# Elec 240 Fall 2018 Lab #1

# Experiment 1.1

This material is adapted from the old Elec 240 website.The formatting and background material are better over there, but for questions of what has officially been assigned please use this document.

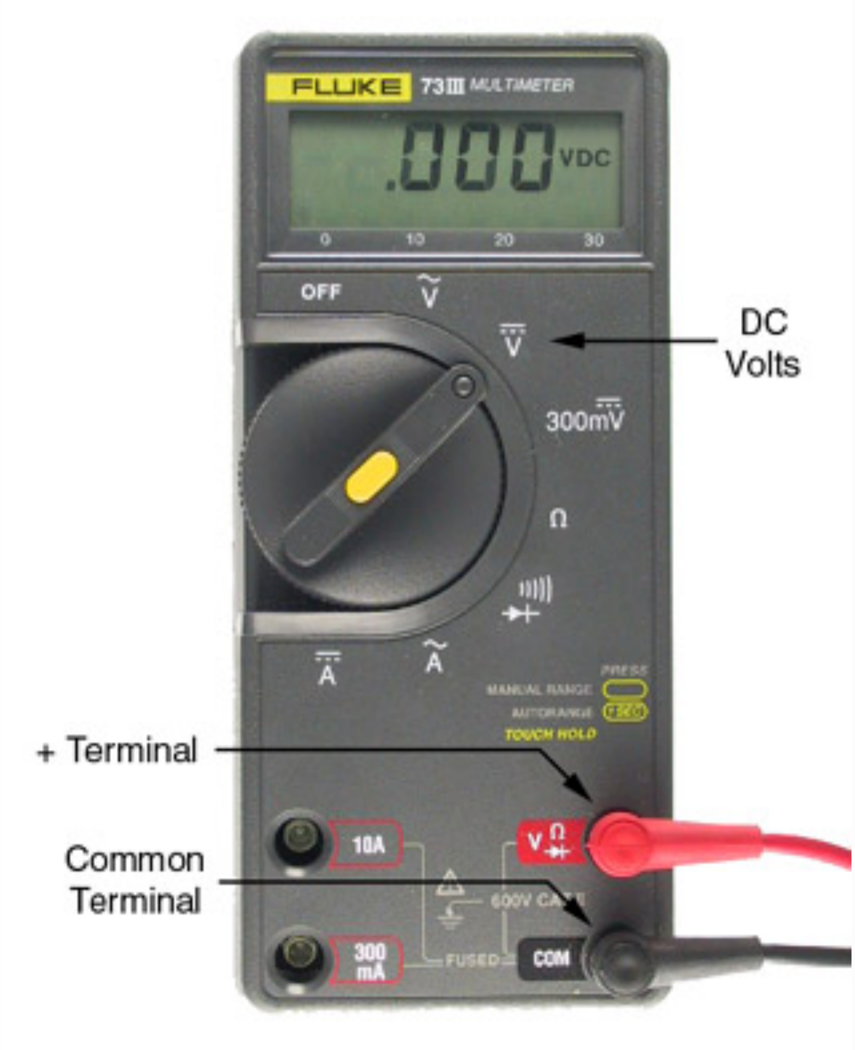
# DC Measurements: the DMM

## Equipment

- Battery Pack and Batteries
- Lightbulb Socket Board
- Digital Multimeter
- Banana Plug Patch Cords

## Part A: Measuring Voltage with the DMM

1. Turn on the digital multimeter (DMM) to the setting for DC volts measurement:




2. Make sure the negative (black) lead is plugged into the COM terminal and the positive (red) lead is plugged into the V terminal, as shown in the picture. COM stands for common, or in other words, the termin al that is the point of reference for other terminals.
3. **Measure the voltage of each battery** by holding the positive probe against the top of the battery and the negative probe against the bottom.

