UNIVERSAL CIRCUIT FABRICATOR

UNIVERSITY of CENTRAL FLORIDA

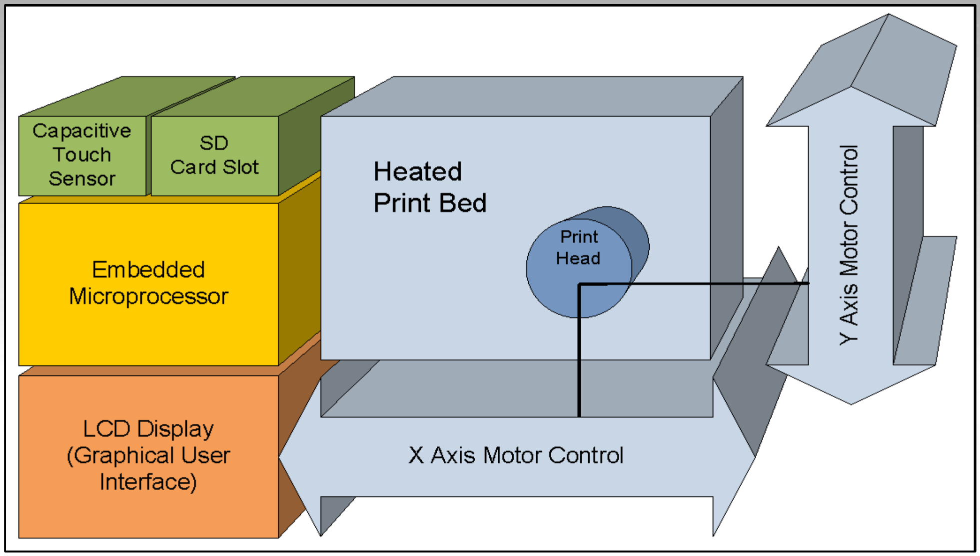
WHO IS UCF?

- Martin Dayuta, EE
- Hector Melendez, EE
- Kyle Scott, EE

GROUP 18

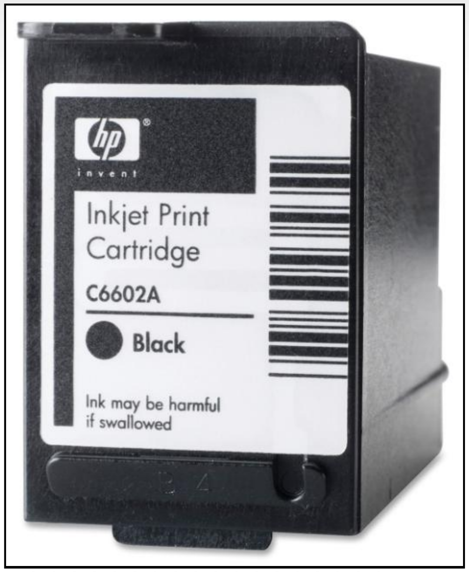
GOALS AND OBJECTIVES

- The Universal Circuit Fabricator is a device that can print conductive ink traces on a nonconductive surface
- The goal is to allow a user to create an image file that is converted to a 2D ink trace
- Purpose is to help users prototype circuits without the use of a breadboard



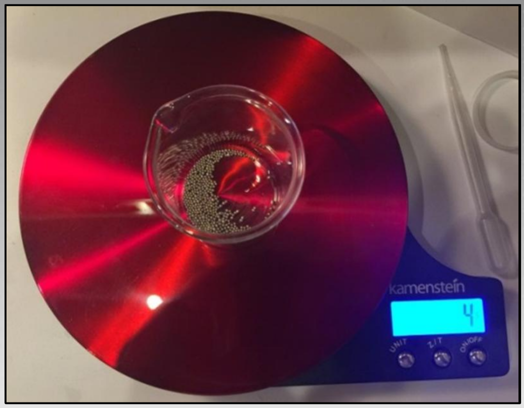
CONDUCTIVE INK RESEARCH

- Conductive Ink Choices
  - The optimal ink variety is selected by choosing the ink with the best performance to price ratio, keeping in mind the importance of low resistivity (Ω•m)
  - Some of the conductive ink configurations require annealing to transform the ink into a finalized state.
    - Annealing is the process of heating a material and allowing it to cool down slowly in an effort to fuse the material into a continuous structure.
- Conductive Ink Design Requirements
  - The HP C6602 inkjet cartridge must be able to store the conductive ink without leaking.
  - The HP C6602 inkjet cartridge print head must be able to print a continuous line of conductive ink without clogging.

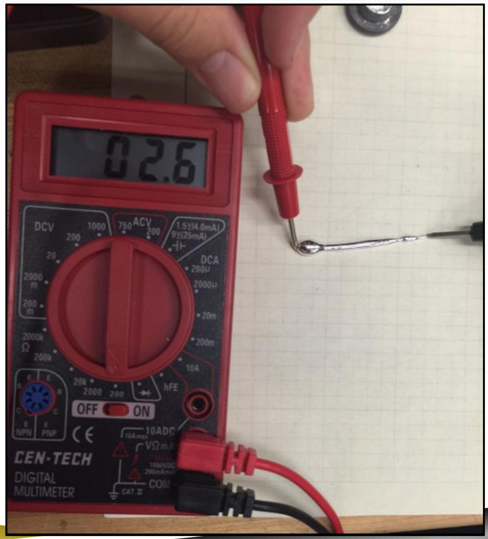


GALLIUM-INDIUM INK

- 75.5% Gallium
- 24.5% Indium
- Heated to 50° C to fuse the elements into an alloy

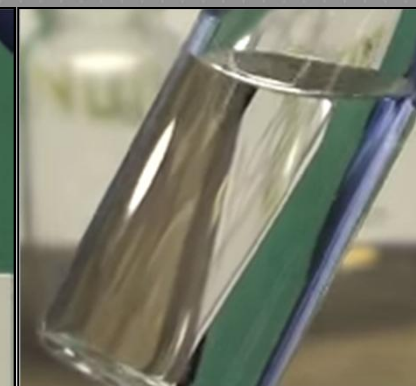


- The Gallium – Indium Ink is liquid at room temperature.The viscosity of the ink and its inability to cure at room temperature must be considered when testing against the design requirements.



SILVER ACETATE INK

- 1g Silver Acetate
- 2.5ml Ammonia Hydroxide
- 0.2ml Formic Acid



- As the clear ink dries, the ammonia evaporates and the formic acid reacts with silver ions to form elemental silver
- The Silver Acetate Ink is annealed by heating to 100°C forming a continuous conductive bond

CONDUCTIVE INK DECISION

We chose to use the Silver Acetate ink because:

- Silver Acetate ink is less expensive to produce than Gallium-Indium
- Silver Acetate ink is particle free, so it will not clog the inkjet cartridge
- After annealing, the Silver Acetate is structurally permanent

PRINT SUBSTRATE RESEARCH

- Printing Substrate Design Requirements:
- The substrate must be able to resist high temperatures (at least 212°F)
- The substrate must have a high resistivity (non-conductive)
- Preferably low in cost

PRINT SUBSTRATE OPTIONS

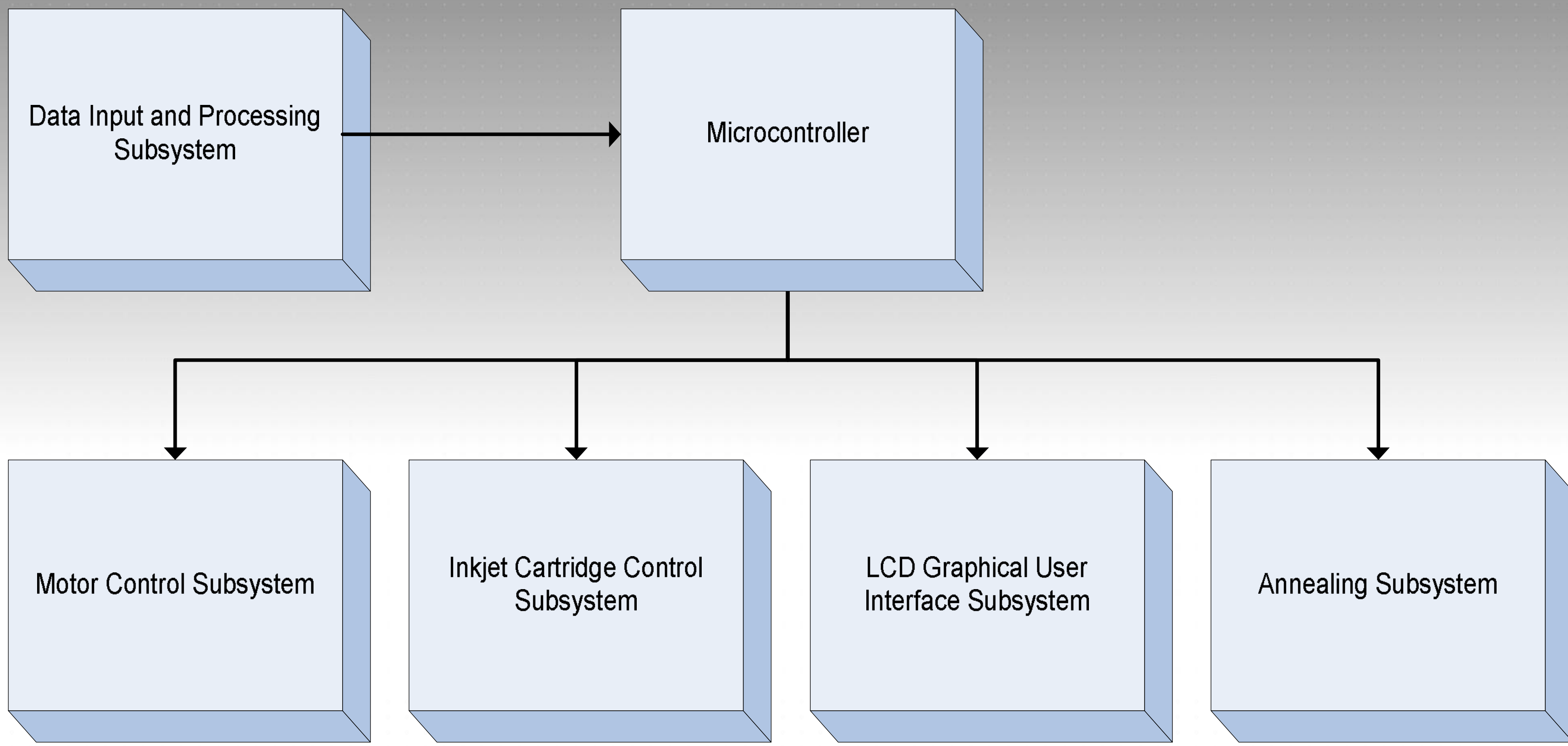
- Possible Substrate Choices:
  - Glass - A smooth surface that can withstand the annealing process. It provides a solid insulating surface for the conductive ink to adhere to without leakage current into the substrate
  - Acrylic Film – Similar properties of glass, less fragile, but less heat resistive. It can be flexible depending on the thickness.
  - PET transparency - Thermoplastic polyester film. Also known as Mylar® Film, which has a large range of uses. This polyester film is heat resistant up to 440°F, but a flexible substrate might crack the fused conductive ink traces

PRINT SUBSTRATE DECISION

We chose to use Glass because:

- Glass can withstand the high temperatures of annealing
- Glass is rigid and inflexible providing a surface that will avoid cracking the solidified conductive ink

UCF: OVERALL BLOCK DIAGRAM

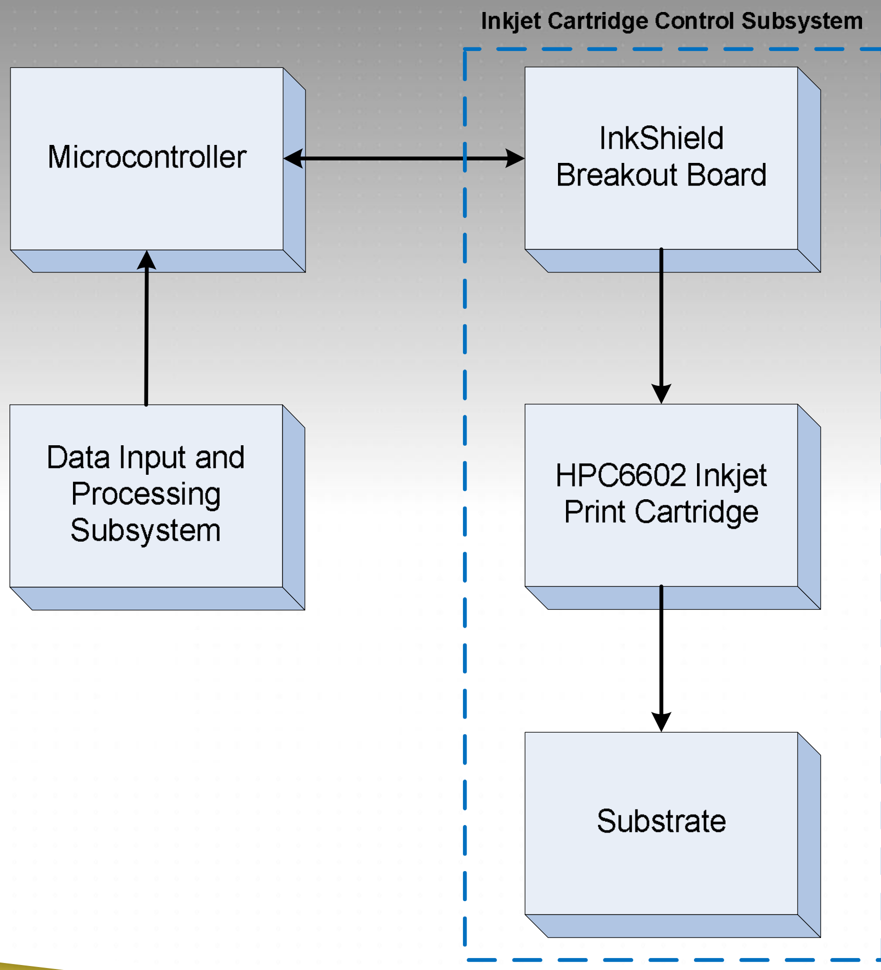


INKJET CONTROL SYSTEM

presented by: Kyle Scott

INKJET CARTRIDGE CONTROL SYSTEM

- Responsible for controlling the flow of conductive ink from the HPc6602a inkjet cartridge
- Microcontroller will receive instructions from G-code input file to start and stop the flow of ink



REQUIREMENTS & SPECIFICATIONS

Printing Process

- The UCF will have the ability to print continuous conductive traces with a maximum line thickness of 10 mm
  - Optimally the line thickness will be ≈ 1 mm
- Conductive traces will have a resistivity $\rho \leq 10^{-7}$ Ω•m
- The printing surface will allow for a printing area of 10 by 10 inches.

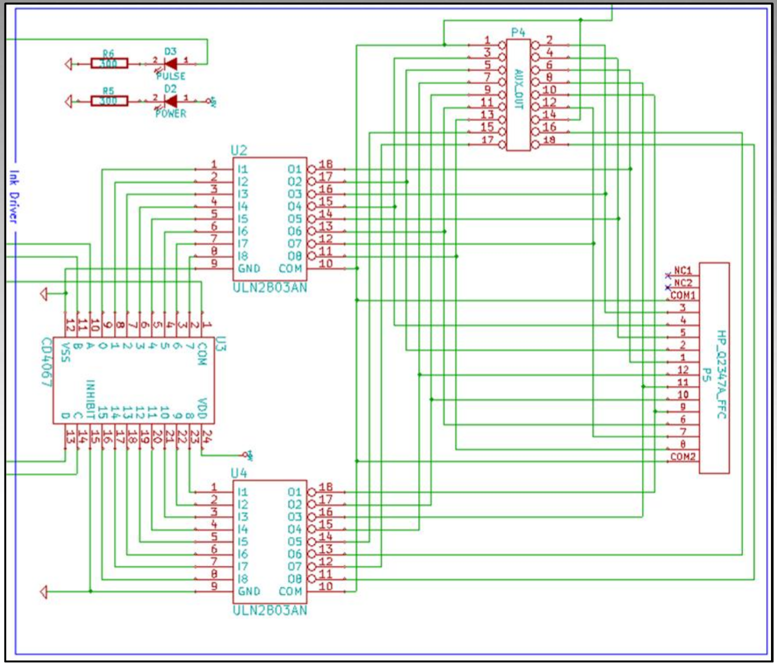
$$\rho = \frac{E}{J} = R \cdot \frac{A}{l}$$

Material	Resistivity ρ (Ω·m)
Superconductors	0
Metals	10^{-8}
Semiconductors	variable
Electrolytes	variable
Insulators	10^{16}

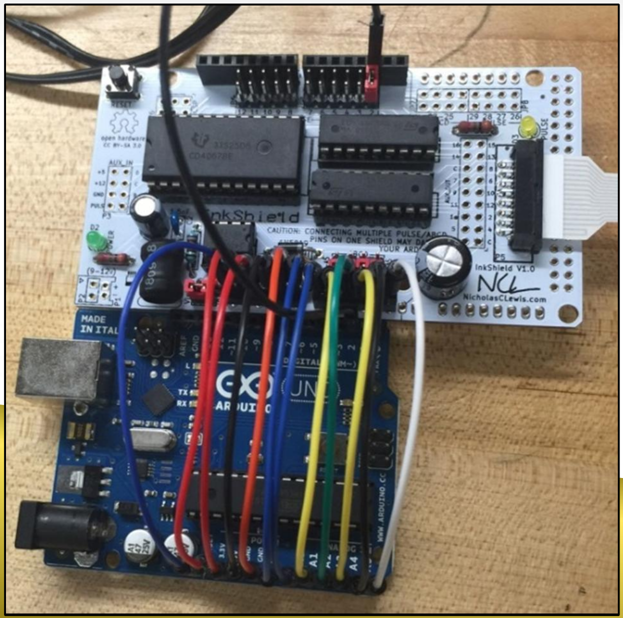
Typical Resistivity Values

INKSHIELD

- Supplies 20V to HP C6602 inkjet cartridge via boost converter
- HP C6602 is 96dpi with 12 inkjet nozzles
- Sold as kit with through-hole design and all needed components (soldering required)
- Libraries designed for Arduino

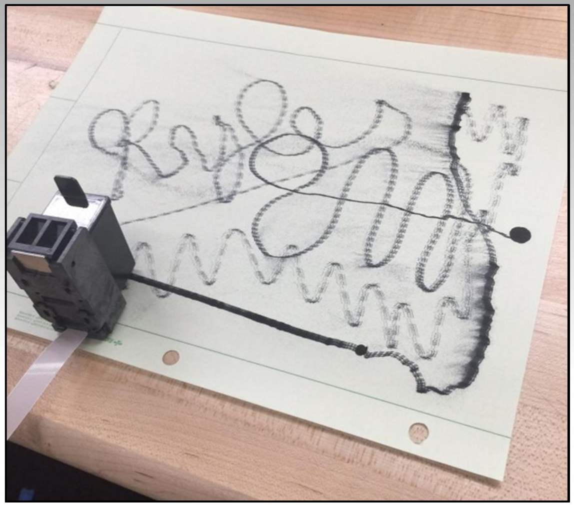


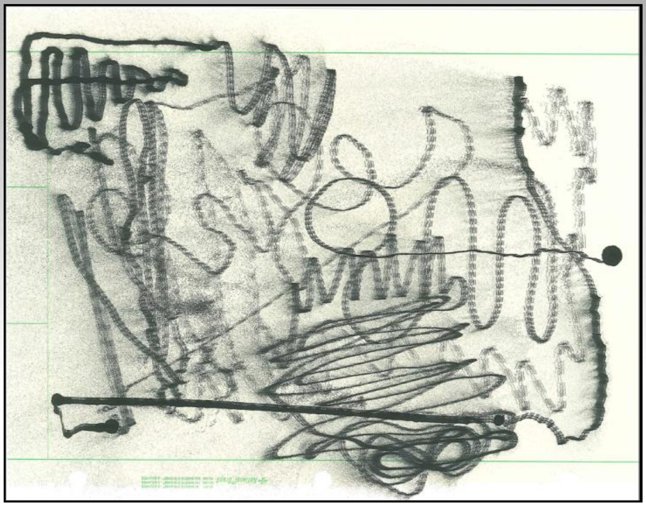
InkShield Schematic



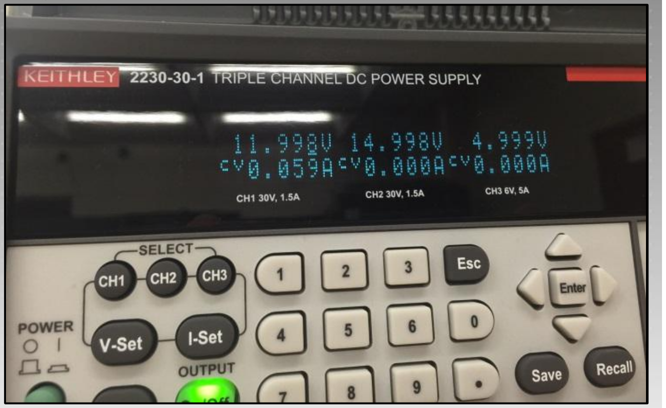
InkShield Breakout Board
interfaced with Arduino Uno

PROTOTYPING

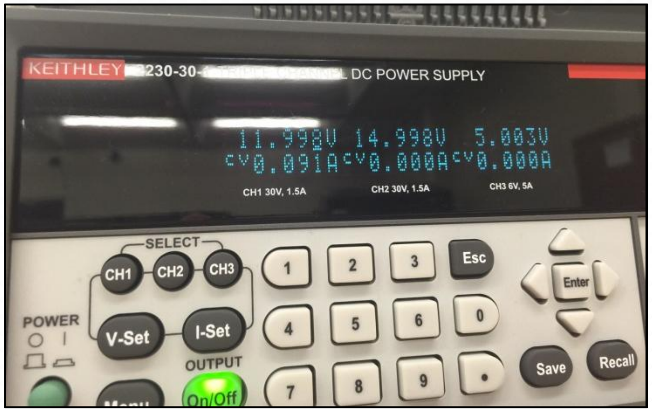




Moving the print head by hand



0.708 W load when cartridge is disconnected



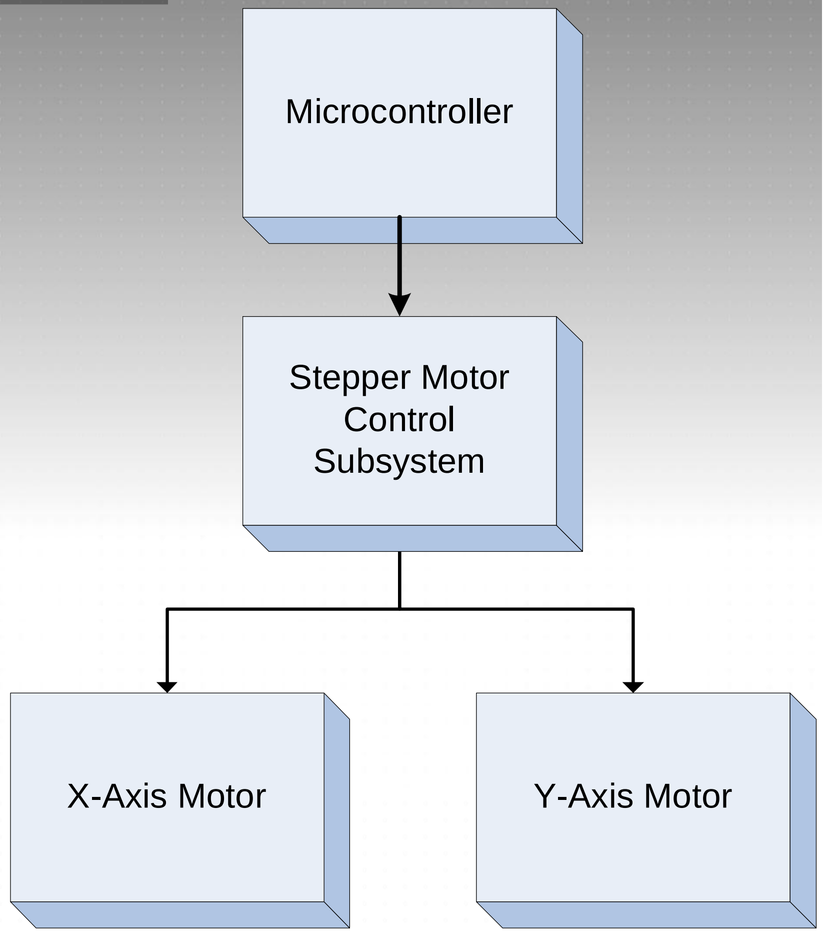
1.092 W load when cartridge is spraying ink

MOTOR CONTROL SYSTEM

presented by: Martin Dayuta

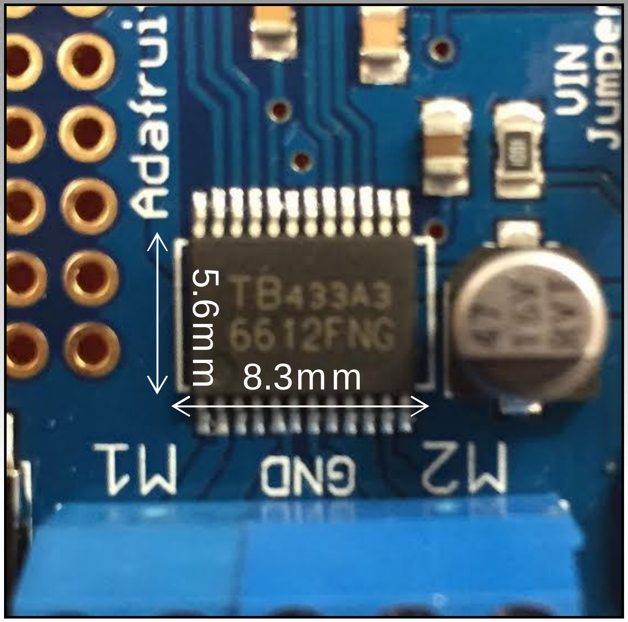
MOTOR CONTROL SYSTEM

- Responsible for controlling the movement of the X and Y stepper motors
- Microcontroller will receive instructions from the user and subsequently transmit the data to the motor control system to create movement
- Movement is split in X and Y axis motor to increase accuracy of circuit trace drawing on the substrate

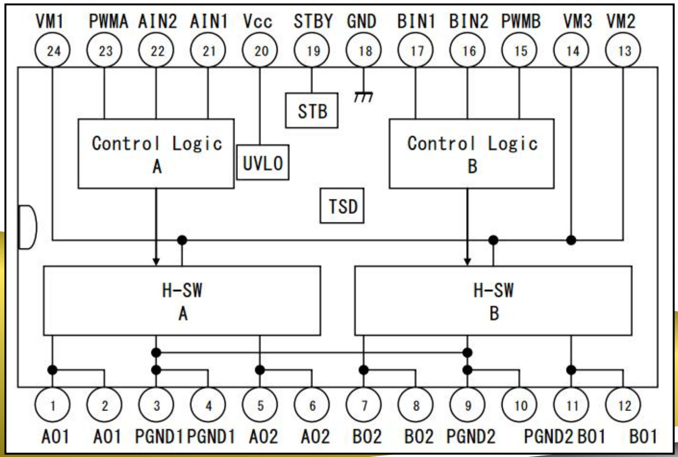


TB6612 MOTOR CONTROL DRIVER

- TB6612FNG is a driver IC for DC motors with a MOSFET structure
- 1.2A per channel
- 3A peak current capability
- Each chip contains 2 H-Bridges
- Can run motors on 4.5VDC to 13.5VDC
- Chip creates lower voltage drops across motors to increase torque and accuracy



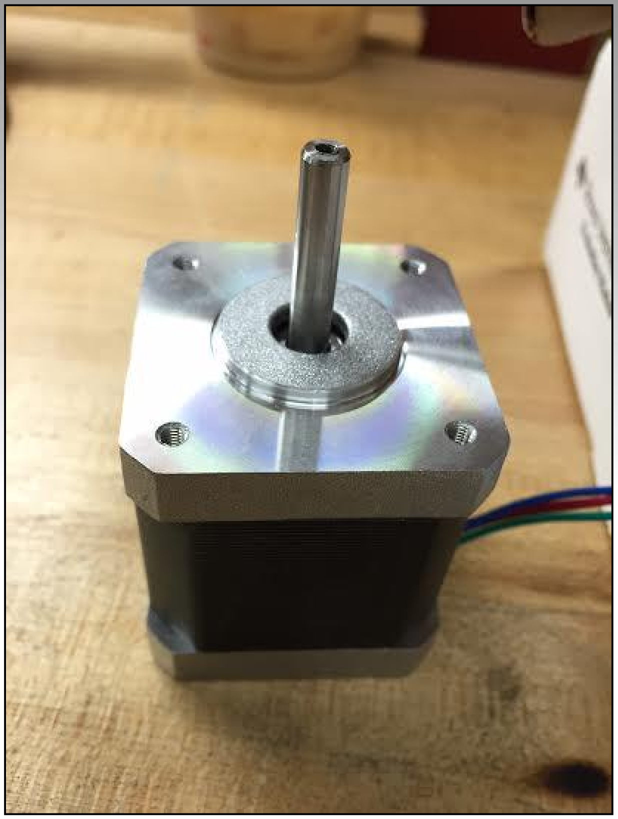
TB6612 on Adafruit Motor/Stepper/Servo Shield for Arduino v2



TB6612 Schematic

STEPPER MOTOR

- NEMA-17 bipolar motor
- 400 steps per revolution; 0.9° per step
- 12V rated voltage
- 350mA max current
- 20 N•cm holding torque per phase
- Stepper motors are used for their precise speed control and accurate positioning due to their discrete steps.



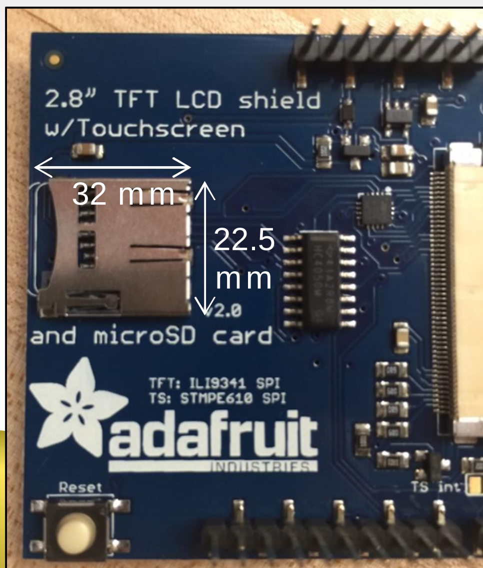
NEMA-17 Stepper Motor

DATA COLLECTION & PROCESSING

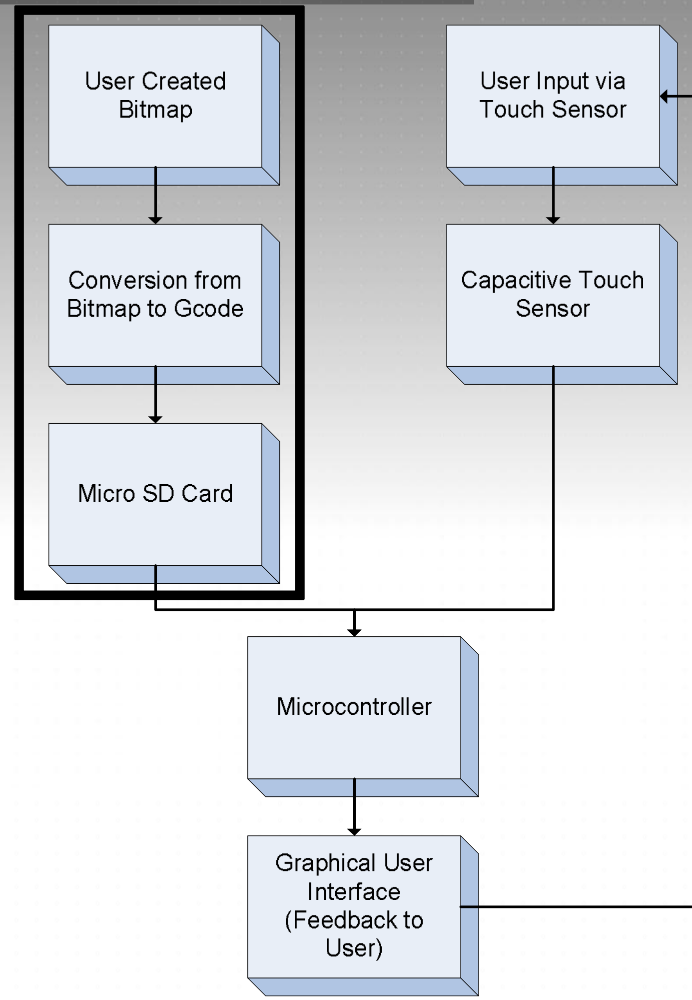
presented by: Kyle Scott

DATA INPUT & PROCESSING SYSTEM

- UCF will contain a Micro-SD Card slot for input file transmission
- Allows user to input custom layout trace designs
- Facilitates serial communication between Micro-SD Card and ATMEL ATMega328



Micro-SD Card Interface on 2.8" TFT Touch Shield for Arduino with Resistive Touch Screen



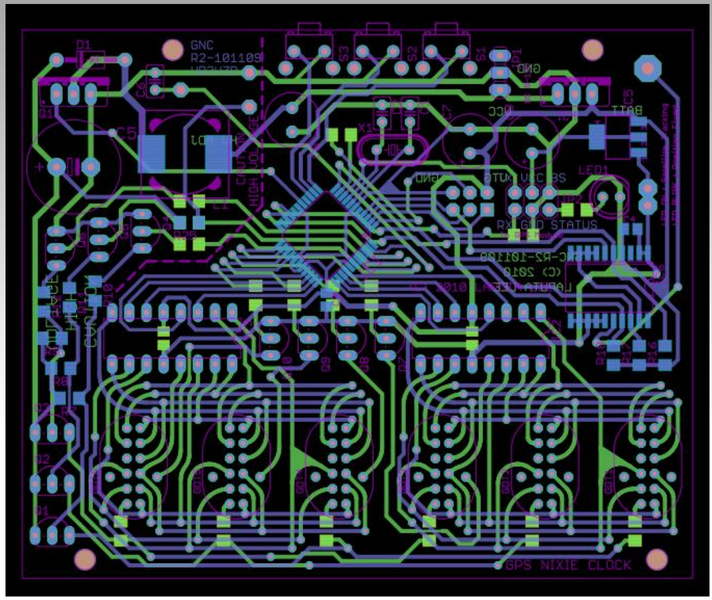
REQUIREMENTS & SPECIFICATIONS

Data Transmission

- The Micro-SD Card will communicate with the microcontroller via SPI (Serial Peripheral Interface) communication
  - SPI devices have 3 common lines (MISO, MOSI, SCK) and one specific line for each device (SS). Allowing multiple devices to share the same three common lines.
- The input file will be a .txt file written in G-code
  - The input file is saved on a Micro-SD Card via an external computer

ORIGINAL FILE TYPE SELECTION

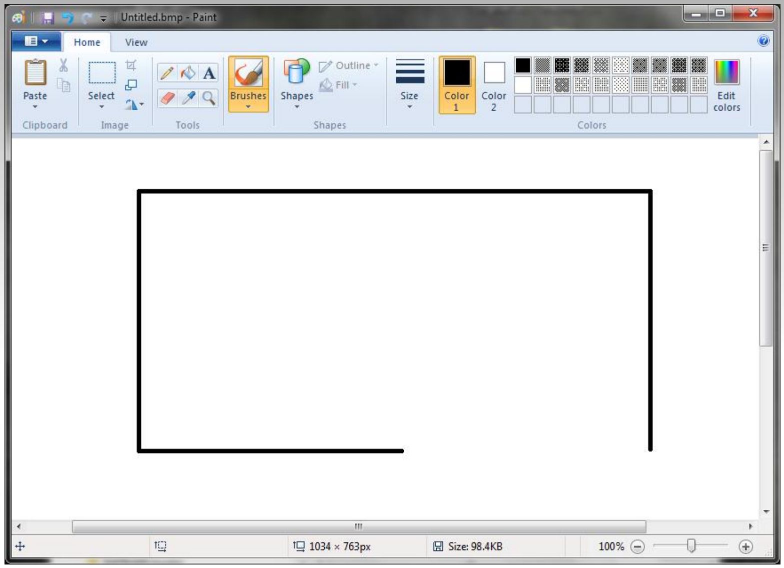
- Originally the supported file type that was selected for the UCF was the Gerber file format (.gbr)
- Gerber files are the standard file type used in the PCB design industry
  - Gerber files contain PCB details that would bloat the file size with unnecessary data in our application (multiple layers, solder mask, legend, through holes, etc.)



Example of PCB Gerber file

FINAL FILE TYPE SELECTION

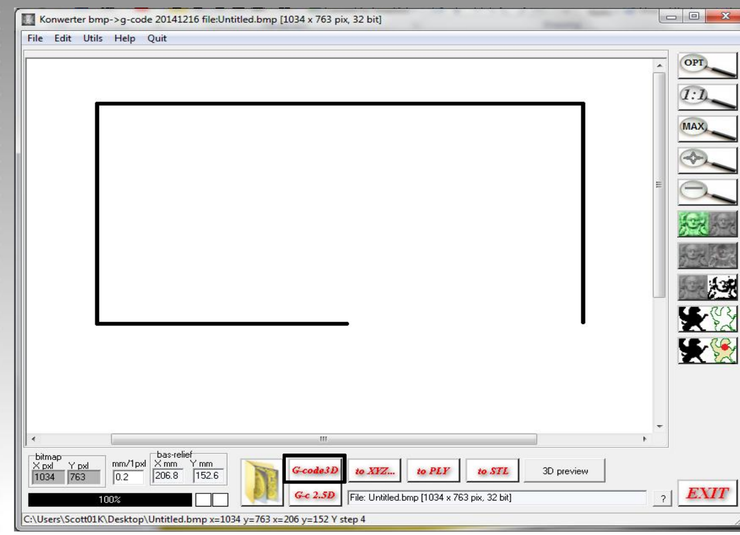
- Our team has decided on using a method that is open source and user friendly for creating UCF print files
  - The user creates a custom circuit trace design using Microsoft paint or another image editor that exports a bitmap file (.bmp)



Schematic bitmap created in Microsoft Paint

BITMAP TO G-CODE CONVERSION

- The user created bitmap is converted using open source freeware called Bitmap2Gcode
- B2G is designed for converting graphic files in .bmp format to .txt files in g-code format
  - Bitmap2Gcode analyses the brightness of image points and translates it to Z values in g-code file. In our application, we will not need Z values, so a black trace on white background is sufficient



B2G converting bitmap to G-code

```
G90 ; use absolute coordinates
G1 F1800.000
G1 Z0.500 F7800.000
G1 X32.001 Y30.526 F7800.000
G1 X32.226 Y30.301 F1080.000
G1 X34.137 Y28.952
G1 X37.100 Y28.282
G1 X152.725 Y28.282
G1 X155.031 Y28.679
G1 X157.599 Y30.301 F1080.000
```

G-code generated by B2G

G-CODE

- G-code is widely used in the 3D printing industry for xyz planar translation and print/extrusion control.
- The UCF will use the G-code text file that was saved on the Micro-SD Card to control the motor control system and inkjet control system.

G00 = Rapid linear move example: G00 X## Y## Z## (X,Y,Z = position)
G01 = Feed linear move example: G01 F## X## Y## Z## (F=feedrate to move at)
G02 = Circular move CW example: G02 X## Y## I## J## (XY=end point, IJ=center point)
G02 = Circular move CW example: G02 X## Y## R±## (R=size of radius arc to swing. R+ if radius < 180°, R- if radius is > 180°)
G03 = Circular move CCW example: G03 X## Y## I## J## (XY=end point, IJ=center point)
G03 = Circular move CCW example: G03 X## Y## R±## (R=size of arc radius to swing. R+ if radius < 180°, R- if radius is > 180°)
G04 = Dwell time example: G04 P## (P=time to dwell. P20000 is 2 seconds)

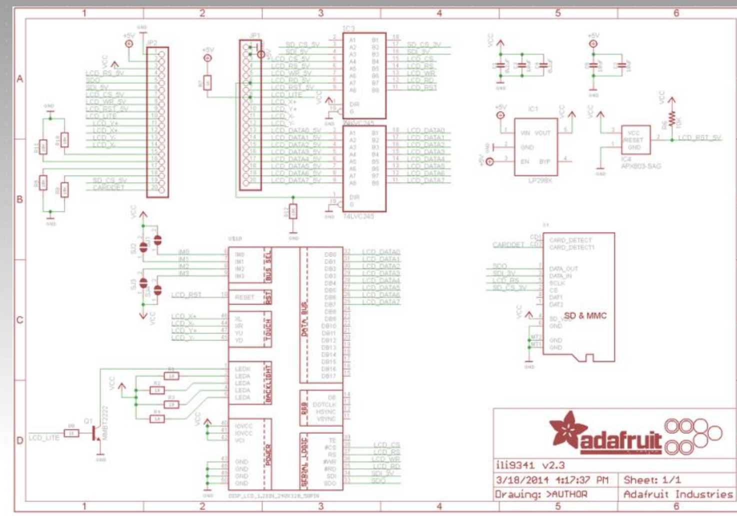
Example of typical G-code commands

LCD/GUI SYSTEM

presented by: Hector Melendez

TFT LCD Single Chip Driver (ILI9341)

- Display Resolution: 240 x 320 pixels
- Display Mode: Full color mode 262K-Color
- TFT-LCD Driver RAM: 172.8 KB
- LCD Driving Voltage: 4.5V – 5.5V
- Operating temperature range: -40°C to 85°C

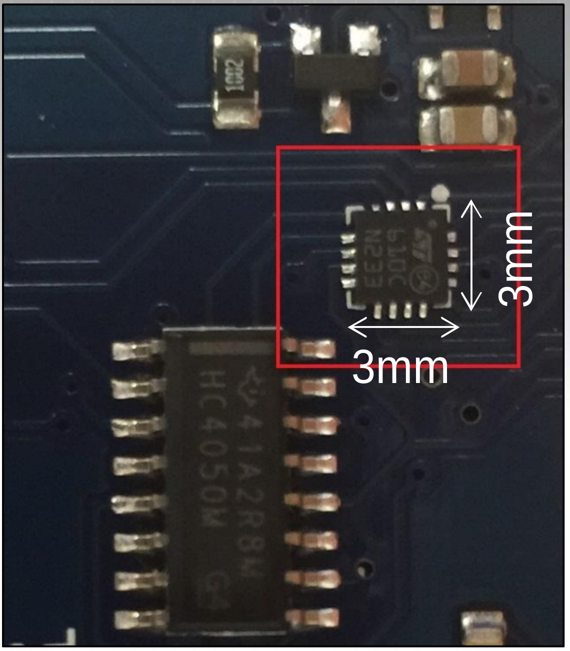


2.8" TFT Touch Shield for Arduino with Resistive Touch Screen Schematic

2.8" TFT Touch Shield for Arduino with Resistive Touch Screen

STMPE610 TOUCH SENSOR

- S-Touch: advanced touch controller with 6-bit port expander
- 6 general purpose input/output port expander
- Operating voltage: 1.8V - 3.3V
- Touch Screen detection algorithm
- SPI and I2C Interface
- 128-depth buffer touchscreen controller



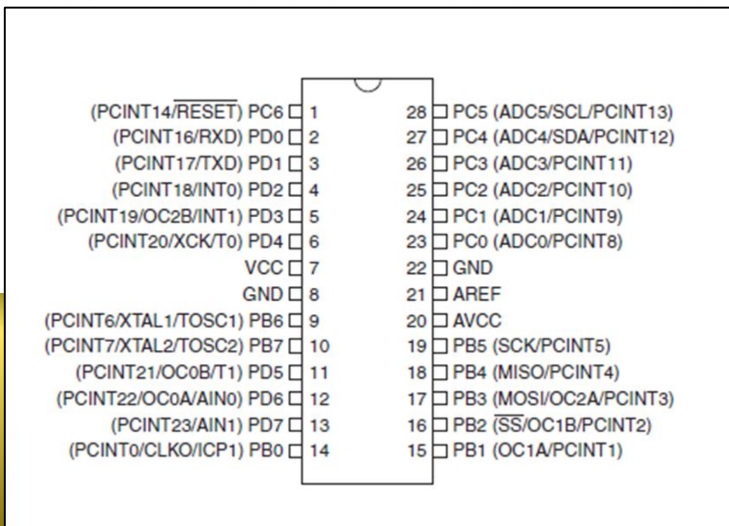
STMPE610 on the 2.8" TFT Touch Shield for Arduino with Resistive Touch Screen

MICROCONTROLLER

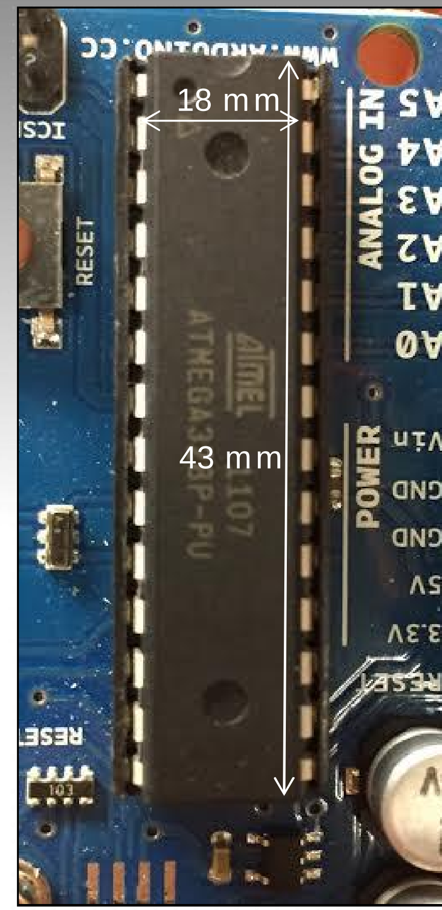
presented by: Martin Dayuta

ATMEL ATMEGA328

- Low power 8 bit RISC microcontroller
- Clock frequency operation at 20 MHz
- 6 channel 10-bit analog to digital converter
- Operates from 1.8 – 5.5V
- Chosen due to ease of PCB design and integration with InkShield inkjet controller. Arduino IDE also provides ease of use.

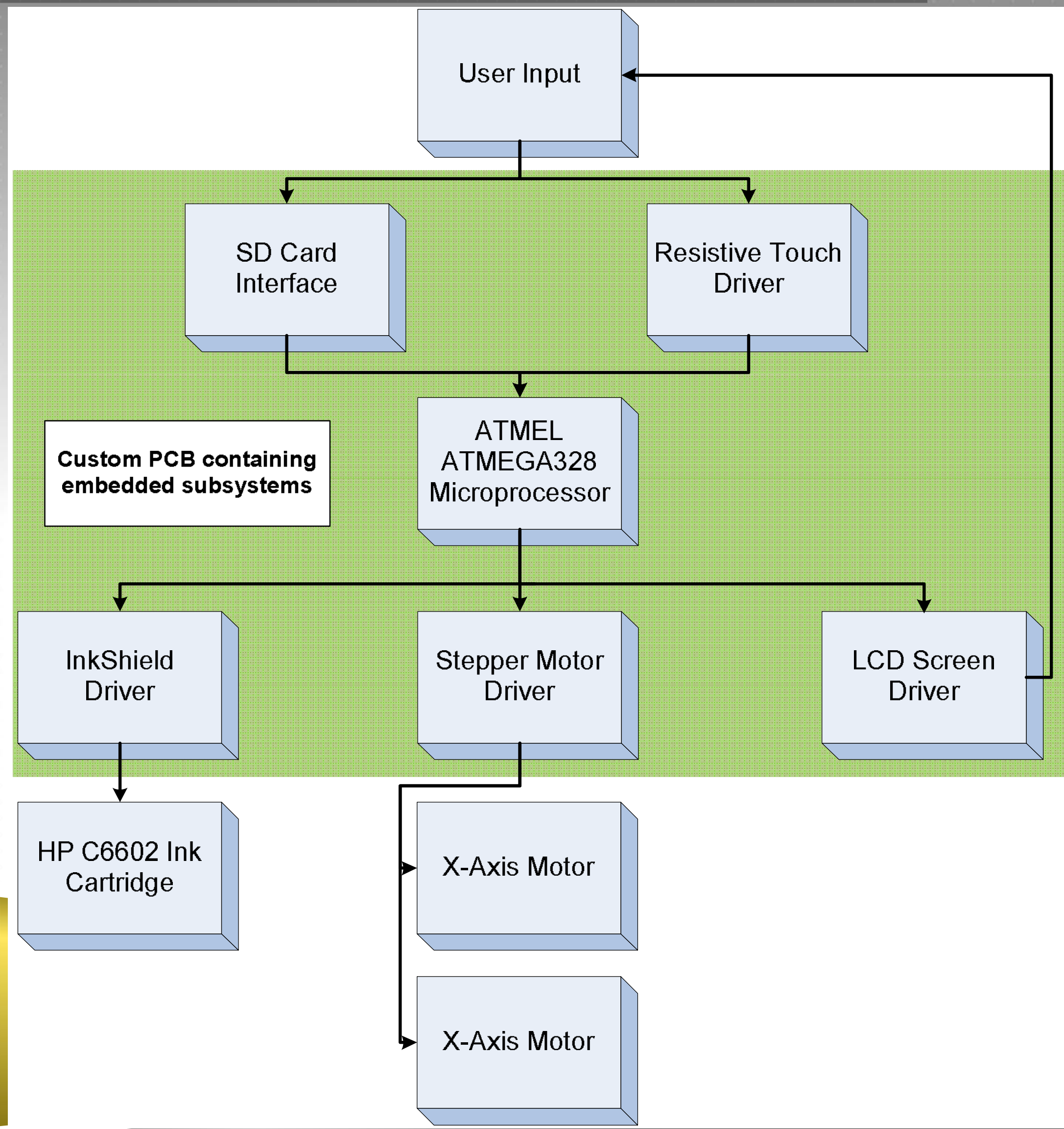


ATMega328 Schematic

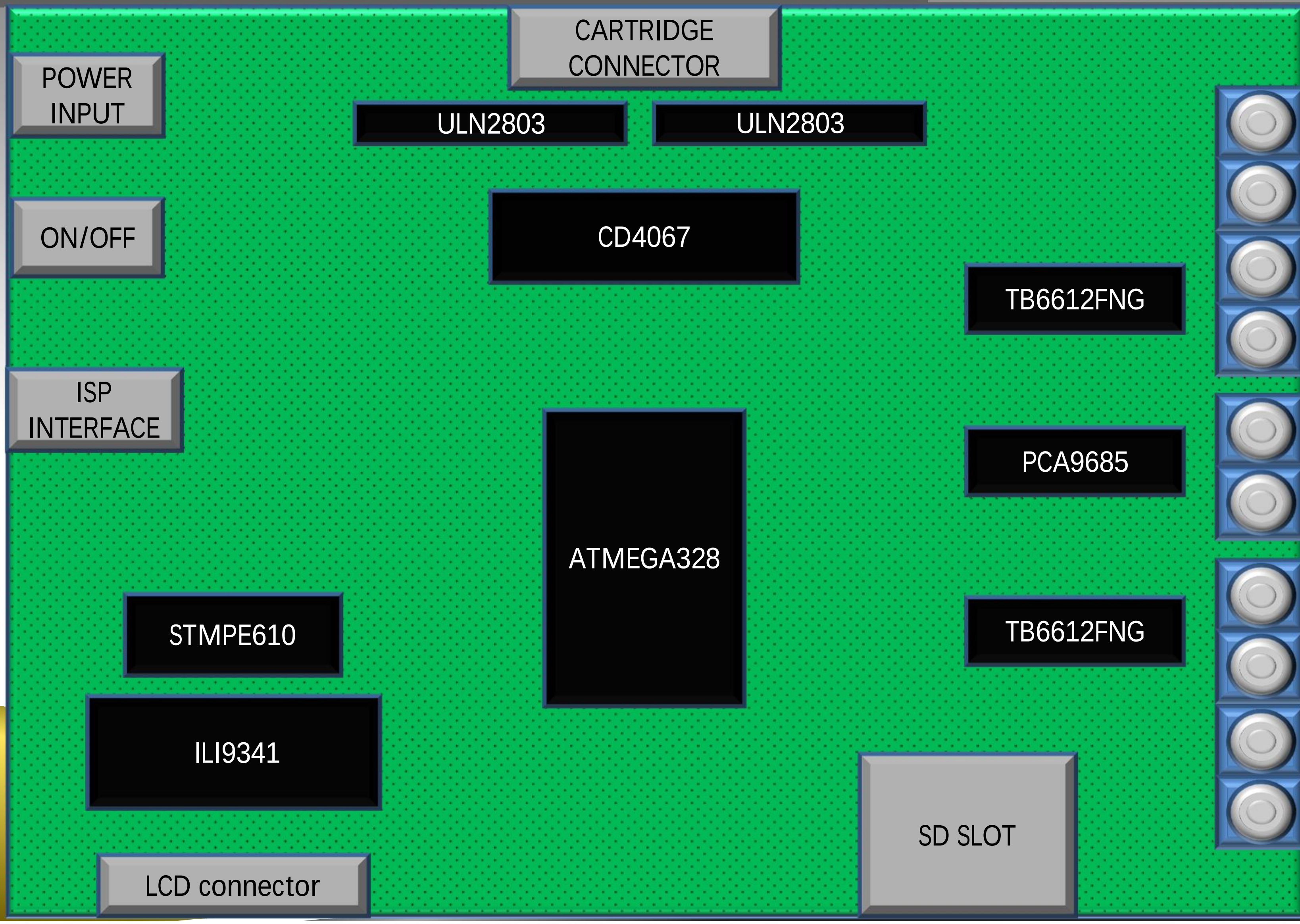


ATMega328 on Arduino Uno

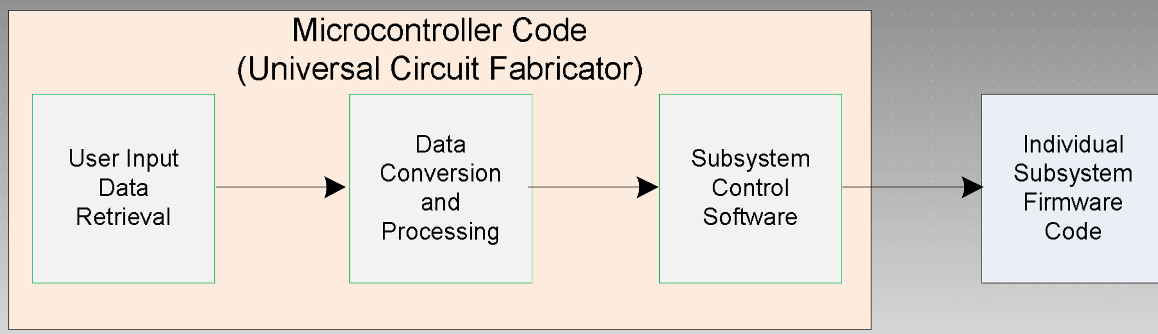
MICROCONTROLLER SYSTEM



THEORETICAL PCB LAYOUT

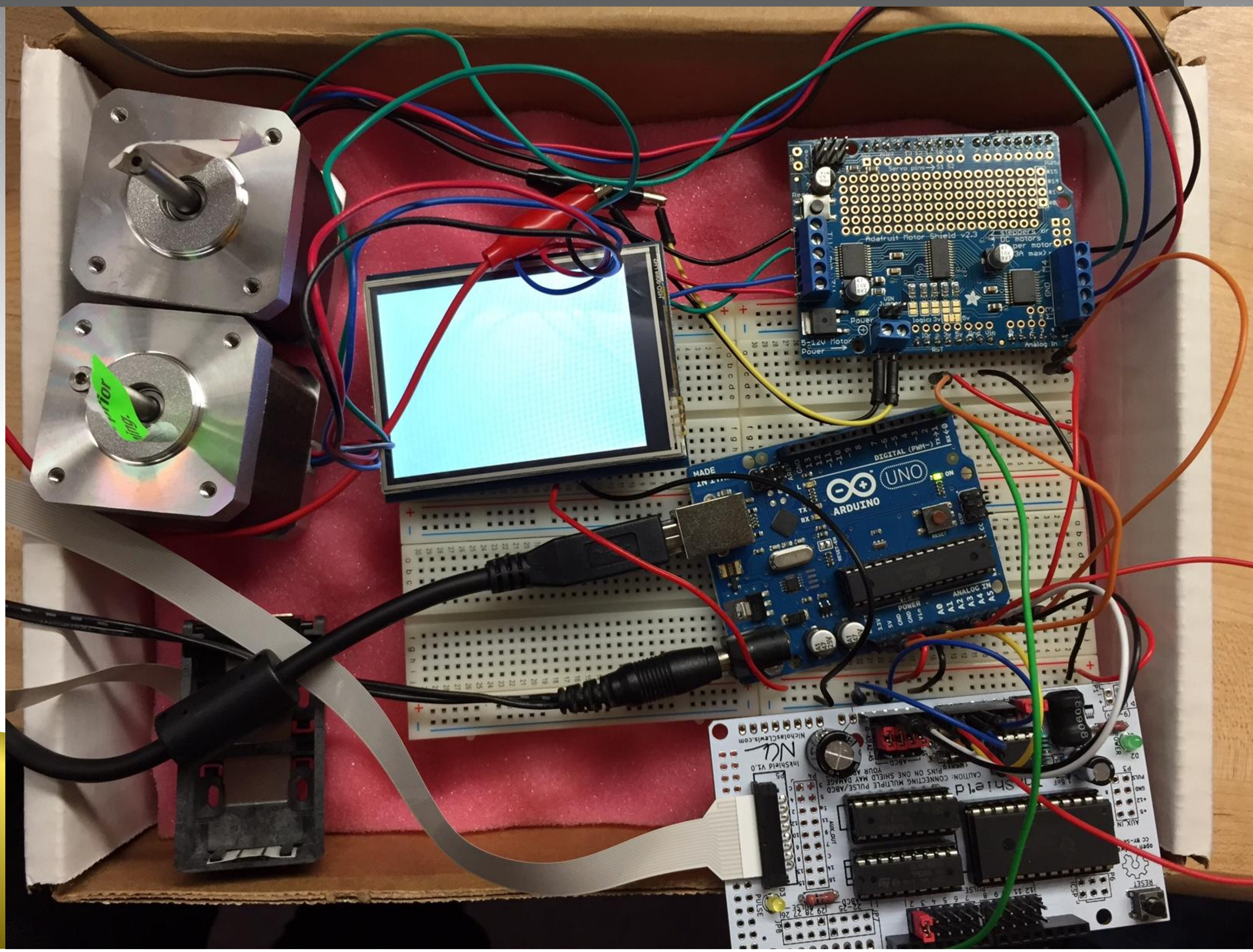


MICROCONTROLLER CODE

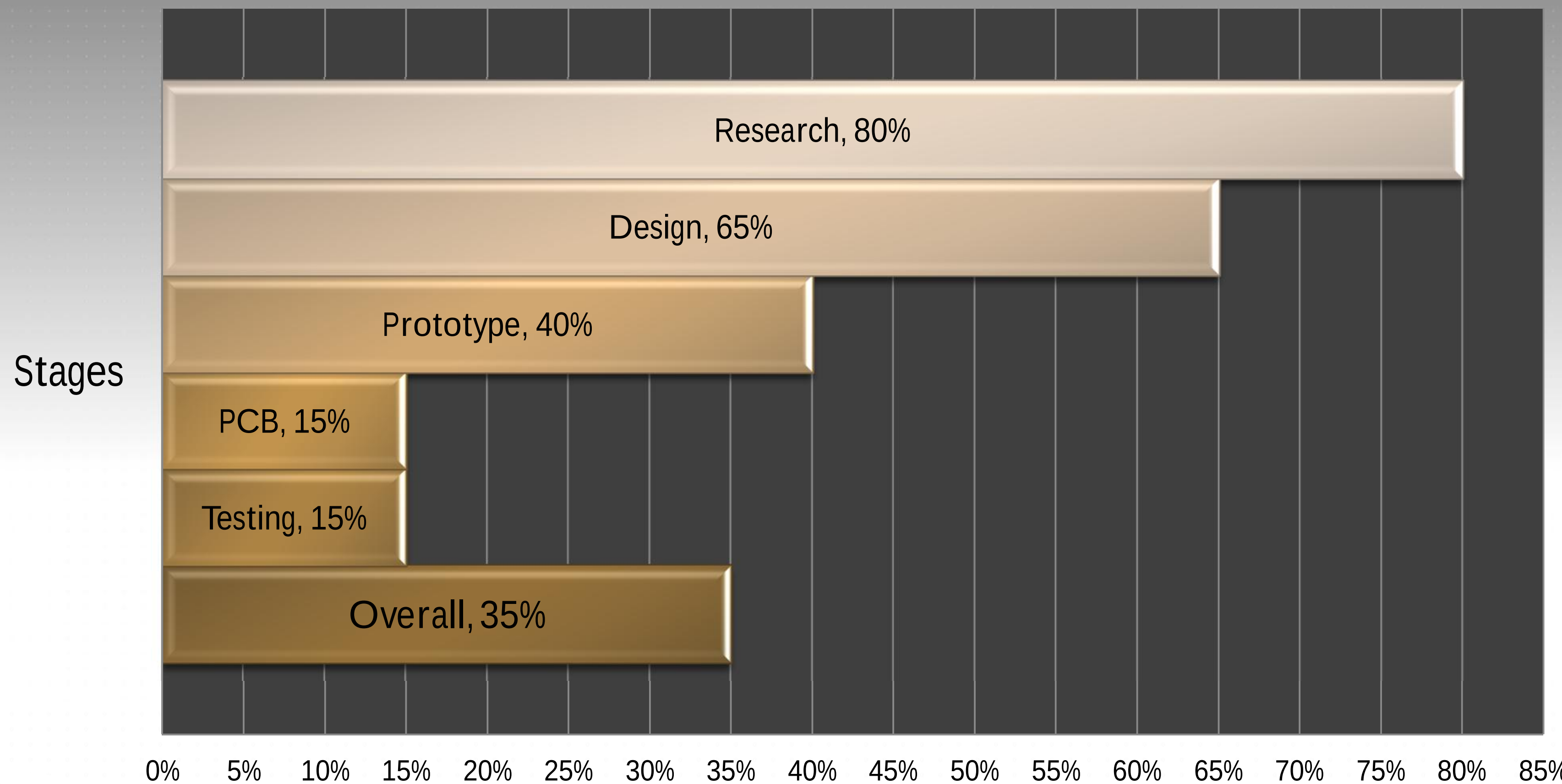


Variable Name	Type	Description
InputData	string	Raw data received from user input
PackagedData	string	After processing and conversion, the packaged data will leave the microcontroller and be used for the subsequent individual subsystem codes.
X_motor_step	Int	The pin number of the microprocessor in relation to the X-axis step motor. Used as either an input or output to read/write to the motor.
X_axis_dir	int	The pin number of the microprocessor in relation to the x-axis step motor. Used as an input to determine the direction of movement in the x axis direction.
Nozzle_enable	int	The pin number of the microprocessor in relation to the inkjet print nozzle. Used as an output to turn on the nozzle on the print head to start spraying conducive ink

DEVELOPMENT BOARD PROTOTYPE



PROGRESS GRAPH



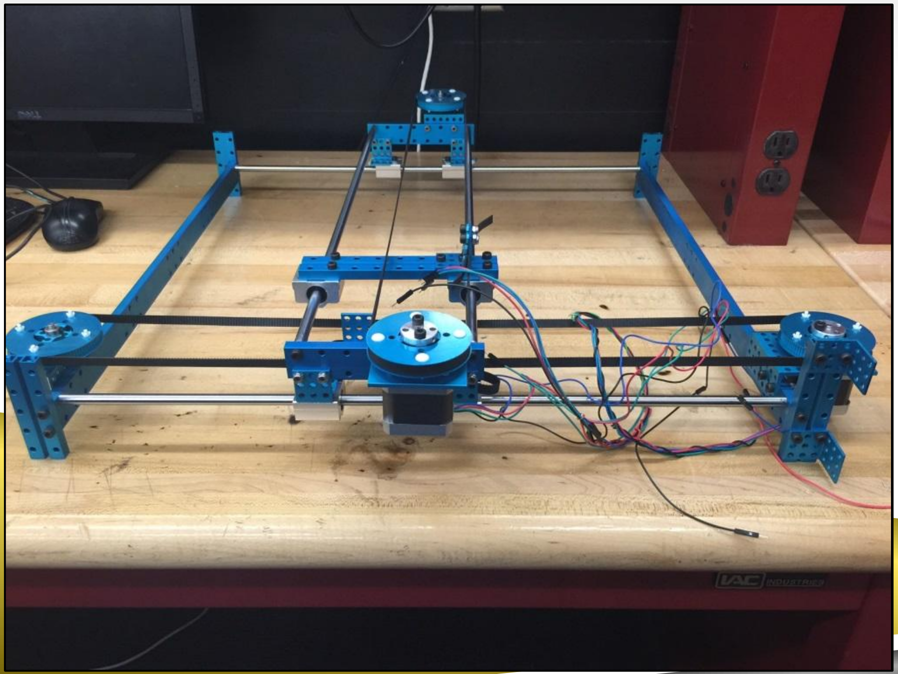
CHALLENGES

- Converting the G-Code file into printing instructions
- Creating a GUI that doesn't occupy too much space in the microcontroller internal memory
- Integrating the Inkshield into the final PCB Design
- Mounting the inkjet cartridge to the frame carriage

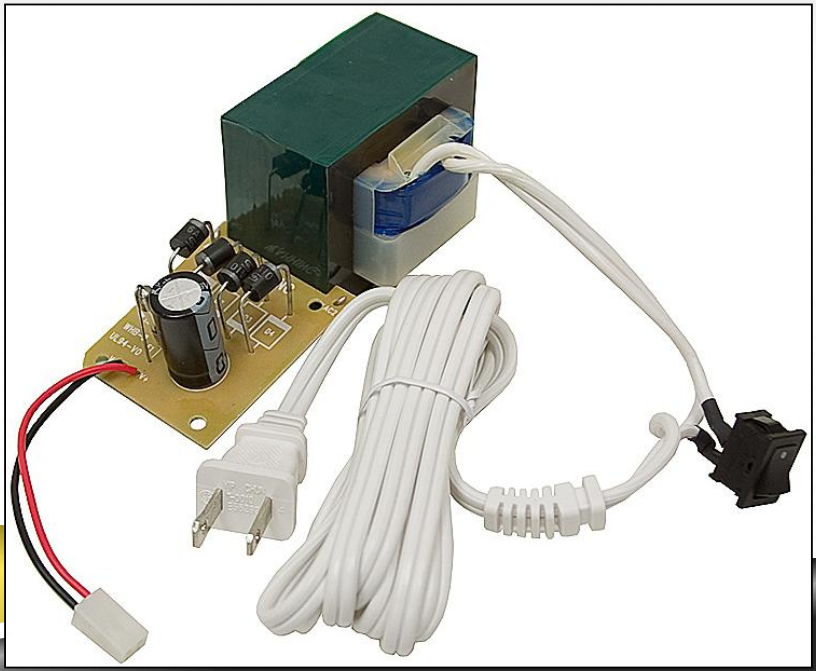
NEXT STEPS

- Optimize the GUI
- Assembling and calibrating the printer frame
- Working on the PCB Design
- Power Calculations and incorporating a Power Supply

XY-Plotter Robot Kit



115 VAC:12 VDC 4 A POWER SUPPLY



BUDGET

Current Spending	
Pipettes	$4.90
Syringe Filters	$19.03
Sterile Vials	$5.75
Beakers	$9.35
Silver Nitrate	$29.95
Sodium Acetate	$10.67
Ammonium Hydroxide	$24.95
Formic Acid	$21.18
Gallium and Indium	$55.95
Stir Plate	$42.00
LCD Screen	$17.75
Stepper Motors x2	$43.03
Printer Frame	$210.00
Boost Capacitive Touch	$10.00
Stepper Motor Booster	$25.00
Adafruit Stepper Servo Shield	$30.09
Touch Shield	$34.95
Ink Shield	$60.00
Ink Cartridge	$13.94
Sub-Total	**$668.49**

Projected Spending	
Sub-Total	$668.49
Printed Circuit Board Fabrication	$60
Atmel Programmer	$35
Glass Sheets	$30
Hot Plate / Annealing System	$30
AC to DC Power Supply	$10
Total	**$833.49**
Budget	**$687.00**

Questions?