2CJ4 – Lab 2 – Set 2 – Schmitt Trigger

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Introduction:

In many electronics applications, signals are noisy and change too slowly. This makes it hard for digital circuits to tell the difference between the high and low states. A Schmitt trigger is a type of comparator that is used to add hysteresis, meaning its voltage level for turning on is different for turning off. This reduces noise that is picked up and makes the signal much more stable. Schmitt triggers are often made using op-amps or logic gates with feedback. Their main feature is that they produce a clear and stable digital output, even when the input signal is weak or fluctuating. Schmitt triggers are commonly used to remove noise, shape waveforms, stabilize signals, and stop switches from false triggering.

Operational principle of the experimental circuit:

In this lab, a Schmitt trigger circuit was built using an operational amplifier. The circuit is made by an op-amp, a voltage divider (two resistors), and a feedback loop that determines the switching thresholds. Unlike a standard comparator, the Schmitt trigger has an upper threshold, where if Vin rises above this value, the output switches to a low state, and a lower threshold, where if Vin drops below this value, the output switches to a high state. Since there are two thresholds, the output does not change unless Vin moves a lot. The feedback network is connected to the op-amps non-inverting input, which ensures that once the output changes, it stays in that state until the input crosses the other threshold.

Measurement Results:

i) From the background section, explain why when we increase or decrease $v_{in}(t)$ such that $V_{th2} < V_{in}(t) < V_{th1}$ the output remains the same.

A Schmitt trigger keeps the output the same until the input voltage crosses a set threshold. This prevents unwanted switching due to small changes or noise in the signal. When $V_{in}(t)$ is between V_{TH2}, and V_{TH1}, the circuit holds its previous output because of positive feedback. This makes the circuit more stable. The output only changes when the input goes beyond V_{TH1}, or V_{TH2}, switching between its two states.

ii) Given the circuit from Figure 2 in the example section, fill in the following table using V_{ref} = 0V, 2V, R_1= 4.7kΩ, 22kΩ and R2 = 4.7kΩ. (assuming V_{sat+} = 5V and V_{sat-} = -5V). Include one sample calculation for any row.

<u>(0V, 4.7kΩ, 4.7kΩ) Sample Calculation:</u>

$$V_{th} = (\frac{4.7k\Omega}{4.7k\Omega+4.7k\Omega})(5V + 0V),\ V_{th1} = 2.5V$$

$$V_{th} = (\frac{4.7k\Omega}{4.7k\Omega+4.7k\Omega})(-5V + 0V),\ V_{th2} = -2.5V$$

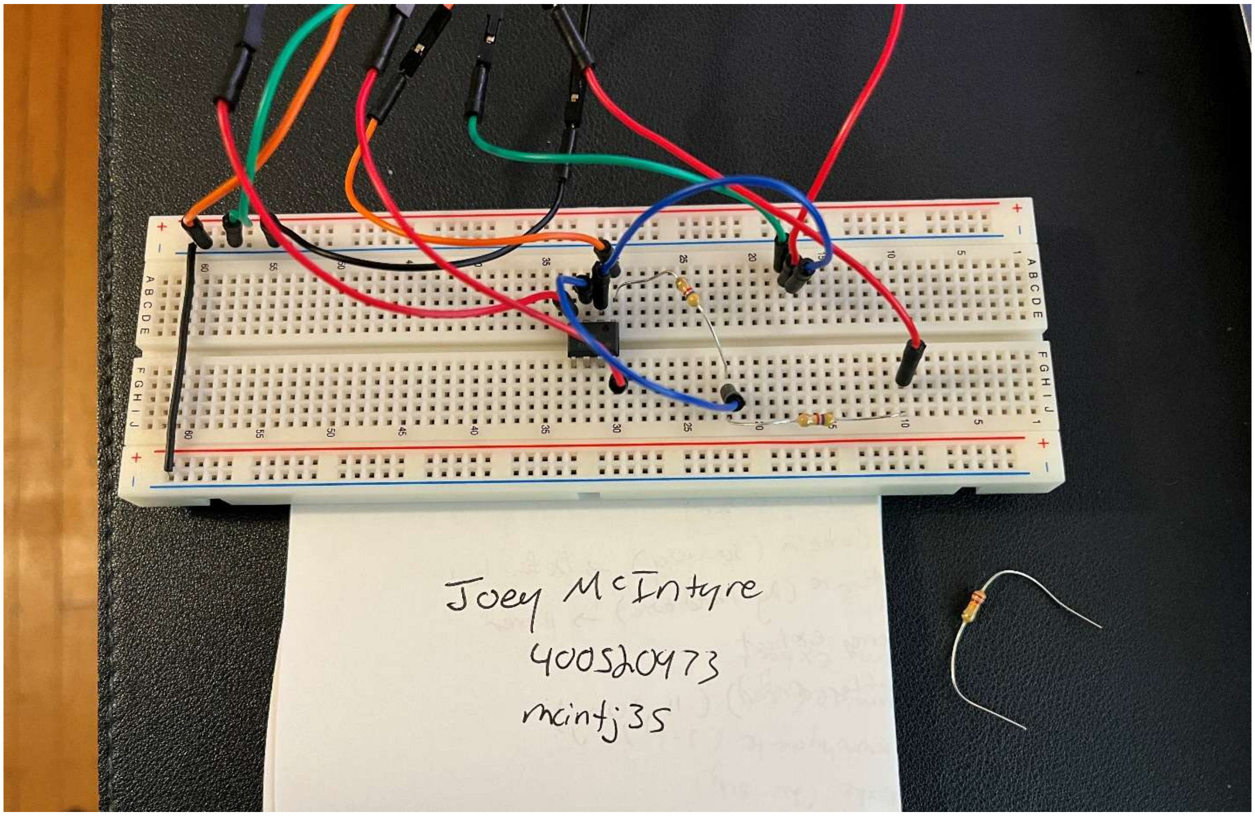
$$V_{gap} = 2.5V - (-2.5V),\ V_{gap} = 5V$$

