

## EXP3: Operational Amplifiers II.

### OBJECTIVES.

This experiment will continue on the Operational Amplifiers study.

### INTRODUCTION AND TEST CIRCUITS.

In order to generate a signal without having any input it is required to have an Oscillator. We will study the Wien Oscillator using Op-Amp.

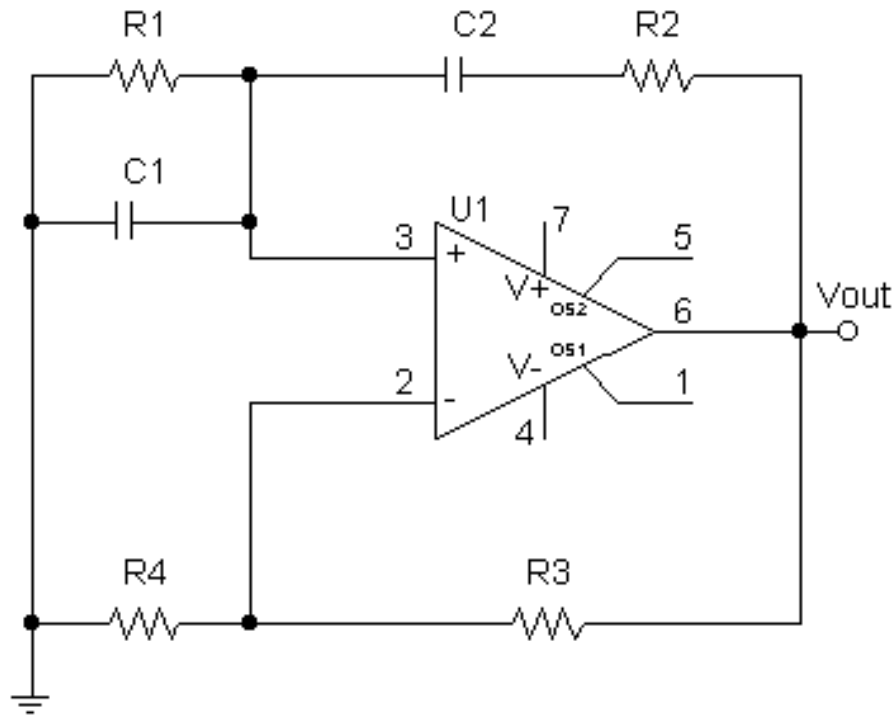


Figure 3-1: Wien Bridge Oscillator.

**Wien-Bridge Oscillator:** A Wien oscillator is an average op-amp based oscillator which gives as output a sinusoidal waveform. Figure 3-1 shows an example of such circuit. This circuit consist of a noninverting amplifier with an additional RC filter network connected between the output terminal, the  $v^+$  terminal and ground. This filter network applies an attenuated, phase shifted version of  $v_{OUT}$  to the noninverting amplifier input  $v^+$ . The circuit is designed to have a self-sustaining output, hence no input terminal is indicated. We can have three diferent cases:

1.  $R_1 \neq R_2$  and  $C_1 \neq C_2$ . For this case we can find that the resonant frequency is given by the equation 3-1.

$$\omega_F = \frac{1}{\sqrt{R_1 R_2 C_1 C_2}} \quad (3-1)$$

2.  $R_1 \neq R_2$  and  $C_1 = C_2$ . For this case we have the resonant frequency given by the equation 3-2.

$$\omega_F = \frac{1}{\sqrt{R_1 R_2 C}} \quad (3-2)$$

3.  $R_1 = R_2$  and  $C_1 = C_2$ . Now we use equation 3-3 to find the resonant frequency.

$$\omega_F = \frac{1}{RC} \quad (3-3)$$

For all of the above cases the relationship between  $R_3$  and  $R_4$  must satisfy the following.

$$\frac{1}{3} = \frac{R_4}{R_3 + R_4} \quad (3-4)$$

Now it is the turn to study some other configurations, such as.

