**Lab – Introduction to AC Circuits and the Oscilloscope**

**Objectives**

-To learn how to use an oscilloscope and function generator

-To wire up various circuits on a breadboard, connect them to an AC source and measure voltage waveforms across the various components

-To learn about RC circuits

-To learn about low pass and high pass filters

**Equipment**

Measuring Equipment: Instek 1052-U Digital Oscilloscope, BK Precision 4012 A Function Generator; Powered Breadboard, jumper wires, BNC (Bayonet Neill–Concelman) cables

Resistors: Two10k Ohm, one 15k Ohm

Capacitor: 0.01F

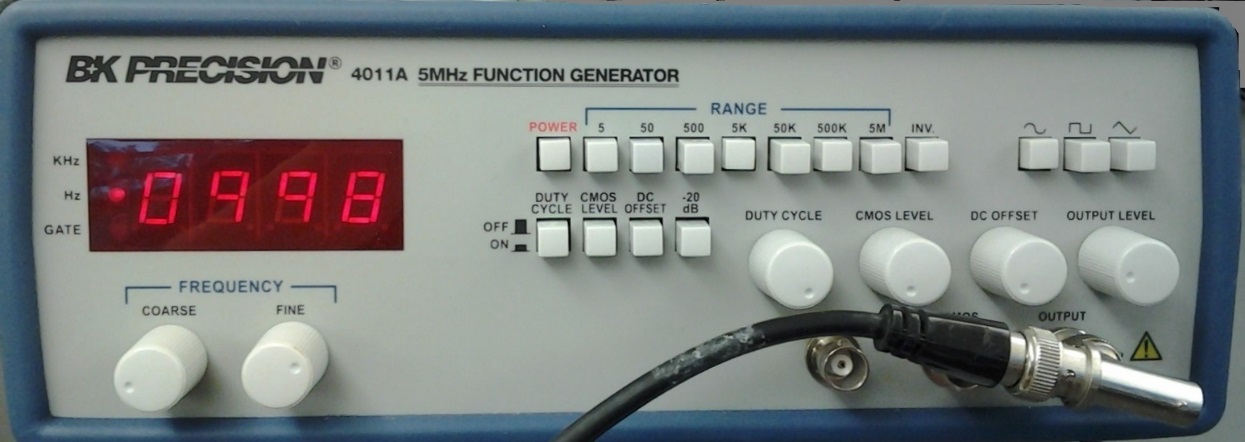
**Introduction**

In the first lab you used a DMM to measure the voltages across various components in an electric circuit. In that experiment, you found that the voltages and currents in the circuit were constant in time. In those circuits, the voltage across a resistor was constant because the source of that voltage (i.e. – the power supply) was also constant. These type of circuits are commonly known as DC (direct current) circuits. In many cases you will find that the power source responsible for setting up a voltage at a certain point in the circuit might be varying in time. An example of this is the voltage at an electrical outlet in your home. In the typical US home the voltage is varying periodically at a frequency of 60 Hz. These type of circuits are known as AC (alternating current) circuits.

In this experiment you will be building AC circuits and measuring the voltages across various components using an oscilloscope. You can think of an oscilloscope as a voltmeter that measures and graphs voltages as a function of time. Your typical scope can measure voltage waveforms with a wide range of frequencies. To generate the varying voltage in your circuit you will be using a function generator as the power source. This is a voltage source that produces waveforms of different shapes, frequencies and amplitudes.

**Function Generator**

A function generator can produce a wide variety of periodic voltage waveforms. The front panel of the FG used in this lab is shown below.

