Internet of Things Lab:
Smart Light

Form teams of two to complete this laboratory.

Objective:
This project is an excellent way to become familiar with the possibilities of what you can do with Internet of Things and electrical engineering. Internet of Things (IoT) is a system of devices connected through the internet which enables them to collect and exchange data. This also allows a device to be controlled remotely across a network infrastructure.

In this lab, you will be creating a "Smart Light" whose brightness can be controlled by your smart phone or by the amount of ambient light in the room.

Figure 1:

- Pin 2 (Red wire) on the Raspberry Pi to the power rail
- Pin 6 (Black wire) on the Raspberry Pi to the ground rail
- Pin 7 (Green/Teal wire) on the Raspberry Pi to the capacitor and the photoresistor
- Pin 13 (Blue wire) on the Raspberry Pi to the MOSFET "gate" pin.

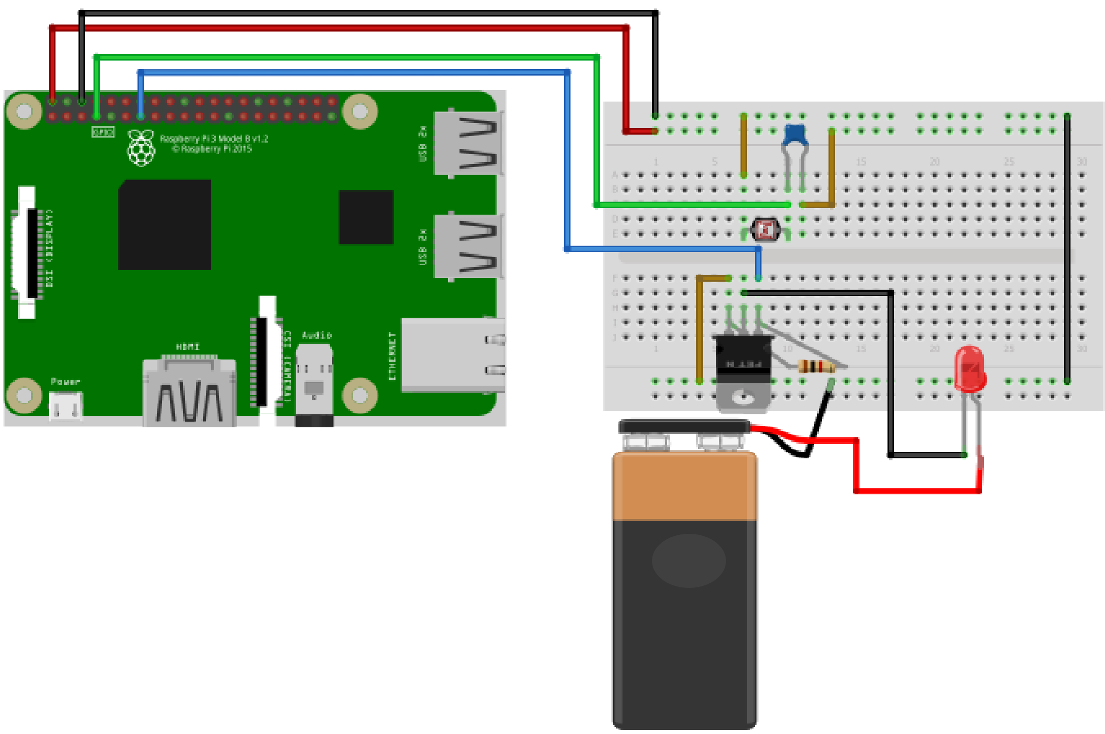


Figure 1: Smart Light Schematic

You will be creating the circuit shown in Figure 1 which will be able to control a lamp light with your smartphone. Ready to get started?

