Project HULK

Group 26

Critical Design Review Presentation

Meet the team

Myesha Rahman

Electrical Engineering

Madeline Moran

Electrical Engineering

Labiba Ibrahim

Electrical Engineering

Janani Nagaraj

Computer Engineering

Motivation & Background

- RERL lab equipment used for x-ray irradiation needs dose rate to be measured
- Dosimetry:
  - Measuring radiation dose absorbed by sample
- Design and build portable machine to calculate dose rate from machine

Goals and Objectives

Basic Objectives:

- Build a transimpedance amplifier circuit with precision, low-noise, low-input-bias-current operational amplifiers for diode current readout.
- Implement a program on ESP32 to convert diode current into dose rate.
- Log data using a high-resolution Analog-to-Digital Converter (ADC), then process these values with to convert them into dose rates. The dose rates will be displayed on a LCD display.

Advanced Objectives:

- Add digital calibration curves for different filters (no filter, 2 mm Al filter, 2 mm Al + 1 mm Pb) to convert raw diode current to accurate dose-rates.
- Implement a real-time benchmarking mode to compare dosimeter measurements with MOSFET degradation data collected from a parameter analyzer.
- Display the dose-rates in real time with high accuracy.

Goals and Objectives

Stretch Objectives:

- Include wireless connectivity and mobile app to display dose-rates on a real-time dashboard for remote monitoring.
- Use a microSD card to store data that can later be retrieved into a PC to access historical files.

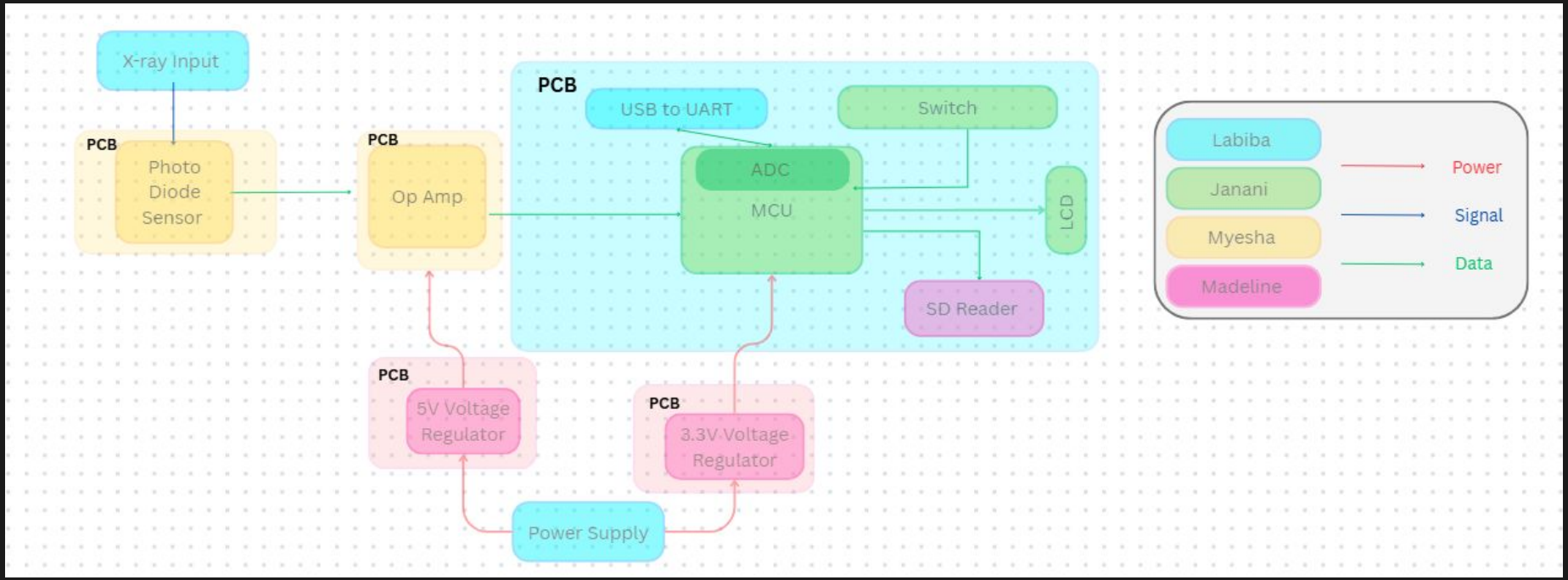
Work Distribution

Team Member	Responsibility
Myesha	Diode PCB design, Filter PCB design, hardware testing, integration
Madeline	Regulator Design, hardware testing, integration
Labiba	MCU board design, Power supply selection, hardware testing, integration
Janani	Software architecture design, ESP32 firmware development, LCD implementation, system integration

Specifications

Parameter	Value/Spec
Dimensions of Housing	50mm L x 20mm W x 20mm H
X-ray energy limit	<320 keV
Minimum detectable dose rate	>3 Gy/min
Weight	<3lbs
Power supply	6v AC to DC
Cost	$2000
Display time	2-5 seconds
Accuracy	>95%
Display	Onboard 480×320 SPI TFT (3.5inch)
Sensor	Photodiode (AXUV20HS1)

