



## LTC1440/LTC1441/LTC1442

# Ultralow Power Single/Dual Comparator with Reference

## FEATURES

- **Ultralow Quiescent Current: 2.1 $\mu$ A Typ (LTC1440)**
- **Wide Supply Range:**  
Single: 2V to 11V  
Dual:  $\pm 1$ V to  $\pm 5.5$ V
- **Input Voltage Range Includes the Negative Supply**
- **Reference Output Drives 0.01 $\mu$ F Capacitor**
- **Adjustable Hysteresis (LTC1440/LTC1442)**
- **TTL/CMOS Compatible Outputs**
- **12 $\mu$ s Propagation Delay with 10mV Overdrive**
- **No Crowbar Current**
- **40mA Continuous Source Current**
- **Pin Compatible Upgrades for MAX921/922/923**

## APPLICATIONS

- Battery-Powered System Monitoring
- Threshold Detectors
- Window Comparators
- Oscillator Circuits

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## DESCRIPTION

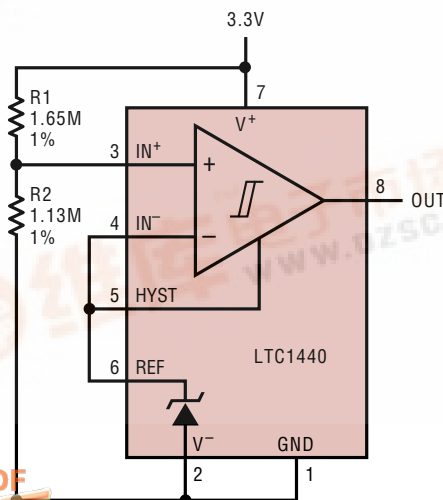
The LTC<sup>®</sup>1440/LTC1441/LTC1442 are ultralow power single and dual comparators with built-in references. The comparators feature less than 3.7 $\mu$ A supply current over temperature (LTC1440), a 1.182V  $\pm 1\%$  reference, programmable hysteresis (LTC1440/LTC1442) and TTL/CMOS outputs that sink and source current. The reference output can drive a bypass capacitor of up to 0.01 $\mu$ F without oscillation.

The comparators operate from a single 2V to 11V supply or a dual  $\pm 1$ V to  $\pm 5.5$ V supply (LTC1440). Comparator hysteresis is easily programmed by using two resistors and the HYST pin (LTC1440/LTC1442). Each comparator's input operates from the negative supply to within 1.3V of the positive supply. The comparator output stage can continuously source up to 40mA. By eliminating the cross-conducting current that normally happens when the comparator changes logic states, the power supply glitches are eliminated.

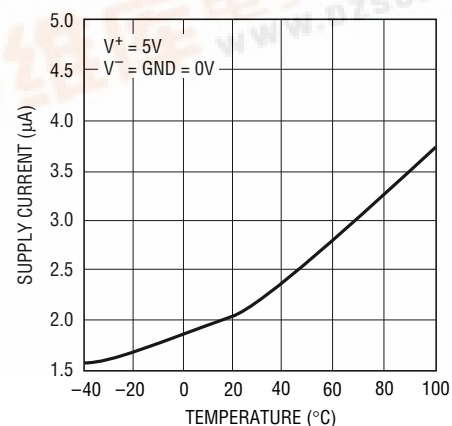
The LTC1440 is available in 8-pin PDIP, SO and MSOP packages. The LTC1441/LTC1442 are available in 8-pin PDIP and SO packages.

## TYPICAL APPLICATION

Micropower 2.9V  $V_{CC}$  Threshold Detector



LTC1440 Supply Current vs Temperature

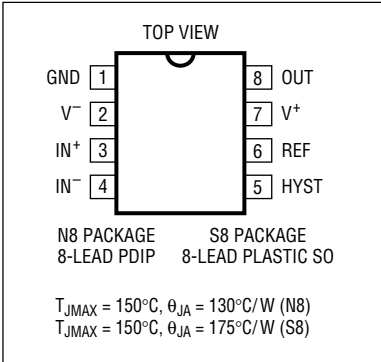
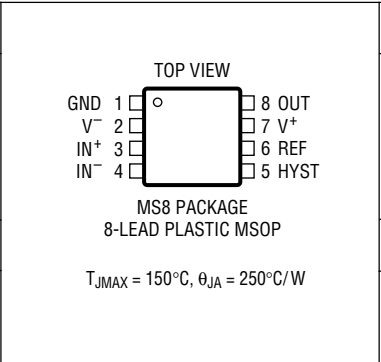
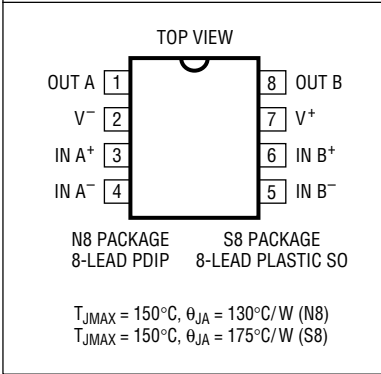
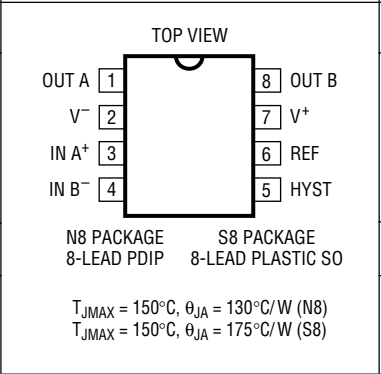


LTC1440/LTC1441/LTC1442

ABSOLUTE MAXIMUM RATINGS

|                                                   |                                                      |                                            |                                 |
|---------------------------------------------------|------------------------------------------------------|--------------------------------------------|---------------------------------|
| Voltage                                           | OUT Short-Circuit Duration ( $V^+ \leq 5.5V$ ) ..... | Continuous                                 |                                 |
| $V^+$ to $V^-$ , $V^+$ to GND, GND to $V^-$ ..... | 12V to $-0.3V$                                       |                                            |                                 |
| $IN^+$ , $IN^-$ , HYST .....                      | ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )                 | Power Dissipation .....                    | 500mW                           |
| REF .....                                         | ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )                 | Operating Temperature Range                |                                 |
| OUT (LTC1440) .....                               | ( $V^+ + 0.3V$ ) to (GND $- 0.3V$ )                  | LTC144XC .....                             | $0^{\circ}C$ to $70^{\circ}C$   |
| OUT (LTC1441/LTC1442) ...                         | ( $V^+ + 0.3V$ ) to ( $V^- - 0.3V$ )                 | LTC144XI .....                             | $-40^{\circ}C$ to $85^{\circ}C$ |
| Current                                           | Storage Temperature Range .....                      | $-65^{\circ}C$ to $150^{\circ}C$           |                                 |
| $IN^+$ , $IN^-$ , HYST .....                      | 20mA                                                 | Lead Temperature (Soldering, 10 sec) ..... | $300^{\circ}C$                  |
| REF .....                                         | 20mA                                                 |                                            |                                 |
| OUT .....                                         | 50mA                                                 |                                            |                                 |

