

## LM4040

### PRECISION MICROPOWER SHUNT VOLTAGE REFERENCES

#### Description

The LM4040 is a family of bandgap circuits designed to achieve precision micro-power voltage references of 2.5V, 3.0V and 5.0V. The devices are available in 0.2% B-grade, 0.5% C-grade and 1% D-grade initial tolerances.

They are available in small outline SOT23 and SC70-5 surface mount packages which are ideal for applications where space is at a premium.

Excellent performance is maintained over the 60µA to 15mA operating current range with a typical temperature coefficient of only 20ppm/°C. The device has been designed to be highly tolerant of capacitive loads so maintaining excellent stability.

This device offers a pin for pin compatible alternative to the LM4040 voltage reference.

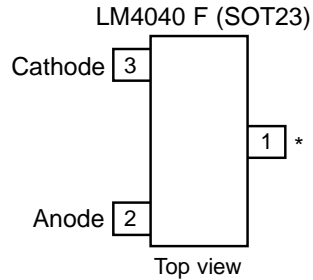
#### Features

- Small packages: SOT23 & SC70-5
- No output capacitor required
- Output voltage tolerance
  - LM4040B ±0.2% at 25°C
  - LM4040C ±0.5% at 25°C
  - LM4040D ±1% at 25°C
- Low output noise
- (10Hz to 10kHz) ..... 45µV<sub>RMS</sub>
- Wide operating current range 60µA to 15mA
- Extended temperature range -40°C to +125°C
- Low temperature coefficient 100 ppm/°C (max)

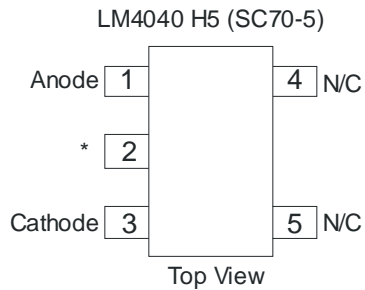
#### Applications

- Battery powered equipment
- Precision power supplies
- Portable instrumentation
- Portable communications devices
- Notebook and palmtop computers
- Data acquisition systems

#### Pin Assignments



\* Pin 1 must be left floating or connected to pin 2



\* Pin 2 must be left floating or connected to pin 1

### Absolute Maximum Ratings (Voltages to GND Unless Otherwise Stated)

| Parameter                      | Rating     | Unit |
|--------------------------------|------------|------|
| Continuous Reverse Current     | 20         | mA   |
| Continuous Forward Current     | 10         | mA   |
| Operating Junction Temperature | -40 to 150 | °C   |
| Storage Temperature            | -55 to 150 | °C   |

Operation above the absolute maximum rating may cause device failure. Operation at the absolute maximum rating, for extended periods, may reduce device reliability.

Unless otherwise stated voltages specified are relative to the ANODE pin.

### Package Thermal Data

| Package | $\theta_{JA}$ | $P_{DIS}$<br>$T_{AMB} = 25^{\circ}C, T_J = 150^{\circ}C$ |
|---------|---------------|--|
| SOT23   | 380°C/W       | 330mW  |
| SC70-5  | 380°C/W       | 330mW  |

### Recommended Operating Conditions

|                                     | Min. | Max. | Units |
|-------------------------------------|------|------|-------|
| Reverse Current                     | 0.06 | 15   | mA    |
| Operating Ambient Temperature Range | -40  | 125  | °C    |

### Electrical Characteristics (Test conditions: $T_{amb} = 25^{\circ}C$ , unless otherwise specified.)

#### LM4040-2.5

| Symbol                  | Parameter                             | Conditions                                   |   | Typ.         | LM4040<br>B Limits | LM4040<br>C Limits | LM4040<br>D Limits | Units             |        |
|-------------------------|---------------------------------------|--|---|--------------|--------------------|--------------------|--------------------|-------------------|--------|
|                         |                                       | $I_R$  | $T_{AMB}$   |              |                    |                    |                    |                   |        |
| $V_{REF}$               | Reverse breakdown voltage             | $I_R = 100\mu A$                             | 25°C  | 2.5          |                    |                    |                    | V                 |        |
|                         | Reverse breakdown voltage tolerance   | $I_R = 100\mu A$                             | 25°C<br>-40 to 85°C<br>-40 to 125°C                       |              | ±5<br>±21<br>±30   | ±12<br>±29<br>±38  | ±25<br>±49<br>±63  | mV                |        |
| $I_{RMIN}$              | Minimum operating current             |  | 25°C<br>-40 to 85°C<br>-40 to 125°C                       | 45           | 60<br>65<br>68     | 60<br>65<br>68     | 65<br>70<br>73     | µA                |        |
|                         |                                       | $\Delta V_R/\Delta T$                        | Average reverse breakdown voltage temperature coefficient | $I_R = 10mA$ | -40 to 125°C       | ±20<br>±15<br>±15  | ±100<br>±100       | ±150              | ppm/°C |
|                         |                                       |  |   | $I_R = 1mA$  |                    |                    |                    |                   |        |
| $I_R = 100\mu A$        |                                       |  |   |              |                    |                    |                    |                   |        |
| $\Delta V_R/\Delta I_R$ | Reverse breakdown change with current | $I_{RMIN} < I_R < 1mA$                       | 25°C  | 0.3          | 0.8                | 0.8                | 1.0                | mV                |        |
|                         |                                       |  | -40 to 85°C   |              | 1.0                | 1.0                | 1.2                |                   |        |
|                         |                                       |  | -40 to 125°C  |              | 1.0                | 1.0                | 1.2                |                   |        |
|                         |                                       | $1mA < I_R < 15mA$                           | 25°C  | 2.5          | 6.0                | 6.0                | 8.0                |                   |        |
|                         |                                       |  | -40 to 85°C   |              | 8.0                | 8.0                | 10.0               |                   |        |
|                         |                                       |  | -40 to 125°C  |              | 8.0                | 8.0                | 10.0               |                   |        |
| $Z_R$                   | Dynamic output impedance              | $I_R = 1mA, f = 120Hz$<br>$I_{AC} = 0.1I_R$  |   | 0.3          | 0.8                | 0.9                | 1.1                | Ω                 |        |
| $e_n$                   | Noise voltage                         | $I_R = 100\mu A$<br>10Hz < f < 10kHz         |   | 35           |                    |                    |                    | µV <sub>RMS</sub> |        |
| $V_R$                   | Long term stability (non cumulative)  | t = 1000Hrs $I_R = 100\mu A$                 |   | 120          |                    |                    |                    | ppm               |        |
| $V_{HYST}$              | Thermal hysteresis                    | $\Delta T = -40^{\circ}C$ to $=125^{\circ}C$ |   | 0.08         |                    |                    |                    | %                 |        |

