EEAP 243
Lab 1

Lab Work:
Questions Due:

TEST INSTRUMENT FUNDAMENTALS

Reading Assignment: Horowitz, pgs. 1-8, 638-642, 645-649

Abstract:
This laboratory introduces the test equipment and measurement procedures used in the electronic circuits lab. It also describes some of the common problems you will encounter.

> One common problem is the failure to recognize and report faulty equipment. If you ever suspect that an instrument is faulty, call a teaching assistant to check it out. Remember that the clip board which hangs next to the lab bulletin board is used to report faulty test equipment. Always report faulty equipment immediately so that it can be repaired promptly.

This assignment contains both background material and instructions for work to be done in the lab. For this lab only, instructions are started with the symbol "[ ]" so that you can check off your progress.

Part 1 - The Lab Station, Front Panel, and Tool Box

Each lab station contains the following test equipment: an oscilloscope (scope), a signal generator, a digital multimeter (DMM), and four DC power supplies. The test station is pictured in Fig. 1.1.

The main power switch (Fig. 1.1D-1) on the front panel controls the power for the whole station.

[ ] Turn the main power switch on at the beginning of your lab session and leave it on for the entire period. You will usually want to turn on the lab equipment every time you start a lab session.

Your tool box contains the following items: one screwdriver, one pair of pliers, one wire cutter, one wire stripper, one resistor board, ten test leads, ten alligator clips, and one solderless "breadboard". The breadboard consists of a plastic frame with an array of holes and metal clip assemblies under the holes. A wire or component inserted in a hole will be held by the clip and electrically connected to other components inserted in the same row or column. Figure 1.2 shows the protoboard and how the holes in the board are electrically connected.

Part 2 - The RSB and Ohmmeter

The Resistor Substitution Board (RSB) is a printed circuit board containing seven strings of resistors connected to a common point. You can generate almost any resistor value you might need using the RSB. Its schematic is shown in Fig. 1.3. With a little practice, using this board will simplify lab procedures and reduce the number of resistors you will need from the instrument room.

NEVER SOLDER TO THE RSB

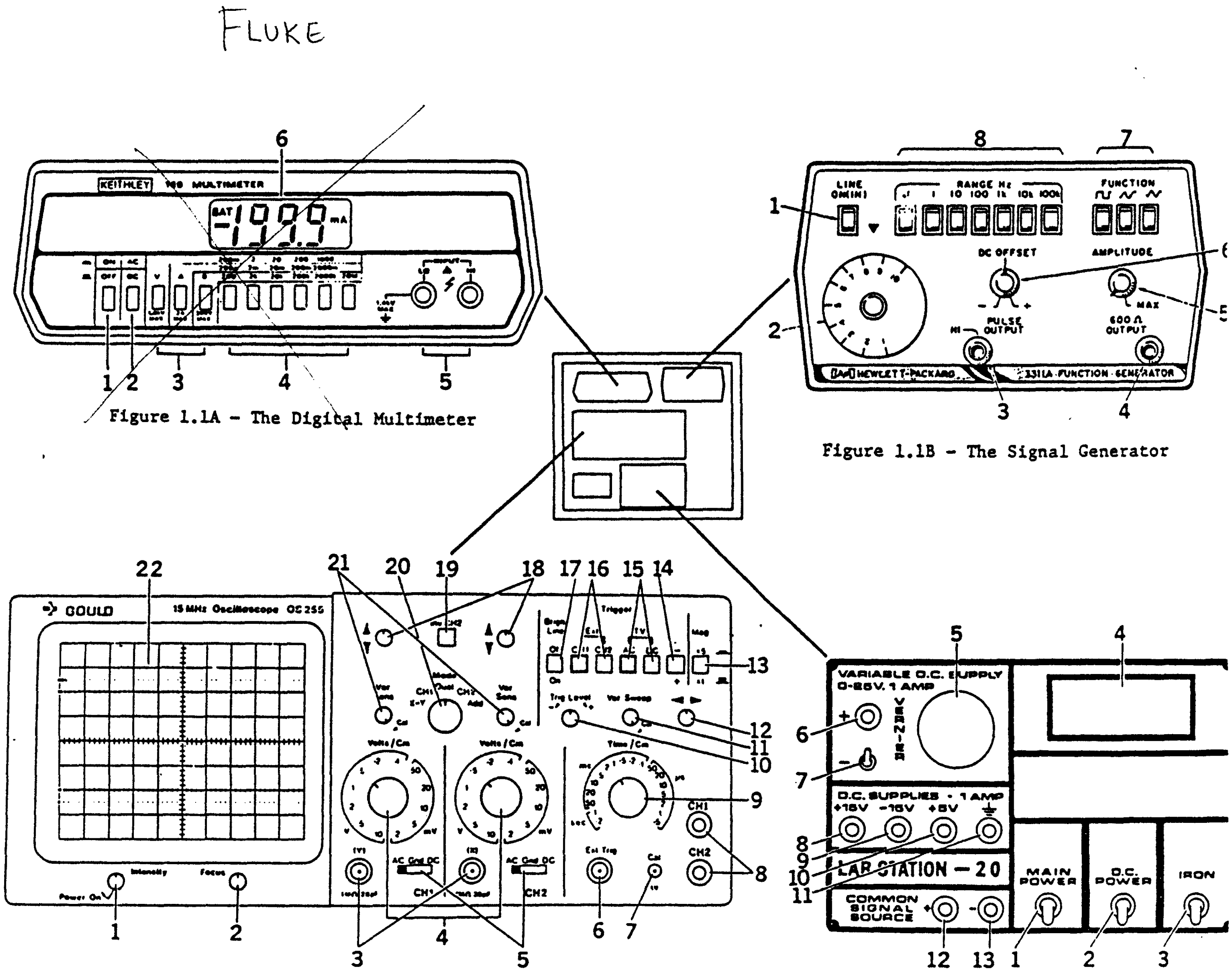

Figure 1.1A - The Digital Multimeter

Figure 1.1B - The Signal Generator

Figure 1.1C - The Oscilloscope

Figure 1.1D - The Front Panel

Figure 1.1 - Lab station

Make it a point to use 22 gauge wire. !
larger wire will damage board !