PACKAGE/ORDER INFORMATION

|                                                                                     |                                                                               |                                                                                      |                                                                               |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|
|   | ORDER PART NUMBER<br><br>LTC1440CN8<br>LTC1440CS8<br>LTC1440IN8<br>LTC1440IS8 |   | ORDER PART NUMBER<br><br>LTC1440CMS8                                          |
|                                                                                     | S8 PART MARKING<br><br>1440<br>1440I                                          |                                                                                      | MS8 PART MARKING<br><br>LTBX                                                  |
|  | ORDER PART NUMBER<br><br>LTC1441CN8<br>LTC1441CS8<br>LTC1441IN8<br>LTC1441IS8 |  | ORDER PART NUMBER<br><br>LTC1442CN8<br>LTC1442CS8<br>LTC1442IN8<br>LTC1442IS8 |
|                                                                                     | S8 PART MARKING<br><br>1441<br>1441I                                          |                                                                                      | S8 PART MARKING<br><br>1442<br>1442I                                          |

Consult factory for Military grade parts.

ELECTRICAL CHARACTERISTICS  $V^+ = 5V$ ,  $V^- = GND = 0V$ ,  $T_A = 25^{\circ}C$  unless otherwise noted.

| SYMBOL       | PARAMETER            | CONDITIONS                   | MIN | TYP | MAX  | UNITS   |
|--------------|----------------------|------------------------------|-----|-----|------|---------|
| Power Supply |                      |                              |     |     |      |         |
| $V^+$        | Supply Voltage Range |                              | ●   | 2.0 | 11.0 | V       |
| $I_{CC}$     | Supply Current       | $IN^+ = IN^- = 80mV$         | ●   | 2.1 | 3.7  | $\mu A$ |
|              |                      | HYST = REF (LTC1440/LTC1442) | ●   | 3.5 | 5.7  | $\mu A$ |
|              |                      | LTC1440                      | ●   | 3.5 | 5.7  | $\mu A$ |
|              |                      | LTC1441                      | ●   |     |      |         |
|              |                      | LTC1442                      | ●   |     |      |         |

# LTC1440/LTC1441/LTC1442

## ELECTRICAL CHARACTERISTICS $V^+ = 5V$ , $V^- = GND = 0V$ , $T_A = 25^\circ C$ unless otherwise noted.

| SYMBOL            | PARAMETER                                 | CONDITIONS                                                 |   | MIN          | TYP        | MAX          | UNITS              |
|-------------------|-------------------------------------------|------------------------------------------------------------|---|--------------|------------|--------------|--------------------|
| <b>Comparator</b> |                                           |                                                            |   |              |            |              |                    |
| $V_{OS}$          | Comparator Input Offset Voltage           | $V_{CM} = 2.5V$                                            | ● |              | $\pm 3$    | $\pm 10$     | mV                 |
| $I_{IN}$          | Input Leakage Current ( $IN^+$ , $IN^-$ ) | $V_{IN^+} = V_{IN^-} = 2.5V$                               | ● |              | $\pm 0.01$ | $\pm 1.0$    | nA                 |
|                   | Input Leakage Current (HYST)              |                                                            | ● |              | $\pm 0.02$ | $\pm 1.0$    | nA                 |
| $V_{CM}$          | Comparator Input Common Mode Range        |                                                            | ● | $V^-$        |            | $V^+ - 1.3V$ | V                  |
| CMRR              | Common Mode Rejection Ratio               | $V^-$ to $V^+ - 1.3V$                                      |   |              | 0.1        | 1            | mV/V               |
| PSRR              | Power Supply Rejection Ratio              | $V^+ = 2V$ to $11V$                                        |   |              | 0.1        | 1            | mV/V               |
| NOISE             | Voltage Noise                             | 100Hz to 100kHz                                            |   |              | 100        |              | $\mu V_{RMS}$      |
| $V_{HYST}$        | Hysteresis Input Voltage Range            | LTC1440/LTC1442                                            | ● | REF – 50mV   |            | REF          | V                  |
| $t_{PD}$          | Propagation Delay                         | $C_{OUT} = 100pF$<br>Overdrive = 10mV<br>Overdrive = 100mV |   |              | 15<br>8    |              | $\mu s$<br>$\mu s$ |
| $V_{OH}$          | Output High Voltage                       | $I_O = -13mA$                                              | ● | $V^+ - 0.4V$ |            |              | V                  |
| $V_{OL}$          | Output Low Voltage                        | $I_O = 1.8mA$                                              | ● |              |            | GND + 0.4V   | V                  |
|                   |                                           | LTC1440<br>LTC1441/LTC1442                                 | ● |              |            | $V^- + 0.4V$ | V                  |

### Reference

|                  |                                 |                                          |              |   |       |       |       |               |
|------------------|---------------------------------|------------------------------------------|--------------|---|-------|-------|-------|---------------|
| $V_{REF}$        | Reference Voltage               | No Load                                  | C Temp Range | ● | 1.170 | 1.182 | 1.194 | V             |
|                  |                                 | LTC1440/LTC1442                          | I Temp Range | ● | 1.164 |       | 1.200 | V             |
|                  |                                 | No Load LTC1440 (MSOP)                   | C Temp Range | ● | 1.164 |       | 1.200 | V             |
| $I_{SOURCE}$     | Reference Output Source Current | $\Delta V_{REF} \leq 1mV$ (LTC1442)      |              | ● | 100   | 200   |       | $\mu A$       |
| $I_{SINK}$       | Reference Output Sink Current   | $\Delta V_{REF} \leq 2.5mV$ (LTC1442)    |              |   | 10    | 20    |       | $\mu A$       |
| $\Delta V_{REF}$ | Reference Source Current        | $0 \leq I_{SOURCE} \leq 2mA$ (LTC1440)   |              | ● |       | 0.8   | 5     | mV            |
|                  | Reference Sink Current          | $0 \leq I_{SINK} \leq 10\mu A$ (LTC1440) |              |   |       | 0.5   | 1.5   | mV            |
|                  |                                 |                                          | ●            |   |       |       | 5     | mV            |
| NOISE            | Voltage Noise                   | 100Hz to 100kHz                          |              |   |       | 100   |       | $\mu V_{RMS}$ |

$V^+ = 3V$ ,  $V^- = GND = 0V$ ,  $T_A = 25^\circ C$  unless otherwise noted.