(V_{ref}, R_1, R_2)	V_{th1}(theoretical)	V_{th2}(theoretical)	V_{gap}(theoretical)
(0V, 4.7kΩ, 4.7kΩ)	2.50V	-2.50V	5.0V
(0V, 22kΩ, 4.7kΩ)	0.88V	-0.88V	1.76V
(2V, 4.7kΩ, 4.7kΩ)	3.5V	-1.50V	5.0V
(2V, 22kΩ, 4.7kΩ)	1.23V	-0.528V	1.76V

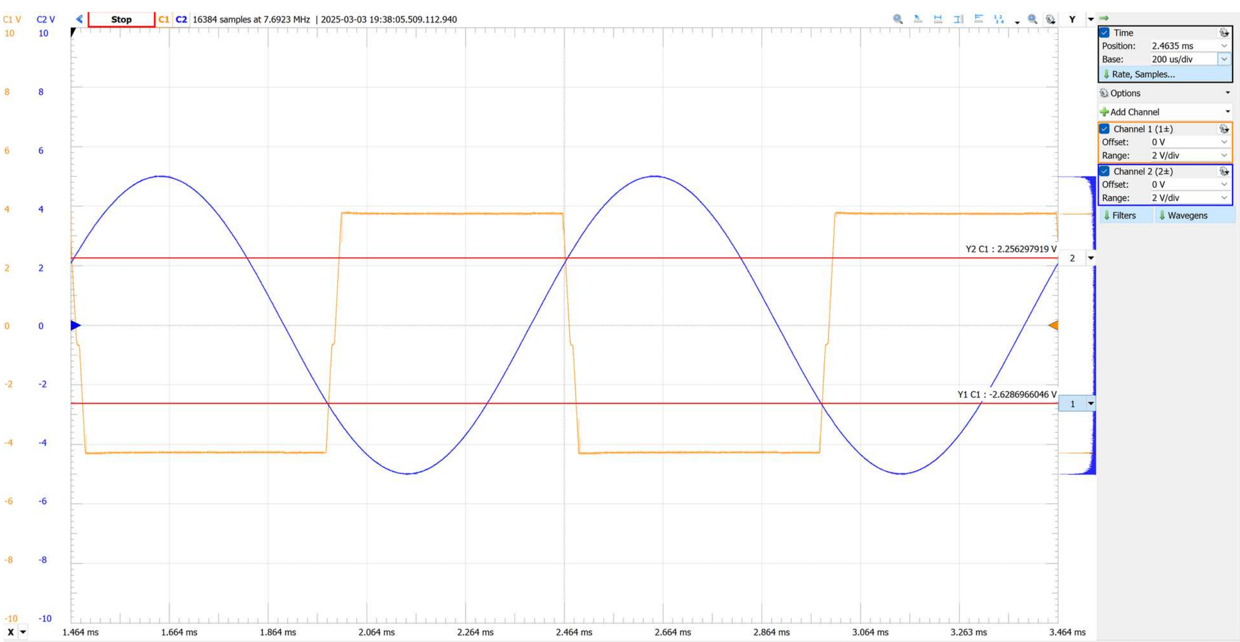
iii) Measure the actual V_{thl}, V_{th2}, and V_{gap} by building the circuits with $v_i(t)$ being a sine wave, square wave, or a triangular wave of amplitude 5V with a 0V offset and filling in the values in the following table. Include the resulting waveforms as well as circuits. (Hint: you will need to analyze the circuit if V_{ref} is a value that is not zero)

