Sim Lab 8 Part 3 – PWM Motor Drive

Derived, in part, from the hardware-version of Lab 7 from your binder.

Prerequisites

- Please make sure you have completed the following:
  - Lab 7LTspiceTutorial Part 1 (Download and Installation)
  - Lab 7LTspiceTutorial Part 2 (Components and Basic Interface)
  - Lab 7LTspiceTutorial Part 3 (Basic Circuits)
  - Lab 7LTspiceTutorial Part 4 (Intermediate Circuits)

Background

Recall the squarewave oscillator that we built earlier. By placing a capacitor at the input of the inverter (see Figure 1 in next slide), 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 as determined by one or more RC time constants.

Figure 1: Basic Oscillator

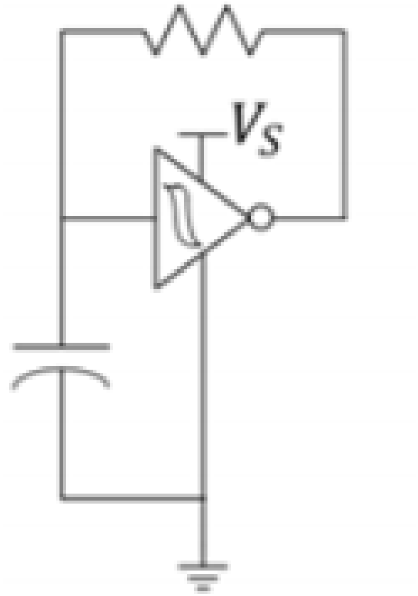


Figure 1: Basic oscillator circuit.

Schmitt Trigger Introduction

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.

Schmitt Trigger Introduction

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}.

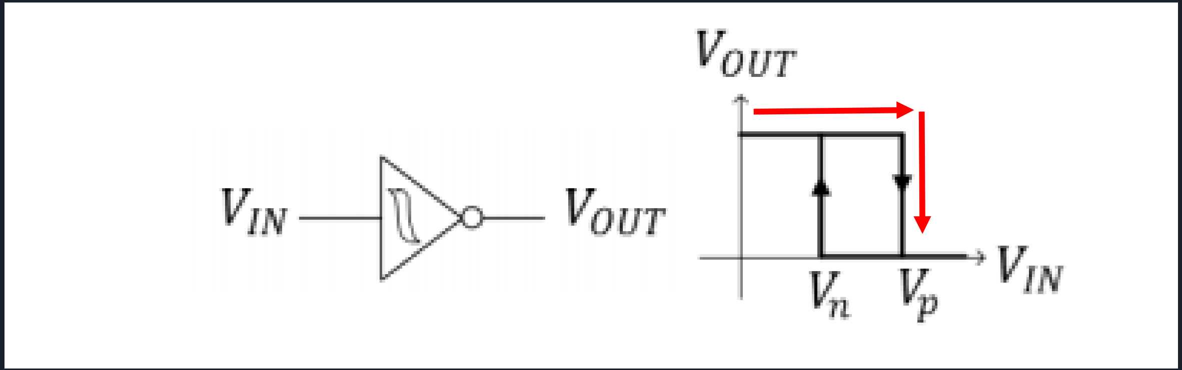


Figure 2: Schmitt trigger upper threshold

Schmitt Trigger Introduction

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.

