

## APPLICATION NOTE 4046

## Overview of 2.1 (Satellite/Subwoofer) Speaker Systems

*Abstract: This application note provides an overview of conventional 2.1 audio designs for portable computers, and it considers the ways in which they address the unequal output power requirements of satellite speakers and the subwoofer. The article then details Maxim's highly efficient, low-cost 2.1 solution, which provides 2 x 2W and 1 x 7W of output power.*

### Introduction

Audio designers for portable computers are constantly working on improvements to the sound of the system. In space-constrained designs, one of the better solutions is a 2.1 configuration, which uses stereo satellites for mid and high frequencies (typically 500Hz and above in portable computer systems) and a single subwoofer for low frequencies (typically 500Hz and below in portable computer systems).

This application note presents a highly efficient, low-cost 2.1 solution, which provides 2 x 2W and 1 x 7W of output power. We introduce the [MAX9737](#) Class D amplifier which has a wide power-supply range (8V to 28V) and eliminates the need for any voltage regulators.

### Overview of Conventional Solutions

One of the main problems faced by audio system designers has been the unequal output power requirements of the satellite speakers and subwoofer. Typically, the subwoofer requires four to five times more output power for proper sound balance. With only a 5V power supply available, a variety of audio power-amplifier solutions have been employed, each of which has its own disadvantages.

1. The most common solution has been to use two stereo power amplifiers of the same output power level. One of the amplifiers drives the satellites, and the other drives the subwoofer. The satellites use 8 $\Omega$  speakers, while the subwoofer uses 4 $\Omega$  speakers. This results in a 2.1 solution with 2 x 1W satellites and a 1 x 2W subwoofer. Although this solution is simple, it does not provide enough power to the subwoofer to produce a substantial amount of bass. Also, using 8 $\Omega$  speakers for the satellites does not maximize the satellites' sound pressure level (SPL). Consequently, the overall sound level of this approach is limited.
2. By changing the speaker impedances of the above solution, one can use 4 $\Omega$  speakers for the satellites and 2 $\Omega$  speakers for the subwoofer. This creates a 2.1 solution with 2 x 2W for the satellites and 1 x 4W for the subwoofer. This solution increases the sound level by doubling the output power; however, sourcing 2 $\Omega$  speakers and power amplifiers to drive these speakers is difficult and costly. In addition, the supply-current requirements are roughly doubled and the solution's efficiency suffers, resulting in possible thermal-dissipation issues, especially in space-constrained systems.
3. A better solution than the two above is to use a 2 x 2W amplifier for the satellites and a 1 x 7W amplifier for the subwoofer. In this configuration, the satellites are 4 $\Omega$  and fully utilize the potential of the 5V power supply, while the subwoofer is 8 $\Omega$  and provides a substantial amount of bass at 7W. However, this 7W subwoofer amplifier requires a 12V power supply, which adds complexity to the solution. With only a 5V power supply available, a 12V power supply needs to be created.

### Analysis of the Conventional Solutions

The advantage of using a 2.1 speaker system is that it provides a "big" sound from a small space. To achieve this, the subwoofer amplifier needs to have at least three to four times more power than the satellites. For 2W satellites, the subwoofer amplifier should have at least 6W to 8W.

Solutions 1 and 2 above are simple to implement since they only require a single 5V supply. However, these solutions do not

solve the problem since both lack an adequate amount of power to drive the subwoofer.

Solution 3 would be ideal, if not for the complexity introduced by creating an additional 12V power supply.