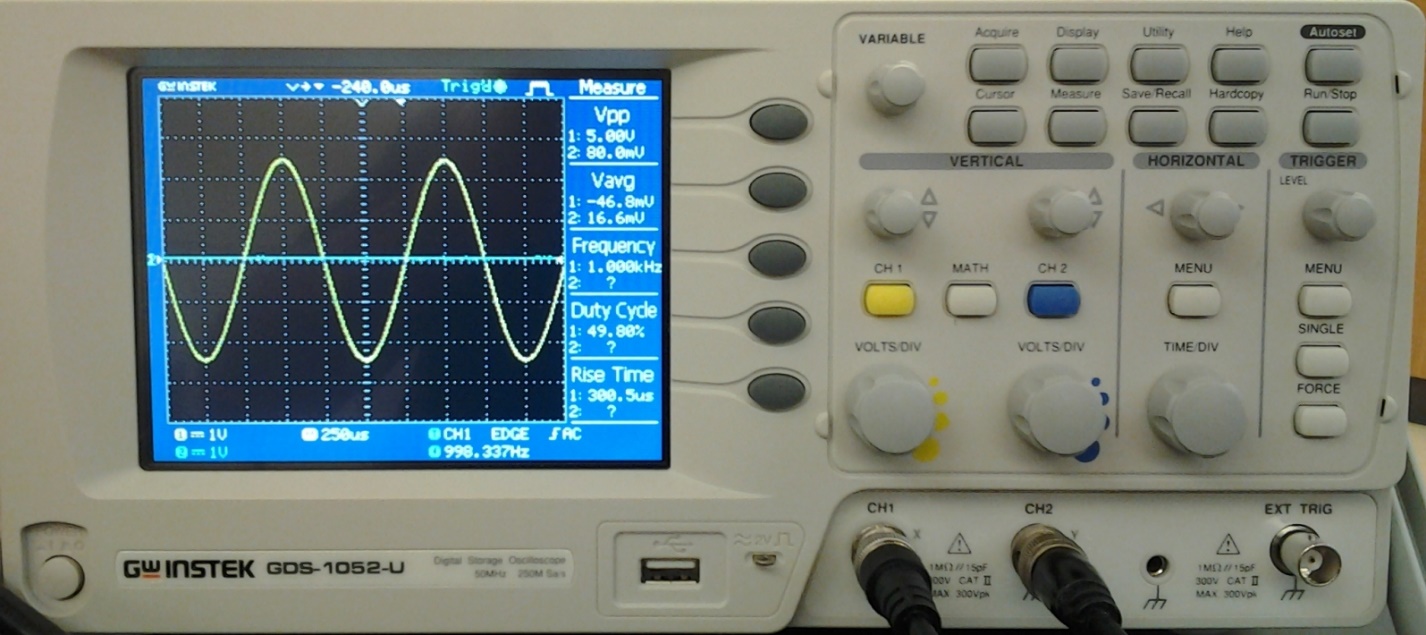
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*Figure 1 – Function Generator Front Panel*

The LED display shows the frequency of the waveform and the knobs on bottom left labeled ‘COARSE’ and ‘FINE’ allow you to adjust the frequency of that waveform. The buttons in the RANGE section of the front panel allow you to change the frequency of the waveform by a factor of 10. The three buttons on the top right of the panel are used to change the shape of the waveform. The FG can output a sine, a square or triangle waveform. The voltage signal is sent out the BNC jack labeled ‘OUTPUT’. You will need to connect a BNC cable to this output in order to send the signal to an oscilloscope or circuit. The voltage level (amplitude) of the AC waveform is controlled by the ‘OUTPUT LEVEL’ knob. In some cases, you might also need to add a DC voltage to an AC signal. To add a DC voltage, the function generator has a ‘DC OFFSET’ button that needs to be set to ON and the amount of offset is then controlled by the ‘DC OFFSET’ level knob. Turning this knob will essentially move the waveform up or down with respect to a horizontal axis when displayed on an oscilloscope.

