Logic Design I – Laboratory 02 - Familiarization with Laboratory Instruments: Oscilloscope, Function Generator

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Objective

This exercise is of a particularly practical nature, namely, introducing the use of the oscilloscope. The various input scaling, coupling, and triggering settings are examined along with a few specialty features

Introduction

Oscilloscope is probably the single most versatile and useful Test and Measurement instrument invented for Electronic measurement applications. It is a complex instrument capable of measuring or displaying a variety of signals. This is the basic equipment used in almost all electronic circuit design and testing applications. The major subsystems in an oscilloscope are Power supplies (high and low voltage supplies),

Display subsystem, Vertical and Horizontal amplifiers and display systems. There are two major types of oscilloscopes, viz. Cathode Ray Oscilloscopes (CRO) also called Analog Oscilloscopes, and Digital Storage Oscilloscopes (DSO), occasionally called Digital oscilloscopes. There are some analog oscilloscopes which also have the extra facility to store waveforms in digital form; these are called mixed-mode (i.e. Analog/Digital) oscilloscopes.

The main use of an oscilloscope is to obtain the visual display of an electrical voltage signal. If the signal to be displayed is not in the voltage form, it is first converted to this form. The signal voltage is then transmitted to the oscilloscope along a cable (usually a coaxial cable) and enters the oscilloscope where the cable is connected to the scope input terminals. Often the signal at this point is too small in amplitude to activate the scope display system. Therefore, it needs to be amplified.

Analog Oscilloscope: Cathode Ray Oscilloscope (CRO)

In a CRO the X and Y signals are applied to the horizontal and vertical plates, respectively of the cathode ray tube (CRT) after amplification. Within the CRT, an electron beam is created by an electron gun.

The electron beam is focused and directed to strike the fluorescent screen, creating a spot of light, where impact is made with the screen.

The beam is deflected vertically in proportion to the amplitude of the voltage applied to the CRT vertical deflection plates.

The amplified input signal is also monitored by the horizontal deflection system. This subsystem has the task of sweeping the electron beam horizontally across the screen at a uniform rate. A sawtooth type signal (a triangular/ramp signal with long time
duration for the rising part of the ramp and very small time duration for the falling part) is internally generated in a CRO as a time-base signal (sweep signal).
This signal is amplified and applied to the horizontal deflection plates of the CRO. Again, the beam is deflected horizontally in proportion to the amplitude of the voltage applied to the CRT horizontal deflection plates.
The simultaneous deflection of the electron beam in the vertical direction (by the vertical deflection system and the vertical deflection plates) and in the horizontal direction (by the time-base circuitry and the horizontal deflection plates) causes the spot of light produced by the electron beam to trace a path across the CRT screen.
For example, if the input signal to the CRO were a sine wave, the trace produced on the CRT screen will be a sine wave. It is important to obtain a stable display on the CRT screen. If the input signal is periodic and the time base circuitry properly synchronizes the horizontal sweep with the vertical deflection, the spot of light will trace the same path on the screen over and over again.
For a periodic signal the input signal can be synchronized with the time-base signal using the Trigger controls and the time base controls. If the frequency of the periodic signal is high enough (say greater than 40 Hz), the repeating trace will appear to be a steady pattern painted by solid lines of light on the screen.

2 Digital Storage Oscilloscope (DSO)

A DSO samples the input waveform and uses an analog-to-digital converter (or ADC) to convert the voltage being measured into digital information. It then uses this digital information to reconstruct the waveform on the screen.
The ADC in the acquisition system samples the signal at discrete points in time and converts the signal's voltage at these points to digital values called sample points .
The horizontal system's sample clock determines how often the ADC takes a sample.
The rate at which the clock "ticks" is called the sample rate and is measured in samples per second. The sample points from the ADC are stored in memory as waveform points .

