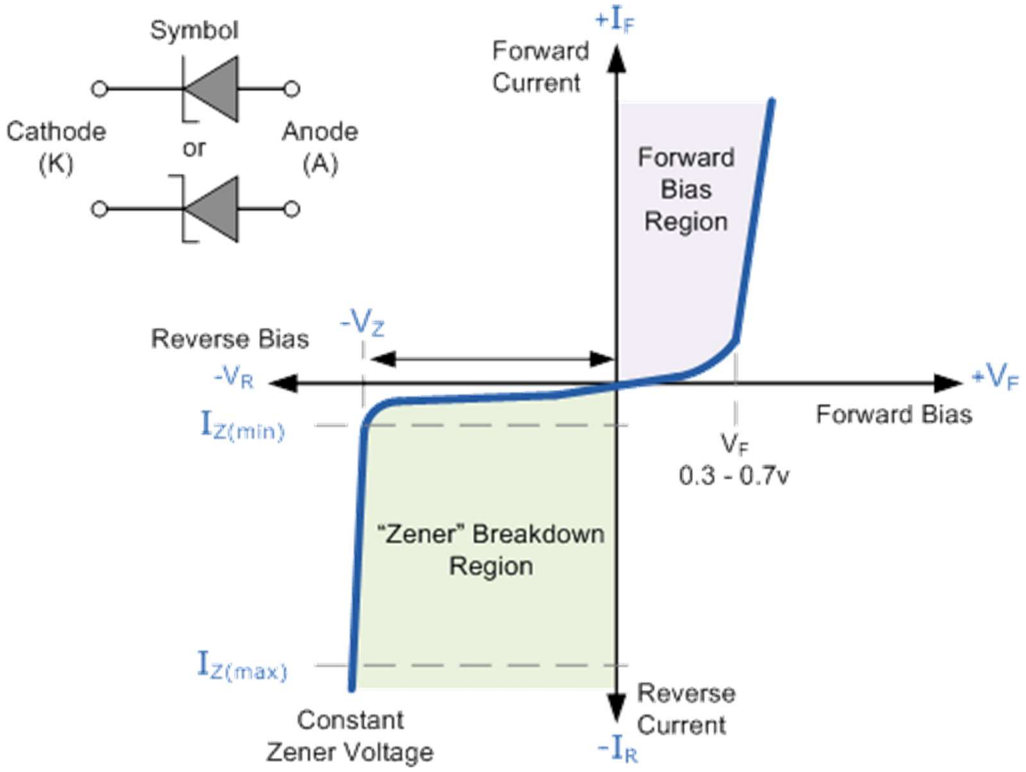
Lab 4: I-V Curve Plotter

Objective

In this lab, we are going to obtain the I-V characteristic (current vs voltage) curve of a resistor and two types of diodes, the 1N4148 small signal diode and the 3.3v zener diode.

