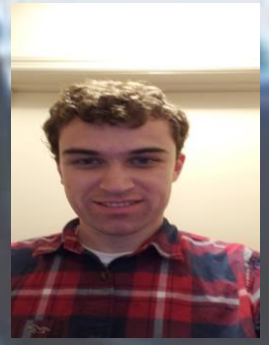
TRAFFIC STOP WATCHDOG

Felipe Solanet – Computer Engineer



Group #26

Jordi Niebla – Electrical Engineer

Michael Gendreau - Electrical Engineer

Mentor: Dr. Chung Yong Chan

PROJECT MOTIVATION

- Law enforcement officials are involved in countless stressful situations and highly reactive environments
- Higher precision information is needed during law enforcement interactions with the public
- Body & Dash Cam recordings do not always capture optimal field of views and angles

GOALS AND OBJECTIVES

- To design and implement a system capable of capturing and recording valuable information during law enforcement interaction with the public
- Utilize machine vision algorithms to track law enforcement officer, with a pan and tilt vehicle roof mounted camera, in 180 degrees of rotation
- Integrate a wireless handheld speech recognition device that supports user interface

SPECIFICATIONS AND REQUIREMENTS

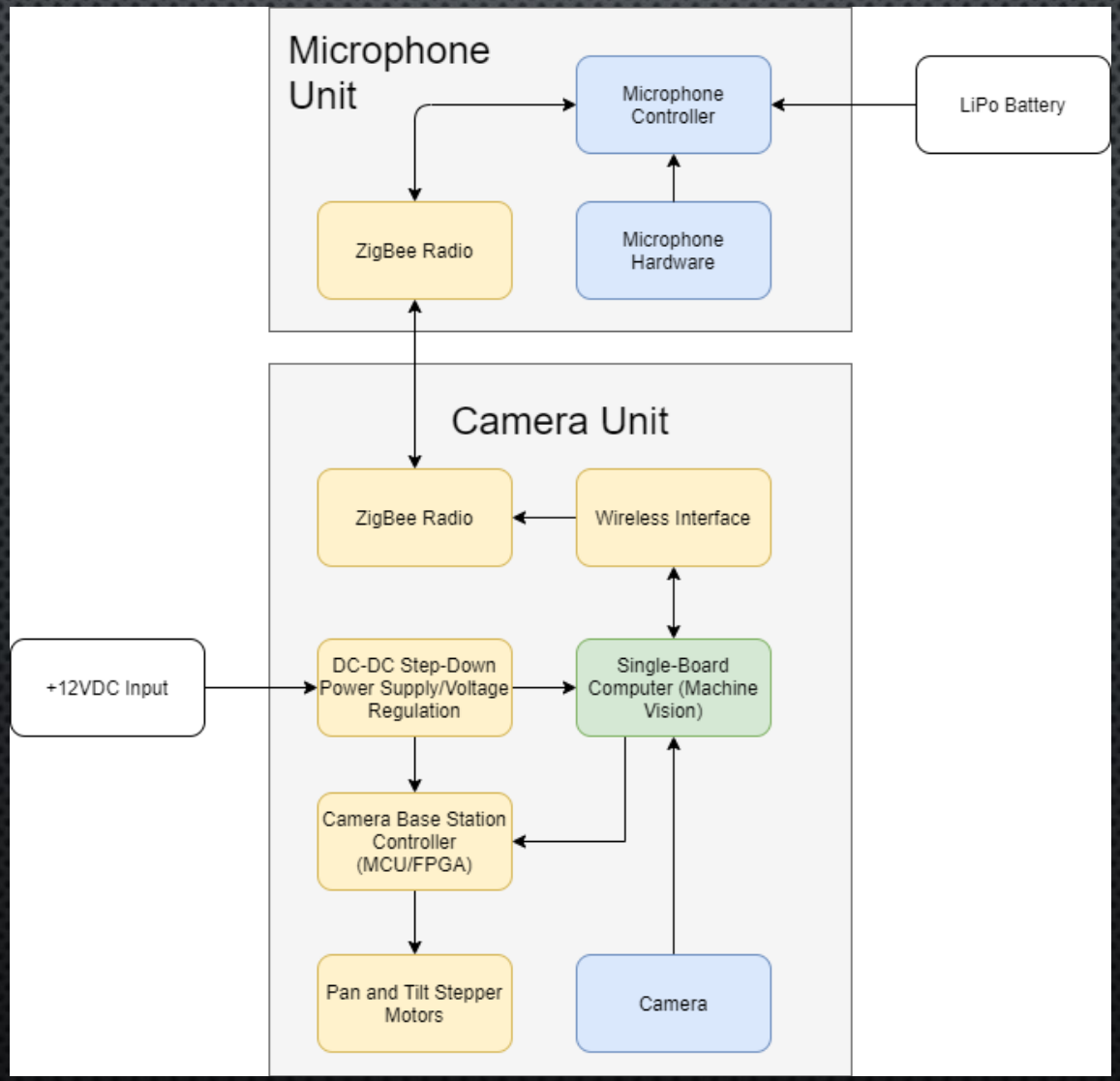
HARDWARE REQUIREMENTS

- 180-DEGREE PAN ANGLE, 180-DEGREE TILT ANGLE FOR VEHICLE ROOF MOUNTED CAMERA
- CAMERA SYSTEM SHALL BE POWERED BY 12V CAR BATTERY
- XBEE DEVICE FOR WIRELESS COMMUNICATION BETWEEN HANDHELD DEVICE & CAMERA SYSTEM (UP TO 300FT)
- HANDHELD MICROPHONE DEVICE:
  - POWERED BY RECHARGEABLE LITHIUM POLYMER BATTERIES
  - ACTIVATE/DEACTIVATE CAMERA SYSTEM

SOFTWARE REQUIREMENTS

- TRAINED OBJECT DETECTION MODEL FOR POLICE OFFICERS
- LESS THAN 500MS RESPONSE TIME ON IMAGE INFERENCES
- 32GB MAX STORAGE OF CAMERA RECORDED FOOTAGE
- SMOOTH AND ACCURATE CAMERA RESPONSE MOVEMENTS
- OFFICER-SYSTEM INTERFACE ON HANDHELD DEVICE
- KEYWORD RECOGNITION FOR AT LEAST 5 WORDS, ON HANDHELD SPEECH RECOGNITION DEVICE

HARDWARE DESIGN



EMBEDDED MICROPHONE DEVICE

- User interface that includes 3 buttons, along with an LCD screen
- Speech recognition module to detect keywords during police traffic stop
- Communicate with Odroid through wireless Xbee modules
- Dimensions are about 4 x 3.7 inches