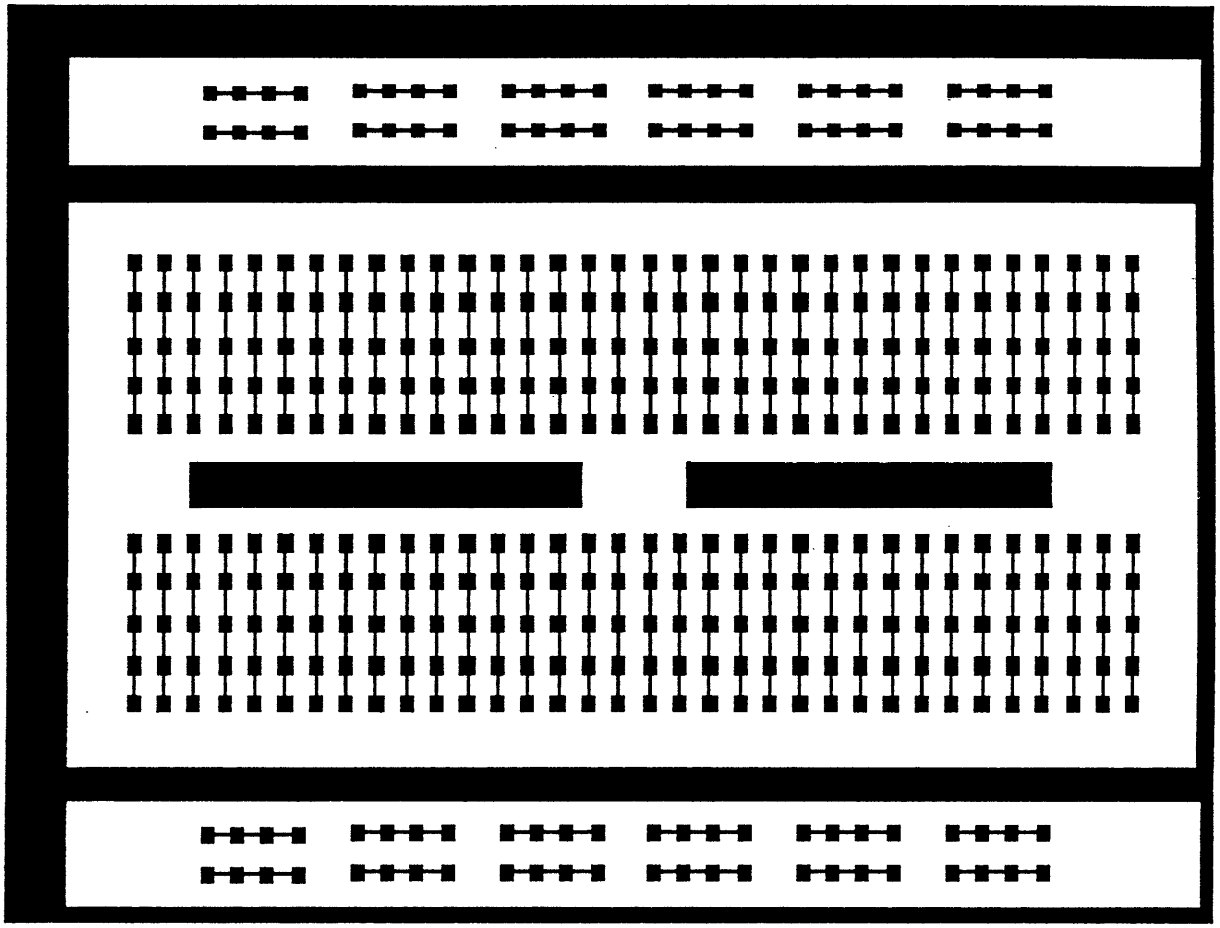

Figure 1.2 - Solderless breadboard

Always connect to the RSB by using test leads and/or alligator clips–do NOT solder to the RSB. Clipping test leads to resistor junctions in adjacent rows allows you to obtain any two digit resistor value. The resistance between the clips is simply the sum of the values printed at the resistor junctions. For example, to get a 470 ohm resistance you would clip to 400 and 70. These connections are shown in Fig. 1.3(b). In another example, connecting to 6M and 300K would give you a 6.3 M resistance. The left end of each resistor string is connected to a common point. To get a 50 K resistance, you would connect to 50K and one of the "common" junctions. You will not normally make more than two connections to the RSB–it can only be used for one resistance in a circuit.

Your DMM can measure AC and DC volts, AC and DC amps, and ohms. The three function buttons (A-3)* are used to select the measurement of volts, amps, or ohms. The separate button which selects AC or DC (A-2) should be in the DC position for measuring ohms. NEVER SELECT THE OHMS FUNCTION WHILE THE DMM IS CONNECTED TO A CIRCUIT TO WHICH POWER IS APPLIED. Otherwise, you may damage the circuit or your DMM.

