

## LM10 Operational Amplifier and Voltage Reference

Check for Samples: [LM10](#)

### FEATURES

- **Input Offset Voltage: 2 mV (max)**
- **Input Offset Current: 0.7 nA (max)**
- **Input Bias Current: 20 nA (max)**
- **Reference Regulation: 0.1% (max)**
- **Offset Voltage Drift: 2  $\mu\text{V}/^\circ\text{C}$**
- **Reference Drift: 0.002%/ $^\circ\text{C}$**

### DESCRIPTION

The LM10 series are monolithic linear ICs consisting of a precision reference, an adjustable reference buffer and an independent, high quality op amp.

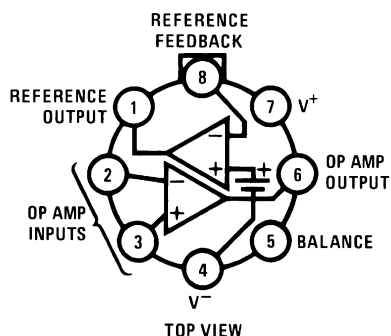
The unit can operate from a total supply voltage as low as 1.1V or as high as 40V, drawing only 270 $\mu\text{A}$ . A complementary output stage swings within 15 mV of the supply terminals or will deliver  $\pm 20$  mA output current with  $\pm 0.4\text{V}$  saturation. Reference output can be as low as 200 mV.

The circuit is recommended for portable equipment and is completely specified for operation from a single power cell. In contrast, high output-drive capability, both voltage and current, along with thermal overload protection, suggest it in demanding general-purpose applications.

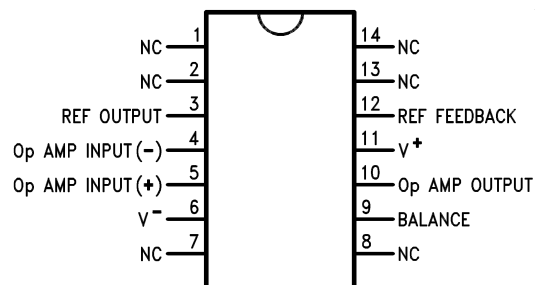
The device is capable of operating in a floating mode, independent of fixed supplies. It can function as a remote comparator, signal conditioner, SCR controller or transmitter for analog signals, delivering the processed signal on the same line used to supply power. It is also suited for operation in a wide range of voltage- and current-regulator applications, from low voltages to several hundred volts, providing greater precision than existing ICs.

This series is available in the three standard temperature ranges, with the commercial part having relaxed limits. In addition, a low-voltage specification (suffix "L") is available in the limited temperature ranges at a cost savings.

### Connection and Functional Diagrams



**Figure 1. TO Package (NEV)**  
See Package Number NEV0008A

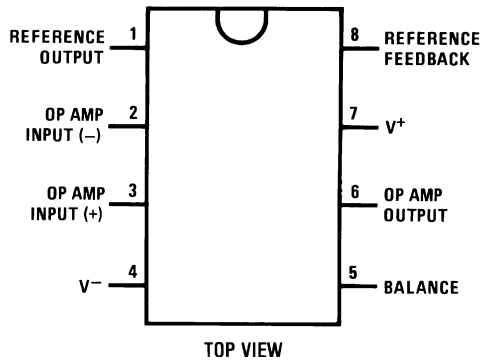


**Figure 2. SOIC Package (NPA)**  
See Package Number NPA0014B

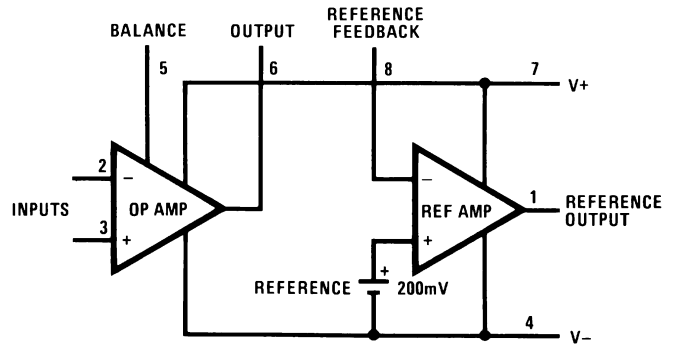


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**Figure 3. PDIP Package (P)**  
See Package Number P (R-PDIP-T8)



**Figure 4.**



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### Absolute Maximum Ratings<sup>(1)(2)(3)</sup>

|  | LM10/LM10B/        | LM10BL/ |
|--|--------------------|---------|
|  | LM10C              | LM10CL  |
| Total Supply Voltage                         | 45V                | 7V      |
| Differential Input Voltage <sup>(4)</sup>    | ±40V               | ±7V     |
| Power Dissipation <sup>(5)</sup>             | internally limited |         |
| Output Short-circuit Duration <sup>(6)</sup> | continuous         |         |
| Storage-Temp. Range                          | -55°C to +150°C    |         |
| Lead Temp. (Soldering, 10 seconds)           |                    |         |
| TO   | 300°C              |         |
| Lead Temp. (Soldering, 10 seconds) DIP       | 260°C              |         |
| Vapor Phase (60 seconds)                     | 215°C              |         |
| Infrared (15 seconds)                        | 220°C              |         |
| ESD rating is to be determined.              |                    |         |
| Maximum Junction Temperature                 |                    |         |
| LM10   | 150°C              |         |
| LM10B  | 100°C              |         |
| LM10C  | 85°C               |         |

- (1) Refer to RETS10X for LM10H military specifications.
- (2) Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits.
- (3) If Military/Aerospace specified devices are required, please contact the TI Sales Office/Distributors for availability and specifications.
- (4) The Input voltage can exceed the supply voltages provided that the voltage from the input to any other terminal does not exceed the maximum differential input voltage and excess dissipation is accounted for when  $V_{IN} < V^-$ .
- (5) The maximum, operating-junction temperature is 150°C for the LM10, 100°C for the LM10B(L) and 85°C for the LM10C(L). At elevated temperatures, devices must be derated based on package thermal resistance.
- (6) Internal thermal limiting prevents excessive heating that could result in sudden failure, but the IC can be subjected to accelerated stress with a shorted output and worst-case conditions.

## Operating Ratings

|                            |  |         |
|----------------------------|--|---------|
| Package Thermal Resistance |  |         |
| $\theta_{JA}$              |  |         |
| NEV Package                |  | 150°C/W |
| P Package                  |  | 87°C/W  |
| NPA Package                |  | 90°C/W  |
| $\theta_{JC}$              |  |         |
| NEV Package                |  | 45°C/W  |

## Electrical Characteristics

 $T_J = 25^\circ\text{C}$ ,  $T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$  (Boldface type refers to limits over temperature range)<sup>(1)</sup>

| Parameter                           | Conditions   | LM10/LM10B |       |              | LM10C       |       |             | Units                        |
|-------------------------------------|--|------------|-------|--------------|-------------|-------|-------------|------------------------------|
|                                     |  | Min        | Typ   | Max          | Min         | Typ   | Max         |                              |
| Input offset voltage                |  |            | 0.3   | 2.0          |             | 0.5   | 4.0         | mV                           |
|                                     |  |            |       | <b>3.0</b>   |             |       | <b>5.0</b>  | mV                           |
| Input offset current <sup>(2)</sup> |  |            | 0.25  | 0.7          |             | 0.4   | 2.0         | nA                           |
|                                     |  |            |       | <b>1.5</b>   |             |       | <b>3.0</b>  | nA                           |
| Input bias current                  |  |            | 10    | 20           |             | 12    | 30          | nA                           |
|                                     |  |            |       | <b>30</b>    |             |       | <b>40</b>   | nA                           |
| Input resistance                    |  | 250        | 500   |              | 150         | 400   |             | k $\Omega$                   |
|                                     |  | <b>150</b> |       |              | <b>115</b>  |       |             | k $\Omega$                   |
| Large signal voltage gain           | $V_S = \pm 20\text{V}$ , $I_{OUT} = 0$   | 120        | 400   |              | 80          | 400   |             | V/mV                         |
|                                     | $V_{OUT} = \pm 19.95\text{V}$  | <b>80</b>  |       |              | <b>50</b>   |       |             | V/mV                         |
|                                     | $V_S = \pm 20\text{V}$ , $V_{OUT} = \pm 19.4\text{V}$  | 50         | 130   |              | 25          | 130   |             | V/mV                         |
|                                     | $I_{OUT} = \pm 20\text{ mA}$ ( <b><math>\pm 15\text{ mA}</math></b> )  | <b>20</b>  |       |              | <b>15</b>   |       |             | V/mV                         |
|                                     | $V_S = \pm 0.6\text{V}$ ( <b><math>0.65\text{V}</math></b> ), $I_{OUT} = \pm 2\text{ mA}$                        | 1.5        | 3.0   |              | 1.0         | 3.0   |             | V/mV                         |
|                                     | $V_{OUT} = \pm 0.4\text{V}$ ( <b><math>\pm 0.3\text{V}</math></b> ), $V_{CM} = -0.4\text{V}$                     | <b>0.5</b> |       |              | <b>0.75</b> |       |             | V/mV                         |
| Shunt gain <sup>(3)</sup>           | $1.2\text{V}$ ( <b><math>1.3\text{V}</math></b> ) $\leq V_{OUT} \leq 40\text{V}$ ,<br>$R_L = 1.1\text{ k}\Omega$ | 14         | 33    |              | 10          | 33    |             | V/mV                         |
|                                     | $0.1\text{ mA} \leq I_{OUT} \leq 5\text{ mA}$  | <b>6</b>   |       |              | <b>6</b>    |       |             | V/mV                         |
|                                     | $1.5\text{V} \leq V^+ \leq 40\text{V}$ , $R_L = 250\Omega$   | 8          | 25    |              | 6           | 25    |             | V/mV                         |
|                                     | $0.1\text{ mA} \leq I_{OUT} \leq 20\text{ mA}$   | <b>4</b>   |       |              | <b>4</b>    |       |             | V/mV                         |
| Common-mode rejection               | $-20\text{V} \leq V_{CM} \leq 19.15\text{V}$ ( <b><math>19\text{V}</math></b> )                                  | 93         | 102   |              | 90          | 102   |             | dB                           |
|                                     | $V_S = \pm 20\text{V}$   | <b>87</b>  |       |              | <b>87</b>   |       |             | dB                           |
| Supply-voltage rejection            | $-0.2\text{V} \geq V^- \geq -39\text{V}$   | 90         | 96    |              | 87          | 96    |             | dB                           |
|                                     | $V^+ = 1.0\text{V}$ ( <b><math>1.1\text{V}</math></b> )  | <b>84</b>  |       |              | <b>84</b>   |       |             | dB                           |
|                                     | $1.0\text{V}$ ( <b><math>1.1\text{V}</math></b> ) $\leq V^+ \leq 39.8\text{V}$                                   | 96         | 106   |              | 93          | 106   |             | dB                           |
|                                     | $V^- = -0.2\text{V}$   | <b>90</b>  |       |              | <b>90</b>   |       |             | dB                           |
| Offset voltage drift                |  |            | 2.0   |              |             | 5.0   |             | $\mu\text{V}/^\circ\text{C}$ |
| Offset current drift                |  |            | 2.0   |              |             | 5.0   |             | $\text{pA}/^\circ\text{C}$   |
| Bias current drift                  | $T_C < 100^\circ\text{C}$  |            | 60    |              |             | 90    |             | $\text{pA}/^\circ\text{C}$   |
| Line regulation                     | $1.2\text{V}$ ( <b><math>1.3\text{V}</math></b> ) $\leq V_S \leq 40\text{V}$                                     |            | 0.001 | 0.003        |             | 0.001 | 0.008       | %/V                          |
|                                     | $0 \leq I_{REF} \leq 1.0\text{ mA}$ , $V_{REF} = 200\text{ mV}$  |            |       | <b>0.006</b> |             |       | <b>0.01</b> | %/V                          |

- (1) These specifications apply for  $V^- \leq V_{CM} \leq V^+ - 0.85\text{V}$  ( **$1.0\text{V}$** ),  $1.2\text{V}$  ( **$1.3\text{V}$** )  $< V_S \leq V_{MAX}$ ,  $V_{REF} = 0.2\text{V}$  and  $0 \leq I_{REF} \leq 1.0\text{ mA}$ , unless otherwise specified:  $V_{MAX} = 40\text{V}$  for the standard part and  $6.5\text{V}$  for the low voltage part. Normal typeface indicates  $25^\circ\text{C}$  limits. **Boldface type indicates limits and altered test conditions for full-temperature-range operation**; this is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the LM10,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for the LM10B(L) and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for the LM10C(L). The specifications do not include the effects of thermal gradients ( $\tau_1 = 20\text{ ms}$ ), die heating ( $\tau_2 = 0.2\text{ s}$ ) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).
- (2) For  $T_J > 90^\circ\text{C}$ ,  $I_{OS}$  may exceed  $1.5\text{ nA}$  for  $V_{CM} = V^-$ . With  $T_J = 125^\circ\text{C}$  and  $V^- \leq V_{CM} \leq V^- + 0.1\text{V}$ ,  $I_{OS} \leq 5\text{ nA}$ .
- (3) This defines operation in floating applications such as the bootstrapped regulator or two-wire transmitter. Output is connected to the  $V^+$  terminal of the IC and input common mode is referred to  $V^-$  (see [Typical Applications](#)). Effect of larger output-voltage swings with higher load resistance can be accounted for by adding the positive-supply rejection error.

