# Fire Fighting Robot

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Faculty Advisor: Airs Lin

# Introduction

- <u>Problem/Background</u>
  - 354,400 home structure fires per year
  - Property Damage: $6.9 Billion
  - Firefighter Tasks (During Fire)
    - rescue
    - limiting exposure
    - Confinement
    - Extinguishment

# Project Objective/Scope

- Robot Tasks
  - Fire suppression assistance
  - Clean-Up overhaul
  - Communication
  - Gas Detection
  - Local Area Mapping
  - Thermal Imaging
  - Modularity
    - Detachable Subsystems
  - Cost Reduction

- Society Impact Factors
- Allow firefighters to allocate resources to other objectives
- Help prevent ~2,560 civilian fire deaths/year
- Reduce property damage
- Modernize Firefighting

# Chassis

- Material: AISI 4130 Alloy Steel
  - Tensile strength: 95000 psi
  - Yield strength: 60200 psi
  - Hardness, Rockwell B: 92
- Form-factor:
  - 1.25” W x 0.75” H X 0.095” t
  - Square Tubing
- Benefits
  - Hardness
  - Cost
  - Robust

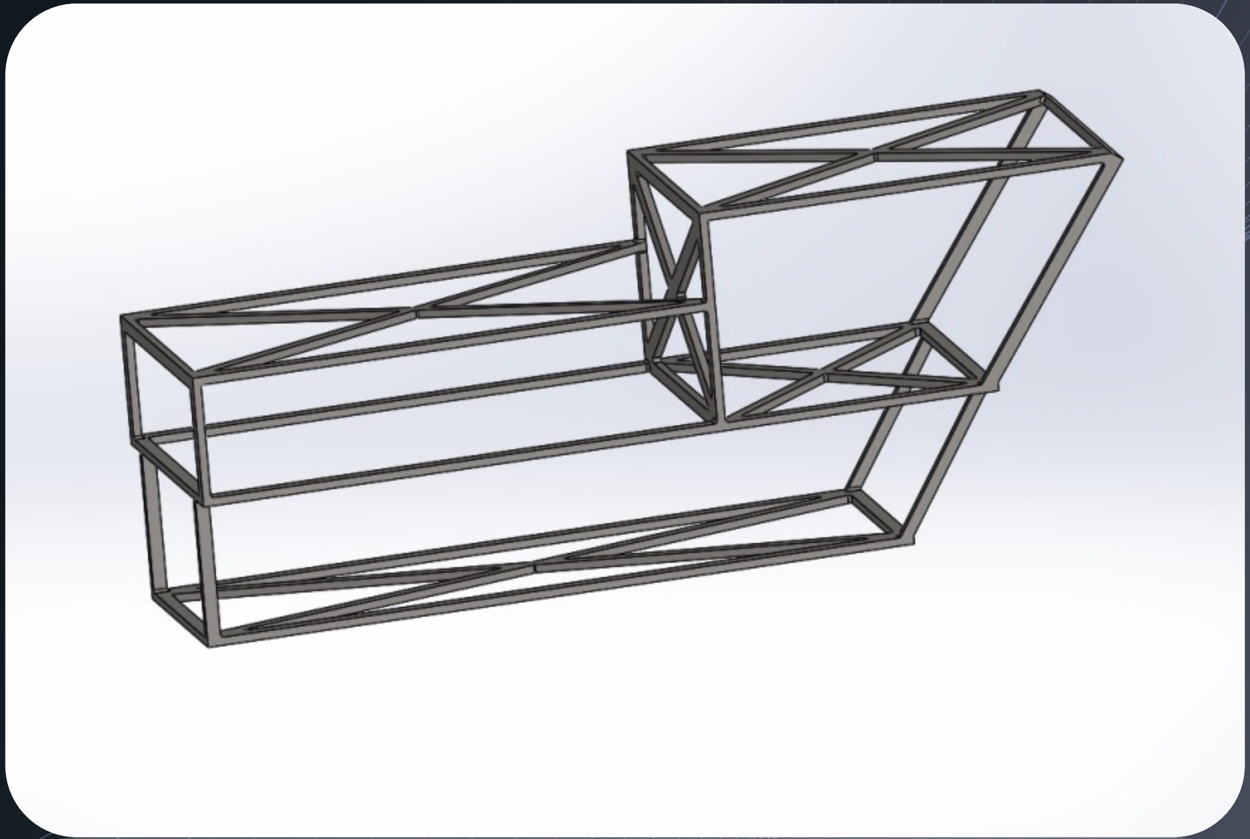
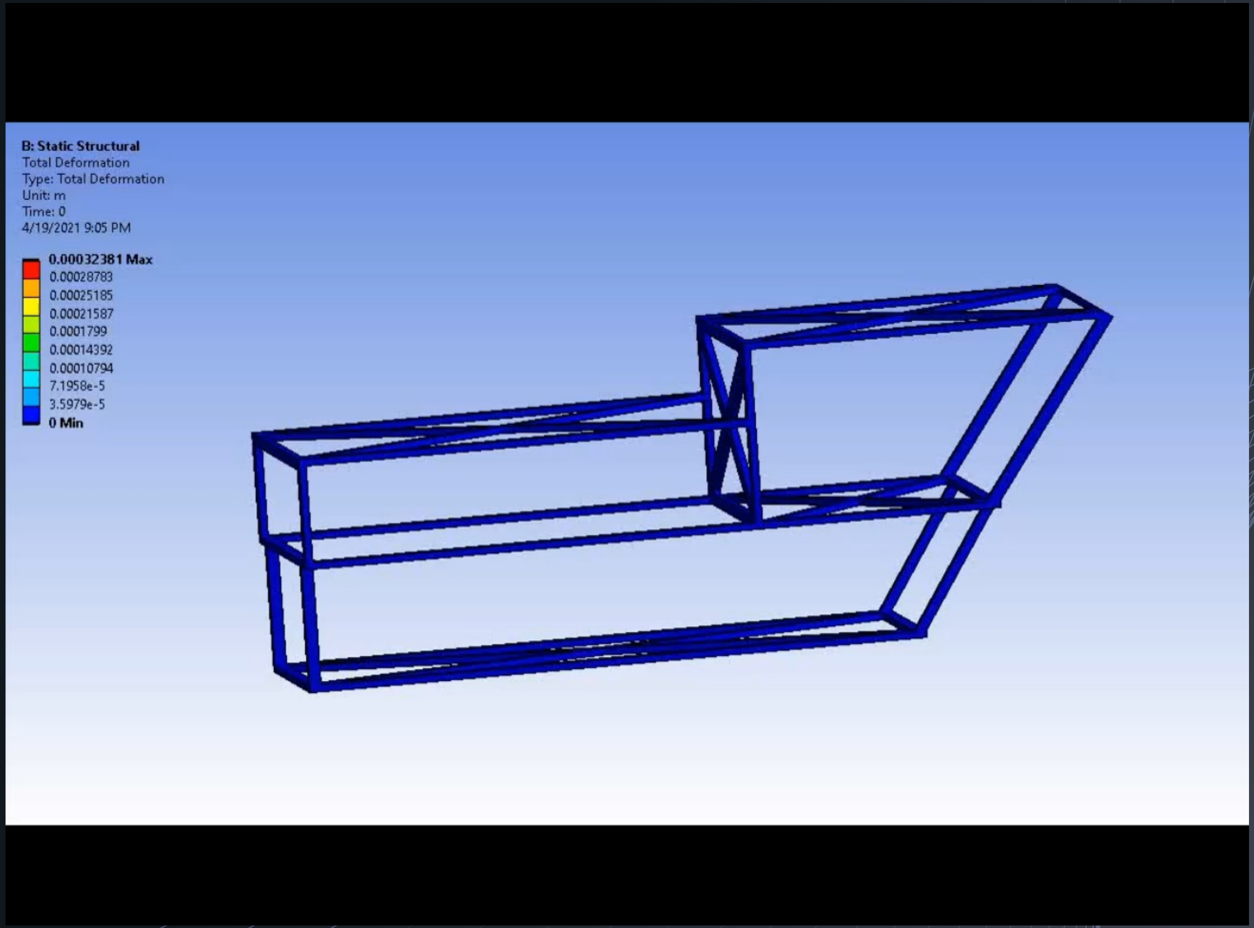


*Fig. 1 Chassis Design Concept*

# Chassis FEA

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
4/19/2021 9:15 PM
0.00032381 Max
0.00028783
0.00025185
0.00021587
0.0001799
0.00014392
0.00010794
7.1958e-5
3.5979e-5
0 Min

B: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 0
4/19/2021 9:05 PM
0.00032381 Max
0.00028783
0.00025185
0.00021587
0.0001799
0.00014392
0.00010794
7.1958e-5
3.5979e-5
0 Min

# Body Panels

- Material: AISI 1020 Mild Steel, Cold Rolled
  - Tensile strength: 57249 psi
  - Yield strength: 42748 psi
  - Hardness, Rockwell B: 64
- Form-factor:
  - Sheet Metal
  - 18 Gauge Steel (0.05” t)
- Benefits
  - Machinability
  - Cost
  - Automotive Standard

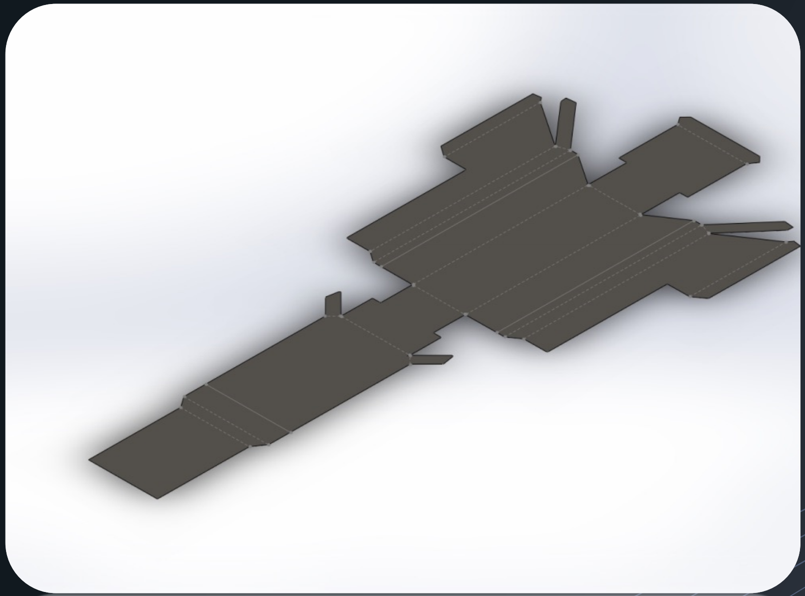


*Fig. 4 Sheetmetal (Pre-Bend)*

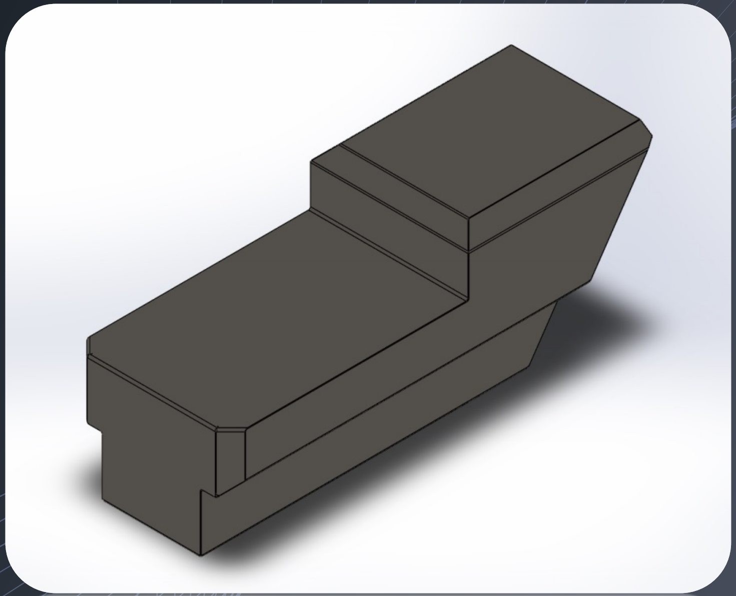
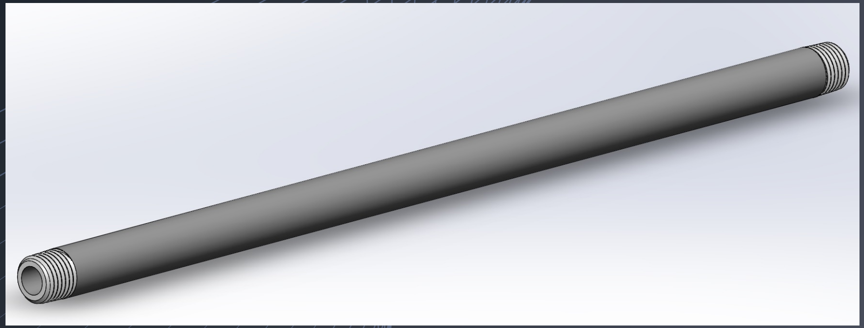