Hardware Design Block Diagram



Diode Selection

Parameter	Why It Matters	ARACOR	AXUVH25	AXUV20HS1	AXUV20A
Sensitive Area	Larger area = more signal collected	10 mm²	1 mm²	**20 mm²**	**23 mm²**
Signal Strength	Determines if signal is easy to amplify	High	Low	**High**	High
Capacitance	Lower = lower noise & easier analog design	N/A	15–50 pF	**300–900 pF**	500–1500 pF
Response Speed	Important for real-time or pulsed measurements	N/A	Very Fast (0.7 ns)	**3.5 ns**	2 µs
X-ray Energy Range	Must match source spectrum	8–60 keV	8–60 keV	**10–100 keV**	10–100 keV
Best Use Case	Ideal application	Absolute dose reference	Fast lab measurements	**High-signal research systems**	Low-voltage systems

Op-Amp selection

Parameter	TI OPA141	ADI ADA4530-1	ADI LTC6268
Input Type	JFET	CMOS	CMOS
Input Bias Current	10 pA	20 fA	3 fA
Input Offset Voltage	120 µV	20 µV	200 µV
Input Voltage Noise	5.1 nV/√Hz	7 nV/√Hz	4 nV/√Hz
Slew Rate	20 V/µs	1.5 V/µs	500 V/µs
Supply Voltage Range	4.5–36 V	4.5–16 V	2.7–5.25 V
Typical Supply Current	1.8 mA	1 mA	16 mA
Package Options	SOT-23-5, SOIC-8	SOIC-8	SOIC-8, DFN-8

MCU Selection

Parameter	ESP32-DevKitC	ESP32-WROOM-32	ESP32-WROVER	ESP32-S3 DevKit
ADC Resolution	12-bit	12-bit	12-bi	12-bit
Processing Power	Dual-core Xtensa	Dual-core Xtensa	Dual-core Xtensa	Dual-core Xtensa LX7
Memory (RAM/PSRAM)	~520 KB RAM, no PSRAM	~520 KB RAM, no PSRAM	520 KB RAM + 4–8 MB external PSRAM	512 KB RAM + optional PSRAM
Display	Reliable, but limited memory for complex graphics	Library support depends on the clone board	PSRAM allows smoother display updates and data logging	Improved GPIO count and memory help multitasking
Connectivity	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth, USB
Community / Library Support	Strong, official Espressif docs	Very strong, widely used in education/prototyping	Strong but fewer examples than WROOM	Currently expanding

SD Card Reader Selection

Feature	DM3AT-SF-PEJM5	MEM2067-02-180-00-A	MEM2075-00-140-01-A	MEM2052-00-195-00-A
Voltage	125 V AC	100V AC/DC	30 V AC	10V AC/DC
Current	0.5 A	0.5A AC/DC	0.5A per pin	0.5A AC/DC
Operating Temp	-25°C to +85°C	-40°C to +85°C	-25°C to +85°C	-40°C to +85°C
Price	$2.85	$1.06	$1.80	$1.08
No. of Pins	10(8+2)	8	9(8+1)	9(8+1)
Insertion, removal method	Push in, push out	Hinged	Push in, push out	Push in, push out

LCD Display Selection

Feature	Parallel TFT LCD	Character LCD	SPI TFT LCD	I2C TFT Touch LCD
Screen Size	3.5–5.0 in., full graphics	16×2 or 20×4, text only	2.4–3.5 in., graphics	3.5–4.0 in., graphics + touch
Resolution/ Output	High (320×480+)	Limited to text characters	240×320 – 480×320	320×480, interactive
Interface Complexity	High (many GPIO lines)	Low (simple but limited)	Moderate (4 to 5 pins)	Only 2 data lines
Integration with ESP32	Difficult, heavy routing	Easy but non-scalable	Good, requires optimized drivers	Minimal wiring, easy PCB integration
Data visualization	Supports plots and graphics	Only numeric text	Supports plots and graphics	Full graphics + touch interaction
Power Consumption	Moderate	Very-low	Moderate	Moderate

Regulators- 3.3V

Quality	LM25575	LM2592	LM20242	LM22680
Input Voltage	6V-42V	4.5V-60V	4.5V-36V	4.5V-42V
Output Voltage	3.3V	3.3V	3.3V	3.3V
Output Voltage Tolerance	2.76%	4.00%	2.35%	2.73%
Output Current	1.5A	2A	2A	2A
Efficiency	83.7%	76%	88.8%	84.2%
Price	$3.63	$6.97	$4.90	$4.84

