EE 101	Fall 2007	Date:	Lab Section #
Lab #3		Name:	
AC Signals and the Oscilloscope		Partner:	

Abstract

AC (alternating current) signals have a time-varying magnitude. Common AC signals in electrical engineering are periodic oscillations used for communications and electrical power transmission. Because AC signals vary with time, engineers have developed a test instrument called the oscilloscope that can display AC signal measurements as a voltage vs. time graph.

After completing this experiment you should:

(1) Be able to determine the value of a capacitor using the standard three-digit code,
(2) Be able to use an oscilloscope to make a DC voltage measurement,
(3) Be able to use a function generator to establish an AC signal with a specified amplitude and frequency,
(4) Be able to use an oscilloscope to identify the properties (amplitude, frequency, period and phase shift) of AC waveforms,
(5) Be able to calculate the phase shift between two AC waveforms given their period (or frequency) and their time offset.

Introduction and Theory

AC signals are very useful in electrical engineering. Often the AC signal is a sinusoidal variation in voltage, so we can describe the signal in terms of its amplitude (peak) value and its frequency (oscillation rate).

Oscilloscope

The oscilloscope is arguably the most fundamental measurement device in electrical engineering. The usefulness of the oscilloscope–or 'scope' for short–is due primarily to its ability to display electrical signal information directly in visual form. A block diagram of a basic oscilloscope is shown in Figure 1 on the following page.

Although it may appear complicated, the basic oscilloscope is quite simple in concept:

§ The *vertical position*, or *vertical deflection*, of the electron beam of a cathode ray tube (CRT) is linearly proportional to the input voltage. The input voltage is measured between a particular circuit node and the circuit ground reference. A calibrated variable amplifier is used to boost low-level signals in order to produce a visible beam deflection. The input voltage can thus be determined by measuring the amount of beam deflection for a particular input amplifier gain. Vertical deflection calibration is usually indicated as volts per division, where "division" refers to the grid lines etched on the face of the CRT.

§ The *horizontal deflection* is controlled either by another input signal or more commonly by a calibrated sweep generator. The sweep generator moves the electron beam at a selectable, constant rate from left to right across the CRT screen. The calibrated sweep rate is usually indicated as time per division, where "division" again refers to the CRT display grid lines.

The most important use of oscilloscopes is in the observation of periodic signals: repetitive waveforms (oscillations) can be viewed by synchronizing the sweep generator with the repetition rate of the input signal. This is accomplished using a *trigger generator* which starts the horizontal sweep when the input signal exceeds an adjustable voltage threshold. The trigger can be selected to occur for either a positive or negative slope at the threshold voltage. Thus, by adjusting the vertical gain, trigger level, and the sweep speed, time varying input signals can be viewed directly as a voltage-vs.-time display.

Oscilloscopes have many other features for producing displays of particular types of signals. For example, most scopes have two or more independent input amplifiers for displaying two or more input signals simultaneously. Some special features will depend upon the instrument manufacturer and the sophistication of the scope itself. Some of these "advanced" features will be considered later in this course.
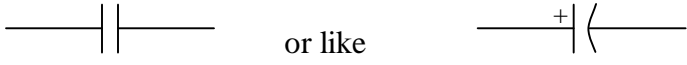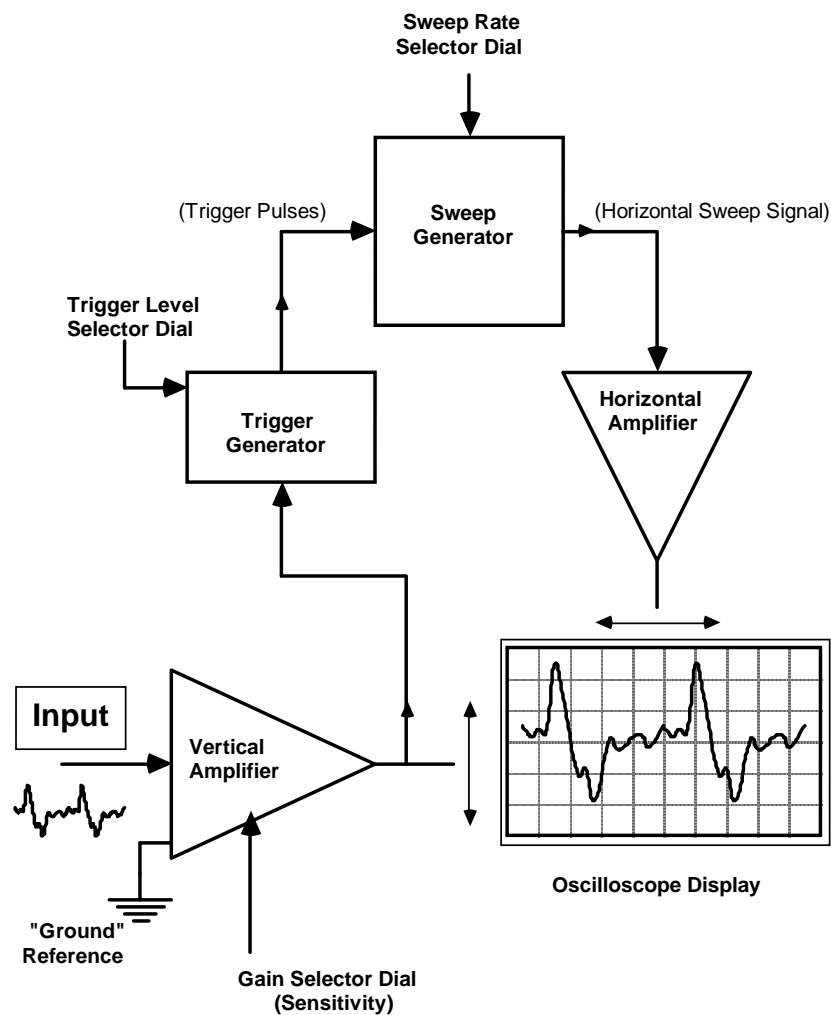
Figure 1: Block Diagram of a Basic Oscilloscope

