ESC201 Introduction to Electronics General Lab Manual for Lab Instrument Digital Multi-Meter, DC Supply, Function Generator, Digital Storage Oscilloscope

The aim of the manual is to familiarize yourself with four basic instruments in any electronics laboratory: Digital Multi-Meter (DMM), Power Supply, Function Generator (FG), Digital Storage Oscilloscope (DSO). You will learn the operation of these instruments through experimentation with some simple resistive circuits.

Part A: Digital Multi-Meter (DMM)

Digital Multi-Meter (DMM) is a cheap and portable instrument used for measuring voltages (dc and ac), currents (dc and ac) as well as resistances – hence the name multi-meter. Earlier, analog multi-meters were used for measuring the above. Analog multi-meters used a standard milli-ammeter with different calibrated dials for voltages, currents and resistances. These instruments were bulky and lacked accuracy. Presently, analog multi-meters are seldom used. Digital multi-meters are more accurate, handy and easy to use.

The DMM that you will use in the ESC201 laboratory is either the Model DM3540A manufactured by the Motwane Manufacturing Company Pvt. Ltd., India, or Model DT115 manufactured by Mextech Technologies India Pvt. Ltd, as shown below. The DMM in the lab has an input resistance of 20 Mega-Ohms (MΩ), which makes it an excellent instrument for measuring voltages. In addition to the standard functions (voltage, current and resistance measurements), it also has auto-ranging, diode check, and continuity check facilities.

In the ESC201 lab, you will be using the DMM mainly for measuring DC voltages and resistances. The DMM used in this lab cannot measure ac signals above 50 Hz. Also, the DMM is not very accurate for current measurements. The DMM is used mostly for measuring voltages and resistances.

Part B: DC Power Supply

The DC power supply which will be used in the ESC201 lab is a multiple-source power supply PSD3304 by Scientific Mes-Technik Pvt. Ltd., India. The PSD3304 is a multiple-source power supply with A: 30 V – 2 A source, B: ± 15 V – 1A dual source, C: a single 5V – 5A source, designed as a constant current and constant voltage source for educational labs, industries and field testing due to its low power loss, compactness and light weight applications. It provides isolated, adjustable, and floated DC output voltages suitable for circuit testing. These floated DC outputs allow operating them in series or parallel. There are three power supplies (in the order A, C, B) and outputs are adjustable 0 to 30 V, 2A; 4.5V to 5.5V, 5A, and 0 V to ± 15 V, 1A; respectively. A 3-digit display is provided for switchable reading of the instantaneous values of voltage and current for any of these three power supplies. To see the value for any of the power supply, you have to press the corresponding button. Similarly, to see the value of the negative supply from the dual power supply, you have to press the B button and then the ± 15 V button. The front panel of PSD3304 is shown above.

Part C: Function Generator (FG)

Another major equipment commonly required in electronic circuit testing is a Function Generator (FG). As the name indicates, an FG generates different voltage signals, such as ‘Sine’, ‘Pulse’, and ‘Triangle’. All three signals are commonly used in electronic circuit testing and measurement. ‘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 time periods for the ‘High’ and ‘Low’ level are different. Square wave is a special case of ‘Pulse’ when the periods are equal. The ‘Triangle’ wave signals are required for measuring various electrical characteristics of a circuit or device. In an 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, which you will learn later.

In a Synthesized FG (SFG), the waveforms are generated by digitally stored signals through digital to analog converters (DACs). The SFG uses Direct Digital Synthesis (DDS) technology to output stable waveforms. In DDS, the waveform data is contained in and generated from a memory, and a clock controls the counter for memory addressing. The output of the digital memory is converted to analog signal by a DAC followed by a low pass filter. In the ESC201 lab, you will be using the Model SFG2110, a Synthesized Function Generator by GW Instek, Taiwan. Model SFG2110 shown below is a 10 MHz FG with 50 Ω output impedance.

