Adjusting Amplifier Gain to Achieve Settings Between Preset Gain Steps

HPL - Audio Power Amplifiers

ABSTRACT

This application report describes two methods to obtain a gain setting for a fixed-gain audio power amplifier. Included is a detailed operation analysis.

In order to obtain a gain setting for a fixed-gain audio power amplifier, the circuit shown in Figure 1 is recommended. In this application report, the TPA0212 is used as an example, although any TI fixed-gain audio amplifier functions similarly.

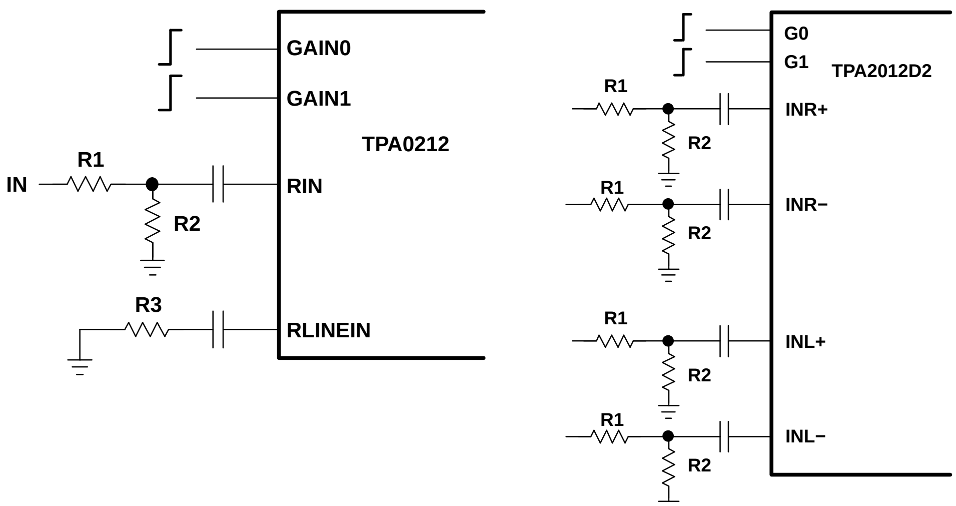

Figure 1. Gain Adjustment Circuit

Using the gain setting provided by the amplifier manufacturer is recommended because this generally gives the best performance. However, if a gain setting between the preset values is desired, the circuit shown in Figure 1 can be used with a slight increase in the circuit pop. If another slight increase in pop is tolerable, the R3 resistor can be set to zero (short) to remove an external component. The preset gain is one of the four gain settings determined from GAIN0 and GAIN1.

1 Method 1

Method 1 for determining the resistor values takes into account the effects of the resistor divider on the input impedance of the amplifier. Because the input impedance is different for each gain setting, the resistors must be selected to prevent large deviations from the desired gain value.

The resistor values in the circuit shown in Figure 1 can be determined by using the preset gain that is higher than the desired gain and then using the resistor divider to obtain the desired gain.

The following equations show how these values are determined.

$$R_{in(adjust)} = \left(R_{in(preset)} \parallel R2\right) + R1 = \left(\frac{R_{in(preset)} \times R2}{R_{in(preset)} + R2}\right) + R1 \quad (1)$$

$$R2 = \frac{A_{v(new)} \times R_{in(preset)} \times R1}{A_{v(preset)} \times R_{in(preset)} - A_{v(new)} \times R_{in(preset)} + A_{v(new)} \times R1} \quad (2)$$

$$R3 = R1 \parallel R2 = \frac{R1 \times R2}{R1 + R2} \quad (3)$$

Where

$R_{in(adjust)}$ = Input impedance after gain adjustment
$R_{in(preset)}$ = Input impedance of preset gain (from data sheet)
$A_{v(new)}$ = Amplifier gain after adjustment
$A_{v(preset)}$ = Amplifier gain – preset gains

Using this method, R1 is set equal to the input resistance required for the input signal source. Equation 2 and Equation 3 are used to calculate the resistance values. The preset values correspond to the values in the TPA0212 data sheet for each gain setting

The values for R2 and R3 have been calculated for R1 = 1 kΩ in Table 1.

Table 1. Values for R2 and R3

DESIRED GAIN (V/V)	PRESET GAIN			R1 (kΩ)	R2 (kΩ)		R3 (Ω)	
	GAIN0	GAIN1	GAIN-$A_{v(preset)}$ (V/V)		CALCULATED	STANDARD[1]	CALCULATED	STANDARD[1]
24	1	1	24	–	–	–	–	–
23	1	1	24	–	–	–	–	–
22	1	1	24	1	51.33	51.1	980.89	976
21	1	1	24	1	14.00	14.0	933.33	931
20	1	1	24	1	7.78	7.68	886.08	887
19	1	1	24	1	5.22	5.23	839.12	845
18	1	1	24	1	3.82	3.83	792.44	787
17	1	1	24	1	2.94	2.94	746.06	750
16	1	1	24	1	2.33	2.32	699.97	698
15	1	1	24	1	1.89	1.91	654.22	649
14	1	1	24	1	1.56	1.54	608.76	604
13	1	1	24	1	1.29	1.30	563.51	562
12	1	0	12	–	–	–	–	–
11	1	0	12	1	19.07	19.1	950.17	953
10	1	0	12	1	6.19	6.2	860.92	866
9	1	0	12	1	3.39	3.40	772.26	768
8	1	0	12	1	2.17	2.15	684.24	681
7	1	0	12	1	1.48	1.47	596.77	600
6	0	1	6	–	–	–	–	–
5	0	1	6	1	5.62	5.62	848.87	845
4	0	1	6	1	2.09	2.10	676.58	680
3	0	1	6	1	1.02	1.02	505.44	510
2	0	0	2	–	–	–	–	–

(1) 0603 resistors available from Digikey.

