Pin Transfer Robot for Chemical Screening

Group H

Meet the team!

Yousef Abdelsalam	Computer Engineering
Dominic Simon	Computer Engineering
Brenden Morton	Computer Engineering
Christopher Clifford	Electrical Engineering

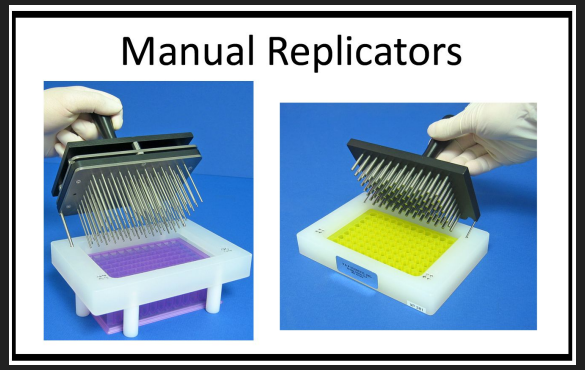
Project Overview

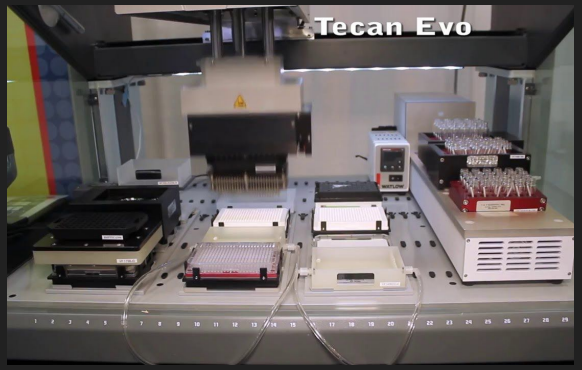
Christopher Clifford - Electrical Engineering

Motivation

The motivation of our project is to make an autonomous pin transfer solution that is accessible to smaller labs enabling exploratory drug or small molecule testing that will not be cost prohibitive.

