LPC662

LPC662 Low Power CMOS Dual Operational Amplifier

Literature Number: SNOS555B
LPC662
Low Power CMOS Dual Operational Amplifier

General Description
The LPC662 CMOS Dual operational amplifier is ideal for operation from a single supply. It features a wide range of operating voltage from +5V to +15V, rail-to-rail output swing in addition to an input common-mode range that includes ground. Performance limitations that have plagued CMOS amplifiers in the past are not a problem with this design. Input V\text{OS}, drift, and broadband noise as well as voltage gain (into 100 k\Omega and 5 k\Omega) are all equal to or better than widely accepted bipolar equivalents, while the power supply requirement is typically less than 0.5 mW.

This chip is built with National’s advanced Double-Poly Silicon-Gate CMOS process.

See the LPC660 datasheet for a Quad CMOS operational amplifier and LPC661 for a single CMOS operational amplifier with these same features.

Applications
- High-impedance buffer
- Precision current-to-voltage converter

Features
- Rail-to-rail output swing
- Micropower operation (<0.5 mW)
- Specified for 100 k\Omega and 5 k\Omega loads
- High voltage gain 120 dB
- Low input offset voltage 3 mV
- Low offset voltage drift 1.3 \mu V/\degree C
- Ultra low input bias current 2 fA
- Input common-mode includes GND
- Operating range from +5V to +15V
- Low distortion 0.01% at 1 kHz
- Slew rate 0.11 V/\mu s
- Full military temperature range available

Application Circuit

![Howland Current Pump Diagram]
**Absolute Maximum Ratings** (Note 3)

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Typ</th>
<th>LPC662AM</th>
<th>LPC662AMJ/883 Limit (Notes 4, 8)</th>
<th>LPC662AI Limit (Note 4)</th>
<th>LPC662I Limit (Note 4)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Offset Voltage</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td></td>
<td></td>
<td>mV max</td>
</tr>
<tr>
<td>Input Offset Voltage Average Drift</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>µV/C</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>0.002</td>
<td>20</td>
<td>100</td>
<td>4</td>
<td>4</td>
<td></td>
<td>pA max</td>
</tr>
<tr>
<td>Input Offset Current</td>
<td>0.001</td>
<td>20</td>
<td>100</td>
<td>2</td>
<td>2</td>
<td></td>
<td>pA max</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>&gt;1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tera Ω</td>
</tr>
<tr>
<td>Common Mode Rejection Ratio</td>
<td>0V ≤ V CM ≤ 12.0V</td>
<td>83</td>
<td>70</td>
<td>70</td>
<td>63</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V + = 15V</td>
<td>83</td>
<td>68</td>
<td>68</td>
<td>61</td>
<td>min</td>
<td></td>
</tr>
<tr>
<td>Positive Power Supply Rejection Ratio</td>
<td>5V ≤ V + ≤ 15V</td>
<td>83</td>
<td>70</td>
<td>70</td>
<td>63</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td>V O = 2.5V</td>
<td>83</td>
<td>68</td>
<td>68</td>
<td>61</td>
<td>min</td>
<td></td>
</tr>
<tr>
<td>Negative Power Supply Rejection Ratio</td>
<td>0V ≤ V − ≤ −10V</td>
<td>94</td>
<td>84</td>
<td>84</td>
<td>74</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>82</td>
<td>83</td>
<td>73</td>
<td></td>
<td>min</td>
<td></td>
</tr>
<tr>
<td>Input Common-Mode Voltage Range</td>
<td>V + = 5V and 15V For CMRR ≥ 50 dB</td>
<td>−0.4</td>
<td>−0.1</td>
<td>−0.1</td>
<td>−0.1</td>
<td>V max</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Large Signal Voltage Gain Sourcing</td>
<td>R L = 100 kΩ (Note 5)</td>
<td>1000</td>
<td>400</td>
<td>400</td>
<td>300</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td>300</td>
<td>200</td>
<td>min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>180</td>
<td>180</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td>120</td>
<td>70</td>
<td>min</td>
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<tr>
<td>Large Signal Voltage Gain Sinking</td>
<td>R L = 5 kΩ (Note 5)</td>
<td>1000</td>
<td>200</td>
<td>200</td>
<td>100</td>
<td>V/mV</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>160</td>
<td>80</td>
<td>min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>250</td>
<td>100</td>
<td>50</td>
<td>V/mV</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>35</td>
<td>60</td>
<td>40</td>
<td>min</td>
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**Operating Ratings** (Note 3)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Range</td>
<td></td>
</tr>
<tr>
<td>Supply Range</td>
<td>4.75V to 15.5V</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td></td>
</tr>
<tr>
<td>Thermal Resistance (θ JA) (Note 10)</td>
<td>100˚C/W</td>
</tr>
</tbody>
</table>