**Electrical Characteristics (Continued)** (Test conditions:  $T_{amb} = 25^{\circ}\text{C}$ , unless otherwise specified.)

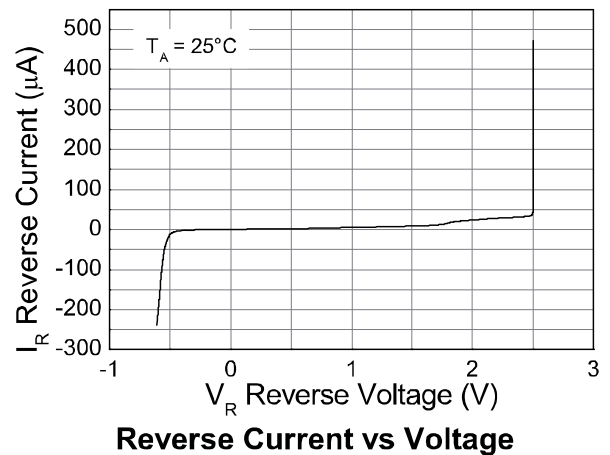
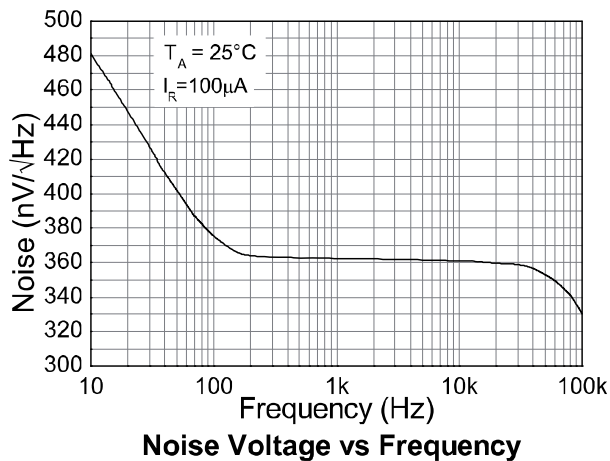
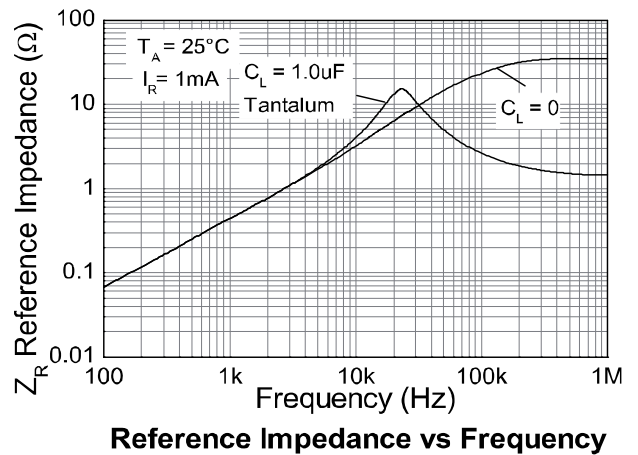
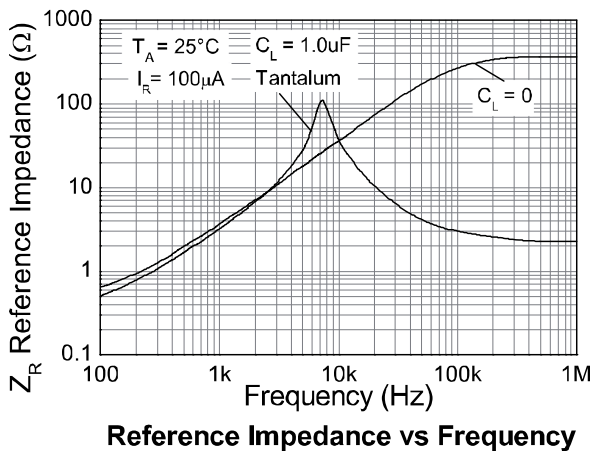
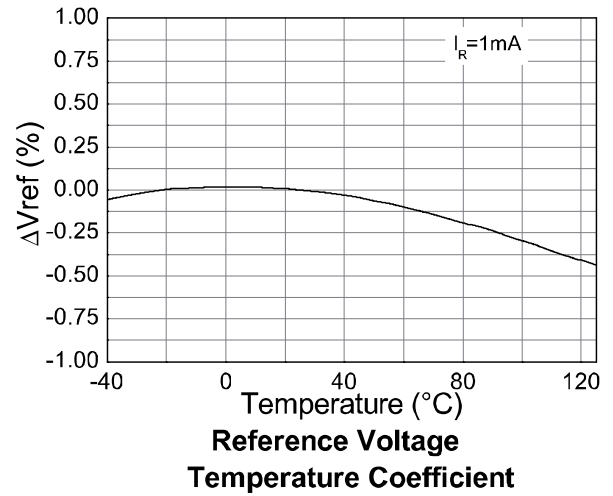
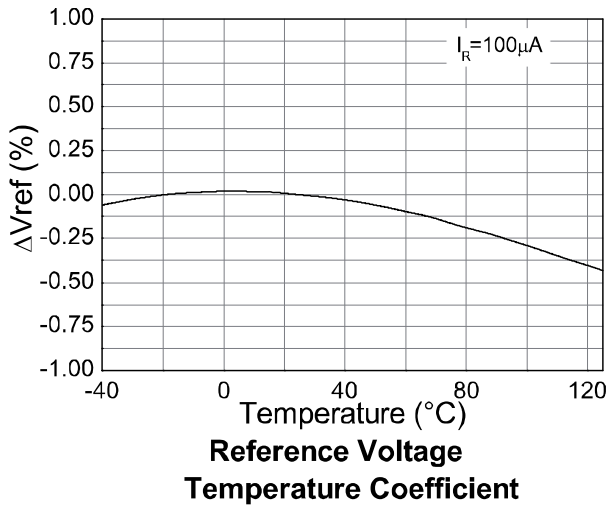
**LM4040-3.0**

