

## Lab Assignment: Simple pendulum

In this first introductory lab, you will

1. Learn to make measurements with the Analog Discovery on a simple physical system.
2. See the important step of calibration – converting a measured voltage to a physical value.
3. Learn how to create plots of experimental data.

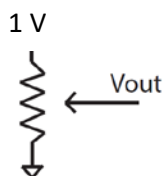
Mainly, this first week is a warm up to get you working with some of the equipment that you will be using all semester.

### Set up the Analog Discovery

First you will need to download and install the [WaveForms 2015](#) software from the Digilent website. The software should only take a few minutes to download and install. Once you have installed the software, plug your Analog Discovery hardware into your computer's USB port and the hardware should now be recognized. You may need to wait a few moments and possibly reboot your computer. Open the waveforms software and your device should show up automatically. On the main screen, select "Scope" on the left to open the oscilloscope. Press the run button. Since nothing is connected to the device input you should see zero volts displayed on the graph. We will explain how to read the scope screen in class, but in short the scope plots voltage versus time.

### Set up the experiment

Get one of the metal plates with the bearing and potentiometer attached. A potentiometer is a variable resistor (we will discuss resistors in the next class). There are three header pins sticking out from the side of the small yellow circuit board. These pins will connect to the potentiometer to build the following circuit (this schematic will make more sense next week):

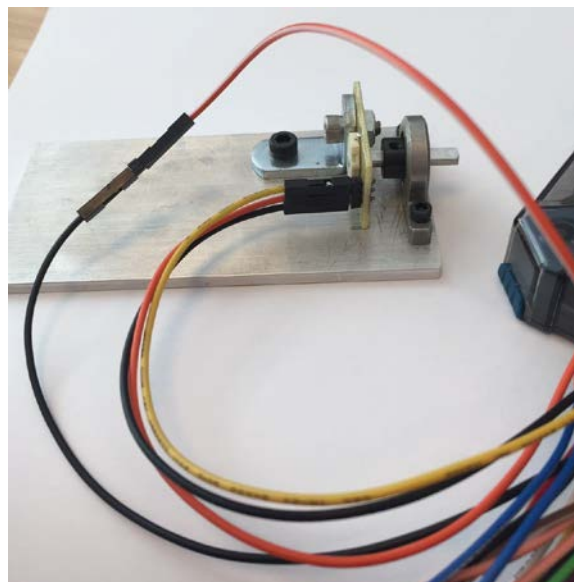


The potentiometer will act as two resistors in series. The total resistance across the potentiometer (measured from the 1 volt connection to ground) will always be 10,000 Ohms or 10K Ohms. The middle pin is connected between the two resistors in series which always sum to 10K. As you adjust the angle of the potentiometer, the balance between the resistors values change (due to the mechanical insides of the potentiometer). Since this is the first day of class, the previous paragraph likely made absolutely no sense to you. Hopefully after some reading and next week's class, you will go back to read this paragraph and it will make sense.

Look at the labels on the set of wires coming from the Analog Discovery. We will not use the majority of these wires in this course. The wires labeled 0 to 15 are digital lines that we will not use in this course. You will commonly use the two analog input channels to measure voltages – these are labeled as 1± and 2±. This notation means that channel one will measure the voltage **difference** between the 1+ and 1- labeled wires (orange and orange/white for channel 1 and blue and blue/white for channel 2). You will use the ground wires which are black and labeled with a downward pointing arrow.

For this lab and others, you will also need the yellow wire labeled W1. Go to the main waveforms screen, select the “welcome” tab on the left. Select “Wavegen”. We will use the “Wavegen” (Waveform generator) feature throughout the course as it allows us to create an arbitrary voltage, either constant or as a function of time. The voltage waveform has two outputs that you can control through the software on the yellow W1 and yellow/white W2 wires. For this lab, our waveform will be a constant 1 volt. In the “Wavegen” section of the software, change the “type” to “-----DC”. Set the offset to 1V and click the run button. This will output 1 Volt constant (DC) on the yellow wire (W1) relative to ground.

