print name (first last): ______________________

course: ECET 337 2025/07/27

Arduino PI Motor Speed Control
Optical Encoder Feedback

These procedures should be done by two students working together.

Performance Checks

			In lab or Late
_____	1.	Tuned PI Controlled System – Step Response	(55% or 28%)
_____	2.	Tuned PI Controlled System – Static Response	(45% or 23%)

There is NO lab report.

Lab Performance Scoresheet

Total→ (out of 100%) __________

There is NO lab report.

Objective

Control the speed of a small DC motor.

Approach and Results

1. Setup and Tuning the Proportional-Integral System

a. Carefully mate the interface circuitry with your Arduino.

b. Connect the motor, encoder, $+18V_{DC}$ wall wart, and USB cable to the Arduino-Interface.

c. Connect the oscilloscope to measure the speed as provided by the output of the **f-v** signal.

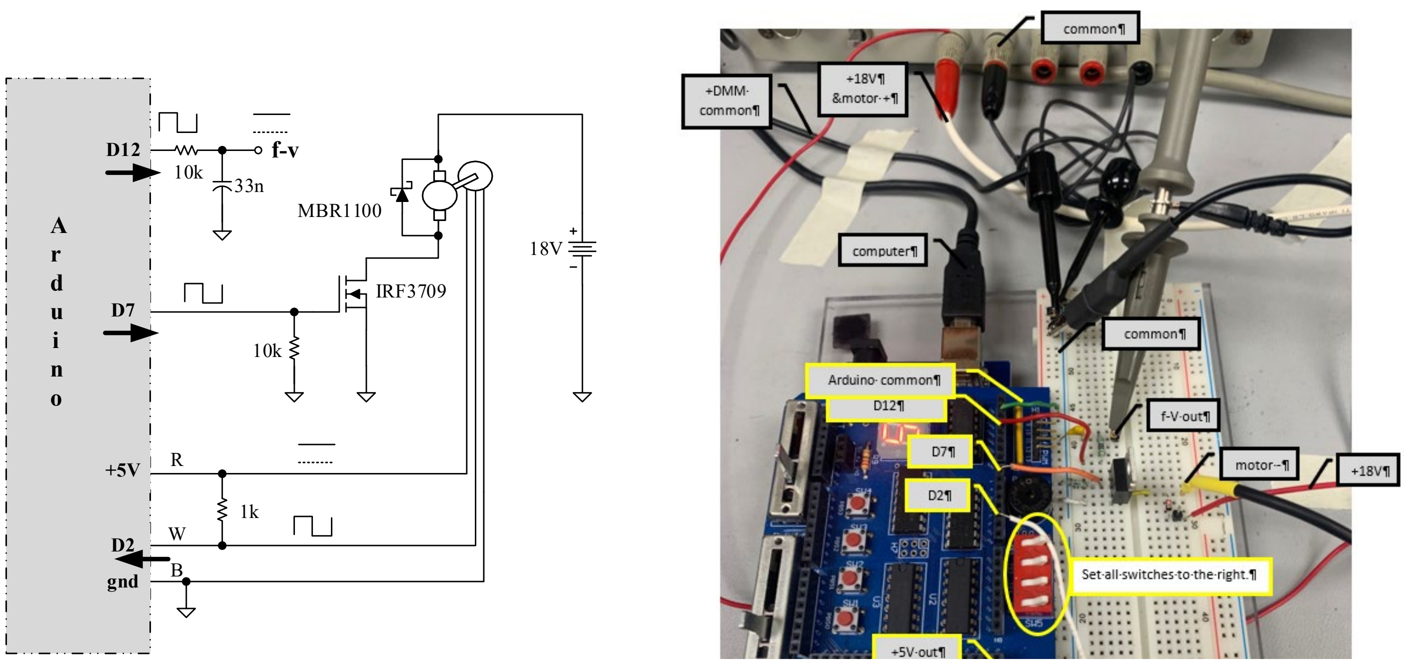


Figure 1 Hardware and instrument connections

d. Adjust the oscilloscope to place the trace one division up from the bottom, DC coupled, 1 V/div, 200 msec/div. Leave the triggering continuously running, *not* single sweep.

