Smart Cooler

Group 23


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Project Overview

Project Motivation

- Recreational enjoyment
- Assortment of technologies
- Practicality
- Previously encountered problems
- Quality of Life (QoL)

Project Goals and Objectives

Basic Goals

- Polymer-Dispersed Liquid Crystal (PDLC) technology
- Solar Panel
- Motion Sensor
- Temperature/Humidity Sensor
- UV Sensor
- LED Lights

Advanced Goals

- USB-A Charging Port
- Rechargeable Battery
- Graphical Interface
- Adjustable transparency on PDLC film

Stretch Goals

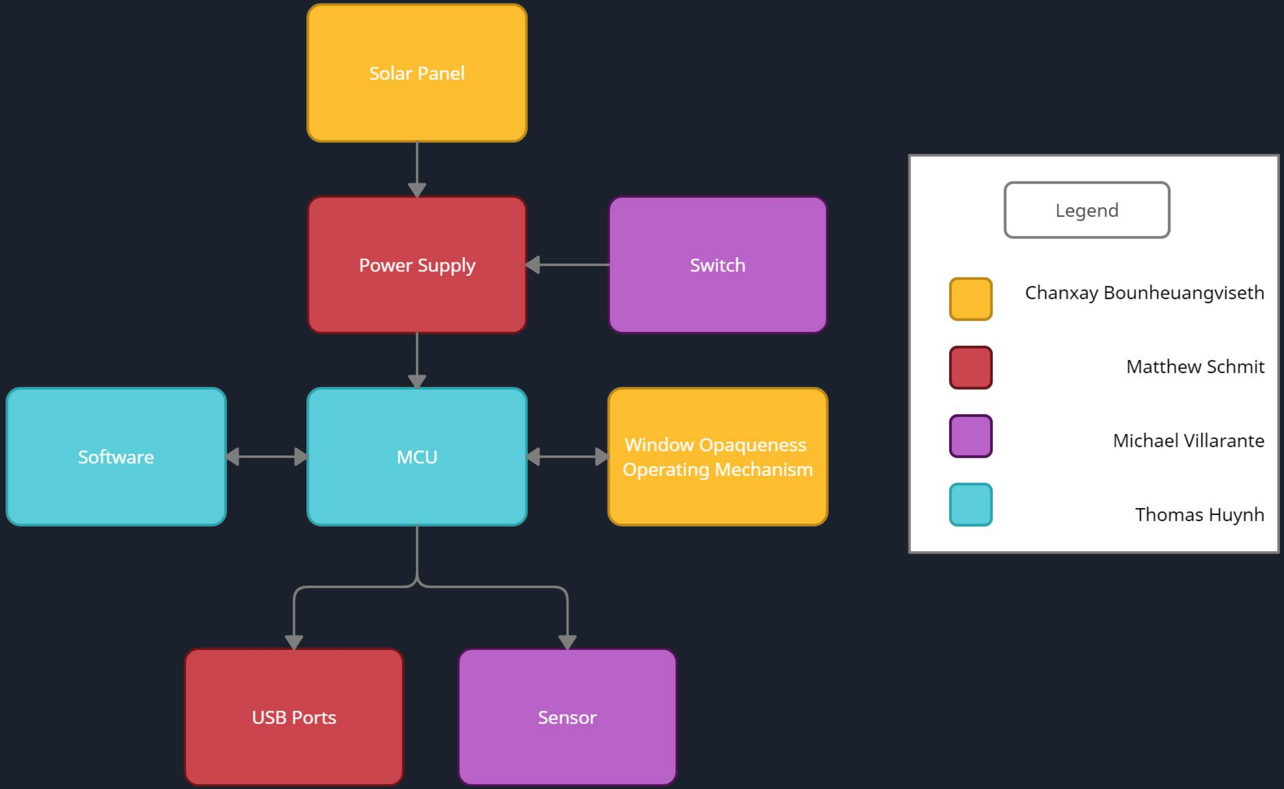
- Bluetooth speakers
- Mobile IOS/Android App
- Camera

Specifications

- The main feature to test is the PDLC Film itself and the overall Cooler weight
- The other components can be tested as an added bonus on top of the chosen specifications

Component(s)	Parameter	Specification
Battery	Discharge Time	4 Hours
PDLC Film	Power Consumption	≤ 10 Watts
PDLC Film	Time to Activate	≤ 5 Seconds
PDLC Film	Transparency	≥ 80%
PDLC Film	Opaqueness	10 - 90 %
Sensor	Accuracy	≥ 95
Cooler	Weight w/o Food/Drinks	≤ 30 Pounds
PV Panel	Power Output	≥ 10 Watts