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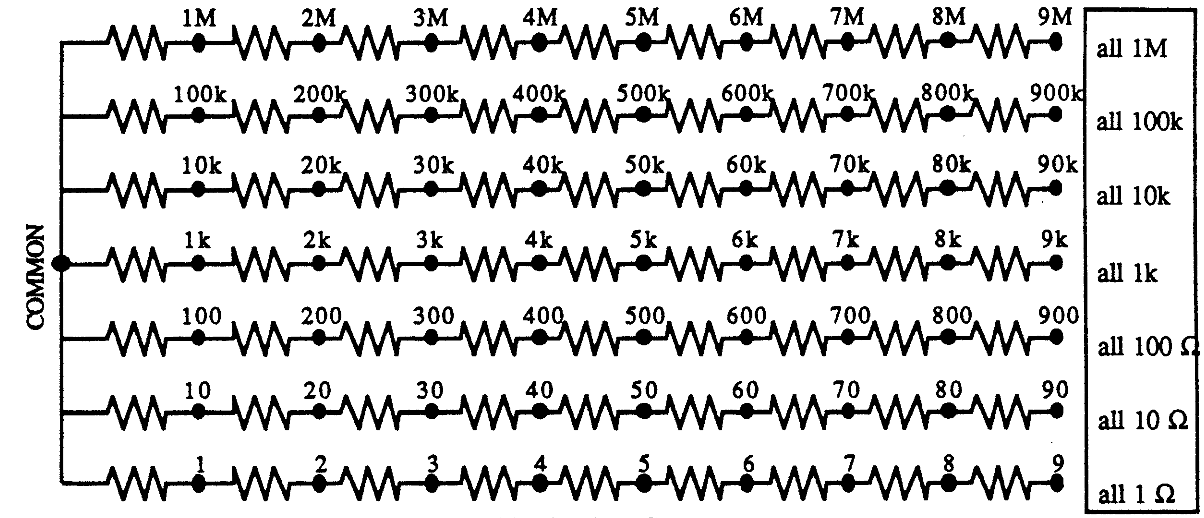
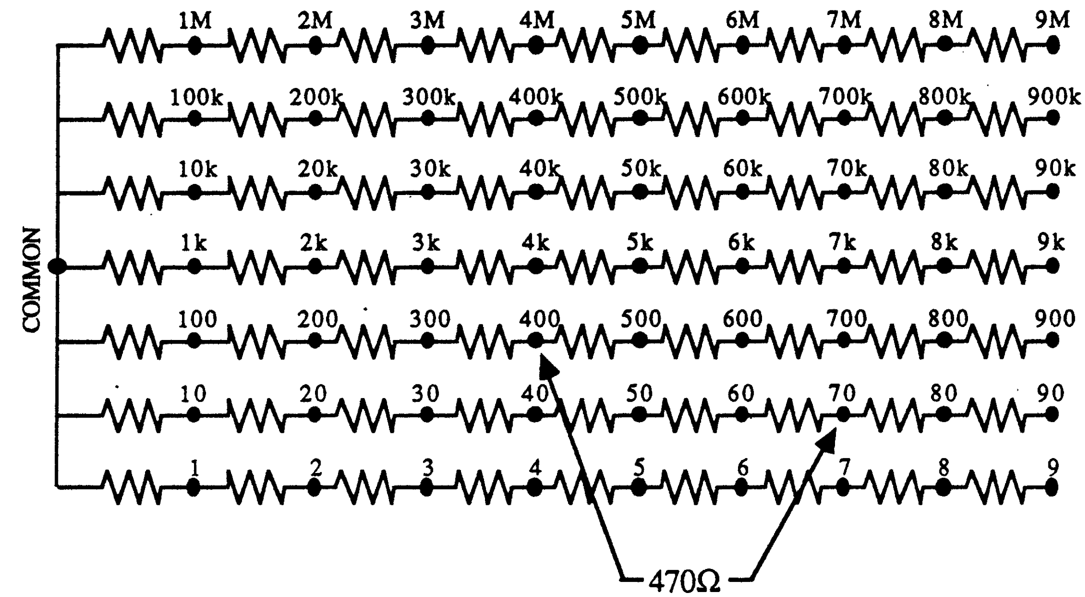
* Labels in parentheses refer to Figure 1.1. For example, A-5 refers to Figure 1A, the switch labeled 5.



(a) The basic RSB



(b) Connections to achieve 470 ohm resistance

Figure 1.3 - Resistance Substitution Board

Each of the five functions is broken down into 5 or 6 ranges which are selected by the range buttons (A-4). For example, the ohms function has ranges of 0-200 ohms, 0-2 K ohms (or just 0-2 K), 0-20 K, 0-200 K, 0-2000 K (0-2 M), and 0-20 M.

When using the DMM, you must be careful to use the proper range. For example, consider the measurement of a 1.234 K resistor. Selecting the 0-200 ohm range would cause an "out of range" condition, indicated by a "1" followed by blanks on the display (A-6). Selecting the 0-20 K range would produce a display of " 1.23 K" which doesn't fully use the instrument's accuracy. The most appropriate range for this measurement is the 0-2 K range, which would display "1.234 K". When measuring widely varying quantities, you should switch the DMM range to get the most accurate reading for each quantity being measured.

The DMM is a sensitive instrument. NEVER TOUCH THE METAL PARTS OF THE TEST LEADS CONNECTED TO THE DMM INPUTS mA, COM, AND VKS (All at A-5) WHILE MAKING MEASUREMENTS. If you do, the DMM may measure noise and resistance from your hands instead of from your circuit.

[ ] Turn on the DMM (A-1) and set it to ohms. Plug a test lead into the VKS input (A-5), another into the common (A-5), and put alligator clips on the free ends of the leads. Connect one clip to 40 on the RSB and the other to 7. Starting with the 200 ohm range button, press each range button in its turn and record the resulting display. (Some readings will display an out of range condition and others will not use all available significant digits.) Do the same for connections to 100 and 50, 1K and 800, 2K and 200, 50K and "common", 900K and 10K, and 5M and 500K. Record your readings below.