e. Load into your Arduino the Step Test sketch from the course site, Lab/14-Lab-Arduino PI Motor Speed Control module.

f. Leave the k_i at 0. Set $k_p = 2$.

g. Open the Serial Monitor. Verify that the system responds properly to adjustments in the A0 potentiometer from low to high. The speed should go from stopped or slow when the potentiometer is fully one direction to a steady faster speed when the potentiometer is turned fully the opposite direction. The Serial Monitor should indicate SP (25 or 75), PV and CO all in %.

h. Verify that this proportional control system is stable, but has a lot of residual error when the SP is stepped from 25% to 75%.

Residual error at SP=25% = _________

Residual error at SP=75% = _________

Capture this oscilloscope display of PV going up then back down, to show to the instructor.

i. The damping for the closed loop PI control of a first order system is

$$\xi = \frac{1 + mk_p}{2\sqrt{mk_i\tau}}$$

Calibration of the system to express SP, PV, and CO in % makes $m = 1$. Solve the above equation for k_i.

k_i = ________________________ an equation

j. Solve this equation for critical damping.

k_i = _____________ a number

k. Set k_i to the value that produces critical damping.

l. Enter these values for k_p and k_i into the controller of the *simulation*. Run a transient response simulation. If necessary, repeatedly alter the *integral* constant, k_i, until the system shows the correct response to a step in SP. Capture this display.

m. Once you have verified controller constants from the simulation, enter these values into the Arduino. Verify that the hardware functions as the simulation predicted. Adjust your simulation and/or hardware and code as necessary.

n. Without changing k_p, cut k_i to ¼ of its value above. Run the simulation and the hardware and capture this display.

o. Without changing k_p, increase k_i * 4 of its value in step **j**. Run the simulation and the hardware and capture this display.

p. Return k_i to its value in step **j**, and verify that the simulation and the hardware still run optimally.

q. Without changing k_i, double k_p from its value in step **m**. Run the simulation and the hardware and capture this display.

r. Without changing k_i, halve k_p from its value in step **m**. Run the simulation and the hardware and capture this display.

s. Return k_i and k_p to the values in step **m** (critically damped $k_p = 1$). Run the system to verify that it is a critically damped system with little residual error and SP=25% and SP=75%.

t. Residual error at SP=25% = __________

u. Residual error at SP=75% = __________

Demonstrate the circuit's performance, displays, and the data to your lab instructor.

2. Static Test

a. Change the program so that the SP is set by A(0), and can be varied from 0% to 100%. Verify that k_P and k_i are the values in step m above.

b. Adjust the SP potentiometer to 0, then upload that program to your Arduino.

c. Carefully adjust the set point to each of the values in Table 1, and record all data once the system stabilizes.

Table 1 Tuned motor controller system static test

Set point, SP %	Process Variable, PV %	Controller output, CO %
10		
30		
50		
70		
90		

c. Make a plot with SP on the *x* axis and with two lines, PV and CO. Properly scale and label the plot. Should both lines be linear? Is it important that each line is linear? Why or why not?

d. Add a trend line for each line. What should the slope and offset of the PV vs SP line be? What is causing deviation from this ideal performance?

