Equipment Demonstration

Overview

In this activity, you will learn to use the standard lab equipment used for analog and digital computer development, including the **function generator**, **oscilloscope**, **power supply**, and **digital multimeter**. You will be able to practice with the equipment in the lab before demonstrating its use and submitting your report. The estimated time for the demonstration is approx. 5 minutes.

Learning Objectives

Upon successful completion of this lab, students should know how to…

- Manually use a function generator, oscilloscope, power supply, and multimeter for testing;
- Debug hardware problems through test-driven troubleshooting; and
- Interface with test equipment through a computer to collect data.

Specification

After learning to use the equipment, you will need to 1) complete exercises in the document and submit a report; and 2) demonstrate its use during lab hours before the due date. Note that if many people show up on the same day to demonstrate, you may have to wait – and may not be able to complete it on time as a result! There **will not be special consideration given** to demonstrations delayed due to capacity issues in the days of and just before the due date.

This demonstration will be completed in two steps.

Wave Generation & Display

Generate a 1kHz, +/-1V peak square wave with a +100mV offset using the function generator. Display the resulting waveform on the oscilloscope by adjusting position, scale, and trigger settings until displayed waveform is not drifting and at least two full periods are on-screen. Trigger on the rising edge of the waveform. The full positive and negative peaks of the waveform should be visible.

Voltage Test

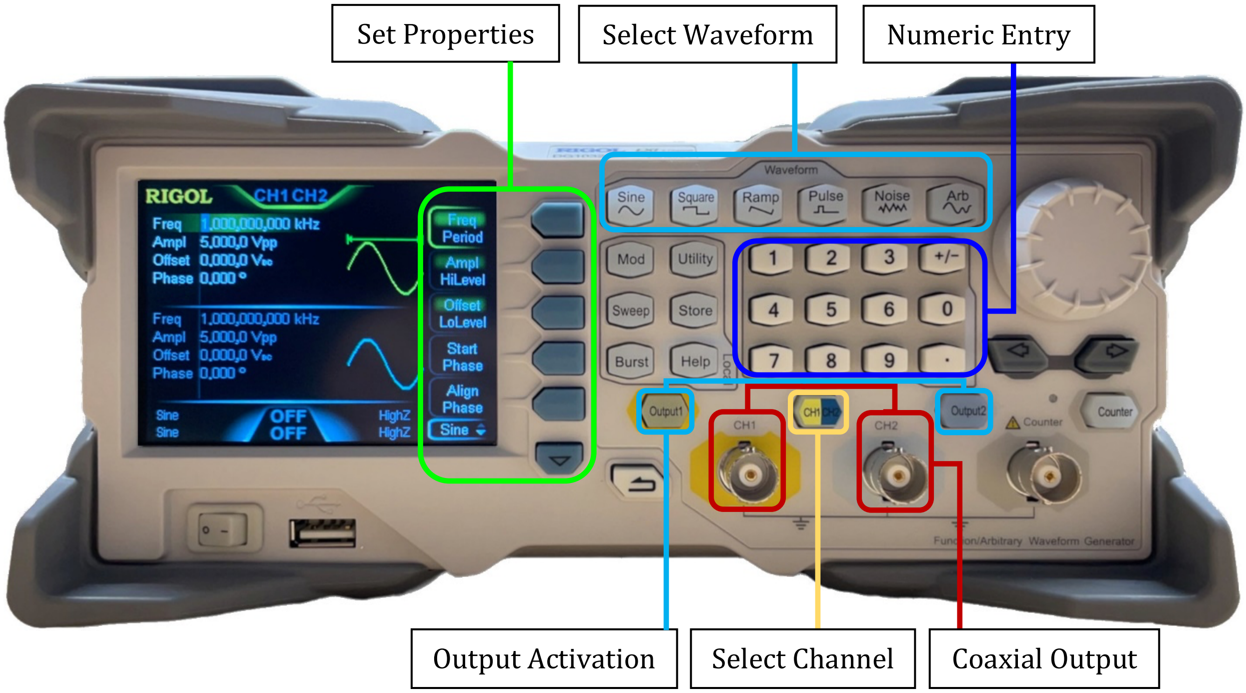
Using the +5V max channel of the power supply, determine the voltage needed to supply 100mA of current to a 10Ω resistor. Verify by placing the digital multimeter (in current meter mode) in series with the resistor and power supply set to the correct voltage. Set the power supply current limit to 50mA and turn up the voltage. Show that current through the resistor does not exceed 50mA.