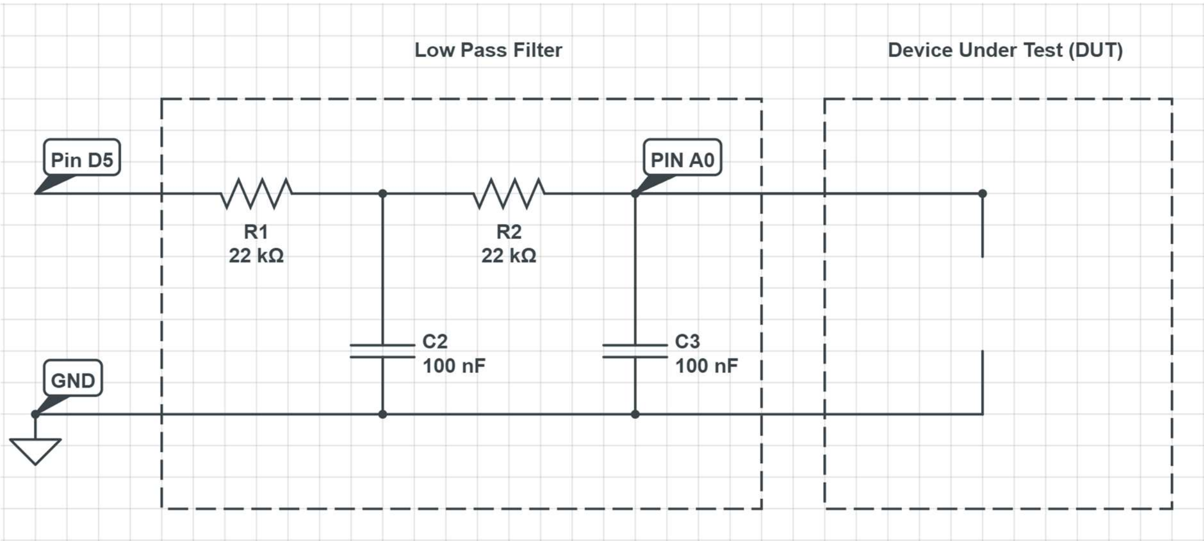


Source: WikiCommons

The I-V curve is a useful tool for engineers to predict the behavior of various components in a circuit. In the industry, these measurements are made with a source measurement unit (SMU), a device that can source a current through a device under test (DUT) to measure the voltage and current through the DUT. Professional SMU costs several ten thousand HKD, but we are going to build a simple one with an Arduino and a few passive components in this lab!

The Keithley 2400 SMU costs 62000 HKD brand new!   Source: Tektronix

Hardware Setup



The circuit consists of a low pass filter and a connection to the device under test (DUT). The DUT can be a resistor or a diode.

Arduino pin D5 is the signal source. Using the analogWrite(int) function with integer input ranging from 0 to 255, we can generate a PWM signal with duty cycle ranging from 0% to 100%.

The two 22k resistors and two 100nF capacitors form a 2nd order passive R-C low pass filter. We will not dive into the theory of how the filter works, but for the purpose of this lab, we can assume the following <u>when there is no DUT connected</u>:

$$Vout = Vin \times Duty\ Cycle\ (\%)$$

where:
Vout is a steady DC voltage present at the output, connected to pin A0.
Vin is the Arduino Nano nominal output voltage of 5V.
Duty Cycle is the Arduino Pin 5 PWM output duty cycle.

From the formula above, we see we can output a steady DC voltage ranging from 0V to 5V by adjusting the duty cycle.

Task 1

Build the circuit as described above and finish Task 1 of the code calculating vin in volts (V). Upload and run the program with the Serial Monitor open. The Serial Monitor should print the value of onPeriod and vin, the voltage measured by analog pin 0, with onPeriod sweeping from 0 to 255.

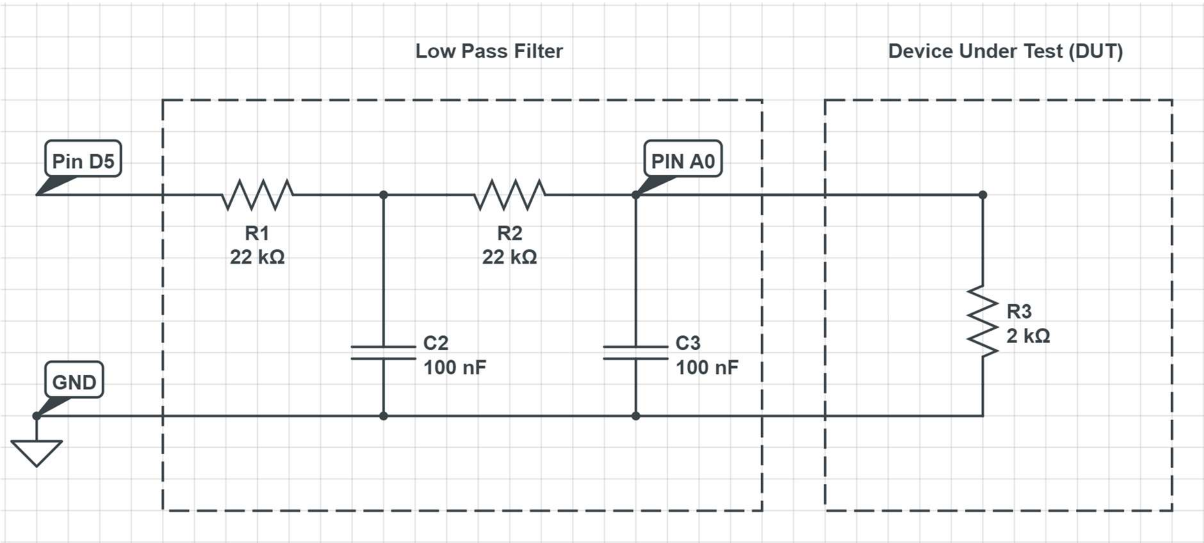
Copy and paste the values to a spreadsheet (Excel, Google Sheets etc.), and create a plot of onPeriod vs Vin.

