Shear Stress Sensor Design

EML 4552C-Senior Design- Spring 2013

OPERATION MANUAL

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Product Specs and expected performance of individual (or equivalent) components

Load Cell

The load cell is used to measure the shear force exerted on the cholesteric crystals by the shear block. The output of the load cell is in Volts and must be calibrated before use to determine the forces. The load cell works in tension and compression by transducers converting the mechanical energy to an electrical energy.

Manufacturer:
Interface Inc.
Part:
Load Cell- SMT1-10N
http://www.interfaceforce.com/smt-s-type-overload-protected-load-cell-us-metric-p-31.html

Manufacturer:
Interface Inc.
Part:
Force transducer
Model SMTI – 10N
Capacity – 10N
Serial – 693890

Manufacturer:
Interface Inc.
Part:
Strain gage amplifier
Model SGA/A
Supply voltage – 110-230 V_{AC} / 50-60Hz
Supply power – 4-10 W
http://www.interfaceforce.com/sga-acdc-powered-signal-conditioner-p-95.html

Figure 1- Interface Load Cell-SMT1-10N

The load cell is overload protected in both tension and compression. The safe overload protection is 10 times greater than its capacity.

Accuracy (Max Error)
Nonlinearity -%FS – 0.05%
Hysteresis -% FS – 0.03%
Non-repeatability -% RO – 0.02%
Creep, in 20 min - % - 0.025%

Linear Servo Motor

The linear actuator is needed to apply the shear force to the crystals. Its linear characteristic allows the movement to be one degree of freedom, which will cause a shear force on the liquid crystals. The motor is a stepper motor, which means that the speed and distance that the actuator moves can be regulated through programming. This is ideal for accurately changing the force that is applied to the crystals.

Manufacturer:
Haydon Kerk
Part:
28H41-2.1-915
prototypes.haydonkerk.com/ecatalog/hybrid-linear-actuators/en/28H41-2.1-915

Specifications

Series	28000
Actuator Type	Captive
Step Angle	1.8°
Linear Travel per Step (in.)	0.001
Dimensions of Backing(H x L x D) (in.)	1.1 x 1.1 x 1.1
Dimension of Screw Length (in.)	11
Maximum Thrust (Chopper Drive, 100% Duty Cycle) (lb)	7
Power (W)	4.2
Wiring	Bipolar

Figure 2- Haydon Kerk Linear Servo Motor- 28H41-2.1-915

Motor Driver

The motor driver is the component that stores and delivers the operating instructions to the linear servo motor. Connected by a USB cable to the PC, the motor driver from Haydon Kerk uses the *Idea Software* to encode the program and sends the information to the servo motor in the form of electrical pulses which controls the stepping motion resulting in the prescribed distance, velocity, and acceleration. The motor driver chosen is the PCM4826-1046 because it corresponds to the servo motor being used in the experiment.

Manufacturer:

Haydon Kerk

Part:

PCM4826-1046

www.haydonkerk.com/LinearActuatorProducts/IDEAStepperMotorController/PCM4826StepperMotorController/tabid/332/Default.aspx

Drive input Voltage	**Maximum Drive Current (per phase)**	**Communication**	**Maximum Temperature**
12-48 V_{DC}	2.6 A_{rms}	USB(Mini B Connector)	70°C

Figure 3-Haydon Motor Driver PCM4826 1046

Spectrometer

The use of a spectrometer will allow the collection of light to determine the intensity at different wavelengths. This equipment consists of a fiber optic cable attached to a 2MHz analog to digital converter and outputs the signal via USB. The sensor is able to detect light between 200nm and 1025nm.

Manufacturer:

Ocean Optics

Part:

XR-Series Miniature Fiber Optics Spectrometer

USB2000+XR1

http://www.oceanoptics.com/Products/xrseries.asp

Spectrometer Type	Grating	Spectral Range	Optical Resolution
USB2000+XR1	#31.500 lines/mm, blazed at 250 nm	200-1025 nm	1.7-2.1 nm

Figure 4-Ocean Optics USB 2000 + XR

BluLoop Multi-LED Light Source

The BluLoop light source is a quad-LED source; used to integrate four different types of LED's to have a complete visible wavelength spectrum in comparison to other single LED or Halogen light sources.

Manufacturer:

Ocean Optics

Part:

BluLoop Multi-LED Light Source

www.oceanoptics.com/Products/bluloop.asp

Dimensions (H x L x D)	62x60x150 (mm)
Weight (kg):	0.5
Power consumption:	up to 12 W
Wavelength range:	395-750 nm
Bulb lifetime:	>10,000 hours
Temperature:	5-35 °C

LED's Used

Type	Wavelenth (nm)
Blue	420
Cyan	505
Cold White	454
Warm White	570

Figure 5- BluLoop Light Source from Ocean Optics

DAQ Board

In order for the computer to receive data from the load cell a Data Acquisition Board (DAQ Board) is required. There are several DAQ boards available, but the one that was chosen for the experiment is a National Instrument- BNC 2110. The lab in which the experiments are currently being held already had the DAQ board, so choosing another DAQ board was not a necessity. Another type of DAQ board can be used as long as it has a ±10V input and output.

