Ground Isolation Amplifier
BA3121F

General Description
BA3121F is a ground isolation amplifier developed for car audio applications. This IC efficiently eliminates problems caused by wiring resistance and removes noise generated by other electrical devices used in automobiles. The external capacitor values required for this IC are so small that it allows for compact and reliable set design.

Features
- Large Capacitors not Required
- High Common-mode Rejection Ratio
- Low Noise
- Low Distortion
- Two Channels

Applications
- Car audio systems

Key Specifications
- Power Supply Voltage Range: 4V to 18V
- Quiescent Current: 9.0mA (Typ)
- High Common-mode Rejection Ratio (1kHz): 57dB (Typ)
- Low Noise: $V_{NO} = 3.5 \mu V_{rms}$(Typ)
- Low Distortion: THD = 0.002% (Typ)
- Operation temperature range: -30°C to +85°C

Package
- SOP8
  - 5.00mm x 6.20mm x 1.71mm

Typical Application Circuit
Block Diagram and Pin Configuration

![Block Diagram](image-url)

**Absolute Maximum Ratings** (Ta = 25°C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limit</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>VCC</td>
<td>18</td>
<td>V</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>Pd</td>
<td>0.45</td>
<td>W</td>
</tr>
<tr>
<td>Operation Temperature</td>
<td>Topr</td>
<td>-30 to +85</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>Tstg</td>
<td>-55 to +125</td>
<td>°C</td>
</tr>
</tbody>
</table>

(Note 1) Reduced by 4.5mW in Ta of 1°C over 25°C.

**Caution:** Operating the IC over the absolute maximum ratings may damage the IC. The damage can either be a short circuit between pins or an open circuit between pins and the internal circuitry. Therefore, it is important to consider circuit protection measures, such as adding a fuse, in case the IC is operated over the absolute maximum ratings.

**Recommended Operating Conditions** (Ta = 25°C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Supply Voltage</td>
<td>VCC</td>
<td>4</td>
<td>12</td>
<td>18</td>
<td>V</td>
</tr>
</tbody>
</table>

**Electrical Characteristics**

(Unless otherwise noted, Ta = 25°C, VCC = 12V, f = 1kHz, Rg = 1.8kΩ)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiescent Current</td>
<td>Iq</td>
<td>5.6</td>
<td>9.0</td>
<td>14.0</td>
<td>mA</td>
<td>VIN = 0Vrms</td>
</tr>
<tr>
<td>Output Noise Voltage</td>
<td>VNO</td>
<td>-</td>
<td>3.5</td>
<td>8.0</td>
<td>μVrms</td>
<td>BPF = 20Hz-20kHz</td>
</tr>
<tr>
<td>Voltage Gain</td>
<td>GV</td>
<td>-1.5</td>
<td>-0.04</td>
<td>+1.5</td>
<td>dB</td>
<td>VOUT = -10dBm, Rg = 0Ω</td>
</tr>
<tr>
<td>Maximum Output Voltage</td>
<td>VDM</td>
<td>1.8</td>
<td>2.0</td>
<td>-</td>
<td>Vrms</td>
<td>THD = 0.1%, VCC = 8V</td>
</tr>
<tr>
<td>Total Harmonic Distortion</td>
<td>THD</td>
<td>-</td>
<td>0.002</td>
<td>0.02</td>
<td>%</td>
<td>VOUT = 0.7Vrms</td>
</tr>
<tr>
<td>Common-mode Rejection Ratio</td>
<td>CMRR</td>
<td>41</td>
<td>57</td>
<td>-</td>
<td>dB</td>
<td>VC = 8V,CMRR = 40dB</td>
</tr>
<tr>
<td>Common-made Voltage</td>
<td>VDM</td>
<td>2.5</td>
<td>3.75</td>
<td>-</td>
<td>Vrms</td>
<td>VIN = -10dBm, VCC = 8V</td>
</tr>
<tr>
<td>Ripple Rejection Ratio</td>
<td>RR</td>
<td>72</td>
<td>80</td>
<td>-</td>
<td>dB</td>
<td>fRR = 100Hz, VRR = -10dBm, Rg = 0Ω</td>
</tr>
<tr>
<td>Channel Separation</td>
<td>CS</td>
<td>-</td>
<td>82</td>
<td>-</td>
<td>dB</td>
<td>VIN = -10dBm, Rg = 1.8kΩ/OPEN</td>
</tr>
<tr>
<td>Slew Rate</td>
<td>SR</td>
<td>-</td>
<td>2.0</td>
<td>-</td>
<td>V/μS</td>
<td></td>
</tr>
<tr>
<td>Input Resistance</td>
<td>RIN</td>
<td>44</td>
<td>55</td>
<td>66</td>
<td>kΩ</td>
<td></td>
</tr>
</tbody>
</table>
Typical Performance Curves