Available pin transfer robotic solutions today





Manual

~$3000

Time consuming

Inaccurate

Small number of samples

Liquid Handling Conversion Kits

~$10,000+

Not purpose built

Requires additional robotics to fully automate many plates

Quickly gets more expensive

Commercial Robotics

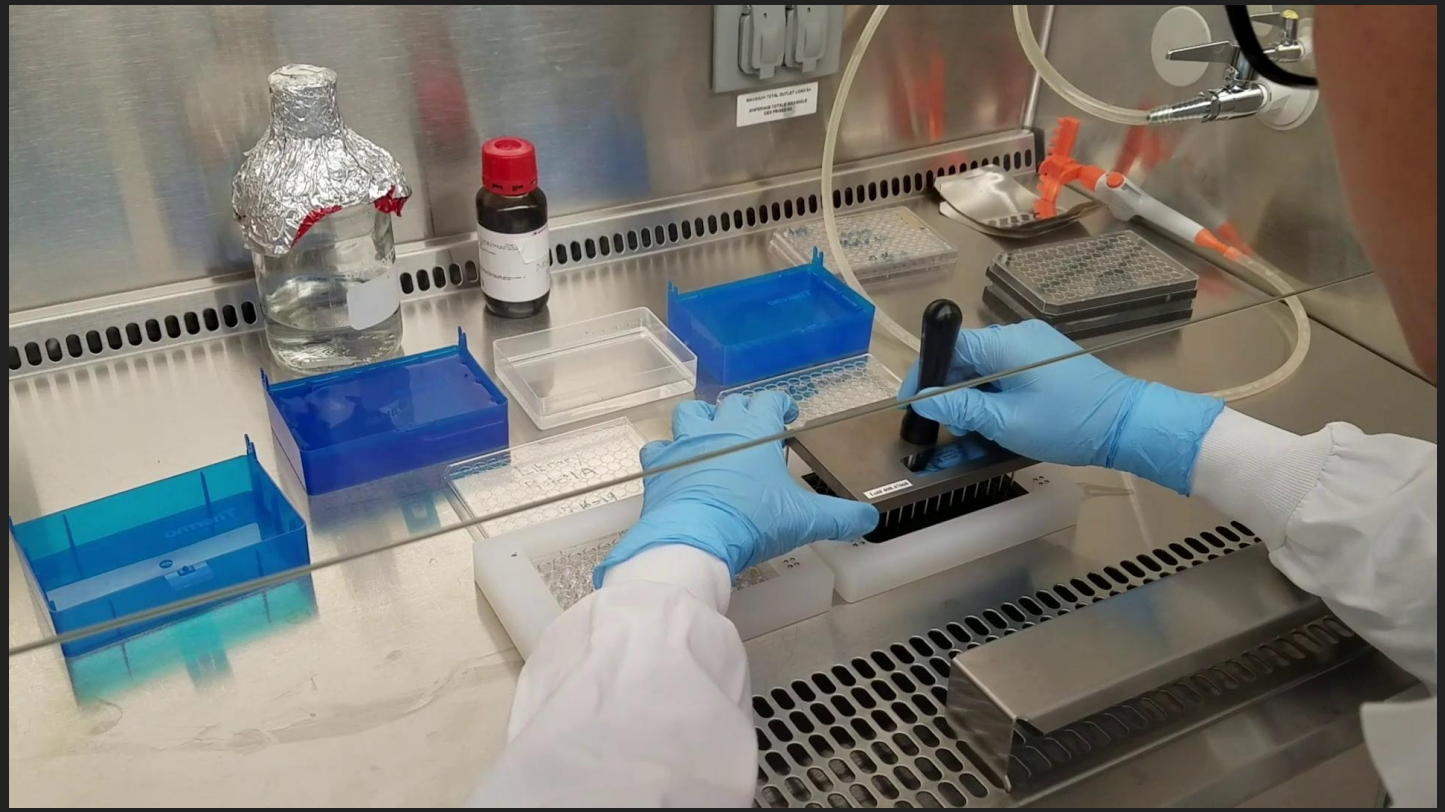
~$1,000,000+

Purpose built for drug discovery

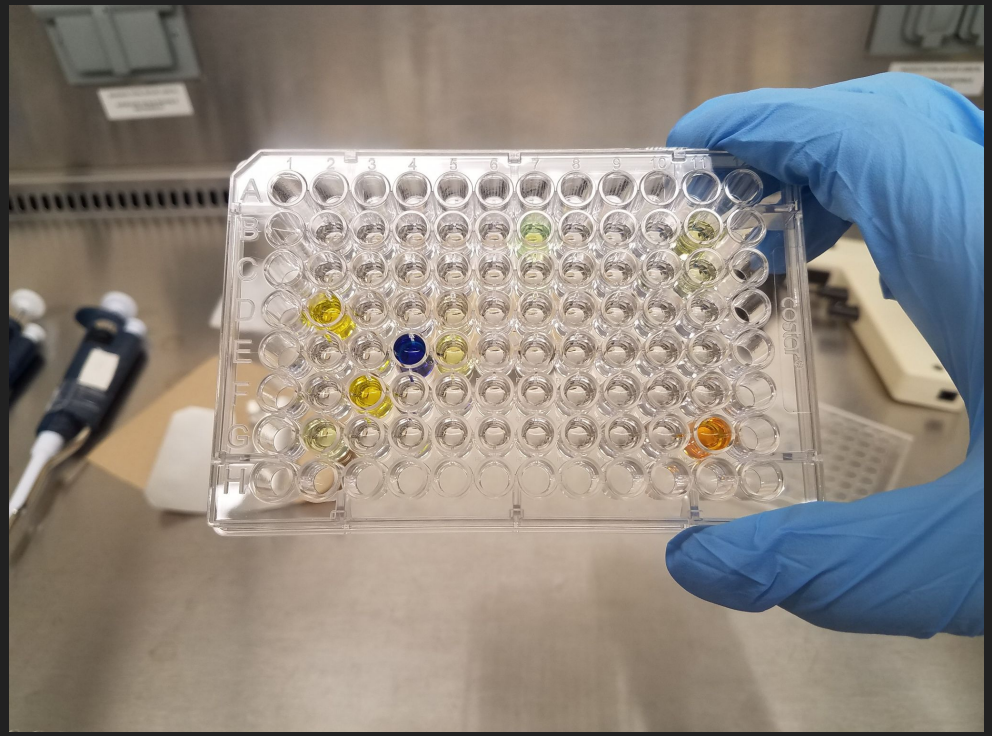
Huge (entire rooms)

