Design and development of a tensile test machine for stress and strain on carbon fiber on CMS Phase II Pixel Detector

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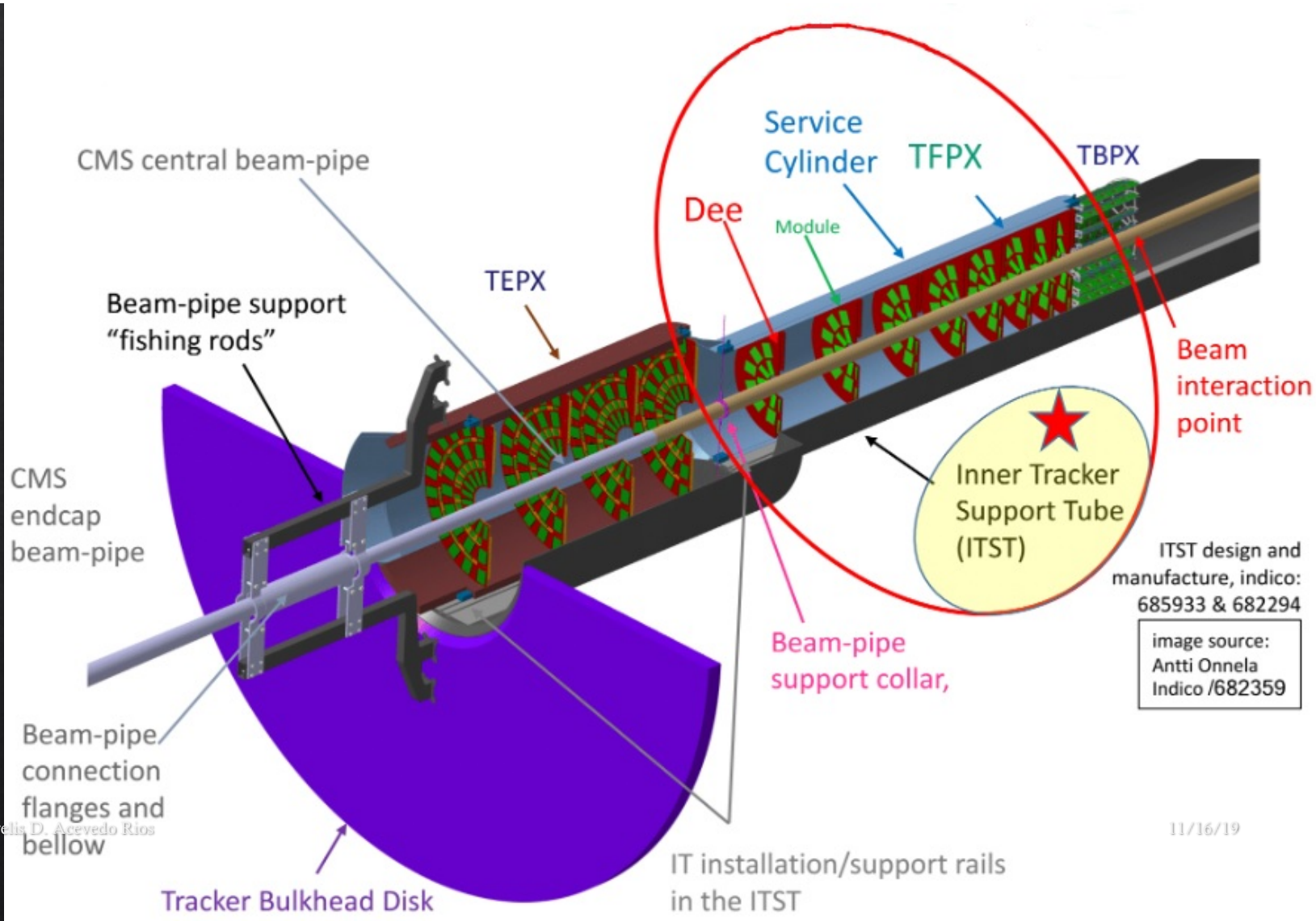
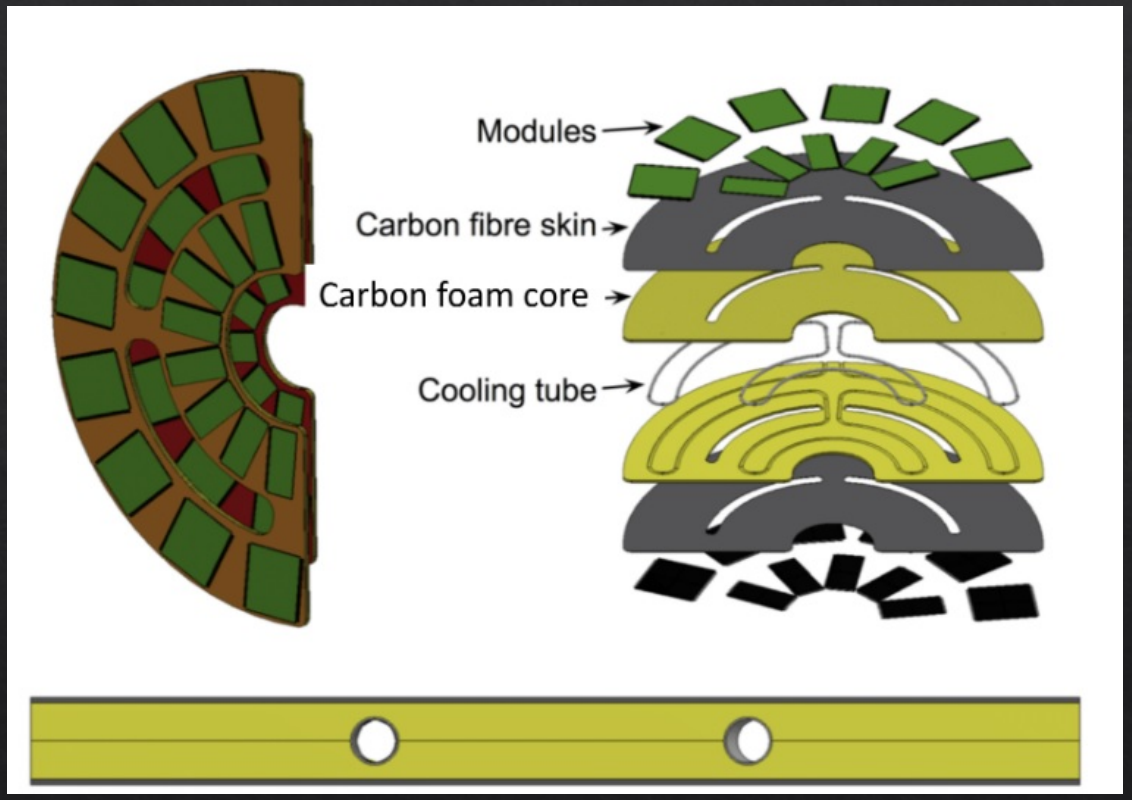

