



## COMPLETE AUDIO AMPLIFIER with Volume, Balance, and Treble Controls

By John Austin

Burr-Brown is known as an industry leader of high-precision, audio quality op amps. These ICs can be used in a variety of audio applications. This Application Bulletin will discuss a basic audio amplifier circuit, as shown in Figure 1, utilizing some of Burr-Brown's op amps from Texas Instruments for both pre-amp and power-amp stages.

Figure 1 shows a basic audio-amplifier circuit implementing volume, balance, treble, and bass controls. This circuit utilizes the OPA134 for the pre-amp, and the OPA548 for the power amp. The circuit can produce up to 35W of power across a 4Ω load while operating from dual ±18V supplies.

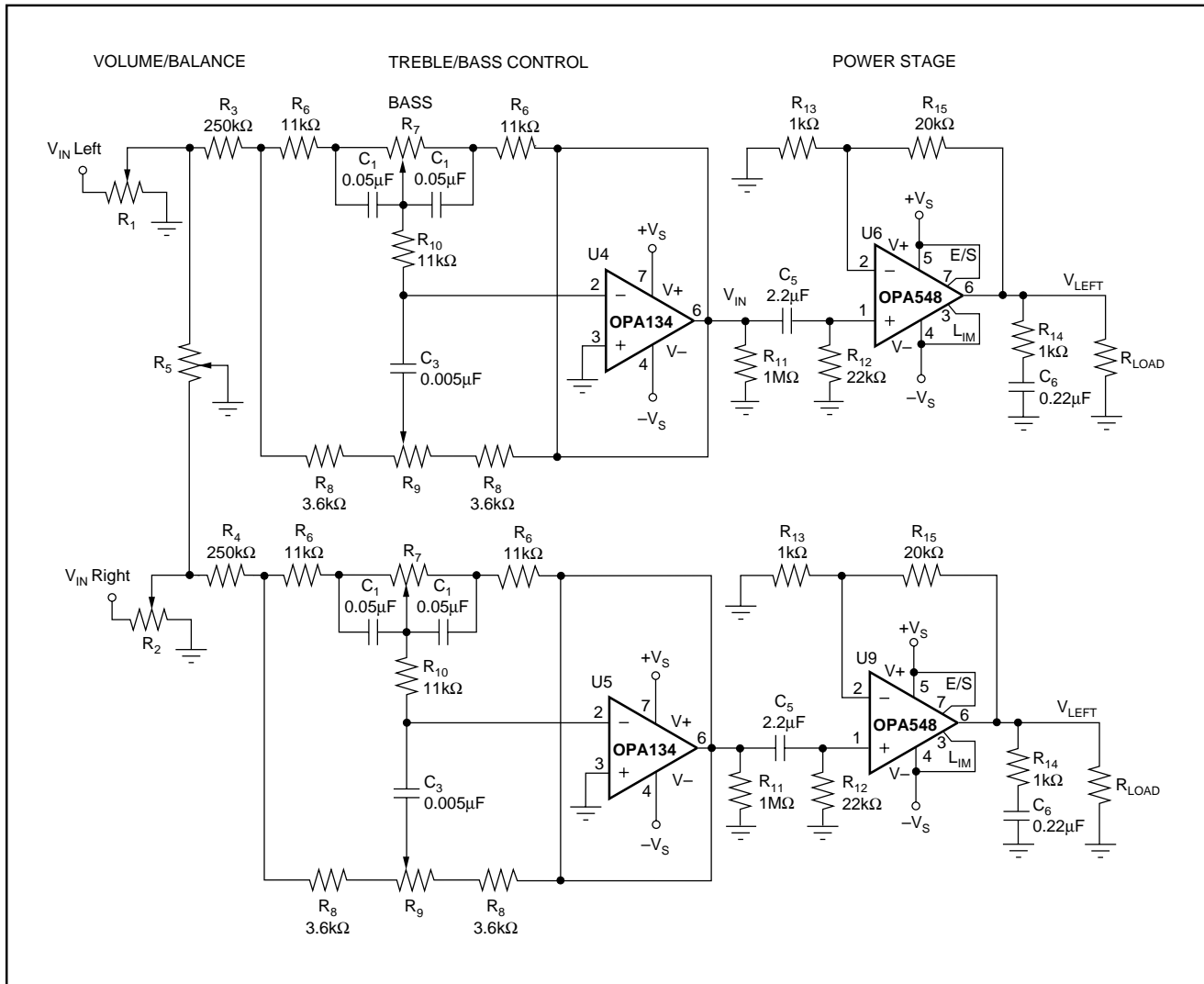


FIGURE 1. Audio Amplifier with Volume, Balance, Bass, and Treble Controls.