Demonstrate the circuit's performance, displays, and the data to your lab instructor

3. Changes to the System

a. Adjust SP = 50%. Allow the system to stabilize and record PV. $PV_{motor\ 1}$ = _____

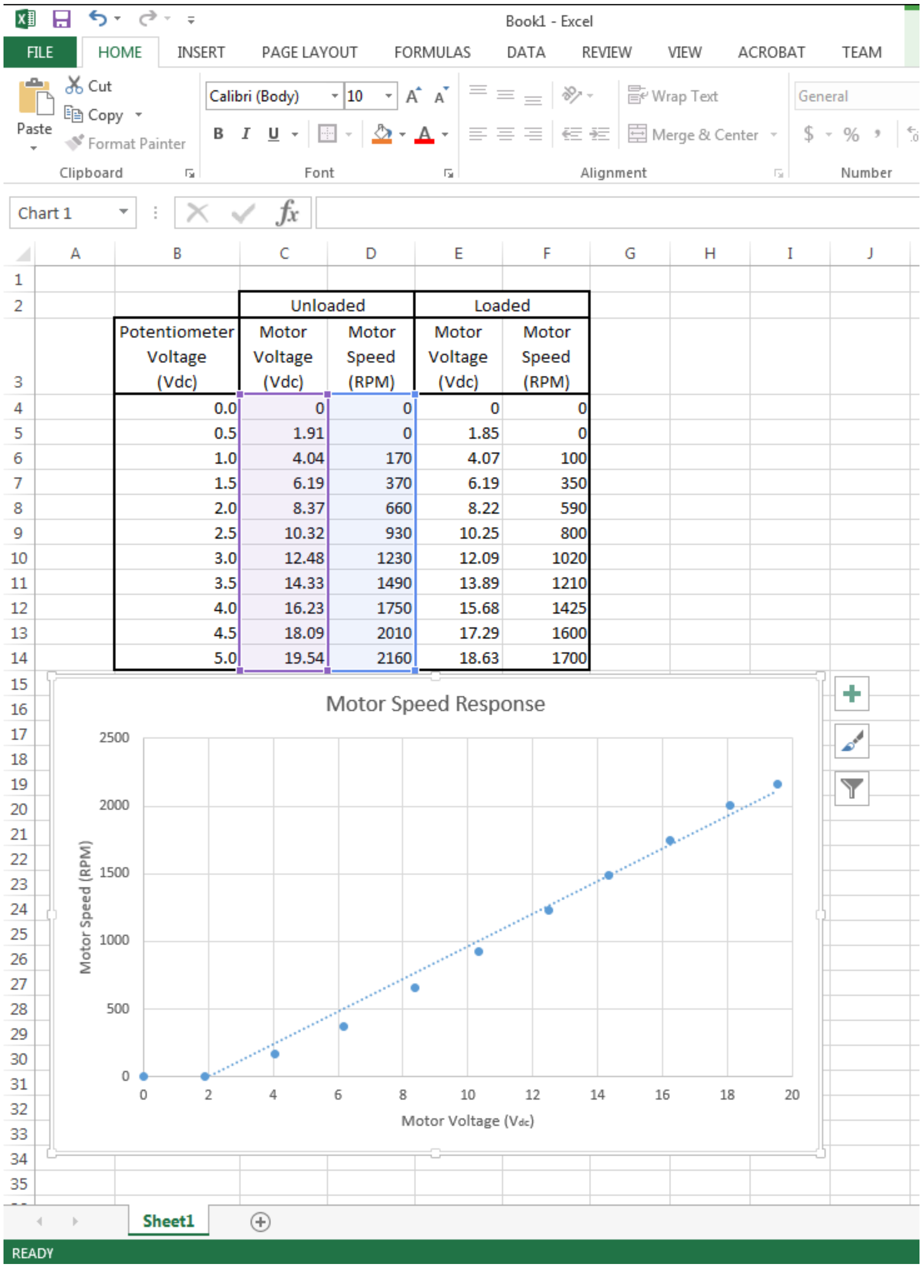
b. Replace *your* motor with a different motor. Without changing k_i or k_p run the system at SP = 50% for the new motor. $PV_{motor\ 2}$ = ________

c. Reload the Step Test software and set k_p and k_i to the values used in step **2.m.** Capture and save a *single* oscilloscope sweep showing the system's step response as SP is stepped from 25% to 75% and back to 25% for this new motor.