**Note**

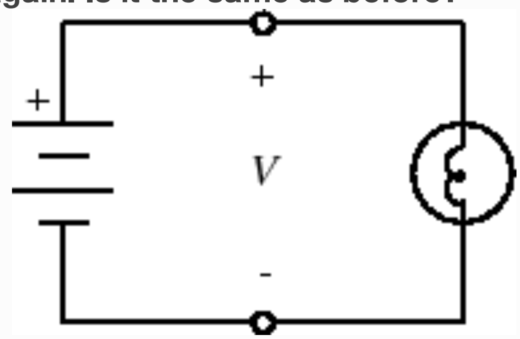
In measuring voltage, we are always measuring the *difference in potential* between two nodes. So the meter is always connected across two points.

4. Place the two batteries into the holder in the orientation indicated. **Measure the voltage of the battery pack. It should be equal to the sum of the two batteries. Is it?**

**Warning**

Be careful not to short the two leads of the battery pack together once the batteries are installed. To be safe, remove at least one of the batteries when the pack is not in use.

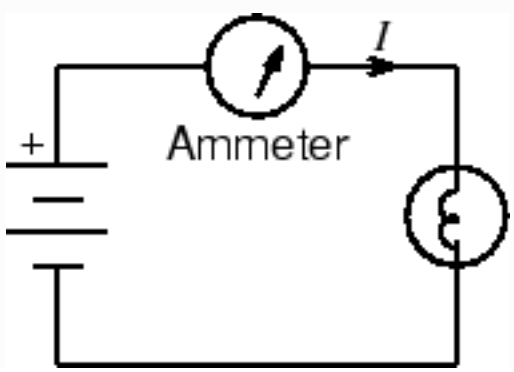
5. Wire the circuit below by screwing the leads from the battery pack to L and R terminals of the lamp board. The bulb should light (though rather dimly). **Measure the battery voltage again. Is it the same as before?**




## Part B: Measuring Current with the DMM

To measure current, we must connect the meter *in series* with the circuit we are measuring, as in the figure below. This is because current flows *through* a conductor, whereas voltage appears *across* two conductors.

This is because current flows *through* a conductor, whereas voltage appears *across* pairs of conductors.



1. With the meter disconnected from the circuit, set the function switch to DC current ("A" with straight solid and dashed lines above it). Move the red meter lead to the 300 mA terminal.

**Warning**

An ammeter must always be connected in series. Connecting an ammeter in parallel with a circuit element can pass very large currents through the ammeter, blowing its internal fuse or damaging it. A good practice is to always reset the DMM to voltage measurement settings after making a current measurement.

2. Use the NC ('not connected') terminal as a node to connect the positive battery terminal to the positive lead of the DMM.
3. **Note the current value displayed on the DMM.**

## Part C: Measuring Resistance with the DMM

1. Set the DMM to Ohms (W) and return the positive meter lead to Volts/Ohms terminal. Touch the two probes together. The meter should read zero resistance. If it reads more than a few tenths of an ohm, check for poor connections or have your meter serviced.
2. Select several resistors at random from your parts kit. For each resistor, determine its nominal value from the color code, then measure its resistance by touching one probe to each lead of the resistor. **Do the nominal and measured values agree?**

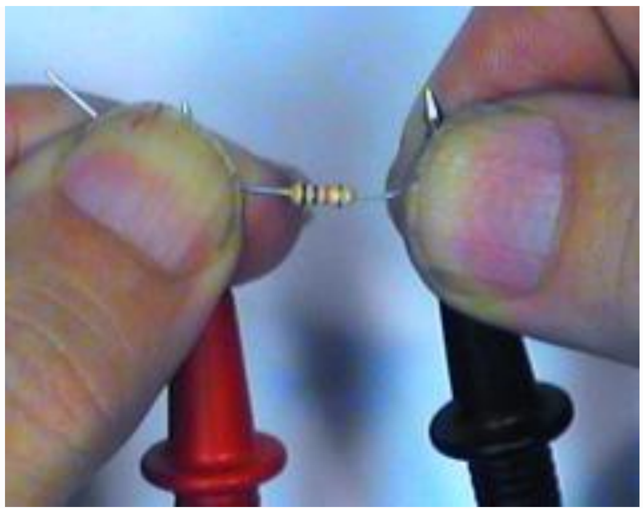
**Note**

To read a 4-band resistor color code, view it with the gold/silver band to the right. The first two band colors correspond to the first two digits of the resistor value and the third band color is the multiplier. The fourth band is the percent tolerance. Tolerance means that the actual resistance value is guaranteed to be within the marked value specified percent.

