



## LM4040/LM4041

### Precision Micropower Shunt Voltage Reference

#### General Description

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

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

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

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

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

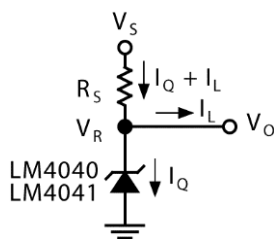
#### Features

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

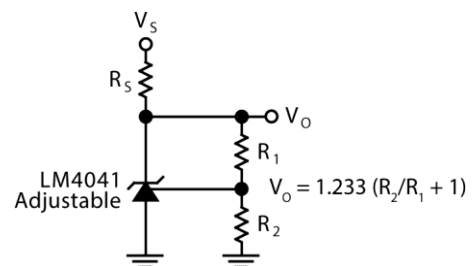
#### Applications

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

#### Typical Application



LM4040, LM4041 Fixed Shunt Regulator Application

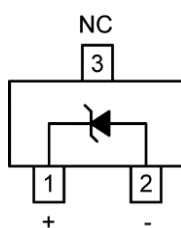


LM4041 Adjustable Shunt Regulator Application

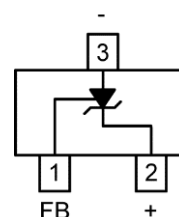
## Ordering Information

| Part Number    | Marking | Voltage      | Accuracy, Temp. Coefficient | Package      |
|----------------|---------|--------------|-----------------------------|--------------|
| LM4040CYM3-2.5 | Y2C     | 2.500V       | ±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<br>Fixed | Pin Number<br>Adjustable | Pin Name | Pin Function                                                                        |
|---------------------|--------------------------|----------|-------------------------------------------------------------------------------------|
| 1                   | 2                        | +        | Cathode, connect to positive voltage.                                               |
| -                   | 1                        | FB       | Feedback, connect to a resistive divider network to set the output voltage.         |
| 2                   | 3                        | -        | Anode, connect to negative voltage.                                                 |
| 3                   | -                        | NC       | Not internally connected. This pin must be left floating or connected to – (Pin 2). |

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

|                                                                |                 |
|----------------------------------------------------------------|-----------------|
| Reverse Current.....                                           | 20mA            |
| Forward Current.....                                           | 10mA            |
| Maximum Output Voltage (LM4041-ADJ).....                       | 15V             |
| Lead Temperature                                               |                 |
| Vapor phase (60s) .....                                        | 215°C           |
| Infrared (15s) .....                                           | 220°C           |
| Power Dissipation (T <sub>A</sub> = 25°C) <sup>(3)</sup> ..... | 306mW           |
| Storage Temperature (T <sub>S</sub> ).....                     | –65°C to +150°C |
| ESD Susceptibility                                             |                 |
| Human Body Model <sup>(4)</sup> .....                          | 2kV             |
| Machine Model <sup>(4)</sup> .....                             | 200V            |

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

|                                                     |                |
|-----------------------------------------------------|----------------|
| Operating Temperature Range (T <sub>A</sub> ) ..... | –40°C to +85°C |
| Reverse Current                                     |                |
| LM4040-2.5.....                                     | 60μA to 15mA   |
| LM4040-4.1.....                                     | 68μA to 15mA   |
| LM4040-5.0.....                                     | 74μA to 15mA   |
| LM4041-1.2.....                                     | 60μA to 12mA   |
| LM4041-ADJ.....                                     | 60μA to 12mA   |
| Output Voltage Range                                |                |
| LM4041-ADJ.....                                     | 1.24V to 10V   |
| Thermal Resistance                                  |                |
| 3-Pin SOT-23 (Θ <sub>JA</sub> ).....                | 326°C/W        |

