

Team P.V.I.R.

Powervault Inspection Robot

ECE 4011/4012 Senior Design (sd19p06)

My Contact Info:

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Important Links:

~~Spring 2019~~ - First meeting

1/8/19

(all members besides me present)

Proposal Presentation due next week

* Weekly meetings

Tuesday 4:30 - 5:30

Testing Environment for Expo

→ light boards → foam or wood

1/3 ☒ add dummy gauges to BOM

Stephanie & Lemek

→ GUI design

Nelson

→ RPi & arduino communication

Adrian

→ mechanical arm

Elizabeth

→ controls and hardware

(EKF)

13

Proposal Presentation - all members present 1/15/19

1/19 ✓ update presentation fonts for upload

2/13 ✓ check speed control library for motors / servos

2/13 ✓ power consumption check for pi / arduino

1/22 ○ need a controller mapping for inputs

*"crawling" mode if arm is fully extended

RC servos - small scale, light
servos and load --> stepper motors

3D printer is good basis of how to
make arm -> z-axis on 3D printer ~
elevating camera

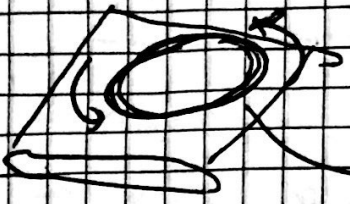
sensitivity is more important than
speed

linear
lead screw, bearing, stepper motor, rails
coupling shaft

Torque ☹

(EAR) 14

1/15/19



aluminum turntable
that everything will be
mounted on

kind of like a lazy susan
heavy duty aluminum turntable

1/21 ✓ check dimensions of robot to
find appropriate turntable size

how are we going to charge this?

separate power for MC

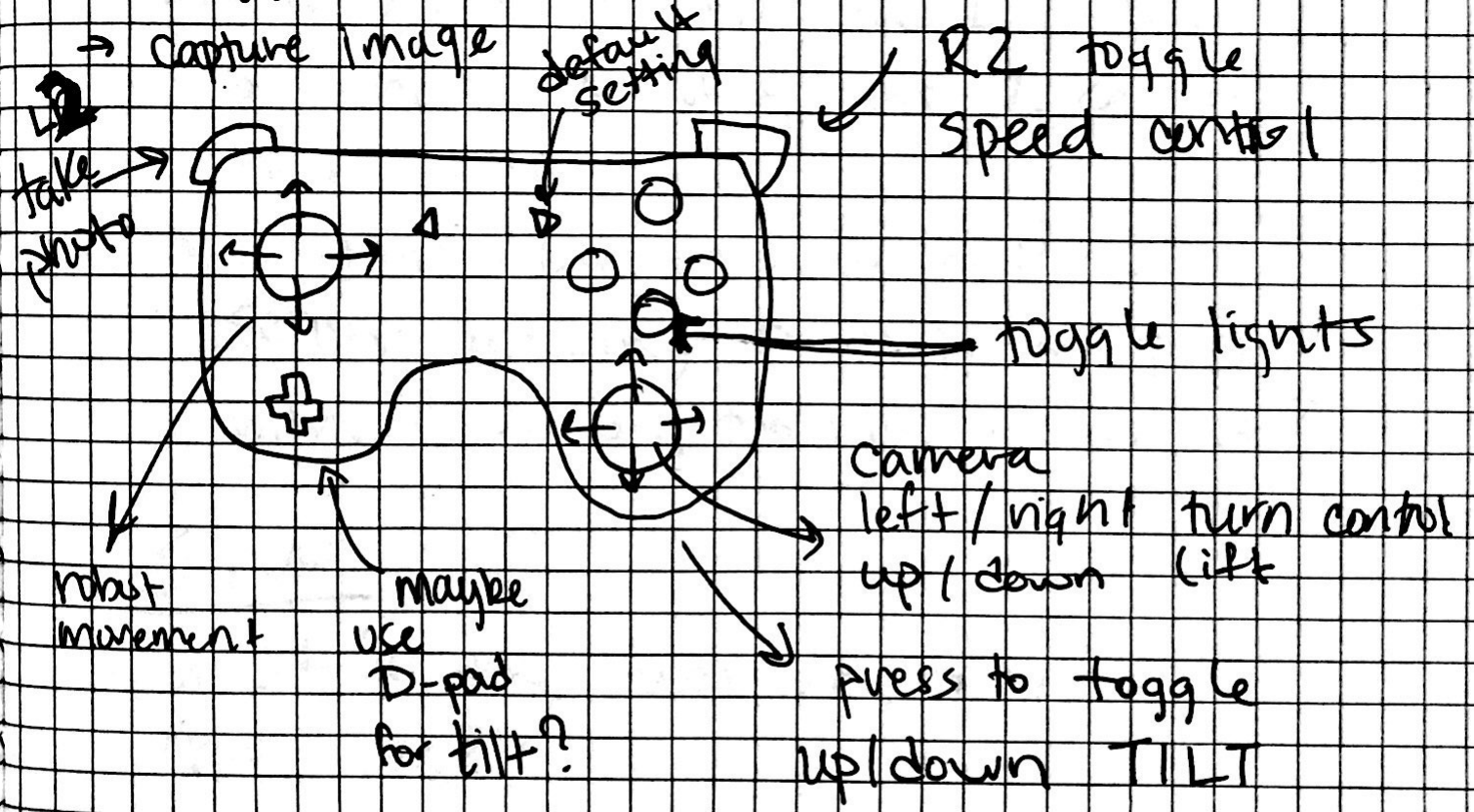
↳ motor shield to drive

1/19 ✓ updated proposal due this week

(EAB) 15

List of functions - controller brainstorm

- turn lights on/off
- robot movement (F, B, L, R)
- rotate 360° plate
- lift camera vertically
- tilt camera
- "RESET" controls (bring everything back to default)
 - ↳ reset sensors etc?
 - ↳ how fast will the sensor data be updating
- toggle speed control



EAB

Schematic Design

Arduino Uno

- has enough PWM outputs for 2 motors / 2 servos? (3) servos will need a servo to turn 360°

tilt camera

lift/lower camera

- 5V barrel jack power

Sensors

- multiple need SD4 / SCL pins! but the UNO only has 1 set of these pins
- is it possible to have multiple sensors leading to this one pin without drawing too much current?

Servo

what is the max weight it can move?

Stepper motor for lazy susan

EXT 17

Weekly Meeting - all members present

1/22/19

- have slides for weekly updates
 - what we accomplished
 - what we plan on doing next week
 - provide structure to meeting
 - can use for final presentation

what about controlling each motor separately
2 analog sticks / left & right motor

end switch for camera height so operator
knows how/where camera is

default camera position

↳ need calibration point

scissor lift for sensor package

↳ needs to be robust / sturdy

↳ can only handle vertical load

✓ Analyze which sensors / testing materials needed
✓ find new microphone

reduce camera resolution to maybe increase
the speed of video stream

↳ Rpi night vision camera - ON ORDER

(EAP)

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Weekly Meeting

1/29/19

* cancelled b/c of snow

1/30 ☒ find gas sensor for carbon monoxide / methane

1/30 ☒ find mount for RPi night vision camera
→ found on thingiverse

(EAF) 19

Meeting in Lab - all members present

1/30/19

12 AUG
↑

- will need to get zip ties, connectors for clipped wires
- need some sort of hole that connects base to sensor package
- using Arduino DUE
 - ↳ has two sets of SDA/SCL
- removing relays / encoders / comms
- keeping motors / speed controllers
- 16 GB SD card for DUE (need)
- need new power supply (12V for motors)
5V for sensors
- 2 separate power supplies to reduce current draw and no need for voltage regulators

1/31 male header pins on motor controls

↳ go into arduino (small black/white)

(1/31 senior design lab)

(EAB) 20

→ Using Arduino IDE

Testing of speed controller (w/ Lemex & Adrian)

① calibration tests

attempting to set max & min PWM
neutral at ~185

ideally should be at 127

↳ if we can figure it out

Neutral at 185 is fine; implies
back speed > fwd speed but we
won't be reaching the max anyway

Advisor Meeting - all members present 2/5/19

- emergency shut off functionality w/ reed relay and magnet would be good to implement (probably what old group was doing with relays)
- hydrogen sulfide is only gas we aren't able to sense (still looking for sensor)
- air quality sensor was unable to be ordered
- voltage regulators might be necessary
- impossible to implement all correct gas sensors

GUT

- audio graph live histogram or recording capability displayed

Battery → 9.1 cm deep in robot

→ round lithium ion cells?

