67 Triggering Circuits

Objectives

1. To test the operation of a simple op amp Schmitt trigger circuit.
2. To examine an "input versus output" oscilloscope plot for an op amp Schmitt trigger circuit.
3. To evaluate the operation of a zero crossing op amp detector circuit.
4. ~~To simulate triggering circuits using Electronics Workbench™ software running in a Macintosh™ or Windows™ environment, or other similar software.~~

Equipment

2 Resistors: 1 kΩ, 4.7 kΩ
1 Capacitor: 10 nF
1 1.5 V battery
1 LM741 operational amplifier

Information

A typical Schmitt trigger circuit is shown in Figure 67-1. If the inputs were reversed in polarity, it would seem the same as a non-inverting op amp with the usual negative feedback. As the circuit is, however, the feedback is positive instead of negative, so the op amp is unstable. This means it will oscillate, in this case, switching back and forth between the positive and negative rails. The voltages at which the circuit switches are of interest to anyone studying this circuit.

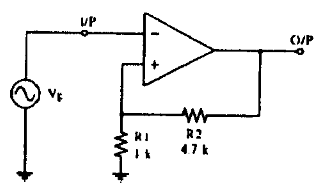

Figure 67-1. Schmitt Trigger Op Amp Circuit

To understand the switching voltages, consider the voltages shown on Figure 67-2 (a). Assume the circuit is powered by ± 15 V split supply. The input could be a 10 Vpp sine wave. At the instant shown, the sine wave could be at 1.00 V, with the polarity as shown in Figure 67-2 (a). Assuming the output was at the positive 15 V rail, voltage divider action of R1 and R2 (see Figure 67-1) would produce a feedback voltage of 2.63 V across R1 in the polarity shown in Figure 67-2 (a). With the input and feedback voltages as shown, the op amp input voltage would be 1.63 V with the polarity shown in Figure 67-2 (a). The 1.63 V would be multiplied by the open loop gain of the op amp, which might easily be 100,000 or more. This would be (−1.63) x (−100,000) and the output of the op amp would be held at the positive rail, or +15 V.

Assume now that the input rises to exactly 2.63 V. Refer to the voltages given in Figure 67-2 (b). From top to bottom, these are the op amp input, the generator input, and the feedback voltage. These voltages now replace the three voltages shown on the schematic. If the input and feedback voltages were both 2.63 V, the op amp input would be 0.00 V. But when the op amp input becomes 0.00 V, the output would also be 0.00 V, and therefore the feedback voltage would drop to 0.00 V as shown in the voltages of Figure 67-2 (c). If the feedback voltage was 0.00 V, and the generator voltage was 2.63 V, the op amp input voltage would become 2.63 V. This would mean that the output voltage would be (+2.63) x (−100,000) and the output of the op amp would be held at the negative rail, or −15 V. This would cause the feedback voltage to become 2.63 V, with the polarity as shown in Figure 67-2 (d). Now the op amp input voltage would become 5.26 V, which would continue to hold the output at −15 V.

The student may wish to use separate diagrams to show the above changes as they occur. A blackboard is ideal since the changes may be made easily, as they happen. Understanding the Schmitt Trigger action is not really difficult, describing it is quite another matter as the preceding paragraph shows.

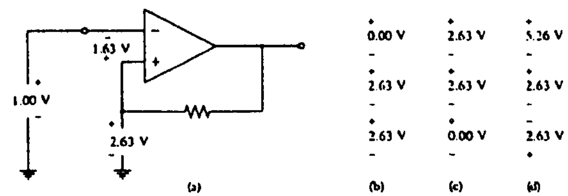

Figure 67-2. Schmitt Trigger Switching Voltages

The output will continue to stay at −15 V until the generator voltage drops to −2.63 V, at which point one can work through a similar scenario to show that the output will change as expected.

The switching points of a Schmitt trigger circuit are often shown on an "input versus output" plot. For this circuit, such a plot is illustrated in Figure 67-3. This may be viewed on most oscilloscopes quite easily. The triggering levels of a Schmitt trigger may be altered by the addition of reference voltages into the circuit.