**Figure 1.** Quiescent Current vs Power Supply Voltage

**Figure 2.** Maximum Output Voltage vs Power Supply Voltage

**Figure 3.** Output Noise Voltage vs Power Supply Voltage

**Figure 4.** Voltage Gain vs Power Supply Voltage

- **V_{IN} = 0Vrms**
- **R_g = 1.8kΩ DIN AUDIO**
- **THD=0.1% R_L = 10kΩ f=1kHz**
- **V_{IN} = -10dBm f=1kHz**
Typical Performance Curves – continued

**Figure 5. Voltage Gain vs Frequency**

**Figure 6. Channel Separation vs Frequency**

**Figure 7. Ripple Rejection Ratio vs Frequency**

**Figure 8. Total Harmonic Distortion vs Output Voltage**

Voltage Gain : G (dB)

Channel Separation : CS (dB)

Ripple Rejection Ratio : RR (dB)

Total Harmonic Distortion : THD (%)
Typical Performance Curves – continued

### Total Harmonic Distortion

- **Equation:** \( \text{THD} = \frac{\text{Total Harmonic Distortion}}{\text{Input Signal}} \)
- **Figure 9:** Total Harmonic Distortion vs Frequency

### Common Mode Rejection Ratio

- **Equation:** \( \text{CMRR} = \frac{\text{Common Mode Input}}{\text{Common Mode Output}} \)
- **Figure 10:** Common Mode Rejection Ratio vs Frequency

### Input Noise Voltage

- **Equation:** \( V_{CM} = \sqrt{\text{Vrms}} \)
- **Figure 11:** Common Mode Rejection Ratio vs Input Noise Voltage

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**Conditions:**
- **Input Signal:** \( V_{CC} = 12V \)
- **Output:** \( V_{OUT} = 0.7\,\text{Vrms} \)
- **Load:** \( R_L = 10\,\text{k}\Omega \)
- **CMRR:** \( V_{CC} = 12V \), \( V_N = -20\,\text{dBm} \), \( R_g = 1.8\,\text{k}\Omega \)
- **Input Capacitance:** \( (V_{M1}, V_{M2}) = (100\,\mu\text{F}, 47\,\mu\text{F}) \), \( (V_{M1}, V_{M2}) = (47\,\mu\text{F}, 22\,\mu\text{F}) \), \( (V_{M1}, V_{M2}) = (22\,\mu\text{F}, 10\,\mu\text{F}) \)
Measurement Circuits

Figure 12

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Application Information

1. Circuit Operation

Car audio systems are grounded to the car body. For this reason, electrical noise generated by the car electrical system can enter the power amplifier input through the chassis and become audible. BA3121F utilizes the common-mode rejection characteristics of an operational amplifier to eliminate this noise. Without BA3121F noise enters the power amplifier input directly. With BA3121F, the CMRR of operational amplifiers 1-A and 2-A eliminates the noise.

Principle of noise elimination:

To obtain the output voltage \( (e_o) \)

\[
V_i = \frac{R_4}{(R_1 + R_4)} \cdot e_2 \quad \text{①}
\]

\[
e_o = \frac{R_1}{R_i} \cdot e_1 + \frac{R_1 + R_2}{R_i} \cdot V_i \quad \text{②}
\]

From ① and ②

\[
e_o = -\frac{R_2}{R_i} \cdot e_1 + \frac{R_1 + R_2}{R_i} \cdot \frac{R_4}{(R_2 + R_4)} \cdot e_2
\]

\[
= -\frac{R_2}{R_i} \cdot (e_1 - e_2) + \frac{R_1 + R_2}{R_i} \cdot \frac{R_4}{(R_2 + R_4)} \cdot e_2
\]

With BA3121F, the elimination level of the noise is expressed as:

\[
\text{CMRR} = 20\log \left( \frac{e_o}{e_i} \right) = \log \left( \frac{e_1}{e_2} \right)
\]

Therefore, CMRR ≥ 41dB can be guaranteed.