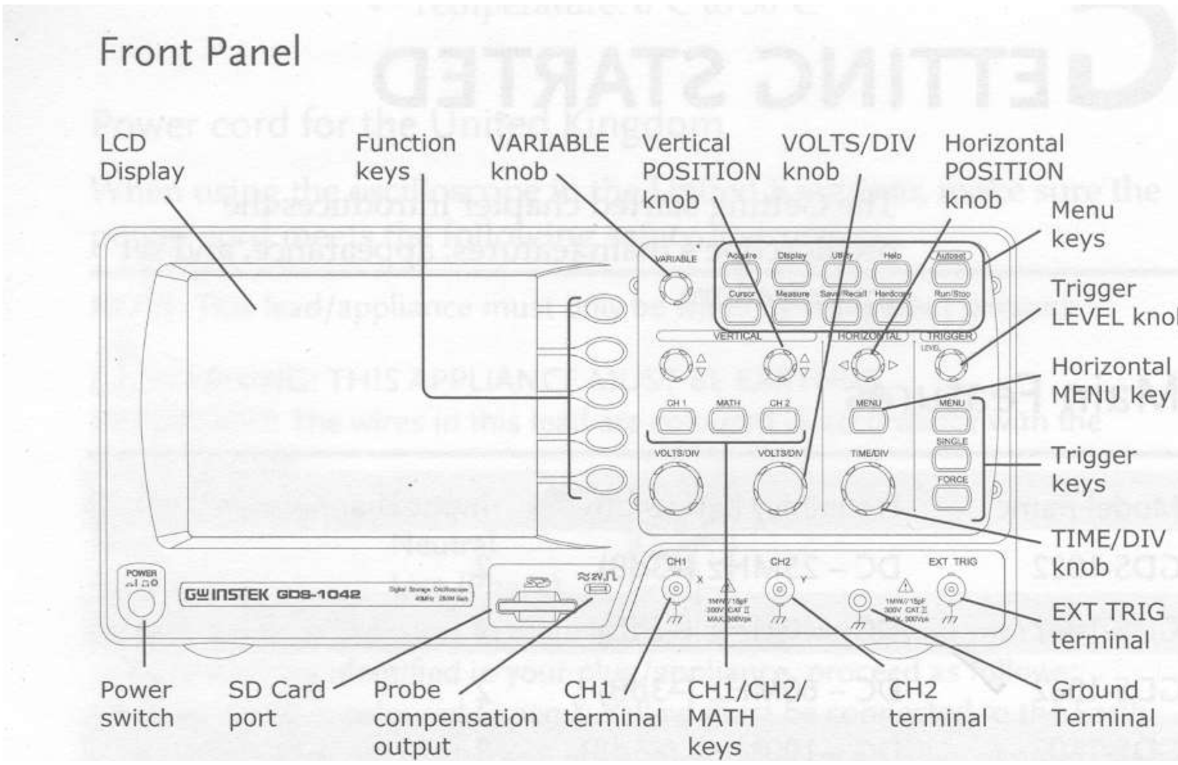
More than one sample point may make up one waveform point.
Together, the waveform points make up one waveform record .
The number of waveform points used to make a waveform record is called the record length .
The trigger system determines the start and stop
points of the record.
The display receives these record points after being stored in memory.
Depending on the capabilities of the oscilloscope, additional processing of the sample points may take place, enhancing the display. Pretrigger may be available, allowing you to see events before the trigger point.
Fundamentally, with a digital oscilloscope as with an analog oscilloscope, you need to adjust the vertical, horizontal, and trigger settings to take a measurement.

FUNCTION GENERATOR

Another major equipment commonly in electronic circuit applications, is a Function Generator (FG).
As the name indicates, a Function Generator generates different voltage signals, such as Sine, Pulse, Triangle.
The most commonly required signals in electronic circuits are Sine and Pulse. Sine wave signals find their use mostly in Analog circuits, such as amplifiers, filters, etc. Pulse signals are useful in testing the time response of circuits and also as Clock signals in Digital circuits. In a general pulse signal, the high and low level time periods are different.
Square wave is a special case when the periods are equal.
In a FG by the touch of a button one can choose a variety of signals. This is possible because of the fact that one can obtain different signals from a starting signal using wave shaping circuits.
The synthesized function generators, the waveforms are generated by digitally stored signals through digital to analog converters.
In the lab you will be using the Model SFG2110 Synthesized Function Generator (by M/s GW Instek, Taiwan) which is a 10 MHz function generator.

