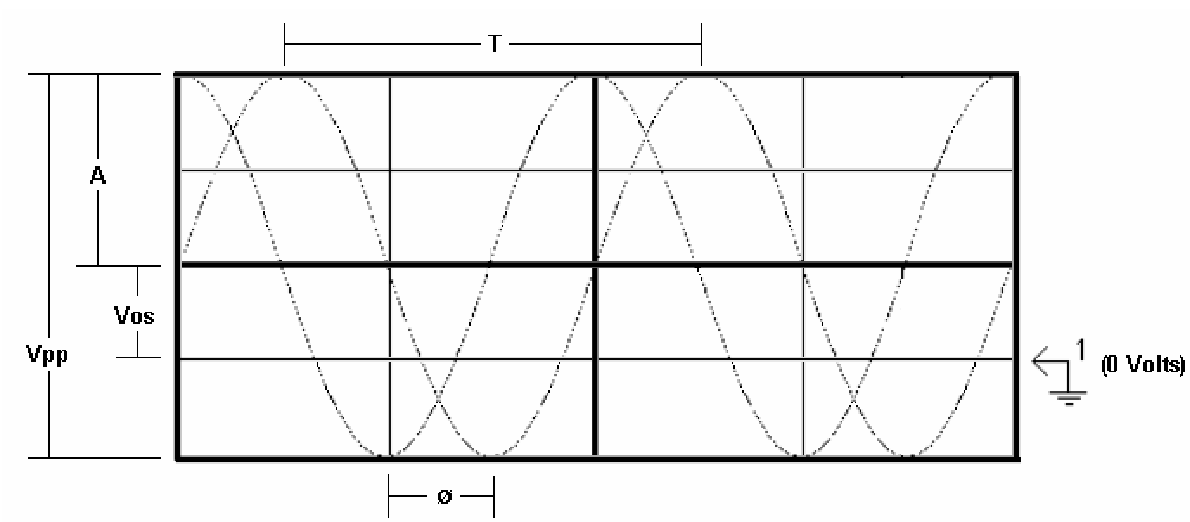
EE 210 Lab Exercise #2:
AC Circuits & Measurements

ITEMS REQUIRED	EE210 crate, DMM, T-connector, 50Ω terminator, Breadboard
ASSIGNMENT	Lab report due at the beginning of the next lab period
Data and results from all of the numbered, bolded material in the procedure sections must be included and clearly numbered in the data section of the lab report.	

Introduction

This is the second of two labs that provide an introduction to basic circuit construction, analysis, and test equipment that is used throughout EE 210. Whereas the first lab dealt with dc (direct current) circuits and measurements, this lab will focus on ac (alternating current) circuits and measurements. Throughout EE 210, when referring to an ac signal, a sinusoidal waveform will be implied. A generalized sinusoidal waveform is shown below.



$$V(t)=A\cos(2\pi ft+\varnothing)+V_{off}$$

A = Amplitude (Volts)
Vpp = Peak-to-Peak Voltage =2*Amplitude
Voff = DC offset (Volts)
T = Period (Seconds)
f = frequency(Hertz) = 1/T =2πω(radians)
∅ = Phase shift (Radians/Degrees)

Exercise 1: The Oscilloscope & Waveform Generator

The **waveform/function generator** can be used to generate a variety of periodic signals with variable frequency and amplitude. A brief description of the HP33120A function generator is provided subsequently.

Outputs: The waveform generator has two simultaneous output terminals, **OUTPUT** and **SYNC**.

