# 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.

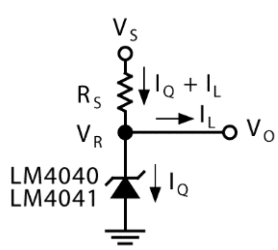
## Features

- 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.

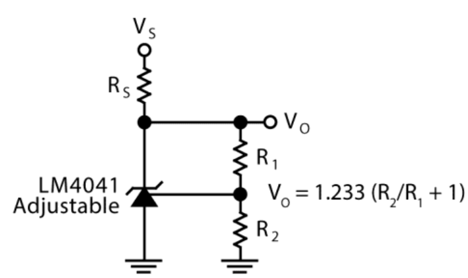
## Applications

- 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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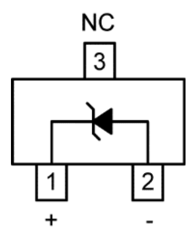
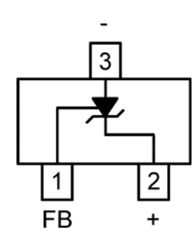
## Ordering Information

| 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. |
| 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[1]

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°C)[3] ........ 306mW
Storage Temperature (Ts) ........ –65°C to +150°C
ESD Susceptibility
  Human Body Model[4] ........ 2kV
  Machine Model[4] ........ 200V

## Operating Ratings[2]

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[5]

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040C** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 2.500 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±12 | mV |
| | | | | | **±29** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 60 | µA |
| | | | | | **65** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $I_R$ = 1mA | | ±15 | **±100** | ppm/°C |
| | | $I_R$ = 100µA | | ±15 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$ 1mA | | 0.3 | 0.8 | mV |
| | | | | | **1.0** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 2.5 | 6.0 | mV |
| | | | | | **8.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.3 | 0.9 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

**Notes:**

1. Exceeding the absolute maximum ratings may damage the device.
2. 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 $T_{JMAX}$ (maximum junction temperature), $\Theta_{JA}$ (junction to ambient thermal resistance), and TA (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°C and the typical thermal resistance, when board-mounted, is 326°C/W for the SOT-23 package.
4. 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 $\pm[(\Delta V_R/\Delta T)(65°C)(V_R)]$. $\Delta V_R/\Delta T$ 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 overtemperature tolerance for the different grades follows:
   a. C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
   b. D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C
   Example: The C-grade LM4040-2.5 has an overtemperature Reverse Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29mV.

## LM4040-2.5 Electrical Characteristics[5] (Continued)

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040D** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 2.500 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±25 | mV |
| | | | | | **±49** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 65 | µA |
| | | | | | **70** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $I_R$ = 1mA | | ±15 | **±150** | ppm/°C |
| | | $I_R$ = 100µA | | ±15 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$1mA | | 0.3 | 1.0 | mV |
| | | | | | **1.2** | mV |
| | | 1mA ≤ $I_R$ ≤ 15mA | | 2.5 | 8.0 | mV |
| | | | | | **10.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.3 | 1.1 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 100µA, 10Hz ≤ f ≤ 10kHz | | 35 | | $µV_{RMS}$ |
| $\Delta V_R$ | Reverse Breakdown Voltage Long Term Stability | t = 1000hrs., T = 25°C ±0.1°C, $I_R$ = 100µA | | 120 | | ppm |

## LM4040-4.1 Electrical Characteristics[5]

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040C** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 4.096 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±20 | mV |
| | | | | | **±47** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 50 | 68 | µA |
| | | | | | **73** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±30 | | ppm/°C |
| | | $I_R$ = 1mA | | ±20 | **±100** | ppm/°C |
| | | $I_R$ = 100µA | | ±20 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$1mA | | 0.5 | 0.9 | mV |
| | | | | | **1.2** | mV |
| | | 1mA ≤ $I_R$ ≤ 15mA | | 3.0 | 7.0 | mV |
| | | | | | **10.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 1.0 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 100µA, 10Hz ≤ f ≤ 10kHz | | 80 | | $µV_{RMS}$ |
| $\Delta V_R$ | Reverse Breakdown Voltage Long Term Stability | t = 1000hrs., T = 25°C ±0.1°C, $I_R$ = 100µA | | 120 | | ppm |

