



## LM4040/4041

### 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 LM4040 and LM4041's advanced design eliminates the need for an external stabilizing capacitor while ensuring stability with any capacitive load, making them easy to use.

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

#### 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 (A grade, 25°C) .. ±0.1% (max)
- Low output noise (10Hz to 100Hz)
 

|              |                           |
|--------------|---------------------------|
| LM4040 ..... | 35μV <sub>RMS</sub> (typ) |
| LM4041 ..... | 20μV <sub>RMS</sub> (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

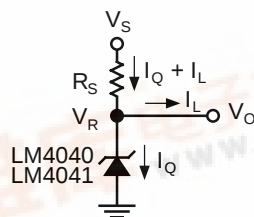


Figure 1. LM4040, LM4041 Fixed Shunt Regulator Application

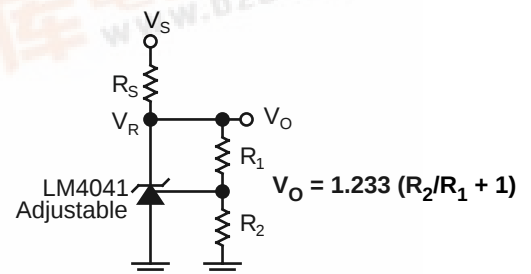
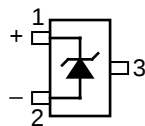


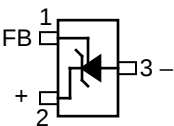
Figure 2. LM4041 Adjustable Shunt Regulator Application

Pin Configuration



Pin 3 must float or  
be connected to pin 2.

Fixed Version  
SOT-23 (M3) Package  
Top View



Adjustable Version  
SOT-23 (M3) Package  
Top View

Ordering Information

| Part Number *  | Voltage | Accuracy,<br>Temp. Coefficient |
|----------------|---------|--------------------------------|
| LM4040AIM3-2.5 | 2.500V  | ±0.1%, 100ppm/°C               |
| LM4040BIM3-2.5 | 2.500V  | ±0.2%, 100ppm/°C               |
| LM4040CIM3-2.5 | 2.500V  | ±0.5%, 100ppm/°C               |
| LM4040DIM3-2.5 | 2.500V  | ±1.0%, 150ppm/°C               |
| LM4040AIM3-4.1 | 4.096V  | ±0.1%, 100ppm/°C               |
| LM4040BIM3-4.1 | 4.096V  | ±0.2%, 100ppm/°C               |
| LM4040CIM3-4.1 | 4.096V  | ±0.5%, 100ppm/°C               |
| LM4040DIM3-4.1 | 4.096V  | ±1.0%, 150ppm/°C               |
| LM4040AIM3-5.0 | 5.000V  | ±0.1%, 100ppm/°C               |
| LM4040BIM3-5.0 | 5.000V  | ±0.2%, 100ppm/°C               |
| LM4040CIM3-5.0 | 5.000V  | ±0.5%, 100ppm/°C               |
| LM4040DIM3-5.0 | 5.000V  | ±1.0%, 150ppm/°C               |

| Part Number *  | Voltage      | Accuracy,<br>Temp. Coefficient |
|----------------|--------------|--------------------------------|
| LM4041AIM3-1.2 | 1.225V       | ±0.1%, 100ppm/°C               |
| LM4041BIM3-1.2 | 1.225V       | ±0.2%, 100ppm/°C               |
| LM4041CIM3-1.2 | 1.225V       | ±0.5%, 100ppm/°C               |
| LM4041DIM3-1.2 | 1.225V       | ±1.0%, 150ppm/°C               |
| LM4041CIM3-ADJ | 1.24V to 10V | ±0.5%, 100ppm/°C               |
| LM4041DIM3-ADJ | 1.24V to 10V | ±1.0%, 150ppm/°C               |

SOT-23 Package Markings

| Example | Field         | Code          |
|---------|---------------|---------------|
| R _ _   | 1st Character | R = Reference |

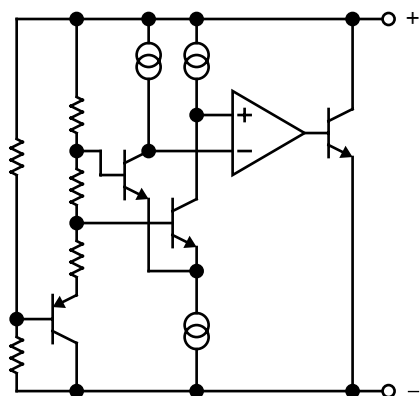
Example: R2C represents *Reference*, 2.500V, ±0.5% (LM4040CIM3-2.5)

| Example | Field         | Code                                                                   |
|---------|---------------|------------------------------------------------------------------------|
| _ 2 _   | 2nd Character | 1 = 1.225V<br>2 = 2.500V<br>4 = 4.096V<br>5 = 5.000V<br>A = Adjustable |

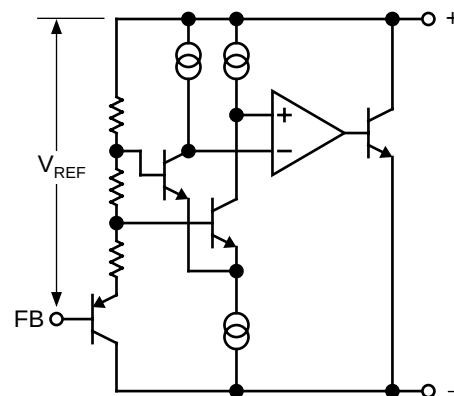
| Example | Field         | Code                                             |
|---------|---------------|--------------------------------------------------|
| _ _ A   | 3rd Character | A = ±0.1%<br>B = ±0.2%<br>C = ±0.5%<br>D = ±1.0% |

