**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: ΔμV/°C
- Reference drift: 0.002%/°C

---

**Connection and Functional Diagrams**

**Metal Can Package (H)**

**Small Outline Package (WM)**

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

---

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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

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.

Maximum Junction Temperature

<table>
<thead>
<tr>
<th>Device</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>LM10</td>
<td>150˚C</td>
</tr>
<tr>
<td>LM10B</td>
<td>100˚C</td>
</tr>
<tr>
<td>LM10C</td>
<td>85˚C</td>
</tr>
</tbody>
</table>

ESD rating is to be determined.

Operating Ratings

Package Thermal Resistance

<table>
<thead>
<tr>
<th>Package</th>
<th>Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>H Package</td>
<td>150˚C/W</td>
</tr>
<tr>
<td>N Package</td>
<td>87˚C/W</td>
</tr>
<tr>
<td>WM Package</td>
<td>90˚C/W</td>
</tr>
</tbody>
</table>

Electrical Characteristics

$T_J=25˚C$, $T_{MIN} \leq T_J \leq T_{MAX}$ (Boldface type refers to limits over temperature range) (Note 5)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM10/LM10B</th>
<th>LM10C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
</tr>
<tr>
<td>Input offset voltage</td>
<td>0.3</td>
<td>2.0</td>
<td>3.0</td>
<td>0.5</td>
</tr>
<tr>
<td>Input offset current (Note 6)</td>
<td>0.25</td>
<td>0.7</td>
<td>1.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Input bias current</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>Input resistance</td>
<td>250</td>
<td>150</td>
<td>500</td>
<td>115</td>
</tr>
<tr>
<td>Large signal voltage gain</td>
<td>V_S=±20V, I_{OUT}=0</td>
<td>V_{OUT}=±19.95V</td>
<td>120</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>V_S=±20V, V_{OUT}=±19.4V</td>
<td>50</td>
<td>130</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>I_{OUT}=±20 mA (±15 mA)</td>
<td>20</td>
<td>15</td>
<td>V/mV</td>
</tr>
<tr>
<td></td>
<td>V_S=±0.6V (0.65V), I_{OUT}=±2 mA</td>
<td>1.5</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>V_{OUT}=±0.4V (±0.3V), V_CCM=−0.4V</td>
<td>0.5</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td>Shunt gain (Note 7)</td>
<td>$1.2V (1.3V) \leq V_{OUT} \leq 40V$, $R_L=1.1$ kΩ</td>
<td>14</td>
<td>33</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>0.1 mA R_{IN}=20 mA</td>
<td>6</td>
<td>6</td>
<td>V/mV</td>
</tr>
<tr>
<td></td>
<td>1.5V V_{S}=±40V, R_L=250 kΩ</td>
<td>8</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>Common-mode rejection</td>
<td>V_S=±20V</td>
<td>93</td>
<td>102</td>
<td>90</td>
</tr>
<tr>
<td>Supply-voltage rejection</td>
<td>$-0.2V \leq V^* \leq 39V$</td>
<td>90</td>
<td>96</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>$V^*=1.0V (1.1V)$</td>
<td>84</td>
<td>84</td>
<td>V/mV</td>
</tr>
<tr>
<td></td>
<td>$1.0V (1.1V) \leq V^* \leq 39.8V$</td>
<td>96</td>
<td>106</td>
<td>93</td>
</tr>
<tr>
<td>Offset voltage drift</td>
<td>2.0</td>
<td>2.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Offset current drift</td>
<td>2.0</td>
<td>2.0</td>
<td>5.0</td>
<td>pA/°C</td>
</tr>
<tr>
<td>Bias current drift</td>
<td>T_{C}=100˚C</td>
<td>60</td>
<td>90</td>
<td>pA/°C</td>
</tr>
<tr>
<td>Line regulation</td>
<td>$1.2V (1.3V) \leq V_{S} \leq 40V$</td>
<td>0.001</td>
<td>0.001</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>$0 \leq I_{REF} \leq 1.0$ mA, $V_{REF}=200$ mV</td>
<td>0.003</td>
<td>0.006</td>
<td>0.01</td>
</tr>
</tbody>
</table>
### Electrical Characteristics (Continued)

