LABORATORY 2

HOW TO USE AN OSCILLOSCOPE AND FUNCTION GENERATOR

OBJECTIVES

1. To interpret specifications for function generators.
2. To learn the operational controls of function generators.
3. To explain the concepts relating to grounding of oscilloscopes.
4. To produce a waveform on an oscilloscope graticule.
5. To analyze the effects of manipulating various typical oscilloscope controls.
6. To manipulate a waveform so as to optimize its appearance.
7. To evaluate a variety of basic oscilloscope waveforms.
8. To operate vertically-related oscilloscope controls.
9. To operate typical horizontally-related oscilloscope controls.

Starting in Lab 3, you will be expected to know how to use the multimeters and oscilloscope as well as how to construct circuits on the breadboard. Your performance in the lab will be marked. **Please make sure that at the end of Labs 1 and 2 you understand how to use the instruments and the breadboard. Simply following instructions without understanding how to make measurements independently is not sufficient.**

INFORMATION

Note: *Actual lab procedure follows this information section.*

1. Function generator

The Wavetek model FG3B Sweep/Function Generator is a precise low distortion instrument, capable of generating sine waves, triangular waves, square waves and ramp signals in the 0.2Hz to 2.0 MHz frequency range. The front panel of the FG3B is shown in Figure 2.1. The main features are shown in Figure 2.2 and explained in Table 2.1.

Figure 2.1 *Front panel of Wavetek FG3B function generator.*

A typical waveform generator is a non-ideal ac voltage source, and is represented symbolically as shown in Figure 2.3. The red lead of the generator's terminal connector is an active output and the black lead is connected to the common ground.