Materials List:

- Raspberry Pi 3
- 12-volt power supply
- Pair of minigrabber probes
- Breadboard
- Photoresistor
- 1μF capacitor (micro)
- 1000Ω resistor
- 12-Volt MOSFET [NDP6060L]
- 12-Volt LED light bulb
- Lamp for the 12-Volt LED bulb
- Male-to-female wires (four of different color)
- Male-to-male wires (three)
- Header pins (two)
- 2.5-amp power supply for Raspberry Pi
- HDMI cable
- Monitor
- Mouse and Keyboard
- Wifi-capable mobile phone (not provided)

Part 1: Understanding Breadboards

In this part of the lab, you will construct a circuit that is capable of turning on an LED light bulb. The breadboard is the base of the circuit. Unlike a printed circuit board (PCB), the components and connections can be quickly and easily changed on a breadboard.

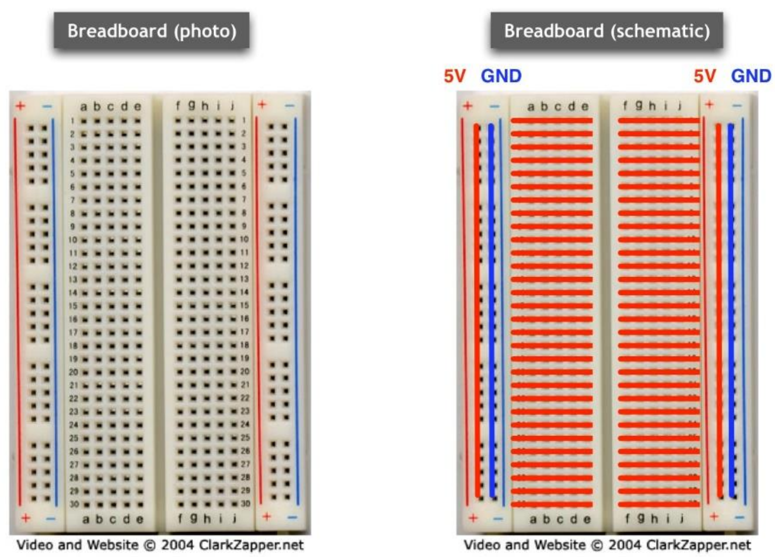


Figure 2: Breadboard Layout

Underneath the surface of a breadboard, there are metal conductive bars that connect each hole along the same row. If power is introduced to just one of the pins in the row, the rest of the pins in that same row will also be powered. The picture of the breadboard in Figure 2 illustrates the internal connections. It also shows that there is a divide in the middle of the board. For example, for any given row, columns *a*-*e* are internally connected, as are *f* through *j*, but *e* is not connected to *f*.

Every row is therefore split into two halves. The outer four (two on each side) columns, usually labeled with red plus and blue minus signs, are the power and ground rails. These rails are unlike the rest in that they are connected in columns. The picture shows how when power is introduced to the power rail, the whole column following the red plus sign is then powered with the same voltage.

It is very important to understand how breadboards work for Electrical Engineering, however, to keep this guide from becoming a small novel, explanations will be added at the bottom in the "**References & Explanations**" section where you can learn more about how specific parts of the project work.

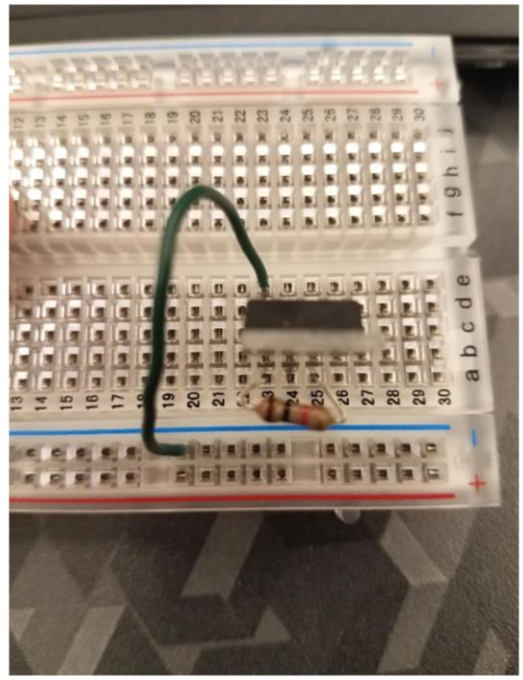


Figure 3: MOSFET Setup

Part 2: Circuit Construction

1. Connect the MOSFET, resistor as shown in the schematic in Figure 1. This corresponds to the physical layout shown in Figure 3.