*Fig. 5 Sheetmetal (Post-Bend)*

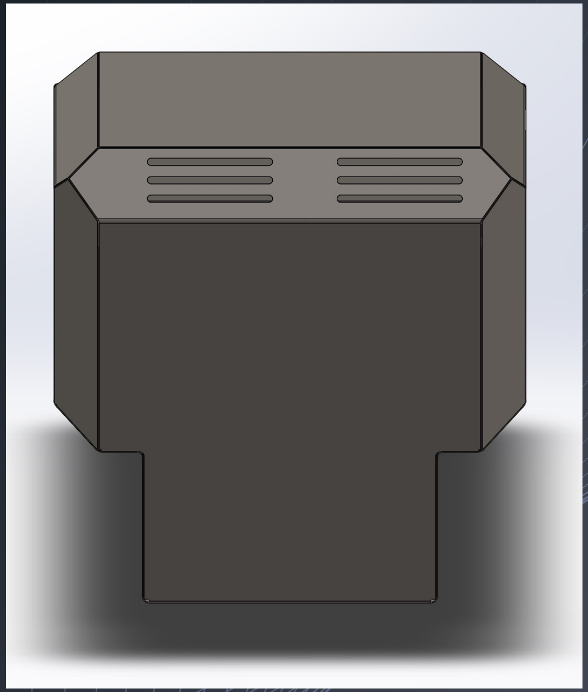
# Deck Gun and Piping System

- Deck gun sprays 2000 GPM
- Maximum pressure of an operating supply hose is psi 275
- 2 ½ diameter 304 stainless steel piping
- Maximum pressure is 300 psi

# Cooling system

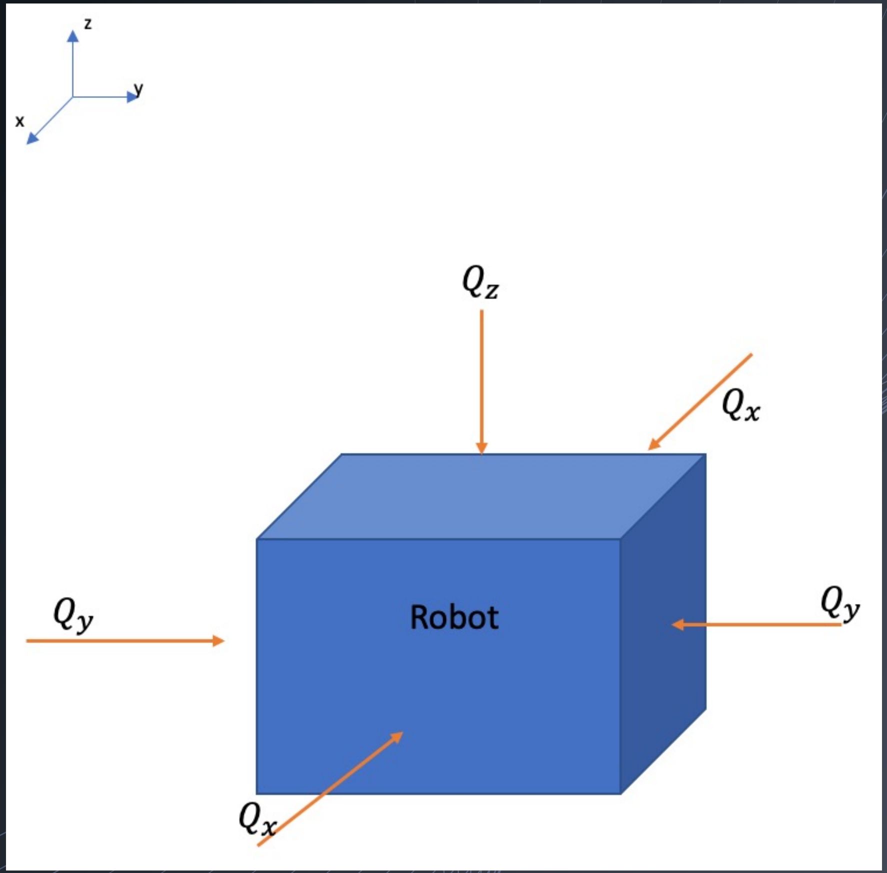
- A mixture of a ventilation and fan cooling system
- The deck gun piping system will also help cool the robot down
- Volume within the robot is approximately 520 cubic inches.



# Insulations

$$Q = \frac{T_{surr} - T_i}{R_{total}}$$

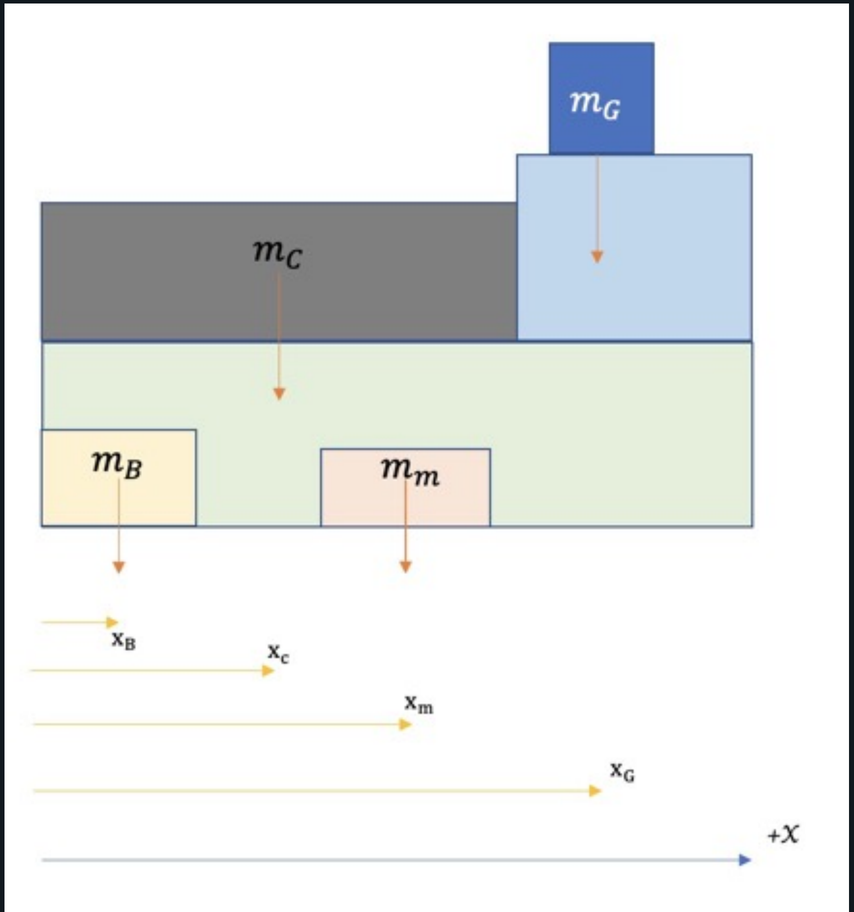
$$R_{total} = \frac{t_{paint}}{K_{paint}} + \frac{t_m}{K_{metal}} + \frac{t_{i1}}{K_{i1}} + \frac{t_{12}}{K_{i2}}$$




| Insulation | Thermal Conductivities W/mK | Density (kg/m^3) |
|---|---|---|
| Aerogel | 0.018 | 2.0 |
| Glass wool | 0.032 | 16 |
| Fiber glass | 0.043 | 80 |
| Foam Glass | 0.047 | 128 |
| Mineral wool | 35 | 70 |

| Insulation | Price ($/m^2) | |
|---|---|---|
| Aerogel | $25.00 | Fireproof insulation blanket (Average) |
| Glass wool | $0.45 | Glass wool mat |
| Fiber glass | $0.80 | Fiberglass Insulation Blanket |
| Foam Glass | $6.00 | Insulation (Average) |
| Mineral wool | $0.35 | (Average) |

# Center of mass




- Help with calculations
  - Equilibrium
  - Moments
- Was calculated based key masses
- Lengths from back of robot to front in X

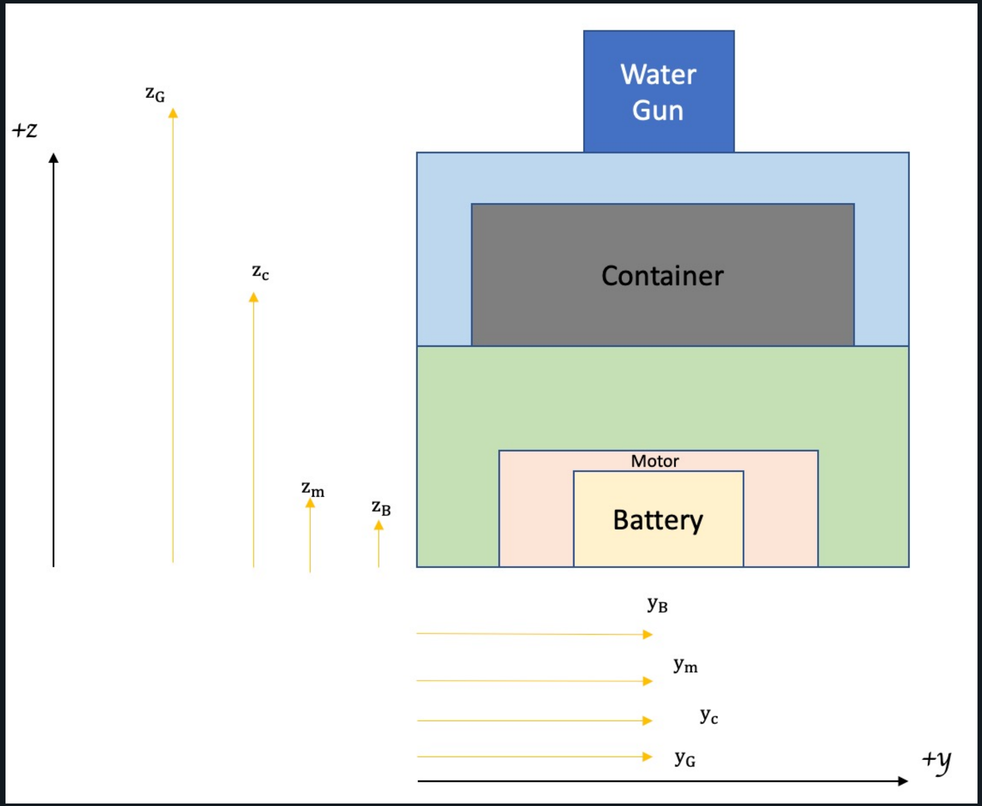
$$\bar{X}_{cm} = \frac{\sum_{i=1}^{n} m_i x_i}{M}$$