Overall Block Diagram



Significant Design Considerations

- Electrical components contained within the cooler should take up as little space as possible
- Electrical components, when power, should not change the temperature of the cooler by a large amount
- Electrical components contained within the cooler should not be disturbed by other items put inside the cooler (i.e. food, drinks, ice, etc.)
- New design of the cooler lid must be able to fit properly back onto the cooler to insure the cooler is still effective

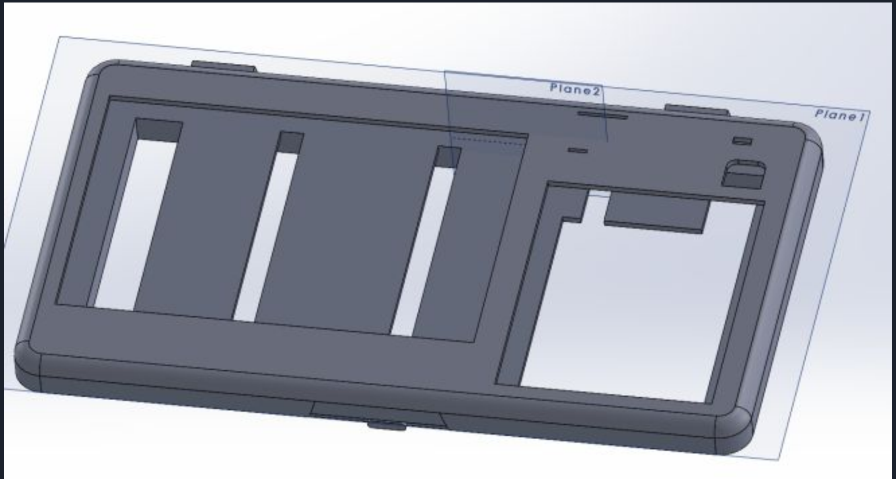
Significant Component Decisions

- Cooler: Large enough to have components embedded, able to be carried
- Sensors: Functionally benefit a cooler and our implementation
- PDLC: Ease of use as a film, size constraints
- Solar Panel: Needed to fit on the cooler lid
- Battery: Price, amount of charge it can hold
- LED lights: bright, efficient

Cooler

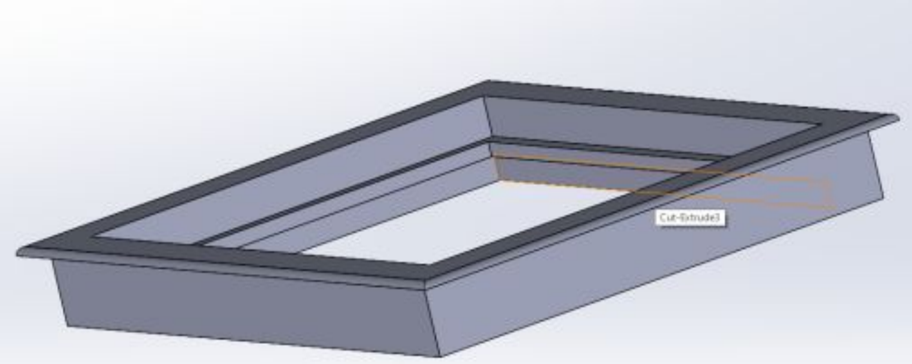
Cooler Lid Design

- Cooler Lid needs a redesign to fit the new components
- Redesign specifically compensates for the Solar Panel, LCD, PDLC Glass, and wiring routes
- Cooler Lid machined using original lid
- Area of the lid is measured to be around 60.1 ± .1 cm x 33.4 ± .1 cm



Frame for PDLC Film

- 3D Printing a specific frame to hold the PDLC Film in
- Frame designed in SolidWorks
- Slight height issue of the PDLC Film
- Frame depth for the size of 2 acrylic sheets