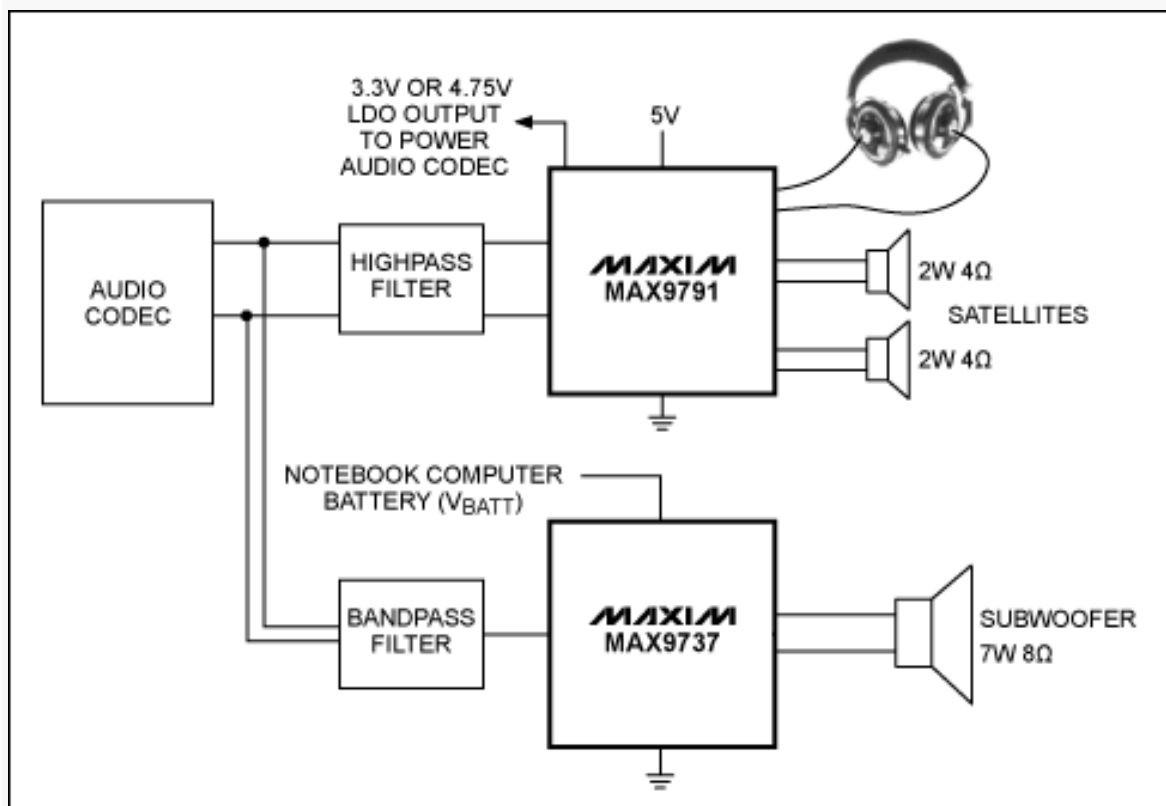


Figure 1. Maxim's complete solution for 2.1 speaker systems.

## Maxim's Solution and Its Advantages

**Figure 1** shows Maxim's complete solution for 2.1 speaker systems. This solution uses the MAX9791 Windows Vista®-compliant 2 x 2W stereo amplifier with stereo headphone driver and the MAX9737, a 1 x 7W mono Class D amplifier connected directly to the notebook computer battery.

The MAX9791 combines a stereo 2W Class D speaker amplifier, which drives the satellites in the 2.1 system, and a stereo 180mW DirectDrive® headphone amplifier into a single device. Designed for use in portable computer systems that use the Windows Vista operating system, the MAX9791 is fully compliant with Windows Vista specifications. The headphone amplifier features Maxim's patented DirectDrive architecture, which produces a ground-referenced output from a single supply, thereby eliminating the need for output-blocking capacitors.<sup>1</sup> This DirectDrive architecture saves cost and board space, reduces component height, and eliminates clicks and pops associated with output-blocking capacitors. Additionally, the MAX9791 integrates a 3.3V or 4.75V adjustable-output LDO to provide a clean supply for an audio codec or other analog circuitry.

The MAX9737 is a filterless output Class D amplifier that provides 7W into 8Ω at 10% THD+N from a 12V power supply. Please note that if necessary, the output power of the MAX9737 can be reduced if the subwoofer in the system requires less power. The MAX9737 has a wide power-supply voltage range (8V to 28V) and can be connected directly to the battery of the notebook computer (typically 9V to 21V). This configuration will eliminate the need for any voltage regulators or DC-DC converters to create a 12V power supply to drive the subwoofer amplifier. The Class D modulation scheme of the MAX9737 does not require output filters to reduce cost and provides an efficient 7W of power for the subwoofer in the 2.1 system. With an efficiency of 90%, the MAX9737 does not require a heatsink. Additionally, its spread-spectrum-modulation scheme allows the device to pass FCC and CE EMI limits with 1m of speaker cable by using only a low-cost ferrite bead and capacitor on each output.<sup>2</sup> (See **Figure 2** below for a CE emissions scan of the MAX9737 customer EV (evaluation) kit using pink noise input and a 1m speaker cable.)

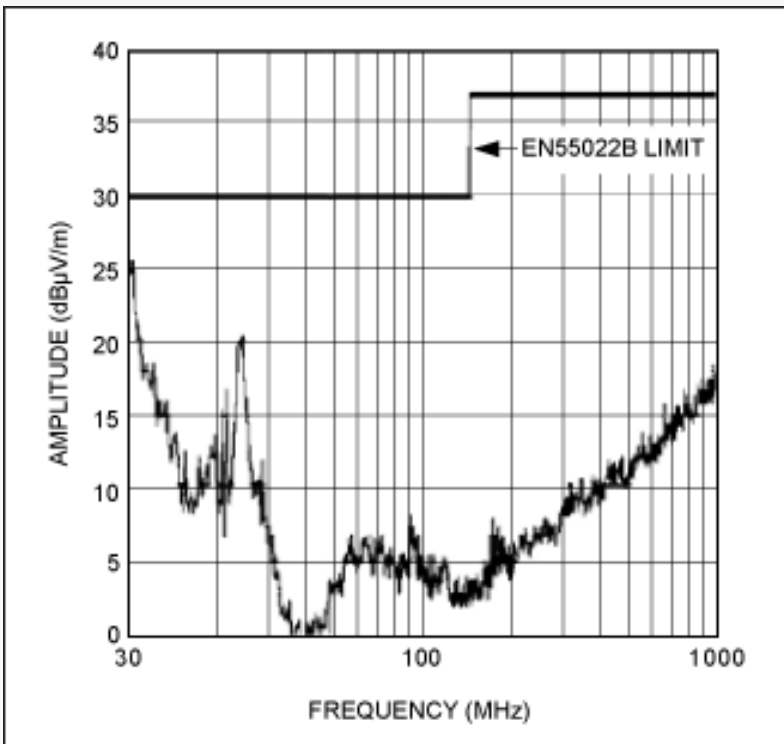


Figure 2. The MAX9737 filterless EMI measurement using 1m speaker cable.

## Highpass and Lowpass Filtering for the Satellites and Subwoofer

2.1 solutions such as the one shown in Figure 1 will require a highpass filter at the input of the MAX9791 for the satellite speakers, and a bandpass filter at the input of the MAX9737 for the subwoofer. In **Figure 3** an op amp is used to create a second-order multiple feedback highpass filter used before the MAX9791 to drive the satellite speakers.

