EXPERIMENT 2: THE OSCILLOSCOPE AND AC MEASUREMENTS (Sept. 10, 2003)

The main purpose of this laboratory is to gain some experience in the use of the laboratory digital oscilloscopes. The scope is an extremely versatile and powerful instrument that we will use throughout the semester for observing time-varying electronic signals. Prior to the lab, you should read the section of the appendix that describes the scopes we will be using.

We used to have analog oscilloscopes in the laboratory but we now have digital oscilloscopes. The main obvious difference to a new user is that digital scopes have an LCD screen and have a smaller case than analog scopes. Analog scopes have a glass viewing screen and have a larger case because they contain a cathode ray tube (CRT).

An analog oscilloscope consists of a cathode ray tube and various circuits to deflect the cathode ray beam in the vertical or horizontal direction. The CRT has a glass envelope which is evacuated to high vacuum and a cathode which is heated to boil off electrons. The electrons emitted by the cathode are accelerated by a potential difference between the anode and the cathode (typically 20 kV) and focussed into a beam. The beam produces a fine, bright spot when it hits the fluorescent screen on the face of the CRT. The electron beam can be deflected to an arbitrary point (x,y) on the screen by voltages that are applied to horizontal and vertical deflection plates.

In contrast, the input to a digital scope goes to a very high speed analog to digital converter which samples the input waveform up to as many as 1.25×10^9 samples per second (for our scopes). There is thus a set of x,y coordinates for every sampling point. Each x,y pair corresponds to a particular pixel on the LCD screen and the waveform is thus displayed on the LCD screen with points so close together that it appears as a continuous waveform.

The scope has two distinct modes of operation. In <u>x-y mode</u> the user supplies both the horizontal (x) and the vertical (y) deflection signals through input connectors located on the front of the scope, so that what appears on the screen is a plot of y vs x. In <u>time base</u> <u>mode</u> the time samples are drawn across the screen from left to right at a constant speed (which the user can select) while the vertical deflection is generated from an input signal supplied by the user. This makes it possible to view the input signal directly as a function of time.

In time base mode the sweep does not begin until the scope has been <u>triggered</u>. Learning how to set and adjust the trigger controls is one of the more difficult aspects of learning to use the scope. Basically, the trigger circuit works by looking at some time-varying signal (called the <u>trigger source</u>) and generating a "trigger" whenever that signal passes some preset <u>level</u> (which the user can adjust) with the proper <u>slope</u> (either positive or negative, as selected by the user). The trigger source can either be an <u>external</u> signal (EXT) provided by the user, the 60 Hz AC <u>line</u> voltage (LINE), or some other <u>internal</u>

signal (INT). If the trigger source switch is set to INT then the trigger source will be one of the scope input channels (CH 1-4). One of these channels will be connected to your input signal but you have the ability to trigger on a different signal connected to one of the other channels.

The Tektronix model TDS 3014 oscilloscopes we use in the 321 Lab have ground as the common terminal for all the input signals. This terminal is connected through the AC power line to the grounds of other electronic instruments. This easily forgotten ground connection can lead to confusion and incorrect measurements if you are not careful.

- 1. As you go through the following steps keep notes in your lab notebook describing your observations.
 - a) The first step is to display a sine wave. Set the A Trigger Source to Ch 1. Set the function generator to produce sine waves with a frequency of around 200 Hz and connect to the channel 1 input.
 - b) Set the time base control to 2 ms/division, and then adjust the trigger level and the channel 1 amplitude control (CH 1 volts/div) to get a reasonable display. Play with the <u>level</u> and <u>slope</u> trigger controls until you understand what they do. Observe the effects of changing the frequency and amplitude of the generator signal, and the effects of changing the time base and channel 1 dispersion controls.
 - c) Now look at the same sine wave using the channel 2 input. You will need to change the vertical mode to display channel 2 and the trigger control to trigger on the channel 2 input.
 - d) Next make sure you understand the function of the input coupling switch (AC/GND/DC). For this step, adjust the DC offset of the function generator to produce a sine wave that is offset from zero by some amount. Set the input coupling switch to GND, which grounds the input (this prevents the trigger circuit from firing, but you can still observe the trace by using the AUTO trigger feature). Adjust the vertical position to center the trace on the screen, and then observe the input signal with the input coupling set to AC and DC. Do you understand what you see in each case?
- 2. Connect the function generator to CH 1 and a 6V transformer to CH 2. Display first CH 1 alone, then CH 2 alone, and then BOTH. As you do so observe the effect of changing the trigger source (CH 1, CH 2, VERT MODE, and LINE). Investigate the function of the "+" and "-" operators found under the MATH mode button. Briefly describe your observations, and make a few rough sketches of the wave forms.