BASIC OPERATIONS OF THE DSO

Read the following sections carefully and familiarize yourself with the basic operations of the DSO and the FG.



Basic DSO Operations

A schematic diagram of the DSO front panel is shown above. Other than the LCD display, There are Five major sections on the front panel of the DSO:

Section 1 – The five function keys located on the side of the display

Section 2 – the section below the display consisting of Power switch, and probe compensation output (calibrated source).

Section 3 – A variable knob and Ten Menu keys located on the top side to the left of the display.

Section 4 – Knobs and buttons located in three columns at the centre part, indicated as: VERTICAL, HORIZONTAL, and TRIGGER.

Section 5 – Located at the bottom part to the left of the display are input BNC sockets for CH-1, CH-2 and External Trigger terminals, and an extra socket for GND.

DSO operations require the use of a combination knobs and buttons. You need to familiarize yourself well with all the basic operations in order to perform experiments and make measurements using the
DSO in the lab.

a) Channels CH-1 and CH-2

Note that the DSO can display signals simultaneously on Two channels. The signal display part of the LCD screen is 10cm (X-axis) long and 8cm (Y-axis) high. For convenience these channels are indicated with different colours. Signal connected to Channel 1 (CH-1) would appear YELLOW on the LCD screen.
Numera1-1 is also indicated on the extreme left side of the display. CH-1 controls are also given yellow colour. By pressing the yellow button (CH 1), this channel (and display) can be turned on or off. The Volts/Div knob indicates the Y-scale in volts/full div or volts/cm. Signal to CH-1 should be connected to the BNC connector seen just below the Volts/div knob.
Similarly, the signal to CH-2 should be connected to the socket below the CH-2 Volts/div knob. CH-2 display would appear blue on the LCD screen. Numeral-2 is also indicated.

b) CH-1 and CH-2 Coupling Modes

Press the required channel button (CH-1 or CH-2). Now sub-menu for that channel would appear at the left side of the screen.
Choose the top option, “Coupling” by pressing the first function key. The current coupling mode would be displayed below the line “Coupling”.
The three possible coupling modes are DC(two lines: solid line and broken line), AC(sine wave), and GROUND (ground sign).
As you press this function key the coupling modes keep changing. The present mode would be displayed below the “Coupling” function.
The most common coupling mode is DC, which would enable you to measure both dc and ac levels of the signal.
In the AC mode, the dc content of the signal would be removed. GROUND mode is used to choose the reference zero level for the Y-axis. In this mode DSO disconnects the input signal and connects the channel to ground.

c) Triggering the display

Proper triggering of the signal is required to get a stable display. When the signal is properly triggered, a message in green colour "Trig'd" would appear on the top. By pressing the "MENU" button in the "TRIGGER" column (extreme right column), various options for triggering are obtained.
These are Type: Edge, Pulse, Video
Source: CH 1, CH 2, External, Line
Slope/Coupling: Slope(+ve/ –ve), Coupling (DC/AC), Rejection (Off/LF/HF), Noise Rej(Off/On)
Mode: Auto
For normal use choose Type: Edge, Source: CH1 or CH2, Slope (+ve or –ve), Coupling: DC

d) Single and Continuous Trigger Modes

The signals to be displayed may either be continuously triggered and acquired by the DSO or just once. By pressing the "SINGLE" button on the Trigger submenu (extreme right column), signals are acquired just once, the instant immediately after pressing this button. A message "Stop" appears on the top of the LCD display to indicate that the acquisition has been stopped. The trigger mode also turns to "Normal" as indicated at the extreme right bottom. This mode is useful only when you want to make a measurement and are not interested in displaying the input signals in a continuous fashion.
Most of the time one is interested in the continuous trigger and acquisition mode. To get back to the continuous mode, press on the lower most function button indicated "Mode normal" It would make the trigger mode continuous and the "Mode Auto" message would appear at the lower most
function.
Now the channels would be continuously updated. The message "Trig'd" would appear at the top to indicate that the mode is continuous and that the signal is triggered properly.
Notice also the frequency of the signal displayed at the bottom of the LCD screen.

