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## LM10

# Operational Amplifier and Voltage Reference

### General 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 $\mu$ A. A complementary output stage swings within 15 mV of the supply terminals or will deliver  $\pm 20$  mA output current with  $\pm 0.4$ 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.

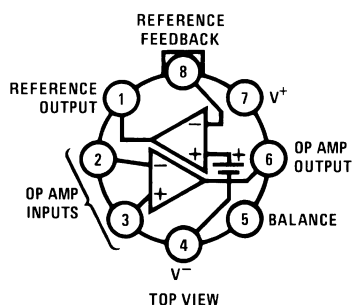
This series is available in the three standard temperature ranges, with the commercial part having relaxed limits. In addition, a low-voltage specification (suffix "L") is available in the limited temperature ranges at a cost savings.

### Features

- input offset voltage: 2.0 mV (max)
- input offset current: 0.7 nA (max)
- input bias current: 20 nA (max)
- reference regulation: 0.1% (max)
- offset voltage drift: 2 $\mu$ V/ $^{\circ}$ C
- reference drift: 0.002%/ $^{\circ}$ C

### Connection and Functional Diagrams

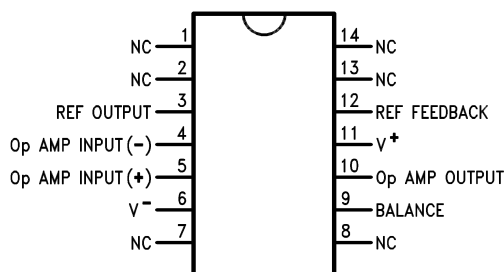
#### Metal Can Package (H)



DS005652-1

Order Number LM10BH, LM10CH,  
LM10CLH or LM10H/883  
available per SMA# 5962-8760401  
See NS Package Number H08A

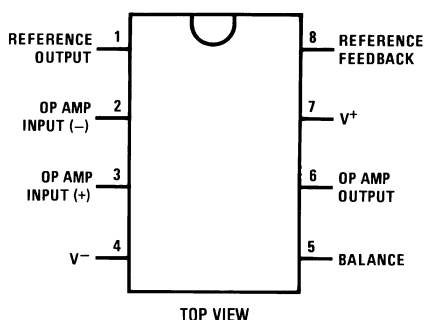
#### Small Outline Package (WM)



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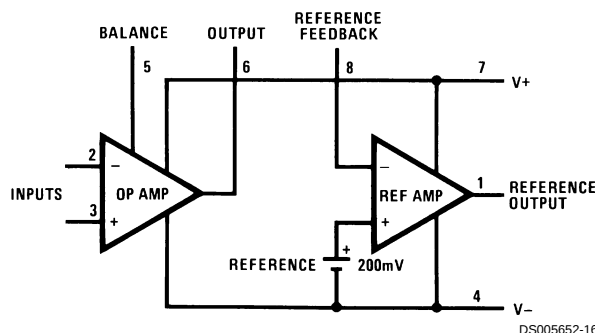
Order Number LM10CWM or LM10CWMX  
See NS Package Number M14B

#### Dual-In-Line Package (N)



DS005652-15

Order Number LM10CN or LM10CLN  
See NS Package Number N08E



DS005652-16

## Absolute Maximum Ratings (Notes 1, 8)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

|                                        | LM10/LM10B/ LM10BL/ LM10C | LM10CL |
|----------------------------------------|---------------------------|--------|
| Total Supply Voltage                   | 45V                       | 7V     |
| Differential Input Voltage (Note 2)    | ±40V                      | ±7V    |
| Power Dissipation (Note 3)             | internally limited        |        |
| Output Short-circuit Duration (Note 4) | continuous                |        |
| Storage-Temp. Range                    | -55°C to +150°C           |        |
| Lead Temp. (Soldering, 10 seconds)     |                           |        |
| Metal Can                              | 300°C                     |        |
| Lead Temp. (Soldering, 10 seconds) DIP | 260°C                     |        |
| Vapor Phase (60 seconds)               | 215°C                     |        |
| Infrared (15 seconds)                  | 220°C                     |        |

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

## 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) (Note 5)

| 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 (Note 6) |                                                                                                                         |            | 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     | $V_S = \pm 20\text{V}$ , $I_{\text{OUT}} = 0$                                                                           | 120        | 400   |              | 80          | 400   |             | V/mV                         |
|                               | $V_{\text{OUT}} = \pm 19.95\text{V}$                                                                                    | <b>80</b>  |       |              | <b>50</b>   |       |             | V/mV                         |
|                               | $V_S = \pm 20\text{V}$ , $V_{\text{OUT}} = \pm 19.4\text{V}$                                                            | 50         | 130   |              | 25          | 130   |             | V/mV                         |
|                               | $I_{\text{OUT}} = \pm 20\text{ mA}$ ( <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> ), $I_{\text{OUT}} = \pm 2\text{ mA}$                        | 1.5        | 3.0   |              | 1.0         | 3.0   |             | V/mV                         |
|                               | $V_{\text{OUT}} = \pm 0.4\text{V}$ ( <b><math>\pm 0.3\text{V}</math></b> ), $V_{\text{CM}} = -0.4\text{V}$              | <b>0.5</b> |       |              | <b>0.75</b> |       |             | V/mV                         |
| Shunt gain (Note 7)           | $1.2\text{V}$ ( <b><math>1.3\text{V}</math></b> ) $\leq V_{\text{OUT}} \leq 40\text{V}$ ,<br>$R_L = 1.1\text{ k}\Omega$ | 14         | 33    |              | 10          | 33    |             | V/mV                         |
|                               | $0.1\text{ mA} \leq I_{\text{OUT}} \leq 5\text{ mA}$                                                                    | <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                         |
|                               | $0.1\text{ mA} \leq I_{\text{OUT}} \leq 20\text{ mA}$                                                                   | <b>4</b>   |       |              | <b>4</b>    |       |             | V/mV                         |
| Common-mode rejection         | $-20\text{V} \leq V_{\text{CM}} \leq 19.15\text{V}$ ( <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                          |
|                               | $0 \leq I_{\text{REF}} \leq 1.0\text{ mA}$ , $V_{\text{REF}} = 200\text{ mV}$                                           |            |       | <b>0.006</b> |             |       | <b>0.01</b> | %/V                          |

ESD rating is to be determined.

Maximum Junction Temperature

|       |       |
|-------|-------|
| LM10  | 150°C |
| LM10B | 100°C |
| LM10C | 85°C  |

## Operating Ratings

Package Thermal Resistance

|               |  |         |
|---------------|--|---------|
| $\theta_{JA}$ |  |         |
| H Package     |  | 150°C/W |
| N Package     |  | 87°C/W  |
| WM Package    |  | 90°C/W  |
| $\theta_{JC}$ |  |         |
| H Package     |  | 45°C/W  |

## 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) (Note 5)

| 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 |            | $\% / ^\circ\text{C}$ |
| Supply current         |                                                                                                          |            | 270   | 400         |            | 300   | 500        | $\mu\text{A}$         |
|                        |                                                                                                          |            |       | <b>500</b>  |            |       | <b>570</b> | $\mu\text{A}$         |
| 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>  | $\mu\text{A}$         |

## 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) (Note 5)

| 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 (Note 6) |                                                                                                                  |            | 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   |             | k $\Omega$                     |
|                               |                                                                                                                  | <b>150</b> |       |             | <b>115</b>  |       |             | k $\Omega$                     |
| 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><math>\pm 0.3 \text{ V}</math></b> ), $V_{\text{CM}} = -0.4 \text{ V}$ | <b>0.5</b> |       |             | <b>0.75</b> |       |             | V/mV                           |
| Shunt gain (Note 7)           | $1.5 \text{ V} \leq V^+ \leq 6.5 \text{ V}$ , $R_L = 500 \Omega$                                                 | 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      | $-0.2 \text{ V} \geq V^- \geq -5.4 \text{ V}$                                                                    | 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                             |
| 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               | $1.2 \text{ V}$ ( <b>1.3V</b> ) $\leq V_S \leq 6.5 \text{ V}$                                                    |            | 0.001 | 0.01        |             | 0.001 | 0.02        | $\% / \text{V}$                |
|                               | $0 \leq I_{\text{REF}} \leq 0.5 \text{ mA}$ , $V_{\text{REF}} = 200 \text{ mV}$                                  |            |       | <b>0.02</b> |             |       | <b>0.03</b> | $\% / \text{V}$                |
| Load regulation               | $0 \leq I_{\text{REF}} \leq 0.5 \text{ mA}$                                                                      |            | 0.01  | 0.1         |             | 0.01  | 0.15        | %                              |
|                               | $V^+ - V_{\text{REF}} \geq 1.0 \text{ V}$ ( <b>1.1V</b> )                                                        |            |       | <b>0.15</b> |             |       | <b>0.2</b>  | %                              |

## 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) (Note 5)

| Parameter              | Conditions                                         | LM10BL            |       |                   | LM10CL            |       |                   | Units                          |
|------------------------|----------------------------------------------------|-------------------|-------|-------------------|-------------------|-------|-------------------|--------------------------------|
|                        |                                                    | Min               | Typ   | Max               | Min               | Typ   | Max               |                                |
| 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    |                   | V/mV<br>V/mV                   |
| Feedback sense voltage |                                                    | 195<br><b>194</b> | 200   | 205<br><b>206</b> | 190<br><b>189</b> | 200   | 210<br><b>211</b> | mV<br>mV                       |
| Feedback current       |                                                    |                   | 20    | 50<br><b>65</b>   |                   | 22    | 75<br><b>90</b>   | nA<br>nA                       |
| Reference drift        |                                                    |                   | 0.002 |                   |                   | 0.003 |                   | %/ $^\circ\text{C}$            |
| Supply current         |                                                    |                   | 260   | 400<br><b>500</b> |                   | 280   | 500<br><b>570</b> | $\mu\text{A}$<br>$\mu\text{A}$ |

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

**Note 2:** 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  $V_{\text{IN}} < V^-$ .

**Note 3:** The maximum, operating-junction temperature is  $150^\circ\text{C}$  for the LM10,  $100^\circ\text{C}$  for the LM10B(L) and  $85^\circ\text{C}$  for the LM10C(L). At elevated temperatures, devices must be derated based on package thermal resistance.