Adding a Second Plot to Excel

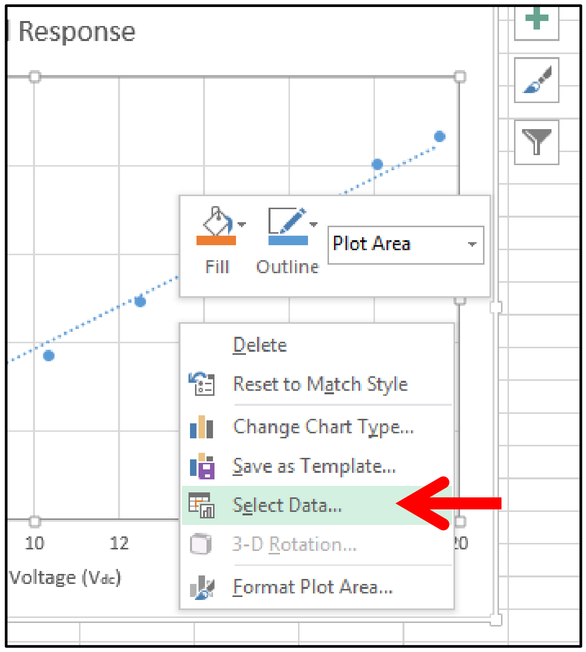
Nathan Soller

1. Create a table containing your collected data.
2. Create a plot for the first set of data.

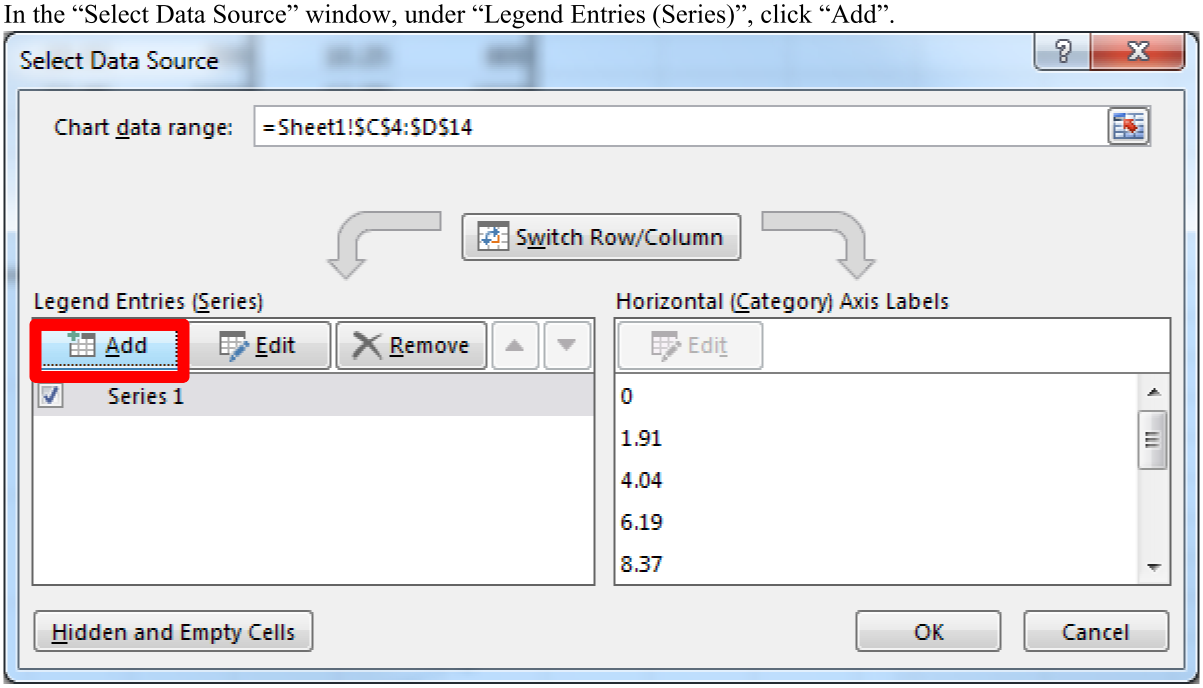


	Unloaded		Loaded	
Potentiometer Voltage (Vdc)	Motor Voltage (Vdc)	Motor Speed (RPM)	Motor Voltage (Vdc)	Motor Speed (RPM)
0.0	0	0	0	0
0.5	1.91	0	1.85	0
1.0	4.04	170	4.07	100
1.5	6.19	370	6.19	350