## LM4040-4.1 Electrical Characteristics[5] (Continued)

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040D** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 4.096 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±41 | mV |
| | | | | | **±81** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 50 | 73 | µA |
| | | | | | **78** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±30 | | ppm/°C |
| | | $I_R$ = 1mA | | ±20 | **±150** | ppm/°C |
| | | $I_R$ = 100µA | | ±20 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$ 1mA | | 0.5 | 1.2 | mV |
| | | | | | **1.5** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 3.0 | 9.0 | mV |
| | | | | | **13.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 1.3 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 100µA, 10Hz ≤ f ≤ 10kHz | | 80 | | $µV_{RMS}$ |
| $\Delta V_R$ | Reverse Breakdown Voltage Long Term Stability | t = 1000hrs., T = 25°C ±0.1°C, $I_R$ = 100µA | | 120 | | ppm |

## LM4040-5.0 Electrical Characteristics[5]

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040C** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 5.000 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±25 | mV |
| | | | | | **±58** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 54 | 74 | µA |
| | | | | | **80** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±30 | | ppm/°C |
| | | $I_R$ = 1mA | | ±20 | **±100** | ppm/°C |
| | | $I_R$ = 100µA | | ±20 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$ 1mA | | 0.5 | 1.0 | mV |
| | | | | | **1.4** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 3.5 | 8.0 | mV |
| | | | | | **12.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 1.1 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 100µA, 10Hz ≤ f ≤ 10kHz | | 80 | | $µV_{RMS}$ |
| $\Delta V_R$ | Reverse Breakdown Voltage Long Term Stability | t = 1000hrs., T = 25°C ±0.1°C, $I_R$ = 100µA | | 120 | | ppm |

## LM4040-5.0 Electrical Characteristics[5] (Continued)

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4040D** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 5.000 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±50 | mV |
| | | | | | **±99** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 54 | 79 | µA |
| | | | | | **85** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±30 | | ppm/°C |
| | | $I_R$ = 1mA | | ±20 | **±150** | ppm/°C |
| | | $I_R$ = 100µA | | ±20 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$1mA | | 0.5 | 1.3 | mV |
| | | | | | **1.8** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 3.5 | 10.0 | mV |
| | | | | | **15.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 1.5 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

## LM4041-1.2 Electrical Characteristics[5]

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4041C** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 1.225 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±6 | mV |
| | | | | | **±14** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 60 | µA |
| | | | | | **65** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $I_R$ = 1mA | | ±15 | **±100** | ppm/°C |
| | | $I_R$ = 100µA | | ±15 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$1mA | | 0.7 | 1.5 | mV |
| | | | | | **2.0** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 4.0 | 6.0 | mV |
| | | | | | **8.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 1.5 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

## LM4041-1.2 Electrical Characteristics[5] (Continued)

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4041D** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA | | 1.225 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | | | | ±12 | mV |
| | | | | | **±24** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 65 | µA |
| | | | | | **70** | µA |
| $\Delta V_R/\Delta T$ | Average Reverse Breakdown Voltage Temperature Coefficient | $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $I_R$ = 1mA | | ±15 | **±150** | ppm/°C |
| | | $I_R$ = 100µA | | ±15 | | ppm/°C |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \le I_R \le$ 1mA | | 0.7 | 2.0 | mV |
| | | | | | **2.5** | mV |
| | | 1mA $\le I_R \le$ 15mA | | 2.5 | 8.0 | mV |
| | | | | | **10.0** | mV |
| $Z_R$ | Reverse Dynamic Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$ | | 0.5 | 2.0 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