Manufacturer:

National Instruments

Part:

DAQ Board- BNC 2110

Specifications:

- BNC connectors for analog I/O
- Terminal block for digital and timing I/O connections
- Interfaces to X Series, M Series, E Series, S Series and analog output devices
- Shielded Enclosure
- Simplifies the connection of analog signals, some digital signals, and two user-defined connections to the DAQ device

Figure 6- BNC 2110-Noise Rejecting, Shielded BNC Connector Block

Breadboard

The Breadboard is the component in which the relay and electrical wires are connected to, for the automatic shutoff for the load cell. A breadboard is used to connect multiple electrical circuits through wires that are built in to the component. With knowledge of electrical systems it is possible to design circuits and relays on the bread board with ease.

Manufacturer:

E-call Inc.

Part:

EIC-104(165-40-1040)

Specifications:
2 Terminal strips, Tie-point 1260
4 Distribution strips, Tie-point 400
Board Size (in.): 6.5x4.33x0.33
Plate Size (in.): 8.46x5.12x0.05

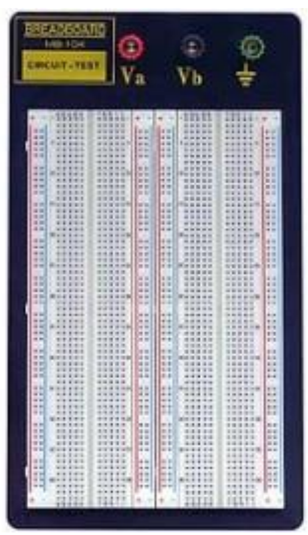


Figure 7-eic-104 Breadboard

Relay

For the prototype a R57-1D.5-12 relay was used to assist in the automatic shut-off of the system. A relay is a component that opens and closes a circuit, in the case of the prototype; the relay grounds the input pin of the microcontroller to trigger an interrupt in the motors movement program. The relay was chosen because the DAQ board can output a maximum of 0.3W and the relay has a smaller gate power requirement.

Manufacturer:

NTE Inc.

Part:

Relay- R57-1D.5-12

NTE Type No.	Norm. Voltage VDC	Contact Arr.	Coil Res. Ohms (typ)	Max Pickup VDC	Min. Drop Out VDC	Max Curr. Amps	Times		Diag. No.
							Max. Separate	Max. Release	
R57-1D.5-12	12	SPST-NO	1200	9.0	1.0	5.0	400µs	75µs	D27C

Figure 8- R57-1D.5-12 Relay

Multi-meter

To help in solving issues in the experiment a multi-meter is very beneficial. Because of the relay and load cell, both having certain power conditions that are being used, checking to make sure they are accurately measuring is important. Also the use of the multi-meter when forces are not what is expected can be useful, because the first step in fixing the problem is to verify the voltage output of the amplifier.

Manufacturer:

Gardner Bender

Part:

GDT-311-(13 Range- 3 Function Digital Multi-meter)

Specifications:

- For testing AC/DC voltage and current resistance
- DC voltage- 250 V_D
- AC voltage - 500 V_{AC}

Figure 9-Gardner Bender GDT-311 13 Range - 3 Function Digital Multi-Meter

Power Supply

To supply the power to the microcontroller 2-pin and 10-pin I/O, a power supply with the capabilities of 12.0- 24.0 Volts and 0.3-1.0 Amps is needed. Also the power supply must have 2 channels, so the separate pins of the microcontroller can receive their specific power.

Manufacturer:

GW Instek

Part:

GPS-2303

Specifications:

- 2 Independent Isolated Outputs
- 0-30 DCV / 0-3 DCA
- Four "3 Digits" LED Displays
- 0.01% Load and Line Regulation
- Low Ripple and Noise
- Output ON/OFF Switch
- Over Load and Reverse Polarity Protection

Figure 10-GW Instek-GPS-2303-Power Supply

Electrical Setup

Do not give power to anything until all connections are securely made.

Initial Setup

- Attach the relay to the bread board.
- Attach one BNC connector to the DAQ board input and one to an output.

Load Cell Setup

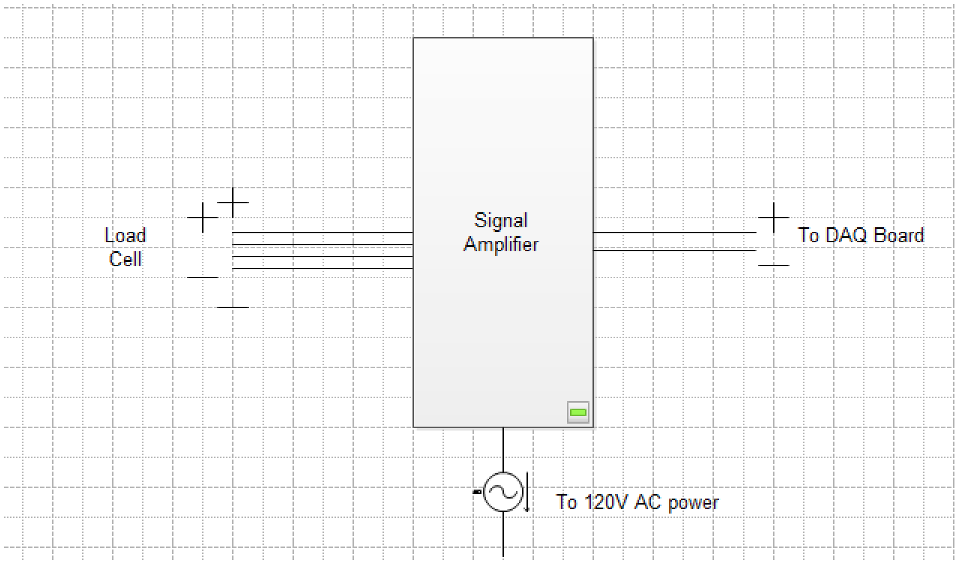


Figure 11- Load Cell to Amplifier to DAQ Board Wiring Diagram

Figure 12-Location of the Amplifier Terminals

- Attach the load cells 4 leads and the shield wire to the J2 terminal in the strain gauge amplifier. Ex. Figure 13

