PHY 242

Lab 2: Function Generator and Oscilloscope.

For this lab we will not be tracking random uncertainties while we are learning to use sophisticated equipment.

Introduction

Last lab we introduced the ideas of Voltage, Current, and Resistance. This week we will explore these ideas again, however these quantities will be changing **in time**. One way to make things change in time is by using the Function Generator-a **power source** that is designed to produce Voltage that follows one of three set patterns, sine, triangle, and square. Today we will only be using "square waves." Because the voltage is changing, the function generator also gives us the freedom to change how quickly the change occurs by adjusting the frequency. A complete guide to the function generator can be found in Canvas but we will walk through the important parts of this device in Part 1 today.

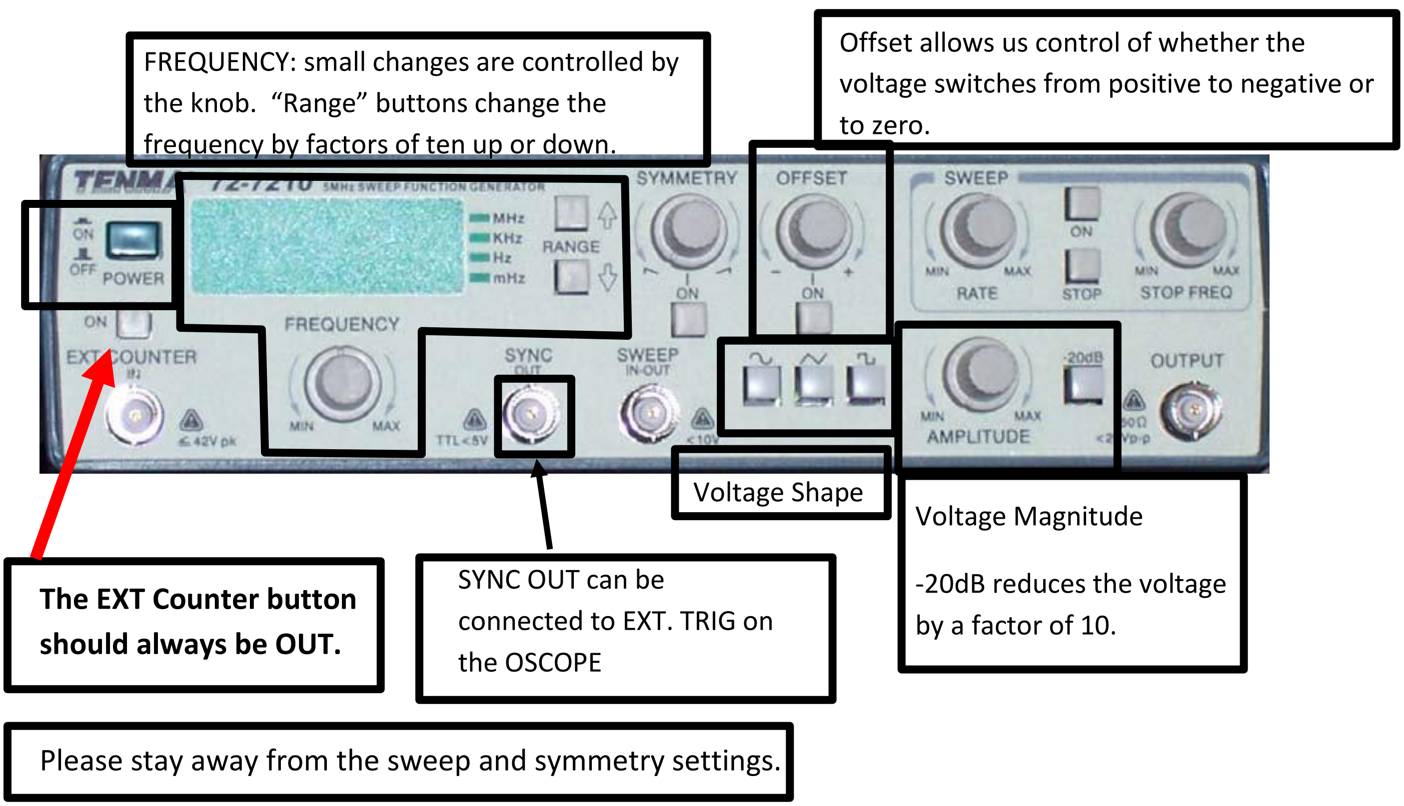
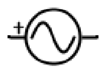


Figure 1

Part 1- Understanding the Function Generator.