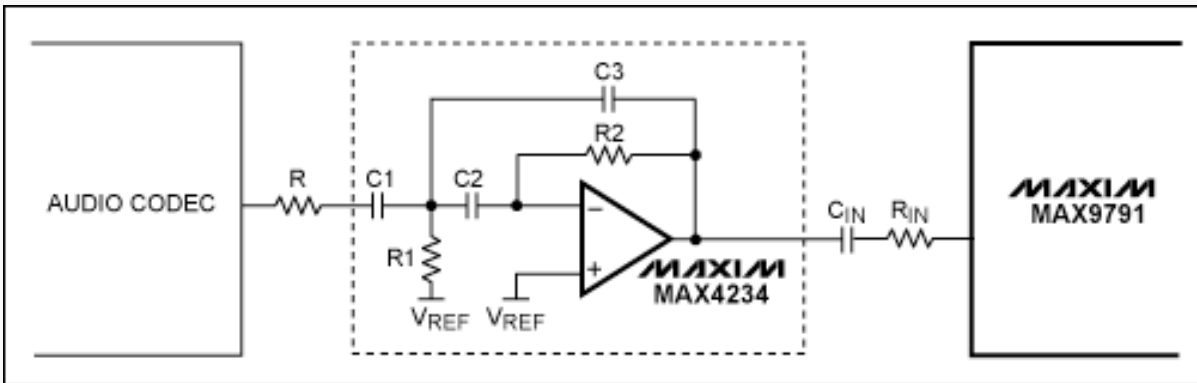


Figure 3. Second-order, multiple-feedback, highpass filter for satellites.

The transfer function for the highpass filter shown in Figure 3 is:

$$T(s) = -A \frac{s^2}{s^2 + \alpha\omega_0 s + \omega_0^2}$$

Then:

$$\frac{V_O}{V_I} = \frac{-s^2 \left( \frac{C1}{C3} \right)}{s^2 + s \frac{(C1 + C2 + C3)}{C2 \times C3 \times R2} + \frac{1}{C2 \times C3 \times R1 \times R2}}$$

If we substitute:

$$\alpha = \frac{1}{Q} \quad C1 = C2 \quad C3 = \frac{C1}{A}$$

$$R1 = \frac{\alpha}{\left(2 + \frac{1}{A}\right) \times 2 \times \pi \times f_0 \times C1} \quad R2 = A \frac{\left(2 + \frac{1}{A}\right)}{2 \times \pi \times f_0 \times \alpha \times C1}$$

Where  $f_0$  is the 3dB rolloff point of the highpass filter and A is the gain in V/V.

**Figure 4** shows the circuit to achieve a highpass filter with  $f_0 = 500\text{Hz}$  for unity gain. Please note that resistor R is needed to minimize capacitive loading caused by the filter stage. The suggested value for R is  $470\Omega$ . In this design the op amps will be powered from a single 5V power supply, therefore they will need to be biased to a DC voltage. For a maximum voltage swing, it is recommended that you bias this voltage to 2.5V. Here we used the bias voltage ( $V_{REF}$ ) from the MAX9737, which is 2.5V. The bias voltage from the MAX9737 was connected to the COM pin and buffered through the MAX4234 op amp (see **Figure 11**). If dual power supplies are used on the MAX4234 op amps, then  $V_{REF}$  would be ground.

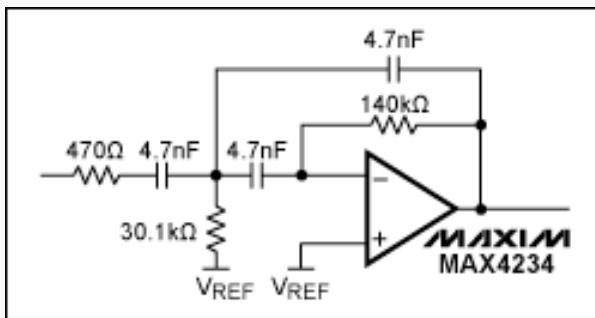


Figure 4. Second-order multiple feedback highpass filter with  $f_0 = 500\text{Hz}$  and  $A = 1\text{V/V}$ .

**Figure 5** shows simulation results with various capacitor values of C1, C2, and C3. For unity gain  $C1 = C2 = C3$  was used;  $R = 470\Omega$ ;  $R1 = 30.1\text{k}\Omega$ ; and  $R2 = 140\text{k}\Omega$ .