MCU CHOICE – MSP430FR6989

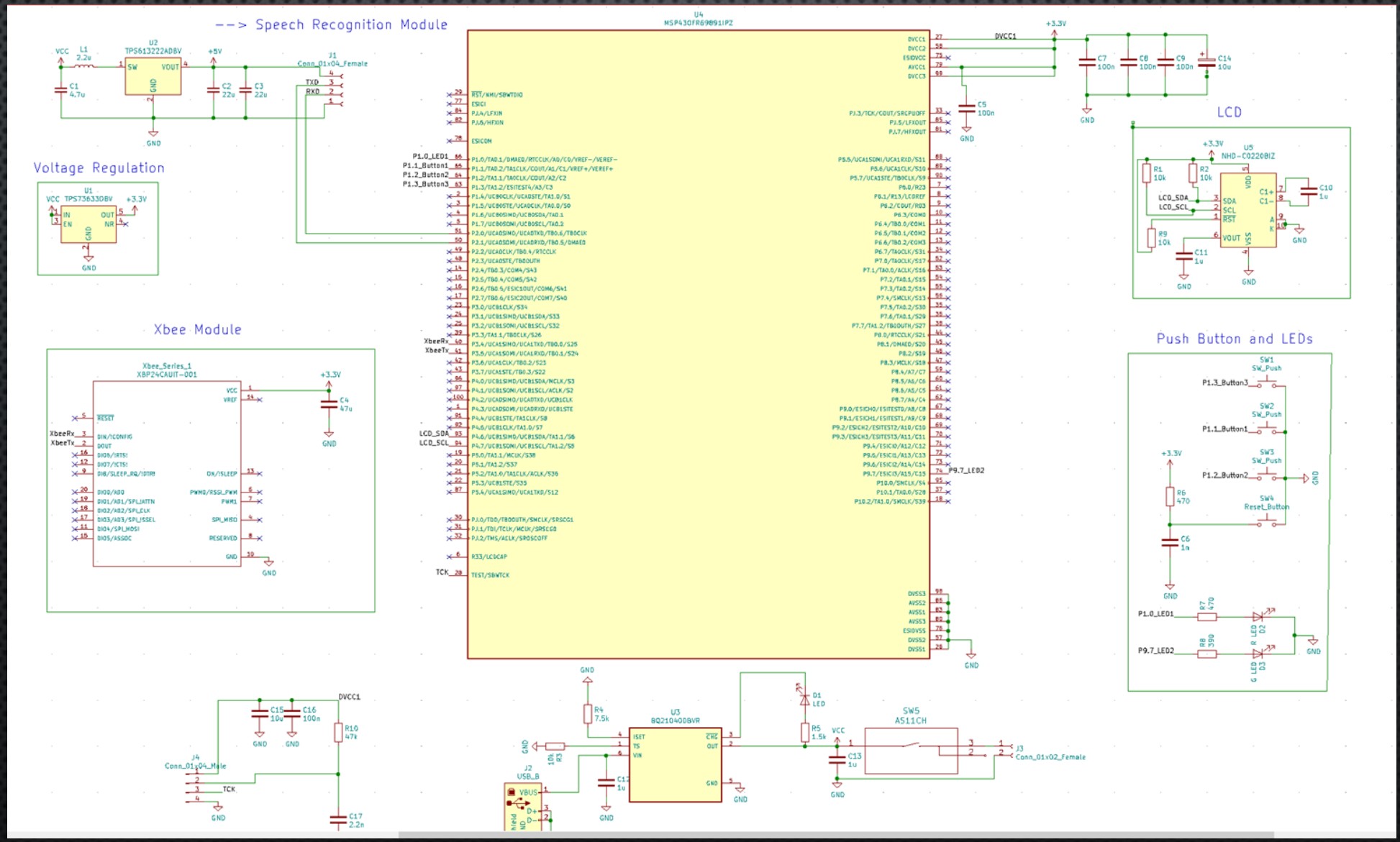
MSP430FR6989 Features:

- Max clock frequency of 16MHZ
- Up to 128KB FRAM program memory size
- 2KB RAM size
- 2 UART and I^2C interfaces
- Cost effectiveness and low power consumption
- Popular MCU throughout the UCF CPE courses

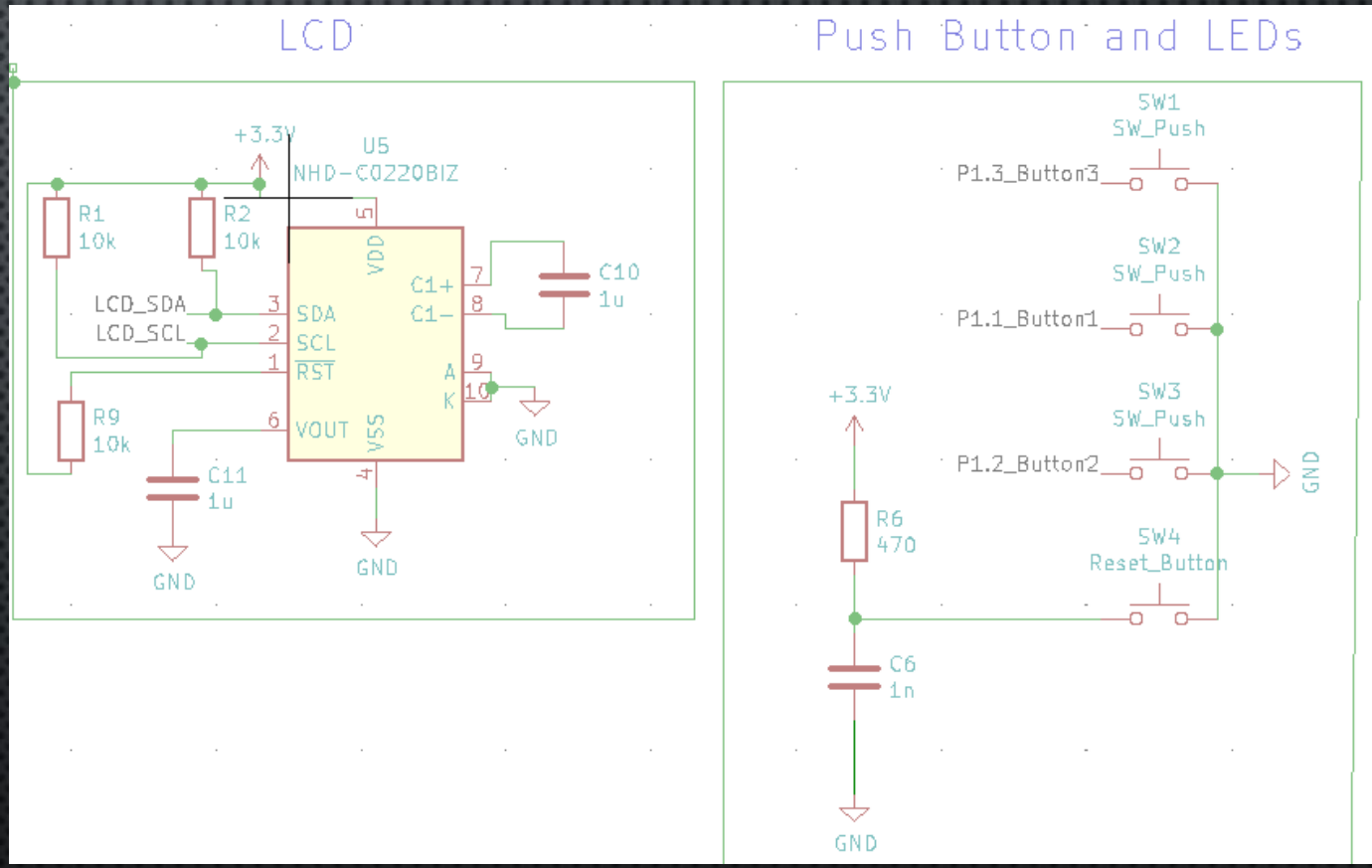
SPEECH RECOGNITION MODULE

- Dimensions: 30mm x 47.5mm
- Requires a supply of 4.5 - 5.5V, with less than 40mA
- UART communication to MSP
- Five words can be stored in a group, and up to three groups can be recorded through serial port interface
- Hex strings are sent from the MSP to the module to signal a command

MICROPHONE DEVICE SCHEMATIC



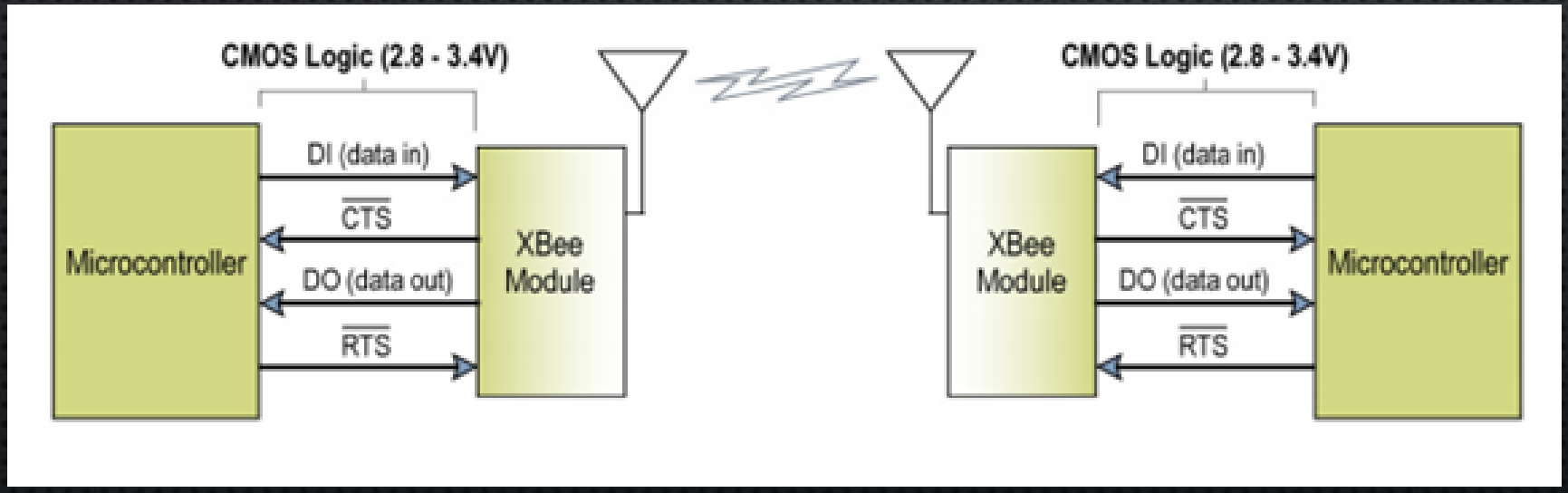
LCD AND PUSH BUTTONS



- Three push buttons used for user interface
- C0220BIZ NewHaven Display
  - 20 x 2 display format
  - 75.70mm x 27.10mm x 6.80mm outline
  - I^2C interface
- Requires 2.7 – 3.5V