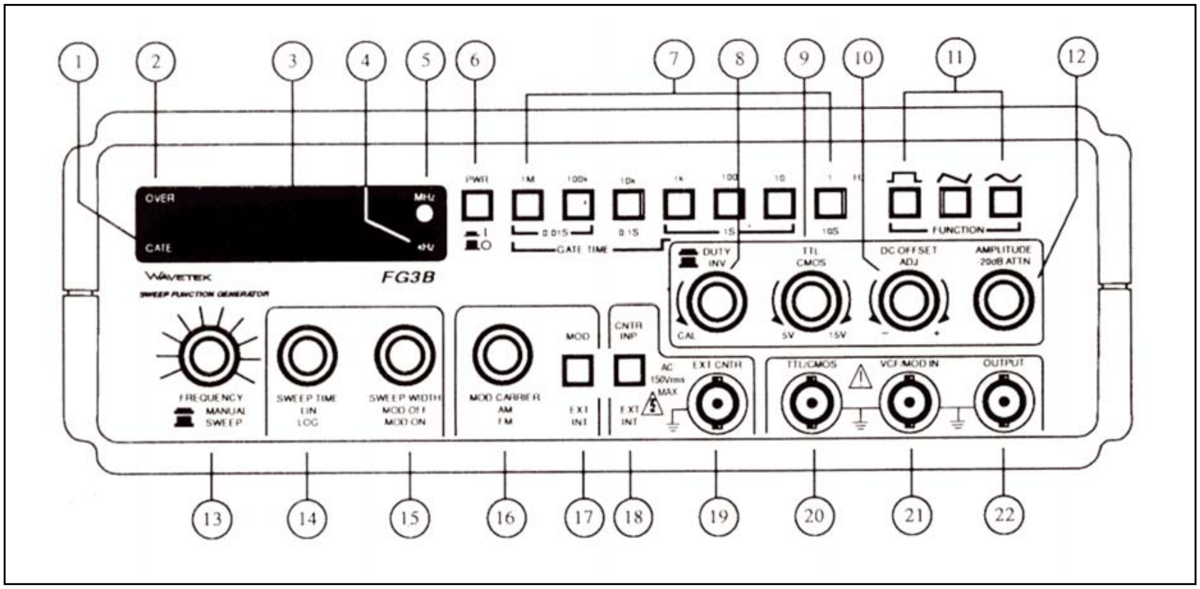

Figure 2.2 *Main features of the Wavetek FG3B function generator.*

No.	Name	Feature description
1	GATE	Indicator flashes when power is on, showing when frequency counter is making a measurement.
3.	COUNTER DISPLAY	5 digit LED display shows frequency value.
4.	KHz	Indicator lights to show Counter Display reading in kHz units.
5.	MHz	Indicator lights to show Counter Display reading in MHz units.
6.	PWR	This switch controls AC power to the instrument.
7.	FREQUENCY RANGE Selector	Pushing one button at a time selects the desired frequency from the generator in decades.
8.	DUTY (push) INV (pull)	Varies duty cycle of signal from 50% (1:1) in CAL position to 10% (10:1). Pull knob to invert duty cycle.
11.	FUNCTION SELECTOR	Selects square, triangle or sine wave output at connector 22.
12.	AMPLITUDE (push)/ -20dB ATTN (pull)	Adjusts output amplitude on Output connector 22. Pull for -20 dB (10% of original input) attenuation.
13.	FREQUENCY (push) / SWEEP (pull)	Sets desired frequency of signal between 0.2 and 2 times the Frequency Range value selected. Pull for sweep mode.
20.	TTL/CMOS	Square wave output for driving digital logic.
22.	OUTPUT	50 Ω square, triangle or sine wave output.

Table 2.1 *Some features of the Wavetek FG3B function generator.*

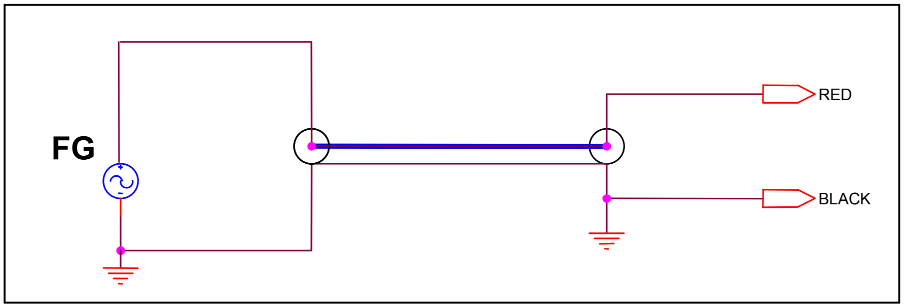

Figure 2.3 *Output connections of the function generator*. FG = *Function generator*.

2. Tektronix TDS 210 Digital Storage Dual-Trace Oscilloscope

This experiment will be concerned with the use of the various controls and switches found on typical oscilloscopes. The TDS200 Series oscilloscopes provide accurate real-time acquisition of signals that supports features such as automatic measurement, peak detect, storage of two reference waveforms and five instrument setups and autoset. The TDS200's reliable, backlit liquid crystal display permits the instrument to be only 12cm from front to back, while its light weight (1.5 kg) and rugged construction allow for portability. The front panel of TDS 210 is shown in Figure 2.4.

Figure 2.4 *Front panel of TDS 210.*

Features And Benefits:

- ✓ 60 MHz or 100 MHz with 1 GS/s Sample Rate on all Channels
- ✓ 2 Channel Models
- ✓ Dual Timebase
- ✓ Automatic Measurements
- ✓ Multi-language User Interface
- ✓ Autoset
- ✓ Waveform and Setup Memories
- ✓ Extended Capabilities Are Provided with Optional Modules, Software and Probing

The front panel of the TDS 201 is divided into several easy to use functional areas. The user interface is similar to that of an analog oscilloscope, but with improvements that reduce learning time and increase efficiency. Knobs and buttons are grouped by function and provide direct access to controls, and each vertical channel has its own dedicated scale and position knobs. Readouts or menus are displayed on-screen at all times, allowing users to more quickly and accurately determine instrument settings. The display responds quickly to control adjustments and has a fast update rate.

Display area

In addition to displaying waveforms, the LCD display is filled with many details about the waveform, such as measurements of amplitude, frequency and period of the displayed signals and the instrument control settings. Different modes of operation and measurement of signal parameters are controlled by 5 “Soft Keys”, assigned to different functions depending on the chosen menu or operational mode.