| Symbol                  | Parameter   | Conditions   |                              | Typ.     | LM4040 B Limits | LM4040 C Limits | LM4040 D Limits | Units                   |
|-------------------------|---|--|------------------------------|----------|-----------------|-----------------|-----------------|-------------------------|
|                         |   |  | $T_{AMB}$                    |          |                 |                 |                 |                         |
| $V_{REF}$               | Reverse breakdown voltage                                 | $I_R = 100\mu\text{A}$                                     | $25^{\circ}\text{C}$         | 3.0      |                 |                 |                 | V                       |
|                         | Reverse breakdown voltage tolerance                       | $I_R = 100\mu\text{A}$                                     | $25^{\circ}\text{C}$         |          | $\pm 6$         | $\pm 15$        | $\pm 30$        | mV                      |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | $\pm 26$        | $\pm 34$        | $\pm 59$        |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | TBD             | $\pm 45$        | $\pm 75$        |                         |
| $I_{RMIN}$              | Minimum operating current                                 |  | $25^{\circ}\text{C}$         | 47       | 62              | 62              | 67              | $\mu\text{A}$           |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 67              | 67              | 72              |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 70              | 70              | 75              |                         |
| $\Delta V_R/\Delta T$   | Average reverse breakdown voltage temperature coefficient | $I_R = 10\text{mA}$  | -40 to $125^{\circ}\text{C}$ | $\pm 20$ |                 |                 |                 | ppm/ $^{\circ}\text{C}$ |
|                         |   | $I_R = 1\text{mA}$   |                              | $\pm 15$ | $\pm 100$       | $\pm 100$       | $\pm 150$       |                         |
|                         |   | $I_R = 100\mu\text{A}$                                     |                              | $\pm 15$ |                 |                 |                 |                         |
| $\Delta V_R/\Delta I_R$ | Reverse breakdown change with current                     | $I_{RMIN} < I_R < 1\text{mA}$                              | $25^{\circ}\text{C}$         | 0.4      | 0.8             | 0.8             | 1.0             | mV                      |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 1.1             | 110             | 1.3             |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 1.1             | 1.1             | 1.3             |                         |
|                         |   | $1\text{mA} < I_R < 15\text{mA}$                           | $25^{\circ}\text{C}$         | 2.7      | 6.0             | 6.0             | 8.0             |                         |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 9.0             | 9.0             | 11.0            |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 9.0             | 9.0             | 11.0            |                         |
| $Z_R$                   | Dynamic output impedance                                  | $I_R = 1\text{mA}, f = 120\text{Hz}$<br>$I_{AC} = 0.1I_R$  |                              | 0.4      | 0.9             | 0.9             | 1.2             | $\Omega$                |
| $e_n$                   | Noise voltage   | $I_R = 100\mu\text{A}$<br>$10\text{Hz} < f < 10\text{kHz}$ |                              | 35       |                 |                 |                 | $\mu\text{V}_{RMS}$     |
| $V_R$                   | Long term stability (non cumulative)                      | $t = 1000\text{Hrs } I_R = 100\mu\text{A}$                 |                              | 120      |                 |                 |                 | ppm                     |
| $V_{HYST}$              | Thermal hysteresis  | $\Delta T = -40^{\circ}\text{C}$ to $=125^{\circ}\text{C}$ |                              | 0.08     |                 |                 |                 | %                       |