## LM4041-ADJ Electrical Characteristics[5]

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

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4041C** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA, $V_{OUT}$ = 5V | | 1.233 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | $I_R$ = 100µA | | | ±6.2 | mV |
| | | | | | **±14** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 60 | µA |
| | | | | | **65** | µA |
| $\Delta V_{REF}/\Delta I_R$ | Reference Voltage Change with Operating Current | $I_{RMIN} \le I_R \le$ 1mA, $V_{OUT} \ge$ 1.6V[7] | | 0.7 | 1.5 | mV |
| | | | | | **2.0** | mV |
| | | 1mA $\le I_R \le$ 15mA, $V_{OUT} \ge$ 1.6V[7] | | 2.0 | 4.0 | mV |
| | | | | | **6.0** | mV |
| $\Delta V_{REF}/\Delta V_O$ | Reference Voltage Change with Output Voltage Change | $I_R$ = 1mA | | -1.55 | -2.0 | mV/V |
| | | | | | **-2.5** | mV/V |
| $I_{FB}$ | Feedback Current | | | 60 | 100 | nA |
| | | | | | **120** | nA |
| $\Delta V_{REF}/\Delta T$ | Average Reference Voltage Temperature Coefficient | $V_{OUT}$ = 5V, $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $V_{OUT}$ = 5V, $I_R$ = 1mA | | ±15 | **±100** | ppm/°C |
| | | $V_{OUT}$ = 5V, $I_R$ = 100µA | | ±15 | | ppm/°C |
| $Z_{OUT}$ | Dynamic Output Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$<br>$V_{OUT} = V_{REF}$ | | 0.3 | | Ω |
| | | $V_{OUT}$ = 10V | | | 2.0 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

**Note:**

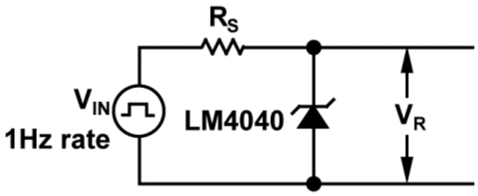
7. When $V_{OUT} \le$ 1.6V, the LM4041-ADJ must operate at reduced $I_R$. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the "Typical Performance Characteristics" section.

## LM4041-ADJ Electrical Characteristics[5]

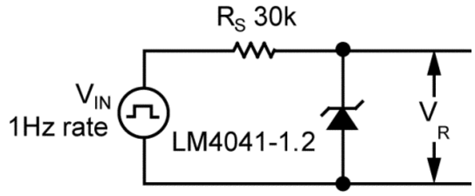
$T_A$ = Operating Temperature Range, **bold** values indicate $T_A = T_J$ = –40°C to +85°C, unless noted.

| Symbol | Parameter | Condition | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| **LM4041D** | | | | | | |
| $V_R$ | Reverse Breakdown Voltage | $I_R$ = 100µA, $V_{OUT}$ = 5V | | 1.233 | | V |
| | Reverse Breakdown Voltage Tolerance[6] | $I_R$ = 100µA | | | ±12 | mV |
| | | | | | **±24** | mV |
| $I_{RMIN}$ | Minimum Operating Current | | | 45 | 65 | µA |
| | | | | | **70** | µA |
| $\Delta V_{REF}/\Delta I_R$ | Reference Voltage Change with Operating Current | $I_{RMIN} \le I_R \le$ 1mA, $V_{OUT} \ge$ 1.6V[7] | | 0.7 | 2.0 | mV |
| | | | | | **2.5** | mV |
| | | 1mA $\le I_R \le$ 15mA, $V_{OUT} \ge$ 1.6V[7] | | 2.0 | 6.0 | mV |
| | | | | | **8.0** | mV |
| $\Delta V_{REF}/\Delta V_O$ | Reference Voltage Change with Output Voltage Change | $I_R$ = 1mA | | -1.55 | -2.5 | mV/V |
| | | | | | **-3.0** | mV/V |
| $I_{FB}$ | Feedback Current | | | 60 | 150 | nA |
| | | | | | **200** | nA |
| $\Delta V_{REF}/\Delta T$ | Average Reference Voltage Temperature Coefficient | $V_{OUT}$ = 5V, $I_R$ = 10mA | | ±20 | | ppm/°C |
| | | $V_{OUT}$ = 5V, $I_R$ = 1mA | | ±15 | **±150** | ppm/°C |
| | | $V_{OUT}$ = 5V, $I_R$ = 100µA | | ±15 | | ppm/°C |
| $Z_{OUT}$ | Dynamic Output Impedance | $I_R$ = 1mA, f = 120Hz, $I_{AC} = 0.1I_R$<br>$V_{OUT} = V_{REF}$ | | 0.3 | | Ω |
| | | $V_{OUT}$ = 10V | | | 2.0 | Ω |
| $e_N$ | Wideband Noise | $I_R$ = 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, $I_R$ = 100µA | | 120 | | ppm |