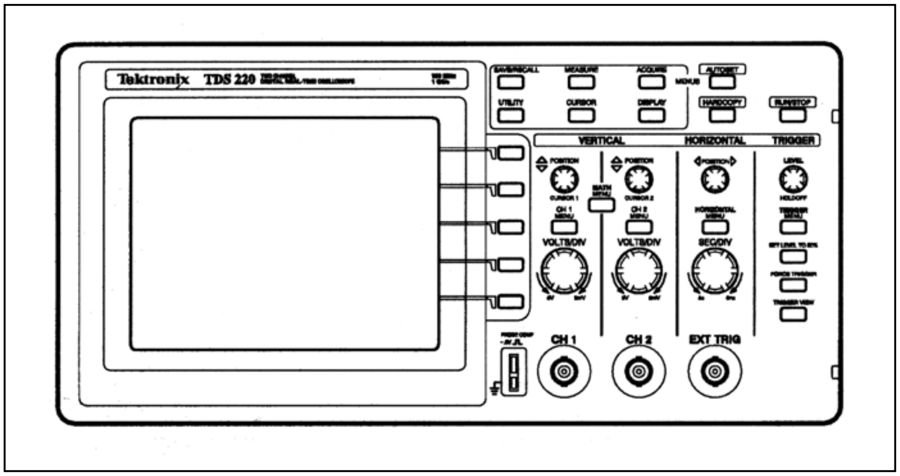

Figure 2.5 *Front panel of the Tektronix TDS 210.*

Scope controls

Scope controls are grouped together as to function.

The ***Vertical Controls*** relate totally to the vertical movement of the scope trace. This oscilloscope has two vertical sections so that it can display two waveforms simultaneously.

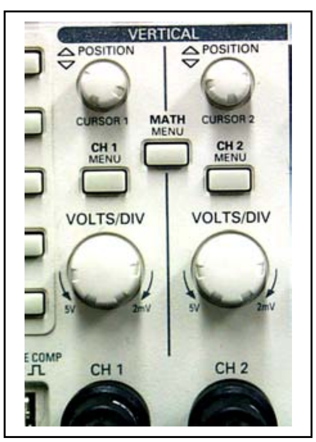

Figure 2.6 *Vertical controls.*

CH1 and CURSOR 1 Position	Vertically adjust the channel 1 display or position cursor 1.
CH2 and CURSOR 2 Position	Vertically adjust the channel 2 display or position cursor 2.
MATH MENU	Displays waveform math operations menu
CH 1 and CH 2 MENU	Displays the channel input menu selections and toggles the channel display on and off
VOLTS/DIV(CH 1 and CH 2)	Selects calibrated scale factors

Table 2.2 *Vertical control descriptions.*

You can use the vertical controls to display waveforms, adjust vertical scale and position and set input parameters. The vertical MENU contains the following items for CH1 and CH2, which could be set individually for each channel. After entering the CH1 / CH2 MENU mode, the following options assigned to separate Soft Keys are available:

Menu	Settings	Comments
Coupling	***DC*** ***AC*** ***GND***	Passes both DC and AC components of the input signal Blocks the DC component of the input signal Disconnects the input signal
BW limit	***20 MHz /Off***	Limits the bandwidth to reduce the display noise
Volts/Div	***Coarse/Fine***	Selects the resolution of the Volts/Div knob
Probe	***1x*** ***10x*** ***100x*** ***1000x***	Set this to match your probe attenuation factor to make the vertical scale readout correct

Table 2.3 *Vertical menu settings*

The ***Horizontal Controls*** relate to the horizontal movement of the scope trace.