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 $T_A = 25^\circ\text{C}$ (Note 2) ..... | 306mW                                       |
| Storage Temperature .....                                    | $-65^\circ\text{C}$ to $+150^\circ\text{C}$ |
| Lead Temperature                                             |                                             |
| Vapor phase (60 seconds) .....                               | $+215^\circ\text{C}$                        |
| Infrared (15 seconds) .....                                  | $+220^\circ\text{C}$                        |
| ESD Susceptibility                                           |                                             |
| Human Body Model (Note 3) .....                              | 2kV                                         |
| Machine Model (Note 3) .....                                 | 200V                                        |

## Operating Ratings (Notes 1 and 2)

|                                                         |                                                     |
|---------------------------------------------------------|-----------------------------------------------------|
| Temperature Range                                       |                                                     |
| ( $T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$ ) ..... | $-40^\circ\text{C} \leq T_A \leq +85^\circ\text{C}$ |
| 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                                        |

## LM4040-2.5 Electrical Characteristics

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ :** all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A, B, C, and D designate initial Reverse Breakdown Voltage tolerance of  $\pm 0.1\%$ ,  $\pm 0.2\%$ ,  $\pm 0.5\%$ , and  $\pm 1.0\%$  respectively.

| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4040AIM3<br>Limits<br>(Note 5)        | LM4040BIM3<br>Limits<br>(Note 5)        | LM4040CIM3<br>Limits<br>(Note 5)       | Units<br>(Limit)                                                                    |
|-------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------|-----------------------------------------|-----------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------|
| $V_R$                   | Reverse Breakdown Voltage                                      | $I_R = 100\mu\text{A}$                                                                         | 2.500               |                                         |                                         |                                        | V                                                                                   |
|                         | Reverse Breakdown Voltage Tolerance                            | $I_R = 100\mu\text{A}$                                                                         |                     | $\pm 2.5$<br><b><math>\pm 19</math></b> | $\pm 5.0$<br><b><math>\pm 21</math></b> | $\pm 12$<br><b><math>\pm 29</math></b> | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$              | Minimum Operating Current                                      |                                                                                                | 45                  | 60<br><b>65</b>                         | 60<br><b>65</b>                         | 60<br><b>65</b>                        | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_R/\Delta T$   | Average Reverse Breakdown Voltage Temperature Coefficient      | $I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                            | 20<br>15<br>15      | <b>100</b>                              | <b>100</b>                              | <b>100</b>                             | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \leq I_R 1\text{mA}$                                                                 | 0.3                 | 0.8<br><b>1.0</b>                       | 0.8<br><b>1.0</b>                       | 0.8<br><b>1.0</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
|                         |                                                                | $1\text{mA} \leq I_R 15\text{mA}$                                                              | 2.5                 | 0.6<br><b>8.0</b>                       | 0.6<br><b>8.0</b>                       | 0.6<br><b>8.0</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
| $Z_R$                   | Reverse Dynamic Impedance                                      | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$                                  | 0.3                 | 0.8                                     | 0.8                                     | 0.9                                    | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                   | Wideband Noise                                                 | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                               | 35                  |                                         |                                         |                                        | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_R$            | Reverse Breakdown Voltage Long Term Stability                  | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$ | 120                 |                                         |                                         |                                        | ppm                                                                                 |

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

## LM4040-4.1 Electrical Characteristics

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A, B, C, and D designate initial Reverse Breakdown Voltage tolerance of  $\pm 0.1\%$ ,  $\pm 0.2\%$ ,  $\pm 0.5\%$ , and  $\pm 1.0\%$  respectively.

| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4040AIM3<br>Limits<br>(Note 5)        | LM4040BIM3<br>Limits<br>(Note 5)        | Units<br>(Limit)                                                                    |
|-------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------|-----------------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------|
| $V_R$                   | Reverse Breakdown Voltage                                      | $I_R = 100\mu\text{A}$                                                                         | 4.096               |                                         |                                         | V                                                                                   |
|                         | Reverse Breakdown Voltage Tolerance                            | $I_R = 100\mu\text{A}$                                                                         |                     | $\pm 4.1$<br><b><math>\pm 31</math></b> | $\pm 8.2$<br><b><math>\pm 35</math></b> | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$              | Minimum Operating Current                                      |                                                                                                | 50                  | 68<br><b>73</b>                         | 68<br><b>73</b>                         | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_R/\Delta T$   | Average Reverse Breakdown Voltage Temperature Coefficient      | $I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                            | 30<br>20<br>20      | <b>100</b>                              | <b>100</b>                              | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \leq I_R 1\text{mA}$                                                                 | 0.5                 | 0.9<br><b>1.2</b>                       | 0.9<br><b>1.2</b>                       | mV<br>mV (max)<br>mV (max)                                                          |
|                         |                                                                | $1\text{mA} \leq I_R 15\text{mA}$                                                              | 3.5                 | 7.0<br><b>10.0</b>                      | 7.0<br><b>10.0</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
| $Z_R$                   | Reverse Dynamic Impedance                                      | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$                                  | 0.5                 | 1.0                                     | 1.0                                     | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                   | Wideband Noise                                                 | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                               | 80                  |                                         |                                         | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_R$            | Reverse Breakdown Voltage Long Term Stability                  | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$ | 120                 |                                         |                                         | ppm                                                                                 |
| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4040CIM3<br>Limits<br>(Note 5)        | LM4040DIM3<br>Limits<br>(Note 5)        | Units<br>(Limits)                                                                   |
| $V_R$                   | Reverse Breakdown Voltage                                      | $I_R = 100\mu\text{A}$                                                                         | 4.096               |                                         |                                         | V                                                                                   |
|                         | Reverse Breakdown Voltage Tolerance                            | $I_R = 100\mu\text{A}$                                                                         |                     | $\pm 20$<br><b><math>\pm 47</math></b>  | $\pm 41$<br><b><math>\pm 81</math></b>  | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$              | Minimum Operating Current                                      |                                                                                                | 50                  | 68<br><b>73</b>                         | 73<br><b>78</b>                         | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_R/\Delta T$   | Average Reverse Breakdown Voltage Temperature Coefficient      | $I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                            | 30<br>20<br>20      | <b>100</b>                              | <b>150</b>                              | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \leq I_R 1\text{mA}$                                                                 | 0.5                 | 0.9<br><b>1.2</b>                       | 1.2<br><b>1.5</b>                       | mV<br>mV (max)<br>mV (max)                                                          |
|                         |                                                                | $1\text{mA} \leq I_R 15\text{mA}$                                                              | 3.0                 | 7.0<br><b>10.0</b>                      | 9.0<br><b>13.0</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
| $Z_R$                   | Reverse Dynamic Impedance                                      | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$                                  | 0.5                 | 1.0                                     | 1.3                                     | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                   | Wideband Noise                                                 | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                               | 80                  |                                         |                                         | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_R$            | Reverse Breakdown Voltage Long Term Stability                  | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$ | 120                 |                                         |                                         | ppm                                                                                 |