### Power Supply

|          |                      |                              |         |   |   |     |     |         |
|----------|----------------------|------------------------------|---------|---|---|-----|-----|---------|
| $V^+$    | Supply Voltage Range |                              |         | ● | 2 |     | 11  | V       |
| $I_{CC}$ | Supply Current       | $IN^+ = IN^- = 80mV$         | LTC1440 | ● |   | 2   | 3.6 | $\mu A$ |
|          |                      | HYST = REF (LTC1440/LTC1442) | LTC1441 | ● |   | 3.5 | 5.7 | $\mu A$ |
|          |                      |                              | LTC1442 | ● |   | 3.5 | 5.7 | $\mu A$ |

### Comparator

|            |                                           |                                                            |         |   |              |            |              |                    |
|------------|-------------------------------------------|------------------------------------------------------------|---------|---|--------------|------------|--------------|--------------------|
| $V_{OS}$   | Comparator Input Offset Voltage           | $V_{CM} = 1.5V$                                            |         | ● |              | $\pm 3$    | $\pm 10$     | mV                 |
| $I_{IN}$   | Input Leakage Current ( $IN^+$ , $IN^-$ ) | $V_{IN^+} = V_{IN^-} = 1.5V$                               |         | ● |              | $\pm 0.01$ | $\pm 1$      | nA                 |
|            | Input Leakage Current (HYST)              |                                                            |         | ● |              | $\pm 0.02$ | $\pm 1$      | nA                 |
| $V_{CM}$   | Comparator Input Common Mode Range        |                                                            |         | ● | $V^-$        |            | $V^+ - 1.3V$ | V                  |
| CMRR       | Common Mode Rejection Ratio               | $V^-$ to $V^+ - 1.3V$                                      |         |   |              | 0.1        | 1            | mV/V               |
| PSRR       | Power Supply Rejection Ratio              | $V^+ = 2V$ to $11V$                                        |         |   |              | 0.1        | 1            | mV/V               |
| NOISE      | Voltage Noise                             | 100Hz to 100kHz                                            |         |   |              | 100        |              | $\mu V_{RMS}$      |
| $V_{HYST}$ | Hysteresis Input Voltage Range            | LTC1440/LTC1442                                            |         | ● | REF – 50mV   |            | REF          | V                  |
| $t_{PD}$   | Propagation Delay                         | $C_{OUT} = 100pF$<br>Overdrive = 10mV<br>Overdrive = 100mV |         |   |              | 14<br>5    |              | $\mu s$<br>$\mu s$ |
| $V_{OH}$   | Output High Voltage                       | $I_O = -8mA$                                               |         | ● | $V^+ - 0.4V$ |            |              | V                  |
| $V_{OL}$   | Output Low Voltage                        | $I_O = 0.8mA$                                              | LTC1440 | ● |              |            | GND + 0.4V   | V                  |
|            |                                           | LTC1441/LTC1442                                            | ●       |   |              |            | $V^- + 0.4V$ | V                  |

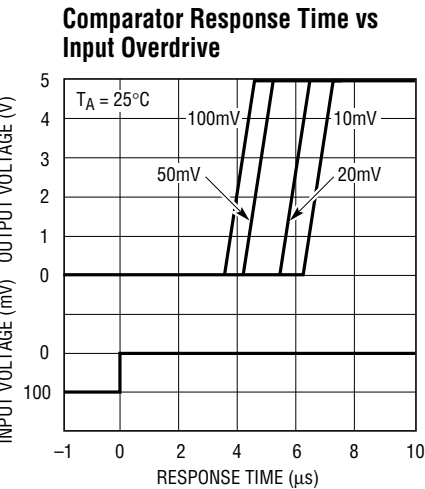
# LTC1440/LTC1441/LTC1442

## ELECTRICAL CHARACTERISTICS $V^+ = 3V$ , $V^- = GND = 0V$ , $T_A = 25^\circ C$ unless otherwise noted.

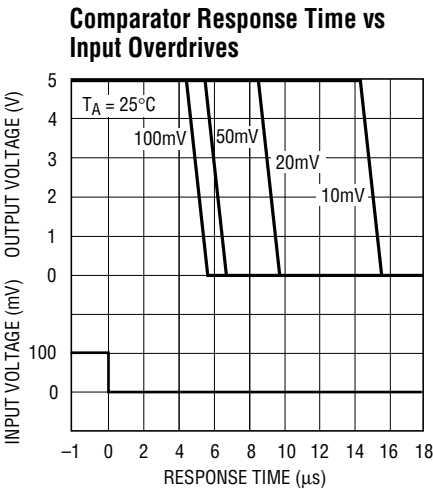
| SYMBOL              | PARAMETER                       | CONDITIONS                              |              |   |       | MIN   | TYP   | MAX      | UNITS             |
|---------------------|---------------------------------|-----------------------------------------|--------------|---|-------|-------|-------|----------|-------------------|
| Reference           |                                 |                                         |              |   |       |       |       |          |                   |
| V <sub>REF</sub>    | Reference Voltage               | No Load                                 | C Temp Range | ● | 1.170 | 1.182 | 1.194 |          | V                 |
|                     |                                 | LTC1440/LTC1442                         | I Temp Range | ● | 1.164 |       | 1.200 |          | V                 |
|                     |                                 | No Load LTC1440 (MSOP)                  | C Temp Range | ● | 1.164 |       | 1.200 |          | V                 |
| I <sub>SOURCE</sub> | Reference Output Source Current | ΔV <sub>REF</sub> ≤ 1mV (LTC1442)       |              |   | ●     | 60    | 120   |          | μA                |
| I <sub>SINK</sub>   | Reference Output Sink Current   | ΔV <sub>REF</sub> ≤ 2.5mV (LTC1442)     |              |   |       | 10    | 20    |          | μA                |
| ΔV <sub>REF</sub>   | Reference Source Current        | 0 ≤ I <sub>SOURCE</sub> ≤ 1mA (LTC1440) |              |   | ●     |       | 0.8   | 5.5      | mV                |
|                     | Reference Sink Current          | 0 ≤ I <sub>SINK</sub> ≤ 10μA (LTC1440)  |              |   | ●     |       | 0.5   | 1.5<br>5 | mV<br>mV          |
| NOISE               | Voltage Noise                   | 100Hz to 100kHz                         |              |   |       |       | 100   |          | μV <sub>RMS</sub> |

The ● denotes specifications which apply over the full operating temperature range.

