Dyson School of Design Engineering, Imperial College London

DE1.3 Electronics 1

Lab 1 – Signals and Scope

Peter Cheung, 14 May 2020

Introduction

Welcome to your first Electronics Home Laboratory Session. I have designed four lab experiments to form the central pillar of your DE 1.3 module. Given the home working environment, you have the flexibility to spend as much time you want on them. However, I strongly encourage you to arrange to work with your assigned team members together – it is much more fun and give all of you the opportunity to help each other.

The first experiment is about the use of oscilloscope to measure electrical signals. By so doing, you will also gain some insights into the shapes and forms of electrical signals. As with the lectures, all materials related to the laboratory sessions are available on the course webpage.

I have designed these laboratory sessions to be exploratory in nature. That is, I won't be telling you how to do things step-by-step. Instead, I will tell you what I want you to achieve, and you will discover this yourself through trial and error. This will hopefully help you to retain what you have seen and done, and gradually gain confidence in the subject.

The Digital Multimeter

Digital Multimeter (**DMM**) is the most basic equipment you can find to any electrical engineer's tool bag. The one included in the Kit is on loan to you. However, once you have gain confidence in using one, you may want to invest in purchasing one for yourself. It is not expensive.

Below is a diagram showing how the black and red probes should be connected for different measurements using the DMM, and its summary specifications.


For voltage & resistance measurements

For current and capacitance measurements

SPECIFICATIONS:
DC Voltage: 200mV-2V-20V-200V-1000V, ± (0.5% + 1dgt)
AC voltage: 200mV-2V-20V-200V-750V, ± (0.8% + 3dgt)
DC Current: 20mA-200mA-20A, ± (0.5% + 1dgt)
AC current: 2mA-20mA-200mA-20A, ± (1.0% + 3dgt)
Resistance: 200Ω-2KΩ-20KΩ-200KΩ-2MΩ-20MΩ-2000MΩ, ± (0.8% + 1dgt)
Capacitance: 2nF-20nF-200nF-2uF-20uF-200µF, ± (2.5% + 3dgt)
Measuring 50uF above values are for reference only
Diode test
Transistor test
Off measurement
Sleep mode

Task 1: Learning to control the Signal Generator

You should have completed Lab 0 and constructed the Signal Generator as shown below:
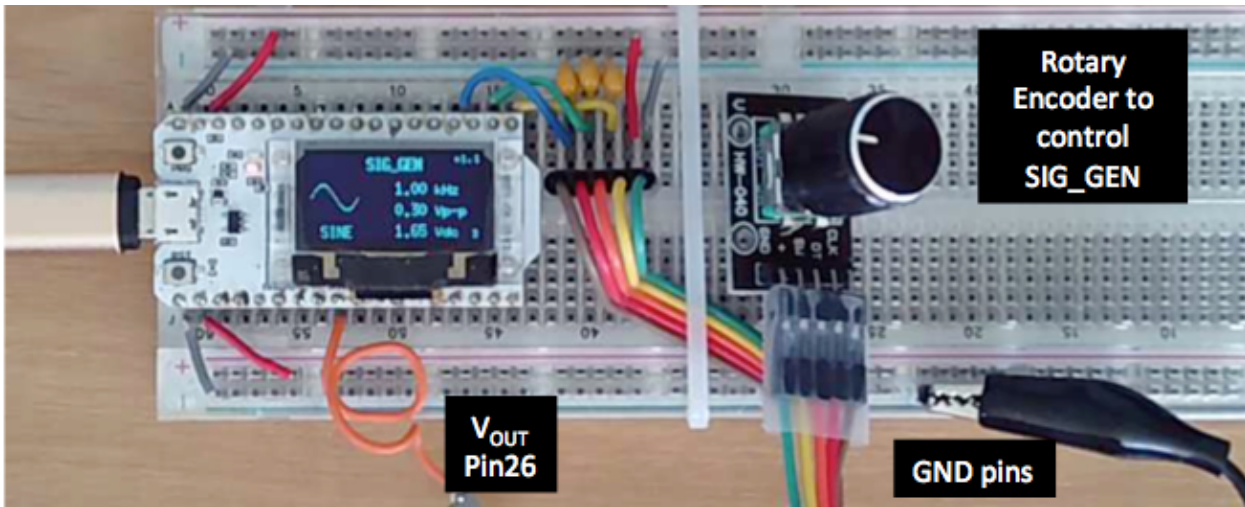
The Signal Generator (SIG_GEN) is implemented on the ESP32 module and is control using the rotary switch. Rotating the knob left or right select different signal types. Pressing the knob switches to parameter setting mode and an arrow will point to the relevant parameter. Rotation the knob again changes the parameters. Pressing the switch again moves to the next parameter etc. The following table shows the type of signals SIG_GEN can generate.