$$\bar{X}_{cm} = \frac{\sum_{i=1}^{4} m_i x_i}{M}$$

$$\bar{X}_{cm} = \frac{m_B x_B + m_c x_B + \ m_m x_B + \ m_G x_B}{M}$$

$$M = m_B + m_c + m_m + m_G$$

# Center of mass continued

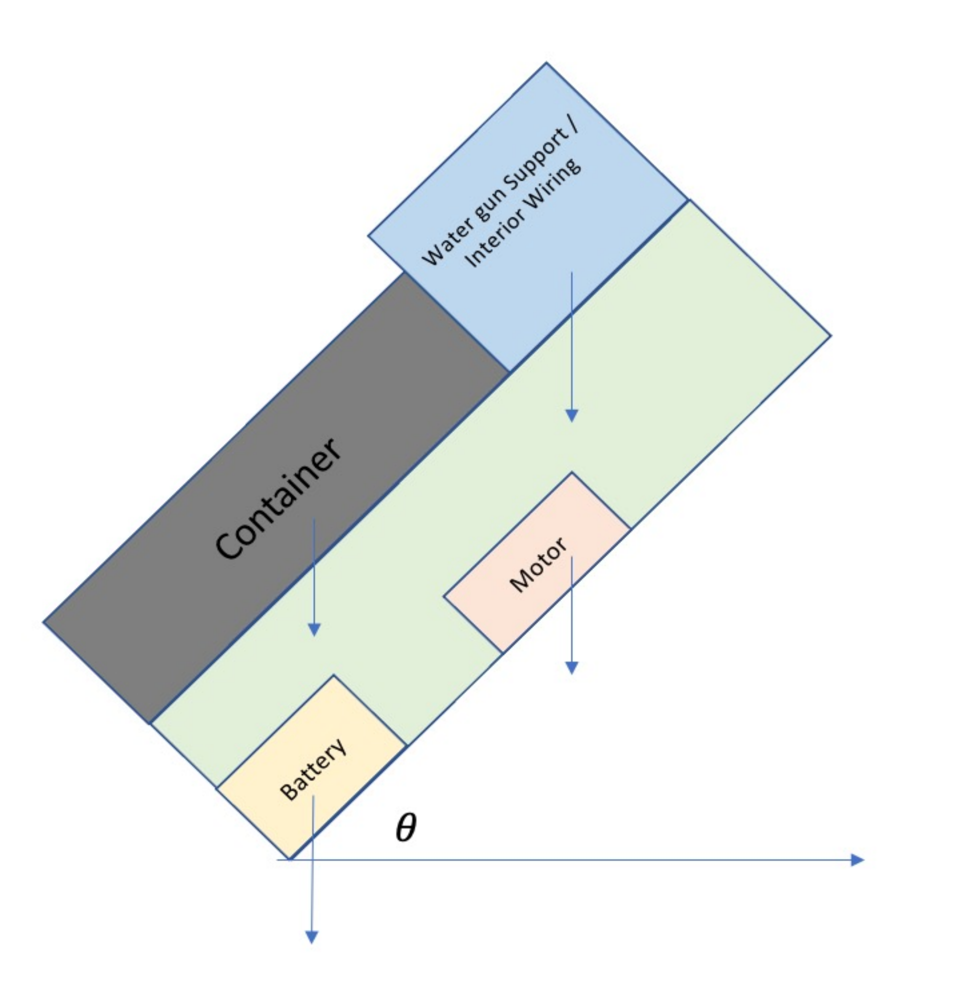



Editor – /Users/brayamh7/Documents/MATLAB/Center_of_mass.m*

Center_of_mass.m*

```
m_B=0.15; %mass of battery (kg)
m_C=35; %mass of container (kg),
%this is assuming that the robot is fully equipped
m_m=23; %mass of motor
m_g=20; %mass of water gun

%The following lengths are measured from the back of the robot moving
%forward. They are also measurements to the center of each object
%When looking at the robot through the Z-Y axis, the side view of the robo
x_1=0.15; %length from back of robot to center of battery (m)
x_2=0.5; %length from back of robot to center of container (m)
x_3=0.8; %length from back of robot to center of motor (m)
x_4=1.5; %length from back of robot to center of water gun (m)
```

# Center of mass continued



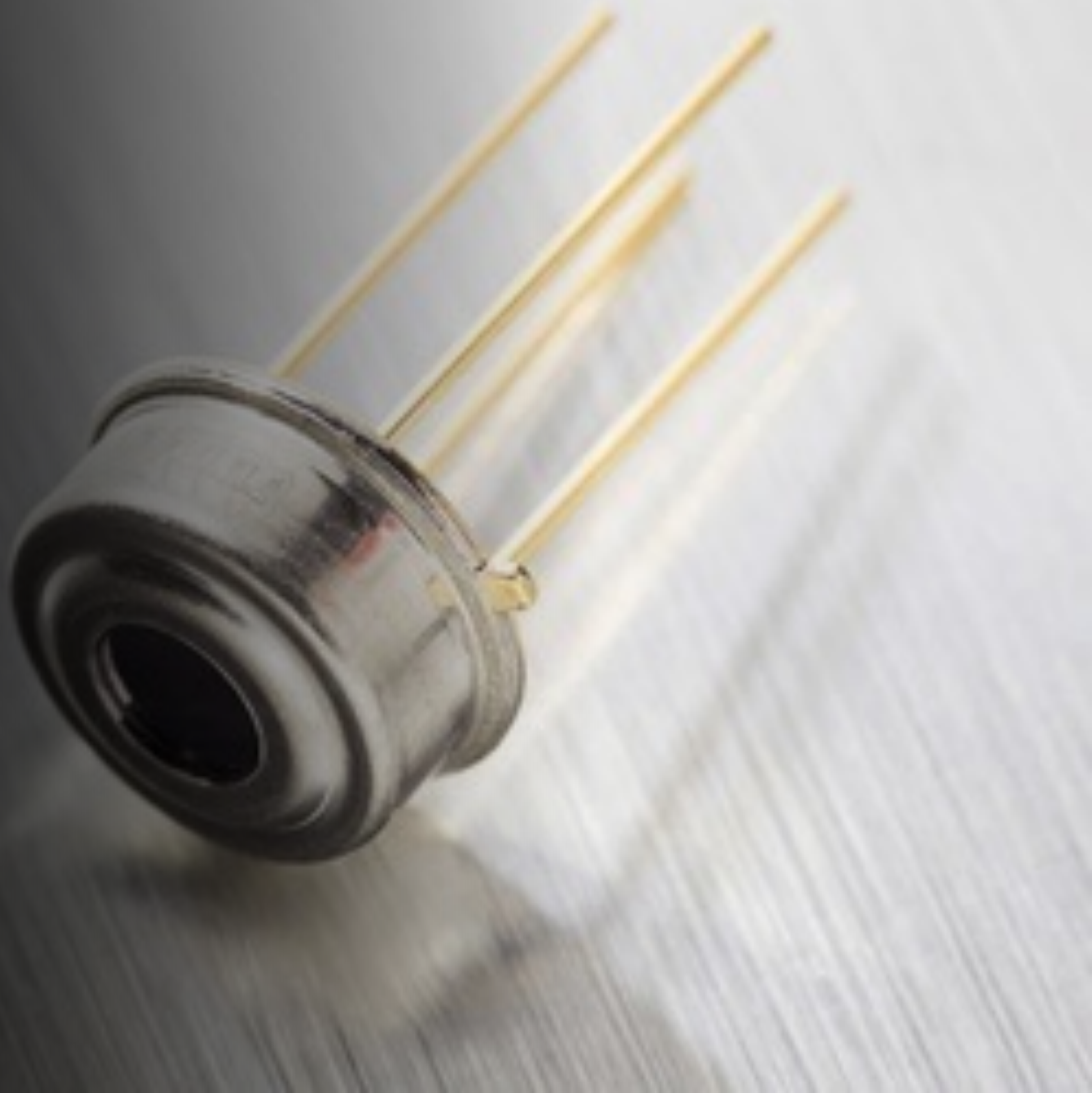

- Analysis going up the stairs
  - Effects on forces
- Making sure it does not tip over
- $\theta$ *of stairs ranges from* $30-50°$

- If deck gun is placed too far towards the front the robot might tip

# 3V Non-Contact IR Temperature Sensor

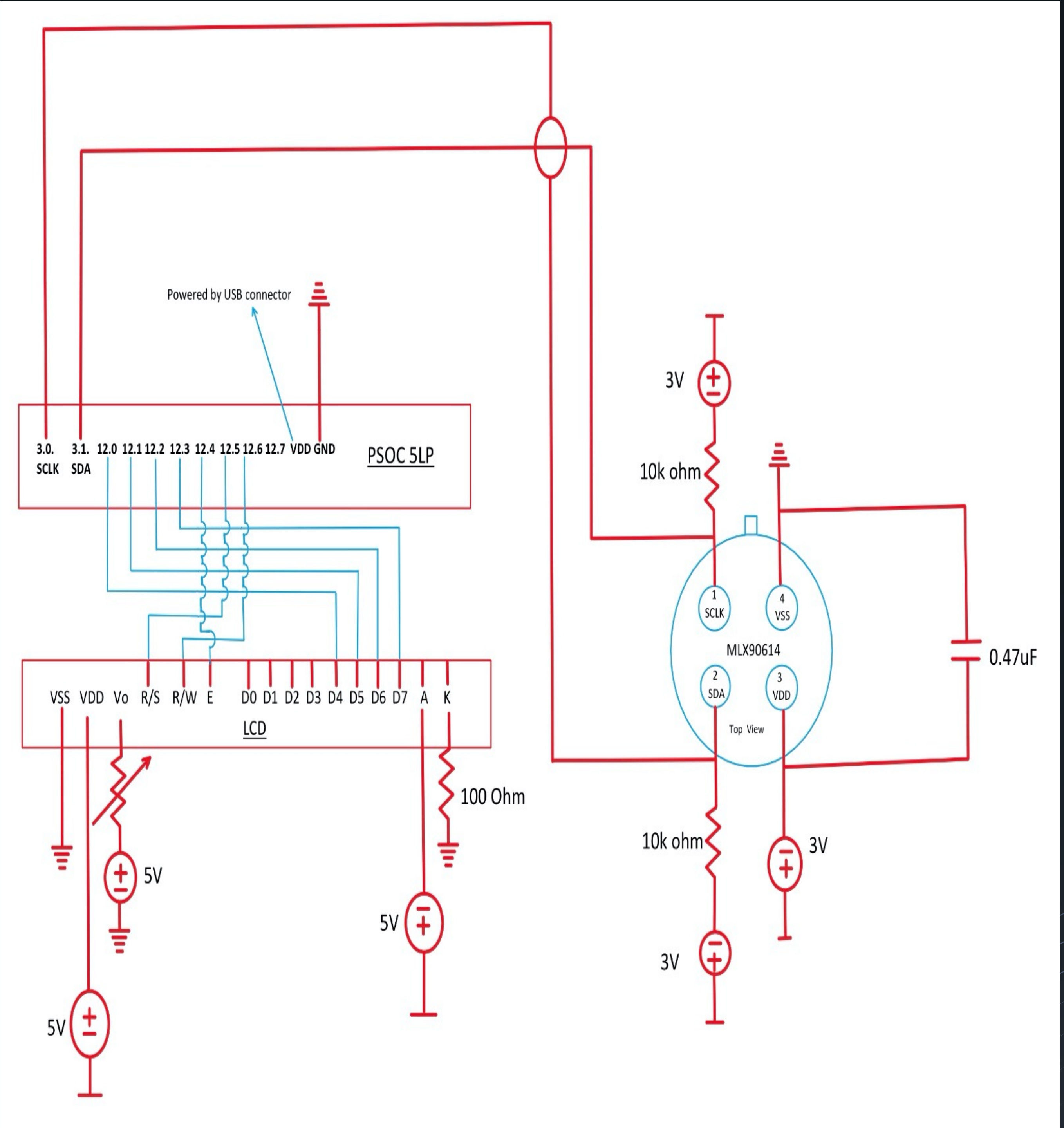
MLX90614BSF-AAA

By: Lelibeth Bryan



# Things to be Covered

- Wiring
- SMBUS communication via I2C
- Command: Processing Object Temperature
- Results
- Further Research