**Note**

To measure resistance, lay the resistor on the bench and test as shown below.

3. **What's wrong with holding the leads and probes between your fingers?**



4. The actual resistance $R$ of a resistor having nominal values $R_0$ and tolerance $d$ lies in the range $R_0(1+d)$. **What is the tolerance of a series connection of two such resistors? Of a parallel connection?**
5. Obtain ten resistors with the same marked value. Measure the resistance of each resistor. **Does your batch have the stated accuracy?**
6. Holding one DMM lead in each hand, measure your own resistance. The reading may be unstable, therefore the resolution is limited to the digit that changes least often. **What is the value and resolution of your resistance?**
7. **Does your resistance change when you wet your fingers? If so, speculate why. What voltage would be necessary to produce a 5mA current through you?** (Why 5mA? Read Safety).

8. Using the DMM, **measure the resistance of the light bulb. Does this correspond to the value you would expect from Ohm's Law given the values of voltage and current you measured in Parts A and B?**

**Warning**

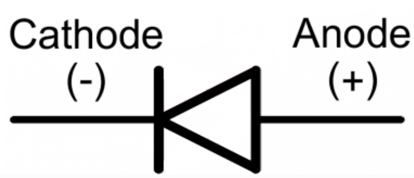
The DMM can only measure the resistance of an element when it is disconnected from the circuit. Remember to turn off the power source or the value measured will be inaccurate.

## Part D: Continuity and diode testing using a DMM

1. Set the DMM to continuity testing/ diode testing (diode symbol). Touch the leads together and verify you get a beep when the DMM sees a short circuit. This is a very useful mode when you are debugging circuits and you need to know whether two points are shorted together (by design or otherwise.)
2. Try testing some diodes

In diode testing mode the DMM will attempt to force a small current and measure the resulting voltage across the device. If the device is a regular diode the DMM will measure something like 0.5-0.7V.

This only happens if the diode is connected in the forward direction: diodes only conduct current in the direction of the arrow on their symbol, which requires the + terminal to be at a higher voltage than the – terminal. The forward direction is to have Red to + (anode) and Black to – (cathode.)




If you have the DMM backwards across the diode no current will flow and the DMM will tell you the device looks like an open circuit by displaying something like “OL” instead of a numeric value.

First, test regular PN junction diode: record the readings you get when the connect the DMM correctly and backwards across the diode.

Then test a light emitting diode LED that is designed to emit visible light (red, yellow, green, blue, white; not infrared or ultraviolet). LEDs require more forward voltage than a PN junction diode. You probably will get “OL” in both directions but you will see some light from the diode when it is connected in the forward direction.

## Part E: Measuring the I-V Characteristics of the Light Bulb

An ideal resistor obeys Ohm's law: $I=V/R$, i.e. the current through the element is proportional to the voltage across it. But for most real materials, the resistance changes as the temperature changes, and clearly, the temperature of the light bulb's filament increases as more current flows through it. Let's find out how the current and voltage of our light bulb are related.

For this measurement, we will need to vary the voltage applied to the bulb, so we will need a variable voltage source. This is provided by the DC Power Supply on the VirtualBench. The DC power supply actually contains two variable voltage sources, but we will be using only one of them, the $0-6V$ supply.

