Audio ICs

Pre/power amplifier and motor governor for 3V headphone stereos
BA3528AFP/BA3529AFP

The BA3528AFP and AB3529AFP have been developed for headphone stereos. They run off a 3V power supply, and include dual pre- and power amplifiers, and a motor governor.
The preamplifiers are direct-coupled, and the power amplifiers use a fixed-gain NF circuit. An on-chip Vref amplifier makes output coupling capacitors unnecessary, and the motor governor uses a bridge ratio system to minimize the external parts count and make reliable and compact designs possible.

● Applications
3V portable stereo equipment

● Features
1) All the functions required for headphone stereo units on a single chip.
2) Preamplifier includes a mute amplifier.
3) Direct-coupled preamplifier.
4) No output coupling capacitors required for the power amplifiers.
5) Power amplifiers do not require oscillation prevention measures.
6) Power amplifier gain allows use of noise reduction (BA3529AFP).

● Block diagram

![Block diagram of pre/power amplifier and motor governor](image)
### Absolute maximum ratings (Ta = 25°C)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Limits</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>(V_{cc})</td>
<td>6</td>
<td>V</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>(P_d)</td>
<td>1.7*</td>
<td>W</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>(T_{opr})</td>
<td>-25~75</td>
<td>°C</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>(T_{stg})</td>
<td>-55~150</td>
<td>°C</td>
</tr>
</tbody>
</table>

* Reduced by 13.6mW for each increase in Ta of 1°C over 25°C (when mounted on a 90mm x 50mm x 1.6mm glass epoxy PCB).

### 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>Supply voltage</td>
<td>(V_{cc})</td>
<td>1.8</td>
<td>3.0</td>
<td>6.0</td>
<td>V</td>
</tr>
</tbody>
</table>
### Audio ICs

#### Electrical characteristics (unless otherwise specified Ta = 25°C, Vcc = 3V, and f = 1kHz)

<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 circuit current</td>
<td>Iq</td>
<td>—</td>
<td>11</td>
<td>18</td>
<td>mA</td>
<td>Vcm=0V,vcc</td>
</tr>
<tr>
<td>Channel separation</td>
<td>CS L-R</td>
<td>30</td>
<td>40</td>
<td>—</td>
<td>dB</td>
<td>Rl=2.2kΩ, Rl=32.Ω</td>
</tr>
<tr>
<td>Preampifier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rl=10kΩ</td>
</tr>
<tr>
<td>Open-circuit voltage gain</td>
<td>GVC</td>
<td>72</td>
<td>80</td>
<td>—</td>
<td>dB</td>
<td>Vc=200mVra</td>
</tr>
<tr>
<td>Closed-circuit voltage gain</td>
<td>GVC1</td>
<td>33</td>
<td>36</td>
<td>39</td>
<td>dB</td>
<td>Vc=100mVra</td>
</tr>
<tr>
<td>Maximum output voltage</td>
<td>VOM</td>
<td>350</td>
<td>500</td>
<td>—</td>
<td>mVra</td>
<td>THD=1.5%</td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td>THD1</td>
<td>0.03</td>
<td>0.2</td>
<td>—</td>
<td>%</td>
<td>Vc=200mVra</td>
</tr>
<tr>
<td>Input conversion-noise voltage</td>
<td>Vin</td>
<td>1.0</td>
<td>1.8</td>
<td>1.8</td>
<td>μVrms</td>
<td>Rg=2.2kΩ, BPF=20~20kHz</td>
</tr>
<tr>
<td>Ripple rejection</td>
<td>RR1</td>
<td>43</td>
<td>53</td>
<td>—</td>
<td>dB</td>
<td>fcm=100Hz, Vcm=-20dBm</td>
</tr>
<tr>
<td>Input bias current</td>
<td>Iq</td>
<td>—</td>
<td>355</td>
<td>650</td>
<td>nA</td>
<td>Vcm=0V,vcc</td>
</tr>
<tr>
<td>Mute level</td>
<td>MUTE</td>
<td>—</td>
<td>80</td>
<td>—</td>
<td>dB</td>
<td></td>
</tr>
<tr>
<td>Power amplifier</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rl=32Ω (excluding Poul)</td>
</tr>
<tr>
<td>Rated output 1</td>
<td>POUT1</td>
<td>25</td>
<td>34</td>
<td>—</td>
<td>mWch</td>
<td>Rl=16Ω, THD=10.5%</td>
</tr>
<tr>
<td>Rated output 2</td>
<td>POUT2</td>
<td>14.5</td>
<td>20</td>
<td>—</td>
<td>mWch</td>
<td>Rl=32Ω, THD=10%</td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td>THD2</td>
<td>0.2</td>
<td>1.0</td>
<td>—</td>
<td>%</td>
<td>P0=1mW</td>
</tr>
<tr>
<td>Output noise voltage</td>
<td>VNO</td>
<td>65</td>
<td>100</td>
<td>100</td>
<td>μVrms</td>
<td>BPF=20~20kHz</td>
</tr>
<tr>
<td>Ripple rejection</td>
<td>RR2</td>
<td>53</td>
<td>61</td>
<td>—</td>
<td>dB</td>
<td>fcm=100Hz, Vcm=-20dBm</td>
</tr>
<tr>
<td>Closed-circuit voltage gain</td>
<td>GVC2</td>
<td>33</td>
<td>36</td>
<td>36</td>
<td>dB</td>
<td>Vc=300mVra</td>
</tr>
<tr>
<td>Input resistance</td>
<td>Rin</td>
<td>13</td>
<td>18</td>
<td>23</td>
<td>kΩ</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 13**