2.0	8.37	660	8.22	590
2.5	10.32	930	10.25	800
3.0	12.48	1230	12.09	1020
3.5	14.33	1490	13.89	1210
4.0	16.23	1750	15.68	1425
4.5	18.09	2010	17.29	1600
5.0	19.54	2160	18.63	1700

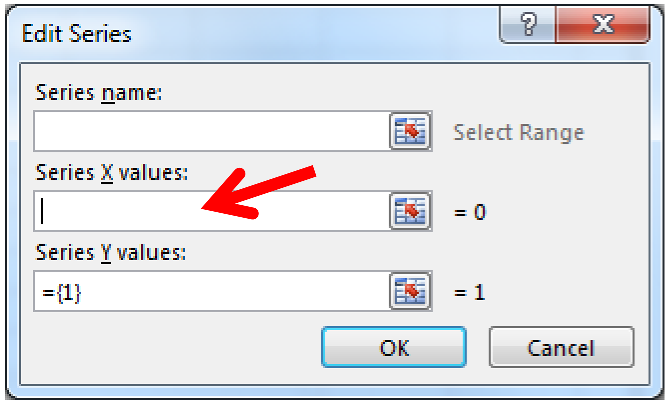
3. Right-click anywhere on the plot, and click “Select Data”.



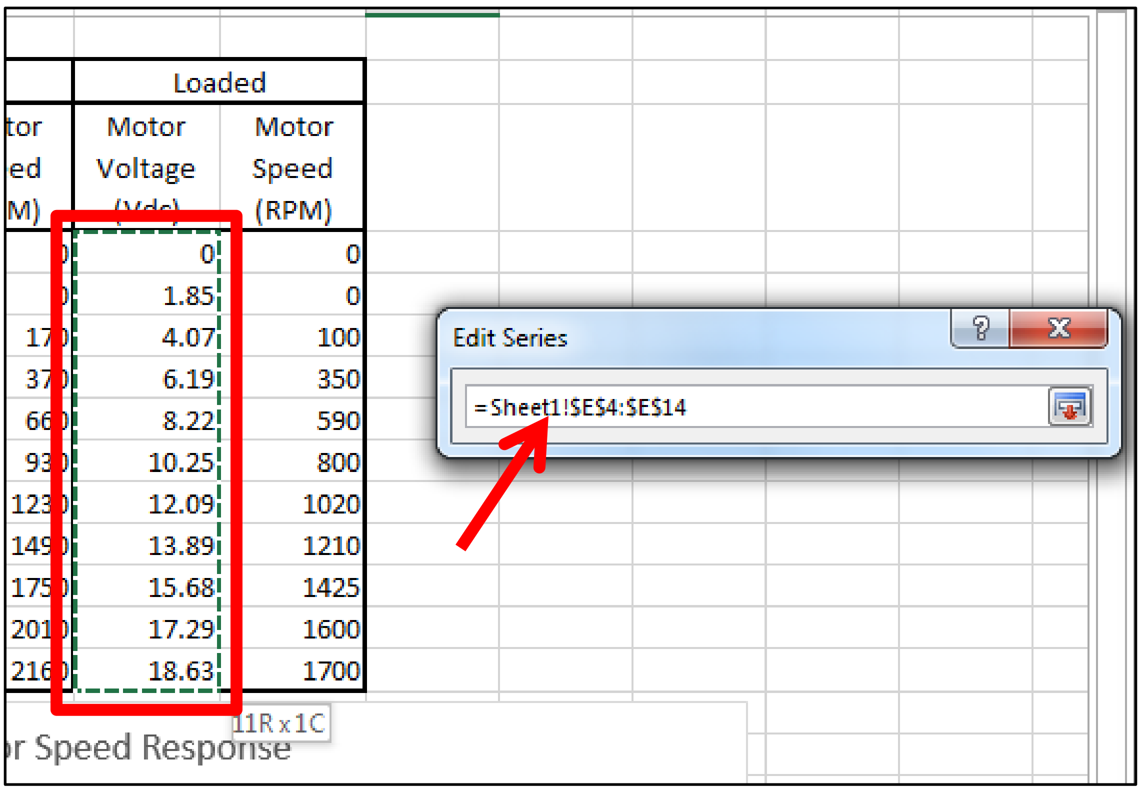
4. In the “Select Data Source” window, under “Legend Entries (Series)”, click “Add”.



