Lab 3: Oscilloscope and Signal Generator Automation

Reference Reading: N/A

Time: Two lab periods will be devoted to this lab.

Goals:

1. Become familiar with the Linux operating system.
2. Gain more experience programming in Python.
3. Become familiar with using a computer to control the operation of both the DG1022Z and DS1074Z.
4. Understand the importance of documenting measurements and the use of measurement files to accomplish this.

Expectations:

1. All sections of code should be clearly commented. These comments need to indicate the purpose of the section of code as well as the methods used.
2. All data tables need to be clearly labeled. Labels must include units and descriptive names. Appropriate precision should be used for all displayed data.
3. Where it makes sense, you are expected to make plots of your data. For frequency-response measurements, these are typically a Bode plot and a phase-difference plot.
4. On Bode plots, you should clearly identify the -3 dB point as well as measure the roll off of your data. (We will work on how to do this as part of the lab.)
5. If it is possible to compare your measurements with an expectation or a prediction, you are expected to do so.
6. Write your own measurement files that can be used as input for computer control of the oscilloscope and function generator.

3.1 Introduction

This lab is designed to help you gain familiarity with using a computer to control the function generator and the oscilloscope you will be using throughout the semester. When measuring the frequency response of an electronic component, you often have to make the same measurement repeatedly using slightly different settings each time. This can be very tedious and is ripe for human error (Did I remember to change the frequency? Did I change that to 3 kHz or 3 MHz? Is the measurement I just recorded for channel 1 or channel 2? etc.). When you have made 20 of these types of measurements it can be very hard to determine if you slipped up along the way and all of your data is off by one point. Automation is the solution to this potential problem. Developing a set of files that will control both the function generator and oscilloscope will provide a record of just what inputs were used and what measurements were made. It does not guarantee that you have made the measurements that you planned, only that you have a record of what measurements were made.

Both the DG1022Z and DS1104Z have USB ports on the back (Figure 1) and can communicate with a computer using simple text commands. We will not use all of the commands available for these devices. They can be found in the manuals available on Black Board and in the classroom. The types of measurements that you will make in this lab activity are no different from the ones that you have already made; they will just be made automatically and the results stored in a text file for later analysis.

Figure 1 Back of the DS1104Z and the DG1022Z. You can see the USB port on each instrument.

3.2 Equipment and Parts

In this lab we will utilize the following equipment. This equipment is located at your lab station.

1 A Rigol DS1054Z digital oscilloscope.
2 Two probes for the oscilloscope.
3 A Rigol DG1022Z signal generator.
4 One BNC-to-alligator clip cable for the signal generator.
5 A digital multi meter.
6 A proto-board
7 Two USB cables
8 One laptop with Unbuntu 22.04 installed

You will also need the following components in order to carry out this lab.

1 One resistor: 4.7 kΩ.
2 Four precision 10 kΩ resistors.
3 Five precision 20 kΩ resistors.

3.3 Procedure.

3.3.1 The Linux Operating System

The computer that we will be using in lab are older model PC’s that have Ubuntu 22.04 installed as the operating system. This is a public domain Linux system. The username for your computer is given on the label on the computer. It will be “engr2447-x”, where x is one of a-e. The password for each of the machines is “spring2024”. You should plan on using your own cloud storage or a thumb drive to store your work. You will note when you log in, that you are in a windows-like environment. You can point and click on apps to run them. There is a launch icon (the icon of 3x3 squares) down in the bottom left of the screen that will show you all of the apps installed. Feel free to explore and see what is available.

The Terminal Window

To control the equipment, we will be using a terminal window to move around in the file system and to launch any control programs. You can open a new terminal window using the icon on the Favorites bar located on the left side of the screen. Left clicking the icon once will bring up one new window. Clicking twice will bring up two. Table 3.1 shows a few common commands. You should run them and get comfortable with moving around in the file structure.

Command	**Result**
ls	provides a content list of the current folder
ls -a	list all files even hidden ones
ls -al	list all files with information on each one
cd *directory*	move into directory
mv *filename new.filename*	Change the name of a file to *new.filename*
mv *filename new.directory/finename*	Can also be used to move a file from one directory to another
rm *filename*	delete a file
clear	clear the screen on the terminal
pwd	returns the current path, where you are in the file structure
man *command*	return the manual page for *command*
jupyter notebook	starts an instance of Jupyter Notebook in the current directory

Table 1 Some simple commands to get you started in Linux.