> **OUTPUT** is the general output used for generating waveforms of variable type, frequency, and amplitude. ***IMPORTANT: The T-connector and 50Ω terminating resistor must be used whenever the OUTPUT terminal of the function generator is used throughout the semester in order to achieve the correct voltage output.***
>
> **SYNC** is used to generate clock/timing signals in logic circuits such as counters seen in CSE 275. It generates square wave from fixed 0-5V with adjustable frequency. ***The 50Ω terminating resistor is not needed with the SYNC output.***

Amplitude and Frequency: The amplitude and frequency may be adjusted by pressing the **AMPL** and **FREQ** buttons respectively on the front panel of the waveform generator. Press the <or> arrow keys to change the digit to be adjusted and rotate the wheel to change the value. Values can also be entered by pressing the **Enter Number** button and pressing the desired digit buttons, then **Enter**.

Waveforms: Sinusoidal, square, and saw-tooth waves can be generated by pressing the buttons ***pictured with the desired waveform.***

The **oscilloscope** can be used to analyze a variety of electrical signals that include voltage, current (using a test resistor), time, frequency, and phase. Internally, an electron beam is focused on the screen of the oscilloscope. For an analog oscilloscope, the electron beam is deflected horizontally and vertically using a set of charged plates in each direction. The vertical plates cause a deflection proportional (V/div) to the voltage on each channel, while the horizontal plates cause deflections that occur at a uniform rate (time/div) traveling from left to right on the screen. This produces a plot of voltage vs. time. The *triggering* of the oscilloscope causes the display to appear stable by beginning the plot of the signal at the same point on the screen. For the oscilloscopes used in this lab, these deflections are captured and displayed digitally. The basic functions of the HP54600 A/B digital oscilloscope are described subsequently.

Vertical Position: Adjusts the vertical position of the trace on the screen.

Vertical Sensitivity or V/div: The voltage that is required to deflect the beam by 1 division, i.e. scale the waveform vertically. The typical range is 10 mV/div to 10 V/div.

Sweep time or time/div: The time that is required for the trace spot to move horizontally across one division of the screen i.e. scale the waveform horizontally. The typical range is 1 μs/div to 5 s/div.

Source or Trigger Source: Selects the source of the triggering signal. There are three types:

Internal: The input signal controls the triggering. Choose Channel 1 or Channel 2, depending on the measured source. This type of triggering is appropriate for most applications.

Line: This position uses the 60-Hz line voltage as the triggering signal.

External: An external signal must be applied to trigger the sweep waveform. The external signal should have a frequency that is comparable to the frequency of the measured signal.

Slope Coupling: This switch specifies if the time base will trigger on an input signal with a positive or negative slope.

Trigger Level: This switch selects the amplitude at which the trigger will cause the sweep to begin.

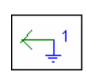
Coupling: Selects direct (dc) or capacitive (ac) coupling of the input signal to the scope. ac coupling subtracts any dc component that is present in the waveform.

Vertical Mode: Selects the Channel 1 and/or the Channel 2 trace for display on the screen.

Exercise 1: Procedure

1. Attach the T-connector and the 50Ω terminating resistor to the OUTPUT terminal on the function generator. Adjust the function generator for a 500Hz sine wave with amplitude 4V and no offset. Using a BNC-to-BNC connector, connect the output of the waveform generator to Channel 1 of the oscilloscope.

2. To set up the oscilloscope perform the following functions. ***It is important that this procedure is followed each time the scope is used!***

   A. Turn on the scope power.
   B. Select CH 1
   C. Make sure that the trigger source is set to CH 1 and that CH 1 is set for dc couple – ac coupling is used to remove the dc component of the signal.
   D. Adjust the vertical position such that ground is centered on the screen.
   Note: the 0V point (ground) of the waveform is labeled as: 
   When determining the dc offset, be sure to reference the waveform with respect to ground. The oscilloscope does not change any of the properties of the signal when the presentation is varied.
   E. Select CH 1 and set the CH 1 V/DIV to 2 V/DIV. and set the Time/Div to give one division equal to 1/frequency of the input waveform (1/500Hz in this case).
   F. If a problem occurs hit *Setup* then *Default Setup* to return the scope to its original settings then repeat A-F. ***** The "*Autoscale*" button may also be pressed to fit the waveform onto the screen when the trace doesn't appear in the view, or there**

is difficulty attaining an acceptable view manually. The oscilloscope may not autoscale to DC or slowly varying signals.***

