Name: _____

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Module 9C: The Voltage Comparator
(Application: PWM Control via a Reference Voltage)

Laboratory Outline

A voltage comparator considers two voltage waveforms, A and B, and outputs a binary (two-valued) voltage waveform indicating which is larger (a high voltage for V_{out} states that A is larger and a low voltage that B is larger, see Figure 1). In this module, we will study the application of the voltage comparator for PWM control via a reference voltage.

In the ECE110 laboratory exercise (Lab 8), you will have learned how to control the duty cycle of a PWM signal using a variable resistor in the feedback portion of an oscillator. This method is somewhat restrictive. Many sensors provide only access to the voltage output of a voltage divider circuit or, like an infrared receiver, a transistor-based voltage proportional (or *inversely-proportional*) to the received infrared intensity. These types of active sensors will require a different electronic mechanism to produce a sensor-controlled PWM signal than that used in Lab 8. A basic method of implementing PWM control via a reference voltage is made possible by comparing a triangular waveform to a slowing-varying reference voltage from the sensor.
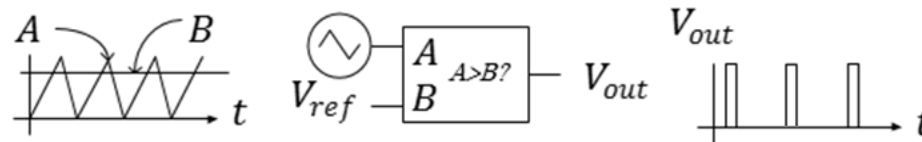
Figure 1: *A block diagram demonstrating how a triangular waveform might be transformed into a PWM signal controlled by a reference voltage. When the reference voltage, V_{ref}, rises, the duty cycle of the PWM signal decreases.*

Prerequisites

- Laboratory Exercise #5, the construction of a simple oscillator circuit.
- *Explore More!* Module: The Voltage-Follower Buffer.
- (recommended prerequisite) Laboratory Exercise #8, the construction of an oscillator with a selectable duty cycle.

Parts Needed

- The completed oscillator circuit (Lab#5)
- (1) LM358 Op Amps and (1) LM311 Voltage Comparator (2 per IC) (optionally, (2) LM358 Operational Amplifier)
- Trimpot 10 $k\Omega$ with knob (may be substituted with another trimpot…value is non-critical)

Notes: ***Inversely-proportional*** means that as one signal gets larger, the other gets proportionally smaller.
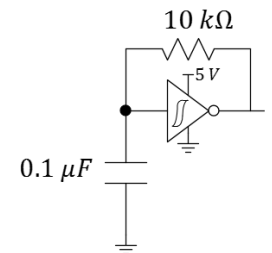
Recall: Relaxation oscillator circuit from Lab 5.
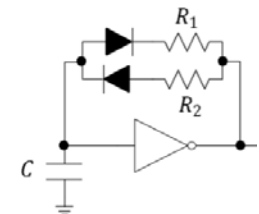
Recall: A method to use (variable) resistance to control PWM duty cycle from Lab 8.
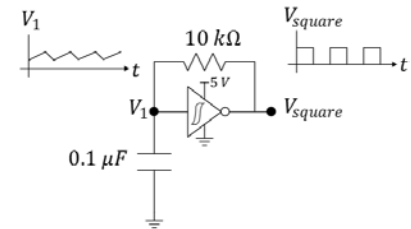
At Home: Construction

✓ Create a triangular waveform generator by following the procedures for the ***Explore More!* Module: The Voltage-Follower Buffer**. That module may be submitted to your TA for separate module credit. When finished with that module, continue with the procedure here.

Question 1: Use the datasheet to add the schematic symbols for power and ground to the pinout below of the LM358 or LM311 used in the comparator circuit. We will use a 5- or 6-volt supply and ground the negative supply pin. What is the range of acceptable supply voltages?
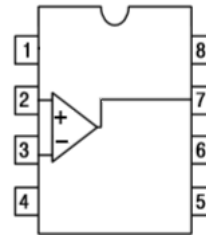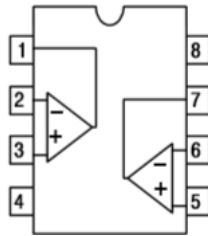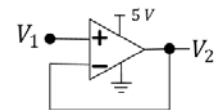