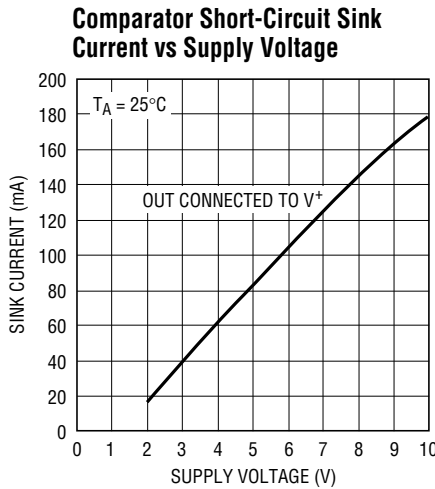
## TYPICAL PERFORMANCE CHARACTERISTICS



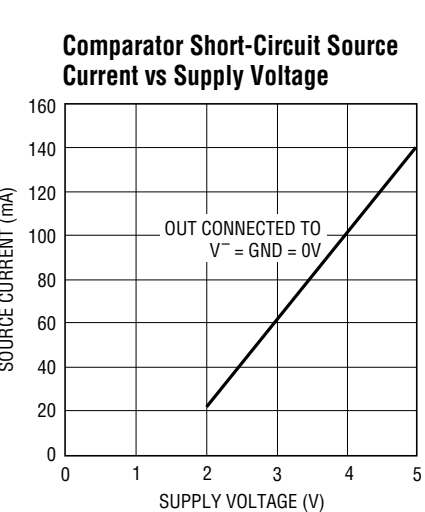
1440/1/2 G01



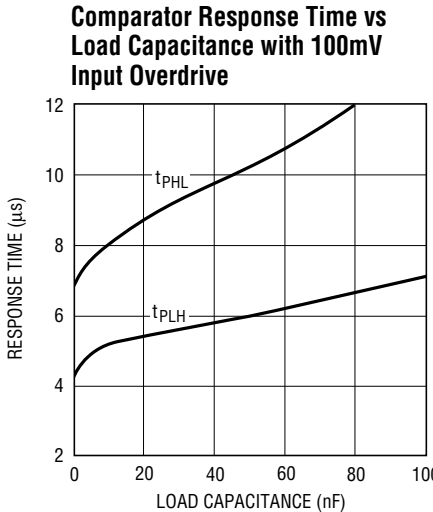
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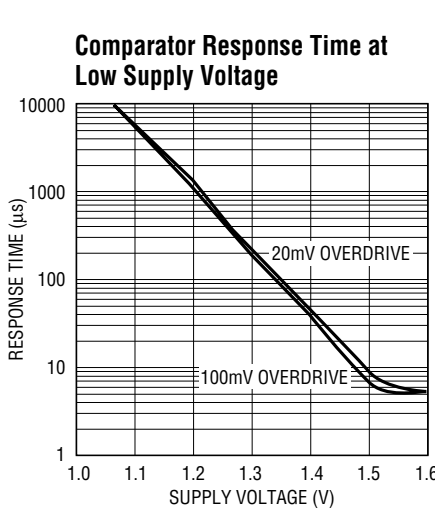
1440/1/2 G03



1440/1/2 G04



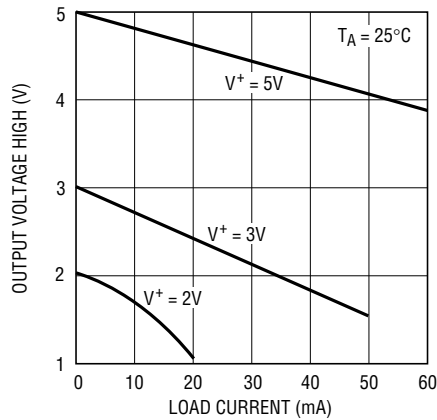
1440/1/2 G05



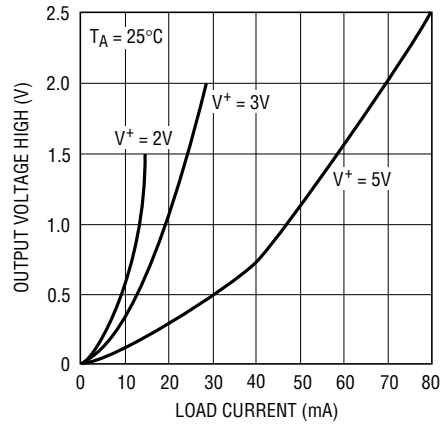
1440/1/2 G06

# TYPICAL PERFORMANCE CHARACTERISTICS

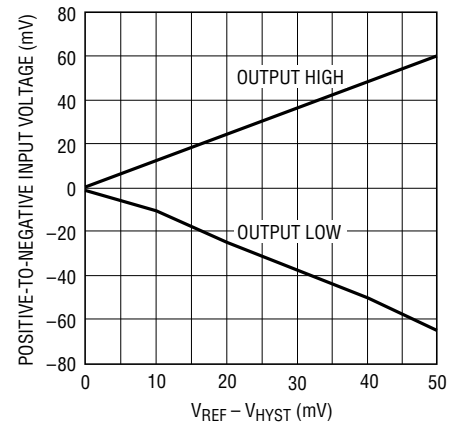
**Comparator Output Voltage High vs Load Current**



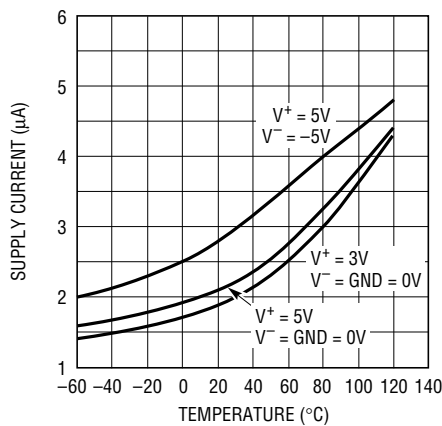
**Comparator Output Voltage Low vs Load Current**



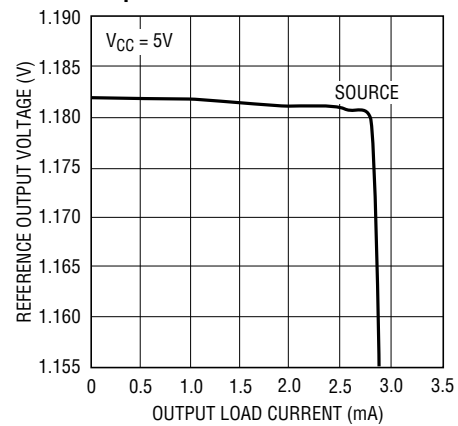
**LTC1440/LTC1442 Hysteresis Control**



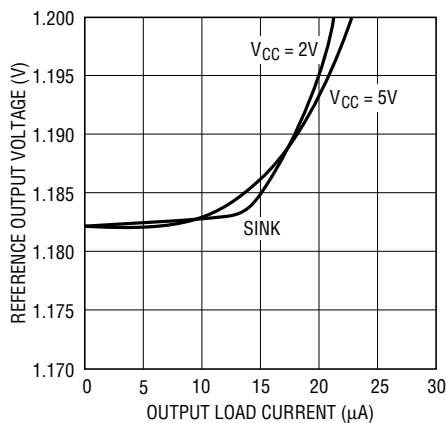
**LTC1440 Supply Current vs Temperature**