To practice working with this new system, complete the following commands.

1 Open a terminal window by clicking on the icon on the left of the screen.
2 In the terminal window do the following:
   a) Use the "cd" command to move into the Documents folder.
   b) Use "ls" to get a list of the files and folders in Documents. What do you see?
   c) Use the command "mkdir *stuff*" to create a folder called stuff in the Documents folder.
   d) Move into your "stuff" folder.
3 Using the app launch icon, start the text editor app.
   a) Create a new file (name it what you want to) and put the following in it.
   b) Today's date on the first line.
   c) Your name on the second.
   d) Your major on the third.
   e) Save this file in the stuff folder.
4 Move back to the terminal window…Run "ls", what do you see?
5 In the Text Editor
   a) Create another file in the stuff folder using the text editor.
   b) Name this file ".secretstuff.txt".
   c) Put what you want for your birthday in this file and save it.

6 Move back to the terminal window
   a) Run “ls” in the stuff folder. What do you see?
   b) Run “ls -a”, what do you see now.
   c) Run “cd ~”. This will take you back to your home folder. The ~ is a shortcut for the path to your home folder.

You will want to use some method of backing up your work. The computer at your station is yours to use for the entire semester, however, should there be a problem you want to make sure the you lose as little work as possible. I would suggest either using a thumb drive or your UCA Google Drive as a backup. You will be able to drag and drop files in to either backup.

Jupyter Notebooks

We will use Jupyter Notebooks as the platform for our data acquisition automation. A Jupyter Notebook is a web-based interactive platform for working with code, data analysis, and reporting. The notebooks that we will be running will be able to evaluate and run Python code interactively. You can set these notebooks up to use other platforms for computation and analysis such as: MATLAB, Octave, Wolfram (Mathematica), and many others. We will work through a sample notebook (*Rigol_lab.ipynb*) that uses Python to control the function generator and oscilloscope. Download that files from Black Board and place it in the *Lab_03* folder on your computer.

Geany IDE

You also have access to the Geany IDE app. Using the launch window select the magic lamp icon to launch. You can use this app to create code in python by itself. I will personally go back and forth between the two depending on what I am doing. Geany will provide you with color coded text that is very helpful when developing code. You can run programs inside Geany for debugging as well. You should use what you are most comfortable with.

3.3.2 Controlling the DG1022Z or DS1104Z

Both of the DG1022Z and DS1104Z can be controlled via USB or internet connections. There are text commands corresponding to every combination of front panel button pushes. There are two PDF files available in Blackboard (one for each instrument) that provide the full list of possible commands. There are also printed copies of each on the shelf with the scopes and function generators. We will not need to use all of the commands this semester. The example file provided shows how the commands and queries are used. You will need to be able to modify this file to complete the measurements for this lab. Commands are sent to the two instruments by writing text to the USB ports and data from the instruments is read from these ports. All of the information exchanged with the instruments is in the form of strings. When you query the scope to determine the time scale of a measurement, the result that comes back is a string that represents the number. We will discuss how to use this data in class.

3.3.3 Data Collection

As part of Lab 2, you made Bode plots for two measurements. The comparison of DC and AC coupling and the frequency response of the R2R ladder. This involved determining the frequency values to use, pushing buttons on the function generator, and rescaling the front panel of the oscilloscope over and over again. These are the types of processes that are perfect for automation. The balance of this lab will deal with automating that process.

You have already looked at the file *Lab-03-notebook.ipynb* (because you completed the pre-lab activity). This file automates a set of measurements, plotting the results. Copy this file into a new folder for Lab03 (it is always better to work with a copy of a file that you intend to edit).

Modify the new file to reproduce the Bode plot of the frequency response of the R-2R ladder from 2.4.6 of Lab 02. This was the activity comparing the AC and DC coupling responses. Things to consider for this when editing this file:

1. How can you monitor and adjust the horizontal scale to make the most accurate measurements given the frequency of the output signal?
2. How can you monitor and adjust the vertical scale to make the most accurate measurements possible given the amplitude of the output signal?
3. How can you control the timing of your measurements to make sure you are measuring the event you are interested in?
4. How should you format your output?