## LM4040-5.0 Electrical Characteristics

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$** ; all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A, B, C, and D designate initial Reverse Breakdown Voltage tolerance of  $\pm 0.1\%$ ,  $\pm 0.2\%$ ,  $\pm 0.5\%$ , and  $\pm 1.0\%$  respectively.

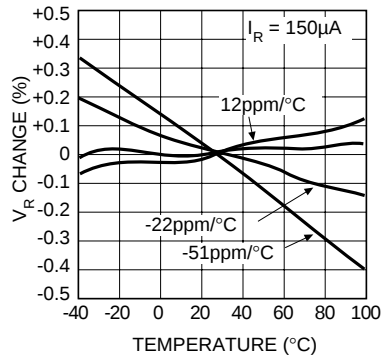
| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4040AIM3<br>Limits<br>(Note 5)        | LM4040BIM3<br>Limits<br>(Note 5)       | Units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

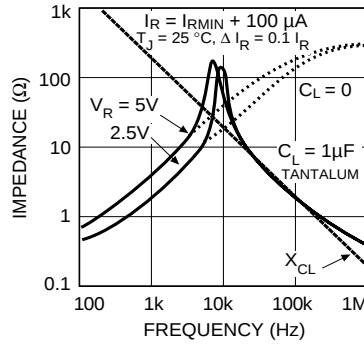
| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4040CIM3<br>Limits<br>(Note 5)       | LM4040DIM3<br>Limits<br>(Note 5)       | Units<br>(Limits)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

## LM4040 Typical Characteristics

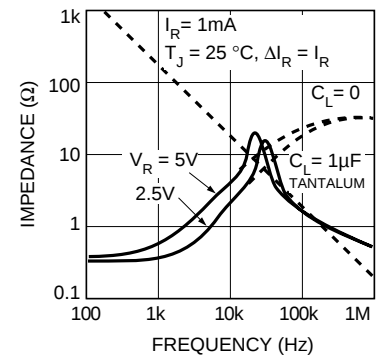
Temperature Drift for Different  
Average Temperature Coefficient



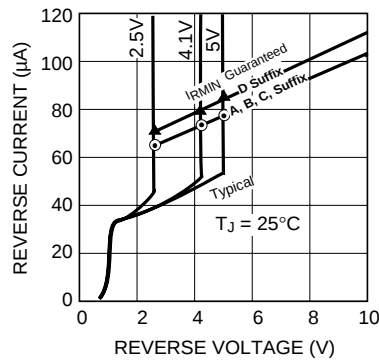
Output Impedance  
vs. Frequency



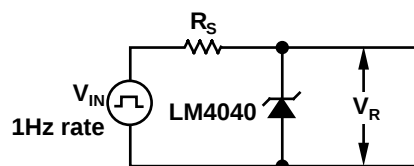
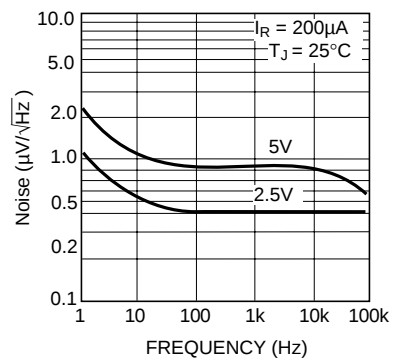
Output Impedance  
vs. Frequency



Reverse Characteristics and  
Minimum Operating Current

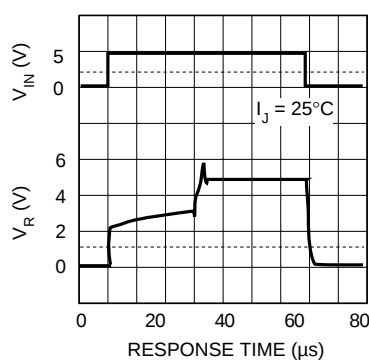


Noise Voltage  
vs. Frequency

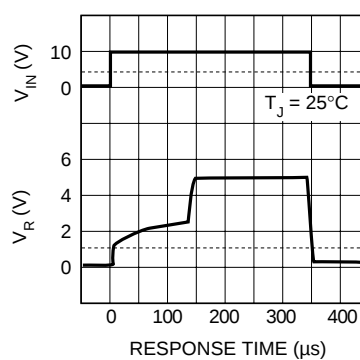


Test Circuit

LM4040-2.5  $R_S = 30k$



LM4040-5.0  $R_S = 30k$



## LM4041-1.2 Electrical Characteristics

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ :** all other limits  $T_A = T_J = 25^\circ\text{C}$ . The grades A, B, C, and D designate initial Reverse Breakdown Voltage tolerance of  $\pm 0.1\%$ ,  $\pm 0.2\%$ ,  $\pm 0.5\%$ , and  $\pm 1.0\%$ , respectively.

| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4041AIM3<br>Limits<br>(Note 5)         | LM4041BIM3<br>Limits<br>(Note 5)          | LM4041CIM3<br>Limits<br>(Note 5)      | Units<br>(Limit)                                                                    |
|-------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------|------------------------------------------|-------------------------------------------|---------------------------------------|-------------------------------------------------------------------------------------|
| $V_R$                   | Reverse Breakdown Voltage                                      | $I_R = 100\mu\text{A}$                                                                         | 1.225               |                                          |                                           |                                       | V                                                                                   |
|                         | Reverse Breakdown Voltage Tolerance                            | $I_R = 100\mu\text{A}$                                                                         |                     | $\pm 1.2$<br><b><math>\pm 9.2</math></b> | $\pm 2.4$<br><b><math>\pm 10.4</math></b> | $\pm 6$<br><b><math>\pm 14</math></b> | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$              | Minimum Operating Current                                      |                                                                                                | 45                  | 60<br><b>65</b>                          | 60<br><b>65</b>                           | 60<br><b>65</b>                       | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_R/\Delta T$   | Average Reverse Breakdown Voltage Temperature Coefficient      | $I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                            | 20<br>15<br>15      | <b><math>\pm 100</math></b>              | <b><math>\pm 100</math></b>               | <b><math>\pm 100</math></b>           | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \leq I_R 1\text{mA}$                                                                 | 0.7                 | 1.5<br><b>2.0</b>                        | 1.5<br><b>2.0</b>                         | 1.5<br><b>2.0</b>                     | mV<br>mV (max)<br>mV (max)                                                          |
|                         |                                                                | $1\text{mA} \leq I_R 15\text{mA}$                                                              | 4.0                 | 6.0<br><b>8.0</b>                        | 6.0<br><b>8.0</b>                         | 6.0<br><b>8.0</b>                     | mV<br>mV (max)<br>mV (max)                                                          |
| $Z_R$                   | Reverse Dynamic Impedance                                      | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$                                  | 0.5                 | 1.5                                      | 1.5                                       | 1.5                                   | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                   | Wideband Noise                                                 | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                               | 20                  |                                          |                                           |                                       | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_R$            | Reverse Breakdown Voltage Long Term Stability                  | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$ | 120                 |                                          |                                           |                                       | ppm                                                                                 |

| Symbol                  | Parameter                                                      | Conditions                                                                                     | Typical<br>(Note 4) | LM4041DIM3<br>Limits<br>(Note 5)       | LM4041EIM3<br>Limits<br>(Note 5)       | Units<br>(Limit)                                                                    |
|-------------------------|----------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------|----------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------|
| $V_R$                   | Reverse Breakdown Voltage                                      | $I_R = 100\mu\text{A}$                                                                         | 1.225               |                                        |                                        | V                                                                                   |
|                         | Reverse Breakdown Voltage Tolerance                            | $I_R = 100\mu\text{A}$                                                                         |                     | $\pm 12$<br><b><math>\pm 24</math></b> | $\pm 25$<br><b><math>\pm 36</math></b> | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$              | Minimum Operating Current                                      |                                                                                                | 45                  | 65<br><b>70</b>                        | 65<br><b>70</b>                        | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_R/\Delta T$   | Average Reverse Breakdown Voltage Temperature Coefficient      | $I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                            | 20<br>15<br>15      | <b><math>\pm 150</math></b>            | <b><math>\pm 150</math></b>            | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $\Delta V_R/\Delta I_R$ | Reverse Breakdown Voltage Change with Operating Current Change | $I_{RMIN} \leq I_R 1\text{mA}$                                                                 | 0.3                 | 2.0<br><b>2.5</b>                      | 2.0<br><b>2.5</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
|                         |                                                                | $1\text{mA} \leq I_R 15\text{mA}$                                                              | 2.5                 | 8.0<br><b>10.0</b>                     | 8.0<br><b>10.0</b>                     | mV<br>mV (max)<br>mV (max)                                                          |
| $Z_R$                   | Reverse Dynamic Impedance                                      | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$                                  | 0.3                 | 2.0                                    | 2.0                                    | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                   | Wideband Noise                                                 | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                               | 35                  |                                        |                                        | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_R$            | Reverse Breakdown Voltage Long Term Stability                  | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$ | 120                 |                                        |                                        | ppm                                                                                 |

## LM4041-Adjustable Electrical Characteristics

**Boldface limits apply for  $T_A = T_J = T_{MIN}$  to  $T_{MAX}$ ;** all other limits  $T_J = 25^\circ\text{C}$  unless otherwise specified (SOT-23, see Note 7),  $I_{RMIN} \leq I_R < 12\text{mA}$ ,  $V_{REF} \leq V_{OUT} \leq 10\text{V}$ . The grades C and D designate initial Reverse Breakdown Voltage tolerance of  $\pm 0.5\%$  and  $\pm 1\%$ , respectively for  $V_{OUT} = 5\text{V}$ .