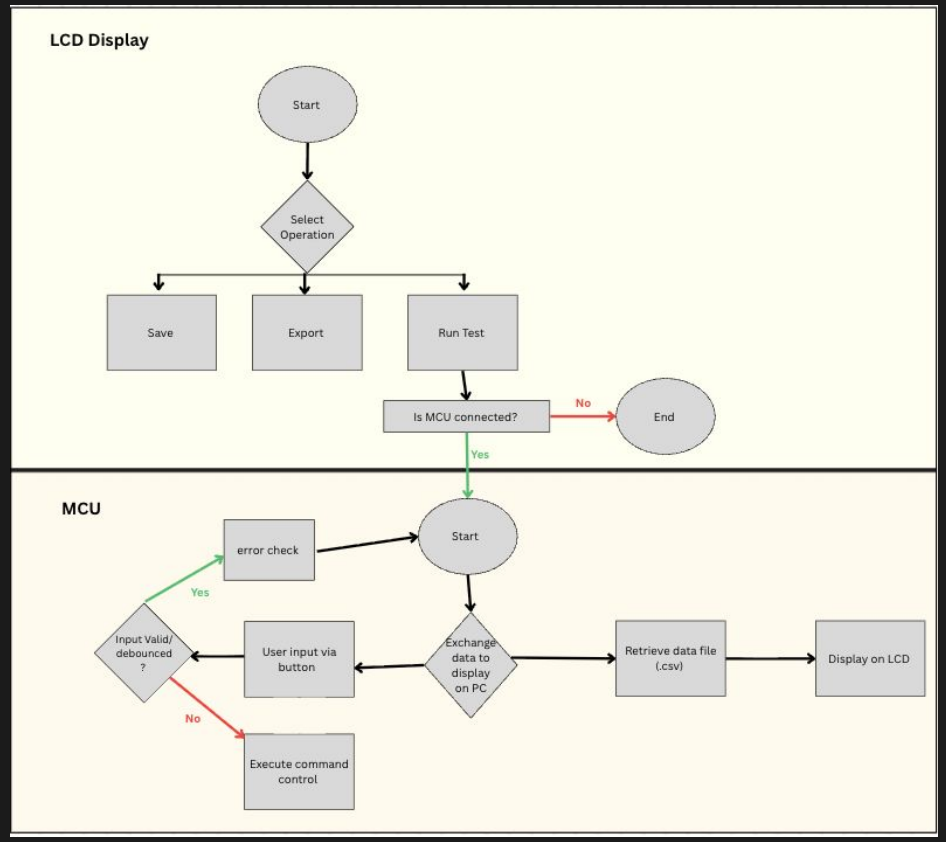
Regulators- 5V

Quality	LM25575	LM2592	LM20242	LM22680
Input Voltage	6V-42V	7-60V	4.5V-36V	4.5V-42V
Output Voltage	5.02V	N/A	5.02V	5V
Output Voltage Tolerance	3.02%	N/A	3.22%	3.00%
Output Current	0.5A	N/A	0.5A	0.5A
Efficiency	92.8%	N/A	94.8%	92%
Price	$3.63	$6.97	$4.90	$4.84

Power Supply Selection

Parameter	AA Alkaline batteries	Zinc-carbon batteries	6V AC to DC
Voltage	4X1.5 = 6 V	4X1.5 = 6 V	6V
Current	50 – 250 mA	1,100 mAh	2 A
Temperature	-18°C to 55°C	-18ºC to 55ºC	0~40℃
Cost	$3.02	$0.49	$6.39
Life span	10 years at 21°C	2-3 years at 21°C	3-10 years

Software Block Diagram



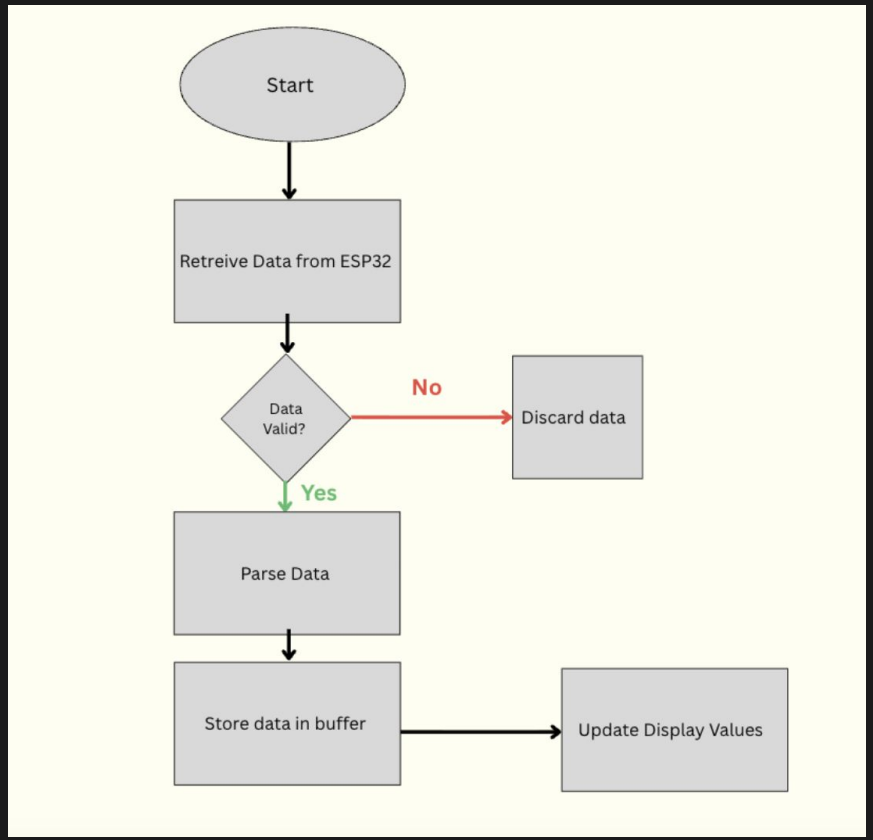
Software Component selection

Component	Description
ADC reading module	Configures and reads analog voltage from the photodiode through the ESP32 ADC. Handles sampling timing and resolution control.
Dose Calculation Module	Converts raw ADC values into voltage and applies the project's calibration curve to compute dose rate in Gy/min.
Filtering and Averaging Module	Reduces measurement noise through averaging windows and smoothing algorithms to produce stable dose-rate readings.
Communication Handler	Packages processed dose-rate data and transmits it to the LCD using SPI or I²C. Manages acknowledgments and retry logic for reliability.
LCD display handler	Updates the numerical dose-rate readout, refreshes graph frames, and switches between display modes selected by the user.
Error Detection Module	Detects invalid ADC values, communication failures, or signal outliers. Initiates corrective routines and triggers on-screen warnings when necessary.
Display mode controller	Allows the LCD to toggle between showing the graph only, the numerical reading only, or both simultaneously.