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

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

| Symbol                           | Parameter                                                      | Condition                                                            | Min. | Typ.  | Max.        | Units             |
|----------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------|------|-------|-------------|-------------------|
| <b>LM4040C</b>                   |                                                                |                                                                      |      |       |             |                   |
| V <sub>R</sub>                   | Reverse Breakdown Voltage                                      | I <sub>R</sub> = 100μA                                               |      | 2.500 |             | V                 |
|                                  | Reverse Breakdown Voltage Tolerance <sup>(6)</sup>             |                                                                      |      |       | ±12         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>±29</b>  | mV                |
| I <sub>RMIN</sub>                | Minimum Operating Current                                      |                                                                      |      | 45    | 60          | μA                |
|                                  |                                                                |                                                                      |      |       | <b>65</b>   | μA                |
| ΔV <sub>R</sub> /ΔT              | Average Reverse Breakdown Voltage Temperature Coefficient      | I <sub>R</sub> = 10mA                                                |      | ±20   |             | ppm/°C            |
|                                  |                                                                | I <sub>R</sub> = 1mA                                                 |      | ±15   | <b>±100</b> | ppm/°C            |
|                                  |                                                                | I <sub>R</sub> = 100μA                                               |      | ±15   |             | ppm/°C            |
| ΔV <sub>R</sub> /ΔI <sub>R</sub> | Reverse Breakdown Voltage Change with Operating Current Change | I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA                             |      | 0.3   | 0.8         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>1.0</b>  | mV                |
|                                  |                                                                | 1mA ≤ I <sub>R</sub> ≤ 15mA                                          |      | 2.5   | 6.0         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>8.0</b>  | mV                |
| Z <sub>R</sub>                   | Reverse Dynamic Impedance                                      | I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub> |      | 0.3   | 0.9         | Ω                 |
| e <sub>N</sub>                   | Wideband Noise                                                 | I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz                             |      | 35    |             | μV <sub>RMS</sub> |
| ΔV <sub>R</sub>                  | Reverse Breakdown Voltage Long Term Stability                  | t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA                |      | 120   |             | ppm               |

**Notes:**

- Exceeding the absolute maximum ratings may damage the device.
- The device is not guaranteed to function outside its operating ratings.
- The maximum power dissipation must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub> (maximum junction temperature), Θ<sub>JA</sub> (junction to ambient thermal resistance), and T<sub>A</sub> (ambient temperature). The maximum allowable power dissipation at any temperature is PD<sub>MAX</sub> = (T<sub>JMAX</sub> – T<sub>A</sub>)/Θ<sub>JA</sub> or the number given in the Absolute Maximum Ratings, whichever is lower. For the LM4040 and LM4041, T<sub>JMAX</sub> = 125°C and the typical thermal resistance, when board-mounted, is 326°C/W for the SOT-23 package.
- Devices are ESD sensitive. Handling precautions are recommended. Human body model, 1.5kΩ in series with 100pF. The machine model is a 200pF capacitor discharged directly into each pin.
- Specification for packaged product only.
- The boldface (overtemperature) limit for Reverse Breakdown Voltage Tolerance is defined as the room temperature Reverse Breakdown Voltage Tolerance ±[(ΔV<sub>R</sub>/ΔT)(65°C)(V<sub>R</sub>)]. ΔV<sub>R</sub>/ΔT is the V<sub>R</sub> temperature coefficient, 65°C is the temperature range from –40°C to the reference point of 25°C, and V<sub>R</sub> is the reverse breakdown voltage. The total overtemperature tolerance for the different grades follows:
  - C-grade: ±1.15% = ±0.5% ±100ppm/°C × 65°C
  - D-grade: ±1.98% = ±1.0% ±150ppm/°C × 65°C
 Example: The C-grade LM4040-2.5 has an overtemperature Reverse Breakdown Voltage tolerance of ±2.5 × 1.15% = ±29mV.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