- Samsung INR 18650 or ~~18650~~
3 in series
2 sets in parallel

EAR 22

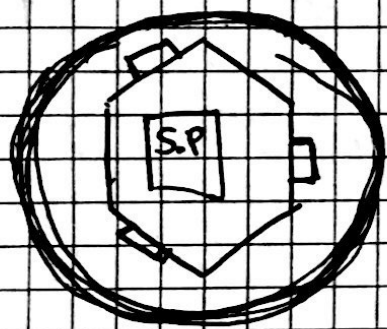
Battery

pouch cells

* look into small cylinder cells

→ if weight is an issue we can just insert weights into robot

→ make sure to order charger w/ battery

→ Voltage regular to get the 5V
LM7805

hexagonal platform
for sensor package
3 places for T-slots
extra stability
center of gravity calculations

add overheating of inside the robot

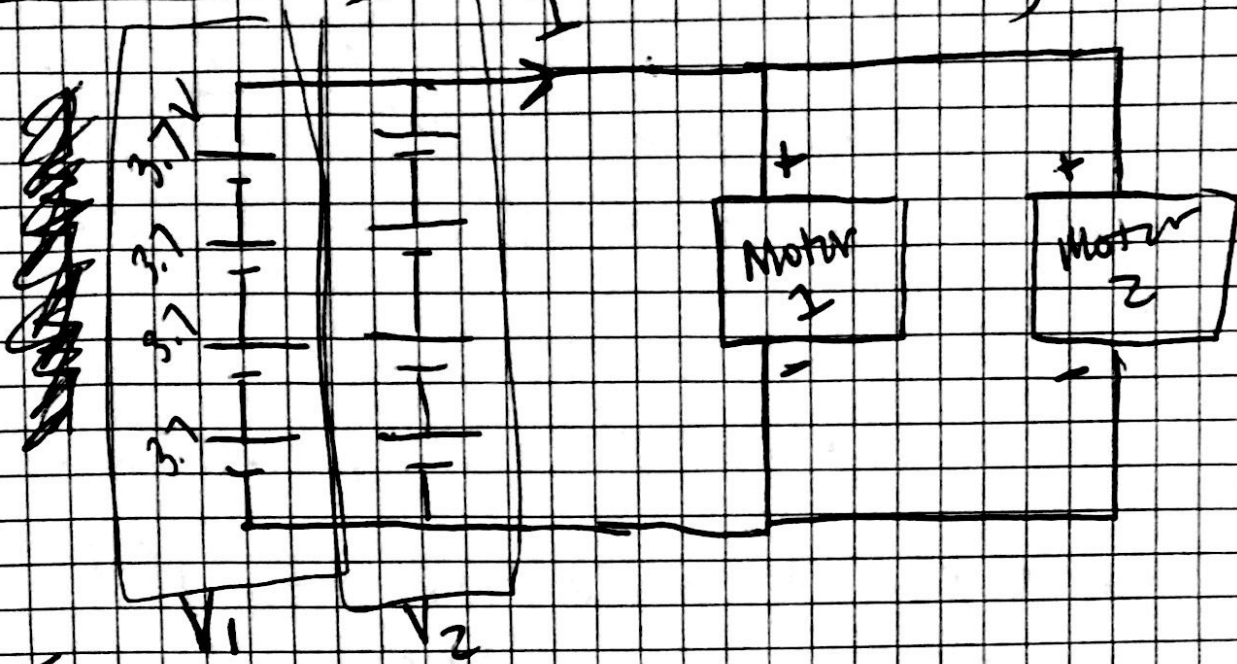
Control System Design

→ how arduino knows signals
and does it check speed

2/13 ✓ Begin ~~later~~ drawing schematic

Power Schematic Brainstorming

2/11/16



I needs to be ~ 30 Amps for motors

3.7 V INR batteries

2500 mAh

$$\text{total voltage} = V_1 \parallel V_2 = \frac{V_1 \cdot V_2}{V_1 + V_2}$$

more than
12 V
initially

$$\text{total current} = I_1 + I_2$$

Voltage Regulator $\rightarrow \sim 5$ V for sensors

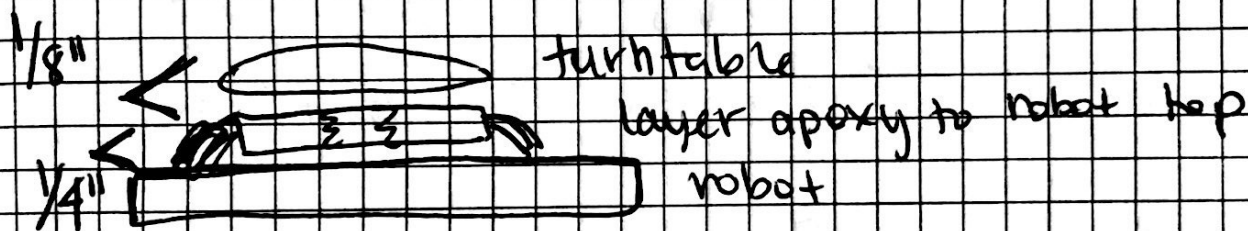
need heat sink for voltage regulator

END 24

Advisor Meeting - all members present 2/12/19

Mechanical arm

- Aluminum local is really hard to bend
- have parts to be ordered for arm
- need to replace the top of robot ($\frac{1}{4}$ ")
- use epoxy to make sheet waterproof
 - ↳ OR thicker sheet & drill half way into the sheet for best water tight solution



- remember to look at bolts! rust-free stainless steel
- what size bolts are we looking for? smaller so they can be secure in half way through plate

- * T-slot sliders
- * tension belt spring
- * alligator clips
- GT2 timing belt (Mercury)

flat nema 17 motor for pulley system

grabcad → CAD files library

2/12/19

IR camera

- ↳ great for navigation
- ↳ IR can't see quages behind glass
- ↳ great for navigation
- ↳ add white LED?
- ↳ polarizing lens

Voltage Regulator 7812

* if we need 12V regulated

* don't need current regulator circuit

To 220 Heat Sink?

To 120

2/13 ☒ Test sensors that came in
(MQ2 & IR temp sensor & RPi camera)

2/13 ☒ Find testing environment boards
to order

(AP) 26

Sensor Testing and calibration

2/13/19

Sensors to be tested

- MQ2 gas sensor
- IR temp sensor
- RPi Night vision camera

Testing Procedure for MQ2 gas sensor

- ~10 output reading from arduino indicates clean air
- testing in presence of 91% Isopropyl rubbing alcohol
value changes significantly
 < 5
changes based off exposure (closer to 0 is worse)
- can't tell you which gas it is sensing

Testing Procedure for IR temp sensor

- set up calibration
- determine if ambient & object temps are accurate
- correctly can determine obj temp
(pointed IR cam at the laptop fan and temp was higher than ambient temp)

(GAF)

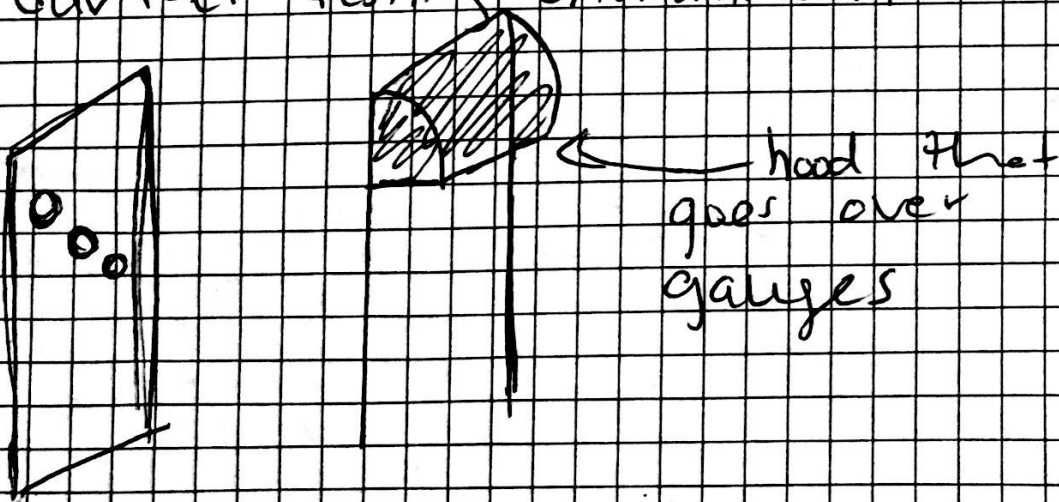
2A

RPI Night Vision Camera Test

- picture and video capability
- functionality in darkness
- lights do no toggle on and off
↳ produces a glare