Equipment

1 Function generator 

1 resistor 

1 Ammeter connected to Logger pro 

Setup and Procedure

1) When you arrive you should build the following circuit. Starting from the red port of the Function generator, we want a red wire to the red port of the ammeter. From the black port of the ammeter, let's use another red wire over to the lightbulb. From the other side of the lightbulb, please use a black wire to go to the black port on the function generator.

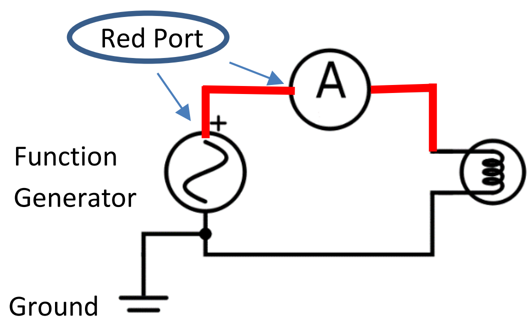


Figure 2

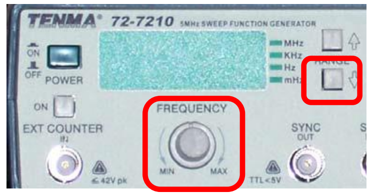
A few important things to notice:

The arrow,  is a representation of the "Ground," a place where current can flow and a connection that forces the voltage to be ZERO. We will use BLACK WIRES to represent parts of the circuit we know are at zero volts. So long as we only have one ground, current will not flow along this path and we can ignore it. We are including it in the diagram because the black port coming out of the function generator has a small tab that says "GND." If we are not careful later in the lab we will get confusing results from our equipment.

2) Before you turn anything on, make certain
   a. the Amplitude is turned down.

b. the function generator has the square wave button pressed IN.
c. all other push buttons are OUT.
d. Logger Pro is on and the ammeter has been zeroed. (Experiment->Zero)

3) When you first turn on the Function generator the frequency may be so high that the ammeter will not have time to measure the current. Press the “Range Down” button

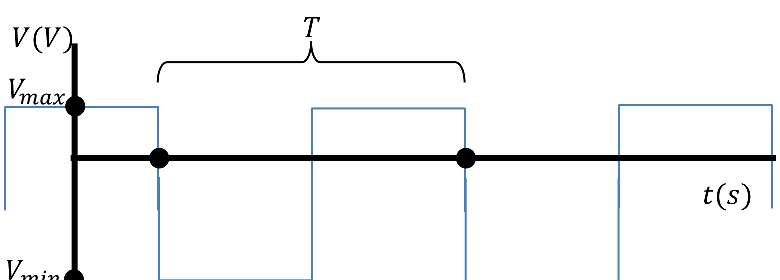


and adjust the frequency knob until the display gives a frequency around 2 Hz (check the little light to see the units of the frequency display). In this range, you should be able to see the ammeter positive to negative. Adjust the frequency to make sure you understand what effect this knob has on the ammeter readings. Return to 2 Hz.

4) Click the collect button in Logger Pro Adjust the “Amplitude” knob on the function generator. Notice, the effect it has on our meter and the lightbulb. Leave the amplitude knob about ½ on, (pointed roughly up) so you can see a little glow from the lightbulb. Make a note for yourself as to the effect of the amplitude knob.

5) Adjust the Offset knob to be straight up and press the “Offset On.” Slowly adjust the Offset knob and observe the behavior of the lightbulb and the ammeter readings. It is possible you will notice that the ammeter is no longer recording nice square waves, we will investigate that effect later in part 3 of the lab.

6) Researcher: Since the function generator has the (square wave) button pressed, it is supposed to make voltage which looks like



i) Record the effect of the Frequency knob on $V_{max}, V_{min}, and\ T$.

ii) Record the effect of the Amplitude knob on $V_{max}, V_{min}, and\ T$.

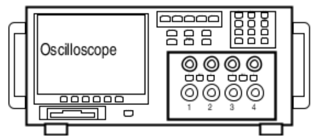
iii) Record the effect of the Offset knob on $V_{max}, V_{min}, and\ T$.