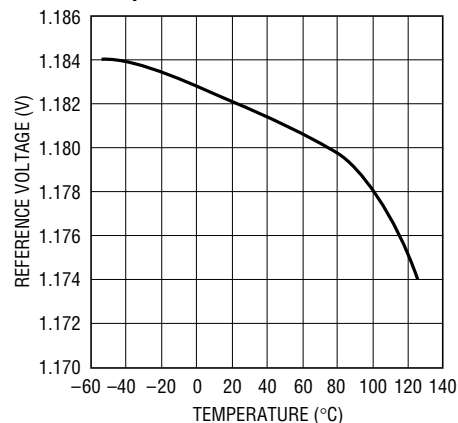
**Reference Output Voltage vs Output Load Current**



**Reference Output Voltage vs Output Load Current (Sink)**

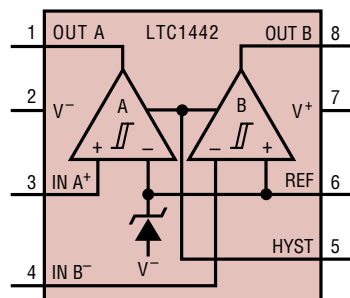
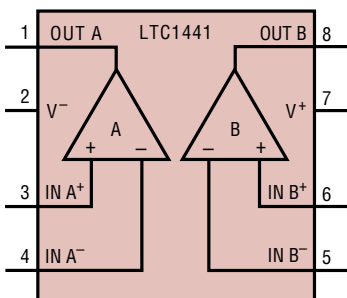
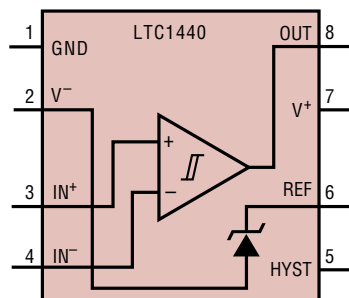


**Reference Voltage vs Temperature**



# LTC1440/LTC1441/LTC1442

## PIN FUNCTIONS



1440/1/2 PD

### LTC1440

**GND (Pin 1):** Ground. Connect to  $V^-$  for single supply operation.

**$V^-$  (Pin 2):** Negative Supply. Connect to ground for single supply operation. Potential should be more negative than GND.

**$IN^+$  (Pin 3):** Noninverting Comparator Input. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$IN^-$  (Pin 4):** Inverting Comparator Input. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**HYST (Pin 5):** Hysteresis Input. Connect to REF if not used. Input voltage range is from  $V_{REF}$  to  $V_{REF} - 50mV$ .

**REF (Pin 6):** Reference Output. 1.182V with respect to  $V^-$ . Can source up to 200 $\mu A$  and sink 15 $\mu A$  at 25°C. Drive 0.01 $\mu F$  bypass capacitor without oscillation.

**$V^+$  (Pin 7):** Positive Supply. 2V to 11V.

**OUT (Pin 8):** Comparator CMOS Output. Swings from GND to  $V^+$ . Output can source up to 40mA and sink 5mA.

### LTC1441

**OUT A (Pin 1):** Comparator A CMOS Output. Swings from  $V^-$  to  $V^+$ . Output can source up to 40mA and sink 5mA.

**$V^-$  (Pin 2):** Negative Supply.

**$IN A^+$  (Pin 3):** Noninverting Input of Comparator A. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$IN A^-$  (Pin 4):** Inverting Input of Comparator A. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$IN B^-$  (Pin 5):** Inverting Input of Comparator B. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$IN B^+$  (Pin 6):** Noninverting Input of Comparator B. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$V^+$  (Pin 7):** Positive Supply. 2V to 11V.

**OUT B (Pin 8):** Comparator B CMOS Output. Swings from  $V^-$  to  $V^+$ . Output can source up to 40mA and sink 5mA.

### LTC1442

**OUT A (Pin 1):** Comparator A CMOS Output. Swings from  $V^-$  to  $V^+$ . Output can source up to 40mA and sink 5mA.

**$V^-$  (Pin 2):** Negative Supply.

**$IN A^+$  (Pin 3):** Noninverting Input of Comparator A. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**$IN B^-$  (Pin 4):** Inverting Input of Comparator B. Input common mode range from  $V^-$  to  $V^+ - 1.3V$ . Input current typically 10pA at 25°C.

**HYST (Pin 5):** Hysteresis Input. Connect to REF if not used. Input voltage range is from  $V_{REF}$  to  $V_{REF} - 50mV$ .

**REF (Pin 6):** Reference Output. 1.182V with respect to  $V^-$ . Can source up to 200 $\mu A$  and sink 15 $\mu A$  at 25°C. Drive 0.01 $\mu F$  bypass capacitor without oscillation.

**$V^+$  (Pin 7):** Positive Supply. 2V to 11V.

**OUT B (Pin 8):** Comparator B CMOS Output. Swings from  $V^-$  to  $V^+$ . Output can source up to 40mA and sink 5mA.

## APPLICATIONS INFORMATION

LTC1440/LTC1441/LTC1442 are a family of micropower comparators with built-in 1.182V reference. Features include programmable hysteresis (LTC1440/LTC1442), wide supply voltage range (2V to 11V) and the ability of the reference to drive up to a 0.01 $\mu$ F capacitor without oscillation. The comparators' CMOS outputs can source up to 40mA and the supply current glitches, that normally occur when switching logic states, have been eliminated.

### Power Supplies

The comparator family operates from a single 2V to 11V supply. The LTC1440 includes a separate ground for the comparator output stage, allowing a split supply ranging from  $\pm 1$ V to  $\pm 5.5$ V. Connecting  $V^-$  to GND on the LTC1440 will allow single supply operation. If the comparator output is required to source more than 1mA, or the supply source impedance is high,  $V^+$  should be bypassed with a 0.1 $\mu$ F capacitor.

### Comparator Inputs

The comparator inputs can swing from the negative supply  $V^-$  to within 1.3V max of the positive supply  $V^+$ . The inputs can be forced 300mV below  $V^-$  or above  $V^+$  without damage and the typical input leakage current is only  $\pm 10$ pA.

### Comparator Outputs

The LTC1440 comparator output swings between GND and  $V^+$  to assure TTL compatibility with a split supply. The LTC1441 and LTC1442 outputs swing between  $V^-$  and  $V^+$ . The outputs are capable of sourcing up to 40mA and sinking up to 5mA while still maintaining microampere quiescent currents. The output stage does not generate crowbar switching currents during transitions which helps minimize parasitic feedback through the supply pins.