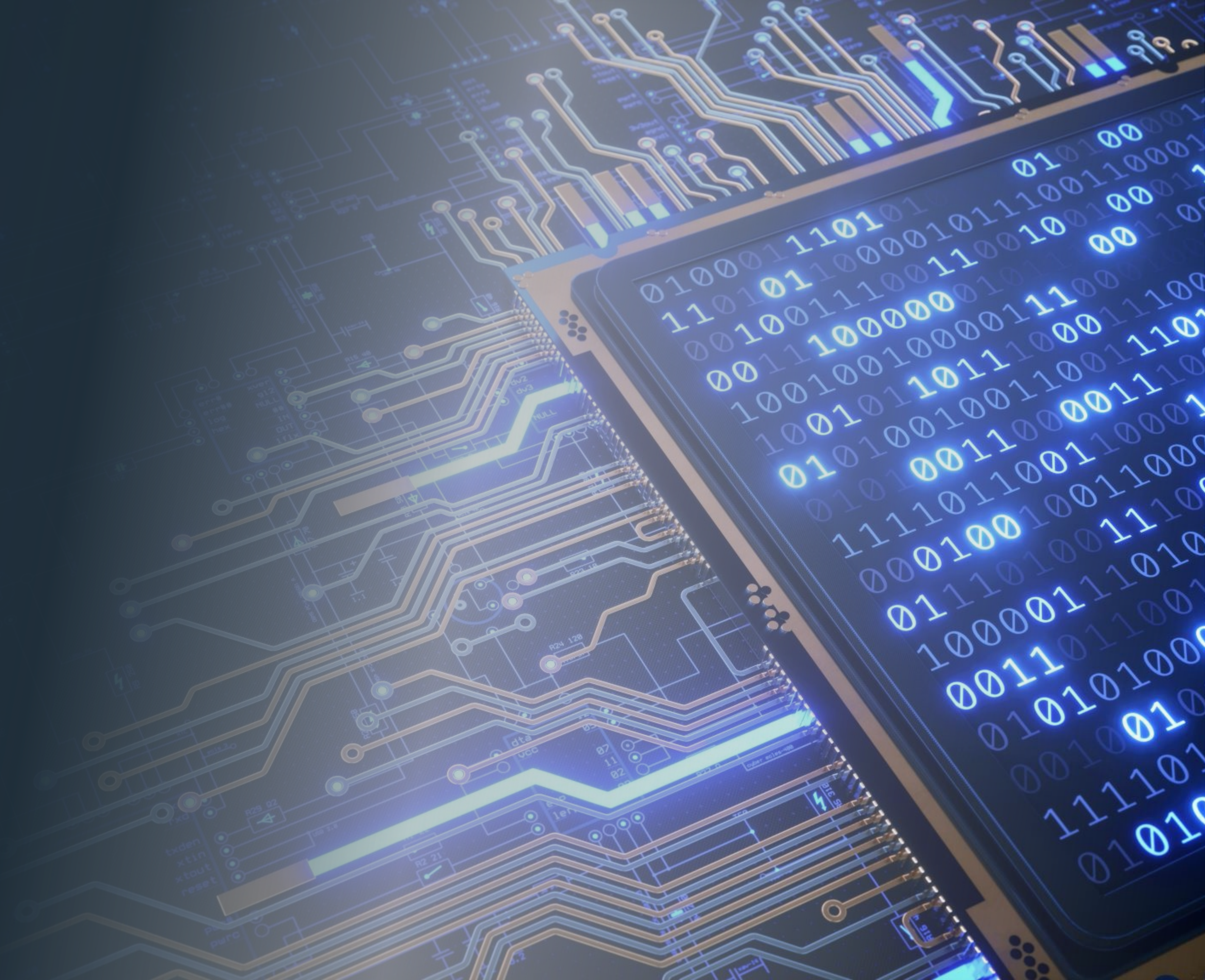


# Wiring

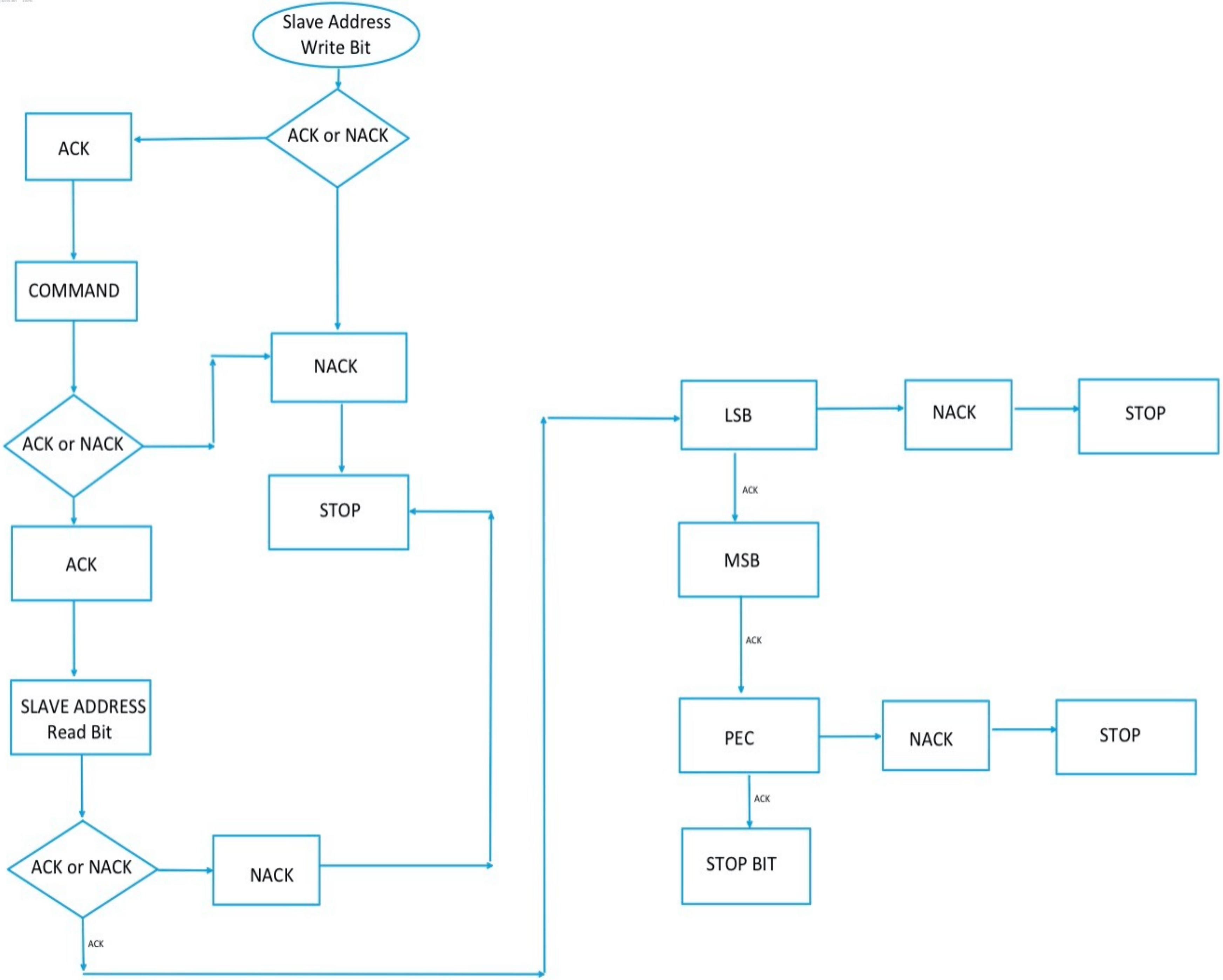
- Voltage Regulator
- Pin location
- LCD
- PSOC 5LP

# I2C: SMBUS PROTOCOL

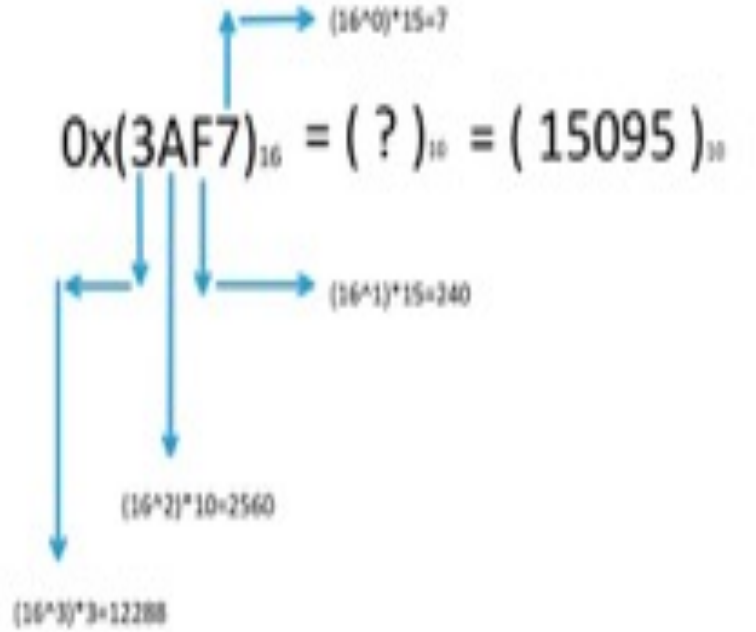
What is SMBus?



# SMBUS FLOWCHART



# Processing Object Temperature

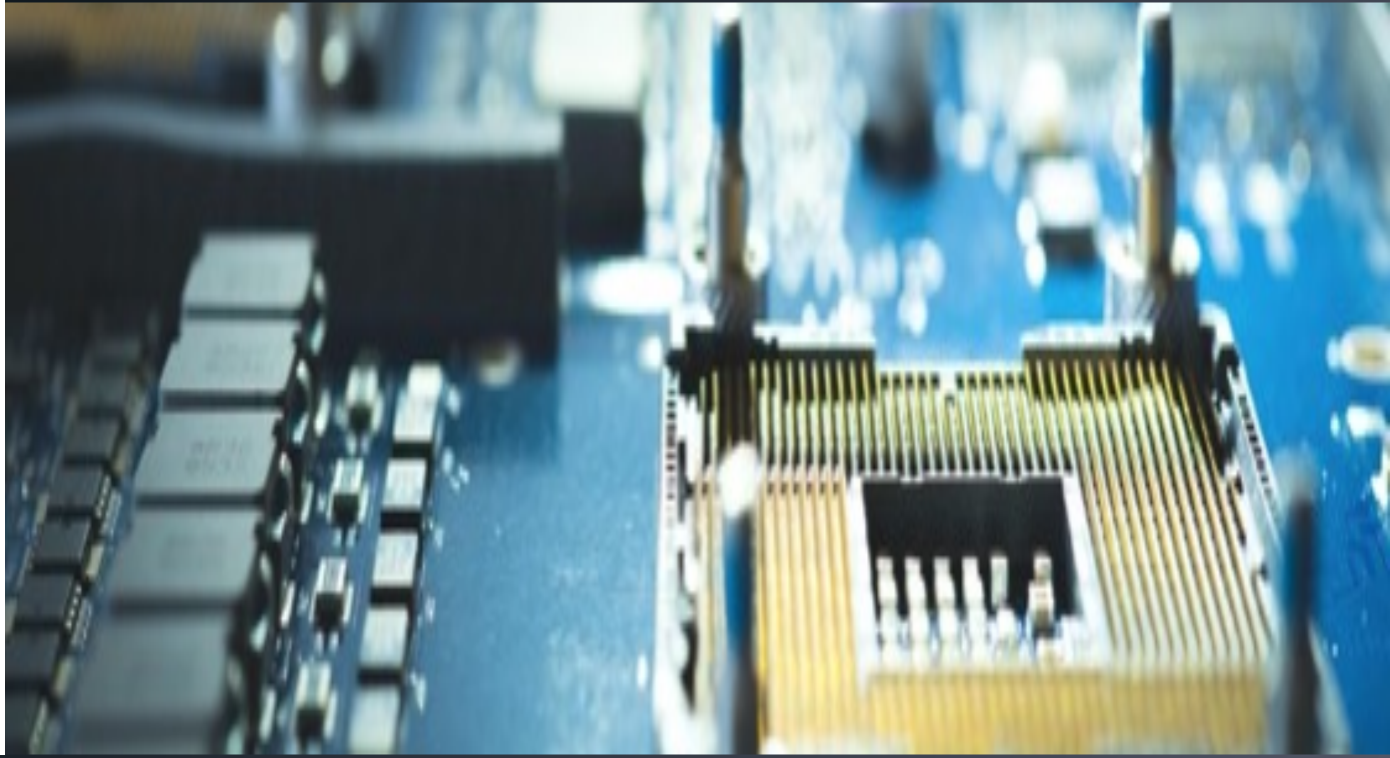



To [degrees K] = Toreg x 0.02

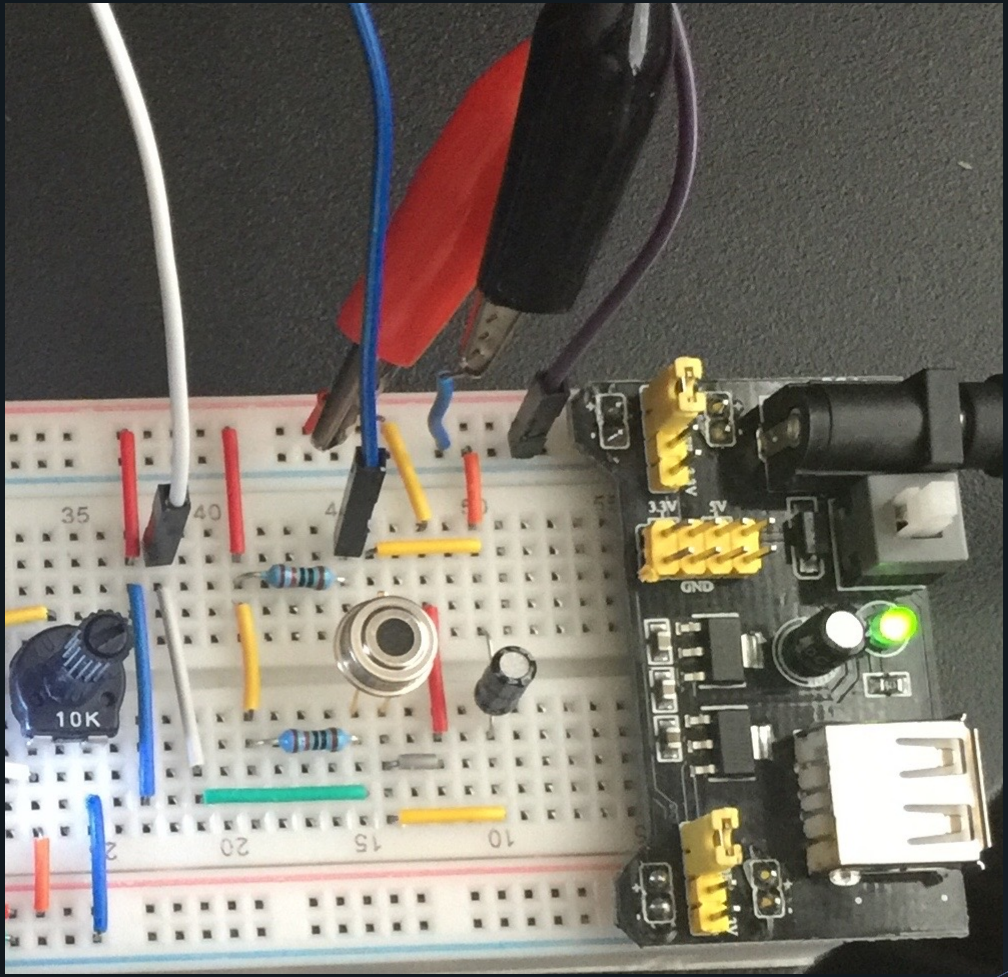
To = 15095 x 0.02 = 301.9K

Convert to Celsius:

K = 301.9 - 273.15 = 28.75 degree Celsius



# Results



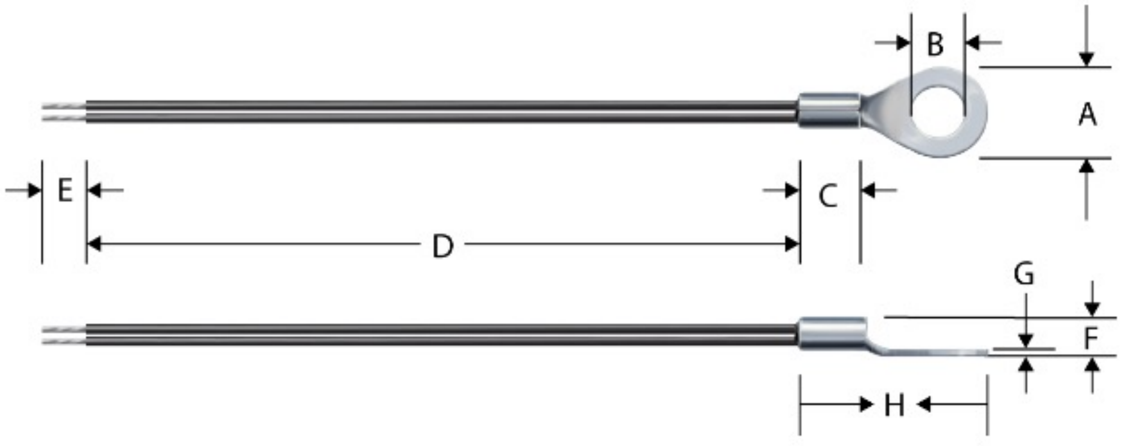

```
#define temperature_sensor  0x5A
#define T_ambient    0x06

bool I2C_Read (uint8_t addr, uint8_t reg, uint8_t *buf, uint8_t len);
bool I2C_Write (uint8_t addr, uint8_t reg, uint8_t *buf, uint8_t len);




int main ( )
{
uint8_t     buf[3];     //3 bytes, low, high, PEC(error) bytes
float temp;
char str[40];
CyGlobalIntEnable;  /* Enable global interrupts. */
/* Place your initialization/startup code here. */
LCD_Start ( );
LCD_ClearDisplay( );
LCD_PrintString("  Senior Design ");
CyDelay(2000);
LCD_ClearDisplay();

I2C_Start( );


for(;;){
   LCD_ClearDisplay();
/* Place your application code here. */
I2C_Read(temperature_sensor, T_ambient, buf, 3);    //stores ambient temp in buf
       // ISSUE with this is giving us bytes over the limit
       // should be between 11748d - 19908d

CyDelay(100);

LCD_Position(0,0);
LCD_PrintDecUint16((((uint16_t)buf[1])<<8)+ buf[0]);
LCD_PrintString("    ");
temp = ((((uint16_t)buf[1])<<8)+ buf[0])*0.02 - 273.15;
sprintf(str,"%.2f  ", temp);
LCD_Position(1,0);
LCD_PrintString(str);
//LCD_Position(1,9);
//LCD_PrintDecUint16(buf[2]);
```

# Further Research: MLX90614

- Long Range Sensor
- Trigger Alert Response

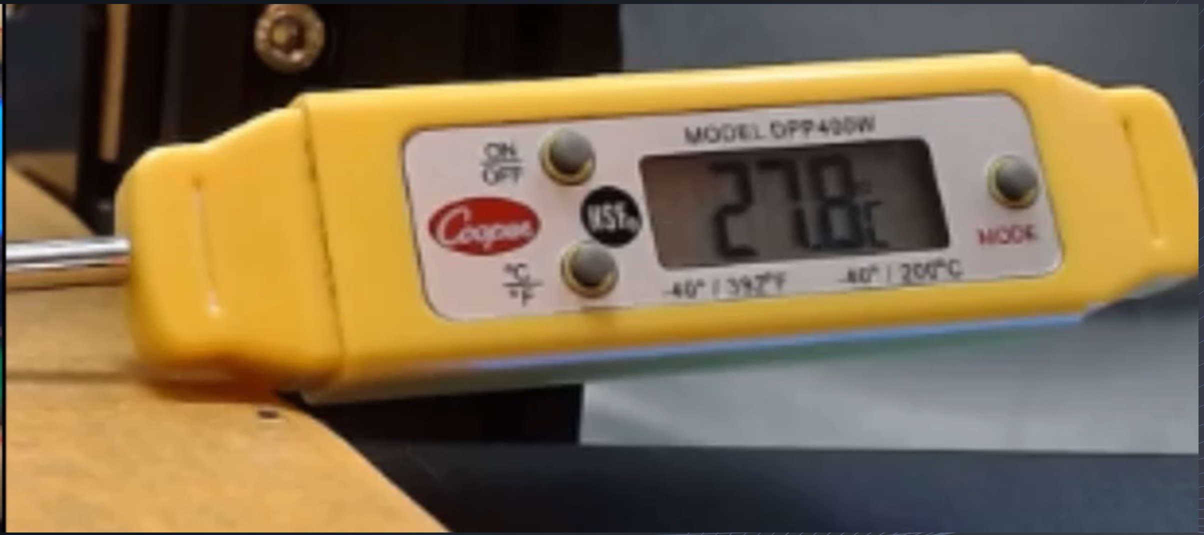
# Contact Temperature Sensor

- Where to implement on robot?
- Cost - $2.55
- Temperature range of
  -50 – 150 °C




| PANR | A1 | Stud | B | C | d | E | F | G |
|---|---|---|---|---|---|---|---|---|
| – | 9.5±0.5mm | #6 | 18.6±0.5mm | 152.4±7.0mm | 5.0±0.5mm | 1.0±0.5mm | 5.5±0.5mm | 6.5±0.5mm |

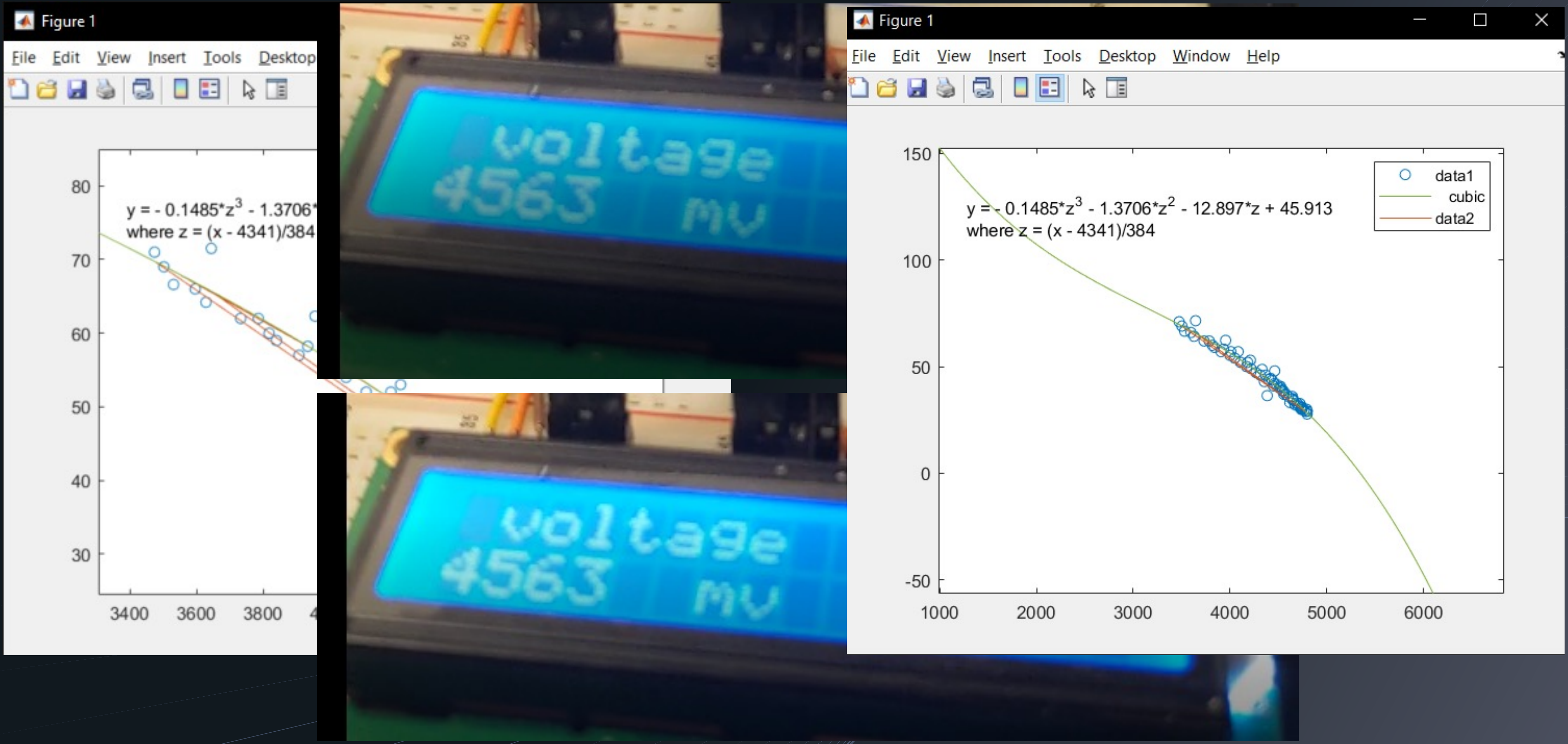
# Video of testing

# Thinking about the display of the future

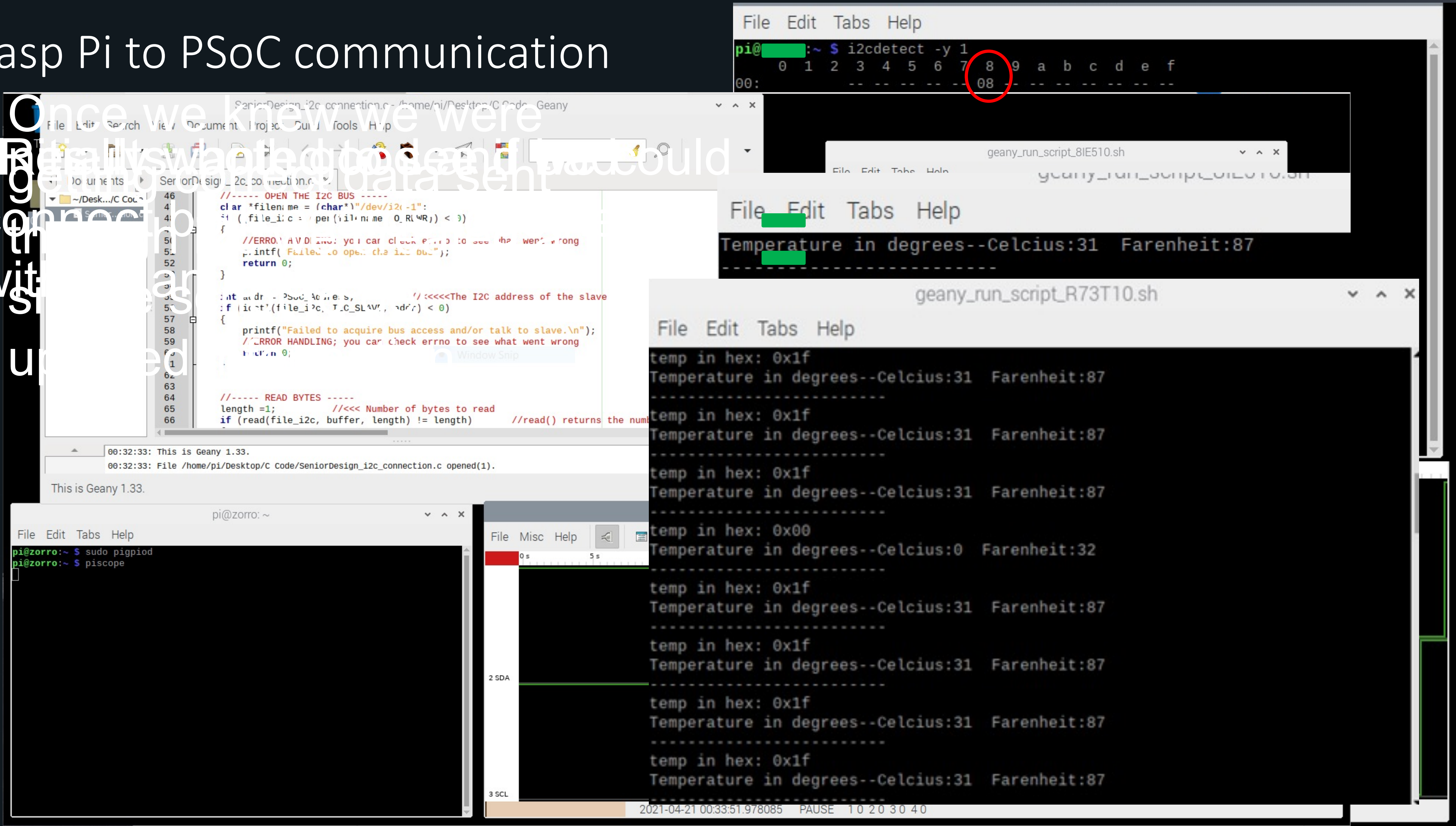
- Raspberry Pi connection to PSoC
- Continued use of i2c communication protocol