Part 2- Using the Oscilloscope

Equipment

Items from Part 1

1 Oscilloscope (sometimes called an O-scope)



Setup

We will be using the following oscilloscope during this semester. Oscilloscopes are very versatile, powerful instrument for measuring how **voltage** changes over time. Unfortunately all of that versatility means that there are setting on the scope that can make it do very strange things. Here are the main settings we are concerned with…

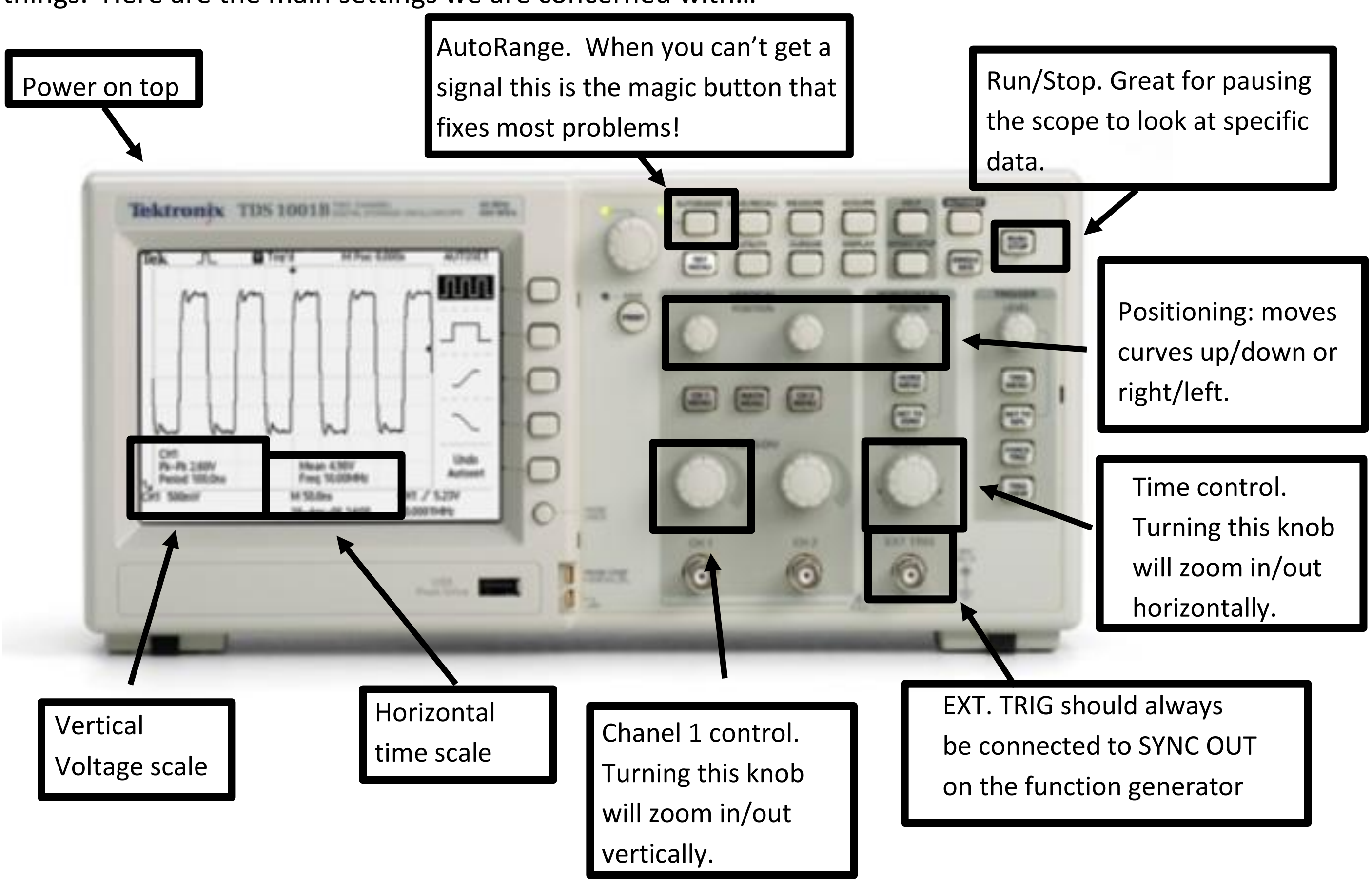
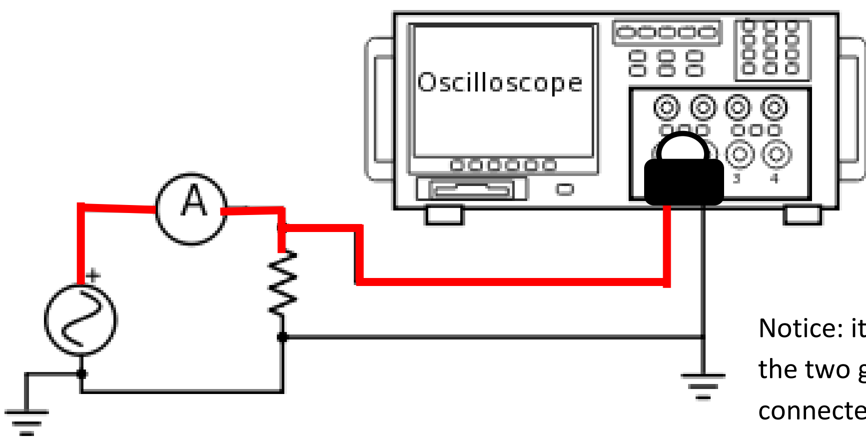