Expo Testing Environment

- dummy gauges need plastic/glass coverings
- gauges need to be placed at variable heights
- foam boxed needs to have removable hood to stimulate darker testing environment



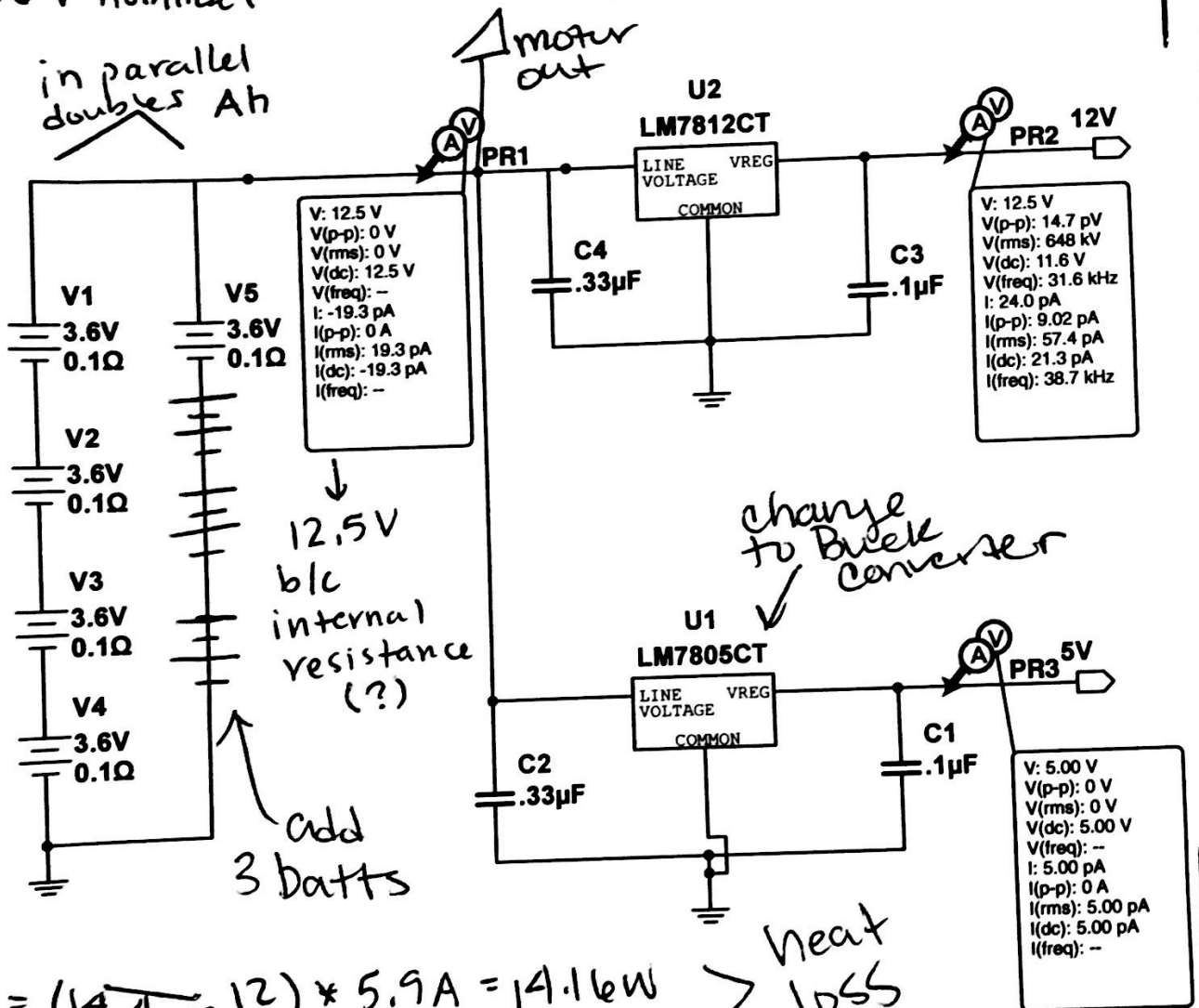
Power Schematic

2/13/19

batteries are @ 3 Ah
3.6 V nominal

Heat generated =
(Input V - output V) * output current

in parallel
doubles Ah



$$P_1 = (14.4 - 12) \times 5.9 A = 14.16 W$$

$$P_2 = [(14.4) - (5)] \times 2.5 A = 23.5 W$$

heat loss

Current draw estimates:

2.5 A per motor → 5 A
.9 A arduino/sensors
2.5 A from Pi

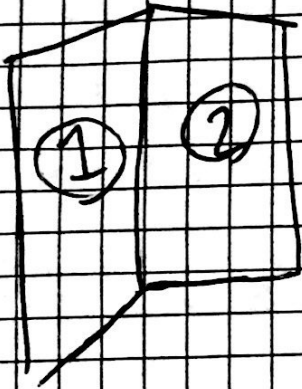
12 V regulated device
5 V regulated device

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Advisor Meeting - Adrian not present (interview)

2/19/19

Testing Environment

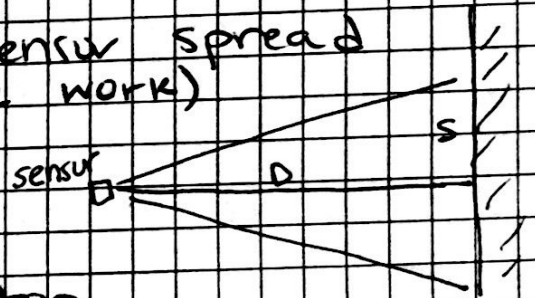


- 2 boards to make corner
- self standing
- spray paint board
- maybe get the gauges to read not zero

2/25 - space to store ??

Stephanie will find place (ask Steinberg)
for test board storage

3/14 do research on IR temp sensor spread
(how well does the IR work)
distance D & target diameter (s)
 $D:s < .5$ for accuracy



MQTT Setup

connecting RPi to laptop

→ Using GDM as network (eduroam doesn't work)

→ RPi can read values being sent to it 'represents key presses that could be from a controller'

Nelson continuing to focus on Serial connection between pi & due

need to update Xbox controller inputs

30

Communication Scheme

2/19/22

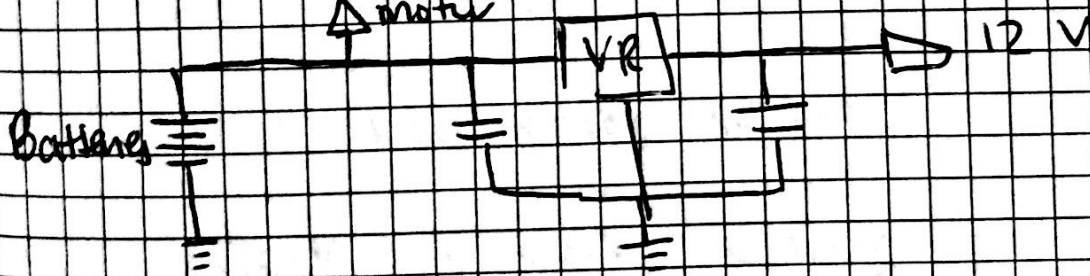
edit:

- motor don't need arrows on connections
- add second speed controller and motor
- add pins to arduino
- signal from sensors $\rightarrow$ DUE
- serial will be bidirectional
- usb is ~~bidirectional~~
- haven't begun to add motors for mechanical arm yet

Power Schematic - need 4 batts || 4 batts
* need to be all charged to same level

$\rightarrow$ low drop version of LM7812

$\rightarrow$ heavy load move to other side of V.R



$\rightarrow$ LM7805 properly can't handle 2.5 A

for RP (replace w/ converter)

☒ 12V to 5V converter (buck converter)
add to order form

GAF 31

2/19/19

Bolts / screws / nuts

how will we be connecting everything?