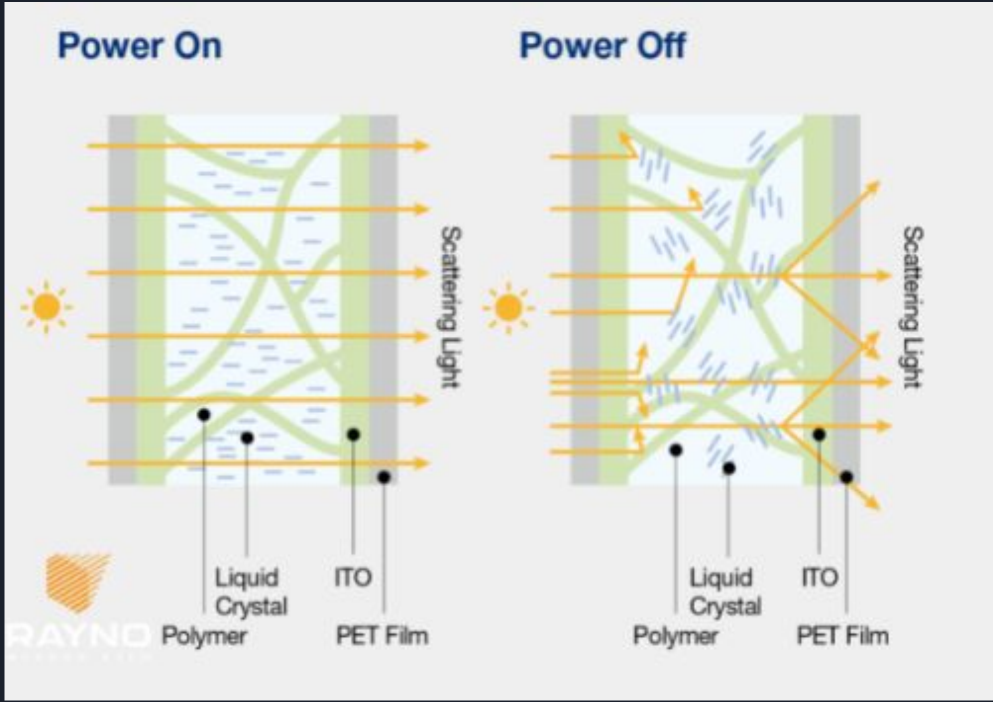


Polymer-Dispersed Liquid Crystal (PDLC) Film

- Opaque state while inactive
- Transparent while active
- Stripping and soldering the wires
- Window of the cooler lid

Smart Glass	Type	State Change	State Trigger
Thermochromic	Passive	Clear to Dark	Heat/solar infrared
Photochromic	Passive	Clear to Dark	Light
SPD	Active	Clear to Dark	Electricity
EC	Active	Clear to Dark	Electricity
PDLC	Active	Opaque to Clear	Electricity

How PDLC Technology Works



Source: Rayno Window Film

Solar Panel

- 10 Watt/12 Volts Panel
- Monocrystalline
- 10 Amp Solar Charge Controller
- Mounting holes
- 34.29 x 23.37 x 1.524 cm
- Waterproof junction box

Solar Panel Type	Cell Composition	Efficiency	Average Cost per Watt
Monocrystalline	Single Silicon Crystal	20% and up	$1-$1.50
Polycrystalline	Multiple Silicon Crystals	15-17%	$0.70-$1
Amorphous	Variety - Cadmium Telluride (CdTe), Non-Crystalline Silicon (a-Si), Copper Indium Gallium Selenide (CIGS)	CIGS: 13-15% CdTe: 9-11% a-Si: 6-8%	CIGS: $0.60-$0.70 CdTe: $0.50-$0.60 a-Si: $0.43-$0.50
PERC	Single Silicon Crystal + Passivation Layer	25% and up	$0.32-$0.65

Solar Charger Regulator

- Regulating current flow from solar panel into battery bank
- Ensures battery is properly changed and not being damaged overtime
- Device acts as a pulse width modulator
- Cheaper compared to maximum power point trackers

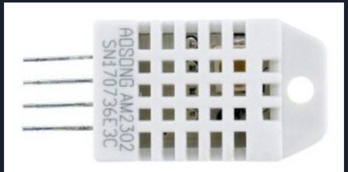
LED Lighting Feature

- Will be placed near the top of the inside of the cooler
- When on allows the contents of the cooler to be seen when lid is closed
- High energy efficiency
- Produces low amounts of heat, bright light, and has a low cost.

Type	Foxdam Flexible LED Strip Lights	Tenmiro Smart LED Strips	String LED Lights
Length (Feet)	16.4	50	10
Color	White	RGB	White
Bluetooth	No	Yes	No
Cost	$12.88	$16.99	$7.99

Temperature/Humidity Sensor

- The DHT22 offered things like:
  - Convenience
  - Affordability
  - Different sizing
- It was easy use and worked well with the other sensors and parts

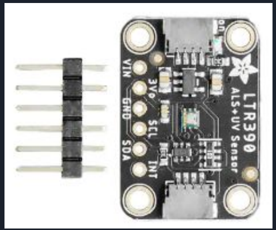


Type	DHT22	SHT31-D	AM2320
Voltage	3.3V-6V	2.4V-5.5V	3.3V-5V
Dimensions	Small size: 14 x 18 x 5.5mm; Big size: 22 x 28 x 5mm	12.7 x 18 x 2.6mm	22.5 x 12 x 4.7mm
Price	$10-$11	$13-$14	$4-$5

UV Sensor

- The Stemma QT LTR390 offered things like:
  - Cost efficiency
  - What was being measured
  - Easy to set up
- Easy to code and able to be compatible with other parts of the project