| Symbol                           | Parameter                                                      | Condition                                                            | Min. | Typ.  | Max.        | Units             |
|----------------------------------|----------------------------------------------------------------|----------------------------------------------------------------------|------|-------|-------------|-------------------|
| <b>LM4041D</b>                   |                                                                |                                                                      |      |       |             |                   |
| V <sub>R</sub>                   | Reverse Breakdown Voltage                                      | I <sub>R</sub> = 100μA                                               |      | 1.225 |             | V                 |
|                                  | Reverse Breakdown Voltage Tolerance <sup>(6)</sup>             |                                                                      |      |       | ±12         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>±24</b>  | mV                |
| I <sub>RMIN</sub>                | Minimum Operating Current                                      |                                                                      |      | 45    | 65          | μA                |
|                                  |                                                                |                                                                      |      |       | <b>70</b>   | μA                |
| ΔV <sub>R</sub> /ΔT              | Average Reverse Breakdown Voltage Temperature Coefficient      | I <sub>R</sub> = 10mA                                                |      | ±20   |             | ppm/°C            |
|                                  |                                                                | I <sub>R</sub> = 1mA                                                 |      | ±15   | <b>±150</b> | ppm/°C            |
|                                  |                                                                | I <sub>R</sub> = 100μA                                               |      | ±15   |             | ppm/°C            |
| ΔV <sub>R</sub> /ΔI <sub>R</sub> | Reverse Breakdown Voltage Change with Operating Current Change | I <sub>RMIN</sub> ≤ I <sub>R</sub> ≤ 1mA                             |      | 0.7   | 2.0         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>2.5</b>  | mV                |
|                                  |                                                                | 1mA ≤ I <sub>R</sub> ≤ 15mA                                          |      | 2.5   | 8.0         | mV                |
|                                  |                                                                |                                                                      |      |       | <b>10.0</b> | mV                |
| Z <sub>R</sub>                   | Reverse Dynamic Impedance                                      | I <sub>R</sub> = 1mA, f = 120Hz, I <sub>AC</sub> = 0.1I <sub>R</sub> |      | 0.5   | 2.0         | Ω                 |
| e <sub>N</sub>                   | Wideband Noise                                                 | I <sub>R</sub> = 100μA, 10Hz ≤ f ≤ 10kHz                             |      | 20    |             | μV <sub>RMS</sub> |
| ΔV <sub>R</sub>                  | Reverse Breakdown Voltage Long Term Stability                  | t = 1000hrs., T = 25°C ±0.1°C, I <sub>R</sub> = 100μA                |      | 120   |             | ppm               |

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

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

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

### Note:

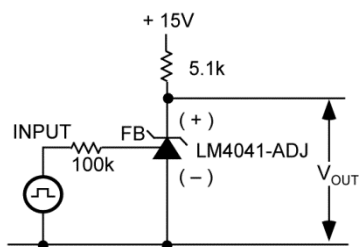
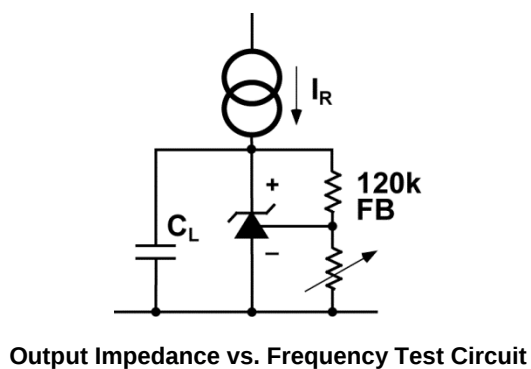
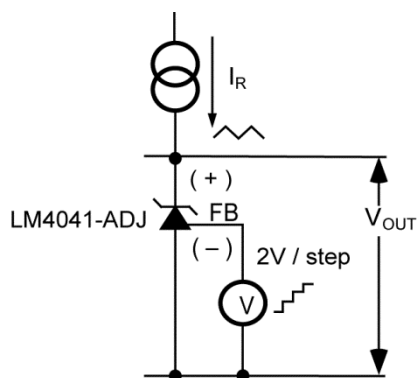
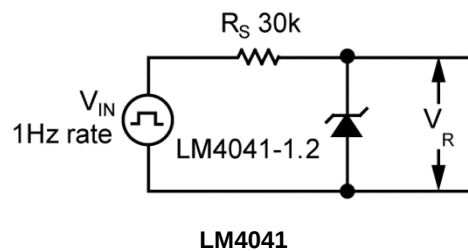
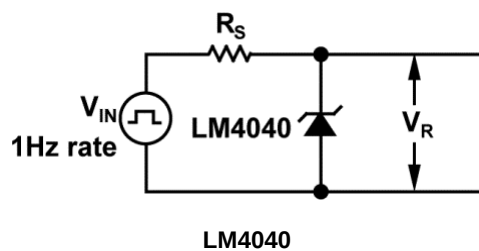
7. When V<sub>OUT</sub> ≤ 1.6V, the LM4041-ADJ must operate at reduced I<sub>R</sub>. This is caused by the series resistance of the die attach between the die (-) output and the package (-) output pin. See the Output Saturation curve in the "Typical Performance Characteristics" section.