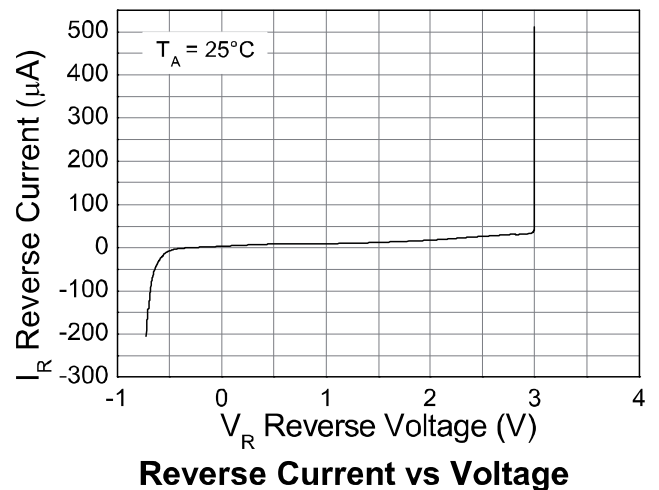
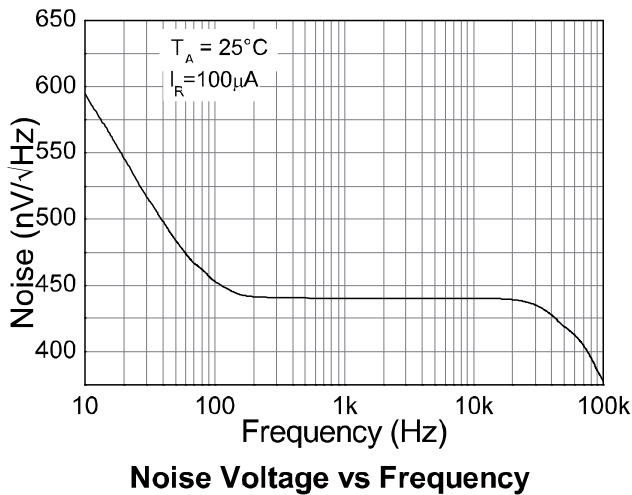
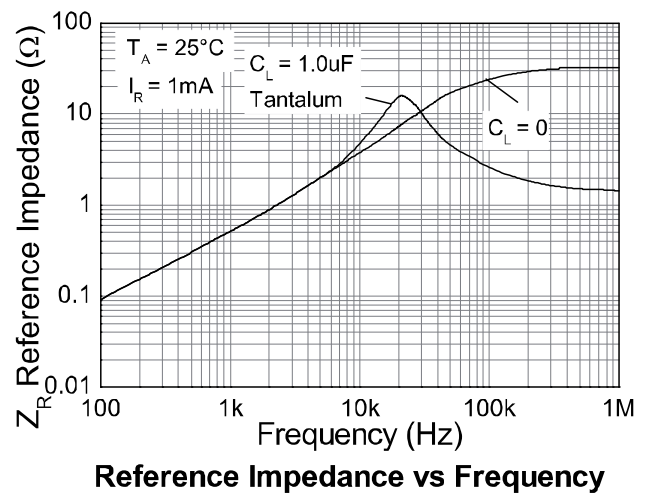
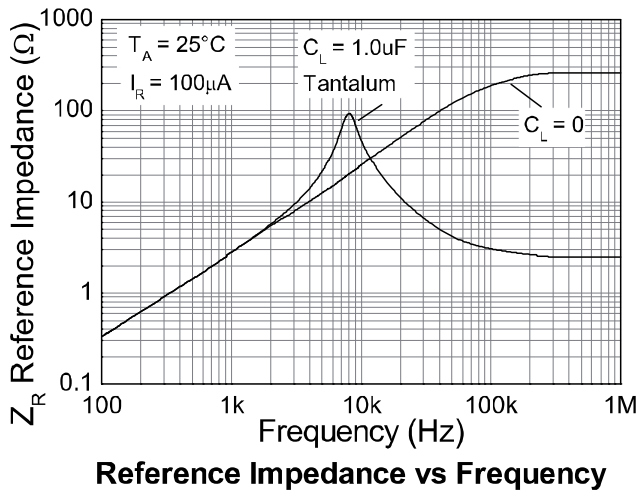
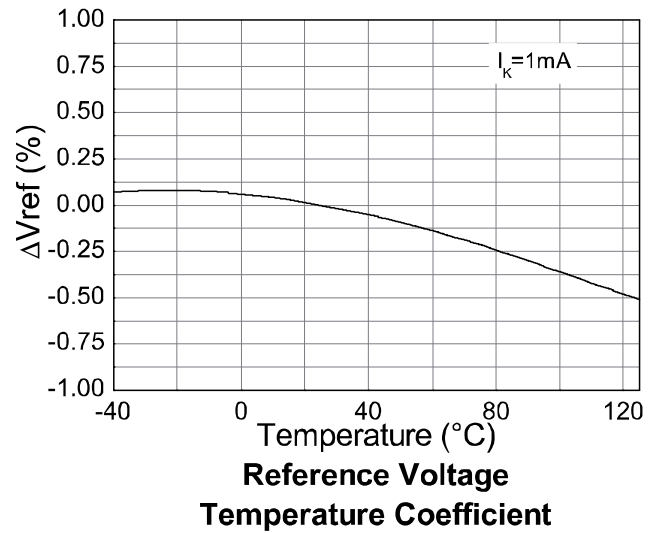
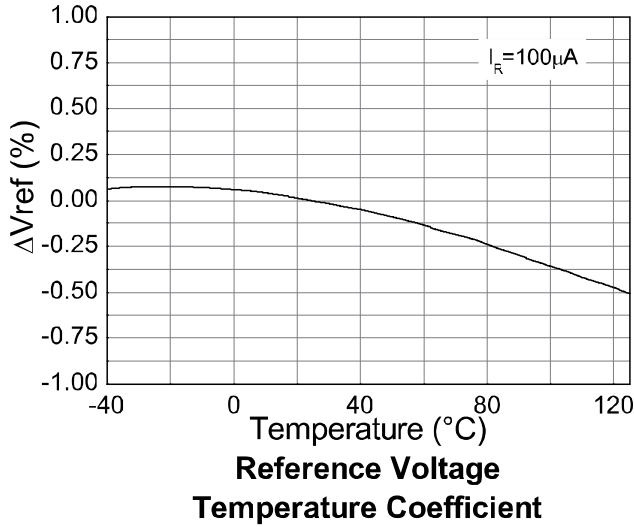
**LM4040-5.0**