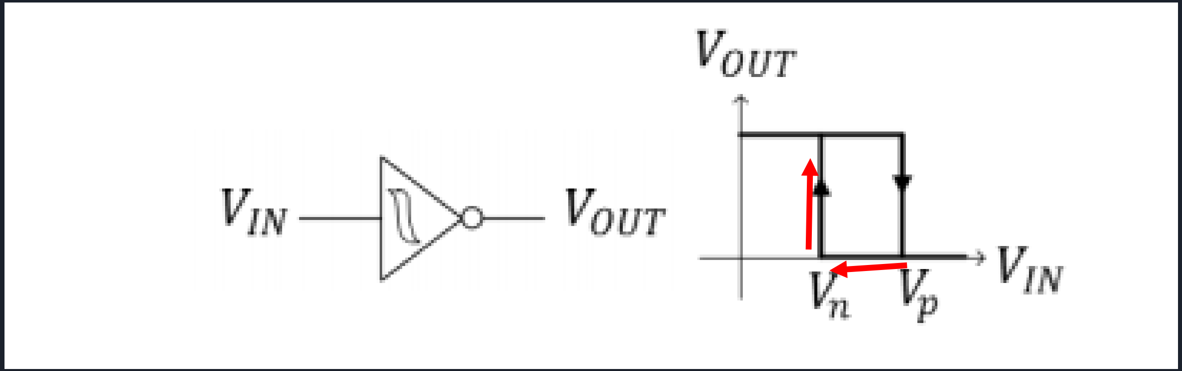


Figure 3: Schmitt trigger lower threshold

Schmitt Trigger Introduction

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. Notes: This relationship is graphed in the figure below. 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.

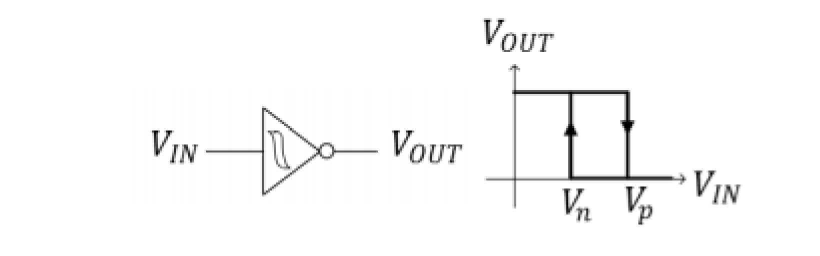


Figure 4: Schmitt trigger hysteresis loop

In the LTspice Tutorial Part 4, we used a generic Schmitt trigger with settings of Vhigh=9 Vt=4.45 Vh=.85 Trise=.1u Tfall=.1u. For this model, the threshold voltage is $V_t = \frac{V_n+V_p}{2}$ and the hysteresis voltage is $V_h = V_p - V_n$.

Schmitt Trigger Application

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 the Schmitt inverter.

Schmitt Trigger Application

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 like so:

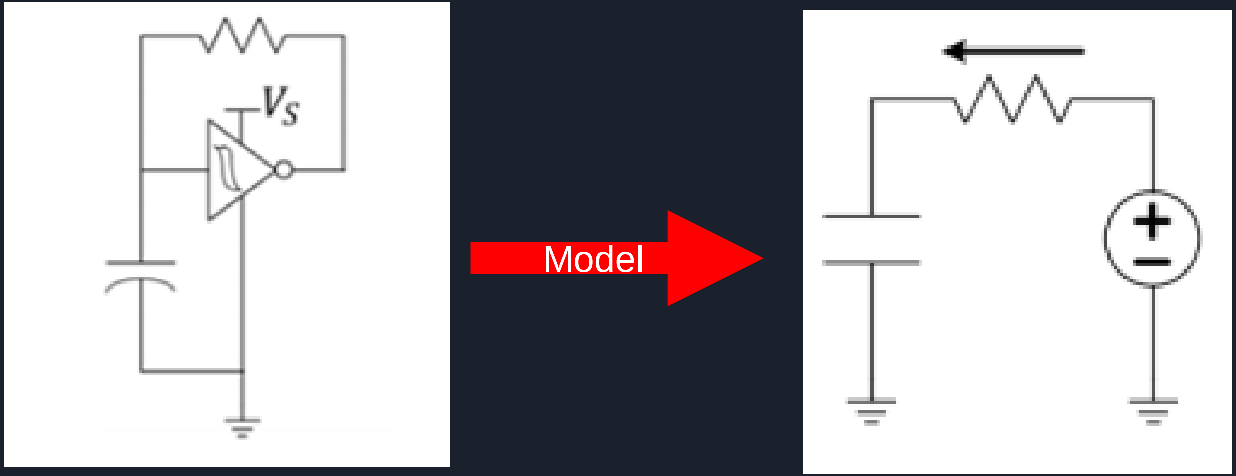


Figure 5: Oscillator high output voltage behavior

Schmitt Trigger Application

When the input voltage is high, the Schmitt Trigger output is low (near ground voltage, 0V) and the oscillator circuit can be modeled like so:

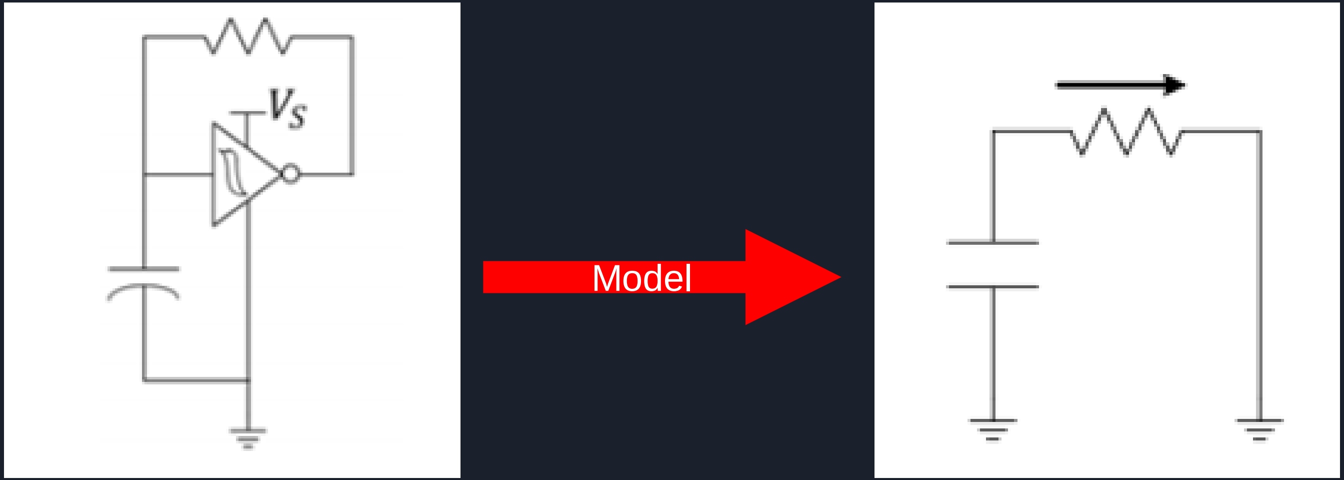


Figure 6: Oscillator low output voltage behavior

Control of Oscillator Behavior

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. For example in this configuration the capacitor will discharge through R_1 and charge through R_2.

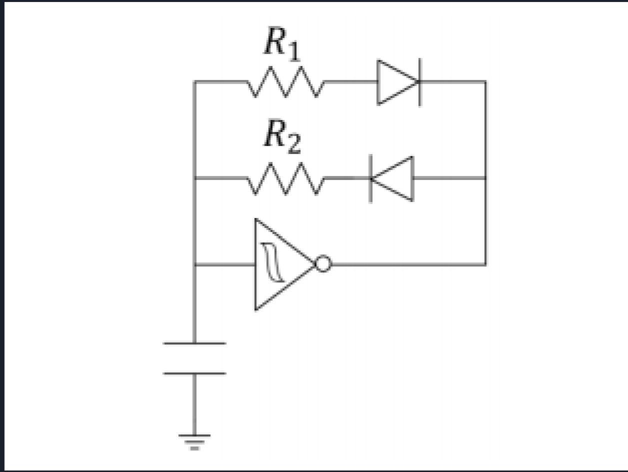
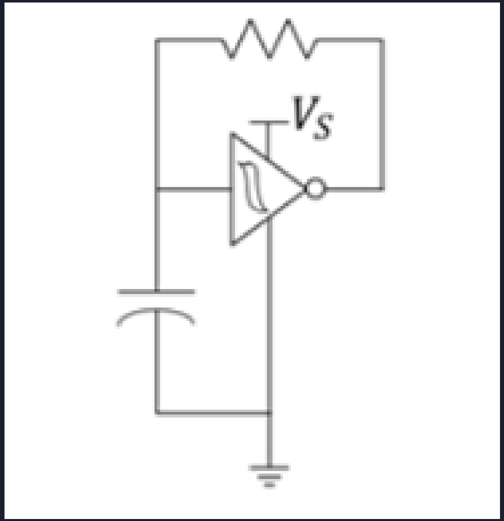
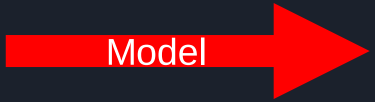