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

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

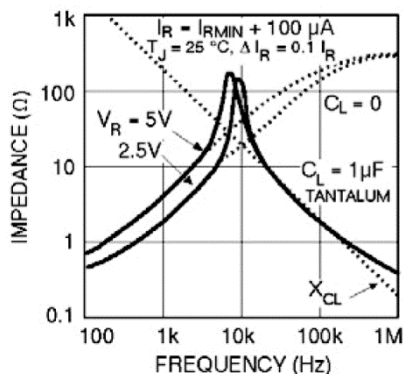
| Symbol                                 | Parameter                                           | Condition                                                                                                   | Min. | Typ.  | Max.        | Units             |
|----------------------------------------|-----------------------------------------------------|------------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

## Test Circuit

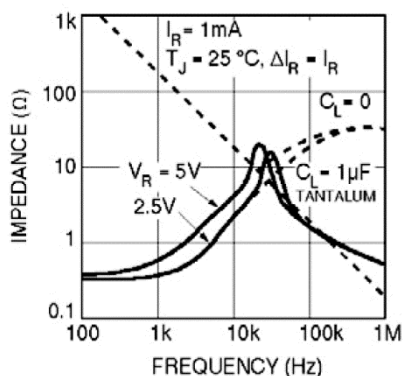


## LM4040 Typical Characteristics

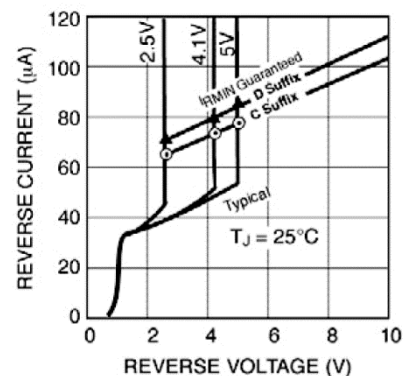
**Output Impedance  
vs. Frequency**



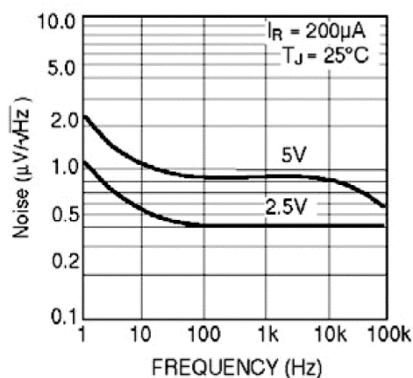
**Output Impedance  
vs. Frequency**



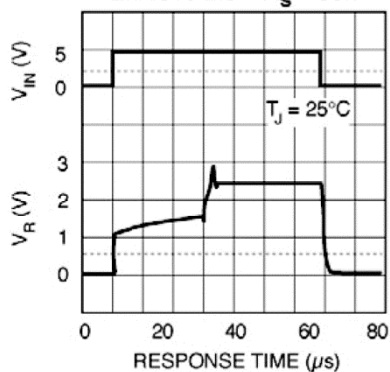
**Reverse Characteristics and  
Minimum Operating Current**