- The Schmitt trigger: This circuit can help us to change a sine or triangular wave to a square wave.
- The Differentiator: This circuit can help us change a triangular wave to a square wave.
- The Integrator: This circuit can help us change a square wave to a triangular wave and a triangular wave to a sine-looking wave.

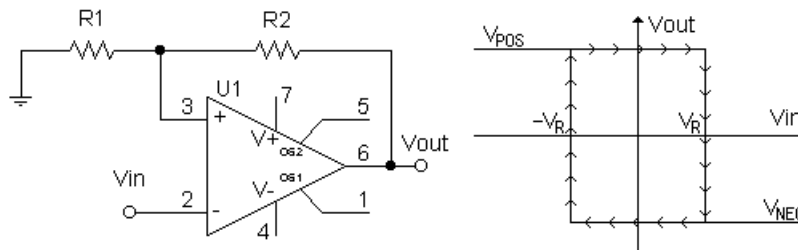


Figure 3-2: Schmitt Trigger.

**Schmitt Trigger:** The Schmitt trigger is essentially a comparator in which the reference voltage is derived from a divided fraction of the output voltage. As in the comparator, the output is forced to either a positive or negative saturation limit whenever the magnitude of  $v_{IN}$  exceeds that of the reference voltage. Unlike the comparator, the Schmitt trigger "remembers" its most recent positive or negative output and hold its output voltage even when the input voltage returns to zero. We can see in figure 3-2 the schmitt trigger configuration as well as its transfer characteristic.

The reference voltages, the most important parameters, are determined using equation 3-5.

$$V_R = \frac{v_{OUT} R_1}{R_1 + R_2} \quad (3-5)$$

**Differentiator:** Figure 3-3 shows the differentiator configuration made by using a capacitor. This circuit is intended to reshape the waveform not to amplify or attenuate, so we should be looking the point where this circuit has a unitary gain. That point in frequency is given by the equation 3-6.

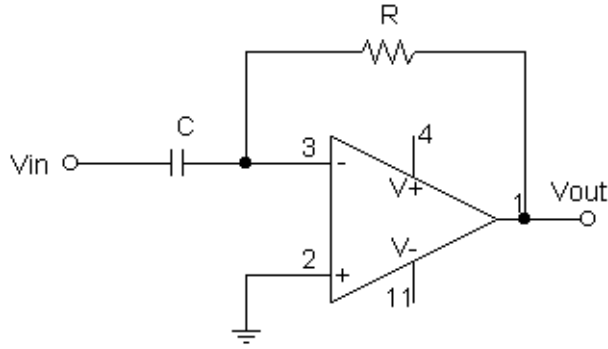


Figure 3-3: Differentiator.

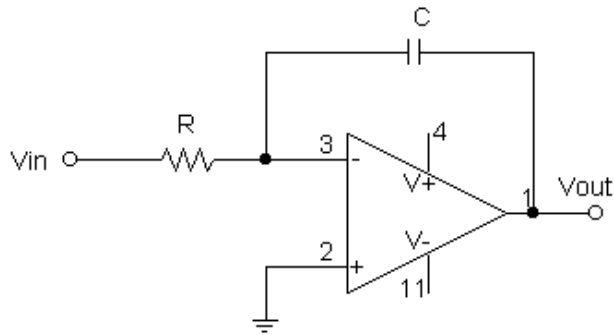


Figure 3-4: Integrator.

$$\omega = 1/RC \tag{3-6}$$

**Integrator:** This circuit, shown in figure 3-4, produces an output voltage proportional to the running time integral of the input voltage. As well as in the differentiator case we do not want to amplify or attenuate the input signal so we want to be working near the point where the inverting amplifier has a unitary gain. We can use the equation 3-6 again to find that point.

## PREPARATION.

**Note:** The supply voltages for all the circuits are  $\pm 10V$ .

**Oscillator:** Using PSpice do the schematics for the Wien Oscillator just for the case where  $C_1 = C_2 = C$  and  $R_1 = R_2 = R$ . Use  $C = 10nF$ ,  $R = 3k$ ,  $R_4 = 1k$  and  $R_3 = 2k$ . Run a transient analysis with the following parameters.