(V_{ref}, R_1, R_2)	V_{th1}(measured)	V_{th2}(measured)	V_{gap}(measured)
(0V, 4.7kΩ, 4.7kΩ)	2.26V	-2.63V	4.89V
(0V, 22kΩ, 4.7kΩ)	0.96V	-1.65V	2.61V
(2V, 4.7kΩ, 4.7kΩ)	3.09V	-1.87V	4.96V
(2V, 22kΩ, 4.7kΩ)	2.39V	-0.26V	2.65V

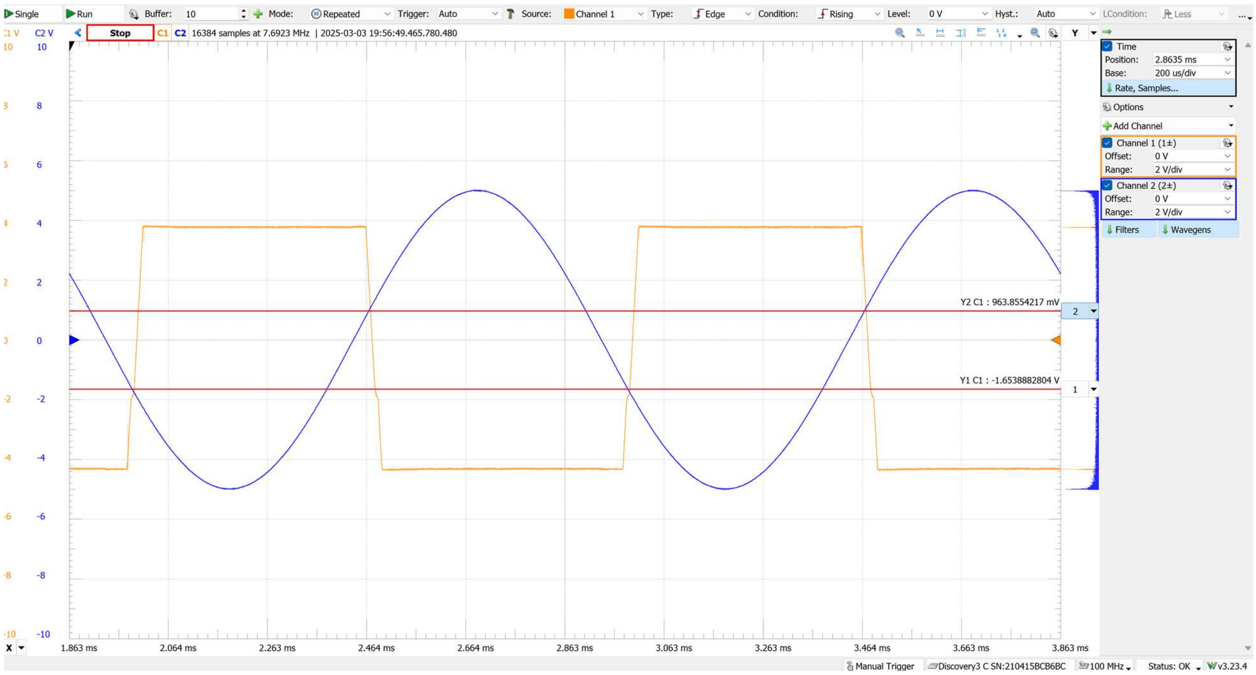
Physical Circuit Implementation:



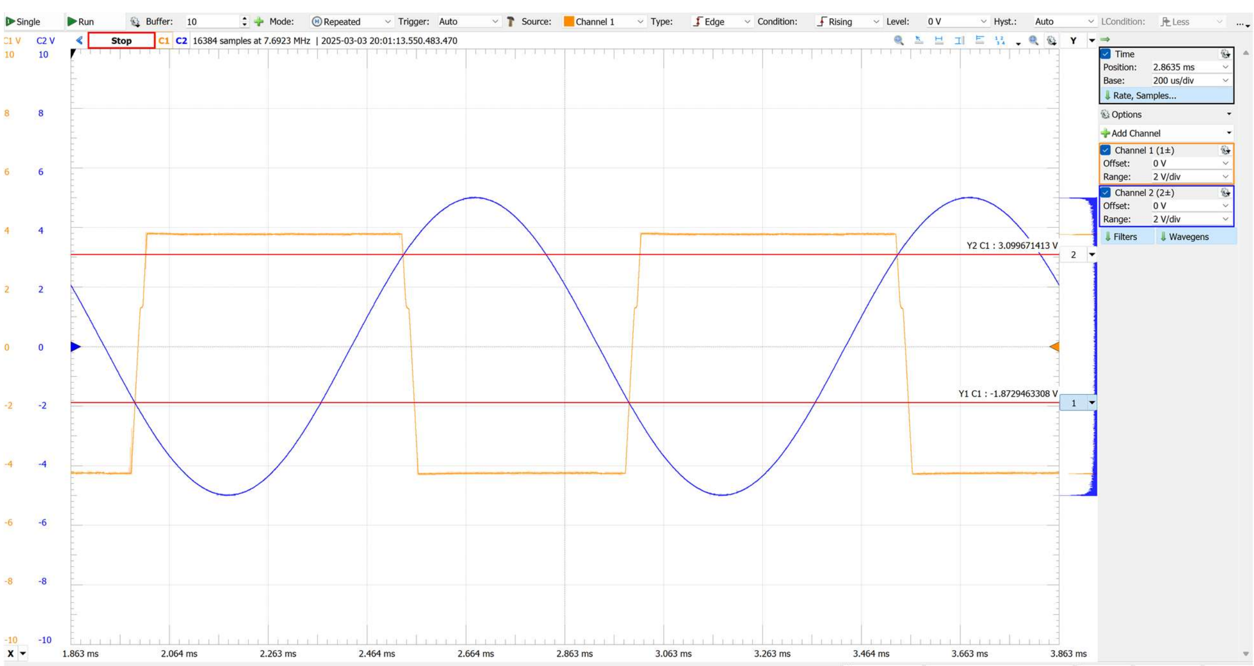
(0V, 4.7kΩ, 4.7kΩ):



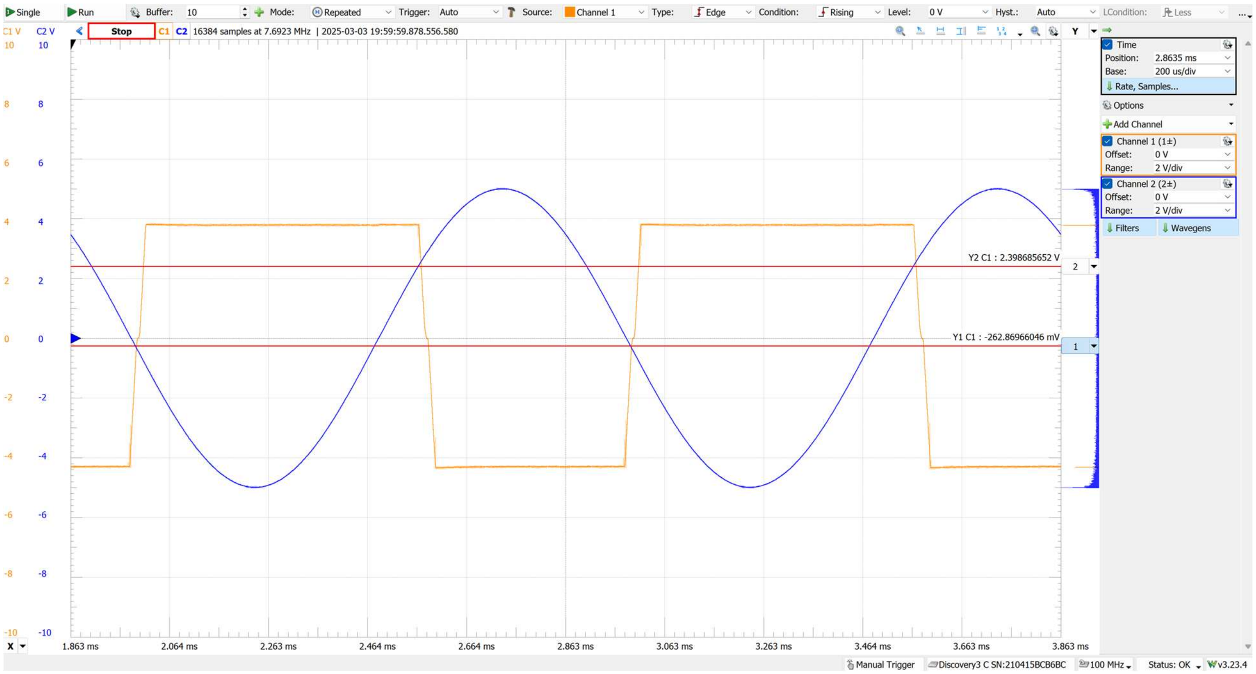
(0V, 22kΩ, 4.7kΩ):