### Motor controller

<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 circuit current</td>
<td>Iq</td>
<td>—</td>
<td>2</td>
<td>3.5</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>Reference voltage</td>
<td>Vmra</td>
<td>1.15</td>
<td>1.23</td>
<td>1.31</td>
<td>V</td>
<td>Voltage between pins 4 and 5 (Rl=±20kΩ)</td>
</tr>
<tr>
<td>Saturation voltage</td>
<td>Vsat</td>
<td>—</td>
<td>0.2</td>
<td>0.9</td>
<td>V</td>
<td>Vcc=1.8V, Rl=4.7Ω</td>
</tr>
<tr>
<td>Voltage characteristic 1</td>
<td>(\Delta V_{CE} / V_{cm} )</td>
<td>1.25</td>
<td>0.1</td>
<td>1.25</td>
<td>%/V</td>
<td>Vcm=1.8V~6V</td>
</tr>
<tr>
<td>Voltage characteristic 2</td>
<td>(\Delta V_{BE} / V_{cm} )</td>
<td>1.2</td>
<td>0.1</td>
<td>1.2</td>
<td>%/V</td>
<td>Vcm=1.8V~6V</td>
</tr>
<tr>
<td>Current characteristic</td>
<td>(\Delta I_{q} / V_{cm} )</td>
<td>0.2</td>
<td>0.01</td>
<td>0.2</td>
<td>%/A</td>
<td>Iq=1mA~20mA</td>
</tr>
<tr>
<td>Temperature characteristic</td>
<td>(\Delta V_{BE} / Ta )</td>
<td>0.01</td>
<td>—</td>
<td>—</td>
<td>%/C</td>
<td>Ta=-25~75°C</td>
</tr>
</tbody>
</table>