**Note 4:** 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.

**Note 5:** 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 ( $\tau_1 \approx 20\text{ms}$ ), die heating ( $\tau_2 \approx 0.2\text{s}$ ) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).

**Note 6:** 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  $V^- \leq V_{\text{CM}} \leq V^- + 0.1\text{V}$ ,  $I_{\text{OS}} \leq 5\text{nA}$ .

**Note 7:** 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.

**Note 8:** Refer to RETS10X for LM10H military specifications.

## 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.

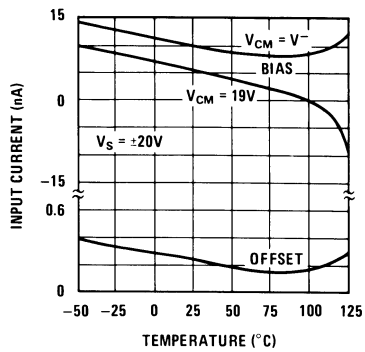
**Reference amplifier gain:** The ratio of the specified reference output change to the change in feedback sense voltage required to produce it.

**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.

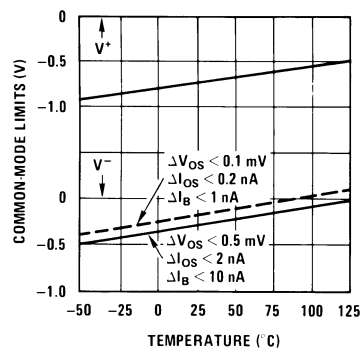
# Typical Performance Characteristics (Op Amp)

## Input Current



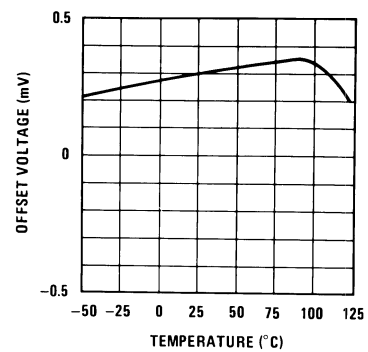
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## Common Mode Limits



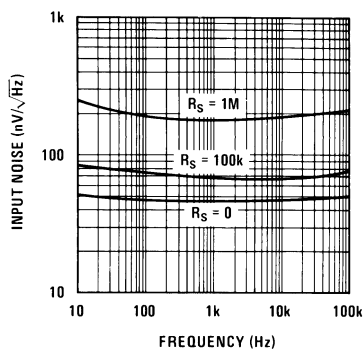
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## Output Voltage Drift



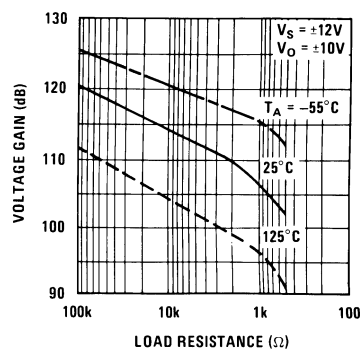
DS005652-20

## Input Noise Voltage



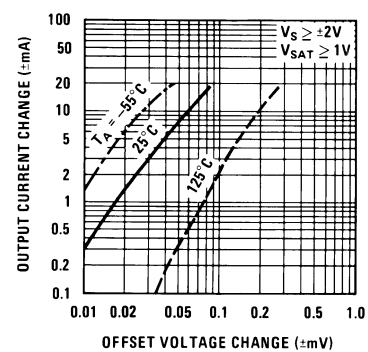
DS005652-21

## DC Voltage Gain



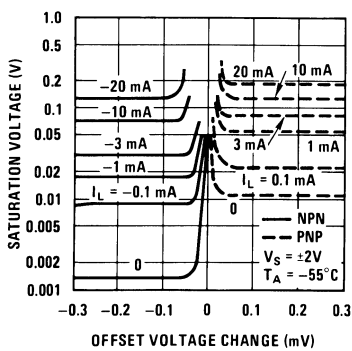
DS005652-22

## Transconductance



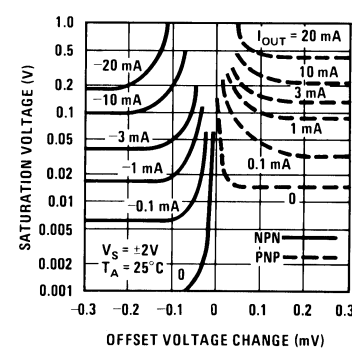
DS005652-23

## Output Saturation Characteristics



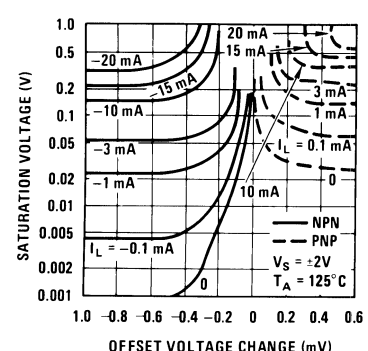
DS005652-24

## Output Saturation Characteristics



DS005652-25

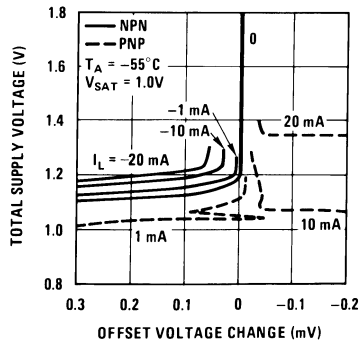
## Output Saturation Characteristics



DS005652-26

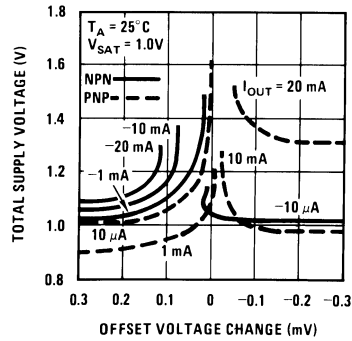
# Typical Performance Characteristics (Op Amp) (Continued)