# Contact Temperature Sensor Results



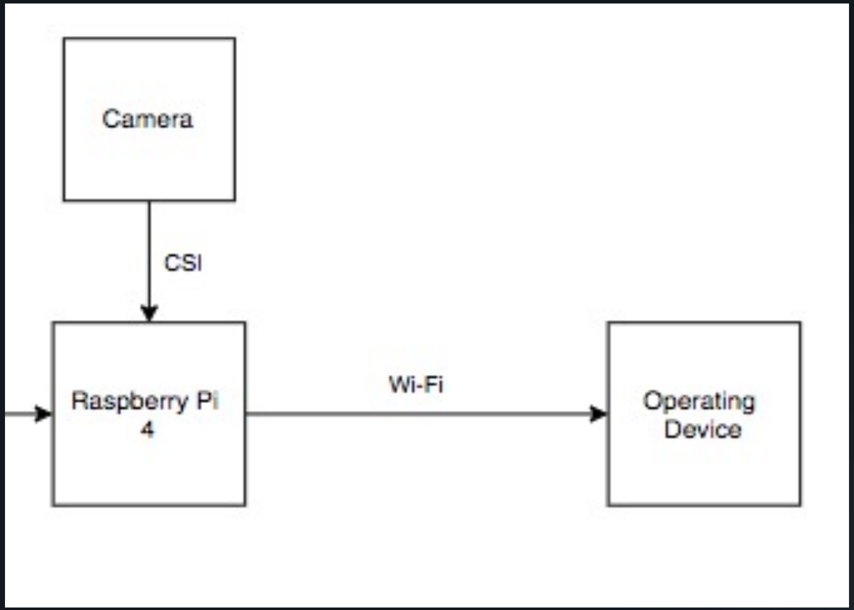
# Rasp Pi to PSoC communication

- Once we knew we were getting correct data sent



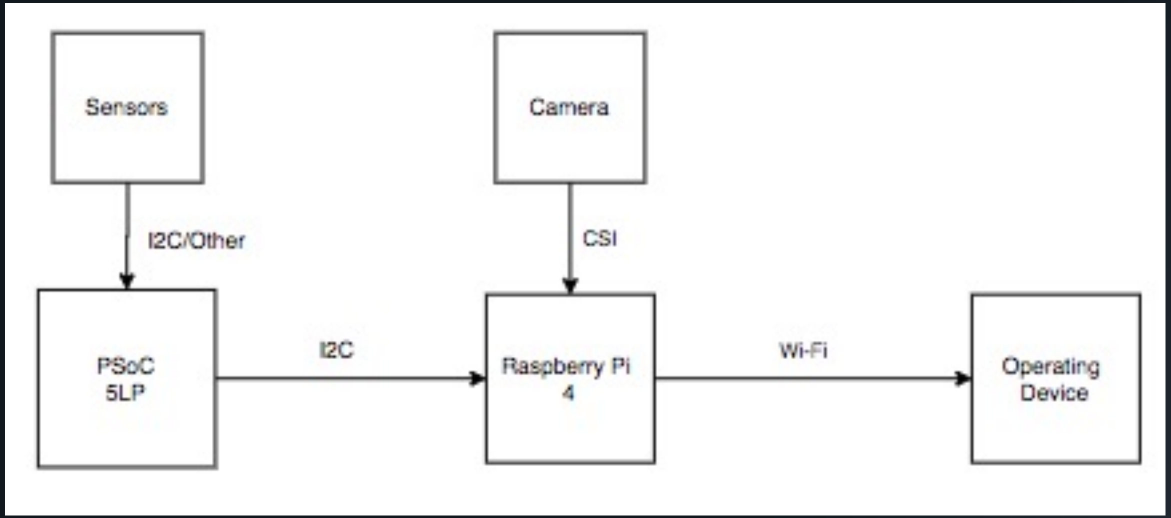
# Video Communication

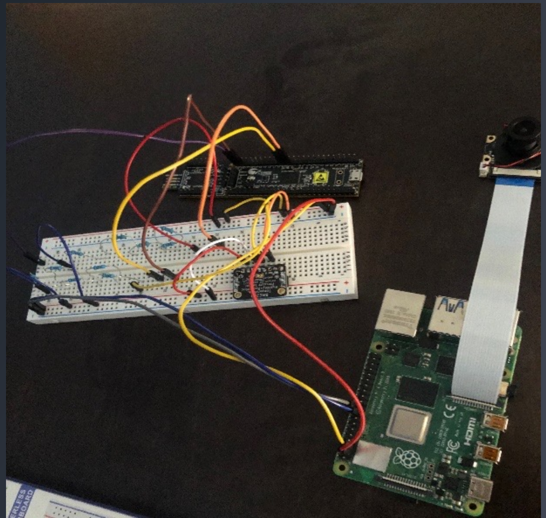
- Raspberry Pi 4 Model B was the main microprocessor (MPU) for the robot.
- The Raspberry Pi Camera, a 5MP 1080p camera module, was the camera used.
- Resolution, sample rate, compatibility and cost.
- Communication was established over Wi-Fi, both devices on a local network.




# PSoC 5LP Coprocessor

- PSoC 5LP microcontroller was responsible for collecting all sensor data.
- Connected to Raspberry Pi (via I2C), it passes on desired data for further processing.
- Python script running on Raspberry Pi for image stream, sensor data processing and communication to operator.
- C code/PSoC creator to configure PSoC with all sensors and Raspberry Pi.



# User Interface

<u>Accomplished</u>

- Image stream with real time sensor data text overlay from PSoC 5LP.
- The frame rate from image stream is 10fps.
- Resolution of 680x420p.

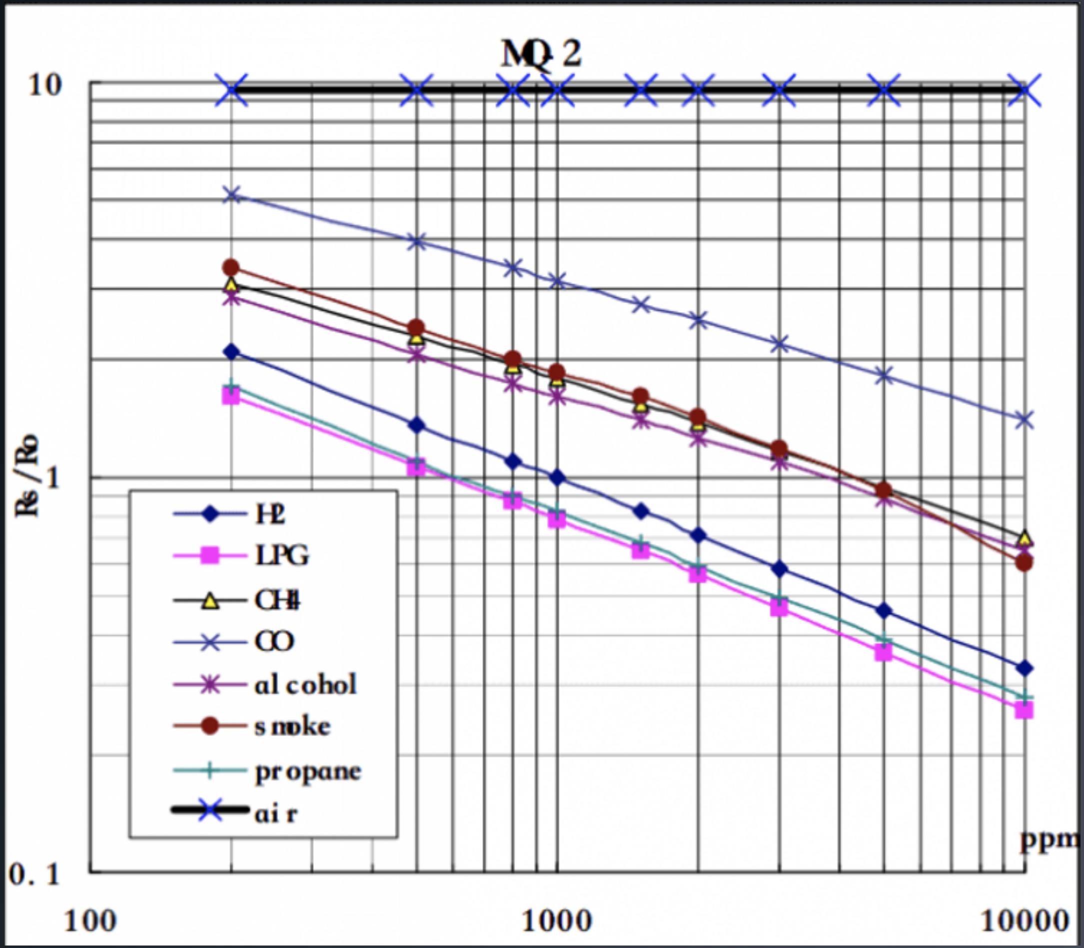
<u>Future Goals</u>

- Longer transmission range.
- Thermal mapping.
- Faster frame rate.
- Friendlier user interface with additional data.

# User Interface

# Gas Detection

- •MQ-2 Gas sensor capable of detecting a variety of flammable gases
- •Flammable gasses include Hydrogen, Methane, Propane, and LPG
- •Low cost




Formula for calculating gas concentration:

- $\log\left(\frac{Rs}{Ro}\right) = m * \log(PPM) + b$
- $PPM = 10^{\frac{\log\left(\frac{Rs}{Ro}\right) - b}{m}}$

# Gas Detection

- •Analog output connected to PSoC ADC
- •LCD displays concentration of gas detected
- •Visual and audio notification if detected gas is above predefined threshold