G. At this point, a stable sinusoidal waveform should be displayed on the oscilloscope. Verify that your waveform is correct by pressing the "*Voltage*" button on the oscilloscope and using the resulting menu to display the peak-to-peak, RMS, and average voltages. Load the waveform displayed on the oscilloscope to the computer by logging into the computer and selecting ***Programs…HP Bench Link Suite…HP Benchlink Scope*** from the Start menu. Select *Image…New* from the File menu to capture the scope image. **(1) Add your names, a title, and exercise number to the plot using the text tool in Benchlink and print the plot including the specified measurements.** ***Always add your names, a title, and exercise number to all plots generated throughout the semester.***

3. The following steps will demonstrate the effect of changing the scope parameters.

   A. Change the frequency of the sine wave to 200 kHz. **(2) Determine the time base required for 1 horizontal division to equal 1/frequency. Change the time base on the scope to the calculated Time/Div and describe the voltage trace displayed on the scope.**
   B. Verify that your calculation is correct by pressing the *"Cursors"* button on the oscilloscope and positioning the two time (t1,t2) cursors in a manner to determine the period of the waveform. **(3) Print the waveform displayed on the oscilloscope including the period as determined by the cursor.** The voltage (v1,v2) cursors can be adjusted in a similar fashion to determine amplitude values.
   C. The period and frequency can also be determined by pressing the *"Time"* button on the oscilloscope and selecting frequency and period from the resulting menu to display these values on the screen.
   D. Adjust the DC offset of the function generator such that the waveform is centered at -1 V from ground. Change the coupling of CH 1 from dc to ac in the CH 1 menu. **(4) Describe the differences in the voltage trace when viewed on dc coupling and on ac coupling.**

4. Return CH 1 to dc couple and remove the dc offset. Disconnect the BNC-to-BNC from the waveform generator and replace it with a BNC-to-Clip connector. Change the frequency back to 500Hz and adjust the sec/div accordingly. Build the circuit shown in Figure 1 using the waveform generator as the source, given R1=R5=24kΩ, R2=12kΩ, R3=11kΩ, R4=13kΩ, R6=5.1kΩ (same as Lab #1).

5. Using two BNC-to-Clip connectors, measure the input voltage on CH 1 and the open circuit output voltage on CH 2. Select both channels to view the waveforms simultaneously. *Both oscilloscope channels should typically be set to the same V/div for comparison purposes. Always select the V/div and Time/div such that both waveforms are clearly displayed.*
   (5) Analytically determine the peak-to-peak voltage of the input voltage and the peak-to-peak voltage of the output voltage and compare to the measured values.

Important:

- ***The black lead from the oscilloscope is ground, connecting it to a point on the circuit will force it to zero volts.***
- ***Always connect oscilloscope, waveform generator, and dc power supply grounds (black leads) together in the circuit.***
- ***Always make measurements with reference to ground unless otherwise specified.***
- ***The trigger source should usually be set to the channel measuring the function generator output or the signal of interest for proper display. Otherwise, signals may appear unstable.***

6. Now that two voltage waveforms are displayed, **(6) use the channel invert, add, and subtract functions and describe the results in each case.**

7. Use one of the functions from step 6 to display Vout properly, with reference to ground (note the polarity). **(7) Print the waveform, along with the input, including the Vpp measurements of each. Remember to use the same V/div for each channel.**

8. Use one of the functions from step 6 to display the voltage across R3, since it can't be measured directly. **(8) Print the resulting waveform displayed on the oscilloscope including the Vp-p measurement as determined by the cursors. (9) Record the peak voltages at each of the nodes for comparison to Lab #1.**