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Rohm
### Electrical characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
<th>Conditions</th>
<th>Measurement Circuit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quiescent circuit current</td>
<td>Iq</td>
<td>10</td>
<td>11</td>
<td>18</td>
<td>mA</td>
<td>$V_{in}=0$V</td>
<td></td>
</tr>
<tr>
<td>Channel separation</td>
<td>CS L-R</td>
<td>35</td>
<td>45</td>
<td>-</td>
<td>dB</td>
<td>$R_L=2.2$Ω, $R_L=32$Ω</td>
<td></td>
</tr>
<tr>
<td>Preamp</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$R_{L}=10$Ω</td>
<td></td>
</tr>
<tr>
<td>Open-circuit voltage gain</td>
<td>$G_{ov}$</td>
<td>72</td>
<td>80</td>
<td>-</td>
<td>dB</td>
<td>$V_o=200$mV</td>
<td></td>
</tr>
<tr>
<td>Closed-circuit voltage gain</td>
<td>$G_{vc}$</td>
<td>33</td>
<td>36</td>
<td>39</td>
<td>dB</td>
<td>$V_o=100$mV</td>
<td></td>
</tr>
<tr>
<td>Maximum output voltage</td>
<td>$V_{om}$</td>
<td>350</td>
<td>500</td>
<td>-</td>
<td>mV/m</td>
<td>$THD=1.5%$</td>
<td></td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td>THD1</td>
<td>-</td>
<td>0.03</td>
<td>0.2</td>
<td>1.5%</td>
<td>$V_o=200$mV</td>
<td></td>
</tr>
<tr>
<td>Input conversion-noise voltage</td>
<td>$V_{in}$</td>
<td>1.0</td>
<td>1.8</td>
<td>1.8</td>
<td>μV/m</td>
<td>$R_g=2.2$Ω, BPF=20~20kHz</td>
<td></td>
</tr>
<tr>
<td>Ripple rejection</td>
<td>RR1</td>
<td>43</td>
<td>53</td>
<td>-</td>
<td>dB</td>
<td>$f_m=100$Hz, $V_{in}=-20$dBm</td>
<td></td>
</tr>
<tr>
<td>Input bias current</td>
<td>$i_e$</td>
<td>-</td>
<td>355</td>
<td>850</td>
<td>nA</td>
<td>$V_{in}=0$mV</td>
<td></td>
</tr>
<tr>
<td>Mute level</td>
<td>MUTE</td>
<td>-</td>
<td>80</td>
<td>-</td>
<td>dB</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Power amplifier                |        |      |      |      |      | $R_{L}=32$Ω (excluding Pown)       |                     |
| Rated output 1                 | Pown   | 25   | 34   | -    | mW/m | $R_{L}=16$Ω, THD=10%               |                     |
| Rated output 2                 | Poutn  | 14.5 | 20   | -    | mW/m | $R_{L}=32$Ω, THD=10%               |                     |
| Total harmonic distortion      | THD 2  | -    | 0.1  | 0.9  | 1.5% | $P_o=1$mW                         |                     |
| Output noise voltage           | $V_{no}$ | -    | 25   | 50   | μV/m | $BPF=20$~$20$kHz                   |                     |
| Ripple rejection               | RR2    | 51   | 69   | -    | dB   | $f_m=100$Hz, $V_{in}=-20$dBm       |                     |
| Closed-circuit voltage gain    | $G_{vc}$ | 27   | 29   | -    | dB   | $V_o=300$V                       |                     |
| Input resistance               | $R_{in}$ | 13   | 18   | 23   | kΩ   |                                        |                     |

| Motor controller               |        |      |      |      |      |                                       |                     |
| Quiescent circuit current      | $i_d$  | -    | 2    | 3.5  | mA   |                                       |                     |
| Reference voltage              | $V_{ref}$ | 1.16 | 1.23 | 1.31 | V    | Voltage between pins 4 and 5 ($R_{load}=25$Ω) |                     |
| Saturation voltage             | $V_{sat}$ | -    | 0.2  | 0.6  | V    | $V_{CC}=1.8$V, $R_{L}=4.7$Ω         |                     |
| Voltage characteristic 1      | $\frac{\Delta V_{in}}{V_{ref}}$ | -1.25 | 0.1  | 1.25 | %/V | $V_{CC}=1.8$V~$6$V                   |                     |
| Voltage characteristic 2      | $\frac{\Delta V_{in}}{V_{sat}}$ | -1.2  | 0.1  | 1.2  | %/V | $V_{CC}=1.8$V~$6$V                   |                     |
| Current characteristic        | $\frac{\Delta I_{in}}{V_{ref}}$ | -0.2  | 0.2  | 0.2  | %/A | $I_{L}=1mA$~$20mA$                  |                     |
| Temperature characteristic    | $\frac{\Delta T_{a}}{V_{ref}}$ | -0.01 | -    | -    | %/°C | $T_{a}=-25$~$75$°C                  |                     |

