

Electronic Instruments

Make sure you read and understand these weekly lab manuals *before* you come to the lab! The best use of lab time is performing the lab, with the instructors nearby, not reading the lab manual.

Purpose

This experiment introduces the three basic electronic instruments you will use in the course: the oscilloscope, the function generator, and the digital multimeter. Make sure you make full use of this lab this week to familiarize yourself with the instruments on your lab bench. You will be using these for the rest of the semester. **It will save you a lot of time and frustration throughout the semester if you know how to set up the power supply and how to trigger and read the oscilloscope correctly!** There are no pre-lab homework problems for this first lab, and you do not have to write a report. In place of the report, there are homework problems on dc and ac circuit theory at the end of this chapter.

Introduction

Any time you develop a new circuit, repair an electronic instrument, or measure the performance of an electronic component or system, you will need to use one or more items of test equipment. Almost every task requires an oscilloscope, the basic instrument for visualizing the time dependence of electronic signals. A signal or function generator is used to produce periodic signals of the frequency, amplitude, and waveform needed for input to the device under test. The digital multimeter measures voltages, currents, resistance, and it can test silicon diodes and transistors. Everything you do in an electronics laboratory depends upon your familiarity with these instruments. The instructions for this experiment are designed to help you start seeing patterns on the oscilloscope screen as soon as possible, and to familiarize you with the controls of each instrument.

Suggested reading

1. Fischer-Cripps (FC) chapters 1 (electricity), 2 (dc circuits), and 3 (ac circuits) provide an introduction to important topics relevant to the first two weeks of lecture. Note: we will revisit various sections in these chapters in more detail later – for example filters and oscillators. Also look at p. 274 for the resistor color code (or google it).
2. The following documents on the course website will be useful:
 - a) AGILENT 33220A function generator manual pp. 17-24
 - b) Tektronix 3014 Scope Users Manual, pp. 15-32, 46-49
 - c) Math review (complex numbers)
 - d) Decibels overview
3. Chapter 1, Sections 1.01-1.12 of Horowitz and Hill (H&H).

Post-Lab Problems

Before the next class, answer the questions at the end of this lab manual. Turn these in *before* the beginning of your second lab period.

Experiment

TEKTRONIX 3014 OSCILLOSCOPE

The 3014 has four independent vertical channels so that four separate signals can be displayed at once. It also has two separate horizontal sweeps (called A and B) which allow traces with two different sweep speeds to be displayed at the same time. (The main use for this is to zoom in and magnify a small part of a trace while still displaying the full trace.) Finally there are built-in measurement and cursor capabilities that are useful for making measurements on the screen. But a note of caution: while these built in measurement capabilities are extremely convenient, care must be used to not let their limitations interfere with your ability to get accurate measurement of what you are investigating.

There are a few precautions to observe when operating the oscilloscope:

- Avoid overheating the instrument. Do not block ventilation of the interior by laying books or clothes on the case. This precaution applies to any instrument.
- Do not apply more than 400 V to any input terminal.
- Avoid serious or fatal injury from electrical shock. Do not remove the cover or insert anything metallic through the vent holes.

Otherwise, the instruments are robust and cannot be damaged by wrong settings. So try whatever you're curious about and see what happens. (This is a 'learning by doing' course!)

We will begin by setting up the scope for basic one-channel operation. First, remove all cables left by previous users, and turn the scope on by depressing the ON/OFF button. The settings are remembered from the last user, so you need to verify the state of the setup; refer to the manual if you can't spot the right control. Now set the following using the panel and menu controls as follows (you may want to use this standard setup in the future if you have trouble):

<u>Display Intensity</u>	WAVEFORM INTENSITY 50%	Intensity of the A sweep.
	B TRIG Off	Turn off B sweep.

