Chapter 2

Familiarization: The Digital Storage Oscilloscope (DSO)

Oscilloscopes are electronic instruments used to observe time-varying electrical signals. Plots of signal voltage values can be displayed as a function of time. Two types of oscilloscopes are usually used:

- Cathode-ray oscilloscope (CRO): A CRO uses analog circuits to sense and display information on a screen. Typically, it does not have the ability to store information about captured waveforms.
- Digital storage oscilloscope (DSO): A DSO typically digitizes and stores captured signals in an internal memory. The stored signals can then be analyzed and displayed on a screen. This offers great flexibility in analysis of the captured waveforms.

2.1 The Tektronix TDS 200 series Digital Storage Oscilloscope

We will describe the Tektronix TDS 200 series DSO[1]. A representation of its front panel is shown in Figure 2.1.

This DSO has the following features:

- Handle signals of frequency upto 60 MHz
- Can display two signals simultaneously

[1]Some other DSOs available in the lab are *TDS1002*, *TDS1002B* and *GDS-1072A-U-GW INSTEK*

Figure 2.1: TDS 210/220 two channel digital real-time oscilloscope

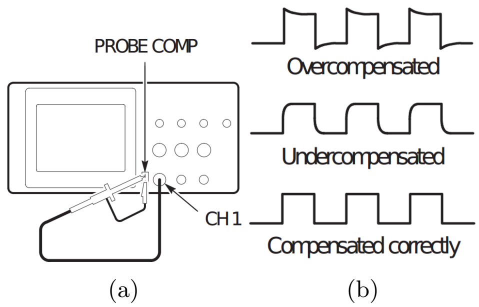
- Cursors with readout
- Autoset for quick setup

2.1.1 First look: verify that the instrument is working correctly

Let's do a quick functional check to verify that instrument is working correctly. See Figure 2.1 to identify the connection points on the DSO front-panel.

- Turn on the device and wait until the display shows that all the self tests passed.
- Take the signal probe (Eg: TDS2200). This probe has two attenuation settings, 1X and 10X. Set the attenuation button at the tip of the probe to 1X.
- Now, attach the probe tip to the *PROBE COMP* 5V connector and the probe reference lead to the *PROBE COMP* ground connector.
- Plug the probe into *Channel 1* on the oscilloscope and push the *AUTOSET*[2] button. On the display you should see a square wave of approximately 5V peak-to-peak at 1KHz, as shown in Figure 2.2. This

[2] ① in Figure 2.1



(a) (b)

Figure 2.2: Testing the probe

ensures proper probe compensation[3]). Inform the lab staff if you observe something very different.

2.2 Capture a signal using the DSO

We will construct a test circuit and capture its waveforms using the DSO. The test circuit is shown in Figure 2.3.

Connect the output of our circuit (node 2) to *Channel 1* of the DSO as shown in Figure 2.3[4]. Are you able to see a stable waveform? If not you may need to use a triggering mechanism to capture the waveform.

2.3 Use triggering to observe stable waveforms

If the signal being observed is not stable[5], we can use a trigger to tell the oscilloscope the point from which the display of information should start. Note that the signal must be approximately periodic. There are three types of triggering.

- *Auto*: In this mode, DSO will display stable waveform in the presence of a valid trigger and unstable waveforms when no valid trigger is given
- *Normal*: DSO will display stable waveforms in the presence of a valid trigger and will retain the previous stable waveform in the presence of invalid trigger

[3] Probe compensation is a method to match the probe impedence to the input channel of the DSO

[4] The ground wire of the probe has to be connected to node 3

[5] Either moving waveforms or multiple waveforms displayed on screen

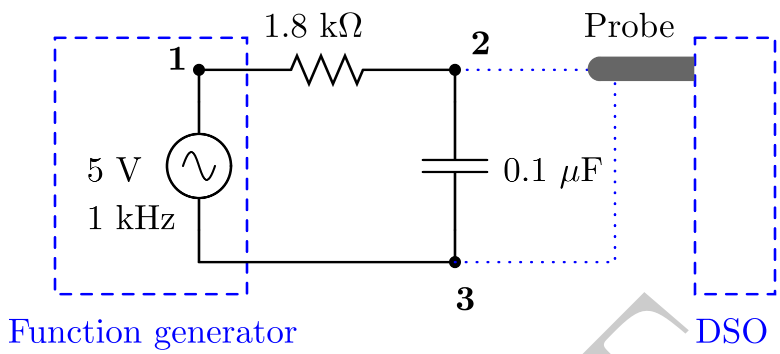


Figure 2.3: Test circuit with nodes for observing the signals

- *Single*: In this mode, waveform is acquired each time when the *RUN/STOP*[6] button is pressed and a trigger condition is detected

Use the following steps to obtain a stable waveform.