Figure 7: Oscillator with controllable duty cycle

Control of Oscillator Behavior

Charging the capacitor (charging will last until $V_{in} \approx V_p$)





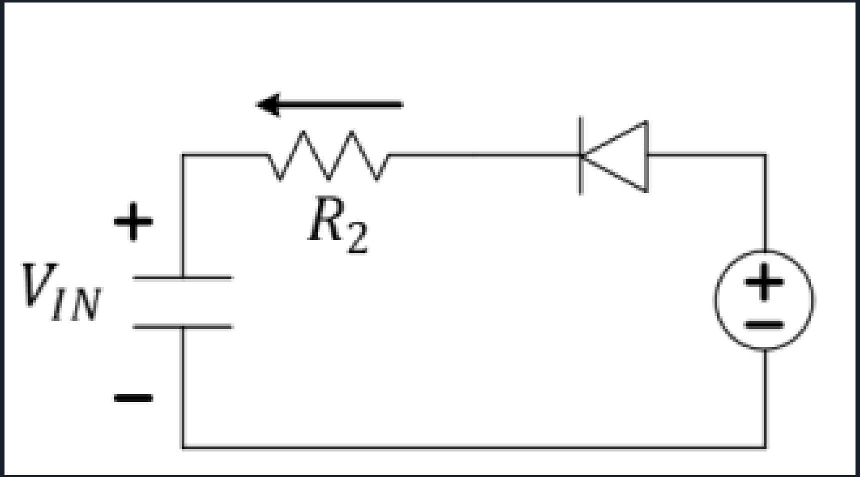


Figure 8: Oscillator high output voltage behavior with duty cycle

Control of Oscillator Behavior

Discharging the capacitor (dischargingwill last until $V_{in} \approx V_n$)

