's web site at 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.

Key Specifications

- Output voltage tolerance .... ±0.1% (max)
- Low output noise (10Hz to 100Hz)
  - LM4040 .... $35\mu V_{RMS}$ (typ)
  - LM4041 .... $20\mu V_{RMS}$ (typ)
- Wide operating current range
  - LM4040 .... 60µA to 15mA
  - LM4041 .... 60µA to 12mA
- Industrial temperature range .... –40°C to +85°C
- Low temperature coefficient .... 100ppm/°C (max)

Applications

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

Typical Applications

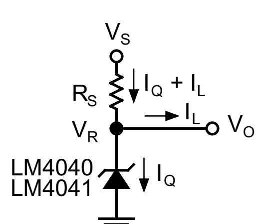

Figure 1. LM4040, LM4041 Fixed Shunt Regulator Application

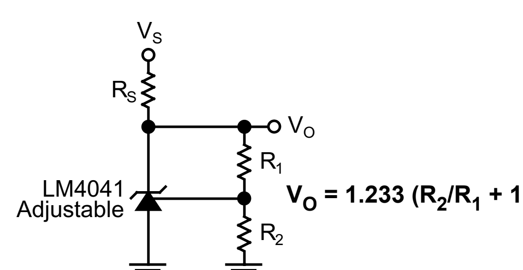

Figure 2. LM4041 Adjustable Shunt Regulator Application

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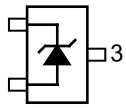
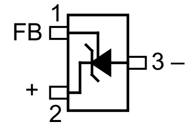
Pin Configuration



Pin 3 must float or be connected to pin 2.

Fixed Version
SOT-23 (M3) Package



Adjustable Version
SOT-23 (M3) Package

Ordering Information

Part Number Standard	Pb-Free	Voltage	Accuracy, Temp. Coefficient
LM4040CIM3-2.5	**LM4040CYM3-2.5**	**2.500V**	**±0.5%, 100ppm/°C**
LM4040DIM3-2.5	**LM4040DYM3-2.5**	**2.500V**	**±1.0%, 150ppm/°C**
LM4040CIM3-4.1	**LM4040CYM3-4.1**	**4.096V**	**±0.5%, 100ppm/°C**
LM4040DIM3-4.1	**LM4040DYM3-4.1**	**4.096V**	**±1.0%, 150ppm/°C**
LM4040CIM3-5.0	**LM4040CYM3-5.0**	**5.000V**	**±0.5%, 100ppm/°C**
LM4040DIM3-5.0	**LM4040DYM3-5.0**	**5.000V**	**±1.0%, 150ppm/°C**
LM4041CIM3-1.2	**LM4041CYM3-1.2**	**1.225V**	**±0.5%, 100ppm/°C**
LM4041DIM3-1.2	**LM4041DYM3-1.2**	**1.225V**	**±1.0%, 150ppm/°C**
LM4041CIM3-ADJ	**LM4041CYM3-ADJ**	**1.24V to 10V**	**±0.5%, 100ppm/°C**
LM4041DIM3-ADJ	**LM4041DYM3-ADJ**	**1.24V to 10V**	**±1.0%, 150ppm/°C**

SOT-23 Package Markings

Example	Field	Code
R _ _	1st Character	R = Reference
Y _ _	1st Character	Y = Pb-Free

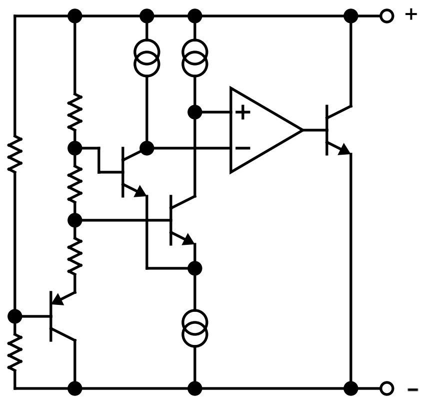
Example: R2C represents *Reference, 2.500V, ±0.5%* (LM4040CIM3-2.5)

Example: Y1C represents *Pb-Free, 1.225V, ±0.5%* (LM4040CYM3-1.2)