- Push the *MENU* button[7] in the *TRIGGER* section
- Select *Auto* in the *Mode* section[8]
- Select *CH1* in the *Source* section since we have connected the output of the circuit to channel 1
- Adjust the *LEVEL* knob[9] and keep the trigger level somewhere between the peaks of the input waveform. You will be able to see a small arrow on the right side moving up and down with your *LEVEL* knob
- You should be able to see a stable waveform on the display. Try out *Normal* and *Single* triggering modes by varying the trigger level and frequency of the input sine waveform (in function generator)

Type of triggering and various sources used for triggering are discussed in the Appendix

[6] 2 in Figure 2.1
[7] 3 in Figure 2.1
[8] Mode button can be found from the set of buttons shown at the right side of the DSO panel. Labelled 12 figure 2.1
[9] 4 in Figure 2.1

2.4 Measure signal parameters

To measure signal frequency, period peak-to-peak amplitude etc. of the output waveform follow the steps given below

- Push the *AUTOSET* button footnoteIt automatically sets the trigger levels and displays the waveforms
- Push the *MEASURE* button[10] to go to the Measure menu
- Push the top menu box button to select *Source*
- Select *CH1* for the first three measurements
- Push the top menu box button to select *Type*
- Push the first *CH1* menu box button to select *Freq*
- Push the second *CH1* menu box button to select *Period*
- Push the third *CH1* menu box button to select *Pk-Pk*

2.5 Use cursors to take measurements

Using this one can vary the position of two cursor lines, get the voltage and time values corresponding to the position of the cursors, difference between them etc.

- Push the *CURSOR* button to go to the Cursor menu
- Push the top menu box button and select *Type* as *Voltage*[11]
- Set the *Source* option to *CH1*
- Vary the position of the two horizontal cursor lines using the *CURSOR 1* and *CURSOR 2* knobes
- Observe the voltage values corresponding to cursors under *Cursor 1* and *Cursor 2* the difference between them under *Delta*
- Push the top menu box button and select *Type* as *Time*
- Vary the cursors using the previous knobs and observe the time values

[10] ⑤ in Figure 2.1

[11] Two horizontal lines will appear if you set *Type* as *Voltage* and two vertical lines will show up if you set it as *Time*

2.6 Display two waveforms

There are two channels in the DSO which can be controlled independently

- Take another probe and plug it to the *Channel 2* on the oscilloscope
- Connect its tip to the node 1 in the example circuit
- Push *AUTOSET* button
- Push *CH 1 MENU*[12]
- Push the *Coupling* button on the right side of the display and see the various coupling options
- Push *Invert* button to invert polarity of the signal
- Push *CH 2 MENU*[13] and repeat the above two steps

You can also get a plot of one signal versus the other (its called XY mode). Follow the steps below to get a plot with channel-1 voltage on the X-axis and channel-2 voltage on the Y-axis

- Push *CH 1 MENU* and use *Coupling* button to change the coupling to *Ground*
- Use the *POSITION*[14] knob of channel-1 to bring the ground line of channel-1 to the center of the display
- Change the coupling back to *AC*
- Push *CH 2 MENU* and use *Coupling* button to change the coupling to *Ground*
- Use the *POSITION* knob of channel-2 to bring the ground line of channel-2 to the center of the display
- Change the coupling back to *AC*
- Push the *DISPLAY* button[15]

[12] 7 in Figure 2.1
[13] 8 in Figure 2.1
[14] 9 in Figure 2.1
[15] 10 in Figure 2.1

- Push the *FORMAT* button and select *XY* format
- You will see a ellipse shaped plot on the display
- Change the amplitude and frequency of the input sine wave. What do you observe?

Change the *Format* back to *XT* when you are done

2.7 Perform mathematical operations

DSO has the capability to perform some basic mathematical operations with the input signals.