Expensive and therefore inaccessible for small labs with little funding

Manual process used by small biology labs

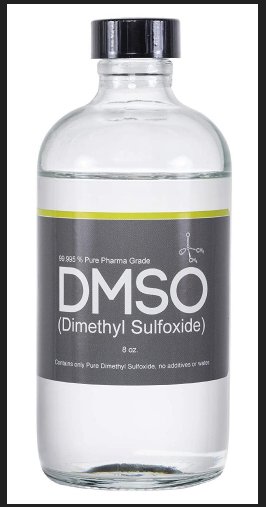


96 Perkin Elmer® Well plate

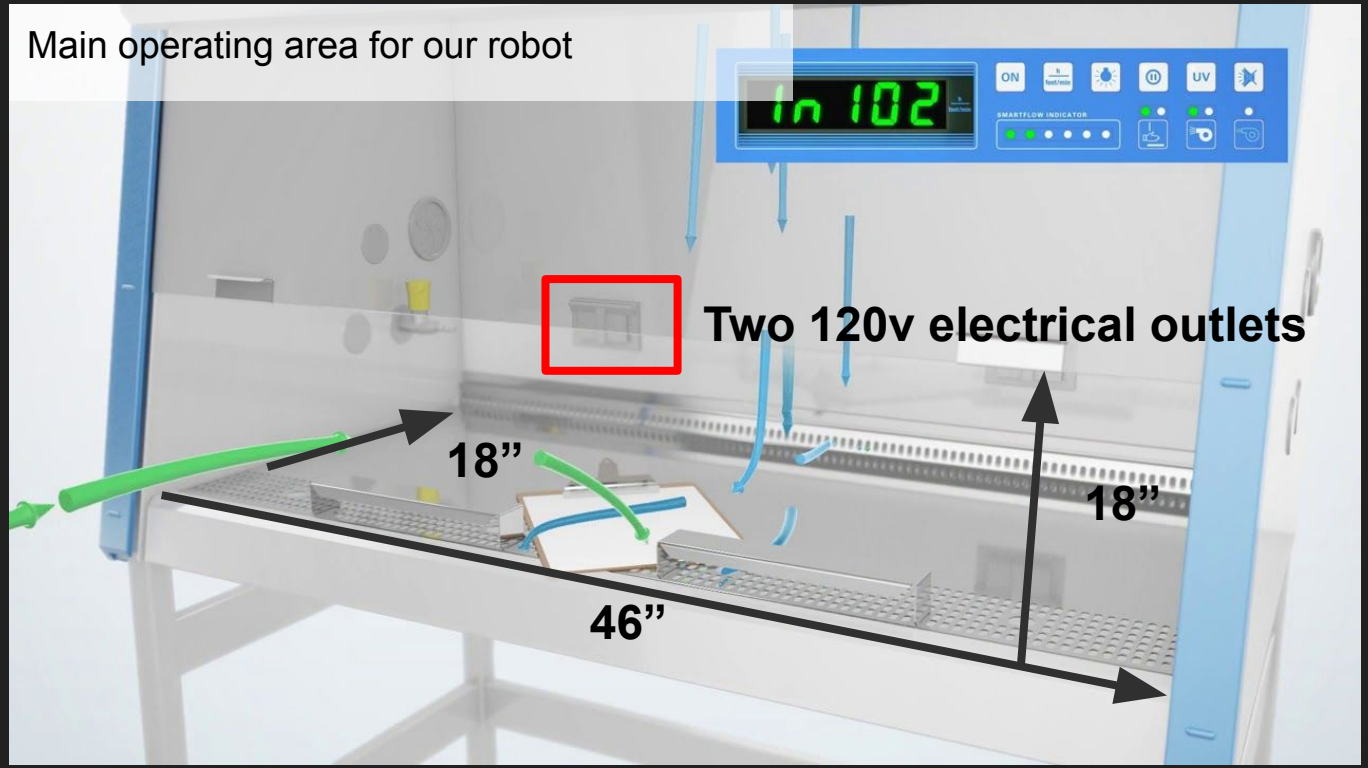


Washing and Drying the pin tool

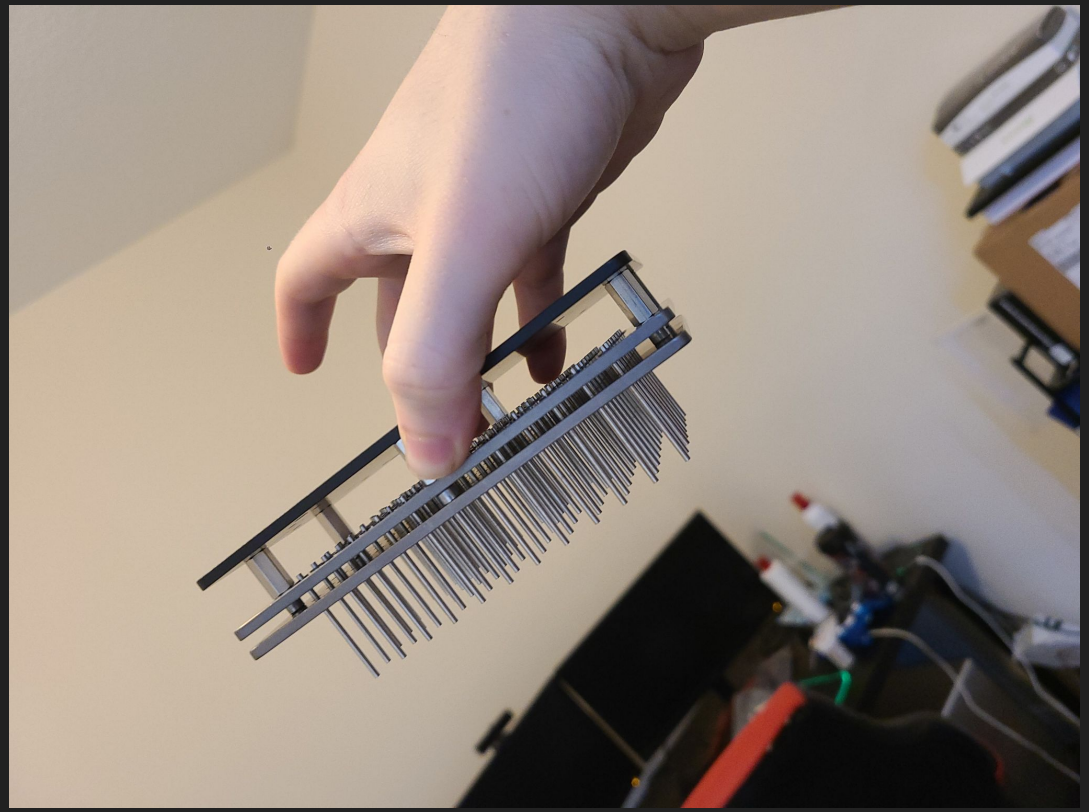
- Can vary from one experiment to another.
- Typical procedure is dipping the pin tool into DMSO and deionized water 3-4 times each, then isopropyl alcohol.
- Once the pin tool has been removed from the cleaning solution, it’d have to dry before it can be used again



Biosafety Cabinet

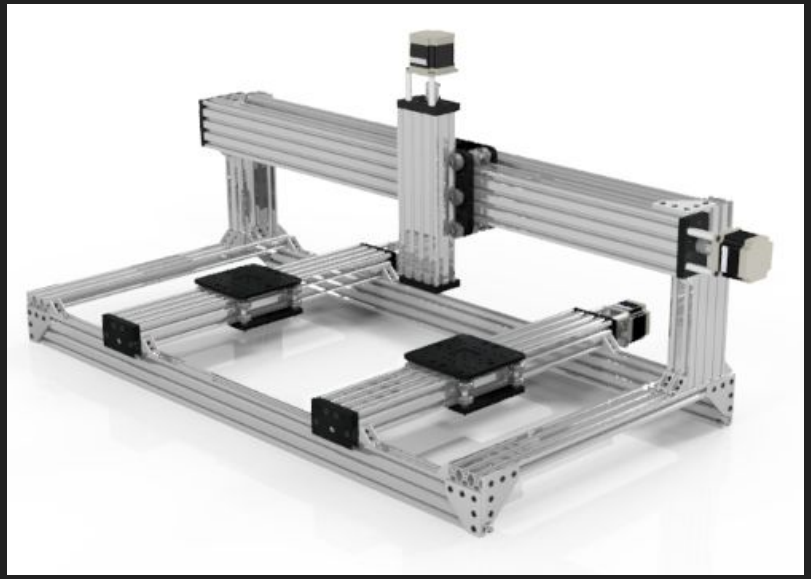


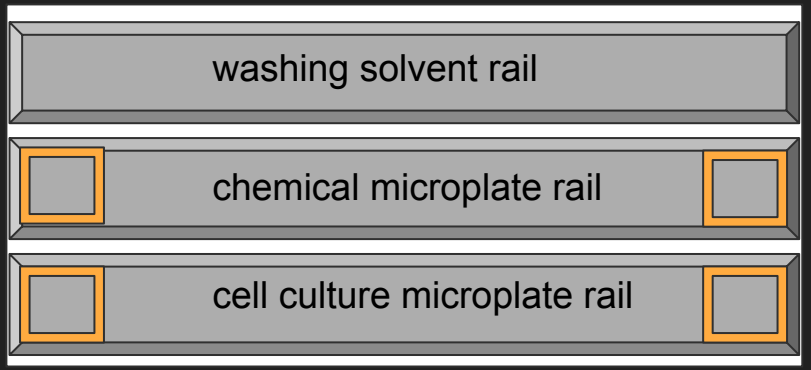
Robotic Pin Transfer Tool



Robotic design

- CNC, 3-axis gantry base
- 2 input and 2 output microplate stacks
- Three X-axis linear rails used for chemical library microplates, cell culture microplates, and up to 3 washing solvents. Each is powered by a linear actuator.
- Pin tool can move vertically(z-axis) and laterally(y-axis) between conveyor rails