1. Make sure the DC power dongle is attached to your VirtualBench (VB).

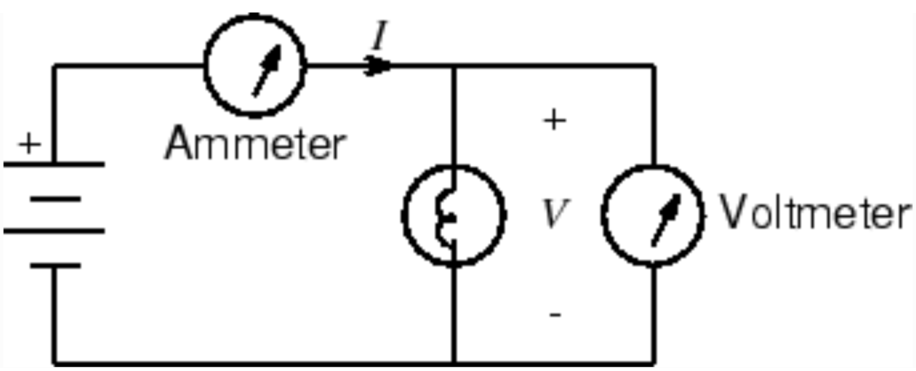

2. Set the DMM to DC Volts. Connect the black (-) probe to the black $0–6\mathrm{V}$0–6V output terminal and the red (+) probe to the red terminal.
3. Press the power button on the power supply interface below the oscilloscope screen. Gradually increase the output voltage by raising the voltage in the $+6\mathrm{V}$+6V setting. Both the power supply and the DMM should show increasing voltage values. For several different values, note both the power

supply $+6\mathrm{V}$+6V setting and the DMM reading. **How do the two compare?** Return the voltage output to zero.

**Note**

For the rest of this part, you will need to use VirtualBench as your second DMM. To use the DMM feature of VirtualBench, plug in the leads to the digital multimeter feature of VirtualBench. Note that VirtualBench contains two pairs of sockets for the leads: the left socket pair can be used for measuring voltage and resistance, while the right socket pair can be used for measuring current.


4. Wire the circuit below. You will need [banana plug patch cords]() for this.



5. Measure the current for voltages between $0V$ and $1V$, in steps of about $0.2V$. and between $1V$ and $5V$ in steps of about $0.5V$. It is not necessary to have $V$ exactly equal to $1.000, 1.500,$ etc. Just get it close and write down the numbers accurately.
6. **Plot $I$ as a function of $V$. How?**
7. **To what point on this curve does the value of resistance you measured with the ohmmeter correspond?**
8. Now generate a $I$ vs. $V$ curve for a $1000$-ohm resistor (brown-black-red). You can use the NC and L binding posts to hold the resistor for this measurement. **Is our assumption that $I=V/R$ for all $V$ a valid one?**
9. When finished, turn off the DMM.

# Plotting X vs. Y

One way to plot one variable versus another is with the `Plot()` function of Matlab.

Begin by opening up Matlab on the desktop, and entering the data in as vectors. Note that Matlab plots in the order that the points are given, so be careful that each value in the $x$x and $y$y vector corresponds with the next point.

```
x=[1 2 3 4 5];
```

```
y=[1 4 9 16 25];
```

```
plot(x,y);
```

Of course, it would be useful to title the plots. This can be done in Matlab with the following lines:

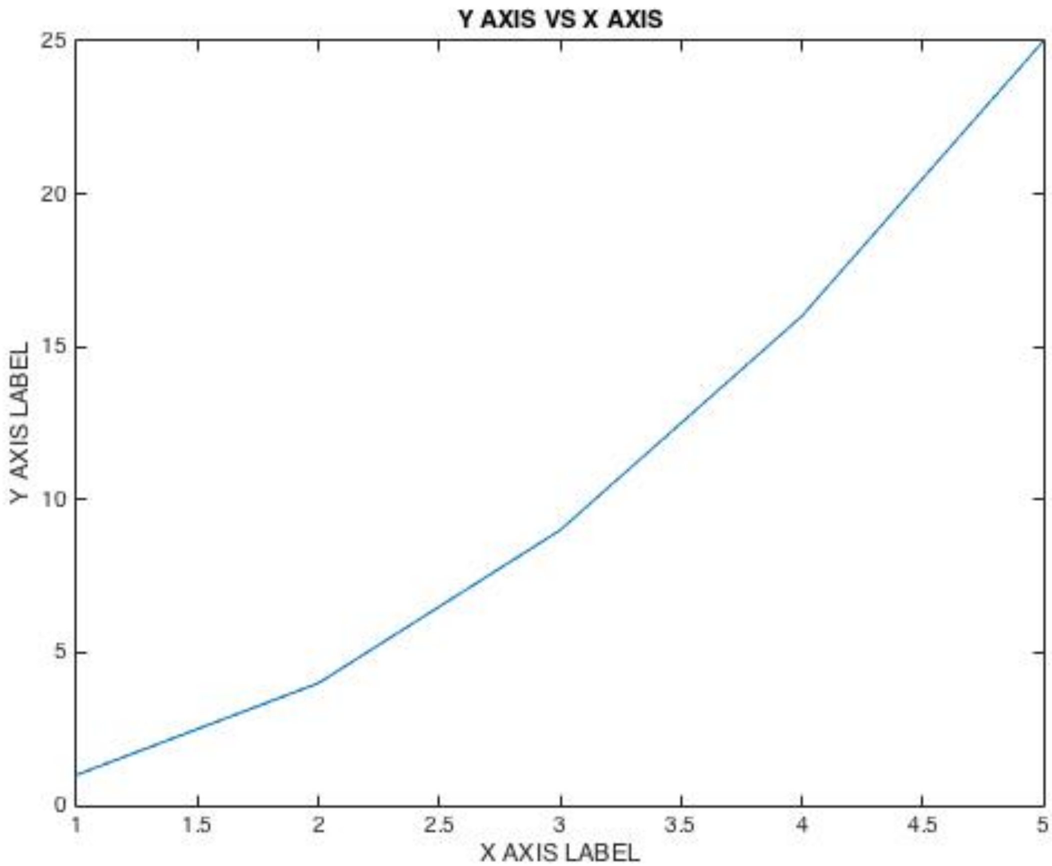
```
title('Y AXIS VS X AXIS')
```

```
xlabel('X AXIS LABEL')
```

```
ylabel('Y AXIS LABEL')
```

Note that you can do $\LaTeX$LATEX Style subscripts using underscores in Plot Titles.

Once you're done naming the plots, save them by clicking "file" and then "save as". Make sure to save as a JPG. Example plot:


Y AXIS VS X AXIS
Y AXIS LABEL
X AXIS LABEL
25
20
15
10
5
0
1
1.5
2
2.5
3
3.5
4
4.5
5

# Interlude

## Grounds and Grounding

Since a voltage is actually a *difference* in potential, it is always measured *between* two points in the circuit. In most circuits there is a single point (actually many physical points tied together by low resistance conductors into a single electrical point) with respect to which all other voltages are expressed. This point is called the "common", "reference", or "ground" node. The term "ground" arises from the fact that in the early days of telegraphy, one leg of the circuit was formed by the earth itself by driving a conductive rod into the ground at each of the two stations so that only a single wire was required between them.

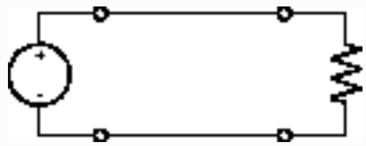
In our circuits, we will actually use a wire, rather than dirt, to form the ground connection, but we must bear in mind that all of our ground terminals are connected together (sometimes without our doing so explicitly). This concept of a common ground terminal becomes important when we look at our next two instruments, the Function Generator and the Oscilloscope.

So far most of the the instruments and components we've used have had their terminals connected to banana jacks. For example:

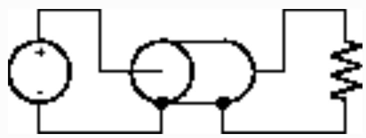
| instrument | image |
|---|---|
| power supply |  |
| DMM |  |

| instrument | image |
|---|---|
| lamp breadboard |  |

The function generator and 'scope don't have banana jacks. Instead they have what are called "BNC" connectors. These are a type of *coaxial* connector where the outer (ground) conductor surrounds the inner (signal) conductor. So instead of:



we have:



This type of connection has a number of advantages. The shielding by the outer conductor reduces interference *to* low level signals and *by* high level ones. The single connector allows both terminals to be connected simultaneously.

