EXPERIMENT VIII

ACTIVE FILTERS

A filter is a circuit designed to pass a certain band of frequencies while attenuating all frequencies outside this band. There are three basic types of filters: low-pass, high-pass, and band-pass.

A low-pass filter passes all frequencies from DC (zero frequency) up to its cutoff frequency $f_c$. At frequencies above its cutoff frequency, the output is greatly attenuated.

A high-pass filter passes all frequencies above its cutoff frequency and attenuates all frequencies below the cutoff frequency.

A band-pass filter passes a band of frequencies between a lower cutoff frequency and an upper cutoff frequency and attenuates all frequencies outside this band.

Filter circuits are either active or passive. Passive filters consist of passive R, C, and/or L circuit elements; active filters contain some form of amplifier in addition to the passive R, C, and L circuit elements.

A filter built around an amplifier is called an "active-filter." An active filter usually just an op-amp with a frequency selective feedback network. The frequency selective feedback network shapes the frequency response curve of the op-amp.

**Low-Pass Filter:**

There are a number of active low-pass filter circuits and one of the more commonly used is shown in Fig 10.2. This circuit is a second order low-pass active filter and is a type of voltage-controlled-voltage-source (VCVS). It is also known as a Sallen-Key filter. It is a second order because there are two R-C pairs that control the frequency response. These are $R_1$, $C_1$ and $R_2$, $C_2$

![Figure 10.2: Active low-pass filter](image)

the cutoff frequency is given by:

$$f_c = \frac{1}{2\pi \sqrt{(R1)(R2)(C1)(C2)}}$$
High-Pass Filter:

The complement of the low-pass filter is the high-pass filter. A high-pass version of the second order VCVS filter shown in Fig. 10.3

![High-Pass Filter Diagram](image)

Figure 10.3: High-Pass Filter

the cutoff frequency is given by:

\[ f_c = \frac{1}{2\pi \sqrt{(R1)(R2)(C1)(C2)}} \]

Band-Pass Filter:

A band-pass filter is a circuit designed to pass signals only in a certain band of frequencies while rejecting all signals outside this band. The bandwidth BW (see figure 10.1) of the filter is defined as the difference between the upper cutoff frequency \( f_H \) and the lower cutoff frequency \( f_L \). The center frequency is \( f_c \). Actually \( f_c \) is a geometric mean, because the frequency scale of Fig 10.1 is logarithmic.

\[ f_0 = \sqrt{f_H \times f_L} \]

The ratio of the center frequency to the bandwidth is called Q or quality factor. It is measure of selectivity of the circuit.

\[ Q = \frac{f_0}{(BW)} \]

A band-pass filter may readily be formed by cascading a low-pass filter and a high-pass filter with a wide bandwidth. Figure 10.4 shows the circuit of a band-pass filter which uses a twin-T notch filter in the feedback path.
The center frequency is given by; \( f_0 = \frac{1}{2\pi RC} \) in this circuit.

**EXPERIMENTS:**

**Experiment1:**

Schematic diagram of circuit:
Part List:
741 CP op-amp, 2 pieces 10 k resistors, 22 k resistor, 3 pieces 0.01 µF capacitor, Frequency counter (if available), Dual channel oscilloscope, power supply and board.

Basic Relationships: \[ f_c = \frac{1}{2\pi \sqrt{(R_1)(R_2)(C_1)(C_2)}} \]

Procedure:
Step 1: Build the circuit of figure 10.5. The 0.02 µF capacitor consists of two 0.01 µF capacitor in parallel. The signal source is taken directly from the sine-wave output of the frequency generator.

Step 2:
Set the oscilloscope controls as follows:
- Channel 1 at 1V/div
- Channel 2 at 1V/div
- Time base at 1ms/div
- AC coupling

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Measured Gain (Vo/Vin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200Hz</td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
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<tr>
<td>1000Hz</td>
<td></td>
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<tr>
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<tr>
<td>1200Hz</td>
<td></td>
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<tr>
<td>2000Hz</td>
<td></td>
</tr>
<tr>
<td>10 kHz</td>
<td></td>
</tr>
</tbody>
</table>

Measure the cutoff frequency. This is the frequency where Vo/Vin = 0.707. If a frequency counter is not available, measure the period of one cycle on the oscilloscope and calculate the frequency from the relation: \( f = \frac{1}{T} \).

\( f_c \) (measured) = ................................................................. Hz
\( f_c \) (calculated) = ................................................................. Hz
Experiment II:

Part List:
741 CP op-amp, 2 pieces 10 k resistors, 22 k resistor, 3 pieces 0.01μF capacitor, Frequency counter (if available), Dual channel oscilloscope, power supply and board.

Basic Relationships: $f_c = \frac{1}{2\pi \sqrt{(R_1)(R_2)(C_1)(C_2)}}$

Procedure:
Step 1: Build the circuit of figure 10.6. The 20 k resistors consists of two 10 k resistor in series. The signal source is taken directly from the sine-wave output of the frequency generator.

Step 2:
Set the oscilloscope controls as follows:
- a) Channel 1 at 1V/div
- b) Channel 2 at 1V/div
- c) Time base at 1ms/div
- d) AC coupling

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Measured Gain (Vo/Vin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200Hz</td>
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<tr>
<td>500Hz</td>
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<td>2000Hz</td>
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<td>10 kHz</td>
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</table>

Measure the cutoff frequency. This is the frequency where $Vo/Vin = 0.707$. If a frequency counter is not available, measure the period of one cycle on the oscilloscope and calculate the frequency from the relation: $f = 1/T$. 

\[ \frac{<\ldots>}{2} \]
fc (measured) = ...................................................Hz
fc (calculated) = ...................................................Hz

Experiment 3:

Basic Relationships: \( f_0 = \frac{1}{2\pi RC} \), \( BW = f_h - f_l \), \( Q = \frac{f_0}{BW} \)

\[ A_v = \frac{470\, \text{k}}{47\, \text{k}} = 10 \]

Part List: 741 CP
Op-amp, 10 k resistors, 470 k resistor, 47 k resistor, 22 k resistor, 4 pieces 0.047 \( \mu \)F capacitors, 0.2 \( \mu \)F capacitor, Frequency counter (if available), Dual channel oscilloscope, power supply and board.

Procedure:
Step 1:
Build the circuit of figure 10.7. R/s is two 10 k resistors in parallel. 2 C is two 0.047 \( \mu \)F capacitors in parallel. The signal source is taken directly from the sine-wave output of the frequency generator.

Step 2:
Set the oscilloscope controls as follows:
e) Channel 1 at 1V/div
f) Channel 2 at 1V/div
g) Time base at 1ms/div
h) AC coupling
<table>
<thead>
<tr>
<th>X</th>
<th>( x_0 )</th>
<th>Measured Gain (( V_o/V_{in} ))</th>
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</thead>
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</tr>
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<td>1.3</td>
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</table>

\( x_0 \) (calculated) = \( \ldots \) \( \frac{f_o}{f_L} \) \( \ldots \) Hz

Measure the upper and lower cutoff frequencies. These are the frequencies where the gain drops to 0.707 of its maximum value.

\( f_u \) (upper cutoff frequency) = \( \ldots \) Hz

\( f_L \) (lower cutoff frequency) = \( \ldots \) Hz

Calculate the filter bandwidth and \( Q \):

\( \text{BW} = f_u - f_L = \ldots \) Hz

\( Q = \frac{f_u}{(\text{BW})} \) \( \ldots \)