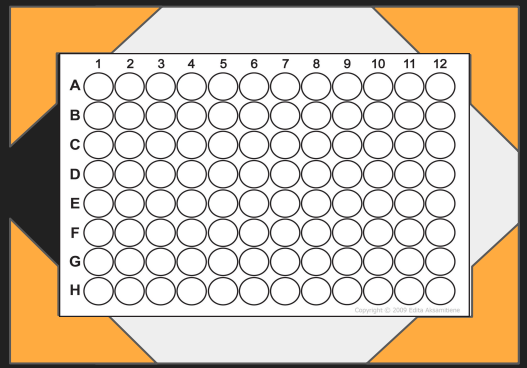


Stacking Design Concepts

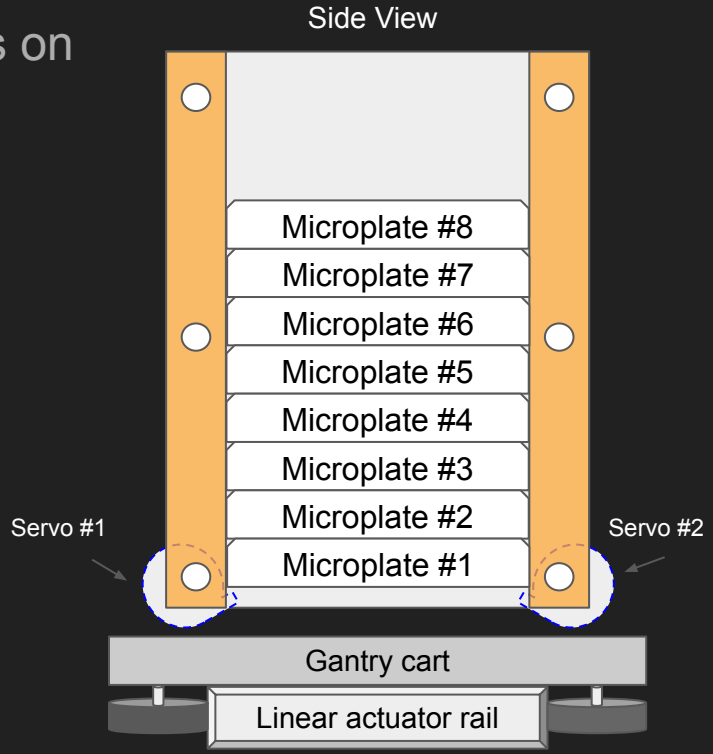
Servo motors will deliver microplates to/from gantry carts on the linear rail.

Non-backdrivable servo motor.

Top View



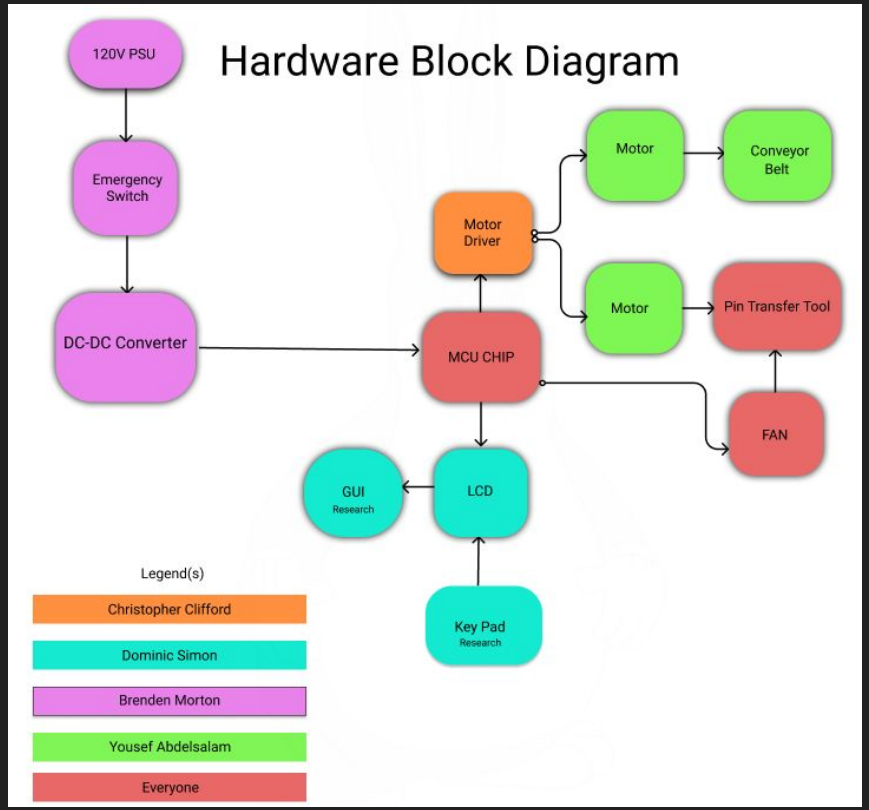
Side View



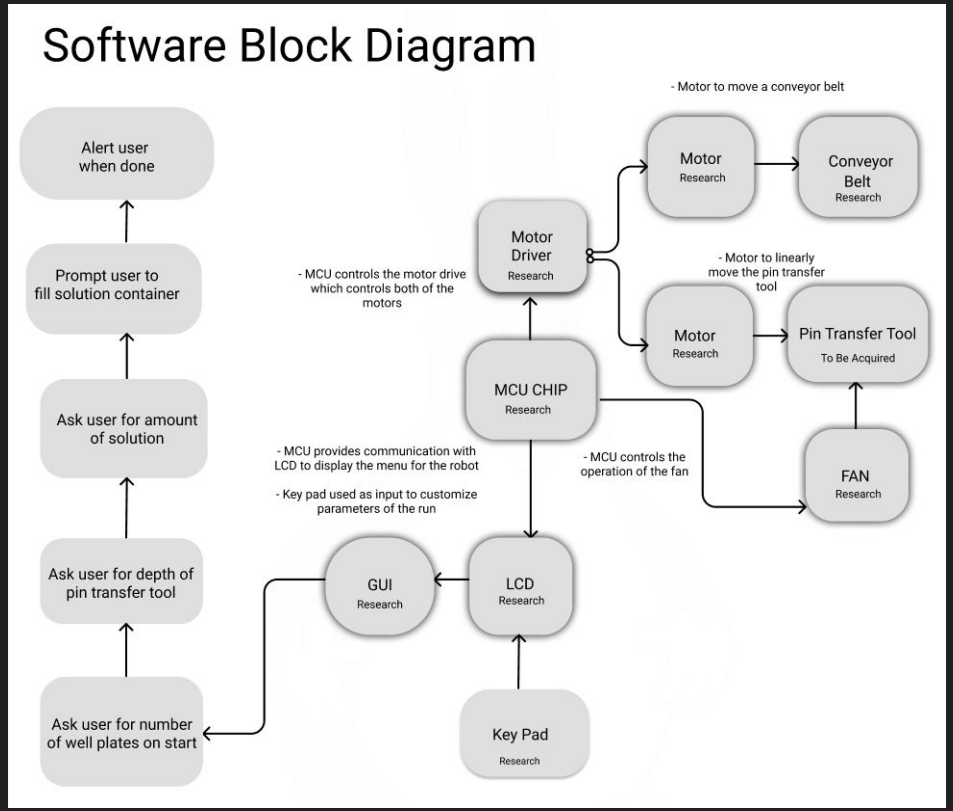
Technical Specifications

- Should be within 18” x 46” x 18” to fit within a biosafety cabinet
- Should be less than 50 lbs
- Should be sanitizable with 70% isopropyl alcohol
- Should have a failure rate of <1%
    - Any error that results in a failed pin transfer constitutes a failure.
- Robot work status can be sent to phones or PCs wirelessly
- Emergency shut off button
- Input stacks can take 8 microplates at a time