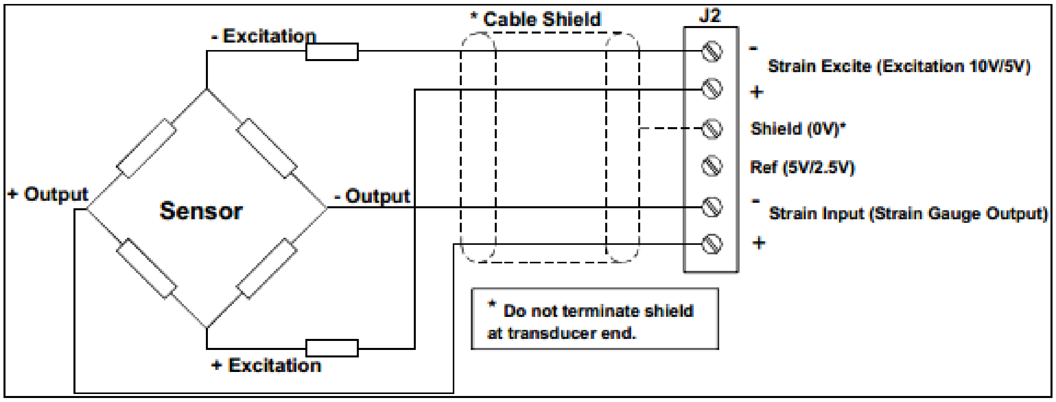


Figure 13- Load Cell to Amplifier Connections

- Attach the output cables to the J1 terminal and to the BNC connectors attached to the DAQ Board. Ex. Figure 14

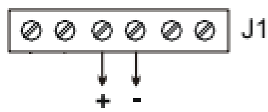


Figure 14- Amplifier Output

Microcontroller Setup

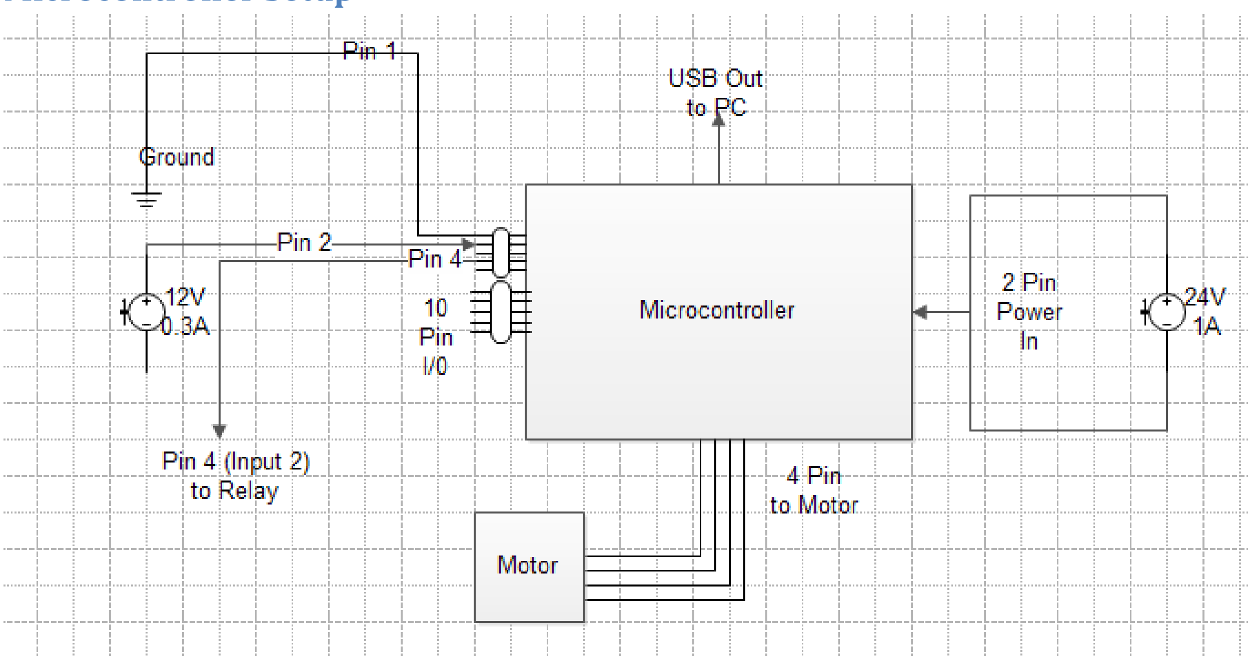


Figure 15- Microcontroller Wiring Diagram

- Connect the USB connector to the microcontroller and the PC. Ex. Figure 16
- Attach the 2-pin, 4-pin, and 10-pin connectors to the microcontroller. Ex. Figure 16

- Connect the 2 wires from the 2-pin connector to a power supply with 1A and 24V. Ex. Figure 16
- Connect the 4-pin connector to the servo motor. Ex. Figure 16
- Attach pin 1 and 2 to a power supply with 0.3A and 12V. Ex. Figure 16

PIN POSITION	DESCRIPTION
PIN 1	GROUND I/O SUPPLY
PIN 2	+ I/O SUPPLY
PIN 3	INPUT 1
PIN 4	INPUT 2
PIN 5	INPUT 3
PIN 6	INPUT 4
PIN 7	OUTPUT 1
PIN 8	OUTPUT 2
PIN 9	OUTPUT 3
PIN 10	OUTPUT 4

Figure 16- 10-Pin Assignments

- Attach pin 4 to the input of the relay on the bread board.