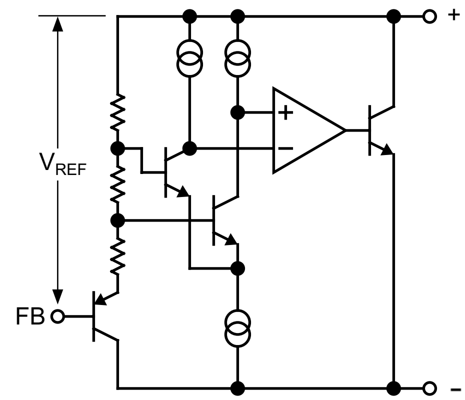
Example	Field	Code
_ 2 _	2nd Character	1 = 1.225V 2 = 2.500V 4 = 4.096V 5 = 5.000V A = Adjustable

Example	Field	Code
_ _ C	3rd Character	C = ±0.5% D = ±1.0% X = ±0.5% Pb-Free Y = ±1.0% Pb-Free

Note: If 3rd character is omitted, container will indicate tolerance.



Functional Diagram
LM4040, LM4041 Fixed



Functional Diagram
LM4041 Adjustable

Absolute Maximum Ratings

Reverse Current 20mA
Forward Current 10mA
Maximum Output Voltage
  LM4041-Adjustable.. 15V
Power Dissipation at T_A = 25°C (**Note 2**) 306mW
Storage Temperature................................ –65°C to +150°C
Lead Temperature
    Vapor phase (60 seconds)............................... +215°C
    Infrared (15 seconds)...................................... +220°C
  ESD Susceptibility
    Human Body Model (**Note 3**) 2kV
    Machine Model (**Note 3**) 200V

Operating Ratings (Notes 1 and 2)

Temperature Range
  ($T_{MIN} \le T_A \le T_{MAX}$)...........................$-40°C \le T_A \le +85°C$
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

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 specification 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), θ_{JA} (junction to ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is $P_{DMAX} = (T_{JMAX} - T_A)/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4040 and LM4041, T_{JMAX} = 125°C, and the typical thermal resistance (θ_{JA}), when board mounted, is 326°C/W for the SOT-23 package.

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

LM4040-2.5 Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ±1.0 respectively.

Symbol	**Parameter**	**Conditions (Note 5)**	**Typical Limits**	**LM4040CIM3 Limits (Note 6)**	**LM4040DIM3 (Limit) (Note 6)**	**Units**
V_R	Reverse Breakdown Voltage	I_R = 100µA	2.500			V
	Reverse Breakdown Voltage Tolerance **(Note 7)**	I_R = 100µA		±12 **±29**	±25 **±49**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		45	 60 **65**	 65 **70**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	I_R = 10mA I_R = 1mA I_R = 100µA	±20 ±15 ±15	 **±100**	 **±150**	ppm/°C ppm/°C (max) ppm/°C (max)
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R$ 1mA	0.3	 0.8 **1.0**	 1.0 **1.2**	mV mV (max) **mV (max)**
		1mA ≤ I_R 15mA	2.5	 6.0 **8.0**	 8.0 **10.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1mA, f = 120Hz $I_{AC} = 0.1\ I_R$	0.3	 0.9	 1.1	Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	 35			 μV_{RMS}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	 120			 ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 over temperature tolerance for the different grades follows:

C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

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

LM4040-4.1 Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ± 1.0% respectively.

Symbol	Parameter	Conditions	Typical (Note 5) (Note 6)	LM4040CIM3 Limits (Note 6)	LM4040DIM3 Limits	Units (Limits)
V_R	Reverse Breakdown Voltage	I_R = 100µA	4.096			V
	Reverse Breakdown Voltage Tolerance **(Note 7)**	I_R = 100µA		±20 **±47**	±41 **±81**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		50	68 **73**	73 **78**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	I_R = 10mA I_R = 1mA I_R = 100µA	±30 ±20 ±20	±**100**	±**150**	ppm/°C ppm/°C (max) ppm/°C (max)
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R$ 1mA	0.5	0.9 **1.2**	1.2 **1.5**	mV mV (max) **mV (max)**
		1mA ≤ I_R 15mA	3.0	7.0 **10.0**	9.0 **13.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1mA, f = 120Hz $I_{AC} = 0.1\ I_R$	0.5	1.0	1.3	Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	80			μV_{RMS}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	120			ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 over temperature tolerance for the different grades follows:

C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

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

LM4040-5.0 Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ± 1.0% respectively.

