THE OSCILLOSCOPE

INTRODUCTION

You may have been exposed to oscilloscopes in the past. This exercise gives you the opportunity to perfect your mastery of the use of the instrument by doing a series of exercises designed to lead you through most of its functions.

There are very many controls on an oscilloscope and it will take you many times using the instrument before you can take advantage of all of them.

On all oscilloscopes, the controls can be grouped from the point of view of three basic systems:

- Vertical system controls: y-motion of the beam; vertical position and sensitivity (volts-per-division), CH1↔CH2 beam selection, DC-AC-Ground input coupling switches.
- Horizontal system controls: x-motion of the beam; acquisition horizontal sweep speed, position and x sensitivity (time-per-division) when in the y-x mode.
- Trigger system: the trigger function synchronizes the horizontal sweep at the correct point of the signal (stabilizes the waveform). Controls are: trigger level and slope, modes and coupling.

Recognizing these aspects makes understanding the multiplicity of controls easier.

The layout of the Tektronix TDS210 or TDS1002 involves knobs and buttons, all grouped according to the above systematic. With the knobs you dial-up vertical sensitivities, sweep speeds, vertical and horizontal positions, and trigger levels. Each of the main buttons calls up a menu on the right of the screen and the buttons beside the menu allow you to select the various functions.

TAKING MEASUREMENTS

Oscilloscopes display graphs of voltage versus time (waveforms) that can be measured by using the grid, the cursors (voltage or time), or an automated method.

EQUIPMENT USED

The voltages used in Exercises A-C are provided by a Wavetek wave generator.

In Exercise D you will use a box which supplies various variations of 60 Hz AC and DC.

This BOX provides the following voltages:

- V_{DC}: about 11 V DC [between the *DC* and the *COMMON* terminals].
- V_{ACDC}: a small AC (1 V peak-to-peak) superimposed on about 11 V DC [between the *DC and AC* and the *COMMON* terminals].
- V_{REF}: about 8 V RMS (11 V amplitude) AC [between the *AC REFERENCE* and the *COMMON* terminals].
- V_{PH}: about 8 V RMS AC with phase relative to the V_{REF} voltage adjustable by means of a phase control knob (which is totally un-calibrated). [This voltage appears between the *AC PHASE* and the *COMMON* terminals].
- (V_{REF} - V_{DC}): about 8 V RMS AC superimposed on about 11 V [between the *AC REFERENCE* and the *DC* terminals].

These five outputs will be referred to in the following instructions by the names V_{DC}, V_{ACDC}, V_{REF}, V_{PH}, (V_{REF}-V_{DC}).

THE EXERCISES

EXERCISE A - Plotting one voltage on a Y input as a function of time

Here you use the oscilloscope in the time-base mode, with only one beam turned on. You also will observe the functions of the y sensitivity and input coupling switches. Notice that when you first turn on

the oscilloscope you will be starting with the settings that the person who used it before you last used. You might wish to push *AUTOSET*' which sets the instrument to the setting it thinks would be most appropriate for you. (Caution: what it thinks and what you want may differ).
From the *TRIGGER* menu select the *EDGE* function. Choose *MODE* as *AUTO* and select *SOURCE* as CH1. Make sure you have selected only the display of Channel 1 (CH1) by pushing the CH2 button so that the CH2 trace disappears, and then pushing the CH1 button till the CH1 trace appears. (Note that the zero on the vertical scale is indicated by the position of the small arrow on the left side of the screen, accompanied by the channel number ("1").)
Connect the CH1 signal input to the ***Function Generator Main Out*** **(50Ω output).** Use the sine waveform with 10kHz frequency. From the *CH1* menu available on the oscilloscope screen, observe and understand the displays for each of the following cases:

- Set the beam at vertical centre using the vertical position knob with the *COUPLING* set to *GROUND*.
- With the *COUPLING* set at *DC*, adjust the DC OFFSET on the Function Generator to ~2 divisions '+' or '-'. Observe the signal.
- Switch the *COUPLING* to *AC*, observe the signal
- With the *COUPLING* set at *DC* cancel the DC Offset
- With the *COUPLING* set at *AC*, and the DC Offset cancelled, observe the signal

Comment: Normally you should use the oscilloscope in the *DC* setting, as this gives a display on the screen of the actual voltage. The other two settings provide special useful functions.
Work out what the switch does.
Under what conditions would you use it on the *AC* position? (The answer is not "when you are observing AC signals"!) *Hint*: - in the AC position, the oscilloscope lies to you as the frequency components from 30 Hz down to DC are removed from the trace which appears on the screen.)
➔Write and comment your observations

EXERCISE B - Using the oscilloscope to plot voltages as a function of time - Different ways of triggering

If you wish to understand what triggering is, start by using the oscilloscope in an un-triggered condition. Connect the CH1 input to the Function Generator as you did in exercise "A" and in the *TRIGGER* menu select *SOURCE* as *EXT* and *MODE* as *AUTO*. Notice the unusable trace you get on the screen. The sweeping of the display has no synchronization to the timing of the arrival of the input signal. Triggering instructs the oscilloscope to start the sweep of the trace across the screen according to specification you give as to when in the signal the scope should start sweeping.
STRATEGIES FOR USING THE TRIGGERING CONTROLS – With the Trigger setup on EDGE, you will notice the four options on the *TRIGGER* menu:

SLOPE (Rising, Falling)
SOURCE (CH1, CH2, EXT, EXT/5, AC LINE)
MODE (Auto, Normal, Single)
COUPLING (AC, DC, Noise Reject, HF Reject, LF Reject)

- TRIGGER *SOURCE* decides which signal is the one which will determine the triggering,
- TRIGGER *SLOPE* decides whether triggering takes place on the rise or the fall of the signal,
- TRIGGER *MODE* decides whether triggering takes place strictly according to a voltage level of the signal ("normal mode") or whether the oscilloscope improvises its triggering by free-running when no signal is present ("auto mode"),
- TRIGGER *COUPLING* decides the filtering the oscilloscope gives to the trigger signal to make it

respond only to some AC or DC voltage levels of the input signal.

- Moreover there is a TRIGGER *LEVEL* knob: this decides at what voltage of the signal the triggering will take place (this control is quite ineffective in the AUTO triggering mode). The following two exercises will help you learn what each of these triggering controls does.

In exercise B you use the oscilloscope in the time-base mode with Channel 1 on. Position the trace horizontally so that the trigger (indicated by the arrow at the right of the screen) is near the horizontal centre of the screen. Set the *SEC/DIV* sweep speed control so that one to two cycles of the signal appear across the screen.

With *AUTO* trigger mode, observe the trace changing as you change the trigger source from *CH1* to *CH2* to *EXT*, to *AC LINE*. While on external trigger, try connecting the oscilloscope external trigger input to the same output of the Function Generator by using a TEE (T-connector).

With *NORMAL* trigger mode and *CH1* as the trigger source, explore what happens when you change the trigger *LEVEL* and when you change the trigger *SLOPE*. Also explore the effects of changing the horizontal position knob. Here you are really only interested in the effects on the CH1 trace.

➔**Write all your observations in your lab report.**

Comment *on limitations of the connections to the oscilloscope when feeding two or more signals into it: The three input connectors to the oscilloscope, although feeding signals into three separate places, are not completely independent. The outer ring of the BNC connector which is connected to the black banana plug on the cable you use, is connected to a "common" or "ground" in the oscilloscope. This ground is connected to the round pin of the power plug which is connected to a water pipe in the basement of the building. This applies to all the BNC input connectors. Thus, if you use two input leads on your oscilloscope, the black lead of one is connected to the black lead of the other. This implies that your circuit connection strategies must result in all the black leads being connected together with the voltages being measured being those of the red leads relative to the black leads.*

EXERCISE C - Frequency measurement and the calibration signal

Using whatever TRIGGER settings you consider appropriate, measure the period and frequency of a MHz, saw tooth wave signal of your choice. Using the same setup, find out how the scope will do measurements for you. Push the *MEASURE* button and select *SOURCE* as *CH1*. Now find out what it tells you for *TYPE* set for each of *FREQ, PERIOD, MEAN, PK-PK, CYC RMS*. You should figure out what each of the measurements means.