| Signal Type	Parameter 1	Parameter 2	Parameter 3
DC voltage source	**Voltage**: 0 to 3.3V		
AC voltage source	**Frequency**: 20 – 100kHz with ±5% accuracy	**Vpk-pk**: 0.4, 0.83,1.65, 3.3V (±10%)	**Offset**: 0 – 3.3V
Digital clock	**Frequency**: 20 – 100kHz		
PWM	**Frequency**: 20 – 100kHz	**Duty cycle**: 0 - 100%	
Noisy sine wave	**Frequency**: 20 – 100kHz	Duty cycle: 0 - 100%	
Exponential	**Frequency**: 0 – 100Hz	**Time-constant**: 0 to 50% of period	
UART	**Baudrate**: 600, 1200, 2400, 9600, 19200, 115200	**Parity**: None, Odd, Even	**Message**: '#', 'ABC', '0123', 'Hello!'
Unknown Test Signal	**Test number**: 1 - 6		

Task 2: Setting up the Oscilloscope

1. Connect the 9V power socket on the Digital Storage Oscilloscope (DSO) to a 5V USB power source using the supplied 5V to 9V up converting cable. The power source can be a USB port on your laptop, a power pack (as shown in diagram below) or a USB charging adaptor (e.g. your phone charger).
2. Attach the supplied scope probe to the BNC connector.
3. Clip the probe onto the 1kHz signal source next to the BNC connector onto the small hole in the metal tab.

Specifications:

- Maximum real-time sampling rate: 1 MSa/s
- Analog bandwidth: 0 - 200 KHz
- Sensitivity range: 5 ndash 20 mV/div
- Maximum input voltage: 50 Vpk (1X probe)
- Input impedance: 1M ohms/20pF
- Accuracy: 12 bits
- Record length: 1024 points
- Coupling modes: DC / AC / GND
- Time Base Range: 500s/Div ndash 10us / Div
- Trigger modes: Auto, normal, and single
- Trigger position: Center of buffer
- Supply voltage: DC 9 V (8 ndash 10 V)
- Current consumption: ~120 mA @ 9 V
- Main board size: 94 x 65 mm (3.7 x 2.56 in)
- Analog board size: 65 x 47 mm (2.56 x 1.85 in)
- Screen size: 52 x 40 mm (2 x 1.57 in)
- Package size: 14.5 x 10 x 3.7 cm (5.7 x 3.94 x 1.45 in)
- Package weight: 179 grams (6.33 oz)