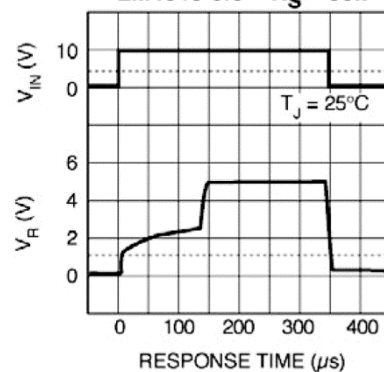
**Noise Voltage  
vs. Frequency**



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

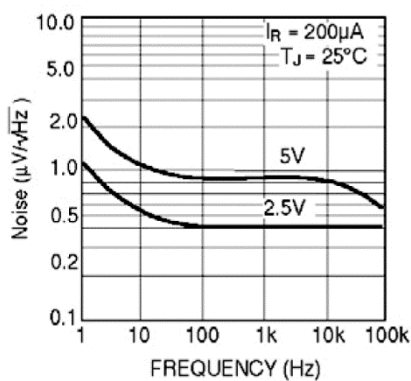


**Start-up Characteristics  
LM4040-5.0  $R_S = 30k$**

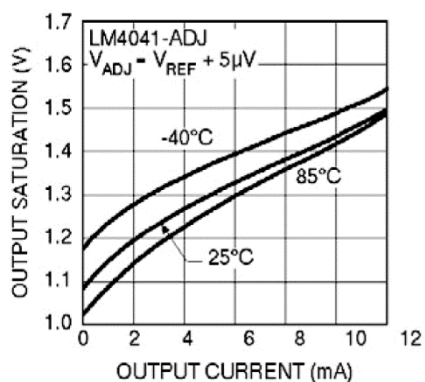


## LM4041 Typical Characteristics

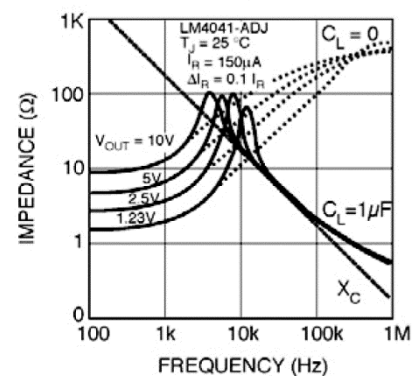
**Noise Voltage  
vs. Frequency**



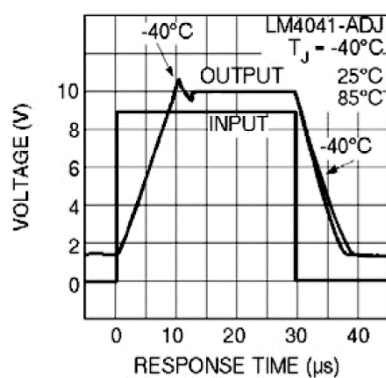
**Output Saturation**



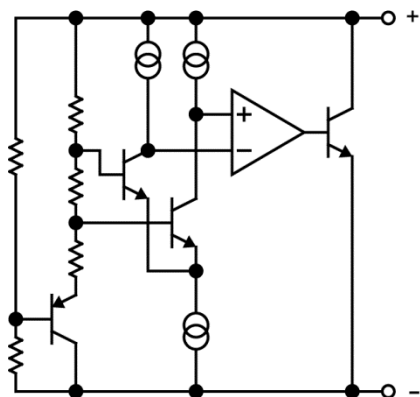
**Output Impedance  
vs. Frequency \***



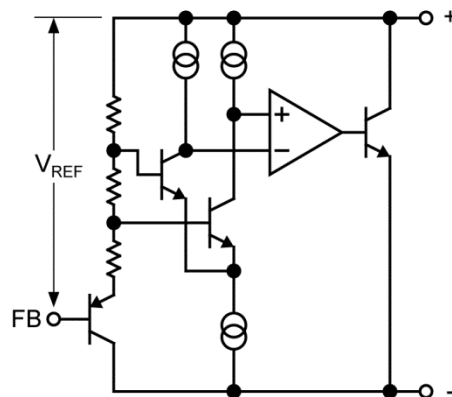
**Large Signal Response ‡**



## Functional Diagrams



LM4040, LM4041 Fixed



LM4041 Adjustable

## Applications Information

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

### Schottky Diode

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

### Conventional Shunt Regulator

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

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

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

