An introduction to the Active Bandpass filter

Active Filters

An active filter is a filter implementation that involves the use of active components such as operational amplifiers. The use of these devices also allows us to not use inductors as their passive counterparts do. This is because inductors are relatively expensive compared to an operational amplifier. Inductors also introduce unwanted phenomenon into your circuit such as EMI. Their placement in a circuit makes all the difference in high frequency electronics.

The Active Bandpass Filter

The circuit

We first start out with the passive component representation of the bandpass filter in Figure [1].

![Fig. 1: Circuit for a passive Bandpass filter.](image)

The transfer function of this system is of the second order. We note the transfer function of this system for use in the future:

\[
T(s) = \frac{s/CR}{s^2 + s/CR + 1/LC}
\]

Eq. 1: Transfer function of Bandpass filter

Note: The transfer function takes the standard form of a second order transfer function.

The Antoniou Inductance simulation circuit can be used to replace the inductor in the aforementioned circuit. This will allow us to improve the overall performance of our circuit as we transform it into an active bandpass filter. The Antoniou inductance simulation circuit is also very tolerant to the properties of a real world operational amplifier (non-ideal). Substituting this circuit for the inductor of the circuit in Figure [1]. This gives us the active bandpass circuit shown in Figure [2].
Fig. 2: Active Bandpass filter showing Inductor simulation circuit.

We can make note of the circuit that is inserted for the inductor. We can clearly see the original bandpass circuit.

For our purposes assume that the output gain stage, shown as K, has a gain of one and therefore not necessary. The transfer function of this system is shown in Equation [2].

\[
T(s) = \frac{Ks}{C_6/R + (s/C_6R_6) + (R_2/C_6R_1R_3R_5)}
\]

Eq. 2: transfer function of Figure 2.

We now need to go to the general definition of the bandpass filter. The transfer function in general form is given in Equation [3]

\[
T(s) = \frac{a_1s}{s^2 + (sw_0/Q) + w_0^2}
\]

Eq. 3: General form of bandpass filter transfer function.

In Equation [3] we see the terms \(a_1, w_0,\) and \(Q\). We see that \(a_1\) is merely a coefficient however we define \(w_0\) and \(Q\) as the center frequency and the pole quality factor, respectively. A detailed image graph of the amplitude versus frequency graph for a bandpass filter is shown in Figure [3]. Note the 3dB points \(w_1\) and \(w_2\).
1. Determine the relationship between the center frequency and our resistor/capacitor variables.
   Hint: You can assume $R_1 = R_2 = R_3 = R_5 = R$ and $C_4 = C_6 = C$.

2. Determine a suitable value for the capacitors.
   Hint: This value can be assumed. For instance, .01μF.

3. Given a passband from 1 kHz to 1.5 kHz find the center frequency of the system.
   Hint: the pass band limits given should be considered the 3 dB points of the system.

4. Use the equation developed in task 1 to determine a value for $R$.

5. Derive and prove that there is a relationship between $Q, R$, and $R_6$.
   Use this relationship to find the value for $R_6$.

6. Simulate this circuit in a circuit simulation software such as TI-Tina and show the bode plot to show that your calculations are correct.

Theoretical Questions
1. Describe how you could verify this circuit using test equipment.
2. What are some uses for this type of filter?
3. How do the properties of the particular operational amplifier you use affect your overall circuit performance.

Extra Credit
1. Build and validate this circuit using test equipment

References