 Name:____________________

PASSIVE RC FILTERS

OBJECTIVES:

1. To observe the frequency response characteristics of passive RC filters.
2. To observe the frequency response characteristics of lowpass, highpass, bandpass, and bandstop filters.

INTRODUCTION:

In electronic communications circuits, it is often necessary to separate a single frequency or a specific band (range) of frequencies from the total frequency spectrum. Frequency separation is accomplished with filter circuits. In essence, a filter is a circuit that either amplifies or attenuates a particular band of frequencies more than others.

There are four basic types of filter responses: lowpass, highpass, bandpass, and bandstop. The name describes its response: a lowpass filter passes relatively low frequencies, a highpass filter passes relatively high frequencies, a bandpass filter passes a specific band of frequencies, and a bandstop filter stops or blocks a specific band of frequencies. In addition, filters can be classified as either active (with voltage gain) or passive (with no voltage gain). A passive filter generally introduces a signal loss for all frequencies, including those that fall within its passband. The loss incurred by a frequency that falls within the passband of a filter is called insertion loss.

The simplest filters are constructed from resistors and passive frequency dependent components such as capacitors and inductors. In this exercise, the four basic types of filters are constructed using resistors and capacitors, and their frequency response characteristics are examined. The number of stages in a filter determines how rapidly its output voltage decreases (rolls off) with frequency. A stage is often referred to as a pole. The filters examined in this experiment are single-pole passive RC filters.

MATERIALS REQUIRED:

Equipment:

1 - protoboard
1 - medium frequency signal generator (1 MHz)
1 - standard oscilloscope (10 MHz)
1 - assortment of test leads and hookup wire

Parts List:

2 - 10 k-ohm resistors
1 - 4.7 k-ohm resistor
1 - 47 k-ohm resistor
2 - 100 k-ohm resistors

2 - 0.001 μF capacitors
1 - 0.002 μF capacitor
1 - 0.0022 μF capacitor

SECTION A Lowpass Filter

In this section the frequency response of a passive RC lowpass filter is examined. The schematic diagram for the lowpass filter circuit used in this section is shown in Figure 1-1. The output voltage is taken across C_1. At relatively high frequencies, the capacitive reactance is extremely low and at relative low frequencies, the capacitive reactance is extremely high. Therefore, C_1 looks like a short circuit to high frequencies and an open circuit to low frequencies. Thus, high frequencies are shorted to ground, and low frequencies appear across C_1.

The break frequency of a filter is the frequency at which the output voltage decreases by a factor of 0.707. The term break frequency implies that the output amplitude breaks into a different response at that frequency. For a lowpass filter, all frequencies below the break frequency produce approximately the same output voltage for a given input voltage, and the output voltage for all frequencies above the break frequency decreases at a rate of -20 dB per decade (i.e., -6 dB per octave). The break frequency for a lowpass filter is often called the upper cutoff frequency because it is the upper frequency limit of the filter. A factor of 0.707 was chosen as the reference value because a voltage decrease of 0.707 causes a reduction in power of 50% [i.e., $P = E^2/R$ and $(0.707)^2 = 0.5$].

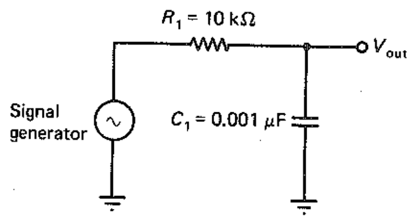

FIGURE 1-1 Passive RC lowpass filter

Procedure

1. Construct the RC lowpass filter circuit shown in Figure 1-1.

2. Calculate the upper cutoff frequency for the filter using the following formula.

$$f_u = \frac{1}{2\pi RC}$$

where f_u = upper cutoff frequency (hertz)
$R = R_1$ (ohms)
$C = C_1$ (farads)

3. Measure the output voltage for each of the following signal generator frequencies in kHz: 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 40, 60, 80, and 100. (Keep the signal generator output voltage constant at 4 Vp-p.)

4. Convert the voltages measured in step 3 to decibel values using the following formula:

$$\text{dB} = 20 \log \frac{V_{out}}{V_{in}}$$ where V_{in} = signal generator voltage, 4 Vp-p

5. Using two cycle or more semilog graph paper, plot the decibel values calculated in step 4. Use a smooth curve to connect the points on the curve.

