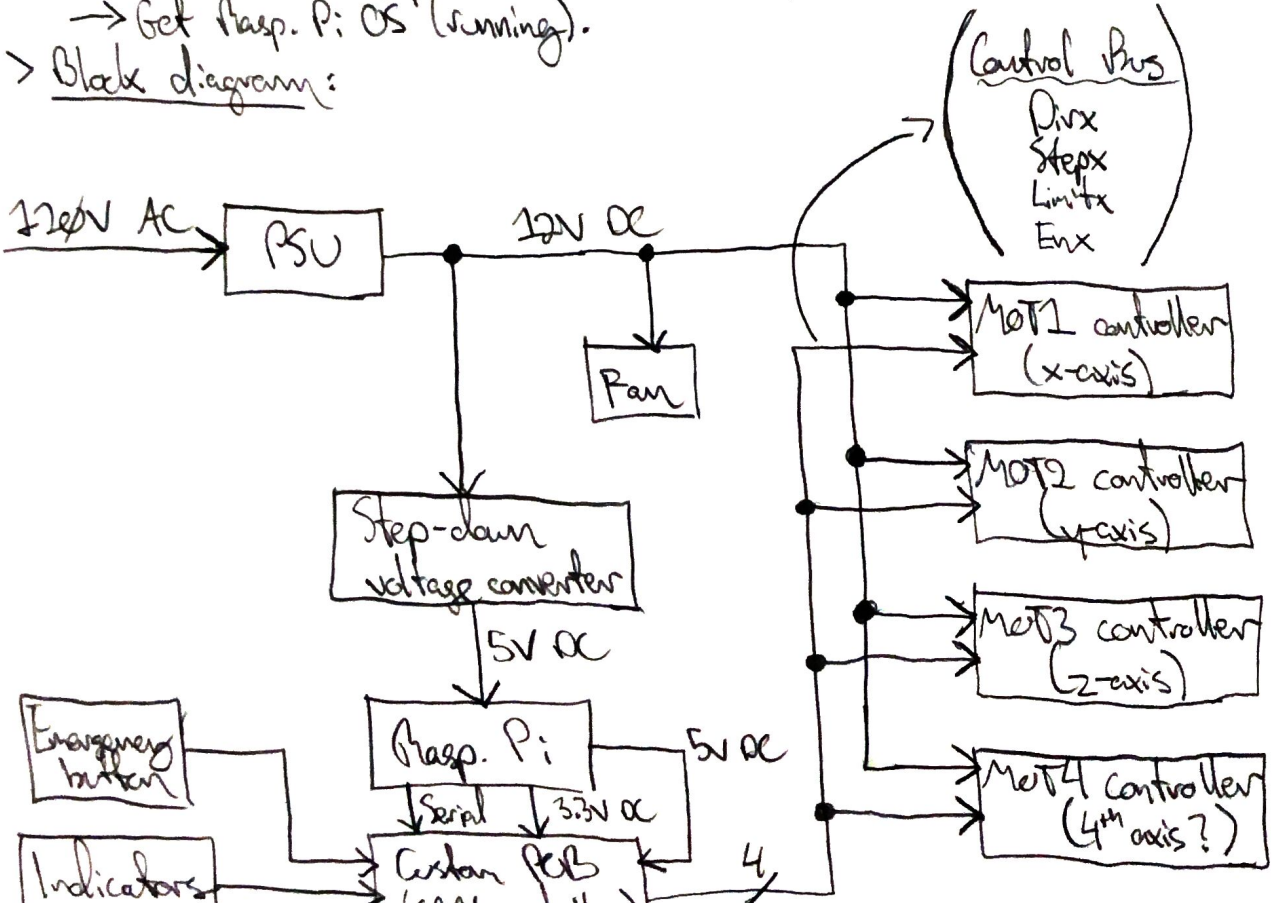
**Project Initiation**

- *Presentation of the project and its goals.*
- *List the project's technical challenges.*
- *Identify key system components.*
- *Make a sketch of the project showing all external interfaces.*
- *Create a component purchase list containing the following columns: quantity description, manufacturer, vendor, price/unit, web-link.*
- *Add the components given by the instructor to your purchase list if needed.*

> 4 axis/3 axis gantry motor project introduction.
> Project parts list (main parts):
→ 12V cooling fan.
→ 12V 10A PSU.
→ IEC 320 C14 plug (fused protected).
→ 12V to 5V step-down voltage converter (5A).
→ DB9 male connectors (for motor connections).
→ Rasp. Pi 3B+.
→ 4x 6600 CNC motor drivers.
> Software:
→ CNC milling software (free open-source) on Rasp. Pi.
→ Custom code on pcb (GRBL firmware).
→ Get Rasp. Pi OS (running).
> Block diagram:



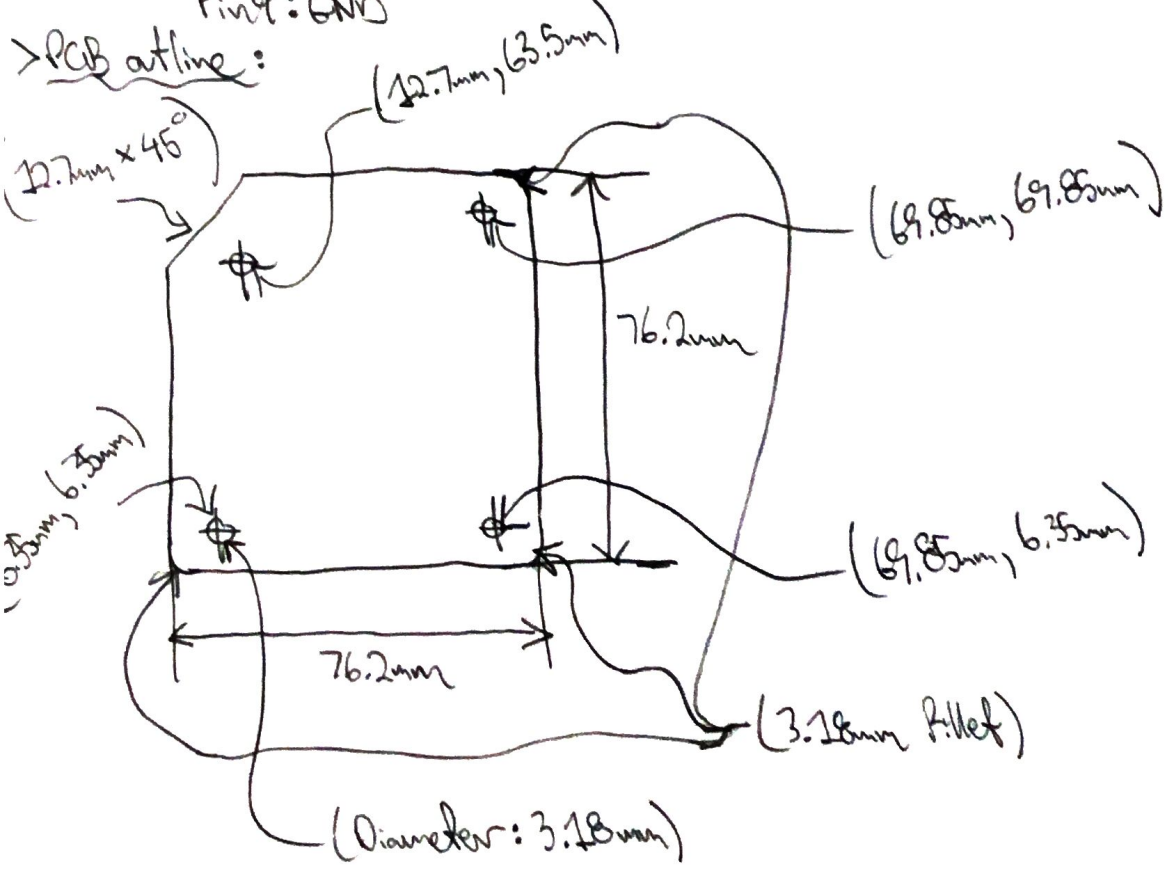
> Pinouts:
→ Oleg

Pin1: A+
Pin2: A-
Pin3: B+
Pin4: B-
} Motor direction
Pin5: +12V
Pin6: COM
Pin7: SW1
Pin8: SW2
Pin9: GND

For next lab:

> Produce a purchase list.
> Produce a detailed schematic.
> Plan simple PCB component placement.
> Review GRBL firmware and CNC software requirement

> PCB outline:

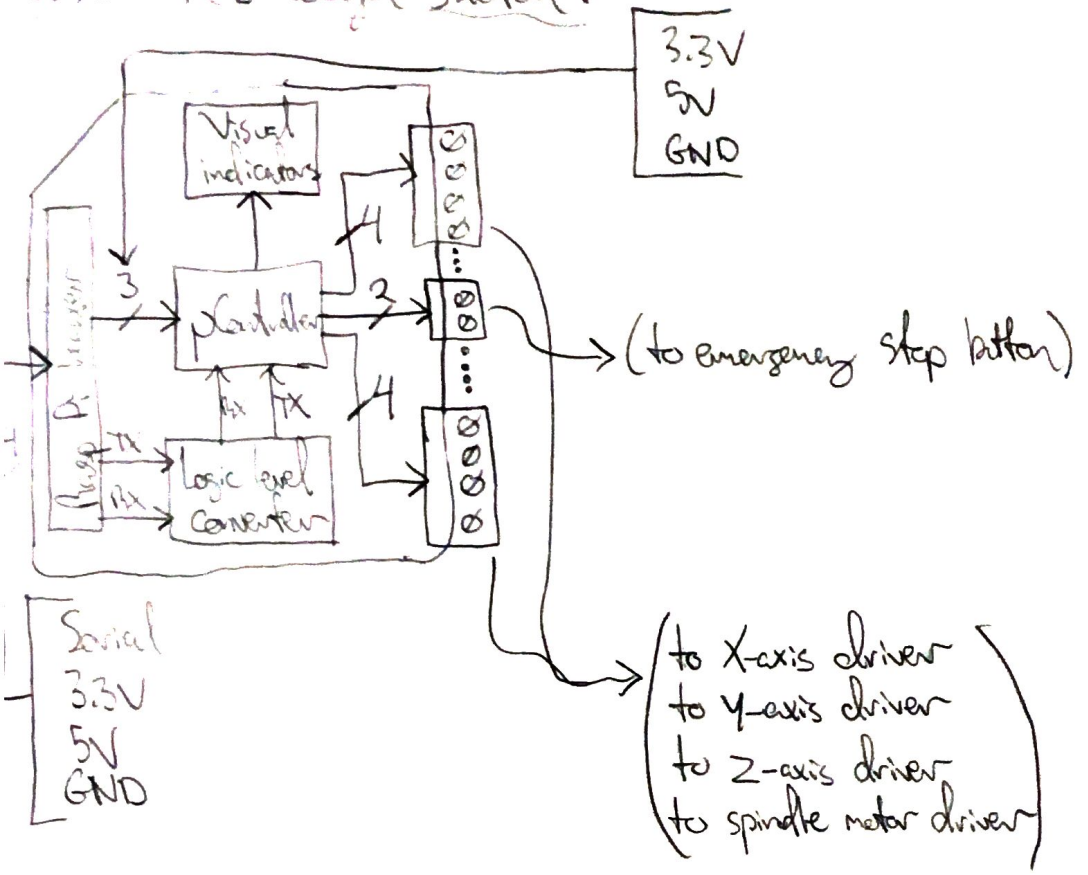



> GRBL firmware:
→ Supported MCUs
> Atmega 328p
> Atmega 168

**Functional Design**

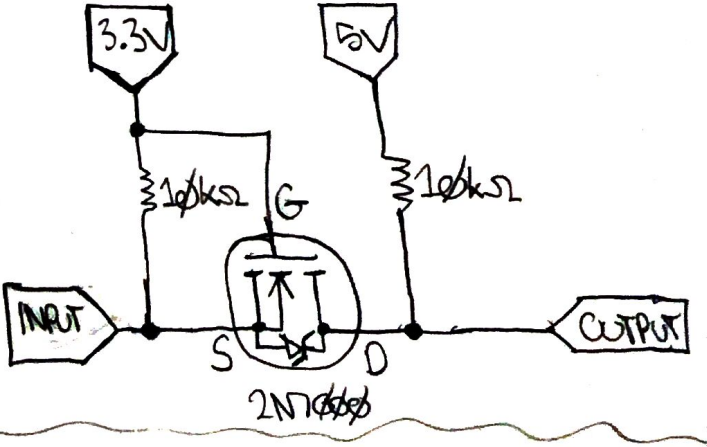
- *Draw a functional block diagram connecting key subsystems. Be sure to include all external interfaces.*
- *Decompose each sub-system into a diagram, schematic or clear description*
- *Identify the subsystem that must be designed as a PCB. Identify any switches, connectors, plugs or displays.*
- *For each PCB interface to the system, define the physical connector type.*
- *Source each connector and add them to your purchase list.*

System PCB weight Sketch:




* Board components must be facing towards the outside of the

Logic level converter circuit:

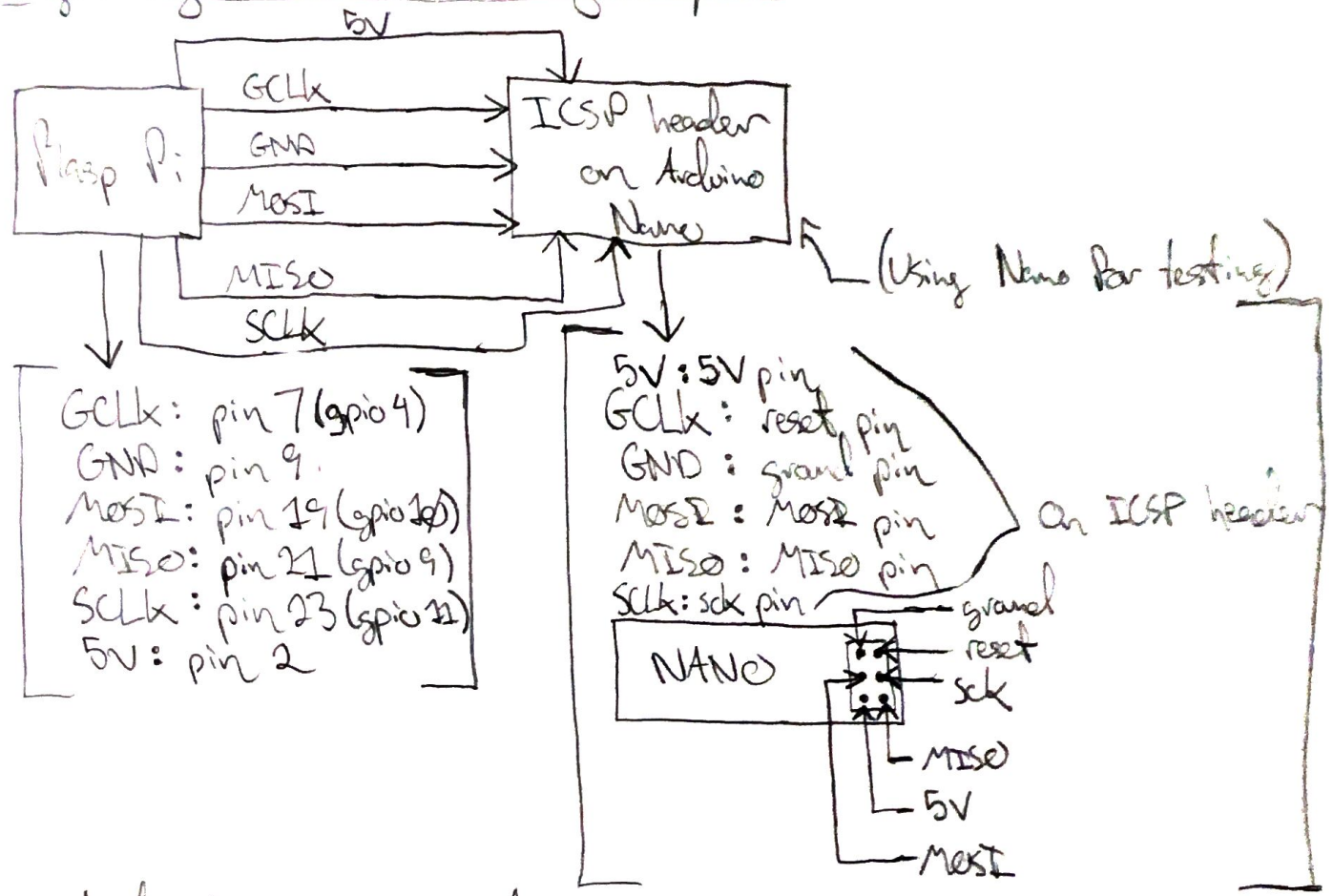



Short term purchasing list:

(1x) Arduino UNO
(2x) TB6600 CNC motor drivers
(1x) 12V 10A PSU

For next lab:
> Produce a ATMEGA 328P test circuit (to test GRBL firmware)
> Find CNC G-code software for Raspi:

# Programming ATMEGA 328P using Raspi:




## Essential AVRDUDE commands:

sudo avrdude -c linuxspio -p m328p -v

(programmer type flag) (processor type flag) → Verifies processor functionality

---

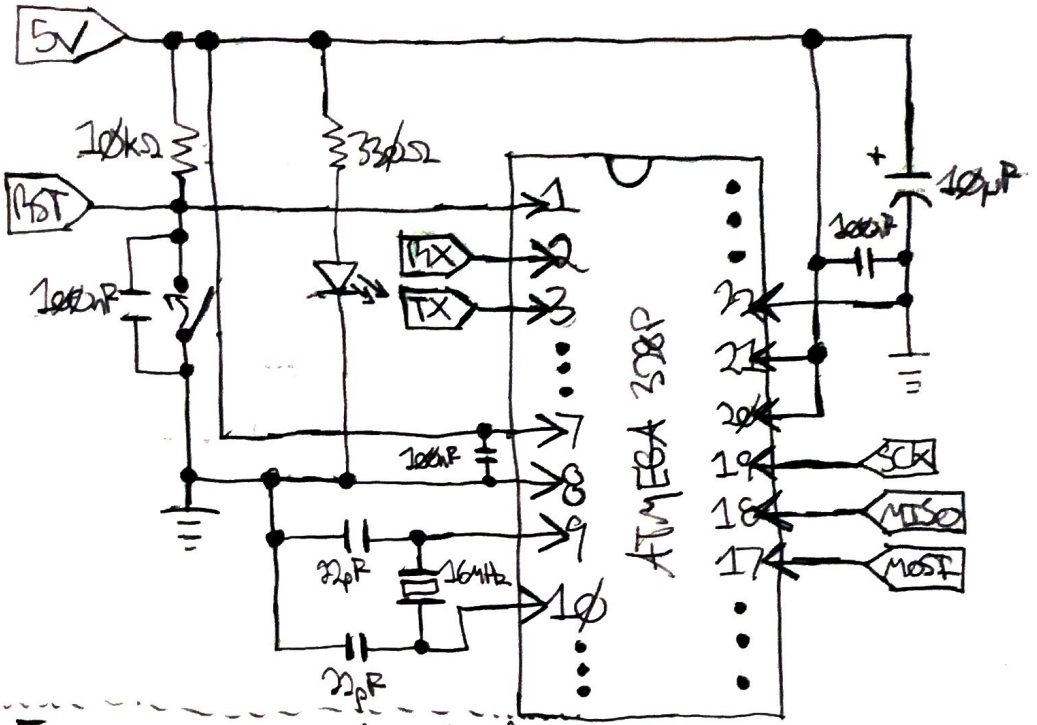
sudo avrdude -c linuxspio -p atmega328p -v -U flash:w:<hex file location>:i

↳ programs processor (flashes)

## Schematic Design - Week 3 ##



ATMEGA 328P test circuit:




[ATMEGA 328P connection header]

- 5V -> 5V power
- GND -> ground
- RST -> reset for MCU
- SCK -> serial clock signal (SPI)
- MISO -> MISO pin (SPI)
- MOSI -> MOSI pin (SPI)
- RX -> receiver pin (connects to logic level converter)
- TX -> transmit pin (connects to logic level converter)

**Schematic Design**

- *Identify any key electronic components needed for the PCB.*
- *Obtain data-sheets for connectors and all key components.*
- *Create a library for the connectors.*
- *Create a library for any specialized components.*
- *Create a schematic implementing the PCB's function.*
- *Do a design review with colleagues and the instructor.*
- *Make all necessary purchases at this time.*

(Config. bits)

## ATMEGA328P fuse low byte:

| (bits) 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| CKDIV8 | CKOUT | SUT1 | SUT0 | CKSEL3 | CKSEL2 | CKSEL1 | CKSEL0 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |

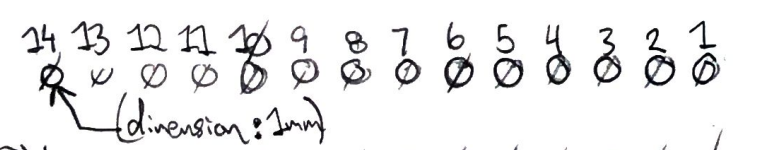
1: unprogrammed
0: programmed

CKDIV8: divides the clock by 8.
CKOUT: outputs clock on Port B0.
SUT1, SUT0: selects start-up time.
CKSEL3, CKSEL2, CKSEL1, CKSEL0: selects clock source.

For next week: (breadboard)

- continue prototyping
- continue PCB design
- purchase new PSU

## ATMEGA328P through-hole PCB footprint:




(0mm, 0mm)

11: 15.24mm, 0mm
12: 17.78mm, 0mm
13: 20.32mm, 0mm
14: 22.86mm, 0mm
15: 25.4mm, 0mm
16: 27.94mm, 0mm
17: 30.48mm, 0mm
18: 33.02mm, 0mm

14: 0mm, 7.62mm
13: 2.54mm, 7.62mm
12: 5.08mm, 7.62mm
11: 7.62mm, 7.62mm
10: 10.16mm, 7.62mm
9: 12.7mm, 7.62mm
8: 15.24mm, 7.62mm
7: 17.78mm, 7.62mm
6: 20.32mm, 7.62mm
5: 22.86mm, 7.62mm
4: 25.4mm, 7.62mm
3: 27.94mm, 7.62mm
2: 30.48mm, 7.62mm
1: 33.02mm, 7.62mm
15: 0mm, 0mm
16: 2.54mm, 0mm
17: 5.08mm, 0mm
18: 7.62mm, 0mm
19: 10.16mm, 0mm
20: 12.7mm, 0mm

## Pins used on ATMEGA328P for GRBL v1.1+ Firmware:

| (On Arduino UNO) | (Function) | (On ATMEGA328P) |
|---|---|---|
| Pin A0 | Reset/Abort* | Pin #23 |
| Pin A1 | Feed Hold* | Pin #24 |
| Pin A2 | Cycle Start/Resume* | Pin #25 |
| Pin A3 | Coolant Enable | Pin #26 |
| Pin A4 | not used | Pin #27 |
| Pin A5 | Probe* | Pin #28 |
| Pin D2 | Step pulse X-axis | Pin #4 |
| Pin D3 | Step pulse Y-axis | Pin #5 |
| Pin D4 | Step pulse Z-axis | Pin #6 |
| Pin D5 | Direction X-axis | Pin #11 |
| Pin D6 | Direction Y-axis | Pin #12 |
| Pin D7 | Direction Z-axis | Pin #13 |
| Pin D8 | Stepper Enable/Disable | Pin #14 |
| Pin D9 | Limit X-axis* | Pin #15 |
| Pin D10 | Limit Y-axis* | Pin #16 |
| Pin D11 | Variable spindle PWM | Pin #17 |
| Pin D12 | Limit Z-axis* | Pin #18 |
| Pin D13 | Spindle direction | Pin #19 |

Note: pins with * symbol are input pins. These pins are held high with internal pull-up resistors.

**PCB Design**

- *Obtain the PCB geometry from the requirements.*
- *Create a CAD drawing for the geometry.*
- *Import the PCB geometry into the design tool.*
- *Place connectors and other components on the PCB.*
- *Route connections ensuring proper trace widths.*
- *Generate and inspect Gerber files.*