- 3. Use the output from the transformer (which will be 60 Hz to a very high accuracy) to check the sweep calibration of the scope. Set the sweep time to 20 ms/cm and determine the time it takes for the trace to cross the screen by counting the number of waves. How accurately is the scope calibrated? How precisely do you think you could measure the time between two points on a wave form? Let the scope make the measurement by pressing the MEASUREMENT button and selecting PERIOD and FREQUENCY measurements.
- 4. Use a DC voltage supply and a DMM to check the voltage calibration for either channel 1 or 2. Set the amplitude control to 1 V/cm. Adjust the zero setting of the trace as in Part 1(d) and then adjust the output of the power supply to obtain a deflection of 3 cm. Then measure the voltage with the DMM. Repeat the measurements for settings ranging from 0.1 V/cm to 5 V/cm. Tabulate your results and the errors. How accurately is the scope calibrated? Do the same for the AC input signal and also let the scope make an AMPLITUDE measurement. Try an RMS measurement as well and see if you get the expected result.
- 4. There are two selectable input impedances for the scope input: $1 \text{ M}\Omega$ and 50Ω . The 50 Ω input impedance is normally used as an impedance match to coaxial cables to prevent signal reflections. Select the $1 \text{ M}\Omega$ impedance and measure the DC input impedance of the oscilloscope using the method described in part 5 of experiment 1. Measure the AC input impedance by the same method using a 1 kHz sine wave from the function generator as the voltage source. Remeasure the AC input impedance with a 10 kHz sine wave. Does the impedance depend on frequency?
- 5. The ratio of the frequencies of two AC voltages can be measured by using the x-y mode of the scope. Set up the first Lissajous figure as follows.
 - a) The 6V transformers have two yellow connectors (the two sides of the transformer) and a black connector (the transformer center tap). Connect one side of the transformer to both Ch 1 and Ch 2 scope inputs and the center tap to the ground inputs of both channels. You will now have identical signals on Ch 1 and 2. Observe the Lissajous pattern by running the scope in x-y mode. Sketch the waveform and explain what you see.
 - b) Now set up two signals 180° out of phase by connecting one yellow connector to Ch 1 and the other yellow connector to Ch 2. Leave the center tap as is. Sketch the waveform and explain what you see.
- 6. Now set up for additional Lissajous figures using the 60 Hz transformer output for the Ch 1 scope input and and a sinusoidal output from the function generator for the Ch 2 scope input. Observe the Lissajous patterns for function generator frequencies of 20, 30, 60, 120, and 180 Hz. You will notice that unless you get the frequency set exactly right, the pattern will slowly rotate as the relative phase of the signals changes. Sketch

waveforms and explain what you see. Below are examples of Lissajous figures taken from the lab setups. Identify the phase and frequency ratio for each figure.



Physics 321 – Supplement for Experiment 2

1 Introduction

The x-y mode of the oscilloscope can be used to display the current-voltage characteristics of both linear and non-linear two-terminal devices. Later on in the course you will use a Curve-Tracer which is simply an oscilloscope which only runs in x-y mode. It has additional features, however, which permit the voltage or current stepping of a third terminal parameter so a whole family of characteristics can be accumulated rather than just one x-y curve.

We can make simple x-y Current-Voltage measurements of a small 6 V light bulb using the x-y mode of the scope. The light bulb has a tungsten filament which will increase in resistance as the bulb current increases. You will be able to measure this property of the bulb using the x-y mode technique.

The main idea is to connect an AC voltage from the Function Generator to the circuit consisting of a resistor in series with the bulb. The voltage across the resistor will be proportional to the device $\operatorname{current}(y)$ and the voltage across the bulb is the device $\operatorname{voltage}(x)$. For a given bulb voltage you will observe a straight line on the scope display, the slope of which can be used to determine the resistance for that particular bulb voltage. You can then vary the Generator voltage and note that the slope of the x-y display will change due to the change in resistance of the bulb. The circuit is shown below.



2 Procedure

- 1. Connect the circuit as indicated above. The placement of the ground is critical since you will use two scope inputs which have to have a common ground. Unlike the scope, the Function Generator output voltage does not have to be grounded.
- 2. Use the 'high' sine curve output of the Function Generator so you can get about two volts across the bulb. Set the scope to x-y mode making sure that x(Ch 1) is the bulb voltage and y(Ch 2) is the voltage across the resistor. The scope input impedance should be set to 1 M Ω not 50 Ω . You should see the bulb light up.
- 3. Measure the slope of the x-y display for about six different bulb voltages. Compute the bulb resistance for each case.
- 4. Plot the measured resistance of the bulb as a function of the bulb current.