Relay Setup

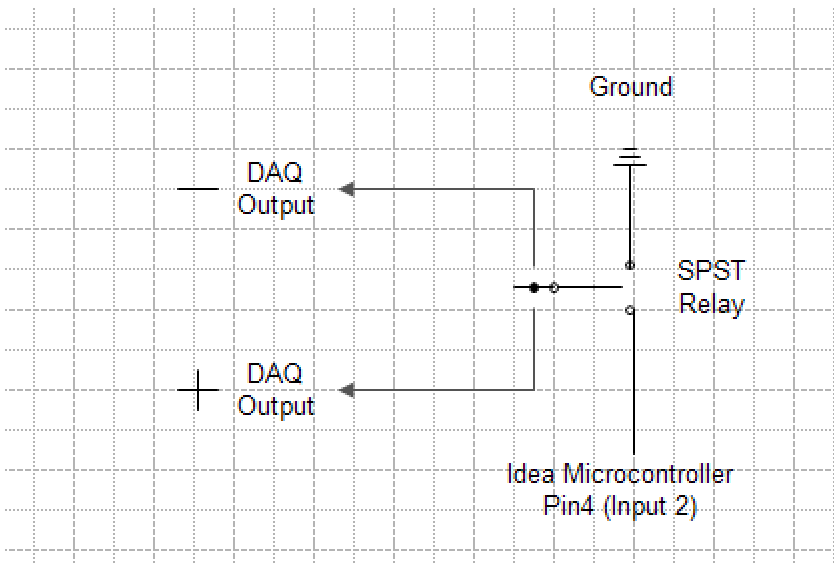


Figure 17- Relay Wiring Diagram

- Make sure the wire attached to pin 4 is also attached to the relays input. Ex. Figure 17
- Ground the output of the relay. Ex. Figure 17
- Attach the DAQ cables to the gate of the relay. Ex. Figure 17

Final Setup

- Plug in the amplifier and turn on the power supply(s).

Operation Instructions

Before testing can begin liquid crystals must be made from the powder cholesteric crystals. To make the liquid crystals follow the instruction given by Pressure Chemical Company in which the ratios of cholesteric crystals are given. Once all of the samples have been measured turn on a hot plate, and place a large beaker on the hot plate half filled with water. Once the temperature of the water reaches 180 degrees Fahrenheit place a small beaker in the water, and then add the samples of powder cholesteric crystals. Wait for the cholesteric crystals to start melting, and then occasionally stir the crystals to break up the smaller pieces. After the cholesteric crystals have completely melted take the small beaker out of the water and place to the side for cooling. If other types of liquid crystals are desired repeat the same steps and follow the Pressure Chemical Company instructions for the ratios.