The balance and volume controls shown in Figure 2 implement a simple resistor network.

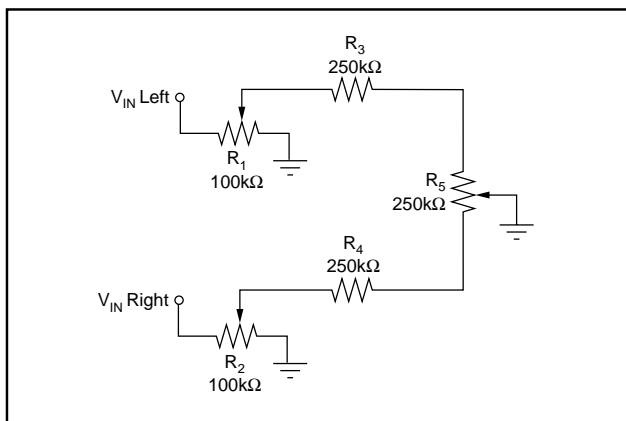


FIGURE 2. Volume and Balance Control Circuit.

Dual potentiometers are used in order to simultaneously increase or decrease the voltages across  $R_1$  and  $R_2$ . This allows for control of the volume.  $R_5$  controls the balance by providing a voltage divider.  $R_3$  and  $R_4$  provide a current limit. Choosing  $R_3 = R_4 = R_5$  allows for the potentiometer to maintain the best linearity, but causes the maximum voltage on either channel to be half of the input voltage.

Shown in Figure 3 is the pre-amplifier circuit, which implements bass and treble controls. This circuit can be easily understood by looking at the basic characteristics of a capacitor. At low frequencies, the capacitors are seen as very high impedance and can be considered open circuits. At high frequencies, the capacitors are seen as very low impedance and can be considered short circuits.

Potentiometer  $R_7$  controls the gain for the low-frequency signals, being equal to Equation 1:

$$A_{VB} = 1 + \frac{R_7}{R_6}, \text{ assumes } R_7 \gg R_6 \quad (1)$$

Potentiometer  $R_9$  provides gain for the high-frequency signals providing the treble control, being equal to Equation 2:

$$A_{VT} = 1 + \frac{R_6 + 2R_{10}}{R_8}, \text{ assumes } R_9 \gg R_6 + R_8 + 2R_{10} \quad (2)$$

Equation 2 is best understood by recognizing that the bass circuit forms a wye-connected load across the treble circuit. The effective loading is  $(R_1 + 2R_5)$  which is in parallel with  $(R_3 + R_4)$ . The constraint on  $R_9$  is:

$$R_9 = 10(R_6 + R_8 + 2R_{10})$$

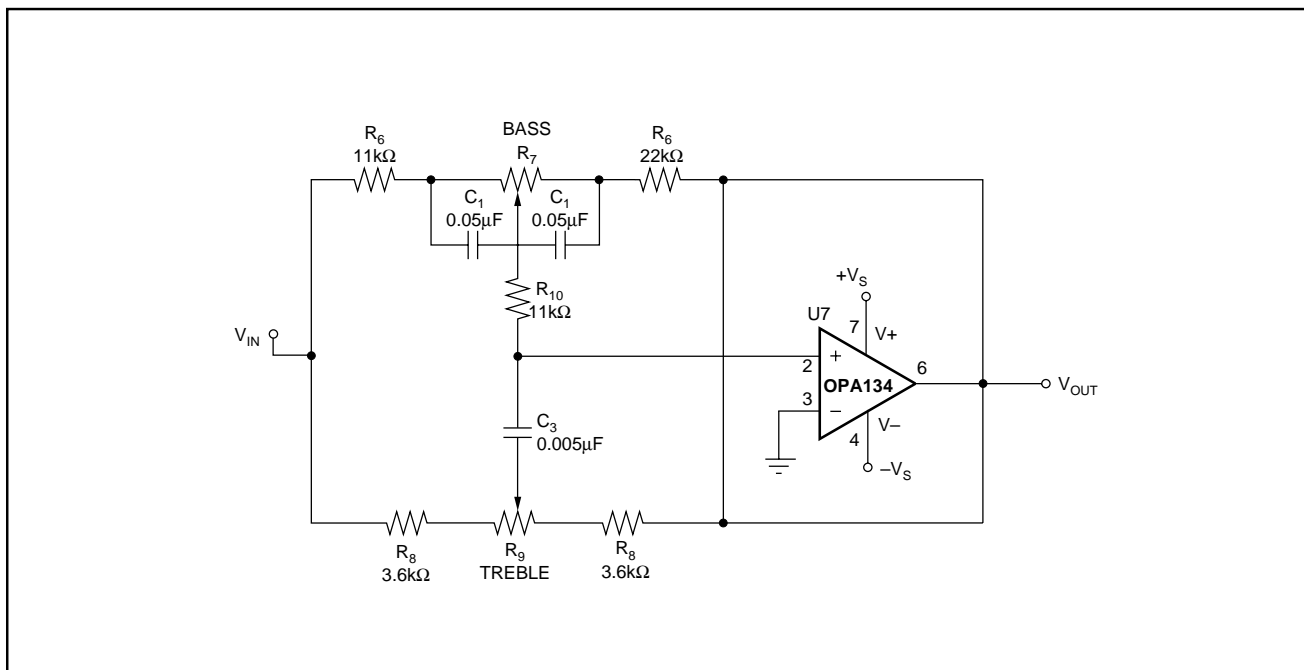


FIGURE 3. Treble and Bass Control.

The variables  $f_L$ ,  $f_{LB}$ ,  $f_H$ , and  $f_{HB}$  are defined by the 3dB corner frequencies of the gain versus frequency plot shown in Figure 4, and are expressed as Equations 3 through 6.

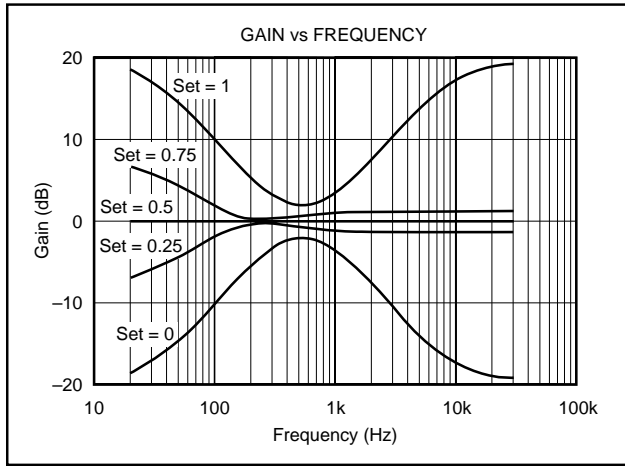


FIGURE 4. SPICE Simulation of “Closed-Loop Gain vs Frequency”. The various curves represent the “set” value of potentiometer  $R_2$  and  $R_4$ .

$$f_L = \frac{1}{2\pi \cdot R_7 \cdot C_1} \quad (3)$$

$$f_{LB} = \frac{1}{2\pi \cdot R_9 \cdot C_1} \quad (4)$$

$$f_H = \frac{1}{2\pi \cdot R_8 \cdot C_3} \quad (5)$$

$$f_{HB} = \frac{1}{2\pi \cdot (R_6 + R_8 + 2R_{10}) \cdot C_3} \quad (6)$$

The component values of Figure 3 correspond to a  $\pm 20$ dB gain with a low-frequency upper 3dB corner at 30Hz, and a high-frequency upper 3dB corner at 10kHz. Knowing the

maximum gain ( $A_{VB} = 10(20\text{dB})$ ) and selecting  $R_{10}$  to be 100k $\Omega$  (linear), the value of  $R_9$  can be determined using Equation 1.

$$R_9 = \frac{R_{10}}{10 - 1} = \frac{100\text{k}\Omega}{9} = 1.11 \cdot 10^4$$

$$R_9 = 11\text{k}\Omega$$

$$R_8 = \frac{R_6 + 2R_{10}}{10 - 1} = \frac{11\text{k}\Omega + 2(11\text{k}\Omega)}{9} = 3.67 \cdot 10^3$$

$$(R_{10} = R_6 = 11\text{k}\Omega, \text{arbitrary choice})$$

$$R_8 = 3.6\text{k}\Omega$$

For a gain of 20dB,  $f_L$  and  $f_{LB}$  (or  $f_H$  and  $f_{HB}$ ) are 14dB apart in magnitude, and the slope response is 4dB/octave, therefore, it is possible to relate the two, as shown in Equation 7.

$$\frac{f_{LB}}{f_L} = \frac{f_{LB}}{f_L} \approx 10 \quad (7)$$

The capacitor values,  $C_1$  and  $C_3$ , can be calculated for a low-frequency upper 3dB corner at 30Hz and a high-frequency upper 3dB corner at 10kHz using Equations 4, 5 and 7.