Minimum Supply Voltage



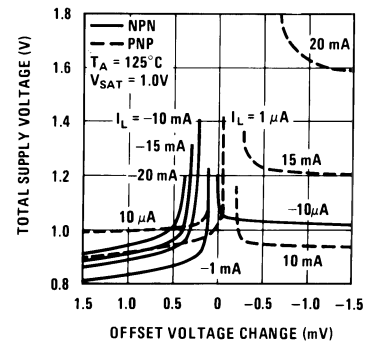
DS005652-27

Minimum Supply Voltage



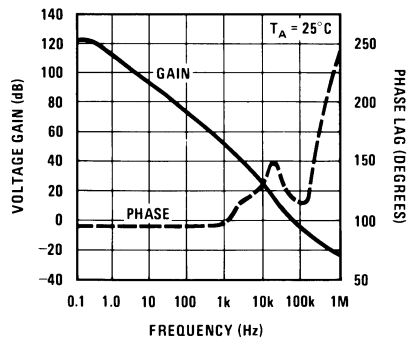
DS005652-28

Minimum Supply Voltage



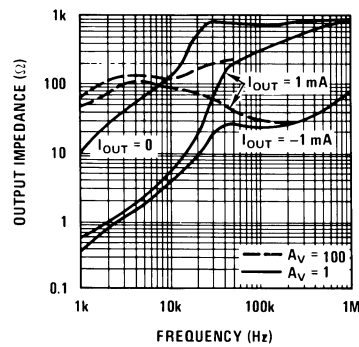
DS005652-29

Frequency Response



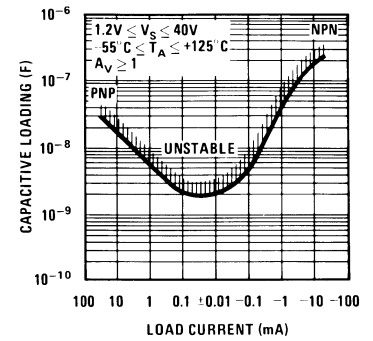
DS005652-30

Output Impedance



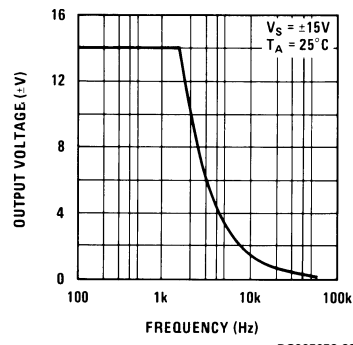
DS005652-31

Typical Stability Range

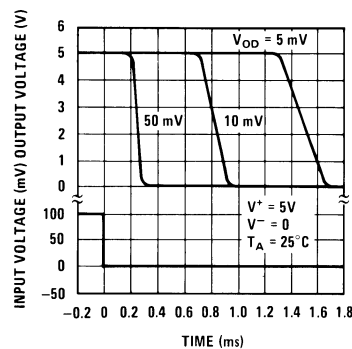


DS005652-32

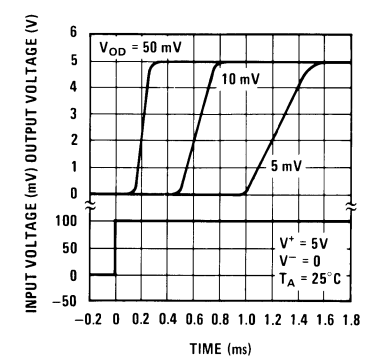
Large Signal Response



DS005652-33

Comparator Response  
Time For Various  
Input Overdrives

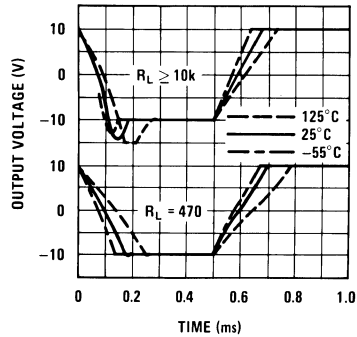
DS005652-34

Comparator Response  
Time For Various  
Input Overdrives

DS005652-35

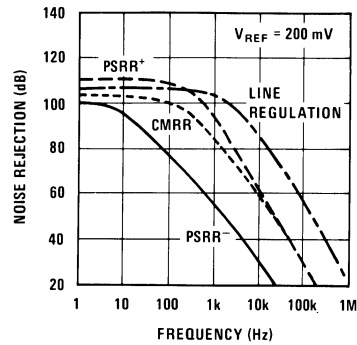
# Typical Performance Characteristics (Op Amp) (Continued)

## Follower Pulse Response



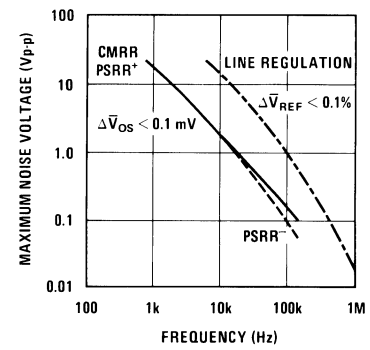
DS005652-36

## Noise Rejection



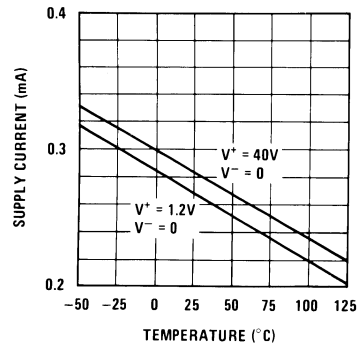
DS005652-37

## Rejection Slew Limiting



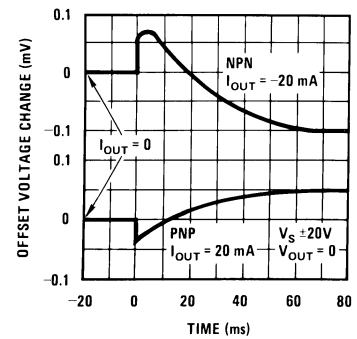
DS005652-38

## Supply Current



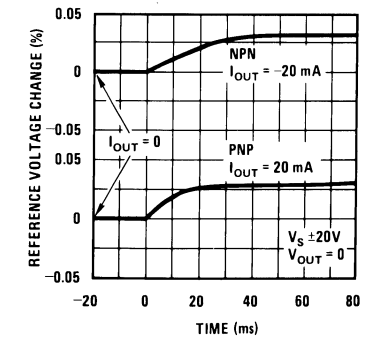
DS005652-39

## Thermal Gradient Feedback



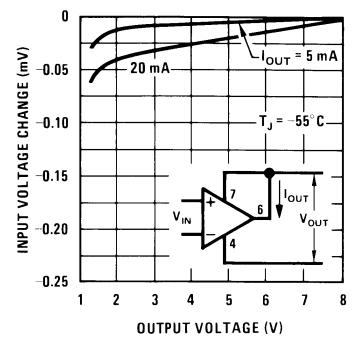
DS005652-40

## Thermal Gradient Cross-coupling



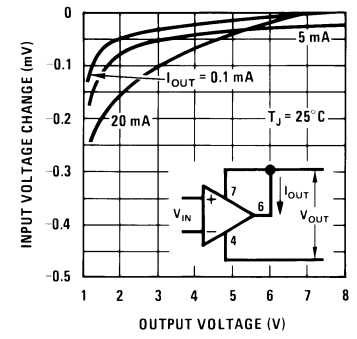
DS005652-41

## Shunt Gain



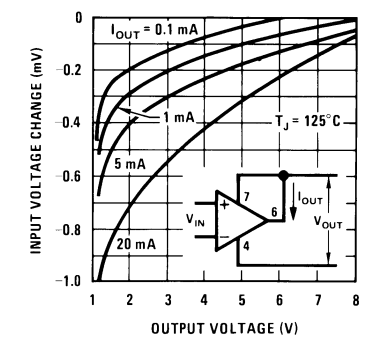
DS005652-42

## Shunt Gain



DS005652-43

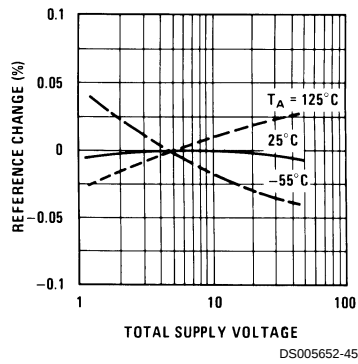
## Shunt Gain



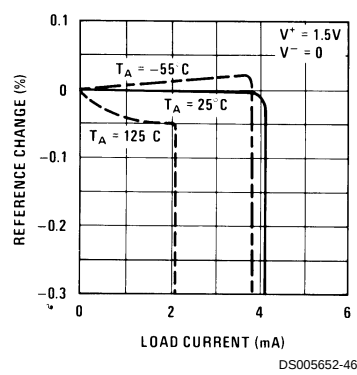
DS005652-44

## Typical Performance Characteristics (Reference)

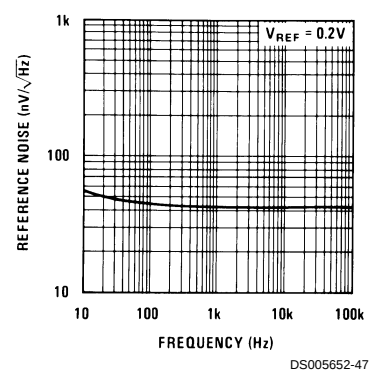
Line Regulation



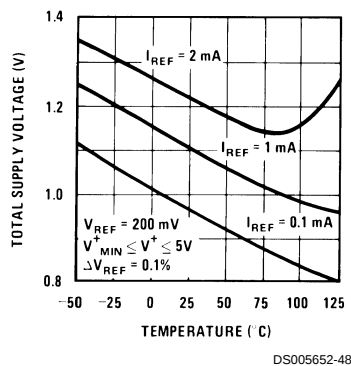
Load Regulation



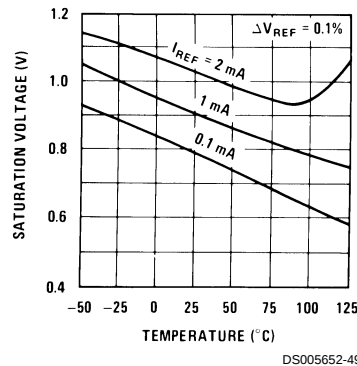
Reference Noise Voltage



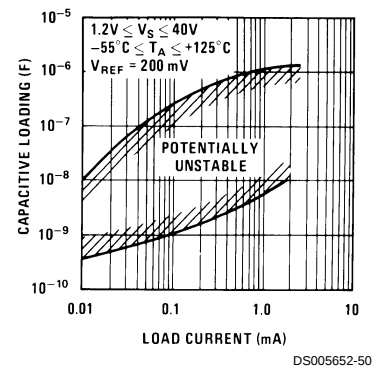
Minimum Supply Voltage



Output Saturation



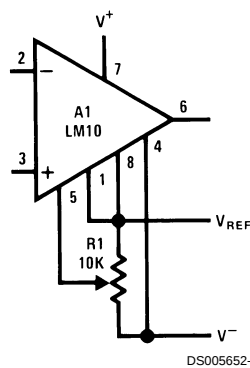
Typical Stability Range



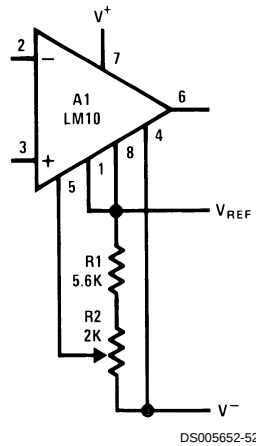
## Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages)