A MOSFET acts as a solid-state switch (rather than a mechanical switch), which we will use to control the power to the light bulb.

The MOSFET can be placed in any column other than the power and ground rails. Make sure that each of the three pins of the MOSFET is inserted into a different row.

The resistor is connected across the outer pins of the MOSFET, so that ends of the resistor straddle where the center MOSFET pin is connected.

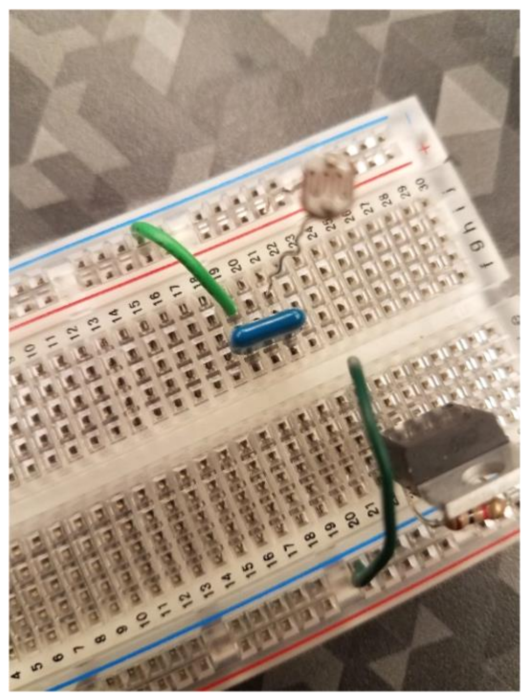


Figure 4: Photoresistor Setup

A male-to-male wire should be connected from the ground rail (any row) to the "**source**" terminal of the MOSFET. If you are unsure which terminal of the MOSFET this is, see the explanation in the References section below and reference the Figure 3.

2. Connect the capacitor and photoresistor as shown in the schematic in Figure 1, and pictorially in Figure 4. The photoresistor is a light sensor that we will use to adjust the brightness of the light based upon how bright the room is.

It is easiest if the capacitor and photoresistor are connected across the channel from the MOSFET and resistor. Make sure the capacitor's pins are on different rows. The photoresistor is connected to the power rail and one end of the capacitor, while a male-to-male wire is connected to the other end of the capacitor and the ground rail.

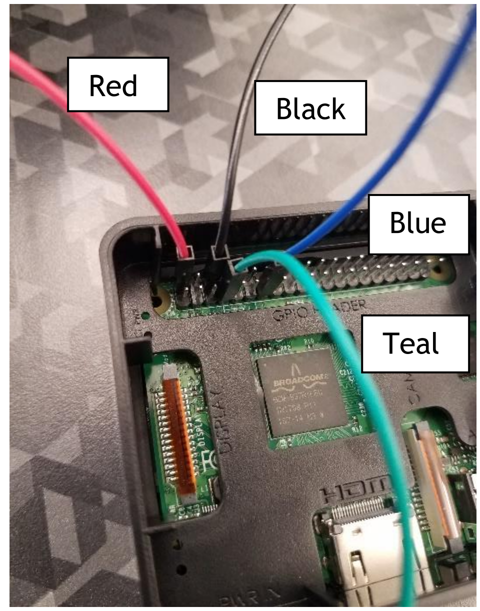


Figure 5: Raspberry Pi GPIO Connections

3. Now connect wires to the Raspberry Pi 3, as shown in Figure 5. Four female-to-male wires are needed. Figure 5 uses red, black, blue and teal, but you can use whichever four different colors you desire. There is a schematic of the Raspberry Pi pin layout ("pinout") in the Reference Section.