**Digital Oscilloscope**

The front panel of a digital oscilloscope is shown in the picture below. A voltage signal enters the scope through an input channel. This particular scope has two channels which are labeled CH1 and CH2 and to bring a voltage signal into a scope you will need to connect a BNC cable to either the CH1 or CH2 input jacks on the front panel. Two channels allows the user to look at two different voltage signals simultaneously and the buttons labeled CH1 and CH2 allow you to switch between the two signals being displayed on the screen. Notice that the screen on the scope is divided into many squares by a grid. Each square is called a division. The vertical axis on the screen represents the voltage and the horizontal axis typically represents the time. The size and width of the voltage signal displayed on the screen can be changed by adjusting the VOLTS/DIV knob and TIME/DIV on the oscilloscope panel. These two knobs change the vertical and horizontal scales of the signal being displayed. The small knob in the ‘VERTICAL’ section of the scope panel moves the voltage signal display up and down on the screen while the small knob in the ‘HORIZONTAL’ section moves the voltage signal left and right. The marker on the left edge shows the position of the voltage zero for each channel. The small down marker on the top edge shows the position of the time zero.

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*Figure 2 – Digital Oscilloscope Front Panel*

**Experimental Procedure**

**SETTING UP A BASIC MEASUREMENT.** Use twoBNC cables toconnect the channel 1 output of the function generator (FG) to the channel 1 input of the oscilloscope (scope). Connect the red clip of the BNC cable of the FG to the red clip of the BNC cable connected to the oscilloscope. Connect the black clips of the two BNC cables to a ground point on the breadboard. Turn on the scope and then the FG. Note: It might take a few seconds for the display screen on the scope to come on.

**Basic FG set up.**

Adjust the output of the FG so that the channel 1 signal is a sine wave with an amplitude of 5 VPP. You will determine the output amplitude on the oscilloscope. Recall that VPP or peak to peak voltage is the voltage measured from the min point on the waveform to the maximum point. Adjust the frequency of the signal to 1000 Hz and set the ‘DC Offset’ knob down to zero. Make sure all of the other buttons on the FG are in the ‘Off’ position.

**Basic Oscilloscope set up.**

You should see one or two signals from the channels 1 and 2 on the oscilloscope display screen.

-On the Instek Oscilloscope, press the CH1 button (yellow) a few times so that only the signal from channel 1 is being displayed on the scope screen.

-The scope has two modes of operation: DC and AC coupling. When set in DC coupling mode the oscilloscope allows you to see the exact voltage on the screen. In AC coupling mode, the scope removes all the DC components of the waveform allowing you to see just the AC components. The digital oscilloscope usually defaults to DC coupling mode but you need to make sure that it is set correctly.

-Set the vertical scale (VOLTS/DIV) to 1 V/div and the horizontal scale (TIME/DIV) to 250 μs/div. The bottom left of the scope screen should display the volts/div and secs/div values (See Figure 2).

-Position the zero volts level and the zero time to coincide with the center lines. Note the ‘1’ and a marker on the left end of the waveform. This marks the zero voltage level for channel 1.

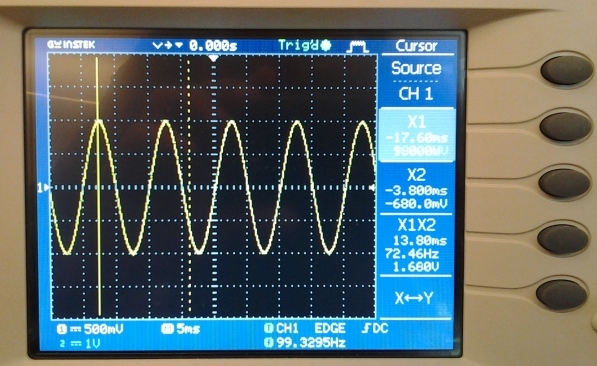
**Activity 1 – Making Measurements with an Oscilloscope**

In this part of the lab you will use the oscilloscope screen to manually determine the Vpp and frequency of various waveforms. You will need to determine the period of your waveform first and then from the inverse of the period get the frequency. Recall that the period is the time it takes the wave to complete one cycle. Once you’re done with these measurements, you will then compare these values with the automatic measurements given to you by the oscilloscope. Automatic measurements are not always accurate so it is important to always check your values against a manual measurement to see if there are any discrepancies or errors.

