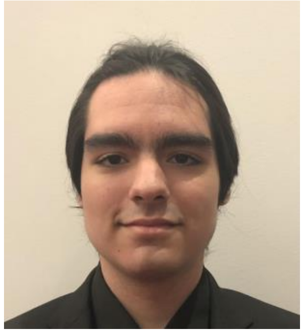
Automated Pet Door with LED Collar

Group 21 (C) - Spring/Fall 2024

Group Members



Daniel Hemmerde
College of Electrical Engineering (EE)

Davis Rozel
College of Electrical Engineering (EE)

Christopher Vanle
College of Optics and Photonics (PSE)

Christopher Vanle

Motivation and Background

Motivation

- Give our pets a way back in the house
- Protection from the rain after their adventures
- Owners do not have to physically let them in (stay comfortable in bed)
- Owners do not have to be home

Background

- Pets can be left alone at home for 8+ hours
- Pets can be stuck outside, hiding under cars to stay out of the rain
- Cat doors that utilize microchips can cost upwards to $250
- Using IR LEDs is cheaper, and does not require paying for microchipping

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Goals and Objectives

Basic Goals

- Initial step that will turn on our system
- Collar to function as a key to prevent rodents
- A way to verify pet passed through the door or still in the doorway

Advance Goal

- Improvement to the initial step to prevent randomly turning on our system

Stretch Goals

- Security feature for the owner, such as a camera just in case of system failure
- Improved “key” code

Basic Objectives

- IR motion sensor as initial step to detect our pet and turn on our system
- IR LEDs (940 nm) on collar to communicate with the cat door to open
- IR LEDs and photodiodes to verify when the pet has passed or is still in the doorway

Advance Objective

- Use an active IR motion sensor, relying on reflection of radiation from the emitter

Stretch Objectives

- Live camera on the door that can be viewed from computer/app
- Randomized communication to improve

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Subsystem Specifications

Subsystem	Parameter	Specification
Motion Sensor	Maximum Response Time	< 3 ms
	Range	0 < x ≤ 3 meters
	Detection Reliability *	~ 90%
Power Supply	Maximum power usage while offline	< 100 milliwatts
	Maximum power usage while online	< 10 watts
Microcontroller	Time Before Door Closes(Cat Enters)	10 Seconds
	Time Before Door Closes(Cat Leaves)	60 seconds
IR LEDs	Collar Weight	< 100 grams
Collar Battery	Battery Life *	~ 8 hours

Component Spec.

Component	Parameter	Specification
IR LED	Voltage	1.2 V < V < 3 V
IR Photodiode	Detection Range	0 < x < 1 m
Fresnel Lens	Focal Length	0 < f < 50 mm
Solar Panels	Power Generated Under Ideal Conditions	500mW < p < 1500mW
DC Motor	Power Draw	1W < P < 2W
Main Microcontroller	Operating Voltage	3 V < V < 3.6 V
Collar Microcontroller	Operating Voltage	2.7 V < V < 5.5 V
Door battery	Capacity	~12Wh
Collar Battery	Capacity	~0.9Wh

*Note: Subsystem Spec. changed from Collar Battery Life to Motion Sensor Detection Reliability

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Comparison: Door Opening Mechanism

Door Design	Flap	Vertical Sliding	Rolling Shutter
Ease of Use	Hardest	Easiest	Middle
Simplicity	Simplest	Middle	Most Complex
Cost	Cheapest	Middle	Most Expensive
Noise	Least	Middle	Loudest
Space	Least	Largest	Middle
Is Automatic?	No	Yes	Yes
Security	Least	Most	Middle

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Comparison: Door Material

Properties	Plywood	PVC (extruded)	Acrylic (extruded)	Polycarbonate (extruded)
Tensile Strength (Yield) (MPa)	N/A	14.8 – 57.4 (average 42.4)	44.9 – 86.0 (average 68.9)	39.0 – 120 (average 65.9)
Tensile Strength (Ultimate) (MPa)	27.6 – 34.5	0.00123 – 60.8 (average 23.9)	29.0 – 75.0 (average 57.7)	28.0 – 75.0 (average 65.9)
Density (g/cm^3)	0.4 – 0.75	1.13 – 1.85	0.942 – 1.19	1.03 – 1.26
Temperature Range	-184° C - 93° C	0° C – 60° C	-34.4° C – 82.2° C	-40° C – 137.8° C
Continuous Weather Exposure	No	Yes but not in cold	Yes	Yes but susceptible to yellowing due to UV exposure
Cost Comparison	Lowest	Low	High	Highest

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Comparison: Motor Technologies

Motor Type	DC Motor (Brushed)	DC Motor (Brushless)	AC Motor
Power Efficiency	Middle	Highest	Lowest
Variable Load	Lowest	Lowest	Highest
Control Circuitry	Simplest	Complex	Complex
Heat Dissipation	Middle	Best	Worst
Average Lifespan	Lowest	Highest	Highest
Required Maintenance	Medium	Low	Medium
Speed Control	Middle	Best	Worst
Cost	Middle	Highest	Lowest

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Comparison: DC Motors

Specifications	BRINGSMART	CHANCS	STEPPERONLINE
Rated Current	0.5 A	0.33 A	0.6 A
Output Power (W)	3 W	2 W	3.6 W
No-Load Current (mA)	60 mA	20 mA	100 mA
Rated Torque (Nm)	0.441 Nm	0.588 Nm	0.392 Nm
RPM	40 RPM	60 RPM	50 RPM
Shaft Diameter (mm)	6 mm	7 mm	6 mm
Shaft Length (mm)	15 mm	15 mm	15.5 mm
Cost	$14.99	$12.90	$7.01 ($15.11 with shipping)

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Comparison: Microcontrollers

MCU	ATmega328	ATxmega64A4U	ATxmega128A4U	PIC24FJ128GA006	ESP-WROOM-32D
Max Clock Speed	20 MHz	32 MHz	32 MHz	16 MHz	240 MHz
Flash Memory	32 KB	64 KB	128 KB	128 KB	4 MB
RAM	2 KB	4 KB	8 KB	8 KB	520 KB
EEPROM	1 KB	2 KB	2 KB	N/A	N/A
Pin Count	23	44	44	64	34
Bit Size	8-bit	8/16-bit	8/16-bit	16-bit	32-bit
Recommended Operation Voltage	1.8V - 5.5V	1.6V - 3.6V	1.6V - 3.6V	2.5V - 3.6V	3.0V - 3.6V
Low Power Mode Current	0.9 µA @ 3V	1.4 µA @ 3V	1.4 µA @ 3V	27 µA @ 3.3V	5 µA - 150 µA
Active Mode Power Consumption	5.2 mA @ 8 MHz	8.2 mA @ 32 MHz	9.5 mA @ 32 MHz	32 mA @ 16 MHz & 3.3V	20 mA - 31 mA @ 80 MHz with RF disabled
Availability of Programming Tool	Limited	Limited	Limited	Middle	High
Cost	$2.63	$5.13	$6.18	$4.80	$9.99

MCU	ATtiny85	ATtiny212	ATtiny402	MSP430G2230-EP
Max Clock Speed	20 MHz	16 MHz	20 MHz	16 MHz
Flash Memory	8 KB	2 KB	4 KB	2 KB
RAM	512 B	128 B	256 B	128 B
EEPROM	512 B	64 B	128 B	N/A
Pin Count	8	8	8	4
Bit Size	8-bit	8-bit	8-bit	16-bit
Recommended Operation Voltage	2.7V - 5.5V	2.7V - 5.5V	1.8V - 5.5V	2.2V - 3.6V
Idle Current	0.1 µA (power down mode, no clocks running)	4 µA @ 32.768 kHz & 3V	4 µA @ 32.768 kHz	0.5 µA in LPM3 (only ACLK clock enabled) & 2.2V
Active Mode Power Consumption	300 µA @ 1 MHz, 1.8 V	11 µA @ 32.768 kHz & 3V	10 µA @ 32.768 kHz & 3V	300 µA @ 1 MHz & 3V
Cost	$1.66	$0.55	$0.54	$1.95

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LEDs vs Laser Diodes

Light Source	**Power Consumptio n**	**Weight**	**Cost**	**Example**
IR LED	70 mW	9 grams	< $1	Gikfun 5mm 940nm LEDs IR Emitter and Receiver EK844
Laser Diode	100 mW	14 grams	< $1	HiLetgo 10pcs 5V 650nm 5mW Red Dot Laser Head

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Comparison: IR LEDs and Photodiodes

IR LEDs (Emitter)			
	Amazon Gikfun 5mm 940nm LEDs IR Emitter and Receiver EK844	Thorlabs LED940E – 940 nm Epoxy-Encased LED	Adafruit Super-bright 5mm IR LED – 940nm
Cost (per)	$0.31 per emit.	$2.73 per emit.	1-9 $0.75 10-99 $0.68 per emit.
Power Consumption	Max 70 mW	Max 140 mW	Max 150 mW
Forward Voltage	1.4 V	1.45 V	1.4 V
Transmitting Angle (Half-Angle)	40 degrees	10 degrees	10 degrees
Transmitting/Receiving Distance	7-8 m	-	-
Item Weight	8.96 g	13.61 g	-
Dimensions	53.3 mm L x 5 mm W 5mm diameter	35 mm L x 5 mm W 5 mm diameter	35 mm L x 5 mm W 5 mm diameter