### Voltage Reference

The internal bandgap reference has a voltage of 1.182V referenced to  $V^-$ . The reference accuracy is 1.5% from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ . It can source up to 200 $\mu$ A and sink up to 20 $\mu$ A with a 5V supply. The reference can drive a bypass

capacitor of up to 0.01 $\mu$ F without oscillation and by inserting a series resistor, capacitance values up to 100 $\mu$ F can be used (Figure 1).

Figure 2 shows the resistor value required for different capacitor values to achieve critical damping. Bypassing the reference can help prevent false tripping of the comparators by preventing glitches on  $V^+$  or reference load transients from disturbing the reference output voltage.

Figure 3 shows the bypassed reference output with a square wave applied to the  $V^+$  pin. Resistors R2 and R3 set 10mV of hysteresis voltage band while R1 damps the reference response. Note that the comparator output doesn't trip.

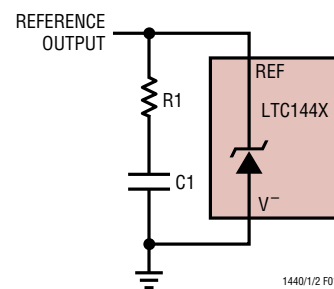


Figure 1. Damping the Reference Output

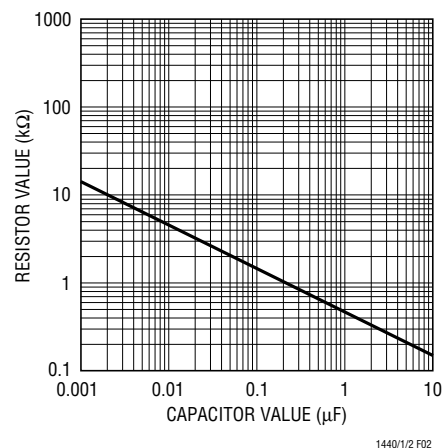


Figure 2. Damping Resistance vs Bypass Capacitor Value

## APPLICATIONS INFORMATION

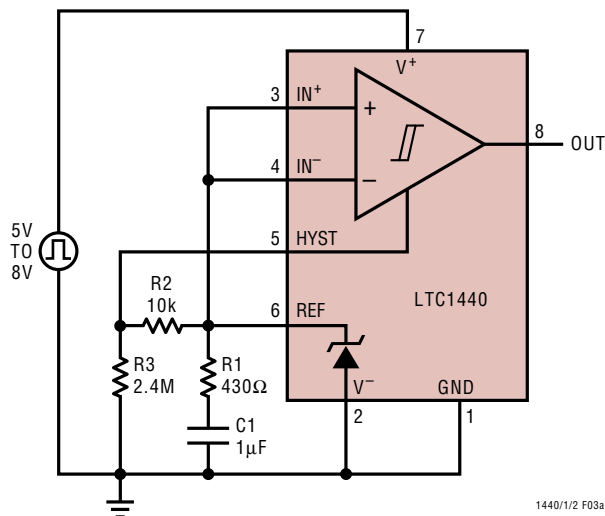


Figure 3a. Reference Transient Response Test Circuit

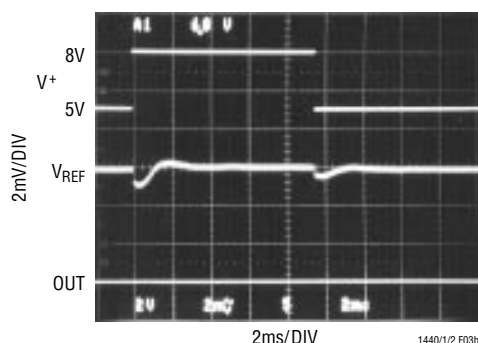


Figure 3b. Reference and Comparator Output Transient Response

### Hysteresis

Hysteresis can be added to the LTC1440 by connecting a resistor (R1) between the REF and HYST pins and a second resistor (R2) from HYST to V<sup>-</sup> (Figure 4).

The difference between the upper and lower threshold voltages, or hysteresis voltage band (V<sub>HB</sub>), is equal to twice the voltage difference between the REF and HYST pins.

When more hysteresis is added, the upper threshold increases the same amount as the low threshold decreases. The maximum voltage allowed between REF and HYST pins is 50mV, producing a maximum hysteresis voltage band of 100mV. The hysteresis band could vary by

up to 15%. If hysteresis is not wanted, the HYST pin should be shorted to REF. Acceptable values for I<sub>REF</sub> range from 0.1μA to 5μA. If 2.4M is chosen for R2, then the value of R1 is equal to the value of V<sub>HB</sub>.

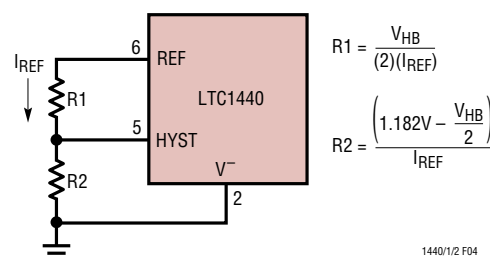


Figure 4. Programmable Hysteresis

### Level Detector

The LTC1440 is ideal for use as a micropower level detector as shown in Figure 5. R1 and R2 form a voltage divider from V<sub>IN</sub> to the noninverting comparator input. R3 and R4 set the hysteresis voltage, and R5 and C1 bypass the reference output. The following design procedure can be used to select the component values:

1. Choose the V<sub>IN</sub> voltage trip level, in this example 4.65V.

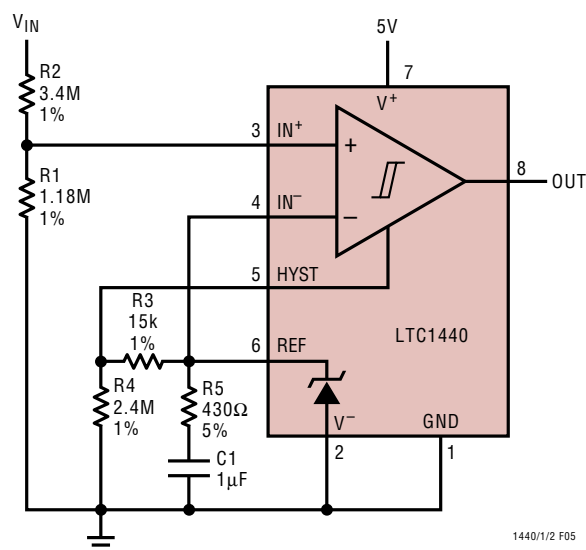


Figure 5. Glitch-Free Level Detector with Hysteresis

## APPLICATIONS INFORMATION

2. Calculate the required resistive divider ratio.

$$\text{Ratio} = V_{\text{REF}}/V_{\text{IN}}$$

$$\text{Ratio} = 1.182\text{V}/4.65\text{V} = 0.254$$

3. Choose the required hysteresis voltage band at the input  $V_{\text{HBIN}}$ , in this example 60mV. Calculate the hysteresis voltage band referred to the comparator input  $V_{\text{HB}}$ .