Manual Measurements

To make a more accurate manual measurement, go to the top of the scope front panel and press the button labeled ‘CURSOR’. This will display two cursors or lines on the screen which you can move with the knob labeled ‘VARIABLE’. Pressing the button next to X**🡨🡪**Y switches between the horizontal and the vertical cursors.

To measure time, for example, press the button next to X**🡨🡪**Y to bring up two vertical lines. Pressing the button on the screen next to ‘X1’ enables the left cursor while pressing the one labeled ‘X2’ enables the right cursor. Use the ‘VARIABLE’ knob to set the location of each of these two cursors.



*Figure 3 - Vertical Cursors are shown on the display screen*

Table 1.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Waveform | FG Display | Manual Frequency Measurement | | | | Manual Amplitude Measurement | | |
| Frequency  (Hz) | Horizontal scale (secs/div) | Period  (div) | Period  (secs) | Frequency  (Hz) | Vertical  Scale  (volts/div) | Amplitude  (divisions) | Amplitude  (Vpp) |
| Sine |  |  |  |  |  |  |  |  |
| Square |  |  |  |  |  |  |  |  |

Auto Measurements

To determine the automatic measurements, go to the top of the scope front panel and press the button labeled ‘MEASURE’. This will display the Vpp and Frequency on the right side of the screen as shown in Figure 2. If these are not displayed ask your instructor for assistance.

Table 2.

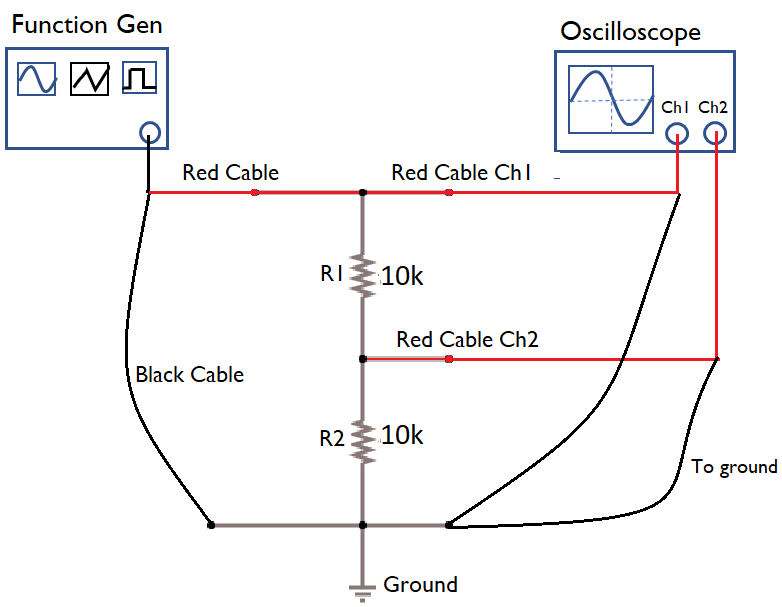
|  |  |  |
| --- | --- | --- |
| Waveform | Automatic Measurement | |
| Frequency  (Hz) | Amplitude  (Vpp) |
| Sine |  |  |
| Square |  |  |

WARNING ABOUT AUTOMATIC MEASURMENTS. The automatic measurements are derived from the digitized waveforms displayed. If the waveform is clipped the measurement will fail. If the wave form is significantly smaller than a division, the measurement can be wildly inaccurate. This issue is true for both amplitude and time measurements. The rule of thumb: set the horizontal and vertical scales so you can see the waveform clearly defined over many divisions. You have a 12×8 division area—use it!