Receiver			
	Amazon Gikfun 5mm 940nm Photodetector EK844	Thorlabs FDS100 – Si Photodiode, 10 ns Rise Time, 350 – 1100 nm	Adafruit IR Photodetector Sensor – TSOP38238
Wavelength	940 nm	350 – 1100 nm 980 nm peak	940 nm
Cost (per)	$0.31 per receiv.	$16.40 per	1-9 $1.95 10-49 $1.76 per receiv.
Power Consumption	Max 70 mW	Max 125 mW	10 mW
Forward Voltage	1.4 V	(Max Reverse) 25 V	2.5 V
Receiving Angle (Half-Angle)	40 degrees	-	30 degrees
Transmitting/Receiving Distance	7-8 m	-	45 m
Item Weight	8.96 g	4.54 g	0.43 g
Dimensions	53.3 mm L x 5 mm W 5mm diameter	41.6 mm L x 8.3 mm W Active Area 9.36 mm^2	30.5 mm L x 5 mm W 5mm thick

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Comparison: Motion Sensors

Sensor	Detection Method	Distance	Cost	Example
Infrared	Light Waves	< 8 m	< $1	Gikfun 5mm 940nm LEDs IR Emitter and Receiver EK8443
LiDar	Light Waves	< 8 m	$25	MakerFocus LiDar Range Finder Sensor
Ultrasonic	Ultrasonic Waves	< 5 m	< $2	Smraza Ultrasonic Module HC-SR04
Radar	Radio Waves	< 7 m	$3.50	Radar Sensor RCWL-9196

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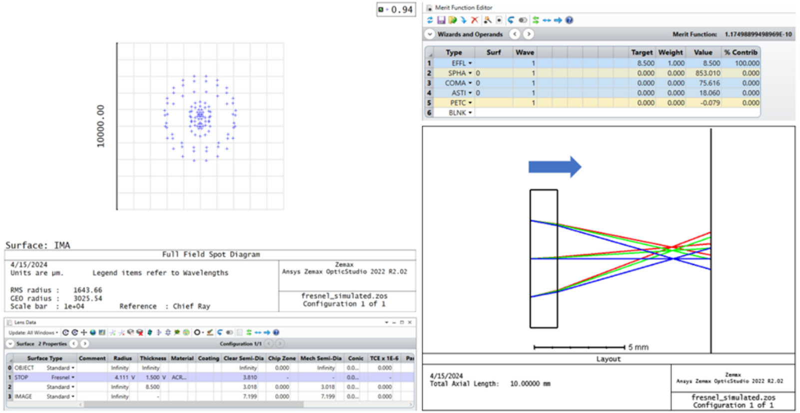
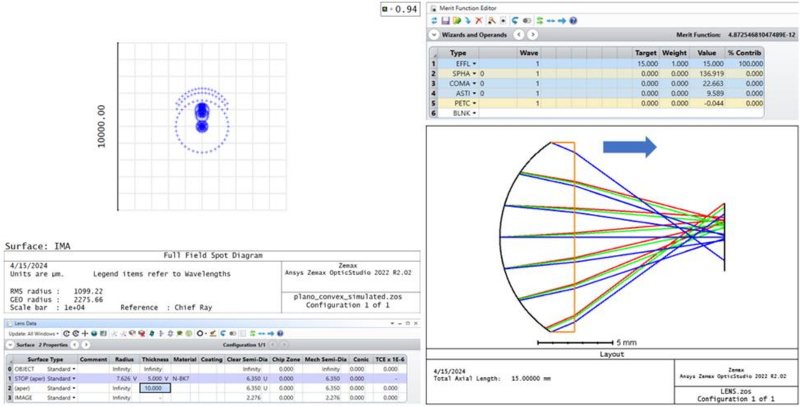
Comparison: Focusing Lens

Focusing Lens			
	Amazon FUCAS Credit Card Size 300% Magnifying Lenses	Thorlabs FRP0510 Fresnel Lens	Thorlabs LA1540 Plano-Convex Lens
Cost	$0.40 each	$20.68 + 13.87 shipping	$25.18 + 13.87 shipping
Focal Length	~210 mm	10 mm	15 mm
Material	Plastic	Acrylic	N-BK7 glass
Dimensions	3.25" x 2" (Can be cut)	½" Diameter	½" Diameter

Fresnel Lens Simulation



Plano-Convex Lens Simulation



Comparison: Power Source

Source	Outlet	Disposable Battery	Solar
Location Convenience	Medium	Highest	High
Initial Cost	Lowest	Low	High
Post-Purchase cost	Low	Medium	Lowest
Charge Rate	High	N/A	Low
Maintenance Required	Lowest	High	Low
Efficiency	Low	High	High

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Comparison: Door Battery

Battery Chemistry	Lithium Ion	LiFePO4	NiMH	NiCd
Voltage	3.7V	3.2V	1.2V	1.2V
Amp-Hours	3400mAH	1500mAH	900mAH	1000mAH
Length	65mm	65mm	44.5mm	50mm
Diameter	18mm	18mm	10.5mm	14.2mm
Price	$7.95	$8.99	$2.79	$3.49
Maintenance required	No	No	Yes	Yes
Brand	MORNGC	Power Portable	Power Portable	Power Portable

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Comparison: Collar Battery

Battery	LIR2032	VL3032	LiFePO4 10440	⅔ AAA NiMH	LP502030
Brand	PK Cell	Panasonic	Power Portable	Power Portable	EEMB
Weight (g)	3.1	6.2	17	7	5
Length x Diameter (mm)	3.2 x 20	3.2 x 30	44 x 10	28 x 10	20.5 x 32 x 5.3(WxLxH)
Voltage	3.6V	3V	3.2V	1.2V	3.7V
Capacity (mAh)	40	100	300	320	250

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Comparison: Solar Panels

Solar Panel	Option 1	Option 2	Option 3
Current(mA)	1000	200	30
Dimensions(in)	6.89 x 4.76	4.33 x 2.36	2.08 x 1.18
Connector Type	USB C	None(wire must be soldered on)	Soldered Wire
Brand	YCTechCam	FellDen	AOSHIKE
Price Per Unit	$19.99	$2.10	$1.60

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Comparison: Solar Panel Manager

Brand	DFROBOT	xicoolee	waveshare
Accepted Input(V)	4.5 - 6	5 - 24	6 - 24
Output Voltage(V)	5	5/3.3	5
Output Current(A)	1	1.5(5V)/1(3.3V)	3
Price	$13.90	$12.95	$19.99

*Note: Solar Panel Manager will have its own PCB.

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Comparison: Wall Adapter

Brand	Arkare	EIKS	N\C
Maximum Current(A)	2	1	3
Connector options	Barrel, micro-usb, usb c, DC Terminal	Barrel	Barrel, DC Terminal
Price	$7.59	$8.59	$5.00

Comparison: Software Language

Programming Language	**C/C++**	**Python**
Use in Embedded Systems	More common	Less common
Processing Speed	Faster	Slower
Power Consumption	Less	More
Complexity	More	Less
Use of IDEs	Yes	No

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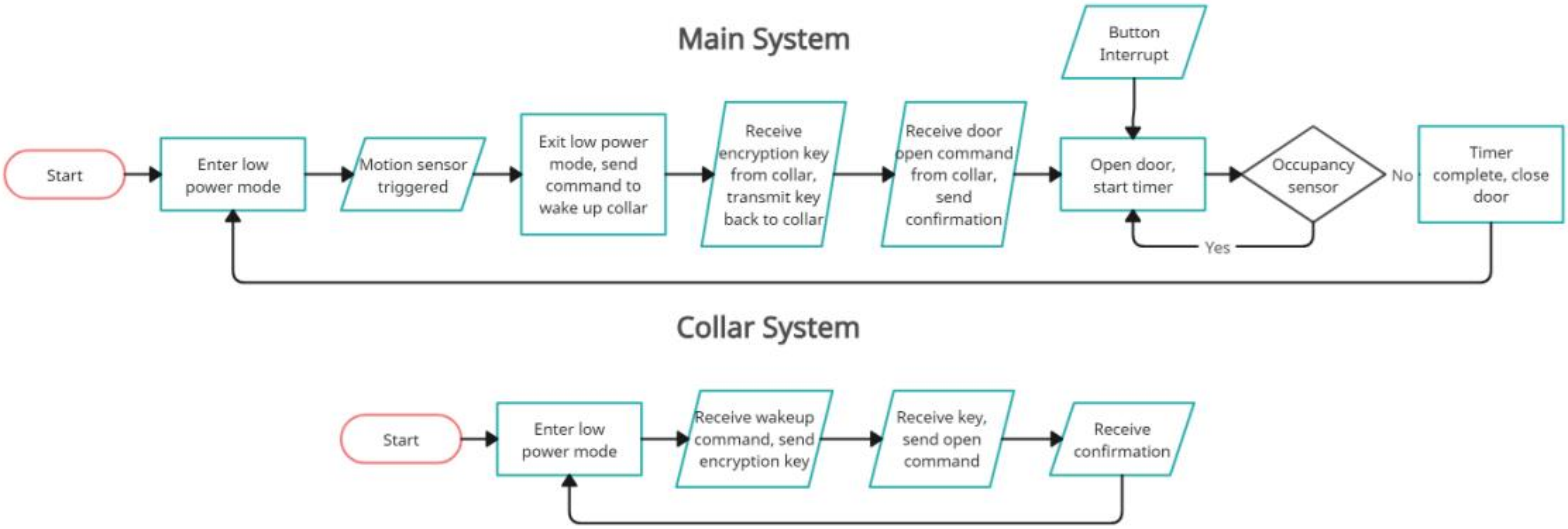
Software Flowchart



