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.

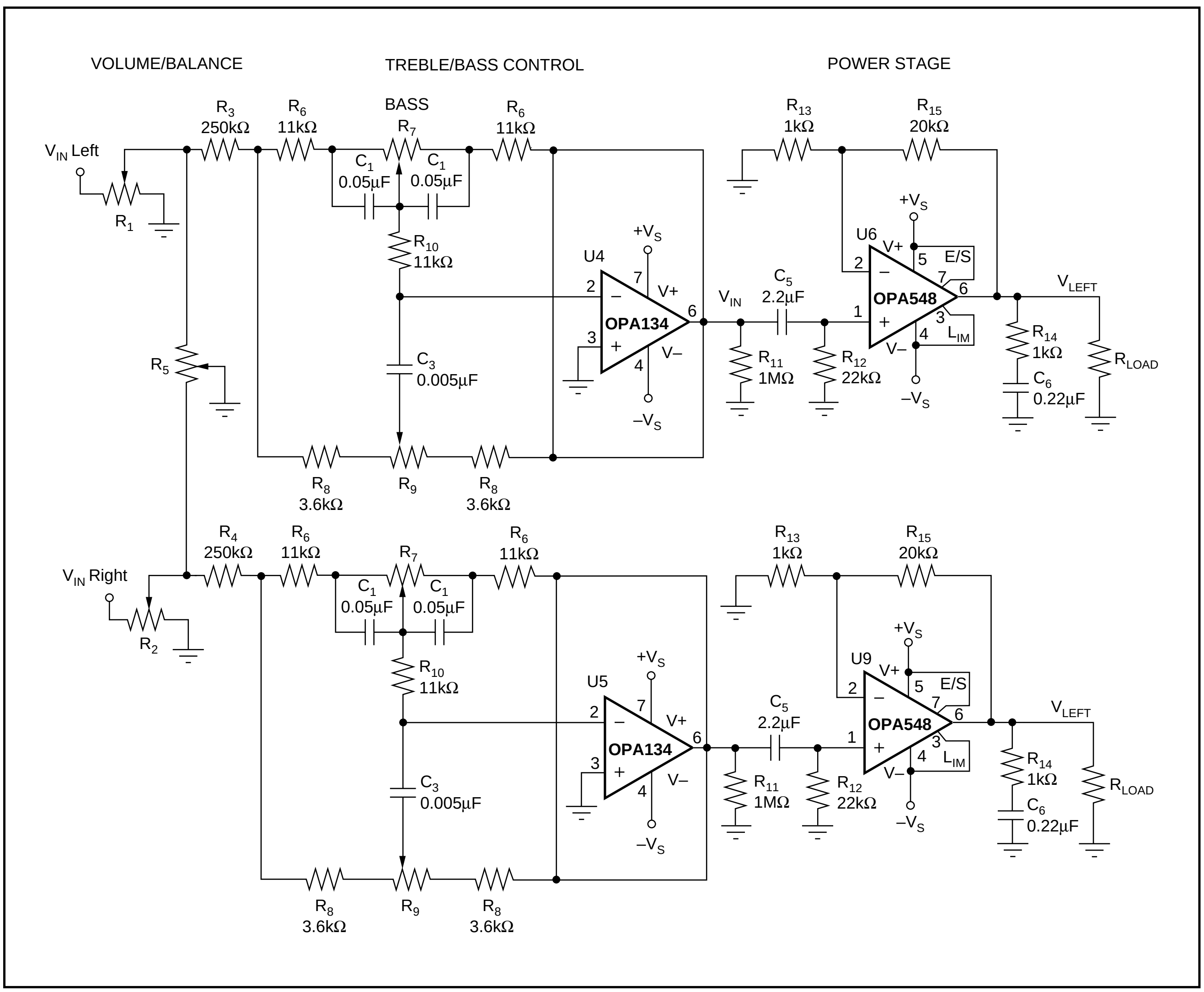

FIGURE 1. Audio Amplifier with Volume, Balance, Bass, and Treble Controls.

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

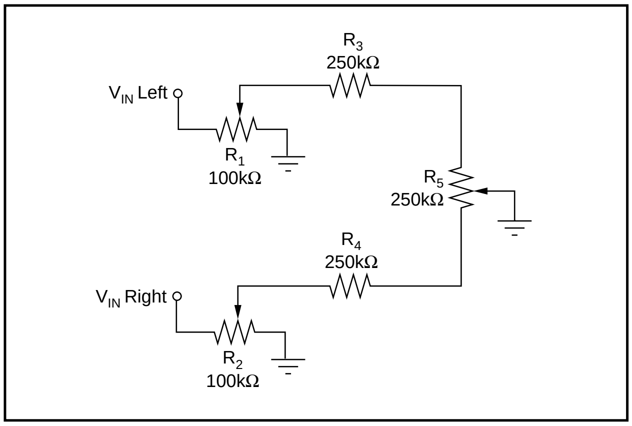

FIGURE 2. Volume and Balance Control Circuit.