$$C_1 = \frac{1}{2\pi \cdot R_6 \cdot f_{LB}} = \frac{1}{(2\pi)(11\text{k}\Omega)(300)} = 4.82 \cdot 10^{-8}$$

$$C_1 = 0.05\mu\text{F}$$

$$C_3 = \frac{1}{2\pi \cdot R_8 \cdot f_H} = \frac{1}{(2\pi)(3.6\text{k}\Omega)(10\text{kHz})} = 4.42 \cdot 10^{-9}$$

$$C_3 = 0.005\mu\text{F}$$

The value of potentiometer  $R_9$  was chosen using the constraint mentioned previously:

$$R_9 = 10(R_6 + R_8 + 2R_{10}) = 3.66 \cdot 10^5\Omega$$

Texas Instruments has many Burr-Brown op amps that could be used in place of the OPA2134. These op amps are listed in the chart of Table I, along with their major audio specifications.

| PRODUCT | V <sub>S</sub> (V) | THD+N (% at 1kHz) | S <sub>R</sub> (V/μs) | I <sub>Q</sub> (mA) |
|---------|--------------------|-------------------|-----------------------|---------------------|
| OPA2604 | ±4.5 to ±24        | 0.0003            | 25                    | 5.3                 |
| OPA2132 | ±2.5 to ±18        | 0.00008           | 20                    | 4                   |
| OPA2134 | ±2.5 to ±18        | 0.00008           | 20                    | 4                   |
| OPA627  | ±4.5 to ±18        | 0.00003           | 55                    | 7                   |

TABLE I. Suitable Op Amps for Pre-Amp Applications.

The final stage implements the OPA548 for the power amplifier. This circuit is shown in Figure 5.

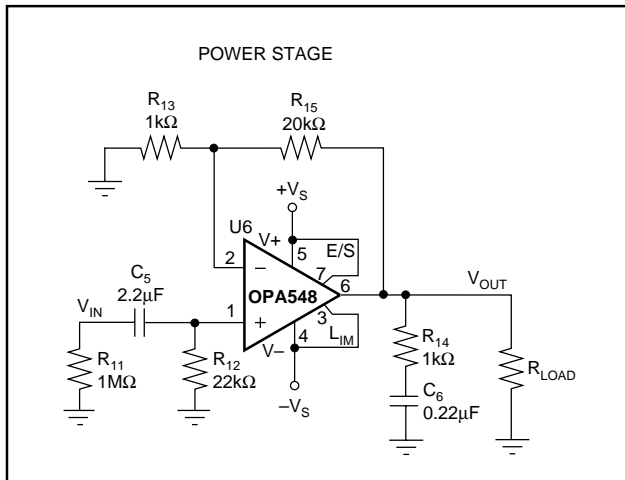


FIGURE 5. Power Amplifier Circuit.

The power amplifier is configured for a non-inverting gain and follows Equation 8:

$$A_{VP} = (1 + R_{15}/R_{13}) \quad (8)$$

The OPA548 can operate from supply voltages of ±10V to ±40V. It has the ability to provide currents of 3A of continuous and 5A peak. Specifications for the OPA548 and other op amps that could be used as audio power amplifiers are listed in Table II.

| PRODUCT | V <sub>S</sub> (V) | THD+N (% AT 1kHz)     | SR (V/μs) | I <sub>OUT</sub> (A) |
|---------|--------------------|-----------------------|-----------|----------------------|
| OPA549  | ±4 to ±30          | 0.01 <sup>(1)</sup>   | 9         | 8                    |
| OPA541  | ±10 to ±40         | 0.06 <sup>(2)</sup>   | 10        | 5                    |
| OPA548  | ±4 to ±30          | 0.0015 <sup>(2)</sup> | 10        | 3                    |
| OPA544  | ±10 to ±35         | 0.03 <sup>(2)</sup>   | 8         | 2                    |
| OPA547  | ±4 to ±30          | 0.0015 <sup>(3)</sup> | 6         | 0.5                  |

NOTES: (1) Specified for a power output of 75W (min). (2) Specified for a power output of 30W (min). (3) Specified for a power output of 6W (min). (4) I<sub>OUT</sub> is specified for the minimum continuous rating.

TABLE II. Power Amplifier Selection Table. T<sub>C</sub> = 25°C, V<sub>S</sub> = ±35V for OPA541 and OPA544, V<sub>S</sub> = ±30V for OPA547, OPA548, and OPA549.

This is a relatively simple amplifier design that could be used in a variety of applications. This circuit can provide up to 35W of power across a 4Ω load as long as the power-supply is capable of supplying the required current.

## **IMPORTANT NOTICE**

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.