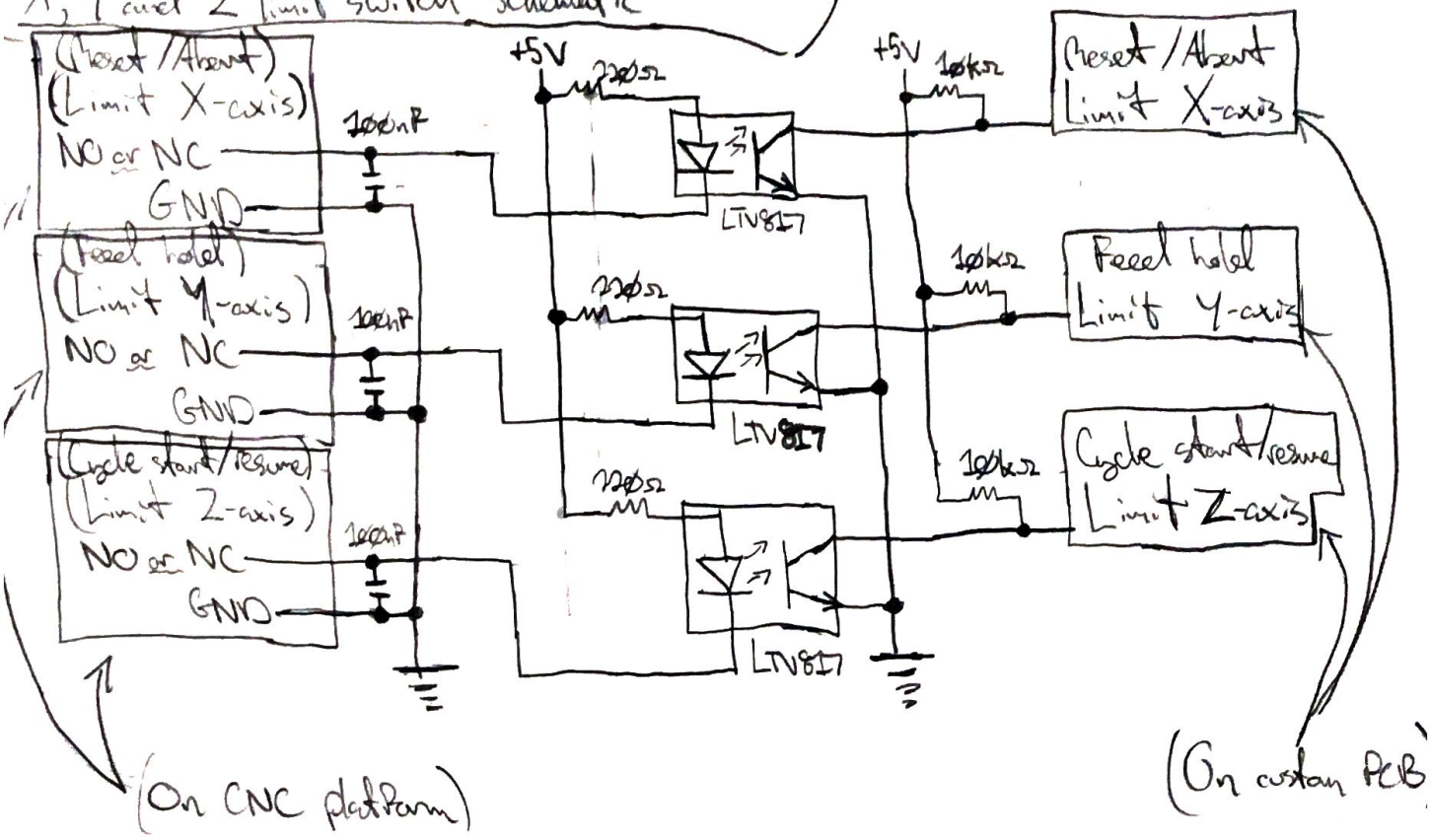
For next week:
> Continue PCB design.
> Assemble complete PCB on perfboard.

## Grbl inputs / outputs:

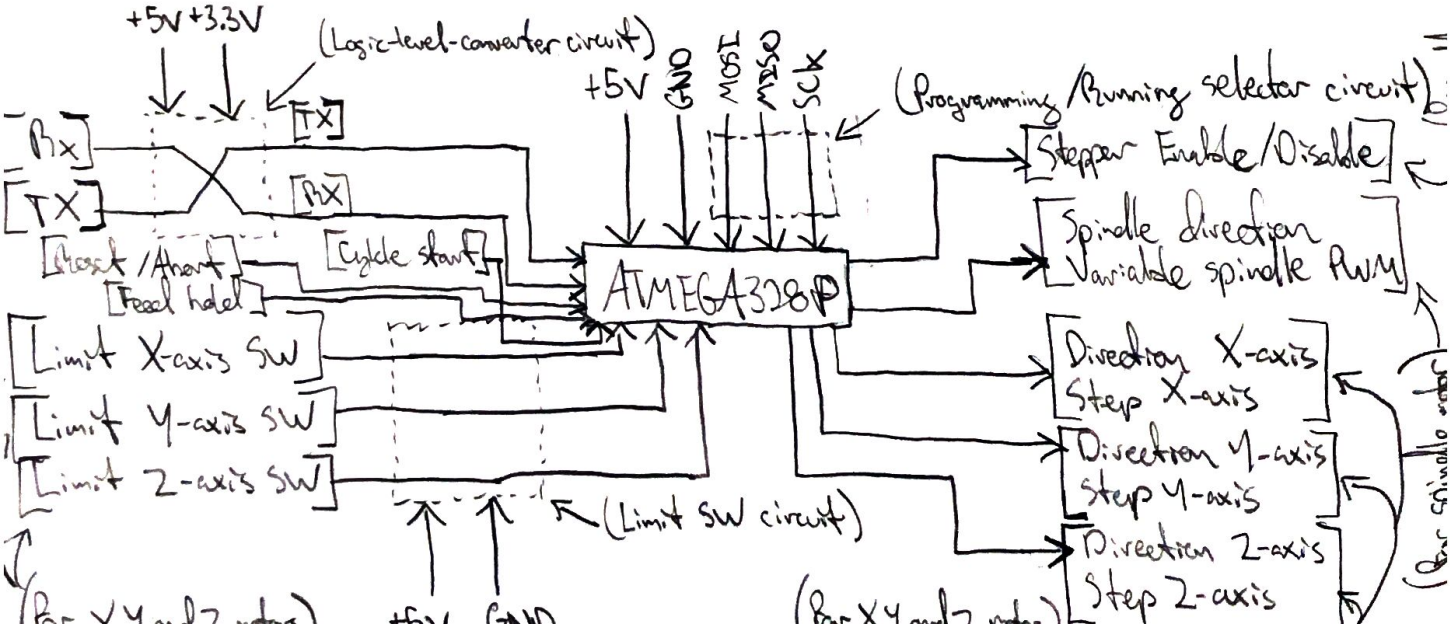
Reset / Abort -> IN_1
Feed Hold -> IN_2
Cycle Start/Resume -> IN_3
Limit x to z-axis -> IN_4-6

Step pulse x to z-axis -> OUT_1-3
Direction x to z-axis -> OUT_1-3
Stepper Enable/Disable -> OUT_1-3
Variable spindle PWM, Spindle direction -> OUT_4

Reset/Abort, Feed hold and Cycle start/resume schematic
X, Y and Z limit switch schematic




More detailed PCB block diagram:



## List of components used on PCB prototype:

> 1x 40-pin shrouded GPIO male header.
> 6x 2-pin 2.54mm screw terminal.
> 4x 4-pin 2.54mm screw terminal.
> 2x SB150 schottky diodes (1A/50V).
> 2x 100µF 50V electrolytic capacitors.
> 3x 5mm green LEDs.
> 6x 5mm red LEDs.
> 8x 330Ω 1/4W resistors.
> 1x 160Ω 1/4W resistor.
> 11x 10kΩ 1/4W resistor.
> 6x 220Ω 1/4W resistor.
> 6x LTV-817 optoisolators.
> 1x pushbutton (black -> Adafruit).
> 2x 22pF 50V ceramic capacitors.
> 3x 100nF 50V ceramic capacitors.
> 1x 16MHz crystal oscillator.
> 2x 2N7000 N-type MOSFETs.
> 1x DIP28 IC socket.
> 1x ATMEGA328-P-U.
> 1x Raspberry PI GPIO female-female cable (Adafruit).
> ?x 22AWG multi-color wire.