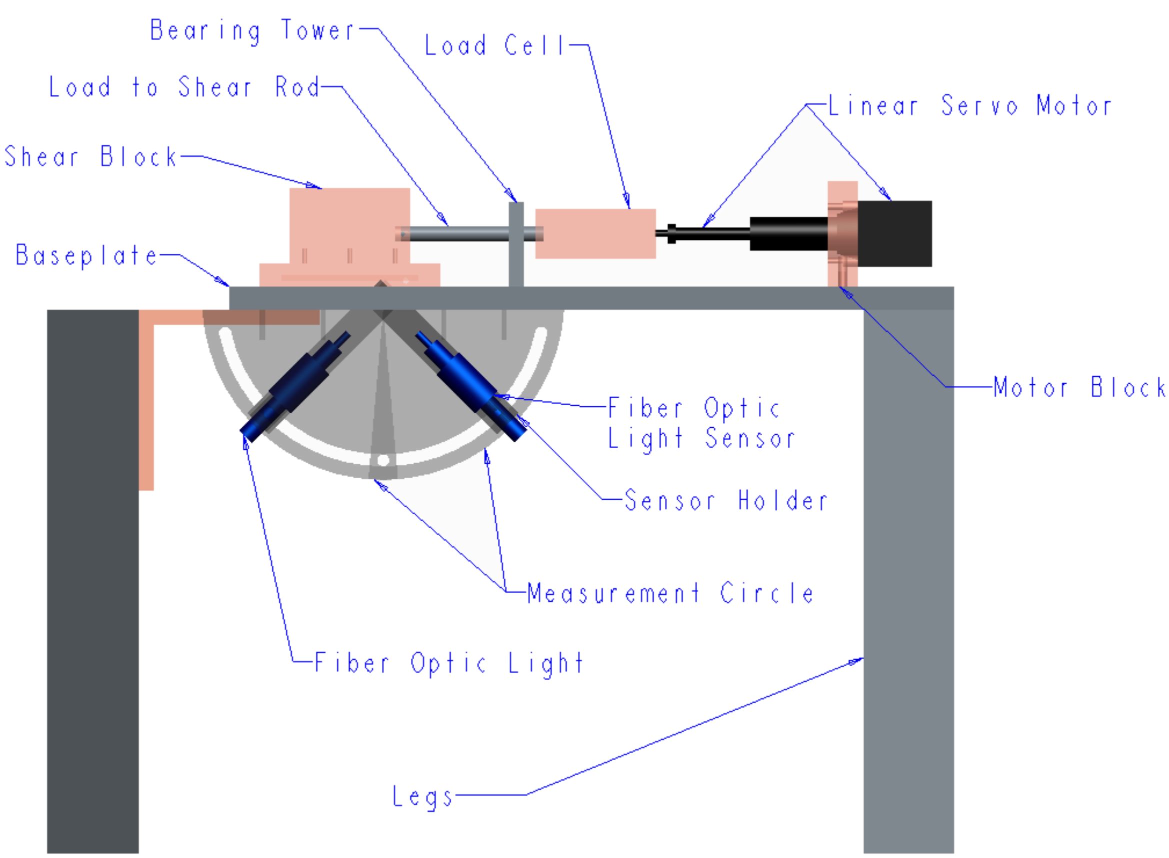


Figure 18- Apparatus Part Names and Locations

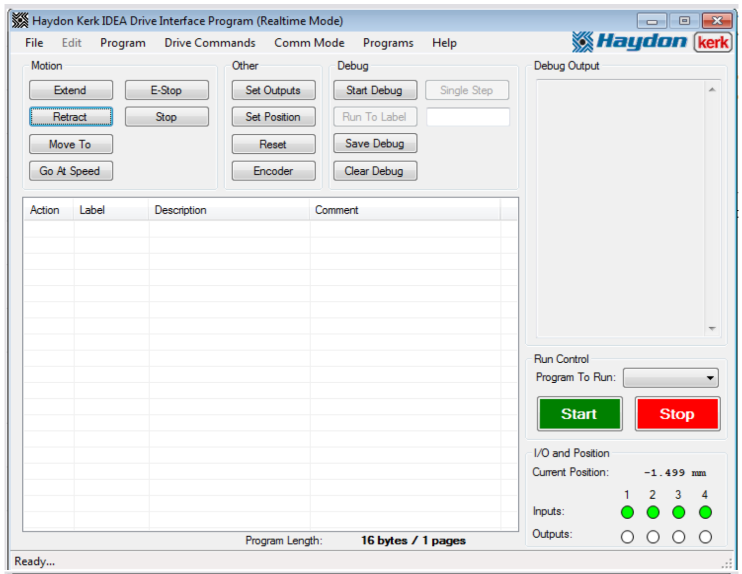
The apparatus needs to be completely assembled before the testing can begin. Make sure that the linear servo motor is connected to the motor block, the load cell is screwed in to the servo motor, and the connecting rod is attached to the load cell. Select which shear block base is going to be tested, and place the liquid crystals in the correct location on the apparatus. Place the liquid crystals on a glass slide or on the base of the shear block depending on the type of shear block base being used. Also be sure to spread the liquid crystals evenly as to have a consistent thickness and to increase the area in which the spectrometer can detect. Once the liquid crystals have been applied to the shear block, attach the shear block to the connecting rod by tightening the set screw. Also be sure to check that the shear block is over the glass slide slot in which the liquid crystals are placed. Set the location of the spectrometer and fiber optic cable to the angles desired as marked on the measurement circles. Then turn on the BluLoop light source for the apparatus to be ready for testing. The final pre-testing step is to turn on the power source:

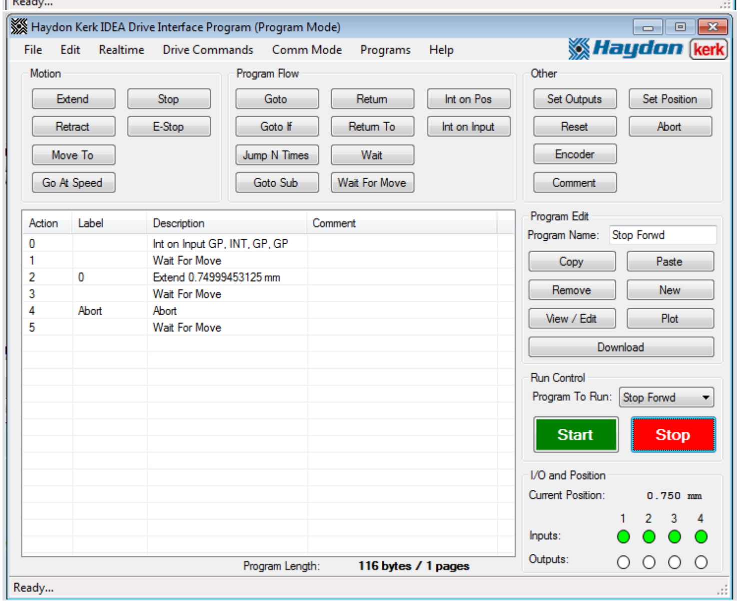
- For the side connected to the 10-pin I/O of the microcontroller select a voltage of 12.0V±0.01V and 0.3A±0.01A.
- For the side connected to the 2-pin of the micro controller select a voltage of 24.0V±0.01V and 1.0A±0.01A

To begin the testing open the programs *LabVIEW*, *MatLab*, and *Idea Software*. In the *LabVIEW* software run the Reference Spectrum 2.0 and Spectrum 2.1 Overload files, which controls the information from the spectrometer. In the Spectrum 2.1 Overload interface, input all of the values that correspond to the experiment that is being run (i.e. light source=1 [BluLoop]). In MatLab open the file Experiment_02_1, keep this file in the background because it will be used at the end of the testing to determine the outcomes. In *Idea Software* select the file “Stop Forwd”, this file commands the linear servo motor on its movements.