ESP32 Development Environment Selection

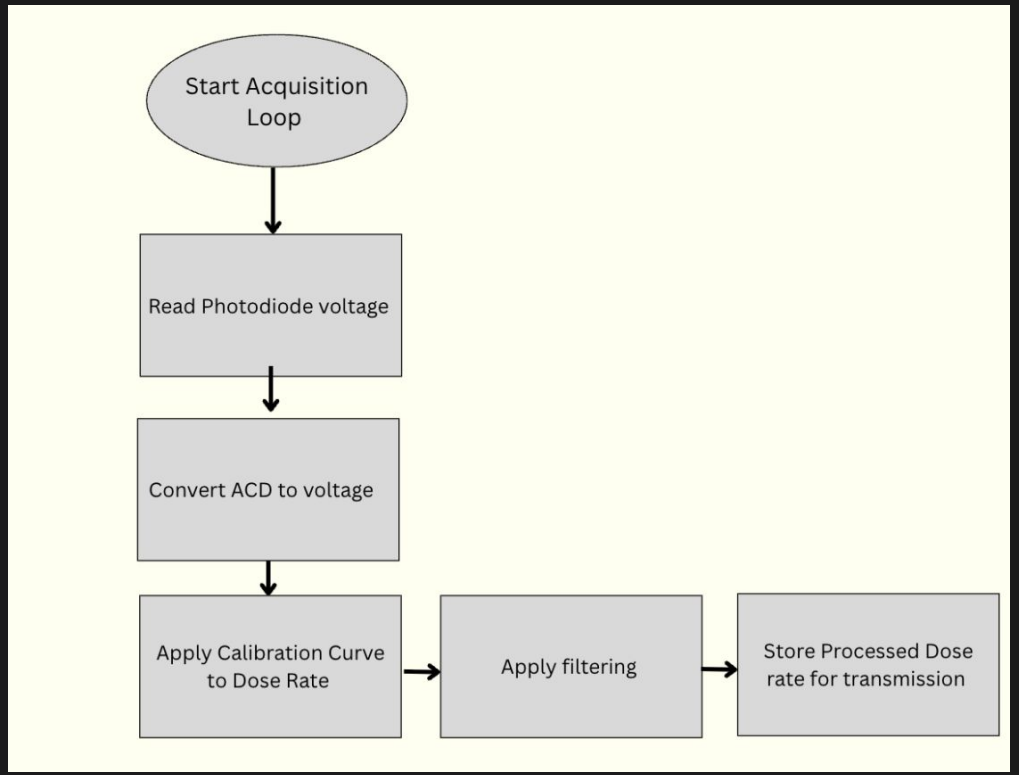
IDE	Advantages	Disadvantages
Arduino IDE	Faster Prototyping, Strong ESP support	Less low-level control
VS Code + ESP-IDF	Full framework access	Steeper learning curve
EspressifIDE	Native tools	Limited familiarity

LCD Application Design



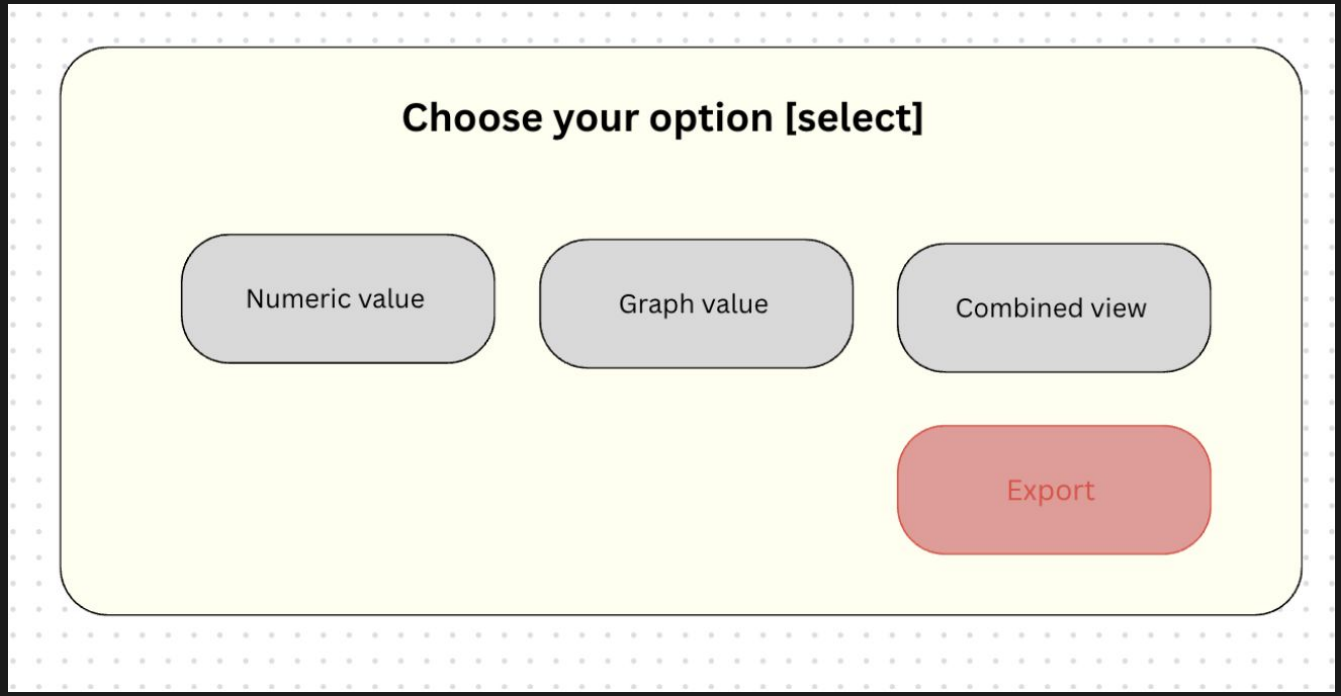
- Receives dose-rate packets from ESP32
- Validates and parses numeric + timestamp data
- Buffers readings for graph rendering
- Updates numeric display in real time
- Refreshes graph at defined sampling interval