Op Amp Offset Adjustment

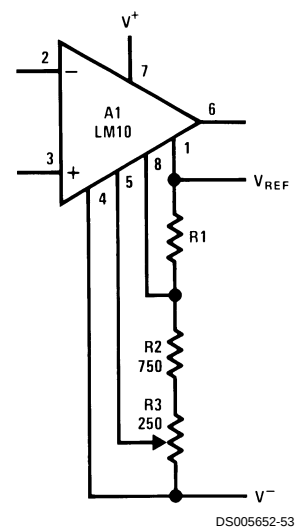
Standard



Limited Range



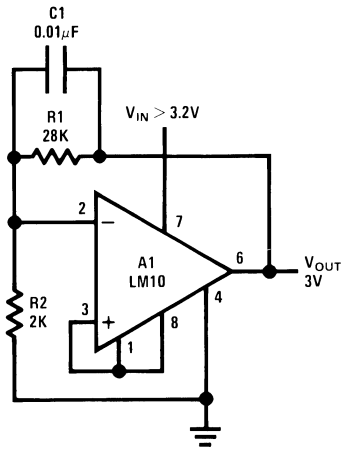
Limited Range With Boosted Reference



# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

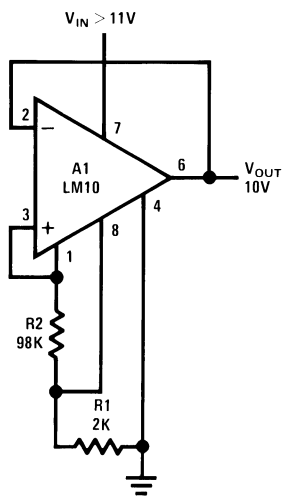
## Positive Regulators (Note 9)

### Low Voltage



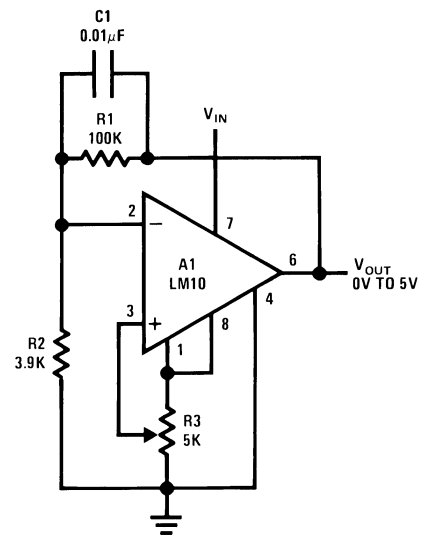
DS005652-54

### Best Regulation



DS005652-55

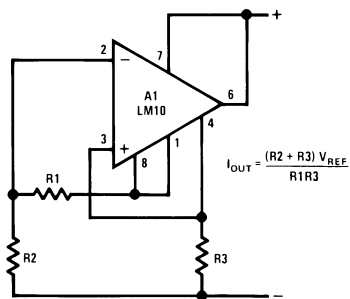
### Zero Output



DS005652-56

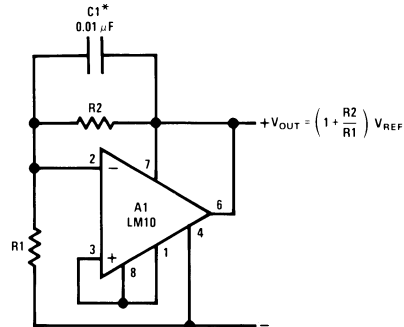
**Note 9:** Use only electrolytic output capacitors.

### Current Regulator



DS005652-57

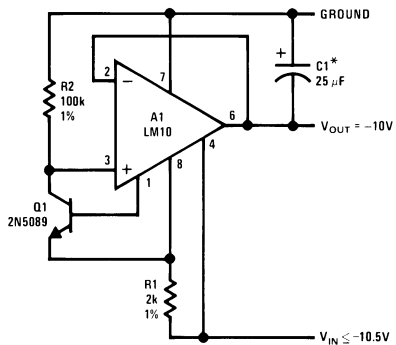
### Shunt Regulator



DS005652-58

Required For Capacitive Loading

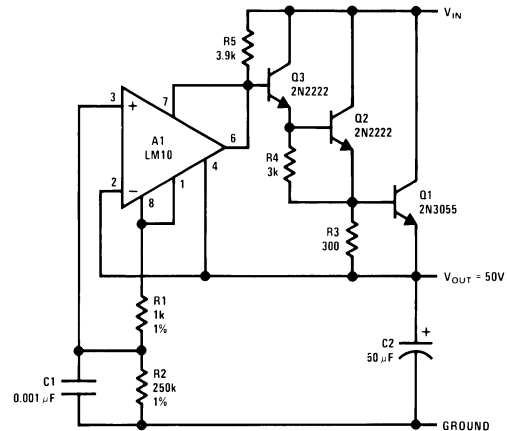
### Negative Regulator



DS005652-59

\*Electrolytic

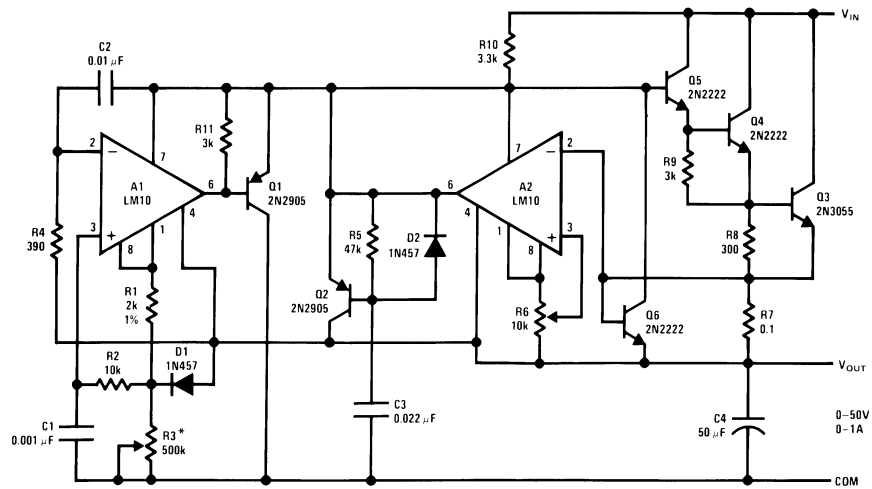
### Precision Regulator



DS005652-60

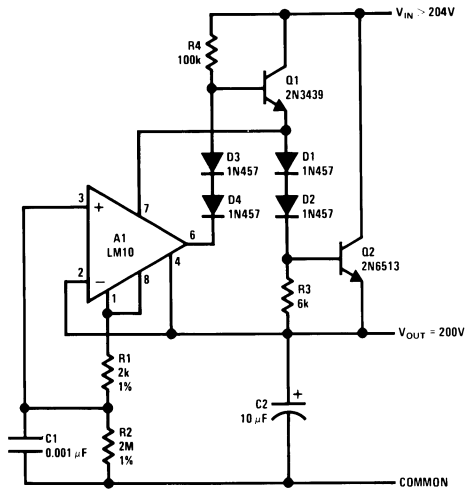
# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

## Laboratory Power Supply



$$*V_{OUT} = 10^{-4} R_3$$

## HV Regulator

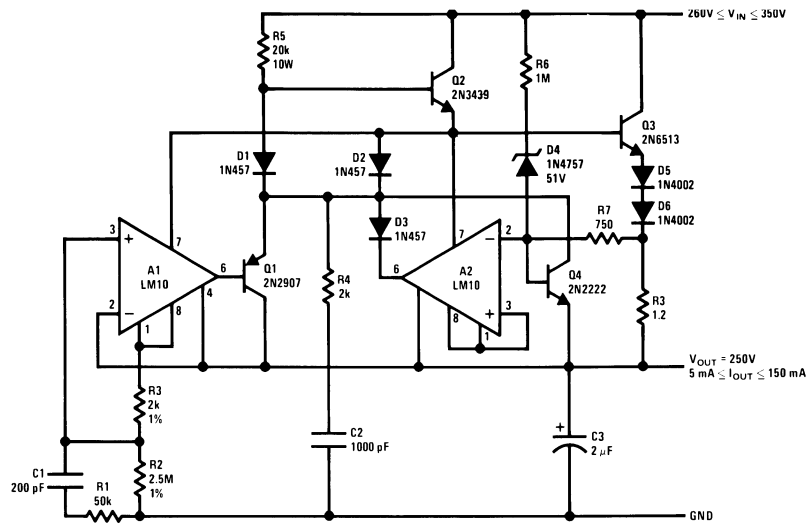


$$V_{OUT} = \frac{R_2}{R_1} V_{REF}$$

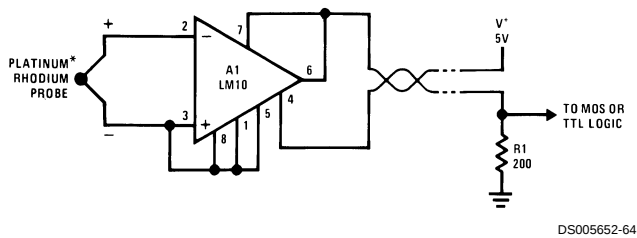
DS005652-84

# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

## Protected HV Regulator

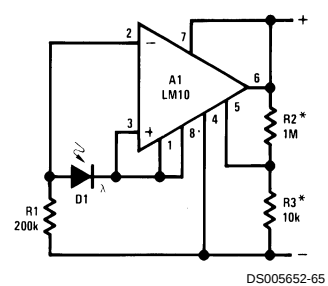


## Flame Detector



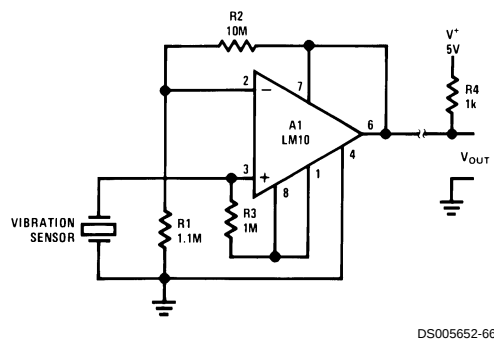
\*800°C Threshold Is Established By Connecting Balance To  $V_{REF}$ .