<u>Cursor Controls</u>	CURSOR Menu	Off option	Turns off digital measurement system.
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<u>Vertical Controls</u>	CH 1, then Menu		Select channel 1 to display.
	POSITION (CH1)	Midrange	Vertical position for Channel 1
	SCALE Knob	0.2 V/div	Note value displayed on screen.
	FINE SCALE	“Off”	Variable sensitivity.
	COUPLING (CH1)	GND	Gives 0V input for setting baseline
	COUPLING	1 M Ω	Input Termination of 1 M Ω
	BANDWIDTH	FULL	
	INVERT	OFF	
<u>Horizontal Controls</u>	POSITION	Midrange	Horiz. position. (Knob)
	SCALE	1 ms/div	Sweep speed(displayed on screen)
	MAGNIFY	OFF	(Let you expand the scale)
	DELAY	OFF	
<u>Trigger Controls</u>	MENU	Pick CH 1	Use CH 1 signal for triggering.
	B TRIG	OFF	Selects A sweep only(Green light off)
	MODE	AUTO	Sweep even when no signal present.
	COUPLING	DC	Send CH 1 to trigger with no filtering.

The baseline beam trace should appear as a horizontal straight line. Readjust Waveform Intensity for desired brightness, move the trace vertically until it coincides with the X-axis using the POSITION knob. Position the start of the trace so that it is visible at the left hand side of the screen using the horizontal POSITION control.

You may need to turn CH 2, 3, or 4 off. Press the button CH #, then the off button under the vertical position knob. If no yellow trace is visible, check that the trigger MODE is on AUTO. If that fails, depress AUTO SETUP. If you still don't see a trace, get help from an instructor.

Next we will try to display the signal from the scope CALIBRATOR output on the screen. Connect the CALIBRATOR output to the CH 1 input with a short coaxial cable and the alligator clip probes. Note that the outside of the coax is always ground, and the inner conductor carries the signal. The inner conductor is connected to the red clip, so connect the red clip to the CALIBRATOR output. Now set the CH 1 vertical COUPLING to DC. A signal should appear on screen. Adjust the TRIGGER LEVEL (upper right corner of panel) to give a stable and stationary waveform. Note the little arrow on the display which indicates the value of the trigger level. Get some help if you can't see the waveform.

Explore the effect of the following controls one at a time. Return each control back to the original setting before you change the next.

- CH 1 VOLTS/DIV, both the calibrated control and FINE ADJUST (variable). Note that DIV means one of the big divisions. There are usually 10 of these across the screen horizontally.
- HORIZ SCALE, (sec/div)
- CH 1 COUPLING: AC/DC/GND. Observe and understand the change in level.
- TRIGGER LEVEL and SLOPE.

The trigger level controls the voltage at which the trace starts. Stability is lost when the trigger level lies outside range of the displayed voltage. Change TRIGGER MODE to NORMAL. Note that the trace now “freezes” when the trigger level is misadjusted. You can see whether the scope is actually being triggered by looking for the small writing TRIG'D or TRIG? at the top of the display.

NOTE: Oscilloscopes can only distinguish about 100 different values on the vertical axes of the screen. So before you use the oscilloscope to measure anything make sure that the trace covers at least 50% of the vertical screen without clipping at the top or bottom. This way you get a resolution/accuracy of approximately $\pm 2\%$.

Measure the peak-to-peak (p-p) voltage and the period of the waveform using the screen scale. The peak-to-peak voltage is the difference between the high and low extremes of the waveform. You must multiply the number of divisions by VOLTS/DIV to get the p-p voltage. First adjust the scale factors to give a large trace—between 50% and 95% of the screen in height and about two periods horizontally. Finally measure the dc voltages of the lowest and highest part of the waveform, and measure the time for a complete cycle. Be sure to multiply the number of horizontal divisions for a complete waveform by SEC/DIV. What is the frequency of the waveform? Do the peak-to-peak amplitude and the frequency agree with the markings on the scope display screen?

Now try to get the same trace showing the CALIBRATOR signal, but use the CH 2 vertical input.

AGILENT 33120A FUNCTION GENERATOR

The 33120A provides sine, square, triangle, pulse and ramp waveforms over the frequencies from 0.0001 Hz to 15 MHz in ten decades. The output amplitude is 50 mV to 10 V peak-to-peak with an output impedance of 50 Ω . The frequency may be controlled manually or swept automatically between START and STOP frequency settings set in a menu. The symmetry of the waveform may be varied, enabling square waves to be turned into pulses and triangle waves into ramps. The output may be modulated either by amplitude modulation or frequency modulation.


Again there are a few precautions to keep in mind:

- Do not cover the perforated outer case—the instrument will overheat.
- Do not connect any output of the 33120A directly to dc power or to the output of any other instrument or circuit. Doing so will burn out the output amplifier!