Symbol	Parameter	Conditions	Typical (Note 5) (Note 6)	LM4040CIM3 Limits (Note 6)	LM4040DIM3 Limits	Units (Limits)
V_R	Reverse Breakdown Voltage	I_R = 100µA	5.000			V
	Reverse Breakdown Voltage Tolerance **(Note 7)**	I_R = 100µA		±25 **±58**	±50 **±99**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		54	74 **80**	79 **85**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	I_R = 10mA I_R = 1mA I_R = 100µA	±30 ±20 ±20	**±100**	**±150**	ppm/°C ppm/°C (max) ppm/°C (max)
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R$ 1mA	0.5	1.0 **1.4**	1.3 **1.8**	mV mV (max) **mV (max)**
		1mA ≤ I_R 15mA	3.5	8.0 **12.0**	10.0 **15.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1mA, f = 120Hz $I_{AC} = 0.1\ I_R$	0.5	1.1	1.5	Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	80			μV_{RMS}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	120			ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

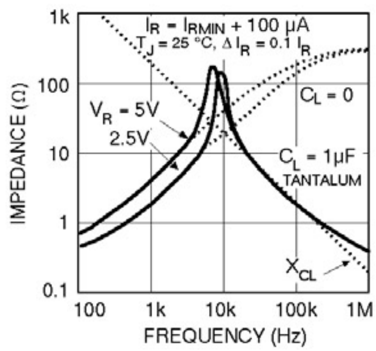
Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ is the V_R temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V_R is the reverse breakdown voltage. The total over temperature tolerance for the different grades follows:

C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

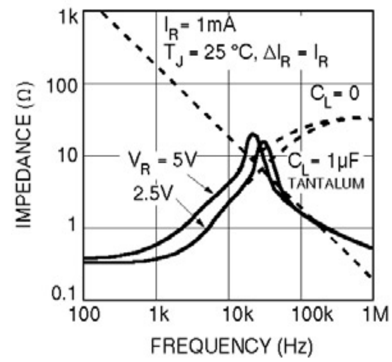
Example: The C-grade LM4040-2.5 has an over temperature Reverse Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29mV.