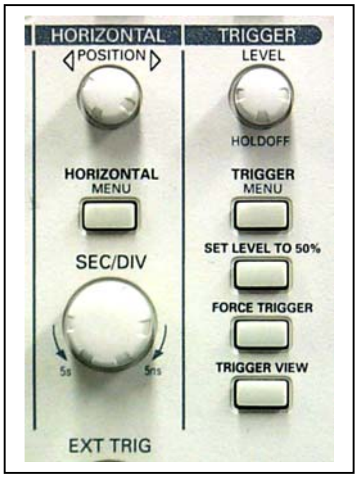

Figure 2.7 *Horizontal controls*

POSITION	Horizontally adjust the position of all channels
HORIZONTAL MENU	Displays horizontal menu
SEC/DIV	Selects the horizontal time/div (scale factor) for the main timebase and the Window Zone

Table 2.4 *Descriptions of horizontal controls*

The ***Trigger Controls*** are used for the synchronization or triggering of the waveform.

LEVEL and HOLDOFF	- As a trigger level control it sets the amplitude level the signal must cross to cause an acquisition. - As a holdoff control it sets the amount of time before another trigger event can be accepted.
TRIGGER MENU	Displays the trigger menu.
SET LEVEL TO 50%	The trigger level is set to 50% of the signal level.
FORCE TRIGGER	Starts acquisition regardless of an adequate trigger signal.
TRIGGER VIEW	Displays the trigger waveform in place of the channel waveform while the TRIGGER VIEW button is held down.

Table 2.5 *Descriptions of trigger controls*

Triggering

Two types of triggering are available: *Edge* and *Video*. Since the Edge triggering is most important for our course applications, we will study it in detail. Use *Edge* triggering to trigger on the edge of the input signal at the trigger threshold.
The different types of trigger settings are shown in Table 2.6.

Menu	Settings	Comments
Edge		With the *Edge* highlighted the rising or falling edge of the input signal is used for the trigger
Slope	***Rising*** ***Falling***	Select to trigger on either the rising or falling edge of the signal
Source	***CH1*** ***CH2*** ***EXT*** ***EXT/5*** ***AC Line***	Select the input source as the trigger signal – some of the input channels, external source, external source with signal divided by 5 or 60Hz AC power line.
Mode	***Auto*** ***Normal*** ***Single***	Use *Normal* mode to trigger only on a valid trigger. Use *Auto* mode to let the acquisition free-run in the absence of a valid trigger. Use Single mode to capture a single acquisition of an event.
Coupling	***AC*** ***DC*** ***Noise Reject*** ***HF Reject*** ***LF Reject***	Select the components of the trigger signal applied to the trigger circuitry

Table 2.6 *Different types of trigger settings.*

The ***Control buttons*** provide features to be used for both channels, as listed in Table 2.7.

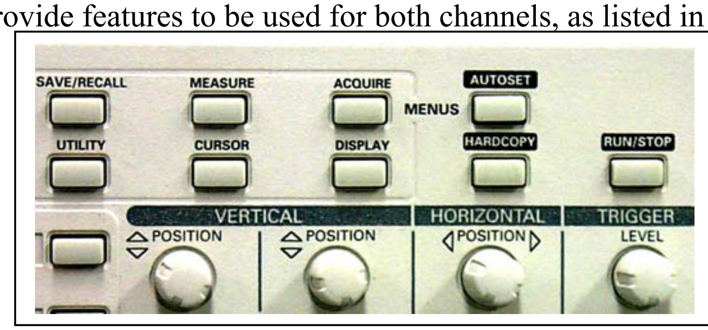

Figure 2.8 *Control buttons*

SAVE/RECALL	Displays the save/recall menu for setups and waveforms.
MEASURE	Displays the automated Measurements menu.
ACQUIRE	Displays the acquisition menu.
DISPLAY	Displays the display type menu.
CURSOR	Displays the Cursor menu. Vertical position controls adjust cursor position while displaying the cursor menu. Cursors remain displayed after leaving the cursor menu but are not adjustable.
UTILITY	Displays the Utility menus.
AUTOSET	Automatically sets the instrument controls to produce a usable display of the input signal.
HARDCOPY	Starts print operations.
RUN / STOP	Starts and stops waveform acquisition.

Table 2.7 *Control button functions*

Waveform parameters measurement

Push the MEASURE button to access the automated measurement capabilities. There are five measurements available and the ability to display up to four at a time. The upper "Soft Key" allows you to choose between the *Source* of the signal and the *Type* of measurement to be performed. With *Source* highlighted, you define the channel you want the measurement to be performed on each of the other four "Soft Keys" positions. By pressing of each key you could choose either CH1 or CH2 signal to be measured.

