ENGR 210 Lab 8

Non-linear Op-amp Circuits

Equipment Required:

• 1 - HP 54xxx Oscilloscope
• 1 - HP 33120A Function Generator
• 1 - Protoboard
• 1 – 741 Op-Amp
• 1 - 0.1-μF capacitor
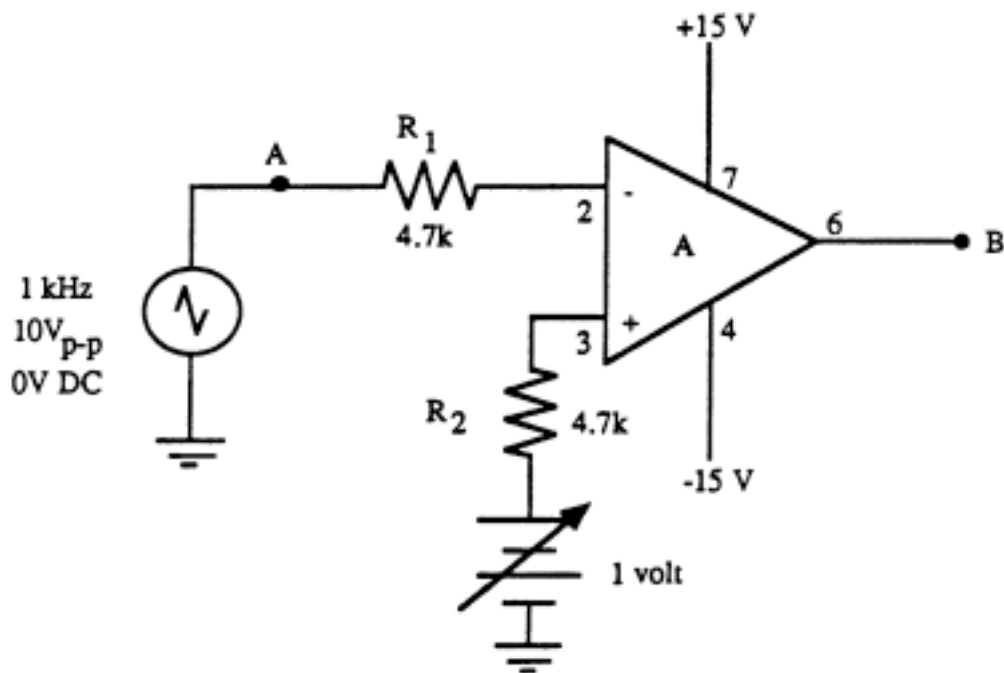• 1 - 1.1-k Ω resistor
• 1 - 0.22-μF capacitor
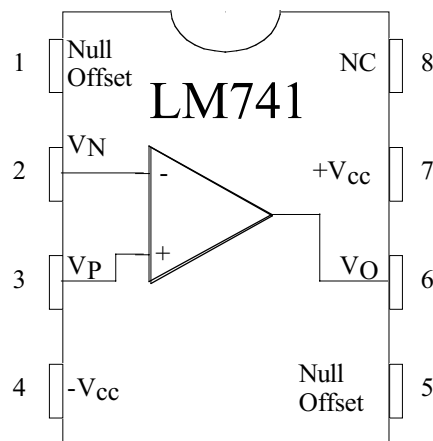