$$V_{\text{HB}} = (V_{\text{HBIN}})(\text{Ratio})$$

$$V_{\text{HB}} = (60\text{mV})(0.254)$$

$$V_{\text{HB}} = 15.24\text{mV}$$

4. Choose the values for R3 and R4 to set the hysteresis.

$$R4 = 2.4\text{M}$$

$$R3(\text{k}\Omega) = V_{\text{HB}} = 15\text{k}$$

5. Choose the values for R1 and R2 to set the trip point.

$$R1 = \frac{V_{\text{REF}}}{I_{\text{BIAS}}} = \frac{1.182\text{V}}{1\mu\text{A}} = 1.18\text{M}$$

$$R2 = R1 \left[ \frac{V_{\text{IN}}}{V_{\text{REF}} + \frac{V_{\text{HB}}}{2}} - 1 \right]$$

$$R2 = 1.18\text{M} \left[ \frac{4.65\text{V}}{1.182\text{V} + \frac{15\text{mV}}{2}} - 1 \right]$$

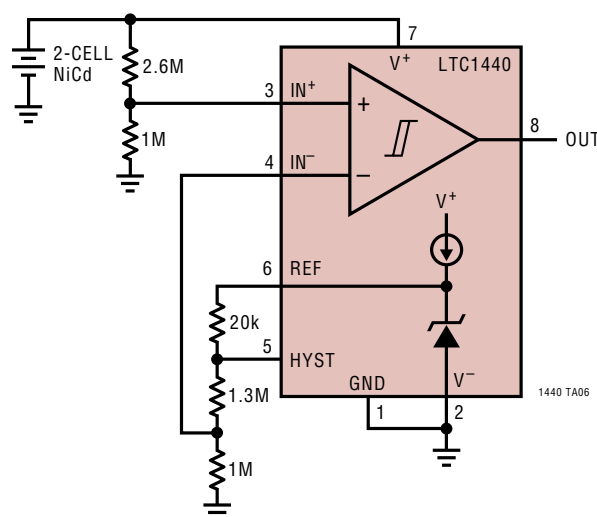
$$R2 = 3.40\text{M}$$

### Low Voltage Operation

The guaranteed minimum operating voltage is 2V or ( $\pm 1\text{V}$ ). As the total supply voltage is reduced below 2V, the performance degrades and the supply current falls. Both the reference and the comparator are still functioning with supply voltage down to 1.5V. The reference will have slightly worse temperature coefficient. While the comparator would have less output drive and the propagation delay increases. The useful input voltage range extends from the negative supply to a little under 1V below the positive supply, which is slightly closer to the positive rail than the device operating from higher supply voltages.