- Push *MATH MENU* button[16]
- Push the *Operation* button to change the operation to +, - and *FFT*

2.8 Appendix

2.8.1 More about triggering

- *Trigger sources*: The source for triggering can be AC line, External sources or one of the input oscilloscope channels
- *Type of triggering*: Two types of triggering exists - edge triggering and video triggering. In edge triggering, an edge occurs when the trigger input passes through a specified voltage level in the specified direction. Video triggering is used on fields or lines of standard video signals

2.8.2 Data acquisition

On acquiring analog data, the oscilloscope converts it into a digital form. The 3 different acquisition modes include: Sample, Peak Detect and Average.

- *Sample*: The signal is sampled at equal intervals to reconstruct the waveform and is more accurate. But sampling will not include the narrow pulses in between the sampling intervals

[16] 11 in Figure 2.1

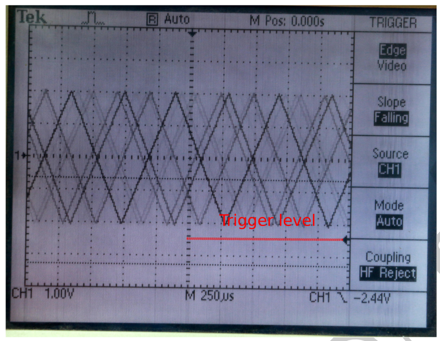


Figure 2.4: Untriggered waveform

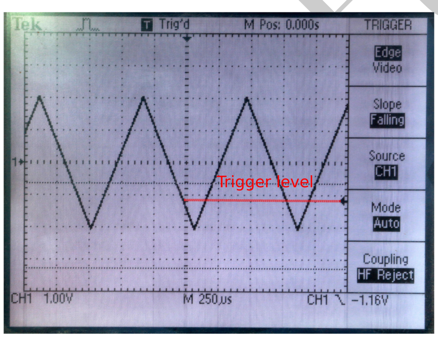


Figure 2.5: Displayed waveform with trigger level set below zero

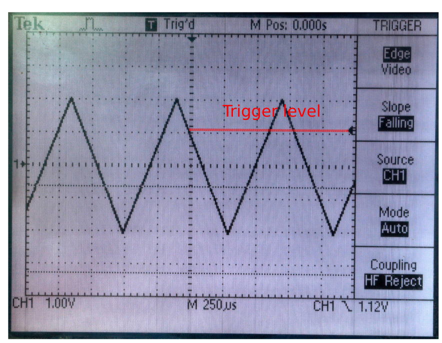


Figure 2.6: Dispayed waveform with trigger level set above zero

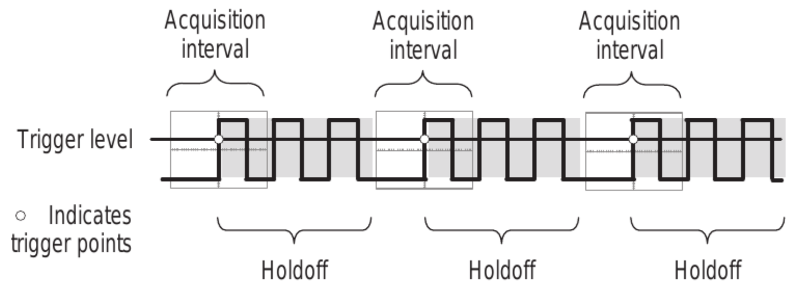


Figure 2.7: Holdoff- triggering not done

- *Peak Detect*: Detects the peaks over a specified interval and these are used to display the waveform. Detecting the peaks will enable the detection of narrow pulses

- *Average*: In this mode the average of several samples are acquired and displayed.

2.8.3 Hold off

Hold-off time is the period that follows each acquisition. Triggers are not recognized during the hold-off time. Sometimes for complex signals like a digital pulse train, it might be required to use hold-off. Ref Fig 2.7 .

Bibliography

[1] http://mmrc.caltech.edu/Oscilliscope/TDS210%20Digital%20Os%20User%20 Manual.pdf (Accessed: 03-09-2015)

[2] www.tek.com/datasheet/tds200-series (Accessed: 04-09-2015)

[3] Photo credits: Anil R. Gawai, WEL, IIT Bombay