Type	Stemma QT LTR390	SI1145	TCS34725
Voltage	3.3V-5V	3V-5V	3.3V-5V
Dimensions	28 x 17 x 3mm	20 x 18 x 2mm	20.44 x 20.28 x 2mm
Measured	Ambient Light and UVA	Visible Light and IR Light	RGB and CLear Light
Price	$4-$5	$9-$10	$7-$8



Motion Sensor

- The AM312 offered things like:
  - Cost efficiency
  - Easy to set up
- Compatible with other parts and fit nicely into the cooler

Type	AM312	Tilt Ball	Breaker Beam
Voltage	2.7V-12V	Up to 20V	3.3V-5V
Dimensions	12 x 25mm	23 x 5 x 5mm	20 x 10 x 8mm
Price	$8-$9 (3ct)	$2-$3	$5-$6

Switches

- Switch that was chosen to use was the micro-push button switch
- Very simple to use for operating the LED lights and PDLC film and cost effective for the project
- Other modifications can be made in the future for better functionalities

Type of Switch	Voltage	Size	Operation	Price Range
LED	N/A	Small	Physically push button	~$2.00-$3.00
Limit	125V AC	Small	Presence/absence of object	~$1.00-$2.00

LCD Screen

- 16x2 character display
- Allows for the data received from the sensors to be displayed
- Will cycle through the different readings from the sensors to allow everything to be displayed

Type	Sunfounder LCD	TFT Touch Screen	OLED Display Module
Display Size (Inches)	2.56	2.8	0.91
Color	White on Blue	RGB	Blue
Bluetooth	No	No	Yes
Costs	$7.99	$15.99	$9.99

Power Management

- The system will be powered by a 12 Volt 7200 mAh battery.
- The 12 Volts will power the PDLC film and LED Lights
- The 5 Volt Regulator and 3.3 Volt Regulator will step down the 12 Volts from the battery into manageable power for the other electronics.
- Solar panel will provide charging to the battery while on the go.

Type	Lead Acid	Nickel-cadmium	Nickel–metal hydride	Lithium-ion	Lithium-ion polymer
Specific Energy Density (Wh/kg)	30-50	45-80	60-120	100-265	90-190
Life Cycle (80% discharge)	200-300	1000	300-500	2000	500-2000
Fast Charge	8-16 hours	~1 hour	2-4 hours	Less than 1 hour	Less than 4 hours
Cell Voltage	2 V	1.2 V	1.2 V	3.7 V	3.3 - 3.6 V

Microcontrollers

- Chosen microcontroller is the ESP32-WROOM-32E on the HUZZAH32 breakout board
- Cheap and allows for potential upgrades in the future
- Allows for easy testing before creating final product

Description	ESP32	STM32	MSP430FR6989	ATmega4809
Architecture	32-bit	32-bit	16-bit	8-bit
Integrated Development Environment	Arduino	Eclipse and GCC		AVR Studio
Bluetooth	Dual Mode Bluetooth (Classic and BLE)	Bluetooth 5	n/a	n/a
Wi-Fi	802.11 b/g/n ~2.4 MHz	n/a	n/a	n/a
Microprocessor Speed	240 MHz	80 MHz	16 MHz	20 MHz
Voltage Supply	3 V ~ 3.6 V	1.71 V ~ 3.6 V	1.8 V ~ 3.6 V	1.8 V ~ 5.5V
Operating Temperature	-40°C ~ 105°C	-40°C ~ 85°C	-40°C ~ 85°C	-40°C ~ 125°C
Memory Type	4 MB, Flash	1 MB, Flash	128 kB, FRAM	48 kB, Flash
ROM	448 kB	n/a	n/a	256 kB
SRAM	536 kB	256 KB	2 kB	6 kB
I/O	48	72	63	41
Costs	$13.50	$42.88	$20.00	$20.89