Capacitors

Capacitors are electrical circuit elements that can store temporarily an electrical charge. The amount of charge stored depends on the size (capacitance) of the capacitor. The capacitance is measured in farads: coulombs (charge) divided by volts. Typical capacitors found in the lab might be 1.0 microfarads (10^{-6} farads), or 0.1 microfarads, or 0.001 microfarads. The schematic circuit symbol for a capacitor looks like

       or like   if the capacitor is *polarized*, meaning that the component must be placed in the circuit with a specified polarity.

Capacitors are frequently labeled with a three-digit code that is somewhat similar in format to the code for resistors. Referring to the three digit sequence as ABD, the nominal value of the capacitor is given by AB x 10^D in picofarads (pF). For example, the label "103" (A=1, B=0, D=3) would mean 10 x 10^3 pF, or 0.01 µF (microfarads).

The three digit nominal value code is usually followed by a letter, which is used to indicate the *tolerance* of the capacitance value. Common tolerance indication letters are: M=20%, K=10%, J=5%, G=2%, F=1%, and E=0.5%. Recall that the tolerance refers to what range of actual (measured) capacitance expected for the particular device, expressed as a ± percentage of the nominal value. For example, if a capacitor is labeled "103K", that means its capacitance will be somewhere in the range 0.01 µF ± 10%, or between 0.009 µF and 0.011 µF.

Some capacitors (e.g., aluminum electrolytic devices) are physically large enough that they have the capacitance printed directly on the case without using the three-digit code.

Applications of capacitors include using them in circuits, along with resistors, to create electrical *filters*. Filters will tend to reduce the amplitude of electrical signals in selected frequency ranges. Thus, the output signal from a filter circuit that is supplied by a sinusoidal input signal will have amplitude that depends on both the amplitude and frequency of the input signal. For example, a frequency-selective filter is found in a radio "tone" control: adjusting this control can cause an increase in the level of bass (low frequency) sounds relative to high frequency sounds, or vice versa.

In this experiment you will explore the characteristics of simple lowpass filters made using one resistor and one capacitor. At low frequencies, the capacitor will have sufficient time to become "charged" with one polarity as the current flows through the circuit during one half cycle of the sinusoidal input signal, and then discharged and recharged in the opposite polarity during the next half cycle. The output voltage will therefore be about as large as the input signal. But at very high frequencies, the *period* (cycle duration, 1/frequency) of the input signal is so short that the capacitor cannot charge or discharge before the next cycle of the waveform. This means that the output voltage amplitude is expected to decrease as the input frequency increases.

Prelab

PL1. What is the three-digit (nominal value) code to indicate a 0.1 µF capacitor? In the space provided on the following page show how your code, when used in the formula: AB x 10^D in picofarads (pF), results in 0.1 µF.