| Symbol                  | Parameter   | Conditions   |                              | Typ.     | LM4040 B Limits | LM4040 C Limits | LM4040 D Limits | Units                   |
|-------------------------|---|--|------------------------------|----------|-----------------|-----------------|-----------------|-------------------------|
|                         |   |  | $T_{AMB}$                    |          |                 |                 |                 |                         |
| $V_{REF}$               | Reverse breakdown voltage                                 | $I_R = 100\mu\text{A}$                                     | $25^{\circ}\text{C}$         | 5.0      |                 |                 |                 | V                       |
|                         | Reverse breakdown voltage tolerance                       | $I_R = 100\mu\text{A}$                                     | $25^{\circ}\text{C}$         |          | $\pm 10$        | $\pm 25$        | $\pm 50$        | mV                      |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | $\pm 43$        | $\pm 58$        | $\pm 99$        |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | $\pm 60$        | $\pm 75$        | $\pm 125$       |                         |
| $I_{RMIN}$              | Minimum operating current                                 |  | $25^{\circ}\text{C}$         | 54       | 74              | 74              | 79              | $\mu\text{A}$           |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 80              | 80              | 85              |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 83              | 83              | 88              |                         |
| $\Delta V_R/\Delta T$   | Average reverse breakdown voltage temperature coefficient | $I_R = 10\text{mA}$  | -40 to $125^{\circ}\text{C}$ | $\pm 30$ |                 |                 |                 | ppm/ $^{\circ}\text{C}$ |
|                         |   | $I_R = 1\text{mA}$   |                              | $\pm 20$ | $\pm 100$       | $\pm 100$       | $\pm 150$       |                         |
|                         |   | $I_R = 100\mu\text{A}$                                     |                              | $\pm 20$ |                 |                 |                 |                         |
| $\Delta V_R/\Delta I_R$ | Reverse breakdown change with current                     | $I_{RMIN} < I_R < 1\text{mA}$                              | $25^{\circ}\text{C}$         | 0.5      | 1.0             | 1.0             | 1.3             | mV                      |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 1.4             | 1.4             | 1.8             |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 1.4             | 1.4             | 1.8             |                         |
|                         |   | $1\text{mA} < I_R < 15\text{mA}$                           | $25^{\circ}\text{C}$         | 3.5      | 8.0             | 8.0             | 10.0            |                         |
|                         |   |  | -40 to $85^{\circ}\text{C}$  |          | 12.0            | 12.0            | 15.0            |                         |
|                         |   |  | -40 to $125^{\circ}\text{C}$ |          | 12.0            | 12.0            | 15.0            |                         |
| $Z_R$                   | Dynamic output impedance                                  | $I_R = 1\text{mA}, f = 120\text{Hz}$<br>$I_{AC} = 0.1I_R$  |                              | 0.5      | 1.1             | 1.1             | 1.5             | $\Omega$                |
| $e_n$                   | Noise voltage   | $I_R = 100\mu\text{A}$<br>$10\text{Hz} < f < 10\text{kHz}$ |                              | 80       |                 |                 |                 | $\mu\text{V}_{RMS}$     |
| $V_R$                   | Long term stability (non cumulative)                      | $t = 1000\text{Hrs } I_R = 100\mu\text{A}$                 |                              | 120      |                 |                 |                 | ppm                     |
| $V_{HYST}$              | Thermal hysteresis  | $\Delta T = -40^{\circ}\text{C}$ to $=125^{\circ}\text{C}$ |                              | 0.08     |                 |                 |                 | %                       |