With the *Measure* menu displayed and *Type* highlighted, you define the menu structure by selecting the type of measurement to display in each of the available four menu locations.

Making measurements

You can display up to four automated measurements at a time for a single waveform, or divided between the two waveforms. The waveform channel must be ON (displayed) to make a measurement. Automated measurements cannot be taken on reference or math waveforms or while using XY or Scan mode. The different types of measurements are shown in Table 2.8.

Menu	Settings	Comments
Type		With the *Type* highlighted choose the type of measurement to display next to the on-screen-menu button ("Soft Key").
	Cyc RMS	Provides a true RMS measurement of <u>one completed cycle</u> of the waveform
	Mean	Provides the arithmetic MEAN voltage <u>over the entire record</u>
	Period	Provides the time for one cycle
	Pk-Pk	Provides the absolute difference between the maximum and minimum peaks of the entire waveform
	Freq	Provides the frequency of the waveform
	None	

Table 2.8 *Different types of measurements*

EQUIPMENT

1. Function generator Wavetek FG3B
2. Dual trace oscilloscope Tektronix TD 210, with x 1 and x 10 probes.
3. Circuit construction breadboard PROTOBOARD PB503
4. Digital Multimeter FLUKE 8010A, BK PRECISION 2831B or BK PRECISION 2831C
5. Resistors: 1kΩ
6. Capacitors: 22nF

PRE-LAB PREPARATION

1. Study the function generator shown in Figures 2.1 and 2.2, along with the explanations of the various controls described in Table 2.1.
2. Study the TDS 210 oscilloscope shown in Figures 2.4 to 2.8, along with the explanations of the various controls described in Tables 2.2 to 2.8 and Appendix E.

