

Inexpensive Diffraction Based Spectrometer for Monochromatic Light

Proposed by William Suber

Abstract:

Overview:

This spectrometer will use a phototransistor (PT) that is moved translationally to measure the $n=0$ and $n=1$ principal maxima of an interference pattern produced by a monochromatic light source (laser) that is incident on a diffraction grating. An Arduino Uno micro-controller is used to actuate a stepper motor that moves a sensor bay holding the PT. At each step of the motor, the Arduino will take an analog input from the PT circuit, corresponding to the relative intensity of the incident light. From these relative intensities (which are stored in an array, indexed by step number), the angle between the two maxima can be determined, allowing the Arduino to calculate the wavelength of the incident light. This peak wavelength will then be displayed on a seven-segment display.

Concepts:

- Use Arduino Uno microcontroller to take an analog input from a common collector amplifier that uses a 3DU5C PT with emitter grounded through a 10k resistor. The output voltage across the load resistor is proportional to the intensity incident on the PT's photosensitive junction. These outputs will be stored in an array that is indexed by step number.
- Use a L298N H-bridge motor driver to actuate a bipolar stepper motor using the Arduino.
- Have Arduino wait for push-button input from the user to begin the scan.
- Write a function in C, **float** Theta (**byte** *data_array[step_number]*), to identify the center of the two relative maxima in the data array and return the angle between the points.
- Write a function in C, **int** Young (**float** *angle*), that takes in the angle returned from Theta() and uses the classic equation, $d \times \sin \theta = n \times \lambda$ to calculate and return the wavelength of the incident light as an integer in nanometers.
- Print the peak wavelength to a seven-segment display.

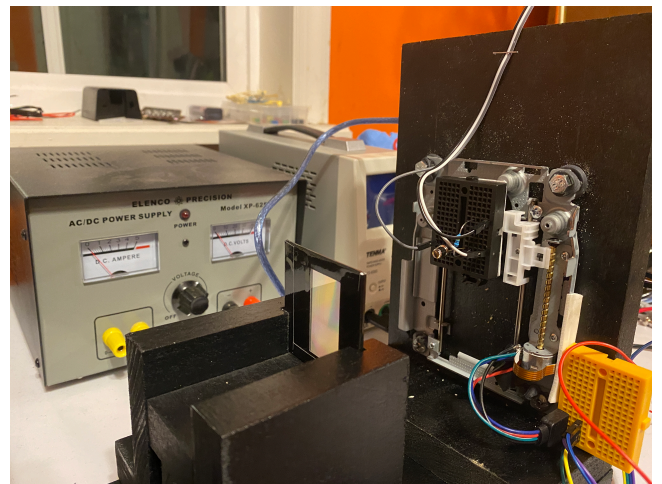
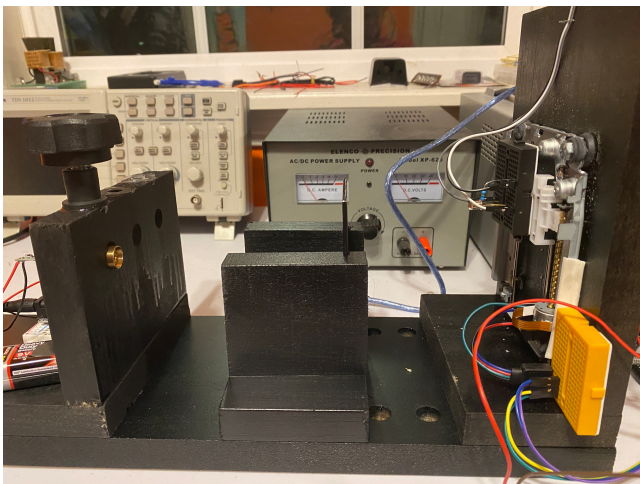
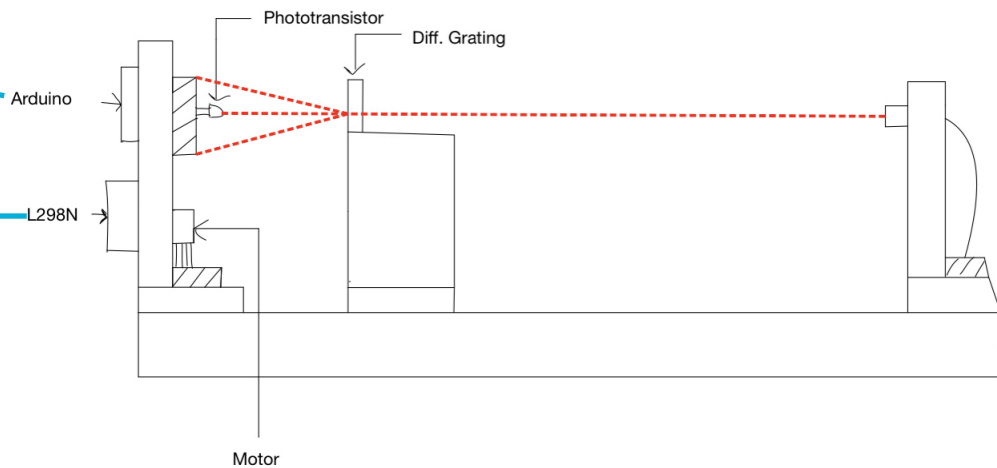
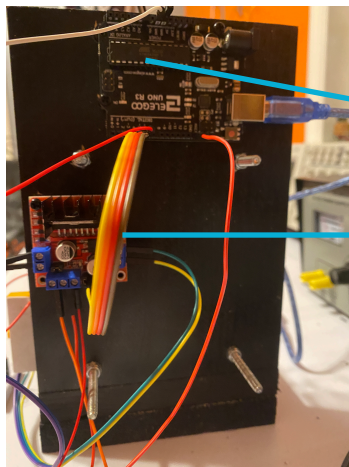
Key Components:

- Bipolar stepper motor connected to a rail mounted sensor bay from a PC disc drive
- L298N H-bridge motor driver (REF1 on Piazza)
- 3DU5C phototransistor (PT) (REF2 on Piazza)
- 532 nm +/- 1nm laser (REF3 & REF4 on Piazza)
- 655nm +/- 10nm laser (REF5 on Piazza)
- 600 slit/mm diffraction grating
- Seven-segment display (REF6 on Piazza)

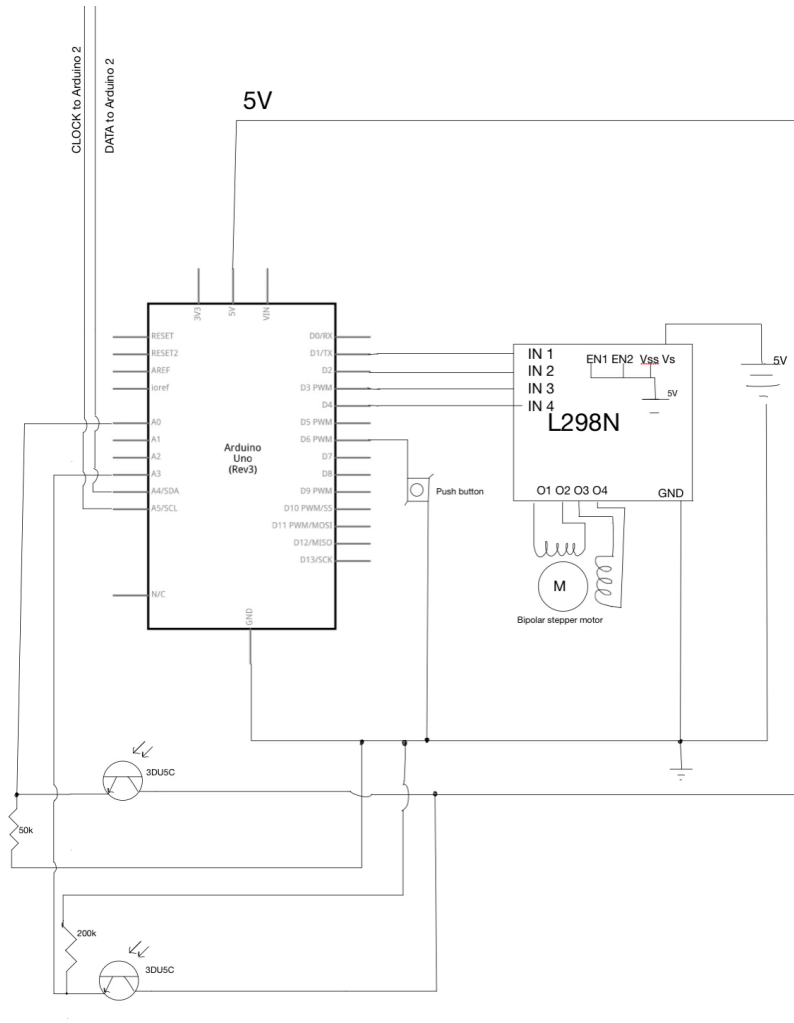
Plan of implementation (Numbered by week):

1. Deconstruct a PC disk drive, keeping only the bipolar stepper motor and rail mounted sensor bay. Solder new 4-pin connector to motor pins.
2. Connect the stepper motor to the L298N controller. This particular controller requires only an external 12VDC for power if the proper jumpers are in place.
3. Build the PT common collector circuit and mount it to the sensor bay. Write code for Arduino to take an analog input from the common collector output.
4. Mount the entire rail system perpendicular to an optical table (See physical set-up section for images). Write code to make the motor scan once a button is pushed. Measure the maximum displacement of the sensor bay, number of steps per revolution of the motor, and then calculate the distance moved on each step.
5. Insert a diffraction grating in the light source's path, causing an interference pattern. Write $\Theta(\)$ and $Y_{\text{young}}(\)$.
6. Check the performance with a laser of a known wavelength. Calibration will be done during this step.
7. Display the calibrated peak wavelength and pass the raw data array to python for additional processing, time permitting. At the very least, I would like to be able to graph the results using the Arduino's serial plotter.