Figure 3

You must connect the oscilloscope to the circuit that we already have in the following way. You must attach the two wires from the oscilloscope to the two sides of the resistor (red to red, black to black). **It is vitally important that the black wire from the scope connect at the resistor on the same side as the black wire from the function generator, this basically takes the ground from the function generator and connects it directly to the ground from the oscilloscope.** If the two grounds are not connected to each other directly, then stray current can flow into or out of our circuit and we will have built a circuit that has a completely different behavior than this lab intends.

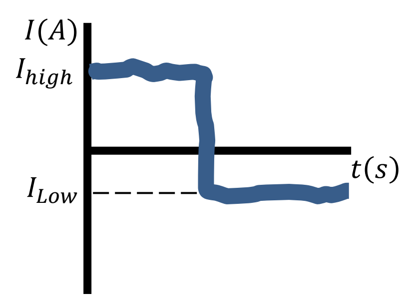


Notice: it is important that the two grounds are connected directly with wires.

Figure 4

Procedure

7) Now that the oscilloscope is part of the circuit, make certain that the function generator is approximately 2 Hz and the ammeter should behave identically to how it behaved before in Part 1. If the ammeter has changed its behavior then your circuit is incorrect, call the instructor over.
8) First we will need to enter our measurement of the Resistance of the Resistor from Lab 1 into the Excel template for Lab 2. This value should be $(10 \pm 1)\Omega$.
9) Second we want to record the maximum and minimum current from our ammeter in excel right next to "High values" and "Low Values."



10) We can calculate V_{Ohm} using Ohm's Law $\Delta V = I * R$. Remember: your formula should start with an equals, the current should not use $'s because it will change between the rows, while the resistance should use dollar signs because we always have the same resistance. So you should type something like "=B9*C6" as your formula to calculate V_{Ohm}.

11) Now we want to explore the oscilloscope and see if we can get matching readings for the Oscope. Make sure you do not adjust the function generator until you reach Part 3.

12) On the oscilloscope hit the AutoRange button. On the screen you should see a graph that looks roughly like a “step” (either up or down)

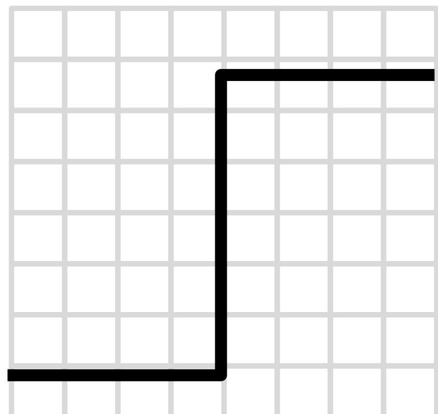
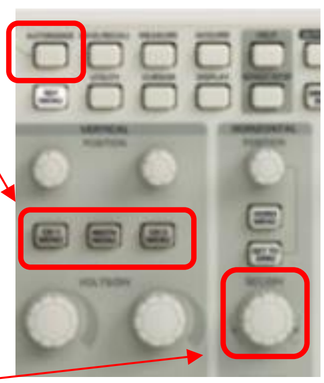


Figure 5



If you see two or three lines you need to hit the “CH 2 Menu” button or the “Math Menu” button until the other lines disappear. If needed, push the AutoRange button again so you have a nice large step on the screen.