Equipment

This section describes the equipment in the lab, what it does, and how to use it.

Function Generator

The **function generator** is typically used to generate periodic (AC) waveforms and arbitrary waveforms (noise). It can be used to generate input signals for testing frequency-dependent circuits (e.g., filters or amplifiers) and clock signals for digital circuits. [Manual] [Programming]

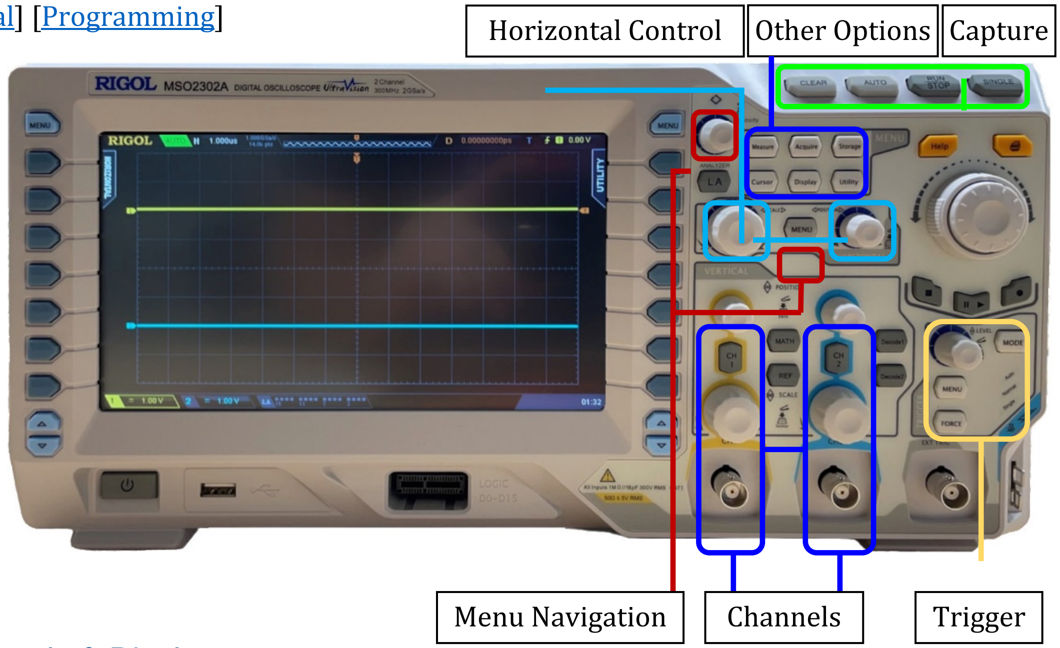


Users can select a ***waveform*** (e.g., sine, square, and ramp) and set ***amplitude***, ***frequency***, ***period***, ***phase***, and ***offset***. This model can set up two outputs; we can connect a coaxial cable for each.

The probe shown on the right is the typical way of connecting the function generator outputs to the test circuit. Attach the BNC connector (coaxial cable connector) to the instrument, the black alligator clip to the circuit ground, and the red alligator clip to the circuit input.

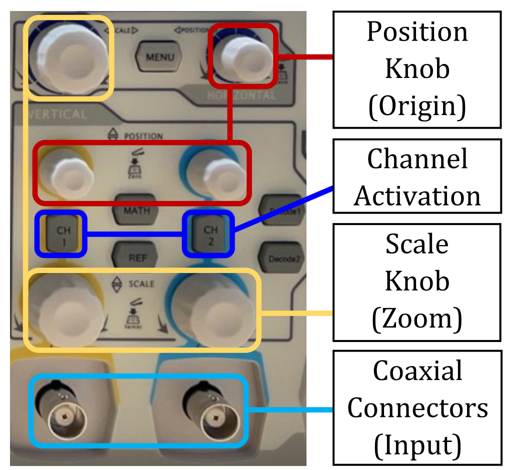
Oscilloscope

The **oscilloscope** can measure periodic (AC) waveforms (e.g., from an oscillator, filter, or digital protocol such as I2C or SPI). Features include triggering, scaling, positioning, and coupling. [Manual] [Programming]



Channels & Display

The channels share the ***horizontal*** scale / position (time) but have their own ***vertical*** scale / position (amplitude). The ***position*** defines an offset (move graph origin), while ***scale*** lets us to zoom in / out.