Hardware Block Diagram



Software Block Diagram



Budget Analysis

Part	Description	Quantity	Unit Cost	Total Cost
-	Pin Transfer tool	1	$0 - $200	$0 - $200
Arduino Atmega 2560	MCU	1	$0 - $20	$0 - $20
OpenBuild	workspace rails	1	$100 - $130	$500
TI	12V Fan	1	$10	$10
Youngneer	12V Relay (8 pc)	1	$11.99	$11.99
MEANWELL 24V	Power Supply Unit	1	~$100	~$100
TI	DC-DC	1	$3	$6
JLCPCB	PCB	5	$20	$20
BIQU A4988	Motor Driver	2	$9.50	$19.00

Budget Analysis

Usongshine 17HS4401S	Motor	2	$9.97	$19.94
Any LCD	LCD (16x4)	1	~$15	~$15
COM-1466	Key pad	1	$4.50	$4.50

Hardware

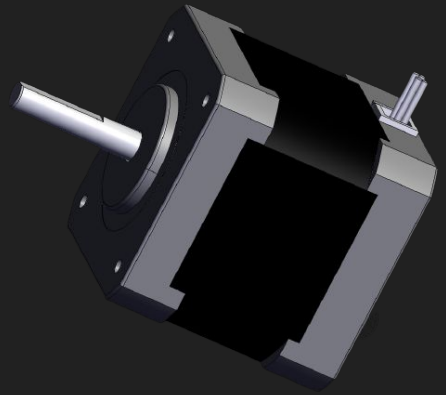
Brenden Morton - Computer Engineering

Motors

Stepper motors

- Used in similar applications
  - CNC machines
  - 3D printers
- Inexpensive (~$15)
- Compatible with many different motor drivers
- Accuracy
  - Configurable steps

NEMA 17 and NEMA 23 stepper motors



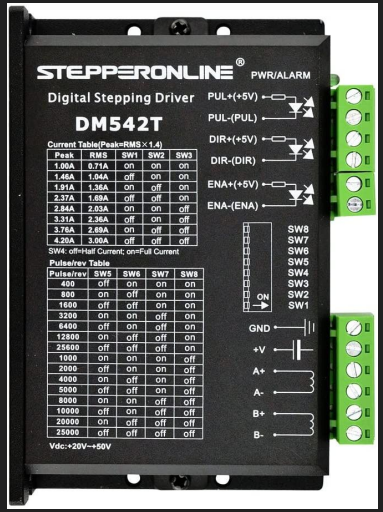
NEMA 17
- 76 oz*in of torque
- 1.7 in diagonal
- Used for X-axis actuator

NEMA 23
- 175 oz*in of torque
- 2.3 in diagonal
- Used for Z and Y axes

Motor Drivers

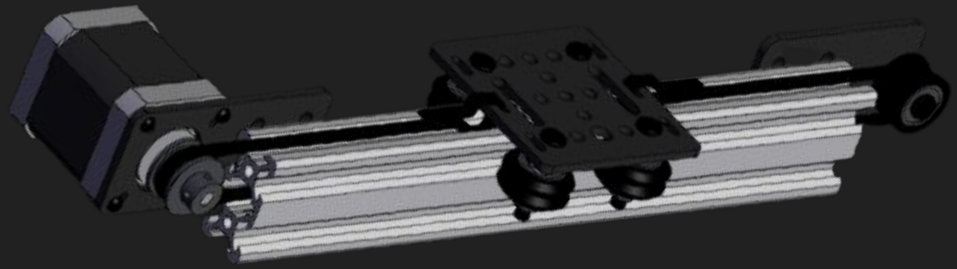
DM542T Driver

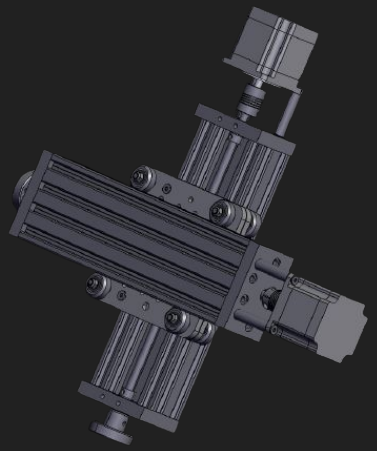
- Compatible with NEMA-17 and NEMA-23 stepper motors
- Configurable steps
  - Dip-switches for changing steps and current draw
- Works well with the AccelStepper library which is used for interfacing the motor drivers through C++ software
- Simple wiring and set-up

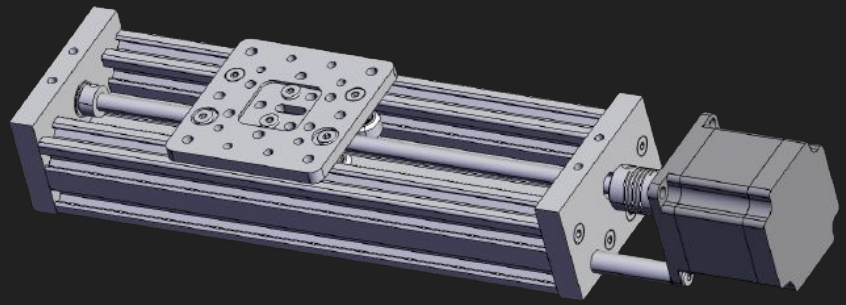


Linear Actuators

- V-slot belt-driven linear actuators
  - Used for X-axis linear actuators
- C-beam
  - Used for Z/Y configuration







Limit Switches

- On the ends of each linear actuator

- Used for determining the bounds
  - As gantry card activates the switch, interrupt service routine (ISR) is executed to stop motor
- Safety precaution for motors, motor drivers, belts, etc.