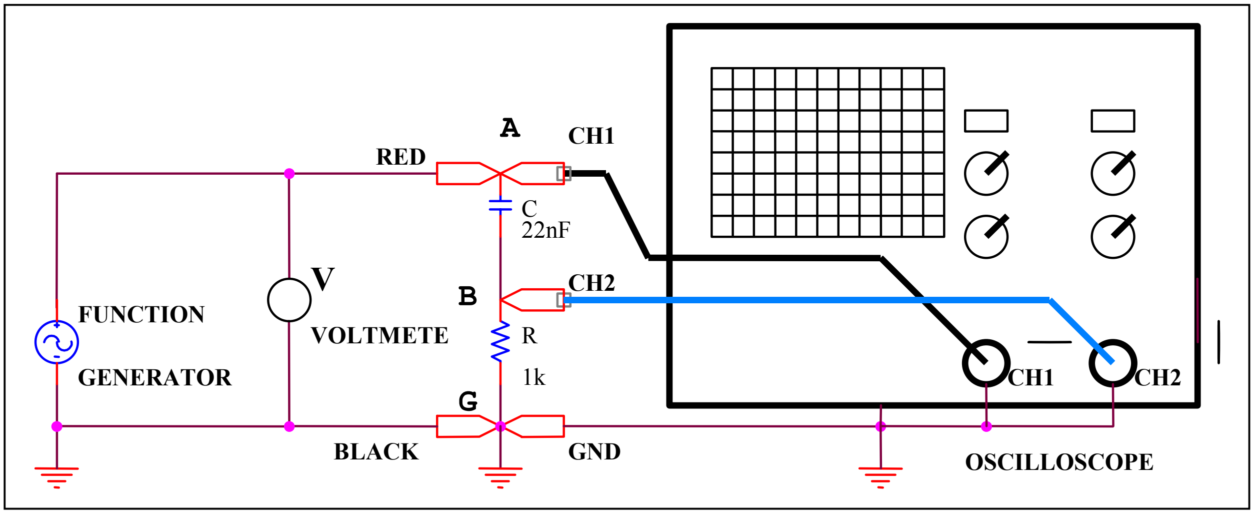

Figure 2.9 *Test circuit connections.*

PROCEDURE

1. Construct the circuit shown in Figure 2.9 on your breadboard and connect the function generator and both oscilloscopes' inputs. Be sure to connect ground leads of both devices (black lead of the function generator and the alligator clips of the oscilloscope probe) to the same common point to provide "*common ground connection*" to your circuit. This circuit will be used in steps 2 to 20, so do not dismantle it.
   When the layout has been completed, have your TA check your breadboard for errors and get his/her signature in the Signature section of the Lab Measurements Sheet. You will be penalized marks if your sheet is not initialed.
2. Set the digital voltmeter to AC mode.
3. Set the frequency of the generator to 1 kHz sine wave, and reduce the RMS amplitude to 300 mV as measured on the voltmeter. To lower the signal amplitude, pull out the AMPLITUDE knob (Figure 2.2. No. 12) and turn it.
4. Turn on your scope and you may continue with the procedure, which has been designed to allow students to become familiar with the effect that various controls have upon the displayed waveforms. The procedure is separated into vertical related controls, horizontal related controls, trigger controls and measurements.
5. Try switching from a sine waveform to square and triangle waveforms, and observe the effects upon the voltmeter reading. Record the voltmeter measurements into Table 2.9 in the Lab Measurements Sheet. Sketch the waveforms on CH1 and CH2 into the graphs in question 9 of the Lab Measurements Sheet.
6. Turn the oscilloscope to Measurement mode using the menu controls, described in Table 2.8, and display simultaneously the *Cyc RMS* and *Peak-to-Peak* value of the signal, as well as its *Period* and *Frequency*. Record the *Cyc RMS*, *Peak-to-Peak*, *Period* and *Frequency* measurements for the different waveforms displayed on channel 1 in Table 2.9.
7. Switch back to a sinusoidal output and use the voltmeter to measure both the minimum and maximum output voltages of the generator, using both Amplitude knob positions. Record the results in Table 2.10 of the Lab Measurements Sheet.

Vertical Related Controls

8. Use your ac voltmeter to set the function generator to 3.0 V, and adjust the frequency to 400Hz.

9. Set the following scope controls to the indicated positions and connect a "times one" probe from the CH 1 scope input to the generator.

VERTICAL MODE: *Select channel 1 MENU*
Find on display which button is assigned to Coupling mode and set:
COUPLING: *select DC*
VOLTS/DIV: *2 V/DIV*
SEC/DIV: *1 ms/DIV*
TRIGGER MENU:
Find on display which button is assigned to Source and set:
SOURCE: *Select CH 1*

10. About four cycles of a sine wave should now be observable on the screen. The display should be using about 10 divisions horizontally and between 4 and 5 divisions vertically.
11. Adjust the vertical POSITION control to observe the effect of this control on the displayed waveform. Answer question 1 on the Lab Measurements Sheet at this time.
12. Adjust the vertical VOLTS/DIV control to observe the effect of this control on the displayed waveform. Answer questions 2 and 3 on the Lab Measurements Sheet at this time. Use the space in section 4 of the Lab Measurements Sheet to record any observations you wish to make.
13. Switch probe key attenuator from "x1" to "x10" position. Adjust the vertical VOLTS/DIV to observe the effect of this control on the displayed waveform. Answer questions 5 and 6 on the Lab Measurements Sheet at this time.

Horizontal Related Controls

14. Adjust the horizontal POSITION control to observe the effect of this control on the displayed waveform. Use section 7 of the Lab Measurements Sheet to record any observations you wish to make.
15. Adjust the horizontal SEC/DIV switch to observe the effect of this control on the displayed waveform. Answer question 8 on the Lab Measurements Sheet at this time.