## Electrical Characteristics (continued)

 $T_J = 25^\circ\text{C}$ ,  $T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$  (Boldface type refers to limits over temperature range)<sup>(1)</sup>

| Parameter              | Conditions   | LM10/LM10B |       |             | LM10C      |       |            | Units |
|------------------------|--|------------|-------|-------------|------------|-------|------------|-------|
|                        |  | Min        | Typ   | Max         | Min        | Typ   | Max        |       |
| Load regulation        | $0 \leq I_{\text{REF}} \leq 1.0 \text{ mA}$<br>$V^+ - V_{\text{REF}} \geq 1.0\text{V}$ ( <b>1.1V</b> ) |            | 0.01  | 0.1         |            | 0.01  | 0.15       | %     |
|                        |  |            |       | <b>0.15</b> |            |       | <b>0.2</b> | %     |
| Amplifier gain         | $0.2\text{V} \leq V_{\text{REF}} \leq 35\text{V}$  | 50         | 75    |             | 25         | 70    |            | V/mV  |
|                        |  | <b>23</b>  |       |             | <b>15</b>  |       |            | V/mV  |
| Feedback sense voltage |  | 195        | 200   | 205         | 190        | 200   | 210        | mV    |
|                        |  | <b>194</b> |       | <b>206</b>  | <b>189</b> |       | <b>211</b> | mV    |
| Feedback current       |  |            | 20    | 50          |            | 22    | 75         | nA    |
|                        |  |            |       | <b>65</b>   |            |       | <b>90</b>  | nA    |
| Reference drift        |  |            | 0.002 |             |            | 0.003 |            | %/°C  |
| Supply current         |  |            | 270   | 400         |            | 300   | 500        | μA    |
|                        |  |            |       | <b>500</b>  |            |       | <b>570</b> | μA    |
| Supply current change  | $1.2\text{V}$ ( <b>1.3V</b> ) $\leq V_S \leq 40\text{V}$   |            | 15    | <b>75</b>   |            | 15    | <b>75</b>  | μA    |

## Electrical Characteristics

 $T_J = 25^\circ\text{C}$ ,  $T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$  (Boldface type refers to limits over temperature range)<sup>(1)</sup>

| Parameter                           | Conditions  | LM10BL     |     |            | LM10CL      |     |            | Units |
|-------------------------------------|---|------------|-----|------------|-------------|-----|------------|-------|
|                                     |   | Min        | Typ | Max        | Min         | Typ | Max        |       |
| Input offset voltage                |   |            | 0.3 | 2.0        |             | 0.5 | 4.0        | mV    |
|                                     |   |            |     | <b>3.0</b> |             |     | <b>5.0</b> | mV    |
| Input offset current <sup>(2)</sup> |   |            | 0.1 | 0.7        |             | 0.2 | 2.0        | nA    |
|                                     |   |            |     | <b>1.5</b> |             |     | <b>3.0</b> | nA    |
| Input bias current                  |   |            | 10  | 20         |             | 12  | 30         | nA    |
|                                     |   |            |     | <b>30</b>  |             |     | <b>40</b>  | nA    |
| Input resistance                    |   | 250        | 500 |            | 150         | 400 |            | kΩ    |
|                                     |   | <b>150</b> |     |            | <b>115</b>  |     |            | kΩ    |
| Large signal voltage gain           | $V_S = \pm 3.25\text{V}$ , $I_{\text{OUT}} = 0$                                     | 60         | 300 |            | 40          | 300 |            | V/mV  |
|                                     | $V_{\text{OUT}} = \pm 3.2\text{V}$  | <b>40</b>  |     |            | <b>25</b>   |     |            | V/mV  |
|                                     | $V_S = \pm 3.25\text{V}$ , $I_{\text{OUT}} = 10 \text{ mA}$                         | 10         | 25  |            | 5           | 25  |            | V/mV  |
|                                     | $V_{\text{OUT}} = \pm 2.75 \text{ V}$   | <b>4</b>   |     |            | <b>3</b>    |     |            | V/mV  |
|                                     | $V_S = \pm 0.6\text{V}$ ( <b>0.65V</b> ), $I_{\text{OUT}} = \pm 2 \text{ mA}$       | 1.5        | 3.0 |            | 1.0         | 3.0 |            | V/mV  |
|                                     | $V_{\text{OUT}} = \pm 0.4\text{V}$ ( <b>±0.3V</b> ), $V_{\text{CM}} = -0.4\text{V}$ | <b>0.5</b> |     |            | <b>0.75</b> |     |            | V/mV  |
| Shunt gain <sup>(3)</sup>           | $1.5\text{V} \leq V^+ \leq 6.5\text{V}$ , $R_L = 500\Omega$                         | 8          | 30  |            | 6           | 30  |            | V/mV  |
|                                     | $0.1 \text{ mA} \leq I_{\text{OUT}} \leq 10 \text{ mA}$                             | <b>4</b>   |     |            | <b>4</b>    |     |            | V/mV  |
| Common-mode rejection               | $-3.25\text{V} \leq V_{\text{CM}} \leq 2.4\text{V}$ ( <b>2.25V</b> )                | 89         | 102 |            | 80          | 102 |            | dB    |
|                                     | $V_S = \pm 3.25\text{V}$  | <b>83</b>  |     |            | <b>74</b>   |     |            | dB    |
| Supply-voltage rejection            | $-0.2\text{V} \leq V^- \leq -5.4\text{V}$   | 86         | 96  |            | 80          | 96  |            | dB    |
|                                     | $V^+ = 1.0\text{V}$ ( <b>1.2V</b> )   | <b>80</b>  |     |            | <b>74</b>   |     |            | dB    |
|                                     | $1.0\text{V}$ ( <b>1.1V</b> ) $\leq V^+ \leq 6.3\text{V}$                           | 94         | 106 |            | 80          | 106 |            | dB    |
|                                     | $V^- = 0.2\text{V}$   | <b>88</b>  |     |            | <b>74</b>   |     |            | dB    |

(1) These specifications apply for  $V^- \leq V_{\text{CM}} \leq V^+ - 0.85\text{V}$  (**1.0V**),  $1.2\text{V}$  (**1.3V**)  $< V_S \leq V_{\text{MAX}}$ ,  $V_{\text{REF}} = 0.2\text{V}$  and  $0 \leq I_{\text{REF}} \leq 1.0 \text{ mA}$ , unless otherwise specified:  $V_{\text{MAX}} = 40\text{V}$  for the standard part and  $6.5\text{V}$  for the low voltage part. Normal typeface indicates  $25^\circ\text{C}$  limits. **Boldface type indicates limits and altered test conditions for full-temperature-range operation**; this is  $-55^\circ\text{C}$  to  $125^\circ\text{C}$  for the LM10,  $-25^\circ\text{C}$  to  $85^\circ\text{C}$  for the LM10B(L) and  $0^\circ\text{C}$  to  $70^\circ\text{C}$  for the LM10C(L). The specifications do not include the effects of thermal gradients ( $\tau_1 = 20 \text{ ms}$ ), die heating ( $\tau_2 = 0.2\text{s}$ ) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).

(2) For  $T_J > 90^\circ\text{C}$ ,  $I_{\text{OS}}$  may exceed  $1.5 \text{ nA}$  for  $V_{\text{CM}} = V^-$ . With  $T_J = 125^\circ\text{C}$  and  $V^- \leq V_{\text{CM}} \leq V^- + 0.1\text{V}$ ,  $I_{\text{OS}} \leq 5 \text{ nA}$ .

(3) This defines operation in floating applications such as the bootstrapped regulator or two-wire transmitter. Output is connected to the  $V^+$  terminal of the IC and input common mode is referred to  $V^-$  (see [Typical Applications](#)). Effect of larger output-voltage swings with higher load resistance can be accounted for by adding the positive-supply rejection error.

**Electrical Characteristics (continued)**
 $T_J = 25^\circ\text{C}$ ,  $T_{\text{MIN}} \leq T_J \leq T_{\text{MAX}}$  (Boldface type refers to limits over temperature range)<sup>(1)</sup>

| Parameter              | Conditions  | LM10BL            |       |      | LM10CL            |       |      | Units                          |
|------------------------|---|-------------------|-------|------|-------------------|-------|------|--------------------------------|
|                        |   | Min               | Typ   | Max  | Min               | Typ   | Max  |                                |
| Offset voltage drift   |   |                   | 2.0   |      |                   | 5.0   |      | $\mu\text{V}/^\circ\text{C}$   |
| Offset current drift   |   |                   | 2.0   |      |                   | 5.0   |      | $\text{pA}/^\circ\text{C}$     |
| Bias current drift     |   |                   | 60    |      |                   | 90    |      | $\text{pA}/^\circ\text{C}$     |
| Line regulation        | $1.2\text{V (1.3V)} \leq V_S \leq 6.5\text{V}$<br>$0 \leq I_{\text{REF}} \leq 0.5\text{ mA}$ , $V_{\text{REF}} = 200\text{ mV}$ |                   | 0.001 | 0.01 |                   | 0.001 | 0.02 | $\%/V$<br>$\%/V$               |
| Load regulation        | $0 \leq I_{\text{REF}} \leq 0.5\text{ mA}$<br>$V^+ - V_{\text{REF}} \geq 1.0\text{V (1.1V)}$                                    |                   | 0.01  | 0.1  |                   | 0.01  | 0.15 | $\%$<br>$\%$                   |
| Amplifier gain         | $0.2\text{V} \leq V_{\text{REF}} \leq 5.5\text{V}$  | 30<br><b>20</b>   | 70    |      | 20<br><b>15</b>   | 70    |      | $\text{V/mV}$<br>$\text{V/mV}$ |
| Feedback sense voltage |   | 195<br><b>194</b> | 200   | 205  | 190<br><b>189</b> | 200   | 210  | $\text{mV}$<br>$\text{mV}$     |
| Feedback current       |   |                   | 20    | 50   |                   | 22    | 75   | $\text{nA}$<br>$\text{nA}$     |
| Reference drift        |   |                   | 0.002 |      |                   | 0.003 |      | $\%/^\circ\text{C}$            |
| Supply current         |   |                   | 260   | 400  |                   | 280   | 500  | $\mu\text{A}$<br>$\mu\text{A}$ |

**Definition of Terms**

**Input offset voltage:** That voltage which must be applied between the input terminals to bias the unloaded output in the linear region.

**Input offset current:** The difference in the currents at the input terminals when the unloaded output is in the linear region.

**Input bias current:** The absolute value of the average of the two input currents.

**Input resistance:** The ratio of the change in input voltage to the change in input current on either input with the other grounded.

**Large signal voltage gain:** The ratio of the specified output voltage swing to the change in differential input voltage required to produce it.

**Shunt gain:** The ratio of the specified output voltage swing to the change in differential input voltage required to produce it with the output tied to the  $V^+$  terminal of the IC. The load and power source are connected between the  $V^+$  and  $V^-$  terminals, and input common-mode is referred to the  $V^-$  terminal.

**Common-mode rejection:** The ratio of the input voltage range to the change in offset voltage between the extremes.

**Supply-voltage rejection:** The ratio of the specified supply-voltage change to the change in offset voltage between the extremes.

**Line regulation:** The average change in reference output voltage over the specified supply voltage range.

**Load regulation:** The change in reference output voltage from no load to that load specified.

**Feedback sense voltage:** The voltage, referred to  $V^-$ , on the reference feedback terminal while operating in regulation.

**Reference amplifier gain:** The ratio of the specified reference output change to the change in feedback sense voltage required to produce it.

**Feedback current:** The absolute value of the current at the feedback terminal when operating in regulation.

**Supply current:** The current required from the power source to operate the amplifier and reference with their outputs unloaded and operating in the linear range.