The (sometime) disadvantage is that the outer (shield or ground) conductors of *all* the BNC connectors on *all* our instruments are connected together. Within one instrument they are connected together by the metal chassis. Since the chassis is connected to the third (ground) terminal of the power cord, the chassis (and hence the grounds) of all the instruments are connected together. Later we'll see how this can be a disadvantage. For now, let's avail ourselves of some of the advantages.

# Experiment 1.2

# The Oscilloscope and Function Generator

## Equipment

- BNC Patch Cords

So far we've measured only constant (or nearly constant) voltages and currents. A much more interesting class of signals are *time varying* voltages and currents. For a slowly time varying signal, we could just write down the values as they change (as we did in plotting the light bulb I-V curve), but for most time varying signals we need something a bit faster. On the VirtualBench, that would be the *oscilloscope*.

In order to measure time varying signals, we need a source of time varying signals. The DC power supply on the VirtualBench is our source of constant voltages, and the *function generator* is our source for that class of time varying signals known as *periodic signals*.

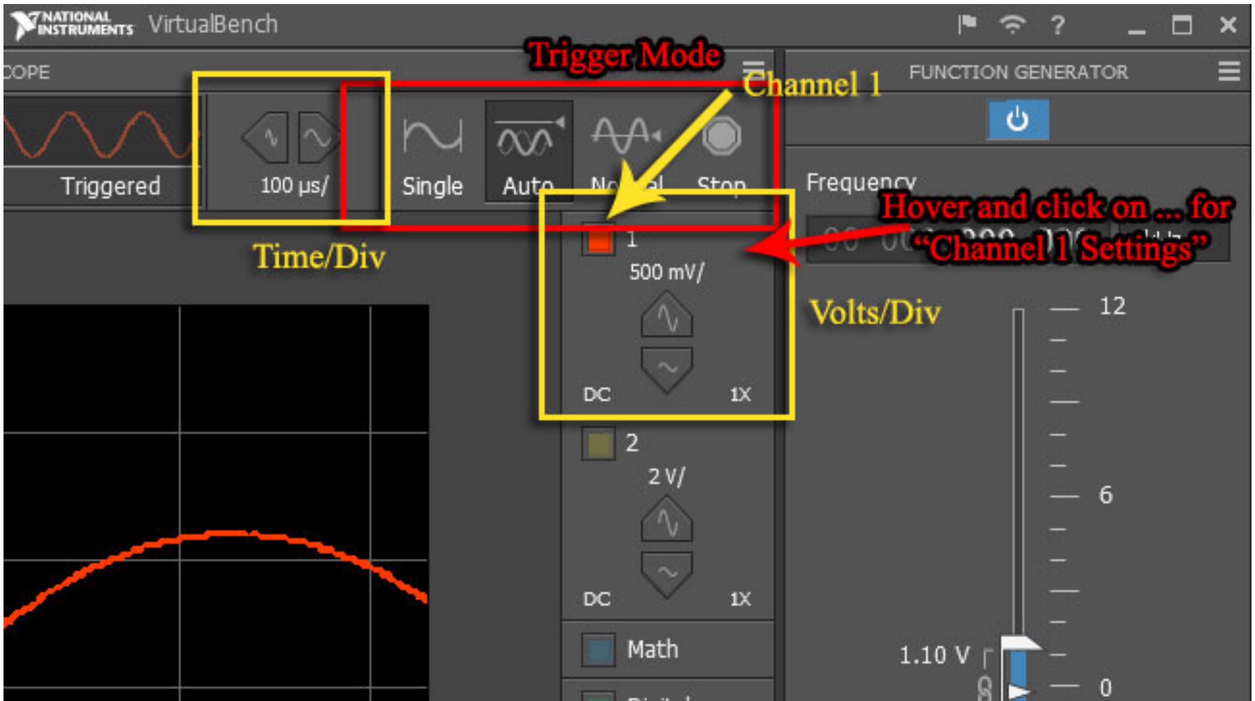
## Part A: Viewing Signals with the Oscilloscope

First get acquainted with the settings of the oscilloscope, even though you will continue using many of them in their default setting. Make sure you are being consistent in using either `CH 1` or `2`.