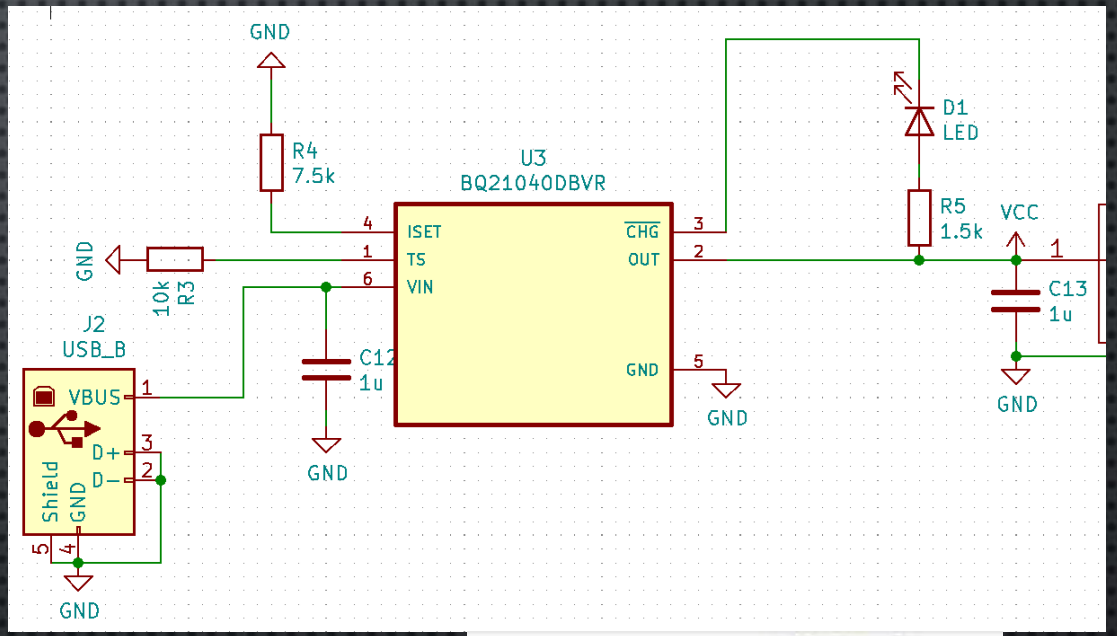
XBEE SERIES 1 MODULE

- XBee Series 1 RF module will be used for wireless communication between MSP & Odroid
- Can support up to 90 meters of outdoor line-of-sight



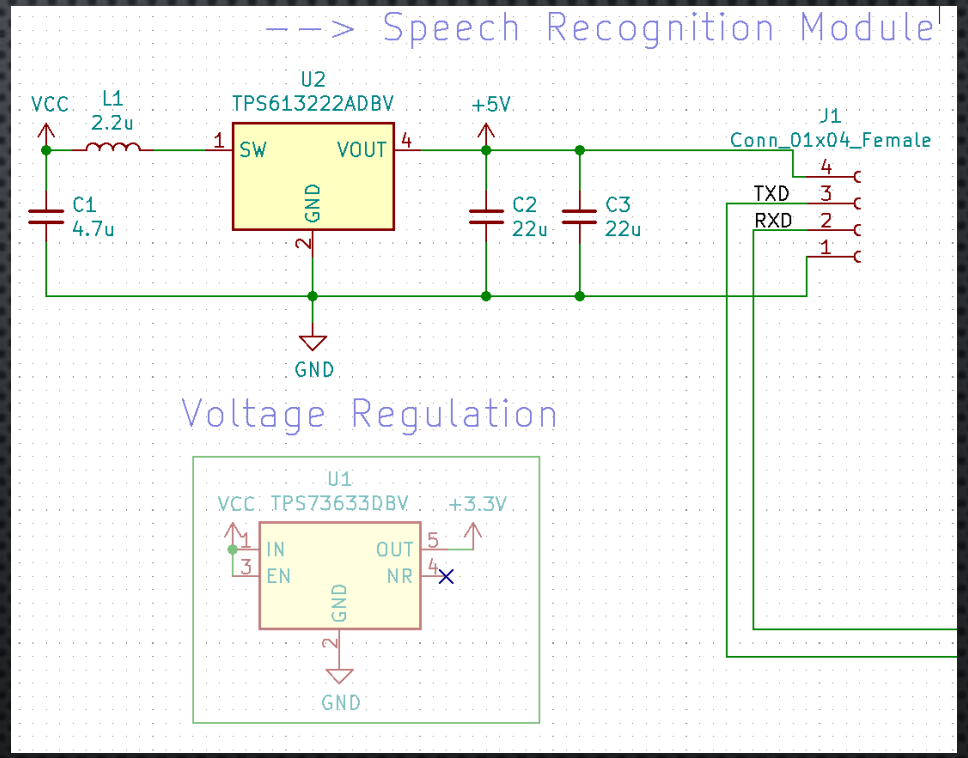
Li-Po Battery & Battery Charger

- The typical nominal voltage of a rechargeable lithium polymer battery is about 3.7V.
- The battery charger used for the device is the BQ21040DBVR IC
  - Can be operated through USB port (police officers have laptops in their car)
  - LED to indicate whether the battery is still charging