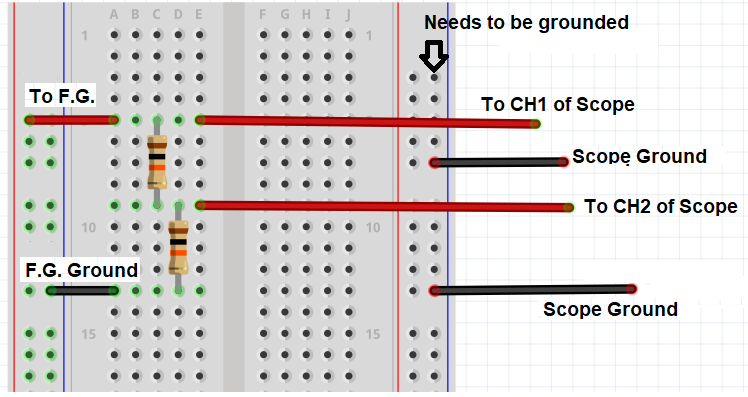
**Activity 2 - Voltage Divider with AC Power Source**

1. Grab two 10k Ohm resistor and determine their value using a DMM. Record these values in your notebook.

2.Wire up the circuit below on your breadboard. The circuit is just two resistors in series, creating a voltage divider. The rest of the wires connect the function generator to the input and the oscilloscope to the output. You will need 3 BNC cables (one for the F.G. and the other two will go into Channels 1 and 2 on the scope). Channel 1 in this setup is used to measure the input signal and channel 2 to measure the output signal or signal across the capacitor. **Important:** Make sure that the black probe for all BNC cables are connected to ground.



*Figure 4a – Voltage Divider Circuit Schematic[[1]](#endnote-1)*



*Figure 4b – Voltage Divider Circuit on a breadboard[[2]](#endnote-2)*

3.Set the function generator to a Sine Wave with a frequency of 1 kHz and adjust the output level of the F.G. until you get a Vpeak of 5V on CH1 of the oscilloscope. **Note:** If you cannot see the entire signal on the scope display screen turn the VOLTS/DIV knob for CH1 until you are able to fit the top and bottom of the signal. On the bottom left corner of the scope display make a note of the VOLTS/DIV value.

4. Adjust the TIME/DIV knob until you can see about 2-3 repetitions of the signal waveform.

5.You should see two signals on the oscilloscope: the input signal coming in through channel1 and the output signal on channel 2. If you only see one signal then press the CH2 button on the scope.

1. Question: Does Vout still equal Vin\* (R2/(R1+R2))?

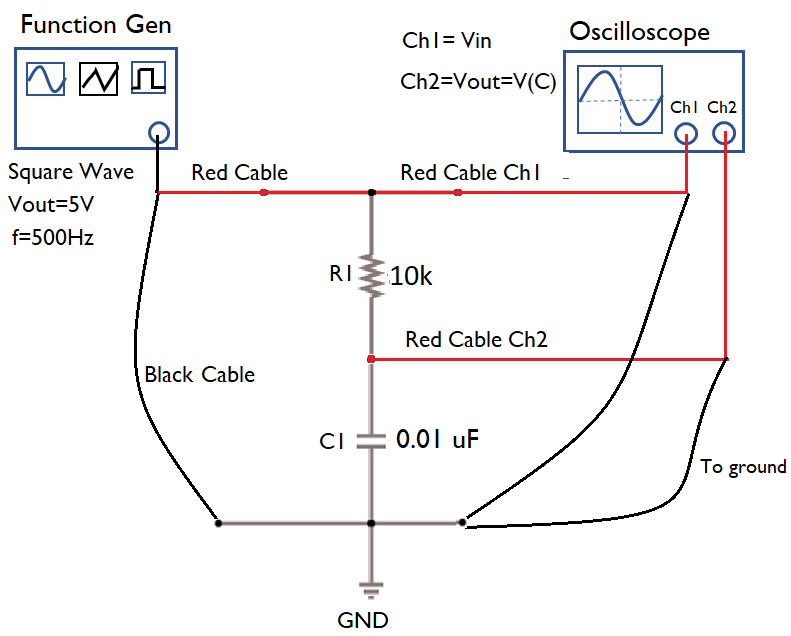
2. On the oscilloscope switch between CH 1, CH 2, and both channels together.