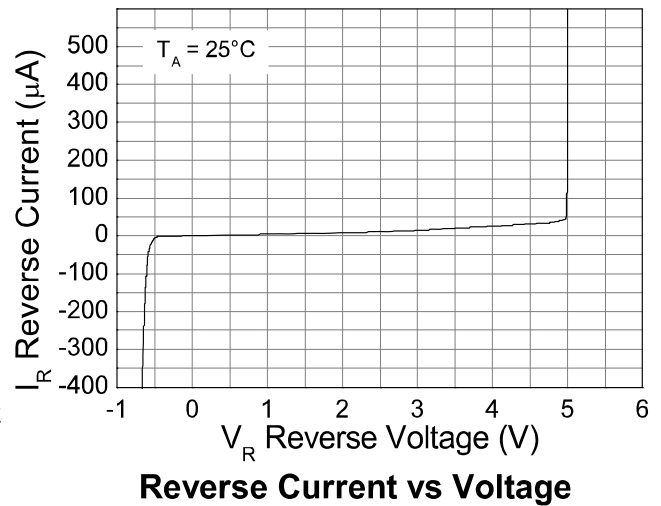
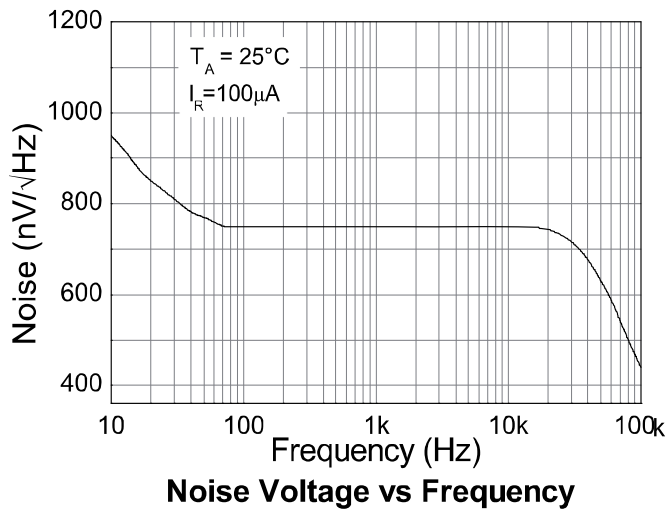
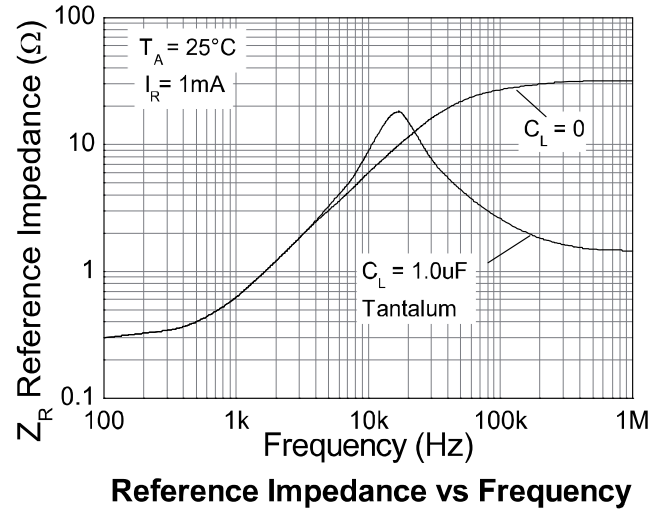
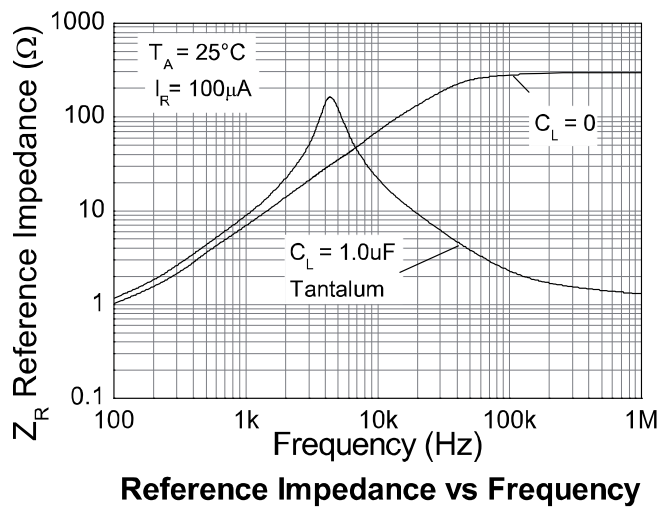
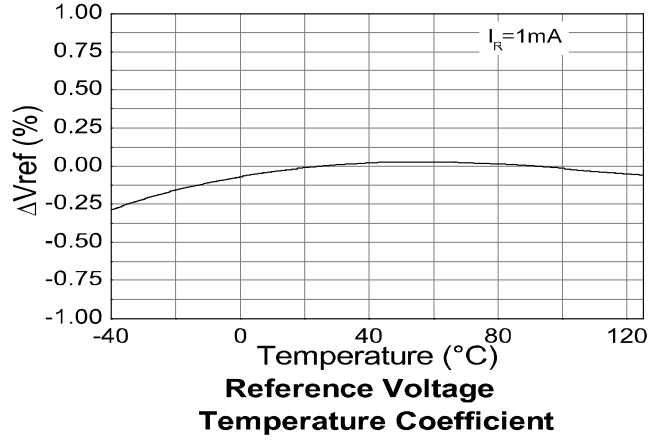
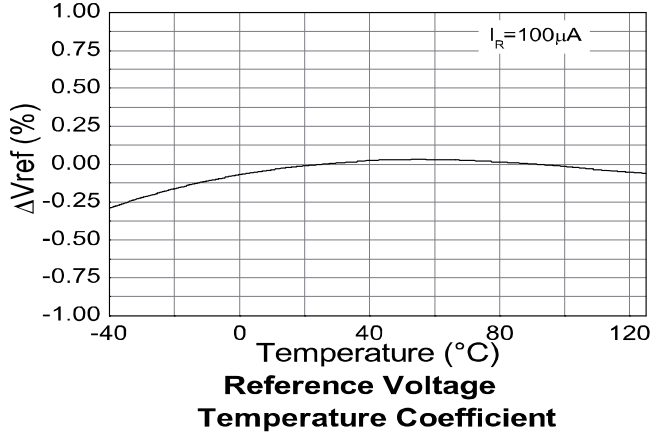
**Typical Characteristics LM4040-2.5**



