Lab 3, Comparators and Diode/Capacitor Circuits V23.2

Saturday Schematic due for Problem 3.

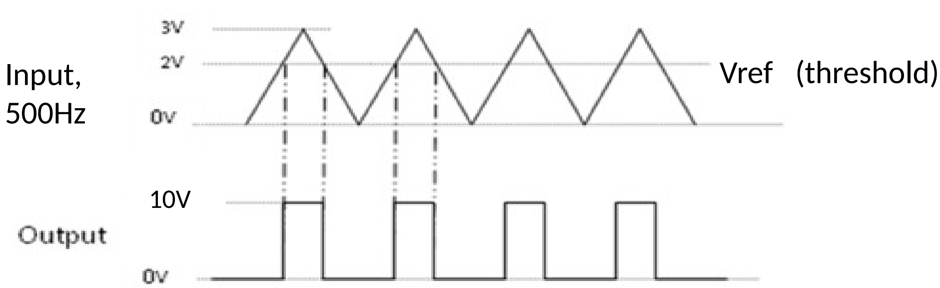
1A: The Basic Comparator:

•Design a comparator circuit that "squares up" a 3Vp, 500 Hz triangular waveform as shown below. Use ¼ of an LM339 comparator operating on a single 10V supply; use a 1K resistor for the pull-up resistor. Do not use any hysteresis (yet). The input waveform will be supplied from the HP 33120A function generator; be sure to use the offset- voltage adjust to produce the zero-referenced triangular waveform shown. Produce Vref with a divider across the supply.

•Record the comparator output waveform. Expand the trace (50nsev/div) or use the *zoom* mode to observe the rise time and fall time in detail; trigger on both the positive and negative slope to view each transition. Are the transitions perfectly clean? Record a scope trace that verifies this.**(P)** Be sure to review the datasheet for the LM339, including the "notes" on the input and output characteristics.

•Change the pullup resistor to 47K and explain the observed changes to the output waveform. **(P) Why are the rise and fall times unequal?** You may have to review the LM339 datasheet to answer this.

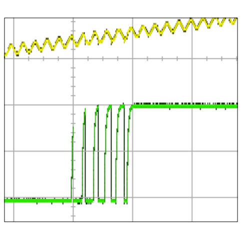
• What happens to the duty cycle of the output waveform as the threshold voltage changes?



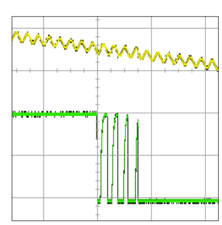
1B: The Comparator with Hysteresis:

•Repeat 1A, but with "noise" added to the comparator input signal: set the 33120 generator to AM and modulate the triangle waveform in 1A with a 20KHz signal*. The amplitude of the noise component should be about 0.1Vpp. Carefully set up your scope so you can see multiple transitions similar to those shown below. or Use *Normal* trigger mode; it may be helpful to carefully adjust trigger level and press Run/Stop to freeze the display to insure that you are not confusing "jitter" with multiple transitions. *Zoom* mode may help. **Record rise and fall waveforms. (P)**

Trigger on **+**slope



Trigger on **-**slope



•Modify your comparator circuit by adding positive feedback to provide hysteresis that exceeds the noise voltage and eliminates the multiple transitions. Carefully observe the rise and fall times for smooth, single transitions. **Record your schematic and rise and fall waveforms. (P)** Also, **Record the waveform at the positive input of the comparator and prepared to discuss it during recitation. (P)**

* Instructions for setting up the function generator can be found in the Canvas Modules for Lab 2/3.
You may, as an option, use the waveform generator built into the DSOX oscilloscopes; use the noise modulation function and set the noise level until you get a waveform similar to the one shown.

2A: Passive Peak Detector:

•Build a simple, passive peak detector with a diode and a .01uFd capacitor. Test your circuit with an input pulse 2 millisecond wide, a frequency of 50 Hz (10% duty-cycle), and an amplitude of 4.0 volts (baseline is zero). Include a 1K resistor in series with the function generator, making the total source resistance 1050 ohms. The output load will consist of the 10 Meg oscilloscope probe only.

•Your peak detector should accurately acquire the peak value and hold it during the interval between pulses, with minimal decay ("droop"). At the same time, this decay is important because it serves to "reset" the peak detector and allows it to follow input pulses that are decreasing in amplitude; without this slow discharging of the capacitor, the peak detector output would stay at its maximum value and never change. Observe this by slowly decreasing the signal generator output pulse height. **Evaluate the performance of this circuit; obviously use two scope channels. In what ways does it not perform well? How does the source resistance affect operation? (P)**

2B: Active Peak Detector

•Design a peak detector that uses active components and accepts the pulse input described in Part 2A. Your circuit will use 741 op amp(s) operating on +/_ 15V; the "hold" capacitor will again be .01uFd. Remember that you must accommodate the input bias current of the op amp(s). Make sure that the output of your peak detector will track peak inputs that are slowly increasing and decreasing. **(P)**

•How does the addition of op amp(s) improve the performance over that of the "passive" peak detector?