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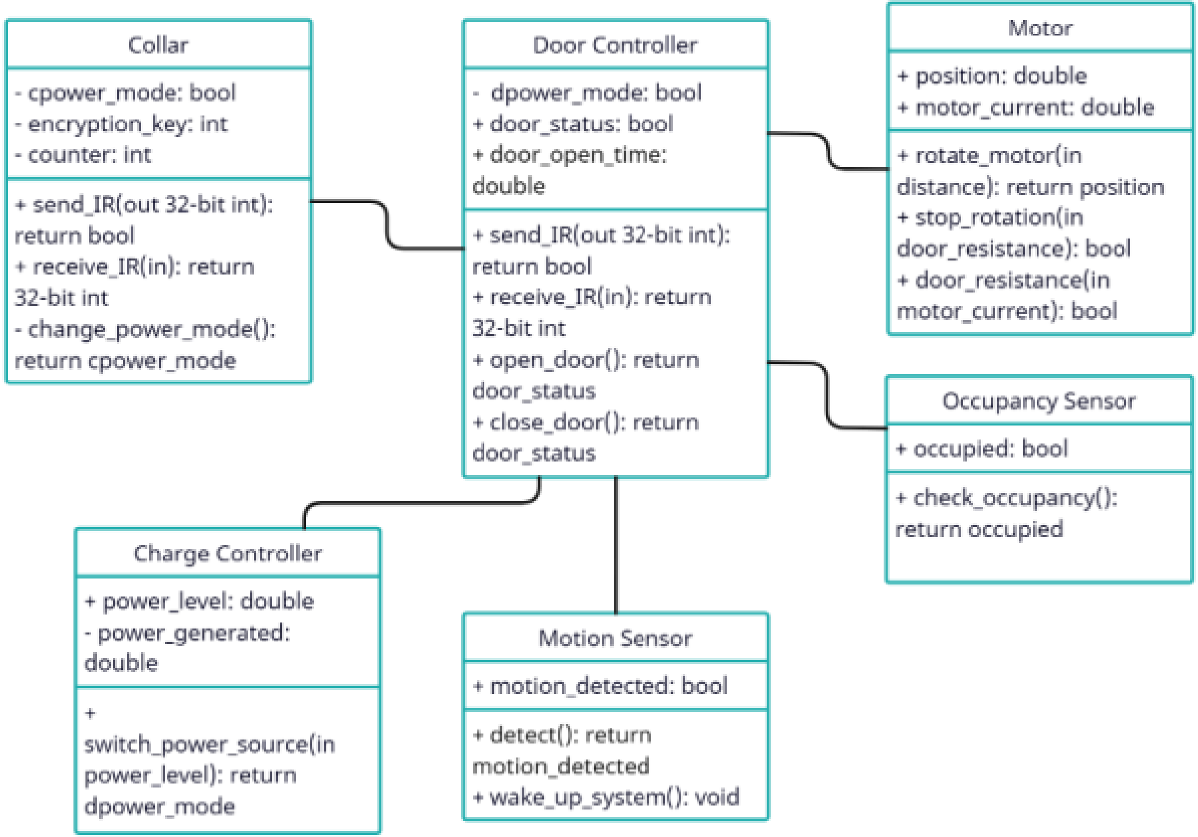
Class Diagram



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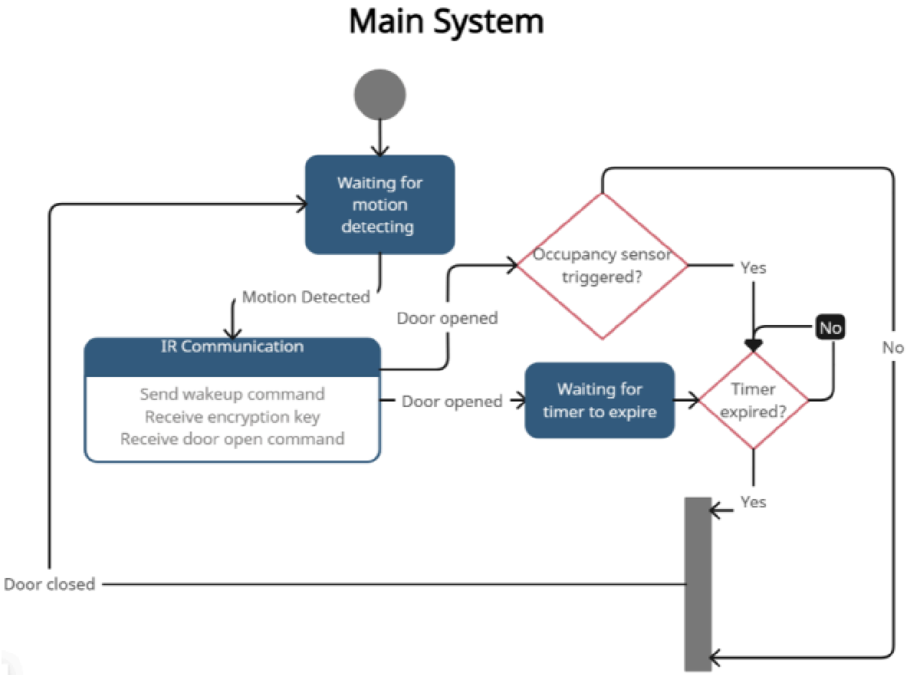
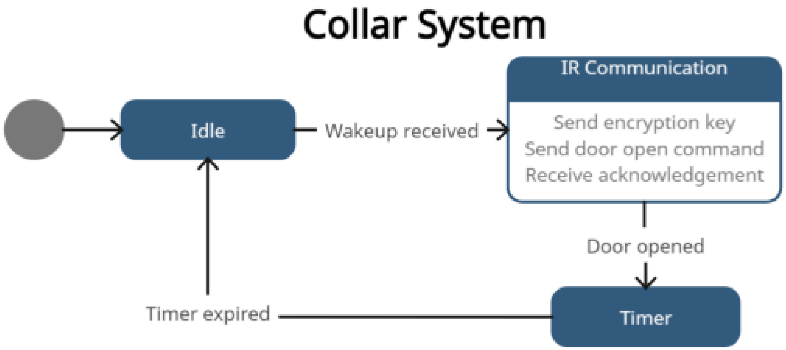
State Diagram





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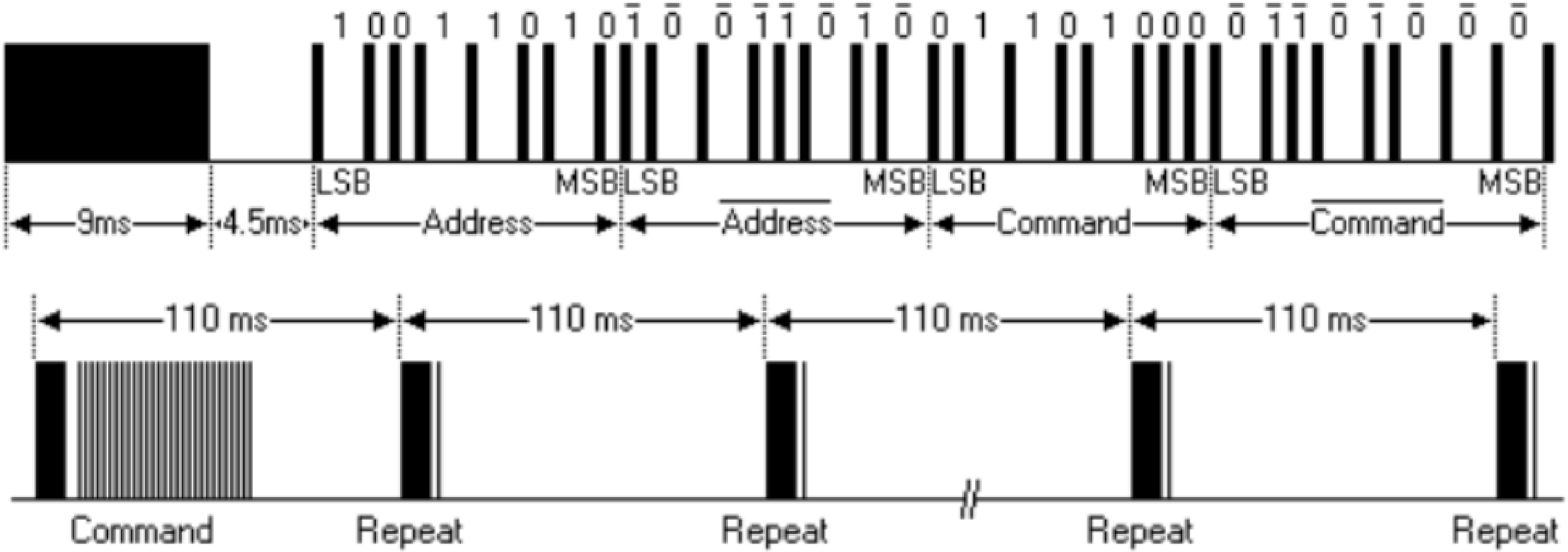
IR Communication