Question 2: On the physical pinout diagram above, add the circuit-schematic symbols of the components used to construct the circuit buffer of Figure 2.
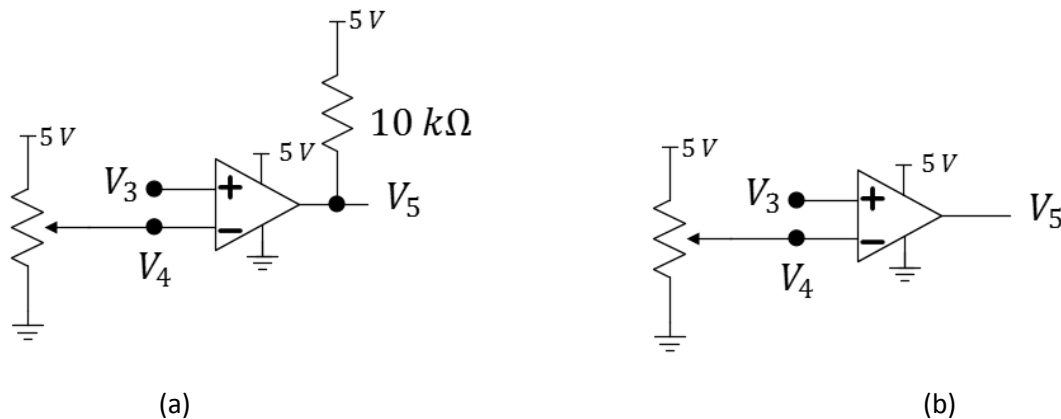
✓ Construct the voltage comparator circuit as shown in the figure below. The trimpot (10 $k\Omega$) is not part of the voltage comparator, but is rather used to provide a controllable reference voltage. It may be substituted with another trimpot.

(a) (b)

Figure 2: *Configuration of a comparator test circuit based on (a) the LM311 comparator or (b) the LM358 op amp.*

Notes: For the LM311-based circuit, the output pin is an "open collector" that should be biased towards V_{CC} using a so-called *pullup resistor* (shown in the figure to be 10 $k\Omega$). While the LM358 is readily available from your kit, the LM311 comparator chip offers faster response time and a larger output voltage range, the latter of which may be beneficial in this application. **NOTE**: If using the LM358, you may need to buffer the output using two consecutive Schmitt-trigger inverters (like in Lab #8).

✓ Construct the PWM circuit as shown in the figure below, where the node voltage V_4 will control the duty cycle of V_5.
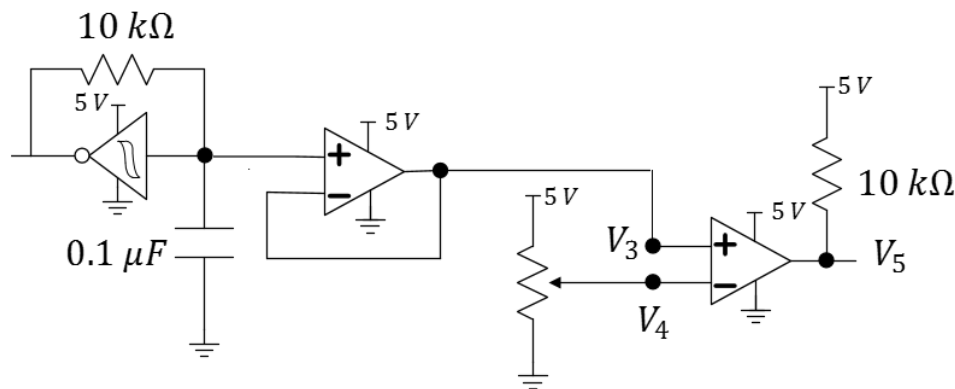
Figure 3: *The final PWM circuit controlled by a reference voltage (assuming the LM311 was used).*

In the Laboratory: Analysis

With the circuit completed as in Figure 3, adjust the voltage output of the potentiometer-based voltage divider while simultaneously monitoring the three waveforms V_3, V_4, and V_5 on the oscilloscope.

Question 3:   Describe what you see as the potentiometer (trimpot) is adjusted. Be sure to note the range of V_4 that results in changes to the duty cycle of V_5. Think how V_3 appears different that the representation of Figure 4.

Figure 4: *Comparison of the inputs and output of a voltage comparator circuit used for PWM control.*

Question 4:   Produce a graph including all three plots for a duty-cycle near 30% and attach it to this report.

Back at Home: Drawing Conclusions

You should have noticed that this implementation of the triangular waveform is not ideal. Our triangular waveform is a scaled and offset version of that plotted in Figure 4. The triangular waveform of Figure 4 goes from 0 V to nearly the full supply voltage of 5 V.

Question 5: Discuss why the V_3 waveform of Figure 4 would be a better triangular waveform than ours when the reference voltage varies from 0 to 5 V.

Learning Objectives

- To properly bias a voltage comparator based on either an LM358 Op Amp or a LM311 Voltage Comparator chip.
- To create a PWM waveform that is controlled by a reference voltage using the voltage comparator circuit.
- To gain experience in using the oscilloscope to assess a circuit while making and recording time-varying voltage waveforms.

Learn More!

In *Explore More!*: **The Amplifier**, we will learn to convert the triangular waveform of the relaxation oscillator into a full-range waveform similar to that in Figure 4. In *Explore More!*: **PWM Control via an Active Sensor**, we will amend this method using the circuital tools learned in other lab modules to make the sensor-controlled PWM signal more *robust*.

Note: *Robust* is a term often used very loosely in engineering. It most often refers to a system that is insensitive to deviations in parameters or outside forces.