**FunctionalPrototyping**

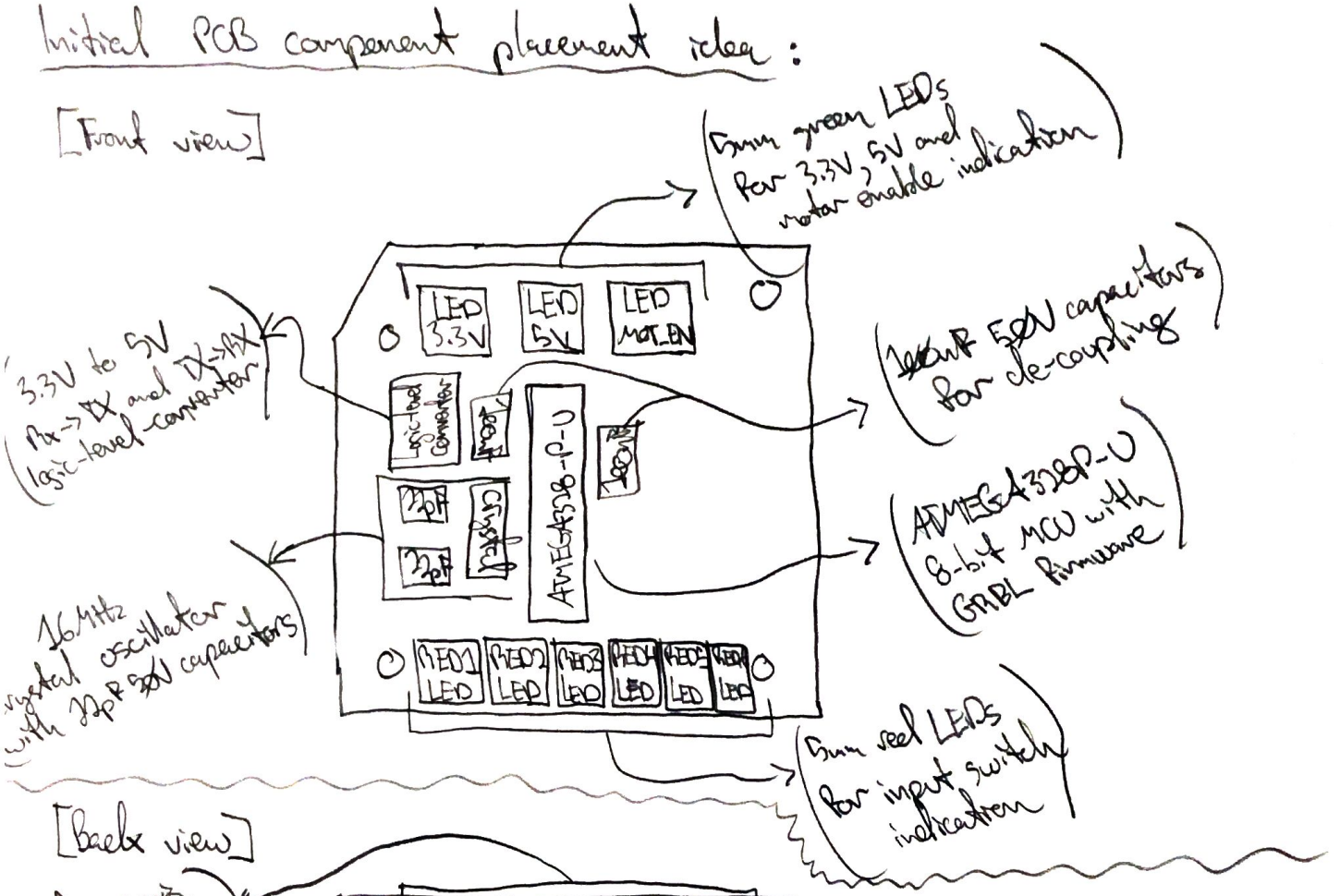
- *Identify key functions in the schematic/PCB design that must be tested in the laboratory.*
- *For each function identified, design a test with a clear objective.*
- *Record any key measurements and observations that result from the designed tests.*
- *Record any changes that may be necessary to achieve the functional requirements in the PCB design.*
- *Submit PCB design to fabricator.*

## For next week:

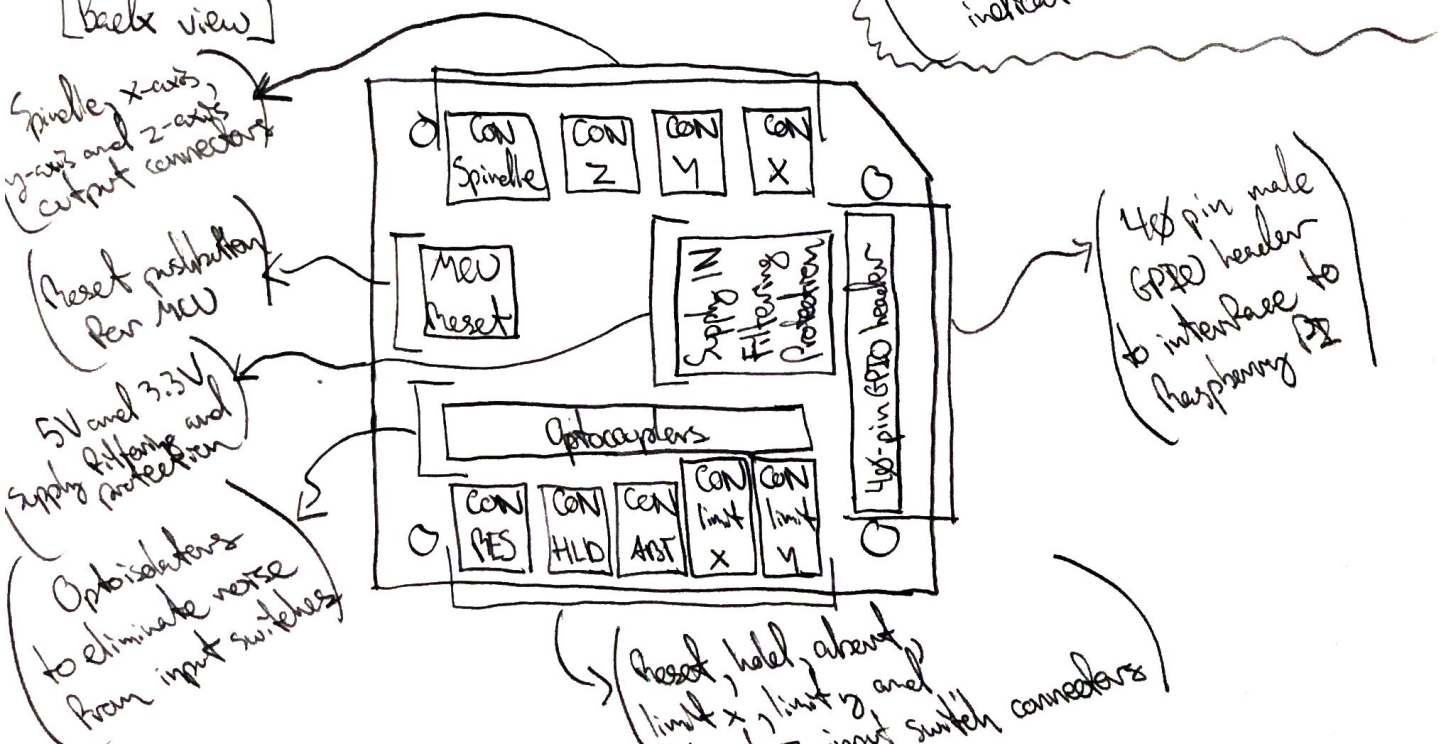
> Test GRBL PCB prototype with real stepper motors.
> Install and test CNC software on Raspberry Pi with GRBL PCB prototype.
> Continue schematic and board capture in EAGLE.
> Place PCB manufacturing order by the end of next week?

# Initial PCB component placement idea:

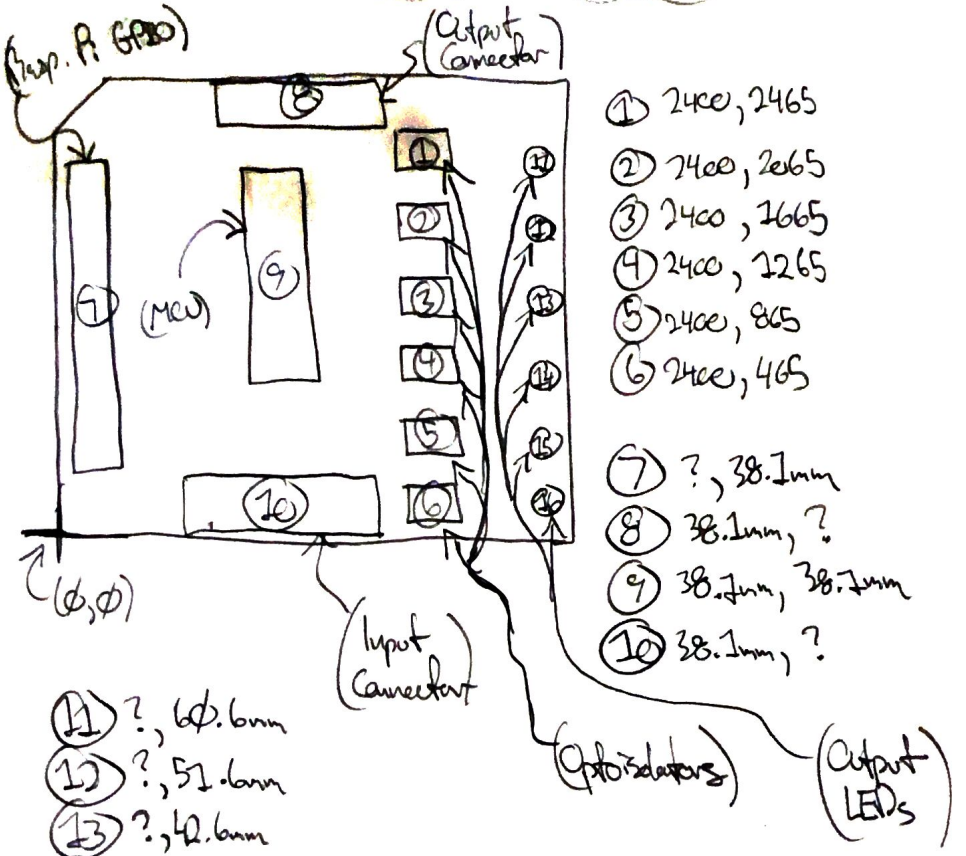
[Front view]




[Back view]



# PCBs Component Placement Dimensions




① 24cc, 2465
② 24cc, 2cc65
③ 24cc, 1665
④ 24cc, 1265
⑤ 24cc, 865
⑥ 24cc, 465

⑦ ?, 38.1mm
⑧ 38.1mm, ?
⑨ 38.1mm, 38.1mm
⑩ 38.1mm, ?