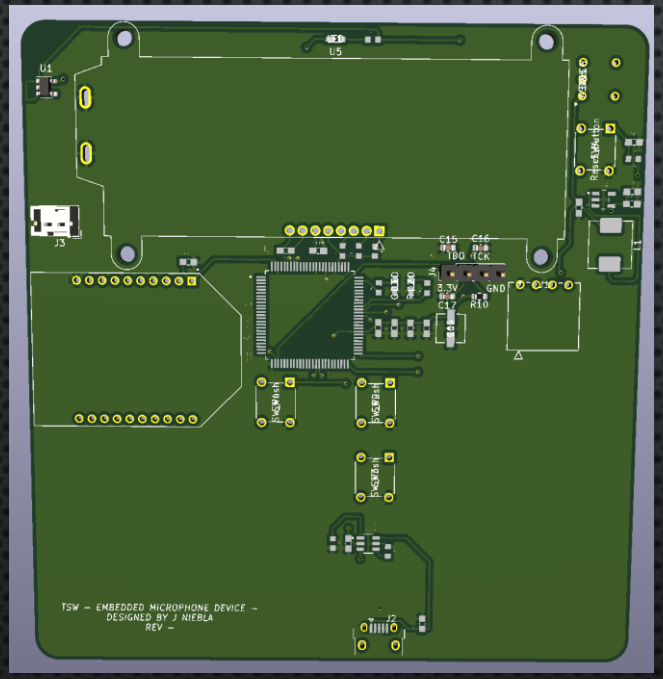


BOOST CONVERTER & VOLTAGE REGULATION

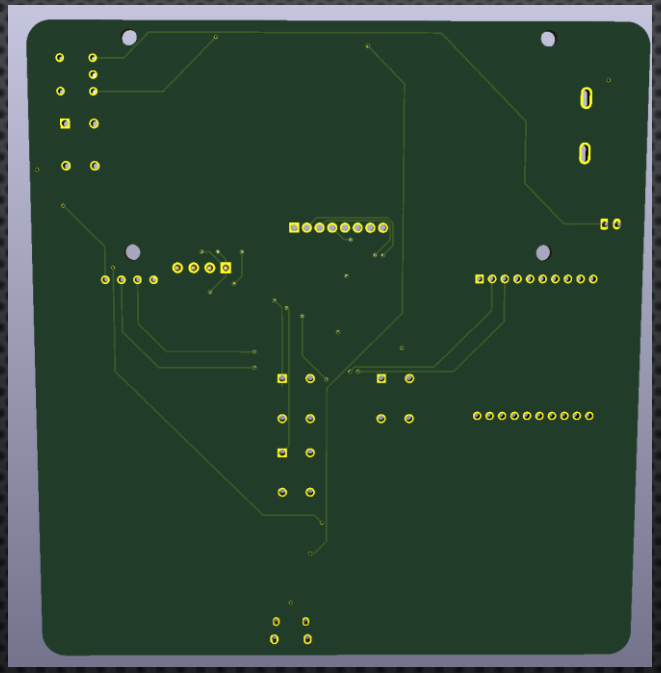
- TPS613221 IC Boost Converter will boost Li-Pol battery to 5V.
- TPS73633DBV is a low dropout voltage regulator used to drop the Li-Pol battery to 3.3V.
- 3.3V regulation is needed for the MSP, XBee module, and LCD



Embedded Microphone Device PCB

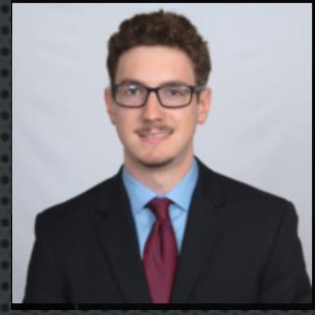


Front View

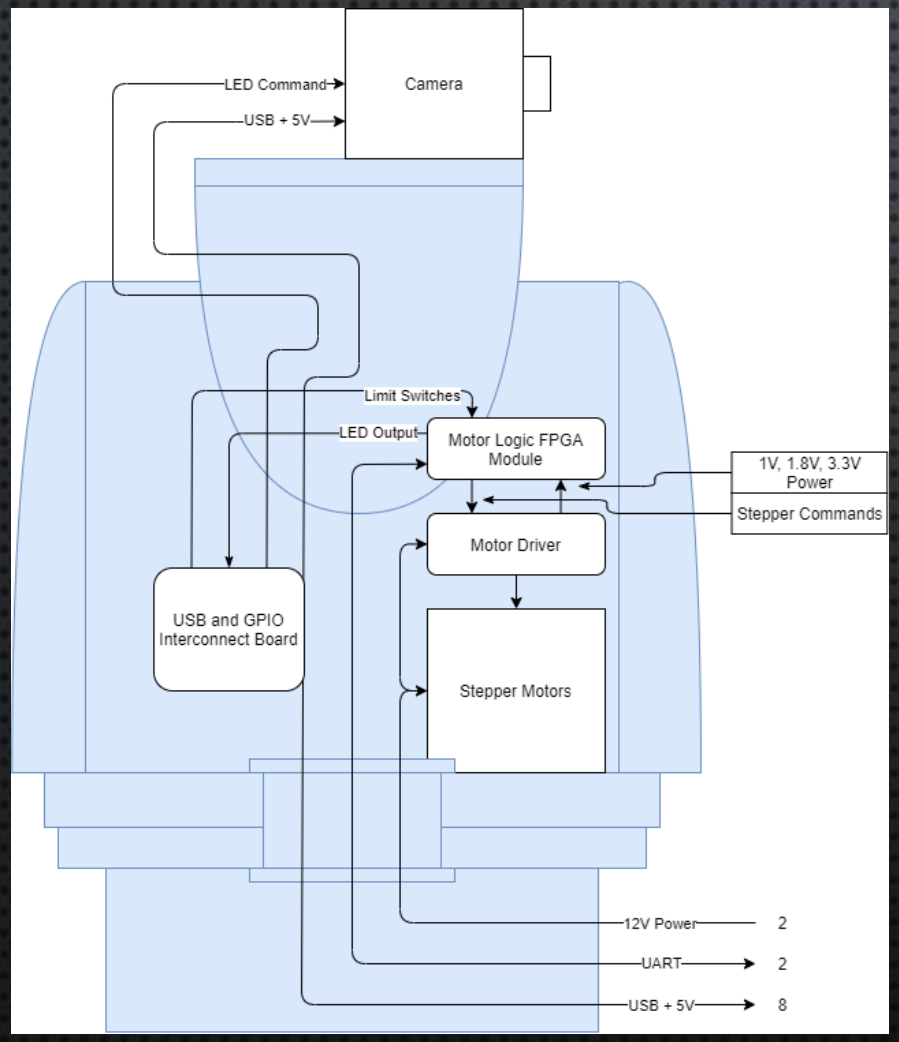


Rear View

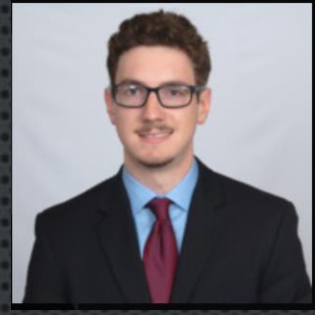
Actual Populated PCB



HARDWARE BLOCK DIAGRAMS - CAMERA

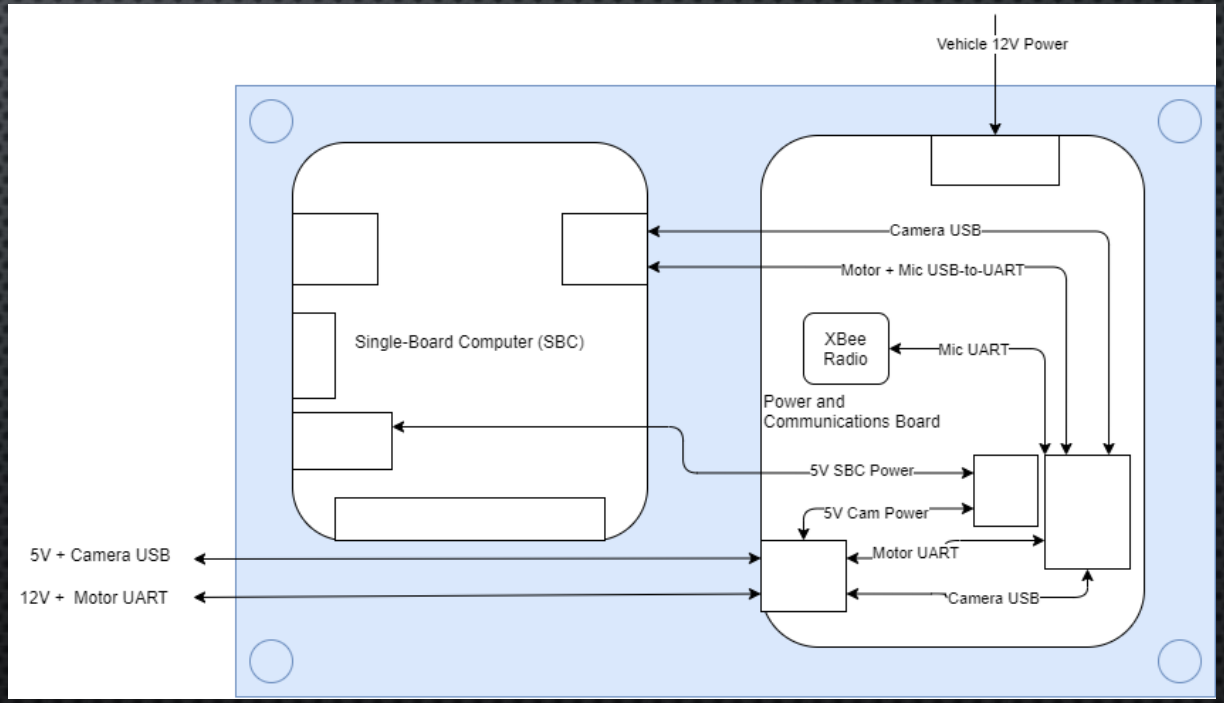


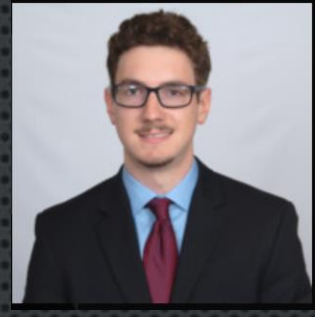
- CAMERA SUBSYSTEM CONSISTS OF STEPPER MOTORS, DRIVER AND CONTROLLER CIRCUIT, POWER AND INTERCONNECT BOARDS, SENSORS, CAMERA, AND MECHANICAL SUBASSEMBLIES
- I/O CONSISTS OF 5V AND 12V DC POWER INPUT WITH UART AND USB COMMUNICATION TO HOST SINGLE-BOARD COMPUTER