What is the relationship of onPeriod vs Vin?

Paste the resulting graph here:

Task 2

Insert a 2k resistor into the DUT slot as follows:



Complete Task 2 in the Arduino program. Calculate the current in amps (A) flowing through the resistors and thus DUT by calculating the voltage drop across the two 22k resistors. You may follow these steps:

- Calculate the source voltage generated by PWM pin 5, given the PWM duty cycle, and the fact that Arduino outputs a nominal 5V PWM signal.
- Calculate, from the analogRead reading, the voltage present at pin A0, and thus the voltage drop across the two 22k resistors.
- Calculate the current flowing through the two 22k resistors, using the calculated voltage drop and ohm's law.

Run the program with the Serial Monitor open. Copy and paste the values to a spreadsheet (Excel, Google Sheets etc.), and create a plot of Vin vs current.

Paste the resulting graph here:

What is the slope of the graph?

Derive from Ohm’s Law the theoretical slope of the curve:

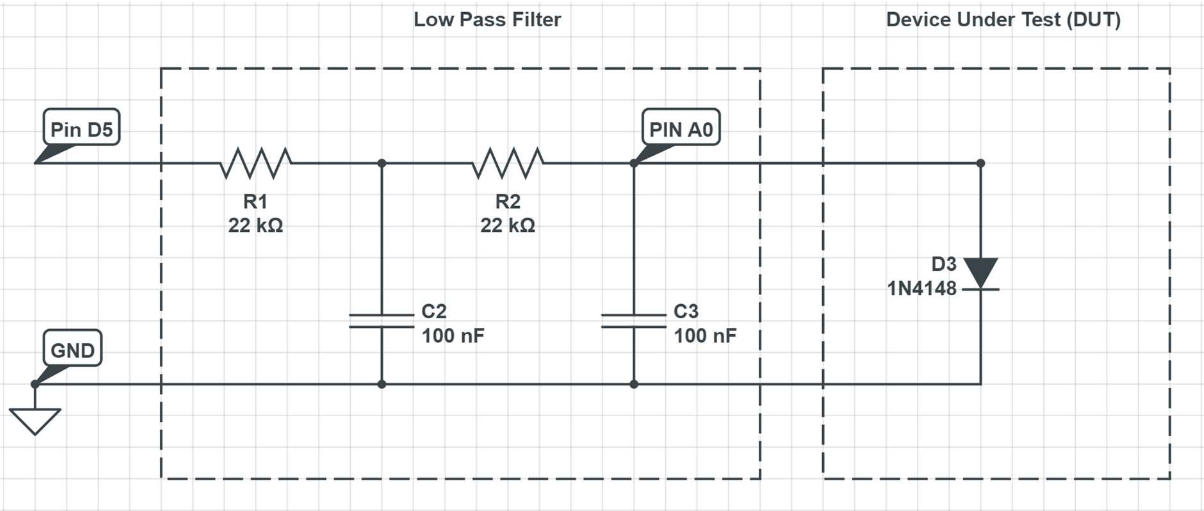
Does the theoretical slope value match the observed value exactly? Why?

