1 Features

- For Cost-Optimized Systems
- Nanopower Supply Current: 425 nA/channel
- Offset Voltage: 500 µV (max)
- TcVos: 1 µV/°C
- Gain-Bandwidth: 6 kHz
- Unity-Gain Stable
- Low Input Bias Current: 100 fA
- Wide Supply Range: 1.7 V to 5.5 V
- Rail-to-Rail Output
- No Output Reversals
- EMI Protection
- Temperature Range: –40°C to 125°C
- Industry Standard Packages:
  - Single in 5-pin SOT-23
  - Dual in 8-pin VSSOP

2 Applications

- Gas Detectors (CO and O₂)
- PIR Motion Detectors
- Current Sensing
- Thermostats
- IoT (Internet of Things) Remote Sensors
- Active RFID Readers and Tags
- Portable Medical Equipment
- Portable Glucose Monitors

3 Description

The TLV8811 (single) and TLV8812 (dual) family of precision ultra-low-power operational amplifiers are ideal for cost-optimized, “Always ON” sensing applications in battery powered wireless and low power wired equipment. With 6 kHz of bandwidth from 425 nA of quiescent current and a trimmed offset voltage to under 500 µV, the TLV881x amplifiers provide high precision while minimizing power consumption in equipment such as CO gas detectors and portable electronic devices where operational battery-life is critical. They also have a CMOS input stage enabling fempto-amp bias currents, thereby reducing I_{BIAS} and I_{OS} errors that would otherwise impact high source impedance sensing applications. Additionally, built-in EMI protection reduces sensitivity to unwanted RF signals from mobile phones, WiFi, radio transmitters, and tag readers.

The TLV8811 (single) and TLV8812 (dual) channel versions are available in industry standard 5-pin SOT-23 and 8-pin VSSOP packages respectively.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLV8811</td>
<td>SOT-23 (5)</td>
<td>2.90 mm x 1.60 mm</td>
</tr>
<tr>
<td>TLV8812</td>
<td>VSSOP (8)</td>
<td>3.00 mm x 3.00 mm</td>
</tr>
</tbody>
</table>

LPV81x and TLV881x Nanopower Amplifiers

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>CHANNELS</th>
<th>SUPPLY CURRENT (Typ per Channel)</th>
<th>OFFSET VOLTAGE (Max at 25°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV811</td>
<td>1</td>
<td>450 nA</td>
<td>370 µV</td>
</tr>
<tr>
<td>LPV812</td>
<td>2</td>
<td>425 nA</td>
<td>300 µV</td>
</tr>
<tr>
<td>TLV8811</td>
<td>1</td>
<td>450 nA</td>
<td>550 µV</td>
</tr>
<tr>
<td>TLV8812</td>
<td>2</td>
<td>425 nA</td>
<td>500 µV</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the orderable addendum at the end of the data sheet.
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4 Revision History

Changes from Original (October 2016) to Revision A Page

• Changed Description text ................................................................. 1
• Deleted large family table, moved to front page. .............................................. 1
• Added Family table to front page ............................................................ 1
• Deleted "LPV8811 specs prelim until release" table footnote ....................................... 5
• Added separate CMRR Spec row for TLV8811 .............................................. 5
5 Pin Configuration and Functions

TLV8811 5-Pin SOT-23 DBV Package Top View

TLV8812 8-Pin VSSOP DGK Package Top View

Pin Functions: TLV8811 DBV

<table>
<thead>
<tr>
<th>PIN</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>O</td>
<td>Output</td>
</tr>
<tr>
<td>-IN</td>
<td>I</td>
<td>Inverting Input</td>
</tr>
<tr>
<td>+IN</td>
<td>I</td>
<td>Non-Inverting Input</td>
</tr>
<tr>
<td>V-</td>
<td>P</td>
<td>Negative (lowest) power supply</td>
</tr>
<tr>
<td>V+</td>
<td>P</td>
<td>Positive (highest) power supply</td>
</tr>
</tbody>
</table>