ESP Software Integration

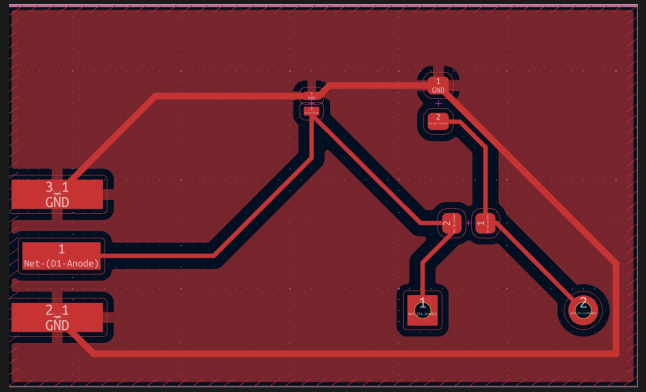


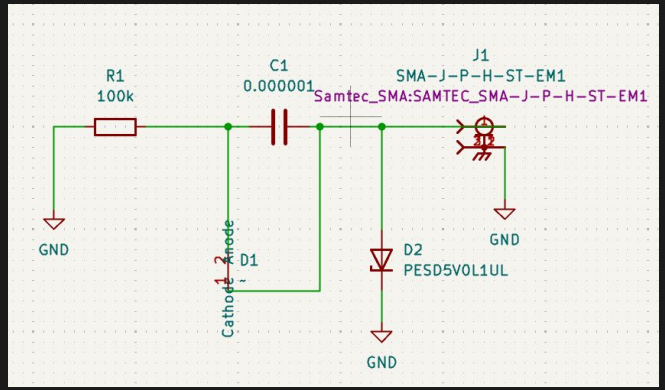
- Samples amplified photodiode voltage via ADC
- Converts analog voltage to digital value
- Applies calibration curve (Gy/min conversion)
- Implements averaging filter for noise reduction
- Packages processed data for SPI transmission