Task 3: Understanding the DSO display
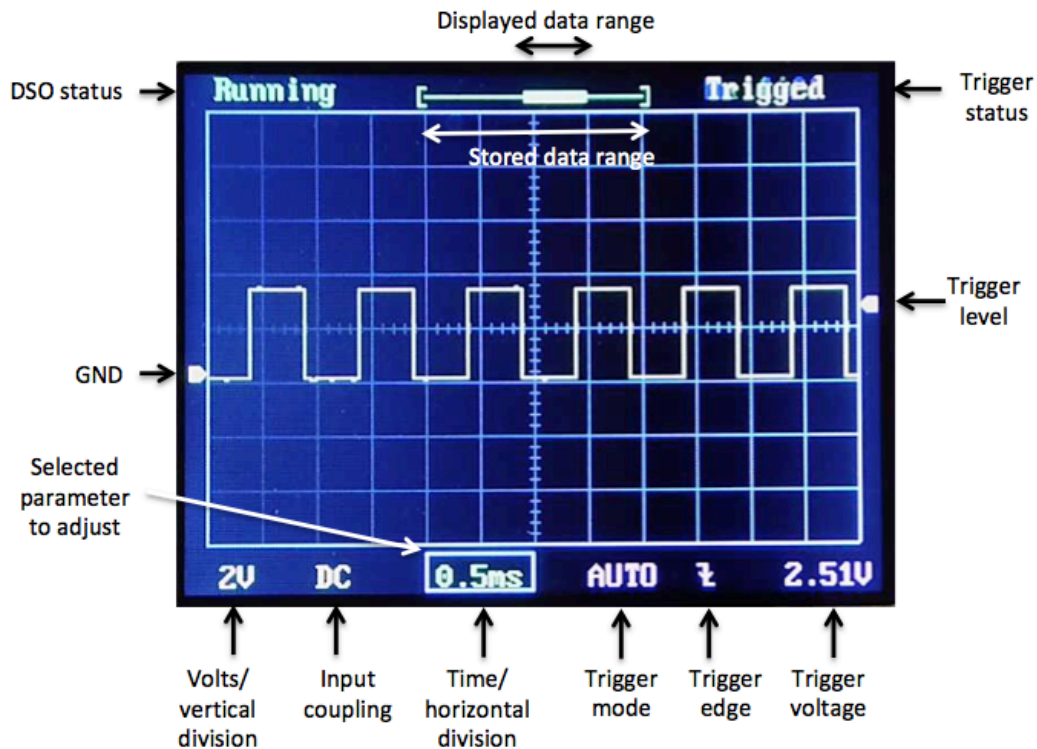
The display of the DSO contains lots of information about the waveform that it is measuring. The grid allows you to read off the length in the x axis (time) and the y axis (voltage).

LEFT:
- **Status** of the DSO - 1) "Running", meaning that the displayed waveform is constantly refreshed, or 2) "Hold", meaning that the waveform is capture, stored and displayed, but not being refreshed. You can toggle between the two (run or hold) by pressing the OK button.
- **Arrow** - It indicates where 0V or GND level is on the Y axis.

BOTTOM (left to right):
- **Voltage scale** – volts per division of the vertical grid.
- **Input coupling** – this can be GND (i.e. connect input to ground), DC (i.e. connect in directly to scope), or AC (i.e. connect input to scope through a capacitor, to measure voltage changes around the mean or dc level).
- **Timebase** – time per horizontal division.
- **Trigger mode** (to be explained later) – this can be AUTO, NORMAL or SINGLE.
- **Trigger edge** (to be explained later) – this can be rising or falling edge.
- **Trigger level** (to be explained later) – the voltage level at which trigger occurs.

RIGHT:
- **Trigger status** – this can be "Triggered" or "Waiting".
- **Arrow** - It indicates the trigger voltage on Y axis.

TOP:
- **Capture data range** - It shows the entire capture data range of 1024 data points.
- **Displayed data range** - It shows the window of the data currently displayed.

Base on the displayed information describe the characteristic of the waveform being shown in the diagram above (i.e. amplitude, voltages, period and frequency).

Task 4: Controlling the DSO with the buttons and the rotary switch

Make sure that the probe is hooked onto the internally generated 1kHz signal, which you can find at the top edge of the DSO. The sliding switch is in the middle position (DC).
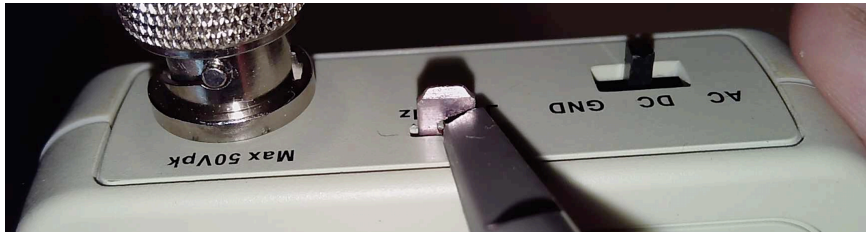
- Press the left-most button V/DIV. You will see the 2V parameter highlighted with a rectangle: 2V. Turn the ADJ knob slowly changes this parameter to different values between 5mV/div to 20V/div and the displayed waveform will stretch or shrink in the vertical direction accordingly. Now go back to 2V/div, and press the V/DIV button again. The highlight rectangle will disappear. Now turn the knob again. Describes what happens and thus record how you can adjust the vertical scaling and position. Why is this useful?