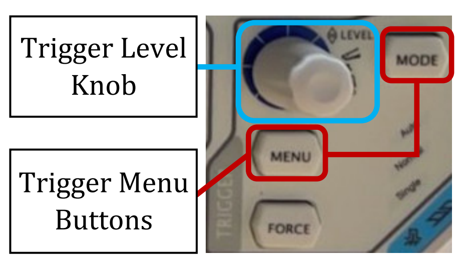


As with the waveform generator, the coaxial connectors are used to connect our devices. However, unlike the waveform generator, which produces output, the oscilloscope channel connectors accept input that will be displayed on the oscilloscope. Like the waveform generator, we can active or deactivate each of our channels.

Capture Controls

There are two main ways to capture waveforms – via a ***single*** snapshot and via a ***run*** and ***stop***. Run continuously records the waveform, and on stop, displays the last recorded section. By comparison, in single mode, a single recording is taken on a trigger, and then recording is stopped. The user can also ***clear*** the recorded data, and the display can be ***auto***-formatted from the capture controls.

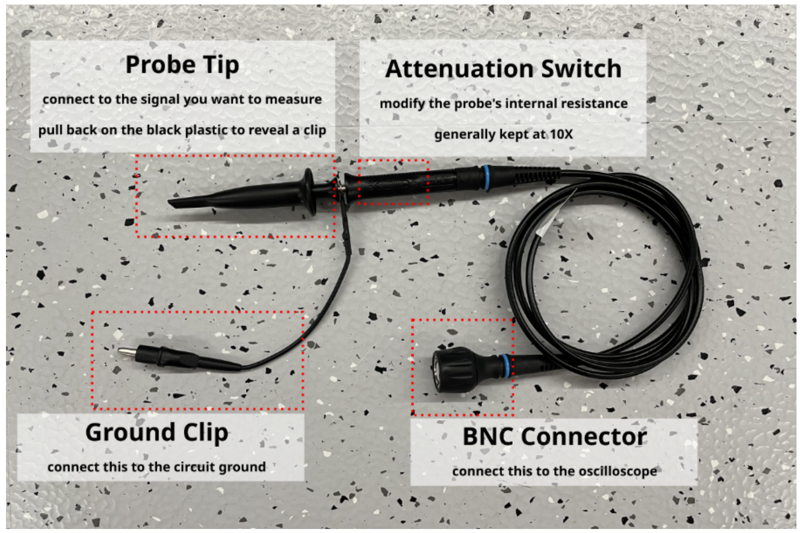
The trigger can be set by using the menu and mode buttons, and the trigger threshold can be set with the trigger knob.



Math & Special Operations

The oscilloscope also has built-in functions that can be performed on recorded data via the ***math*** button – e.g., Fast Fourier Transforms (FFTs). There are also additional options / menus for adjusting waveform capture.