Except for these precautions the instrument will likely not be damaged by incorrect settings.






We will set up the 33120A as a free running oscillator with manual control of frequency. This is almost always the way we will use it. Remove any cables left by previous users, and turn the function generator on. There are several methods of setting numbers for amplitude, freq and offset; to become familiar with these, read the manual pp. 17-24.

Set the panel controls as follows to generate a 1 V p-p sine wave at 1 kHz with no dc offset (you may want to use this standard setup in the future if you have trouble). You will need to set the output termination to HIGH Z (see page 35 of the manual).

<u>Frequency</u>	1.000 kHz	(See p. 17)	
<u>Shape</u>		Button	Select sine waveform.
	DUTY CYCLE	50%	No asymmetry (p. 23)
<u>Amplitude</u>	1.0 VP-P	(See p. 18-19)	
<u>DC Level</u>	OFFSET 0.0 VDC	(See p. 20)	
<u>Frequency Sweep</u>	SWEEP DURATION	OFF (button)	Default is off at power up

Use a BNC coaxial cable to connect the function generator OUTPUT (lower right corner of panel) to the CH 1 input of the oscilloscope. Set up the scope to view the signal on channel 1 with dc coupling. Adjust the scope trigger level to obtain a stable waveform. Observe the sine wave and verify that the amplitude and frequency are as expected from the function generator controls.

Explore the effect on the waveform of the following controls. Vary only one control at a time and return it to its original value before changing to the next.

- Depress the  (square),  (triangle), and  (sine) buttons and observe the waveforms.
- Use the knob to change AMPL. Observe the amplitude changes.
- Use the knob to change the OFFSET value. Note the change in dc level.
- Set to  (square), use the knob to change the DUTY CYCLE
- Return to  (sine) and change the FREQUENCY using the knob; note how you need to use the small arrow buttons to get the full range (100 μ Hz – 15 MHz).

Changing the function generator OFFSET control will change the scope display in the same way as the scope's vertical POSITION knob. But these two controls do very different things: the first changes the actual signal while the second only changes the way it is displayed.

The function generator has a trigger output which can be used to trigger the scope (called SYNC). Using the trigger output is more convenient than triggering the scope off of the waveform itself because you avoid having to readjust the scope trigger every time you change the waveform. To see how the trigger output works, first return the function generator to 1 V p-p sine waves at 1 kHz with zero dc offset. Then setup to display both the CH 1 and the CH 4 on the scope. Set the scope trigger SOURCE to CH 4, and connect a coaxial cable from the function generator trigger output to the scope CH 4 input. Observe both the sine wave and the trigger signal on the scope. Adjust the scope trigger level for a stable display. Now change the amplitude and frequency of the sine wave, and notice how the scope remains nicely triggered.

The function generator you are using is actually a synthesizer, which means that its output is derived from a highly stable quartz oscillator. We have some instruments in the lab called counter/timers, which can be used to make very accurate frequency and time interval measurements. There is not much point in using a counter/timer to measure the frequency of a synthesizer, except to check that it is not broken. Counter/timers are useful when studying signals generated by a circuit you build or that come from an outside source of unknown or unstable frequency.

FLUKE 77 DIGITAL MULTIMETER

Most measurements that are done with the digital multimeter could also be made with the scope, but the multimeter is usually more accurate, and it is very convenient for continuously monitoring steady voltages or currents.

Check the accuracy of the ohms range by measuring precision resistors of 1 Ω , 1 k Ω , and 1 M Ω . What value of resistance does the meter display when you connect together the wire leads? Why? Identify an ordinary 1 k Ω 1/4-watt resistor by its color code and measure it with the multimeter.

Determine the frequency range for which the multimeter can be used to measure ac voltage. Generate 500 Hz sine waves of 1 V p-p amplitude with the function generator and arrange that the oscilloscope and multimeter both measure the same signal. Be sure that the scope input is dc coupled. Determine the amplitude from the oscilloscope trace and compare with the multimeter reading. Note that the multimeter measures rms amplitudes and recall that for a sine wave $p-p = 2\sqrt{2}$ rms. Now vary the frequency from 10 Hz to 10 kHz. What is the frequency range over which the multimeter reading is constant to within 2%? Remember in the future that this is the usable frequency range for the ac setting of the multimeter (you will need this in a later lab).