Once all of the programs are open on the desktop, go to the Reference Spectrum 2.0 interface and select the “Run” icon. While looking at the graph being displayed on the interface adjust the Spectrometer and BluLoop Fiber optic cables for the desired intensities. When the desired intensities are found, press the “Stop” button to take a snapshot of the spectrum to assign the image as the reference. (Note the file number that the reference spectrum has been saved to because it will be needed for the MatLab file)

After the Reference Spectrum has been determined open the *Idea Software* window and select the “Communication” tab. From the communication tab choose the option “Single” and press ok; there will be a pop-up that appears to select which communication port the micro controller is connected to (ex. Comm4), select the port then press “Ok”. Select the program that is wanted to run, to select the program press the “Program” tab. If a new program is to be written, write the operations wanted in the experiment to the table. For example:





Extend and Retract both have options in which the distance, velocity, and acceleration can all be chosen by double clicking the line of code. This is also where adjustments can be made to the experiment in how the servo motor will operate. Once programming is complete name the program in the "Name" box, and then select the "Download" icon. A pop-up will appear with the option of overriding the current servo motor program (select "Yes"). After the program has been downloaded to the micro controller select "Real Time" tab, and another pop-up will appear asking is to save the program (select "No"). When the *Idea Software* steps have all been completed move the window to the right half of the screen, as to easily select the "Start" button.

Select the Spectrum 2.1 Overload interface, and place the interface on the left half of the screen. Click the “Run” icon to start recording the spectrum data. Once “Run” is selected, go to the *Idea Software* window and press “Start” to initiate the servo motor. Go back to the Spectrum 2.1 Overload interface and wait for the servo motor to complete movement(s). After the servo motor has stopped running press the “Stop” icon. (Note the file number of the spectrum for the MatLab file)

Go to the MatLab Command Window, and run the file Experiment_02_1. Once the program is running, it will ask for “file number:?” and “Reference Spectrum number:?” (ex. file number=28, Reference Spectrum number= 11). The “file number:?” is the file from the Spectrum 2.1 Overload, which was noted by the previous steps. And the “Reference Spectrum number” is the file noted in the Reference Spectrum program. After the files have been chosen, the program will run and display figures representing the wavelength, intensity, load, and time. Some of the figures will display *Wavelength vs. Time, Intensity and Wavelength* vs. Time, and *Load vs. Time*. On each of the figures that will appear points can be selected on the lines to show the actual data values collected during the experiment.

In a lab notebook, note all of the variables (i.e. distance, velocity, acceleration, etc.) and all of the important features of the figures (such as the max. and min. wavelengths, load, and any unusual values). If another experiment is going to be run make sure that the servo motor is retracted back to the original placement before running the next test. When all testing is complete or changing of liquid crystals/bases return the servo motor to the original start position.

After all testing is completed; close all software programs without saving any changes to the program files. Also turn off the power supply to the relay and micro controller. Then loosen the set screw to the shear block, and slide off the shear block from the apparatus. Clean off all of the components that have liquid crystals on them, which include the shear block, apparatus, and glass slides, with a paper towel and rubbing alcohol. The paper towel is allowed to be put in the garbage can per the Safety Manual.

Regular/Routine Maintenance

Routine maintenance for the apparatus and other experiment items is to clean all parts after testing is completed. Also over time the Teflon bearing may wear down, which is solved by replacing the Teflon bearing with another.

Major repair and/or replacement decisions of key component

(Amplifier, Load Cell, Servo Motor, Motor Driver, Spectrometer, BluLoop, and DAQ Board)

Major in-house repair on the key components of the apparatus will not be required due to cost of repair and the odds of repairing the components. For there to be repairs on the key components the repair price may be close to the cost of the repurchasing the components. Since all of the key components are electrical systems, with exception to the servo motor, once the items are damaged enough to require major repair the chance of recovering the item is unlikely. For the replacement process, if a key component is severely damaged then either the purchasing of the same or equivalent item will be necessary if the manufacturer cannot repair the item. The reasoning behind the purchasing of a new servo motor rather than major repair is because of the low cost of the servo motor, and because after testing a different type could possibly be wanted. If there is to be a new servo motor there is the possibility that the new motor may not be configurable with the current motor driver and software, so the servo motor purchasing should coincide with both the motor driver and software. For the load cell, amplifier, and DAQ board once those components have been damaged to require major repair then the possibility of repairing is unlikely, due to all of the components being purely electrical. But minor repairs as to the dials, cords, and external wires can all be fixed. The BluLoop and Spectrometer may be repaired for minor damages such as damages to cables and cords; because cables and cords are not a part of the items, they are attachments. With major damage to the BluLoop and Spectrometer repairs are feasible depending on the problem, but depending on the part that needs repair it can be unlikely that the component can be fixed. The important piece of information for all of the components is the warranty on all of the components. Due to the cost of each component the warranty of the parts will cover multiple years, so replacing under warranty is a strong possibility.

List of Spare Parts

- Glass Slides
- Thermochromic Liquid Crystals
- Beakers
- Hot Plate
- Stirring Rods
- Rubbing Alcohol
- Paper Towels
- Alligator Clamps
- Power Supply
- Electrical Wires
- Multi-meter

The above listed spare parts are all necessary due to either the large quantity consumed during testing or the low cost of having a replacement. Also all of the parts are crucial to the experiment running, so having spare parts will help continue the research process without interruption for long periods of time.