Hardware Block Diagrams – Single-Board Computer

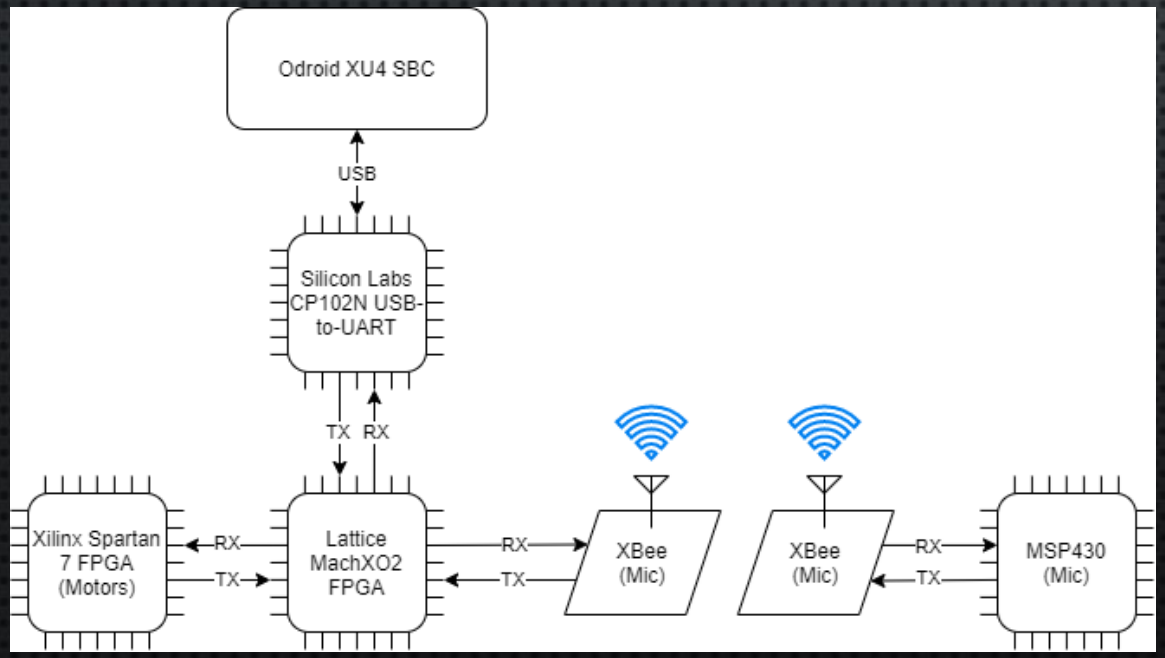
- Single-Board Computer Enclosure Subsystem consists of computer and power/communications board
- Power/communications board facilitates UART and USB comms with voltage regulation for subsystems using the host vehicle's 12V bus

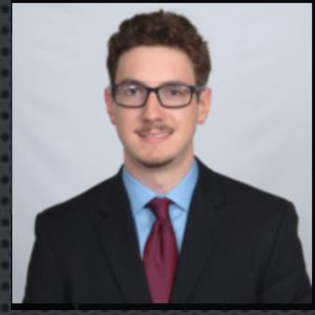




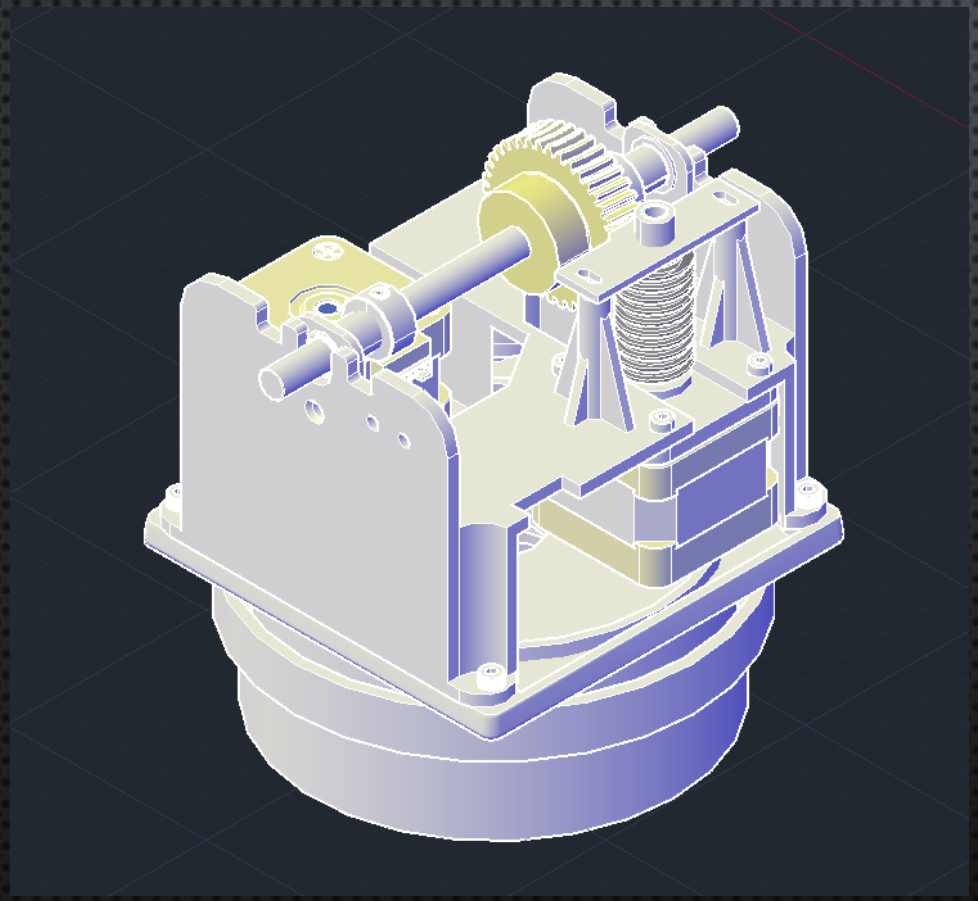
COMMUNICATION BETWEEN SUBSYSTEMS

- DEVICES COMMUNICATE WITH EACH OTHER PRIMARILY THROUGH UART SERIAL PROTOCOL
- MULTI-SLAVE UART PROTOCOL ACHIEVED THROUGH FPGA-BASED BUS MANAGER
- WIRELESS COMMUNICATION ACHIEVED OVER XBEE DIGITAL RADIOS

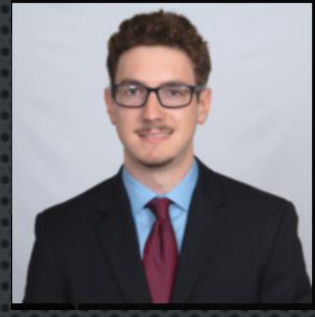




MOTOR CONTROL



- MOTION ACHIEVED BY TWO 12V STEPPER MOTORS DRIVEN BY TI DRV8846 MOTOR DRIVER IC'S
- ONE MOTOR CONTROLS THE PAN AXIS, ONE CONTROLS THE TILT AXIS
- DISCRETE STEPS IN ROTATION ARE PROCESSED BY XILINX SPARTAN 7 FPGA TO GENERATE SMOOTH MOTION PROFILE