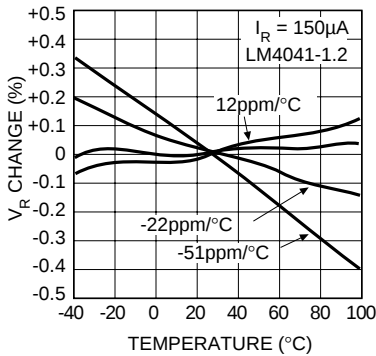
| Symbol                        | Parameter                                                  | Conditions                                                                                                     | Typical<br>(Note 4) | LM4041CIM3<br>Limits<br>(Note 5)        | LM4041DIM3<br>Limits<br>(Note 5)       | Units<br>(Limit)                                                                    |
|-------------------------------|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|---------------------|-----------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------|
| $V_{REF}$                     | Reference Breakdown Voltage                                | $I_R = 100\mu\text{A}$<br>$V_{OUT} = 5\text{V}$                                                                | 1.233               |                                         |                                        | V                                                                                   |
|                               | Reference Breakdown Voltage Tolerance (Note 8)             | $I_R = 100\mu\text{A}$                                                                                         |                     | $\pm 6.2$<br><b><math>\pm 14</math></b> | $\pm 12$<br><b><math>\pm 24</math></b> | mV (max)<br>mV (max)                                                                |
| $I_{RMIN}$                    | Minimum Operating Current                                  |                                                                                                                | 45                  | 60<br><b>65</b>                         | 65<br><b>70</b>                        | $\mu\text{A}$<br>$\mu\text{A}$ (max)<br>$\mu\text{A}$ (max)                         |
| $\Delta V_{REF} / \Delta I_R$ | Reference Voltage Change with Operating Current Change     | $I_{RMIN} \leq I_R 1\text{mA}$<br>SOT-23:<br>$V_{OUT} \geq 1.6\text{V}$<br>(Note 7)                            | 0.7                 | 1.5<br><b>2.0</b>                       | 2.0<br><b>2.5</b>                      | mV<br>mV (max)<br>mV (max)                                                          |
|                               |                                                            | $1\text{mA} \leq I_R 15\text{mA}$<br>SOT-23:<br>$V_{OUT} \geq 1.6\text{V}$<br>(Note 7)                         | 2                   | 4<br><b>6</b>                           | 6<br><b>8</b>                          | mV<br>mV (max)<br>mV (max)                                                          |
| $\Delta V_{REF} / \Delta V_O$ | Reference Voltage Change with Output Voltage Change        | $I_R = 1\text{mA}$                                                                                             | -1.3                | -2.0<br><b>-2.5</b>                     | -2.5<br><b>-3.0</b>                    | mV/V<br>mV/V (max)<br>mV/V (max)                                                    |
| $I_{FB}$                      | Feedback Current                                           |                                                                                                                | 60                  | <b>100</b><br><b>120</b>                | <b>150</b><br><b>200</b>               | nA<br>nA (max)<br>nA (max)                                                          |
| $\Delta V_{REF} / \Delta T$   | Average Reference Voltage Temperature Coefficient (Note 8) | $V_{OUT} = 5\text{V}$<br>$I_R = 10\text{mA}$<br>$I_R = 1\text{mA}$<br>$I_R = 100\mu\text{A}$                   | 20<br>15<br>15      | <b><math>\pm 100</math></b>             | <b><math>\pm 150</math></b>            | ppm/ $^\circ\text{C}$<br>ppm/ $^\circ\text{C}$ (max)<br>ppm/ $^\circ\text{C}$ (max) |
| $Z_{OUT}$                     | Dynamic Output Impedance                                   | $I_R = 1\text{mA}$ , $f = 120\text{Hz}$<br>$I_{AC} = 0.1 I_R$<br>$V_{OUT} = V_{REF}$<br>$V_{OUT} = 10\text{V}$ | 0.3<br>2            |                                         |                                        | $\Omega$<br>$\Omega$ (max)                                                          |
| $e_N$                         | Wideband Noise                                             | $I_R = 100\mu\text{A}$<br>$10\text{Hz} \leq f \leq 10\text{kHz}$                                               | 20                  |                                         |                                        | $\mu\text{V}_{RMS}$                                                                 |
| $\Delta V_{REF}$              | Reference Voltage Long Term Stability                      | $t = 1000\text{hrs}$<br>$T = 25^\circ\text{C} \pm 0.1^\circ\text{C}$<br>$I_R = 100\mu\text{A}$                 | 120                 |                                         |                                        | ppm                                                                                 |

## LM4040 and LM4041 Electrical Characteristic Notes

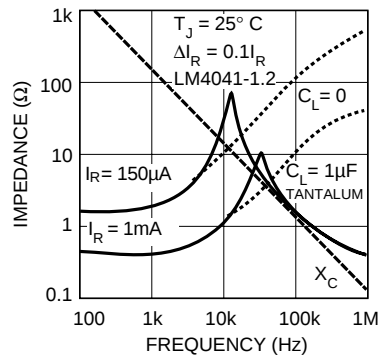
- Note 1.** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. For guaranteed specification and test conditions, see the Electrical Characteristics. 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),  $\theta_{JA}$  (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 ( $\theta_{JA}$ ), when board mounted, is  $326^\circ\text{C/W}$  for the SOT-23 package.
- Note 3.** The human body model is a 100pF capacitor discharged through a 1.5k $\Omega$  resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.
- Note 4.** Typicals are at  $T_J = 25^\circ\text{C}$  and represent most likely parametric norm.
- Note 5.** Limits are 100% production tested at  $25^\circ\text{C}$ . Limits over temperature are guaranteed through correlation using Statistical Quality Control (SQL) methods.
- Note 6.** The boldface (over temperature limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance  $\pm[(\Delta V_R/\Delta T)(65^\circ\text{C})(V_R)]$ .  $\Delta V_R/\Delta T$  is the  $V_R$  temperature coefficient,  $65^\circ\text{C}$  is the temperature range from  $-40^\circ\text{C}$  to the reference point of  $25^\circ\text{C}$ , and  $V_R$  is the reverse breakdown voltage. The total over temperature tolerance for the different grades follows:  
 A-grade:  $\pm 0.75\% = \pm 0.1\% \pm 100\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$   
 B-grade:  $\pm 0.85\% = \pm 0.2\% \pm 100\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$   
 C-grade:  $\pm 1.15\% = \pm 0.5\% \pm 100\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$   
 D-grade:  $\pm 1.98\% = \pm 1.0\% \pm 150\text{ppm}/^\circ\text{C} \times 65^\circ\text{C}$   
 Example: The A-grade LM4040-2.5 has an over temperature Reverse Breakdown Voltage tolerance of  $\pm 2.5 \times 0.75\% = \pm 19\text{mV}$ .
- Note 7.** When  $V_{OUT} \leq 1.6\text{V}$ , 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 8.** Reference voltage and temperature coefficient will change with output voltage. See Typical Performance Characteristics curves.

