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Section AB/BB:

PRELAB #7: Pulse-Width-Modulated (PWM) Beacon

Background

Recall the square-wave oscillator that we built earlier. By placing a capacitor at the input of the inverter (see Figure 1), discharging the capacitor will cause the output of the inverter to be near the battery voltage. By charging the capacitor, the output of the inverter will be near 0 volts. By inserting a resistor between the output and the input (where the capacitor sits), the output does the job of both charging and then discharging the capacitor, thus forming an oscillator. An **oscillator** is a device that changes values over time in a periodic manner.

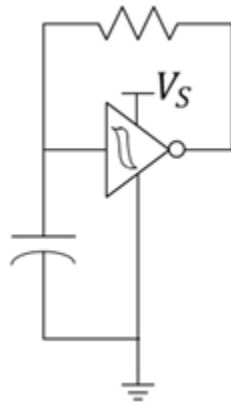


Figure 1: Circuit schematic of a square-wave oscillator producing a beacon.

To gain a deeper appreciation for the operation of the oscillator, we first need to understand the operation of the Schmitt trigger inverter. The datasheet for the CD40106 Schmitt Trigger Inverter will describe a hysteresis (a form of memory) within the device where the input/output relationship for changing input values will depend on the time history of the input. For example, if the input voltage V_{IN} starts at 0 volts (ground) and climbs, the output voltage V_{OUT} will remain high until the input voltage

reaches the value V_p as demonstrated in Figure 2. At this point, the output voltage will drop to 0 volts. As the input voltage then falls back below V_p , the output voltage persists in staying low (0 volts) until finally the input falls below a value of V_n . This means that there is not a one-to-one relationship between V_{IN} and V_{OUT} like we are mostly accustomed to in previous math courses. This relationship is graphed in Figure 2. We consider V_p to be the positive-going threshold voltage and V_n to be the negative-going threshold voltage of the Schmitt Trigger.

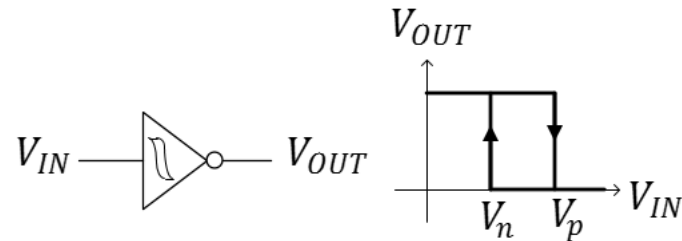


Figure 2: The input/output relationship of the Schmitt trigger from Texas Instruments, the TI 40106.

Knowing that the *input* of the Schmitt trigger inverter has a high resistance, we can ignore it for purposes of determining how the capacitor and resistor of the oscillator interact. For the *output* of the Schmitt trigger, we will need two models to each correspond with the two output voltages of Figure 2.

- 1) When the input voltage, V_{IN} , is small, the output of the Schmitt trigger output is high (near the supply voltage, V_S). Therefore, for the charging cycle, the oscillator circuit can be modeled by Figure 3a.
- 2) When the input voltage is high, the Schmitt trigger output is low (near ground voltage, 0 V) and the oscillator circuit can be modelled by Figure 3b.

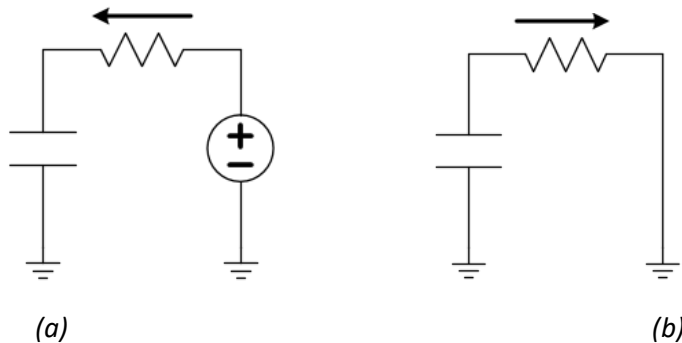


Figure 3: Charging (a) and discharging (b) schematics for the oscillator circuit after making modeling assumptions for the Schmitt trigger. The arrow shows the direction positive-valued current will flow as the capacitor charges and discharges, respectively.

If we desire control over the duty cycle of our square wave, we can consider using different resistance in the charging phase than in the discharging phase of oscillation. We can use diodes to change which resistive path is used. Consider the circuit of Figure 4.

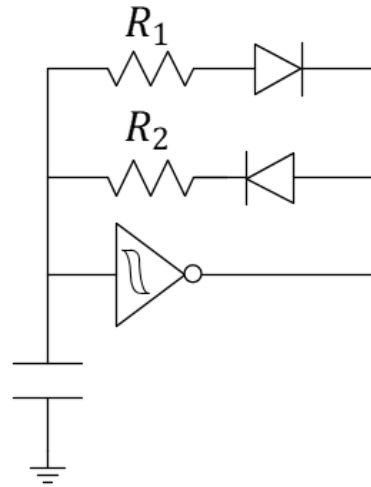
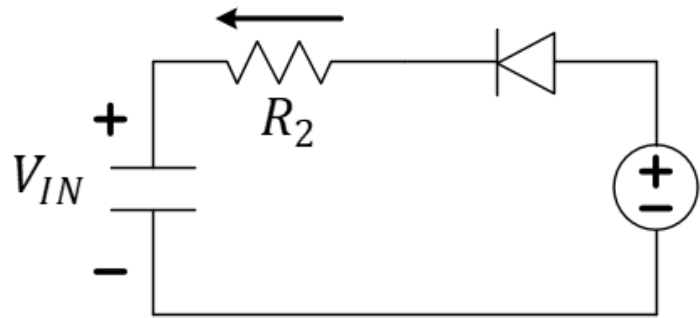
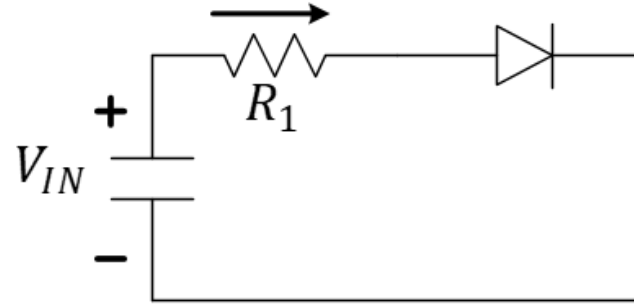


Figure 4: Circuit schematic of an oscillator with a selectable duty cycle.

In this configuration, the capacitor will discharge through R_1 , but charge through R_2 . See Figure 5.



(a)



(b)

Figure 5: Charging (a) and discharging (b) schematics for the oscillator circuit including the diodes.

To clean this circuit up and make the duty cycle easily controllable, we might rearrange it as in Figure 6 where a single turn pot becomes the control knob.

Notes:

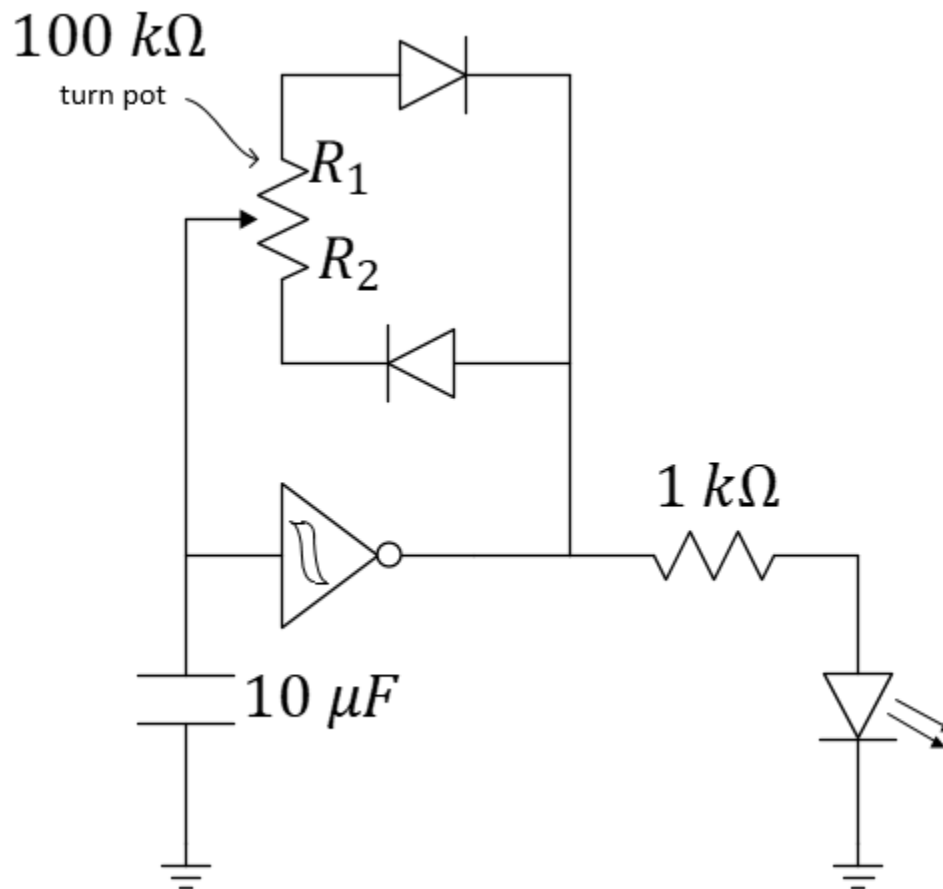


Figure 6: Circuit schematic of an oscillator with a selectable duty cycle.

Build the oscillator circuit as shown in Figure 6. Use an LED to complete the design with a visible output. Your LED should be flashing every one to three seconds. Turn the knob and watch how the duty cycle of the yellow LED changes.

Turn your knob fully counterclockwise.

Question 1: Estimate the duty cycle of your LED.

Turn your knob fully clockwise.

Question 2: Again, estimate the duty cycle of your LED.

Think about the charging and discharging phases of your oscillator as described in Figure 5. The resistors R_1 and R_2 control the rates at which the capacitor discharges and recharges.

Question 3: When you turn your knob counterclockwise, which resistor, R_1 or R_2 , is being made small? Explain based on your observations in the above questions.

As always, bring your functional circuit to the next lab session for grading.

Learning Objectives

- Build a circuit by following the design specified on a circuit schematic
- Learn to control the duty cycle of a PWM signal using a turn pot and diodes
- Use observations of your circuit to discern the change of certain components.