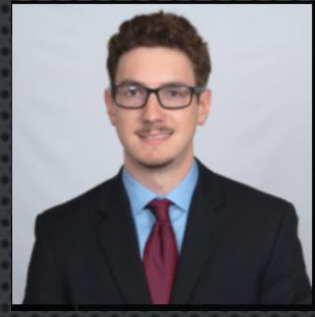
MOTOR CONTROL: FPGA VS MCU

MCU

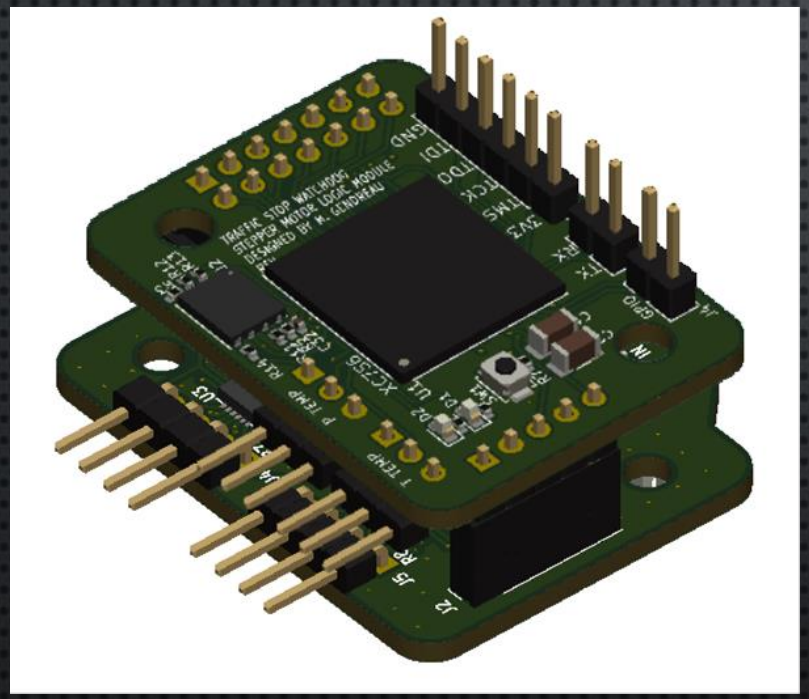
- Fixed hardware design, pipelined architecture
- Ready-made peripherals and associated hardware-software interface, fixed performance
- Higher latency for a given sequence of operations that can be paralleled in hardware
- Easy PCB layout, few external components needed, low cost

FPGA

- Flexible hardware design
- Large capacity for parallel processing
- Higher cost, less space efficient
- Huge amount of customization using proven IP's from digital designers
- Much higher performance for dedicated, high-speed processing tasks like motor control
- Complex PCB layout

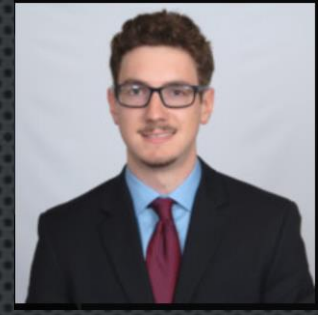


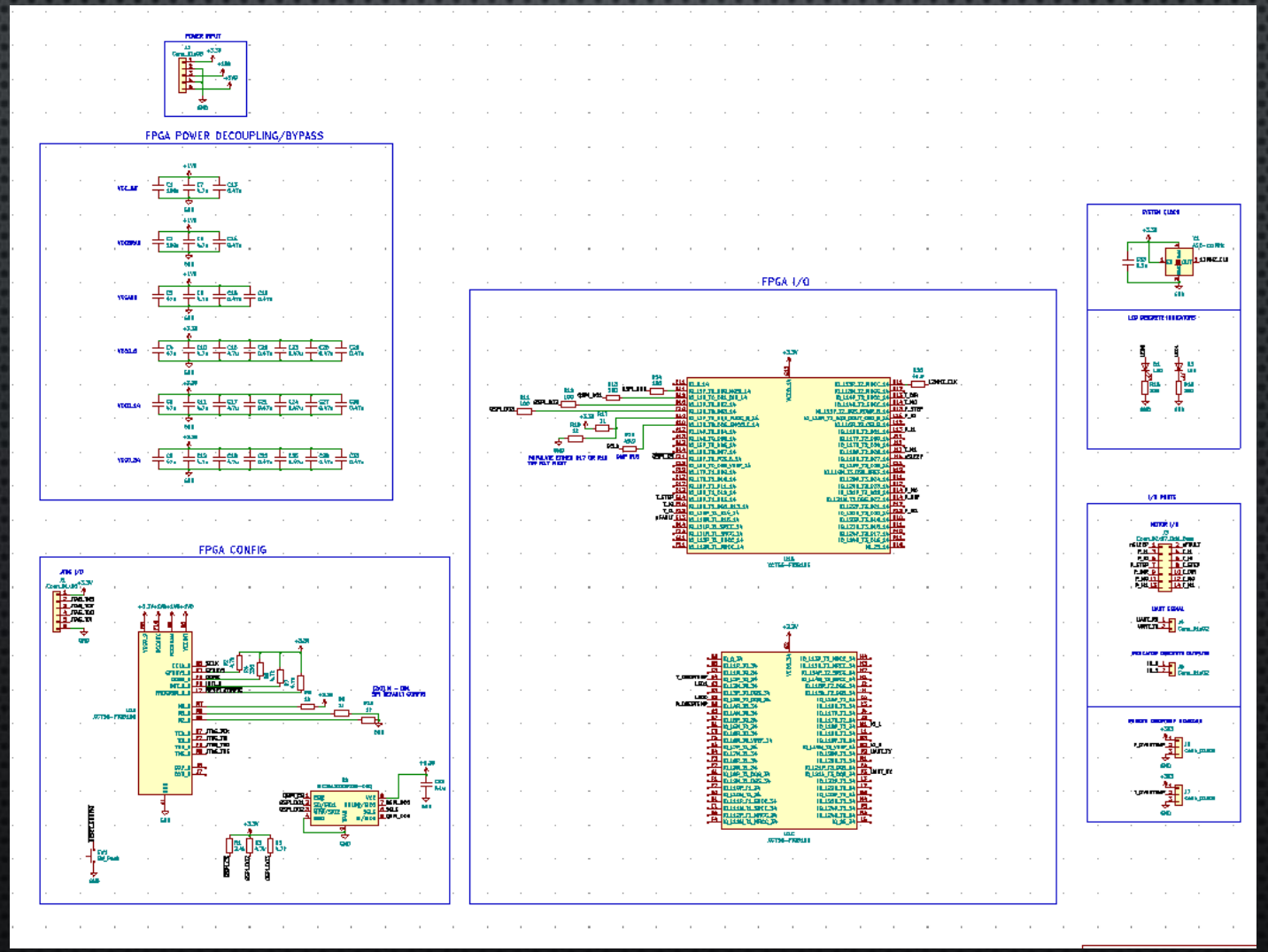
MOTOR CONTROL PCB DESIGN – TOP BOARD

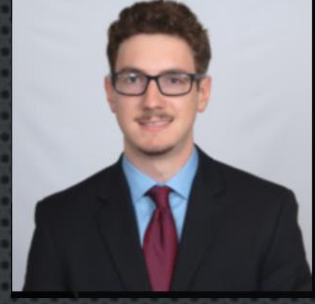


- Xilinx Spartan 7 FPGA used for rapid computation of motor angular velocity profiles, generates step pulses
- 12 MHz system clock
- UART Transceiver Integrated in HDL
- Low voltage digital electronics isolated from higher voltage power electronics