<u>(2V, 4.7kΩ, 4.7kΩ):</u>



<u>(2V, 22kΩ, 4.7kΩ):</u>



iv) What is the percentage difference between the calculated and measured voltages?

(0V, 4.7kΩ, 4.7kΩ):

Vth1 (theoretical) = 2.5V, Vth1 (measured) = 2.26V, Percent difference = 9.6%

Vth2 (theoretical) = -2.5V, Vth2 (measured) = -2.63V, Percent difference = 5.2%

Vgap (theoretical) = 5V, Vgap (measured) = 4.89V, Percent difference = 2.2%

(0V, 22kΩ, 4.7kΩ):

Vth1 (theoretical) = 0.88V, Vth1 (measured) = 0.96V, Percent difference = 9.1%

Vth2 (theoretical) = -0.88V, Vth2 (measured) = -1.65V, Percent difference = 87.5%

Vgap (theoretical) = 1.76V, Vgap (measured) = 2.61V, Percent difference = 48.3%

(2V, 4.7kΩ, 4.7kΩ):

Vth1 (theoretical) = 3.5V, Vth1 (measured) = 3.09V, Percent difference = 11.7%

Vth2 (theoretical) = -1.5V, Vth2 (measured) = -1.87V, Percent difference = 24.5%

Vgap (theoretical) = 5V, Vgap (measured) = 4.96V, Percent difference = 0.8%

(2V, 22kΩ, 4.7kΩ):

Vth1 (theoretical) = 1.23V, Vth1 (measured) = 2.39V, Percent difference = 94.3%

Vth2 (theoretical) = -0.528V, Vth2 (measured) = -0.26V, Percent difference = 50.8%

Vgap (theoretical) = 1.76V, Vgap (measured) = 2.65V, Percent difference = 50.6%

v) What do you notice about the hysteresis gap V_{gap} if we change V_{ref} from zero to some non-zero value?

When the reference voltage (V_{ref}) is changed from zero to some non-zero value (2V in this experiment), the hysteresis gap V_{gap} does not change. The reference voltage just shift the waveforms, but the difference between threshold voltages remains the same.

Discussion:

This experiment focused on understanding how the Schmitt trigger circuit worked. Our goal was to compare the theoretical threshold voltages with the actual measured voltages to see how the circuit's switching thresholds, and the gap between them, behaved.

The experimental results obtained from the Schmitt trigger circuits generally aligned with our theoretical predictions, demonstrating the hysteresis behavior. However, there were some small discrepancies we observed in certain configurations.

For the (0V, 4.7kΩ, 4.7kΩ) and (2V, 4.7kΩ, 4.7kΩ) configurations, the measured values matched the theoretical values, with percentage differences remaining relatively low, especially for Vgap. However, the configurations involving the 22kΩ resistor, (0V, 22kΩ, 4.7kΩ) and (2V, 22kΩ, 4.7kΩ), showed higher percentage differences. These were likely due to factors like measurement errors or component tolerances.

One challenge we faced during the experiment was getting accurate measurements. Factors like component tolerances made it harder to ensure our results were correct. Resistors, for example, can have a 5% tolerance, which affects voltage divider ratios and threshold voltages. Additionally, the oscilloscope's precision likely contributed to some discrepancies, requiring more trial and error to get reliable results.

In conclusion, the experiment successfully demonstrated the fundamental principles of the Schmitt trigger. While the results were mostly consistent with theory.