LM4040 Typical Characteristics

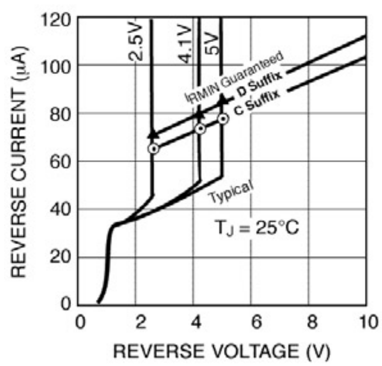
Output Impedance vs. Frequency



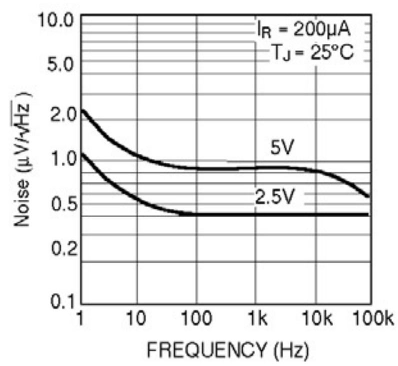
Output Impedance vs. Frequency

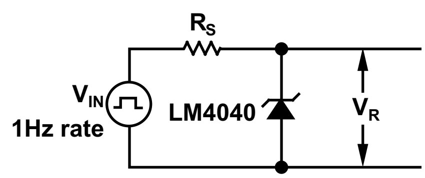


Reverse Characteristics and Minimum Operating Current



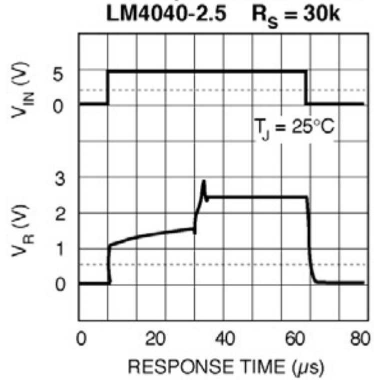
Noise Voltage vs. Frequency



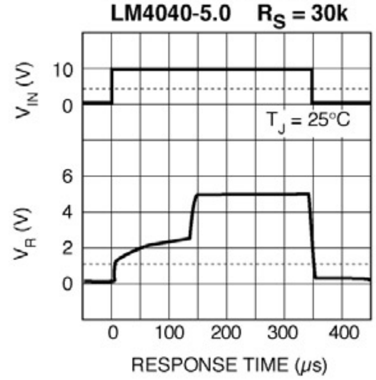


Test Circuit

Start-up Characteristics LM4040-2.5 R_S = 30k



Start-up Characteristics LM4040-5.0 R_S = 30k



LM4041-1.2 Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ± 1.0%, respectively.

Symbol	**Parameter**	**Conditions (Note 5)**	**Typical**	**LM4041CIM3 Limits (Limit) (Note 6)**	**Units**
V_R	Reverse Breakdown Voltage	I_R = 100µA	1.225		V
	Reverse Breakdown Voltage Tolerance **(Note 7)**	I_R = 100µA		±6 **±14**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		45	 60 **65**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	I_R = 10mA I_R = 1mA I_R = 100µA	±20 ±15 ±15	 **±100**	ppm/°C ppm/°C (max) ppm/°C (max)
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \leq I_R$ 1mA	0.7	 1.5 **2.0**	mV mV (max) **mV (max)**
		1mA $\leq I_R$ 15mA	4.0	 6.0 **8.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1mA, f = 120Hz I_{AC} = 0.1 I_R	0.5	 1.5	Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	20		μV_{RMS}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	120		ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 over temperature tolerance for the different grades follows:

C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

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

LM4041-1.2 Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits $T_A = T_J = 25°C$. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ± 1.0%, respectively.

Symbol	Parameter	Conditions	Typical (Note 5)	LM4041DIM3 Limits (Note 6)	Units (Limit)
V_R	Reverse Breakdown Voltage	I_R = 100µA	1.225		V
	Reverse Breakdown Voltage Tolerance **(Note 7)**	I_R = 100µA		±12 **±24**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		45	 65 **70**	µA µA (max) µA (max)
$\Delta V_R/\Delta T$	Average Reverse Breakdown Voltage Temperature Coefficient	I_R = 10mA I_R = 1mA I_R = 100µA	±20 ±15 ±15	**±150**	ppm/°C ppm/°C (max) ppm/°C (max)
$\Delta V_R/\Delta I_R$	Reverse Breakdown Voltage Change with Operating Current Change	$I_{RMIN} \le I_R$ 1mA	0.7	 2.0 **2.5**	mV mV (max) **mV (max)**
		1mA ≤ I_R 15mA	2.5	 8.0 **10.0**	mV mV (max) mV (max)
Z_R	Reverse Dynamic Impedance	I_R = 1mA, f = 120Hz $I_{AC} = 0.1\ I_R$	0.5	 2.0	Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	20		μV_{RMS}
ΔV_R	Reverse Breakdown Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	120		ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 over temperature tolerance for the different grades follows:

C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

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

LM4041-Adjustable Electrical Characteristics (Note 4)

Boldface limits apply for $T_A = T_J = T_{MIN}$ to T_{MAX}; all other limits T_J = 25°C unless otherwise specified (SOT-23, see Note 8), $I_{RMIN} \le I_R$ < 12mA, $V_{REF} \le V_{OUT} \le$ 10V. The grades C and D designate initial Reverse Breakdown Voltage tolerance of ±0.5% and ±1%, respectively for V_{OUT} = 5V.