Pin Functions: TLV8812 DGK

<table>
<thead>
<tr>
<th>PIN</th>
<th>TYPE</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT A</td>
<td>O</td>
<td>Channel A Output</td>
</tr>
<tr>
<td>-IN A</td>
<td>I</td>
<td>Channel A Inverting Input</td>
</tr>
<tr>
<td>+IN A</td>
<td>I</td>
<td>Channel A Non-Inverting Input</td>
</tr>
<tr>
<td>V-</td>
<td>P</td>
<td>Negative (lowest) power supply</td>
</tr>
<tr>
<td>+IN B</td>
<td>I</td>
<td>Channel B Non-Inverting Input</td>
</tr>
<tr>
<td>-IN B</td>
<td>I</td>
<td>Channel B Inverting Input</td>
</tr>
<tr>
<td>OUT B</td>
<td>O</td>
<td>Channel B Output</td>
</tr>
<tr>
<td>V+</td>
<td>P</td>
<td>Positive (highest) power supply</td>
</tr>
</tbody>
</table>
6 Specifications

6.1 Absolute Maximum Ratings
Over operating free-air temperature range (unless otherwise noted) (1)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage, ( V_s = (V^+) - (V^-) )</td>
<td>(-0.3)</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>Input pins</td>
<td>Voltage (2)(3) Common mode ((V^-) - 0.3 \quad (V^+) + 0.3)</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Differential ((V^-) - 0.3 \quad (V^+) + 0.3)</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Input pins</td>
<td>Current</td>
<td>-10</td>
<td>10</td>
</tr>
<tr>
<td>Output short current (4)</td>
<td>Continuous</td>
<td>Continuous</td>
<td></td>
</tr>
<tr>
<td>Storage temperature, ( T_{stg} )</td>
<td>(-65)</td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Junction temperature</td>
<td></td>
<td></td>
<td>150</td>
</tr>
</tbody>
</table>

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) Not to exceed -0.3V or +6.0V on ANY pin, referred to V-

(3) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3 V beyond the supply rails should be current-limited to 10 mA or less.

(4) Short-circuit to Vs/2, one amplifier per package. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C.

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{(ESD)} ) Electrostatic discharge</td>
<td>Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)</td>
<td>±1000</td>
</tr>
<tr>
<td></td>
<td>Charged-device model (CDM), per JEDEC specification JESD22-C101(2)</td>
<td>±250</td>
</tr>
</tbody>
</table>

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions. Pins listed as ±2000 V may actually have higher performance.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions. Pins listed as ±750 V may actually have higher performance.

6.3 Recommended Operating Conditions
over operating free-air temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage ((V^+ - V^-))</td>
<td>1.7</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>Specified temperature</td>
<td>-40</td>
<td>125</td>
<td>°C</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>TLV8811 DBV (SOT-23) 5 PINS</th>
<th>TLV8812 DGK (VSSOP) 8 PINS</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \theta_{JA} ) Junction-to-ambient thermal resistance</td>
<td>177.4</td>
<td>177.6</td>
<td>°C/W</td>
</tr>
<tr>
<td>( \theta_{JC\text{top}} ) Junction-to-case (top) thermal resistance</td>
<td>133.9</td>
<td>68.8</td>
<td></td>
</tr>
<tr>
<td>( \theta_{JB} ) Junction-to-board thermal resistance</td>
<td>36.3</td>
<td>98.2</td>
<td></td>
</tr>
<tr>
<td>( \psi_{JT} ) Junction-to-top characterization parameter</td>
<td>23.6</td>
<td>12.3</td>
<td></td>
</tr>
<tr>
<td>( \psi_{JB} ) Junction-to-board characterization parameter</td>
<td>35.7</td>
<td>96.7</td>
<td></td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.
## 6.5 Electrical Characteristics