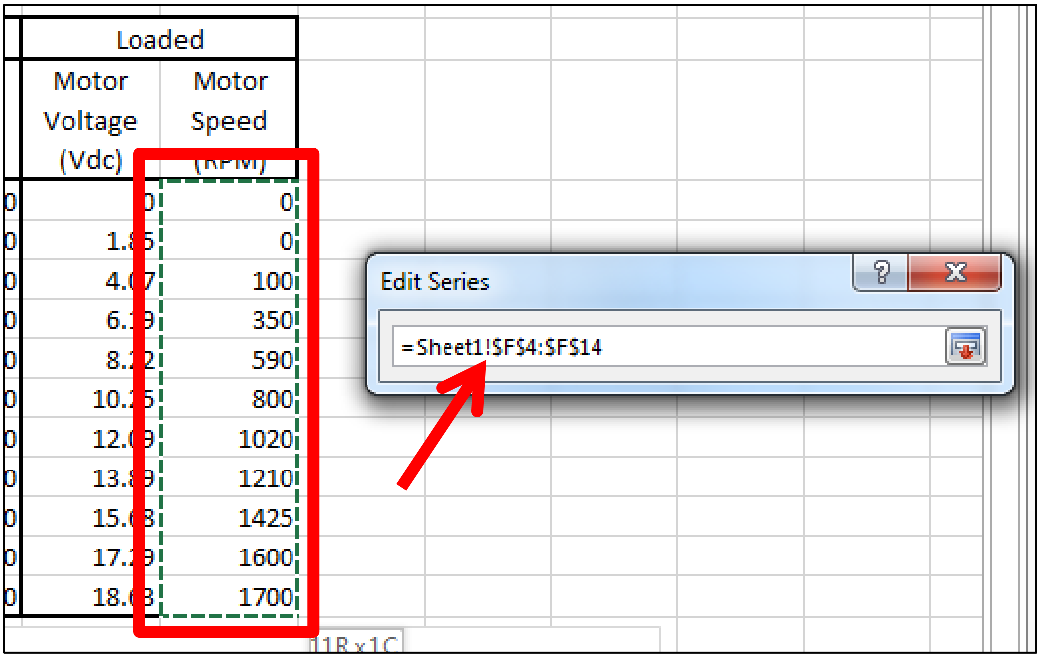
5. In the "Edit Series" window, move the cursor to the "Series X values:" box.