e) Horizontal Functions

There are three controls under HORIZONTAL (middle column). Top one is the horizontal position knob used to move the display in the X-direction. Bottom one is the "TIME/DIV" knob used to select the timebase scale (X-scale). This can range from 10sec/div to 1ns/div. The current time base scale setting will be displayed at the bottom, a little left to the centre line. A proper setting of the channel Volts/div and Time/div are required to get a clear display. The middle button “MENU” in this column is used to choose the Display mode.

f) Display Modes: Main and XY Modes

Press the “MENU” button, located just above the TIME/DIV knob located among the Horizontal controls (middle column). For normal operations, where you want to display the input signal continuously, the mode should be “Main”. To get the XY mode, press the XY function key in this menu. XY mode is occasionally used to get the XY plot of the two signals connected to CH-1 and CH-2. In the XY mode, CH-1 signal is taken as the X-axis input and CH-2 the Y-axis.

g) AUTOSET Function

This button may be thought of as the ‘panic’ button. This button may be pressed when you think that you are lost and needs help (with regard to displaying the signals on the DSO properly!). Once the AUTOSET button is pressed (extreme top right button) the DSO measures the amplitudes and time periods of the input signals connected to CH-1 and CH-2 and automatically chooses the correct Volts/Div, Time/Div, and Trigger mode settings.

Experiment

Theory Overview

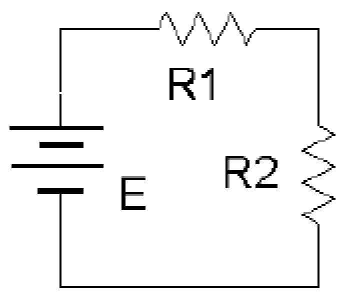
The oscilloscope (or simply scope, for short) is arguably the single most useful piece of test equipment in an electronics laboratory. The primary purpose of the oscilloscope is to plot a voltage versus time although it can also be used to plot one voltage versus another voltage, and in some cases, to plot voltage versus frequency. Oscilloscopes are capable of measuring both AC and DC waveforms, and unlike typical DMMs, can measure AC waveforms of very high frequency (typically 100 MHz or more versus an upper limit of around 1 kHz for a general purpose DMM). It is also worth noting that a DMM will measure the RMS value of an AC sinusoidal voltage, not its peak value.

While the modern digital oscilloscope on the surface appears much like its analog ancestors, the internal circuitry is far more complicated and the instrument affords much greater flexibility in measurement. Modern digital oscilloscopes typically include measurement aides such as horizontal and vertical cursors or bars, as well as direct readouts of characteristics such as waveform amplitude and frequency. At a minimum, modern oscilloscopes offer two input measurement channels although four and eight channel instruments are increasing in popularity.

Unlike handheld DMMs, most oscilloscopes measure voltages with respect to ground, that is, the inputs are not floating and thus the black, or ground, lead is always connected to the circuit ground or common node. This is an extremely important point as failure to remember this may lead to the inadvertent short circuiting of components during measurement. The standard accepted method of measuring a non-ground referenced potential is to use two probes, one tied to each node of interest, and then setting the oscilloscope to subtract the two channels rather than display each separately. Note that this technique is not required if the oscilloscope has floating inputs (for example, in a handheld oscilloscope). Further, while it is possible to measure non-ground referenced signals by floating the oscilloscope itself through defeating the ground pin on the power cord, this is a safety violation and should not be done.

Procedure

1. Build the circuit of figure, using E=10 V, R1=10 kohm and R2= 33kohm.
Connect a probe from the channel one input to the power supply (red or tip to plus, black clip to ground).
Connect a second probe from channel two to R2 (again, red or tip to the high side of the resistor and the black clip to ground).



2. Switch both inputs to DC coupling. The yellow and blue lines should have deflected upward. Channel one should be raised two divisions (2 divisions at 5 volts per division yields the 12 volt source).
Using this method, determine the voltage across R2 (remember, input two should have been set for 2 volts per division).
Calculate the expected voltage across R2 using measured resistor values and compare the two in Table 1. Note that it is not possible to achieve extremely high precision using this method (e.g., four or more digits).
Indeed, a DMM is often more useful for direct measurement of DC potentials. Double check the results using a DMM and the final column of Table 1.