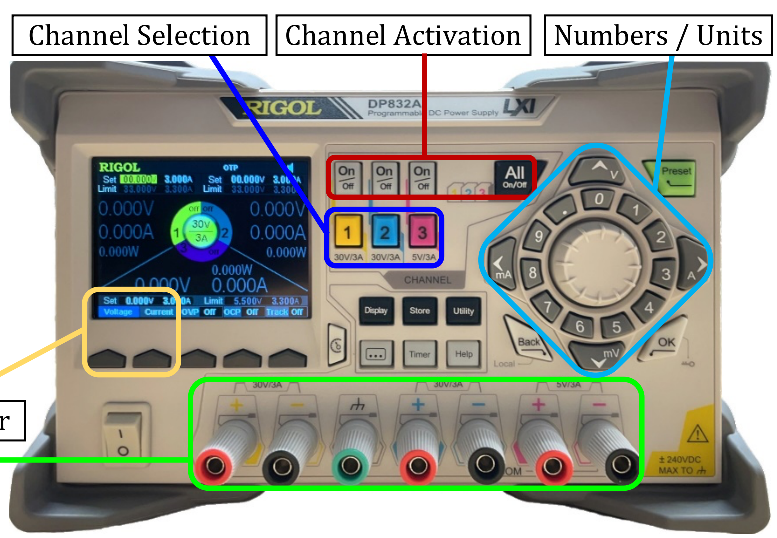
Oscilloscope Probe



The oscilloscope probe is the proper tool to use to connect to the circuit being measured. The **tip** is used to connect to the measurement point on the circuit, and the **ground clip** is used to reference the circuit ground. The **attenuation switch** modifies the internal resistance of the probe, and in general is kept in the 10x position (meaning the voltage fed into the instrument is reduced by a factor of 10 from the true value by virtue of a voltage divider). This is used to increase the impedance of the probe to minimize its effect on the operation of the circuit. The **channel ratio** must be setup properly for the probe you are using. Find this in the channel 1 and 2 menus on the scope.

Power Supply

The **power supply** provides DC power (voltage or current) to a circuit. It allows the user to set the voltage / current output and limit the voltage output/current. It can be used to supply DC voltage (e.g., a 5V supply for a chip, or an input voltage to test a voltage regulator). [Manual] [Programming]

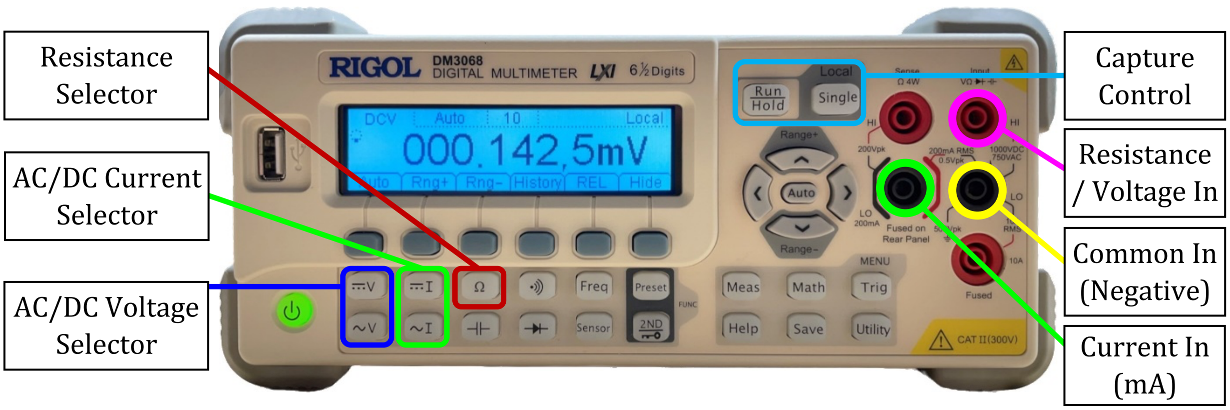


The power supply has three channels – one with a max of 5V, and two at 30V – with all up to 3A. Each channel has a selection button (to make it the current channel), terminal outputs (for voltage / current out), and an activation button (on / off). There is also a button to turn all channels on / off. There is also a "true ground" (chassis ground), but this should only be used when floating / relative voltage is not sufficient for the application.

To set a constant voltage or current for the selected channel, choose "Voltage" or "Current" from the on-screen menu. Once selected, use the numeric pad to enter the value, and select the units using the "units" buttons. You can return to the previous digit using the "Back" button or reset the units using the "OK" button.

Digital Multimeter

The **digital multimeter** will measure steady-state values in a circuit (e.g., resistance, voltage, and current). It continually measures these values with high precision. [Manual] [Programming]



While the multimeter is generally only useful for checking the steady-state values, this model does have the ability to measure operating point of a circuit (power supply voltage/current) or resistance/continuity between two points (e.g., verifying output of a voltage regulator, checking for shorts between different traces on a printed circuit board before operation, or checking continuity on traces that are supposed to be connected.)