Symbol	Parameter	Conditions (Note 5)	Typical Limits	LM4041CIM3 Limits (Note 6)	LM4041DIM3 (Limit) (Note 6)	Units
V_{REF}	Reference Breakdown Voltage	I_R = 100µA V_{OUT} = 5V	1.233			V
	Reference Breakdown Voltage Tolerance **(Note 9)**	I_R = 100µA		±6.2 **±14**	±12 **±24**	mV (max) mV (max)
I_{RMIN}	Minimum Operating Current		45	60 **65**	65 **70**	µA µA (max) **µA (max)**
$\Delta V_{REF}/\Delta I_R$	Reference Voltage Change with Operating Current Change	$I_{RMIN} \le I_R$ 1mA SOT-23: $V_{OUT} \ge$ 1.6V **(Note 8)**	0.7	1.5 **2.0**	2.0 **2.5**	mV mV (max) mV (max)
		1mA $\le I_R$ 15mA SOT-23: $V_{OUT} \ge$ 1.6V **(Note 8)**	2	4 **6**	6 **8**	mV mV (max) mV (max)
$\Delta V_{REF}/\Delta V_O$	Reference Voltage Change with Output Voltage Change	I_R = 1mA	–1.55	–2.0 **–2.5**	–2.5 **–3.0**	mV/V mV/V (max) mV/V (max)
I_{FB}	Feedback Current		60	100 **120**	150 **200**	nA nA (max) nA (max)
$\Delta V_{REF}/\Delta T$	Average Reference Voltage Temperature Coefficient **(Note 9)**	V_{OUT} = 5V I_R = 10mA I_R = 1mA I_R = 100µA	±20 ±15 ±15	**±100**	**±150**	ppm/°C ppm/°C (max) ppm/°C (max)
Z_{OUT}	Dynamic Output Impedance	I_R = 1mA, f = 120Hz I_{AC} = 0.1 I_R $V_{OUT} = V_{REF}$ V_{OUT} = 10V	0.3 2			Ω Ω (max)
e_N	Wideband Noise	I_R = 100µA 10Hz ≤ f ≤ 10kHz	20			$µV_{RMS}$
ΔV_{REF}	Reference Voltage Long Term Stability	t = 1000hrs T = 25°C ±0.1°C I_R = 100µA	120			ppm

Note 4. Specification for packaged product only.

Note 5. Typicals are at T_J = 25°C and represent most likely parametric norm.

Note 6. Limits are 100% production tested at 25°C. Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.

Note 7. The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 over temperature tolerance for the different grades follows:

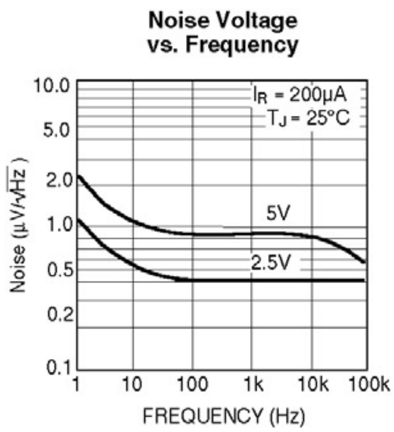
C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C

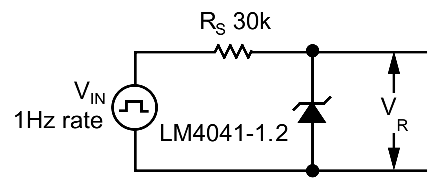
Example: The C-grade LM4040-2.5 has an over temperature Reverse Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29mV.

Note 8. 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.

Note 9. Reference voltage and temperature coefficient will change with output voltage. See *"Typical Performance Characteristics"* curves.