Typical Performance Characteristics (Op Amp)

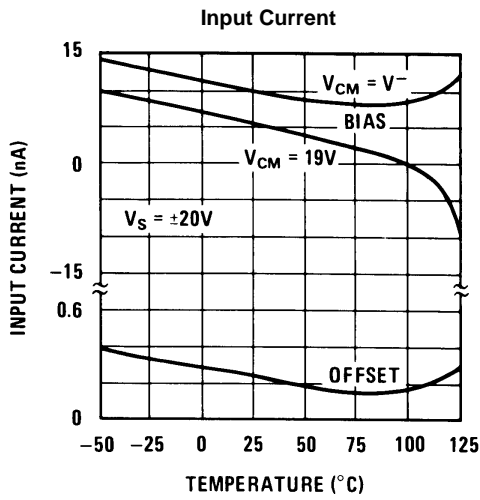


Figure 5.

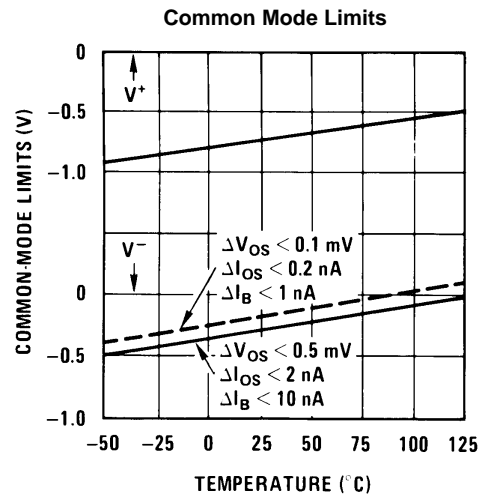


Figure 6.

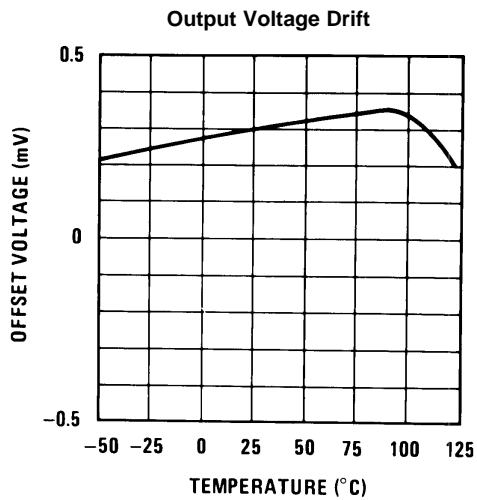


Figure 7.

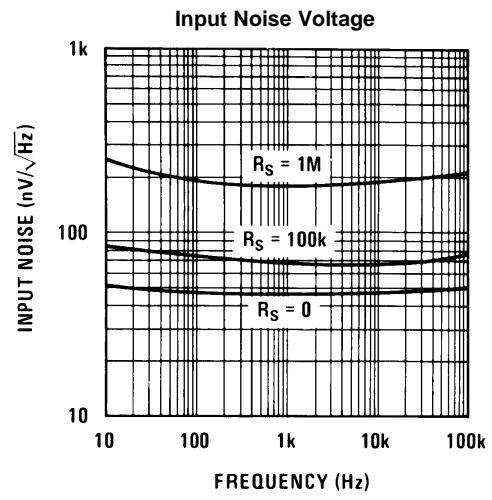


Figure 8.

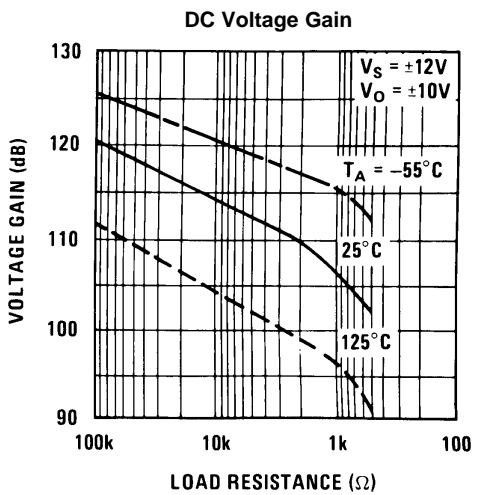


Figure 9.

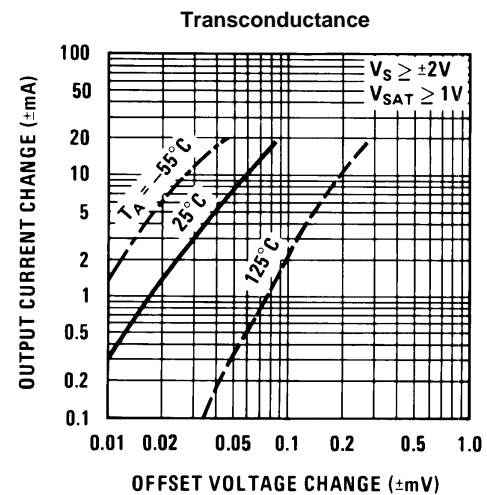


Figure 10.

Typical Performance Characteristics (Op Amp) (continued)

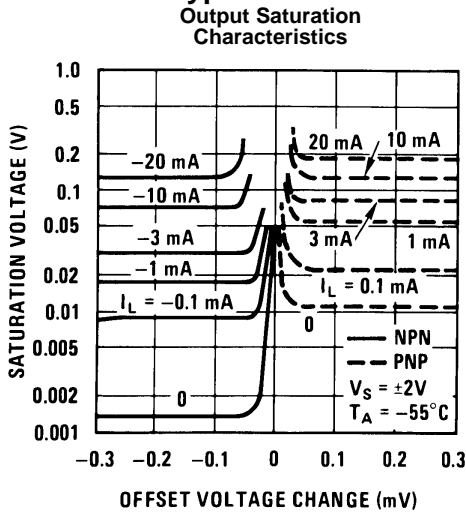


Figure 11.

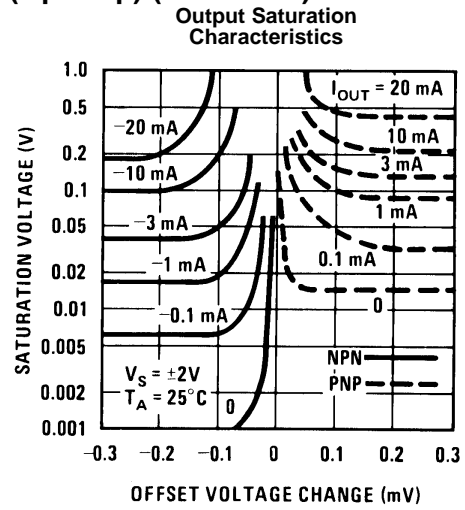


Figure 12.

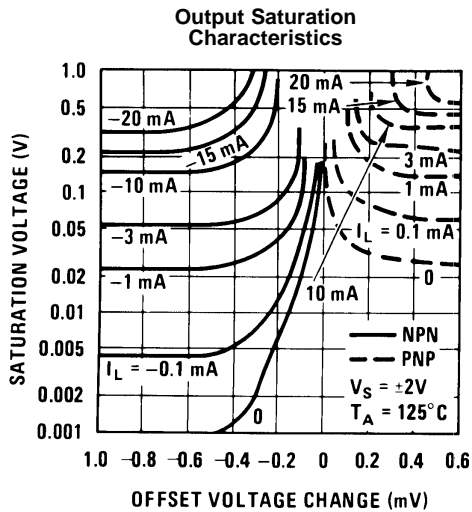


Figure 13.

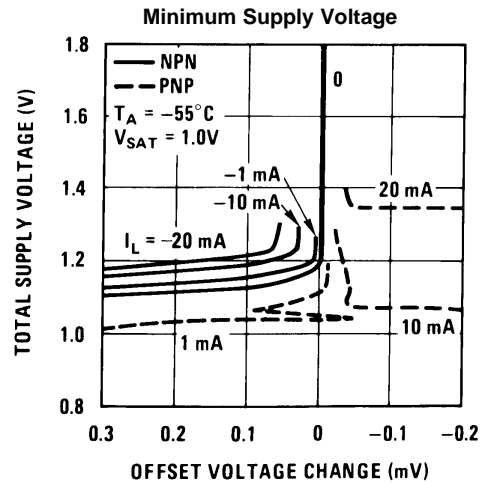


Figure 14.

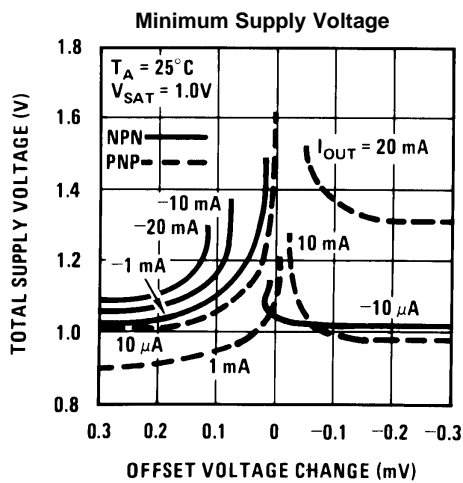


Figure 15.

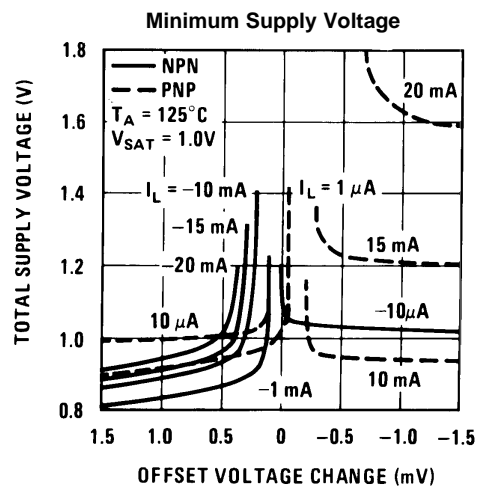


Figure 16.

**Typical Performance Characteristics (Op Amp) (continued)**

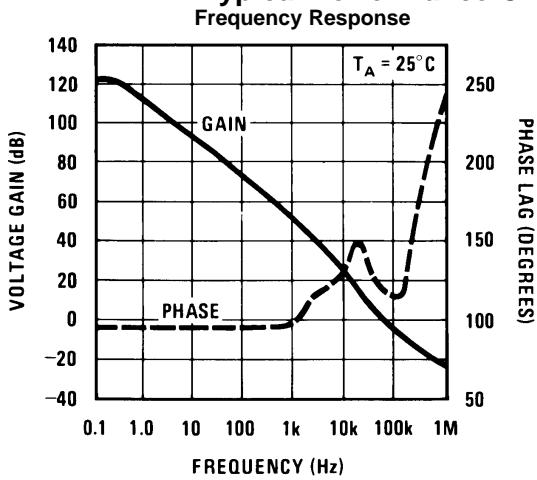


Figure 17.

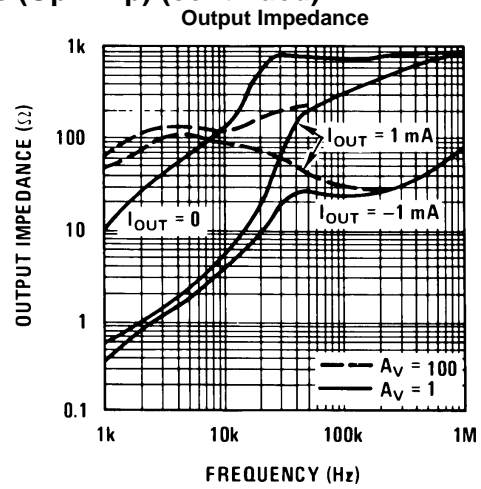


Figure 18.

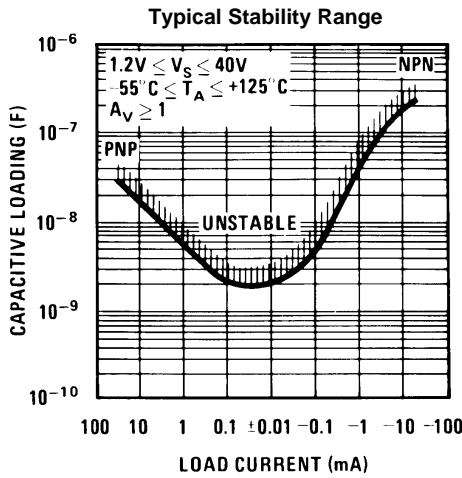


Figure 19.