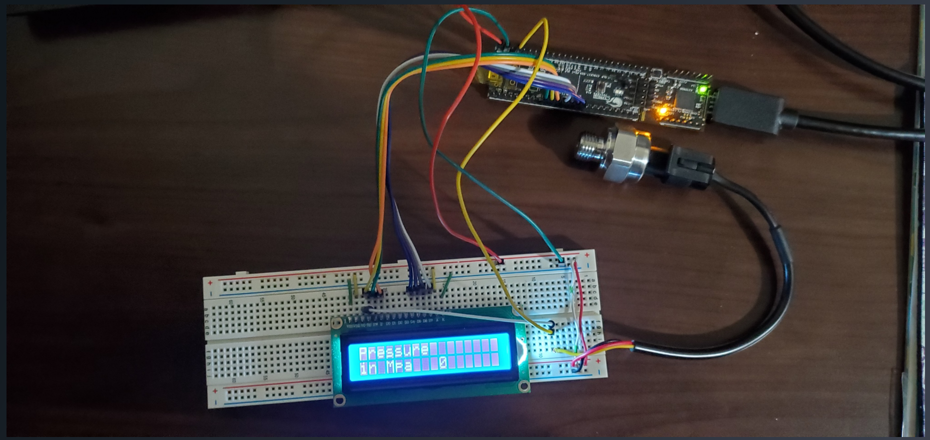
# Lighting System

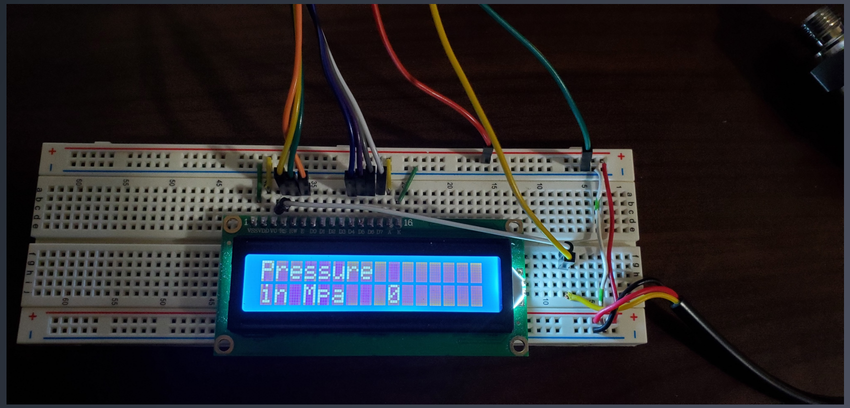
# Lighting System

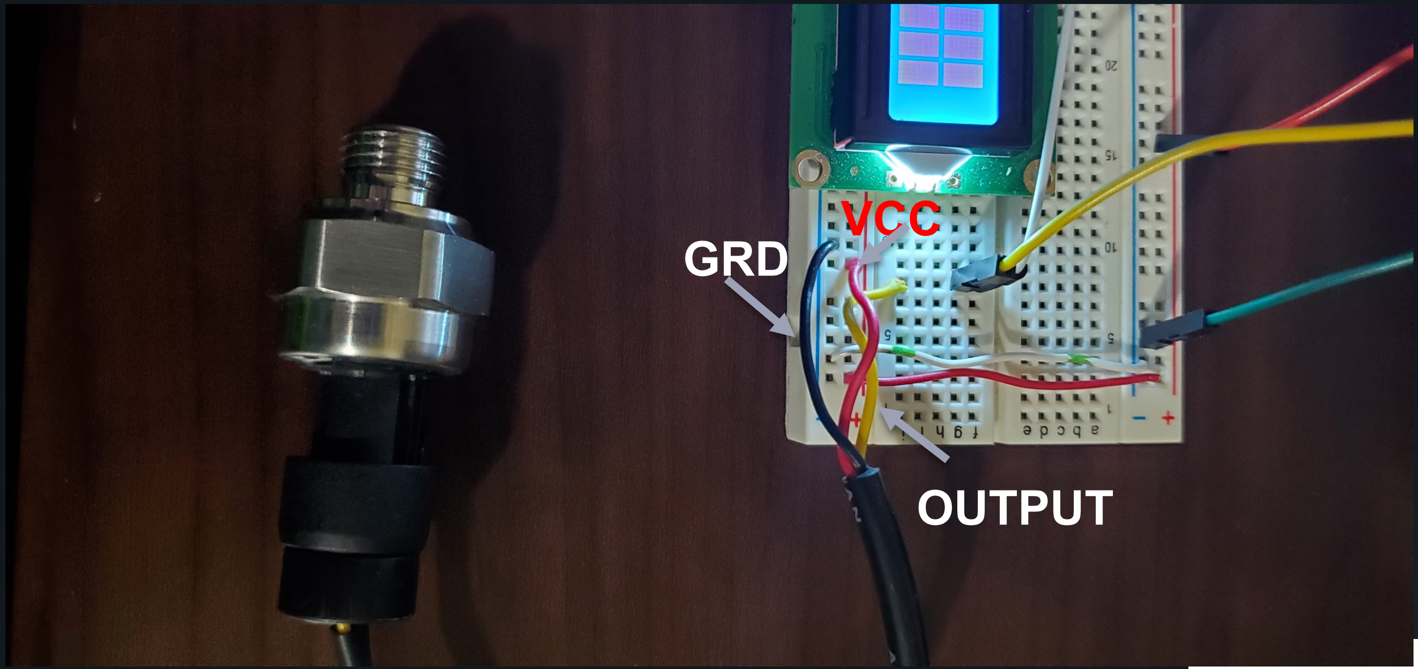
- •22W LED light pods
- •1600 Lumen output
- •Low Cost
- •Low maintenance and durable
- •50000 Hour lifetime
- •Located on the front left and front right of robot

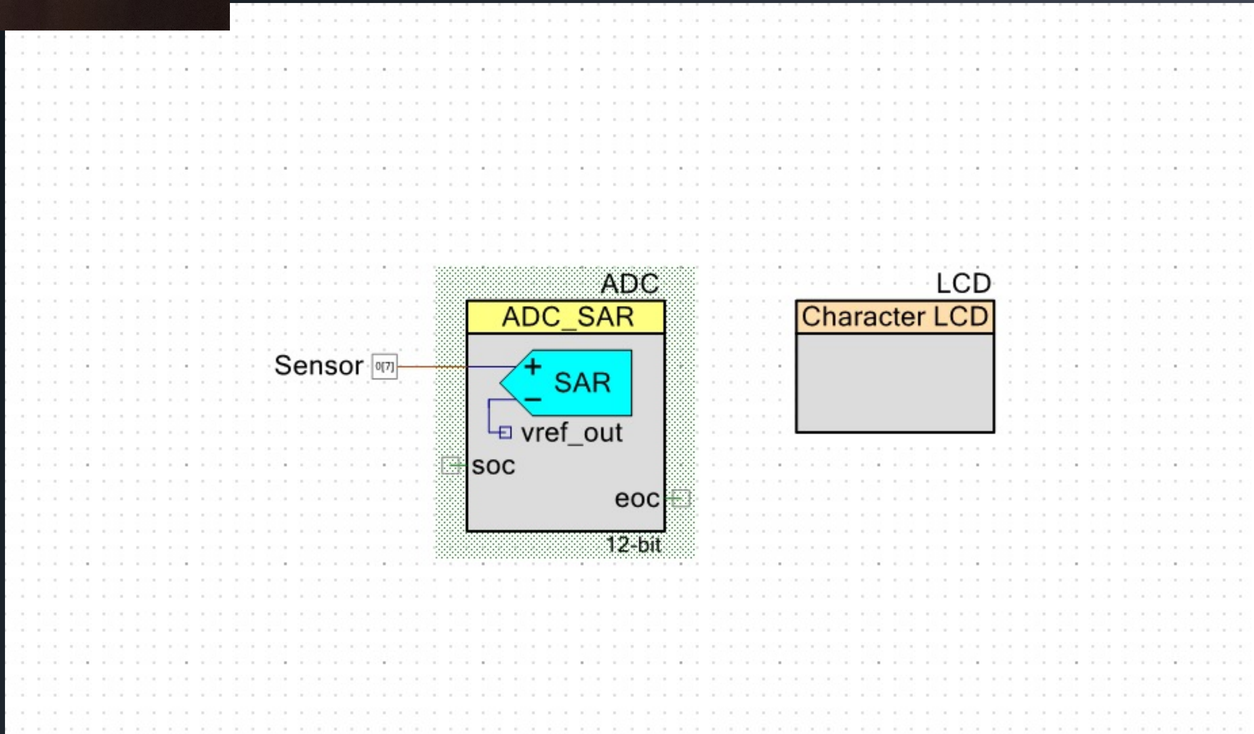
# Water Pressure Sensor

- Sensor that can be used in
  - Liquid
  - Non-corrosive gas
- Working pressure range 0~1.2 Mpa
- Temperature range: -4~221 Fahrenheit




VCC
GRD
OUTPUT


ADC
ADC_SAR
Sensor
SAR
vref_out
soc
eoc
12-bit
LCD
Character LCD

# Motor

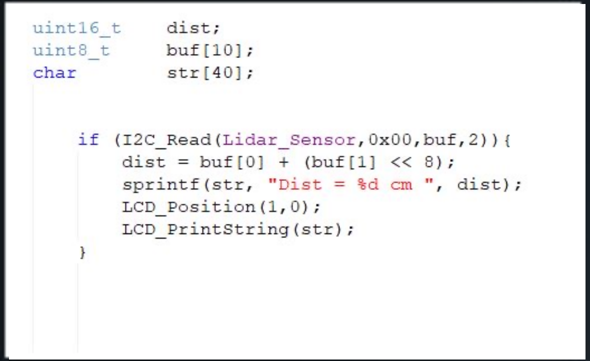
- Wheelchair Motor
  - One left and right motor
  - Right angle gear drives
  - Encoders installed
- Great heavy duty robot motors
- Rated Power: 320 Watt
- Rated Voltage: 24VDC
- Output Speed: 120rpm

# Calculations for motor size

- Requirements:
  - Want to go up the stairs at 5mph at a 30% grade.
  - Robot Weight at 350lbs
  - Multiply the speed going up the incline, by the weight of the robot
  - Results 700 Watt motors

# TF-Luna LiDAR Module

Figure 1



```
uint16_t    dist;
uint8_t     buf[10];
char        str[40];


    if (I2C_Read(Lidar_Sensor,0x00,buf,2)){
        dist = buf[0] + (buf[1] << 8);
        sprintf(str, "Dist = %d cm ", dist);
        LCD_Position(1,0);
        LCD_PrintString(str);
    }
```

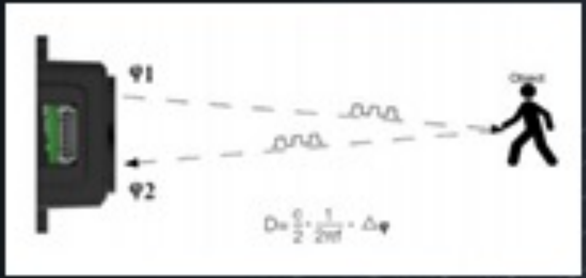



Figure 2

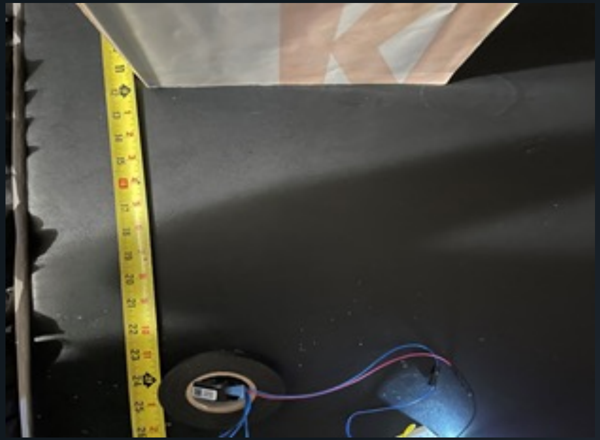
- Light is emitted from a rapidly firing laser.
- The light is then reflected to the LiDAR sensor and is recorded.
- Distance is given based on the time it takes for the light to be reflected.