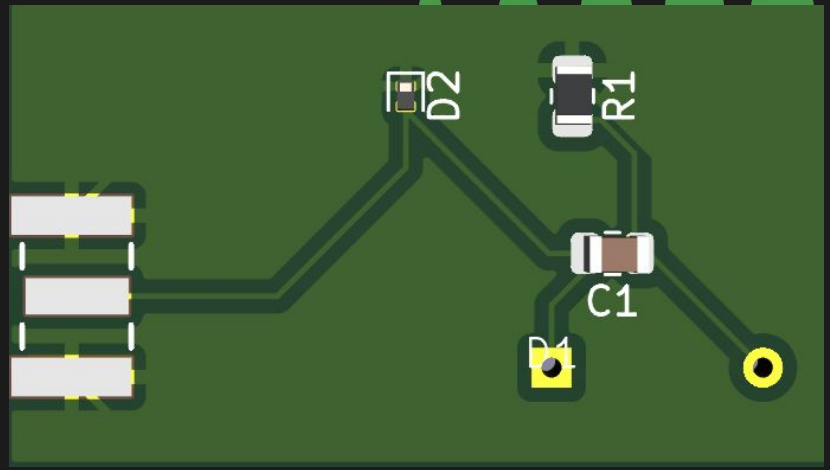
LCD Display View



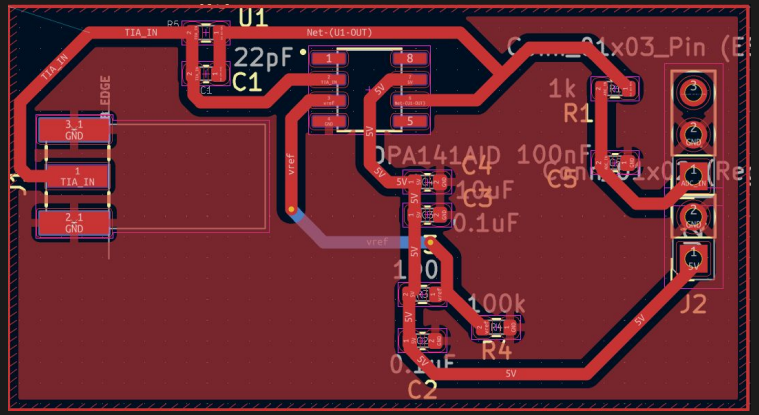
Diode PCB designs

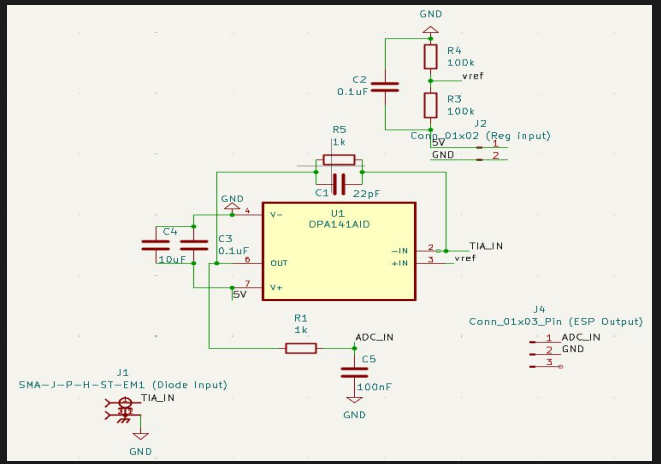


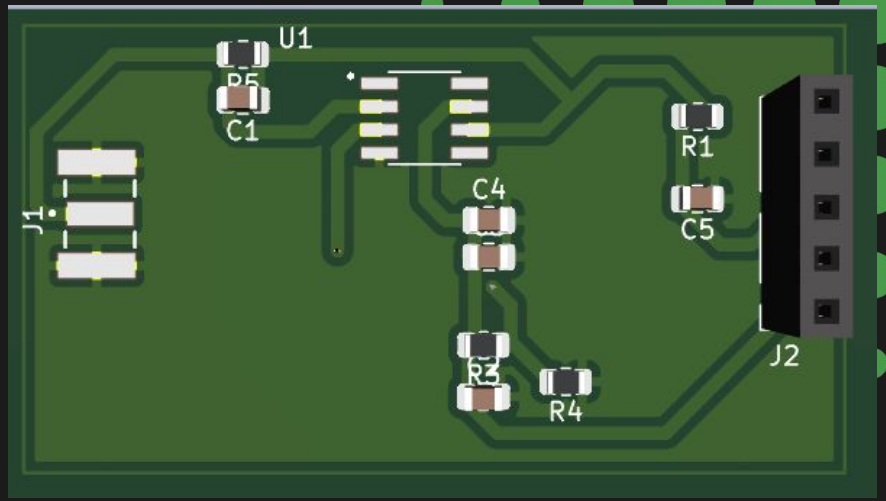




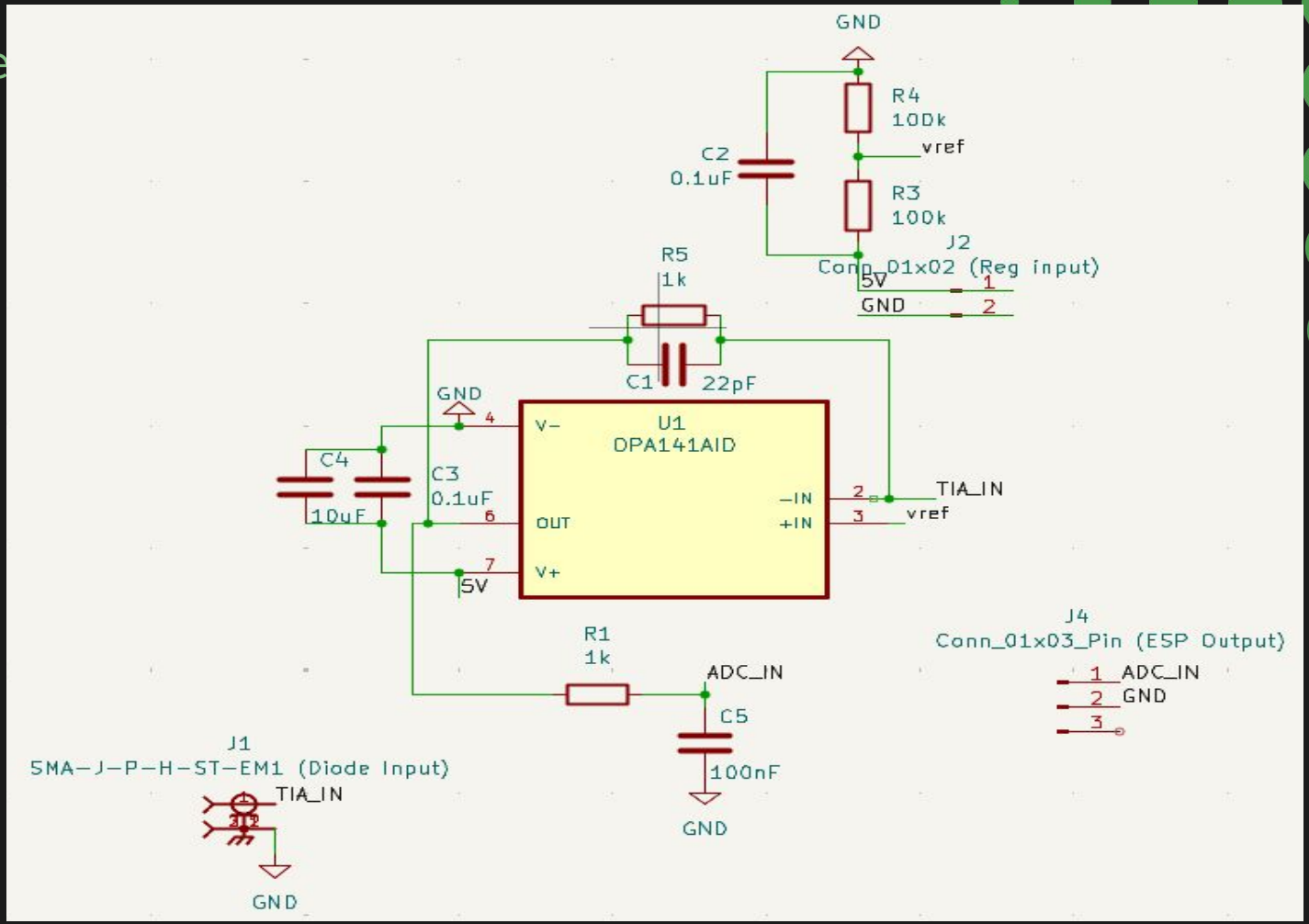
Filter PCB designs



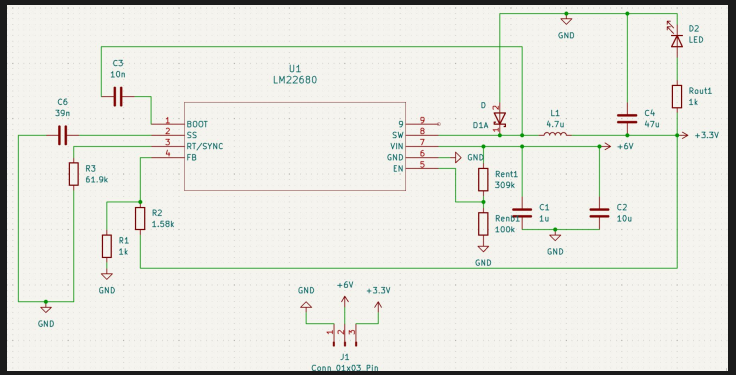


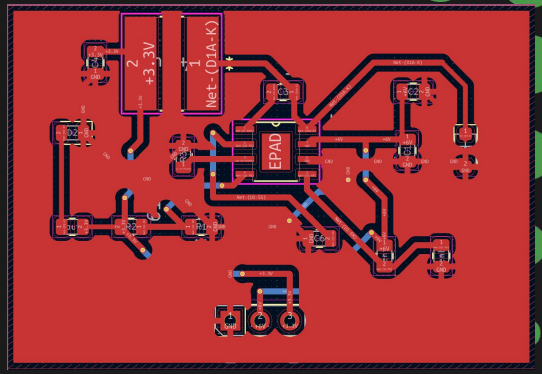