CURSOR MEASUREMENTS WITH THE OSCILLOSCOPE

Digital measurements of voltage, time, and frequency can be made for signals of the oscilloscope. There are several modes of operation: a manual mode using CURSORS and an automatic mode

called up with the measurement menu. The CURSORS are more accurate but the menu buttons are easier to use. A menu system is used to access the functions. The cursor measurements will be most accurate when the displayed signal nearly fills the oscilloscope screen. Set the amplitude to cover about 5 divisions vertically and the sweep speed to give about 2 periods horizontally.

Try using the CURSORS to measure the p-p amplitude of a 1 kHz sine wave from the function generator. If you get lost in the menu system, you can always get back to the beginning by pressing the MENU OFF button.

Next try out the MEASURE system using the same 1 kHz sine wave. Measure the peak-to-peak amplitude and the dc level. Then introduce some dc offset from the function generator and note the changed readings. Try all the different measurements available.

Note that the automatic mode searches for the very top and bottom of the signals. For example, in the schematic of a noisy sine wave below, automatic mode will return the upper and lower most lines which will include the noise contribution. A careful manual measurement indicated by the inner (shorter) lines can remove the noise from the amplitude measurement. **With small or noisy signals, the automatic mode will give very poor results.**

SET UP TEST WAVEFORMS

This is an important checkpoint to evaluate your understanding and skill. If you are having trouble, be sure to get help from an instructor.

Set the oscilloscope vertical and horizontal controls such that the display covers about 5 vertical divisions and about 2 periods across the screen. Use the digital measurements on the oscilloscope to verify that you have obtained the signal you are seeking.

1. 5 Hz triangle waves with a peak-to-peak amplitude of 3 V. (You will have to use NORMAL triggering, not AUTO. Why?)
2. 15 MHz sine waves with an amplitude of 500 mV. (If you have trouble getting the scope to trigger at high frequencies turn the time/div knob. You can also try pushing the AUTO SETUP, but this will mess up all your previous settings! So use that function with care.)
3. 10 kHz square waves with low value at 0 V and high value at + 5.0 V. Do the scope scales agree with the output of the function generator?
4. Pulses at a frequency of 1 kHz, with an 800 μ s low level at 0 V and a 200 μ s high level at + 5.0 V. (This could be used as a logic signal).

Homework Problems

Turn these problems in at the start of your second lab session. This assignment takes the place of both, the first pre-lab problems and the first lab report, and is thus worth 40 points (the remaining 10 points are from the lab notebook).

1. Learn the color code for resistors (e.g. FC p. 274). The sequence of colors

black brown red orange yellow green blue violet gray white

can be learned by memorizing the backpacker's lament:

Black bears resting on your gear bring very gray weather.

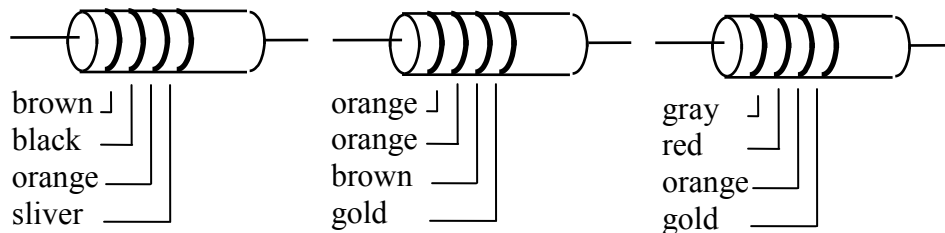


Figure 1.1 Color Coded Resistors

What are the values and uncertainties of the resistors in Figure 1.1? Write the resistance using the most appropriate units of Ω , $k\Omega$ or $M\Omega$, and include the % tolerance. (For example, $1.8 k\Omega \pm 5\%$.) Resistors labeled with color bands are usually carbon composition and 5% or 10% tolerance. 1% metal-film resistors are labeled by a different scheme.