Now let’s connect the wires. Hook up the yellow W1 wire to the “top” of the potentiometer and one of the black ground wires to the bottom. Hook up the measurement for channel 1 positive input to the middle pin of the potentiometer (solid orange wire). Since channel one needs to measure a voltage difference you need to connect the negative input for channel one (orange/white wire) to one of the ground wires on the Analog Discovery. You can make the extra connection with an extra header pin. If you don’t connect the channel 1 negative input, you can get weird results since the voltage on this wire is floating. The basic setup is shown in the figure below.



On the welcome tab you are going to now open the “Scope”. Scope is short for oscilloscope, which is an instrument that allows us to measure voltage as a function of time. Once the scope opens, click the Run button at the top left. While watching the Scope screen, move the axle of the device around by hand. If everything is working, you should see the voltage change as you adjust the angle. The

voltage should vary between 0 and 1 volts. You will need to adjust the x and y axis settings. On the right of the Scope screen, turn off channel 2, adjust the time scale to be something like 1 second per division and the Channel 1 range to be 1 volt per division. We will explain how to adjust the settings and read the scope display in class.

### **Conduct the experiment**

Once you think everything is working, attach the pendulum to the output shaft. Before doing so, rotate the shaft so the **flat shaft edge is facing up** and then gently press the pendulum onto the shaft by hand. Use a bar clamp to hold the metal plate to your desk with the pendulum free to swing over the edge. Raise the angle and release the pendulum - you should see a signal which is proportional to the angle of the pendulum and over time should look like a damped sine wave. You may need to adjust the time scale per division on the Scope to see the pendulum come to rest.

Now you need to calibrate your pendulum. Note that the calibration will be sensitive to the initial angle of the shaft when you press on the pendulum - thus you will want to conduct all your experiments and record your data with the same physical setup. Decrease the time scale to something like 200 ms per division. Click on "view", select "measurements". Add a "defined measurement" of the average voltage for channel 1 ("average" is a vertical measurement). Take one of the protractors. Change the angle of the pendulum by hand and hold it stationary at a known angle. Record the voltage (use the value in the average display) as a function of angle - i.e. just write the numbers on a piece of paper. Take a measurement for every 20 degrees, obtaining data for angles plus and minus 80 degrees where zero degrees is defined as rest straight up and down (what direction is the positive angle is arbitrary). If you are ambitious you could collect more calibration data. This step of calibration is an important concept - we will usually need some way to connect the voltage that we measure to something physical (angle).

Now let's record the pendulum dynamics - angle as a function of time. Increase the time scale per division such that you can collect a cycle of raising the pendulum, releasing it, and watching it come to rest. Collect one such run on the scope and simply hit the "stop" button once the pendulum has stopped moving. Under file, click "export". Select the source as "scope". Save the file as a .csv file and set the location for the file somewhere logical (i.e. make a directory on your computer for this course with sub-directories such as Lab1, Lab2, etc). Name the file something that makes sense when you go back to it. **When you export the data, you should turn OFF, comments and headers, and turn ON labels.**

### **Make some plots**

Finally, let's create our figures. The first figure will be your calibration data - measured angle versus measured voltage plotted as data points. This data was recorded by hand and you will need to type in the results into MATLAB. An example is found on the course website.

You can now generate a calibration curve by hand using the functional form  $\theta = a(V - V_0)$  where  $V_0$  is the voltage measured when the pendulum angle is at rest (this should be around, but not exactly, 0.5 V). You can find the approximate slope of the line,  $a$ , by inspection of your plot. You can test your calibration curve by overlaying the experimental data and the best fit line. There are

formal ways to best fit a line through data, but for now you can just approximate by eye. Again, the example MATLAB commands to do this are on the website.

Next create the plot for your recorded pendulum dynamics. Please see the plotting examples on the ISIM website to see how to generate plots in MATLAB.

**Deliverables:**

The most frequent question we are asked is “what do I turn in”. In general, we will provide some guidance in the lab writeup of what is required, but you will also need to learn to use your best judgment and not rely on us to tell you exactly what to do as the semester goes on. You DO NOT need to write a lengthy lab reports each week. The lab reports focus on results. Each week, we will provide some guidance about what you need to include.

For this lab, you should include your calibration curve (angle versus  $V_{out}$ ) and your measured pendulum dynamics in terms of angle versus time. For this lab, since the data are so simple, you do not need to provide very much commentary on the results. One page with two figures and a figure caption should be sufficient for your first lab. The figure caption should briefly explain what the figure is showing. For the plots, don't forget to label your axis and provide units.