### Adjustable Regulator

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

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

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

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

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

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

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

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

## Typical Application Circuits

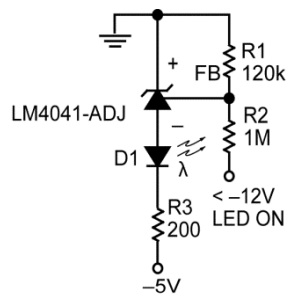


Figure 1. Voltage Level Detector

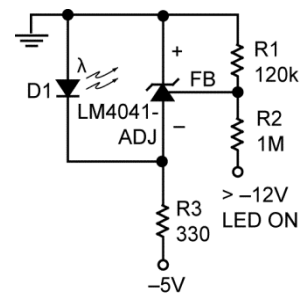
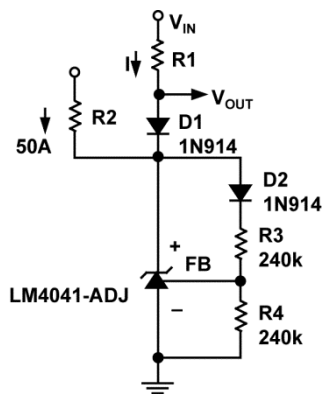
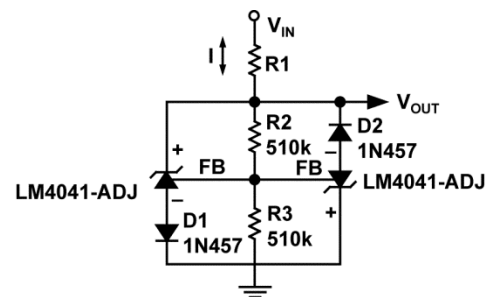
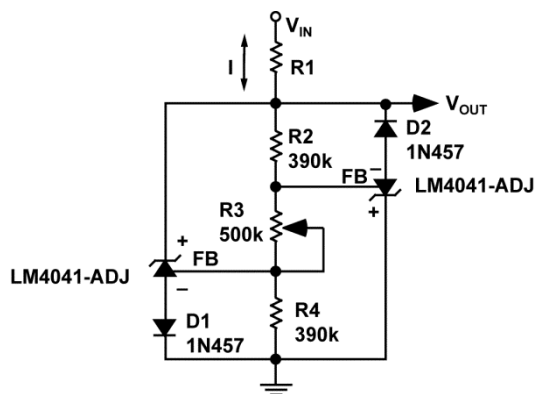
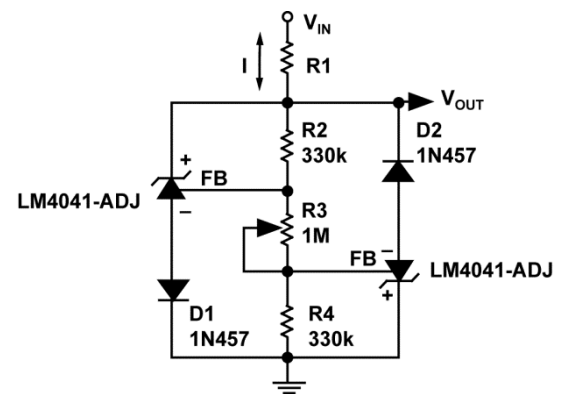
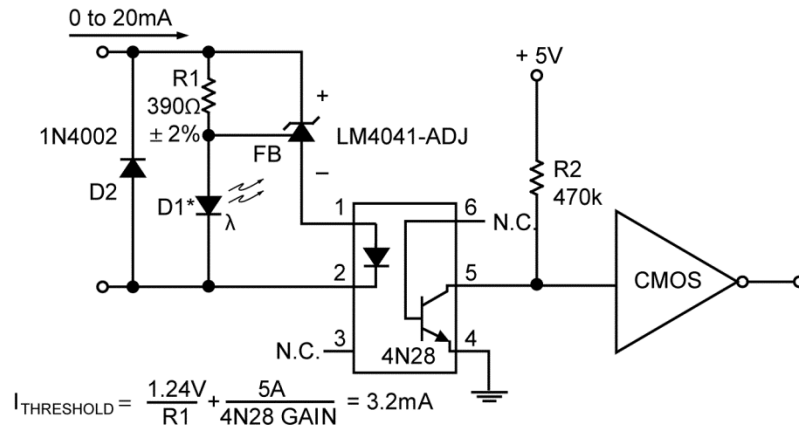


Figure 2. Voltage Level Detector

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

## Typical Application Circuits (Continued)



\* 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  $I = 0$ .