13) If you look to the bottom of the screen it will let you know how much time is represented with each horizontal block- “horizontal time scale.” Turn the “Sec/Div” knob which controls how much time is displayed until the horizontal time scale states “M 1.00s.” Now you should see:

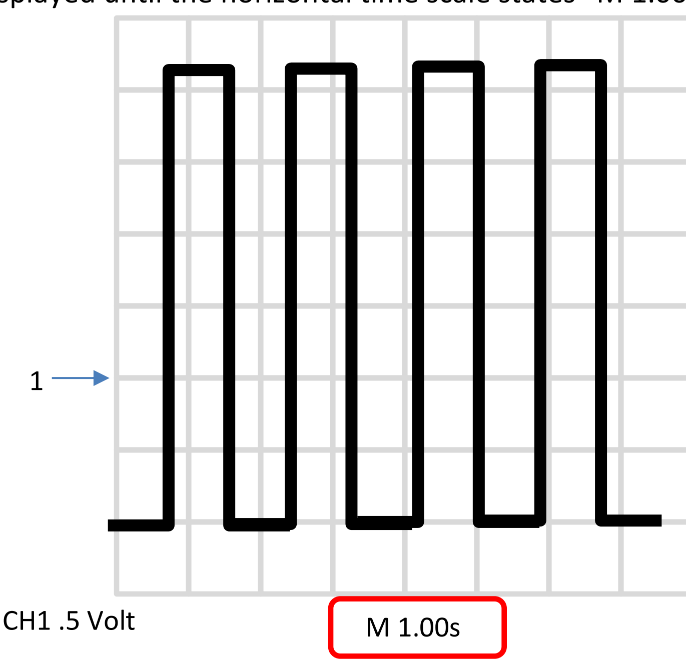
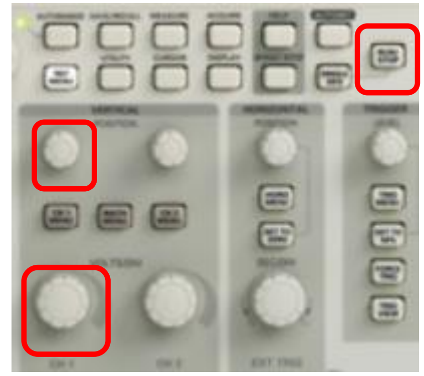


Figure 6



Adjust the “Position” and “Volts/Div” knobs above “Ch1” to see what these important knobs do. If the graph keeps writing over itself, you can hit the “Run/Stop” button in the upper right corner of the Oscope.

14) On the left of the graph there is an arrow with a 1 which is important. It tells you where “Zero” is on the vertical scale for channel 1. To figure out how much voltage is being displayed, we take the Vertical Voltage Scale (found on the bottom left corner of the screen) and multiply by the “number of blocks between the arrow and line.”

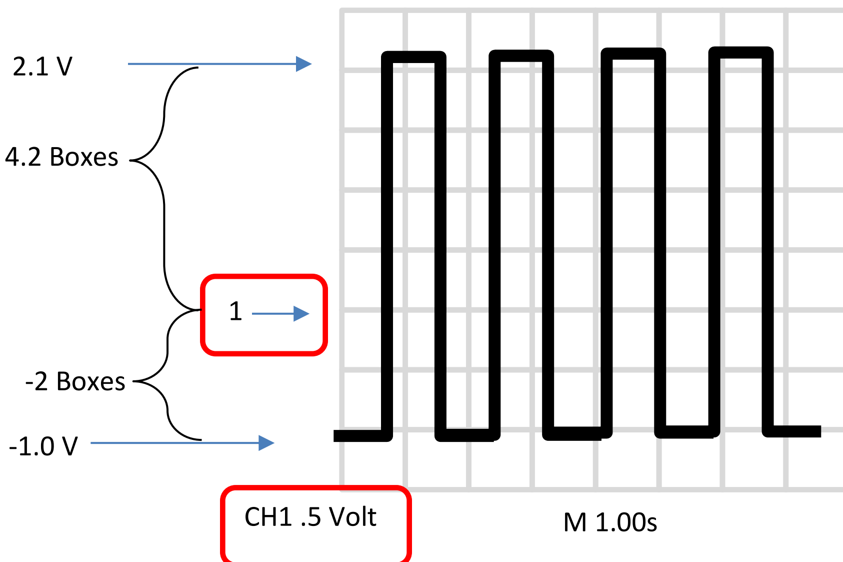


Figure 7

a. For the example above, between the arrow and the top of the plotted line there are about 4.2 boxes. The Vertical Voltage Scale is .5 Volts. Therefore, the voltage at the top of the plot is $4.2\ boxes \times .5 \frac{Volts}{box} = 2.1\ V$.

b. For the example above, the bottom of the plot is 2 boxes below the arrow. So it is at $-2\ boxes \times .5 \frac{Volts}{box} = -1.0\ V$.

15) Measure the top of the square wave as $V_{oscope\ \text{High value}}$, using the instructions in step 14) above. Also measure the bottom of the square wave as $V_{oscope\ \text{Low value}}$.