Use your work on the previous measurement as the starting point to develop a measurement file for the frequency response of the R-2R ladder from Lab 02. Since we are going to automate the process, we will also increase the number of frequencies that we measure. For this measurement record 10 points per frequency decade. The DG1022Z function generator will be the source, $v_{in}(\omega)$, for the R-2R ladder circuit as shown in Figure 2.

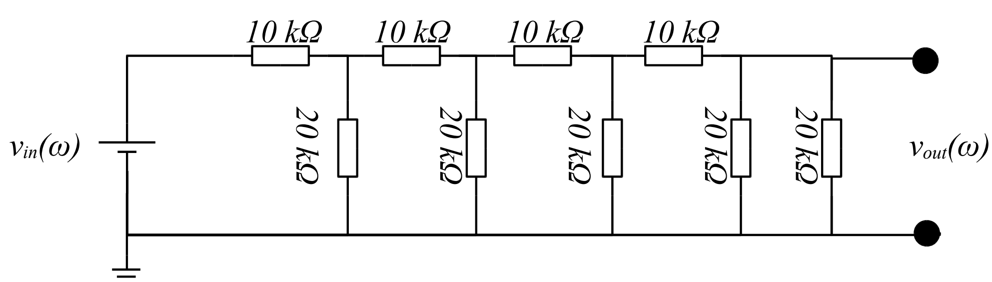

Figure 2 An R-2R resistor ladder.

1. Set the function generator to have a 10V peak-to-peak sine wave with zero offset voltage (check with the function generator to be sure the offset is set to zero). Set the initial frequency to 1kHz and make sure the output mode is set to High Z. *This should all be set through the notebook file that you create for this lab.*
2. Connect the output of the DG1022Z to the input of the ladder circuit.

3. Connect the channel 1 probe of the oscilloscope across the output if the R-2R ladder as shown as $v_{out}(\omega)$ in the circuit.
4. Connect the channel 2 probe of the oscilloscope across the input of the R-2R ladder circuit. We will use this second probe to verify that the observed frequency dependence is not a result of variations in the output of the DG1022Z. With channel 2 connected at the input, this signal will be useful as the trigger source.
5. Be sure that both input channels are set to DC coupling. Also, the black alligator clips of the scope probes must be connected to the black alligator clip from the signal generator.
6. Measure the amplitude of the input and output voltages (either peak-to-peak or RMS, just note which one you are doing in your log book) as a function of frequency over the range 1 Hz to 3MHz. Take data at ten points per decade[1]. There is no reason to start at 1kHz and then work your way up and down. Start your measurements at 1Hz and go up to 3MHz. Save all of your data to a file using commas between the data points.
7. Using the output voltage that you measured at f = 1kHz as your reference voltage, make a Bode plot of the measured frequency response data. In particular, this is a semi-log plot of $20dB\log_{10}[v(f)/v(1kHz)]$ (vertical axis) plotted against the frequency, f (horizontal axis). The vertical axis is referred to as a "decibel" or "dB" scale—it is a standard in electronics.
8. From your Bode plot, determine the -3 dB frequency. Also (if you have sufficient data range which you should) determine the rate of fall-off of the frequency response in dB/decade (this is called the "roll-off" rate).

We would now like to study the difference between the "times 1" and "times 10" setting of the oscilloscope probes. With everything setup as above, we will now switch to the "times 10" setting and repeat our Bode plot measurement. Create a new version of the notebook that you can use for this new measurement.

9. Set both scope probes to the "times 10" setting. Make the appropriate changes in the code to set the scope to use the "times 10" probes setting.
10. Collect sufficient data to repeat your Bode plot from above. From the plot, find the frequency of the -3 dB point and compare it with what you found above.
11. Look carefully at the information on the scope probe. In particular, record the resistance and capacitance for both the "times 1" and "times 10" settings.

[1] As discussed in the introduction to laboratory 2, take data so that when you make a plot with a logarithmic frequency scale the points are roughly equally spaced.