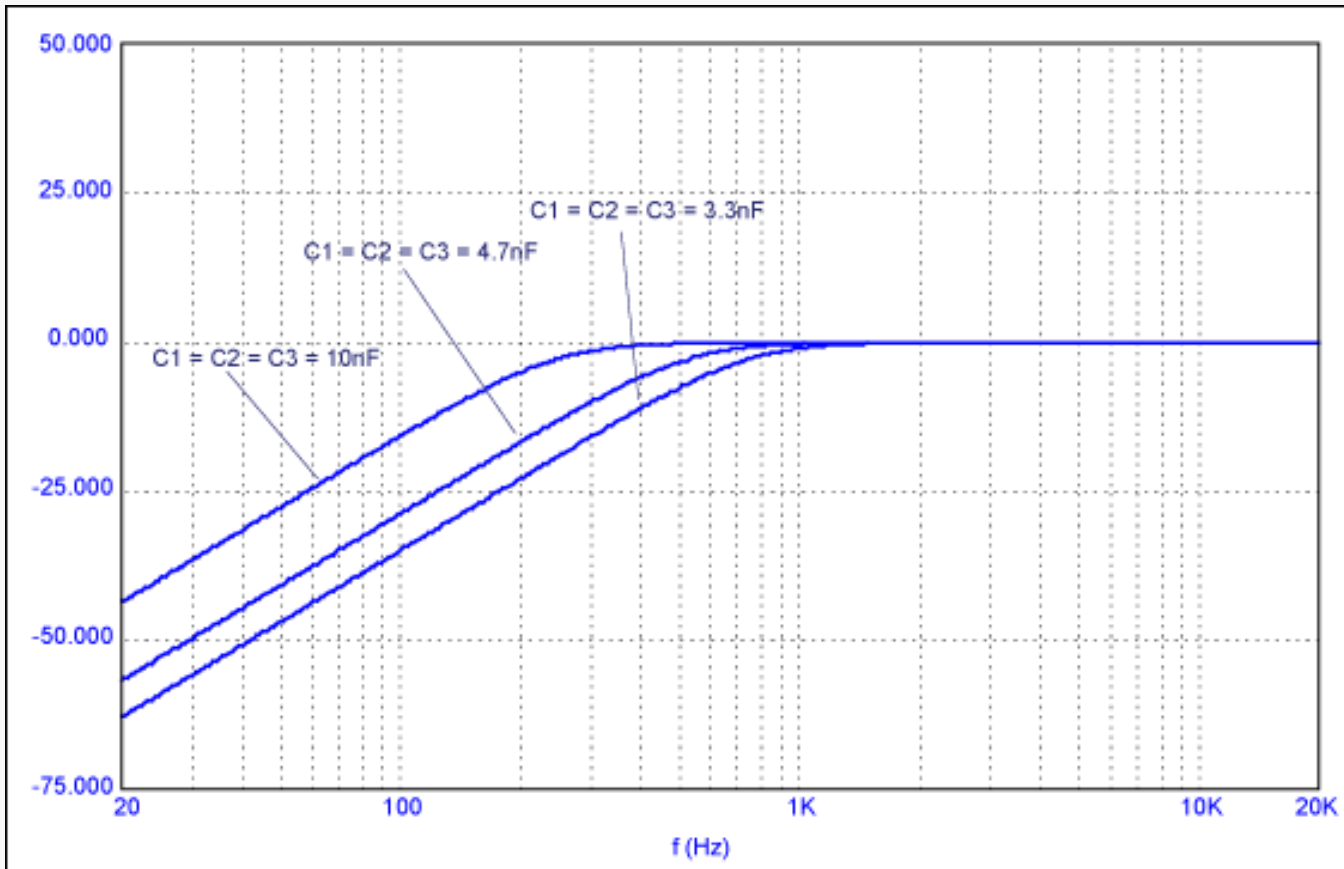


Figure 5. Simulation results of the highpass filter with various capacitor values.

A bandpass filter will be used for the subwoofer; two op amps will be required to create a lowpass and highpass filter for the bandpass filter response. A bandpass filter is used for the subwoofer because typical computer designs use subwoofers that are too small to reproduce frequencies below 80Hz to 100Hz. In this case the bandpass filter will limit response of the subwoofer from 100Hz to 500Hz.

**Figure 6** shows the bandpass filter utilizing the input op amps on the MAX9737 for the highpass filter and an external op amp to create the lowpass filter.

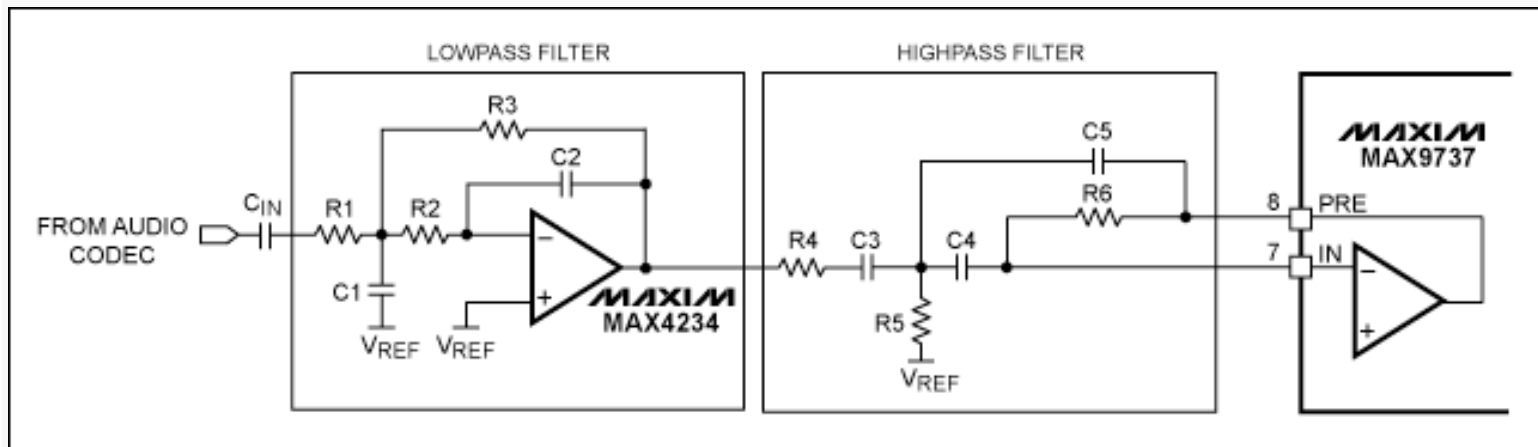


Figure 6. Bandpass filter for the MAX9737.