- Used as interrupts
  - Problem:
    - 10 limit switches (2 for each of the 5 motors)
    - 6 Interrupt pins
    - Solution: Tie control pins together on switches on a single actuator & figure out ISR based on last direction motor was spinning.

Power Supply

Meanwell 24V PSU

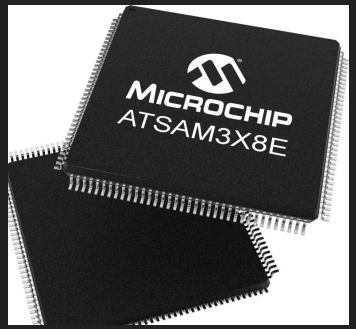
- 24V / 14.6 A power delivery
  - ~350 W Output
- Built-in fan for cooling
- 3 DC outputs
  - Sufficient for 5 motor drivers
- Suitable PSU for driving an array of NEMA-23 and NEMA-17 motors

Microcontroller Selection

ATmega 2560

- Number of GPIOs
- Pins to be configured as interrupts
- Memory size
- Pin operating voltage
- Additional components needed for operation

AT91SAM3X8E



- Availability (chip shortage)
  - Lead times (etc.)
- Cost
- Package type

ATmega2560 vs AT91SAM3X8E

ATmega2560

- 5v operating voltage
- 54 GPIO
  - 6 interrupts
  - 16 analog
- 256kB memory
- Does not require as much additional hardware components for operation

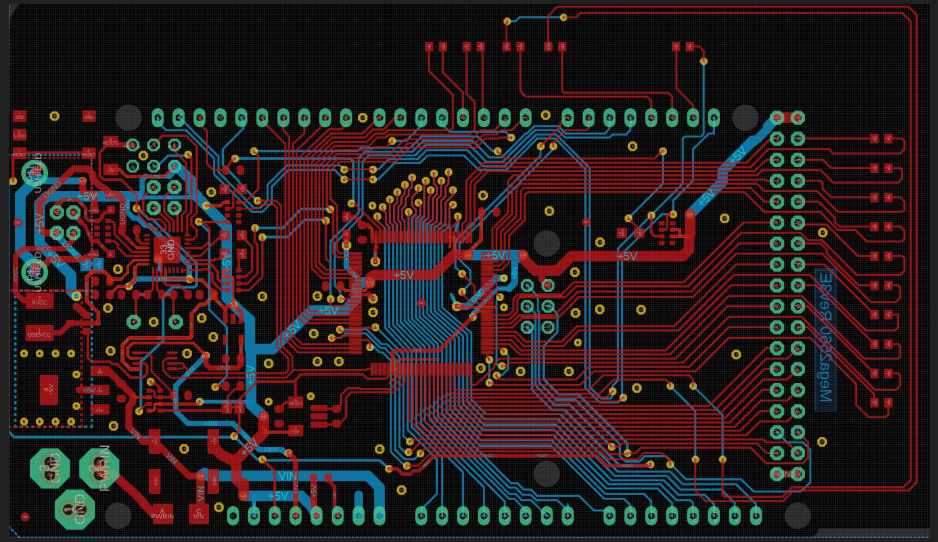
AT91SAM3X8E

- 3.3v operating voltage
  - Requires logic level shifters
- 54 GPIO
  - All can be interrupts
  - 12 analog
- 512kB memory
- Requires more electrical components
- 32-bit ARM core

Schematic and PCB

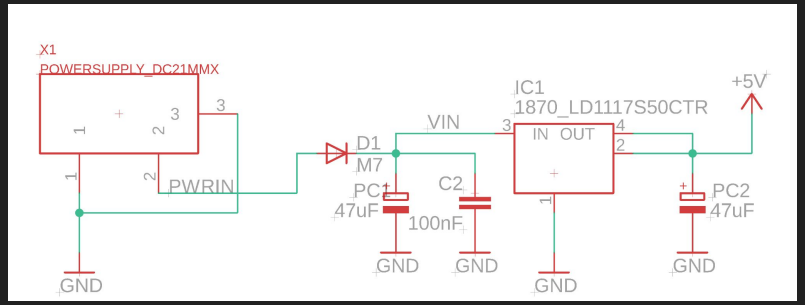
- References:
  - Open-source designs
    - Routing
    - Component selection
  - Forums
    - Component selection
  - ATmel Datasheets
    - Peripheral circuitry
    - Typical applications