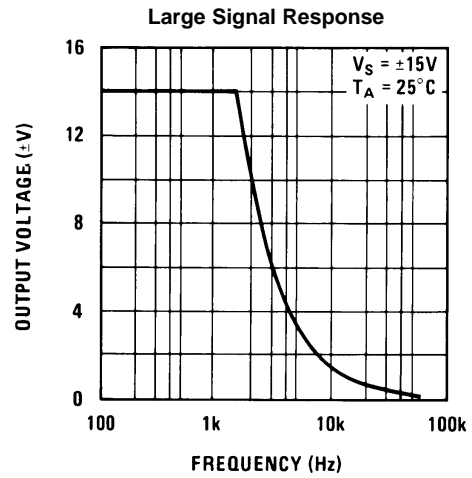


Figure 20.

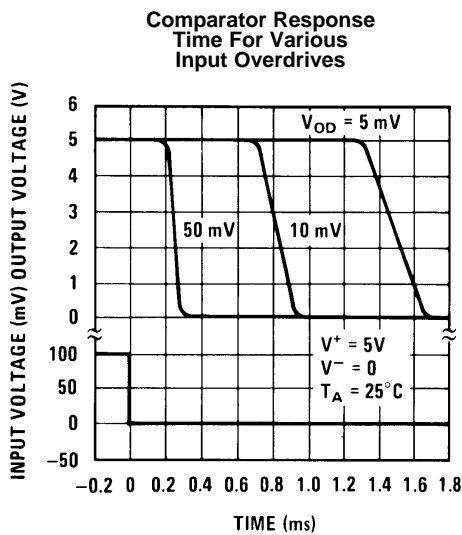


Figure 21.

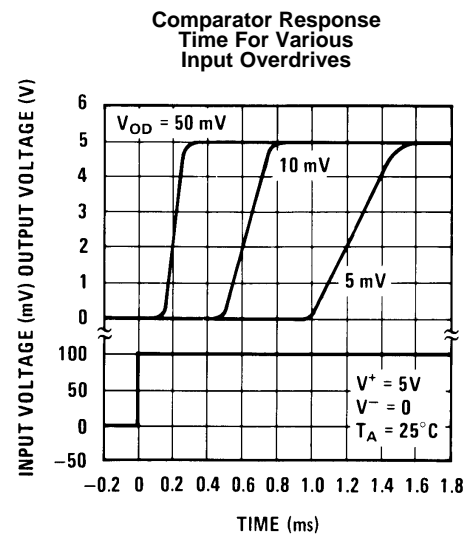


Figure 22.



Typical Performance Characteristics (Op Amp) (continued)

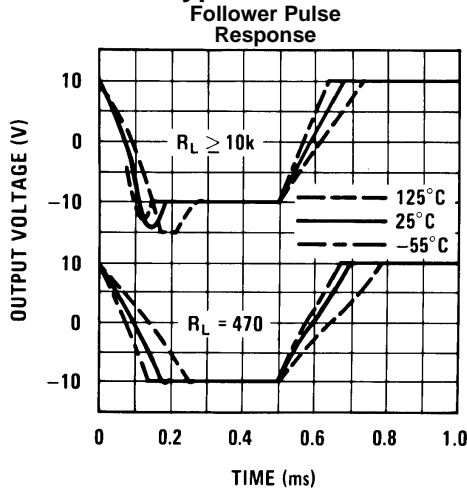


Figure 23.

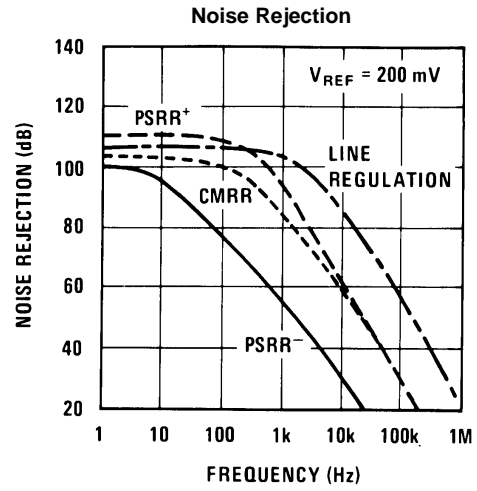


Figure 24.

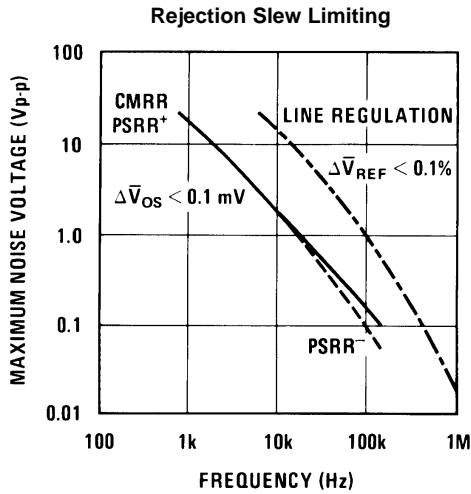


Figure 25.

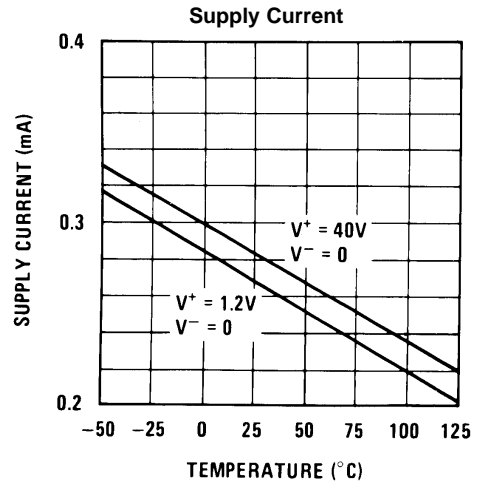


Figure 26.

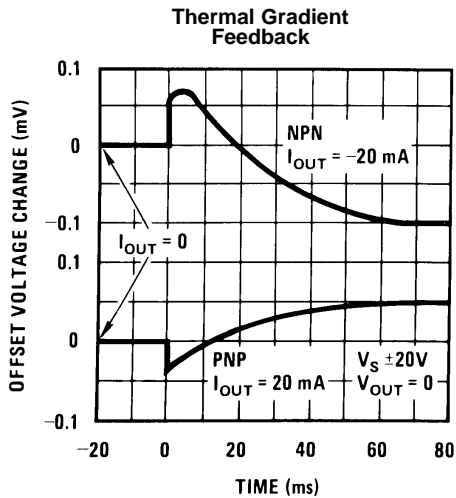


Figure 27.

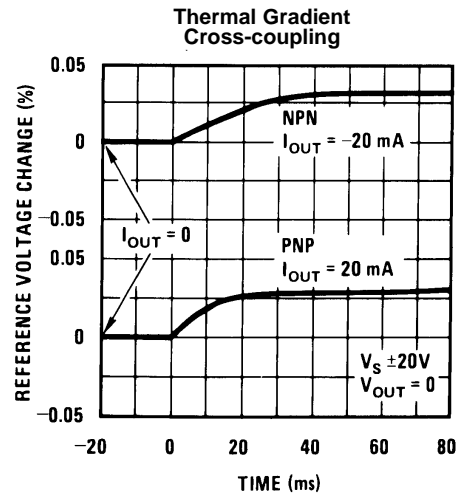


Figure 28.

**Typical Performance Characteristics (Op Amp) (continued)**  
**Shunt Gain**

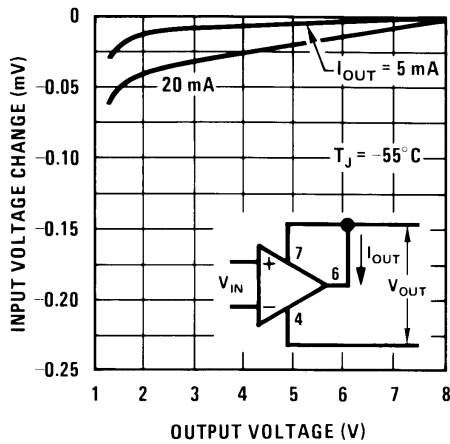


Figure 29.

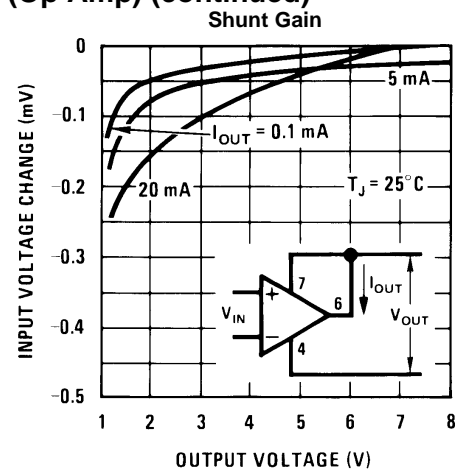


Figure 30.

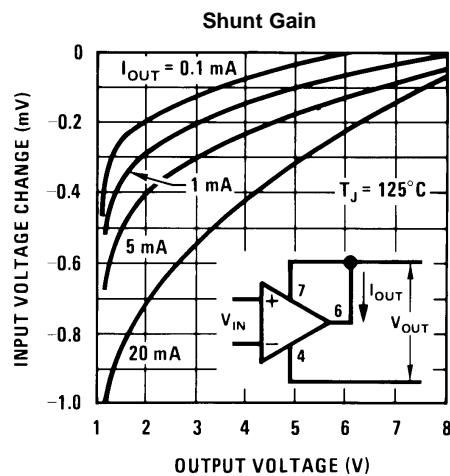


Figure 31.

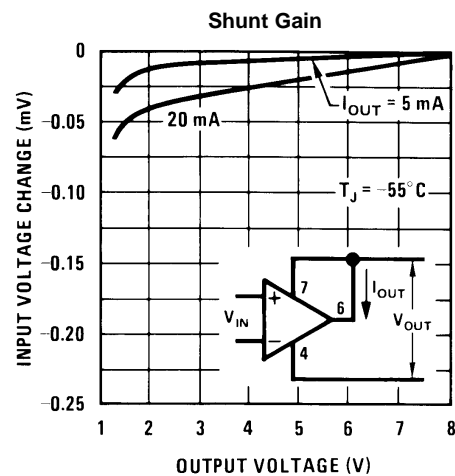


Figure 32.

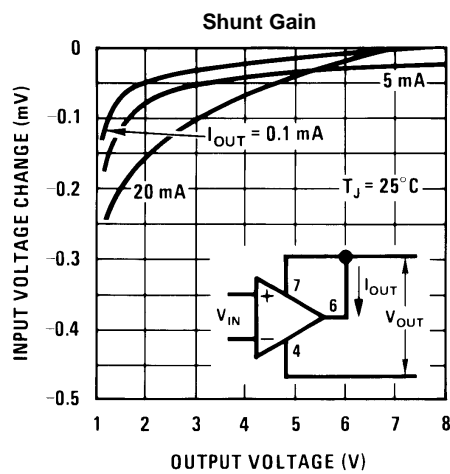


Figure 33.

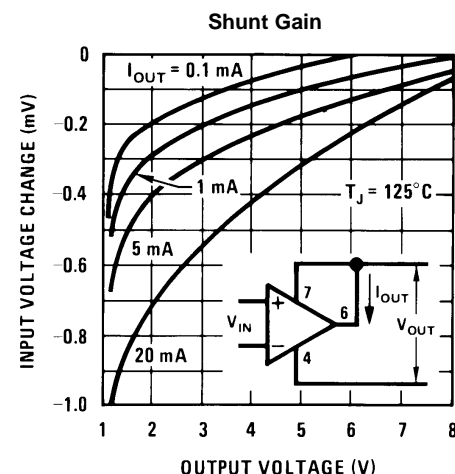


Figure 34.

Typical Performance Characteristics (Reference)

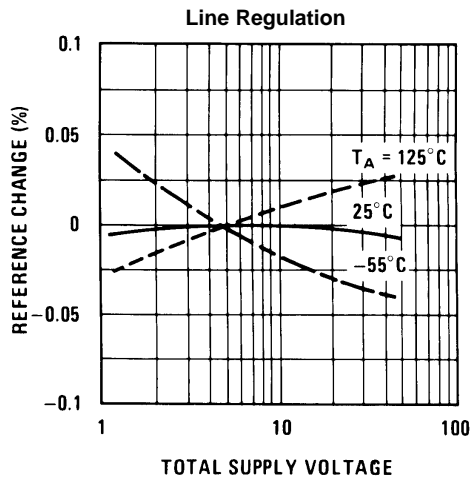


Figure 35.