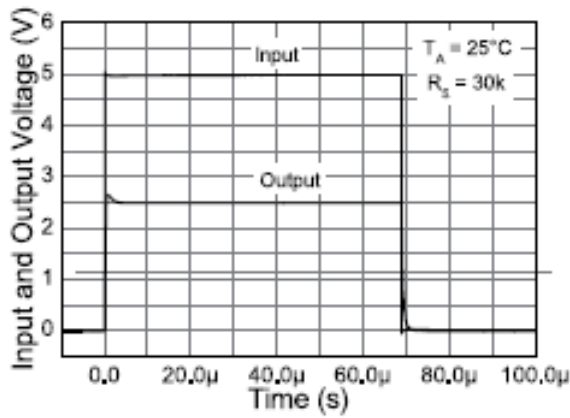
**Typical Characteristics LM4040-3.0**



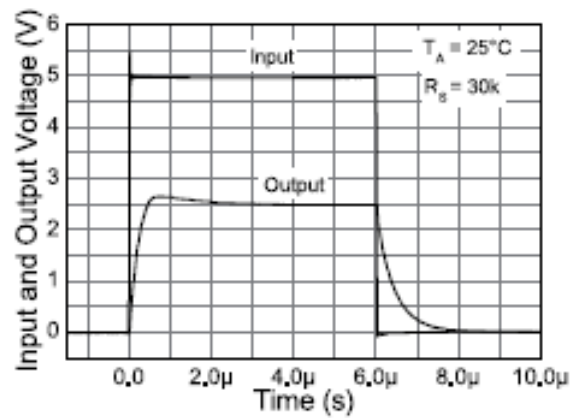
**Typical Characteristics LM4040-5.0**



**Start Up Characteristics LM4040-2.5, 3.0 and 5.0**

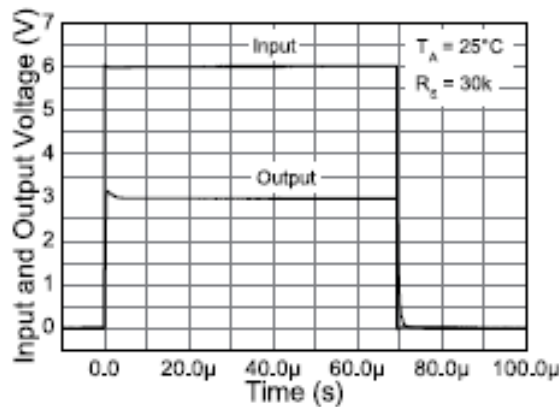


**Long Pulse Response**

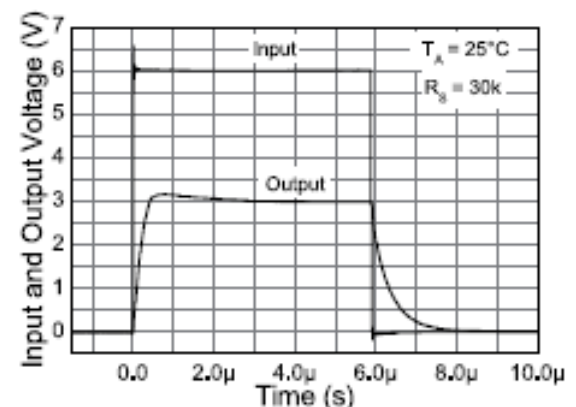


**Short Pulse Response**

**LM4040-3.0**

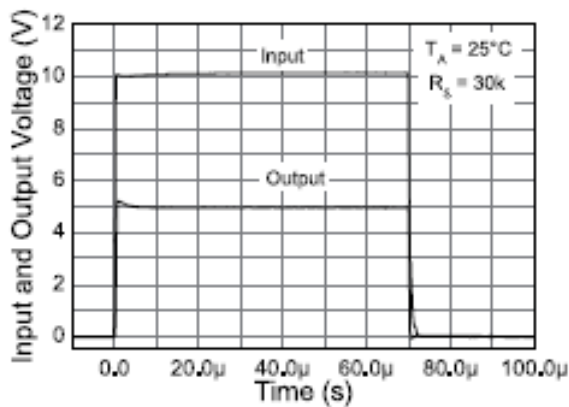


**Long Pulse Response**

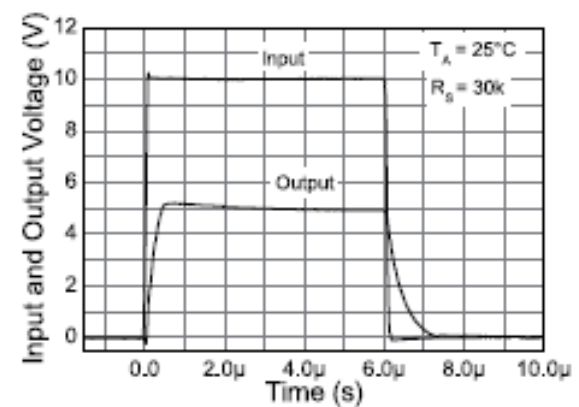


**Short Pulse Response**

**LM4040-5.0**



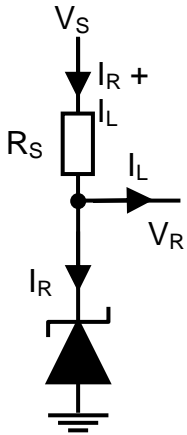
**Long Pulse Response**



**Short Pulse Response**

## Application Information

In a conventional shunt regulator application (*Figure 1*), an external series resistor ( $R_S$ ) is connected between the supply voltage,  $V_S$ , and the LM4040.



$R_S$  determines the current that flows through the load ( $I_L$ ) and the LM4040 ( $I_R$ ). Since load current and supply voltage may vary,  $R_S$  should be small enough to supply at least the minimum acceptable  $I_R$  to the LM4040 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 is less than 15 mA.

$R_S$  is determined by the supply voltage, ( $V_S$ ), the load and operating current, ( $I_L$  and  $I_R$ ), and the LM4040's reverse breakdown voltage,  $V_R$ .

$$R_S = \frac{V_S - V_R}{I_L + I_R}$$

### Printed circuit board layout considerations

LM4040s in the SOT23 package have the die attached to pin 1, which results in an electrical contact between pin 2 and pin 3. Therefore, pin 1 of the SOT-23 package must be left floating or connected to pin 2.

LM4040s in the SC70-5 package have the die attached to pin 2, which results in an electrical contact between pin 2 and pin 1. Therefore, pin 2 must be left floating or connected to pin1.