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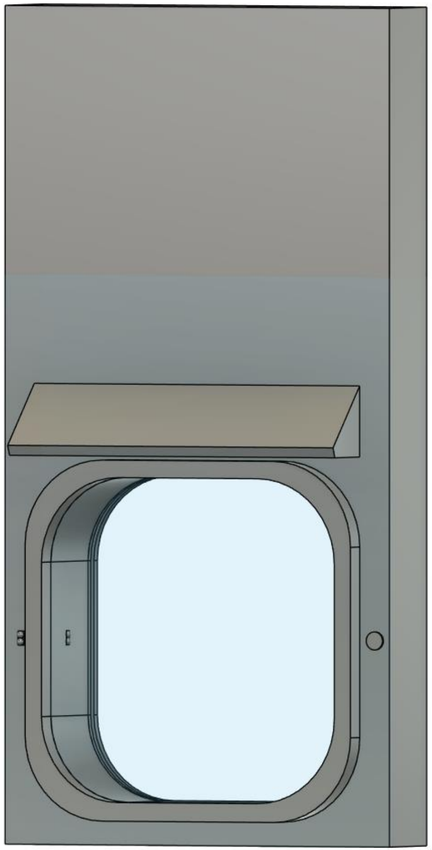
Door Frame Model

Material

- Frame material: Wood (free)
- Door material: acrylic

Dimensions

- Frame: 2’ x 1’
- Door opening: 9” x 9”



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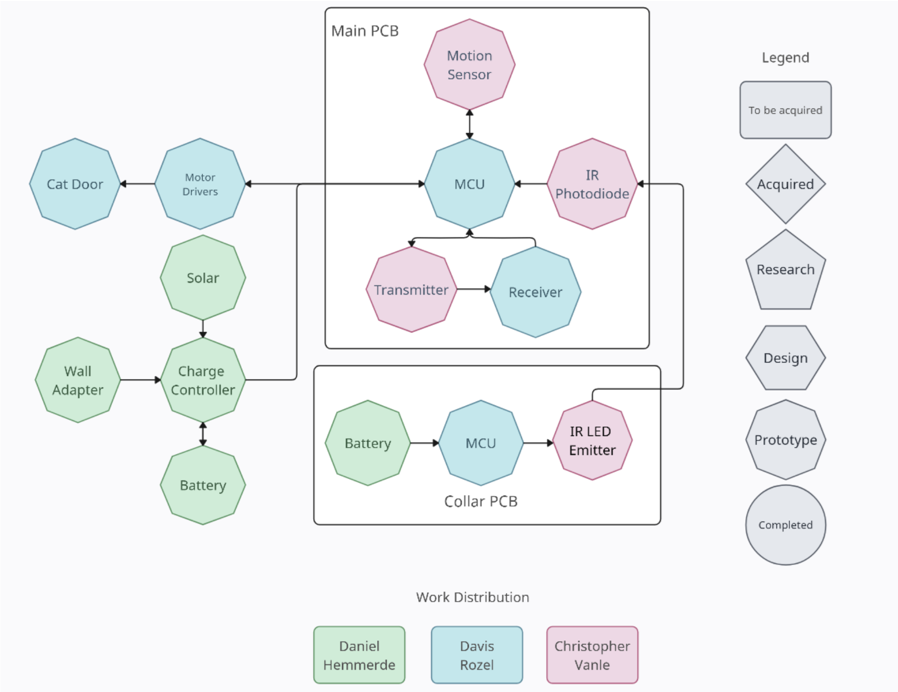
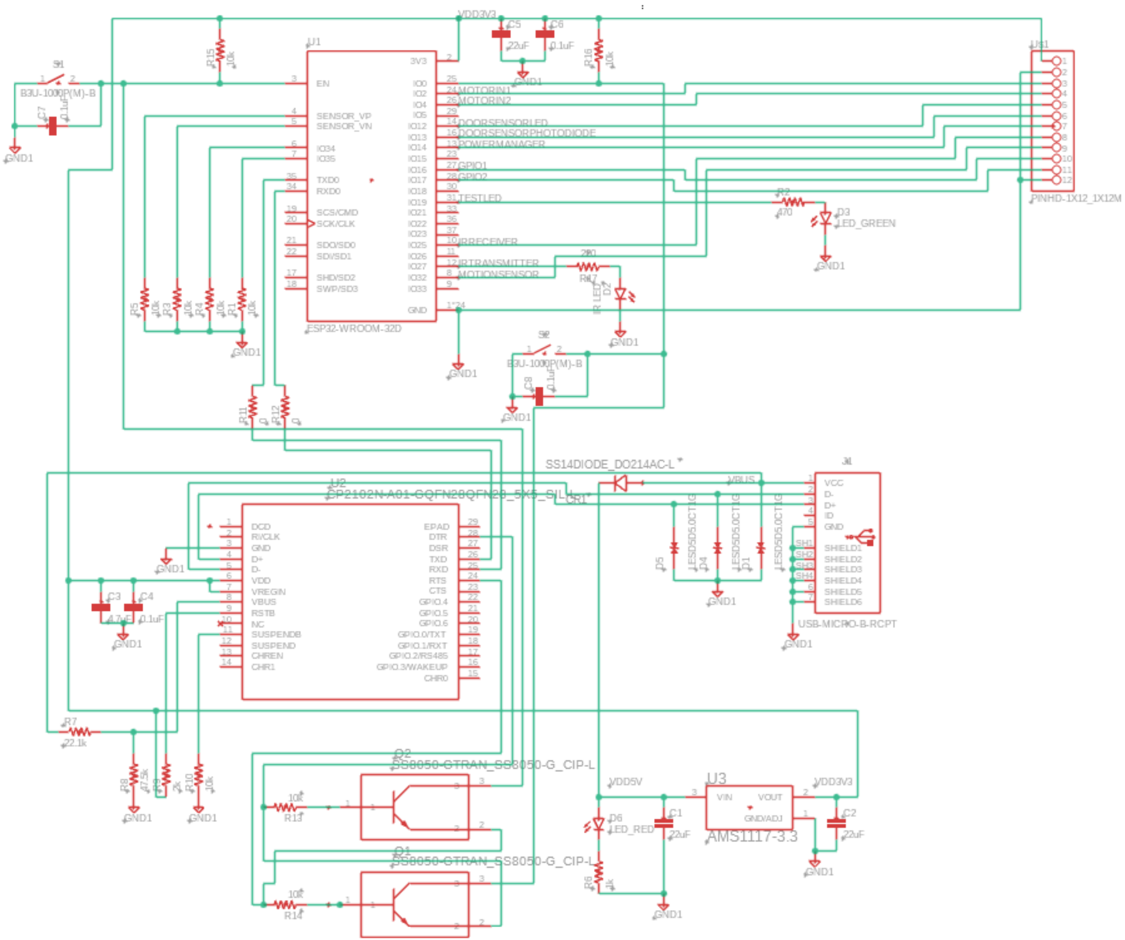
Hardware Block Design



Main Board


VDD3V3
C5
22uF
C6
0.1uF
GND1
R15
10k
R16
10k
U1
3V3
EN
SENSOR_VP
SENSOR_VN
IO34
IO35
TXD0
RXD0
SCS/CMD
SCK/CLK
SDO/SD0
SDI/SD1
SHD/SD2
SWP/SD3
GND
IO0
IO2
IO4
IO5
IO12
IO13
IO14
IO15
IO16
IO17
IO18
IO19
IO21
IO22
IO23
IO25
IO26
IO27
IO32
IO33
MOTORIN1
MOTORIN2
DOORSENSORLED
DOORSENSORPHOTODIODE
POWERMANAGER
GPIO1
GPIO2
TESTLED
IRRECEIVER
IRTRANSMITTER
MOTIONSENSOR
ESP32-WROOM-32D
S1
B3U-1000P(M)-B
C7
0.1uF
R5
R3
R4
R1
10k
R7
470
D3
LED_GREEN
R17
220
D2
IR LED
S2
B3U-1000P(M)-B
C8
0.1uF
R11
R12
0
U$1
PINHD-1X12_1X12M
SS14DIODE_DO214AC-L
VBUS
J1
VCC
D-
D+
ID
GND
SHIELD1
SHIELD2
SHIELD3
SHIELD4
SHIELD5
SHIELD6
USB-MICRO-B-RCPT
ESD5D5.0CT1G
D5
D4
D1
U2
CP2102N-A01-GQFN28QFN28_5X5_SIL
DCD
RI/CLK
GND
D+
D-
VDD
VREGIN
VBUS
RSTB
NC
SUSPENDB
SUSPEND
CHREN
CHR1
EPAD
DTR
DSR
TXD
RXD
RTS
CTS
GPIO.4
GPIO.5
GPIO.6
GPIO.0/TXT
GPIO.1/RXT
GPIO.2/RS485
GPIO.3/WAKEUP
CHR0
C3
4.7uF
C4
0.1uF
R7
22.1k
R8
47.5k
R9
2k
R10
10k
Q2
SS8050-GTRAN_SS8050-G_CIP-L
Q1
SS8050-GTRAN_SS8050-G_CIP-L
R13
R14
10k
VDD5V
D6
LED_RED
R6
1k
C1
22uF
U3
VIN
VOUT
GND/ADJ
AMS1117-3.3
VDD3V3
C2
22uF