16) If you have reasonable agreement between the calculate Voltages in the C column with the Voltages found directly from the Oscope you can move on to part 3. Otherwise check your units and/or discuss with your TA.

Part 3- Why does the resistance of the Light Bulb Change?

In Lab 1 we discovered that the lightbulb did not behave as a normal resistor because the resistance changed as the current increased. **But was this really due to the current or did something else cause this change in resistance?**

Equipment

The same as part 2

1 lightbulb - (It is important that you not switch lightbulbs during this part of the lab. If your bulb burns out retake the data set for Part 3 (This only takes about 10 minutes once you know what you are doing.)

Setup

17) Build the following circuit.
    a. Starting from the red (plus) port of the function generator, red wire to the red port of the ammeter.
    b. From the black port of the ammeter to the lightbulb, red wire.
    c. From the other side of the lightbulb to the resistor, red wire.
    d. From the other side of the resistor to the black port of the function generator, black wire.

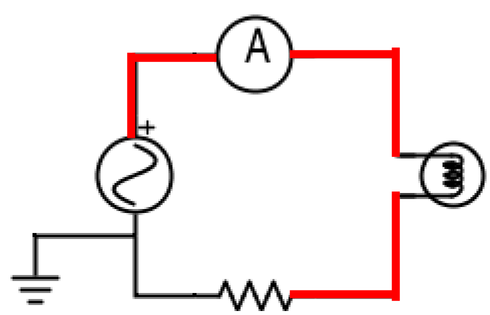


Figure 8

18) On the function generator make sure that your frequency is around $\mathbf{0.2}\ \boldsymbol{Hz}$,. Turn the amplitude **all the way up**. Make sure that the -20dB button is OUT.

19) On the **Function Generator** adjust the "Offset" to the upper right so that the ammeter is reading approximately zero half the time and then jumping to some positive value. This

will cause your lightbulb to switch between totally dark for a few seconds, then very bright for a few seconds.

20) Now we will add the Oscope using both channels! See the diagram is below.
    a. Channel 1 RED wire goes to the red wire on the RESISTOR.
    b. Channel 2 RED wire goes to the lightbulb on the AMMETER side.
    c. Channel 1 AND 2 Black both go the black wire on the RESISTOR.

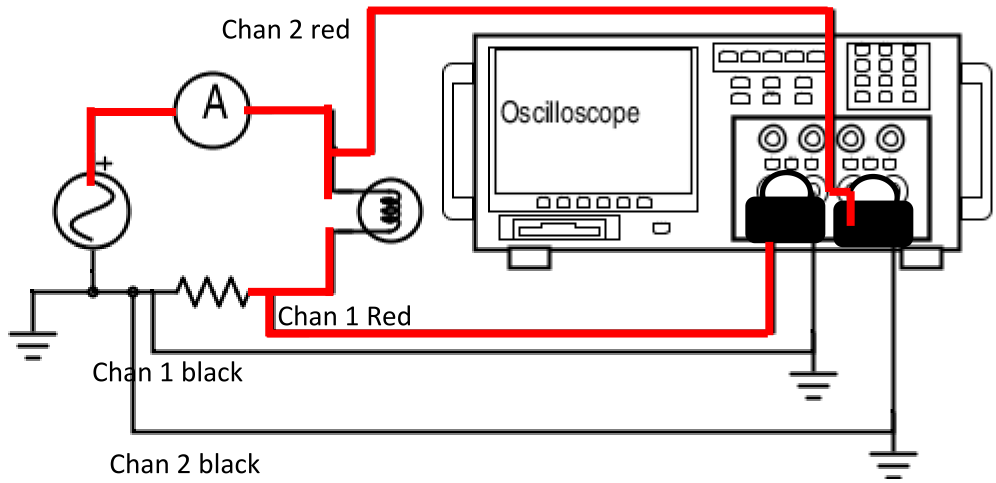


Figure 9

21) Hit the AutoRange button to make sure that you have two plots on your Oscope screen. Adjust the time control until M 1.00 s is in the center of the screen (you can have this setting higher than 1.00 s if needed). Use the "Position" and "Volts/Div" knobs to adjust Channel 1 and Channel 2 until you have a plot roughly like Figure 10 below.