**DC Electrical Characteristics**

Unless otherwise specified, all limits guaranteed for T J = 25˚C. *Boldface* limits apply at the temperature extremes. V + = 5V, V − = 0V, V CM = 1.5V, V O = 2.5V and R L > 1M unless otherwise specified.
**DC Electrical Characteristics** (Continued)

Unless otherwise specified, all limits guaranteed for \( T_J = 25^\circ \text{C} \). **Boldface** limits apply at the temperature extremes. \( V^+ = 5V, V^- = 0V, V_{CM} = 1.5V, V_O = 2.5V \) and \( R_L > 1\text{M} \) unless otherwise specified.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Typ</th>
<th>Limit (Notes 4, 8)</th>
<th>Limit (Note 4)</th>
<th>Limit (Note 4)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Output Swing</strong></td>
<td>( V^+ = 5V )</td>
<td>4.987</td>
<td>4.970</td>
<td>4.970</td>
<td>4.940</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>( R_L = 100 \text{ k}\Omega )</td>
<td></td>
<td>4.950</td>
<td>4.950</td>
<td>4.910</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.004</td>
<td>0.030</td>
<td>0.060</td>
<td>V</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.050</td>
<td>0.050</td>
<td>0.090</td>
<td>max</td>
</tr>
<tr>
<td></td>
<td>( V^+ = 5V )</td>
<td>4.940</td>
<td>4.850</td>
<td>4.850</td>
<td>4.750</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>( R_L = 5 \text{ k}\Omega )</td>
<td></td>
<td>4.750</td>
<td>4.750</td>
<td>4.650</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.040</td>
<td>0.150</td>
<td>0.250</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.250</td>
<td>0.250</td>
<td>0.350</td>
<td>max</td>
</tr>
<tr>
<td></td>
<td>( R_L = 100 \text{ k}\Omega )</td>
<td></td>
<td>14.880</td>
<td>14.880</td>
<td>14.820</td>
<td>min</td>
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<td></td>
<td></td>
<td>0.007</td>
<td>0.030</td>
<td>0.060</td>
<td>V</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.050</td>
<td>0.050</td>
<td>0.090</td>
<td>max</td>
</tr>
<tr>
<td></td>
<td>( R_L = 5 \text{ k}\Omega )</td>
<td></td>
<td>14.600</td>
<td>14.600</td>
<td>14.480</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.110</td>
<td>0.220</td>
<td>0.320</td>
<td>V</td>
</tr>
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<td></td>
<td></td>
<td>0.300</td>
<td>0.300</td>
<td>0.400</td>
<td>max</td>
</tr>
<tr>
<td><strong>Output Current</strong></td>
<td>Sourcing, ( V_O = 0V )</td>
<td>22</td>
<td>16</td>
<td>16</td>
<td>13</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>14</td>
<td>11</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td>Sinking, ( V_O = 5V )</td>
<td>21</td>
<td>16</td>
<td>16</td>
<td>13</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>14</td>
<td>11</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td><strong>Output Current</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sourcing, ( V_O = 0V )</td>
<td>40</td>
<td>19</td>
<td>28</td>
<td>23</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>25</td>
<td>20</td>
<td>min</td>
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<td></td>
<td>Sinking, ( V_O = 13V )</td>
<td>39</td>
<td>19</td>
<td>28</td>
<td>23</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>(Note 11)</td>
<td></td>
<td>19</td>
<td>24</td>
<td>19</td>
<td>min</td>
</tr>
<tr>
<td></td>
<td><strong>Supply Current</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Both Amplifiers</td>
<td>86</td>
<td>120</td>
<td>120</td>
<td>140</td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td>( V_O = 1.5V )</td>
<td></td>
<td>145</td>
<td>140</td>
<td>160</td>
<td>max</td>
</tr>
</tbody>
</table>