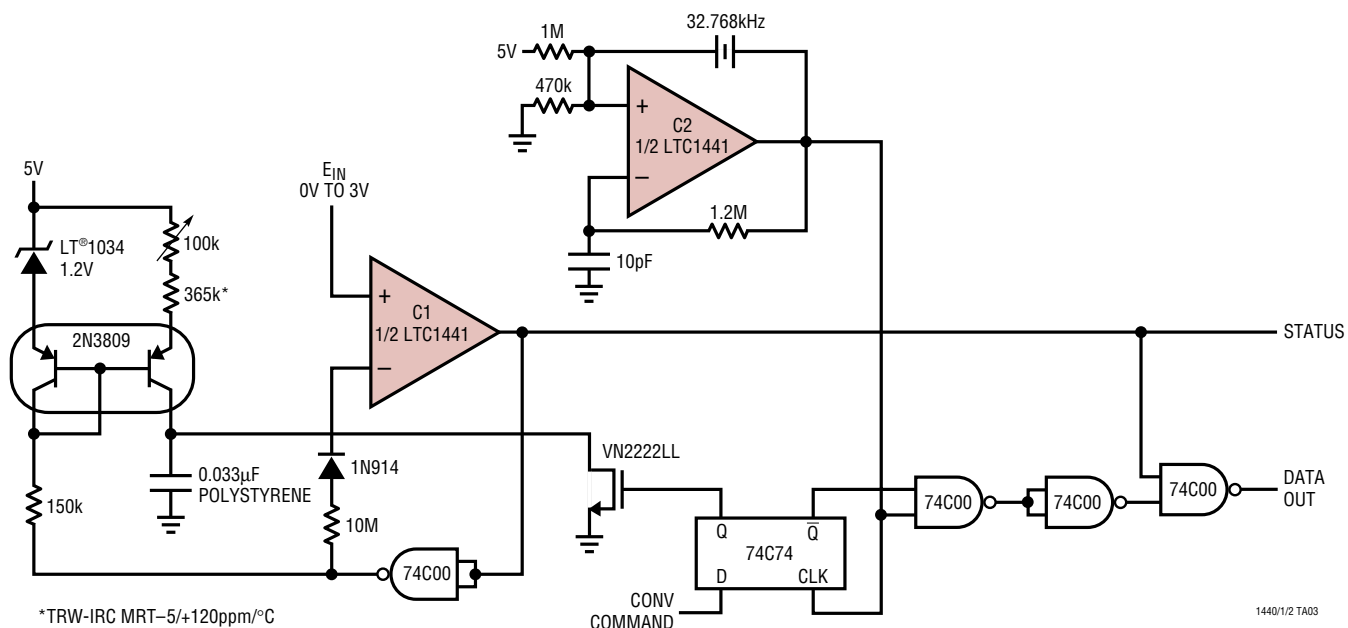
## TYPICAL APPLICATIONS

Low Battery Detect Operates Down to 1.5V

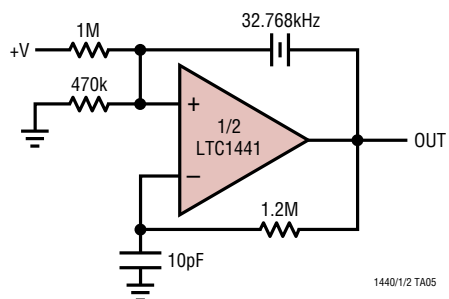


## TYPICAL APPLICATIONS

## 10-Bit 30 $\mu$ A A/D Converter



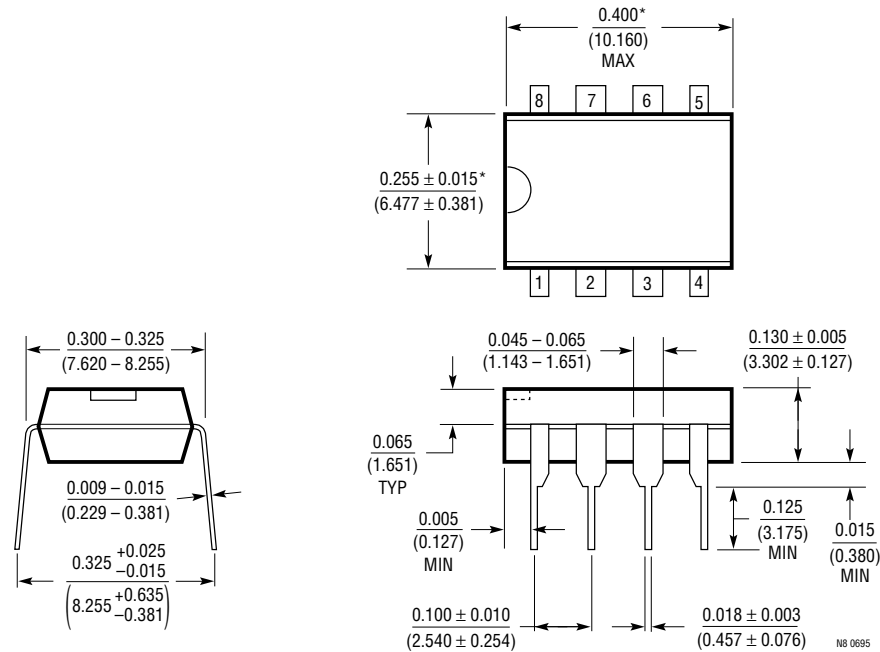
### 32.768kHz “Watch Crystal” Oscillator



## PACKAGE DESCRIPTION

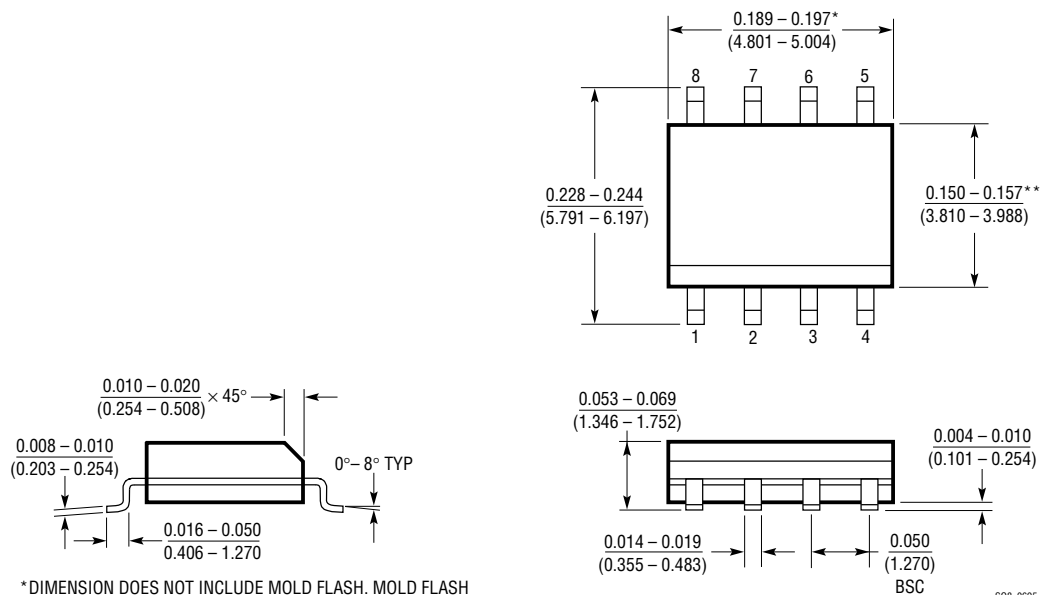
**Dimensions in inches (millimeters) unless otherwise noted.**

**N8 Package**  
**8-Lead PDIP (Narrow 0.300)**  
(LTC DWG # 05-08-1510)



\*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.  
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.010 INCH (0.254mm)

**S8 Package**  
**8-Lead Plastic Small Outline (Narrow 0.150)**  
 (LTC DWG # 05-08-1610)



\*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

\*\* DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

## TYPICAL APPLICATION

INPUT 0V TO 5V → 1.2M\* → 10kHz TRIM 200k → 0.01μF → C1 1/2 LTC1441 (-)

C1 1/2 LTC1441 (+) → 100k → 1N4148 → 2M TYP 100Hz TRIM → 50pF → C2 1/2 LTC1441 (-)

C2 1/2 LTC1441 (+) → 0.1μF → 74C14 → f<sub>OUT</sub> 0kHz TO 10kHz

+V 6.2V TO 12V → LM334 → 2k\* → Q1 1N4148 → C1 1/2 LTC1441 (-)

+V 6.2V TO 12V → LM334 → LT1034-1.2 → LT1034-1.2 → Q8 2N2222 → 0.47μF → f<sub>OUT</sub> 0kHz TO 10kHz

+V 6.2V TO 12V → Q2 2N2222 → Q3 2N2222 → Q4 2N2222 → 2.7M → C2 1/2 LTC1441 (-)

+V 6.2V TO 12V → Q5 2N2222 → Q6 2N2222 → 10M → 100pF\*\* → C2 1/2 LTC1441 (-)

+V 6.2V TO 12V → Q7 2N2222 → 15k → C1 1/2 LTC1441 (+)

\* = 1% METAL FILM  
 \*\* = POLYSTYRENE

1440/1/2 TA04

## RELATED PARTS

| PART NUMBER             | DESCRIPTION                                      | COMMENTS                                                                                      |
|-------------------------|--------------------------------------------------|-----------------------------------------------------------------------------------------------|
| LT1178/LT1179           | Dual/Quad 17μA Precision Single Supply Op Amps   | 70μV Max V <sub>OS</sub> , 5nA Max I <sub>B</sub> IAS                                         |
| LT1351                  | Single 250μA, 3MHz, 200V/μs Op Amp with Shutdown | C-Load™ Op Amp Stable Driving Any Capacitive Load                                             |
| LT1352/LT1353           | Dual/Quad 250μA, 3MHz, 200V/μs Op Amps           | C-Load Op Amps Stable Driving Any Capacitive Load                                             |
| LTC1443/LTC1444/LTC1445 | Micropower Quad Comparator with 1% Reference     | LTC1443 Has 1.182V Reference, LTC1444/LTC1445 Have 1.221V Reference and Adjustable Hysteresis |

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