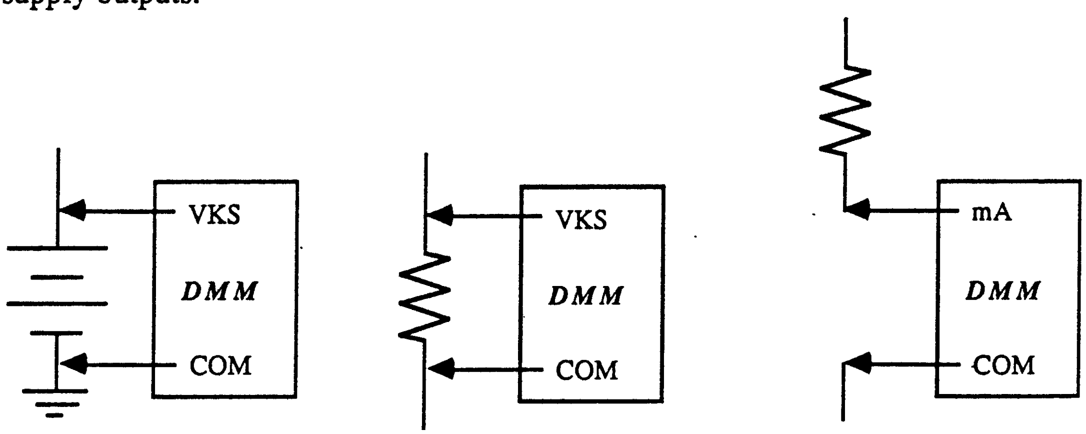
Part 3 - DC Power Supplies and DC Voltmeter

There are four DC power supplies in each lab station: +15 V (D-8), -15 V (D-9), +5 Volts (D-10), and a variable voltage source (D-6). The meter (D-4) monitors the voltage of the variable supply and the vernier (D-5) allows you to adjust the voltage from zero to 25 V. The polarity switch (D-7) makes the variable supply positive (up) or negative (down) with respect to the lab station ground.

The DC POWER switch (D-2) turns the DC power supplies on and off. You will usually want to turn the DC power off before making modifications to a circuit. This will prevent you from accidentally destroying sensitive components.

[ ] In this lab you should turn the DC power supplies on and leave them on. These power supplies are fairly rugged, but they can be damaged if you let their outputs short circuit to one another or to ground.

Two wires, a signal wire and a ground wire (or source and return), are needed to complete the circuit between two instruments. THE OSCILLOSCOPE, SIGNAL GENERATOR, AND POWER SUPPLIES ARE ALL CONNECTED TO A COMMON EARTH GROUND. This ground point (D-11) is included with the power supply outputs.



(a) Voltage to ground
(b) Voltage across (differential measurement)
(c) Current through

Figure 1.4 - How to measure voltage and current

THE DMM IS NOT CONNECTED TO GROUND LIKE THE REST OF YOUR INSTRUMENTS. Therefore, when measuring the voltage from a point to ground, you must connect VKS (A-5) to the point to be measured and COM (A-5) to ground (See Figure 1.4). When measuring the voltage across a component, VKS (A-5) is connected to one end of the component and COM (A-5) is connected to the other end. When measuring the current through a component, disconnect one end of the component and use mA (A-5) and COM (A-5) to bridge the broken connection. This procedure is illustrated in Fig. 1.4.

[ ] To prove that the DMM is not grounded, you will attempt to make some measurements using just one wire. Remove the test leads from the DMM, make sure that the AC/DC button is out, and select the volt function and the 20 volt range. Set the variable supply to +10 V. Plug one end of a test lead into VKS (A-5) and record the display values when the other end is plugged into the power supply outputs +variable (D-6), +15 (D-8), -15 (D-9), +5 (D-10), and COM (D-11).

[ ] A ground reference must be established between a source and the DMM to make meaningful measurements. Use a second test lead to connect COM (A-5) to D-11. Set the DMM to the 200 mV scale, connect VKS (A-5) to +5 (D-10), and record the measured voltage as each of the range buttons is pressed in its turn. (Some readings will indicate an out of range condition and others will not make use of all of the significant digits.) Make the same measurements with VKS (A-5) connected to -15 (D-9), +15 (D-8), variable (D-6) with positive polarity, and variable (D-6) with negative polarity.

Part 4 - The Oscilloscope

Your scope displays a graph of input voltage versus time and provides far more information than your DMM. The functional blocks of the scope are illustrated in Fig. 1.5. The display system contains the cathode-ray tube (CRT) where the graph is drawn. An electron gun at the back of the tube fires a beam of electrons at the screen (C-22). The screen, which is covered with a phosphor coating, glows when it is hit by the electron beam producing the display. The vertical system deflects the beam vertically and controls the amplitude axis of the display. The horizontal system deflects the beam horizontally and controls the time axis of the display. The trigger system turns the beam on and off and synchronizes the display to the input signal.

[ ] Set the scope and signal generator according to the settings shown in Table 1.4. Connect the signal generator output (B-4) to the scope channel 1 input (C-8). If you do not see a straight line and a stationary sine wave on the screen within one minute, call a teaching assistant.

The intensity knob (C-1) controls the scope's power and display brightness. It turns clockwise, with some difficulty and an audible click, to turn on the scope. If the knob is set to its midpoint and the display remains blank after 15 seconds, one of the other knobs or switches is set wrong. The focus of the display is better at lower intensity levels, so the intensity should be set as low as possible for comfortable viewing. Do not set the intensity so low that the display is difficult to see. The focus knob (C-2) should be adjusted after you have selected the proper intensity.

[ ] Adjust the scope intensity and focus at this time.