Ideally, if \( R_1 = R_2R_3 \), and \( e_1 = e_2 \), the noise voltage will be zero. However, due to resistor mismatch, difference in the noise voltages (\( e_1 \) and \( e_2 \)), and tolerances in the operational amplifier, a noise voltage is generated.
Operational Notes

1. **Reverse Connection of Power Supply**
   Connecting the power supply in reverse polarity can damage the IC. Take precautions against reverse polarity when connecting the power supply, such as mounting an external diode between the power supply and the IC's power supply pins.

2. **Power Supply Lines**
   Design the PCB layout pattern to provide low impedance supply lines. Separate the ground and supply lines of the digital and analog blocks to prevent noise in the ground and supply lines of the digital block from affecting the analog block. Furthermore, connect a capacitor to ground at all power supply pins. Consider the effect of temperature and aging on the capacitance value when using electrolytic capacitors.

3. **Ground Voltage**
   Ensure that no pins are at a voltage below that of the ground pin at any time, even during transient condition.

4. **Ground Wiring Pattern**
   When using both small-signal and large-current ground traces, the two ground traces should be routed separately but connected to a single ground at the reference point of the application board to avoid fluctuations in the small-signal ground caused by large currents. Also ensure that the ground traces of external components do not cause variations on the ground voltage. The ground lines must be as short and thick as possible to reduce line impedance.

5. **Thermal Consideration**
   Should by any chance the power dissipation rating be exceeded the rise in temperature of the chip may result in deterioration of the properties of the chip. In case of exceeding this absolute maximum rating, increase the board size and copper area to prevent exceeding the Pd rating.

6. **Recommended Operating Conditions**
   These conditions represent a range within which the expected characteristics of the IC can be approximately obtained. The electrical characteristics are guaranteed under the conditions of each parameter.

7. **Inrush Current**
   When power is first supplied to the IC, it is possible that the internal logic may be unstable and inrush current may flow instantaneously due to the internal powering sequence and delays, especially if the IC has more than one power supply. Therefore, give special consideration to power coupling capacitance, power wiring, width of ground wiring, and routing of connections.

8. **Operation Under Strong Electromagnetic Field**
   Operating the IC in the presence of a strong electromagnetic field may cause the IC to malfunction.

9. **Testing on Application Boards**
   When testing the IC on an application board, connecting a capacitor directly to a low-impedance output pin may subject the IC to stress. Always discharge capacitors completely after each process or step. The IC's power supply should always be turned off completely before connecting or removing it from the test setup during the inspection process. To prevent damage from static discharge, ground the IC during assembly and use similar precautions during transport and storage.

10. **Inter-pin Short and Mounting Errors**
    Ensure that the direction and position are correct when mounting the IC on the PCB. Incorrect mounting may result in damaging the IC. Avoid nearby pins being shorted to each other especially to ground, power supply and output pin. Inter-pin shorts could be due to many reasons such as metal particles, water droplets (in very humid environment) and unintentional solder bridge deposited in between pins during assembly to name a few.

11. **Unused Input Pins**
    Input pins of an IC are often connected to the gate of a MOS transistor. The gate has extremely high impedance and extremely low capacitance. If left unconnected, the electric field from the outside can easily charge it. The small charge acquired in this way is enough to produce a significant effect on the conduction through the transistor and cause unexpected operation of the IC. So unless otherwise specified, unused input pins should be connected to the power supply or ground line.
12. Regarding the Input Pin of the IC

This monolithic IC contains P+ isolation and P substrate layers between adjacent elements in order to keep them isolated. P-N junctions are formed at the intersection of the P layers with the N layers of other elements, creating a parasitic diode or transistor. For example (refer to figure below):

When GND > Pin A and GND > Pin B, the P-N junction operates as a parasitic diode.

When GND > Pin B, the P-N junction operates as a parasitic transistor.

Parasitic diodes inevitably occur in the structure of the IC. The operation of parasitic diodes can result in mutual interference among circuits, operational faults, or physical damage. Therefore, conditions that cause these diodes to operate, such as applying a voltage lower than the GND voltage to an input pin (and thus to the P substrate) should be avoided.

