Lab 10: Schmitt Trigger
U.C. Davis  Physics 116B (Rev. 05)

Reference: Bobrow, pp. 704-710

Prelab Problem: Prove Equation 1 (include in your lab notebook).

INTRODUCTION

Like the Wien bridge oscillator in 116A, the Schmitt trigger is an application of positive feedback. This circuit is a voltage comparator with hysteresis. A voltage comparator will give as its output one of two voltages:

\[ V_{\text{out}} = \begin{cases} +15 \text{V} & \text{for } V_{\text{in}} > V_{\text{th}} \\ -15 \text{V} & \text{for } V_{\text{in}} < V_{\text{th}} \end{cases} \]

where \( V_{\text{th}} \) is a threshold voltage. A voltage comparator with hysteresis will have a different \( V_{\text{th}} \) for rising input voltages than for falling input voltages.

In this lab, we will build a Schmitt trigger using the 741 op amp, our analog circuit workhorse. We will measure \( V_{\text{th}} \) and verify the circuit’s operation as a voltage comparator.

1. SCHMITT TRIGGER

The Schmitt trigger circuit is shown in figure 1. Build this circuit at least twice, each time with a different set of resistors. Some recommended values are 10k\( \Omega \), 10k\( \Omega \), 100k\( \Omega \); or 10k\( \Omega \), 10k\( \Omega \), 1M\( \Omega \); or 10k\( \Omega \), 22k\( \Omega \), 100k\( \Omega \).

Use the variable voltage supply for \( V_{\text{in}} \) and measure it with the voltmeter. Measure \( V_{\text{out}} \) with the oscilloscope and note how fast the output switches from +15V to -15V. For each set of resistors, record \( V_{\text{th}} \) for both positive and negative transitions. See how close they are to the predicted values:

\[ V_{\text{th}} = \frac{R_2 \cdot R_3}{R_2 + R_3} V_{bb} + \frac{R_1 \cdot R_2}{R_3} V_{\text{out}} \]  

(1)

For your lab report, report these measured and predicted voltages and draw them on a \( V_{\text{out}} \) vs \( V_{\text{in}} \) curve showing the hysteresis loop. (Make a separate drawing for each set of \( R \)'s.)

For each set of resistor values, apply a sine wave or a triangle wave to the input and sketch the output. For your lab report, sketch these waveforms, showing the input voltages where the output switches and compare these to the \( V_{\text{th}} \)'s you measured with the voltmeter.

2. SIMULATED NOISY SOURCE

To see how a Schmitt trigger might be useful, we will construct a source with some fake noise introduced into it. Figure 2 shows how to do this using two function generators and a second op amp, used as a summing amplifier. Build this circuit and use it as the input to your Schmitt trigger. Regard the 1 kHz sign wave as the "signal" and the 10 kHz sine wave as the "noise". For your lab report, sketch the input and output waveforms, being careful to show each time the input crosses a \( V_{\text{th}} \) and what the output does in response. Try to determine approximately how much hysteresis is required to filter out a given amount of noise.

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Fig 1: Schmitt trigger circuit.

Fig 2: Simulated noisy source.
Notes on Lab 10 (Schmitt Trigger)

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I. Be sure to set the +15 V and -15 V power supplies to the proper values before connecting them to the rest of the circuit.

II. If available, use an LF411 op amp instead of the LM741 for the Schmitt trigger. The LF411 has a maximum slew rate of 10 V/μs, much faster than the 741 (0.5 V/μs). Use a 741 for the summing amplifier (speed is not an issue here).

III. The breadboards have only two variable voltage sources, which are in use for the ±15 V op amp supplies. You can use the 10 kΩ pot to produce a variable voltage for the Schmitt trigger V_in. One end of the pot resistor should go to +15 V and the other to -15 V. The center connection then provides the variable voltage. Caution: do not use the 1 kΩ pot. It would dissipate too much power and burn out.

Alternatively, you can use a triangle wave input for V_in and simultaneously observe V_in (Ch. 1) and V_out (Ch. 2) on the oscilloscope (you are asked to do this anyway). Trigger on Ch. 1. You can then measure the values of V_in when the output switches and the time required for the output to switch.

You can also use the x-y display feature of the oscilloscope (in the “horizontal” menu) to display V_out (y, Ch 2) vs. V_in (x, Ch. 1). This is the hysteresis loop diagram (excitation curve).