6. From the frequency response curve plotted in step 5, determine the actual upper cutoff frequency for the filter.

SECTION B Highpass Filter

In this section the frequency response of a passive RC highpass filter is examined. The schematic diagram for the highpass filter circuit used in this section is shown in Figure 1-2. The output voltage is taken across R_1. At relatively high frequencies, the capacitive reactance is extremely low and at relative low frequencies, the capacitive reactance is extremely high. Therefore, C_1 looks like a short circuit to high frequencies, and all the signal generator's output voltage is dropped across R_1. C_1 looks like an open circuit to low frequencies and thus prevents them from reaching the output.

For a highpass filter, all frequencies above the break frequency produce approximately the same output voltage for a given input voltage, and the output voltage for all frequencies below the break frequency decreases at a rate of -20 dB per decade (i.e., -6 dB per octave). The break frequency for a highpass filter is often called the lower cutoff frequency because it is the lower frequency limit of the filter.

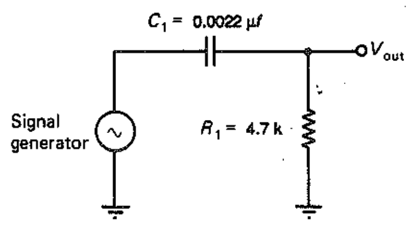

FIGURE 1-2 Passive RC highpass filter

Procedure

1. Construct the RC highpass filter circuit shown in Figure 1-2.

2. Calculate the lower cutoff frequency for the filter using the following formula.

$$f_l = \frac{1}{2\pi RC}$$

where f_u = lower cutoff frequency (hertz)
$R = R_1$ (ohms)
$C = C_1$ (farads)

3. Measure the output voltage for each of the following signal generator frequencies in kHz: 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 40, 60, 80, and 100. (Keep the signal generator output voltage constant at 4 Vp-p.)

4. Convert the voltages measured in step 3 to decibel values.

5. Using two cycle or more semilog graph paper, plot the decibel values calculated in step 4. Use a smooth curve to connect the points on the curve.

6. From the frequency response curve plotted in step 5, determine the actual lower cutoff frequency for the filter.

SECTION C Bandpass Filter

In this section the frequency response characteristics for a passive RC bandpass filter are examined. In essence, a bandpass filter is the combination of a lowpass and a highpass filter. The schematic diagram for the bandpass filter used in this section is shown in Figure 1-3a. The output voltage is taken across the parallel network of R_2 and C_2. At relatively low frequencies, C_2 looks like an open circuit, and at relatively high frequencies, C_2 looks like a short circuit.

The low-and high-frequency equivalent circuits are shown in Figures 1-3b and 1-3c, respectively. The lower cutoff frequency for the bandpass filter is the break frequency for the highpass filter, and the upper cutoff frequency is the break frequency for the lowpass filter. The filter circuit shown in Figure 1-3a has two stages (and thus two poles); however, the poles are at different frequencies. Consequently, each stage acts like an independent filter and has little effect on the frequency response of the other stage.

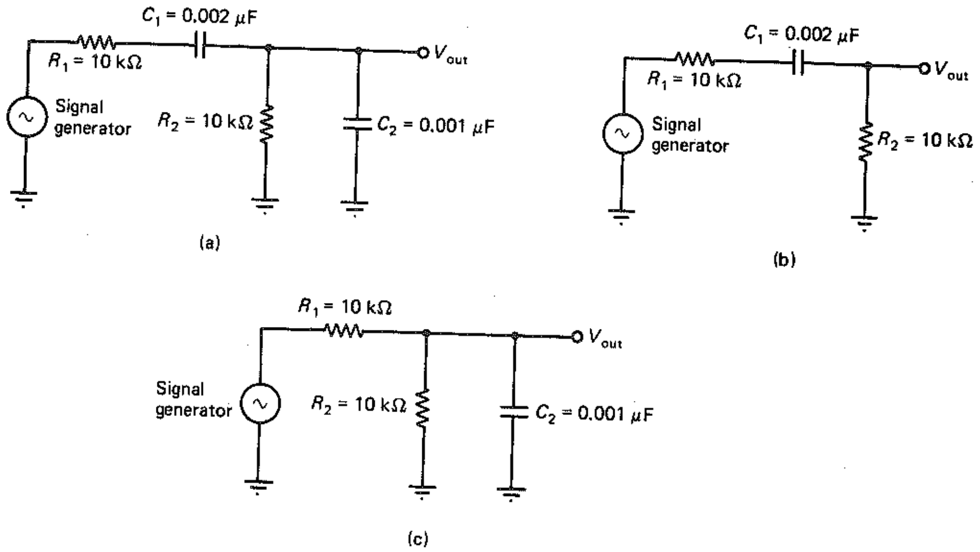

FIGURE 1-3 Passive RC bandpass filter. (a) schematic diagram. (b) low-frequency equivalent circuit. (c) high-frequency equivalent circuit.