The red wire in Figure 5 is connected to the output power supply of the Raspberry Pi (Pin 2, labeled "5V" in the pinout Reference).

The black wire is connected to the Ground (Pin 6, labeled as "GND").

The teal wire is connected to Pin 7 (labeled "GPIO 7").

The blue wire is connected to Pin13 (labeled "GPIO 27").

GPIO (General Purpose Input/Output) pins allow the Raspberry Pi to send and receive signals to external circuits, whereas the power and ground allow the external circuits to be powered.

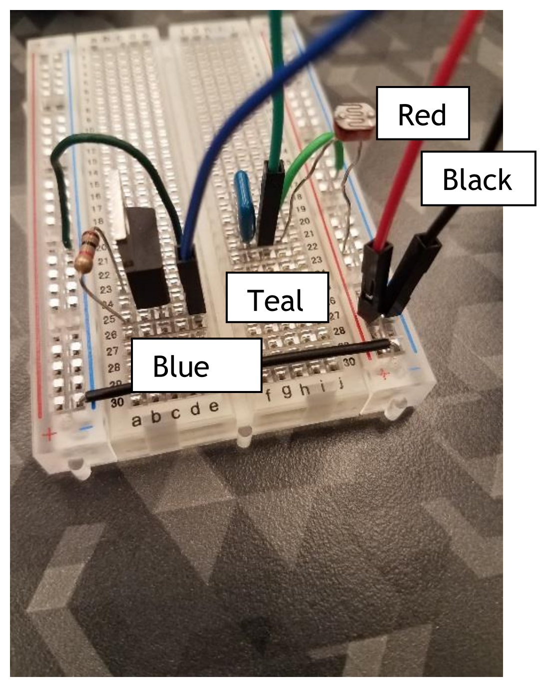


Figure 6: Raspberry Pi to Breadboard Connections

4. Next, connect the wires from the Raspberry Pi to the breadboard as shown in Figure 6. The Raspberry Pi is a mini-computer and is the "brains" of the circuit. It is used to tell the lightbulb when to turn on, control the brightness of the lightbulb based on the amount of ambient light sensed by the photoresistor or as controlled by your smart phone.

Connect the power wire (red wire) from the Raspberry Pi to the power rail on the same side as the photoresistor. The Ground from the Raspberry Pi is connected to the ground rail of the breadboard using the black wire. Connect the GPIO pin 4 (teal wire) to the same row as the capacitor and the photoresistor. Next, connect the GPIO pin 27 (blue wire) to the same row as the "**gate**" terminal of the MOSFET. Use a male-to-male wire to connect the ground rails on either side of the breadboard together.

Part 2: Lightbulb connection

The power from the Raspberry Pi is insufficient to power the lightbulb, so another power supply is needed.

To connect the light bulb to the circuit, we will need a power supply, a pair of minigrabber probes, a 12-Volt LED bulb, a lamp for the bulb, two header pins, and a box with a built-in wall outlet attached.

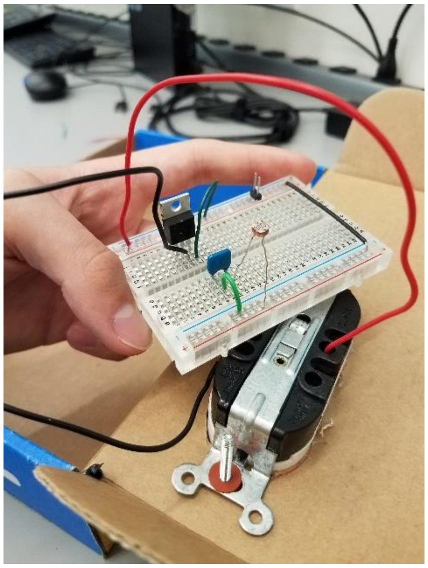


Figure 7: Outlet from box connected to breadboard

1. As in Figure 7, there is a wall outlet attached to your box and you will need to attach the wires from the wall outlet to the breadboard. The black/ground wire from the outlet in the box will connect with the middle "**drain**" terminal of the MOSFET. The red/power wire from the outlet will need to then be connected to the power rail of the breadboard.