Bolts slightly larger than T-slot can
be threaded into top/bottom of T-slots
for top plate

Stepper motors haven't been ordered
yet either

must be mounted as well

figure out how much extra money
we will potentially need
(have \$40 left in budget)

ToDo

2/22 ☒ solder battery holders together

2/22 ☒ test batteries with DC motors

2/22 ☒ check battery charge before
testing w/ team on 2/22 (FRIDAY)
(4V)

2/25 ☒ add speed controllers, motors, arduino
and RPI to schematic

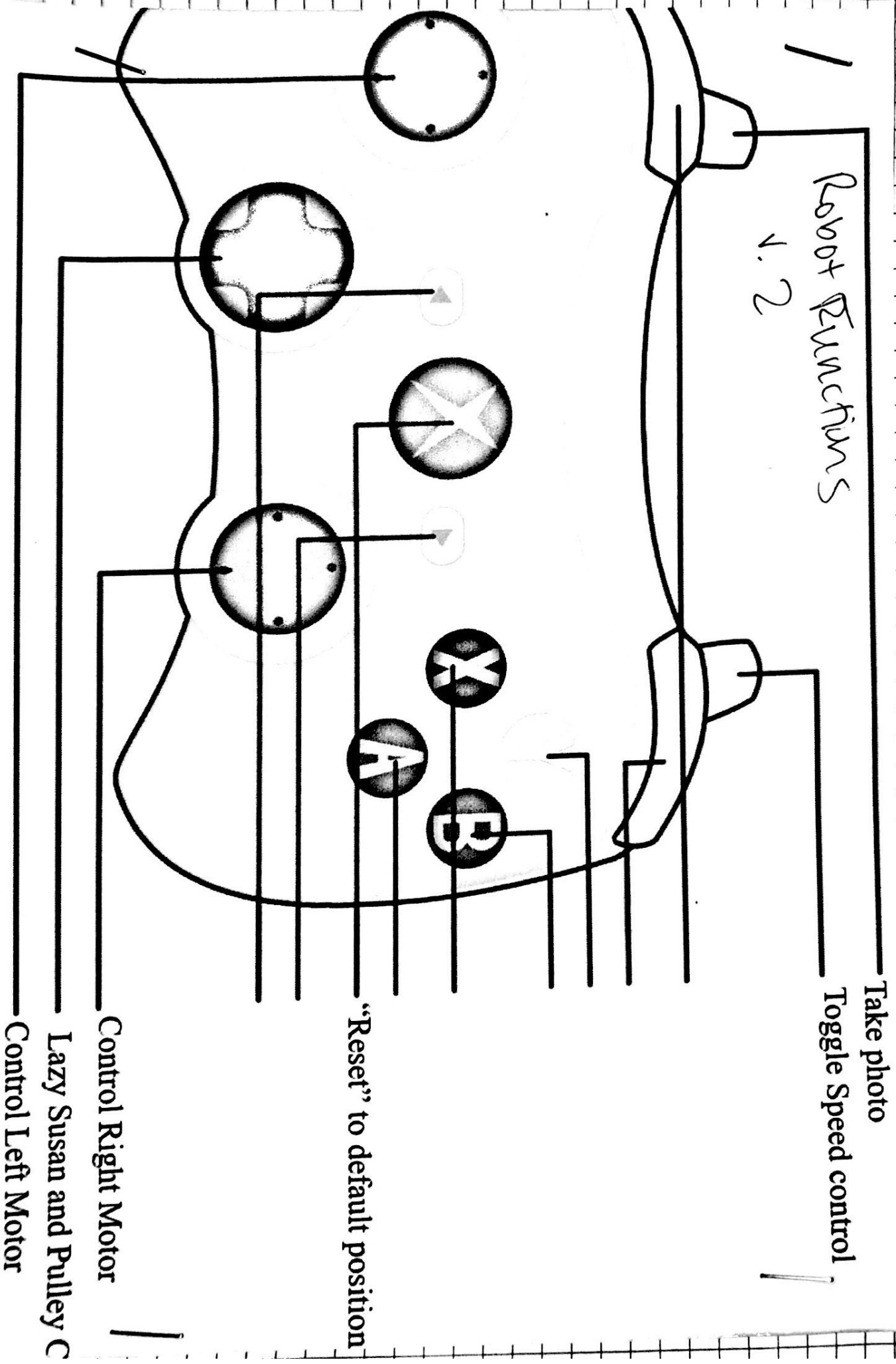
(AP) 32

2/21/19

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Robot Functions

1.2



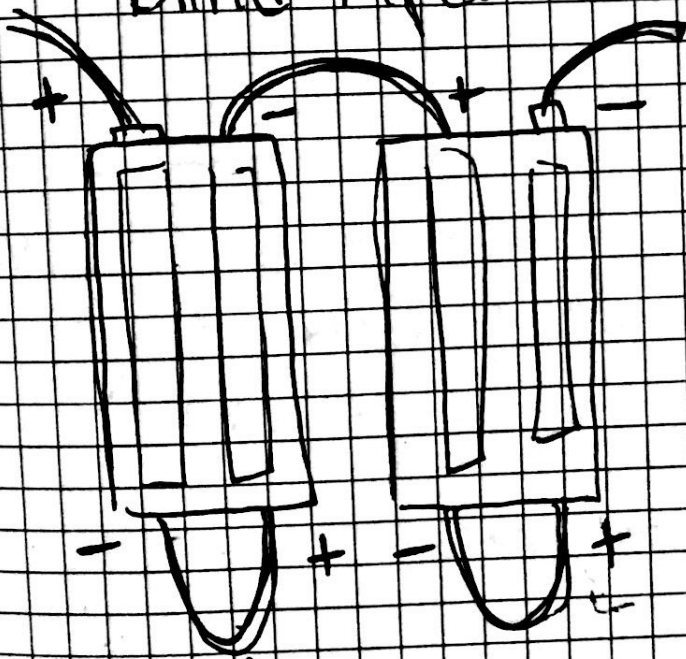
Motor Testing w/ batteries

2/22/19

testing motor w/ 4 batteries in series
~ 30 A / 14 V (both motors work)

aluminum top plate doesn't fit
top of robot - need to weld 2
together

2/22/19
✓ verify size of holes on top of robot
for screws #6 screws 40 threaded
30 holes .13 inches (9/64)
blind-tapped



✓ work with direct power

work with pwm
(speed controller)

want blinking
red/green or
~~solid~~ solid red/green
on VEX SP

4/22/19
3A

PWM

VEX SP LED

2/22/17

150 blinking Red (pwm reverse)

185 solid orange (neutral)

200 blinking green (pwm forward)

Issues: DUE PWM (pin 2) isn't working

PWM works on UNO

↓
★ test out all pins on board ★
isn't smooth

Speed ~~transitions~~ transition

To Do

12/5 ✓ solder other battery holders together (change 8 AWG to 12 AWG)

2/6 ✓ test pwm pins on DUE

□ test both motors at once

the variant.h file in the DUE IDE needs to be edited: change pwm frequency to 490

EAD
35

2/25/19

- Replace 8 AWG wire on current holders w/ 12 AWG so the holder & speed controller have same size for connectors
- need a fuse box for it when using 12 AWG due to potential high current
- DC brushed motors
 - ↳ cheaper but less efficient

EAR
36

Advisor Meeting - all members present

2/26/19

- silicone cork for sealing
- don't charge batteries above ~ 4.2 V
might decrease life expectancy
- "upgrade" 2 person control (one to move robot and other to move camera)

GUI - what about adding a post run result screen?

- #pics taken?
- run time?
- determine overall air quality?