Difficulties and Successes

Difficulties

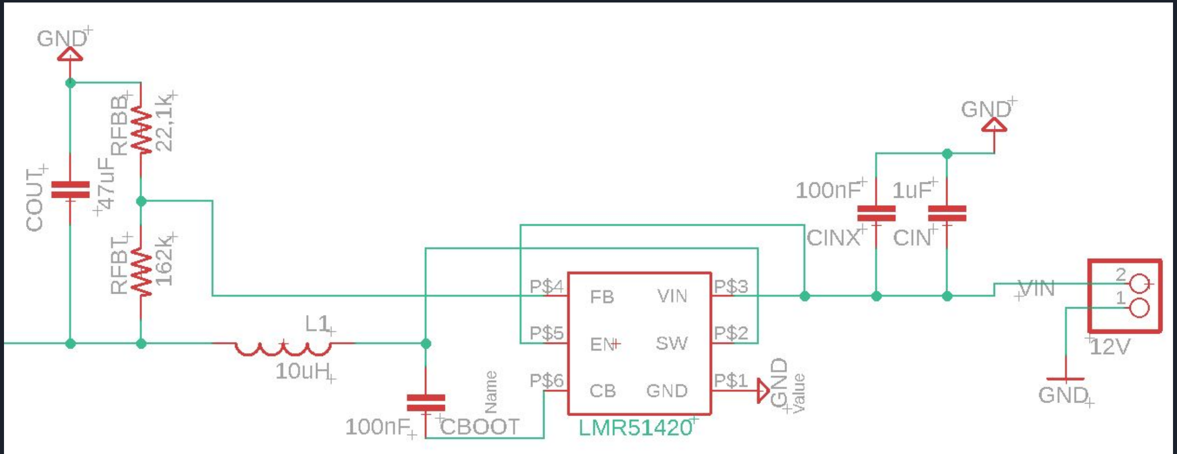
- Learning to operate other programs
- Working around everyone’s schedule
- Certain parts took longer to test compared to others
- Design layout to make sure all the parts can fit with all the wiring and sensors

Successes

- Completing work on the project in a timely manner
- Acquiring skills with new technologies
- Created a working project