Figure 7. Floating Current Detector

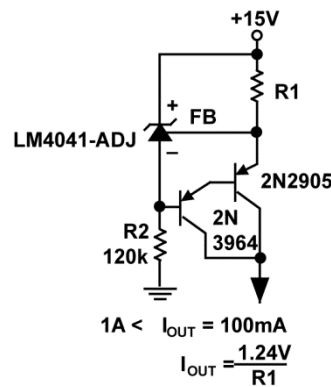
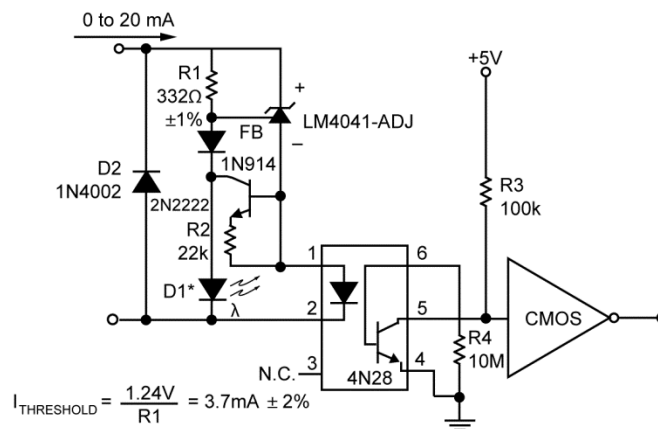


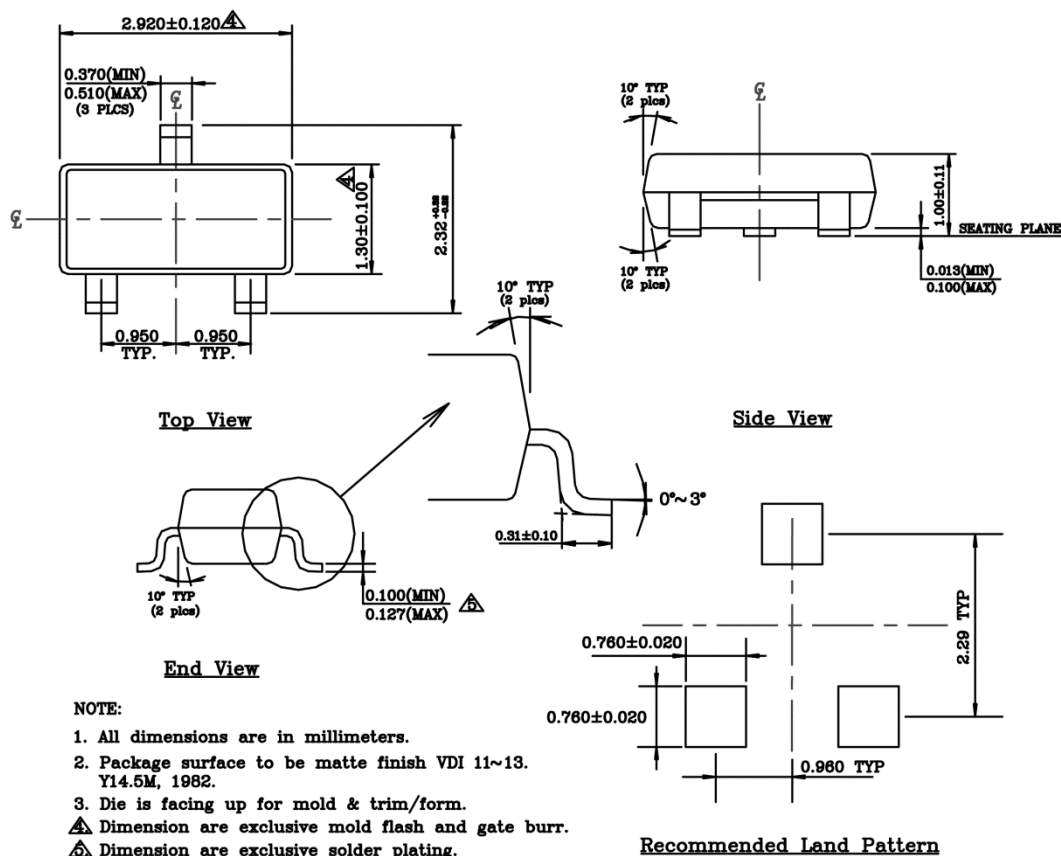
Figure 8. Current Source



\* 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  $I = 0$ .

Figure 9. Precision Floating Current Detector

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



3-Pin SOT-23 (M3)

### Note:

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

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