**Note**

Make sure the oscilloscope controls are as follows:

- Time/Div: 1ms
- Mode: Auto
- Display: CH 1
- Volts/Div: 2V
- AC-DC: DC
- Trigger: Edge; CH 1; Rising




**Note**

If everything is in order, you should see a red horizontal line through the middle of the screen.

1. Set up the function generator to produce a 1kHz sine wave (found to the right of the oscilloscope display). Turn on the power button for the function generator. Set it as follows:
    - Frequency: 1.0 kHz
    - Amplitude 3 Vpp (Volts, peak-to-peak)
    - DC Offset: 0 V
    - Duty Cycle (only used for square wave setting)
    - Function: Sine wave
2. Connect the function generator's `OUTPUT` to the oscilloscope's `CH 1` input. The easiest way to do this is to connect one end of a BNC patch cord to the function generator `FGEN` and the other to the oscilloscope `CH`
3. This connects the generator's ground and signal terminals to the scope's ground and terminals. If all has gone well, you should see 6 full cycles of a sine wave in red.
4. Now examine the effect of each control:
    - Move the display with the positioning controls - click and drag the toolbar at the top.
    - Change the Time/Div and Volts/Div settings to see what effects are produced.

- Click on the ruler in the bottom left of the screen and change the settings of the function generator to observe how the oscilloscope automatically measures signal features such as frequency, period, and amplitude.
- **Why do you think these numbers are slightly different from the function generator settings?**

5. Examine the various waveforms produced by the function generator. Examine the effects of the `DUTY CYCLE` and `DC OFFSET` controls. Before going on, be certain that you are comfortable with the oscilloscope and function generator. If you are having problems, ask your labbie for help.

## Part B: Quantitative Measurements with the Oscilloscope

In addition to allowing us to view the "shape" of a signal, the oscilloscope can also measure voltage, amplitude, time intervals, and frequency.

1. Connect the oscilloscope `CH 2` input to the $0 - 6 V$0–6V output of the DC power supply. For this you can use a BNC patch cord and your BNC to banana plug adapter.

2. Switch to `CH 2` and under Channel Settings, set the vertical offset to 0. This effectively sets the reference to $0$0, known as "zeroing" the signal.
3. Increase the voltage to $2V$2V. Continue to increase the voltage and see how well the scope readings and power supply settings agree.
4. **Why would we want to use the oscilloscope to measure a "DC" voltage?**
5. Switch to `CH 1` and "zero" Channel 1 as above. Set the function generator to produce a 2kHz sine wave. Set the `TIME/DIV` setting to $100\mu s$100μs. Measure the distance between two successive zero crossings of the same slope and multiply by the Time / Div factor to get the *period* of the waveform. Using the formula $f=1/T$f=1/T, determine the measured frequency of the signal. **How does this compare with the nominal frequency?**

**Note**

There are several ways we can express the amplitude of a signal. For the sine wave $y(t)=A\sin(2\pi ft)$ the amplitude A is equal to the distance from the positive (or negative) peaks of the waveform to the t-axis. This peak amplitude measurement is equally useful for any waveform which has equal positive and negative peaks.
Arbitrary waveforms may not have this property, so a more general measurement is the peak-to-peak amplitude, the distance between the positive and negative peaks of the signal.

Other measures of a signal's magnitude include average and rms, which we'll talk about later. Since in general these different measures have different values, it is a good idea always to specify which amplitude measurement you are using.

