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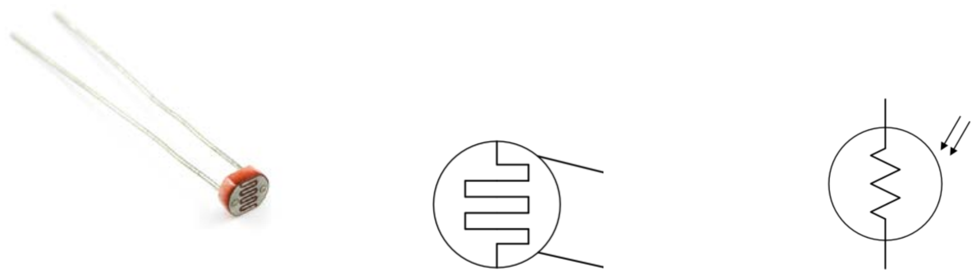
PRE-LAB #4: Voltage-Divider-Based Cloud Detector

Learning Objectives

- Gain experience in reading datasheets of electronic components
- Build a circuit by following the design specified on a circuit schematic

Background

Imagine you are in charge of designing a circuit that triggers power reduction in a solar-powered vehicle when the sunlight is blocked by clouds. We'll call this circuit a cloud detector. A simple circuit component that responds to sunlight is the photoresistor. A photoresistor's resistance is high when shaded, but sunlight will result in an excitation of electrons within the window of the device causing its resistance to decrease significantly.



(a) (b) (c)

Figure 1: The photoresistor (a), a physical representation (b) and its traditional circuit symbol (c).

To learn more about an electronics device, engineers consult the datasheet. The datasheet contains a wealth of knowledge about the physical layout of a component, ranges in its descriptive parameters, typical uses and/or its limitations. Like any resource, it is best to consume this knowledge in small doses. Do not worry that much a datasheet may be difficult to understand at first glance. It is merely important that you can find the data that you most-urgently require and understand.

Notes:

Open the datasheet for the photoresistor (https://cdn.sparkfun.com/datasheets/Sensors/LightImaging/SEN-09088.pdf) and answer the following questions.

Question 1: Based on the datasheet of the photoresistor, what *average* resistance might you expect to see for a darkened sensor (0 Lux)?

Question 2: Based on the datasheet of the photoresistor, what average resistance might you expect to see for a sensor in a dimly lit room (10 Lux)?

Question 3: Based on the datasheet of the photoresistor, what average resistance might you expect to see for a sensor in a very bright setting (100 Lux)?

Question 4: If the photoresistor is used in the following voltage-divider circuit, what output V_1 might you expect under the following conditions (please complete the table)? Assume the battery voltage is $7.2\ V$.

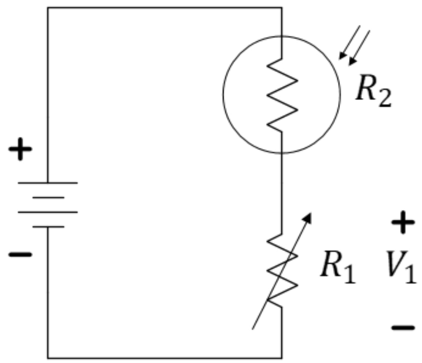


Figure 2: Consider this voltage divider circuit when completed the table below. V_1 is the voltage across R_1.

Notes:

Lux	$R_1\ [k\Omega]$	$V_1\ [V]$	Comments:
10	1		
100	1		
10	10		
100	10		
10	50		
100	50		

Table 1: The photoresistor-based voltage divider predicted responses.

Note that we have already used resistors as a current-limiting device (for the car motors). This is a second common usage of resistors, a voltage divider to control a desired voltage level. There are two other uses that may be discussed during the course of this semester: resistors for power dissipation (like the rear defroster of an automobile) and resistors for pull-up or pull-down uses.

Let's assume $\boldsymbol{R_1 = 10\ k\Omega}$. From Table 1, it should be evident that V_1 is closer to 7.2 V when the voltage-divider is well-lit and closer to 0 V when shadowed. We would like to create the "invert" of this voltage reference creating a signal that goes "high" when shadowed so that this new voltage can trigger the cloud indicator (an LED) to illuminate.

To invert the voltage, we will use a device called an inverter built in an integrated circuit (an IC). Study the datasheet of the Schmitt Trigger Inverter (CD40106). http://www.ti.com/lit/ds/symlink/cd40106b.pdf and/or https://assets.nexperia.com/documents/data-sheet/HEF40106B.pdf.

The circuit contained in each IC is goes through a rigorous design process and tested under a wide range of conditions. Most ICs follow a few sets of universal standards, making it possible to wire them together and implement more complicated design. In general, there are three aspects of ICs that we are concerned with:

1) Chip orientation (pin numbering)
2) Circuit functionality and Schematic
3) Operation envelops and output characteristics.

The first of these points comes deals with a very common set of industry standards while the second two points differ from chip to chip. Let us begin with chip orientation and pin numbering. Below is an illustration of an IC in a dual in-line package (DIP) as seen from an oblique angle and from directly above.

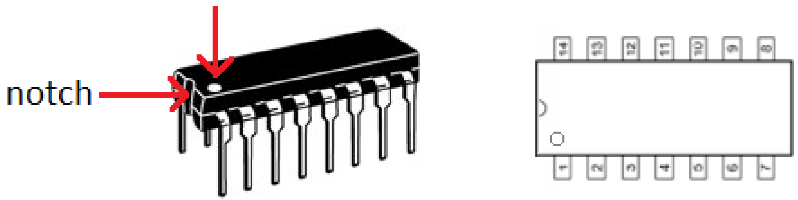


Figure 3: Two views of an IC "DIP" package showing the counter-clockwise pin numbering system.