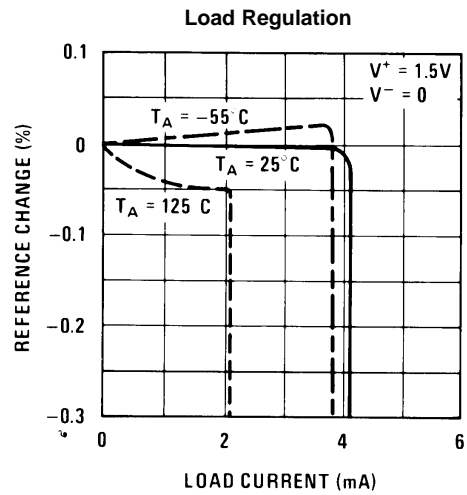


Figure 36.

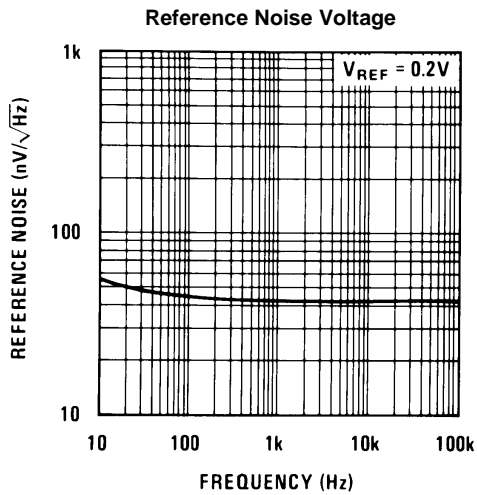


Figure 37.

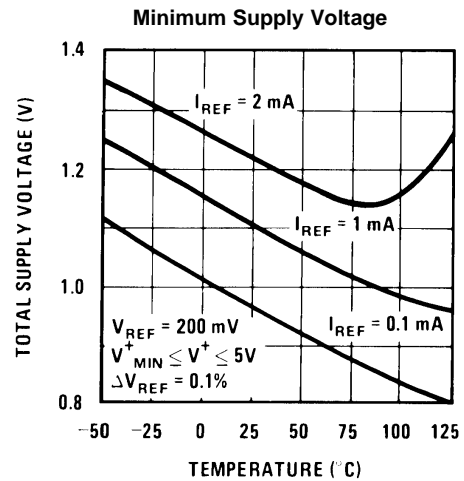


Figure 38.

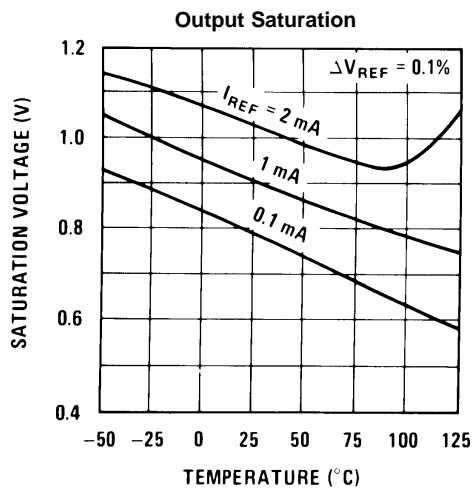


Figure 39.

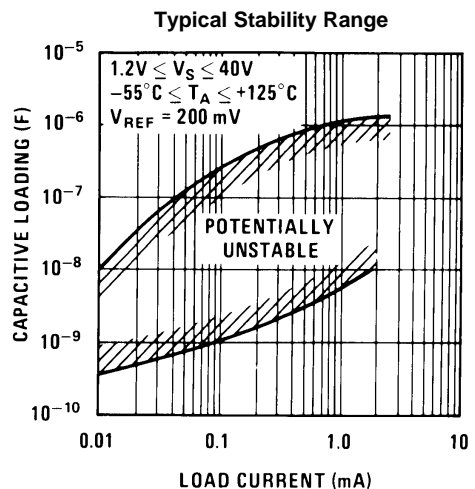


Figure 40.

TYPICAL APPLICATIONS

(Pin numbers are for devices in 8-pin packages)

Circuit descriptions available in application note AN-211 (Literature Number [SNOA638](#)).

Op Amp Offset Adjustment

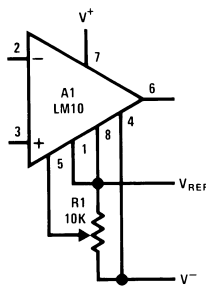


Figure 41. Standard

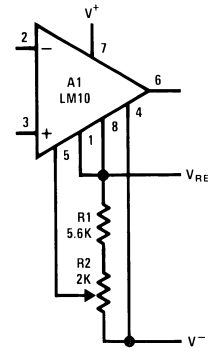


Figure 42. Limited Range

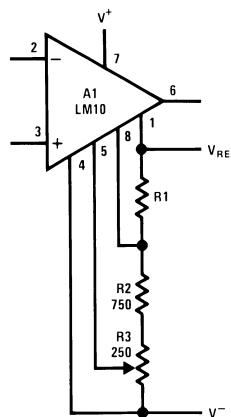


Figure 43. Limited Range With Boosted Reference

Positive Regulators

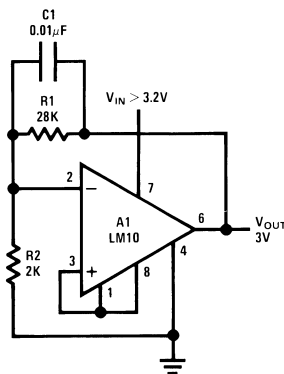


Figure 44. Low Voltage

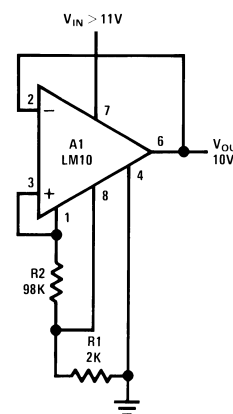
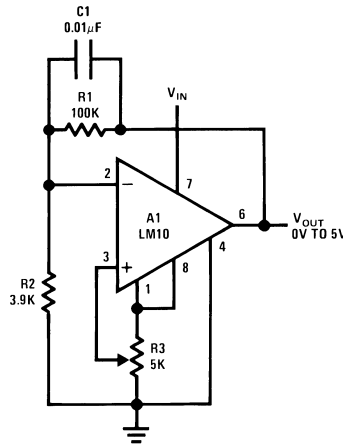


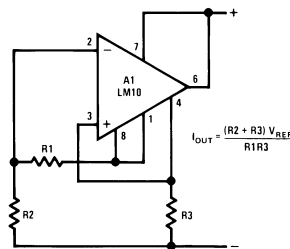
Figure 45. Best Regulation

(Pin numbers are for devices in 8-pin packages)



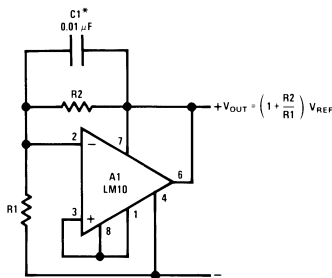
Use only electrolytic output capacitors.

Figure 46. Zero Output



$$I_{OUT} = \frac{(R2 + R3) V_{REF}}{R1 R3}$$

Figure 47. Current Regulator

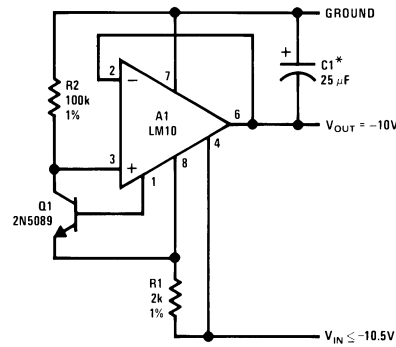


$$+V_{OUT} = \left(1 + \frac{R2}{R1}\right) V_{REF}$$

Required For Capacitive Loading

Figure 48. Shunt Regulator

(Pin numbers are for devices in 8-pin packages)



\*Electrolytic

Figure 49. Negative Regulator

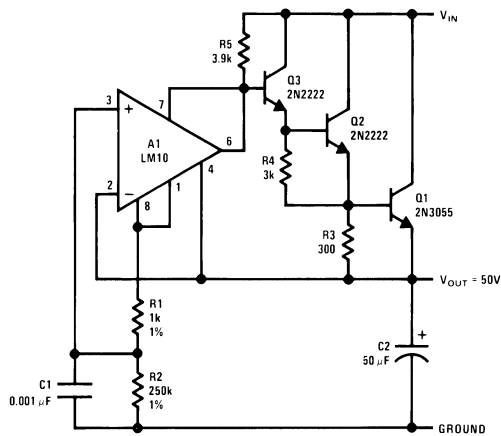
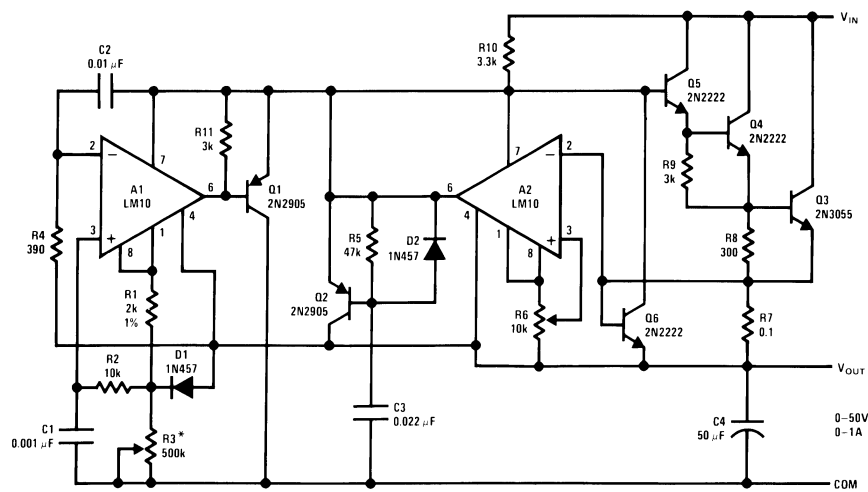


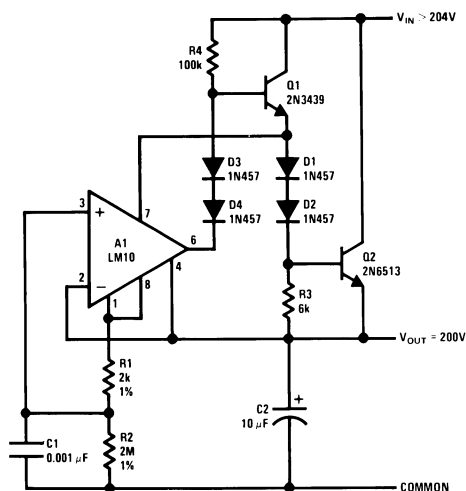
Figure 50. Precision Regulator



\* $V_{OUT} = 10^{-4} R3$

Figure 51. Laboratory Power Supply

(Pin numbers are for devices in 8-pin packages)



$$V_{OUT} = \frac{R_2}{R_1} V_{REF}$$

Figure 52. HV Regulator

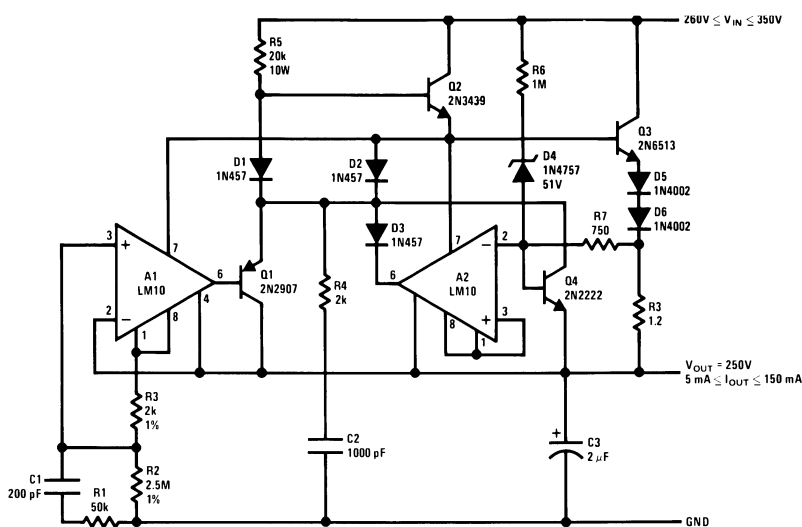
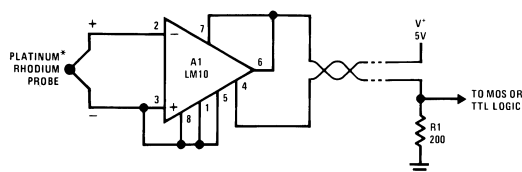


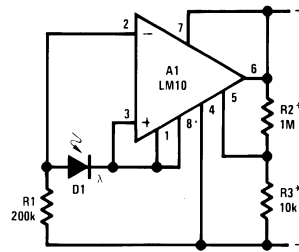
Figure 53. Protected HV Regulator



\*800°C Threshold Is Established By Connecting Balance To VREF.