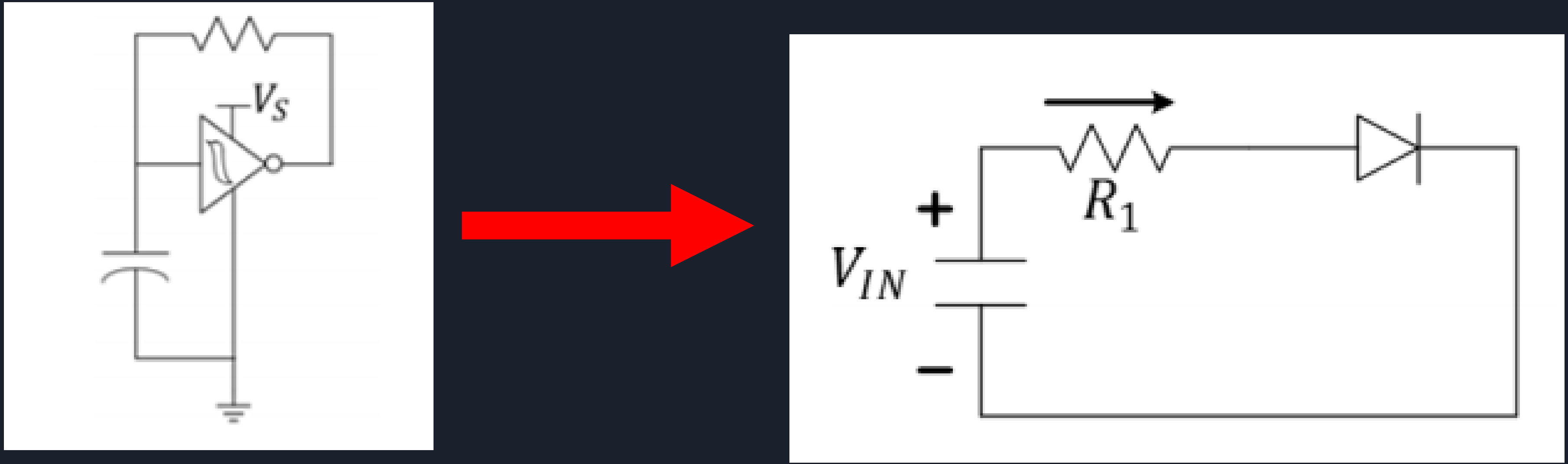
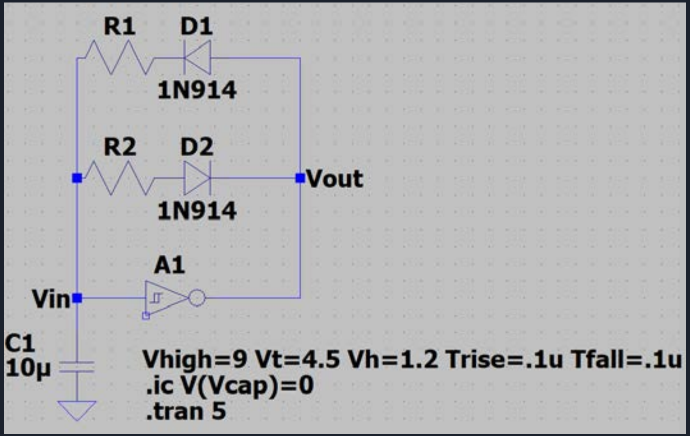


Figure 9: Oscillator low output voltage behavior with duty cycle

Assignment

Start LTspiceand open (or reconstruct) the oscillator from LTspiceTutorial Par 4, shown below.



Here is how to choose the values of the resistors:

Let n = the 9[th] digit of your UIN.

Use the following values for R_1 and R_2 in $k\Omega$,

$$R_1 = 10n$$

$$R_2 = \frac{R_1}{2}$$

Question 1: Submit a graph of V_{in} and V_{out} for your oscillator placing your UIN somewhere in the title.

Question 2: Show on your graph where V_{in} reaches the values of V_p and V_n. Be sure to include a calculation of these two thresholds from your settings of the “schmitinv” component.

Assignment

Question 3: Look up the Texas Instruments datasheet for the CD40106B. Suppose we apply 9V to the chip. Use the datasheet to approximate thresholds for the Schmitt Trigger operating at T~25°C in LTspice. Give a brief explanation for your choices, you do not have to be perfectly correct here.

Question 4: Answer the following questions:

(a) What advantages does the use of a potentiometer rather than 2 resistors provide in the lab? What disadvantages might it have?
(b) How does changing R_1 impact the behavior of V_{in} and V_{out}?
(c) How does changing R_2 impact the behavior of V_{in} and V_{out}?

Experiment with PWM motor wheel balance

Now, you have constructed a square wave signal with an adjustable duty cycle typically called a PulseWidth -Modulated (PWM) signal.

In an earlier lab, you used different resistances to attempt to balance the speed of your two wheels. While this method was effective, it also had a very low power efficiency and was prone to motor stalls if attempting to significantly reduce the speed.

In this lab, we will implement a method of wheel balance that utilizes MOSFET-based motor drives for high efficiency and PWM control for high-motor torque and lower risk of motor stalling. A single potentiometer allows for a simple method of adjustment to make the car run a straight path.

Understanding the Schmitt-trigger model

Figure 10 shows the oscillator with Schmitt Trigger modeled for “input high”. At this stage, the LED should be *off*.