The transfer function for the lowpass filter from Figure 6 is:

$$T(s) = -A \frac{\omega_0^2}{s^2 + \alpha\omega_0s + \omega_0^2}$$

Then:

$$\frac{V_O}{V_I} = \frac{-A \left( \frac{1}{C1 \times C2 \times R2 \times R3} \right)}{s^2 + s \frac{1}{C1} \left( \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} \right) + \frac{1}{C1 \times C2 \times R2 \times R3}}$$

If we substitute:

$$\alpha = \frac{1}{Q} \quad C1 = C2 \times \frac{4}{\alpha^2} (A + 1) \quad R1 = \frac{\alpha}{4 \times \pi \times f_0 \times A \times C2}$$

$$R2 = \frac{\alpha}{(A + 1) \times 4 \times \pi \times f_0 \times C2} \quad R3 = \frac{\alpha}{4 \times \pi \times f_0 \times C2}$$

**Figure 7** shows the resistor and capacitor values to implement a bandpass filter with a response between 100Hz to 500Hz. A lowpass filter is implemented with an external op amp and has  $f_0 = 500\text{Hz}$  with unity gain. The highpass filter is implemented with the internal op amp of the MAX9737, and has  $f_0 = 100\text{Hz}$  with unity gain. **Figure 8** shows the simulation results of the design in Figure 7.

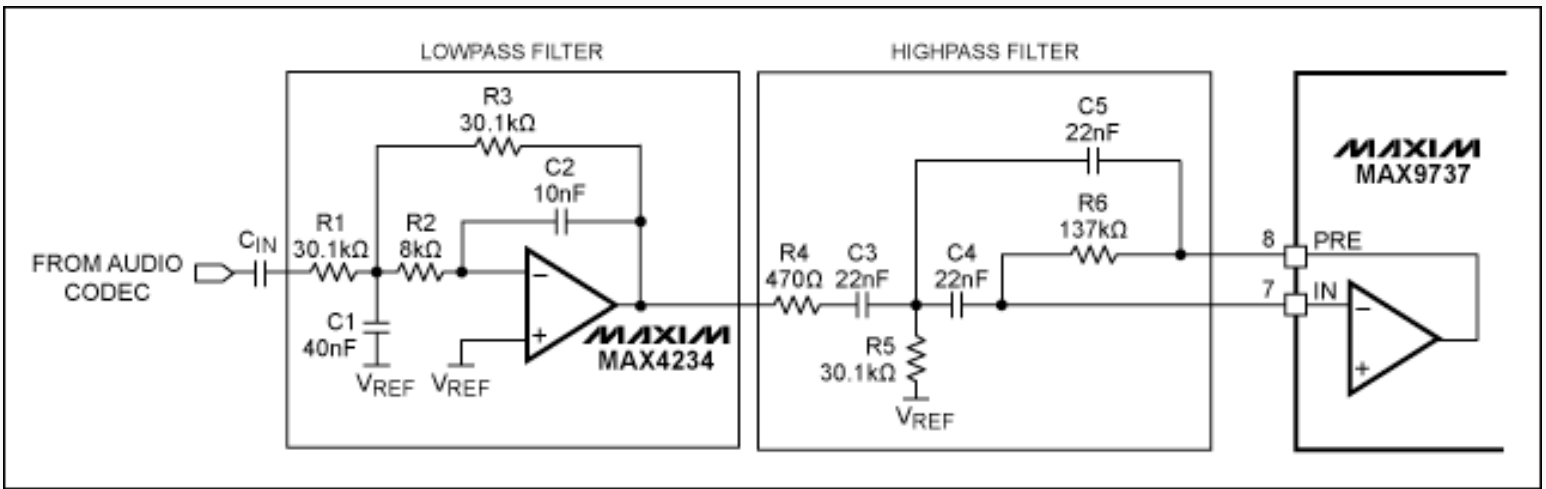


Figure 7. Second-order multiple feedback bandpass filter with  $f_0 = 100\text{Hz}$  and  $500\text{Hz}$  and  $A = 1\text{V/V}$ .