Gauge Graphs

- arm direction & air quality gauge

↓
Have camera facing forward on power ~~on~~ on robot locks if not in default reset position

Mechanical arm

- use steel screws not brass for strength
- maybe find 1 pulley for the top w/ bearing
- pulley kit has pulley w/ bearing already
- mount pulleys under on the top!!

AF
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2/26/19

MQTT

latency between Xbox controller inputs
and RPi

need 100% completed list of other materials
by next week b/c we are over budget

Challenges

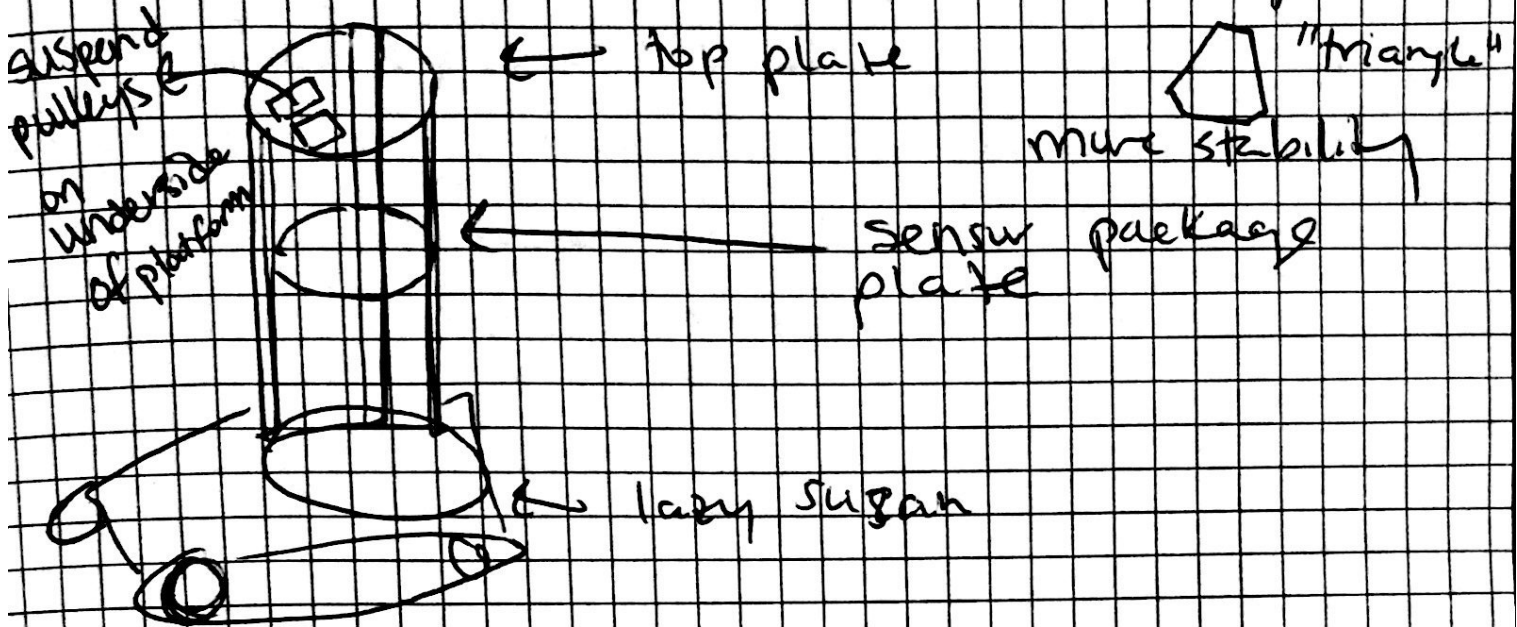
- budget
- mechanical hardware

AP
38

Adrian & I - meeting in mechanical arm design

2/28/19

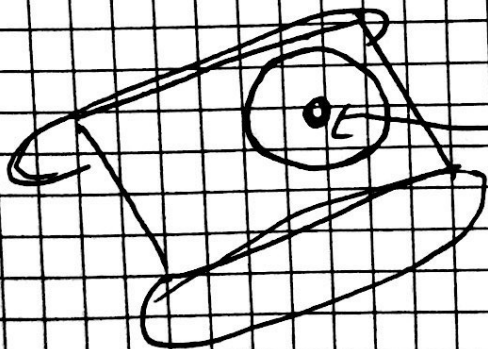
- top plate needs to be a circle - change from



- ✓ verify size of holes in lazy susan for mounting standoffs (using #10-32)

- could not find steel hex standoffs
- found some waterproof cabling solutions

(need to confirm how thick total wire will be / what thread length needs to be to get through top plate)



will need a hole in every plate the size of the wire in center to prevent tangling around T-slots

ENG 39

- 3/5 ☒ discuss as a team the locations of RPi / Arduino as this will affect cabling
- 3/5 ☒ Where will ethernet port be on the robot?
(need longer ethernet cable) → hole USING WIRELESS
- 3/4 ☒ add water proof cable passthrough connectors to BOM
(consider thread length & diameter)
- ☐ get voltage regulator from senior design lab

3/5/19

Order Form Review

→ Verify why we need 14 more L brackets (2" x 2")
(got 16 2" x 2" in first order
so ~~we~~ ~~now~~ shouldn't need more)

→ add 1" x .5" L brackets for pulleys

□ check circumference of turn table
for O-Ring dimension ("Round Belt")

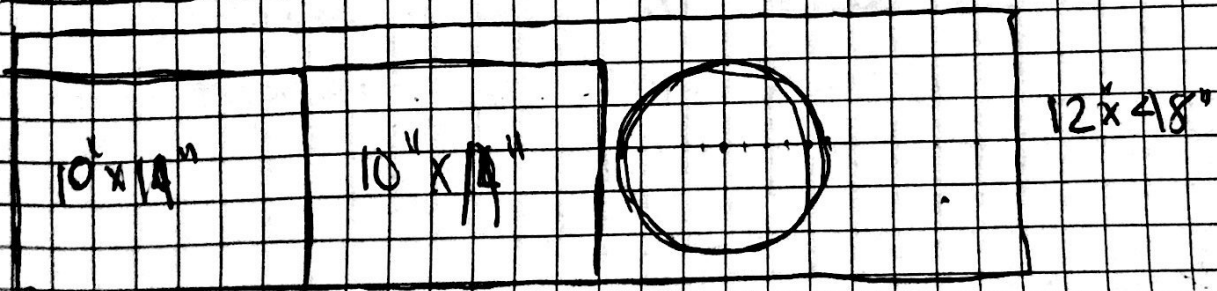
→ no longer need spacers / steel rod /
brass standoff set / O-Ring set

do we need a waterproof case

R Pi → 65mm x 30mm
2.55" x 1.18"

3/5 ✓ check on status of returning 12" x 12"
1/4" for robot lid (not big
enough) (maybe get 12" x ~~18"~~ 18")
→ can return and get anything!!

~~size of robot lid?~~ size of robot lid? 14" x 10"



Advisor meeting - all members present

3/5/19

Fuse 20 Amp

- wire gauge different than battery is fine $\rightarrow$ heat shrink

Waterproof ethernet connector

using wireless RPi communication so no problems w/ ethernet port

not a true 360° of freedom of turning to prevent cord from tangling

3/7 ☒ check for coiled ethernet cables instead of telephone (8 wires)

Mechanical Arm

- moved idlers on bottom of top plate
- top plate is now circular
- collar clamp to keep rod in place or use a bolt & nut
- export 3D model to technical drawing

3/7 ☒ go to invention studio and verify dxf files are compatible and see if we can schedule work

Montgomery machine hall

EAC
A2

GUI (Lemell & Stephanie)

3/5/19

- live video feed
↳ maximize / Fullscreen
- live plotting of sensor data
- Stephanie working on temp bar graph
- Gstreamer to reduce lag (later on)
- need camera "screenshot" feature
- have graphs share X-axis

MQTT communication (Nelson)

- issues w/ serial connection between RPi & DUE
- code clean up

3/11 ☒ add CO sensor, stepper motors to schematic

3/12 ☒ start looking at Arduino sensor functions to code

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3/6/19

- when cutting into aluminum just make a tiny hole w/ water jet to tap screw into
- then use drill to make more accurate sized hole

$\frac{1}{8}$ " top of lazy susan, top plate, sensor plate

$\frac{1}{4}$ " arm base, robot lid

→ need a 12" x 28"