![Figure 15. Example of monolithic IC structure](image)

13. The capacitors of Pin 2 (VM1), and Pin 6 (VM2) should maintain the ratio of 2:1 for ripple rejection characteristics. Maintaining this ratio will prevent the significant decrease on ripple rejection even if the capacitance is reduced to half.

14. Setting the capacitor value to twice or half will make CMRR +6dB or -6dB respectively (Figure 10) in the low frequency range.
Ordering Information

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Packaging and forming specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>B A 3 1 2 1 F</td>
<td>E 2</td>
<td>E2: Embossed tape and reel</td>
</tr>
</tbody>
</table>

Marking Diagram

SOP8 (TOP VIEW)

- Part Number Marking
- LOT Number
- 1PIN MARK
Physical Dimension, Tape and Reel Information

<table>
<thead>
<tr>
<th>Package Name</th>
<th>SOP8</th>
</tr>
</thead>
</table>

**Physical Dimension**

- **Package Name**: SOP8
- **PKG**: SOP8
- **Drawing No.**: EX112-5001-1

**Physical Dimensions (UNIT: mm):**

- Width: 6.2 ± 0.3 mm
- Length: 4.4 ± 0.2 mm
- Height: 0.595 mm

**Tab Height**: 0.42 ± 0.1 mm

**Tape and Reel Information**

<table>
<thead>
<tr>
<th>Tape</th>
<th>Embossed carrier tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>2500pcs</td>
</tr>
</tbody>
</table>

**Direction of feed:**

- The direction is the 1pin of product is at the upper left when you hold reel on the left hand and you pull out the tape on the right hand.
## Revision History

<table>
<thead>
<tr>
<th>Date</th>
<th>Revision</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.Nov.2015</td>
<td>001</td>
<td>New Release</td>
</tr>
</tbody>
</table>
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(Note1) Medical Equipment Classification of the Specific Applications

<table>
<thead>
<tr>
<th>JAPAN</th>
<th>USA</th>
<th>EU</th>
<th>CHINA</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLASS III</td>
<td>CLASS III</td>
<td>CLASS II b</td>
<td>CLASS III</td>
</tr>
</tbody>
</table>

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   [f] Sealing or coating our Products with resin or other coating materials
   [g] Use of our Products without cleaning residue of flux (even if you use no-clean type fluxes, cleaning residue of flux is recommended); or Washing our Products by using water or water-soluble cleaning agents for cleaning residue after soldering
   [h] Use of the Products in places subject to dew condensation

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5. Please verify and confirm characteristics of the final or mounted products in using the Products.

6. In particular, if a transient load (a large amount of load applied in a short period of time, such as pulse, is applied, confirmation of performance characteristics after on-board mounting is strongly recommended. Avoid applying power exceeding normal rated power; exceeding the power rating under steady-state loading condition may negatively affect product performance and reliability.

7. De-rate Power Dissipation depending on ambient temperature. When used in sealed area, confirm that it is the use in the range that does not exceed the maximum junction temperature.

8. Confirm that operation temperature is within the specified range described in the product specification.

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1. When a highly active halogenous (chlorine, bromine, etc.) flux is used, the residue of flux may negatively affect product performance and reliability.

2. In principle, the reflow soldering method must be used on a surface-mount products, the flow soldering method must be used on a through hole mount products. If the flow soldering method is preferred on a surface-mount products, please consult with the ROHM representative in advance.

For details, please refer to ROHM Mounting specification
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1. Product performance and soldered connections may deteriorate if the Products are stored in the places where:
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   [b] the temperature or humidity exceeds those recommended by ROHM
   [c] the Products are exposed to direct sunshine or condensation
   [d] the Products are exposed to high Electrostatic

2. Even under ROHM recommended storage condition, solderability of products out of recommended storage time period may be degraded. It is strongly recommended to confirm solderability before using Products of which storage time is exceeding the recommended storage time period.

3. Store / transport cartons in the correct direction, which is indicated on a carton with a symbol. Otherwise bent leads may occur due to excessive stress applied when dropping of a carton.

4. Use Products within the specified time after opening a humidity barrier bag. Baking is required before using Products of which storage time is exceeding the recommended storage time period.

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