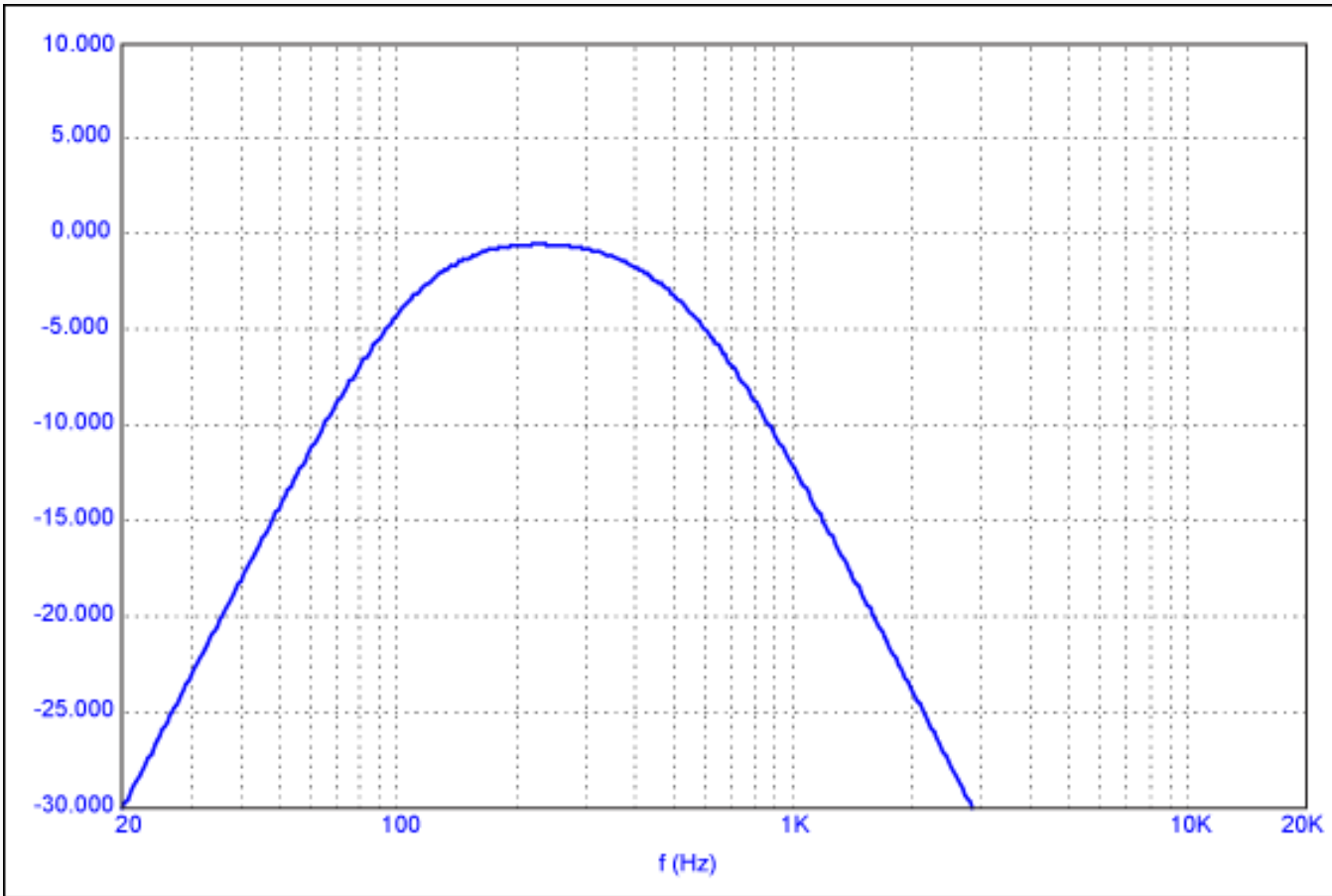


Figure 8. Simulation results of the bandpass filter shown in Figure 7.

Figures 9 below shows the simulation results of the circuit from Figure 7, but with varying values of R2 to illustrate how the lowpass filter portion of the bandpass filter can be adjusted.