2. After all of this is complete, screw the bulb into the lamp if it has not been done so already, and plug the lamp into the outlet attached to the box.

3. The next step is to hook up the 12-Volt power supply with the minigrabber probes to the breadboard. Plug in the red grabber probe to the "**+20V**" output, and the black grabber probe to the "**COM**" output. Next, put the two header pins in the power and ground rails on the same side as the MOSFET and attach the red probe to the power rail header pin and the black probe to the ground rail header pin.

4. Then, turn on the power supply and make sure that the "**+20V**" button is pressed on the meter section of the power supply. Change the "**+20V**" voltage adjust accordingly so that the reading says 12 volts. For reference, see Figure 8.

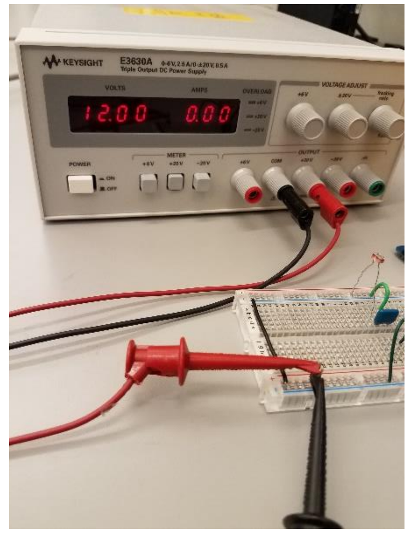


Figure 8: Power Supply and probe connections

Part 3: Raspberry Pi Set-Up

Next you set-up the Raspberry Pi. The code to control the light is preloaded onto the Raspberry Pi's. Connect the HDMI cable, and a 2.5 Amp power supply the Raspberry Pi.
A small red LED should be seen on the Raspberry Pi and the computer monitor should display a desktop (you might need to change the input source of the monitor to "digital").

Now connect a mouse and keyboard into the USB ports on the Raspberry Pi. The operating system running on the Raspberry Pi is Linux, but do not worry, what you will be using is not that much different from Windows or Mac.

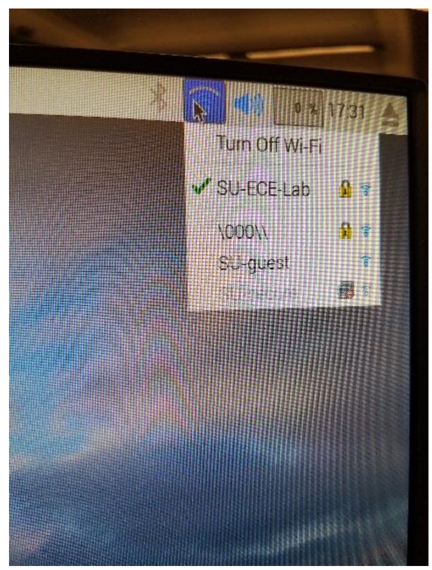


Figure 9: Internet on the Raspberry Pi

1. First, you will want to check if your Raspberry Pi is connected to the internet. In order for the light to work, the Raspberry Pi and your phone need to be connected to the same wifi network. The network we are using is named ***SU-ECE-Lab***. Your Raspberry Pi's should be connected to this network already. If it is not, then ask an instructor for help.

2. Next, connect your mobile phone to the same wifi network. The network is hidden, so you will need to enter the name of the network, and its password into your phone's "find network" or "advanced settings" option. The password will be provided by an instructor in class.

3. Once both the Raspberry Pi and your phone are connected to the ***SU-ECE-Lab*** network, click on the terminal (black box icon) in the task bar up at the top of the screen (Figure 10).