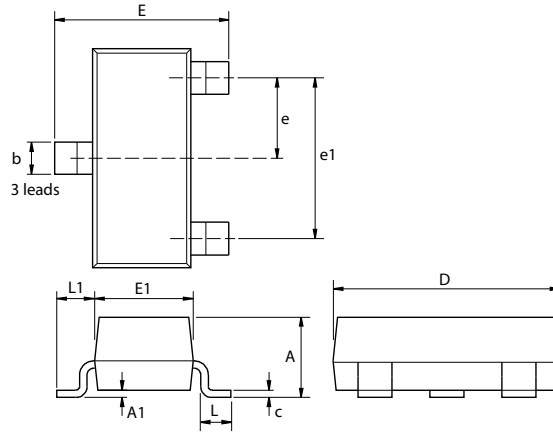
## Ordering Information

| 25°C Tol | Voltage (V) | Order Code    | Package | Part Mark | Reel Size | Tape Width | Quantity per Reel |
|----------|-------------|---------------|---------|-----------|-----------|------------|-------------------|
| 0.2%     | 2.5         | LM4040B25FTA  | SOT23   | R2B       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040B25H5TA | SC70-5  | R2B       | 7", 180mm | 8mm        | 3000              |
|          | 3.0         | LM4040B30FTA  | SOT23   | R3B       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040B30H5TA | SC70-5  | R3B       | 7", 180mm | 8mm        | 3000              |
|          | 5.0         | LM4040B50FTA  | SOT23   | R5B       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040B50H5TA | SC70-5  | R5B       | 7", 180mm | 8mm        | 3000              |
| 0.5%     | 2.5         | LM4040C25FTA  | SOT23   | R2C       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040C25H5TA | SC70-5  | R2C       | 7", 180mm | 8mm        | 3000              |
|          | 3.0         | LM4040C30FTA  | SOT23   | R3C       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040C30H5TA | SC70-5  | R3C       | 7", 180mm | 8mm        | 3000              |
|          | 5.0         | LM4040C50FTA  | SOT23   | R5C       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040C50H5TA | SC70-5  | R5C       | 7", 180mm | 8mm        | 3000              |
| 1%       | 2.5         | LM4040D25FTA  | SOT23   | R2D       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040D25H5TA | SC70-5  | R2D       | 7", 180mm | 8mm        | 3000              |
|          | 3.0         | LM4040D30FTA  | SOT23   | R3D       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040D30H5TA | SC70-5  | R3D       | 7", 180mm | 8mm        | 3000              |
|          | 5.0         | LM4040D50FTA  | SOT23   | R5D       | 7", 180mm | 8mm        | 3000              |
|          |             | LM4040D50H5TA | SC70-5  | R5D       | 7", 180mm | 8mm        | 3000              |



**Package Outline Dimensions**

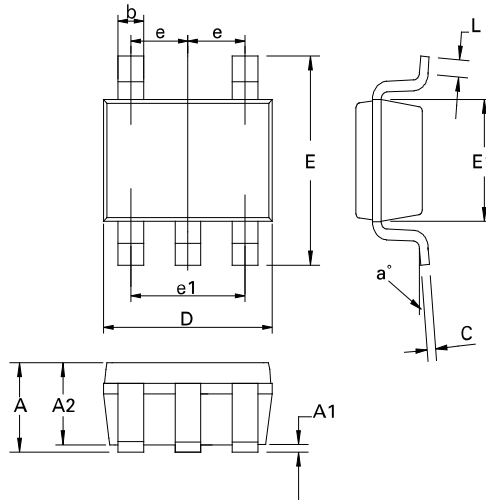
**SOT23**



| Dim. | Millimeters |      | Inches    |       | Dim. | Millimeters |      | Inches    |        |
|------|-------------|------|-----------|-------|------|-------------|------|-----------|--------|
|      | Min         | Max  | Min       | Max   |      | Min         | Max  | Min       | Max    |
| A    | -           | 1.12 | -         | 0.044 | e1   | 1.90 NOM    |      | 0.075 NOM |        |
| A1   | 0.01        | 0.10 | 0.0004    | 0.004 | E    | 2.10        | 2.64 | 0.083     | 0.104  |
| b    | 0.30        | 0.50 | 0.012     | 0.020 | E1   | 1.20        | 1.40 | 0.047     | 0.055  |
| c    | 0.085       | 0.20 | 0.003     | 0.008 | L    | 0.25        | 0.60 | 0.0098    | 0.0236 |
| D    | 2.80        | 3.04 | 0.110     | 0.120 | L1   | 0.45        | 0.62 | 0.018     | 0.024  |
| e    | 0.95 NOM    |      | 0.037 NOM |       | -    | -           | -    | -         | -      |

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

**SC70-5**



| Dim. | Millimeters |      | Inches     |        | Dim. | Millimeters |      | Inches     |        |
|------|-------------|------|------------|--------|------|-------------|------|------------|--------|
|      | Min         | Max  | Min        | Max    |      | Min         | Max  | Min        | Max    |
| A    | 0.80        | 1.10 | 0.0315     | 0.0433 | E    | 2.10 BSC    |      | 0.0826 BSC |        |
| A1   | -           | 0.10 | -          | 0.0039 | E1   | 1.25 BSC    |      | 0.0492 BSC |        |
| A2   | 0.80        | 1.00 | 0.0315     | 0.0394 | e    | 0.65 BSC    |      | 0.0255 BSC |        |
| b    | 0.15        | 0.30 | 0.006      | 0.0118 | e1   | 1.30 BSC    |      | 0.0511 BSC |        |
| C    | 0.08        | 0.25 | 0.0031     | 0.0098 | L    | 0.26        | 0.46 | 0.0102     | 0.0181 |
| D    | 2.00 BSC    |      | 0.0787 BSC |        | a°   | 0           | 8    | 0          | 8      |

**Note:** Controlling dimensions are in millimeters. Approximate dimensions are provided in inches

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