Figure 1 - Op-Amp comparator circuit

Figure 2 - 741 Op-Amp Pinout

Part 1: No noise
   (1) Build the comparator circuit of Figure 1. The variable DC offset shown connected to the positive terminal of the Op-Amp is generated by using the 5V part of the triple power supply. Initially, this voltage is to be set to 0V.
   (2) Using the waveform generator, create a triangular input signal to the negative terminal of the Op-Amp with a frequency of 1kHz, an amplitude of 10 $V_{p\text{-}p}$ and 0 DC offset.
   (3) Display points A and B (input and output respectively) simultaneously on the oscilloscope and record each waveform using HP Benchlink. For more information on how to do this, see Appendix 1. Print these out and turn them in with your lab report.
   (4) Carefully note the phase difference between A and B and note the two switching points in Table 1. The phase difference is defined to be the time difference between the time the input waveform (point A) crosses 0V and the time the output waveform (point B) crosses 0V. To do this, use the cursors and set measurement to time. Place one cursor on the place where the input waveform crosses 0, and place a second cursor on the place where the output crosses 0. Note that this may require manual re-centering of the waveforms, especially if you use autoscale.
   (5) Set the DC offset to +1V and again note the phase difference between points A and B as well as the switching points.
   (6) Repeat step (5) for +2V and +3V DC offset, and at +3V only, again record the waveforms with HP Benchlink Scope.

Noise:
A "noisy" signal can be thought of as the sum of a desired signal and other, unwanted signals. The result is a signal which generally follows the desired one, but which deviates from it. If a noisy signal is fed into a comparator, the noise will cause unwanted changes of state at the output as the desired signal crosses zero volts.

Part 2: with noise
For the second part of this lab, use your signal generator to generate a noisy input signal for your comparator, and see the results. To do this:

   (1) To generate **simulated** noise, similar to that from an electrical power line, on your waveform generator, press shift, then press Arb, next press the right arrow until you see "USHUM", and then press Enter.
   (2) Display the waveforms at A and B and record them in Table 2 making note of the phase difference between them. It may not be possible to get an absolutely stable trace on the scope. Using Benchlink, record the waveforms from the scope at an offset of 0V.
   (3) Make note of exactly what takes place when the waveform at B changes state.
   (4) Repeat measurements with DC offset of +1V,+2V,and +3V. Again record and printout the waveforms at +3V.

Part 3 – The Schmitt Trigger and Noise

The amplifiers you built in previous labs used negative feedback – a resistor feeding the output signal back to the inverting input. By using positive feedback – a resistor feeding the output back to the non-inverting input – the two switching points can be moved further apart. Consider the circuit of Figure 3 and assume that the input is zero, that the output is +15 volts, and that R2=R3. R2 and R3 set the voltage at the non-inverting input to +7.5 volts, (V+-V-) is greater than 0, and the output is indeed forced to +15 volts. If we raise the voltage to slightly above 7.5 volts, e.g., +7.50015 volts, then A(V+-V-) is greater than -15 volts and the output switches to –15 volts. This changes the voltage at the non-inverting input to –7.5 volts which makes (V+-V-) very negative, maintaining the output at –15 volts. The output will stay at –15 volts until the input drops to slightly below –7.5 volts, e.g., –7.50015 volts which will make A(V+-V-) go to +15 volts, setting the output to +15 volts, setting the non-inverting input to +7.5 volts. This makes (V+-V-) very positive, maintaining the output at +15 volts. We can summarize the operation of the circuit by saying that, when the input goes above the upper switching point, the output will go negative and stay negative until the input gores below the lower switching point. This characteristic is called "hysteresis" and this type of circuit is called a "Schmitt trigger."
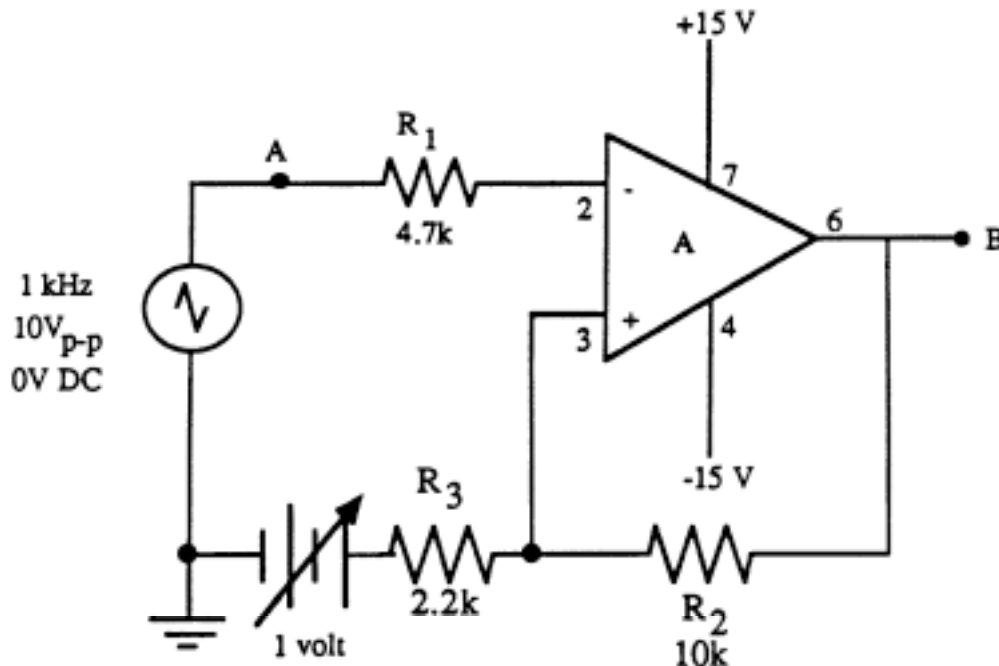