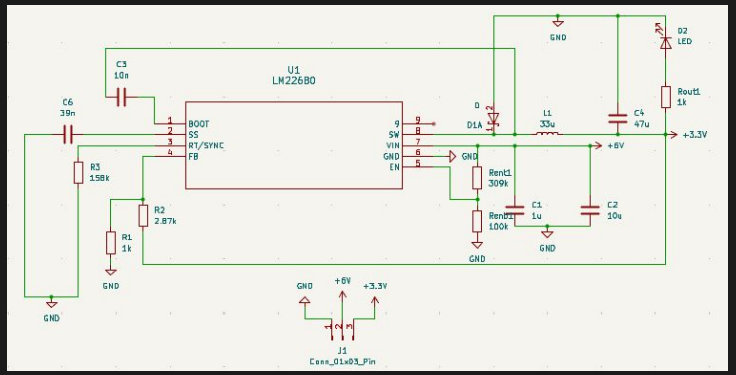
Filte

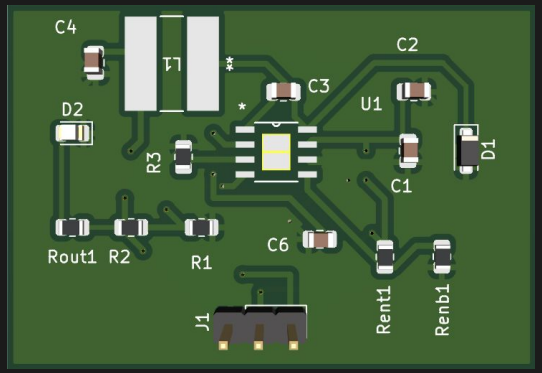

GND
R4
10Dk
vref
C2
0.1uF
R3
100k
J2
Conn_01x02 (Reg input)
5V
1
GND
2
R5
1k
C1
22pF
GND
4
V-
U1
OPA141AID
C4
C3
0.1uF
10uF
6
OUT
-IN
+IN
2
3
TIA_IN
vref
7
V+
5V
J4
Conn_01x03_Pin (ESP Output)
1 ADC_IN
2 GND
3
R1
1k
ADC_IN
C5
100nF
GND
J1
SMA-J-P-H-ST-EM1 (Diode Input)
TIA_IN
GND