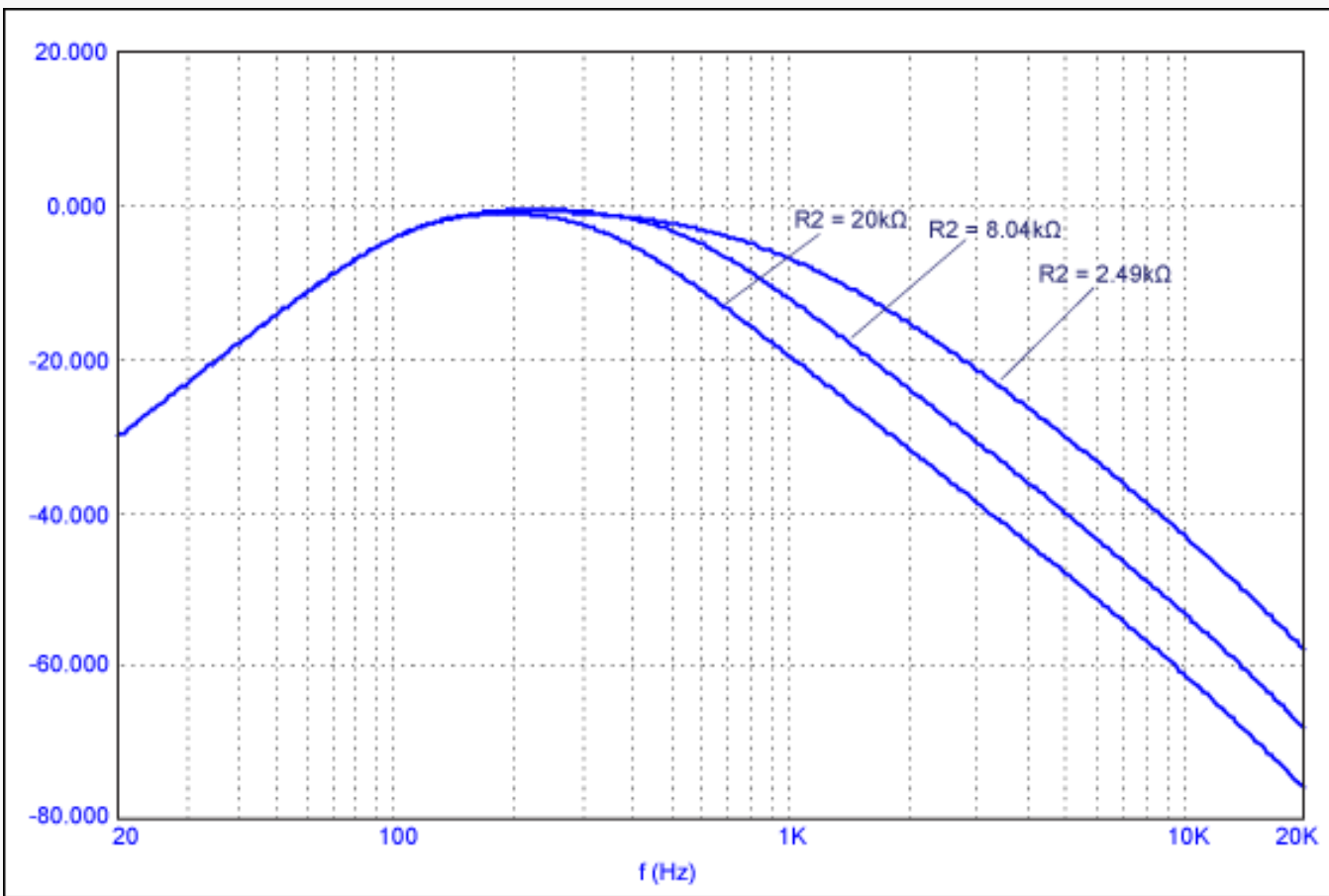


Figure 9. Simulation results varying  $R2$  to adjust the lowpass filter.

**Figure 10** shows the simulation results of the circuit from Figure 7, but with varying values of  $C3$ ,  $C4$ , and  $C5$  to illustrate how the highpass filter portion of the bandpass filter can be adjusted.

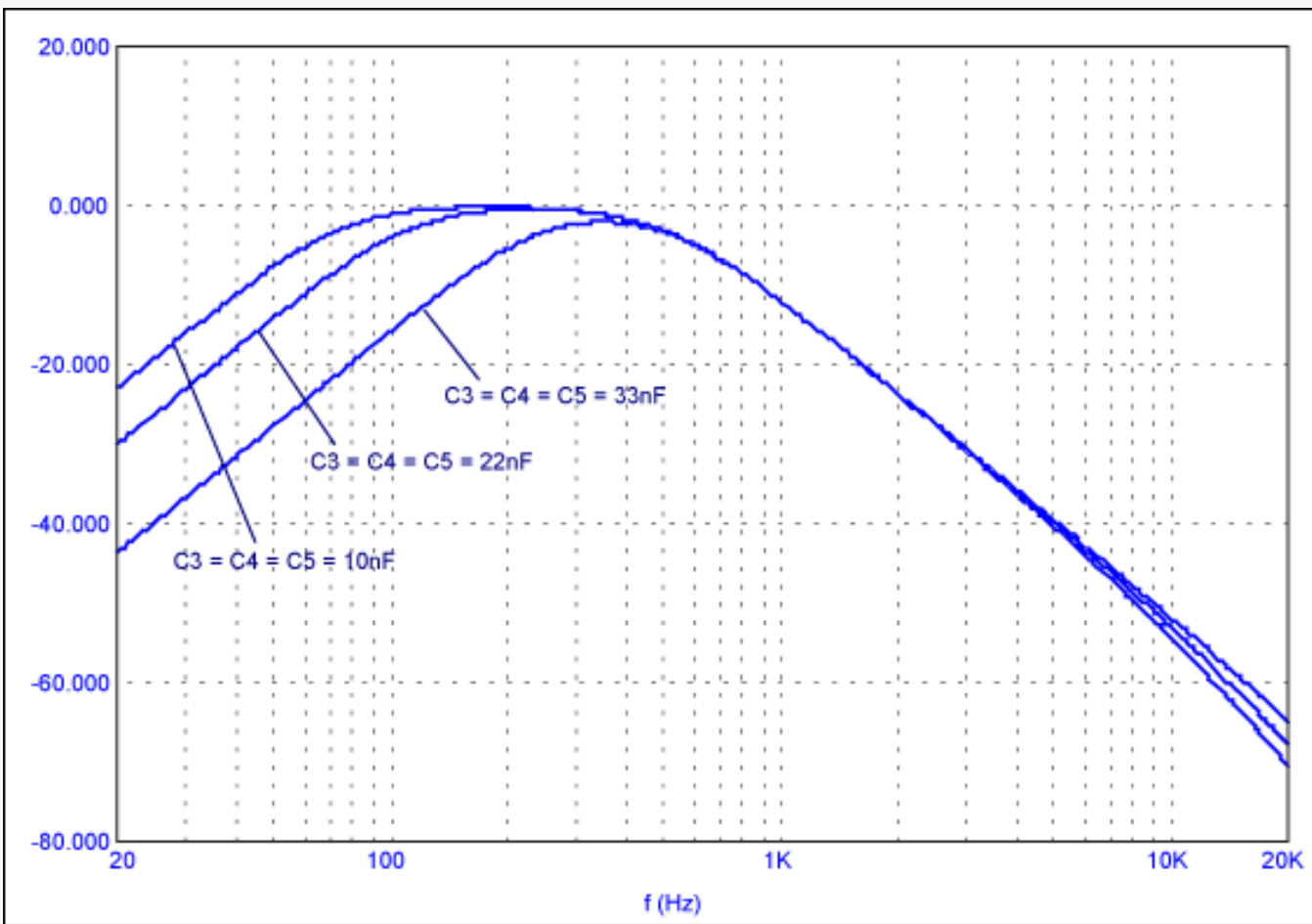


Figure 10. Simulation results varying  $C3$ ,  $C4$ , and  $C5$  to adjust the highpass filter.