(Note 1):
## AC Electrical Characteristics

Unless otherwise specified, all limits guaranteed for $T_J = 25˚C$. **Boldface** limits apply at the temperature extremes. $V^+ = 5V$, $V^- = 0V$, $V_{CM} = 1.5V$, $V_O = 2.5V$ and $R_L > 1M$ unless otherwise specified.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Conditions</th>
<th>Typ</th>
<th>LPC662AM Limit (Note 4, 8)</th>
<th>LPC662AI Limit (Note 4)</th>
<th>LPC662I Limit (Note 4)</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slew Rate</td>
<td>(Note 6)</td>
<td>0.11</td>
<td>0.07</td>
<td>0.07</td>
<td>0.05</td>
<td>V/µs</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>min</td>
</tr>
<tr>
<td>Gain-Bandwidth Product</td>
<td></td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>Phase Margin</td>
<td></td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td>Deg</td>
</tr>
<tr>
<td>Gain Margin</td>
<td></td>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Amp-to-Amp Isolation</td>
<td>(Note 7)</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
<td>dB</td>
</tr>
<tr>
<td>Input Referred Voltage Noise</td>
<td>$F = 1$ kHz</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
<td>nV/√Hz</td>
</tr>
<tr>
<td>Input Referred Current Noise</td>
<td>$F = 1$ kHz</td>
<td>0.0002</td>
<td></td>
<td></td>
<td></td>
<td>pA/√Hz</td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>$F = 1$ kHz, $A_v = -10$, $V^+ = 15V$</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
</tbody>
</table>

**Note 1:** Applies to both single supply and split supply operation. Continuous short circuit operation at elevated ambient temperature and/or multiple Op Amp shorts can result in exceeding the maximum allowed junction temperature of 150˚C. Output currents in excess of ±30 mA over long term may adversely affect reliability.

**Note 2:** The maximum power dissipation is a function of $T_{J(max)}$, $\theta_{JA}$ and $T_A$. The maximum allowable power dissipation of any ambient temperature is $P_D = (T_{J(max)} - T_A)/\theta_{JA}$.

**Note 3:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

**Note 4:** Limits are guaranteed by testing or correlation.

**Note 5:** $V^+ = 15V$, $V_{CM} = 7.5V$ and $R_L$ connected to 7.5V. For Sourcing tests, $7.5V \leq V_O \leq 11.5V$. For Sinking tests, $2.5V \leq V_O \leq 7.5V$.

**Note 6:** $V^+ = 15V$. Connected as Voltage Follower with 10V step input. Number specified is the slower of the positive and negative slew rates.

**Note 7:** Input referred. $V^+ = 15V$ and $R_L = 100 k\Omega$ connected to $V^+/2$. Each amp excited in turn with 1 kHz to produce $V_O = 13 V_{pp}$.

**Note 8:** A military RETS electrical test specification is available on request. At the time of printing, the LPC662AMJ/883 RETS specification complied fully with the boldface limits in this column. The LPC662AMJ/883 may also be procured to a Standard Military Drawing specification.

**Note 9:** For operating at elevated temperatures the device must be derated based on the thermal resistance $\theta_{JA}$ with $P_D = (T_J - T_A)/\theta_{JA}$.