→ smallest size larger than that

1" stainless steel flathead screws to mount lid (total $\frac{1}{2}$ " thickness)



tie rubber band around top to keep it in place

adjustable shaft

how are we to make the pulley move because holes are different sizes?
(gorilla glue should work)

how are we mounting the stepper motor to any surface?
(3D printed mount on Thingiverse)

3/11 ✓

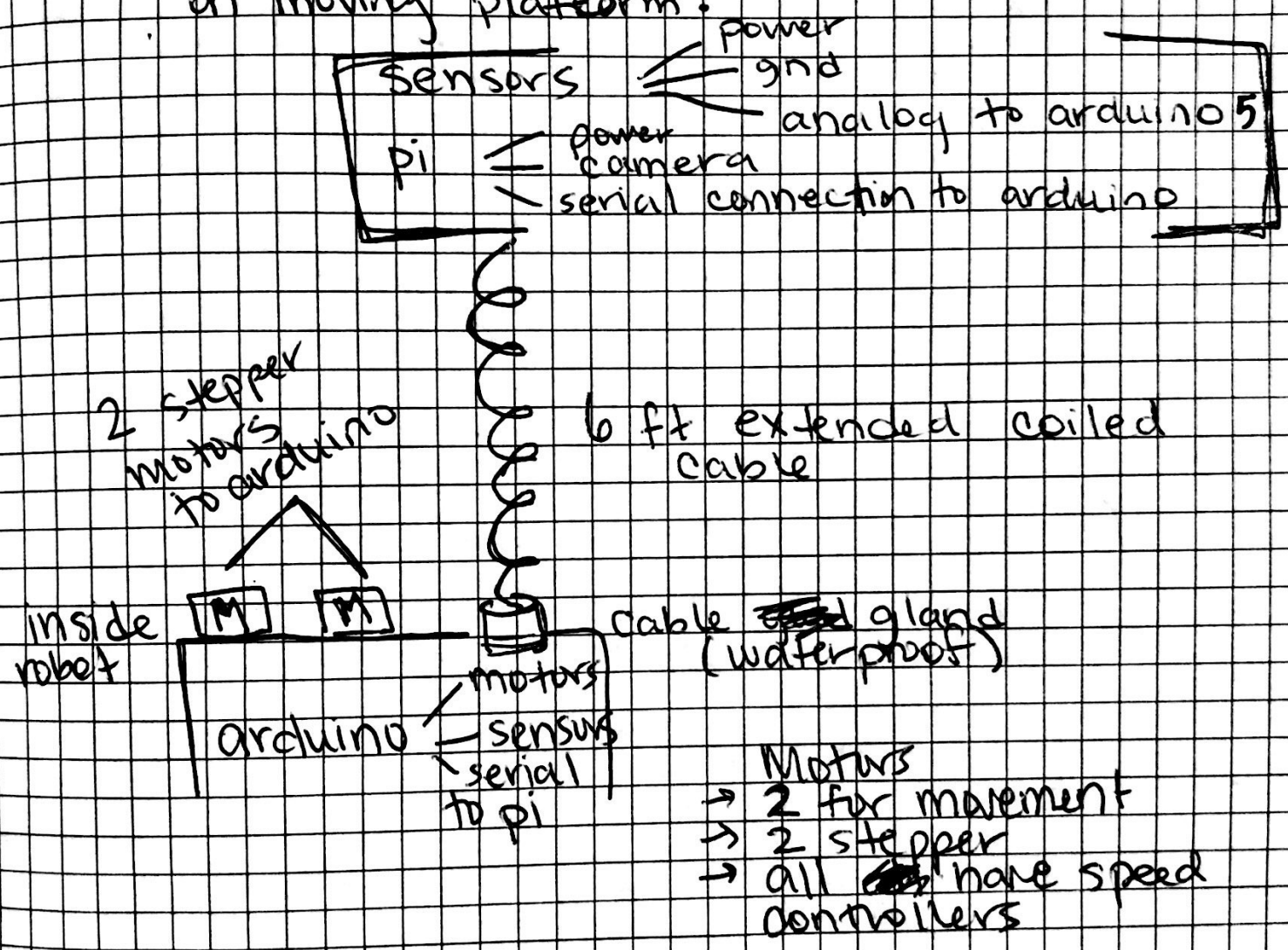
3/11/19

begin control system design

- function
- implementation
- details / specifics

Cabling

on moving platform:

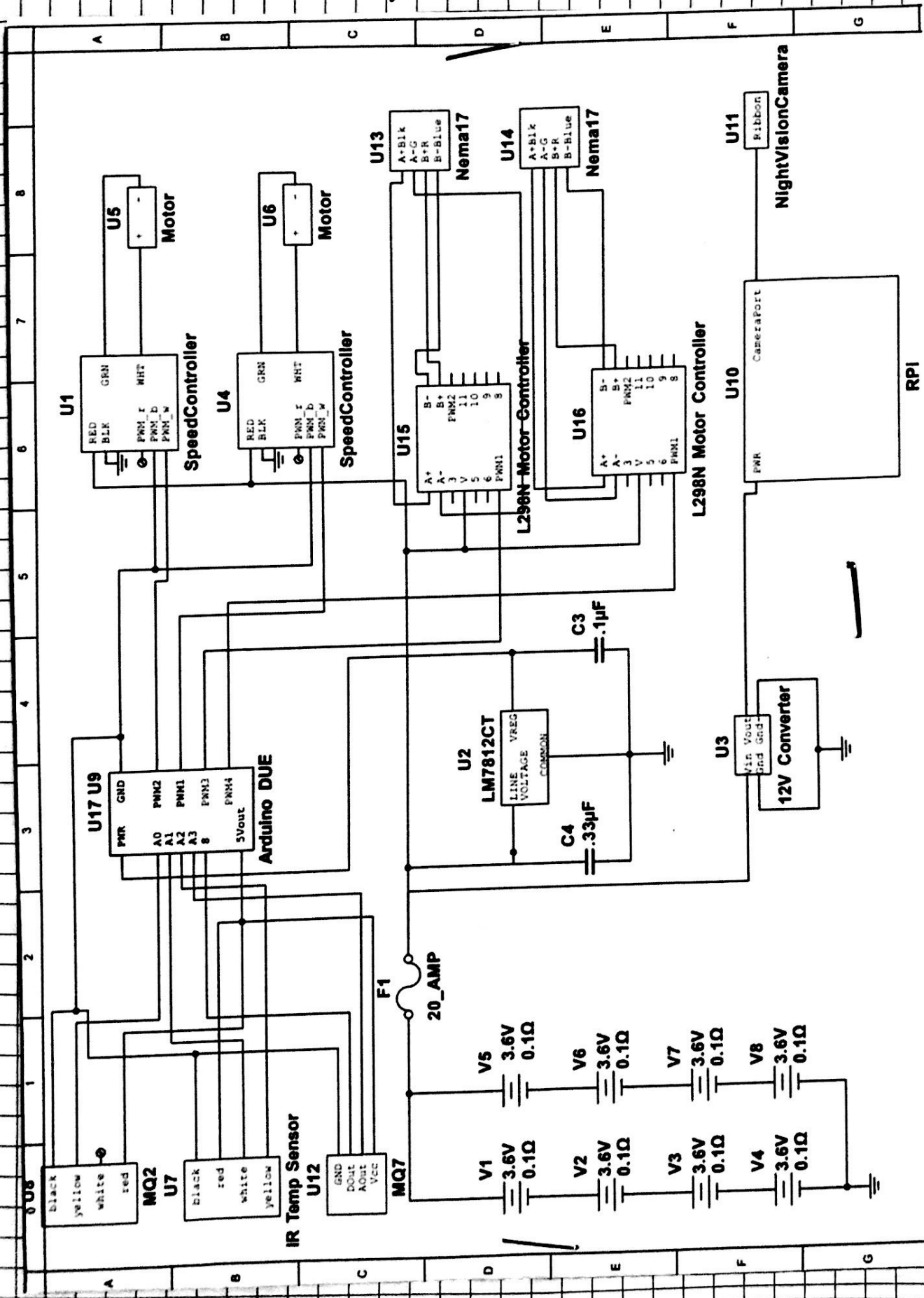


EAE
45

Schematic UPDATE

3/11/19

Look into converting schematic over to Simulink Matlab



Advisor Meeting - all members present

3/12/19

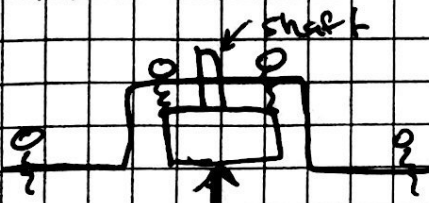
Mechanical Arm Updates

→ 3D PDF for easy viewing

→ have 2D drawings completed

Design Change: instead of welding 2 plates together so just get 1 plate twice as thick

add footnotes to 2D drawings for machining instructions



hole on top for shaft

motor is hanging from under

"bridge" design holder

has threaded holes on the top

make sure to credit 3D printed objects from thingiverse

GUI - no new updates

MOTT

- publisher
- subscriber
- client
 - ↳ broker
 - ↳ topic
 - ↳ port

classes

- subscriber class ~~needs~~ needs to print out test statements

Website (lower priority)