3. In your notebook, make a plot clearly showing Vin and Vout as displayed on the scope. You can also take a picture of the oscilloscope display.

4. When on 'both' see what happens when you press the MATH button and ‘CH1 + CH2‘

**Activity 3– RC Circuit with AC Power Source**

1. Grab a 10k Ohm resistor and a 0.01 mF capacitor and determine their actual values using a multimeter. Record these values in your notebook.
2. Wire up the circuit below on your breadboard. The circuit is just a resistor in series with a capacitor and commonly known as an *RC Circuit*. The rest of the wires connect the function generator to the input and the oscilloscope to the output. You will need 3 BNC cables (one for the F.G. and the other two will go into Channels 1 and 2 on the scope). Channel 1 in this setup is used to measure the input signal and channel 2 to measure the output signal or signal across the capacitor. **Important:** Make sure that the black probe for all BNC cables are connected to ground.



*Figure 5 – RC Circuit*

1. Set the Function Generator to a *Square Wave* with a frequency of f= 500 Hz. After connecting the oscilloscope, select CH1 on the oscilloscope and adjust the output Level knob on the function generator until the peak of the square wave signal reads a Vpp of 5V. **Note:** If you cannot see the entire signal on the scope display screen turn the VOLTS/DIV knob for CH1 until you are able to fit the top and bottom of the signal. On the bottom left corner of the scope display make a note of the VOLTS/DIV value.
2. Adjust the TIME/DIV knob until you can see about 3 repetitions of the square wave (TIME/DIV value will be around 250ms).
3. You should see two signals on the oscilloscope: the input signal coming in through channel1 and the output signal on channel 2. If you only see one signal then press the CH2 button on the scope.
4. Using your Oscilloscope, find the time it takes for Vout to equal 0.63\*Vin. The time it takes for Vout to grow to 0.63Vin or the time it takes Vout to fall to 0.37\*Vin is called the *time constant* ().

First adjust the TIME/DIV knob until you can see about 1 peak of the square wave. Make a note of the output signal (blue) compared with the input signal (yellow). How are they different?

a. Press the ‘Cursor’ button on the scope

b. Look at the dark gray buttons next to the scope display and select the one labeled X**🡨🡪**Y. You should see two horizontal lines (blue) show up if not then press the button again.

c. Next, press the dark gray button labeled Y1, use the ‘VARIABLE’ knob on the scope panel and adjust the horizontal line until it coincides with the lowest point of the output signal.

d. Use your calculator to determine the value of Vout equal to 0.63\*Vin and record this value.

e. Now, press the dark gray button labeled Y2, use the ‘VARIABLE’ knob on the scope panel and adjust this horizontal line until it coincides with the value of Vout calculated in step d. You can read this value on the display (Y1Y2). Remember where this value is located on the display screen.

f. Press the dark gray buttons labeled X**🡨🡪**Y until you get two vertical lines

g. Press the dark gray button labeled X2, use the ‘VARIABLE’ knob on the scope panel and adjust the vertical line until it coincides with the lowest point of the output signal.

h. Press the dark gray button labeled X1, adjust the ‘VARIABLE’ knob on the scope panel until the vertical line coincides with the value of Vout that you measured in step e. Read the value displayed under X1X2. This value is the time it takes the output signal (Vout) to reach 0.63\*Vin. Record this value in your notebook.

1. Neatly draw the waveform in your notebook or take a picture of the scope screen.
2. Use the values of the capacitor and resistor that you determined at the start of this activity and determine the time constant. The theoretical value of the time constant is given by the following equation,

 = R\*C

**Question:** Does that time = R\*C? What could account for any discrepancies between the theoretical and measured values?

1. All schematic diagrams were created with Falstad circuit simulator (https://falstad.com/circuit/) [↑](#endnote-ref-1)
2. The breadboard images were created with Fritzing (<https://fritzing.org>) [↑](#endnote-ref-2)