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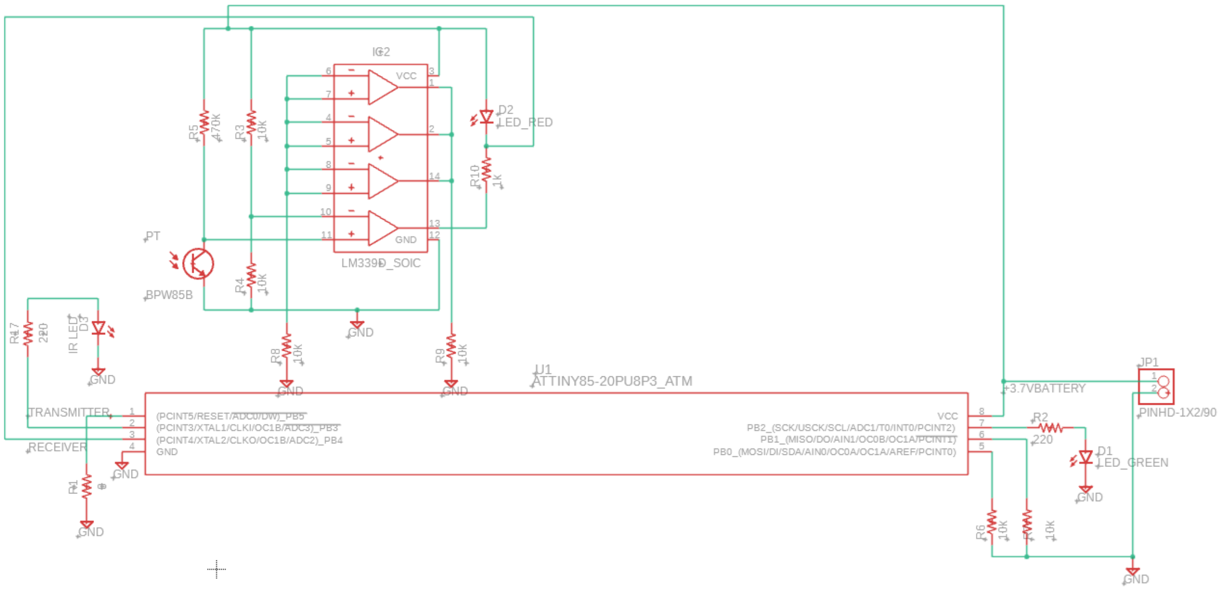
Collar Schematic



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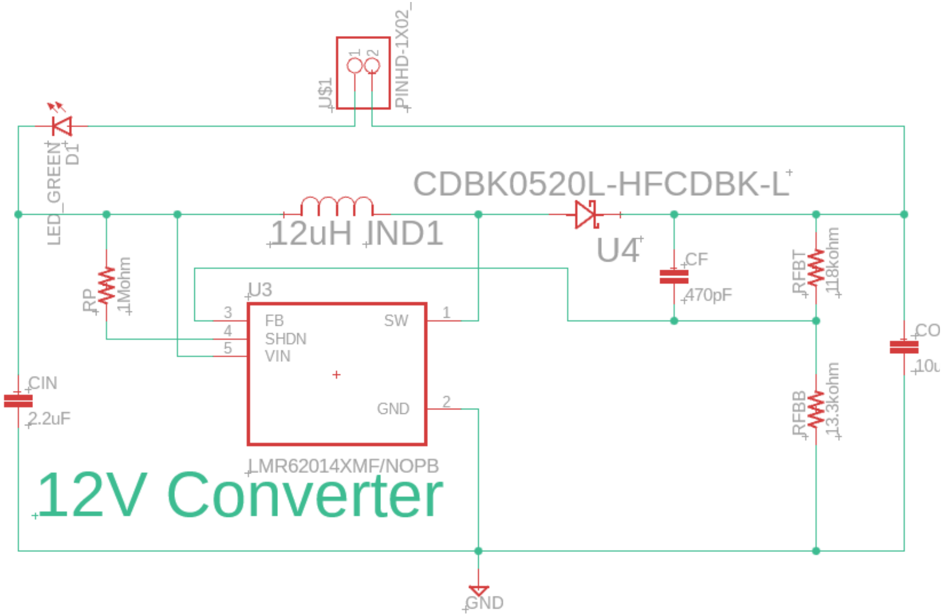
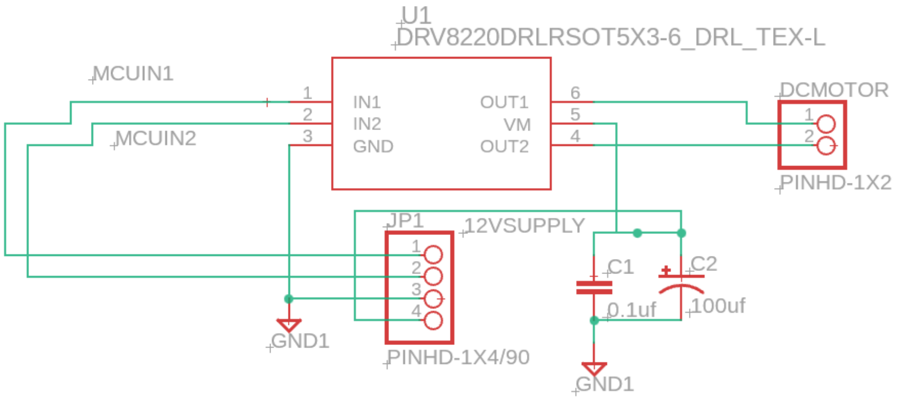
12v Converter



12v Motor Controller



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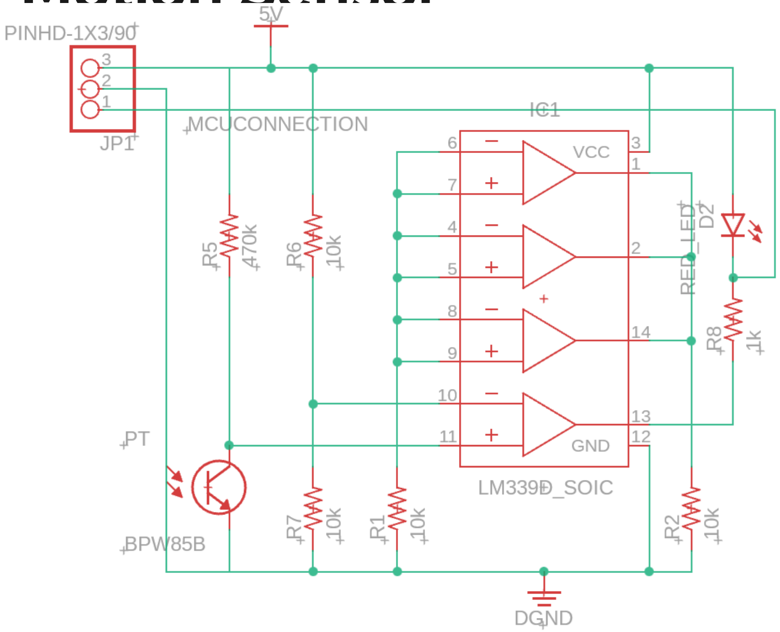
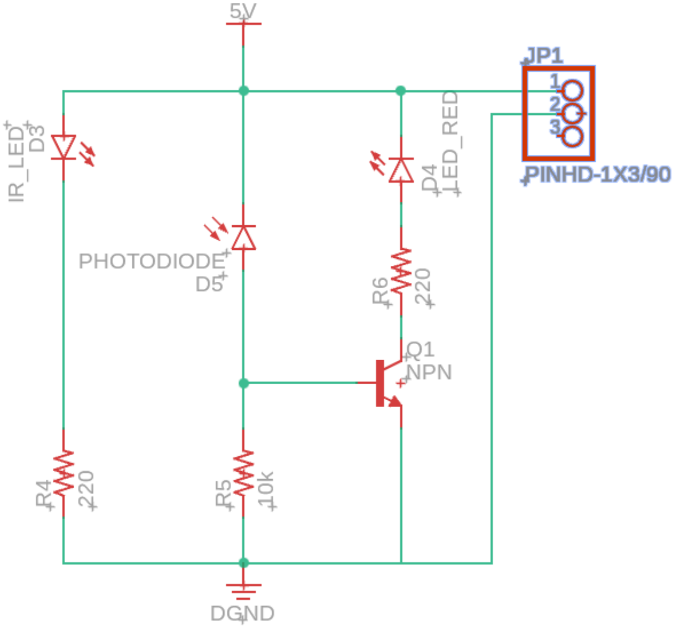
IR Receiver Motion Sensor