Fig.13

*Low-frequency distortion."*
• Electrical characteristic curves

Fig. 1 Power dissipation vs. ambient temperature

Fig. 2 Maximum power dissipation vs. supply voltage

Fig. 3 Quiescent current vs. supply voltage

Fig. 4 Ripple rejection vs. supply voltage

Fig. 5 Maximum output voltage vs. supply voltage

Fig. 6 Total harmonic distortion vs. output voltage

Fig. 7 Voltage gain vs. frequency

Fig. 8 Rated output power vs. supply voltage

Fig. 9 Output noise voltage vs. supply voltage
Electrical characteristic curves

**Fig. 10** Total harmonic distortion vs. output voltage

**Fig. 11** Regulator voltage vs. ambient temperature

**Fig. 12** Rotation speed and motor current vs. torque

Low-frequency amplifiers

Pre-power governors for headphone drivers
(1) Preamplifier
In the preamplifier input stage the pin 22 bias is the input and the negative feedback virtual earth, and the bias for the input stage transistor is taken from pin 22 via the tape head to allow direct coupling. Connect a 1000pF capacitor in parallel with the tape head to prevent high-frequency interference (see Fig. 14).

(2) Mute amplifier
Preamplifier output muting can be switched on and off.
The mute is off when the mute switch input (pin 1) is low or open, and on when the mute switch input is high (tied to Vcc via a resistor), see Fig. 15.

(3) Equalizer
The preamplifier is based on an NAB120 μS NF-type equalizer. It is possible to add a switching function for the equalizer using the mute amplifier. Switching of the equalizer constant is controlled by the voltage on pin 1 (low or high). Note, however, when this is done, preamplifier muting no longer operates (see Fig. 16).

(4) Power amplifier
The power amplifier employs an NF circuit with fixed gain. Gvc = 36dB (BA3528AFP) and Gvc = 27dB (BA3529AFP).

For the input stage, the pin 22 bias point is the input and the negative feedback virtual earth point, and the first stage transistor bias is taken from pin 22. The built-in Vær amplifier uses the same bias point as its input, and its output voltage is about the same as DC output voltage from the power amplifier. This becomes the virtual earth for the headphones (see Fig. 17).
(5) Motor controller circuit
The motor controller circuit uses a resistance bridge to maintain uniform motor speed regardless of changes in supply voltage, ambient temperature and load torque. Speed control is performed by a comparator and a stable on-chip reference voltage (Vref = 1.23V). See Fig. 18.

![Fig. 18](image)

● Application notes
(1) Application circuits
Provided the recommended circuit constants are used, the application circuits should function correctly. However, we recommend that you confirm the characteristics of the circuits in actual use. If you change the circuit constants, check both the static and transient characteristics of the circuit, and allow sufficient margin to accommodate variations between both ICs and external components.

(2) Recommended supply voltage
The values given in the electrical characteristics table are guaranteed only for Ta = 25°C, and Vcc = 3V. However, as long as the IC is operated within the recommended operating temperature and supply voltage ranges, the general circuit functions are guaranteed to operate correctly, and there will not be significant changes in the electrical characteristics.

(3) Power dissipation
The internal power dissipation of the IC depends strongly on the value of the load resistance and the supply voltage. For this reason, when designing sets for mass production, pay due consideration to the power dissipation characteristics of the IC with respect to ambient temperature and supply voltage (see Figs. 1 and 2). Note, that the maximum allowed power dissipation is 1.7W at 25°C, and this decreases by 13.6mW for each increase in temperature of 1°C over this.

(4) PCB layout
In certain cases, the external circuit wiring can induce oscillations in the IC or degrade circuit performance. To avoid this, design the PCB wiring in such a way as to keep external wiring as short as possible, and ensure that it does not have common impedance.
Fig. 19 Application example circuit diagram (headphone stereo with pre-mute).

Notes:
1. For Dolby use (BA3528AFP only).
2. Coupling capacitors not required.
Fig. 20 Application example circuit diagram (headphone stereo metal/normal switch).

Units:
- Resistors: Ω (ΩΩ)
- Capacitors: F (μF)
- Capacitors (electrolytic): F (μF)

Note 1:
For Delay use (BA3529AFP only).
Note 2:
Coupling capacitors not required.
Audio ICs

BA3528AFP/BA3529AFP

● External components

1. Preamplifier
   If the closed-loop voltage gain (GVC) of the preamplifier is below 30 dB for a frequency of f = 1 kHz, oscillation may occur.