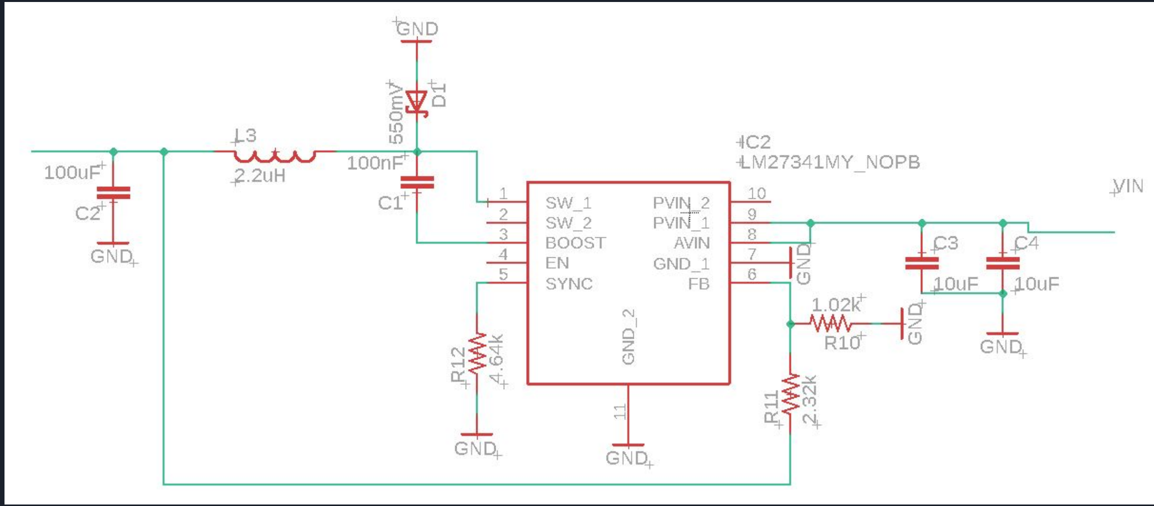
Electrical Schematic/PCB

5V Voltage Regulator



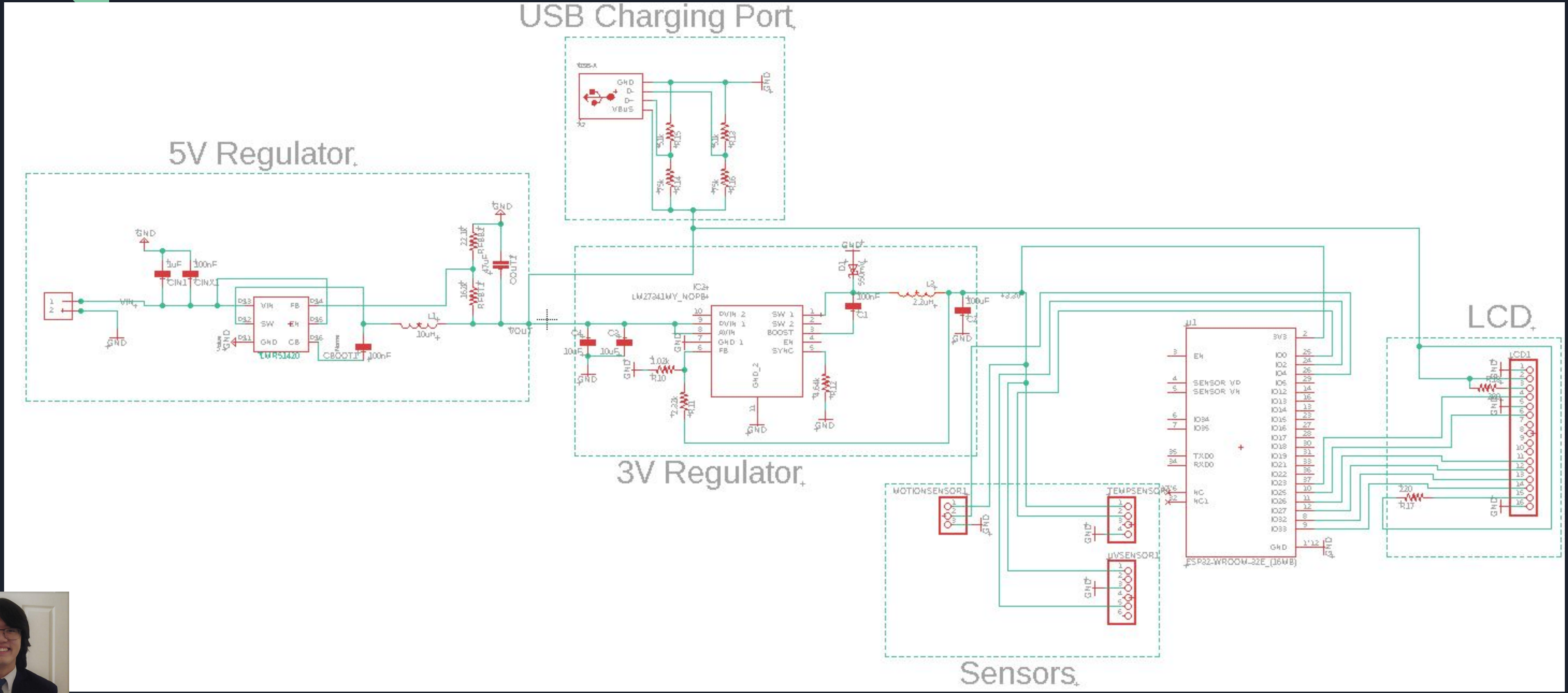
- Schematic of 5V Voltage Regulator
- Using the LMR51420 Part
- Design with assistance of TI-WEBENCH
- Purpose is to power USB-A charging port
- Around 93.3% Efficiency

3.3V Voltage Regulator

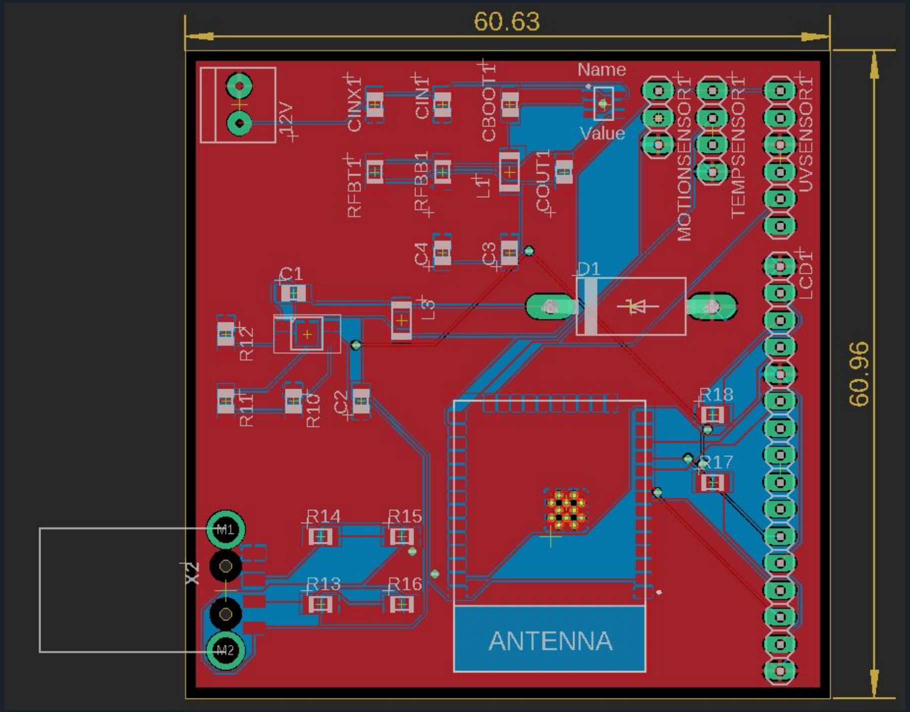


- Schematic of 3.3V Voltage Regulator
- Using the LM27341MY_NOPB Part
- Design with assistance of TI-WEBENCH
- Purpose is to power the ESP32