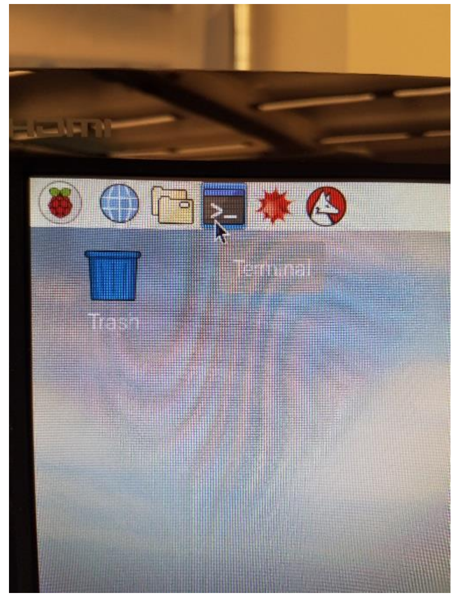


Figure 10: Terminal on the Raspberry

4. Type ***ifconfig*** into the terminal prompt and press "enter" like in Figure 11. You will look for the succession of numbers that come after **inet addr** in the section of information under ***WLan0*** (Figure 12)**.** This number should be in the format of 12.345.6.78. This is the internet address of the Raspberry Pi device and it is how other devices locate it through the internet.

5. Enter that inet address into the search bar of the web browser **<u>on your phone</u>**. This will take you to the smart light menu (Figure 13).

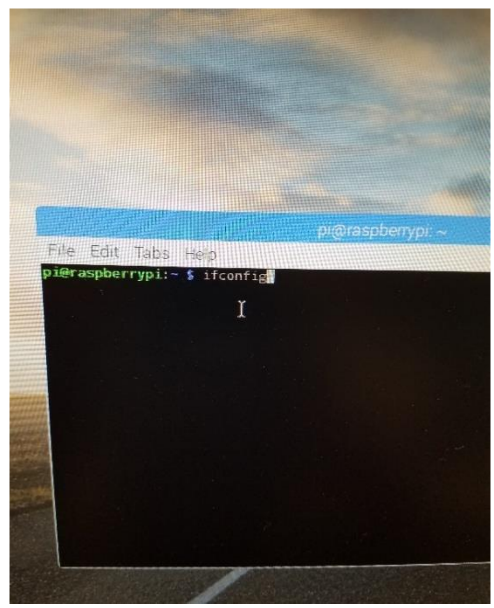


Figure 11: Entering "***ifconfig***" into the

Part 4: Adjusting the Light Bulb

You can then choose the automatic option to have the photoresistor adjust the brightness of the bulb for you by sensing the light in the room, or you can manually choose between 4 brightness levels.