2 Method 2

Method 2 determines the resistor values through a simpler set of equations than Method 1. It does not take into account the effect of the resistor divider on the amplifier. Therefore, the gain that results from the amplifier may differ from the desired circuit gain.

The following equations demonstrate the calculations for Method 2.

$$R_{in(adjust)} = \left(R_{in(preset)} \parallel R2\right) + R1 = \left(\frac{R_{in(preset)} \times R2}{R_{in(preset)} + R2}\right) + R1 \tag{4}$$

$$A_{v(new)} = \frac{R2}{R1 + R2} \times A_{v(preset)} \tag{5}$$

$$R3 = R1 \parallel R2 = \frac{R1 \times R2}{R1 + R2} \tag{6}$$

A comparison between Method 1 and Method 2 is shown in Figure 2. Notice that the gain for Method 2 is slightly less than the desired value obtained for Method 1.

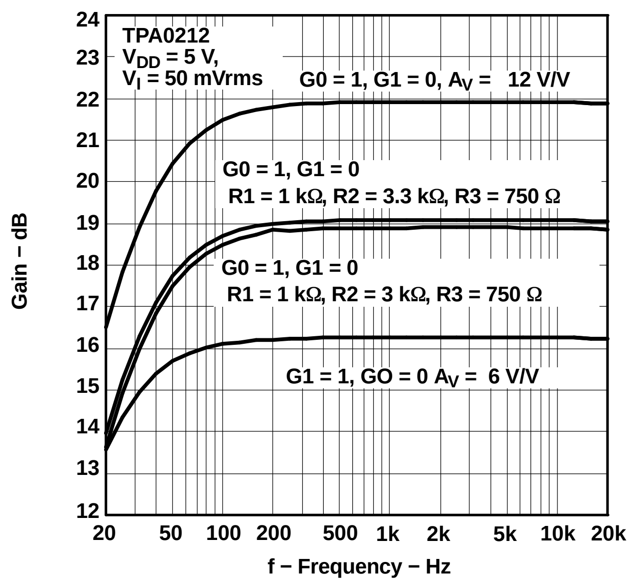

Figure 2. Gain vs Frequency – Method 1 and 2 Comparison

3 Detailed Operation Analysis

The resistor divider added to the circuit allows for the reduction of the amplifier gain. Equation 7 through Equation 11 are the base equations used to determine the gain for both methods.

$$R_{in(adjust)} = \left(R_{in(preset)} \parallel R2\right) + R1 \tag{7}$$

$$A_{v(new)} = A_{v1} \times A_{v2} \tag{8}$$

$$A_{v(new)} = \frac{R2}{R1 + R2} \tag{9}$$

$$A_{v2} = \frac{A_{v(preset)} \times R_{in(preset)}}{R_{in(preset)} + R1 \parallel R2} \tag{10}$$

$$R3 = R1 \parallel R2 \tag{11}$$

By substituting Equation 9 and Equation 10 into Equation 8, the general equation for $A_{v(new)}$ can be derived. Equation 12 shows the general gain equation for the new circuit.

$$A_{v(new)} = \frac{R2}{R1 + R2} \times \frac{A_{v(preset)} \times R_{in(preset)}}{R_{in(preset)} + R1 \parallel R2} \tag{12}$$

The resistor divider that is added to the amplifier circuit interacts with the input resistance of the amplifier. Equation 12 illustrates how the resistor divider affects the amplifier gain. The gain of the amplifier is reduced if large resistor values are used for R1 and R2.

By solving Equation 12 for R2, Equation 2 used in Method 1 can be obtained. This allows the full effect of the resistor divider on the amplifier. The selection of R1 as the minimum load resistance the audio source can drive ensures the input impedance of the amplifier circuit will not be too low. The value of R2 can be determined using the values for gain settings and input resistance found in the audio amplifier datasheet. The value of chosen for R1 in the Method 1 section was based on the ability of the audio source to drive a 1 kΩ load.

For Method 2, the effect of R1 and R2 on the amplifier was neglected. Therefore, the term R1||R2 in Equation 12 will be ignored. The equation can now be simplified to obtain Equation 5 used in Method 2. This method does not take into account the impact of the resistor divider on the input impedance of the amplifier. Ignoring this effect can lower the desired gain of the amplifier as shown in Figure 2.

The resistor R3 can be removed from the circuit shown in Figure 1 if a slight increase in the pop noise is acceptable. The reason for this increase is that the impedance seen by the positive and negative input terminals is no longer equal. This will result in input capacitors charging at slightly different rates to the midpoint voltage and a small audible pop will be heard.