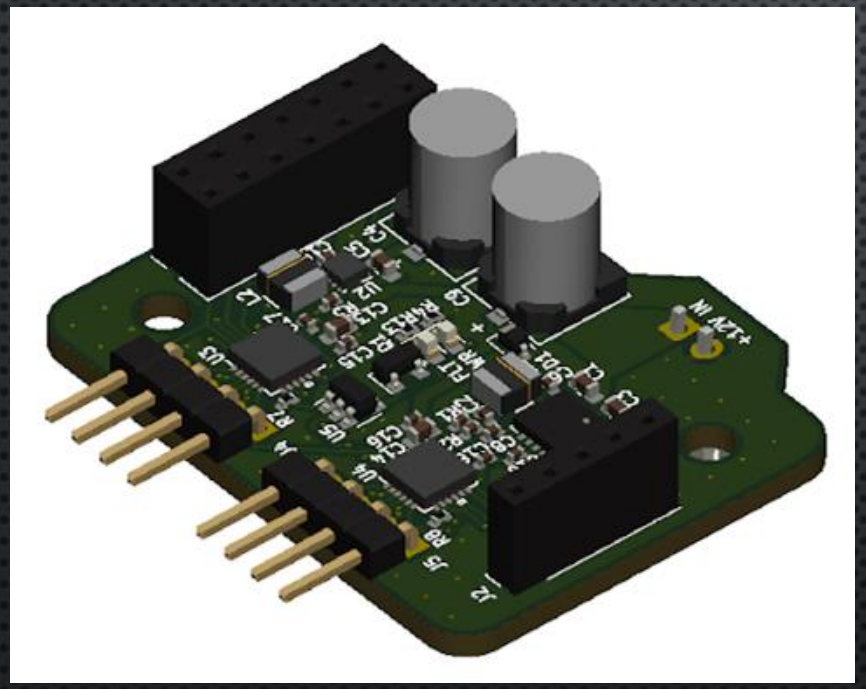
MOTOR CONTROL PCB DESIGN – TOP BOARD





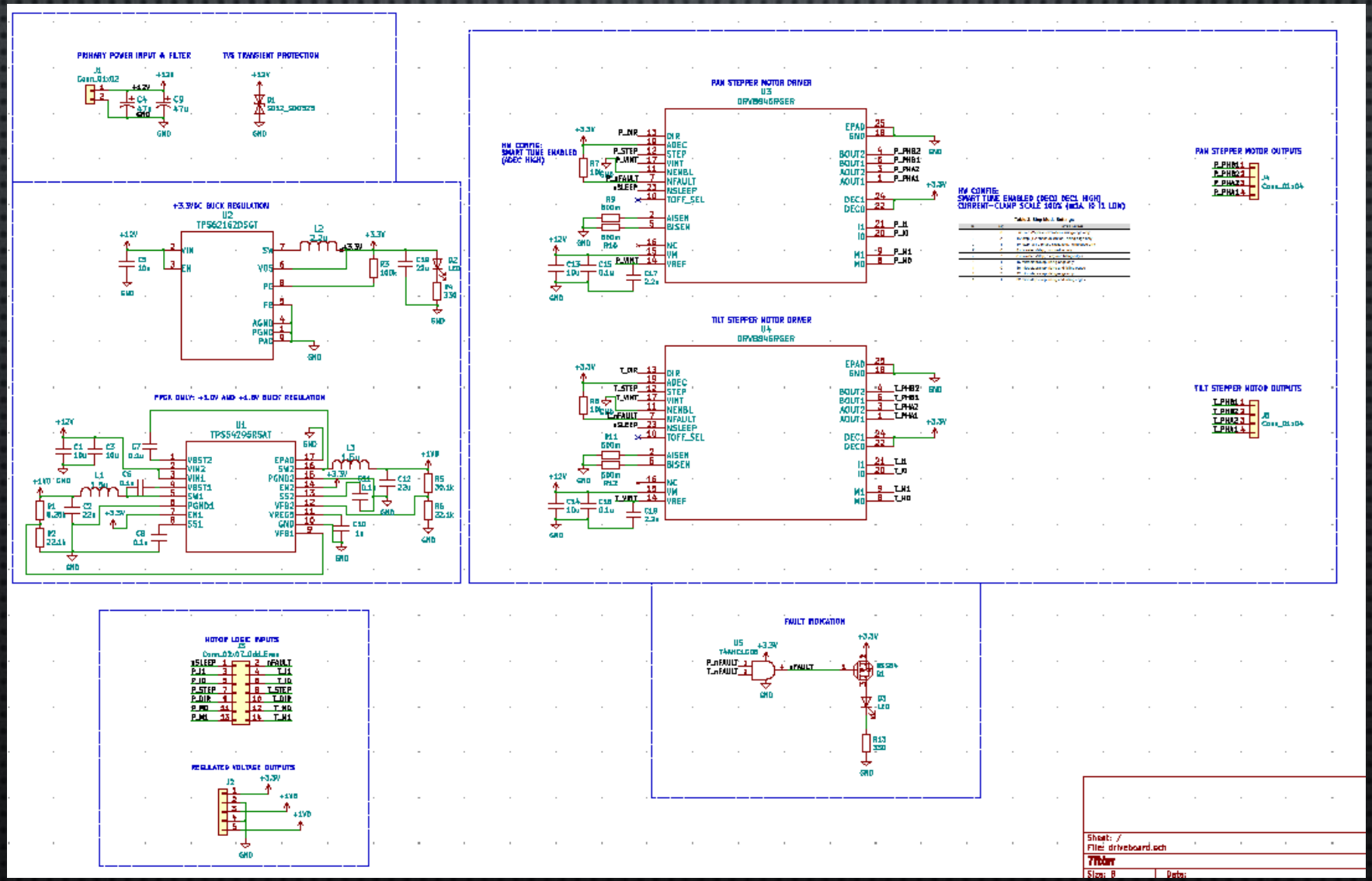


MOTOR CONTROL PCB DESIGN – BOTTOM BOARD

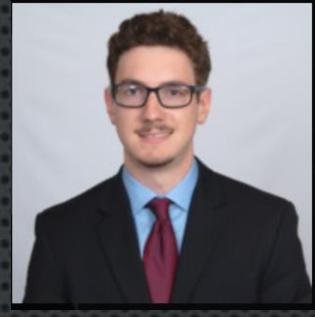


- Each motor driven by Texas Instruments DRV8846, contains two integrated MOSFET H-Bridges for the two sets of phase coils for each stepper motor
- Performs local filtering and regulation of 12V bus voltage for digital electronics (1.0V, 1.8V, and 3.3V)
- Logic and LED indicators for motor fault flags

MOTOR CONTROL PCB DESIGN – BOTTOM BOARD



WORK DISTRIBUTION



Michael Gendreau

Primary: Motor Control,

Enclosure Design + Assembly,

System Power Regulation

Secondary: Handheld Device

Hardware

Jordi Niebla

Primary: Handheld

Device Hardware,

Keyword Recognition

Secondary:

Communication

Interface Testing

Felipe Solanet

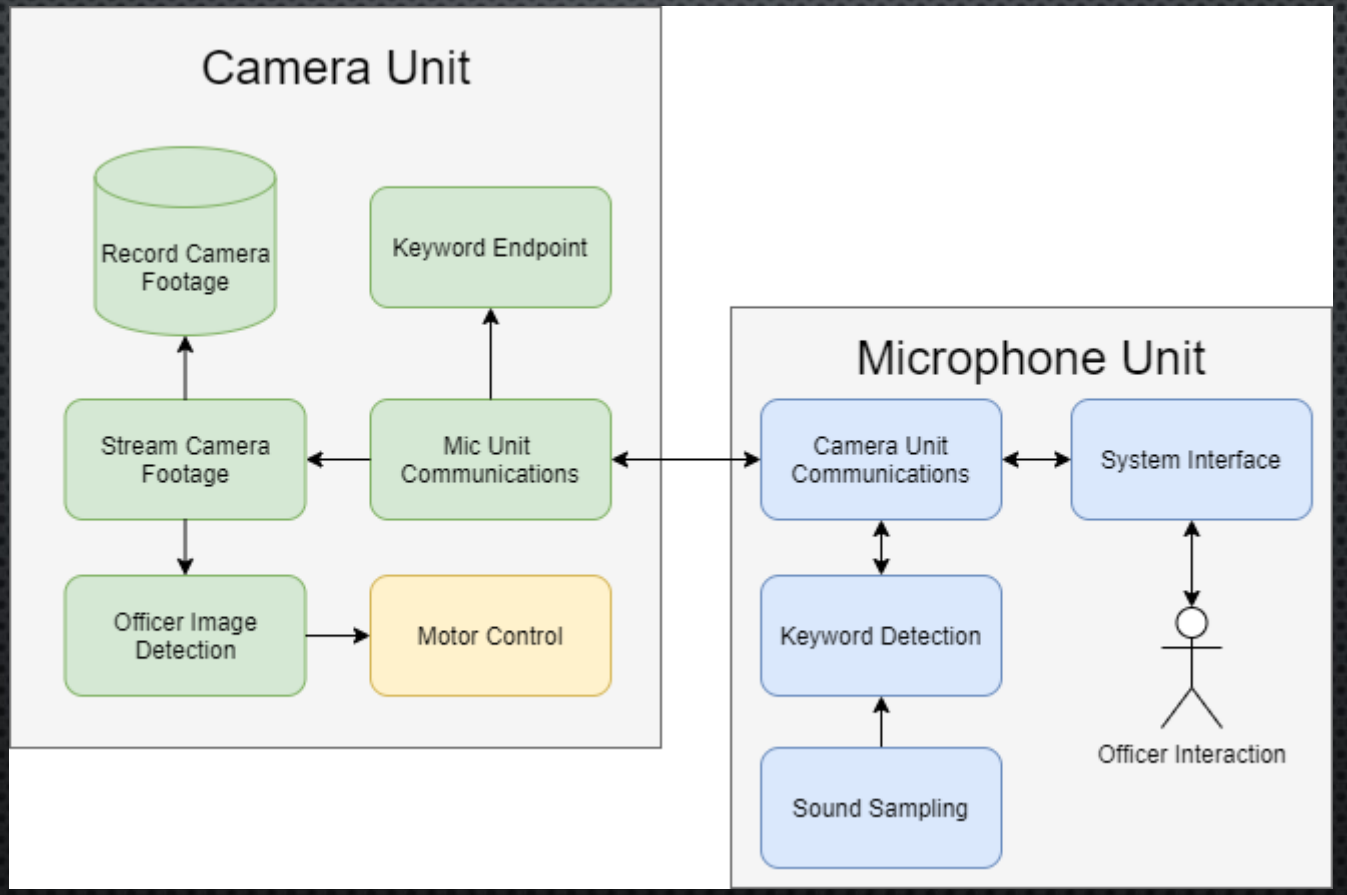
Primary: Camera Integration,

Officer Image Processing,

Device Communication System

Secondary: Embedded Software

SOFTWARE DESIGN



CAMERAS - GIGE

MER-500-14GC-P

- 1280 x 960 Resolution
- 54 FPS
- $218

MER-133-54GC

- 2592 x 1944 Resolution
- 14 FPS
- $196

CAMERAS – FLIR Firefly DL

- USB 3.0
- 1440 x 1080 Resolution
- 60 FPS
- $300
- Built-In Intel Movidius Chip

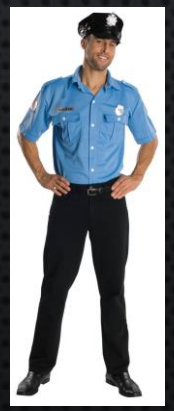
TRAINING – DATASET

Real Dataset

- Data better represents reality
- Labels must be compatible
- Test data won't match dataset
- More time spent training

Custom Dataset

- Full control of data
- Creation takes time
- Easier to acquire test data
- Less time spent training



TRAINING – PREPARATION

Recorded 4 minutes of video in different environments

Sampled ~1800 frames for dataset

Labeled images with PascalVOC format

TRAINING – ALGORITHM

~1800
Images

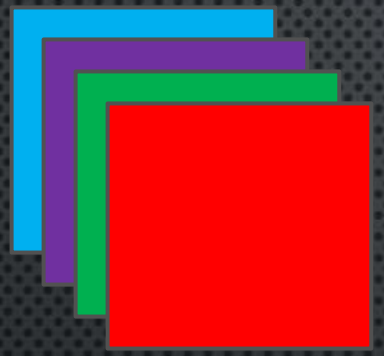


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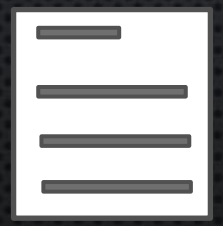
Image
Labels



MobileNet SSD v1

Batch Size = 32

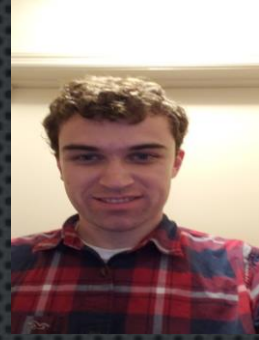
35000
Iterations

Trained Model

ODROID - OVERVIEW

- Cortex A15 + Cortex A7 2Ghz CPU
- 2GB DDR3 RAM
- 2x USB 3.0 Ports + 1x USB 2.0 Port
- HDMI Port
- Ethernet Port
- Runs Ubuntu Mate 16.04

ODROID - SOFTWARE



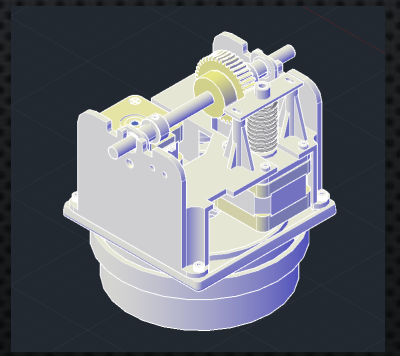
- C++
- FLIR Spinnaker SDK
- OpenCV

Camera Interaction

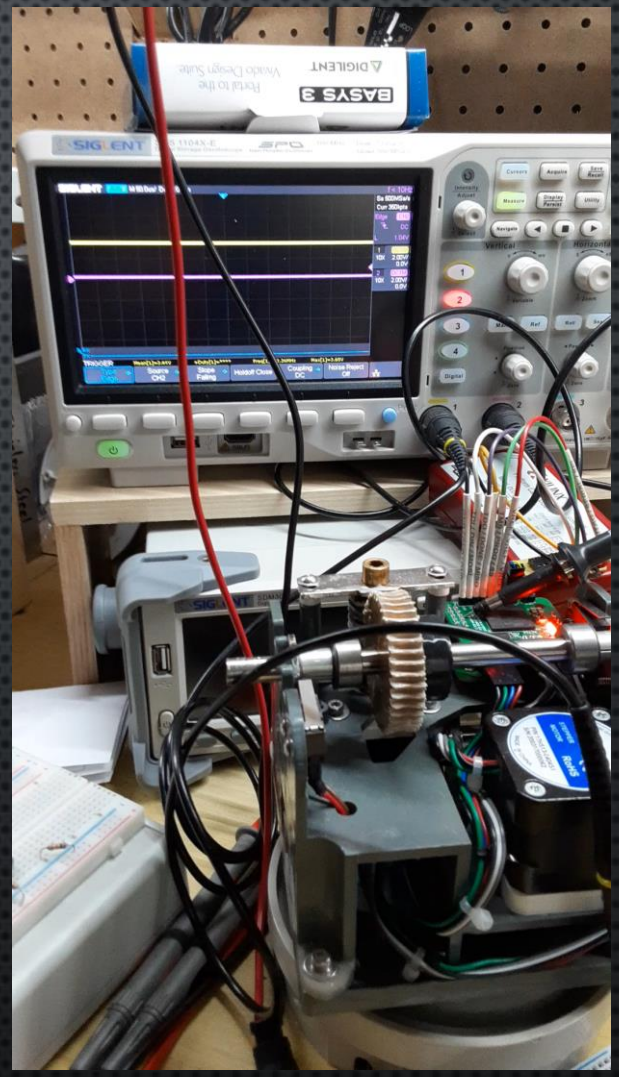
Officer Commands

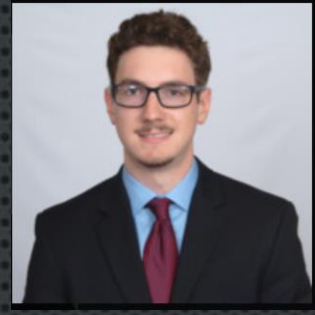
Footage Recording

Motor Commands



FPGA Motion Control Demo





Testing

Project Budget

Component/Item	Expected # of units	Estimated Price/Unit	Estimated Price
Mechanical Components			$160.00
FireFly DL Camera	1	$320.00	$320.00
S Mount Lens	1	$12.00	$12.00
ODROID-XU4 (SBC)	1	$80.00	$80.00
MSP430FR6989	1	$9.00	$9.00
Lattice MachXO2-1200 FPGA	1	$10.00	$10.00
Xilinx Spartan 7 FPGA	1	$17.00	$17.00
PCB Design + Components		$120	$120
Speech Recognition Module	1	$35.00	$35.00
Zigbee Radio	2	$12.50	$25.00
Micro SD Card + Reader	1	$25.00	$25.00
LCD	1	$11.50	$11.50
Total Estimated Cost			$824.50

- Self funded and total cost split between the group
- The project total (including shipping) was calculated to be about $800-850.
- This includes the camera, PCB design & extra components needed, microcontroller, FPGAs, and the Odroid