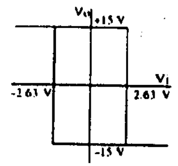

Figure 67-3. Schmitt Trigger Vi versus Vo Plot

The zero crossing detector shown in Figure 67-4 is basically the same comparator circuit as was studied in an earlier experiment, except that an RC shaping circuit has been added to the output.

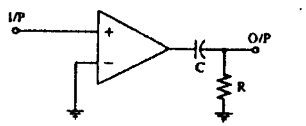

Figure 67-4. Zero Crossing Detector

This circuit would normally have an output of +V whenever the input is positive, an -V whenever the input is negative. The addition of the RC circuit causes the output square wave to change to a spike corresponding to each time the input waveform crosses zero volts.

OMIT

Circuit Simulation

1. Simulate the Schmitt Trigger circuit of Figure 67-5 using Electronics Workbench™ software. As in the previous experiment, set the unity gain bandwidth (fu) and the compensation capacitance (Cc) both to zero.

2. Sketch the input and output waveforms, in proper phase, as required for Table 67-1. Alternately, your instructor may wish you to attach a print of the waveforms to your Simulation Summary sheet.

3. Set the scope for an X versus Y presentation (or B/A). Sketch the resulting waveform as required for Table 67-1.

Table 67-1. Schmitt Trigger Simulator Measurements

Input and Output Waveforms vs Time	Input Waveform vs Output Waveform

4. Alter the circuit by adding a voltage source as shown in Figure 67-6. Repeat the input and output waveforms and the X versus Y presentation as required for Table 67-2.

Table 67-2. Schmitt Trigger With Reference Simulator Measurements

Input and Output Waveforms vs Time	Input Waveform vs Output Waveform

5. Simulate the zero crossing detector circuit of Figure 67-7 using Electronics Workbench™ software. Again, set the unity gain bandwidth (fu) and the compensation capacitance (Cc) both to zero. Use a 0.1 µF capacitor for the simulation circuit.

6. Sketch the input and output (of the op amp) waveforms, in proper phase, as required for Table 67-3.

7. Sketch the input and output (of the circuit) waveforms, in proper phase, as required for Table 67-3.

Table 67-3. Zero Crossing Detector Simulator Measurements

Input and Output (of op amp) Waveforms vs Time	Input and Output (of circuit) Waveforms vs Time

Schmitt Trigger lab – simulation.

The op-amp in gnucap. (not spice)

```
Eopamp  1  0  2  3  TANH  gain=10000 limit=15
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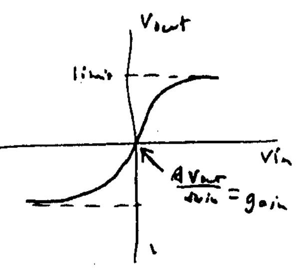
↑ (Eopamp) ↑ out ↑ +in ↑ -in ↑ (TANH)

E = voltage controlled voltage source

smooth clip nonlinear function



Then do a DC sweep –
both directions –
It will behave different sweeping up or down.