2. Playback equalizer terminal (NAB)
   The playback equalizer characteristics are determined by the RC circuit connected between the output and NF pins.
   For the circuit in Fig. 21, with a closed-loop voltage gain of GVC at an input frequency of 1 kHz, the relationships between the values of the RC circuit components are as follows:

\[ C_i = \frac{3180 \times 10^{-6}}{R_i + 200 \times 10^3} \]

\[ R_2 = 2 \times R_i \times 10^{-6} \text{GVC} / 20 \]

![Fig. 21](image)

The equalizer can be switched on and off using the mute amplifier. If equalization for metal tape is added, determine \( R_2 \) as follows:

\[ R_2 = 1.4 \times R_i \]

3. Pre-mute switching noise
   If you use the mute amplifier for pre-muting,

![Fig. 22](image)

the voltage difference between the pre-output and pin 22 will generate switching noise (a "pop" sound) when the mute is switched on and off. To reduce the DC gain and reduce this switching noise, we recommend that you connect a resistor (\( R = 51 \, \text{k} \Omega \)) as shown in Fig. 22. This resistor reduces the gain of the circuit in the bass region of the playback equalizer as shown in the graph in Fig. 23. By using different combinations of component values for \( R \) and \( C_i \), it is possible to compensate for this effect in the low-frequency region as shown in the graph in Fig. 24.

![Fig. 23](image)

![Fig. 24](image)
(4) Mute amplifier output
To switch the mute amplifier on and off, switch
the constant-current supply for the mute amplifier
off and on by switching the voltage on pin 1 (Pre-
mute SW) high or low. When the mute is switched
on, the mute amplifier output goes open circuit
and the output voltage is unstable resulting in the
generation of an audible "pop" sound. To prevent
this, bias pin 22 through the volume control as
shown in Fig. 25.
In applications that use a directly connected out-
put coupling capacitor, connect a resistor as
shown in the circuit diagram in Fig. 26 to reduce
the pre-mute switching noise described in (3)
above.

(5) Preventing oscillation
Connect a capacitor of approximately 1000pF be-
tween the preamplifier input and pin 22 to prevent
oscillation, and as a countermeasure against
strong electric fields. This capacitor can also be
used for treble-region compensation. In this case,
deck on a value for it based on the relationship
with the impedance of the magnetic head (see
Fig. 27).

When countermeasures against strong electric
fields for the power amplifiers are required, con-
nect bypass capacitors between each input pin
and pin 22, and connect choke coils in series
with the output pins and the headphones. The
component values should be about 330pF for the
bypass capacitors, and the 10 μH for the choke
coils so that they do not effect the audible fre-
quency range.
Another effective measure is to connect a bypass
capacitor of about 1000pF in parallel with the fil-
ter capacitor between pin 22 and ground (pin 21).
Refer to the circuit diagram in Fig. 28.

Fig. 25

Fig. 26

Fig. 27

Fig. 28
(6) Motor speed setting

To control the motor speed, the stable built-in reference voltage $V_{ref}$ is divided across $R_x$ and $R_y$, and this voltage is used as the speed control voltage. The balance conditions for the bridge circuit are as follows:

$$E_a = \left( R_1 \times \frac{R_x}{R_y} \right) I_a$$

$$+ \left( 1 + \frac{R_a}{R_y} \right) \left( \frac{R_x}{R_y + R_x} \right) V_{ref}$$

(However, $I_r << I_a$)

From this, the balance conditions for the load fluctuation zero are:

$$R_a = 10 \times R_x$$

$$E_a = 11 \times \frac{R_x}{R_y + R_x} \times V_{ref}$$

However, if $R_x < 10 \times R_x$, the amount of positive feedback increases, and the circuit will be unstable, so within the operating temperature range, always make

$$R_x \geq 10 \times R_x$$  (see Fig. 29).

---

Fig. 29
Audio ICs

PCB layout for application example circuit

PCB thickness: 1.5mm
Copper thickness: 35 μm
Copper side

Silk side

PCB layout for application example circuit (component side)

External dimensions (Unit: mm)

HSOP28

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