3. Select AC Coupling for the two inputs. The flat DC lines should drop back to zero. This is because AC Coupling blocks DC.
This will be useful for measuring the AC component of a combined AC/DC signal, such as might be seen in an audio amplifier.
Set the input coupling for both channels back to DC.

4. Replace the DC power supply with the function generator.
Set the function generator for a one volt peak sine wave at 1 kHz and apply it to the resistor network. The display should now show two small sine waves.
Adjust the Vertical Scale settings for the two inputs so that the waves take up the majority of the display.

If the display is very blurry with the sine waves appearing to jump about side to side, the Trigger Level may need to be adjusted. Also, adjust the Time Scale so that only one or two cycles of the wave may be seen.
Using the Scale settings, determine the two voltages (following the method of step 2) as well as the waveform's period and compare them to the values expected via theory, recording the results in Tables 2 and 3. Also crosscheck the results using a DMM to measure the RMS voltages.

5. To find the voltage across R1, the channel two voltage (VR2) may be subtracted from channel one (E source) via the Math function.
Use the red button to select the Math function and create the appropriate expression from the menu (ch1 – ch2).
This display shows up in red. To remove a waveform, select it and then select Off.
Remove the math waveform before proceeding to the next step.

6. One of the more useful aspects of the oscilloscope is the ability to show the actual waveshape.
This may be used, for example, as a means of determining distortion in an amplifier.
Change the waveshape on the function generator to a square wave, triangle, or other shape and note how the oscilloscope responds.
Note that the oscilloscope will also show a DC component, if any, as the AC signal being offset or "riding on the DC".
Adjust the function generator to add a DC offset to the signal and note how the oscilloscope display shifts. Return the function generator back to a sine wave and remove any DC offset.

7. It is often useful to take precise differential measurement on a waveform. For this, the bars or cursors are useful.
Select the Cursor button toward the top of the oscilloscope. From the menu on the display, select Vertical Bars. Two vertical bars will appear on the display (it is possible that one or both could be positioned off the main display). They may be moved left and right via the function knob (next to the Cursor button). The Select button toggles between the two cursors.

A read out of the bar values will appear in the upper portion of the display. They indicate the positions of the cursors, i.e. the location where they cross the waveform.
Vertical Bars are very useful for obtaining time information as well as amplitudes at specific points along the wave.
A similar function is the Horizontal Bars which are particularly useful for determining amplitudes. Try the Horizontal Bars by selecting them via the Cursor button again.

8. For some waveforms parameters, automatic readings are available. These are accessed via the Meas (Measurement) button.
Select Meas and page through the various options.
Select Frequency.
Note that a small readout of the frequency will now appear on the display. Up to four measurements are possible simultaneously.
Important: There are specific limits on the proper usage of these measurements. If the guidelines are not followed, erroneous values may result.
Always perform an approximation via the Scale factor and divisions method even when using an automatic measurement!

Results and data analysis

Table 1

VR2	Scale (V/Div)	Number of Divisions	Voltage Scope	Voltage DMM
Oscilloscope				
Theory				

Oscilloscope Deviation	
DMM Deviation	

*Deviation % = 100 * (measured*- Theory*)/* Theory

Table 2

	Scale (V/Div)	Number of Divisions	Voltage Peak	Voltage RMS
E Oscilloscope				
E DMM				
E Theory				
VR2 Oscilloscope				
VR2 DMM				
VR2 Theory				

Oscilloscope E Deviation	
DMM E Deviation	
Oscilloscope VR2 Deviation	
DMM VR2 Deviation	

*Deviation % = 100 * (measured*- Theory*)/* Theory

Table 3

	Scale (S/Div)	Number of Divisions	Period	Frequency
Oscilloscope				
E Theory				

E Deviation	

*Deviation % = 100 * (measured-* Theory*)/* Theory

Questions and Conclusions

1. Regarding table 1, which measurement device is suitable for measuring DC voltage (Oscilloscope, DMM). State your answer based on calculated Deviation?

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2. Regarding table 3, which measurement device is suitable for measuring AC voltage (Oscilloscope, DMM). State your answer based on calculated Deviation??

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