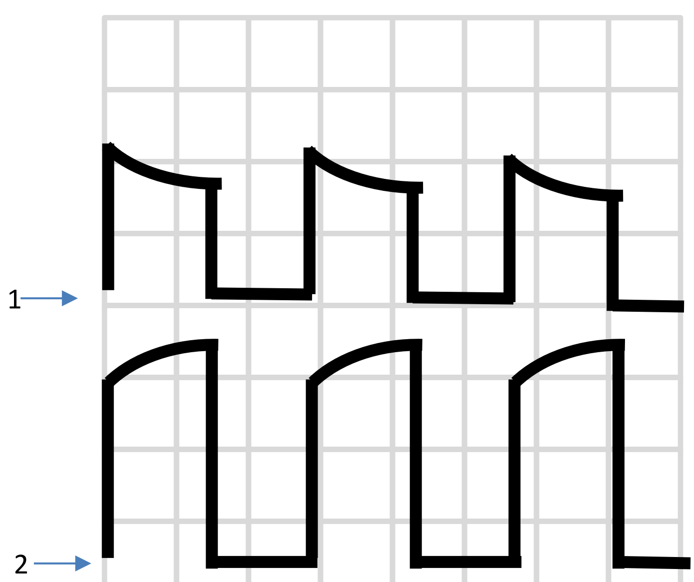


Figure 10

22) Before we analyze this data further, take some time to play with the wiring and see which of the following changes alter your oscilloscope graph and which do not.
    a. Move Channel 1 RED wire to the lightbulb on the resistor side.
    b. Move Channel 2 RED wire to the ammeter on the lightbulb side.
    c. Move Channel 2 Black to the Channel 1 Black port.
    d. Swap the location of the two channel 1 wires.

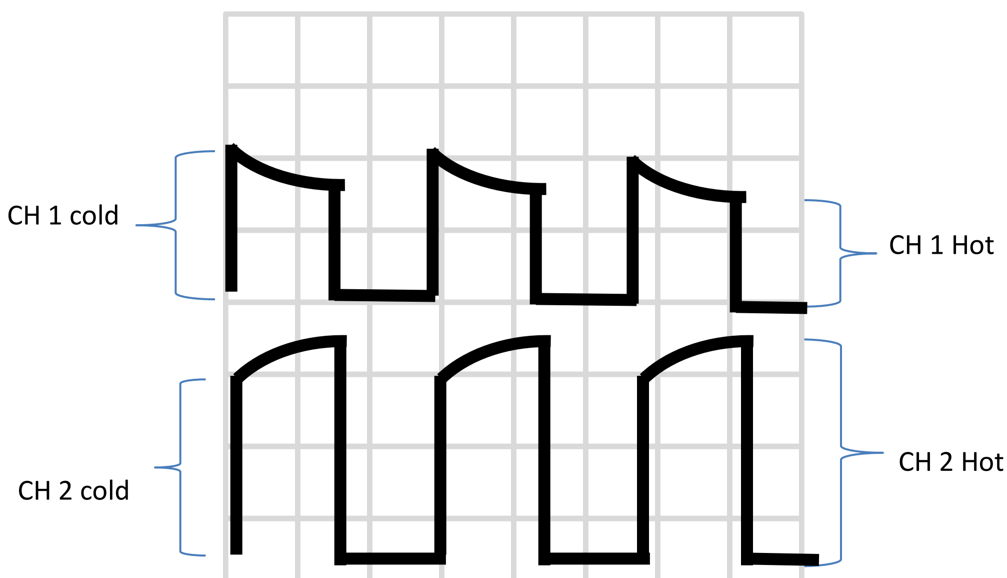
23) Return your wires to a configuration that gives you the Oscope plot you started with in step 22.

24) Because your Ammeter is registering zero volts for half the time, you should notice that the Oscope has the bottom of the plots line up perfectly with the 1 and 2 arrows.

25) Before we take data, make sure you record the Scale factors for each channel in the Excel template. So referencing Figure 11 below, we need X in cell D15 AND D16, while Y goes in G15 and G16.

26) Now we should be ready to take data. Our goal is to measure the resistance of the lightbulb "right when it turns on" or when it is COLD. We also want to measure the resistance "right before it turns off" or when it is HOT.

27) For trial 1, we will record the number of boxes in each channel at the beginning and end of the voltage pulse from the function generator as shown in the diagram below.



CH 1 X Volts

CH 2 Y Volts

Figure 11

28) If our goal is to measure the resistance, we must do some work to find that resistance from what we have measured. If we could measure the current and voltage across the bulb and then we could use Ohm's Law: $R_{bulb} = \frac{\Delta V_{bulb}}{I_{bulb}}$.

   a. In fact, we are not set up to measure ΔV_{bulb} directly. Channel 2 is measuring $\Delta V_r + \Delta V_{bulb}$.
   b. We are set up to measure I_{bulb}, but the current is changing the whole time the lightbulb is on. Therefore, we will use the measurement of ΔV_r through Channel 1, and can use Ohm's Law to measure $I_r = \frac{\Delta V_r}{R_r}$. Because all the current flows from the bulb to the resistor, the two currents must be the same. $I_r = I_{bulb}$. Check your calculations by hitting "Collect" in logger pro and look at the profile of the current as time goes on. Do your hot and cold current measurements match between excel and Logger pro?