6. We can also use the oscilloscope to measure the *amplitude* of a signal. Disconnect your oscilloscope from the function generator and use a BNC clip lead to connect `CH 1` to the square wave and ground outputs of the scope, located to the right of the `CH 2` input socket.
7. **Sketch this signal's waveform.** What is its period? What is its frequency? Adjust the CH 1 Volts/Div switch so that the waveform nearly fills the screen vertically. Measure the peak-to-peak amplitude by counting the number of divisions between the upper and lower peaks and multiplying by the Volts/Div factor. Does your measurement of the waveform's amplitude correspond to the VB's measurement? (Click on the ruler button to look at the signal's measurements.)
8. **Take a screenshot of the waveform** by going to File $\rightarrow$ Export Screenshot

# Experiment 1.3

# Testing the breadboard

This is not part of the lab writeup, but this is a good exercise in using the DVM and understanding your breadboard module. Please perform the tests as indicated in the Breadboard Checkout Sheet below. A hardcopy will be provided by the lab assistants.

| | | |
|---|---|---|
| **Rice University** | | |
| **Department of Electrical and Computer Engineering** | | |
| **AEL-A141 Undergraduate Lab Test Procedures** | | |
| **Updated August 2018** | | |
| ***Circuit Breadboard*** | | |
| **Serial Number:** | | |
| **(+15V) Continuity Test - zero resistance measurement - Set multimeter to resistance. Place leads across following points (insert/jump wires in appropriate holes) then check pass or fail box.** | | |
| **Check the pass or fail box** | **PASS** | **FAIL** |
| (+15V) circuit board JP-1 banana plug to right (+15V) circuit board bus connection holes | | |
| (+15V) circuit board JP-1 banana plug to left (+15V) circuit board bus connection holes | | |
| **TOP BREADBOARD BUS** | | |
| (+15V) circuit board JP-1 banana plug to top row on right and left breadboard top bus strip | | |
| (+15V) circuit board JP-1 banana plug to middle row on right and left breadboard top bus strip | | |
| (+15V) circuit board JP-1 banana plug to bottom row on right left breadboard top bus strip | | |
| **MIDDLE BREADBOARD BUS** | | |
| (+15V) circuit board JP-1 banana plug to top row on right and left breadboard middle bus strip | | |
| (+15V) circuit board JP-1 banana plug to middle row on right and left breadboard middle bus strip | | |
| (+15V) circuit board JP-1 banana plug to bottom row on right and left breadboard middle bus strip | | |
| **BOTTOM BREADBOARD BUS** | | |
| (+15V) circuit board JP-1 banana plug to top row on right and left breadboard bottom bus strip | | |
| (+15V) circuit board JP-1 banana plug to middle row on right and left breadboard bottom bus strip | | |
| (+15V) circuit board JP-1 banana plug to bottom row on right and left breadboard bottom bus strip | | |
| **(-15V) Continuity Test - zero resistance measurement - Set multimeter to resistance. Place leads across following points (insert/jump wires in appropriate holes) then check pass or fail box.** | | |
| **Check the pass or fail box** | **PASS** | **FAIL** |
| (-15V) circuit board JP-3 banana plug to right (-15V) circuit board bus connection holes | | |
| (-15V) circuit board JP-3 banana plug to left (-15V) circuit board bus connection holes | | |
| **(GND) Continuity Test - zero resistance measurement - Set multimeter to resistance. Place leads across following points (insert/jump wires in appropriate holes) then check pass or fail box.** | | |
| **Check the pass or fail box** | **PASS** | **FAIL** |
| (GND) circuit board JP-2 banana plug to right (GND) circuit board bus connection holes | | |
| (GND) circuit board JP-2 banana plug to left (GND) circuit board bus connection holes | | |
| (GND) circuit board JP-2 to Terminal Bus pin 14 | | |
| (GND) circuit board JP-2 to Terminal Bus pin 22 | | |
| (GND) circuit board JP-2 to Terminal Bus pin 41 | | |
| **Mechanical Tests - are mechanical contacts fixed/functional?** | | |
| **Check the pass or fail box** | **PASS** | **FAIL** |
| Tighten screws and check planarity of attachments | | |
| Remove jammed wire pieces | | |