LM4041 Typical Characteristics

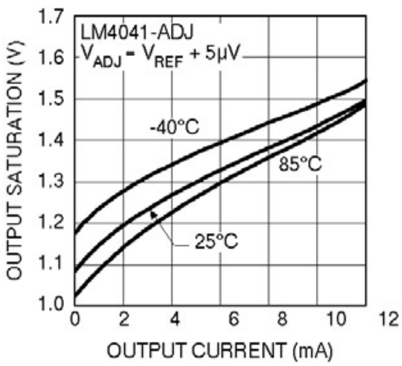


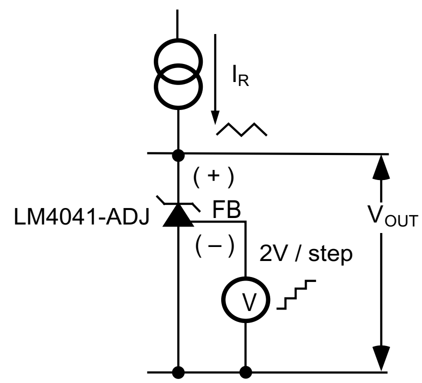


Test Circuit

LM4041 Typical Characteristics

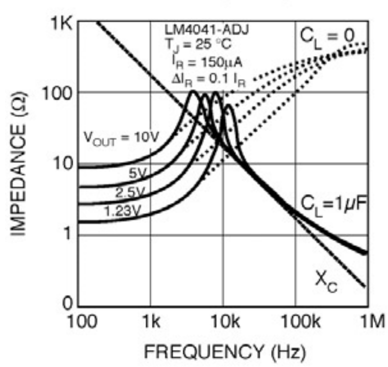
Output Saturation

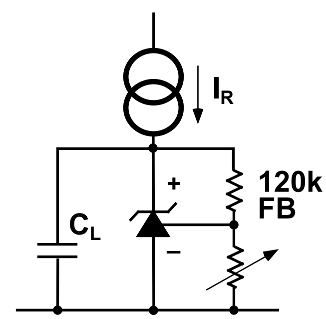




† Reverse Characteristics Test Circuit

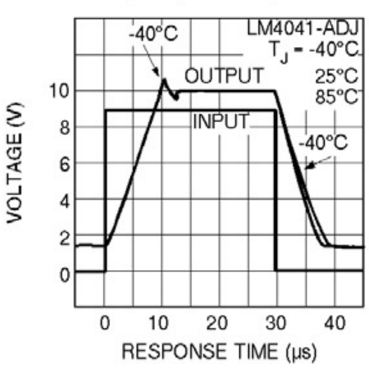
Output Impedence vs. Frequency *

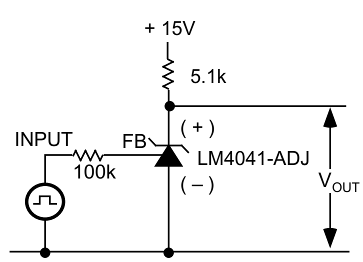




*** Output Impedance vs. Freq. Test Circuit**

Large Signal Response ‡





‡ Large Signal Response Test Circuit

* Output impedance measurement..
† Reverse characteristics measurement.
‡ Large signal response measurement.

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. 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). 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 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):

$$R_s = (V_s - V_R) / (I_L + I_Q)$$

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 equation:

(1) $$V_O = V_{REF} \, [(R2/R1) + 1]$$

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:

(2) $$V_{REF}' = V_O \, (\Delta V_{REF} / \Delta V_O) + V_Y$$

where V_O is the desired output voltage. $\Delta V_{REF} / \Delta V_O$ is found in the *"Electrical Characteristics"* and is typically –1.3mV/V and V_Y is equal to 1.233V. Replace the value of V_{REF} in equation (1) with the value V_{REF} found using equation (2).

Note that actual output voltage can deviate from that predicted using the typical $\Delta V_{REF} / \Delta V_O$ in equation (2); for C-grade parts, the worst-case $\Delta V_{REF} / \Delta V_O$ is –2.5mV/V and V_Y = 1.248V.

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

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 = 10kΩ, R2 = 63.272kΩ. 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