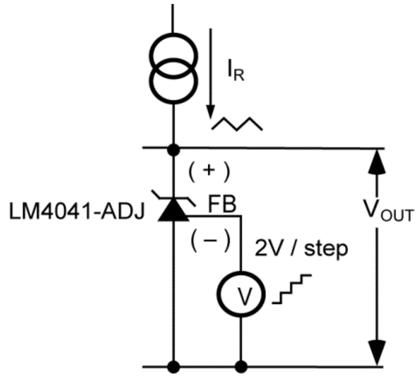
## Test Circuit



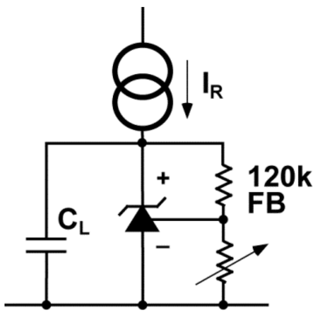

LM4040



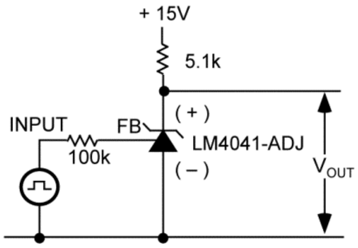

LM4041




**Reverse Characteristics Test Circuit**



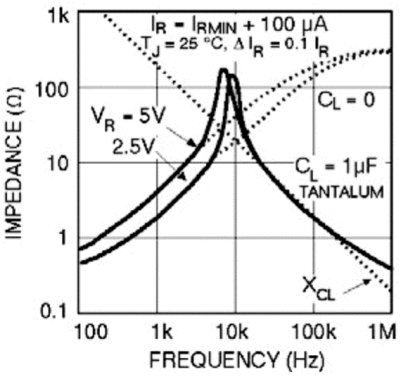

**Output Impedance vs. Frequency Test Circuit**



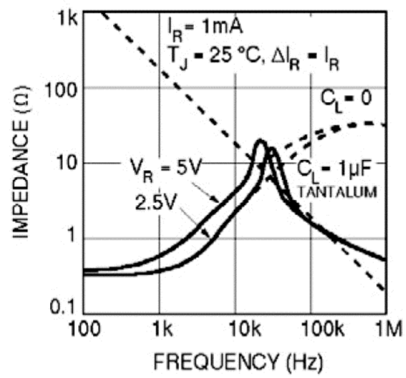

**Large Signal Response Test Circuit**

## LM4040 Typical Characteristics

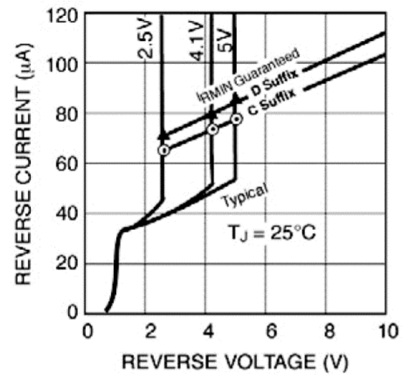
**Output Impedance vs. Frequency**



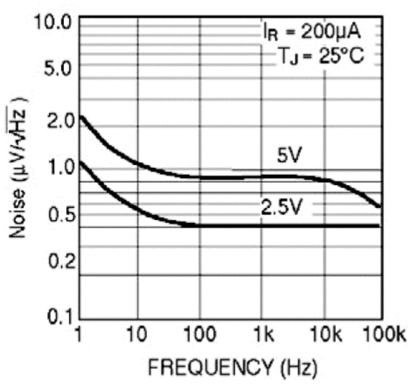

**Output Impedance vs. Frequency**



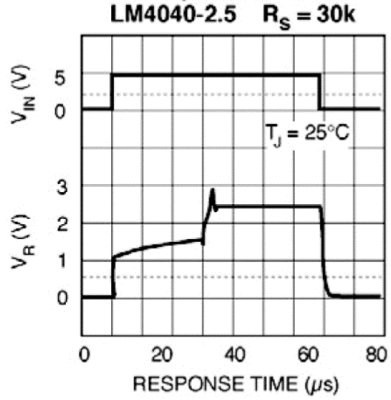

