Design analysis case study

Design

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I will analyse filters as a sub-set of the circuit. I choose filter because it is a core component of the audio equipment I have designed since it is responsible for ‘ generating’ the high and low frequency signals that are fed to the tweeter and woofer respectively.

Filters

Unlike resistors, the opposition (or reactance) to current offered by capacitors and inductors vary with frequency. At lower frequencies, the reactance of inductors is low while that of capacitors is high. At high frequencies, the reverse happens and the reactance of inductors is high while that of capacitors is considerably reduced. Thus at very high frequencies, a capacitor behaves like a perfect conductor while an inductor behaves like an open circuit. The reverse is true at low frequencies.

This property is exploited in the design of filters. Filters, from their name, are devices used to permit or block certain spectra of signals as situations may demand. It follows that we basically have four kinds of filters: Low pass, High pass, Band Pass and Band reject filters. Low pass filters permit low frequency signals; high pass filters permit filters; band pass permit signals in a given spectral range while band reject block signals within a given spectral range. I will not discuss the complex mathematical models used in the intensely accurate state-space approach to filter design for the simple reason that I don't think it useful in this project.

There are many types of filters such as Butterworth, Linkwitz-Riley, Chebychev and Bessel.

In this project, I have used sub-Bessel filter. In this analysis, I will use simple RC filters to introduce the basics of filtering.

RC Filter

Below is a diagram (figure 1) of a hybrid inverted L-type low pass and high pass filters.

Figure 1

In the figure 1 above, the input signal is fed at the terminals A and B while the outputs are at IJ and GH for low and frequencies respectively. The outputs can as well be captured with the woofer and tweeter respectively as shown in the figure. Inductive reactances of chokes (L1 and L2) are given by;

XL = ωL, where ω = 2πf

While the capacitive reactances of capacitors (C1 and C2) are given by;

XC = 1/ωC, where ω = 2πf

From the above it is clear, as I already said elsewhere, that increasing the values of the values of frequency has the effect of reducing XC while increasing XL.

The circuit comprising C2 and L2 is an inverted L-type low pass filter. In this, the L2's (or choke's) inductive reactance blocks high frequencies above the cut-off frequency as C2 shorts them such that they are grounded. This implies that only the low frequencies below the cut-off are permitted to the subwoofer. This is so because, at low frequencies, the inductive reactance is low thus cannot block the signals. The direction of current flow is given below

Figure 2

On the other hand, the circuit comprising C1 and L1 is an inverted L-type high pass filter. In this case, the concept that at higher frequencies, the capacitive reactance of C1 becomes considerably lower while the inductive reactance of L1 becomes high is employed. Thus, in this case, low frequency signals are cut-off while high frequency signals are permitted.

The direction of current flow is shown below

Figure 3

Given that the values of components in the filter above are as follows:

Resistance of tweeter = RL = 8 Ohms

Resistance of woofer = RH = 8 Ohms

Frequency = f = 2550 Hertz

And using the equations below,

C1 = 0. 1125 /(RHf)

C2 = 0. 1125 /(RLf)

L1 = 0. 2251RH/f

L2 = 0. 2251RL/f

We get the required values of the components as enumerated below;

C1 = 5. 515 micro-Farads

C2 = 5. 515 micro-Farads

L1 = 0. 0007 Henries

L2 = 0. 0007 Henries

The above is a simple design which, though perfectly practical, is not suitable for quality conscious realities of the modern world. More sophisticated designs are normally used in everyday engineering practice. While these may look complex, they primarily retain the basics I have just mentioned.

The above design is passive and only used for demonstration purposes. However, the complete active design makes use of op-amps and transistors. The complete circuit design is shown below.

Figure 4

The circuit shown in figure 4 above is that of loudspeaker cross-over circuit for use with four-way speaker output; low and mid-high for both the left and right channel.

The design makes use of operational amplifiers (or op-amps). Op-amp is an analogue electronic device which has the major advantage of using positive feedback to correct any noise or anomaly in the output with net effect that the output is usually an amplified replica of the input.

We see from the figure 4 that filtering of each channel is done in two stages. The op-amps in the column under the red mark in the figure represent the first stage of filtering while those under the second column represent the second stage. We see that for L Mid+High channel, there are transistors R of value 11kΩ connecting the output of each op-amp to its input. It is through this transistor that the feedback signal is fed back to the input from the output. The value of R is selected so that a given quality of signal is attained before being fed to the next stage. For this reason higher quality signals and finer tuning can be done to any signal.

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