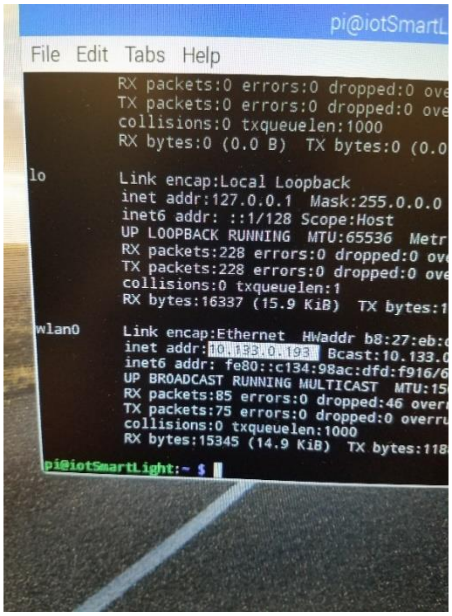


Figure 12: Finding the inet Address for the Raspberry Pi

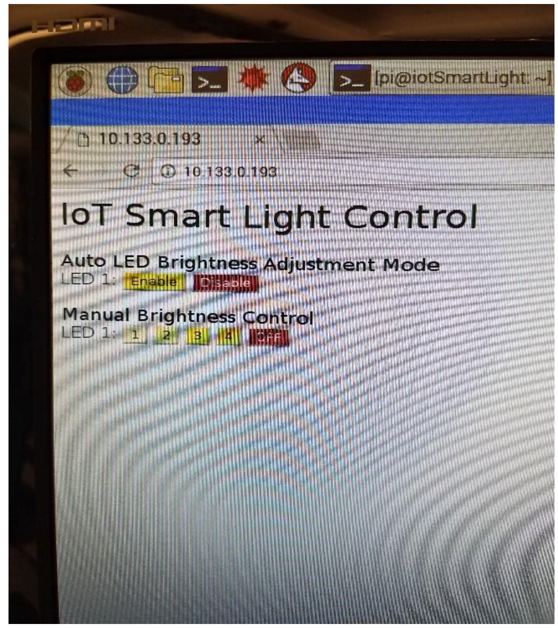
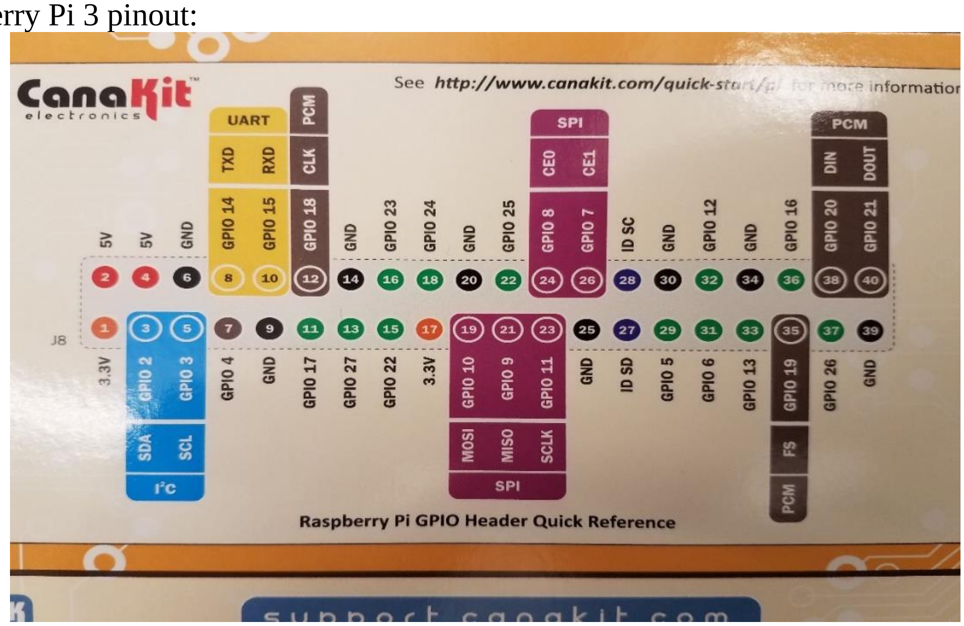


Figure 13: Smart Light Interface

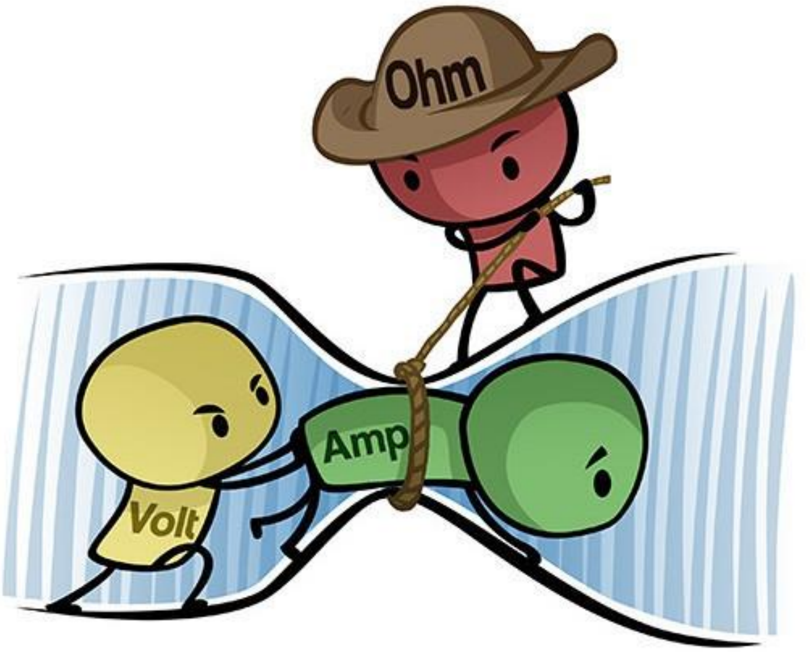
If everything is setup correctly, using the smart light control menu on your phone will control the light bulb. Hooray! Congrats! You have successfully assembled a smart light!