- 2-Layer board
  - Majority SMD components
  - Some through-hole

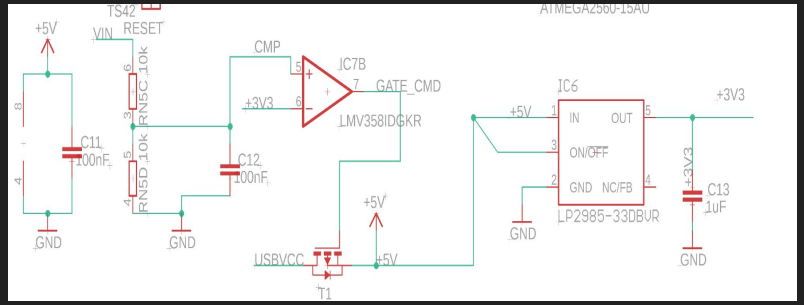


Power

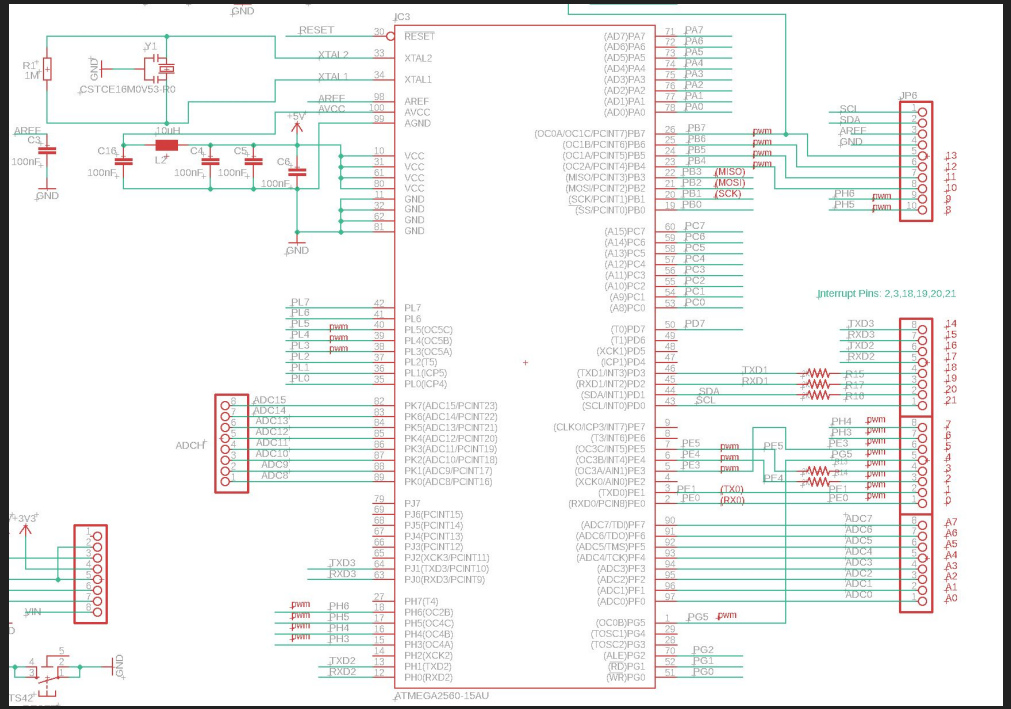
5 V


X1
POWERSUPPLY_DC21MMX
PWRIN
D1
M7
PC1
47uF
C2
100nF
IC1
1870_LD1117S50CTR
VIN
IN OUT
PC2
47uF
+5V
GND

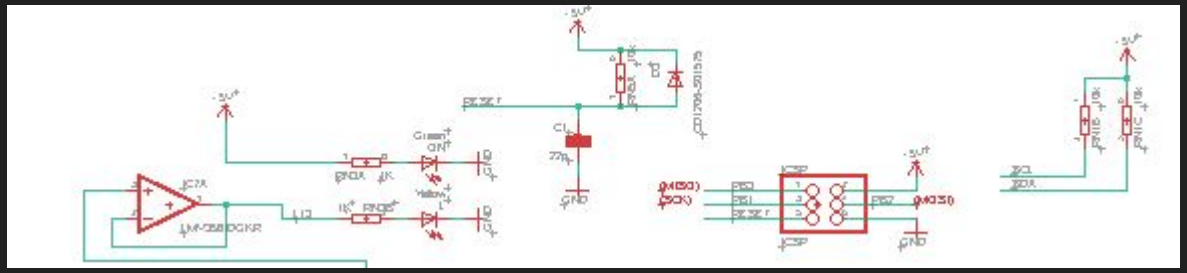
3.3 V


TS42
VIN RESET
+5V
C11
100nF
RN5C 10k
RN5D 10k
CMP
IC7B
+3V3
GATE_CMD
LMV358IDGKR
C12
100nF
USBVCC
T1
ATMEGA2560-15AU
IC6
IN OUT
ON/OFF
GND NC/FB
LP2985-33DBVR
C13
1uF
GND