The main purpose of the FG is to give you the signal you require, sine wave, square wave, or triangular wave. You need to choose both the frequency and amplitude of these functions. The information about the type of waveform selected and the frequency are displayed on the display panel of the FG. The FG knobs and buttons explained below would familiarize you to choose a particular function, its amplitude and frequency. Note that the FG output is taken through a co-axial cable from 'OUTPUT' or 'TTL/CMOS OUTPUT' socket.

a) Waveform Selection Key 'WAVE': This key selects a sine wave, a square wave or a triangular wave.
b) Amplitude/Attenuation Control 'AMPL': Sets the sine/square/triangular waveform amplitude. Turn left to decrease or turn right to increase the amplitude. When pulled out, attenuates the waveform by –20 dB.
c) DC Offset Control 'OFFSET': When pulled out, it will set the DC offset level for sine/square/triangle waveform. Turn left to decrease or turn right to increase the offset. The range is –5V to +5V, in 50 Ω load.
d) 'TTL/CMOS' Amplitude Control: This knob becomes effective when the TTL/CMOS output is enabled. When the knob is pressed, TTL output is selected. When the knob is pulled out, CMOS is selected as output. The level of the CMOS signal is selected by rotating the knob.
e) Waveform 'OUTPUT': The connector outputs the FG waveform. The output impedance is 50 Ω.
f) 'TTL/CMOS OUTPUT': Outputs TTL or CMOS output waveform.
g) 'COUNTER INPUT': Accepts signals for frequency counting (maximum amplitude is AC 30 V rms).
h) 'SHIFT' Key: Selects the function written above each number keys. For example, to set the Duty Cycle, press 'Shift' followed by 'Duty' button and then rotate the editing knob. Similarly, press 'Shift' followed by 'TTL' button to select the TTL output.
i) Two Arrow Key (below the big knob): Selects the significant digit which can be changed by the big knob.
j) Frequency keys: Select the unit for frequency if pressed after pressing any number key.

Part D: Digital Storage Oscilloscope (DSO)

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 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 voltage signal is then transmitted to the oscilloscope along a coaxial cable and enters the oscilloscope where the cable is connected to the channel (input terminals) of the oscilloscope. Often the signal at this point is small in amplitude to activate the display system of the oscilloscope, therefore, it needs to be amplified.

The major subsystems in an oscilloscope are: Power supplies (high and low voltage supplies), Display subsystem, Vertical and Horizontal Amplifiers along with 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 can store waveforms in a digital form, these are called mixed-mode (i.e., Analog/Digital) oscilloscopes.

A DSO samples the input waveform and uses an analog-to-digital converter (ADC) to convert the analog voltage signal 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 entire 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. Pre-trigger may be available, allowing one to see events before the trigger point. Fundamentally, you need to adjust the vertical, horizontal, and trigger settings of a DSO to take a measurement and display the waveform on the DSO screen.

The DSO you will use in the ESC201 lab is Model EDUX1052G by Keysight Technologies, USA. This DSO will be used as a measuring equipment for all the experiments. This DSO model has a bandwidth of 50 MHz and maximum sampling rate capability is 1GSa/s, i.e., 1 Giga-Sample per seconds. This DSO also has an FG capability of 20 MHz. Notice that '1 MΩ, 16 pF' is written in between two input sockets to tell the user that each of the DSO input channels is equivalent to a 1MΩ resistor in parallel with a 16pF capacitor. A diagram of a DSO front panel from Model EDUX1052G is shown above. Other than the main LCD display, there are four major sections on the front panel of the DSO:

Section 1 – The section on lower left of the display: Power switch, USB, Probe Compensation output/Demo.
Section 2 – The section on lower right of the display: one BNC socket for FG output, input BNC sockets for each channel (CH-1, CH-2), and one socket for external trigger terminal.
Section 3 – The five function panels located on the side of the display: Vertical, Horizontal, Trigger, Measure, Math. Also, there are many variable knobs and menu buttons located in each of the function panel.
Section 4 – The panel with one back button and six function buttons located on the right side of the display. These are used along with other menu buttons to choose various operations of the DSO.

<u>Vertical Function Panel: Channel 1 and 2</u>

Note that the DSO can display signals simultaneously on two channels. For convenience, these channels are indicated with different colours. Signal connected to Channel 1 (CH-1) would appear YELLOW on the LCD screen. Numeral-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 for CH-1, this channel and display can be turned on or off. Signal to CH-1 should be connected to the BNC connector marked YELLOW. Signal connected to CH-2 would appear GREEN on the LCD screen. Numeral-2 is also indicated on the extreme left side of the display. CH-2 controls are also given green colour. By pressing the green button for CH-2, this channel and display can be turned on

or off. The signal to CH-2 should be connected to the BNC connector marked GREEN. After selecting the desired channel by pressing the yellow or the green button, the volts/div of the Y-scale can be adjusted by rotating the upper bigger knob in the 'Vertical' panel. For finer adjustment of the vertical scaling, you have to press the bigger knob and then rotate it. The volts/div of the Y-scale is indicated on the extreme left side of the display for each individual channel. The waveform display of the selected channel can be moved up or down using the lower smaller knob in the 'Vertical' panel.