References and Explanations

Raspberry Pi 3 pinout:



Voltage (Volts): The three basic principles for this tutorial can be explained using electrons, or more specifically, the charge they create. Voltage is the difference in charge between two points.



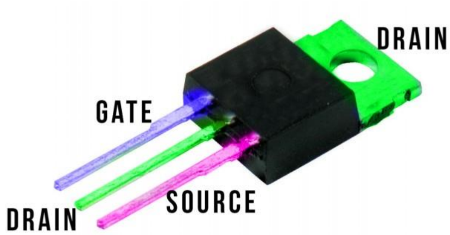
Charge: In physics, charge, also known as electric charge, electrical charge, or electrostatic charge and symbolized *q*, is a characteristic of a unit of matter that expresses the extent to which it has more or fewer electrons than protons.

Current (Amps): Current is the rate at which charge is flowing (Derivative of charge).

Resistance (Ohms): Resistance is a material's tendency to resist the flow of charge (current).

Resistor: A device having a designed resistance to the passage of an electric current. In other words, a component that controls the amount of current flowing through it.

MOSFET: The metal–oxide–semiconductor field-effect transistor (**MOSFET**, MOS-FET, or MOS FET) is a type of field-effect transistor (FET). A MOSFET has two primary purposes. It either acts as a switch only allowing voltage to pass through it when a certain amount of current is introduced to it, or it is used as an amplifier, increasing the incoming voltage. There are three leads coming out of the MOSFET as shown in the picture. The left most lead in the picture is known as the "**gate**" terminal. The middle most lead is known as the "**drain**" terminal, and the right most lead is known as the "**source**" terminal.



Wire: A conductive metal, usually copper, that is surrounded by a non-conductive material for insulation so it safe to touch when the circuit is active. I would not recommend trying to touch the conductive metal ends when the circuit is powered.

IC: An Integrated Circuit or (IC) is an electronic circuit formed on a small piece of semiconducting material, performing the same function as a larger circuit made from discrete components.

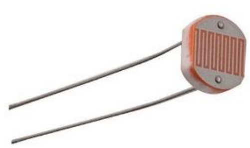
GPIO pins: General-purpose input/output (GPIO) is a generic pin on an integrated circuit or computer board whose behavior—including whether it is an input or output pin—is controllable by the user at run time.

Electrical Circuit: An electric circuit is a path in which electrons from a voltage or current source flow. The point where those electrons enter an electrical circuit is called the "source" of electrons. The point where the electrons leave an electrical circuit is called the "return" or "earth ground".

Ground: In electrical engineering, ground or earth is the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.

Capacitor: Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, a capacitor does not dissipate energy. Instead, a capacitor stores energy in the form of an electrostatic field between its plates.

Photoresistor: A photoresistor (or light-dependent resistor, LDR, or photoconductive cell) is a light-controlled variable resistor. The resistance of a photoresistor decreases with increasing incident light intensity; in other words, it exhibits photoconductivity.



Raspberry Pi: The Raspberry Pi is a low cost, credit-card sized computer that plugs into a computer monitor or TV, and uses a standard keyboard and mouse. It is a capable little device that enables people of all ages to explore computing, and to learn how to program in languages like Scratch and Python. It’s capable of doing everything you’d expect a desktop computer to do, from browsing the internet and playing high-definition video, to making spreadsheets, word-processing, and playing games.