- notebooks
- slides
- software / testing

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Control System Design

3/12/19

→ need limiting values to protect speed control

→ 2 factor auth for speed control

Schematic

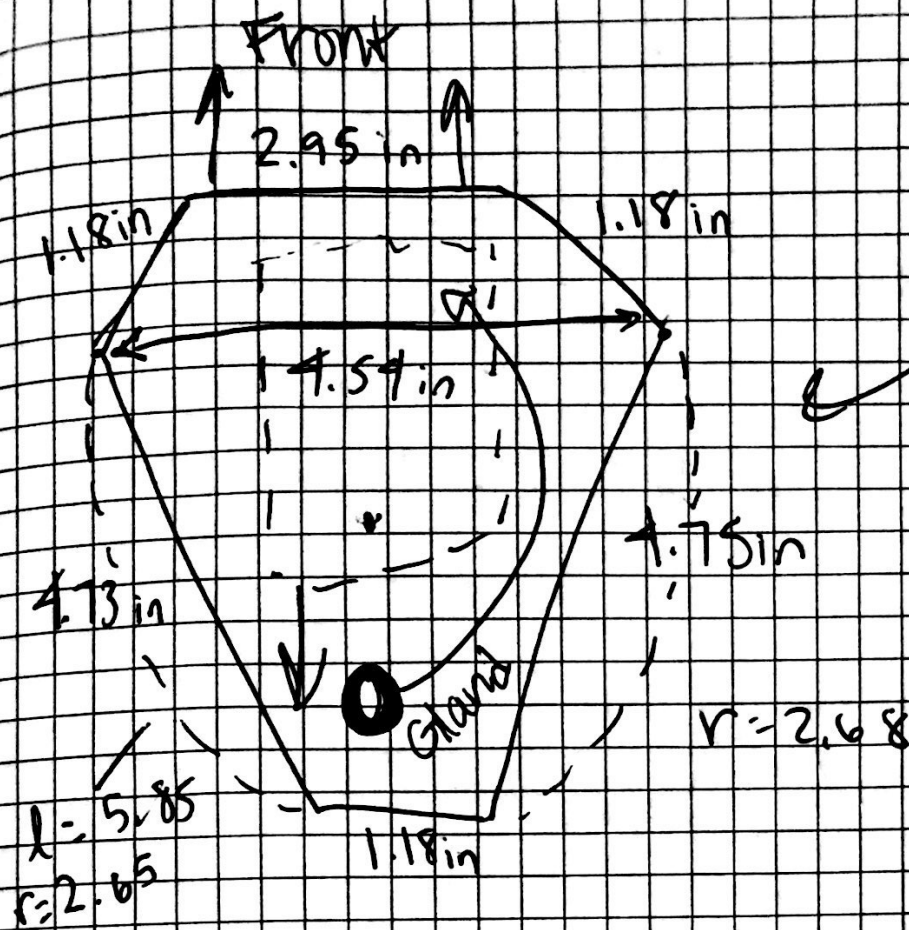
IC need decoupling capacitors

adding coiled Micro usb - ~~usb~~ usb A cable

Nelson - working on bridge holder for stepper motor

48

3/13/19



2.305 in x 3.429 in

48

Advisor Meeting - all members present

3/26/19

Mechanical

95% design done

0% machine work done

smaller pulley - more torque

U bracket being printed

camera mount printed!

GUI

air gauge only redraws arrow to
reduce computation load

air temp bar graph

live graphs - share x axis audio
obj temp

↳ need labels

currently GUI runs w/ random
variables generated

→ have data caps
so works slow when too much
time has passed

add microphone to schematic
not using microphone

FAE

52

- can send strings back & forth

Sensor Package

Input - run motor

No input - sensor update

arduino can't do two things at once

Motors

one function for motors

2 inputs for one motor function

↳ pwm for L & R motor

define all constants

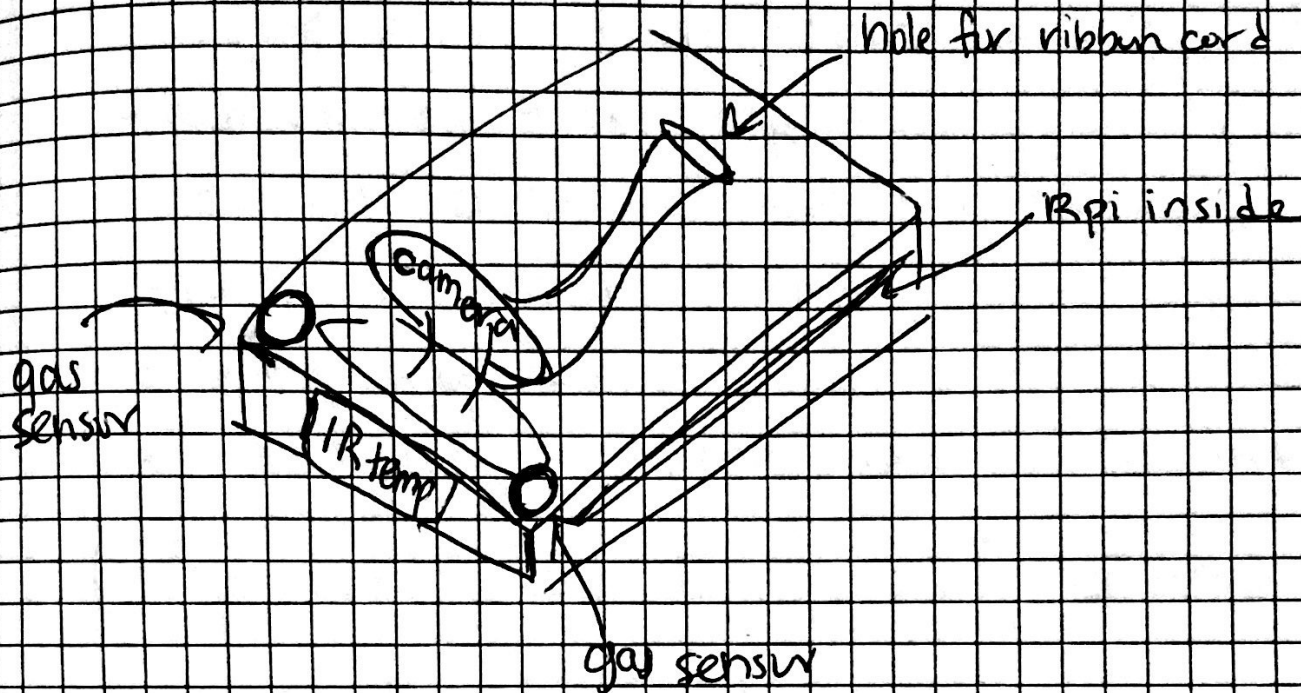
4/18/19 hardware assembly box for sensors