- Run to time: 101ms
- Start saving data after: 100ms

- Maximum Step Size: 10us
- Skip the initial transient bias point calculation: Checked.

This should give you an output with a frequency about 5Khz. If you would like to change the frequency then you need to change the  $R$  value. Note that if you increase  $R$  the frequency will decrease and if you decrease  $R$  the frequency will increase. Run the same circuit simulation but now using  $R = 1k$  and then with  $R = 10k$ .

**Schmitt trigger:** Use PSpice to do the schematics for the Schmitt trigger. Using  $R_1 = 1k$  and  $R_2 = 4.7k$  do the following.

- Use the part called *VPWL\_RE\_FOREVER* to generate a triangle wave and use it as input to the Schmitt Trigger. Plot the output and input.
  - TSF: 1.
  - VSF: 1.
  - FIRST\_NPAIRS: 0,0,50u,5,150u,-5,200u,0.
- Use the part called *Vsin* to generate a sine wave and use it as input to the Schmitt Trigger. Plot the output and input.
  - VOFF: 0 V.
  - VAMPL: 5 V.
  - FREQ: 5 Khz.

**Differentiator:** Use PSpice to do the schematics for the differentiator. Using  $R = 3k$ ,  $C = 1nF$  do the following.

- Use the part called *Vpulse* to generate a square wave and use it as input to the differentiator. Plot the output and the input.
  - V1: -5V.
  - V2: 5V.
  - TD: 0.
  - TR: 1u.
  - TF: 1u.
  - PW: 100u.
  - PER: 200u.
- Use the part called *VPWL\_RE\_FOREVER* to generate a triangle wave and use it as input to the differentiator. Plot the output and input.
  - TSF: 1.
  - VSF: 1.
  - FIRST\_NPAIRS: 0,0,50u,5,150u,-5,200u,0.
- Use the part called *Vsin* to generate a sine wave and use it as input to the differentiator. Plot the output and input.
  - VOFF: 0 V.

- VAMPL: 5 V.
- FREQ: 5 Khz.
- Use the part called *Vac* and do an acsweep. Plot The output/input ratio in dbs.
  - VDC=0 V.
  - VAC=5 V.
  - Set the sweep type *Logarithmic* and select *decades*.
  - Start frequency: 100.
  - Stop frequency: 100K.
  - Points/decade: 20.

**Integrator:** Use Pspice to do the schematics for the integrator. Using  $R = 3K$  and  $C = 10nF$  do the following. Note you should use a resistor in parallel to the capacitor. Use a 6.2K resistor.

- Use the part called *Vpulse* to generate a square wave and use it as input to the differentiator. Plot the output and input.
  - V1: -5V.
  - V2: 5V.
  - TD: 0.
  - TR: 1u.
  - TF: 1u.
  - PW: 100u.
  - PER: 200u.
- Use the part called *VPWL\_RE\_FOREVER* to generate a triangle wave and use it as input to the differentiator. Plot the output and input.
  - TSF: 1.
  - VSF: 1.
  - FIRST\_NPAIRS: 0,0,50u,5,150u,-5,200u,0.
- Use the part called *Vsin* to generate a sine wave and use it as input to the differentiator. Plot the output and input.
  - VOFF: 0 V.
  - VAMPL: 5 V.
  - FREQ: 5 Khz.
- Use the part called *Vac* and do an acsweep. Plot The output/input ratio in dbs.
  - VDC=0 V.
  - VAC=5 V.
  - Set the sweep type *Logarithmic* and select *decades*.
  - Start frequency: 100.
  - Stop frequency: 100K.
  - Points/decade: 20.

At the end you need to have the following plots to turn in as your prelab. The output for the oscillator for each of the three different values of  $R$ , two plots for the Schmitt Trigger, four plots for the differentiator and four for the integrator. The above gives a total of 13 plots.

## **PROCEDURE.**

You need to perform the same things you did in the preparation section.

Use the VI called freqlog to get the frequency response in magnitude. This plot is to be similar to the one you got from the acsweep.

## **ANALYSIS.**

Do a mathematical derivation of the outputs of all the circuits studied in this experiment.