Figure 54. Flame Detector

(Pin numbers are for devices in 8-pin packages)



\*Provides Hysteresis

Figure 55. Light Level Sensor

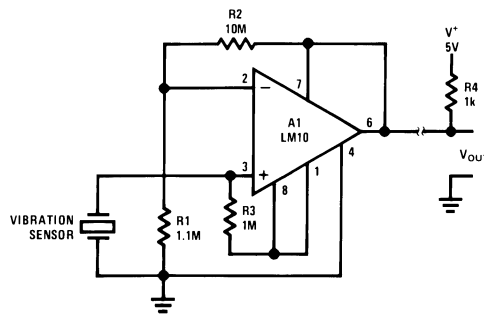


Figure 56. Remote Amplifier

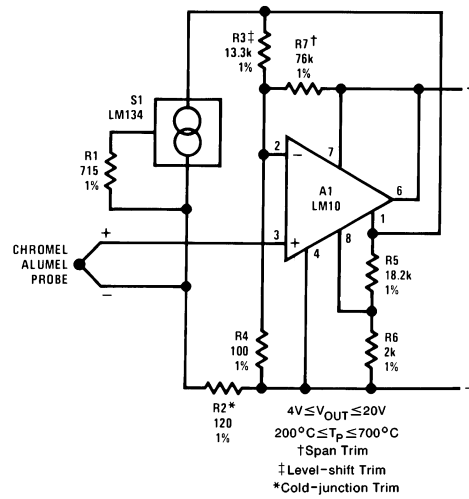


Figure 57. Remote Thermocouple Amplifier



(Pin numbers are for devices in 8-pin packages)

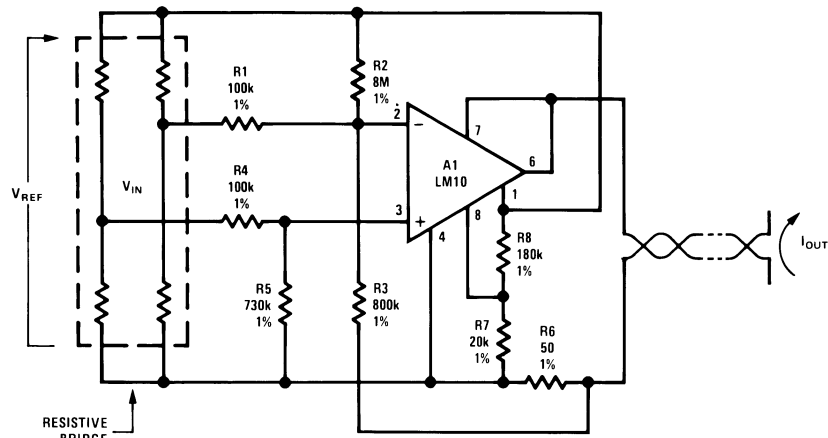
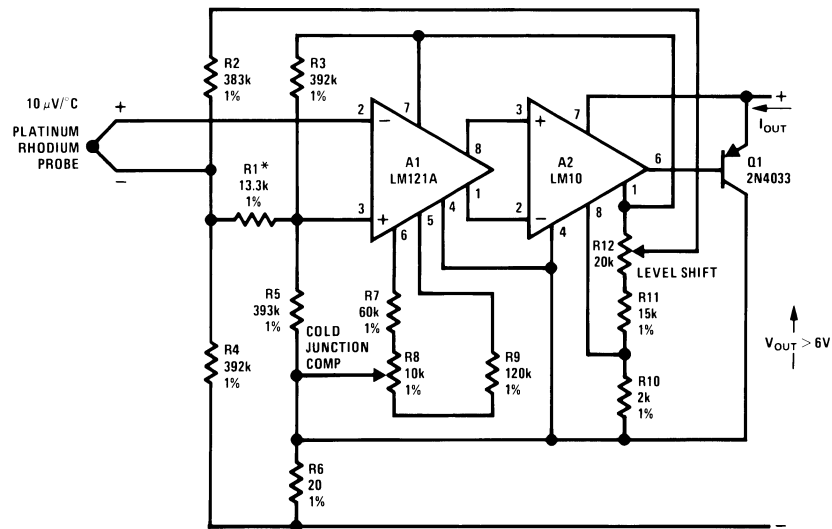


Figure 58. Transmitter for Bridge Sensor



10 mA ≤ I<sub>OUT</sub> ≤ 50 mA  
 500°C ≤ T<sub>P</sub> ≤ 1500°C  
 \*Gain Trim

Figure 59. Precision Thermocouple Transmitter

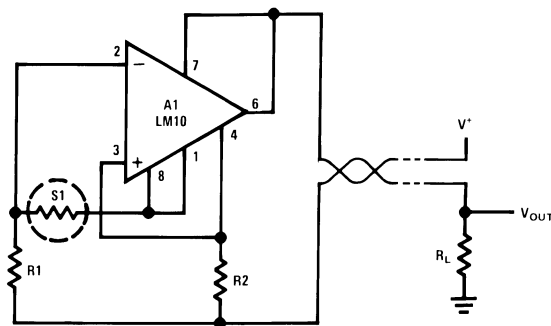
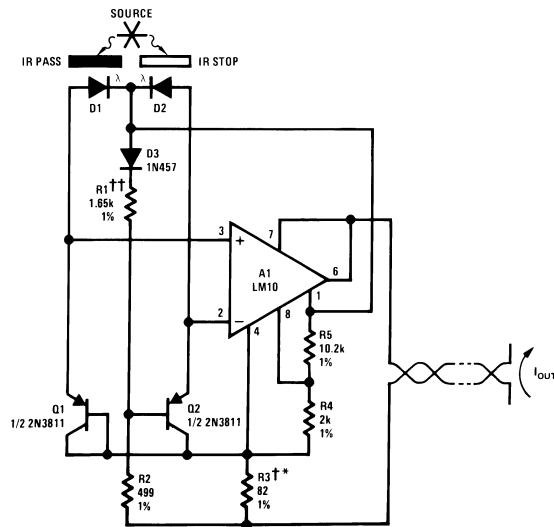


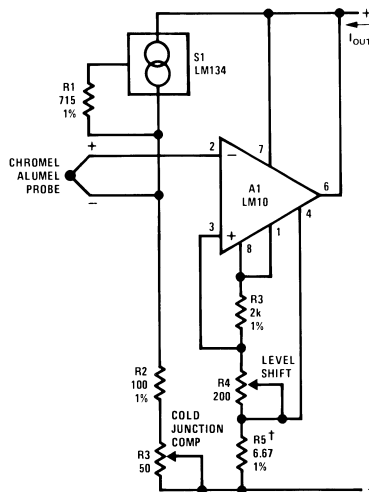
Figure 60. Resistance Thermometer Transmitter

(Pin numbers are for devices in 8-pin packages)



††Level-shift Trim  
 \*Scale Factor Trim  
 †Copper Wire Wound  
 $1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$   
 $0.01 \leq \frac{I_{D2}}{I_{D1}} \leq 100$

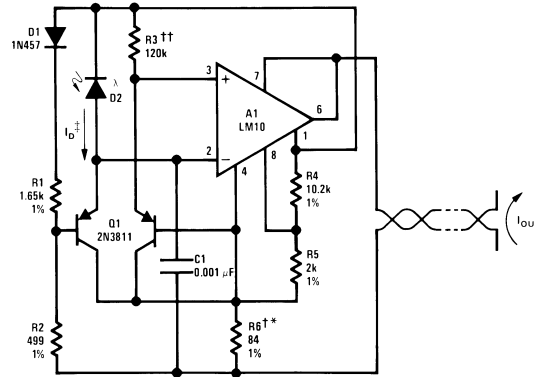
Figure 61. Optical Pyrometer



$200^\circ\text{C} \leq T_p \leq 700^\circ\text{C}$   
 $1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$   
 †Gain Trim

Figure 62. Thermocouple Transmitter

(Pin numbers are for devices in 8-pin packages)



$1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$   
 $\pm 50 \text{ } \mu\text{A} \leq I_D \leq 500 \text{ } \mu\text{A}$   
 ††Center Scale Trim  
 †Scale Factor Trim  
 \*Copper Wire Wound

Figure 63. Logarithmic Light Sensor

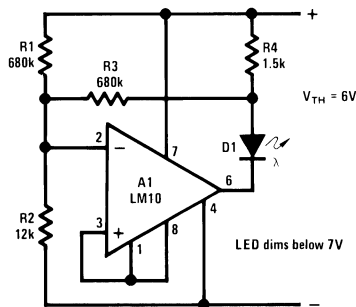


Figure 64. Battery-level Indicator

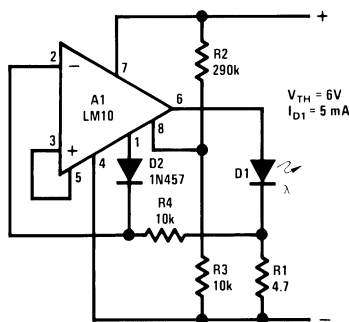
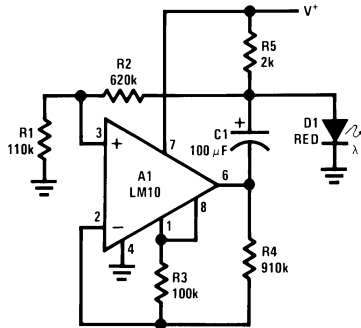


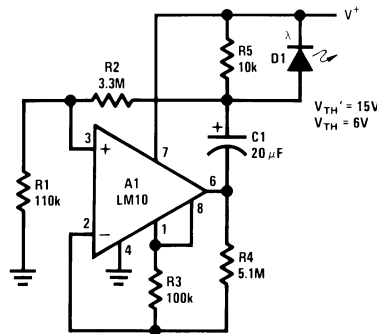
Figure 65. Battery-threshold Indicator

(Pin numbers are for devices in 8-pin packages)



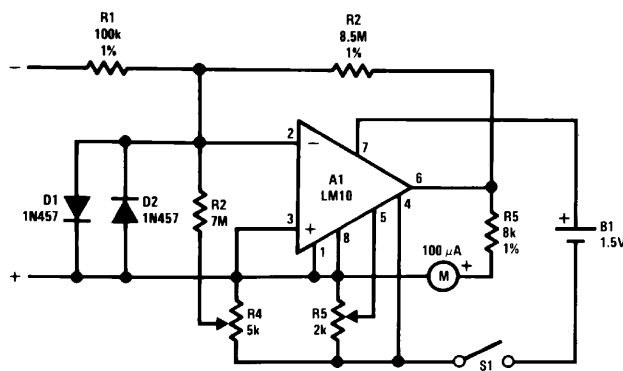
Flashes Above 1.2V  
Rate Increases With  
Voltage

Figure 66. Single-cell Voltage Monitor



Flash Rate Increases  
Above 6V and Below 15V

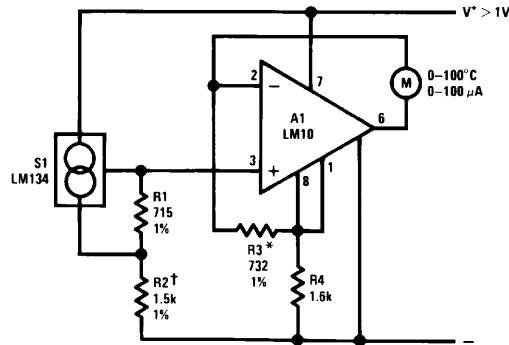
Figure 67. Double-ended Voltage Monitor



INPUT  
10 mV, 100nA  
FULL-SCALE

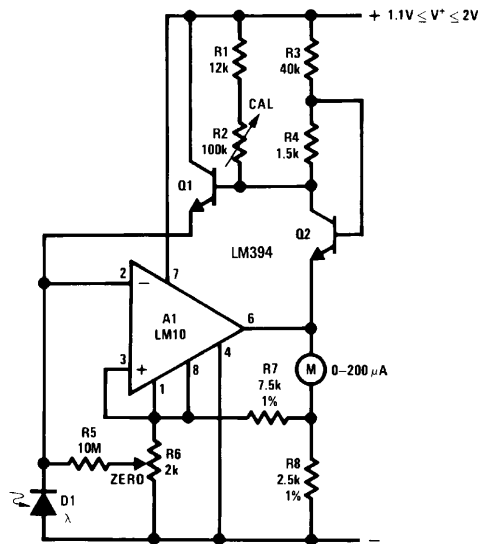
Figure 68. Meter Amplifier

(Pin numbers are for devices in 8-pin packages)