\( T_A = 25^\circ C, \ V_S = 1.8 \text{ V to 5 V, } V_{CM} = V_{OUT} = V_S/2, \text{ and } R_L \geq 10 \text{ M } \Omega \text{ to } V_S / 2, \text{ unless otherwise noted.} \)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{OS} )</td>
<td>Input offset voltage, TLV8811</td>
<td>( V_S = 1.8 \text{ V and 3.3V, } V_{CM} = V_- )</td>
<td>±75</td>
<td>±550</td>
<td>µV</td>
</tr>
<tr>
<td>( V_{OS} )</td>
<td>Input offset voltage, TLV8812</td>
<td>( V_S = 1.8 \text{ V and 3.3V, } V_{CM} = V_- )</td>
<td>±55</td>
<td>±500</td>
<td>µV</td>
</tr>
<tr>
<td>( \Delta V_{OS}/\Delta T )</td>
<td>Input offset drift</td>
<td>( V_{CM} = V_- )</td>
<td>( T_A = -40^\circ C \text{ to } 125^\circ C )</td>
<td>±1</td>
<td>µV/°C</td>
</tr>
<tr>
<td>PSRR</td>
<td>Power-supply rejection ratio</td>
<td>( V_S = 1.8 \text{ V to 3.3V, } V_{CM} = V_- )</td>
<td>±1.6</td>
<td>±60</td>
<td>µV/V</td>
</tr>
</tbody>
</table>

### INPUT VOLTAGE RANGE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{CM} )</td>
<td>Common-mode voltage range</td>
<td>( V_S = 3.3 \text{ V} )</td>
<td>0</td>
<td>2.4</td>
<td>V</td>
</tr>
<tr>
<td>CMRR</td>
<td>Common-mode rejection ratio, TLV8811</td>
<td>( (V-) \leq V_{CM} \leq (V+) - 0.9 \text{ V, } V_S = 3.3 \text{ V} )</td>
<td>77</td>
<td>95</td>
<td>dB</td>
</tr>
<tr>
<td>CMRR</td>
<td>Common-mode rejection ratio, TLV8812</td>
<td>( (V-) \leq V_{CM} \leq (V+) - 0.9 \text{ V, } V_S = 3.3 \text{ V} )</td>
<td>80</td>
<td>98</td>
<td>dB</td>
</tr>
</tbody>
</table>

### INPUT BIAS CURRENT

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_B )</td>
<td>Input bias current</td>
<td>( V_S = 1.8 \text{ V} )</td>
<td>±100</td>
<td>fA</td>
<td></td>
</tr>
<tr>
<td>( I_{OS} )</td>
<td>Input offset current</td>
<td>( V_S = 1.8 \text{ V} )</td>
<td>±100</td>
<td>fA</td>
<td></td>
</tr>
</tbody>
</table>

### INPUT IMPEDANCE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Differential</td>
<td>7 pF</td>
</tr>
<tr>
<td>Common mode</td>
<td>3 pF</td>
</tr>
</tbody>
</table>

### NOISE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_n )</td>
<td>Input voltage noise</td>
<td>for ( f = 0.1 \text{ Hz to } 10 \text{ Hz} )</td>
<td>8</td>
<td></td>
<td>µVp-p</td>
</tr>
<tr>
<td>( e_n )</td>
<td>Input voltage noise density</td>
<td>for ( f = 100 \text{ Hz} )</td>
<td>360</td>
<td></td>
<td>nV/√Hz</td>
</tr>
<tr>
<td></td>
<td>for ( f = 1 \text{ kHz} )</td>
<td></td>
<td>450</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### OPEN-LOOP GAIN

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_{OL} )</td>
<td>Open-loop voltage gain</td>
<td>( (V-) + 0.3 \text{ V} \leq V_O \leq (V+) - 0.3 \text{ V, } R_L = 100 \text{ k} \Omega )</td>
<td>120</td>
</tr>
</tbody>
</table>

### OUTPUT

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{OH} )</td>
<td>Voltage output swing from positive rail</td>
<td>( V_S = 1.8 \text{ V, } R_L = 100 \text{ k} \Omega \text{ to } V^+/2 )</td>
<td>10</td>
<td>3.5</td>
<td>mV</td>
</tr>
<tr>
<td>( V_{OL} )</td>
<td>Voltage output swing from negative rail</td>
<td>( V_S = 1.8 \text{ V, } R_L = 100 \text{ k} \Omega \text{ to } V^-/2 )</td>
<td>2.5</td>
<td>10</td>
<td>mV</td>
</tr>
<tr>
<td>( I_{SC} )</td>
<td>Short-circuit current</td>
<td>( V_S = 3.3 \text{ V, Short to } V_S/2 )</td>
<td>4.7</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>( Z_O )</td>
<td>Open loop output impedance</td>
<td>( f = 1 \text{ KHz, } I_O = 0 \text{ A} )</td>
<td>90</td>
<td></td>
<td>kΩ</td>
</tr>
</tbody>
</table>