Reverse the orientation of the resistor and repeat the test, paste the resulting graph here:

Does the graph change? Why?

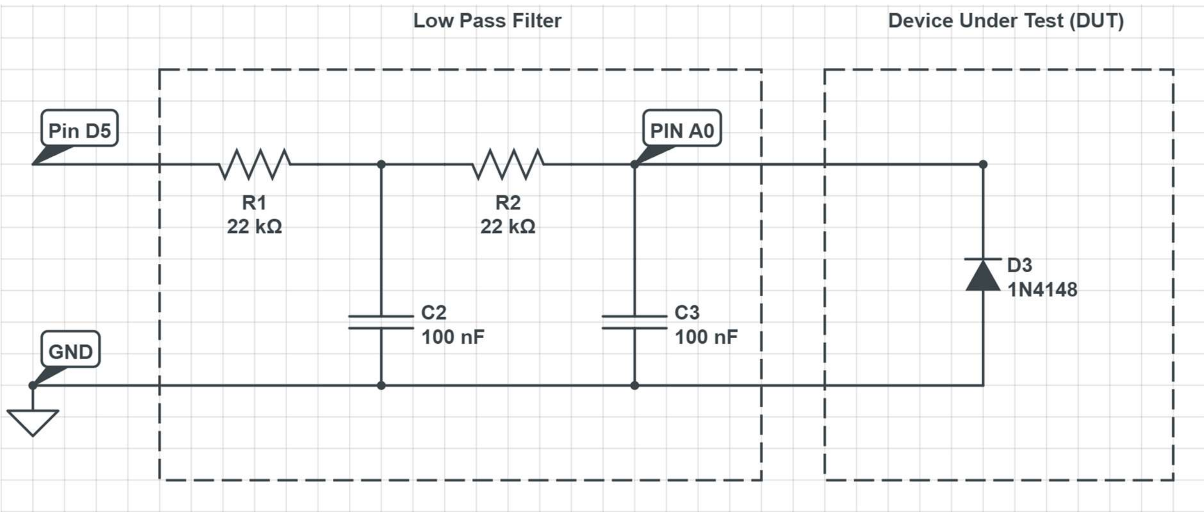
Task 3

Replace the 2k resistor with a 1N4148 diode as follows:



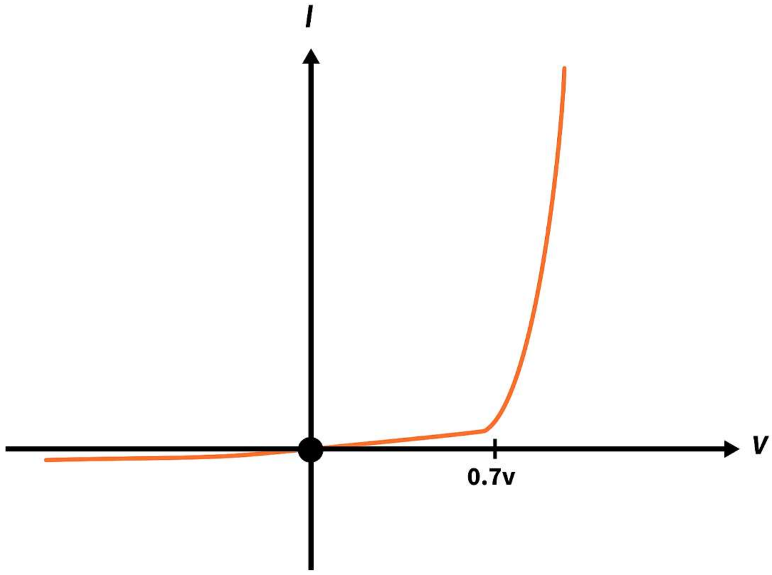
Run the Arduino program and collect the voltage vs current data. Copy and paste the data into a spreadsheet.