## LM4041 Typical Characteristics

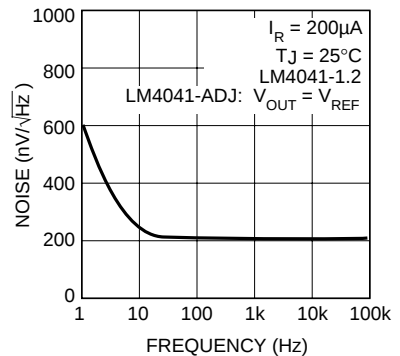
Temperature Drift for Different Average Temperature Coefficient



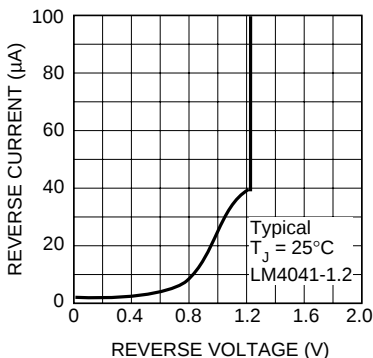
Output Impedance vs. Frequency



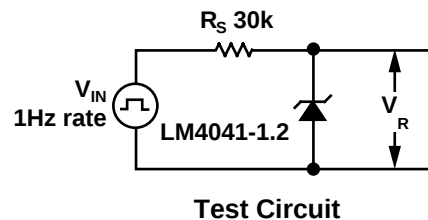
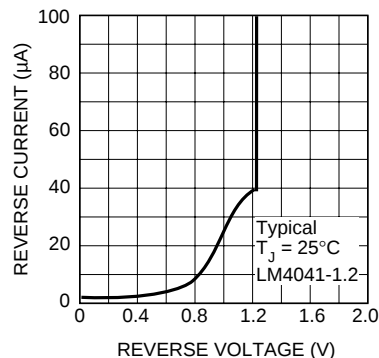
Voltage Impedance



Reverse Characteristics and Minimum Operating Current

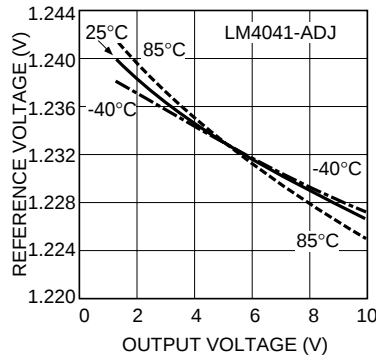


Reverse Characteristics and Minimum Operating Current

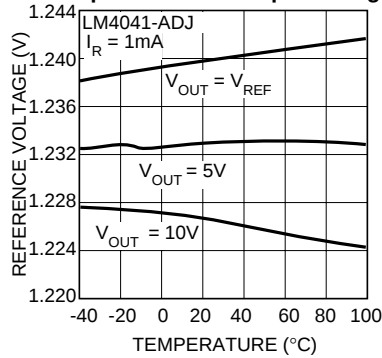


## LM4041 Typical Characteristics

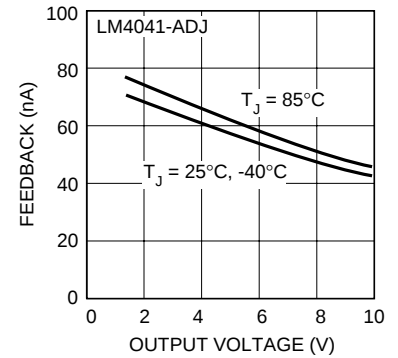
Reference Voltage vs. Output Voltage and Temperature



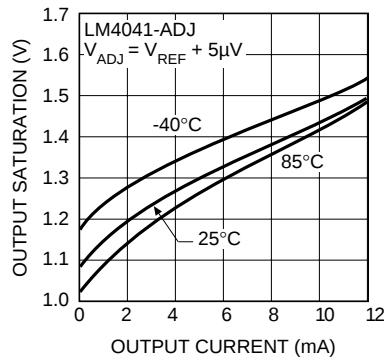
Reference Voltage vs. Temperature and Output Voltage



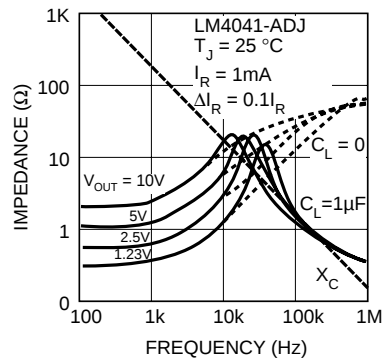
Feedback Current vs. Output Voltage and Temperature



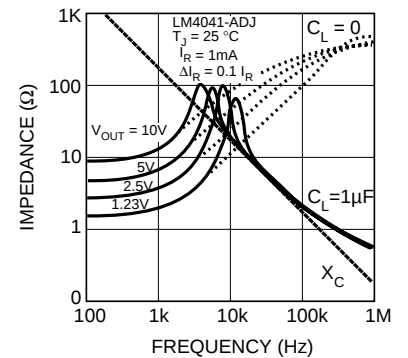
Output Saturation



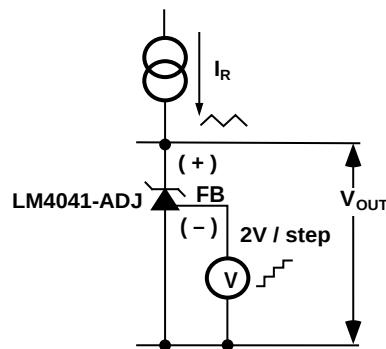
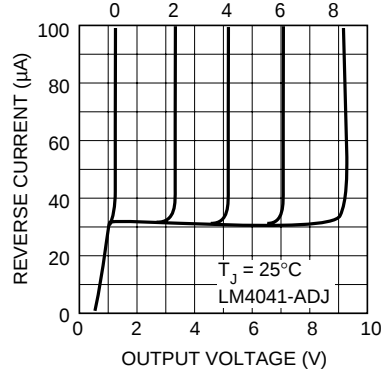
Output Impedance vs. Frequency \*