**T<sub>J</sub> = 25˚C, T<sub>MIN</sub> ≤ T<sub>J</sub> ≤ T<sub>MAX</sub>** (Boldface type refers to limits over temperature range) (Note 5)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM10/LM10B</th>
<th>LM10C</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Load regulation</td>
<td>0.01</td>
<td>0.1</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>Amplifier gain</td>
<td>23</td>
<td>75</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>Feedback sense voltage</td>
<td>195</td>
<td>200</td>
<td>190</td>
<td>200</td>
</tr>
<tr>
<td>Feedback current</td>
<td>20</td>
<td>50</td>
<td>22</td>
<td>75</td>
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<tr>
<td>Reference drift</td>
<td></td>
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<td>0.002</td>
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<tr>
<td>Supply current</td>
<td></td>
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<td></td>
<td>270</td>
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<tr>
<td>Supply current change</td>
<td></td>
<td></td>
<td></td>
<td>15</td>
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</table>

### Electrical Characteristics

**T<sub>J</sub> = 25˚C, T<sub>MIN</sub> ≤ T<sub>J</sub> ≤ T<sub>MAX</sub>** (Boldface type refers to limits over temperature range) (Note 5)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>LM10BL</th>
<th>LM10CL</th>
<th>Units</th>
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<tbody>
<tr>
<td></td>
<td>Min</td>
<td>Typ</td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Input offset voltage</td>
<td>0.3</td>
<td>2.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>Input offset current (Note 6)</td>
<td>0.1</td>
<td>0.7</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Input bias current</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Input resistance</td>
<td>250</td>
<td>500</td>
<td>150</td>
<td>400</td>
</tr>
<tr>
<td>Large signal voltage gain</td>
<td>V&lt;sub&gt;S&lt;/sub&gt;=±3.25V, I&lt;sub&gt;OUT&lt;/sub&gt;=0 V&lt;sub&gt;OUT&lt;/sub&gt;=±3.2V</td>
<td>60</td>
<td>300</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;S&lt;/sub&gt;=±3.25V, I&lt;sub&gt;OUT&lt;/sub&gt;=10 mA V&lt;sub&gt;OUT&lt;/sub&gt;=±2.75 V</td>
<td>40</td>
<td>25</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>V&lt;sub&gt;S&lt;/sub&gt;=±0.6V (0.65V), I&lt;sub&gt;OUT&lt;/sub&gt;=±2 mA V&lt;sub&gt;OUT&lt;/sub&gt;=±0.4V</td>
<td>1.5</td>
<td>3.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Shunt gain (Note 7)</td>
<td>1.5V&lt;sub&gt;S&lt;/sub&gt;/V&lt;sub&gt;OUT&lt;/sub&gt;≤6.5V, R&lt;sub&gt;L&lt;/sub&gt;=5000Ω</td>
<td>74</td>
<td>83</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>0.1 mA&lt;sub&gt;OUT&lt;/sub&gt;≤10 mA</td>
<td>4</td>
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<tr>
<td>Common-mode rejection</td>
<td></td>
<td>80</td>
<td>80</td>
<td>102</td>
</tr>
<tr>
<td>Supply-voltage rejection</td>
<td></td>
<td>86</td>
<td>86</td>
<td>96</td>
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<tr>
<td></td>
<td></td>
<td>80</td>
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<td>94</td>
<td>94</td>
<td>106</td>
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<td>88</td>
<td>88</td>
<td>106</td>
</tr>
<tr>
<td>Offset voltage drift</td>
<td>2.0</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Offset current drift</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bias current drift</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line regulation</td>
<td></td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.001</td>
<td>0.01</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.02</td>
<td></td>
<td>0.03</td>
</tr>
<tr>
<td>Load regulation</td>
<td>0.01</td>
<td></td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td></td>
<td>0.2</td>
<td></td>
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</tbody>
</table>
## Electrical Characteristics (Continued)