- Press the SEC/DIV button, and turn the ADJ knob. See how the waveform is expanded and compressed in time. This is known as adjusting the **timebase** of the oscilloscope. The time scaling can be 10 microsecond (us) to 500 sec per division. Discover for yourself what happens when the timebase is slower than 20ms per division.

- Return the timebase to 0.5ms/div, and press the SEC/DIV button again. Now turn the ADJ knob. What happens next? Why is this useful?

- Switch the top sliding switch to AC position. What happens? Why is this useful?

Triggering on an oscilloscope is a procedure that results in a steady waveform being displayed. When trigger is achieved, the captured and displayed waveform always starts at exactly the same signal voltage (called the **trigger voltage level**, or trigger level for short). For a repetitive signal, the waveform shown appears static. If trigger is not achieved, the waveform will appear moving.

- To achieve trigger, first you press TRIGGER and turn the ADJ know to select AUTO mode. This simply means that the scope will automatically display a waveform no matter whether trigger is achieved or not. This is the simplest mode since you will always see something on the scope.
- Next you press TRIGGER a second time and turn ADJ knob to change the trigger level. The trigger level is displayed on the bottom right and indicated by the right arrow on the Y axis. Try this yourself. What happens the trigger level is outside the signal voltage range?
- Press TRIGGER a third time to select the trigger edge. Now turn the knob carefully and observe and explain what happens.

There are two other modes: NORMAL mode will NOT display a waveform unless trigger is achieved. SINGLE mode captures and display the signal once only. The OK button toggles between HOLD and RUNNING mode while in SINGLE mode. We will NOT explore these two modes at the moment.

Discuss among your team on the concept of trigger in an oscilloscope to make sure that you fully understand what it is and how to achieve trigger.

Task 5: Measure DC voltage

- On SIG_GEN select DC voltage source. Adjust the output voltage to 2.5V. Measure this with both the multimeter and the oscilloscope, and comment on the accuracy of your measurement.
- Change the voltage to some other value and repeat this again to make sure that your can use either method effectively.

Task 6: Measure sine wave signal

- Select SINE wave and adjust the frequency to 2.5kHz, Vpk-pk to 1.65V and offset (i.e. Vdc) to 1.65V. Now measure the maximum and minimum voltages and the frequency of the sine wave using your DSO. Record and explain any discrepancies.
- Now measure the signal again using the multimeter (both ac and dc measurements). Comment and explain your results.
- Adjust the frequency to 100kHz and repeat the measurements.

Task 7: Measure PWM signal

- Select PWM signal and adjust the frequency to 8kHz and duty cycle to 40%.
- Use the scope to measure the period of the waveform and the duty cycle to confirm that they agree with the SIG_GEN settings.
- Use the multimeter and measure the dc voltage of this signal. Explain the results.

Task 8: Measure Exponential signal

- Select Exponential signal and adjust the frequency to 50Hz. Adjust the time constant to 1ms. Explain how you can measure and confirm that the time constant is indeed 1ms on the rising and the fall part of the waveform.
- Explore other frequencies and time constants.

Task 9: UART signal

- Select UART signal. Adjust the baudrate to 9600, even parity and the message '#' character. Observe the signal using the scope and explain what you see.
- Change the parity to NONE and ODD, and explain what happens.
- Change the message to 'ABC', and record the waveform.

Task 10: Test yourself on the unknown signals

- Select unknown test signal. For each of the tests (numbered 1 to 6), use the scope and/or multimeter, measure the signal and record the characteristic for each of them
- You may check your answer by looking up the answer table on the course webpage.
- Your set of unknown signals may be very different from those of your teammates. How can that be? Each ESP32 module has a unique ID. Base on this ID, SIG_GEN derives a number between 1 to 5 for your particular ESP32 module. Each will have a different set of unknown test signals.