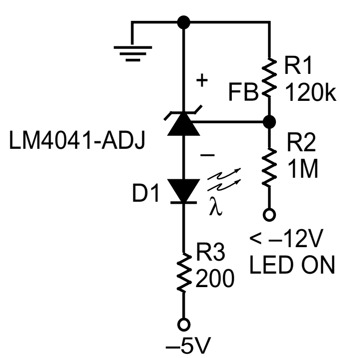


Figure 3. Voltage Level Detector

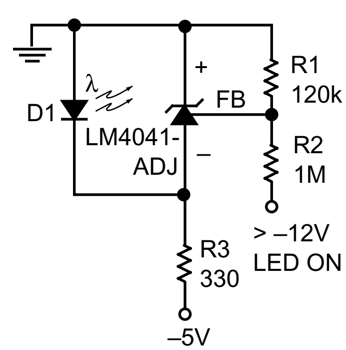


Figure 4. Voltage Level Detector

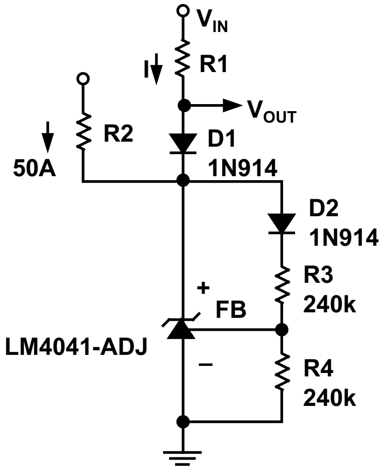


Figure 5. Fast Positive Clamp
$2.4V + \Delta V_{D1}$

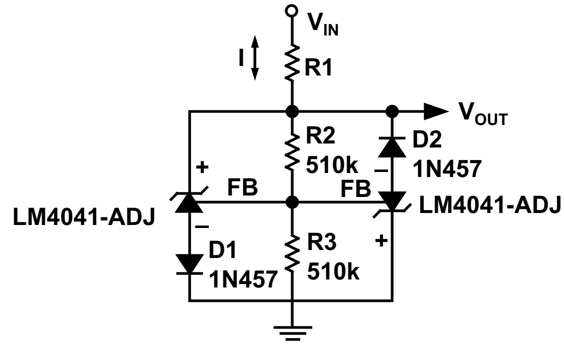


Figure 6. Bidirectional Clamp
±2.4V

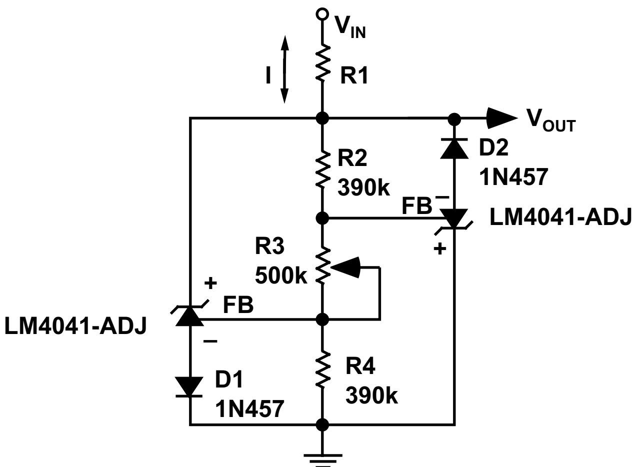


Figure 7. Bidirectional Adjustable Clamp
±18V to ±2.4V

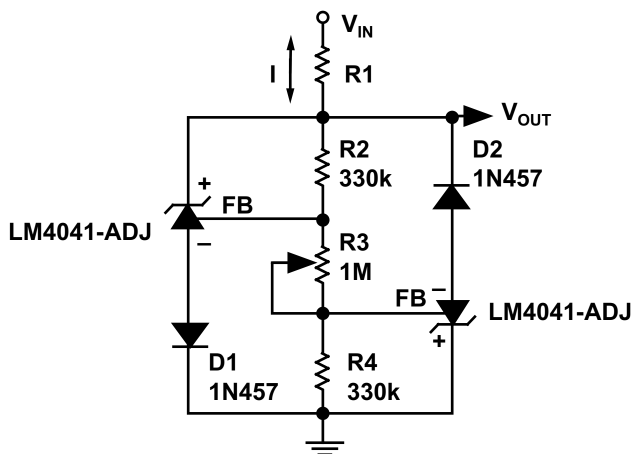
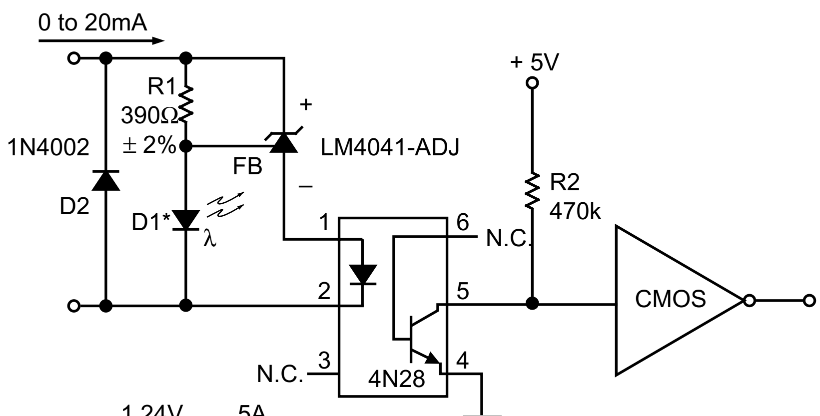


Figure 8. Bidirectional Adjustable Clamp
±2.4 to ±6V



$$I_{THRESHOLD} = \frac{1.24V}{R1} + \frac{5A}{4N28\ GAIN} = 3.2mA$$

* D1 can be any LED, V_F = 1.5V to 2.2V at 3mA. D1 may act as an indicator.
D1 will be on if $I_{THRESHOLD}$ falls below the threshold current, except with I = O.