⑪ ?, 60.6mm
⑫ ?, 51.6mm
⑬ ?, 42.6mm
⑭ ?, 33.6mm
⑮ ?, 24.6mm
⑯ ?, 15.6mm

**Mechanical Assembly**

- *Mount components onto the PCB using standard electronic assembly techniques.*
- *Assemble the project enclosure. Fabricate any parts using laser cutting or 3D printing if necessary.*
- *Test fit components by securing them inside the enclosure.*
- *Communicate any corrective changes that need to be made to the enclosure CAD model.*
- *Assemble and integrate any cable harnesses, connectors or plugs.*

For next week:

> Continue testing assembled prototype.
> Look into CNC software for Raspberry Pi.
> Order other last parts for enclosure.

Free CNC software for Raspberry Pi GRBL control:

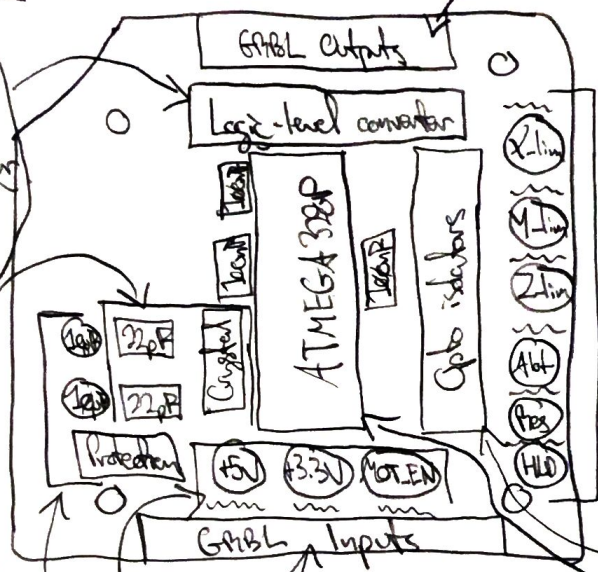
> UGS (universal g-code sender).
> bCNC (GrblHAL → (formerly GRBL) CNC command sender).
> Candle
> CNCjs (web-based for CNC control).
> Lightburn (able to import various vector graphics and image formats).
> Ultimate CNC (visualizes g-code and real time traces in 3D).

## Raspberry Pi Input Schematic:

> Maximum theoretical input voltage of 5.5V.
> Regulator for Raspberry Pi -> XR77004.

# Final PCB Component Placement:

[Top View]




**Level converter:**
- RX→TX
- TX→RX
- Steps up 3.3V to 5V

**Provides various GRBL outputs:**
- Step X
- Step Y
- Step Z
- Motor enable
- Direction X
- Direction Y
- Direction Z
- Spindle PWM
- Direction spindle

**Crystal circuit:**
- 16MHz crystal circuit

**Various other status LEDs:**
- +5V
- +3.3V
- GRBL motor enable

**Provides various GRBL inputs:**
- Limit-X
- Limit-Y
- Limit-Z
- Reset/Abort
- Resume
- Hold

**GRBL input LED statuses:**
- LEDs for status indication for all GRBL inputs

**MCU:**
- 8-bit MCU (ATMEGA328P) loaded with GRBL firmware

**Opto isolators:**
- Eliminates switching noise from GRBL inputs

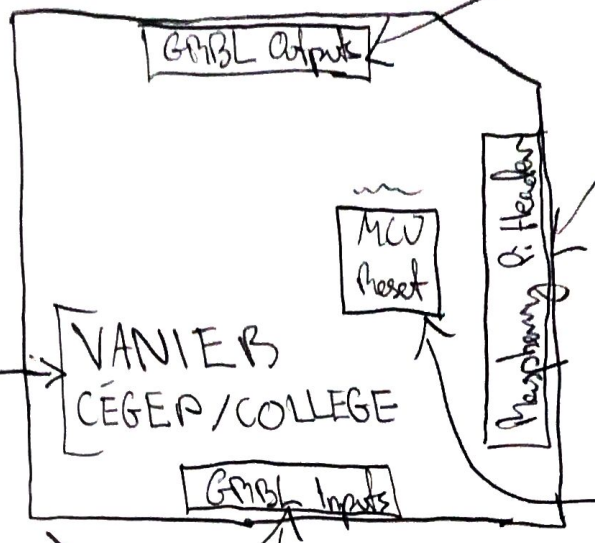
**Input circuitry:**
- Reverse polarity protection for 3.3V and 5V supplies
- Filters for 3.3V and 5V supplies

**For next week:**
- Await PCB arrival, then begin assembly.
- Continue testing with GRBL PCB prototype.
- Continue ordering few remaining parts for enclosure.

**Functional Verification**

- *Do not yet integrate the PCB into the assembly. Repeat the functional tests used to validate the design using standard laboratory methods.*
- *Diagnose issues on the PCB in case of functional failures and take corrective actions. Be sure to notify the instructor with specific details.*
- *Complete the assembly with the PCB integrated.*
- *Repeat functional tests with the integrated PCB. Record any notable observations.*

[Back View]




**Header:**
> Interfaces the Raspberry Pi to the GRBL PCB

**Logo:**
> Vanier school Logo on PCB

**Pushbutton:**
> Reset button for entire MCU

**Provides various GRBL inputs:**
> Limit X
> Limit Y
> Limit Z
> Reset / Abort
> Resume
> Hold

**Provides various GRBL outputs:**
> Step X
> Step Y
> Step Z
> Motor enable
> Direction X
> Direction Y
> Direction Z
> Spindle PWM
> Direction spindle

**What has been done so far?**

> Completed GRBL prototype.
> Ordered GRBL PCB.
> Setup Pi: complete.
> Initial testing complete.
> Ordered parts that haven't been purchased so far.
> Began research for final CNC softwares capable of running CNC jobs (creating sketches).

**SoftwareDevelopment**

- *Download and install any custom libraries, firmware or software making note of them.*
- *Write any software necessary to achieve the project goals.*
- *Take note of successes and failures.*
- *Send a detailed note to your instructor indicating the status of your work.*
- *Complete any software prior to final assembly in two weeks.*

## Farther GRBL PCB prototyping results:

> All inputs read correctly in UGS.
> All outputs set correctly in UGS.
> Jog mode works.
> Emergency mode works.
> Pause / Resume mode works.
> All status LEDs works.

## Motor driver dip switch settings:

| S1 | S2 | S3 | Microstep | Pulse/rev. (pulses-per-revolution) |
|---|---|---|---|---|
| ON | ON | ON | NC | NC |
| ON | ON | OFF | 1 | 200 |
| ON | OFF | ON | 2/A | 400 |
| OFF | ON | ON | 2/B | 400 |
| ON | OFF | OFF | 4 | 800 |
| OFF | ON | OFF | 8 | 1'600 |
| OFF | OFF | ON | 16 | 3'200 |
| OFF | OFF | OFF | 32 | 6'400 |

> Uses TB6600 chip.
> Input range of 9 to 42VDC.