### FREQUENCY RESPONSE

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBP</td>
<td>Gain-bandwidth product</td>
<td>( C_L = 20 \text{ pF, } R_L = 10 \text{ M} \Omega, \ V_S = 5 \text{ V} )</td>
<td>6</td>
</tr>
<tr>
<td>SR</td>
<td>Slew rate (10% to 90%)</td>
<td>( G = 1, \text{ Rising Edge, } C_L = 20 \text{ pF, } V_S = 5 \text{ V} )</td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( G = 1, \text{ Falling Edge, } C_L = 20 \text{ pF, } V_S = 5 \text{ V} )</td>
<td>1.5</td>
</tr>
</tbody>
</table>

### POWER SUPPLY

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_Q )</td>
<td>Quiescent Current, TLV8811</td>
<td>( V_{CM} = V_- \text{, } I_O = 0, \ V_S = 3.3 \text{ V} )</td>
<td>450</td>
<td>750</td>
<td>nA</td>
</tr>
<tr>
<td></td>
<td>Quiescent Current, Per Channel, TLV8812</td>
<td>( V_{CM} = V_- \text{, } I_O = 0, \ V_S = 3.3 \text{ V} )</td>
<td>425</td>
<td>700</td>
<td>nA</td>
</tr>
</tbody>
</table>
6.6 Typical Characteristics

at $T_A = 25^\circ C$, $R_L = 10\,\Omega$ to $V_S/2$, $C_L = 20\,pF$, $V_{CM} = V_S / 2V$ unless otherwise specified.

![Figure 1. Supply Current vs. Supply Voltage, TLV8811](image1.png)

![Figure 2. Supply Current vs. Supply Voltage, TLV8812](image2.png)

![Figure 3. Typical Offset Voltage vs. Common Mode Voltage](image3.png)

![Figure 4. Typical Offset Voltage vs. Common Mode Voltage](image4.png)

![Figure 5. Typical Offset Voltage vs. Common Mode Voltage](image5.png)

![Figure 6. Input Bias Current vs. Temperature](image6.png)
Typical Characteristics (continued)

at $T_A = 25^\circ C$, $R_L = 10\,\Omega$ to $V_S/2$, $C_L = 20\,\text{pF}$, $V_{CM} = V_S/2\,\text{V}$ unless otherwise specified.

Figure 7. Input Bias Current vs. Common Mode Voltage

Figure 8. Input Bias Current vs. Common Mode Voltage

Figure 9. Input Bias Current vs. Common Mode Voltage

Figure 10. Input Bias Current vs. Common Mode Voltage

Figure 11. Input Bias Current vs. Common Mode Voltage

Figure 12. Input Bias Current vs. Common Mode Voltage
Typical Characteristics (continued)

at $T_A = 25^\circ C$, $R_L = 10\,\Omega$ to $V_S/2$, $C_L = 20\,pF$, $V_{CM} = V_S / 2V$ unless otherwise specified.

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>$V_S$</th>
<th>$R_L$</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Output Swing vs. Sourcing Current, 1.8V</td>
<td>1.8V</td>
<td>No Load</td>
</tr>
<tr>
<td>14</td>
<td>Output Swing vs. Sinking Current, 1.8V</td>
<td>1.8V</td>
<td>No Load</td>
</tr>
<tr>
<td>15</td>
<td>Output Swing vs. Sourcing Current, 3.3V</td>
<td>3.3V</td>
<td>No Load</td>
</tr>
<tr>
<td>16</td>
<td>Output Swing vs. Sinking Current, 3.3V</td>
<td>3.3V</td>
<td>No Load</td>
</tr>
<tr>
<td>17</td>
<td>Output Swing vs. Sourcing Current, 5V</td>
<td>5V</td>
<td>No Load</td>
</tr>
<tr>
<td>18</td>
<td>Output Swing vs. Sinking Current, 5V</td>
<td>5V</td>
<td>No Load</td>
</tr>
</tbody>
</table>
Typical Characteristics (continued)

at $T_A = 25^\circ C$, $R_L = 10\, \Omega$ to $V_s/2$, $C_L = 20\, \mu F$, $V_{CM} = V_s / 2V$ unless otherwise specified.