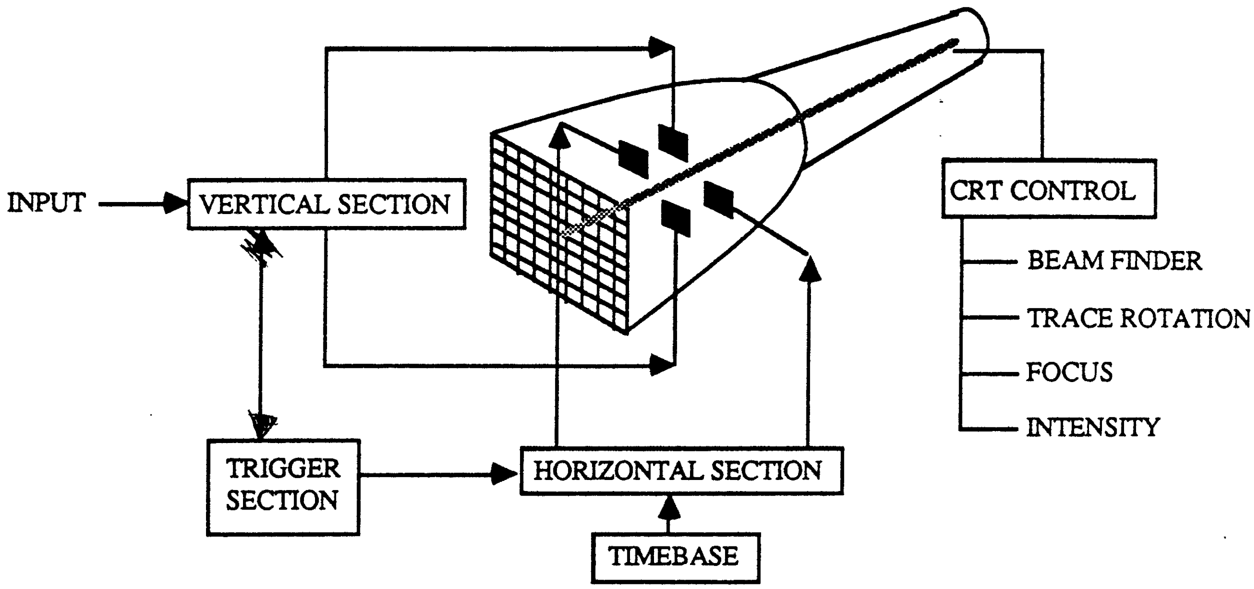


Figure 1.5 - Functional diagram of oscilloscope

OSCILLOSCOPE		GENERATOR	
INTENSITY	midpoint	LINE	in
FOCUS	midpoint	VERNIER	1
		AMPLITUDE	midpoint
VERTICAL POSITION (2)	midpoint	DC OFFSET	fully clockwise
VAR SENS (2)	fully clockwise	FUNCTION	sine
VOLTS/CM (2)	0.5 V	RANGE	1K
AC GND DC (2)	AC		
MODE	dual		
INV CH2	out		
HORIZONTAL POSITION	midpoint		
VAR SWEEP	fully clockwise		
TIME/CM	1 mS		
MAG X5/X1	out		
TRIG LEVEL	midpoint		
BRIGHT LINE	out		
CH1	in		
CH2	out		
AC	in		
DC	out		
+/-	out		

Table 1.4 - Initial Equipment Settings

The vertical system supplies the Y axis, or vertical, information for the graph on the CRT screen. It produces the voltages which deflect the electron beam and provides internal signals for the trigger circuit. Your scope has two input channels, with a set of vertical controls for each, and can display both channels simultaneously.

You will use CH1 (C-8) and CH2 (C-8) as the inputs to your scope. The two BNC connectors (C-3) are also connected to the inputs and are used with special probes which are not needed for this lab.

Both input signals should be visible if the vertical position knobs (C-18) are set to their midpoints.

[ ] Observe what happens as you turn both vertical position knobs. Position the sine wave at the center of the screen.

Five different ways of displaying the two input channels can be selected using the mode switch (C-20). You can select channel 1 alone (CH1), channel 2 alone (CH2), both channels displayed simultaneously (DUAL), both channels algebraically summed (ADD), or a mode in which channel 1 controls the vertical movement of the electron beam and channel 2 controls its horizontal movement (X-Y). If the mode switch is on ADD and you invert channel 2 (C-19), the scope will display the algebraic difference of the two channels.

[ ] Set the mode switch to CH1. The remainder of these instructions apply only to channel 1.

The vertical sensitivity switch (C-4) changes the vertical scale factor (the voltage value) of the major divisions (centimeters) on the screen from 10 volts/cm to 2 millivolts/cm. With a setting of 0.5 V, each of the eight vertical major divisions represents 0.5 volts and the entire screen can show 4 volts from bottom to top.

[ ] Record the peak-to-peak height (the distance in centimeters from the highest to the lowest point on the waveform) of the sine wave in Table 1.5 for the following vertical sensitivity settings: 10 V, 5 V, 2 V, 1 V, 0.5 V, 0.2 V and 0.1 V. Reset the vertical sensitivity to 0.5 V after you take your data.

The variable sensitivity knob (C-21) multiplies the vertical scale factor by up to 2.5. This allows a maximum vertical scale factor of 25 V/cm. The measurements you will be making in this lab call for an absolute measurement of voltage. <u>YOU MUST KEEP THE VARIABLE SENSITIVITY KNOBS TURNED TO THEIR CALIBRATED (CLOCKWISE) POSITIONS UNLESS TOLD OTHERWISE!</u> Since these knobs are a major source of problems in this lab, you must check that they are calibrated at the beginning of each lab session.

[ ] Observe what happens when you turn the variable sensitivity knob and turn it back to its calibrated position.

The input coupling switch (C-5) lets you control how the input signal is connected. DC input coupling lets you see all of the components of the input signal. AC coupling blocks any constant signal component and permits only the alternating portion to be displayed. For frequencies below 100 Hz it is necessary to use DC coupling at all times so that the signals are not distorted.

The middle position of the coupling switch is marked GND for ground. Choosing this position disconnects the input signal and displays the scope's ground reference level. With this switch in the GND position, the ground reference can be moved to a convenient point on the screen with the vertical position knob. Any display in AC or DC mode can then be interpreted with respect to this ground position.