➔Use the CURSOR function to check if these values agree with what you observe from the trace on the screen. Select Type on Amplitude (horizontal cursors) or Time (vertical cursors). To move the cursors, highlight Cursor 1 or 2 by pressing the corresponding button and rotating the knob located at the top left of the oscilloscope.

The *PROBE COMP* terminal provides a standard 1 kHz, approximately 5V (p-p) voltage between that terminal and the 'scope ground that has a very square wave shape. This is useful in checking out calibrations and in particular in checking out the response to a square wave. Observe the `height' and frequency and shape of the signal from this terminal. Use the hook/alligator probe provided.

EXERCISE D - Using the oscilloscope as a two dimensional voltmeter

Up to now you have used the oscilloscope to plot one voltage as a function of time. This application will enable you to plot one voltage as a function of another. Here you use the oscilloscope in the XY mode, so that the spot position is the vector sum of displacements in two perpendicular directions proportional to the two applied voltages. To get into this mode, in the *DISPLAY* menu select *FORMAT, XY*. (The *FORMAT* was previously set to *YT*.) To do this part, make sure that the *COUPLING* for both *CH1* and

CH2 are both set to *DC*.
In this exercise you will view the Lissajous figures obtained by plotting sinusoidal displacements of the same frequency but different phases in two perpendicular directions.
You will use the BOX described in “Equipment Used”.
You will use the reference signal: $V_{REF,}$ taken between the *AC REFERENCE* and the *COMMON* terminals. Apply V_{REF} to the CH1 input and adjust the SEC/DIV to accommodate the new frequency.
You will also use V_{PH}, with phase relative to the V_{REF} voltage adjustable by means of a phase control knob. This voltage appears between the *AC PHASE* and the *COMMON* terminals on the BOX. Apply V_{PH} to channel 2, and observe the patterns on the screen for three phase control settings: 45^o, 60^o and 90^o.
➔Do you understand the shapes of these figures?
➔Explain (with math expressions) what happened in each case.

EXERCISE E – Noise cleaning
Use a BNC-banana cable: connect it to CH1, leaving the banana end open. With a setting of 2mV and 10ms, you should see only electrical noise. Bring the cable closer to an instrument or a power cord.
With ACQUIRE→ ***Average*** functionality you could clean the noise.
➔Try it. Also try ***Average*** with various numbers (4, 16, 64, 128).

NOTE: Be sure you understand what your oscilloscope is doing at every step in these exercises. If, at any time, you do not understand, consult a reference or your demonstrator.

Common terminology:
***DC*, *AC*, *GROUND*.** These stand for DIRECT COUPLING, ALTERNATING-CURRENT COUPLING, and A ZERO VALUE OF VOLTAGE.

RMS means root mean square. For sinusoidal voltage (AC voltage): $V_{rms} = \frac{V_0}{\sqrt{2}}$ where V_0 is the voltage peak value.

BNC connectivity (Bayonett-Neill-Concelman): RF connector for coaxial cable, made to match the characteristic impedance of 50Ω or 75Ω. This connector has a center pin connected to the center cable conductor and a metal tube connected to the outer cable shield.

REFERENCES
TEKTRONIX web page, *XYZs of Analogue and Digital Oscilloscopes*, the URL is
www.tek.com/Measurement/App_Notes/XYZs/
(A copy of this booklet is available in room 229)

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