**Note 10:** All numbers apply for packages soldered directly into a PC board.

**Note 11:** Do not connect output to $V^+$ when $V^+$ is greater than 13V or reliability may be adversely affected.
Typical Performance Characteristics \( V_S = \pm 7.5V, T_A = 25^\circ C \) unless otherwise specified

Supply Current vs Supply Voltage

Input Bias Current vs Temperature

Input Common-Mode Voltage Range vs Temperature

Output Characteristics Current Sinking

Output Characteristics Current Sourcing

Input Voltage Noise vs Frequency
Typical Performance Characteristics $V_S = \pm 7.5V$, $T_A = 25^\circ C$ unless otherwise specified (Continued)

Crosstalk Rejection vs Frequency

CMRR vs Frequency

CMRR vs Temperature

Open-Loop Voltage Gain vs Temperature

Open-Loop Frequency Response

Gain and Phase Responses vs Load Capacitance
Typical Performance Characteristics \( V_S = \pm 7.5 \text{V}, T_A = 25^\circ \text{C} \) unless otherwise specified (Continued)

**Gain and Phase Responses vs Temperature**

- **Gain Error** \((V_{OS} \text{ vs } V_{OUT})\)
- **Non-Inverting Slew Rate vs Temperature**
- **Inverting Slew Rate vs Temperature**
- **Large-Signal Pulse Non-Inverting Response** \((A_V = +1)\)
- **Non-Inverting Small Signal Pulse Response** \((A_V = +1)\)
Typical Performance Characteristics  $V_S = \pm 7.5\text{V}$, $T_A = 25^\circ\text{C}$ unless otherwise specified (Continued)

Inverting Large-Signal Pulse Response

![Inverting Large-Signal Pulse Response](DS010548-47)

Inverting Small-Signal Pulse Response

![Inverting Small-Signal Pulse Response](DS010548-48)

Power Supply Rejection Ratio vs Frequency

![Power Supply Rejection Ratio vs Frequency](DS010548-37)

Stability vs Capacitive Load

![Stability vs Capacitive Load](DS010548-4)

Note: Avoid resistive loads of less than 500$\Omega$, as they may cause instability.
Application Hints

AMPLIFIER TOPOLOGY

The topology chosen for the LPC662 is unconventional (compared to general-purpose op amps) in that the traditional unity-gain buffer output stage is not used; instead, the output is taken directly from the output of the integrator, to allow rail-to-rail output swing. Since the buffer traditionally delivers the power to the load, while maintaining high op amp gain and stability, and must withstand shorts to either rail, these tasks now fall to the integrator.

As a result of these demands, the integrator is a compound affair with an embedded gain stage that is doubly fed forward (via $C_f$ and $C_{ff}$) by a dedicated unity-gain compensation driver. In addition, the output portion of the integrator is a push-pull configuration for delivering heavy loads. While sinking current the whole amplifier path consists of three gain stages with one stage fed forward, whereas while sourcing the path contains four gain stages with two fed forward.

The large signal voltage gain while sourcing is comparable to traditional bipolar op amps for load resistance of at least 5 kΩ. The gain while sinking is higher than most CMOS op amps, due to the additional gain stage; however, when driving load resistance of 5 kΩ or less, the gain will be reduced as indicated in the Electrical Characteristics. The op amp can drive load resistance as low as 500 kΩ without instability.

COMPENSATING INPUT CAPACITANCE

Refer to the LMC660 or LMC662 datasheets to determine whether or not a feedback capacitor will be necessary for compensation and what the value of that capacitor would be.

CAPACITIVE LOAD TOLERANCE

Like many other op amps, the LPC662 may oscillate when its applied load appears capacitive. The threshold of oscillation varies both with load and circuit gain. The configuration most sensitive to oscillation is a unity-gain follower. See the Typical Performance Characteristics.

The load capacitance interacts with the op amp’s output resistance to create an additional pole. If this pole frequency is insufficiently low, it will degrade the op amp’s phase margin so that the amplifier is no longer stable at low gains. The addition of a small resistor (50Ω to 100Ω) in series with the op amp’s output, and a capacitor (5 pF to 10 pF) from inverting input to output pins, returns the phase margin to a safe value without interfering with lower-frequency circuit operation. Thus, larger values of capacitance can be tolerated without oscillation. Note that in all cases, the output will ring heavily when the load capacitance is near the threshold for oscillation.

