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 μA. 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. Some other characteristics of the LM10 are:

- 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 μV/°C
- reference drift: 0.002%/°C

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

Metal Can Package (H)

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

Small Outline Package (WM)

Order Number LM10CWM
See NS Package Number M14B

Dual-In-Line Package (N)

Order Number LM10CN or LM10CLN
See NS Package Number N08E
Absolute Maximum Ratings

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

Note 7

LM10/LM10B/ LM10BL/ LM10C LM10CL
Total Supply Voltage 45V 7V
Differential Input Voltage (note 1) ±40V ±7V
Power Dissipation (note 2) internally limited
Output Short-circuit Duration (note 3) 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

Operating Ratings

Package Thermal Resistance

θJA
Hi Package 150°C/W
N Package 87°C/W
WM Package 90°C/W
θJC
Hi Package 45°C/W

Electrical Characteristics

TJ = 25°C, TMIN ≤ TJ ≤ TMAX (note 4) (Boldface type refers to limits over temperature range)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM10/LM10B</th>
<th>LM10C</th>
</tr>
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<tbody>
<tr>
<td>Input offset voltage</td>
<td></td>
<td>Min Typ Max Min Typ Max</td>
<td>mV</td>
</tr>
<tr>
<td>Input offset current (note 5)</td>
<td></td>
<td>0.25</td>
<td>0.7</td>
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<tr>
<td>Input bias current</td>
<td></td>
<td>10</td>
<td>20</td>
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<tr>
<td>Input resistance</td>
<td></td>
<td>250</td>
<td>500</td>
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<td></td>
<td>1.5</td>
<td>3.0</td>
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<td>0.75</td>
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<td></td>
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<td>4</td>
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<tr>
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<td>90</td>
<td>102</td>
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<tr>
<td>Supply-voltage rejection</td>
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<td>90</td>
<td>96</td>
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<td>96</td>
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<td></td>
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<td>1.3V</td>
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<tr>
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### Electrical Characteristics

*Note: Boldface type refers to limits over temperature range.*

#### Parameter Conditions LM10/LM10B LM10C Units

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<thead>
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<th>Parameter</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
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<td>205</td>
<td>205</td>
<td>190</td>
<td>189</td>
<td>200</td>
<td>210</td>
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<td>300</td>
<td>500</td>
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<td>1.2V (1.3V) ≤ V_S ≤ 40V</td>
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<td>15</td>
<td>75</td>
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<td>µA</td>
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#### Parameter Conditions LM10BL LM10CL Units

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<td>400</td>
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<td>0.75</td>
<td>0.75</td>
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<td></td>
<td>V/mV</td>
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<td>30</td>
<td>6</td>
<td>30</td>
<td></td>
<td></td>
<td>V/mV</td>
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<td>Supply-voltage rejection</td>
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<td>80</td>
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<td></td>
<td></td>
<td></td>
<td>µV/°C</td>
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<td>Offset current drift</td>
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<td>2.0</td>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>µA/°C</td>
</tr>
<tr>
<td>Bias current drift</td>
<td></td>
<td>60</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pA/°C</td>
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<tr>
<td>Line regulation</td>
<td>1.2V (1.3V) ≤ V_S ≤ 6.5V</td>
<td>0.001</td>
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<td>0.001</td>
<td>0.02</td>
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<td>%/V</td>
</tr>
<tr>
<td>Load regulation</td>
<td>V &lt; V_REF ≤ 0.5 mA, V_REF = 200 mV</td>
<td>0.01</td>
<td>0.1</td>
<td>0.01</td>
<td>0.15</td>
<td></td>
<td></td>
<td>%/V</td>
</tr>
<tr>
<td>Amplifier gain</td>
<td>0.2V ≤ V_REF ≤ 5.5V</td>
<td>30 20</td>
<td>70</td>
<td>20</td>
<td>70</td>
<td></td>
<td></td>
<td>V/mV</td>
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</table>

### Notes

1. TJ = 25°C, T_MIN = T_J_MIN, T_MAX = T_J_MAX
2. (note 4)
**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 currents at the input terminals when the unloaded output is in the linear region.

**Input resistance:** The ratio of the change in input voltage to the change in input current on either input with the other held at a fixed voltage.

**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.

**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.

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

**Feedback sense voltage:** The voltage, referred to $V^-$, on the feedback terminal when 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.

**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 feedback terminal when operating in regulation.

**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.

### Electrical Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM10BL</th>
<th>LM10CL</th>
<th>Units</th>
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<tr>
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<td>Min</td>
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<td>Max</td>
</tr>
<tr>
<td>Feedback sense voltage</td>
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<td>195</td>
<td>200</td>
<td>206</td>
</tr>
<tr>
<td>Feedback current</td>
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<td>50</td>
<td>65</td>
</tr>
<tr>
<td>Reference drift</td>
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<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply current</td>
<td></td>
<td>260</td>
<td>400</td>
<td>500</td>
</tr>
</tbody>
</table>

**Note 1:** 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 $V_{IN}<V^-$.

**Note 2:** The maximum, operating-junction temperature is 150°C for the LM10, 100°C for the LM10BL and 85°C for the LM10CL. At elevated temperatures, devices must be derated based on package thermal resistance.