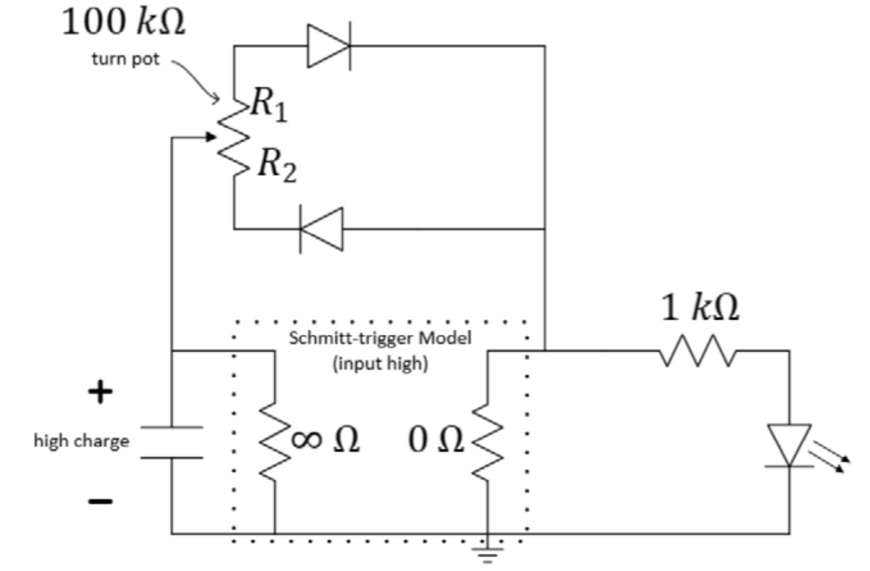


Figure 10: Oscillator with Schmitt Trigger modeled for “input high”.

Understanding the Schmitt-trigger model

Figure 11 shows the oscillator with Schmitt Trigger modeled for “input low”. At this stage, the LED should be *on*.

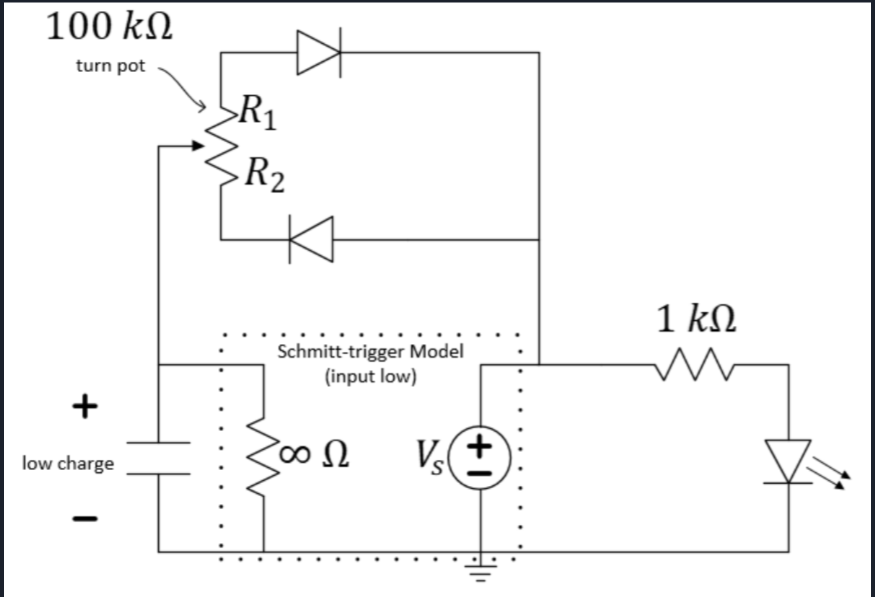


Figure 11: Oscillator with Schmitt Trigger modeled for “input low”.

Understanding the Schmitt-trigger model

Question 5: On Figure 10, mark the “loop” through which the capacitor discharges. Label that loop “L1”.

Question 6: On Figure 11, mark the “loop” through which the capacitor charges. Label that loop “L2”.

You do not need to print the entire procedure, just these slides.