[ ] Set the input coupling to GND and move the line so that there are seven major divisions above it. Change the input coupling to DC and measure the AC and DC

parts of the signal for the following vertical sensitivity settings: 10 V, 5 V, 2 V, and 1 V. The AC part of the signal is measured from the highest point on the waveform to the lowest point. This is called a peak-to-peak measurement. The DC part of the signal is measured from the ground reference point (you set it to 1 cm. from the bottom of the screen) to the center of the waveform (for symmetric waveforms such as sine waves).

[ ] Set the sensitivity back to 0.5 V, set the coupling back to AC, and position the waveform in the center of the screen.

To draw a graph, the scope needs horizontal as well as vertical data. The horizontal system of your scope supplies this data by providing the voltage which moves (or sweeps) the electron beam horizontally at a constant speed. Because the speed is calibrated with time, the horizontal system is often called the time base.

Like the vertical position knobs, there is a horizontal position knob (C-12). This single knob changes the horizontal position of both the input channels.

[ ] Observe what happens as you turn the horizontal position knob. Position the sine wave so that you can see its starting point at the left side of the screen.

The sweep speed switch (C-9) lets you select the speed at which the beam sweeps across the screen (from 0.2 seconds/cm to 0.5 microseconds/cm). It allows you to look at longer or shorter time intervals of the input signal. Like the vertical sensitivity switch, its markings refer to the screen's horizontal scale factor. If the sweep speed is set to 1 mS, each horizontal major division equals one millisecond and the total screen displays a 10 mS time interval.

[ ] Record the period (in centimeters) of the sine wave for the following sweep speed settings: 0.1 mS, 0.2 mS, 0.5 mS, 1 mS, 2 mS, 5 mS, and 10 mS. Set the sweep speed back to 1 mS.

The variable sweep knob (C-11) multiplies the horizontal scale factor by up to 2.5. This makes the slowest possible sweep 0.5 S/cm. The measurements you will be making in this lab call for an absolute measurement of time. <u>YOU MUST KEEP THE VARIABLE SWEEP KNOB TURNED TO ITS CALIBRATED (CLOCKWISE) POSITION UNLESS TOLD OTHERWISE!</u> Since this knob is a major source of problems in this lab, you must check that it is calibrated at the beginning of each lab session.

[ ] Observe what happens when you turn the variable sweep knob and return it to its calibrated position.

Your scope can horizontally magnify the display and stretch the waveforms far beyond the displayable limits of the CRT. The magnify switch (C-13) produces a sweep five times faster than the sweep speed setting. For example, using the 50 µS setting with magnification will give you 10 µS/cm. This magnification provides greater precision when measuring fast voltage changes and allows a maximum sweep rate of 100 nanoseconds per centimeter. YOU MUST KEEP THE MAGNIFICATION OFF UNLESS TOLD OTHERWISE.

[ ] Press the magnify switch, observe what happens, and return it to the out position.

The phosphor on the inside of the CRT glows for only a few milliseconds after the electron beam hits it. The display looks constant because the scope repeats the sweep across the screen at a rate faster than the eye can detect. The display would be a hopeless jumble of lines if each sweep did not start at exactly the same point on the waveform. The trigger system insures that the start of each sweep is synchronized to the waveform being displayed. Fig. 1.6 shows 3 consecutive displays of a waveform.

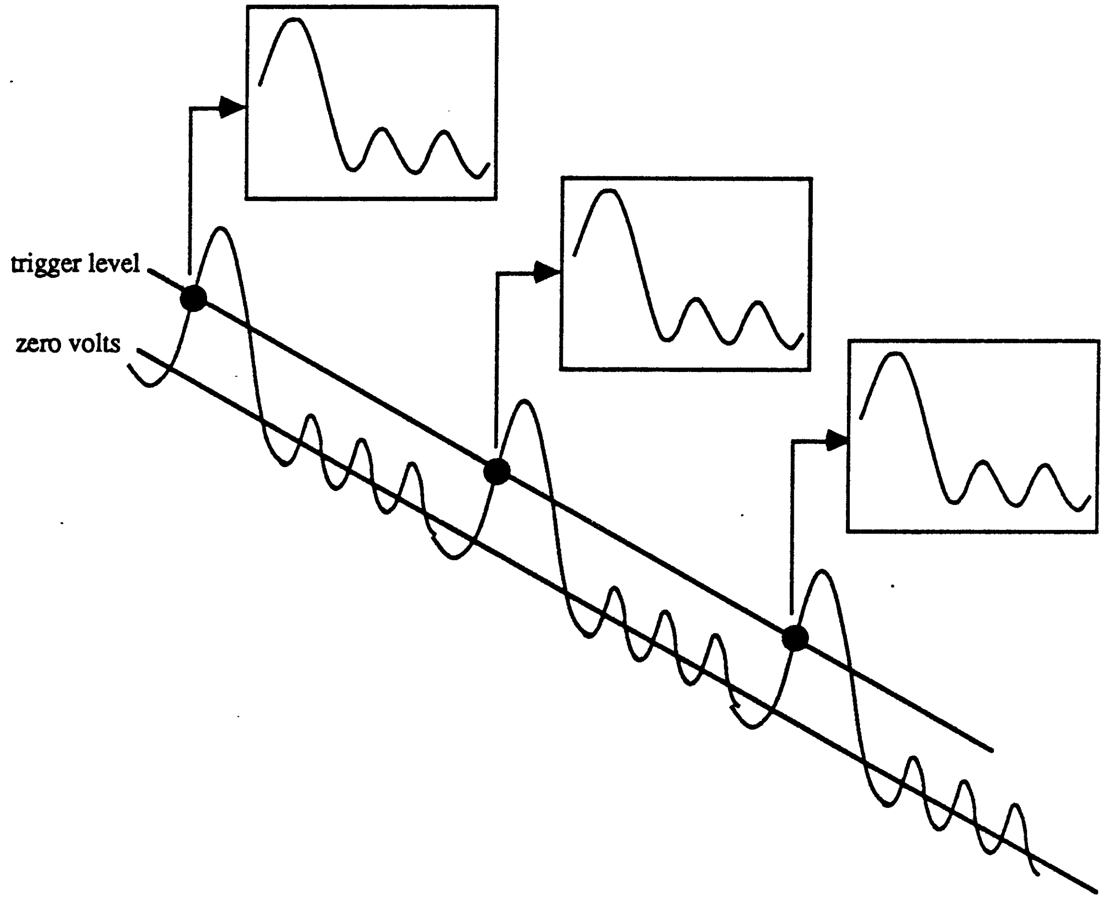


Figure 1.6 - Oscilloscope waveform display

The trigger point, the point at which a sweep is started, is defined by the level knob (C-10) and slope switch (C-14). The slope switch determines whether the trigger point is found on the rising (+) or falling (-) slope of the signal. The level knob sets the voltage of the trigger point.