5/1

3/28/19

SENSOR package Components

- RPi
- 3 sensors
- RPi camera
- Microphone



52

Advisor Meeting - all members present

4/9/19

Assembly Updates

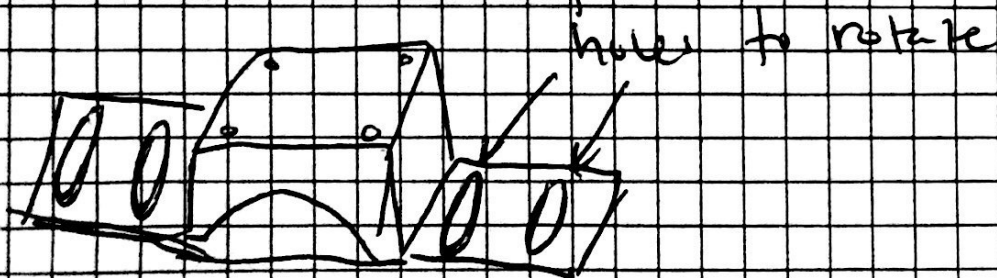
- aluminum machined
- sensor plate has slides on
- top plate holes tapped
- coiled wires connected / stripped
- U-bridge mount reprinted
- cut pulley rod
- drill holes in outer ring of turntable

(take better pics for poster/presentation / website)

Should not have tapped top plate holes

☒ drill the threads out! counter sink them too

U-bridge long holes need to be aligned vertically



53

4/9/19

Software updates

- movement code started (dependant on sensor time)
- arm movement code (rotation and lift) 400 steps in rotation
- update streaming method
- incorporate data streaming
- starting reset code

"travel" and crawl mode for speed
↳ not exactly a speed mode

Project Deliverables

- project summary
- poster / demo material
- final report
- website

next demo meeting in lab
separate final presentation

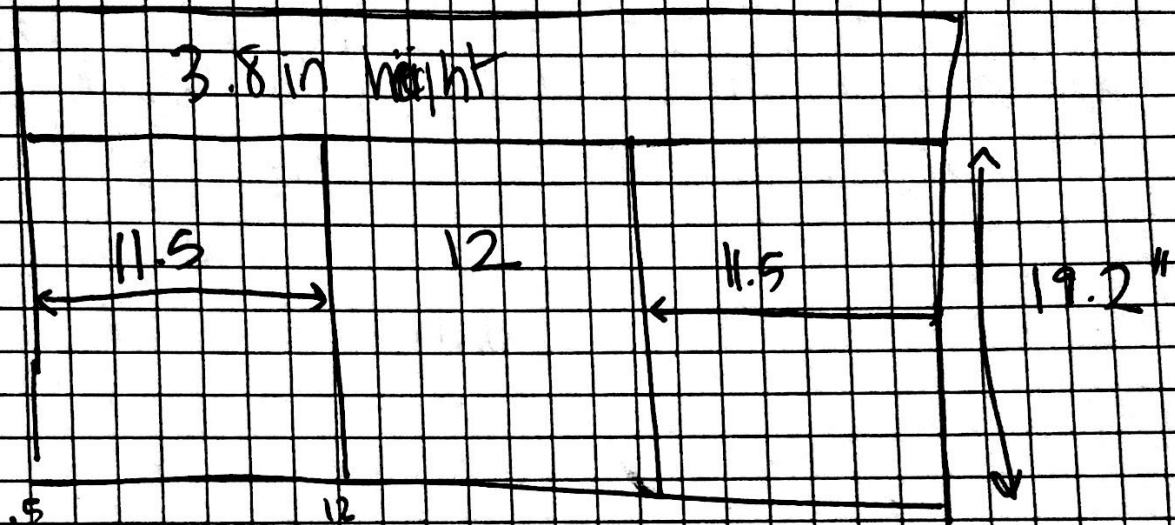
END
5A

4/10/19

24" x 36" poster

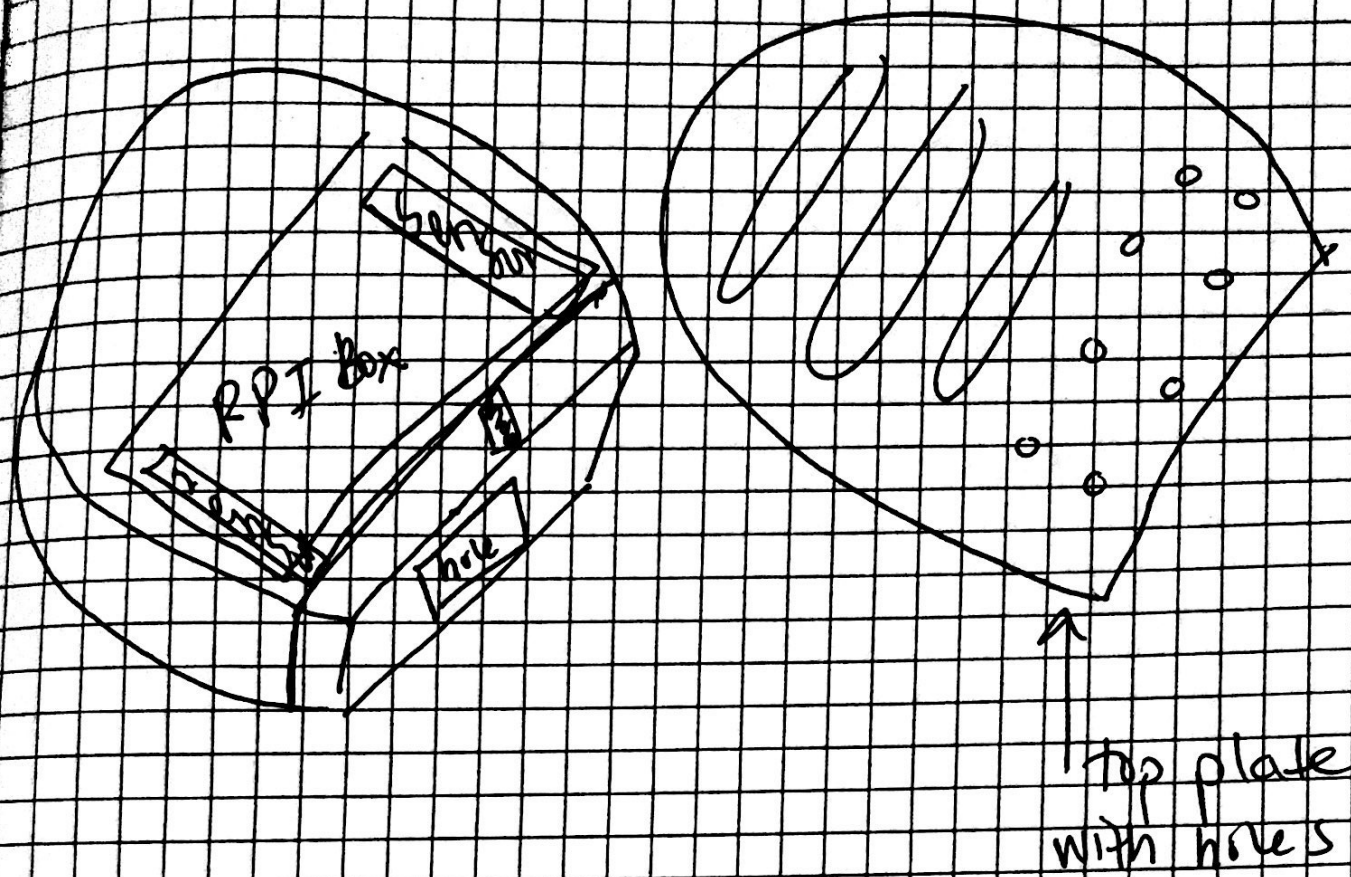
$\frac{1}{2}$ " margin

35" wide



55

4/11/19



56

Advisor Meeting - all members present

4/16/19

12V Buck converter

↳ potentiometer changes
output voltage

NEMA stepper motors 2A

controller need 12V out

1/AS
57

4/17/19

- M2x20 for microswitch hole at top of slider
- female headers for RP power
- pin #2 needs 5V
- pin #6 needs GND

SAF
58

4/22/19

Cabling

PI

- power (Red)

* tie all grounds together on sensor package (WHITE)

Gas Sensor

- 1 analog
- 1 pwr

(Arduino power Green)

Temp IR Sensor

- 2 analog
- 1 power

CO sensor

Stepper Motor ~~Arduino~~ (2)

- 2 power
- 2 gnd
- 4 enable pins

EAG
59