•What critical op amp specification(s) determines the droop of the output?

•How does the performance of your circuit change when using the LF356 op amp in place of the 741? The 356 is available in the lab stock. What is different about the LF356? (P)

3: Audio Impulse Detector

You will be provided with a piezo "beeper". This transducer can function as both a speaker and a microphone. The beeper leads are spaced 0.4 inches apart, and they can be *gently* inserted into your solderless breadboard if you are very careful to not bend them. Before inserting the leads, make sure that the two solderless breadboard holes are clear and loose by inserting a resistor or jumper lead.

You are to design, build, and test a circuit that will reliably produce a single LED pulse every time a 3/8" diameter steel ball is dropped Into the heavy plastic base from a height of about 4 inches. Locate the base about 6 inches from the sensor and place it in the provided paper plate to catch the ball. Only <u>one</u> LED pulse must be produced with each drop of the ball (**NOT** with each bounce), and <u>the ON time must be independent of the audio pulse amplitude **and** the number of bounces.</u> You may use a single or dual supply.

Carefully think about how to approach this problem. With your oscilloscope, carefully measure and record the output waveform. As you would expect from observing the way the ball-bearing bounces ("That's the way the ball bounces"), the microphone will produce a voltage spike every time the ball strikes the base. Therefore, there may be a train of 3 or more short pulses of diminishing amplitude. You should sense the first pulse.

Observing this waveform on the oscilloscope will require that you learn the operation of the "single" sweep mode (with trigger mode "normal", not "auto"). You can also experiment with the "start/stop" mode as another way to conveniently observe the transient waveform. Using the "zoom" function on the oscilloscope will also help you to analyze the waveform of the Individual "spikes". Be prepared to demonstrate these measurement techniques during your recitation. **(P)**

Evaluate the output waveform and think about how you will process the signal. Remember that comparators require relatively large input signals to operate, so a gain stage will probably be needed. What frequency response, gain, and input impedance will an amplifier need to produce a signal with suitable amplitude for processing? Don't forget about gain-bandwidth product.

Since there will be a lot of variability in the audio amplitude, it will be valuable to provide an adjustable comparator threshold as a **sensitivity control**. The LED ON time is not important, but the ON time **must be independent** of the drop height and sensor distance. Also, the LED **must "snap" on and off** and not gradually increase or decrease in brightness. **(P)**

A comment on components for problem #3: I suggest you use the LM324 quad, single-supply op amp. The input transducer pulse will go both positive and negative, but in this case, you can use a single-supply op amp and simply ignore the negative pulse. Note that driving inputs of an op amp or comparator below the negative rail is forbidden for most parts. However, since the amplitude in this case is so small it will not be a problem. We have LM339 quad comparators in the lab which would also be a good choice.

Both of these parts employ PNP transistors at the input differential amplifiers. This means that bias current flows out of the inputs and, most importantly, the inputs can operate down to ground. The maximum input voltage is about two volts below the positive rail.

Please provide a block diagram of your system, as well as a preliminary schematic, of Problem 3 by 6:00 PM Saturday. Be prepared to demonstrate the circuit during recitation.

Optional: If you are up for a small challenge, make the duration of the LED ON time equal to about 20 ms. However, provide the necessary circuitry so that even with this short LED pulse, there is still only a single LED flash with each drop (not each bounce) of the ball. Again, the LED ON-time must be independent of the pulse audio amplitude.

Important:

● Always work stage by stage. It is essential that, with a multi-stage design like this, you get each stage to work independently before you connect them together. If you keep in mind the concept of "loading", and are careful with input and output impedance, you can eventually couple the stages together and you will have a working design. You can may have to go back and adjust gain or frequency response, for example, but Is much easier to troubleshoot a circuit stage-by-stage.

Remember, if you have one crummy stage and connect it to another crummy stage, you will simply end up with crummy^2. I cannot stress this enough.

● Start with a preliminary schematic that you think is close, and then modify it as you test sections and verify the design. You will need this, anyway, for your recitation.

● You can't design your first stage until you have characterized the microphone. You can see the output waveform on the scope, but you must also determine the approximate output resistance of the microphone; otherwise, you don't know what the input resistance requirements are for the first stage. You can do this just as you determined the series resistance of a battery in the first lab.