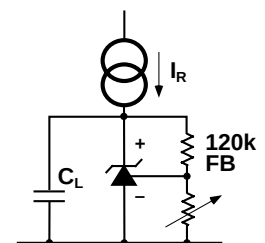
Output Impedance vs. Frequency \*



Reverse Characteristics †

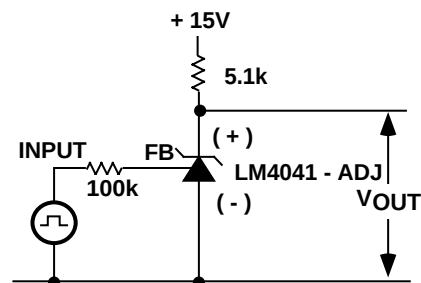
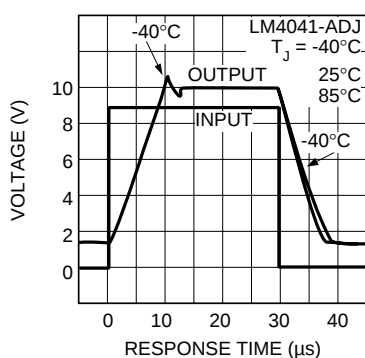


† Reverse Characteristics Test Circuit



\* Output Impedance vs. Freq. Test Circuit

Large Signal Response ‡



‡ Large Signal Response Test Circuit

## Applications Information

The LM4040 and LM4041 have been designed for stable operation without the need of an external capacitor connected between the (+) and (–) pins. If a bypass capacitor is used, the references remain stable.

### 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 1. 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 ( $V_R$ ).

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

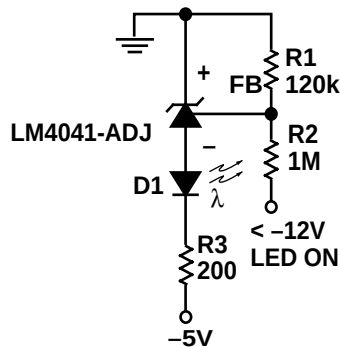


Figure 3. Voltage Level Detector

### 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

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

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

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

where  $V_O$  is the desired output voltage.  $\Delta V_{REF} / \Delta V_O$  is found in the Electrical Characteristics and is typically  $-1.3\text{mV/V}$  and  $V_Y$  is equal to  $1.233\text{V}$ . Replace the value of  $V_{REF}'$  in equation (1) with the value 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  $-2.5\text{mV/V}$  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  $1.223\text{V}$ . Choosing a value of  $R1 = 10\text{k}\Omega$ ,  $R2 = 63.272\text{k}\Omega$ . Using the worst case  $\Delta V_{REF} / \Delta V_O$  for the C-grade and D-grade parts, the output voltage is actually  $8.965\text{V}$  and  $8.946\text{V}$  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.

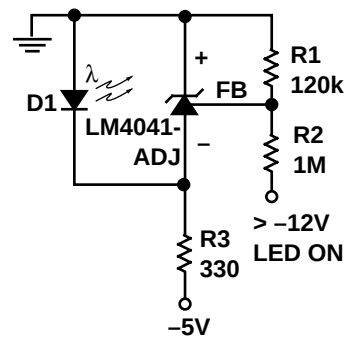
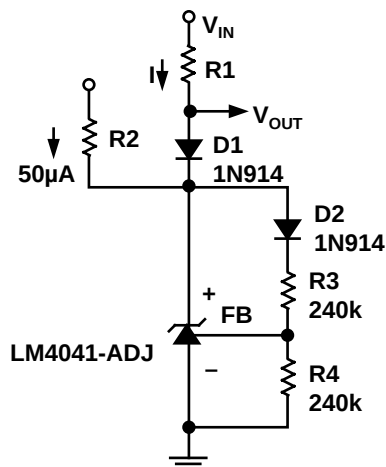
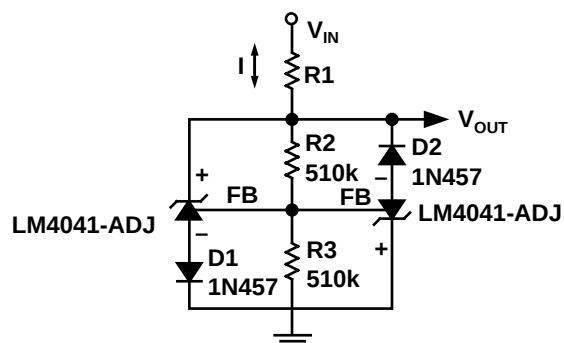


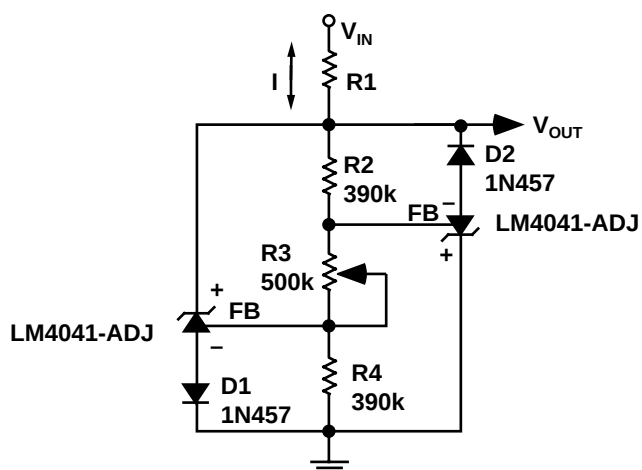
Figure 4. Voltage Level Detector



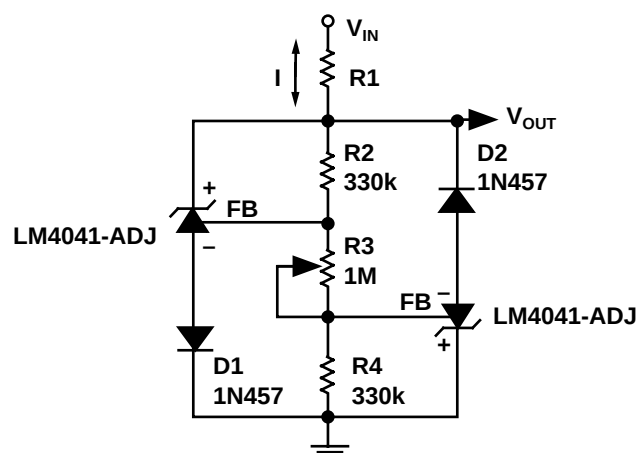
**Figure 5. Fast Positive Clamp**  
 $2.4V + \Delta V_{D1}$