\*Trim For Span  
†Trim For Zero

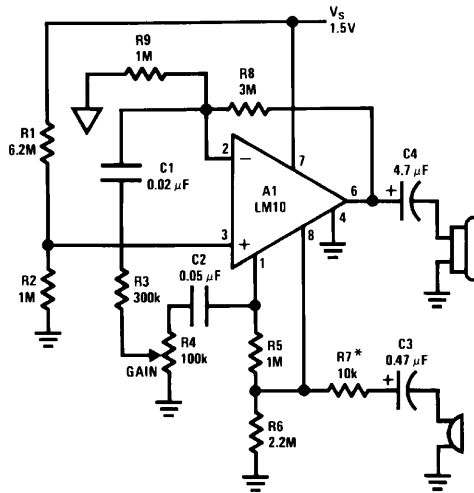
Figure 69. Thermometer



$1 \leq \lambda/\lambda_0 \leq 10^5$

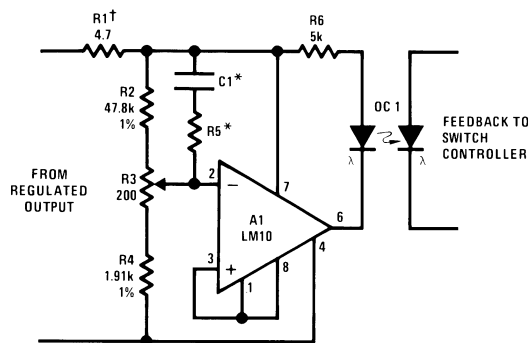
Figure 70. Light Meter

(Pin numbers are for devices in 8-pin packages)



$Z_{OUT} \sim 680\Omega @ 5 \text{ kHz}$   
 $A_V \leq 1k$   
 $f_1 \sim 100 \text{ Hz}$   
 $f_2 \sim 5 \text{ kHz}$   
 $R_L \sim 500$   
 \*Max Gain Trim

Figure 71. Microphone Amplifier



†Controls "Loop Gain"  
 \*Optional Frequency Shaping

Figure 72. Isolated Voltage Sensor

(Pin numbers are for devices in 8-pin packages)

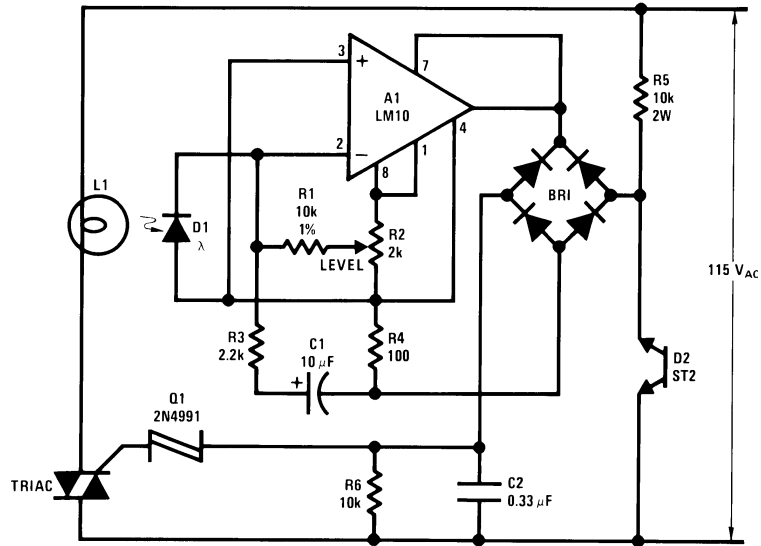


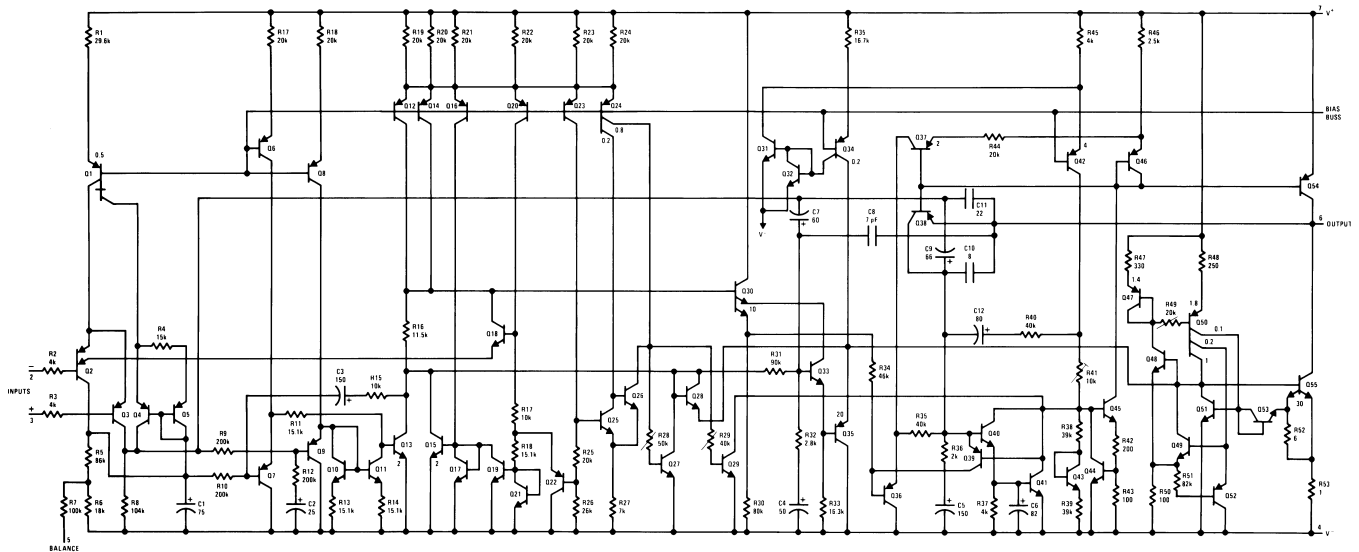
Figure 73. Light-level Controller

## APPLICATION HINTS

With heavy amplifier loading to  $V^-$ , resistance drops in the  $V^-$  lead can adversely affect reference regulation. Lead resistance can approach  $1\Omega$ . Therefore, the common to the reference circuitry should be connected as close as possible to the package.

### Operational Amplifier Schematic

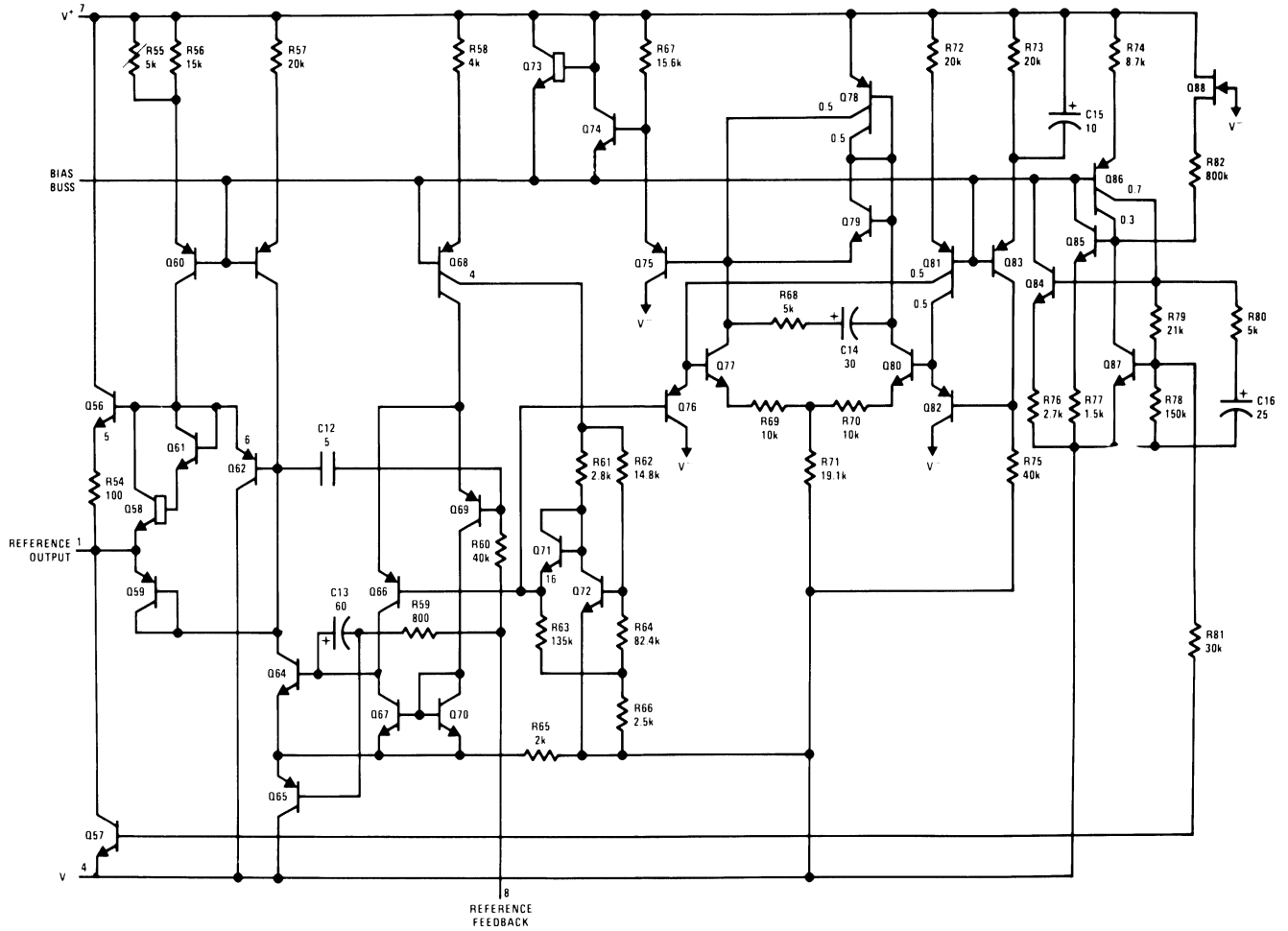
(Pin numbers are for 8-pin packages)



### Reference and Internal Regulator

(Pin numbers are for 8-pin packages)





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## REVISION HISTORY

| Changes from Revision C (March 2013) to Revision D         | Page               |
|--|--------------------|
| • Changed layout of National Data Sheet to TI format ..... | <a href="#">25</a> |

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**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package<br>Drawing | Pins | Package<br>Qty | Eco Plan<br>(2)            | Lead/Ball Finish<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| LM10BH           | ACTIVE        | TO-99        | LMC                | 8    | 500            | TBD                        | Call TI                 | Call TI              | -40 to 85    | ( LM10BH ~ LM10BH)      | <a href="#">Samples</a> |
| LM10BH/NOPB      | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | -40 to 85    | ( LM10BH ~ LM10BH)      | <a href="#">Samples</a> |
| LM10CH           | ACTIVE        | TO-99        | LMC                | 8    | 500            | TBD                        | Call TI                 | Call TI              | 0 to 70      | ( LM10CH ~ LM10CH)      | <a href="#">Samples</a> |
| LM10CH/NOPB      | ACTIVE        | TO-99        | LMC                | 8    | 500            | Green (RoHS<br>& no Sb/Br) | Call TI                 | Level-1-NA-UNLIM     | 0 to 70      | ( LM10CH ~ LM10CH)      | <a href="#">Samples</a> |
| LM10CLN          | LIFEBUY       | PDIP         | P                  | 8    | 40             | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM10CLN                 |                         |
| LM10CLN/NOPB     | ACTIVE        | PDIP         | P                  | 8    | 40             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-1-NA-UNLIM     | 0 to 70      | LM10CLN                 | <a href="#">Samples</a> |
| LM10CN           | LIFEBUY       | PDIP         | P                  | 8    | 40             | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM<br>10CN              |                         |
| LM10CN/NOPB      | ACTIVE        | PDIP         | P                  | 8    | 40             | Green (RoHS<br>& no Sb/Br) | CU SN   Call TI         | Level-1-NA-UNLIM     | 0 to 70      | LM<br>10CN              | <a href="#">Samples</a> |
| LM10CWM          | NRND          | SOIC         | NPA                | 14   | 50             | TBD                        | Call TI                 | Call TI              | 0 to 70      | LM10CWM                 |                         |
| LM10CWM/NOPB     | ACTIVE        | SOIC         | NPA                | 14   | 50             | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | 0 to 70      | LM10CWM                 | <a href="#">Samples</a> |
| LM10CWMX/NOPB    | ACTIVE        | SOIC         | NPA                | 14   | 1000           | Green (RoHS<br>& no Sb/Br) | CU SN                   | Level-3-260C-168 HR  | 0 to 70      | LM10CWM                 | <a href="#">Samples</a> |