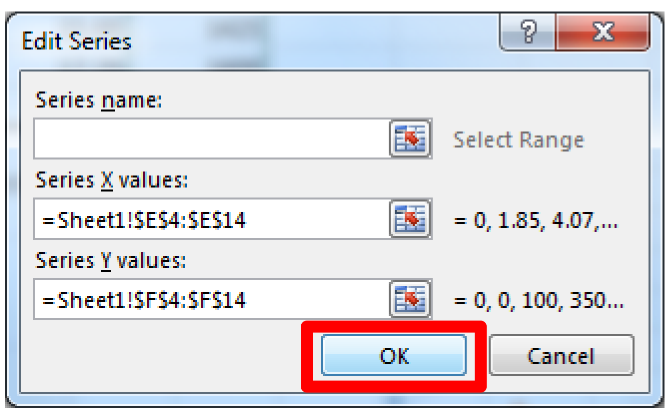
6. On the table, click and drag over the column of values you want on the x-axis for the new data set. This will automatically add the address of these values to the "Series X values:" box.



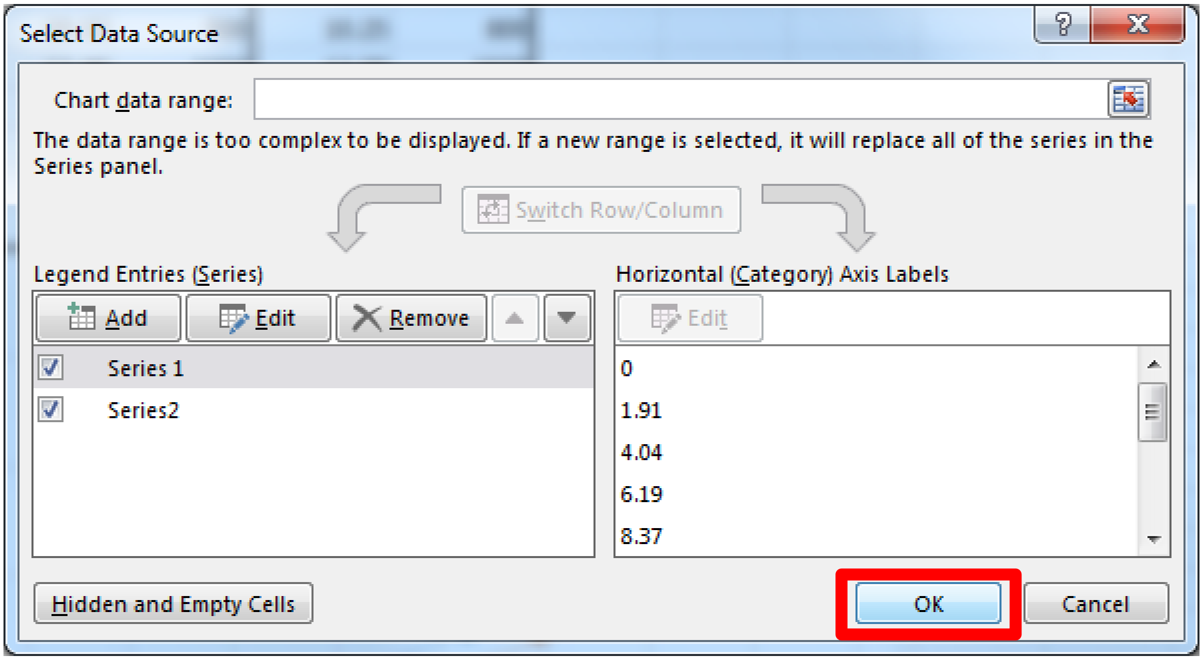
7. Delete everything in the "Series Y values:" box, then click and drag over the table column of values you want on the y-axis. **NOTE:** if you don't erase "={1}" from the box before selecting your data, Excel will pop up with an error message.