## Light Level Sensor

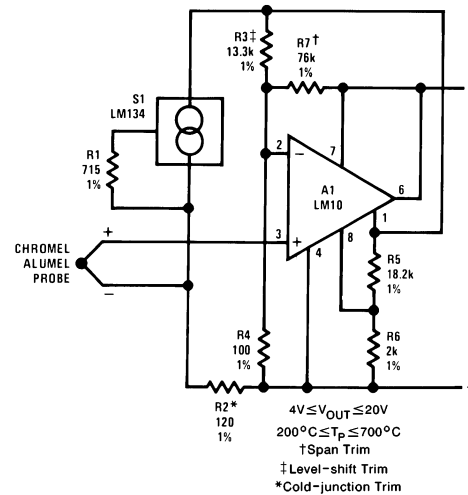


\*Provides Hysteresis

## Remote Amplifier

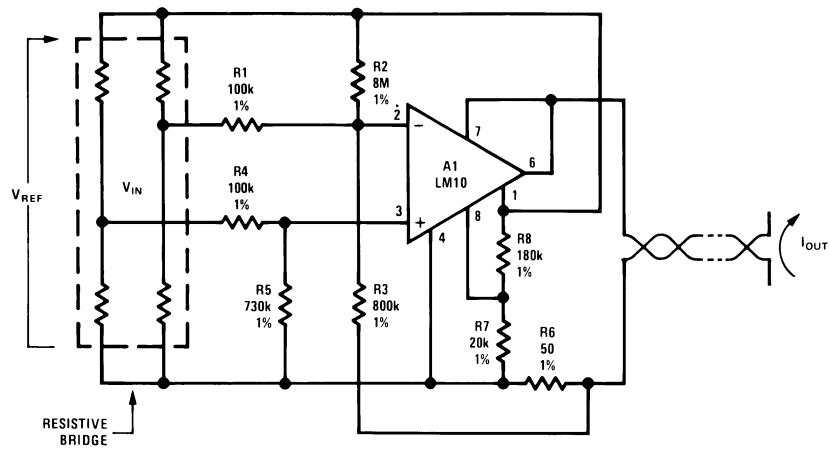


## Remote Thermocouple Amplifier



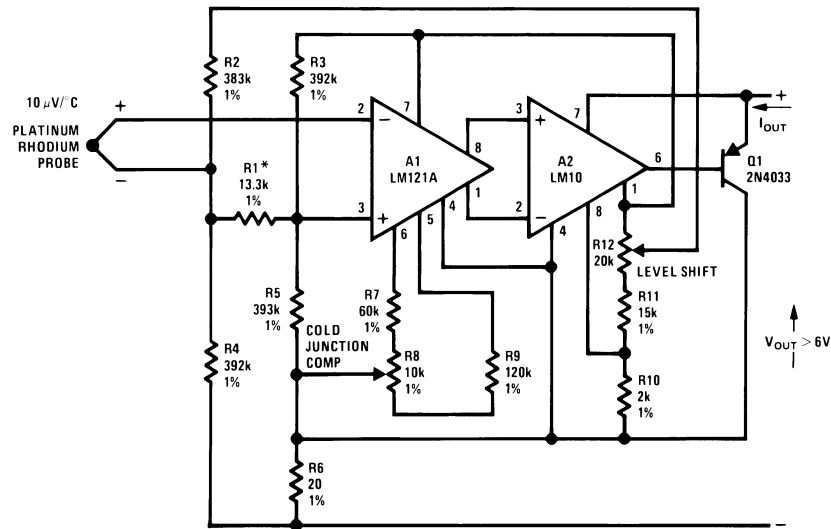
## Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

### Transmitter for Bridge Sensor



DS005652-68

### Precision Thermocouple Transmitter



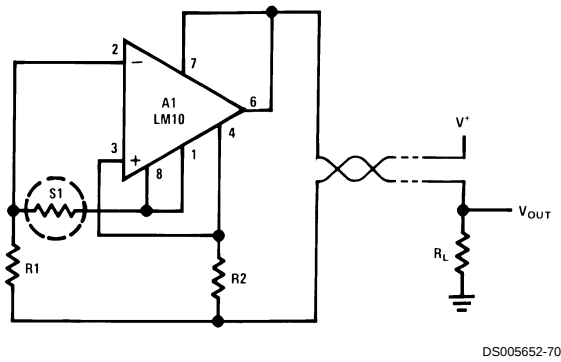
DS005652-69

 $10 \text{ mA} \leq I_{OUT} \leq 50 \text{ mA}$ 
 $500^{\circ}\text{C} \leq T_P \leq 1500^{\circ}\text{C}$ 

\*Gain Trim

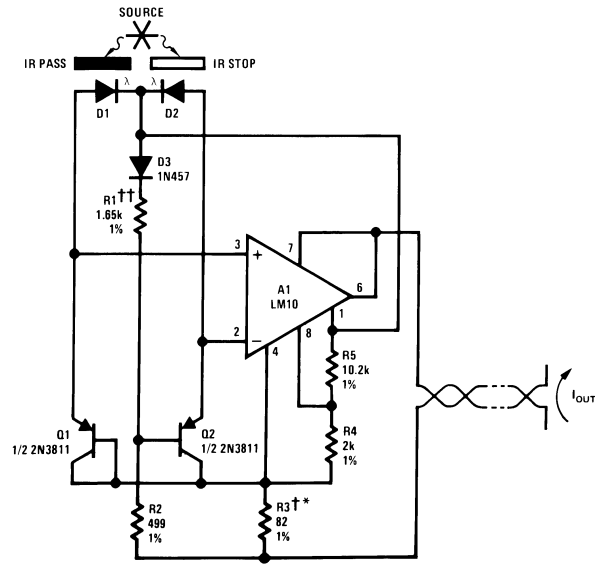
# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Resistance Thermometer Transmitter



DS005652-70

Optical Pyrometer



DS005652-71

††Level-shift Trim

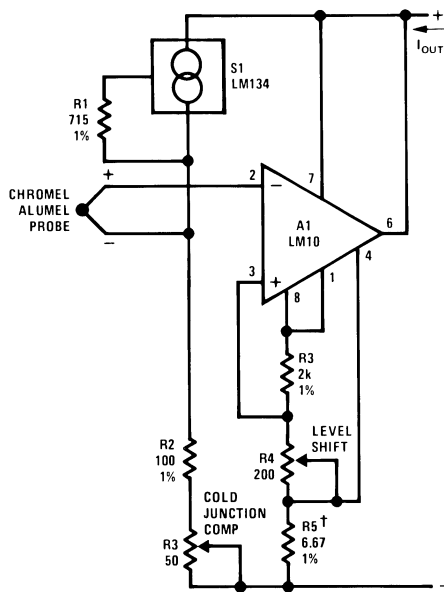
\*Scale Factor Trim

†Copper Wire Wound

$$1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$$

$$0.01 \leq \frac{I_{D2}}{I_{D1}} \leq 100$$

Thermocouple Transmitter



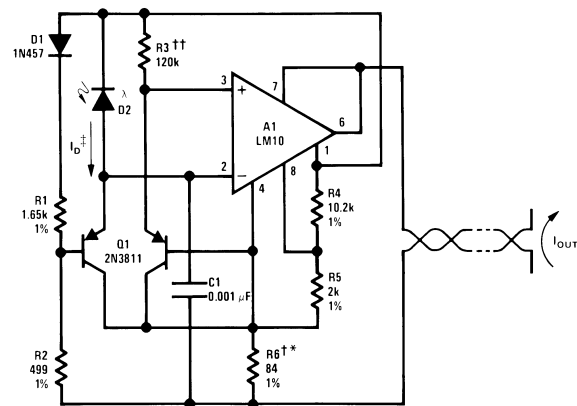
DS005652-72

$$200^{\circ}\text{C} \leq T_p \leq 700^{\circ}\text{C}$$

$$1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$$

†Gain Trim

Logarithmic Light Sensor



DS005652-73

$$1 \text{ mA} \leq I_{OUT} \leq 5 \text{ mA}$$

$$\pm 50 \mu\text{A} \leq I_D \leq 500 \mu\text{A}$$

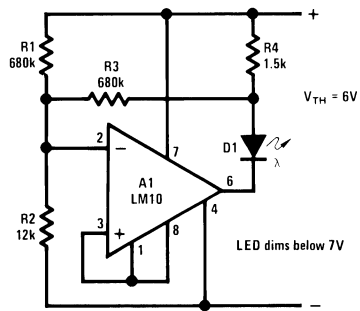
††Center Scale Trim

†Scale Factor Trim

\*Copper Wire Wound

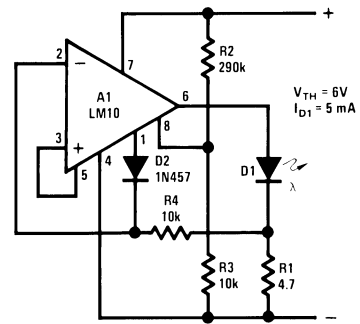
# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

## Battery-level Indicator



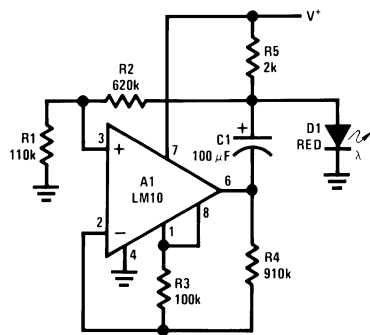
DS005652-74

## Battery-threshold Indicator



DS005652-75

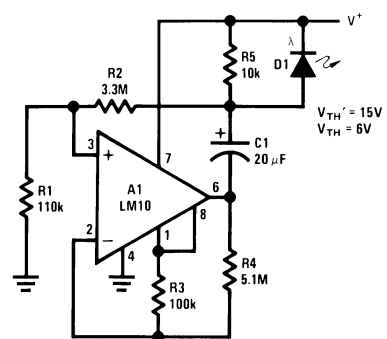
## Single-cell Voltage Monitor



DS005652-76

Flashes Above 1.2V  
Rate Increases With  
Voltage

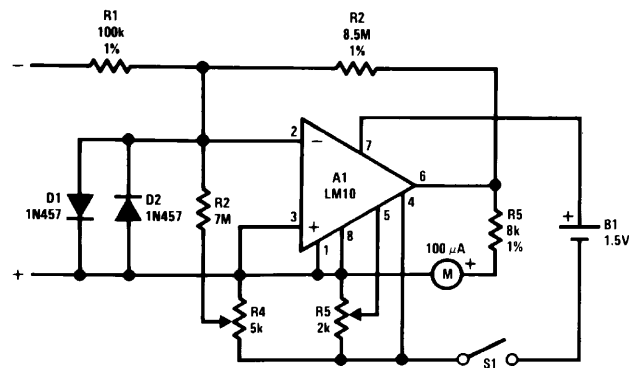
## Double-ended Voltage Monitor



DS005652-77

Flash Rate Increases  
Above 6V and Below 15V

## Meter Amplifier

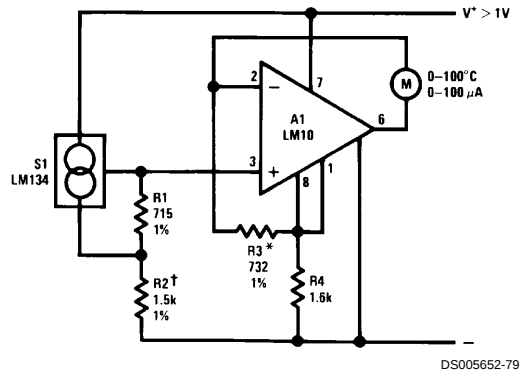


DS005652-78

INPUT  
10 mV, 100nA  
FULL-SCALE

# Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

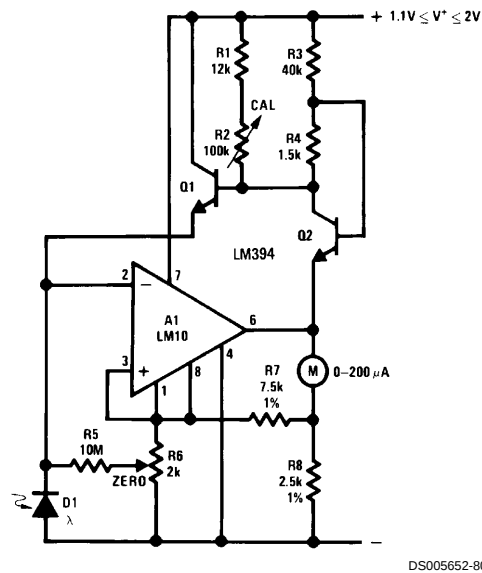
## Thermometer



\*Trim For Span

†Trim For Zero

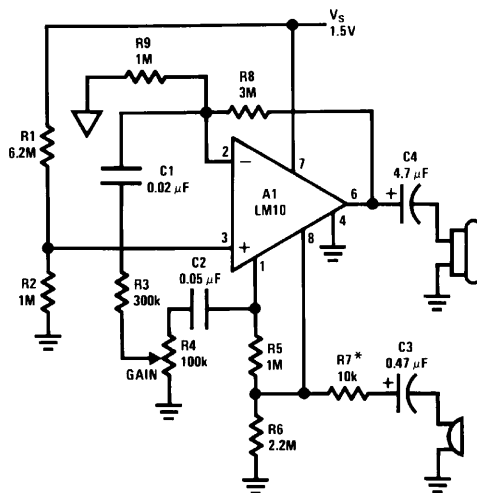
## Light Meter



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

## Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

### Microphone Amplifier



DS005652-81

$Z_{OUT} \sim 680\Omega$  @ 5 kHz

$A_V \leq 1k$

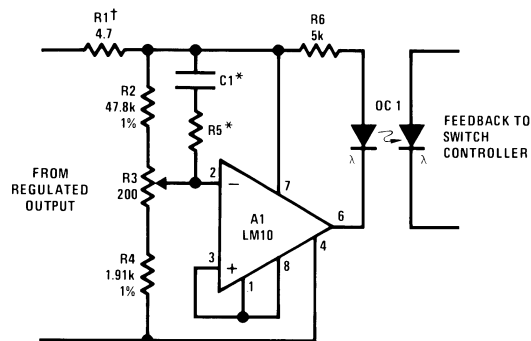
$f_1 \sim 100$  Hz

$f_2 \sim 5$  kHz

$R_L \sim 500$

\*Max Gain Trim

### Isolated Voltage Sensor

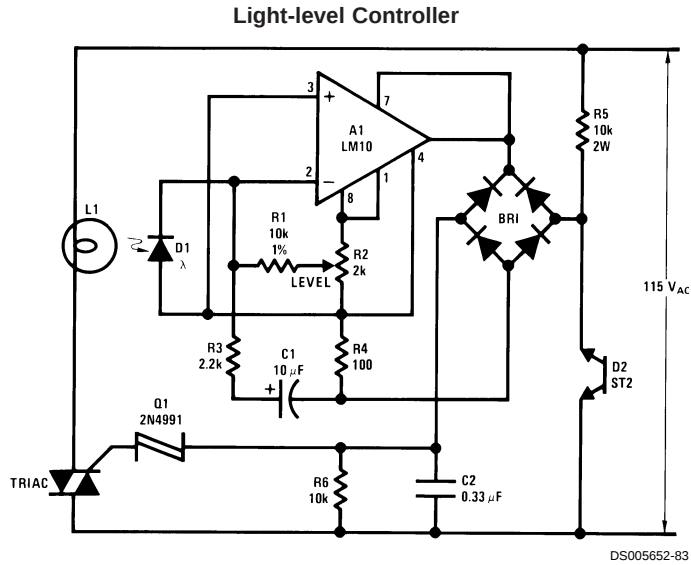


DS005652-82

†Controls "Loop Gain"