Horizontal Function Panel

There are three controls under 'Horizontal' panel (top most row). The leftmost bigger knob is used to select the time scale (X-scale) in time/div, and the rightmost smaller knob is the horizontal position knob used to move the display in the X-direction. The time scale setting will be displayed on the top right of the screen.

Trigger Function Panel: Triggering the display

Triggering is like synchronized picture taking. Proper triggering of the signal is required to get a stable display. When the signal is properly triggered, a text indicating the mode of triggering (auto or normal) will appear on the top. By moving the knob in the 'Trigger' panel (extreme right column), one can change the position of the trigger point on the display. The trigger point is the intersection of the voltage waveform of the selected channel on the Y-axis of the display. Hence, the trigger point always lies in the centre, i.e. on the Y-axis.
By pressing the 'Trigger' button in the 'Trigger' column, various options for triggering can be obtained, e.g., Trigger Type, Mode, Coupling, etc. In selecting the Triger Type, one will get more options: Trigger Type, Source, Slope; each of which can be selected using the corresponding function keys. After selecting the Trigger Type option again, one will get: Edge, Pulse, etc. In the Source option, one can select either CH-1 or CH-2. After selecting Edge option as the Trigger Type, one can select Rise, Fall, or Alternating edge from the Slope option. In the trigger Mode, two options are available: auto, Normal. In the trigger Coupling, options available are DC, AC. For DC Coupling of the trigger, you can change the trigger level by rotating the knob. However, for AC Coupling of trigger, the trigger level is automatically set to zero. For standard case, choose the following: Type: Edge, Slope: Rise or Fall, Trig Mode: Auto, Coupling: DC.

Single Button: Single vs Continuous Trigger Mode

The signals to be displayed may either be continuously triggered and acquired by the DSO or just once. By pressing the "Single" button on top right corner above the 'Trigger' section, signals are acquired just once, the instant immediately after pressing this button. The light on the "Run/Stop" button on the top right corner becomes Red to indicate the acquisition has been stopped. The trigger mode automatically goes into Normal. The "Single" mode of triggering is useful only when you want to make a measurement and are not interested in displaying the input signals in a continuous fashion, for example, if someone wants to observe the start-up activity of the FG. Most of the time one is interested in the continuous trigger and acquisition mode. To get back to the continuous mode, press "Run/Stop" button again. It would also make the trigger mode to Auto.

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 on the screen. Choose the option Coupling by pressing the corresponding function key. The present coupling mode would be displayed below the line Coupling. The two possible coupling modes are DC and AC. You can change the Coupling mode by pressing the corresponding function key or rotating the Entry knob. By pressing the Entry knob, one confirms the entry of the value. The most common coupling mode is DC which would enable one to measure both dc and ac levels of the voltage signal. In the DC mode of the channel, the signal is connected as it is to the vertical amplifier of the DSO. Hence, any DC level already present in the signal will be shown in the display also. However, in the AC mode, the DSO inserts a capacitor in series with the signal before connecting it to the vertical amplifier. Hence, in the AC mode, the dc content of the signal would be removed.

Time Modes: Normal and XY

One of the useful features in a DSO is the facility of XY Plot. This facility can be used to display the CH-2 signal as a function of CH-1 one. The "Acquire" button, which is located just in the middle of the "Horizontal" section (top row) in between the two Horizontal control knobs, is used to choose the Time Mode as Normal or XY mode. For normal operations, when you want to display the input signal continuously, the mode should be Normal. To get the XY mode, press the "Acquire" button and the present Time Mode would be displayed below the line Time Mode. Pressing the corresponding function key for the option Time Mode in the menu, you will get the options for Normal or XY mode. If you keep on pressing the function key, the mode will change from Normal to XY mode and vice versa. The XY mode is used to get the XY plot of the two signals connected to CH-1 and CH-2, in which CH-1 signal is taken as the X and CH-2 signal is taken as the Y.