## Value 1

D = 0.5 ft = 15.24 cm

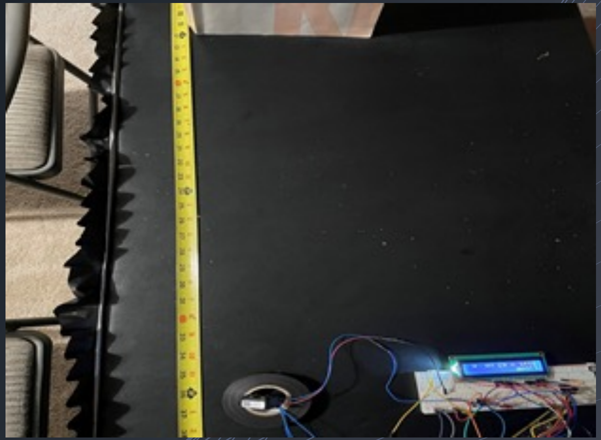

## Value 2

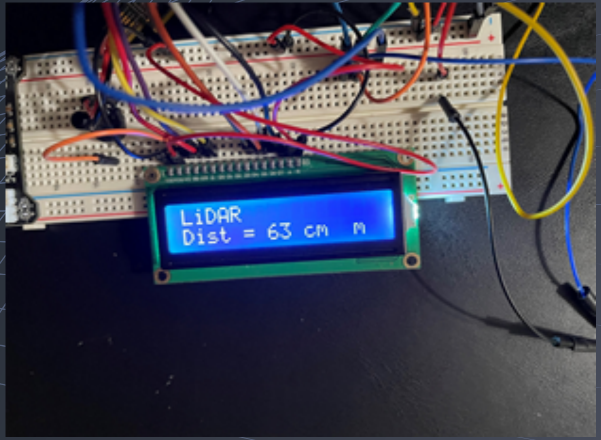
D = 1 ft = 30.48 cm




## Value 3

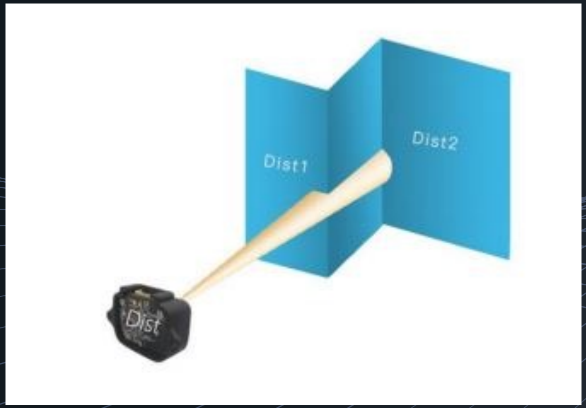
D = 2 ft = 60 cm

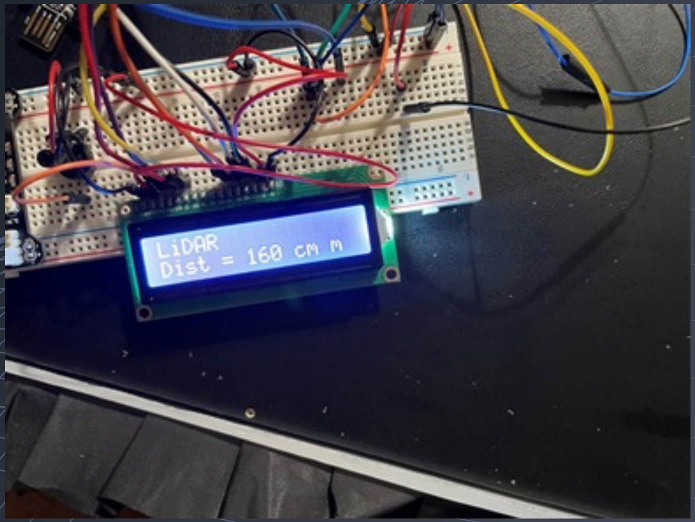




# Inaccuracy During Testing

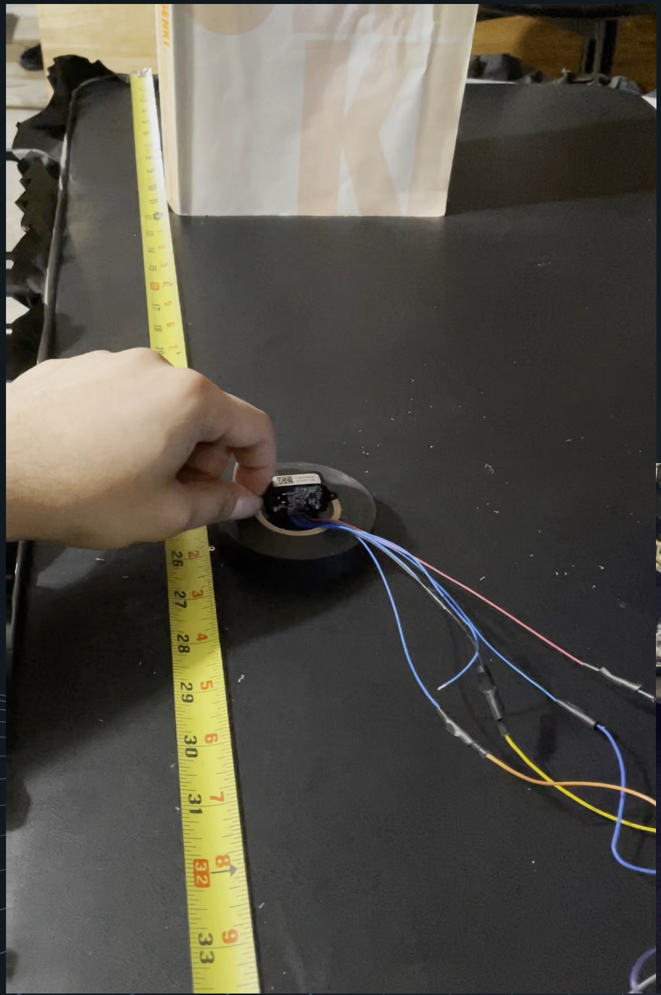
- Lidar is not centered
- LCD is not displaying 2ft instead is displaying 160cm
- 160cm = 5.1ft

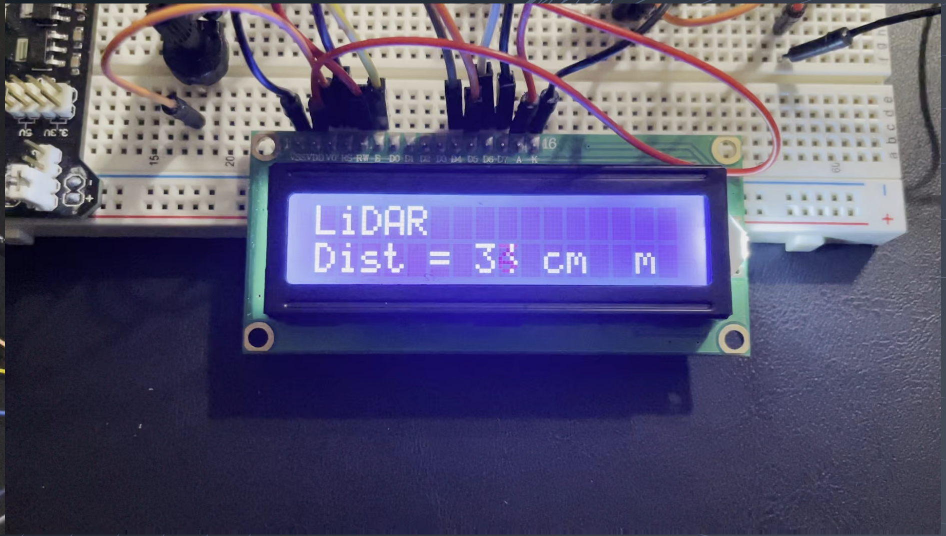


# Results

- LiDAR Module is moved between 1ft and ~1.5ft
- Distance on display shifts between 30 cm to 48 which is mostly consistent with  actual distance moved.

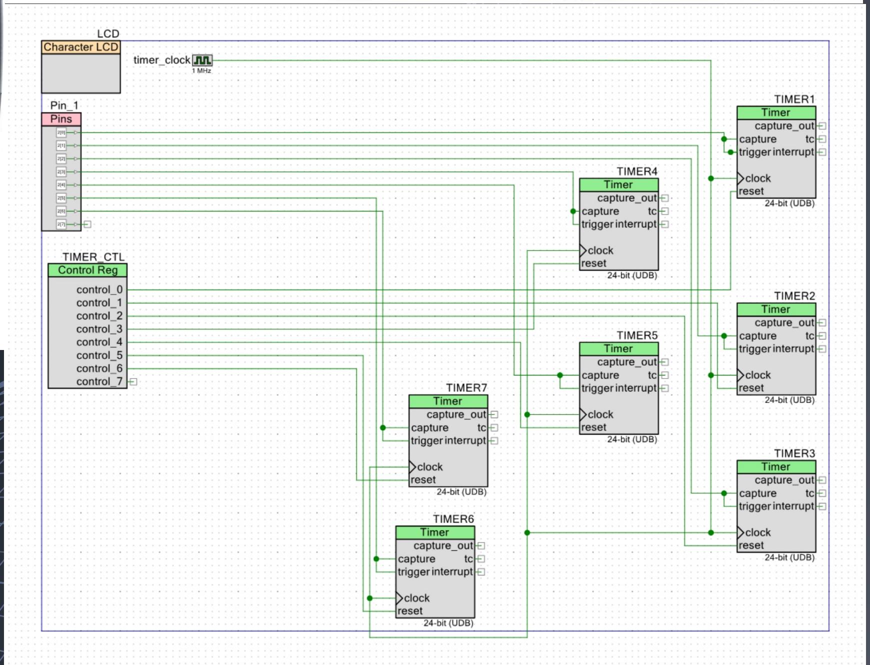




# RC Controller and Receiver

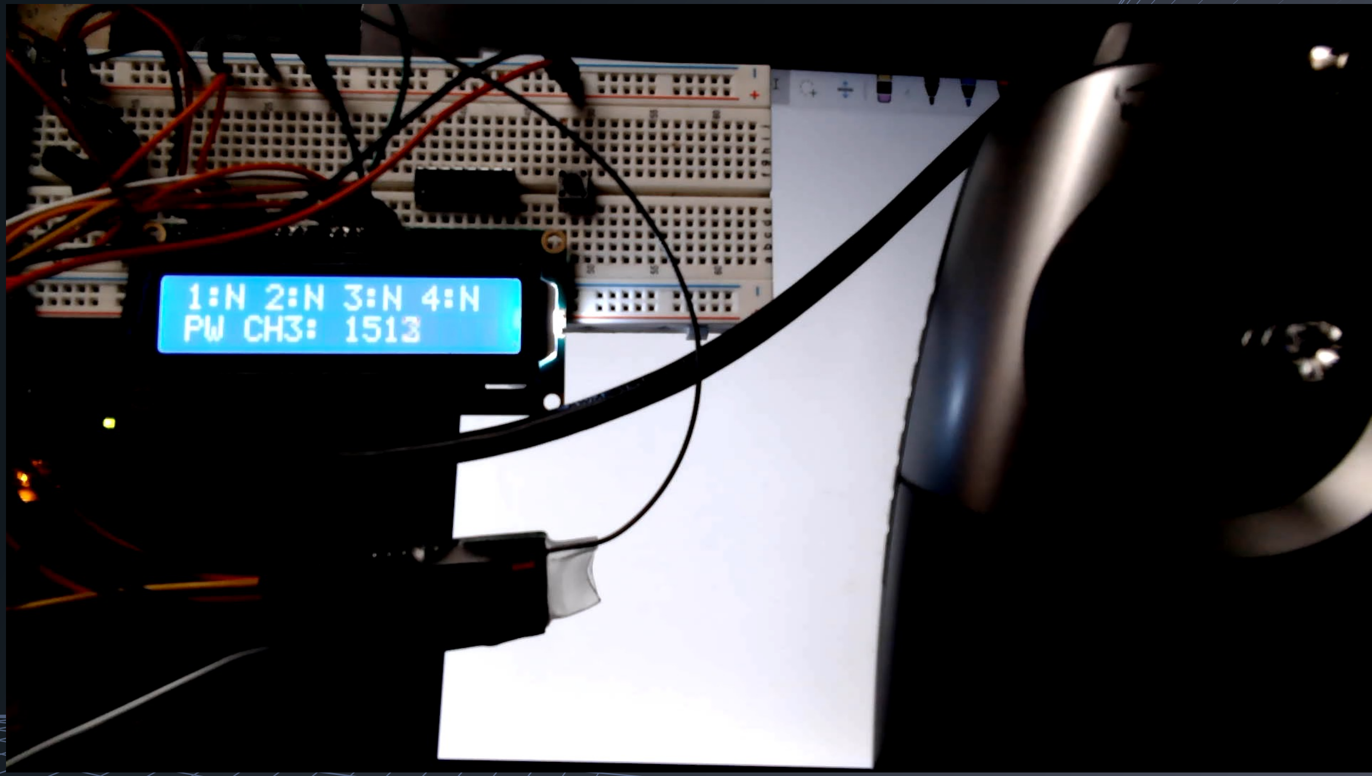
- RC Controller connects to R8EF Receiver wirelessly
- R8EF Transmitter outputs a PWM signal on all 8 channels
- PWM signals are read through PSoC microcontroller
- Operating Voltage: 5 volts
- Our PSoC board utilizes timer modules to read the PWM on our receiver





# RC Controller and Receiver Testing

- Channels Display their 'states' via an LCD
- Channel 3's PWM is demonstrated
- Channel 1 controls robot's left and right movement
- Channel 2 controls camera's up and down movement
- Channel 3 controls if the robot moves forward or backward (D = Drive N = Neutral R = Reverse)
- Channel 4 controls camera's left and right movement
- The other 4 Channels not shown control the deck gun movement and water nozzle adjustments



# Progress so far

- Researched what firefighters need in a robot
- Implemented code for simple hobby type sensors for future teams to reference
- Received data to help future teams understand possible issues of sensors
- Gave list of items we believe to be suitable once a budget is reached
- Have calculations that can be manipulated to fit future teams' possible new requirements

And much more that you can find in our full report!

# Any Questions?

Fire Fighting Robot Team

Team Members: Bryan Casillas, Lelibeth Bryan, Rocio Espinal, Brayam Hernandez, Alan Linan, Marco Lopez, Jason Negrete, Bryan Nunez, Christopher Pineda & Braulio Torres

Faculty Advisor: Airs Lin