2. There is a three-digit number code for labeling capacitors. The label 224 means 22 with 4 zeros, interpreted as a capacitance value in picofarads. ($224 = 220,000 \text{ pF} = 220 \text{ nF}$.) You also will see labels like $22 \mu\text{F}$, 22 uF , 22 MF , and 22 MFD , all of which mean 22 microfarads. Another notation is 220 uuF , which means 220 picofarads (uu = micro micro). Write down the values of the capacitors shown in Figure 1.2. Use the most appropriate unit: pF, nF, or μF .

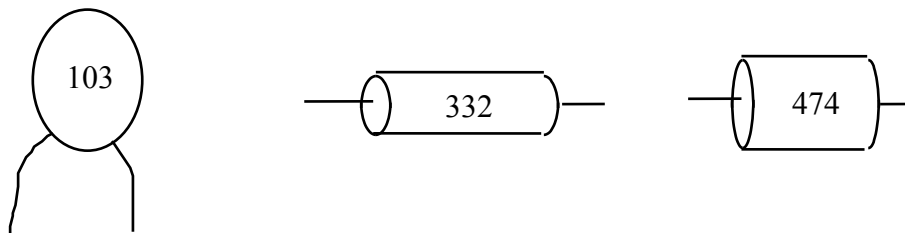


Figure 1.2 Number Coded Capacitors

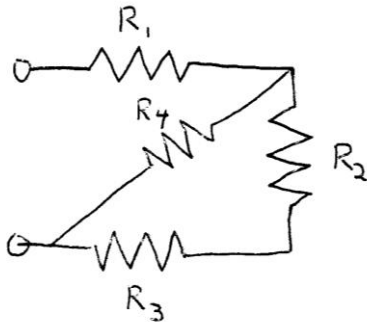
3. A. What is the equivalent resistance of a $6\text{ k}\Omega$ and a $15\text{ k}\Omega$ resistor (a) in parallel and (b) in series?

B. What is the power dissipated in a $12\ \Omega$ resistor across a 9 V voltage source?

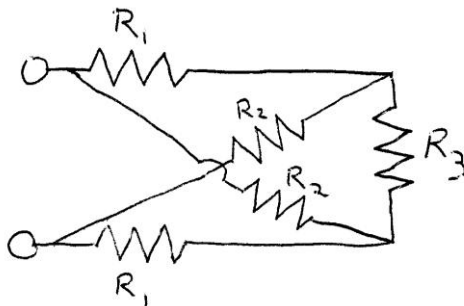
C. What is the power dissipated in the $12\ \Omega$ resistor in the previous problem if you put a $1\ \Omega$ resistor in parallel with it?

4. Find the effective resistance between the circled nodes in the following networks.

A. Hint: use series and parallel laws to simplify the network.



B. Unwelcome hint: the network can't be simplified using series and parallel laws (yikes!). Use Kirchoff's laws to set up a system of linear equation and label your schematic with the current variables that you introduce. You're welcome to use any mathematical software package to solve the series of equations (hint hint) but you must show your derivation of these equations.



5. Find a formula for the impedance Z_1 in Fig.1.4 below. Now evaluate numerically the real and imaginary parts of the impedance for $R = 1\ \Omega$, $C = 150\text{ nF}$, $L = 150\ \mu\text{H}$, at three frequencies $f = 1\text{ kHz}$, 10 kHz , and 100 kHz . Express your results in Ohms with the appropriate SI prefix (k, μ , etc.) and don't forget about the difference between ω and f . In this class it is essential to be able to get the correct numerical results for problems like this.

6. Plot the magnitude and phase of Z_1 as a function of frequency, plotting frequency over the range 100 Hz – 10 MHz, as described below. Use a suitable software package for the graphs (Mathematica preferred, Excel forbidden!). The hints tab of the course web site has lots of help on plotting data. Label your axes with the names of the plotted quantities and their units. Ensure that the numerical labels on the ticks are legible.

A.) Make two separate plots: the magnitude of Z_1 versus frequency and the phase of Z_1 versus frequency, using linear scales for all axes.

B.) Make two separate plots: the magnitude of Z_1 versus frequency and the phase of Z_1 versus frequency. Use logarithmic frequency axis for both plots. Use a logarithmic scale of the magnitude axis and linear scale for the phase axis.

7. Find a formula for the impedance Z_2 in Fig. 1.4.

Fig. 1.4