Overall Schematic



PCB Design


60.63
60.96
12V
CINX1
CIN1
CBOOT1
Name
Value
RFBT1
RFBB1
L1
COUT1
MOTIONSENSOR1
TEMPSENSOR1
UVSENSOR1
C4
C3
C1
D1
L3
LCD1
R12
R11
R10
C2
R18
R17
R14
R15
R13
R16
M1
M2
X2
ANTENNA

Circuit Design Successes and Difficulties

Difficulties

- Footprint building for voltage regulators
- Proper connections to the microcontroller
- Testing voltage regulators
- Soldering components

Successes

- Functioning electrical components
- Solar Panel generates an acceptable amount of energy
- No issues with power

Software/Programming

Arduino IDE

- C/C++
- Program the ESP32 Huzzah (Supported by Adafruit ESP32 Feather on Arduino)
- Testing components and prototyping
- Intuitive application/ease of use
- Support from a wide range of libraries

Software	Arduino IDE	PlatformIO	Eclipse
Simple single-file application development?	Yes	No	No
Full-featured C/C++ IDE?	No	Yes	Yes
Requires plugin?	No	No	Yes

SolidWorks

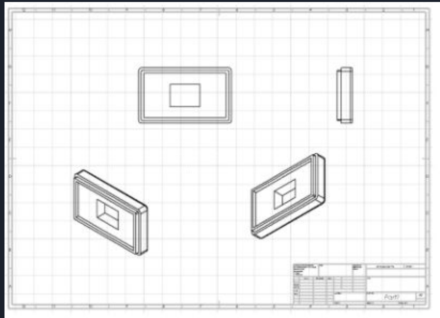


Figure 33: Schematic of Version 1 Lid Design

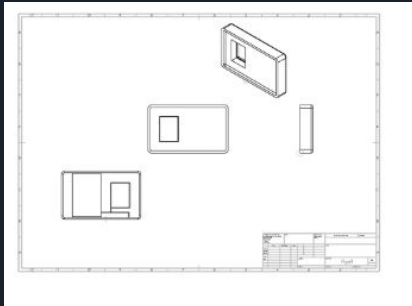


Figure 34: Schematic of Version 2 Lid Design

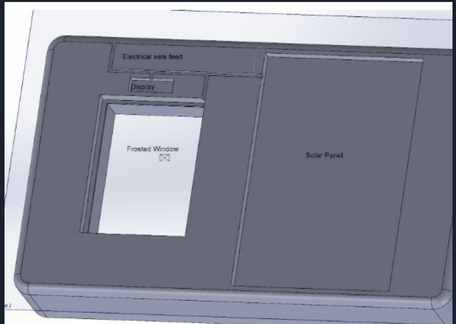


Figure 35: 3D CAD Model of Version 2 Lid Design

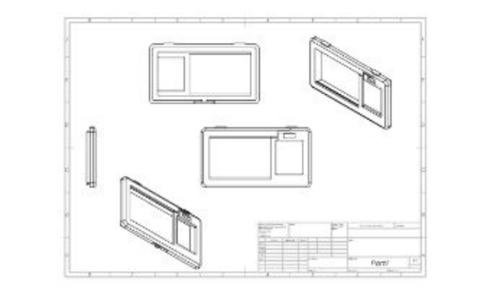


Figure 36: Schematic of Version 3 Lid Design

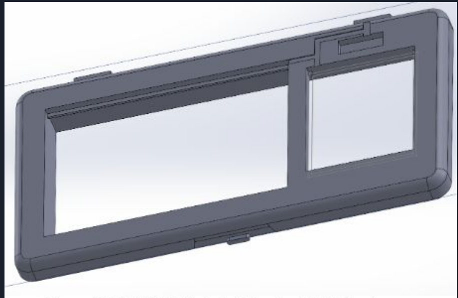
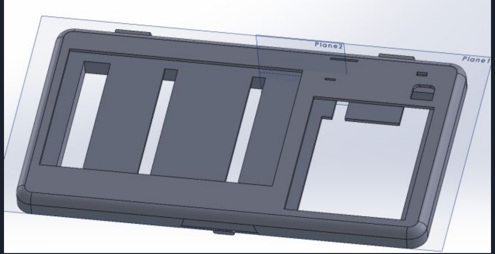