**Figure 19. Small Signal Pulse Response, 1.8V**

$T_A = 25$, $R_L = 10\, \Omega$, $V_{out} = 200\, \text{mVpp}$

$V_s = \pm 0.9\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$

**Figure 20. Small Signal Pulse Response, 5V**

$T_A = 25$, $R_L = 10\, \Omega$, $V_{out} = 200\, \text{mVpp}$

$V_s = \pm 2.5\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$

**Figure 21. Large Signal Pulse Response, 1.8V**

$T_A = 25$, $R_L = 10\, \Omega$, $V_{out} = 1\, \text{Vpp}$

$V_s = \pm 0.9\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$

**Figure 22. Large Signal Pulse Response, 5V**

$T_A = 25$, $R_L = 10\, \Omega$, $V_{out} = 2\, \text{Vpp}$

$V_s = \pm 2.5\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$

**Figure 23. CMRR vs Frequency**

$T_A = 25$, $R_L = 10\, \Omega$, $\Delta V_{CM} = 0.5\, \text{Vpp}$

$V_s = 5\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$

**Figure 24. ±PSRR vs Frequency**

$T_A = 25$, $R_L = 10\, \Omega$, $\Delta V_S = 0.5\, \text{Vpp}$

$V_s = 3.3\, \text{V}$

$C_L = 20\, \mu F$, $A_V = +1$
Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $R_L = 10\, \Omega$ to $V_S/2$, $C_L = 20\, \text{pF}$, $V_{CM} = V_S / 2\, \text{V}$ unless otherwise specified.

Figure 25. Open Loop Gain and Phase, 5V, 10 MΩ Load

Figure 26. Open Loop Gain and Phase, 3.3V, 10 MΩ Load

Figure 27. Open Loop Gain and Phase, 5V, 1 MΩ Load

Figure 28. Open Loop Gain and Phase, 3.3V, 1 MΩ Load

Figure 29. Open Loop Gain and Phase, 5V, 100kΩ Load

Figure 30. Open Loop Gain and Phase, 3.3V, 100kΩ Load
Typical Characteristics (continued)

at \( T_A = 25^\circ \text{C}, R_L = 10\,\text{M}\Omega \) to \( V_S/2, C_L = 20\text{pF}, V_{CM} = V_S/2 \) unless otherwise specified.

---

**Figure 31.** Open Loop Gain and Phase, 1.8V, 10 MΩ Load

**Figure 32.** Open Loop Output Impedance

**Figure 33.** Open Loop Gain and Phase, 1.8V, 1 MΩ Load

**Figure 34.** Input Voltage Noise vs Frequency

**Figure 35.** Open Loop Gain and Phase, 1.8V, 100kΩ Load

**Figure 36.** EMIRR Performance
7 Detailed Description

7.1 Overview
The TLV8811 (single) and TLV8812 (dual) series of nanoPower CMOS operational amplifiers are designed for long-life battery-powered and energy harvested applications. They operate on a single supply with operation as low as 1.7V. The Input Offset is trimmed to less than 500uV and the output is rail-to-rail and swings to within 3.5mV of the supplies with a 100kΩ load. The common-mode range extends to the negative supply making it ideal for single-supply applications. EMI protection has been employed internally to reduce the effects of EMI.

Parameters that vary significantly with operating voltages or temperature are shown in the Typical Characteristics curves.

7.2 Functional Block Diagram

7.3 Feature Description
The amplifier's differential inputs consist of a non-inverting input (+IN) and an inverting input (–IN). The amplifier amplifies only the difference in voltage between the two inputs, which is called the differential input voltage. The output voltage of the op-amp \(V_{\text{OUT}}\) is given by Equation 1:

\[
V_{\text{OUT}} = A_{\text{OL}} (\text{IN}^+ - \text{IN}^-)
\]

where

- \(A_{\text{OL}}\) is the open-loop gain of the amplifier, typically around 120 dB (1,000,000x, or 1,000,000 Volts per microvolt).