Exercise 2: Digital Multimeter for AC Measurements

The Fluke 75 DMM can be used to measure ac voltage and current. The value that is displayed is not the peak-to-peak value but is instead the Root Mean Square (RMS) value. The RMS value can be thought of as the "effective value" of power supplied by the ac source, comparable to that of a dc source. The RMS value of a sine wave is calculated by multiplying the peak voltage or current (not peak to peak) by 0.707. *Note: This is only true for sinusoidal waveforms.*

Exercise 2: Procedure

1. Disconnect the oscilloscope and leave the waveform generator configured for 8Vp-p and 500Hz as in the previous exercise. Set up the DMM to measure voltage (connectors in the V– and COM–plugs). To use the DMM as a voltmeter, turn the dial to the ***ac*** V-setting.

2. **(10) Measure the input voltage and open circuit output voltage.**

3. Set up the DMM to measure current (connectors in the 300mA and COM–plugs). To use the DMM as an ammeter, turn the dial to the ***ac*** A-setting.

4. **(11) Measure the current through R1.**

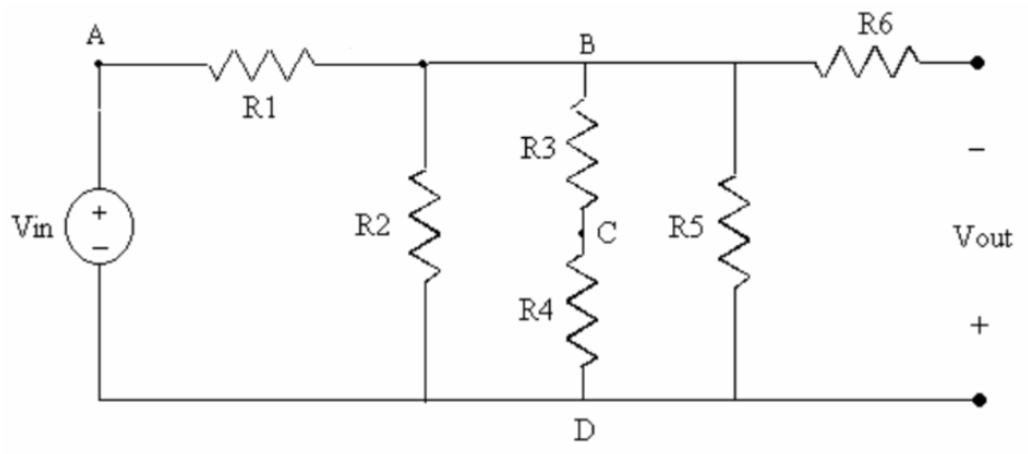


Figure 1. Circuit for AC voltage measurements.

Discussion Questions

Discuss and thoroughly explain each of numbered the concepts below, listed by exercise. When applicable, consider the following items when formulating your responses:

- A comparison of theoretical and experimental results.
- An identification and description of the likely sources of error.
- A description of the purpose and function of each circuit and possible applications.
- A comparison of similar circuits in the lab and the respective functions.
- A discussion of relevant observations, results, and deductions.

Exercise 1

1. Discuss how cursors could be useful in practice, since the oscilloscope has other functions that can easily determine values such as frequency or amplitude.
2. Discuss how add, subtract, invert could be useful in practice.
3. Compare the results to those obtained in Lab #1, discussing AC, DC, and linear circuit properties. How are the peak AC values at each node in Figure 1 related to the DC values obtained in Lab #1?
4. Give the current through each resistor in Figure 1 as a sinusoidal expression using the measured voltages.

Exercise 2

5. Explain RMS measurements and why they are used for a DMM.
6. Compare the RMS values to the peak-to-peak voltages determined using the oscilloscope. How are they related?
7. Compare and contrast the DMM and oscilloscope in terms of AC and DC voltage and current measurements, as well as other functions. Include a discussion of these functions and the advantages/limitations of each measurement device.