\*Optional Frequency Shaping

## Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

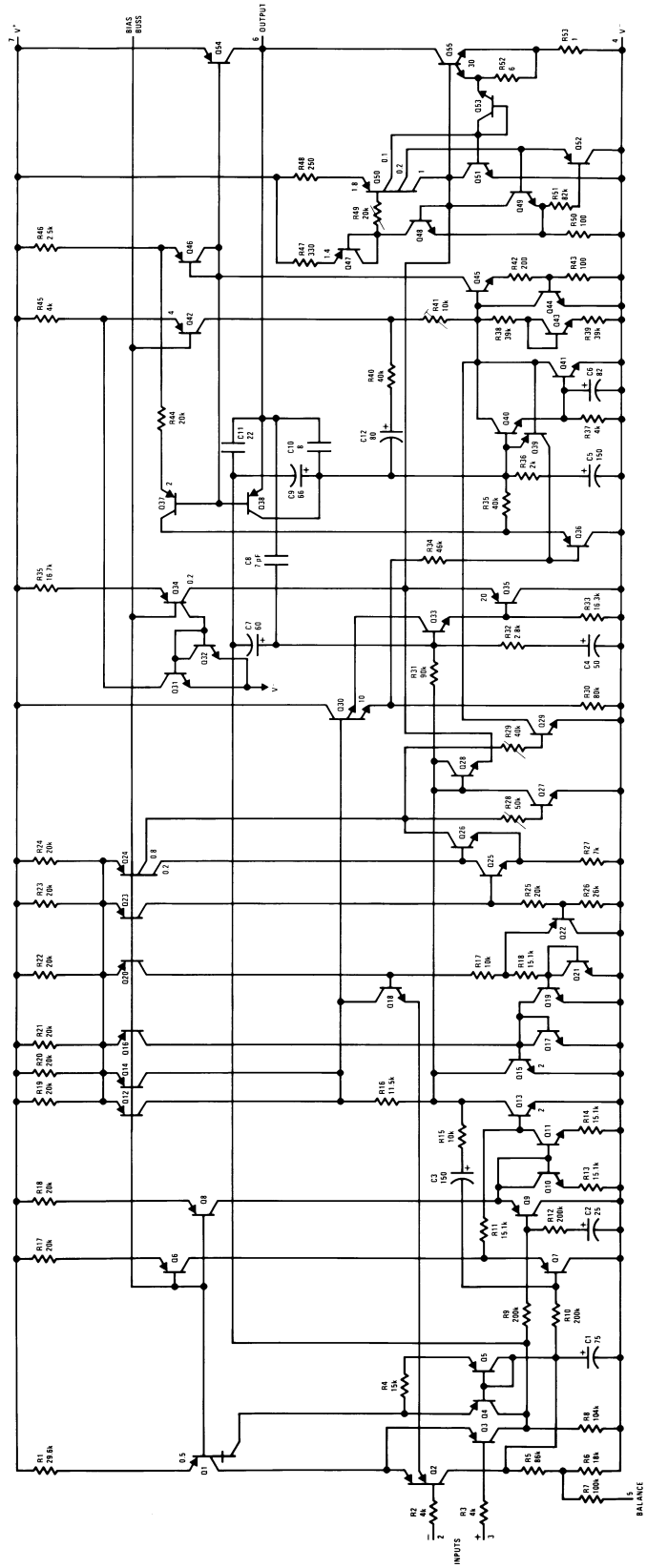


**Note 10:** Circuit descriptions available in application note AN-211.

### 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.

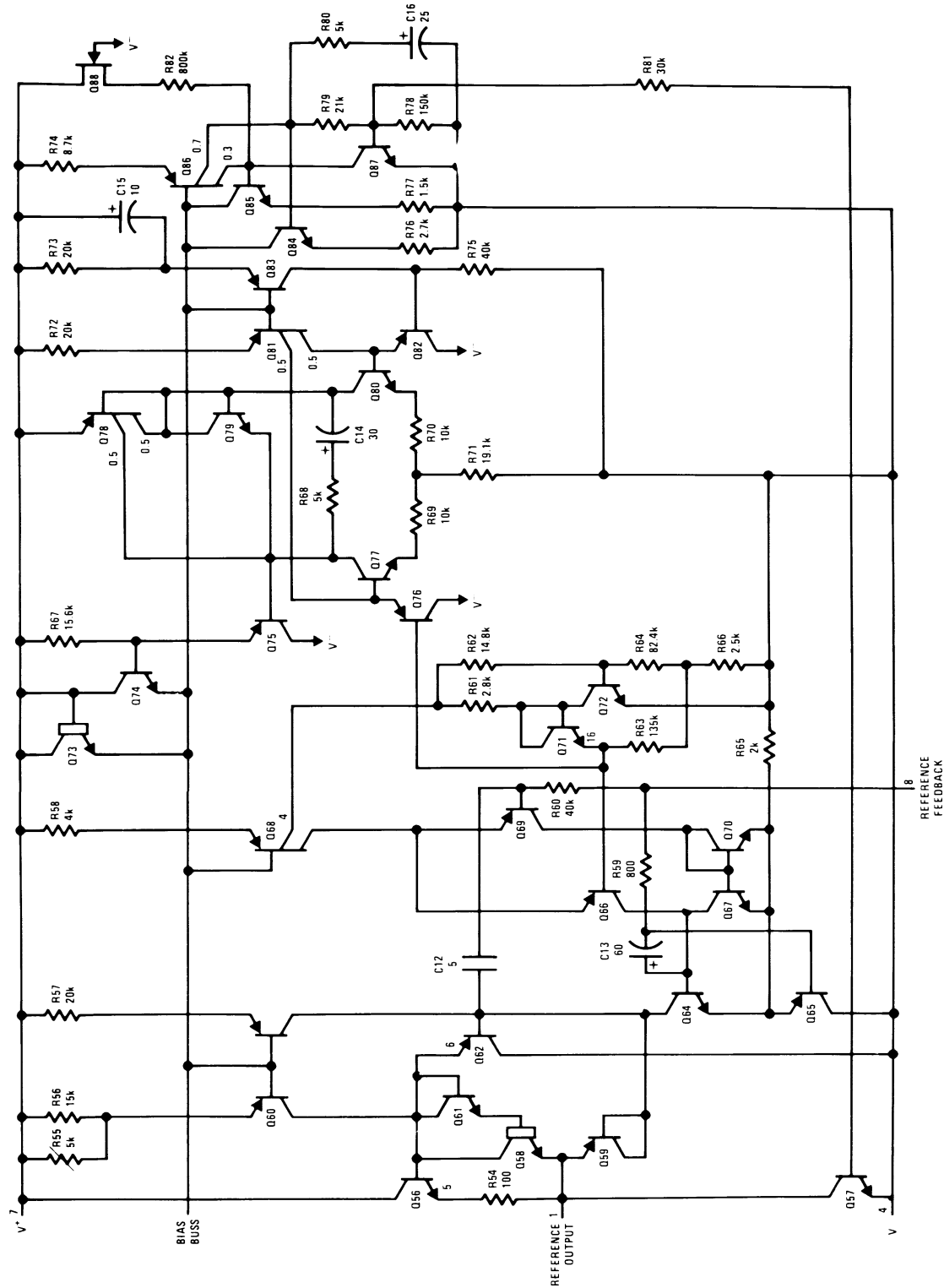
# Operational Amplifier Schematic (Pin numbers are for 8-pin packages)



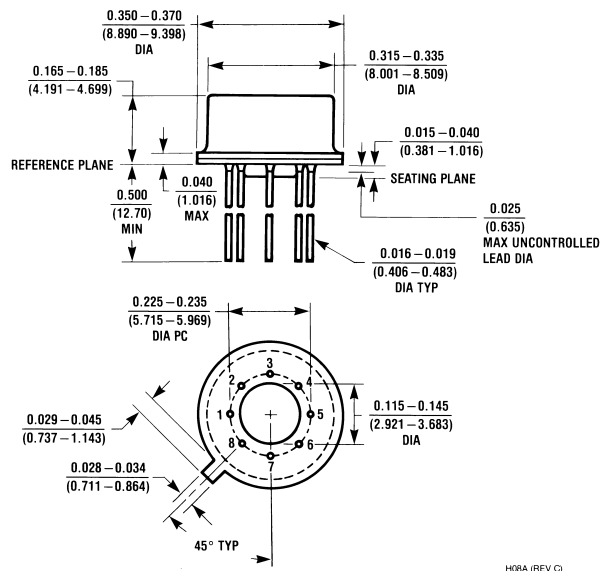
DS006652-13

# Reference and Internal Regulator

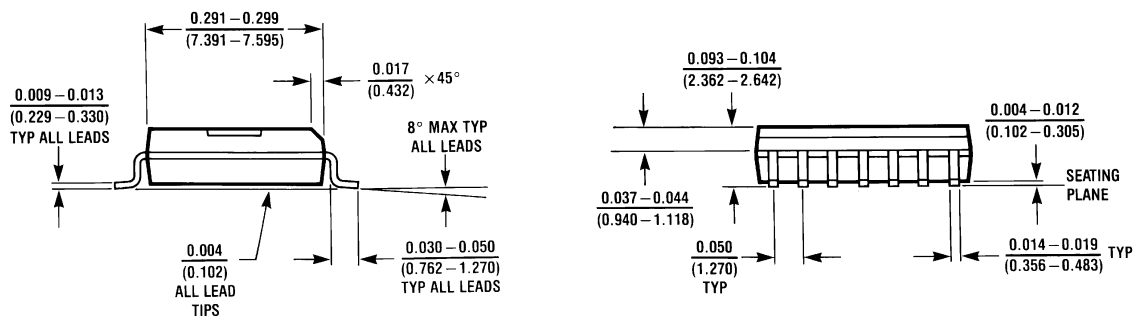
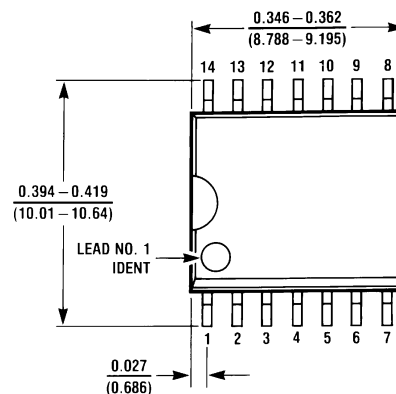
(Pin numbers are for 8-pin packages)