**Reverse Characteristics and Minimum Operating Current**



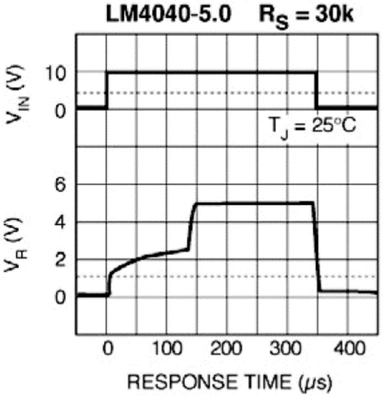

**Noise Voltage vs. Frequency**



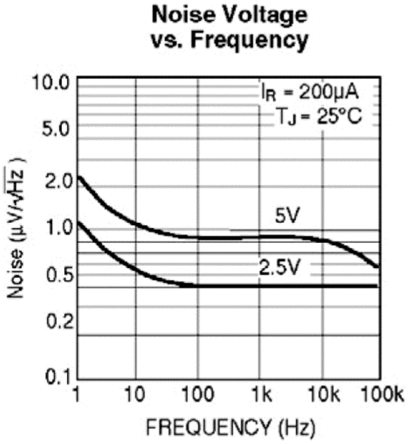

**Start-up Characteristics LM4040-2.5 $R_S = 30k$**

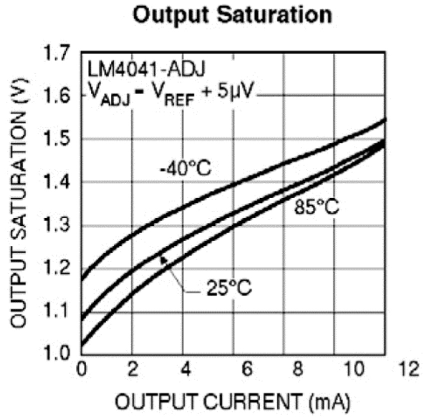


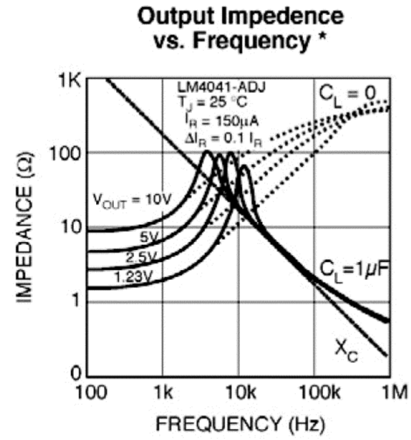

**Start-up Characteristics LM4040-5.0 $R_S = 30k$**

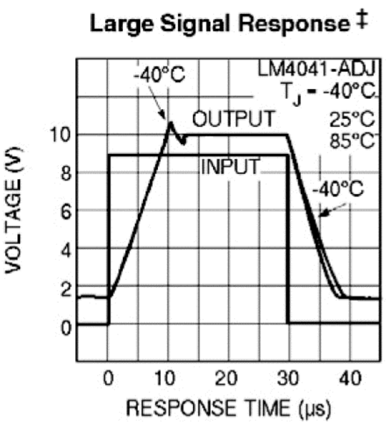


## LM4041 Typical Characteristics

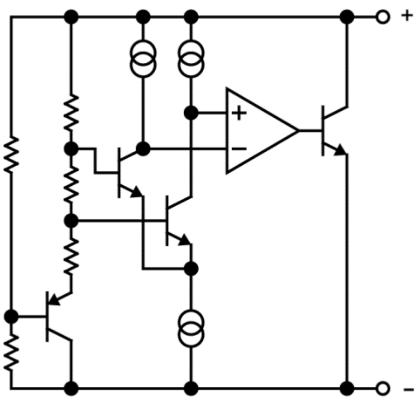


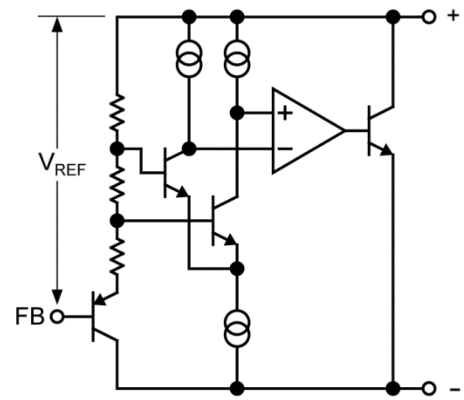



## Functional Diagrams




**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. RS determines the current that flows through the load ($I_L$) and the reference ($I_Q$). Because load current and supply voltage may vary, $R_S$ 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 ($V_R$):

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

### 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:

$$V_O = V_{REF}\,[(R2/R1) + 1] \qquad \text{Eq. 2}$$

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:

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

where $V_O$ is the desired output voltage. $\Delta V_{REF}/\Delta V_O$ is found in the Electrical Characteristics section and is typically –1.3mV/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 –2.5mV/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