[ ] Press the trigger slope button, observe what happens to the display, and return it to the out position. Observe what happens as you slowly turn the trigger level knob. Set the trigger level so that the displayed sine wave starts at the center of the waveform.

The trigger source switches (C-16) select CH1 or CH2 as the input to the trigger system. The scope will trigger from an external source (C-6) if both buttons are pressed. The trigger system must be connected to an active signal which continuously provides trigger points. Otherwise, the scope's display will be meaningless. Be careful not to have the display mode set to CH1 with a CH2 trigger source or vice versa.

[ ] Push the CH2 switch and observe what happens.

The trigger's coupling switches (C-15) work the same way as those for the vertical channels. By using the AC or DC buttons you can trigger from the alternating portion of the signal or from the total signal. These buttons have no effect if the trigger source is taken from an AC coupled input channel.

The trigger mode switch (C-17) selects one of two display modes. With "Bright Line Off" (switch in), a sweep will not be started unless there is a trigger signal present. Otherwise, the screen will be blank. With "Bright Line On" (switch out) there should always be a display on the screen because a timer starts running at the end of each sweep. If another trigger isn't found before the timer runs out, a trigger is generated anyway causing whatever is on the input channel to be displayed. Having the trigger mode switch out lets you observe signals with changing amplitudes without completely losing the display. However, if the trigger frequency is below 50 Hz, the scope will automatically trigger before the next trigger comes from the input. This will make the display unstable. YOU MUST KEEP THE TRIGGER MODE SWITCH OUT UNLESS TOLD OTHERWISE.

[ ] With the triggering still set to CH2, press the trigger mode switch several times and observe what happens. Return the trigger mode switch to the out position and set the trigger source back to CH1.

Part 5 - The Signal Generator

Your signal generator can produce signals from 0.1 Hz to 1 MHz. The signal amplitude is adjustable up to 20 volts peak-to-peak (20 Vp-p) with an adjustable DC offset of up to 10 V positive or negative. The generator has a 600 ohm output impedance (see Figure 1.7) which will affect your selection of resistor values in several experiments.

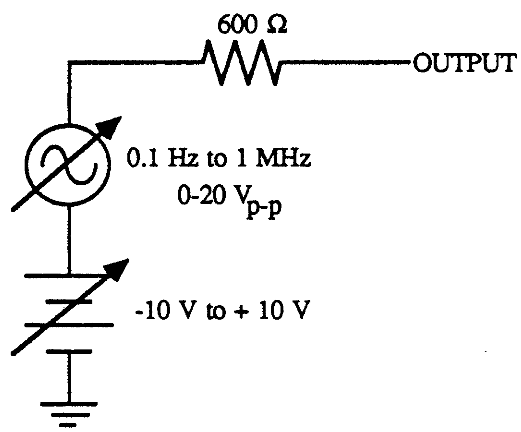


Figure 1.7 - Functional circuit of signal generator

With the three function switches (B-7) you can choose a sine, square, or triangle wave as the output signal.

[ ] Observe what happens as you push each of the function buttons (B-7) and set the function back to a sine wave. The range switches (B-8) allow you to choose base frequencies of 0.1 Hz to 100 KHz.

[ ] Observe what happens as you push each of the range switches and set the range back to 1 KHz. The vernier (B-2) acts as a multiplier on the selected range and allows an order of magnitude increase over the base frequency.

[ ] Observe what happens as you slowly turn the vernier from 1 to 10 and set it back to 1.

The generator also has two knobs which control the amplitude (B-5) and DC offset (B-6) of the signal. You can think of the signal as having an AC (time varying) component and a DC (constant) component, both of which are individually controlled. The amplitude knob controls the top to bottom height of a waveform while the DC offset controls the constant displacement of the center of the waveform from ground. See Fig. 1.8 for an illustration.