7.4 Device Functional Modes

7.4.1 Negative-Rail Sensing Input
The input common-mode voltage range of the TLV881x extends from \((V^-)\) to \((V^+) - 0.9\) V. In this range, low offset can be expected with a minimum of 80dB CMRR. The TLV881x is protected from output "inversions" or "reversals".

7.4.2 Rail to Rail Output Stage
The TLV881x output voltage swings 3.5 mV from rails at 1.8 V supply, which provides the maximum possible dynamic range at the output. This is particularly important when operating on low supply voltages.

The TLV881x Maximum Output Voltage Swing graph defines the maximum swing possible under a particular output load.

7.4.3 Design Optimization for Nanopower Operation
When designing for ultralow power, choose system feedback components carefully. To minimize quiescent current consumption, select large-value feedback resistors. Any large resistors will react with stray capacitance in the circuit and the input capacitance of the operational amplifier. These parasitic RC combinations can affect the stability of the overall system. A feedback capacitor may be required to assure stability and limit overshoot or gain peaking.

When possible, use AC coupling and AC feedback to reduce static current draw through the feedback elements. Use film or ceramic capacitors since large electrolytics may have large static leakage currents in the nanoamps.
Device Functional Modes (continued)

7.4.4 Driving Capacitive Load

The TLV881x is internally compensated for stable unity gain operation, with a 6 kHz typical gain bandwidth. However, the unity gain follower is the most sensitive configuration to capacitive load. The combination of a capacitive load placed directly on the output of an amplifier along with the amplifier’s output impedance creates a phase lag, which reduces the phase margin of the amplifier. If the phase margin is significantly reduced, the response will be under damped which causes peaking in the transfer and, when there is too much peaking, the op amp might start oscillating.

In order to drive heavy (>50pF) capacitive loads, an isolation resistor, $R_{ISO}$, should be used, as shown in Figure 37. By using this isolation resistor, the capacitive load is isolated from the amplifier’s output. The larger the value of $R_{ISO}$, the more stable the amplifier will be. If the value of $R_{ISO}$ is sufficiently large, the feedback loop will be stable, independent of the value of $C_L$. However, larger values of $R_{ISO}$ result in reduced output swing and reduced output current drive. The recommended value for $R_{ISO}$ is 30-50kΩ.

![Figure 37. Resistive Isolation Of Capacitive Load](image-url)
8 Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TLV881x is a ultra-low power operational amplifier that provides 6 kHz bandwidth with only 450nA typical quiescent current, trimmed input offset voltage and precision drift specifications. These rail-to-rail output amplifiers are specifically designed for battery-powered applications. The input common-mode voltage range extends to the negative supply rail and the output swings to within millivolts of the rails, maintaining a wide dynamic range.

8.2 Typical Application: Three Terminal CO Gas Sensor Amplifier

Figure 38. Three Terminal Gas Sensor Amplifier Schematic

8.2.1 Design Requirements

Figure 38 shows a simple micropower potentiostat circuit for use with three terminal unbiased CO sensors, though it is applicable to many other type of three terminal gas sensors or electrochemical cells.

The basic sensor has three electrodes; The Sense or Working Electrode ("WE"), Counter Electrode ("CE") and Reference Electrode ("RE"). A current flows between the CE and WE proportional to the detected concentration. The RE monitors the potential of the internal reference point. For an unbiased sensor, the WE and RE electrodes must be maintained at the same potential by adjusting the bias on CE. Through the Potentiostat circuit formed by U1, the servo feedback action will maintain the RE pin at a potential set by $V_{\text{REF}}$.

R1 is to maintain stability due to the large capacitance of the sensor. C1 and R2 form the Potentiostat integrator and set the feedback time constant.