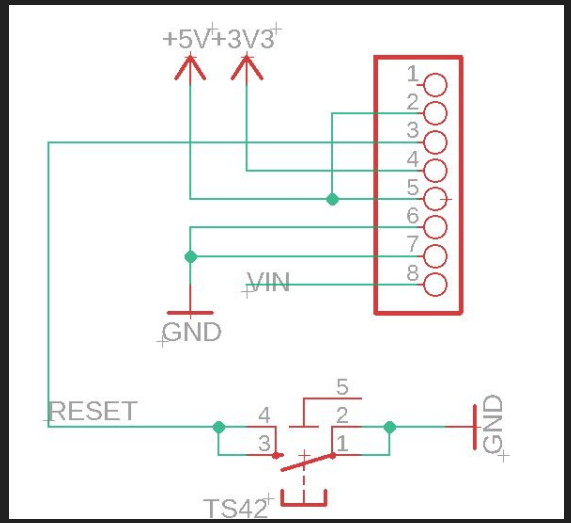
ATmega2560 Schematic



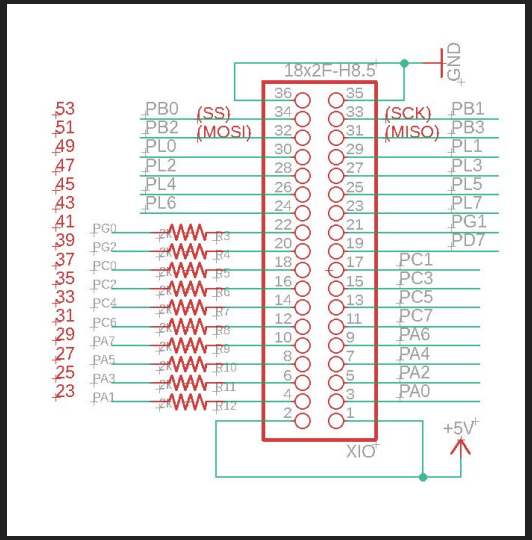
Schematic



Indicator LEDs

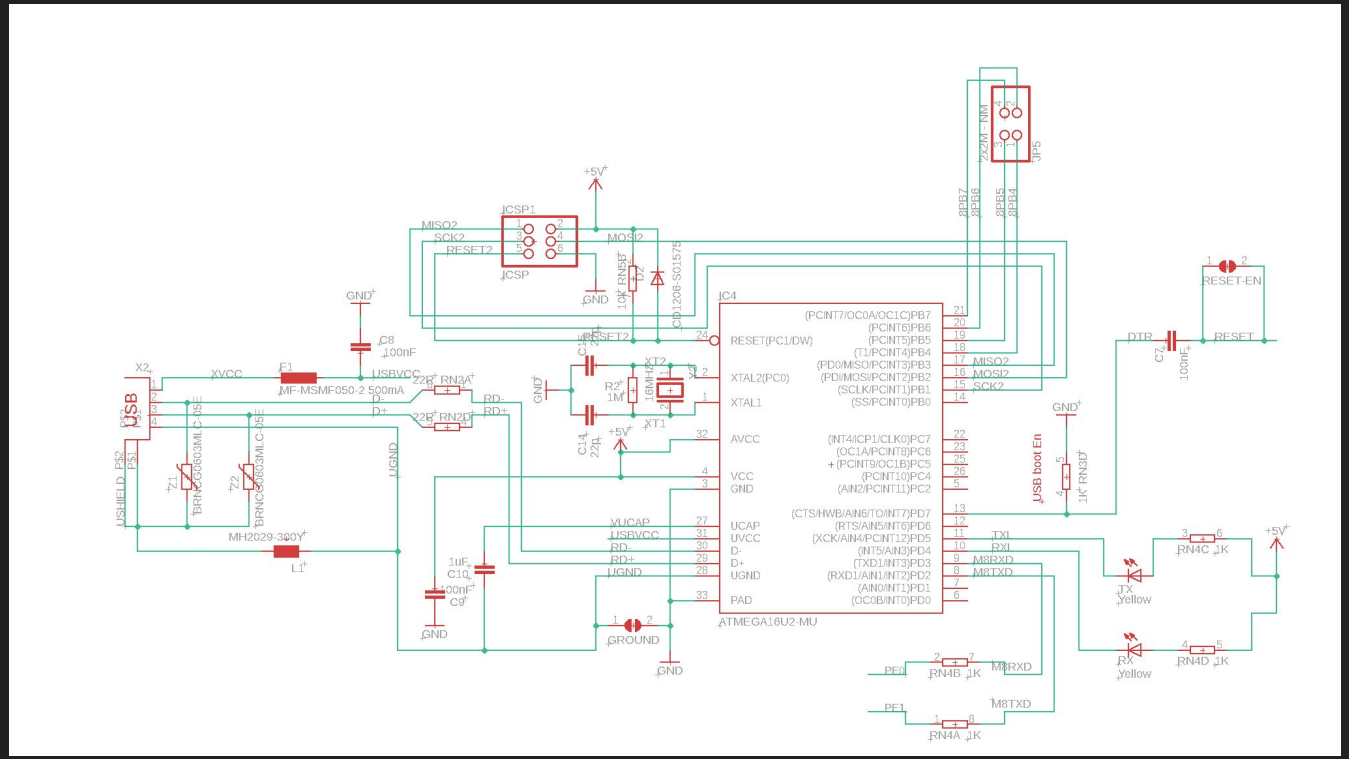


Voltage lines and RESET logic for ATmega2560



Solder pads

ATmega16U2-MU Schematic



User Interface

Dominic Simon - Computer Engineering

Initial User Interface - LCD and Keypad

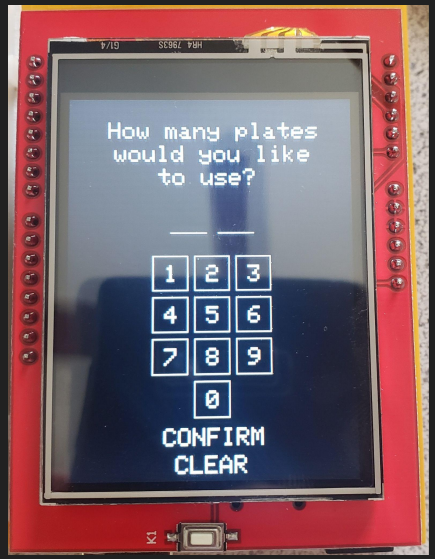
Keypad vs Touchscreen

Keypad

+ Low user error due to large keys
- Not aesthetically pleasing

Touch Screen

+ Looks sleek
+ Compact
- Smaller keys require users to be more precise



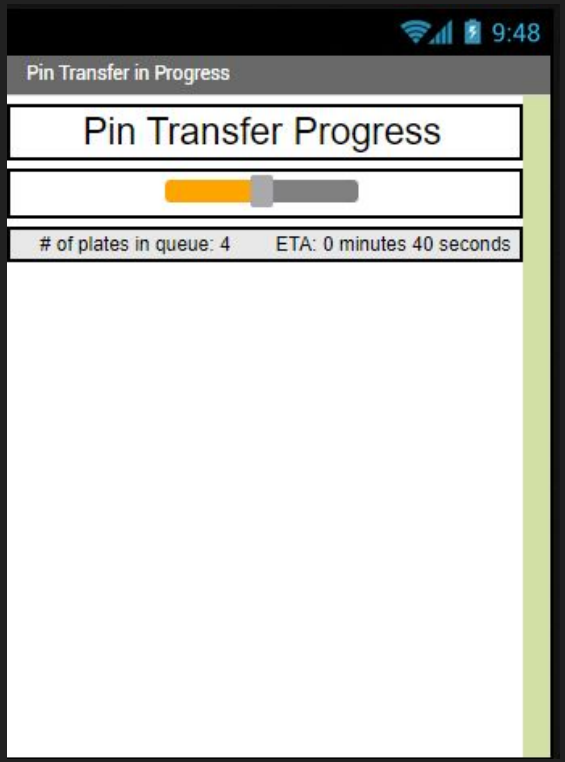
Current User Interface - Touchscreen

- 2.4” display
- 3.3V and 5V compatible
- 18 bits for color
- 9 digital pins
- 4 analog pins

HiLetgo 2.4" ILI9341 240X320 TFT LCD Display

Progress Monitor App

- Keep track of how many plates are still queued
- Send notification when plates are completed
- Provides an ETA for completion of the pin transfer process



Bluetooth Module

- 5V VCC
- Configurable via AT commands that allow for setting the baud rate, # of stop bits, etc...
- Half duplex communication via master slave communication model
- Up to 1 Mbps data transfer
- Up to 10 meter range

Hc-05 bluetooth 2.0 module

Software

Display Software

```
#include <Adafruit_TFTLCD.h>
#include <TouchScreen.h>
```

Touchscreen Software

Adafruit_TFTLCD.h

- Move to different points on the screen
- Write characters
- Create virtual keypad keys
- Reset screen on screen change

```
// Area where the inputted numbers will show up
tft.drawLine(85, 115, 115, 115, WHITE);
tft.drawLine(125, 115, 155, 115, WHITE);

// Buttons
tft.drawRect(70, 135, 30, 30, WHITE);
tft.setCursor(80,143);
tft.println("1");
```

Touchscreen.h

- Determine if the screen is being touched
- Determine where the screen is being touched

```
TSPoint point = ts.getPoint();
if (point.z  >= 200 && point.z <= 1500)
{
  int x = map(point.x, 78, 951, 0, 320);
  int y = map(point.y, 96, 921, 0, 240);
  Serial.println(x);
```

AccelStepper and MultiStepper

- Simple, easy to use APIs for controlling the DM542T steppers
- Allows for manual setting of speed and max acceleration
- Allows for both synchronous(blocking) and asynchronous(non-blocking) behavior for controlling the motors
- If necessary, MultiStepper can make multiple motors reach their destination at the exact same time, regardless of individual distance to travel or step distance.