Procedure

1. Construct the RC bandpass filter circuit shown in Figure 1-3a.

2. Calculate the lower cutoff frequency using the following formula:

$$f_l = \frac{1}{2\pi RC}$$

where f_l = lower cutoff frequency (hertz)
$R = R_1 + R_2$ (ohms)
$C = C_1$ (farads)

3. Calculate the upper cutoff frequency using the following formula:

$$f_u = \frac{1}{2\pi RC}$$

where f_u = upper cutoff frequency (hertz)

$$R = R_{th} = \frac{R_1 \times R_2}{R_1 + R_2} \text{ (ohms)}$$

$C = C_2$ (farads)

4. Measure the output voltage for each of the following signal generator frequencies in kHz: 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 40, 60, 80, and 100. (Keep the signal generator output voltage constant at 4 Vp-p.)

5. Convert the voltages measured in step 4 to decibel values.

6 Using two cycle or more semilog graph paper, plot the decibel values calculated in step 5. Use a smooth curve to connect the points on the curve.

7. From the frequency response curve plotted in step 6, determine the actual upper and lower cutoff frequencies for the filter.

SECTION D Bandstop Filter

In this section, the frequency response characteristics for a passive RC bandstop filter are examined. A bandstop filter, like a bandpass filter, is the combination of a lowpass and a highpass filter. The schematic diagram for the bandstop filter circuit used in this section is shown in Figure1-4a.

The high-frequency equivalent circuit is shown in Figure 1-4b. C_1 and C_2 look like short circuits to high frequencies; thus, high frequencies are passed directly to the output. The low-frequency equivalent circuit is shown in Figure 1-4c. C_1, C_2, and C_3 look like open circuits to low frequencies; thus, low frequencies are passed directly to the output through R_1 and R_2. However, a band of intermediate frequencies are attenuated. The equivalent circuit for frequencies near the upper cutoff frequency is shown in Figure 1-4d. The input signal voltage divides between R_1 and C_3. The upper cutoff frequency occurs at a frequency $f_u = 1/(2\pi R_1 C_3)$. The equivalent circuit for frequencies near the lower cutoff frequency is shown in Figure 1-4e. The input signal voltage divides between R_3 and C_1. The lower cutoff frequency occurs at a frequency $f_l = 1(2\pi R_3 C_1)$. The values for R_1, R_3, C_1, and C_3 are selected such that the two cutoff frequencies are separated by two octaves. Therefore, the minimum output voltage occurs at a frequency an octave above the lower cutoff frequency and an octave below the upper cutoff frequency.

Procedure

1. Construct the RC bandpass filter circuit shown in Figure 1-4a.

2. Calculate the lower cutoff frequency using the following formula:

$$f_l = \frac{1}{2\pi RC}$$

where f_l = lower cutoff frequency (hertz)

$R = R_1$ (ohms)

$C = C_3$ (farads)