Appendix

Operation Instructions: Step by Step

Pre-Testing

- Create the liquid crystal specimens based on the instruction from Pressure Chemical Company.
  - Measure liquid crystal sample masses by the ratios given
  - Turn on hot plate for melting liquid crystals, with a large beaker half way filled with water then place a smaller beaker in the water
  - Place the liquid crystals in the smaller beaker that is on the hot plate
  - Periodically stir (preferably with a stirring rod) the liquid crystals to assist in the melting of the solid
  - Once the liquid crystal is completely liquid then take the smaller beaker out of the larger beaker
  - Place the smaller beaker to the side to cool off
  - Repeat all steps for any other liquid crystals desired
- Make sure the apparatus is assembled
  - The linear servo motor is screwed to the motor block
  - The load cell is screwed to the servo motor
  - The connecting rod is screwed in to the load cell and through the bearing tower
  - Attach the correct bottom plate to the shear block
  - Place the liquid crystal in the desired location(i.e. on a glass slide or on the shear block)
  - The shear block is attached to the connecting rod with the set screw tightened
  - Also the shear block is over the liquid crystal location (above glass slide)
  - Align the light and sensor holder to the correct angle as indicated by the degree markers
  - Turn on the BluLoop light source
- Turn the Power supply on.
  - For the side connected to the 10-pin I/O of the microcontroller select a voltage of 12.0V±0.01V and 0.3A±0.01A.
  - For the side connected to the 2-pin of the micro controller select a voltage of 24.0V±0.01V and 1.0A±0.01A