Capacitive load driving capability is enhanced by using a pull up resistor to $V^+$ Figure 3. Typically a pull up resistor conducting 50 µA or more will significantly improve capacitive load responses. The value of the pull up resistor must be determined based on the current sinking capability of the amplifier with respect to the desired output swing. Open loop gain of the amplifier can also be affected by the pull up resistor (see Electrical Characteristics).

PRINTED-CIRCUIT-BOARD LAYOUT

FOR HIGH-IMPEDANCE WORK

It is generally recognized that any circuit which must operate with less than 1000 pA of leakage current requires special layout of the PC board. When one wishes to take advantage of the ultra-low bias current of the LPC662, typically less than 0.04 pA, it is essential to have an excellent layout. Fortunately, the techniques for obtaining low leakages are quite simple. First, the user must not ignore the surface leakage of the PC board, even though it may sometimes appear acceptably low, because under conditions of high humidity or dust or contamination, the surface leakage will be appreciable.

To minimize the effect of any surface leakage, lay out a ring of foil completely surrounding the LPC662’s inputs and the terminals of capacitors, diodes, conductors, resistors, relay terminals, etc. connected to the op-amp’s inputs. See Figure 4. To have a significant effect, guard rings should be placed on both the top and bottom of the PC board. This PC foil must then be connected to a voltage which is at the same voltage as the amplifier inputs, since no leakage current can flow between two points at the same potential. For example, a PC board trace-to-pad resistance of 10¹² ohms, which is normally considered a very large resistance, could leak 5 pA if the trace were a 5V bus adjacent to the pad of an input.
Application Hints (Continued)

This would cause a 100 times degradation from the LPC662's actual performance. However, if a guard ring is held within 5 mV of the inputs, then even a resistance of $10^{11}$ ohms would cause only 0.05 pA of leakage current, or perhaps a minor (2:1) degradation of the amplifier’s performance. See Figure 5a, Figure 5b, Figure 5c for typical connections of guard rings for standard op-amp configurations. If both inputs are active and at high impedance, the guard can be tied to ground and still provide some protection; see Figure 5d.

The designer should be aware that when it is inappropriate to lay out a PC board for the sake of just a few circuits, there is another technique which is even better than a guard ring on a PC board: Don't insert the amplifier’s input pin into the
Application Hints (Continued)

board at all, but bend it up in the air and use only air as an insulator. Air is an excellent insulator. In this case you may have to forego some of the advantages of PC board construction, but the advantages are sometimes well worth the effort of using point-to-point up-in-the-air wiring. See Figure 6.

FIGURE 6. Air Wiring

BIAS CURRENT TESTING

The test method of Figure 7 is appropriate for bench-testing bias current with reasonable accuracy. To understand its operation, first close switch S2 momentarily. When S2 is opened, then

\[ I_- = \frac{dV_{OUT}}{dt} \times C_2. \]

Typical Single-Supply Applications

Photodiode Current-to-Voltage Converter

Note: A 5V bias on the photodiode can cut its capacitance by a factor of 2 or 3, leading to improved response and lower noise. However, this bias on the photodiode will cause photodiode leakage (also known as its dark current).

Micropower Current Source

Note: (Upper limit of output range dictated by input common-mode range; lower limit dictated by minimum current requirement of LM385.)
Typical Single-Supply Applications \((V^+ = 5.0 \text{ V}_{\text{DC}}\) (Continued)

For good CMRR over temperature, low drift resistors should be used. Matching of \(R_3\) to \(R_6\) and \(R_4\) to \(R_7\) affects CMRR. Gain may be adjusted through \(R_2\). CMRR may be adjusted through \(R_7\).