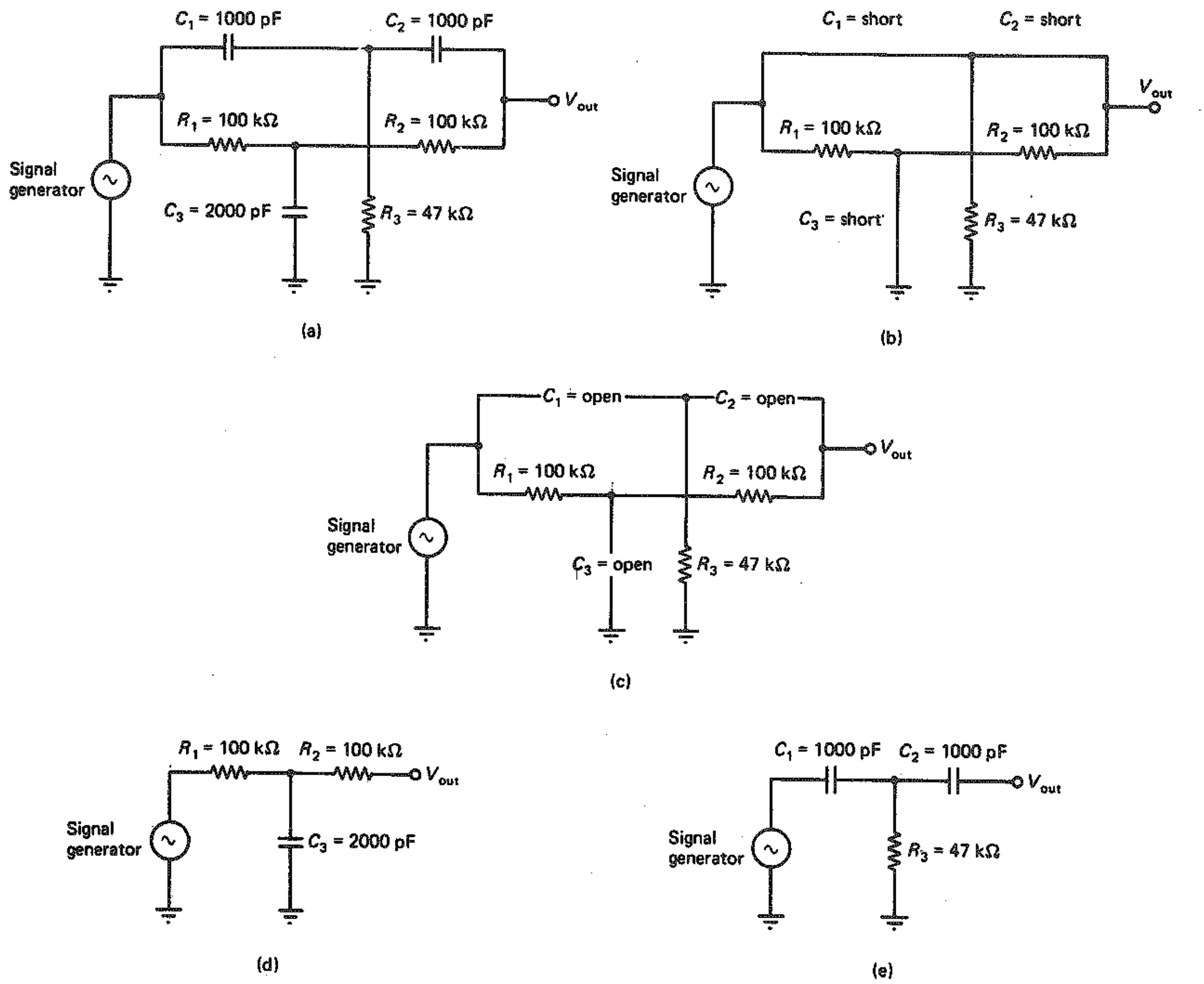

FIGURE 1-4 Passive RC bandstop filter. (a) schematic diagram. (b) high-frequency equivalent circuit. (c) low-frequency equivalent circuit. (d) equivalent circuit for frequencies near the upper cutoff frequency. (e) equivalent circuit for frequencies near the lower cutoff frequency.

3. Calculate the upper cutoff frequency using the following formula:

$$f_u = \frac{1}{2\pi RC}$$

where f_u = upper cutoff frequency (hertz)
R = R_3 (ohms)
C = C_1 (farads)

4. Measure the output voltage for each of the following signal generator frequencies in kHz: 0.1, 0.2, 0.4, 0.6, 0.8, 1, 2, 4, 6, 8, and 10. (Keep the signal generator output voltage constant at 4 Vp-p.)

5. Convert the voltages measured in step 4 to decibel values.

6 Using two cycle or more semilog graph paper, plot the decibel values calculated in step 5. Use a smooth curve to connect the points on the curve.

7. From the frequency response curve plotted in step 6, determine the actual upper and lower cutoff frequencies for the filter.

SECTION E Summary

Write a brief summary of the concepts presented in this experiment on passive RC filters. Include the following items:

1. The characteristics of passive RC filters.
2. The frequency response characteristics of lowpass, highpass, bandpass, and bandstop filters.
3. The concept of upper and lower cutoff frequencies.
4. The roll-off characteristics of single-pole filters.