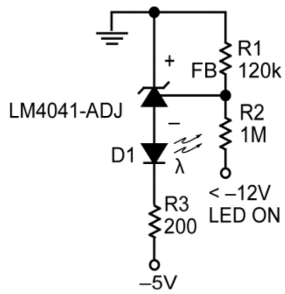



Figure 1. Voltage Level Detector

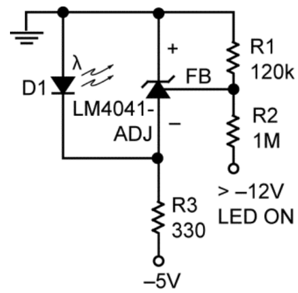



Figure 2. Voltage Level Detector

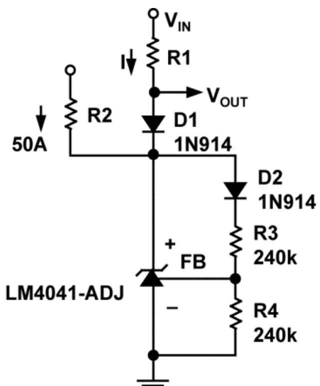



Figure 3. Fast Positive Clamp
$2.4V + \Delta V_{D1}$

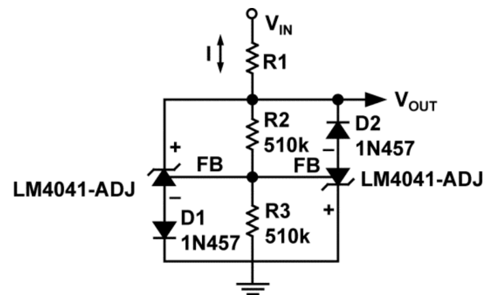



Figure 4. Bidirectional Clamp
±2.4V

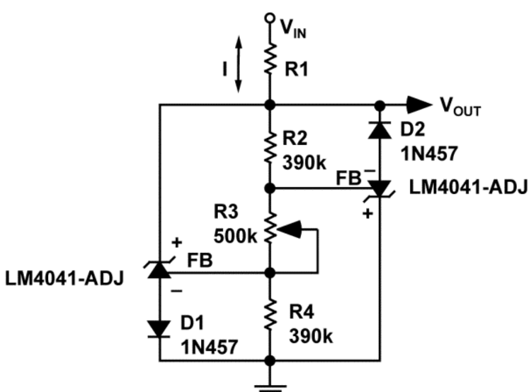



Figure 5. Bidirectional Adjustable Clamp
±18V to ±2.4V

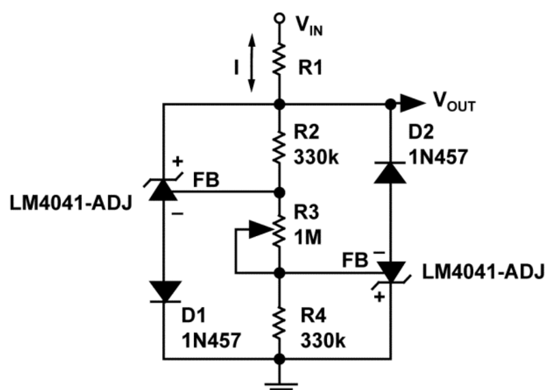
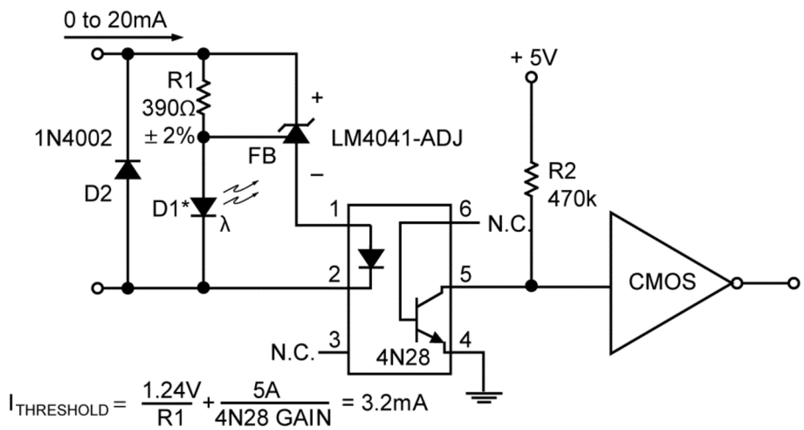



Figure 6. Bidirectional Adjustable Clamp
±2.4V to ±6V

## Typical Application Circuits (Continued)




* 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 7. Floating Current Detector**