Figure 3 - Schmitt trigger

(1) Build the Schmitt trigger circuit of Fig. 3 with R_2 = 10K and R_3 = 2.2K. Use the same input waveform as you used in Part 1 and initially set the DC offset to 0V.
(2) Display points A and B simultaneously on the oscilloscope and record the waveforms using Benchlink.
(3) Carefully note their phase difference and the two switching points.
(4) Slowly vary the DC offset between 0V and +3V and observe what happens at point B.

DATA AND REPORT SHEET FOR LAB 8

Student Name (Print): _____ Student ID: _____

Student Signature: _____ Date: _____

Student Name (Print): _____ Student ID: _____

Student Signature: _____ Date: _____

Student Name (Print): _____ Student ID: _____

Student Signature: _____ Date: _____

Lab Group: _____

Part 1 - No Noise

Data Table 1.

DC Offset	Phase difference	Switching point
0V		
1V		
2V		
3V		

Questions:
Describe what point B does as the triangle wave goes from its lowest to highest and back to its lowest voltage.
Explain why the relative phase acts as it does when you change the DC offset.

Part 2 – with Noise

Data Table 2. Noisy Circuit

DC Offset	Phase difference	Switching point
0V		
1V		
2V		
3V		

Questions Noisy Circuit:
Describe the input waveform at point A in Fig. 2.

Describe why point B changes state several times before stabilizing.

Why does this sort of comparator have problems with a "noisy" signal?

Questions Part 3

Calculate the switching points for the circuit of figure 3 without using your experimental data. SHOW WORK!!

What switching points are indicated by the scope?

Why aren't they the same as your calculated values?

Explain why the signal at point B acts as it does when you change the DC offset.

Don't forget to attach your 5 Benchlink waveform printouts.

Appendix 1
Using Benchlink® Scope to print HP scope waveforms

The Benchlink® Scope software uses the HPIB board inside the PC to read the image that the oscilloscope displays on its screen. This picture file is then displayed on the PC and can be copied, printed and saved as a bit map for use in any program. This software only works with HP 54xxx series scopes like we have in the laboratory.

To use Benchlink® Scope software to capture a waveform:
1. On the PC, from the All Programs menu, go to Benchlink® suite under "Courseware" and choose the Benchlink® Scope program.
2. As Benchlink® opens up it will search for the oscilloscope and (if successful) will display the window shown below:

    If the program brings up an error window claiming that it can't find the device, command the program to search on "National Inst. GPIB," then click "OK."
3. If you get an error message make sure that the scope is turned on.
4. Next, click on the **Image** menu and choose **New....**

5. Click OK on the dialog box when you are ready to capture the scope image.

6. The oscilloscope image is then displayed on the screen as a bitmap. Press F7 to update this image as often as you wish. You can Print or Copy this image or save it as a file.