### Parameter Conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LM10BL</th>
<th>LM10CL</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T J = 25˚C, T MIN ≤ T J ≤ T MAX</strong> (Boldface type refers to limits over temperature range) (Note 5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Note 5</strong>: These specifications apply for V − ≤ V CM ≤ V + −0.85V (1.0V), 1.2V (1.3V) &lt; V S ≤ V MAX, V REF = 0.2V and 0 ≤ IREF ≤ 1.0 mA, unless otherwise specified: V MAX = 40V for the standard part and 6.5V 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 −55˚C to 125˚C for the LM10, −25˚C to 85˚C for the LM10B(L) and 0˚C to 70˚C for the LM10C(L). The specifications do not include the effects of thermal gradients (τ 1 ≅ 20 ms), die heating (τ 2 ≅ 0.2s) or package heating. Gradient effects are small and tend to offset the electrical error (see curves).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Note 6</strong>: For T J &gt; 90˚C, I OS may exceed 1.5 nA for V CM = V −. With T J &gt; 125˚C and V − &lt; V CM &lt; V − +0.1V, I OS ≤ 5 nA.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Note 7</strong>: Refer to RETS10X for LM10H military specifications.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **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 ≤ V Max. |
| **Note 3**: 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. |
| **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. |

### 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 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) (Continued)

**Minimum Supply Voltage**

- DS005652-27
- DS005652-28
- 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

- DS005652-35

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Typical Performance Characteristics (Op Amp) (Continued)

**Follower Pulse Response**

![Follower Pulse Response Graph](image1)

**Noise Rejection**

![Noise Rejection Graph](image2)

**Rejection Slew Limiting**

![Rejection Slew Limiting Graph](image3)

**Supply Current**

![Supply Current Graph](image4)

**Thermal Gradient Feedback**

![Thermal Gradient Feedback Graph](image5)

**Thermal Gradient Cross-coupling**

![Thermal Gradient Cross-coupling Graph](image6)

**Shunt Gain**

![Shunt Gain Graph](image7)

![Shunt Gain Graph](image8)

![Shunt Gain Graph](image9)
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

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**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**

- Required For Capacitive Loading

- DS005652-58

**Negative Regulator**

- DS005652-59

**Precision Regulator**

- DS005652-60

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

**Laboratory Power Supply**

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

**HV Regulator**

\[ V_{OUT} = \frac{R2}{R1} \cdot V_{REF} \]
**Typical Applications** (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

- **Protected HV Regulator**
- **Flame Detector**
- **Light Level Sensor**
- **Remote Amplifier**
- **Remote Thermocouple Amplifier**

*800˚C Threshold Is Established By Connecting Balance To V_{REF}.*

*Provides Hysteresis*

[Images of circuit diagrams for each application]
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Transmitter for Bridge Sensor

Precision Thermocouple Transmitter

10 mA/°C to 50 mA
500°C/°C to 1500°C
*Gain Trim
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Resistance Thermometer Transmitter

Optical Pyrometer

Thermocouple Transmitter

Logarithmic Light Sensor

Resistance Thermometer Transmitter

Optical Pyrometer

Thermocouple Transmitter

Logarithmic Light Sensor

200°C ≤ Tp ≤ 700°C

1 mA ≤ IOUT ≤ 5 mA

1 mA ≤ IOUT ≤ 5 mA

1 mA ≤ IOUT ≤ 5 mA

1 mA ≤ IOUT ≤ 5 mA

150 µA ≤ ID ≤ 500 µA

Gain Trim

Center Scale Trim

Scale Factor Trim

Copper Wire Wound

Copper Wire Wound

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

Battery-level Indicator

Battery-threshold Indicator

Single-cell Voltage Monitor

Flashes Above 1.2V
Rate Increases With Voltage

Double-ended Voltage Monitor

Flash Rate Increases Above 6V and Below 15V

Meter Amplifier

INPUT
10 mV, 100nA
FULL-SCALE

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

*Trim For Span
†Trim For Zero

**Thermometer**

**Light Meter**

10^3 \nu \leq 10^5
Typical Applications (Note 10) (Pin numbers are for devices in 8-pin packages) (Continued)

Microphone Amplifier

Z_{OUT} \approx 680 \Omega \text{ @ } 5 \text{ kHz}
A_{v1} \approx 1 \text{ kHz}
f_{1} = 100 \text{ Hz}
f_{2} = 5 \text{ kHz}
R_{L} = 500

*Max Gain Trim

Isolated Voltage Sensor

*Controls "Loop Gain"
*Optional Frequency Shaping
**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.

---

**Note 10**: Circuit descriptions available in application note AN-211.
Reference and Internal Regulator  (Pin numbers are for 8-pin packages)
Physical Dimensions  inches (millimeters) unless otherwise noted

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

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