**Note 3:** 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 4:** These specifications apply for $V_{CM}$ and input common mode is referred to $V^-$ and $V_{CM}$ for the standard part and $V^-$ for the low voltage part. Normal typeface indicates 25°C limits. **Boldface type indicates limits and altered test conditions for full-temperature-range operation; this is 5°C to 125°C for the LM10, 0°C to 85°C for the LM10BL and 0°C to 70°C for the LM10CL.** The specifications do not include the effects of thermal gradients ($\tau_1=20$ ms), die heating ($\tau_2=0.2$ s) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).

**Note 5:** For $T_J=90°C$, $I_{OS}$ may exceed 1.5 nA for $V_{CM}=V^-$. With $T_J=125°C$ and $V_{CM}=V^-+0.1V$, $I_{OS}$ may exceed 5 nA.

**Note 6:** 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 the $V^-$ terminal (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 7:** Refer to RETS10X for LM10H military specifications.
Typical Performance Characteristics (Op Amp) (Continued)

- Frequency Response
- Output Impedance
- Typical Stability Range
- Large Signal Response
- Comparator Response
- Comparator Response Time for Various Input Overdrives
- Follower Pulse Response
- Noise Rejection
- Rejection Slew Limiting
- Supply Current
- Thermal Gradient Feedback
- Thermal Gradient Cross-coupling
Typical Performance Characteristics (Op Amp) (Continued)

![Graphs showing Shunt Gain characteristics with varying input and output voltages.]

Typical Performance Characteristics (Reference)

![Graphs showing Line Regulation, Load Regulation, Reference Noise Voltage, Minimum Supply Voltage, Output Saturation, and Typical Stability Range characteristics.]

TL/H/5652–4

TL/H/5652–5
Typical Applications

Op Amp Offset Adjustment

Standard

Limited Range

Limited Range With Boosted Reference

Positive Regulators

Low Voltage

Best Regulation

Zero Output

1Use only electrolytic output capacitors.

1Circuit descriptions available in application note AN-211.
Typical Applications†† (Pin numbers are for devices in 8-pin packages) (Continued)

Current Regulator

Shunt Regulator

*Required For Capacitive Loading

Negative Regulator

Precision Regulator

*Electrolytic

Laboratory Power Supply

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

††Circuit descriptions available in application note AN-211.
**Typical Applications**

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

**HV Regulator**

![HV Regulator Circuit Diagram]

**Protected HV Regulator**

![Protected HV Regulator Circuit Diagram]

**Flame Detector**

![Flame Detector Circuit Diagram]

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

**Light Level Sensor**

![Light Level Sensor Circuit Diagram]

*Provides Hysteresis*

**Remote Amplifier**

![Remote Amplifier Circuit Diagram]

**Remote Thermocouple Amplifier**

![Remote Thermocouple Amplifier Circuit Diagram]

4V ≤ VOUT ≤ 20V
200°C ≤ Tp ≤ 700°C

1) Span Trim
2) Level-shift Trim
3) Cold-junction Trim

**TL/H/5652-6**

1) Circuit descriptions available in application note AN-211.
Typical Applications

Transmitter for Bridge Sensor

Precision Thermocouple Transmitter

Resistance Thermometer Transmitter

Optical Pyrometer

Circuit descriptions available in application note AN-211.
Typical Applications †† (Pin numbers are for devices in 8-pin packages) (Continued)

**Thermocouple Transmitter**

- 200°C ≤ Tp ≤ 700°C
- 1 mA ≤ Iout ≤ 5 mA
- Gain Trim

**Logarithmic Light Sensor**

- 1 mA ≤ Iout ≤ 5 mA
- 50 μA ≤ Iout ≤ 500 μA
- Center Scale Trim
- Scale Factor Trim
- Copper Wire Wound

**Battery-level Indicator**

- LED turns below 7V

**Battery-threshold Indicator**

- Vref = 6V
- Iout = 5 mA

**Single-cell Voltage Monitor**

- Flashes Above 1.2V
- Rate Increases With Voltage

**Double-ended Voltage Monitor**

- Flash Rate Increases Above 6V and Below 15V

††Circuit descriptions available in application note AN-211.
Typical Applications † † (Pin numbers are for devices in 8-pin packages) (Continued)

**Meter Amplifier**

- **INPUT:** 10 mV, 100 nA
- **FULL-SCALE**

**Thermometer**

- **V’ > 1 V**
- **Trim For Span**
- **Trim For Zero**

**Light Meter**

- **1 \leq \lambda_{\lambda_0} \leq 10^5**

**Microphone Amplifier**

- **Z_{OUT} = 680\Omega**
- **@ 5 kHz**
- **r_0 < 1 kΩ**
- **f_1 = 100 Hz**
- **f_2 = 5 kHz**
- **R_L = 500**

† †Circuit descriptions available in application note AN-211.
**Typical Applications** † † (Pin numbers are for devices in 8-pin packages) (Continued)

**Isolated Voltage Sensor**

```
\[\text{Circuit diagram of Isolated Voltage Sensor}\]
```

† Controls “Loop Gain”

Optional Frequency Shaping

**Light-level Controller**

```
\[\text{Circuit diagram of Light-level Controller}\]
```

Application Hints

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

† † Circuit descriptions available in application note AN-211.
Operational Amplifier Schematic (Pin numbers are for 8-pin packages)
Reference and Internal Regulator  (Pin numbers are for 8-pin packages)
Physical Dimensions inches (millimeters) (Continued)

![Diagram of the LM10 Operational Amplifier and Voltage Reference](image)

<table>
<thead>
<tr>
<th>Dual-In-Line Package (N)</th>
<th>Order Number LM10CN or LM10CLN</th>
<th>NS Package Number NO8E</th>
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