DS000652-14

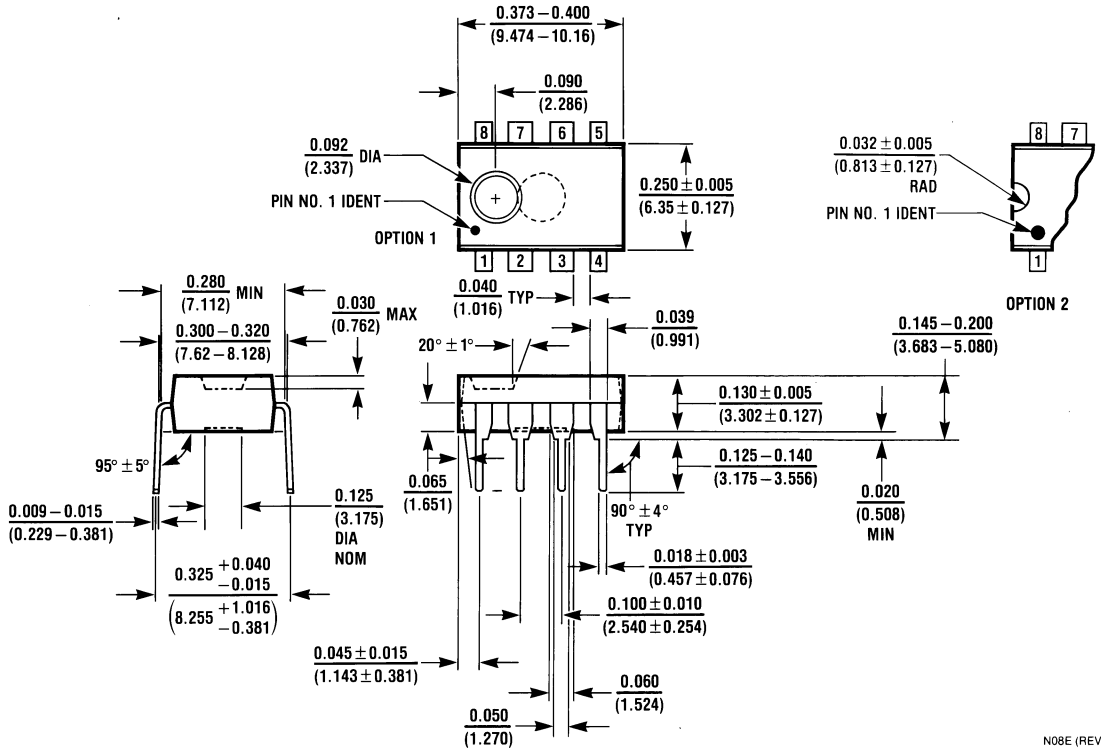


**Metal Can Package (H)**  
**Order Number LM10BH, LM10CH, LM10CLH or LM10H/883**  
**NS Package Number H08A**



**S.O. Package (WM)**  
**Order Number LM10CWM or LM10CWMX**  
**NS Package Number M14B**

# Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



N08E (REV F)

**Dual-In-Line Package (N)**  
**Order Number LM10CN or LM10CLN**  
**NS Package Number N08E**

## LIFE SUPPORT POLICY

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

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# LM10 Product Folder

## Operational Amplifier and Voltage Reference

|                                     |                          |                           |                                      |                                       |                              |                                   |
|-------------------------------------|--------------------------|---------------------------|--------------------------------------|---------------------------------------|------------------------------|-----------------------------------|
| <a href="#">General Description</a> | <a href="#">Features</a> | <a href="#">Datasheet</a> | <a href="#">Package &amp; Models</a> | <a href="#">Samples &amp; Pricing</a> | <a href="#">Design Tools</a> | <a href="#">Application Notes</a> |
|-------------------------------------|--------------------------|---------------------------|--------------------------------------|---------------------------------------|------------------------------|-----------------------------------|

### Parametric Table

|                                      |                    |
|--------------------------------------|--------------------|
| Channels (Channels)                  | 1                  |
| Input Output Type                    | Vcm to V-, R-R Out |
| Bandwidth, typ (MHz)                 | .09, .05           |
| Slew Rate, typ (Volts/usec)          | .20                |
| Supply Current per Channel, typ (mA) | .30, .28, .27      |
| Minimum Supply Voltage (Volt)        | 1.10               |

### Parametric Table

|                                   |             |
|-----------------------------------|-------------|
| Maximum Supply Voltage (Volt)     | 40, 7       |
| Offset Voltage, Max (mV)          | 4, 2        |
| Input Bias Current, Temp Max (nA) | 40, 30      |
| Output Current, typ (mA)          | 20          |
| Voltage Noise, typ (nV/Hz)        | 50          |
| Shut down                         | No          |
| Special Features                  | w/Reference |

### Datasheet

| Title                                                                      | Size in Kbytes | Date      | <div></div><br>View Online  | <div></div><br>Download  | <div></div><br>Receive via Email  |
|----------------------------------------------------------------------------|----------------|-----------|-----------------------------|--------------------------|-----------------------------------|
| LM10 Operational Amplifier and Voltage Reference                           | 687 Kbytes     | 22-Aug-00 | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| LM10 Operational Amplifier and Voltage Reference (JAPANESE)<br><div></div> | 655 Kbytes     |           | <div>View Online</div>      | <div>Download</div>      | <div>Receive via</div>            |
| LM10 Mil-Aero Datasheet MNLM10-X                                           | 12 Kbytes      |           | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |

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### Package Availability, Models, Samples & Pricing

| Part Number | Package                   |      |                     | Status          | Models |      | Samples & Electronic Orders | Budgetary Pricing |           | Std Pack Size | <a href="#">Package Marking</a> |
|-------------|---------------------------|------|---------------------|-----------------|--------|------|-----------------------------|-------------------|-----------|---------------|---------------------------------|
|             | Type                      | Pins | MSL                 |                 | SPICE  | IBIS |                             | Qty               | \$US each |               |                                 |
| LM10CWM     | <a href="#">SOIC WIDE</a> | 14   | <a href="#">MSL</a> | Full production | N/A    | N/A  | <div>24 Hour Buy Now</div>  | 1K+               | \$1.6500  | rail of 50    | [logo]çUçZç2çT LM10CWM          |

|                |                           |    |                     |                 |     |     |                         |      |           |                  |                                                 |
|----------------|---------------------------|----|---------------------|-----------------|-----|-----|-------------------------|------|-----------|------------------|-------------------------------------------------|
| LM10CWMX       | <a href="#">SOIC WIDE</a> | 14 | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 1K+  | \$1.6500  | reel of 1000     | [logo] ¢U¢Z¢2¢T LM10CWM                         |
| LM10CLN        | <a href="#">MDIP</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 1K+  | \$1.3000  | rail of 40       | [logo] ¢U¢Z¢2¢T LM10CLN                         |
| LM10CN         | <a href="#">MDIP</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 1K+  | \$1.6500  | rail of 40       | [logo] ¢U¢Z¢2¢T LM 10CN                         |
| LM10BH         | <a href="#">TO-5</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 250+ | \$11.8000 | box of 500       | [logo] ¢Z¢2¢T LM10BH                            |
| LM10CH         | <a href="#">TO-5</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 1K+  | \$3.0400  | box of 500       | [logo] ¢Z¢2¢T LM10CH                            |
| LM10CLH        | <a href="#">TO-5</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 1K+  | \$3.1200  | box of 500       | [logo] ¢Z¢2¢T LM10CLH                           |
| 5962-8760401GA | <a href="#">TO-5</a>      | 8  | <a href="#">MSL</a> | Full production | N/A | N/A | <a href="#">Buy Now</a> | 50+  | \$37.5000 | tray of 20       | [logo] ¢Z¢S¢4¢A LM10H/883Q¢M 5962-8760401GA \$E |
| LM10CL MDC     | <a href="#">Die</a>       |    |                     | Full production | N/A | N/A | <a href="#">Samples</a> |      |           | tray of N/A      | -                                               |
| LM10CL MWC     | <a href="#">Wafer</a>     |    |                     | Full production | N/A | N/A |                         |      |           | wafer jar of N/A | -                                               |
| LM10 MD8       | <a href="#">Die</a>       |    |                     | Full production | N/A | N/A | <a href="#">Samples</a> |      |           | tray of N/A      | -                                               |
| LM10 MW8       | <a href="#">Wafer</a>     |    |                     | Full production | N/A | N/A |                         |      |           | wafer jar of N/A | -                                               |

## General 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 270µA. A complementary output stage swings within 15 mV of the supply terminals or will deliver ±20 mA output current with ±0.4V 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.

Features

- input offset voltage: 2.0 mV (max)
- input offset current: 0.7 nA (max)
- input bias current: 20 nA (max)
- reference regulation: 0.1% (max)
- offset voltage drift: 2µV/°C
- reference drift: 0.002%/°C

Design Tools

| Title                                           | Size in Kbytes | Date        | <div></div><br>View Online | <div></div><br>Download | <div></div><br>Receive via Email |
|-------------------------------------------------|----------------|-------------|----------------------------|-------------------------|----------------------------------|
| Amplifiers Selection Guide software for Windows | 7 Kbytes       | 12-Jun-2002 | <a href="#">View</a>       |                         |                                  |

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Application Notes

| Title                                                                                                      | Size in Kbytes | Date      | <div></div><br>View Online  | <div></div><br>Download  | <div></div><br>Receive via Email  |
|------------------------------------------------------------------------------------------------------------|----------------|-----------|-----------------------------|--------------------------|-----------------------------------|
| AN-211: New Op Amp Ideas                                                                                   | 296 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-242: Applying a New Precision Op Amp                                                                    | 267 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-247: Using the ADC0808/ADC0809 8-Bit MicroP Compatible A/D Converters with 8-Channel Analog Multiplexer | 287 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-288: Application Note 288 System-Oriented DC-DC Conversion Techniques                                   | 405 Kbytes     | 1-May-98  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-298: Isolation Techniques for Signal Conditioning                                                       | 197 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-299: Application Note 299 Audio Applications of Linear Integrated Circuits                              | 232 Kbytes     | 24-Feb-99 | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-300: Simple Circuit Detects Loss of 4-20 mA Signal                                                      | 105 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |
| AN-460: LM34/LM35 Precision Monolithic Temperature Sensors                                                 | 190 Kbytes     | 4-Nov-95  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via Email</a> |

|                                                                  |               |                  |                             |                          |                                       |
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| LM34/LM35 Precision Monolithic Temperature Sensors<br>(JAPANESE) | 322<br>Kbytes |                  | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via</a>           |
|                                                                  |               |                  |                             |                          |                                       |
| TB-02: Digital Noise Reduction Techniques for COMBO II           | 69<br>Kbytes  | 4-<br>Nov-<br>95 | <a href="#">View Online</a> | <a href="#">Download</a> | <a href="#">Receive via<br/>Email</a> |

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