Trigger related controls

16. Adjust trigger level above the input signal level and then turn it back to the level of about 50% of the input. Answer question 11 of Lab Measurement Sheets.
17. From Trigger menu, described in Table 2.6 change the *Slope* mode from *Rising* to *Falling*. Answer question 12 of Lab Measurement Sheets.
18. For the above experiments trigger source was set to CH1. Now press the TRIGGER MENU button and set the SOURCE control to the CH2. Try to stabilize display picture using "Trigger Level" control.
19. Set the SOURCE control to the EXT mode and finally to the AC LINE mode and observe the effect of this control on the displayed waveform. Try to stabilize display picture using "Trigger Level" control. Answer question 13 on the Lab Measurements Sheet.
20. Try using any other scope controls, which have not specifically been tested by this time. Use the space on the back of the Lab Measurements Sheet to record any observations you wish to make.

OPTIONAL

21. Using the loudspeaker on your breadboard, demonstrate how you can make signals produced by the function generator audible. Set up the necessary connections on your breadboard, and show your connections to your TA before turning on the generator.

22. Before turning on the generator, set the amplitude of the signal to the lowest possible size. Turn on the generator. Select a sinusoidal signal with a frequency of 1 kHz. Turn up the amplitude until the signal is just audible. Please do not turn the amplitude up too high as this will disturb your classmates. Using the oscilloscope measure and record the peak-to-peak amplitude of the waveform that is just audible. Experiment with changing the frequency and observe the effects on the sound. Record your observations in the section of the lab measurements sheet labeled “optional”.

23. Change to a square and then a triangular waveform and describe the sound.

LAB MEASUREMENTS SHEET – LAB 2

Name _________________________

Student No_____________________

Workbench No_____

NOTE: Questions are related to observations, and must be answered as a part of the procedure of this experiment.

1. Does the vertical POSITION control alter the shape or size of the displayed waveform in any way?

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2. If a higher VOLTS/DIV position is selected, does the observed waveform become larger vertically, or smaller?

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3. Does the VOLTS/DIV switch position affect the displayed waveform horizontally?

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4. Record any observations, related to Vertical Controls, you wish to make.

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5. Describe the effect of the vertical magnification switch on the appearance of the display, and on the VOLTS/DIV selected position.

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6. Does the VOLT/DIV control affect the shape of the waveform or its position?

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7. Record any observations, related to Horizontal Controls, you wish to make.

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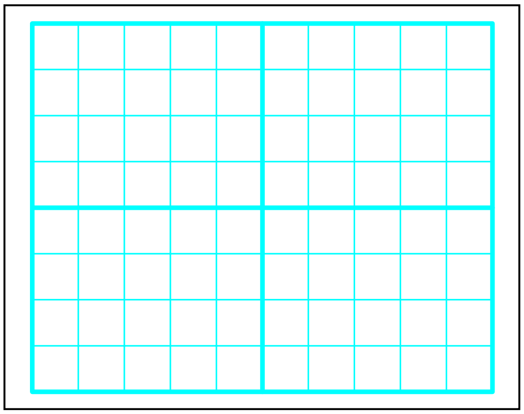
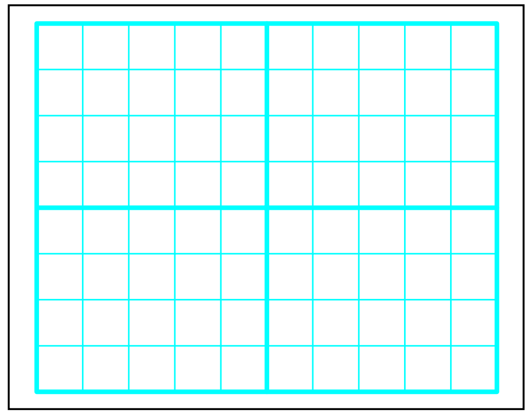
8. If the SEC/DIV switch is changed from 1 ms/DIV to 500 μs/DIV, will you see more or fewer cycles of the display? Is the sweep speed now faster or slower?