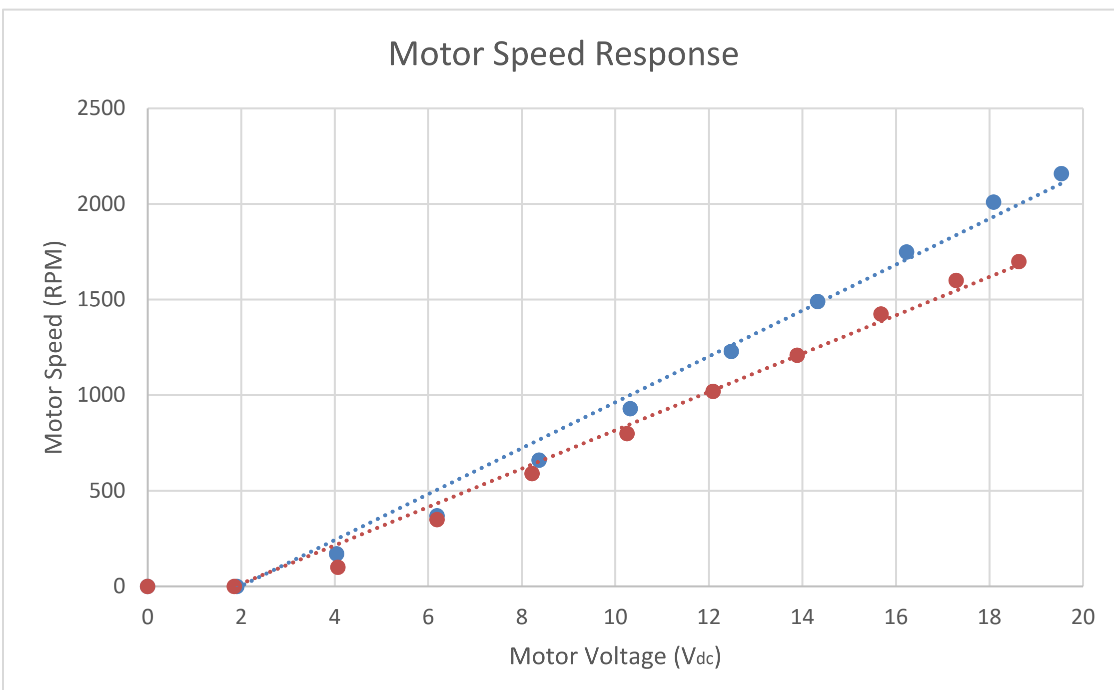
8. Click "OK".



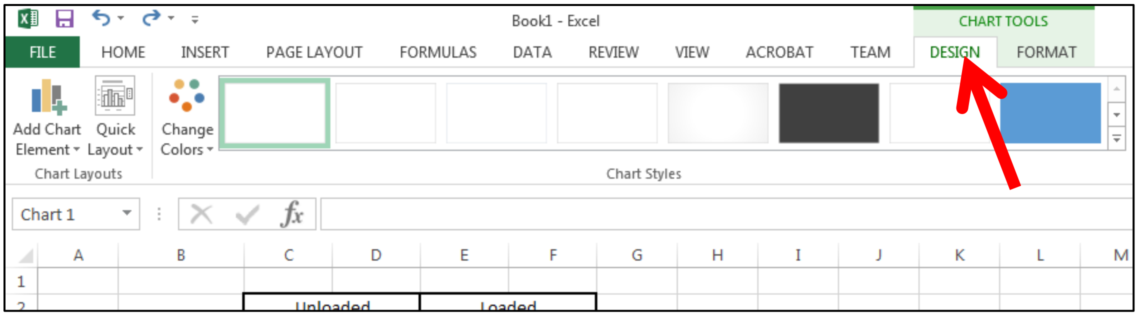
9. Click "OK".



10. The graph should now have an additional data set. Adding a trendline is the same as with the first data set.



11. A legend makes it easier to distinguish between data sets. To add a legend, click on the plot, then click the “Design” tab under “Chart Tools” at the top of the screen.



12. Click “Add Chart Element”, then select “Legend”, and click on your preferred option for location of the legend on the plot.