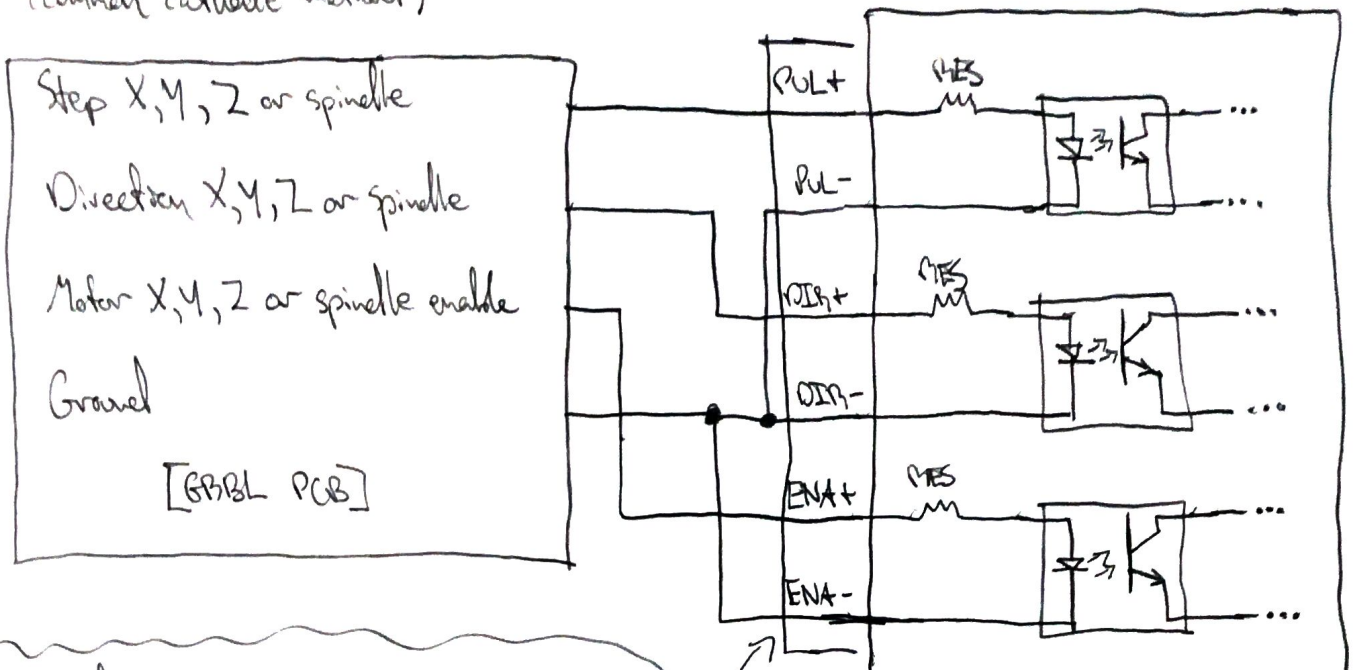
| S4 | S5 | S6 | Current (A) | Pk Current (peak current) |
|---|---|---|---|---|
| ON | ON | ON | 0.5 | 0.7 |
| ON | OFF | ON | 1.0 | 1.2 |
| ON | ON | OFF | 1.5 | 1.7 |
| ON | OFF | OFF | 2.0 | 2.2 |
| OFF | ON | ON | 2.5 | 2.7 |
| OFF | OFF | ON | 2.8 | 2.9 |
| OFF | ON | OFF | 3.0 | 3.2 |
| OFF | OFF | OFF | 3.5 | 4.0 |

## For next week:

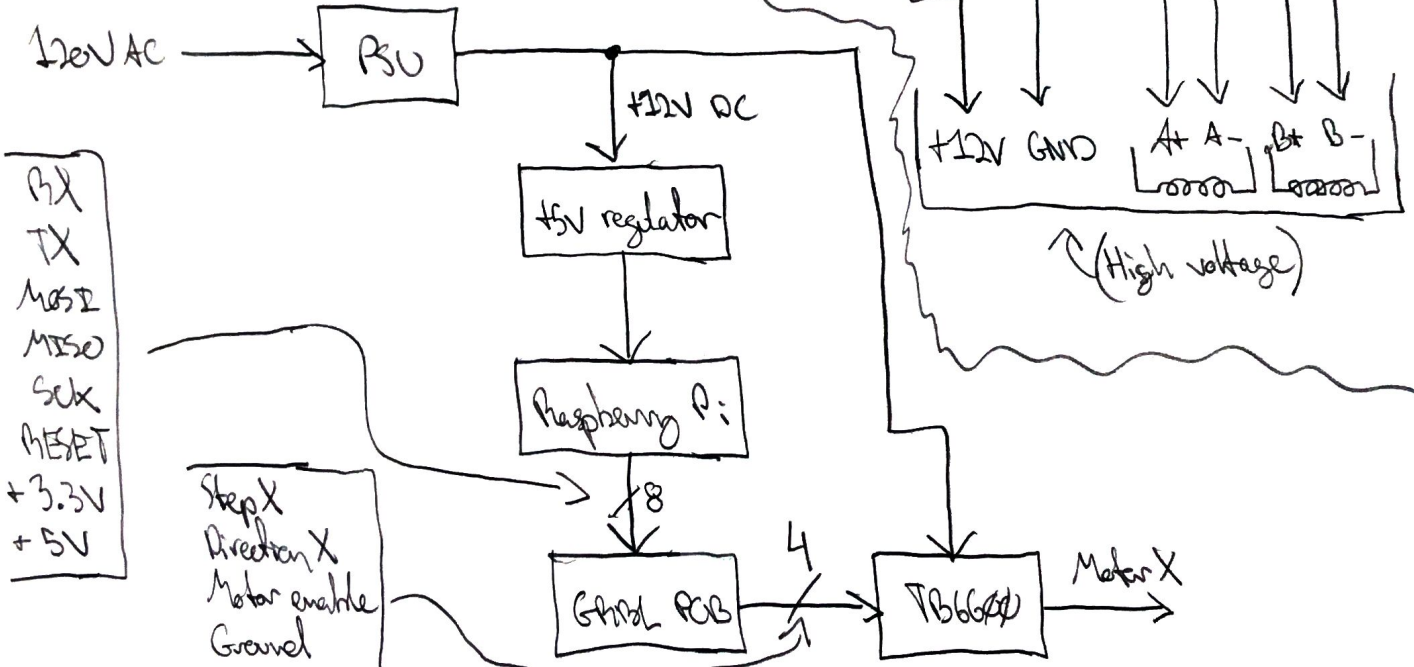
> Finish assembling PCB.
> Test PCB.
> Prep for enclosure.
> Run remaining parts.

# Interfacing between GRBL PCB and TB6600 motor driver:

(common cathode method)




Block diagram with GRBL PCB + TB6600:



# Final PCB price list:

(4x) 4-pin screw terminal block → $13.50
(6x) 2-pin screw terminal block → $8.37
(1x) 40-pin Raspberry Pi shrouded header → $4.42
(1x) 16MHz crystal → $0.70
(2x) 22pF @ 50V ceramic capacitor → $0.51
(3x) 100nF @ 50V ceramic capacitor → $0.59
(2x) 10µF @ 50V electrolytic capacitor → $0.49
(2x) SB150 50V @ 1A schottky diode → $0.87
(8x) 330Ω 1/4W 5% resistors → $0.51
(6x) 220Ω 1/4W 5% resistors → $0.36
(9x) 10kΩ 1/4W 5% resistors → $0.58
(6x) LTV-817 optoisolator → $2.10
(1x) 40-pin Raspberry Pi ribbon cable → $4.04
(1x) 160Ω 1/4W 5% resistor → $0.06
(3x) Yellow 5mm LEDs → $1.16
(3x) Green 5mm LEDs → $1.16
(2x) Red 5mm LEDs → $0.61
(1x) Orange 5mm LED → $0.36
(1x) custom 2-layer PCB → $45.76
(2x) 2N7000 N-type MOSFETs → $1.58
(1x) ATMEGA328P 8-bit MCU → $8.95
(1x) DIP28 socket for ATMEGA328P → $0.45