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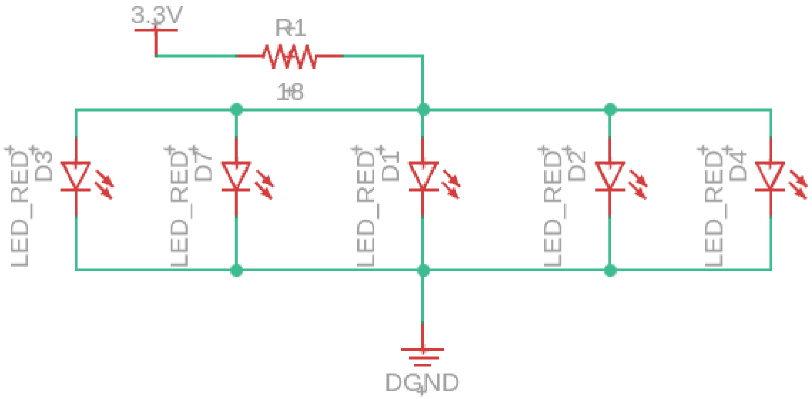
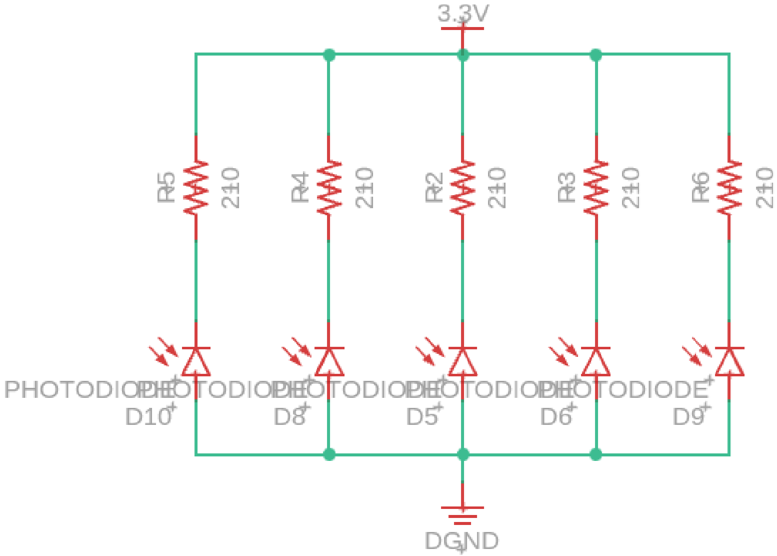
Occupancy Sensor





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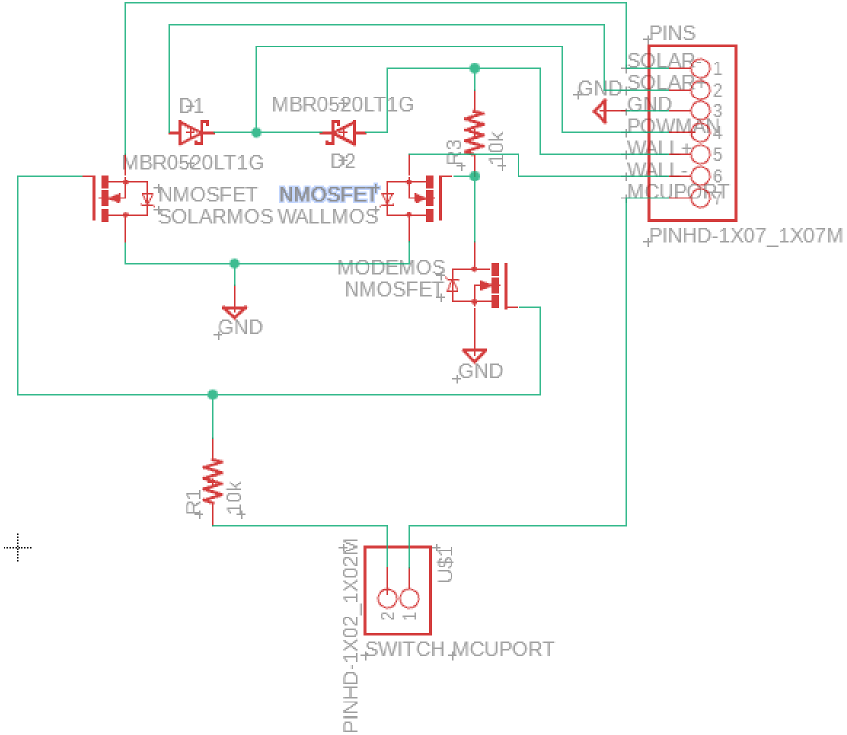
Battery Subsystem



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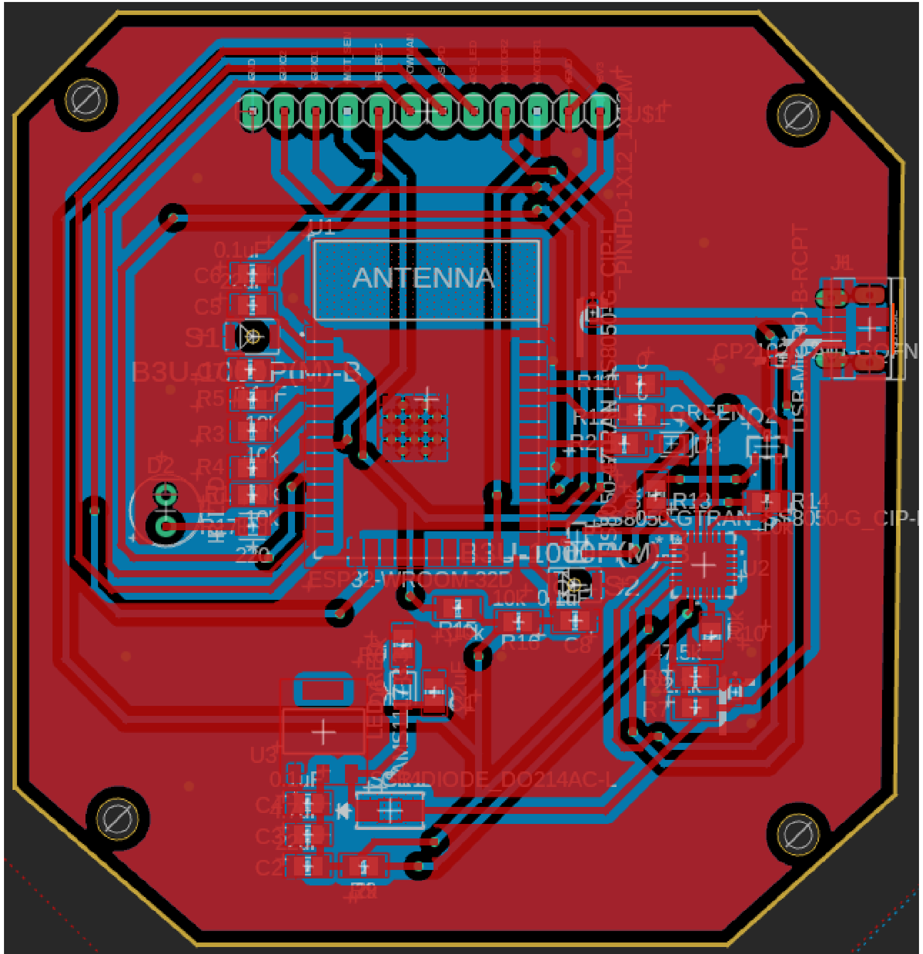
Main Board PCB



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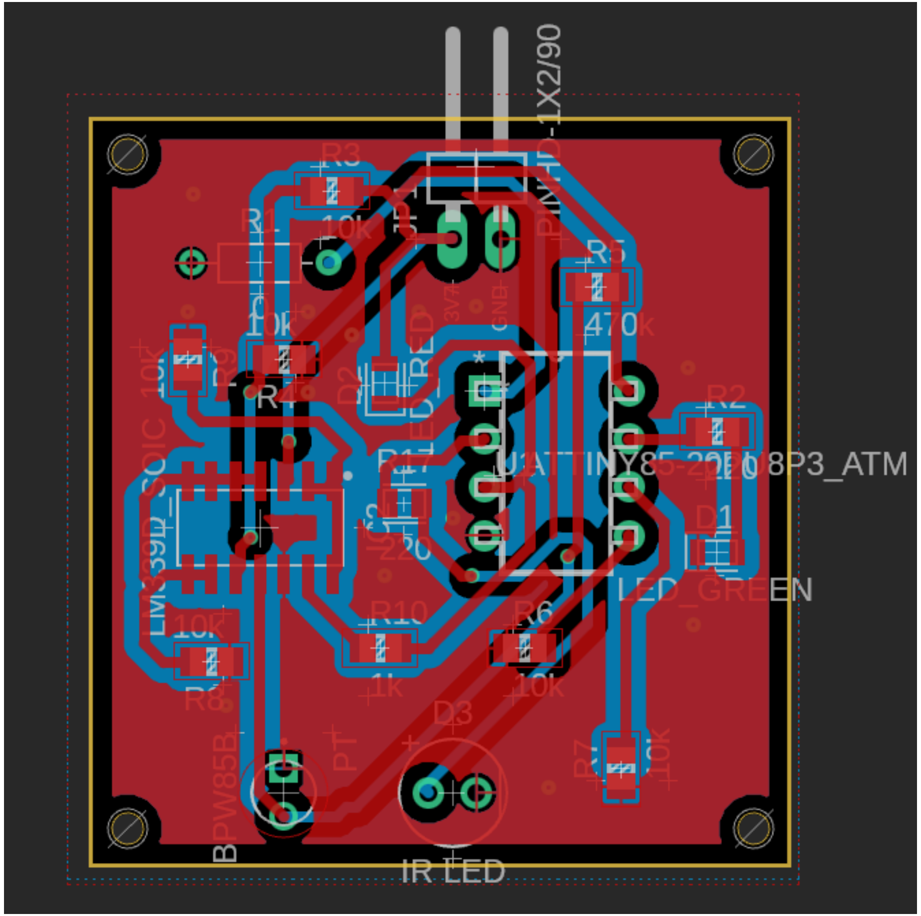
Collar PCB



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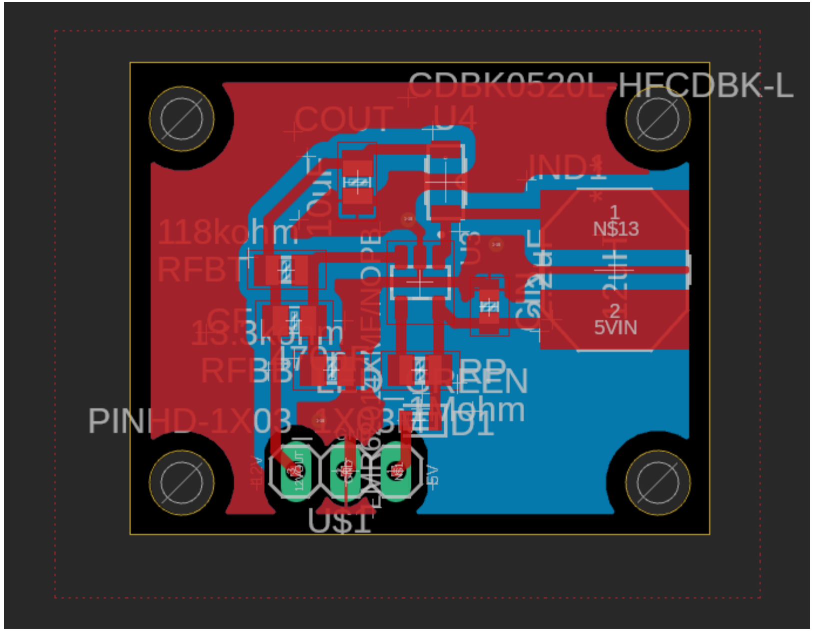
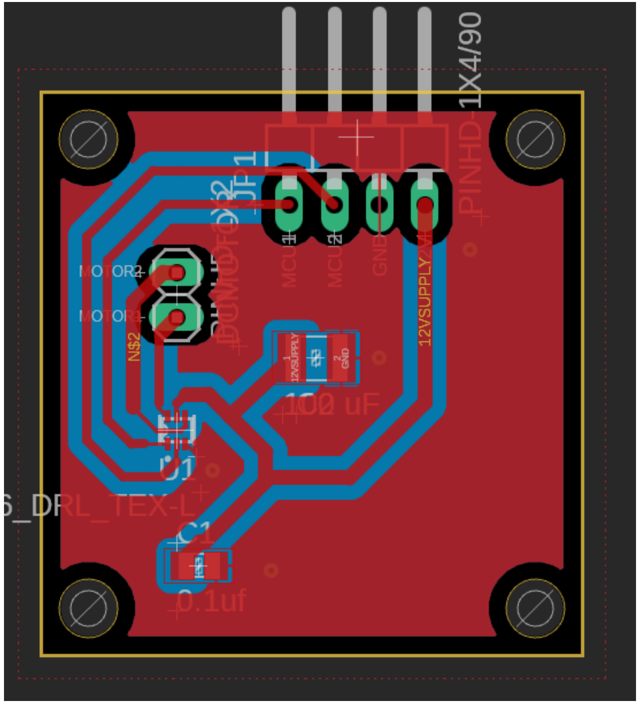
12v Converter



12v Motor Controller



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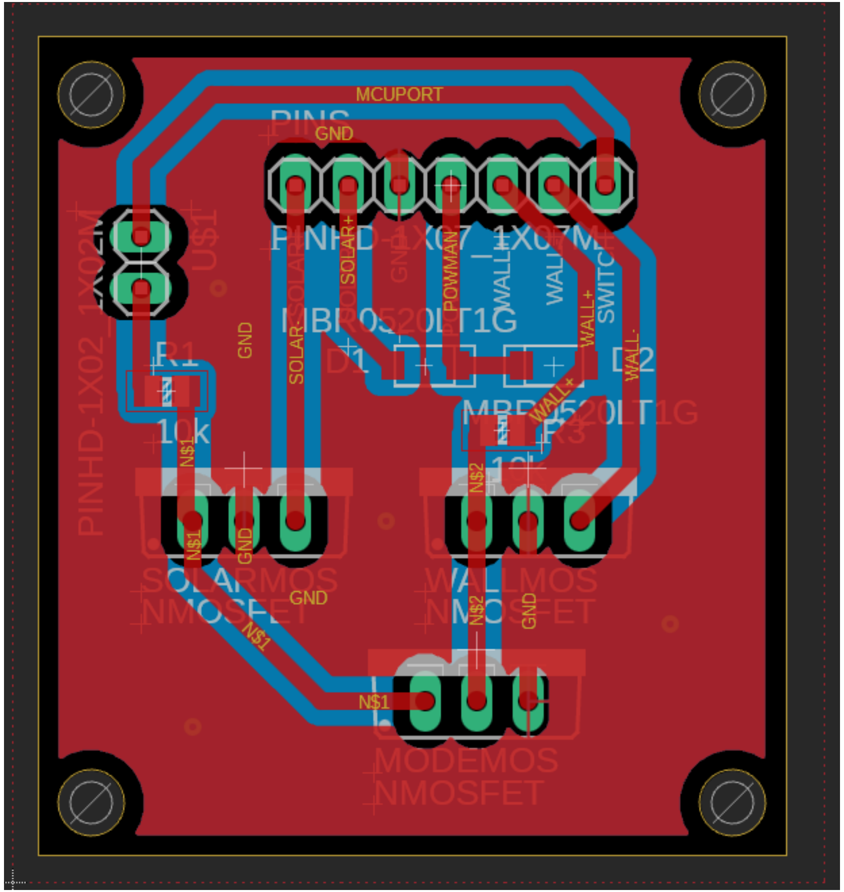
Battery Subsystem PCB



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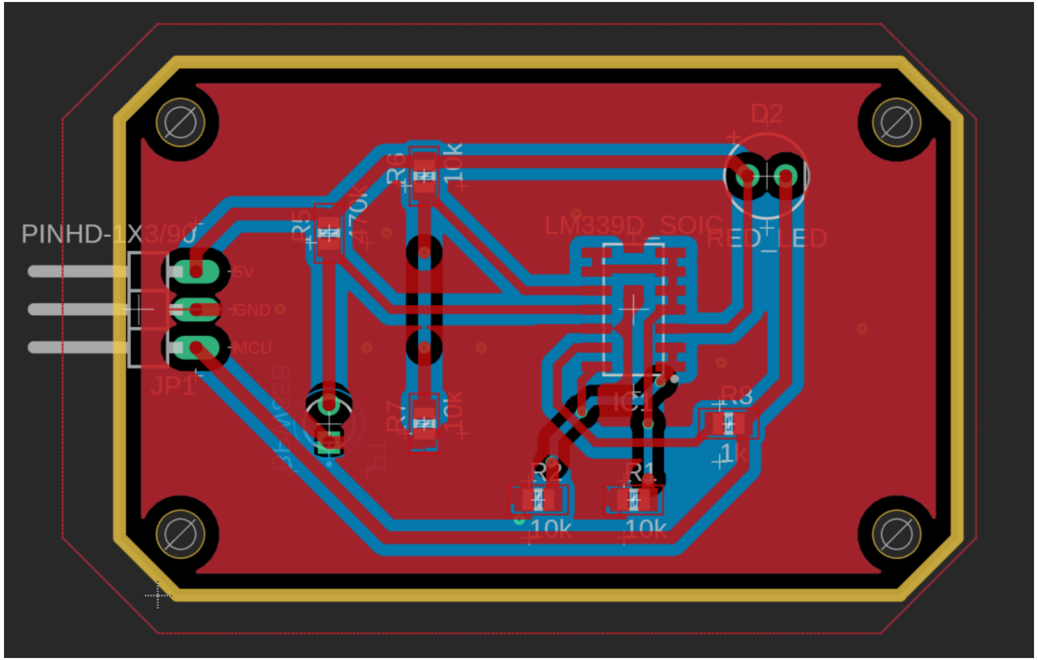
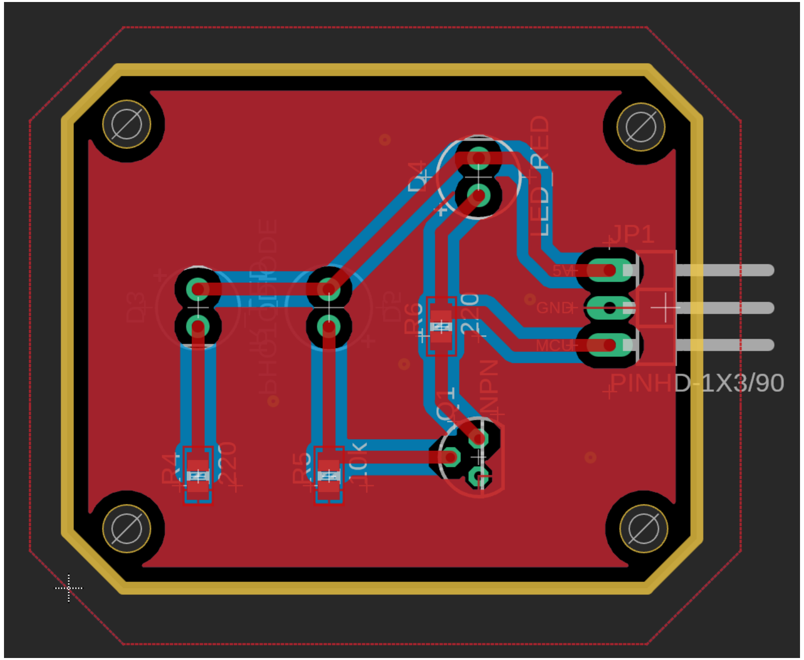
IR Receiver and Motion Sensor PCB





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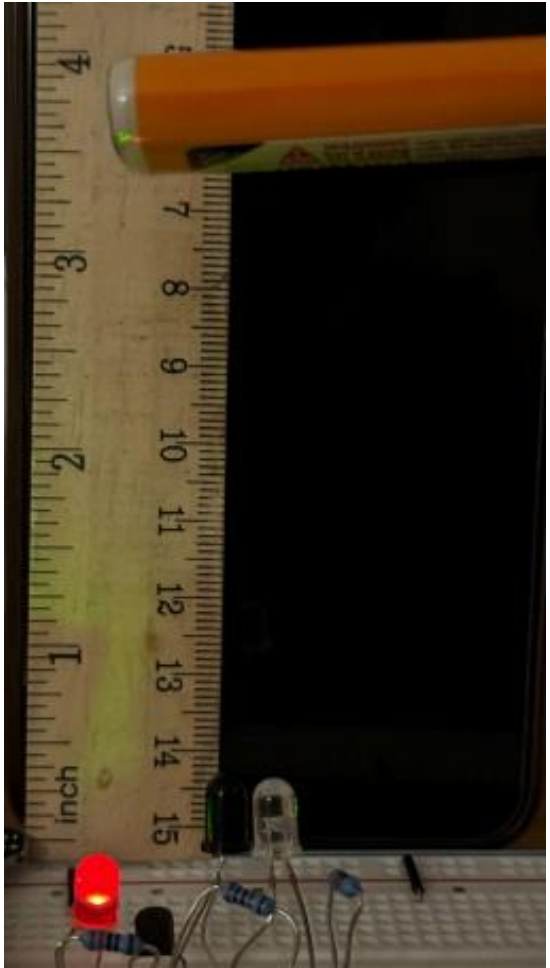
Testing: Motion Sensor

Performance Evaluation

- Range of motion sensor is lacking. From testing, it can detect the reflection of an object up to 4 inches away.

Solution

- Position of motion sensor was moved in our design to have a better chance of reflecting off our pet.



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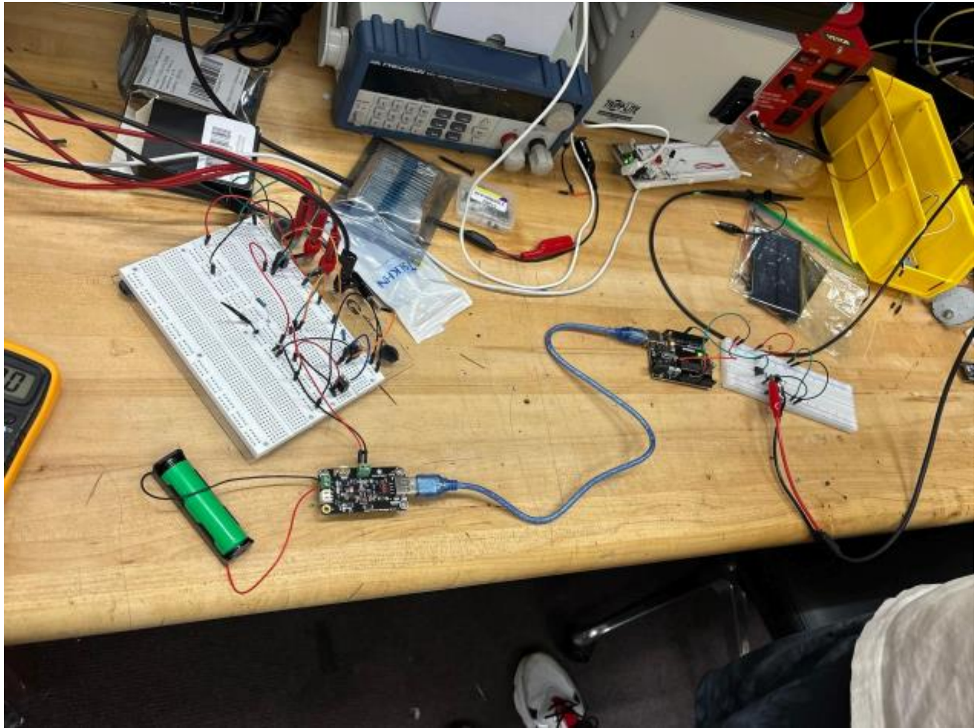
Testing: Power Manager

Performance Evaluation

- Successfully charged the battery with solar and dc wall adapter. Switching circuit successfully blocked unwanted source to prevent a reversed current in used source



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Budget

Component	Quantity	Estimated Budget	Total Budget
Microcontroller	1	$15	$15
Infrared Photodiodes	3	$1	$3
Infrared LED	6	$0.60	$3.60
Infrared Detector	1	$1	$1
Infrared Motion Detector	1	$5	$5
Lens	1	$50	50
Wireless Receiver	2	$3	$6
Wireless Transmitter	1	$3	$3
PCB	10	$200	$200
Motors	3	$5	$15
Motor Drivers	3	$5	$15
Solar Panel	1	$20	$20
Rechargeable Battery (collar)	1	$3	$3
Rechargeable Battery (door)	1	$20	$20
Cat Collar	1	$1	$1
Power Supply Unit (PSU)	1	$15	$15
Total Cost			$375.60

B.O.M.

Component	Quantity	Price Per Unit	Total Cost
Solar Panel	2	$2.10	$4.20
Solar Power Manager	1	$13.90	$13.90
Door Battery	1	$7.95	$7.95
Collar Battery	1	$7.99	$7.99
Wall Adapter	1	$5.00	$5.00
ESP32	1	$9.99	$9.99
ATtiny85	1	$1.66	$1.66
DC Motor	1	$12.90	$12.90
IR LED (940 nm)	10	$0.31	$3.10
Photodiode (940 nm)	10	$0.31	$3.10
Fresnel Lens	1	$20.68	$20.68
Total Cost			$90.47

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Work Distribution

Photonics Engineering	Responsibilities
Christopher Vanle	Optical Design and Implementation
	Computer Integration
	Mechanical Design
	Software Design and Implementation (Secondary)
	Administrative Content

Electrical Engineering	Responsibilities
Davis Rozel	MCU Selection and Implementation
	PCB Design (Secondary)
	Wireless Communications
	Software Design and Implementation (Primary)
	Website Design and Management

Electrical Engineering	Responsibilities
Daniel Hemmerde	PSU Design and Implementation
	PCB Design (Primary)
	Motor Control and Implementation
	Solar Power and Power Storage
	Software Design (Secondary)

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Progress and Plan for Completion

PCB acquired, iterations made.

Currently

PCBs finalized, implement software

10/11/2024

Midterm Demo

10/18/2024

Thorough testing and final changes for the Final Design

11/15/2024

Senior Design Showcase

11/22/2024

Thank you for your time!