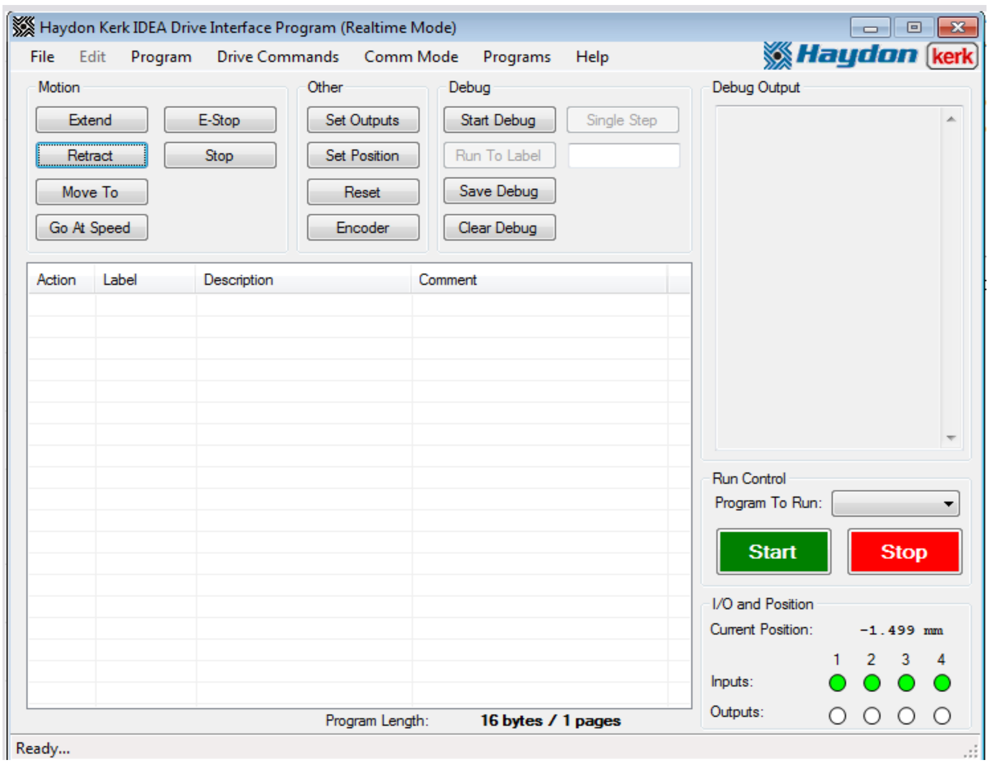
Testing

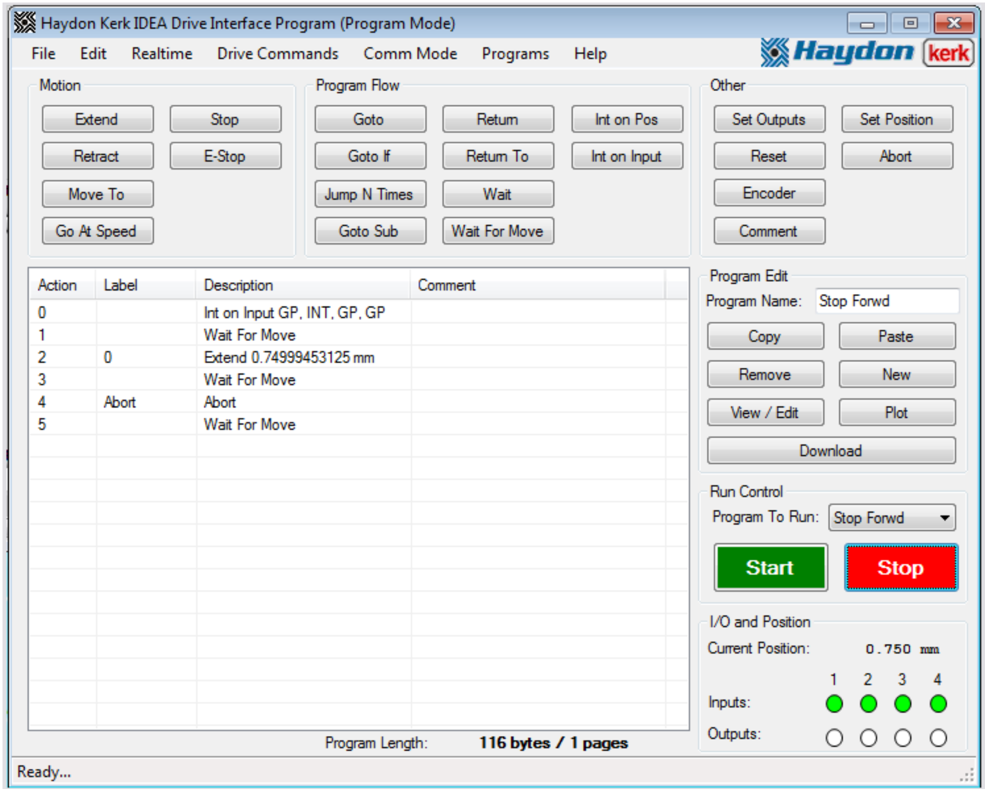
- Launch the software on the computer
  - Open *LabVIEW* and open the program file Reference Spectrum 2.0 and file Spectrum 2.1 Overload
  - Open MatLab and open the program file Experiment_02_1
  - Open *Idea Software* and open the program file “Stop Forwd”

- LabVIEW
  - Go to the Reference Spectrum 2.0 Front Interface and select the run icon.

- Adjust the Spectrometer and BluLoop fiber optic cables for the desired intensities by the graph on the Interface
- Once the desired spectrum intensity is desired hit the “Stop” icon.
- Note the file number that the reference spectrum has been saved as

- Idea Software
  - Click the Communication tab
  - Select the option “Single” and press ok
  - Once the pop up appears select the correct communication port (ex. Comm 4), then click Ok
  - Click the Program tab
  - Input the operations that are wanted for the experiment if another program is desired.
    - Example:





        - In the Extend or Retract command, the distance traveled, velocity, and acceleration can all be defined.
    - Name the program that was created and press the Download icon.
        - Press Yes to replace current program on controller
    - Select the Real Time tab (Same location as Program was located)
        - Press Yes to save the program file
    - Place the *Idea Software* window to the right half of the screen
- LabVIEW
    - Select the Spectrum 2.1 Overload interface
    - Place the interface to the left half of the screen
    - Click the “Run” icon to start recording spectrum data
        - Once Run is selected on the interface go to the *Idea Software* window and press “Start”
    - After the servo has stopped running click the “Stop” icon on the Spectrum 2.1 Overload Interface
    - Note the file number that the spectrum has been saved
- MatLab
    - Run the MatLab file Experiment_02_1
        - The program will ask for “file number:?”. This is the file spectrum number
        - Then the program will ask for “Reference Spectrum number:?”. This is the reference spectrum that was noted previously.

    - The program will then run and display figures representing the wavelength, intensity, time, and load
        - Figures can be altered to display the variables in certain axes
            - For Example:
                - Wavelength vs. Time
                - Intensity and Wavelength vs. Time
                - Load vs. Time
    - From the figures all of the data points can be selected from the plot, so finite values can be determined.
- Record variables in lab notebook. (i.e. distance, velocity, acceleration, wavelength, etc.)
- If another test is going to be run, press the “Retract” button on the *Idea Software* to return to initial starting position
- When testing is complete return servo motor to original start position

Post-Testing

- Close all software programs without saving any changes to the program files.
- Turn off the power source
- Loosen the set screw on the shear block and slide off the shear block from the apparatus
- Clean off the bottom of the shear block, glass slides, and apparatus with rubbing alcohol and paper towels
    - Dispose of paper towels in garbage can due to safety manual allowing disposal in garbage can

Trouble Shooting

Problem: Idea software won't detect the servo motor.

Solutions:

- Make sure the power supply is attached to the microcontroller and that it's powered on.
- Make sure "com 4" is selected as the communication port in the Idea software.
- Close the Idea software & power cycle the power supply.

Problem: Servo Motor is stuck in the retracted position.

Solutions:

- Close the Idea software & power cycle the power supply.
- Move the servo motor back a small increment.
- Disconnect the servo motor from the apparatus.

Problem: Spectrum has more than one peak.

Solutions:

- Make sure the light and sensor are at 45°.
- Add more Liquid crystal.

Problem: Spectrum is too small.

Solutions:

- Make sure the BluLoop is on.
- Make sure the light and sensor are at 45°.
- Increase light and sensor distance from glass slide.

Problem: Emergency shutoff not working.

Solutions:

- Ground the input and check the Idea software to see if the input changes from green to white. If no change occurs the input isn't properly grounded.
- Make sure the gate power for you relay is high enough (above0.25W).
- Make sure the input is being grounded and isn't supplied a voltage.

Problem: Load cell is outputting uncharacteristic data.

Solutions:

- Make sure amplifier is on and is set for the proper mV/V conversion.
- Disconnect the load cell and allow the cell to discharge.

Problem: MatLab spectrum graph is nonexistent in the center of the spectrum.

Solutions:

- Wrong reference spectrum was used.
- If correct reference spectrum was used take another and repeat the experiment.

Problem: LabView spectrum graph in the user interface displays uncharacteristic data or axis.

Solutions:

- Stop the program from running and then start the program running.