29) Use the steps outline in 28) to code equations in the blue cells of Part 3.

30) For Trial 2, turn down the "Amplitude" on the function generator all the way down, and adjust the Offset on the Function Generator so that the Oscope reads zero Voltage half the time and some small positive value half the time ($\approx 1\ V$). (Because we have turned the amplitude way down, you will probably need to adjust the oscope to zoom in on the voltage AND THEREFORE THE OSCOPE BOXES HAVE A DIFFERENT SCALE. Also, you should not be surprised if the plot on the Oscope is much more square and the curved tops of Figure 11 have straightened out.)

31) Repeat steps 25) through 29) to analyze your data. Notice that for the blue cells, you should be just copy/pasting the formulas.

32) For Trial 3, adjust the Amplitude and Offset on the function generator so the lightbulb **barely glows** half the time. Remember to check and ensure that when the lightbulb is not glowing the voltage and current are zero.

33) For trial 4, make sure you adjust the Amplitude and Offset on the function generator so the light bulb achieves some intermediate level of brightness. We just want a total of four trials where the lightbulb glows at four different levels but it is important **that the**

bulb turn completely off half the time so that the Oscope or Ammeter are reading approximately zero half the time.

34) You should now see a plot of four blue dots and four orange/red dots. This plot should become the center of your understanding of why the resistance of lightbulb changes!

DA:

DA1: Create a table which shows a **sample** of raw data for Part 3 of the experiment. Make sure it shows at least **three** examples of each measurement and calculation with proper units displayed.

DA2: To prepare your part 3 graph for the worksheet, please add the appropriate title, axis labels, series labels, Units, etc. to this graph so that it will be a useful tool in explaining the lightbulb's behavior.

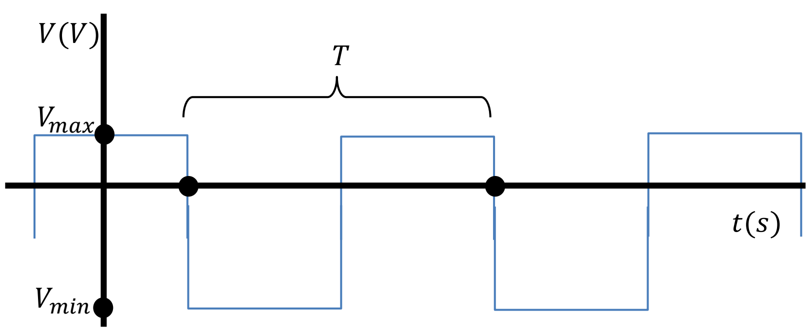
DA3: Create a caption for your graph which explains in words what the image means about your experiment. Make sure you reference the response to PI1 & PI2 in explaining the difference between the blue and orange dots.

Researcher:

R1: Review steps 1), 22) and 28) and discuss the proper way to connect the wires from the Oscope to a circuit so that you can measure the voltage of a circuit element.

R2: Refer to the sample data provided by DA1 and identify each of the columns which depend upon the Law of Conservation of Current, Kirchhoff's Voltage Law, and/or Ohm's Law.

R3: Since the function generator has the (square wave) button pressed, it is supposed to make voltage which looks like



i) Record the effect of the Frequency knob on $V_{max}, V_{min}, and\ T$.

ii) Record the effect of the Amplitude knob on $V_{max}, V_{min}, and\ T$.

iii) Record the effect of the Offset knob on $V_{max}, V_{min}, and\ T$.

PI:

PI1: Use the DA2 plot to evaluate the idea the current is the main reason that the resistance of the lightbulb changes.

PI2: Use the DA2 plot to evaluate the idea that the main reason that the resistance of the lightbulb changes is NOT Current or Voltage but some other quantity of the lightbulb which we have not measured. Identify this quantity and explain why you suspect this is the real reason the lightbulb changes resistance.

PI3: Summarize: What is the resistance of the lightbulb? (Please answer in the form: $R = \bar{R} \pm \delta R$) Why is δR so large?

Before leaving the lab make sure you email your data to the group and clean up your lab bench by returning the correct equipment to the proper drawer/cabinet.