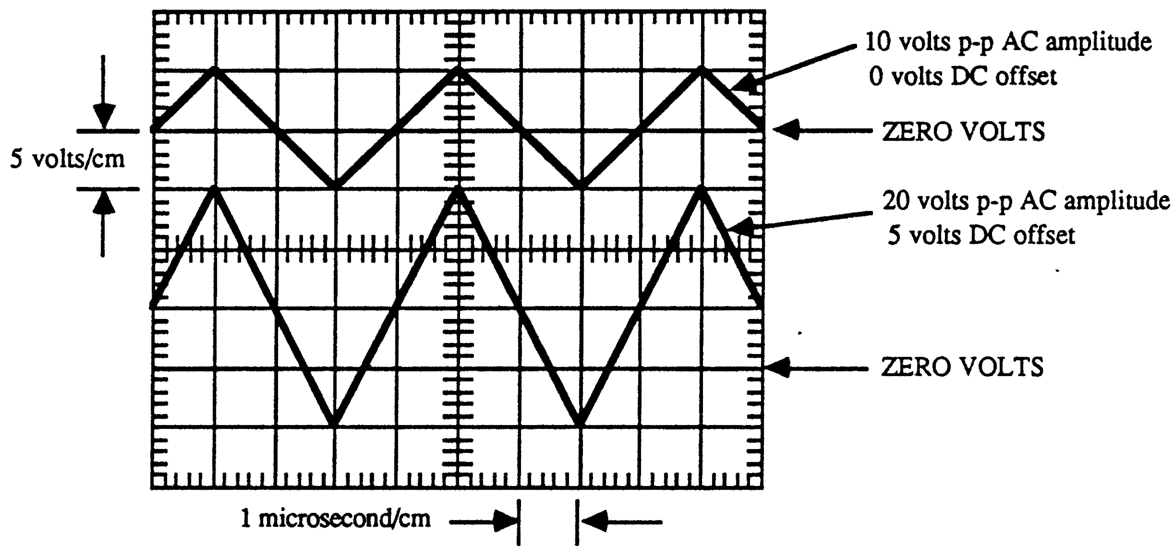


Figure 1.8 - Signal generator output with offset

[ ] Use the scope's input coupling switch and vertical position knob to set ground at the center of the screen. Set the coupling to DC and the sensitivity to 5 V/cm.
  (1) Observe what happens as you turn the DC offset knob. Leave it at its midpoint.
  (2) Observe what happens as you turn the amplitude knob. Leave it at its midpoint.
  (3) Repeat (1) and (2) again with the scope AC coupled.

The signal generator has two output terminals. The pulse output (B-3) provides a pulse that is synchronized with the waveform and can be used to synchronize the scope display with the beginning of each generator waveform. You will normally use the waveform output (B-4) when using the signal generator.

[ ] Move the test lead from the waveform to the pulse output, observe the pulse signal, and return the test lead to the waveform output.

PLEASE CALL A TEACHING ASSISTANT TO CHECK YOUR DATA BEFORE LEAVING.

Questions

Instructions:

The answers to the lab questions need be no more than a few sentences each with the exception of question 7. If you refer to data, indicate which table, etc. you are referring to. Points will be deducted for poorly written answers.

1. List the RSB connections you would make to get the following resistances: 500 ohms, 8.2 M, 44 K, 7 ohms, 250 K, 180 ohms, 59 ohms, 60 ohms, 300 K, 4 M, 10 K, 4.7 K, 6 K.
2. When you performed the DMM measurements of resistance, what was your most accurate measurement for each resistance and on what range was it made? What should have been the value of each resistance? By what percentage was each resistance less or greater than what it should have been?
3. Why was the DMM reading wrong when only one test lead was used?
4. What was the most accurate voltage measurement you made of the four power supply jacks and on what range was it made? By what percentage was each of the power supply voltages different from what it should be?
5. What was the effect of turning the variable sensitivity knob on your oscilloscope? What happened as the vertical sensitivity was increased with AC coupling? With DC coupling?
6. What was the effect of turning the oscilloscope's variable sweep knob? What was the effect of turning on the magnification? Make a table of the actual period (centimeters times setting) you measured for each of the horizontal sweep settings.
7. Explain how the trigger circuitry of an oscilloscope works. Specifically answer what happens when you change the oscilloscope's trigger slope and trigger level? Explain what happened when you selected CH2 and changed the trigger mode in the lab?

EEAP 243 LAB 1 EVALUATION

NAME (print)____________________________ CHECKPOINT #1 ___ DATE _____
GRADE _____/_____ CHECKPOINT #2 ___ DATE _____

With respect to the course material, this lab was: (pick one)
___ highly relevant ___ relevant ___ not relevant ___ completely irrelevant

This lab was: (pick one)
___ too long ___ long ___ just right ___ short ___ too short

This lab was: (pick one)
___ too hard ___ hard ___ just right ___ easy ___ too easy

The background material in the lab assignment was: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

The step by step procedures in the lab assignment were: (pick one)
___ too detailed ___ just right ___ sufficient ___ insufficient ___ totally inadequate

Describe any mistakes made in the lab assignment.

Describe anything that just didn't work right.

Describe how this lab could be made better.

QUIZ

NOTE: THE TEACHING ASSISTANT IS TO SELECT BOTH QUESTIONS FROM THE UNDERLINED OPTIONS AT THE SECOND CHECKPOINT

Question #1

My partner's name is ____.

I am in the Tuesday/Wednesday/Thursday section at 12:30/2:45/3:30/7:00.

Question #2

What is the frequency _______________, AC amplitude _______________, and DC offset _______________ of the pictured signal?

EEAP 243

NAMES: ____

Lab 1 Data

DMM range	200	2k	20k	200k	2M	20M
40 and 7	______	______	______	______	______	______
100 and 50	______	______	______	______	______	______
1K and 800	______	______	______	______	______	______
2K and 200	______	______	______	______	______	______
50K and "common"	______	______	______	______	______	______
900K and 10K	______	______	______	______	______	______
5M and 500K	______	______	______	______	______	______

Table 1.1 - RSB measurements

+variable	__________
+15	__________
-15	__________
+5	__________
COM	__________

Table 1.2 - Ungrounded DMM measurements

DMM range	200mV	2	20	200	2000
+15	______	______	______	______	______
-15	______	______	______	______	______
+variable	______	______	______	______	______
-variable	______	______	______	______	______
+5	______	______	______	______	______

Table 1.3 - DMM power supply measurements

sensitivity setting (volts/cm)	peak-peak voltage (cm)
10	____________
5	____________
2	____________
1	____________
0.5	____________
0.2	____________
0.1	____________

should all be the same. Will not be

Table 1.5 - Vertical sensitivity measurements

sensitivity setting (volts/cm)	AC part (volts p-p)	DC part (volts)
10	___________	___________
5	___________	___________
2	___________	___________
1	___________	___________
0.5	___________	___________
0.2	___________	___________
0.1	___________	___________

Table 1.6 - DC coupled measurements

sweep setting (mS/cm)	period (cm)
10	___________
5	___________
2	___________
1	___________
0.5	___________
0.2	___________
0.1	___________

Table 1.7 - DC coupled measurements