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:

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

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

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

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:

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

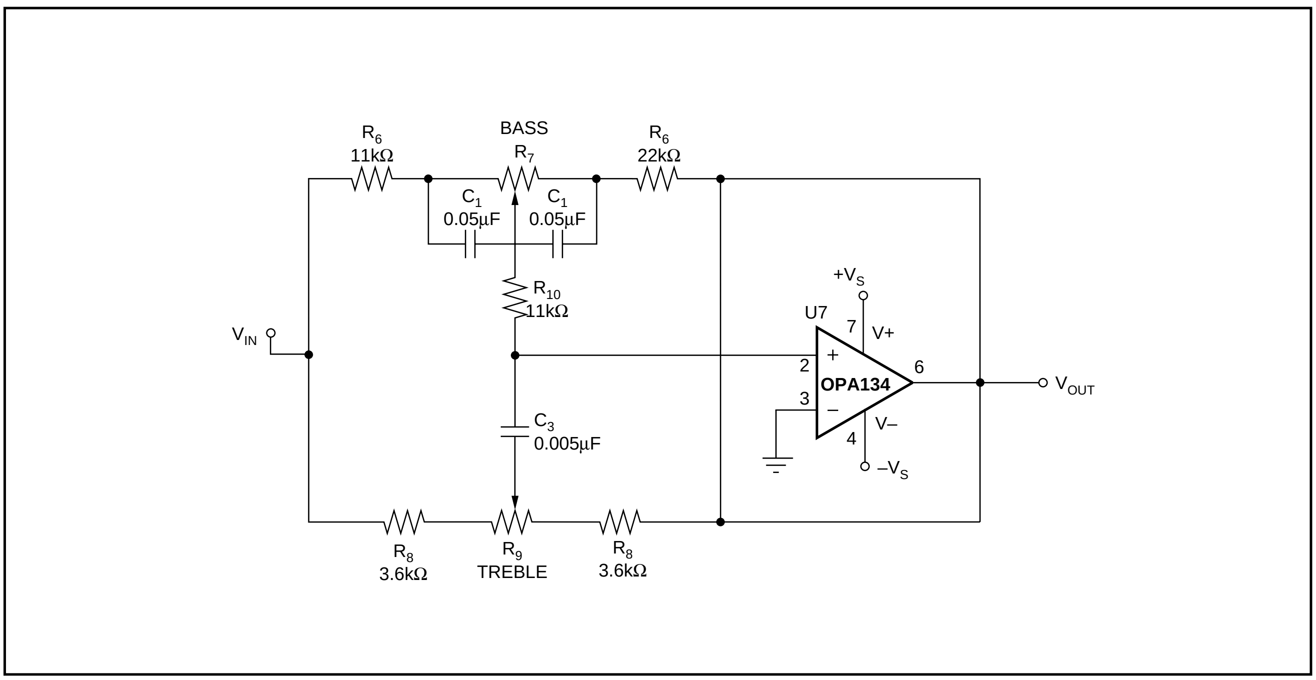

FIGURE 3. Treble and Bass Control.

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.

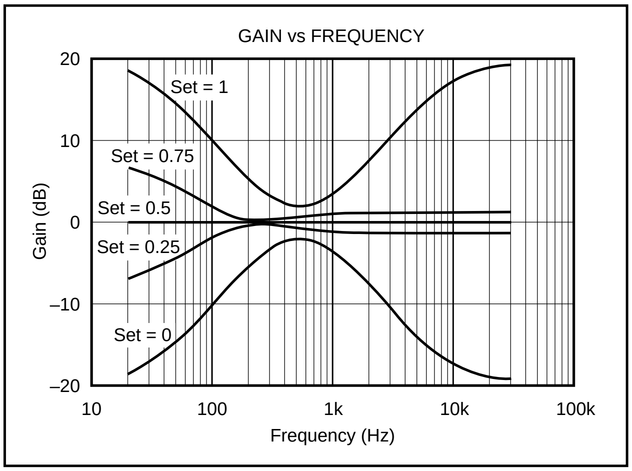

FIGURE 4. SPICE Simulation of "Closed-Loop Gain vs Frequency". The various curves represent the "set" value of potentiometer R_2 and R_4.

$$f_L = \frac{1}{2\pi \bullet R_7 \bullet C_1} \qquad (3)$$

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

$$f_H = \frac{1}{2\pi \bullet R_8 \bullet C_3} \qquad (5)$$

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

The component values of Figure 3 correspond to a ±20dB 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(20dB)) and selecting R_{10} to be 100kΩ (linear), the value of R_9 can be determined using Equation 1.

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

$$R_9 = 11k\Omega$$

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

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

$$R_8 = 3.6k\Omega$$

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.

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

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.

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

$$C_1 = 0.05\mu F$$

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

$$C_3 = 0.005\mu F$$

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

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

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_S (V)	THD+N (% at 1kHz)	S_R (V/µs)	I_Q (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.

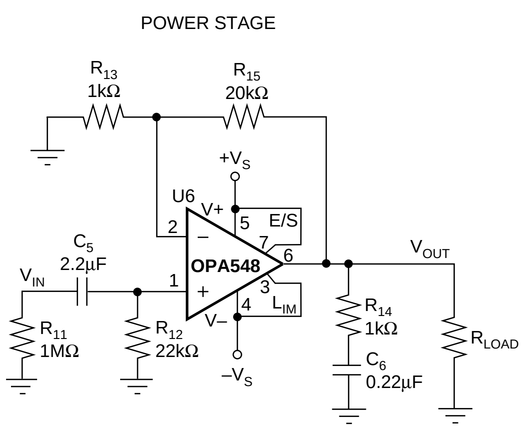

FIGURE 5. Power Amplifier Circuit.

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_S (V)	THD+N (% AT 1kHz)	SR (V/µs)	I_{OUT} (A)
OPA549	±4 to ±30	0.01(1)	9	8
OPA541	±10 to ±40	0.06(2)	10	5
OPA548	±4 to ±30	0.0015(2)	10	3
OPA544	±10 to ±35	0.03(2)	8	2
OPA547	±4 to ±30	0.0015(3)	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_{out} is specified for the minimum continuous rating.

TABLE II. Power Amplifier Selection Table. T_C = 25°C, V_S = ±35V for OPA541 and OPA544, V_S = ±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.