Manual Measurement using Cursors

"Cursor" function can be used for both Normal and XY mode measurement. With Time Mode being Normal, press the "Cursors" button on the 'Measurement' section (located on the middle, 2nd row from top). Then, four cursors would appear at four sides of the display: two vertical cursors for horizontal measurements and two horizontal cursors for vertical measurements. The following features are available with the cursors for X or Y measurements, selection of Source: CH-1 or CH-2, selection of Cursors: X1(X value (time) of the *left* cursor time unit), X2 (X value of the *right* cursor in time unit), X1X2 locked (constant $\Delta X = X1 - X2$), Y1 (Y value of the *top* cursor in volts), Y2 (Y value of the *bottom* cursor in volts), Y1Y2 locked (constant $\Delta Y = Y1 - Y2$). Note that all these options, i.e., X1, X2, Y1, Y2, can be changed by pressing the function key repeatedly, the cursors can be moved by rotating the knob on the right of the "Cursor" button on the measurement section. Cursors can be switched off by pressing the "Cursors" button again. Similarly, cursor can be used in XY mode.

Automatic Parameter Measurement using Measurement Functions

To perform a measurement in Normal Mode, first select the channel by pressing the required channel button (CH-1, CH-2). Then, press the "Meas" button located on the left of the "Cursors" button, and the DSO would show the current list of few measurements. One can clear the list by selecting the Clear Meas option using the corresponding function key. Then, press the function key corresponding to Type from the list, and a list of 32 measurements (14 voltage, 14 time, 4 pulse measurements) will appear. One can assign a new measurement by choosing the desired one from the list by rotating the entry knob and pressing the knob for selection. Results of several recent measurements for both CH-1 and CH-2 can be displayed simultaneously on the screen.

Some of the most useful measurement functions possible for voltage measurements are: **Vpp** (Peak-to-peak voltage), **Vmax** (maximum value of the signal), **Vmin** (minimum value of the signal), **Vamp** (value of the amplitude of the signals, i.e., the difference between **Vhi** and **Vlo**), **Vhi** (steady state high level or **top value**), **Vlo** (steady state low level or **base value**), **Vavg** (average value of the signal), **Vrms** (root mean square value of the signal). Some of the most useful measurement functions possible for voltage measurements are: **Frequency** (frequency of the signal) and **Period** (period of the signal), etc. For pulse signals, functions such as, **+Width** (width of the +ve pulse), **–Width** (width of the –ve pulse), **Duty Cycle** (the ratio of the positive pulse width to the signal period expressed as a percentage), **Rise Time** (time taken from 10% to 90% of the signal), **Fall Time** (time taken from 90% to 10% of the signal), etc., may be used.

Amplification Ratio

Press the required channel button (CH-1 or CH-2). Now sub-menu for that channel would appear on the screen. Choose the option Probe from the bottom using the corresponding function key and more options will appear. In that option, one will find Probe and by selecting that option using the function key, one can see the option Amplification Ratio and change the ratio by rotating the Entry knob. By pressing the Entry knob, one confirms the entry of the value. Keep the amplification ratio for both the channels to be 1:1 unless otherwise specified.

Math Function

Pressing the "Math" button on the math panel, one can select Operator from the list using the corresponding function key. After selecting the Operator, one can select different operations using the Entry knob (rotate the knob to change the operation and press it for selection). One can add, subtract, multiply or divide any two waveforms. Also, other capabilities, such as, doing a Fast Fourier Transform (FFT) or performing a low-pass filtering operation, are possible using the Math functions available in the DSO.

Default Setup Button

The "Default Setup" button is located on top (just right to the display and left to the "Horizontal' panel). Once this button is pressed, the DSO will go to a standard configuration and will turn of all special mode that a prior used might have set. It is a good idea to press the button before you start your lab each time.

Auto Scale Button

The "Auto Scale" button is located on top above the "Default Setup" button. 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 "Auto-Scale" button is pressed, the DSO measures the amplitudes and time periods of the input signals connected to channels, and automatically chooses the correct scaling, i.e., time/div, volts/div, and trigger mode settings to display the signals.

Function Generator Output

The DSO you will use in the lab also has the function generator capability if you connect the signal from the Gen-Out of the DSO. By adjusting the knob and selecting the appropriate function key, you can change the type of signal of the Gen-Out as well as change various parameters of the signal associated with it.

Help Button

Built-in help, regarding all the keys and operations, is provided by the DSO. This is useful in case help is required regarding any key or function. Press the "Help" button (located on the right of the "Math" button) followed by any key to show the help on the display. Press the "Help" button again to exit the Help-mode.