Figure 37: 3D CAD Model of Version 3 Lid Design



Administrative Content

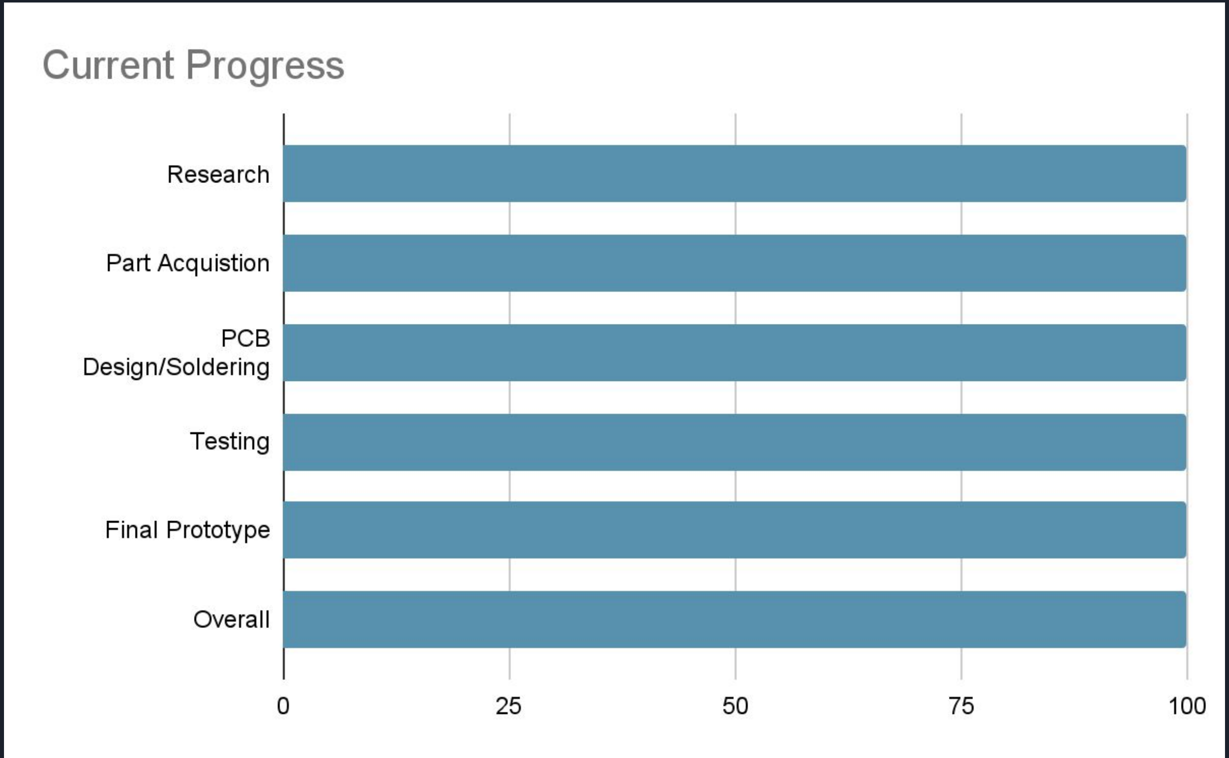
Budget

Item	Supplier	Price/Unit	# Units	Total Cost
Coleman 48 Quart Cooler	Amazon	$34.99	1	$34.99
LED Strip Lights	Amazon	$12.66	31	$12.66
10 Watt 12 Volt Monocrystalline Solar Panel	Amazon	$32.99	1	$32.99
PDLC Switchable Smart Film	Amazon	$35.99	1	$35.99
Adafruit HUZZAH32 – ESP32 Breakout Board	Adafruit	$13.50	1	$13.50
12-Volt 7 Ah Sealed Lead Acid (SLA) Rechargeable Battery	Home Depot	$23.32	1	$23.32
DHT22 Digital Temperature and Humidity Sensor	Amazon	$10.35	4	$41.40
LTR390 UV Sensor	Adafruit	$4.95	4	$19.80
USB-A UJ2-AV-1-TH	Digikey	$0.70	4	$2.80
PIR Human Sensor Module	Amazon	$9.04	1	$9.04

Budget Continued

Item	Supplier	Price/Unit	# Units	Total Cost
Step-Up Voltage Regulator	Amazon	$10.64	1	$10.64
Battery Snap pre-connected to a Micro Push-button Switch	Amazon	$2.75	4	$11.00
LCD1602 Module	Amazon	$7.99	1	$7.99
3.3 and 5 Volt Regulators	Amazon	$2.06	10	$20.64
Push-button Switch	Digikey	$3.06	3	$12.25
PCB	OSH Park	$39.55	3	$39.55
PCB Electronics	Amazon	$39.55	3	$39.55
Pink Insulation Foam	Amazon	$3.19	4	$12.77
Step-down Voltage Regulator	Amazon	$1.95	6	$11.70
Total				**$392.58**

Current Progress



Work Distribution

Project Aspect	Software	PCB Design and Testing	Power Delivery and Circuit Assembly	Administrative Content
Thomas Huynh		Primary		
Chanxay Bounheuangviseth	Primary			
Matthew Schmit			Primary	
Michael Villarante				Primary

Conclusion