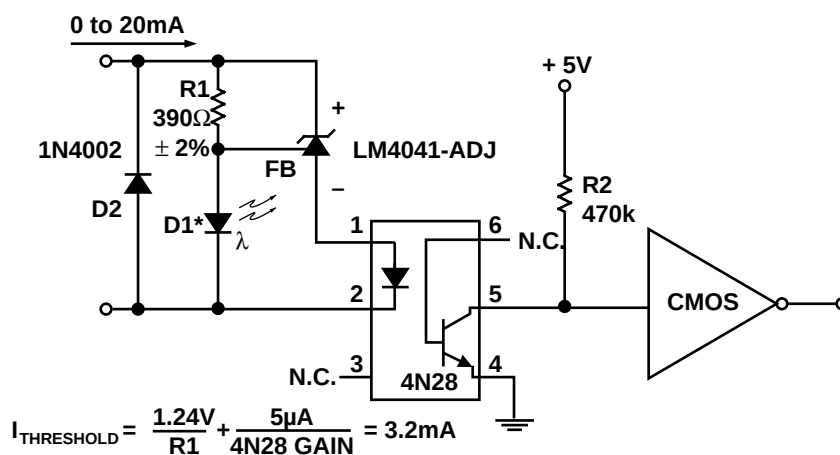
**Figure 6. Bidirectional Clamp**  
 **$\pm 2.4V$**



**Figure 7. Bidirectional Adjustable Clamp  
 $\pm 18V$  to  $\pm 2.4V$**



**Figure 8. Bidirectional Adjustable Clamp  
 $\pm 2.4$  to  $\pm 6V$**



### Figure 9. Floating Current Detector

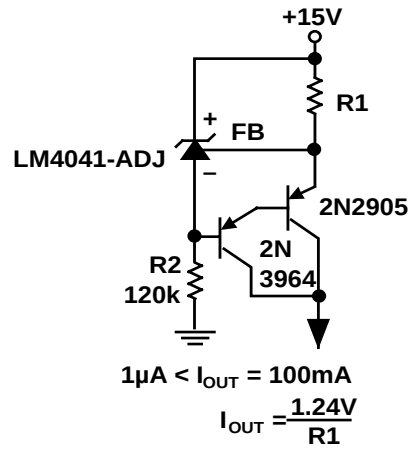


Figure 10. Current Source

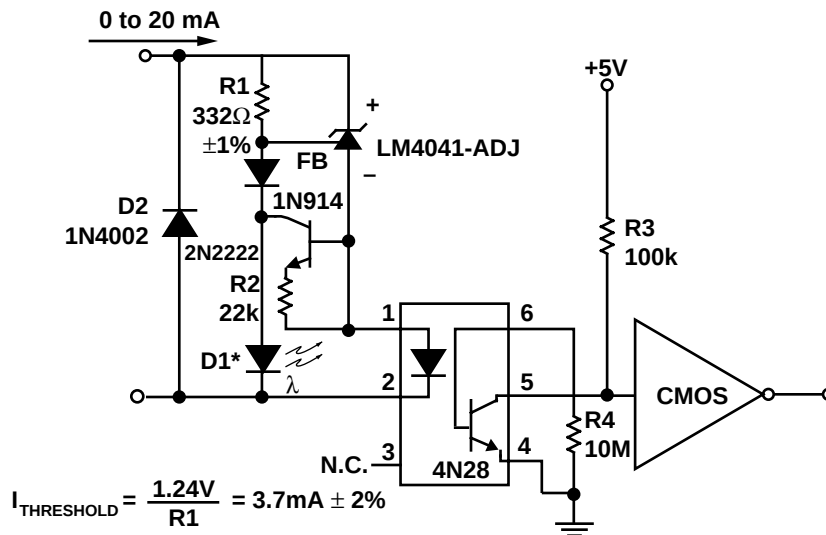
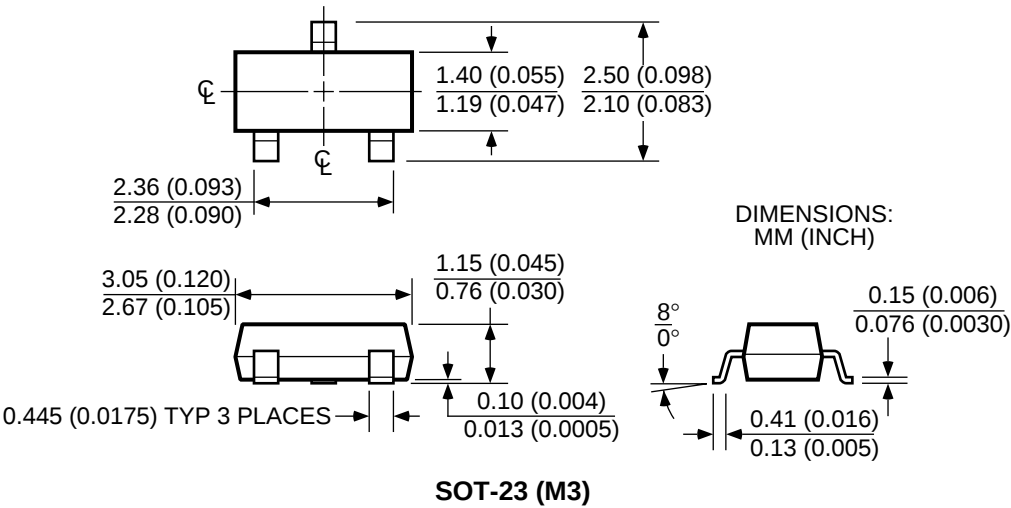


Figure 11. Precision Floating Current Detector

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

Package Information



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