U2 forms a transimpedance amplifier ("TIA") to convert the resulting sensor current into a proportional voltage. The transimpedance gain, and resulting sensitivity, is set by $R_F$ according to Equation 2.

$$V_{\text{TIA}} = (-I \times R_F) + V_{\text{REF}}$$

(2)

$R_L$ is a load resistor of which the value is normally specified by the sensor manufacturer (typically 10 ohms). The potential at WE is set by the applied $V_{\text{REF}}$. $R_{\text{ISO}}$ provides capacitive isolation and, combined with C2, form the output filter and ADC reservoir capacitor to drive the ADC.
Typical Application: Three Terminal CO Gas Sensor Amplifier (continued)

8.2.2 Detailed Design Procedure

For this example, we will be using a CO sensor with a sensitivity of 69nA/ppm. The supply voltage and maximum ADC input voltage is 2.5V, and the maximum concentration is 300ppm.

First the \( V_{\text{REF}} \) voltage must be determined. This voltage is a compromise between maximum headroom and resolution, as well as allowance for "footroom" for the minimum swing on the CE terminal, since the CE terminal generally goes negative in relation to the RE potential as the concentration (sensor current) increases. Bench measurements found the difference between CE and RE to be 180mV at 300ppm for this particular sensor.

To allow for negative CE swing "footroom" and voltage drop across the 10k resistor, 300mV was chosen for \( V_{\text{REF}} \).

Therefore +300mV will be used as the minimum \( V_{\text{ZERO}} \) to add some headroom.

\[
V_{\text{ZERO}} = V_{\text{REF}} = +300\text{mV}
\]

where
- \( V_{\text{ZERO}} \) is the zero concentration voltage
- \( V_{\text{REF}} \) is the reference voltage (300mV) (3)

Next we calculate the maximum sensor current at highest expected concentration:

\[
I_{\text{SENSMAX}} = I_{\text{PERPPM}} \times \text{ppmMAX} = 69\text{nA} \times 300\text{ppm} = 20.7\mu\text{A}
\]

where
- \( I_{\text{SENSMAX}} \) is the maximum expected sensor current
- \( I_{\text{PERPPM}} \) is the manufacturer specified sensor current in Amps per ppm
- ppmMAX is the maximum required ppm reading (4)

Now find the available output swing range above the reference voltage available for the measurement:

\[
V_{\text{SWING}} = V_{\text{OUTMAX}} - V_{\text{ZERO}} = 2.5\text{V} - 0.3\text{V} = 2.2\text{V}
\]

where
- \( V_{\text{SWING}} \) is the expected change in output voltage
- \( V_{\text{OUTMAX}} \) is the maximum amplifier output swing (usually near \( V^+ \)) (5)

Now we calculate the transimpedance resistor \( \|_F \) value using the maximum swing and the maximum sensor current:

\[
R_F = \frac{V_{\text{SWING}}}{I_{\text{SENSMAX}}} = \frac{2.2\text{V}}{20.7\mu\text{A}} = 106.28 \text{ k}\Omega \text{ (we will use 110 k}\Omega \text{ for a common value)}
\]

(6)
Typical Application: Three Terminal CO Gas Sensor Amplifier (continued)

8.2.3 Application Curve

Figure 39. Monitored Voltages when Exposed to 200ppm CO

Figure 39 shows the resulting circuit voltages when the sensor was exposed to 200ppm step of carbon monoxide gas. $V_C$ is the monitored CE pin voltage and clearly shows the expected CE voltage dropping below the WE voltage, $V_W$, as the concentration increases.

$V_{TIA}$ is the output of the transimpedance amplifier U2. $V_{DIFF}$ is the calculated difference between $V_{REF}$ and $V_{TIA}$, which will be used for the ppm calculation.

Figure 40 shows the calculated sensor current using the formula in Equation 7:

$$I_{SENSOR} = \frac{V_{DIFF}}{R_F} = \frac{1.52V}{110 k\Omega} = 13.8\mu A$$  \hspace{1cm} (7)

Equation 8 shows the resulting conversion of the sensor current into ppm.

$$ppm = \frac{I_{SENSOR}}{I_{PERPPM}} = \frac{13.8\mu A}{69nA} = 200$$ \hspace{1cm} (8)

Total supply current for the amplifier section is less than 700 nA, minus sensor current. Note that the sensor current is sourced from the amplifier output, which in turn comes from the amplifier supply voltage. Therefore, any continuous sensor current must also be included in supply current budget calculations.
8.3 Do's and Don'ts

Do properly bypass the power supplies.