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

- (3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.
- (4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.
- (5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.
- (6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| LM10CWMX/NOPB | SOIC         | NPA             | 14   | 1000 | 330.0              | 16.4               | 10.9    | 9.5     | 3.2     | 12.0    | 16.0   | Q1            |

TAPE AND REEL BOX DIMENSIONS

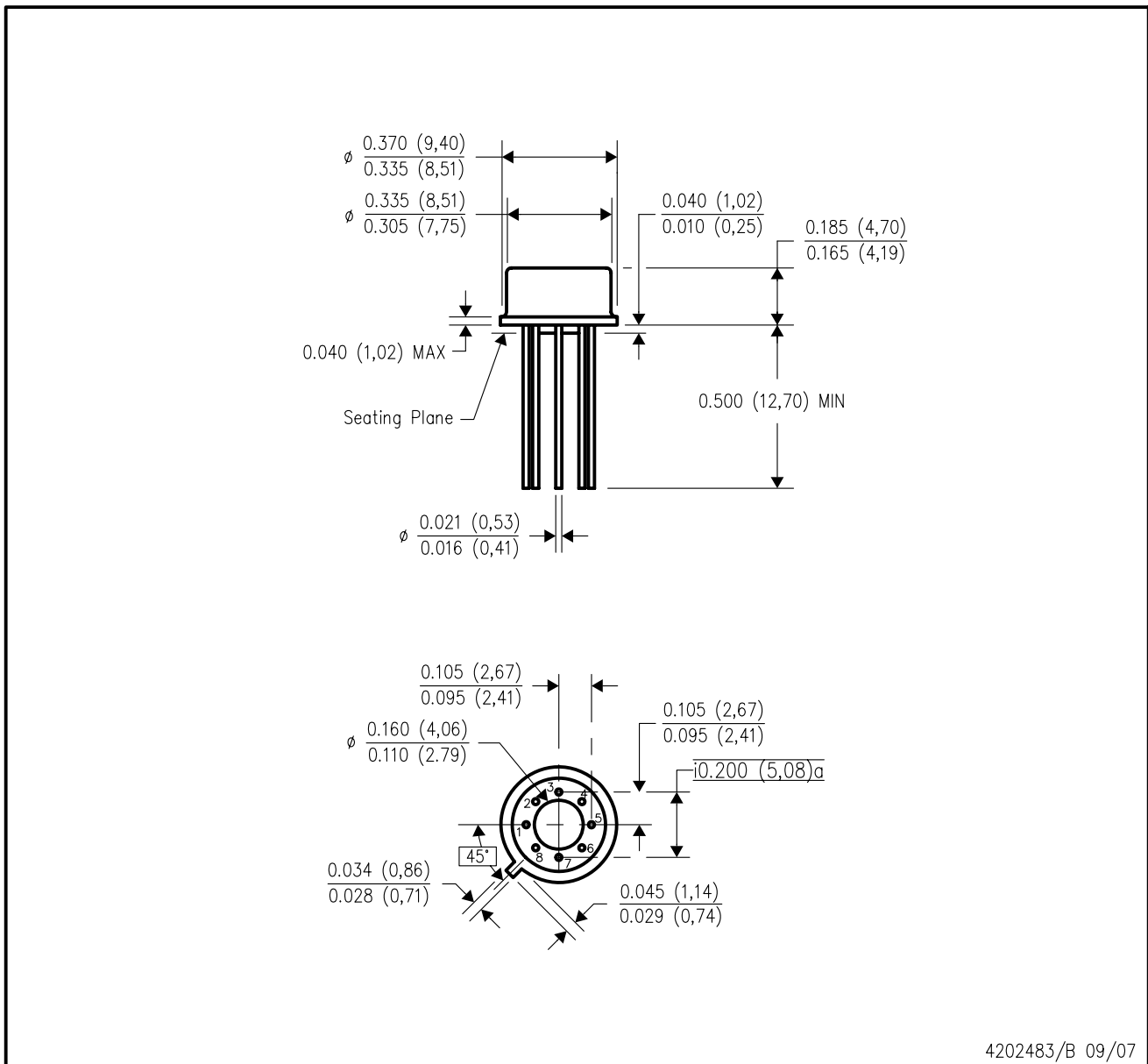


\*All dimensions are nominal

| Device        | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| LM10CWMX/NOPB | SOIC         | NPA             | 14   | 1000 | 367.0       | 367.0      | 38.0        |

LMC (O-MBCY-W8)

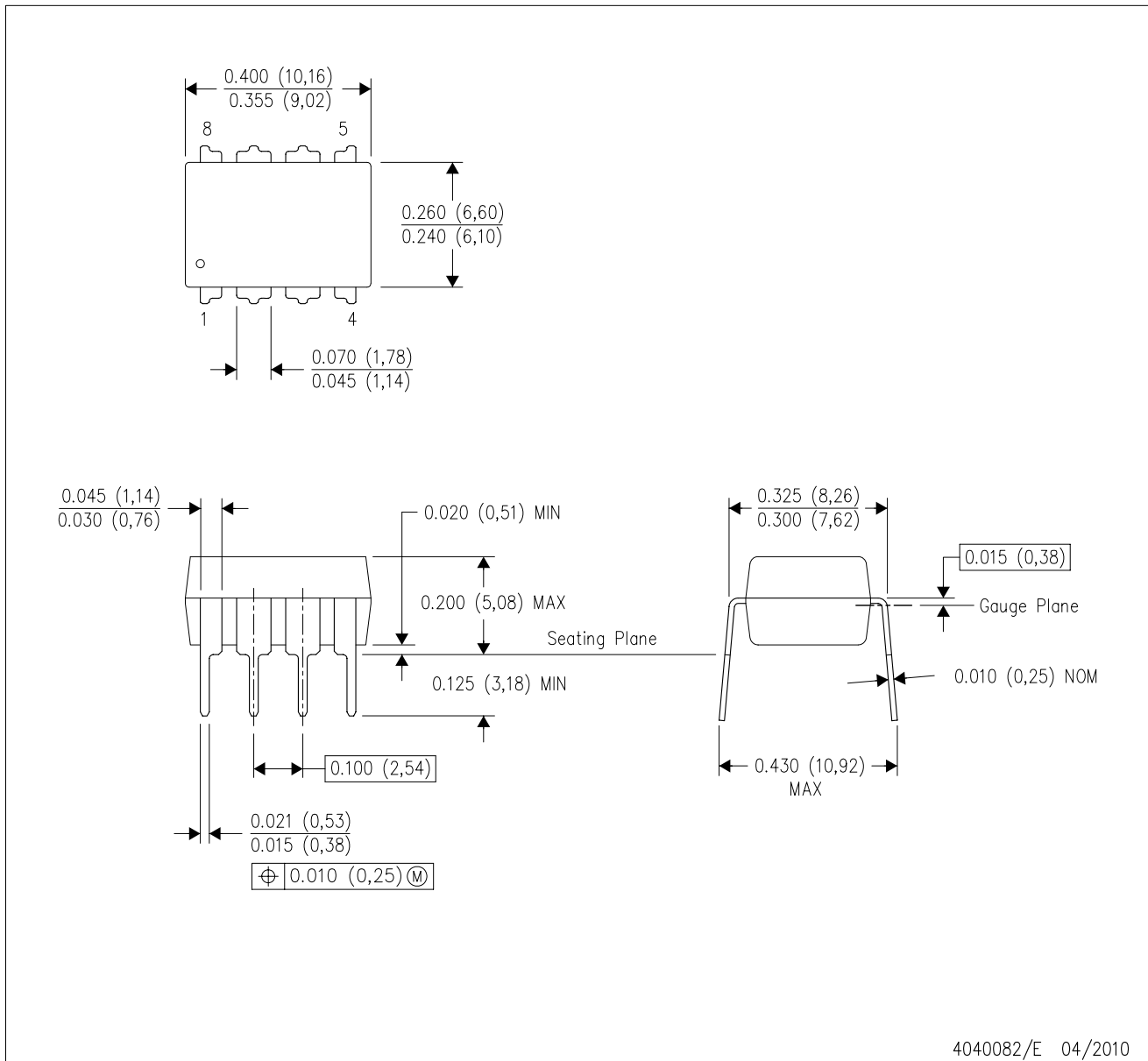
METAL CYLINDRICAL PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
  - D. Pin numbers shown for reference only. Numbers may not be marked on package.
  - E. Falls within JEDEC MO-002/TO-99.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE

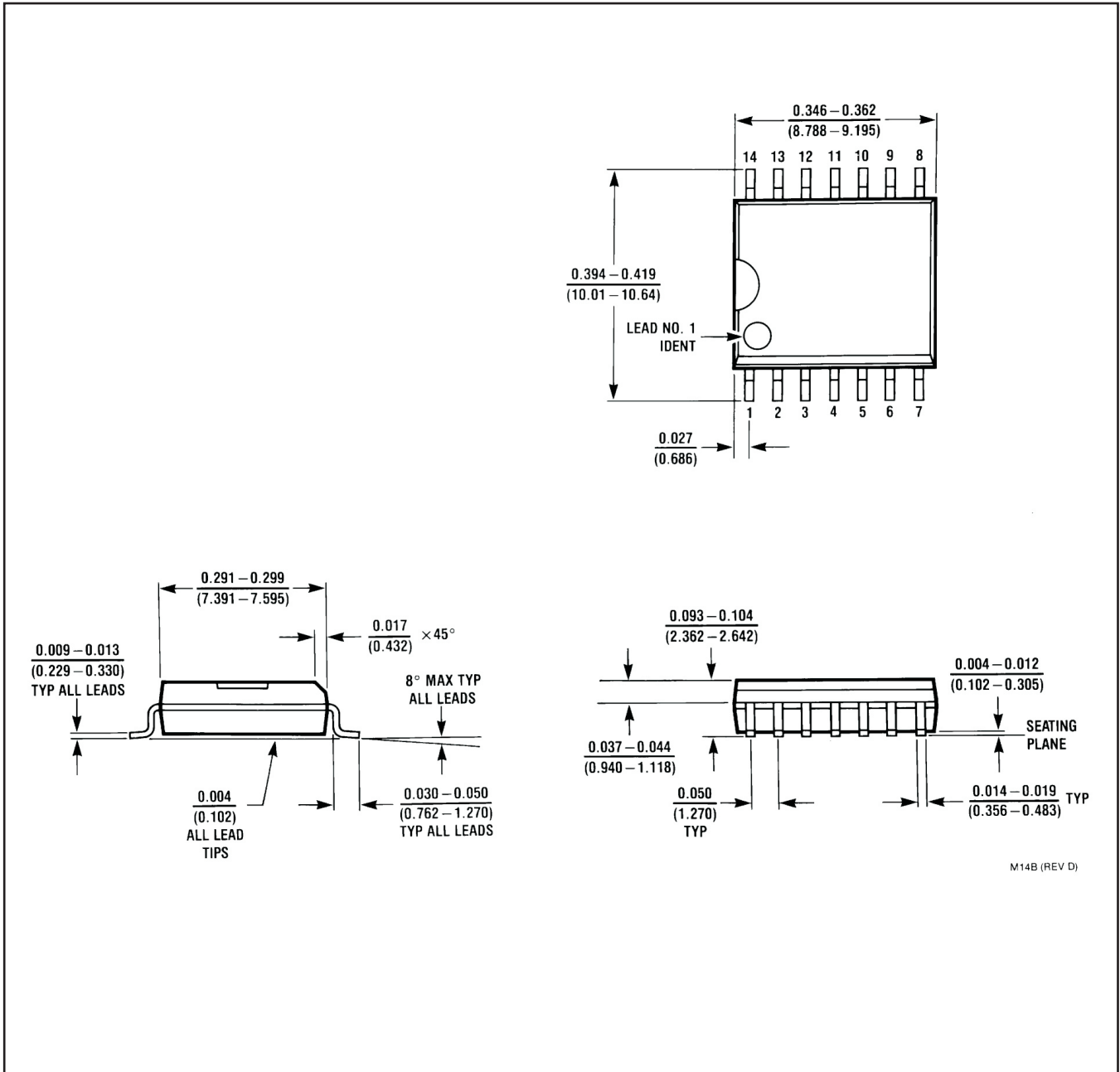


4040082/E 04/2010

- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.



NPA0014B



M14B (REV D)

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|                               |  |
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