```
DC  Vin  -15  15  1
```

← Sweep the value of Vin from -15 to +15 in 1 volt steps.

In Gnucap, you can sweep any simple component.
In spice, only fixed sources

Procedure

Schmitt Trigger Circuit

1. Connect the circuit of Figure 67-5. Connect a 10 Vpp 1 kHz sinewave to the input of the circuit.

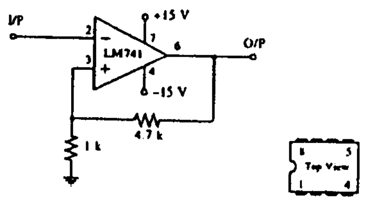


Figure 67-5. Schmitt Trigger Circuit

Also:
Use a third
DC power supply
as the input.
Vary it between
−10 and +10
and see what
happens.

2. Measure and record in Table 67-4 the input and output waveforms of the circuit of Figure 67-5, drawn in proper phase with each other.

3. If possible, set your scope for viewing an X-Y waveform. Connect the X input of the scope to the input of the circuit, and connect the Y input of the scope to the output of the circuit.

4. After making sure that the X-Y waveform is centered vertically and horizontally, measure and record the waveform in Table 67-4.

Table 67-4. Schmitt Trigger Measurements

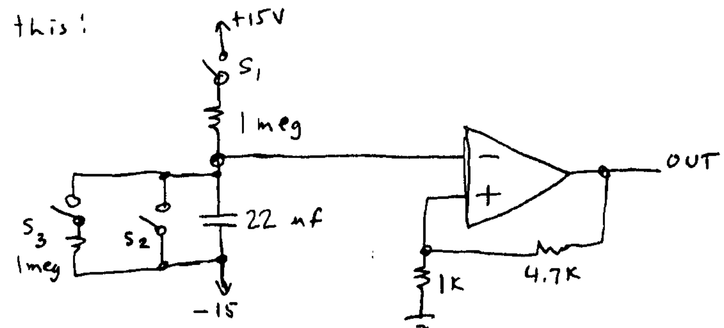
Step	Measurements	Waveforms
2		
4		

Do this after step 4, before step 5.

Take the first circuit "schmitt trigger"

Instead of a sine wave as input.

Try this:



Begin by shorting S_2 to discharge the Capacitor. (with power on)

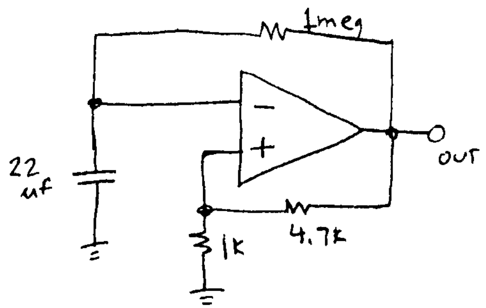
Then open it. What is the output of the op-amp?

Close S_1 and observe the output of the op-amp. What does it do?

After a few minutes, open S_1 and close S_3. What does it do?

You don't really need switches. Just move the wires, with power on.

Now, modify your circuit to this:



(Hook the 1meg resistor to the output instead of + or − power).

It should be an oscillator.

What is the frequency? What is the waveform?

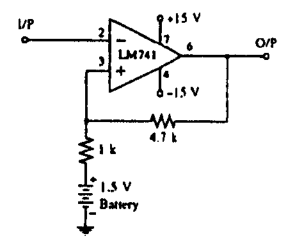
Success if you get this far.

Bonus for going on...

BONUS

Schmitt Trigger Circuit With Reference

5. Modify the circuit of Figure 67-5 into that shown in Figure 67-6. Use the same 10 Vpp 1 kHz sinewave to the input of the circuit.



You can replace the 1k resistor and battery with 2 resistors, connected properly. Find the equivalent circuit and use it instead. Use the nearest standard values.

Figure 67-6. Schmitt Trigger With Reference

6. Measure and record in Table 67-5 the input and output waveforms of the circuit of Figure 67-6, drawn in proper phase with each other.

7. If possible, set your scope for viewing an X-Y waveform. Connect the X input of the scope to the input of the circuit, and connect the Y input of the scope to the output of the circuit.

8. After making sure that the X-Y waveform is centered vertically and horizontally, measure and record the waveform in Table 67-5.

Table 67-5. Schmitt Trigger With Reference Measurements

Step	Measurements	Waveforms
6		
8		

BONUS

Zero Crossing Detector

9. Connect the circuit of Figure 67-7. Connect a 3 Vpp 100 Hz sinewave to the input of the circuit.

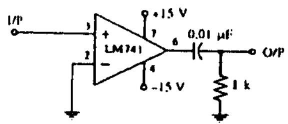


Figure 67-7. Zero Crossing Detector Circuit

10. Measure and record in Table 67-6 the input and Pin 6 waveforms for the circuit of Figure 67-6, drawn in proper phase with each other.

11. Measure and record in Table 67-6 the input and output waveforms for the circuit of Figure 67-6, drawn in proper phase with each other.

Table 67-6. Zero Crossing Detector Measurements

Step	Measurements	Waveforms
10		
11		

STOP HERE

67 Simulation Summary

Name ____________________

1. Complete the simulation data required for Table 67-1 below.

Input and Output Waveforms vs Time	Input Waveform vs Output Waveform

2. Complete the simulation data required for Table 67-2 below.

Input and Output Waveforms vs Time	Input Waveform vs Output Waveform

3. Complete the simulation data required for Table 67-3 below.

Input and Output (of op amp) Waveforms vs Time	Input and Output (of circuit) Waveforms vs Time