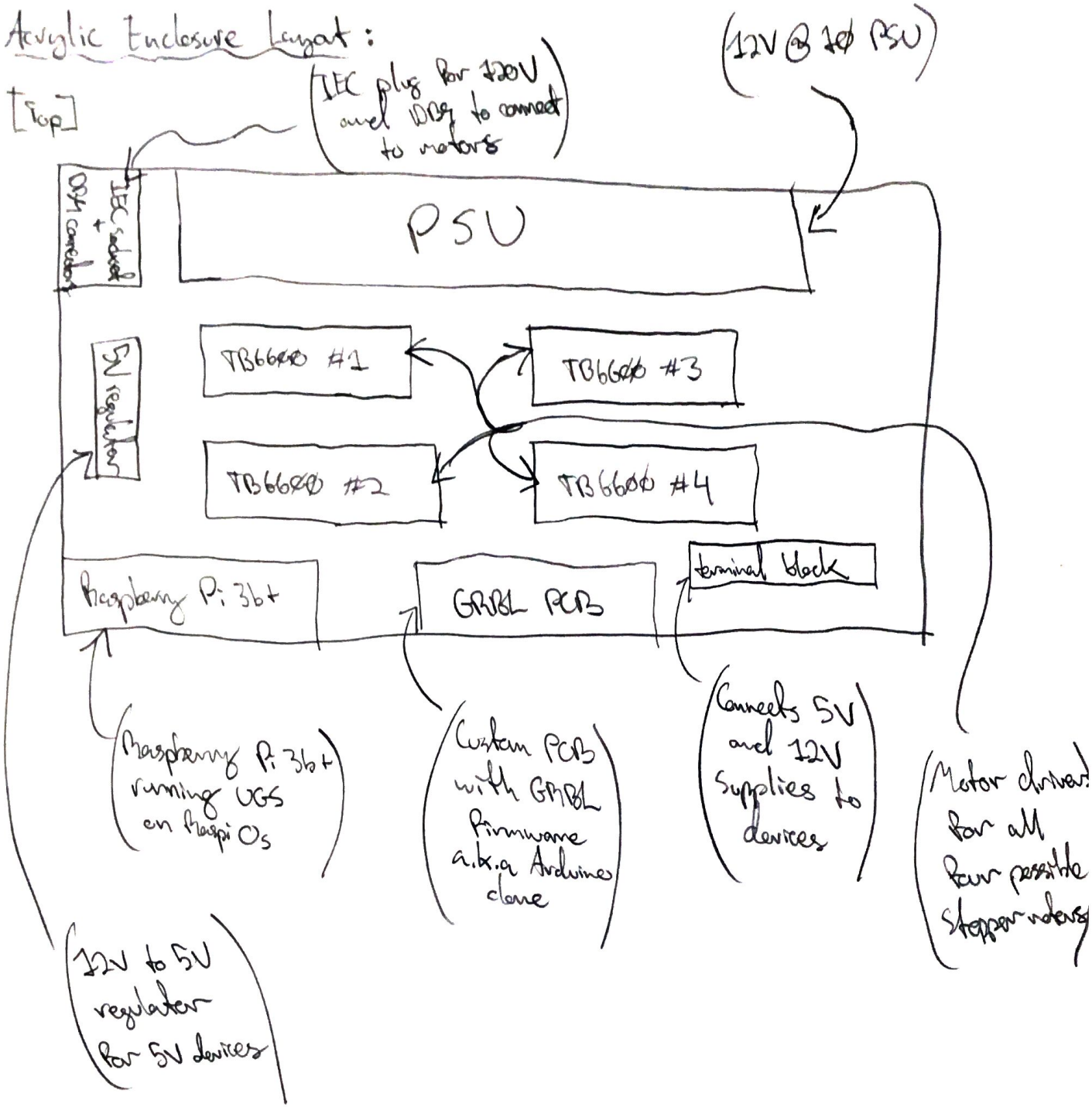
TOTAL: $97.19

For next week:

> Purchase last-minute components.
> Start acrylic assembly / preparation.

**Integration Testing**

- *Ensure all parts assemble as designed with no temporary attachments (glue, tape, etc.)*
- *Complete the assembly of any wired connectors (respecting proper pinouts).*
- *Integrate all wires and harnesses into the enclosure.*
- *Create a list of functional tests, each with an objective.*
- *Ensure each functional test passes. Take a note of these.*


Acrylic Enclosure Layout:
[top]
IEC plug for 220V and DIN to connect to motors
(12V @ 10A PSU)
IEC socket + DIN connector
PSU
5V regulator
TB6600 #1
TB6600 #3
TB6600 #2
TB6600 #4
Raspberry Pi 3b+
GRBL PCB
terminal block
Raspberry Pi 3b+ running UGS on RaspiOs
Custom PCB with GRBL firmware a.k.a Arduino clone
Connects 5V and 12V supplies to devices
Motor drivers for all four possible stepper motors
12V to 5V regulator for 5V devices

**Packaging**

- *Look at online samples of product packaging. Make a sketch of how your packaging will look. Include markings/labels.*
- *Using a CAD tool, design the product packaging from your sketch. Use a graphics program, make any specific markings that will appear on the packaging.*
- *Build the packaging ensuring that the product will fit securely inside.*
- *Create a user-manual to be included in the packaging. Include diagrams and very specific instructions for each function implemented.*

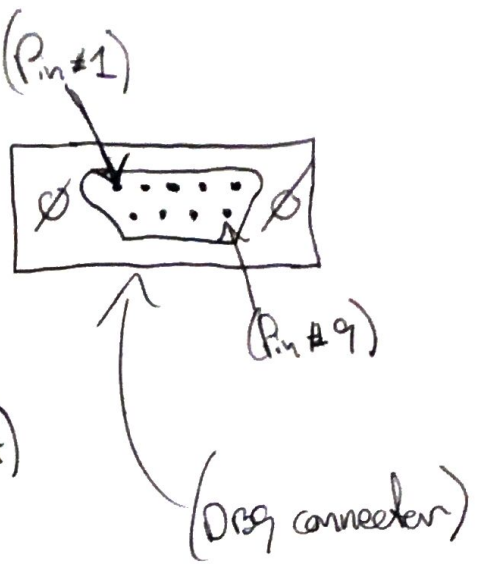
Purchase list for remaining components/parts:

(1x) emergency stop button/assy.
(1x) wire loom with grommets (for outside).
(1x) 12V @ 10A PSU.
(?x) Ferrel caps.
(4x) Female DB9 headers.
(4x) male DB9 headers.
(?x) wire loom clamps.
(1x) wire loom (for inside).
(1x) 10-way terminal block (2x10).
(?x) spade crimp connectors
(?x) 3mm screws (16mm) and hex bolts.
(?x) 3mm mounting screws for DB9 connectors.
(?x) 1A 250V/120V fuses.
(?x) 8A 250V/120V fuses.
(?x) 3mm 15mm-high spacers.
(?x) heatshrink.
(?x) multi-colour 22AWG wire (stranded).
(?x) black and red 12AWG wire (stranded).
(1x) micro-USB cable.
(1x) panel-mount HDMI cable.
(1x) keylock (7/8").
(1x) 80mm fan filter.
(2x) TB6600 motor drivers.
(?x) 2.75mm screws (16mm), hex bolts and washers.

(?x) black and red 18AWG wire (stranded).

For next week:
> Start pre-assembly of DB9 connectors.
> Start pre-wiring of enclosure for motor drivers.
> Start pre-wiring for +12V and +5V system.

## DB9 connecter pinouts:




- Pin #1 → A+
- Pin #2 → A-
- Pin #3 → B+
- Pin #4 → B-

(Stepper motor)

- Pin #5 → +12V
- Pin #6 → GND (to motor driver)
- Pin #7 → SW1
- Pin #8 → SW2

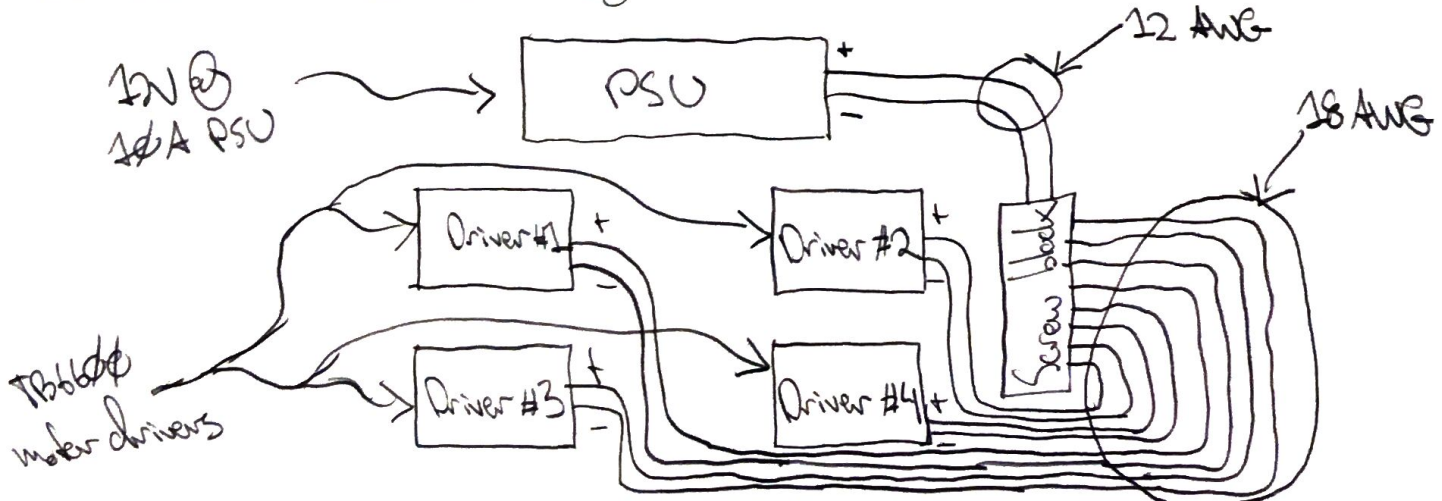
(Connect to limit switch input)

- Pin #9 → GND (to GRBL PCB)

## Delta AR8812SH PC brushless fan pinout:

- Red → +12V
- Black → GND
- Blue → PWM
- Yellow → Tachometer

## TB6600 motor driver wiring:



## Final Assembly

- *Photograph and video the PCB alone, the packaging alone, the fully integrated product outside of its packaging and the fully packaged product.*
- *Consult previous logbook entries and create a short summary of what was done. Highlight specific challenges of the project.*
- *Create a short, 5-minute promotional video for your product using the video, pictures and report you have made. Be sure to mention the school. program, and your instructor.*