Do add series resistance to the output when driving capacitive loads, particularly cables, Muxes and ADC inputs.

Do add series current limiting resistors and external schottky clamp diodes if input voltage is expected to exceed the supplies. Limit the current to 1mA or less (1KΩ per volt).

9 Power Supply Recommendations

The TLV881x is specified for operation from 1.7 V to 5.5 V (±0.85 V to ±2.75 V) over a –40°C to 125°C temperature range. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in the Typical Characteristics.

<table>
<thead>
<tr>
<th>CAUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltages larger than 6 V can permanently damage the device.</td>
</tr>
</tbody>
</table>

For proper operation, the power supplies must be properly decoupled. For decoupling the supply lines it is suggested that 100 nF capacitors be placed as close as possible to the operational amplifier power supply pins. For single supply, place a capacitor between V+ and V– supply leads. For dual supplies, place one capacitor between V+ and ground, and one capacitor between V– and ground.

Low bandwidth nanopower devices do not have good high frequency (> 1 kHz) AC PSRR rejection against high-frequency switching supplies and other 1 kHz and above noise sources, so extra supply filtering is recommended if kilohertz or above noise is expected on the power supply lines.

10 Layout

10.1 Layout Guidelines

The V+ pin should be bypassed to ground with a low ESR capacitor.

The optimum placement is closest to the V+ and ground pins.

Care should be taken to minimize the loop area formed by the bypass capacitor connection between V+ and ground.

The ground pin should be connected to the PCB ground plane at the pin of the device.

The feedback components should be placed as close to the device as possible to minimize strays.

10.2 Layout Example

![Figure 42. SOT-23 Layout Example (Top View)](image-url)
11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support


11.2 Documentation Support

11.2.1 Related Documentation

For related documentation, see the following:
- AN-1798 Designing with Electro-Chemical Sensors, SNOA514
- AN-1803 Design Considerations for a Transimpedance Amplifier, SNOA515
- AN-1852 Designing With pH Electrodes, SNOA529
- Compensate Transimpedance Amplifiers Intuitively, SBOA055
- Transimpedance Considerations for High-Speed Operational Amplifiers, SBOA112
- Noise Analysis of FET Transimpedance Amplifiers, SBOA060
- Circuit Board Layout Techniques, SLOA089
- Handbook of Operational Amplifier Applications, SBOA092

11.3 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

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<th>PARTS</th>
<th>PRODUCT FOLDER</th>
<th>SAMPLE &amp; BUY</th>
<th>TECHNICAL DOCUMENTS</th>
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<tr>
<td>TLV8811</td>
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</tr>
<tr>
<td>TLV8812</td>
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<td>Click here</td>
</tr>
</tbody>
</table>

11.4 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on Alert me to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.5 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

**TI E2E™ Online Community**  *TI's Engineer-to-Engineer (E2E) Community.* Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support**  *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.6 Trademarks

E2E is a trademark of Texas Instruments.
11.6 Trademarks (continued)
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11.7 Electrostatic Discharge Caution

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

11.8 Glossary

SLYZ022 — Ti Glossary.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
## PACKAGING INFORMATION

<table>
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<tr>
<th>Orderable Device</th>
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<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
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<td>SOT-23</td>
<td>DBV  5</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>SN</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>16EM</td>
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<tr>
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<td>DGK  8</td>
<td>2500</td>
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<td>NIPDAUAG</td>
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<td>TLV8812</td>
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<td>NIPDAUAG</td>
<td>Level-1-260C-UNLIM</td>
<td>-40 to 125</td>
<td>TLV8812</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:
- **ACTIVE**: Product device recommended for new designs.
- **LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
- **NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
- **PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
- **OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
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- **Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) **MSL, Peak Temp.** - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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2. This drawing is subject to change without notice.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.
DGK (S–PDSO–G8)  PLASTIC SMALL–OUTLINE PACKAGE

NOTES:
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D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
E. Falls within JEDEC MO-187 variation AA, except interlead flash.
NOTES:
A. All linear dimensions are in millimeters.
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C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
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