CMS central beam-pipe
Service Cylinder
TFPX
TBPX
Dee
Module
TEPX
Beam-pipe support "fishing rods"
Beam interaction point
CMS endcap beam-pipe
Inner Tracker Support Tube (ITST)
ITST design and manufacture, indico: 685933 & 682294
image source: Antti Onnela Indico /682359
Beam-pipe support collar,
Beam-pipe connection flanges and bellow
Tracker Bulkhead Disk
IT installation/support rails in the ITST

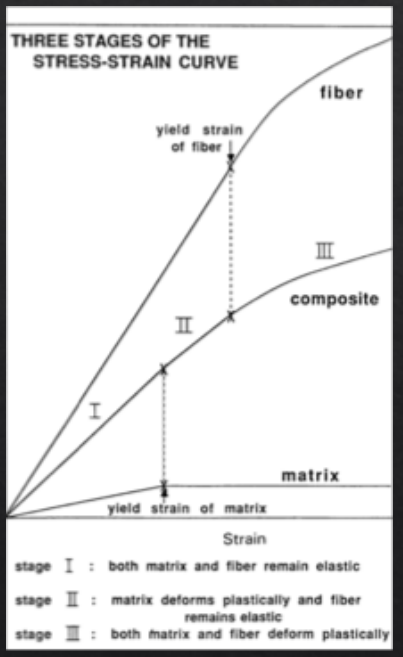
The Dee

- Mechanical Deflection and failure
  - Caused by thermal expansion and contraction of the material
- Due to the mechanical deflection on the material, it's very susceptible to failures.
- Active devices and large connections, heat is generated in the modules and the Dee's.
- Mechanical deflection and failure is inevitable
- In order to have a controlled movement and pressure applied on the Dee, a miniature sized tensile test machine was developed.



Why carbon fiber?

- In the past, the Aluminum 3003 was considered on the built of the Dee, but after seeing the properties of the carbon fiber:
  - Matrix of the fiber
  - Doesn't deform easily
  - A failure in one of the fibers can be compensated with another fiber
  - A very durable material (could be used in long periods of time and it dosen’t deform as fast as other materials as the aluminum
  - More brittle



A tensile test machine?

- For an applied force into the Carbon Fiber, in this case the Dee, we need only about 8Nm to start breaking the fibers of the carbon piece.
- Using the formula to calculate the young's modulus, for a piece of the same dimensions of the dee and the force that the motor can generate we have a 7.789GPa.
- This machine has more force than its needed but to be able to measure without going into the motor's limits its about 33% more powerful.
- Not only can do tests on carbon fiber samples, it can work with other kids of materials

Amount of force needed

- Considering the Young Modulus that the past intern student calculated from the carbon fiber was 5.2GPa

Torque:

$\tau = F \times r$

12Nm = F × 0.007m

F = 1714.286N

Calculating for stress and strain we have:

$$\sigma = \frac{1714.286N}{2.0764 \times 10^{-4}m^2} = 8256048.931[N/m^2]$$

$$\epsilon = \frac{0.000005m}{0.0047m} = 0.00106$$

Now calculating for its Young Modulus ($E = \frac{\sigma}{\epsilon}$) we have:

$$E = \frac{8256048.931N/m^2}{0.00106} = 7788725407N/m^2$$

Converting that to Gigapascals we have:

$$E = 7.789GPa$$

Materials

Ballscrew force limits

Ballscrew:

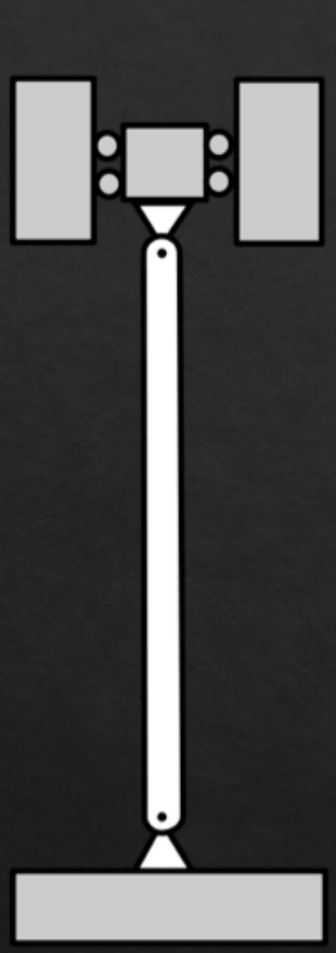
- Driving torque
- torsional force
- axial stress
- equivalent stress
- permissible compressive load