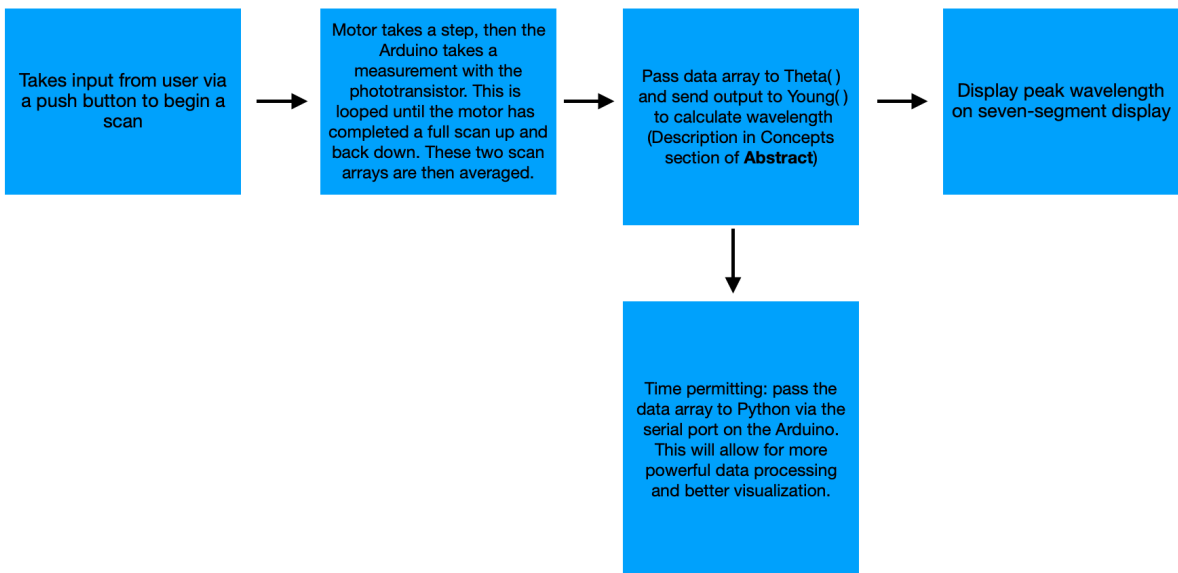
Physical Setup (neglecting display, wiring, and 12V power supply):



Circuit Diagram (neglecting display):



Block Diagram:



Supplies:

- 5V bipolar stepper motor connected to rail mounted sensor bay
- stepper motor driver (L298N H-Bridge Controller)
- Phototransistor (3DU5C)
- 7-segment display
- Diffraction grating (600 lines/mm)
- 10k resistor
- push button switch
- 4 pin connector
- Arduino Uno microcontroller
- 12V DC power supply
- solder and soldering iron

For testing/calibration:

- Laser diodes and corresponding drivers (Known and unknown wavelengths)
- 5V power supply to power lasers
- Safety enclosure

For Mounting:

- Level, amateur optical table made from poplar wood
- Poplar wood to fabricate mounts
- M3 nylon bolts and threaded spacers
- Flat black enclosure to minimize reflection

Data sheets:

REF1: L298N

https://components101.com/sites/default/files/component_datasheet/L298N-Motor-Driver-Datasheet.pdf

REF2: Phototransistor

<https://datasheetspdf.com/pdf-file/972038/ETC/3DU5C/1>

REF3: 532nm Laser (old)

<https://pdf1.alldatasheet.net/datasheet-pdf/view/705587/ROITHNER/CW532-X-831.html>

Note: I am using an outdated model of this laser (which I borrowed), with the following reference sheet. This laser, with the same model number but new power connector has an updated reference sheet cited in REF4.

REF4: 532nm Laser (new)

http://www.roithner-laser.com/datasheets/laser/laser_modules/cw532-5-831.pdf

REF5: 655nm Laser

<https://www.digikey.com/en/datasheets/quartoninc/quarton-inc-vlm-635-650-03-lpa-lpt>

REF6: 7-Segment Display

<http://www.xlitx.com/datasheet/5641AS.pdf>