Usually IC DIP chips have a semi-circle or notch on one side of chip body. Pin numbers always start counter-clock-wise from the notch, wrapping around the chip body and back up the other side. In some cases, a chip may have a small circular indent in one corner of the chip rather than (or, in addition to) a notch. In this case, the indent resides right next to pin 1 and the numbering proceeds in the same fashion.

In most case the chips will have to be powered to work properly. Most chips are powered by a $5\ V$ or $3\ V$ source, however some amplifiers will require $+12\ V$ and $-12\ V$ power. In most cases, the positive terminal of the power source (often called V_{dd}) will be wired to the highest numbered pin, N, and the negative terminal (often called the "ground" and indicated by ⏚) of the power source is connected to the lower left pin, numbered $N/2$.

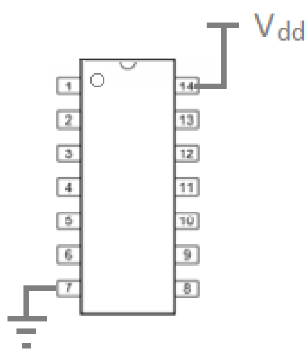


Figure 4: Typical "power and ground" configuration of a DIP package.

Notes:

Although most chips found in the ECE 110 lab are powered in this way, not every IC follows this convention. Countless chips have been DAMAGED due to incorrect powering. Every IC (and virtually all circuit elements) come with a datasheet. The datasheet is a resource that attempts to list all important information on the internal circuit of an IC as well as its operational envelope. It is very important to check the datasheet for each IC for the correct pins and appropriate voltage level before using that IC. The datasheet generally contains all the information necessary for implementing a device in a circuit and gives the user an idea of what limitations the device might have in terms of voltage, current or temperature tolerances. These characteristics vary from chip to chip so it is very important to learn to read and understand the information listed on a datasheet if you ever wish to use a device you haven't seen before.

Build the circuit shown in Figure 5. The small numbers on the circuit schematic are the pin numbers of the IC and correspond to the connections shown on the physical diagram.

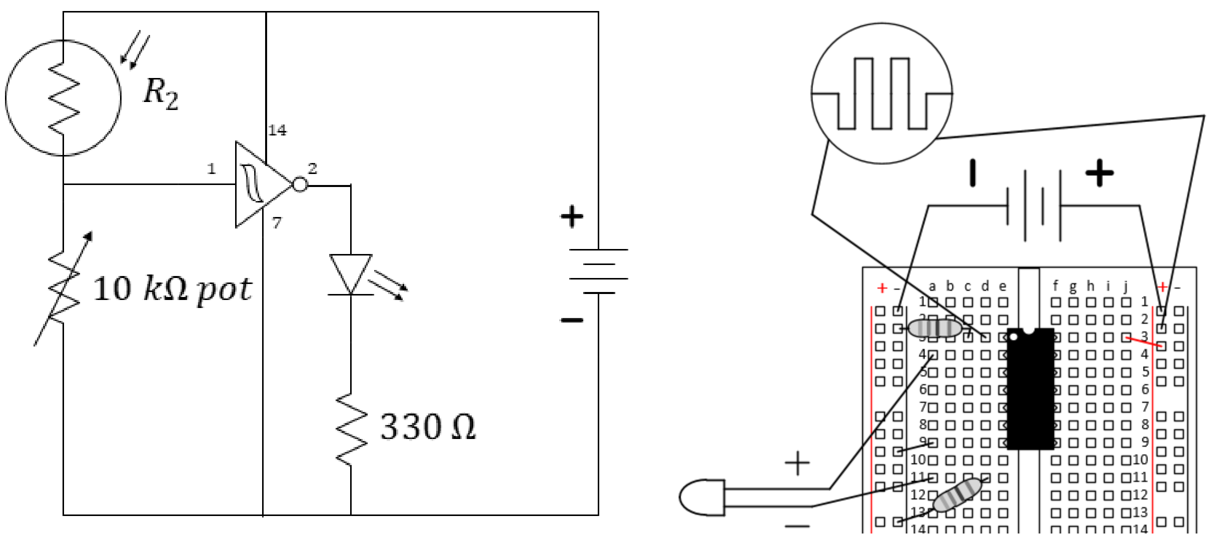


Figure 5: The cloud detector.

Notes:

Potentiometer:

Use the center and one other lead to create a variable resistor. Bend the unused lead out of the way, but **do not cut it off**! Tune its value using this device:

Remember: The power rails (aka power bus) are connected vertically. Each set of five holes a-e or f-j are connected together for each row, but a-e is not connected to f-j. In this way, the IC straddles the board without shorting the left pins to the right pins.

Notes:

Be aware that we cannot generally just cascade interesting circuits together. When adding the inverter to the voltage-divider circuit, we might anticipate that the operation of the voltage divider would be significantly affected. In this case, it will have relatively small effect. The input resistance (actually, "impedance") of the invertor is quite large and comparable to the largest value we might expect for R_2. We'll choose to ignore its effect for now.

Adjust the $10\ k\Omega$ potentiometer (R_1) to improve your circuit performance for the specific lighting conditions in your room. What value for R_1 did you decide was best?

Question 5: Without making any further adjustments, use your cloud detector in both bright and dim light. How well do you anticipate your detector to operate when you enter the lab at your next meeting?

Question 6: Find something interesting to share from one of the datasheets. Write about it below.