Model: SFU1605
Precision: C7 Grade
Diameter: 16mm
Pitch: 5mm

Length: 550mm

Product name: BK12+BF12 Ball Screw End Support
Color: Balck
Material: Carbon steel

Model:DSG16H (fit 1604 1605 1610 ballscrew)
Type: ball screw nut
Color: silver



$F_a = 2028.048N$

- $F_M = 2015.748\text{N}$
- $F_g = 4.9\text{N}$
- $F_f = 4.9N$
- $F_i = 2.5N$
  - $F_i = \frac{mv^2}{R} \rightarrow \frac{(0.5kg)\left(\frac{0.2m}{s}\right)^2}{0.008m} = 2.5N$

$$T = \frac{(2028.048N)(0.005m)}{2\pi(0.96)} = 1.681Nm$$

$$\sigma_{axial} = \frac{2028.048N}{\pi(0.008m)^2} = 10.087MPa$$

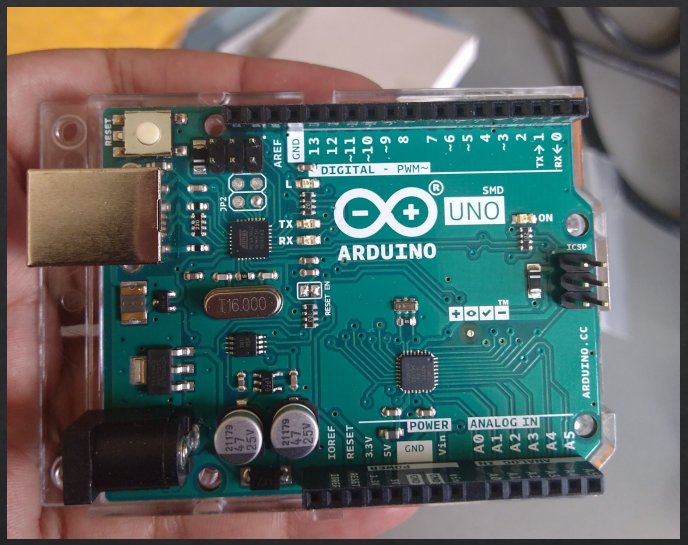
$$\tau_{torcional} = \frac{2(1.681Nm)}{\pi(0.008m)^3} = 2.090MPa$$

$$\sigma_{eq} = \sqrt{(10.087MPa)^2 + 3(2.090MPa)^2} = 10.717MPa$$

$$P_1 = \frac{(2.0)\pi^2(200\times10^{11}Pa)(3.217\times10^{-9}m^4)}{(2m)^2} = 317505.174N$$

- $I = \frac{\pi}{4}m^4 \rightarrow \frac{\pi}{4}(0.008m)^4 = 3.217 \times 10^{-9}m^4$

Arduino Uno

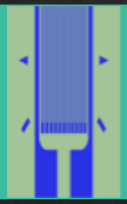


- Microcontroller
- Provides a way to build/connect electronics and program them
- Limitations
  - It cannot multitask
  - Only relays on a setup (one time run) and a loop

Load cell and load cell amp

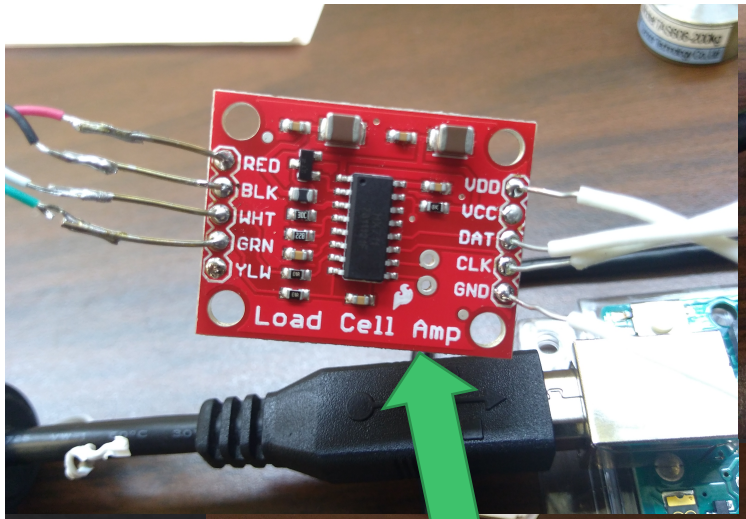
$F = m * a$

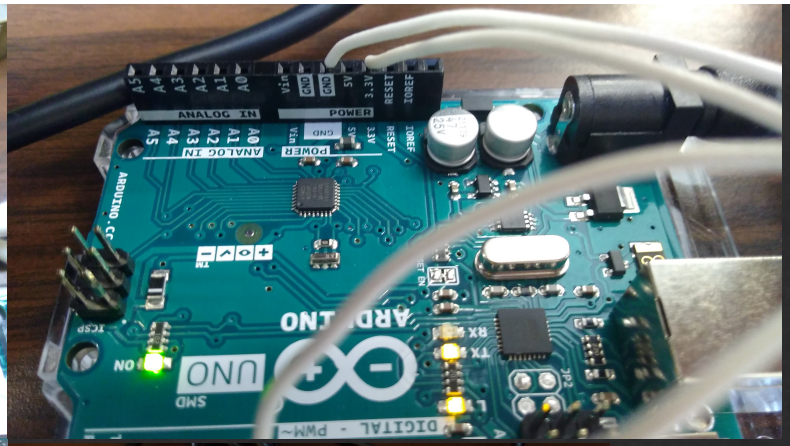
Is a transducer that measures force



Made with strain gauges

Wheatstone half bridge



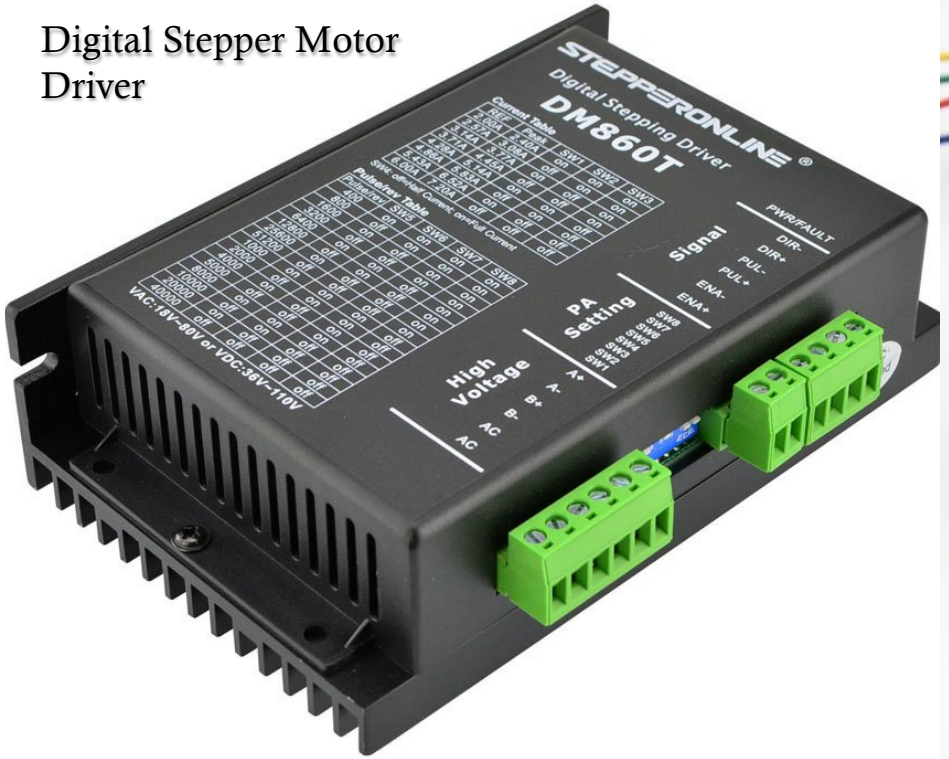


Load cell amplificator

Load cell

Connections for the Load cell

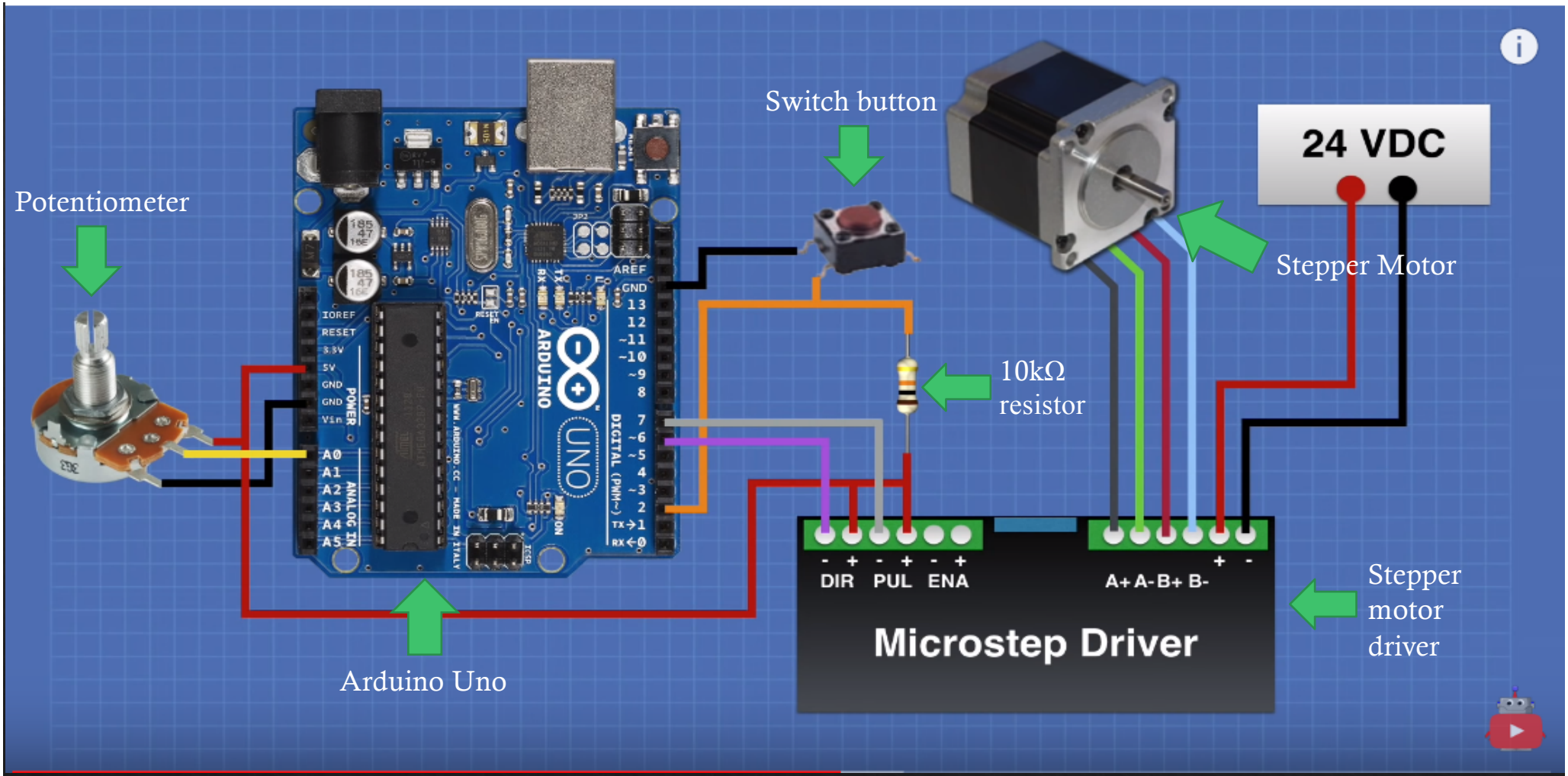
Digital Stepper Motor Driver



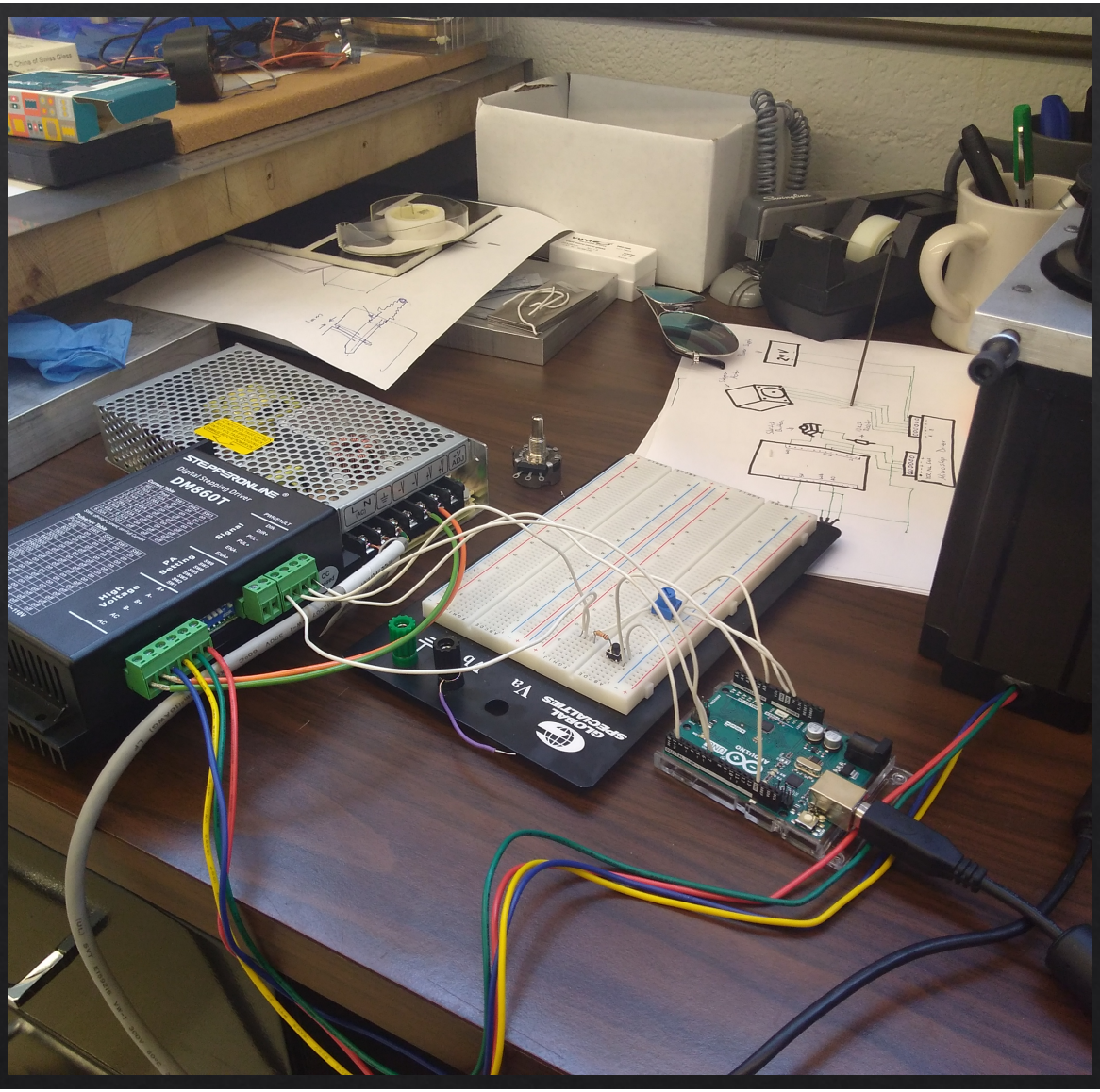
Nema 34 Stepper Motor

Stepper Motor

- Nema 34 Stepper Motor 6A 12Nm (1700 oz-in) 156mm Length for CNC Router Mill Lathe

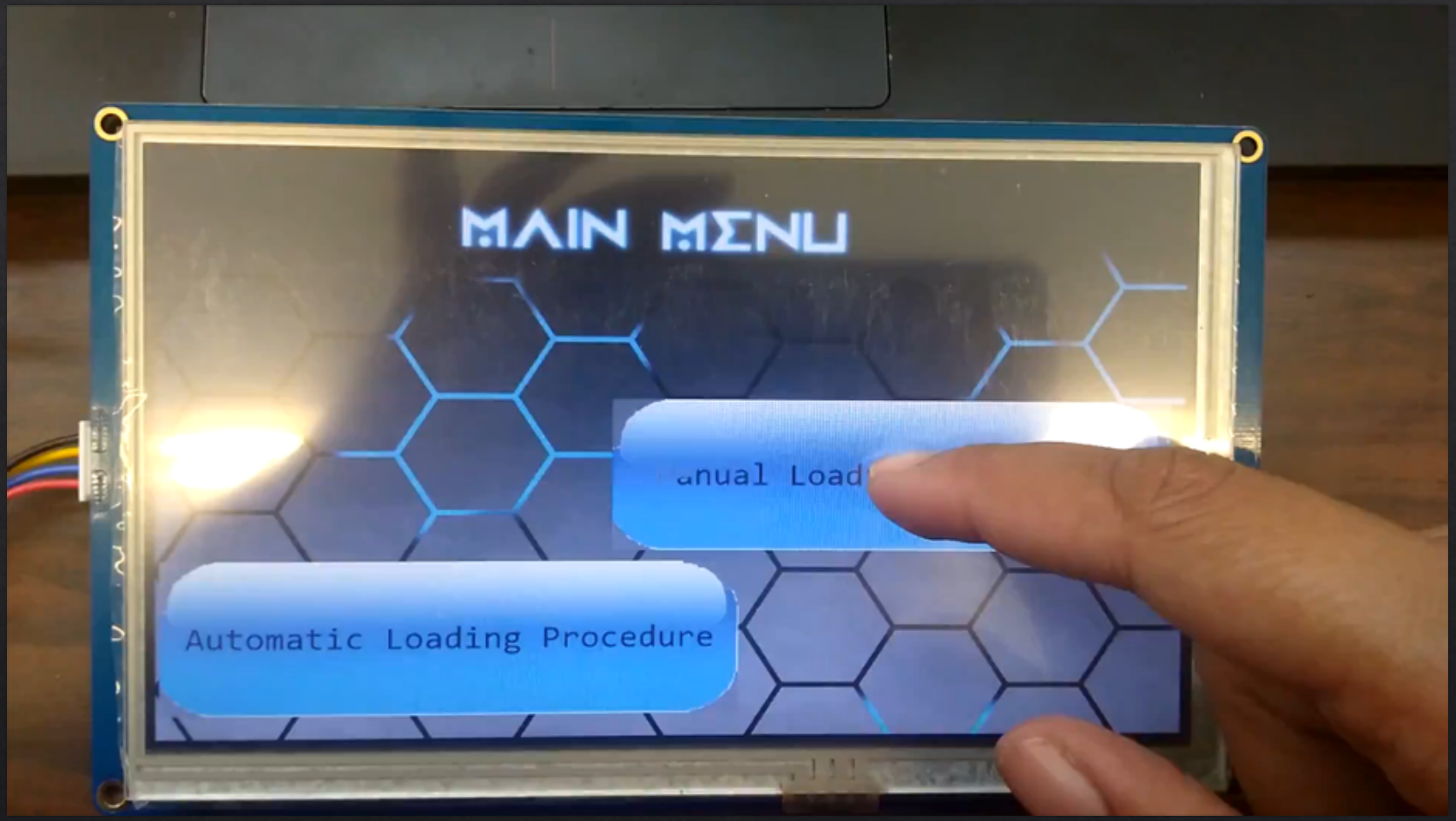


Connections for the motor

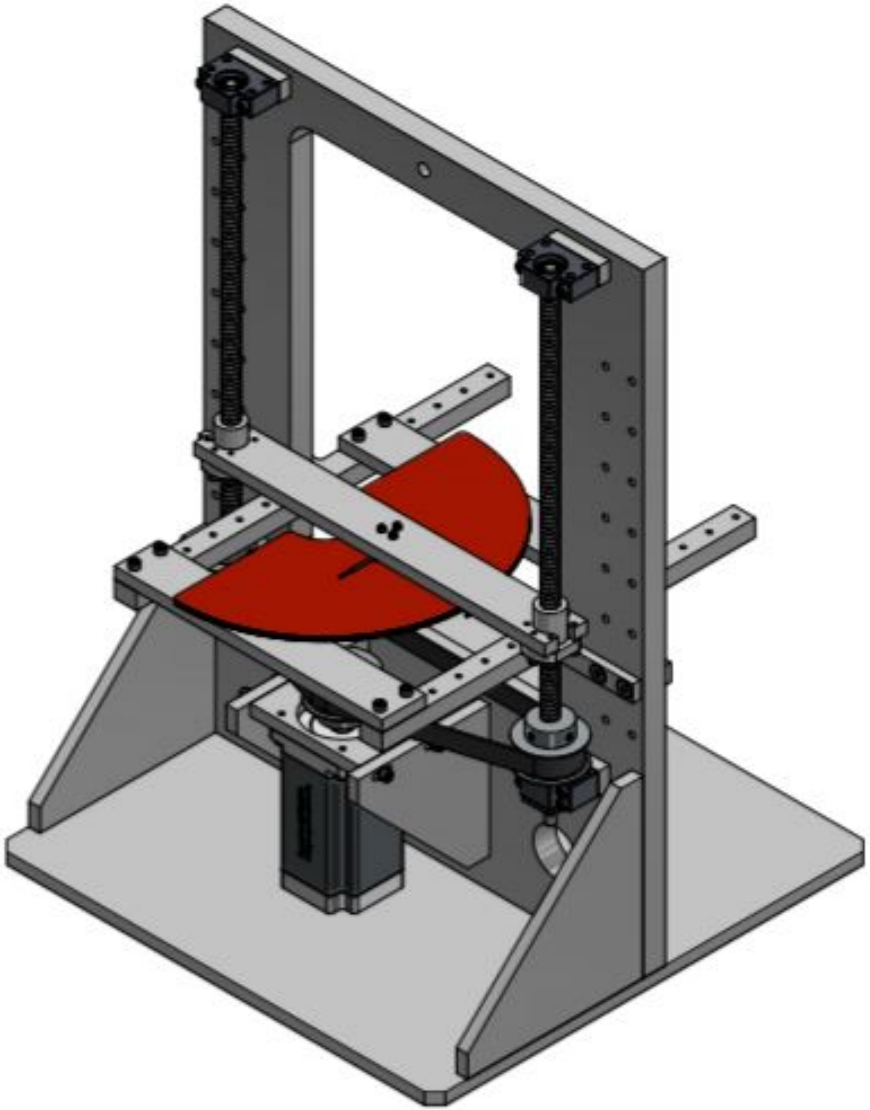

STEPPERONLINE
Digital Stepping Driver
DM860T
High Voltage
PA Setting
Signal
GLOBAL SPECIALTIES
V3

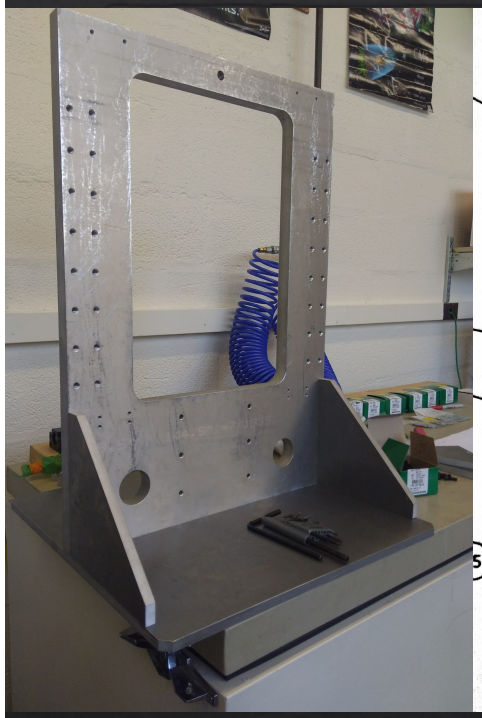
Touchscreen Module

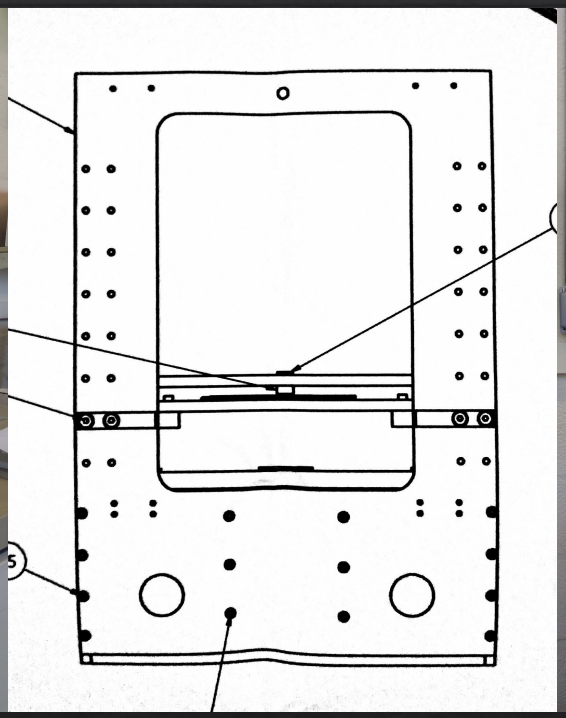
- Nextion 7.0 inch NX8048T070
  - 800x480 resistive touch screen display
  - 16MB Flash Memory
  - 2KByte RAM
  - 65k colors
  - It can be programable with the Nextion Editor
    - Coding of the screen can be combined with the Arduino's code
    - Making of buttons, gauges, progression bars, ect.
  - Requires less cable connections than other atternatives

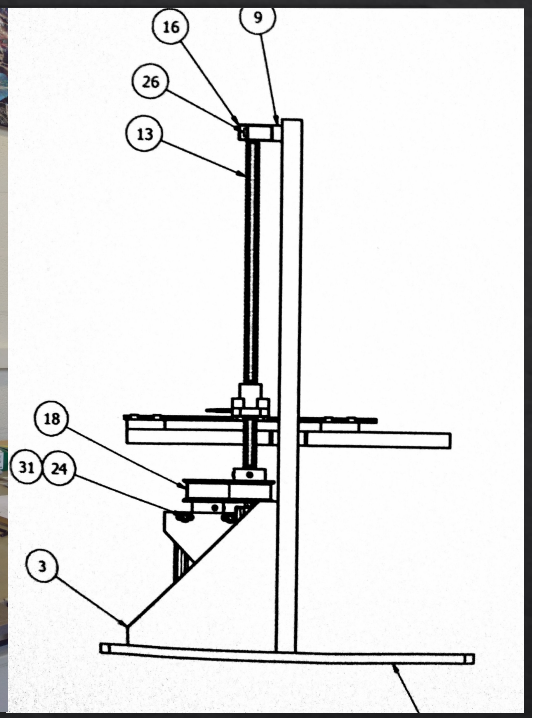

MAIN MENU
anual Load
Automatic Loading Procedure

Design

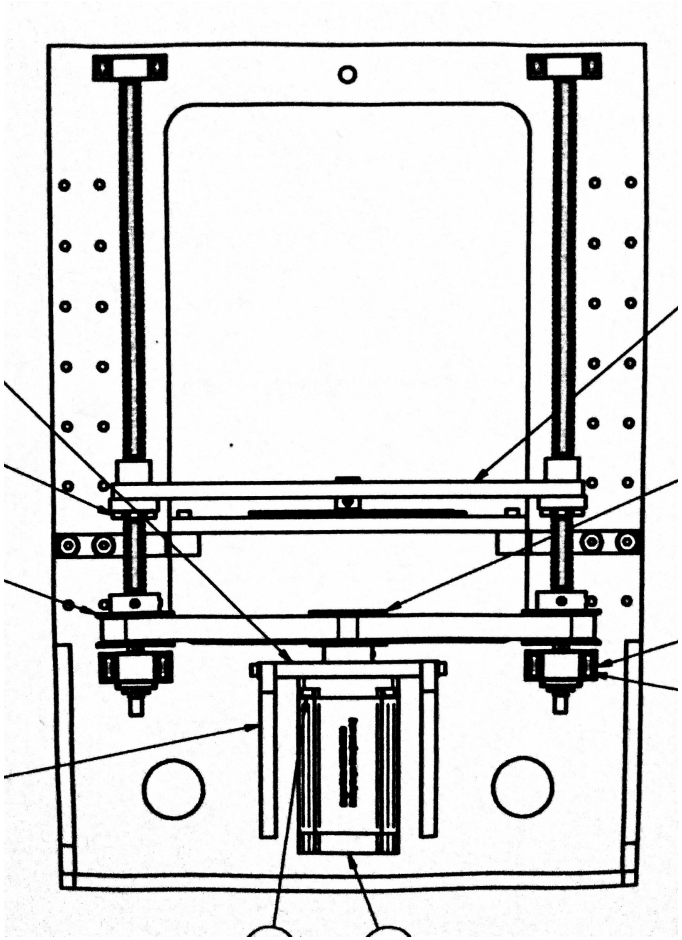


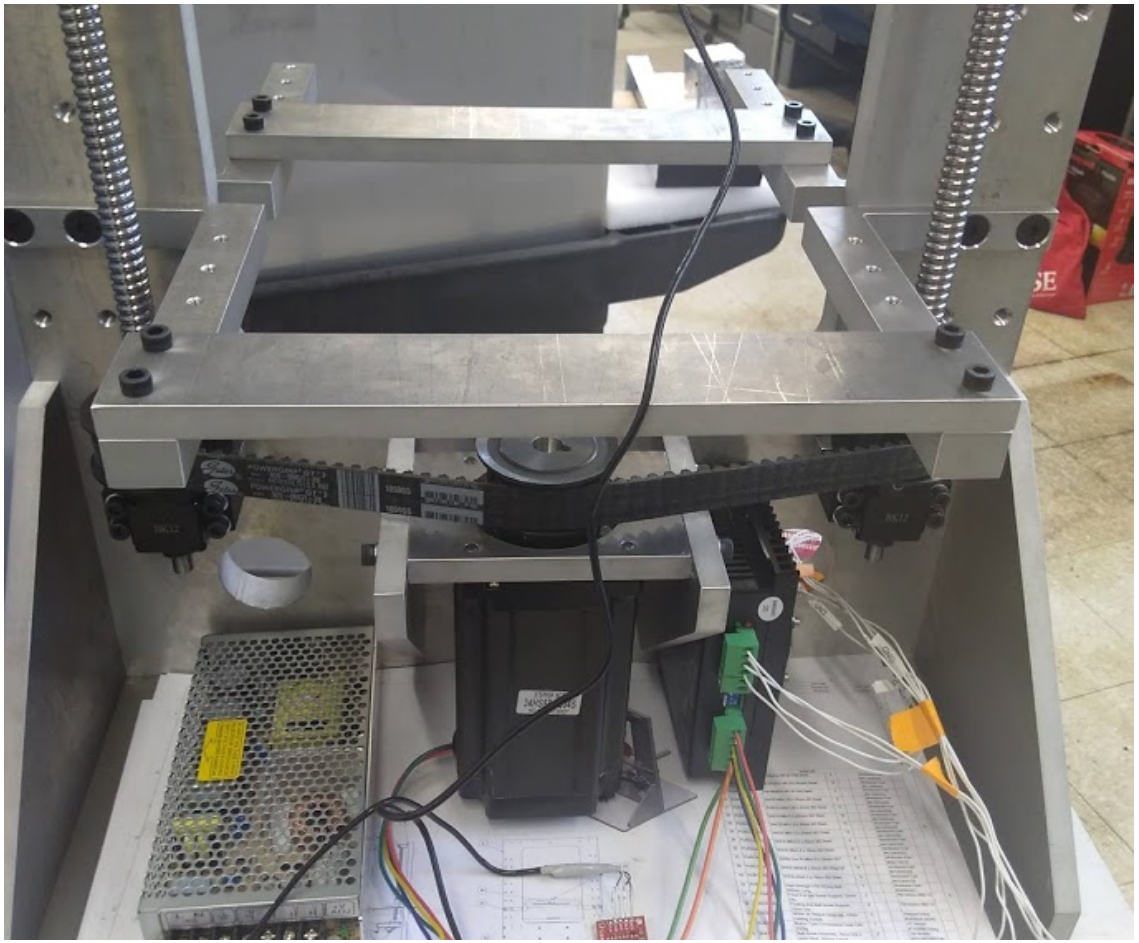






Build Up





Continuing and upgrades

Change from Arduino Uno to Arduino Mega	More Serial ports to communicate between the screen module and the computer
Few upgrades on the mechanics of the machine	Make more contact with the belt on the pulley
Change the load cell	To be able to pull, not just pushing the sample


Questions?