PL2. Imagine that you are investigating the properties of two waveforms using an oscilloscope. You find that the two waveforms share a common period of 250 µs and are offset in time by 20 µs.

Calculate the frequency of the waveforms. Show your work and box your answer.

Calculate the phase shift (in degrees) between the waveforms. Show your work and box your answer.

Instructor's initials_____

Equipment

Your circuit prototype board, your lab kit (containing resistors, resistor color code chart, potentiometer, capacitors, and alligator clips), and the bench power supply, function generator, oscilloscope, DMM, and banana cables furnished in the lab.

Procedures

P1. → Turn on the *function generator* and use the control knobs to produce a 1 kHz (1000 Hz) sinusoidal waveform with an amplitude of $2V_{pp}$. Using a BNC-to-alligator cable, connect the oscilloscope probe tip to the red lead from the function generator and the probe's ground clip to the black lead. Adjust the oscilloscope amplitude knob and time scale knob until you see about one cycle of the sinusoidal waveform on the screen.

→ Measure the *period* of the waveform (horizontal time required for one cycle) and verify its peak-to-peak amplitude.

Waveform Period: _____   Peak-to-peak Amplitude: _____

P2. → Adjust the function generator frequency and scope sweep rate so that approximately two cycles of a *triangle* waveform fit across the display screen. Then adjust the function generator amplitude—observing with the oscilloscope—so that the triangle waveform is exactly 3V peak to peak with a period of 2ms. Record the scope settings.

Scope Vertical Gain Setting (volts/division): _____ How many divisions? _____

Using the numbers you just recorded, show that you established a triangle waveform of the desired peak to peak amplitude of 3V.

Scope Horizontal Sweep Setting (time/division):_____

How many divisions corresponding to one cycle? _____

Using the numbers you just recorded, show that you established a triangle waveform with the desired period of 2 ms.

What is the frequency of the triangle waveform? Show your calculation and box your answer.

P3. → Construct the simple resistor-capacitor (RC) network shown below using your prototype board, and set the function generator to be a 2 volt peak-to-peak sinewave.
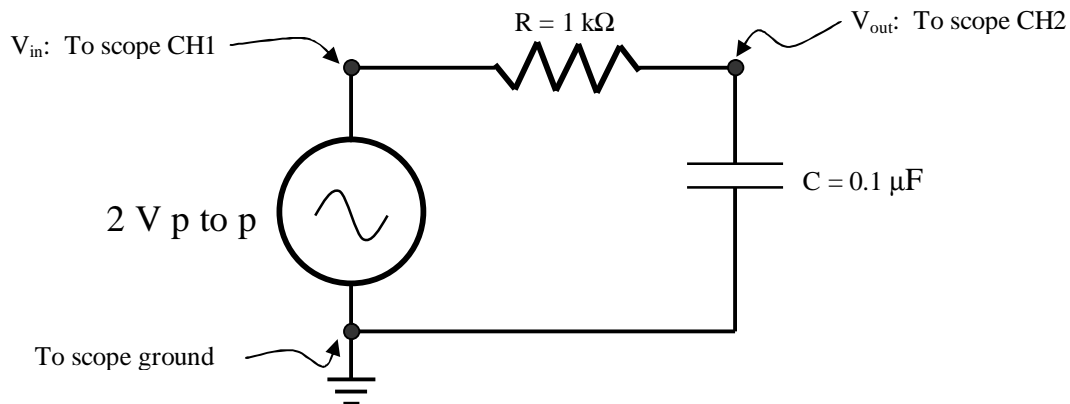
→ Use the two channels of the oscilloscope to display the input voltage waveform (CH1) and the output voltage waveform (CH2) simultaneously. Figure out a way to find the delay (lag) of the output compared to the input. Take a set of measurements to fill out the table below. Below the table show how you calculated the phase shift in the 500 Hz case.

*** *COMPLETE ALL MEASUREMENTS IN A GIVEN ROW BEFORE MOVING ON TO THE NEXT ROW* ***

Input Frequency	V_{in} Amplitude (set 2V p-to-p)	V_{OUT} Amplitude (peak-to-peak)	Time Delay (output vs. input)	Phase Shift (degrees) (output vs. input)
500 Hz				
1 kHz				
2 kHz				
5 kHz				
10 kHz				
20 kHz				
50 kHz				
100 kHz				

Example calculation of the phase shift:

This circuit is called a *lowpass* filter. Based on your measurements, explain in words why you think the term *lowpass* makes sense.