**Figure 11** shows the complete schematic connection for the audio portion of the circuit, including the highpass filters and amplifiers for the satellites and the bandpass filter and amplifier for the subwoofer. The highpass filter is configured for an  $f_0 = 500\text{Hz}$  with unity gain; the bandpass filter is configured for an  $f_0 = 100\text{Hz}$  and  $500\text{Hz}$  with unity gain. Please note that the MAX4234 op amps for the highpass and bandpass filters require a bias voltage since they are powered from a single 5V power supply. The biases for the MAX4234 are taken from the internal bias voltage of the MAX9737 and driven with an op amp configured as a unity-gain buffer.

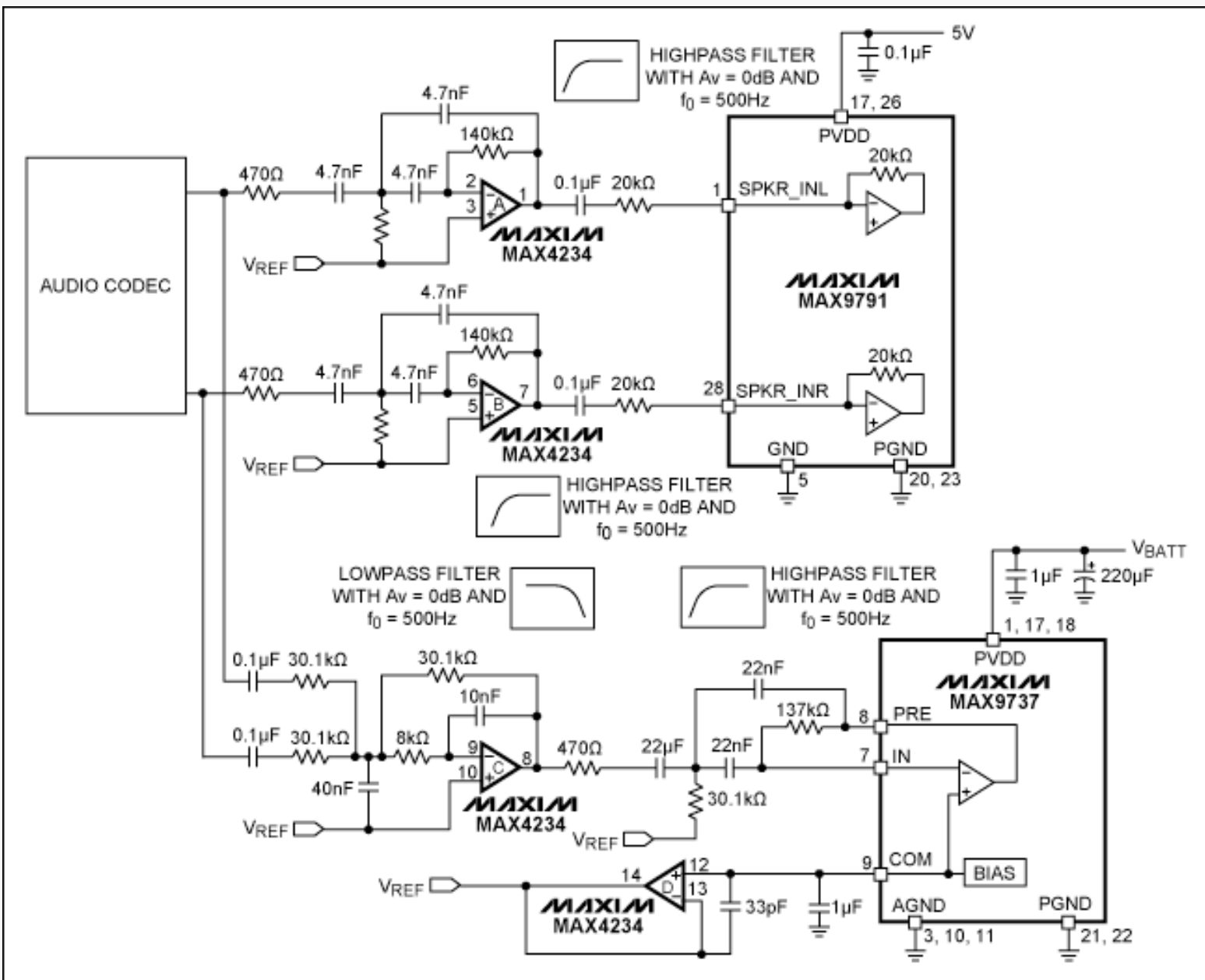


Figure 11. Audio circuit diagram.

## Conclusion

The MAX9791 provides a fully integrated audio solution for portable computer systems running Windows Vista. The MAX9737 provides high output power with high efficiency to sufficiently drive the subwoofer in a portable 2.1 system. With its wide power-supply voltage range (8V to 28V), the MAX9737 can be directly connected to the notebook computer battery and eliminate the need for a DC-DC converter. This wide power-supply voltage range is an advantage unique to the MAX9737.

<sup>1</sup>For a more detailed description of Maxim's patented DirectDrive architecture, refer to application note 3979, "[Overview of DirectDrive Technology.](#)"

<sup>2</sup>For more information on the Spread-Spectrum Modulation scheme of the MAX9737, refer to application note 3881, "[Spread-Spectrum-Modulation Mode Minimizes Electromagnetic Interference in Class D Amplifiers.](#)"

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**Related Parts**

MAX8715: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

MAX9744: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

MAX9768: [QuickView](#) -- [Full \(PDF\) Data Sheet](#) -- [Free Samples](#)

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