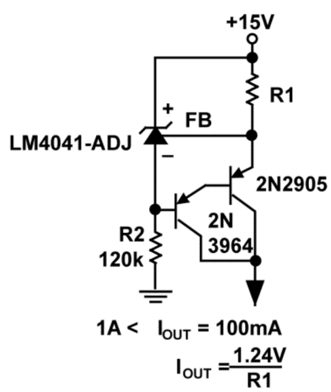
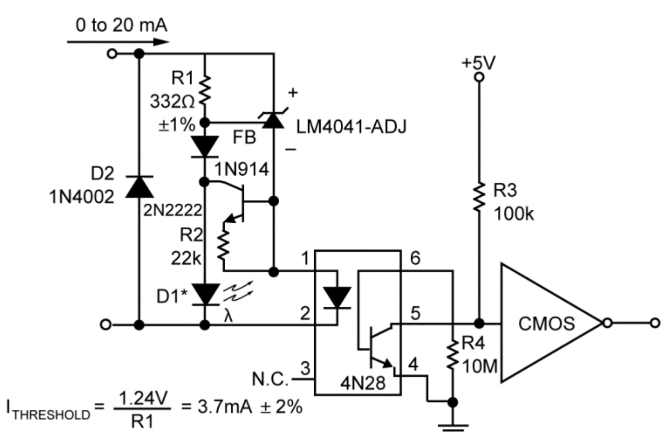


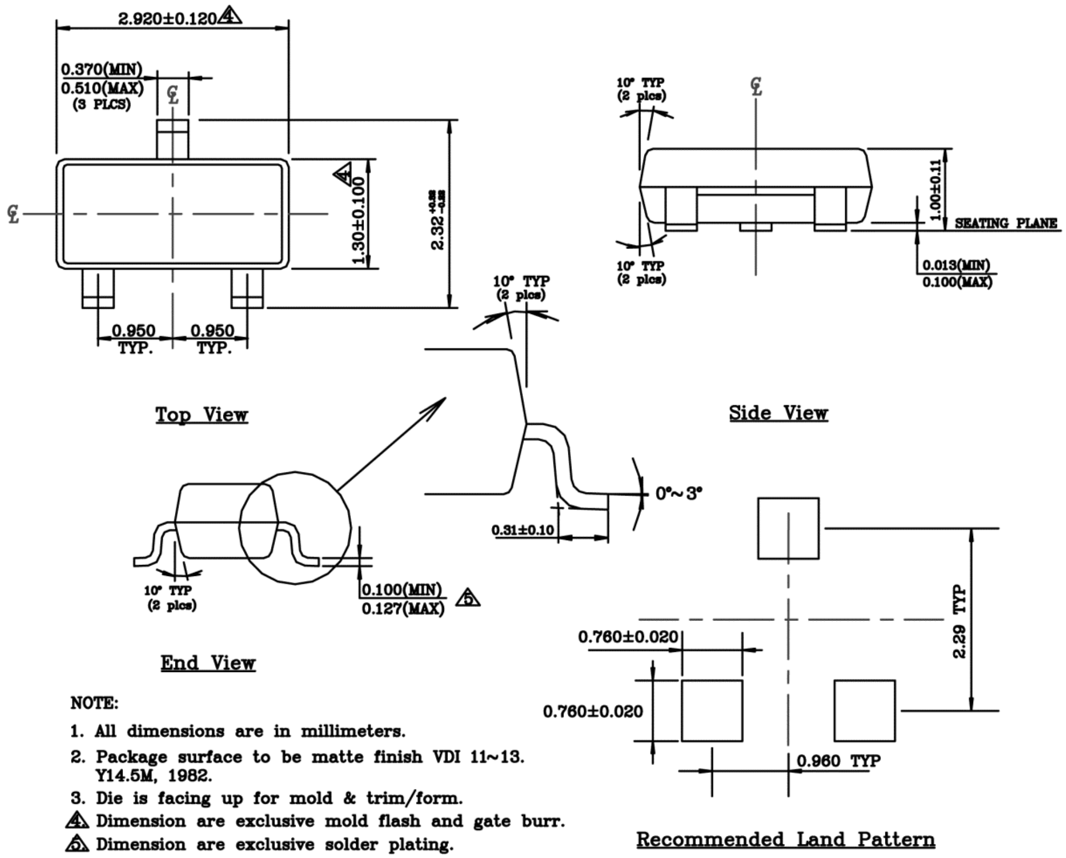

**Figure 8. Current Source**




* 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 9. Precision Floating Current Detector**

## Package Information[8]




**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.

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