The images to the right show the typical cables used with the multimeter and power supply. The left image shows simple banana-to-alligator leads. Use them to connect power and ground from the power supply to the test circuit. The image on the right shows the multimeter test probes. Use them to accurately probe a test point (and ground point) on the circuit being measured.

Remote Control

Electrical test equipment has historically included a means of control through an external interface. One of the first implementations of this technique was by HP in the 1960s – today known as the GPIB (General Purpose Interface Bus). Over time, engineers designed what is now known as the Standard Commands for Programable Instrumentation (SCPI) protocol. The equipment in the lab supports this protocol through more modern electrical interfaces such as USB, TCP/IP, and RS-232 (serial).

Learning to interface with the equipment programmatically is a valuable tool for designing and executing test setups. Take time to acquaint yourself with the SPCI syntax, and practice communicating with equipment over the interfaces. The Oscilloscope Programming Guide contains a detailed introduction to the SCPI syntax. Consider this command to query system time via SCPI:

```
user@host-name ~/s/equipment_demo> echo ":SYST:TIME?" | nc -w1 10.245.26.231 5555
    15,51,49
```

Figure 1: Example of sending an SCPI command using netcat from a bash shell.

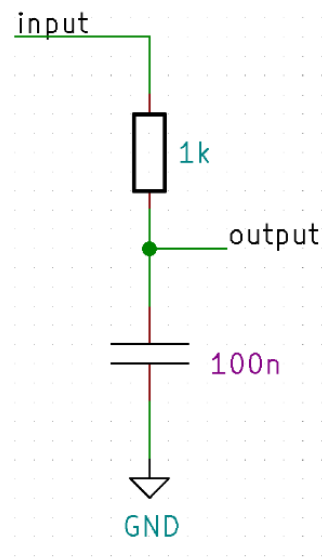
We can consult the product manual to learn how to find the IP address of our instruments (which must be connected to the network!). For example, the MSO2302A Oscilloscope's IP address can be through the **Utility → LAN set** button sequence. Stations on the west side of the lab have function generators and oscilloscopes connected to the LAN for student use.

Report

Students should complete these exercise prompts in their reports.

1. *Warm-up:* Explain the terms **volts per div** and **time per div** as applied to an oscilloscope. Where are they indicated on the scope's display?
2. *Warm-up:* You are designing a class-D audio amplifier that needs a bipolar, +-12V DC power supply for the MOSFETs, as well as a 5V DC supply to power to logic circuitry. Make a labelled diagram showing how this could be done with power supplies available in our lab.
3. *Scenario:* Carsten received a synth PCB he designed by mail. He assembled the board and baked it in the reflow oven. He plugged it in and... pop! The power supply was reversed. ***Oops!***
    a. Briefly describe how a programmable power supply and other equipment could detect which component(s) were damaged with minimal risk (**hint**: faulty components get hot).
    b. With your help, Carsten was able to find and replace the broken parts. He can program his microcontroller, but the SPI interfaced DAC isn't working as he thinks it should. Briefly describe a technique he could use to debug the circuit.
4. You are a test engineer for a drone manufacturer. The flight-ops team describes incidents where drones crash after an aggressive flight maneuver. You think the high motor load during maneuvers is causing the microcontroller to brown out. How could you test this hypothesis?

5. Construct this simple, passive low-pass filter on a breadboard.
    a. Calculate the theoretical cutoff frequency of this filter; Show your calculations.
    b. Write a Python script to collect data on the frequency response of the filter. Starting below the cutoff frequency and ending above, use SCPI to iterate the function generator through a series of frequencies and acquire the attenuation from the oscilloscope. Capture at least 32 data points. Save the data in a file and use **matplotlib** to create a Bode plot for the circuit with labelled axes, a title, and a marker of the experimental cutoff frequency.
    c. Manually measure the resistor and capacitor using the multimeter and use the values to recalculate the cutoff frequency. Does this match the frequency from the Bode plot? If not, what might account for discrepancies?



Submission

Your submission will consist of the following elements:

- In-lab demonstration of your test-equipment knowledge.
- Report in **PDF format** submitted on Canvas, containing your answers to the prompts. Please use the provided report template.
- Python code as a **.py file** submitted on Canvas.