Re-run the test with the diode reverse biased:



Collect the voltage vs current data from the second test. Copy and paste the data into a spreadsheet. <u>The voltage and current data from this test should have a negative sign appended to it.</u>

Combine the data from both tests, and create an I-V characteristic graph of the 1N4148 diode. The graph should hold the following shape:

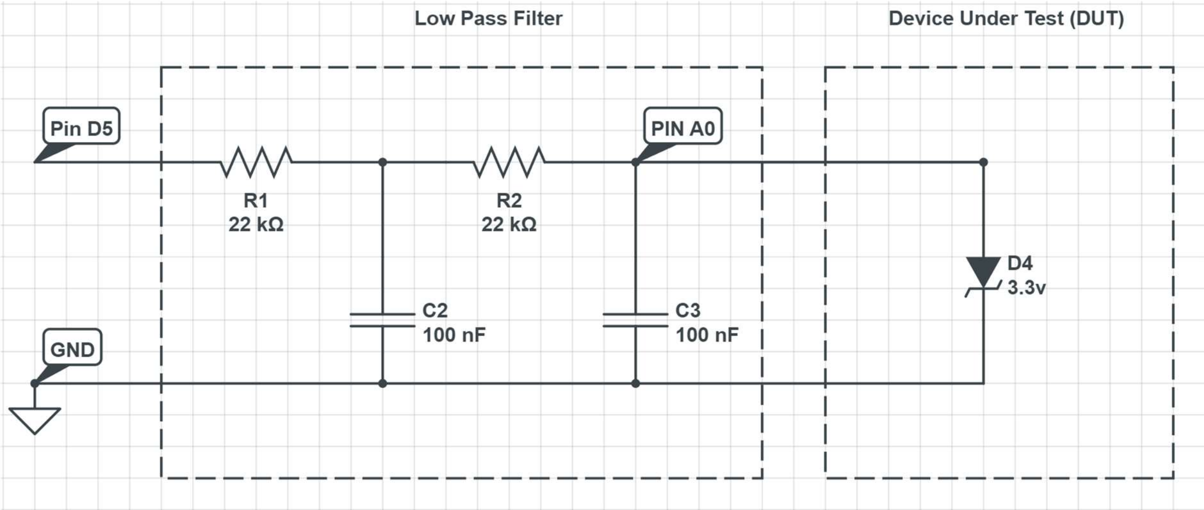


Source: Circuitbread

Paste your work here:

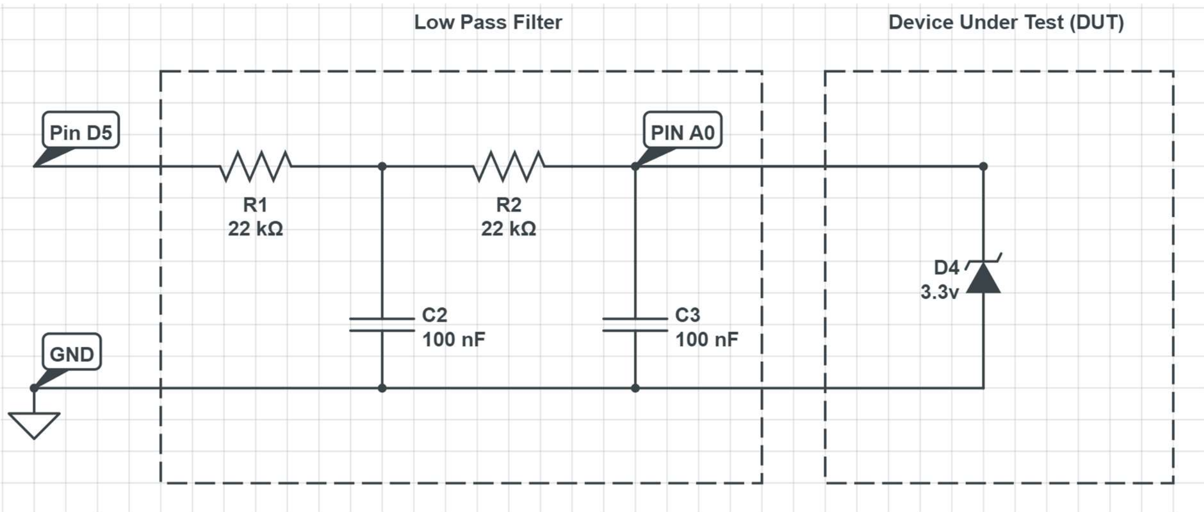
Task 4

Replace the 1N4148 diode with a 3.3v zener diode as follows:



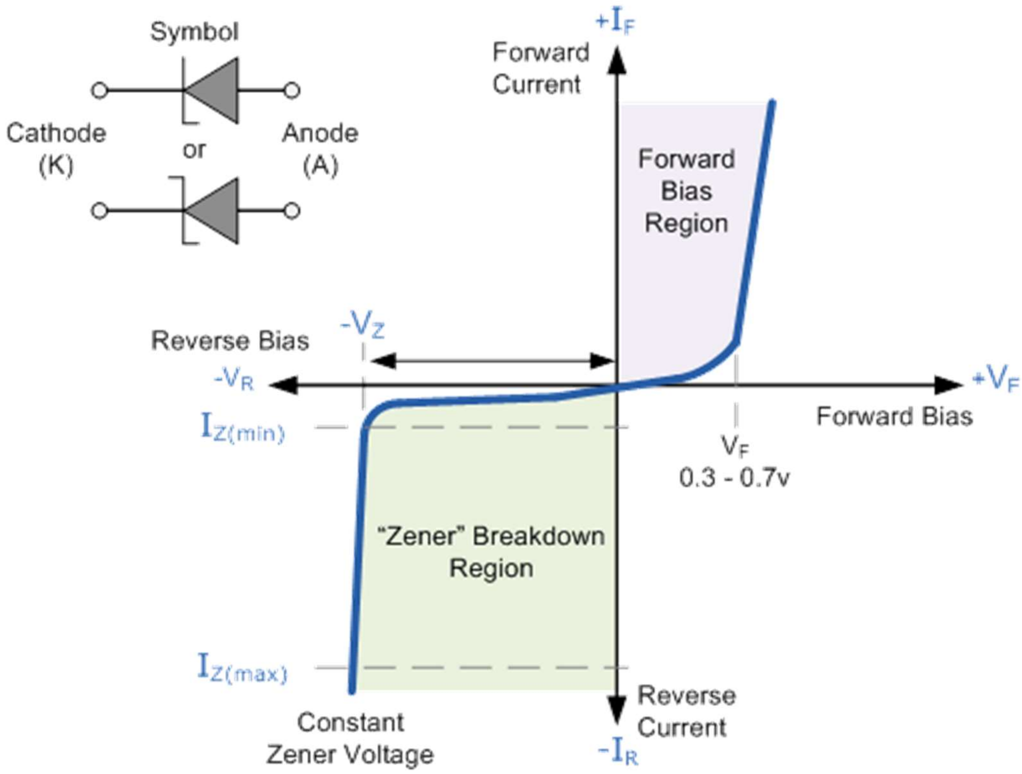
Run the Arduino program and collect the voltage vs current data. Copy and paste the data into a spreadsheet.

Re-run the test with the diode reverse biased:



Collect the voltage vs current data from the second test. Copy and paste the data into a spreadsheet. <u>The voltage and current data from this test should have a negative sign appended to it.</u>

Combine the data from both tests, and create an I-V characteristic graph of the 3.3v zener diode. The graph should hold the following shape:



Source: WikiCommons

Paste your work here: