Active Filtering in Automotive Audio Applications

Phone calls, emergency alerts, and music are just a few of the reasons that a high quality audio system is vital in automotive infotainment and clusters. Operational amplifiers (op amps) are one of the most common building blocks of automotive audio circuits. Many designers choose to incorporate op amps into their automotive audio circuits in order to increase audio performance. Higher order filters, which can be created through a combination of second order filters, attenuate noise more aggressively than lower order filters. Additionally, active filters remove the chance of unwanted interference with the audio signal.

Why Audio Filtering?

Filtering is vital for a car's audio system to ensure high quality sound. A filter with an op amp, or an active filter, maintains the frequency response while amplifying the audio signal. High pass filters (HPF) reject DC components of a signal, leaving only the DC offset that matches the rest of the op amp. Often a capacitor is added in parallel with a feedback resistor to achieve additional filtering and to improve the stability of the circuit. Please refer to the inverting or non-inverting AC-coupled HPF amplifier circuit which are available online with example circuits and accessible calculations. Active low pass filters (LPF), as seen in Figure 1 below, can be used to create the frequency band needed for a subwoofer or an anti-aliasing filter for audio signals at the input of an ADC.

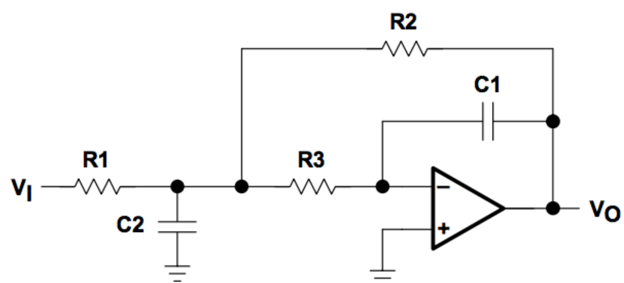

Figure 1. A Multiple-Feedback Low Pass Filter Circuit

Another common use of op amp filters in an automotive audio system is to separate frequency ranges for individual speakers throughout the car. Lower frequency ranges require higher power amplifiers to drive larger speakers, as human hearing is less sensitive to these frequencies. However, the power required to drive a large subwoofer could damage a higher frequency speaker, especially at higher volumes. HPF and LPF can be used to set cutoff frequencies to deliver frequencies to the correct speakers.

Filters that separate frequency bands should be designed so that there are no dips in the frequency response of the sound produced by the speaker, as can be seen in Figure 2. All of these HPF and LPF networks can be designed using the WEBENCH filter design tool.

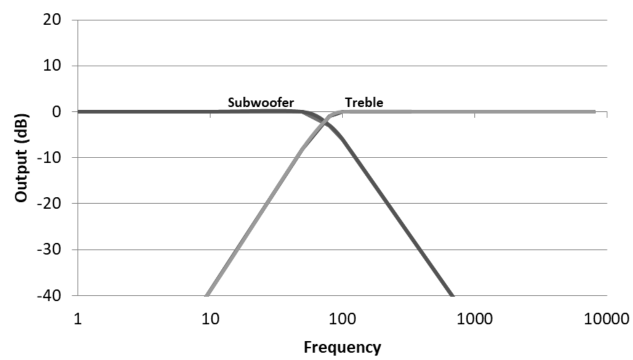

Figure 2. Splitting Frequencies Using Active Filters to Reach Multiple Speakers

Audio Filtering in the Automotive Space

Designers concerned with automotive audio can use these principles to create a quality audio filtering system. While there are many different filter circuits, the multiple-feedback filter circuit is the most commonly used in automotive audio signal chains. More op amps can be added to additionally filter circuits in order to filter out DC and high-frequency noise.

TI's PMP11769 is an automotive audio amplifier design that incorporates these active filters to create a subwoofer system. This design incorporates a high-pass, non-inverting amplifier, seen in Figure 3, which is simply designed to reject any DC signal from the original analog audio signal.

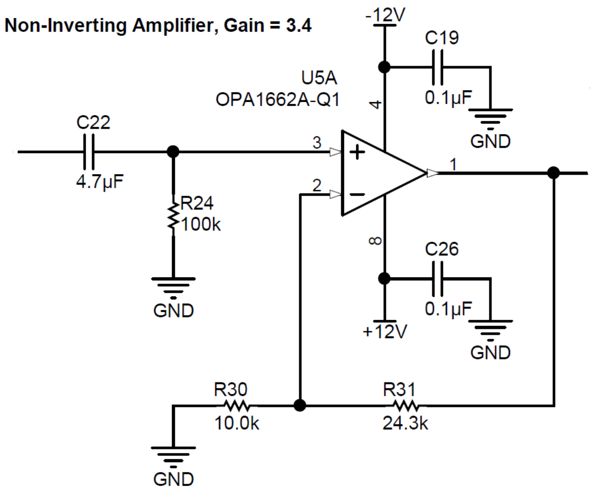

Figure 3. Active Non-Inverting High Pass Filter at 0.3 Hz with a Gain of 3.4

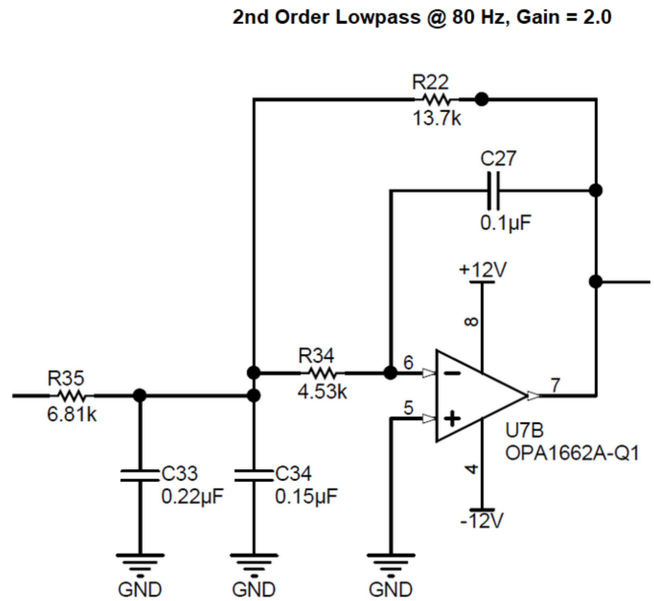

Figure 4. Second-Order Low Pass Filter at 80Hz

The audio signal is then fed into a second-order LPF with a cutoff frequency of 80 Hz, as seen in Figure 4. The range of 0-80 Hz is the true bottom half of audio, so the output is fed to the subwoofer speakers. The audio signal will later be passed through an additional HPF to deliver each frequency to the correct speaker. The signal may be inverted, as well, in order to deliver complementary signals to either side of the speaker as an input.

Many general-purpose op amps smoothly filter out frequencies when placed in a second-order filter configuration. TI's TLV314-Q1 family consists of single-, dual-, or quad-channel lower power, general-purpose op amps. This device has a gain bandwidth product of 3 MHz and low broadband voltage noise of 16 nV/√Hz. Therefore, it is a great balance between cost and performance. Alternatively, TI's TLV316-Q1 is another family of lower-power, general-purpose op amps and features very-low broadband noise of 12 nV/√Hz and a wide bandwidth of 10 MHz.

TI's LM2904-Q1 is another very common choice to build these HPF and LPF networks: it consists of two independent frequency-compensated op amps. However, it has higher broadband voltage noise of 40 nV/√Hz and a gain bandwidth of just 0.7 MHz.

TI has a wide variety of automotive op amps that can be easily incorporated into just about any active filter design. This provides flexibility for each unique audio system. Incorporating op amps into automotive audio filter design allows effective, customizable, and high quality systems that will keep drivers delighted.

Table 1. Device Recommendations

Device	V_{CC}	V_{inCM}	V_{out}	V_N	V_{OS}	I_q	UGBW	SR	#Channels
TLV314-Q1	1.8 to 5.5 V	Rail-to-Rail	Rail-to-Rail	16 nV/√Hz	3 mV	0.15 mA/Ch	3 MHz	1.5 V/us	1, 2, 4
TLV316-Q1	1.8 to 5.5 V	Rail-to-Rail	Rail-to-Rail	12 nV/√Hz	3 mV	0.4 mA/Ch	10 MHz	6 V/us	1, 2, 4
LM2904-Q1	3 to 26 V	Rail-to-Rail	Rail-to-Rail	40 nV/√Hz	2 mV	0.35 mA/Ch	0.7 MHz	0.3 V/us	2
OPA1662-Q1	3 to 36 V	Rail-to-Rail	Rail-to-Rail	3.3 nV/√Hz	1.5 mV	1.1 mA/Ch	22 MHz	17 V/us	2

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