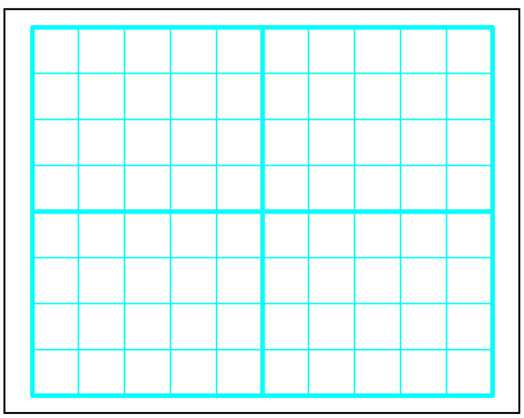
9. Sketch the sine, square and triangle waveforms observed on CH1 and CH2.



a) Sine wave input signal



b) Square wave input signal



c) Triangle wave input signal1

Table 2.9 *AC voltmeter and Oscilloscope readings*

	Vsine (V)	**Vsquare (V)**	**Vtriangle (V)**
Voltmeter			
Oscilloscope:			
RMS			
Pk-Pk			
Period			
Frequency			

10. Generator Output Voltage

Table 2.10 *Range of Generator Output Voltage*

	Minimum	Maximum
Knob in		
Knob out		

11. Describe what you see when triggering level is lower and when it is higher than the signal amplitude.

12. Describe what happens when triggering *Slope* mode has been changed from *Rising* to *Falling*.

13. Describe what you would expect to see if a signal were connected to CH 2, and the TRIGGER SOURCE were set to CH 1, EXT and AC LINE position

14. Do any of the scope controls actually change the ac signal, which is connected at the input terminals?

15. OPTIONAL

QUESTIONS

1. **[2 MARKS]** What is the function of the Horizontal Position Control?

2. **[2 MARKS]** The peak voltage of the sinusoidal waveform is the voltage at maximum value. What is the peak voltage of the waveform displayed below in Figure 2.10?

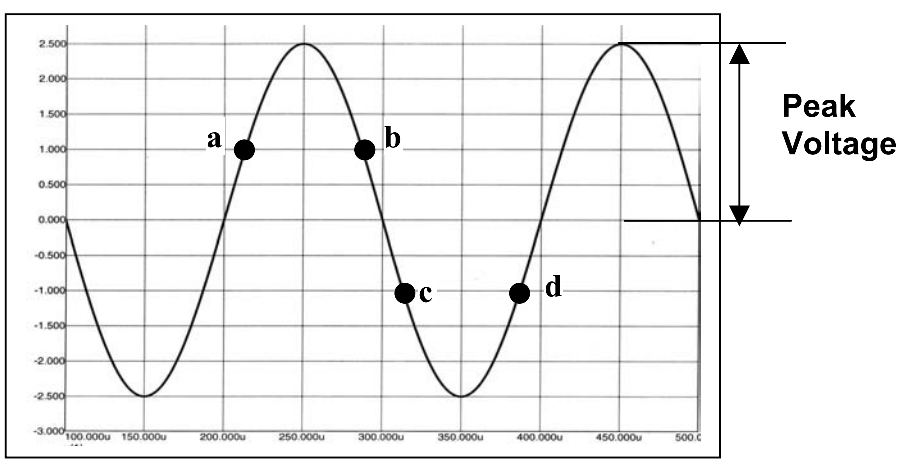


Figure 2.10.

CH1 0.5V **M 50μs**

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3. **[2 MARKS]**. What is the period of the waveform displayed in Figure 2.10?

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4. **[5 MARKS]**. What is the purpose of triggering?

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5. **[2 MARKS]** The trigger level on an oscilloscope is set to 1 V and the trigger slope is set to falling. If the waveform shown in Figure 2.10 is used for triggering, which is the most likely point on the waveform at which data acquisition will start?

(a) Point (a) __________
(b) Point (b) __________
(c) Point (c) __________
(d) Point (d) __________

SIGNATURES **TA name:**_________________________

To be completed by TA during the lab session.

Check Boxes					TA Signature	Student's Task
						Pre-lab completed.
						Circuit of Figure 2.9 connected correctly
						Data collected and observations made
						Final questions completed

MARKS

To be completed by TA after the lab session.

Granted Marks	Max. Marks	Student's Task
	0	Pre-lab preparation
	0	Circuit of Figure 2.9 connected correctly.
	87	Data collected and observations made
	13	Final questions completed
	100	**Total**