Figure 9. Floating Current Detector

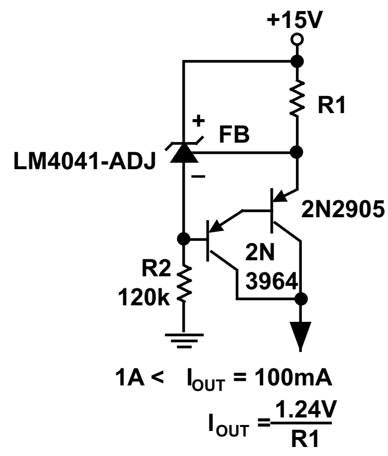
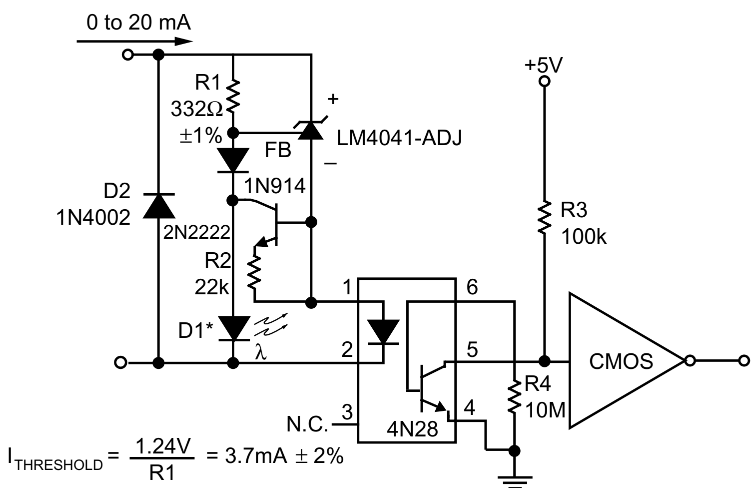


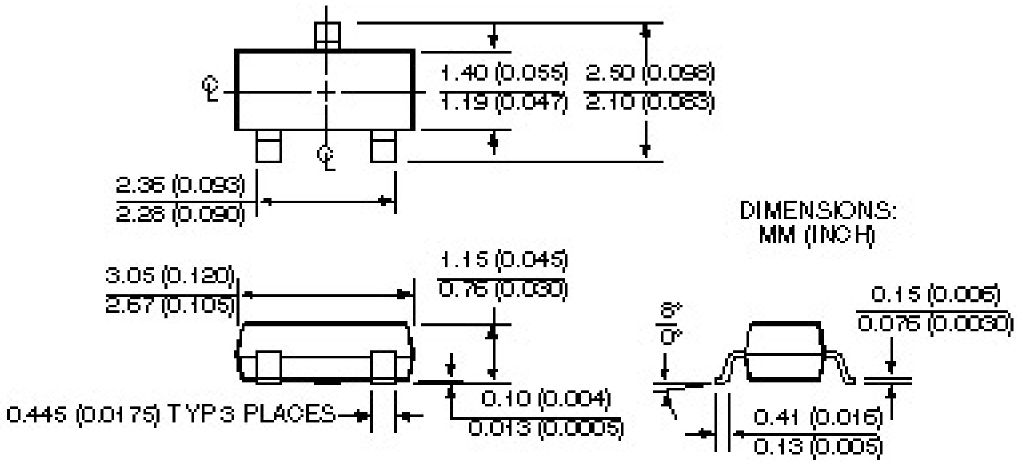
Figure 10. Current Source



* D1 can be any LED, V_F = 1.5V to 2.2V at 3mA. D1 may act as an indicator. D1 will be on if $I_{THRESHOLD}$ falls below the threshold current, except with I = O.

Figure 11. Precision Floating Current Detector

Package Information



SOT-23 (M3)

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