If \(R_1 = R_5, R_3 = R_6\) and \(R_4 = R_7\); then

\[
\frac{V_{\text{OUT}}}{V_{\text{IN}}} = \frac{R_2 + 2R_1}{R_2} \cdot \frac{R_4}{R_3}
\]

\(\therefore A_V \approx 100\) for circuit shown.
Typical Single-Supply Applications \((V^+ = 5.0 \, V_{DC})\) (Continued)

This circuit, as shown, oscillates at 2.0 kHz with a peak-to-peak output swing of 4.5V.

Oscillator frequency is determined by \(R1, R2, C1,\) and \(C2:\)

\[
f_{\text{osc}} = \frac{1}{2\pi RC}
\]

where \(R = R1 = R2\) and \(C = C1 = C2.\)

1 Hz Square-Wave Oscillator

Power Amplifier
Typical Single-Supply Applications \((V^+ = 5.0\ V_{DC})\) (Continued)

10 Hz Bandpass Filter

\[
\begin{align*}
V_{IN} &\rightarrow R1 & 560k &\rightarrow C1 & 0.0068\ \mu F &\rightarrow R4 & 10M &\rightarrow V_{OUT} \\
5V &\rightarrow R2 & 10M &\rightarrow R3 & 6.8M
\end{align*}
\]

\(f_0 = 10\ Hz\)
\(Q = 2.1\)
Gain = \(-8.8\)

10 Hz High-Pass Filter (2 dB Dip)

\[
\begin{align*}
V_{IN} &\rightarrow C1 & 0.015\ \mu F &\rightarrow R1 & 8.2M &\rightarrow \frac{1}{2}\ \text{LPC662} &\rightarrow C2 & 0.015\ \mu F &\rightarrow R2 & 2.7M &\rightarrow R3 & 390k &\rightarrow V_{OUT}
\end{align*}
\]

\(f_0 = 10\ Hz\)
\(d = 0.895\)
Gain = 1

1 Hz Low-Pass Filter
(Maximally Flat, Dual Supply Only)

\[
\begin{align*}
V_{IN} &\rightarrow R1 & 470k &\rightarrow R2 & 8.2M &\rightarrow R3 & 8.2M &\rightarrow C1 & 0.02\ \mu F &\rightarrow C2 & 0.02\ \mu F &\rightarrow R4 & 270k &\rightarrow V_{OUT}
\end{align*}
\]

\(f_c = 1\ Hz\)
\(d = 1.414\)
Gain = 1.57

High Gain Amplifier with Offset Voltage Reduction

\[
\begin{align*}
V_{IN} &\rightarrow R1 & 4.7k &\rightarrow \frac{1}{2}\ \text{LPC662} &\rightarrow C1 & 0.1\ \mu F &\rightarrow R2 & 22k &\rightarrow C2 & 0.1\ \mu F &\rightarrow R4 & 10M &\rightarrow V_{OUT}
\end{align*}
\]
\[
\begin{align*}
V_{BIAS} &\rightarrow R5 & 22k &\rightarrow \frac{1}{2}\ \text{LPC662} &\rightarrow C3 & 0.1\ \mu F &\rightarrow R6 & 15k
\end{align*}
\]

Gain = \(-46.8\)
Output offset voltage reduced to the level of the input offset voltage of the bottom amplifier (typically 1 mV), referred to \(V_{BIAS}\).
Connection Diagram

Ordering Information

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<td>8-Pin Ceramic DIP</td>
<td>LPC662AMJ/883</td>
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Physical Dimensions  inches (millimeters) unless otherwise noted

8-Pin Cavity Dual-In-Line Package (D)
Order Number LPC662AMD
NS Package Number D08C

Ceramic Dual-In-Line Package (J)
Order Number LPC662AMJ/883
NS Package Number J08A
Physical Dimensions inches (millimeters) unless otherwise noted (Continued)

8-Pin Small Outline Molded Package (M)
Order Number LPC662AIM or LPC662IM
NS Package Number M08A

8-Pin Molded Dual-In-Line Package (N)
Order Number LPC662AIN or LPC662IN
NS Package Number N08E
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