Regulator PCB Design

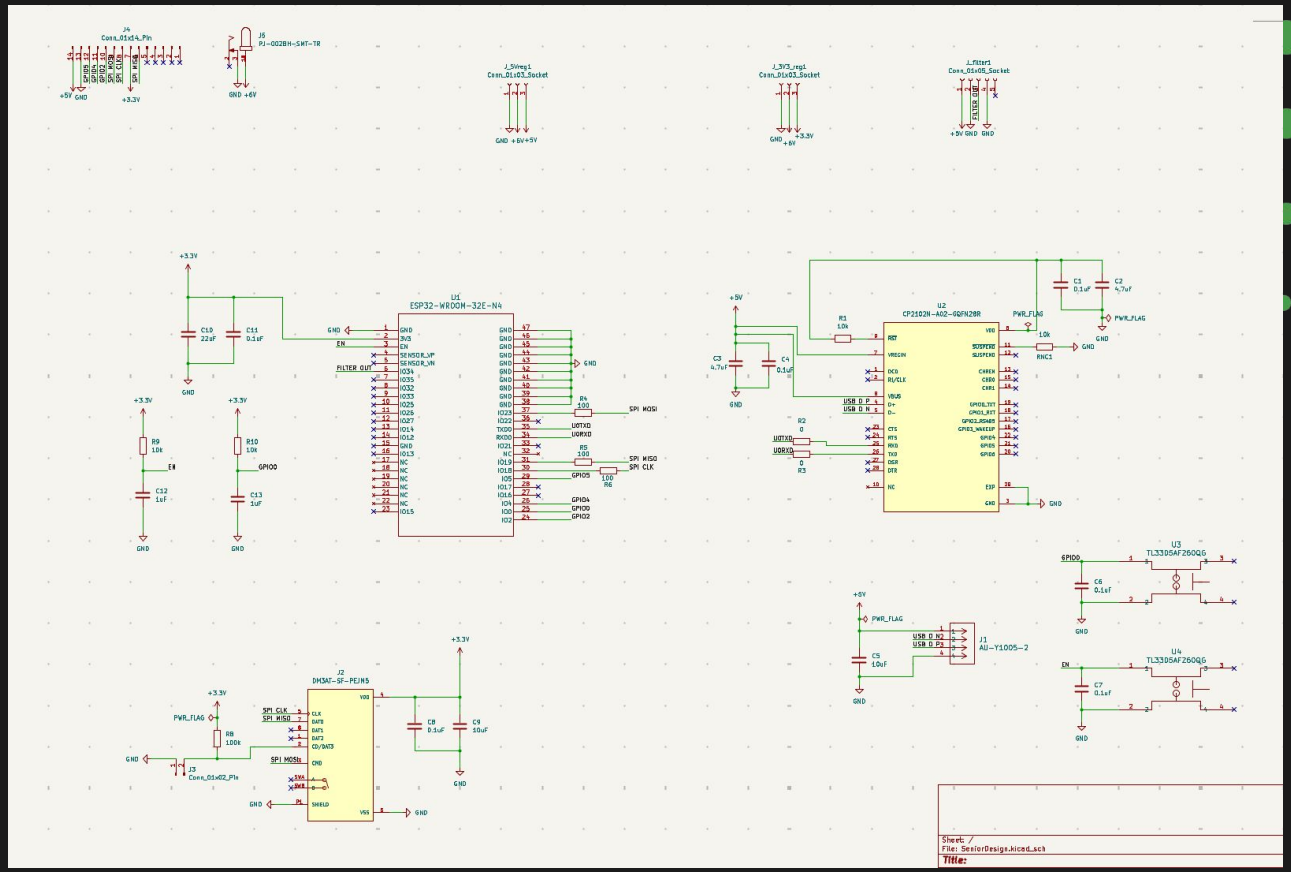


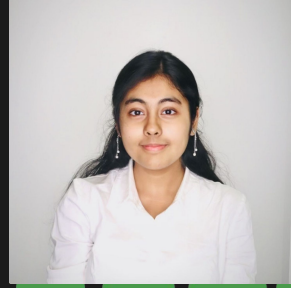




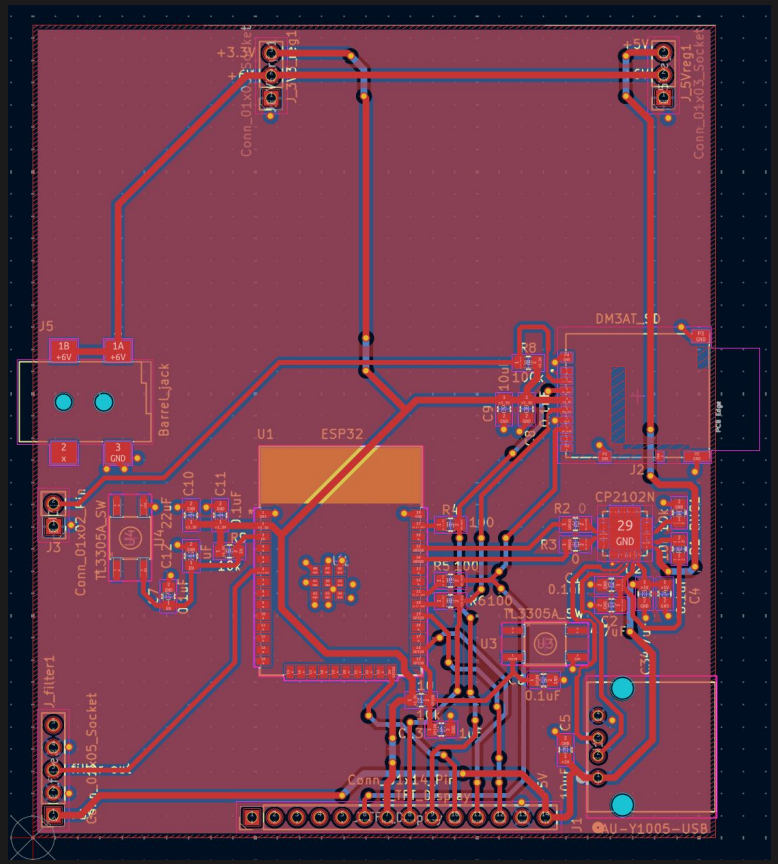


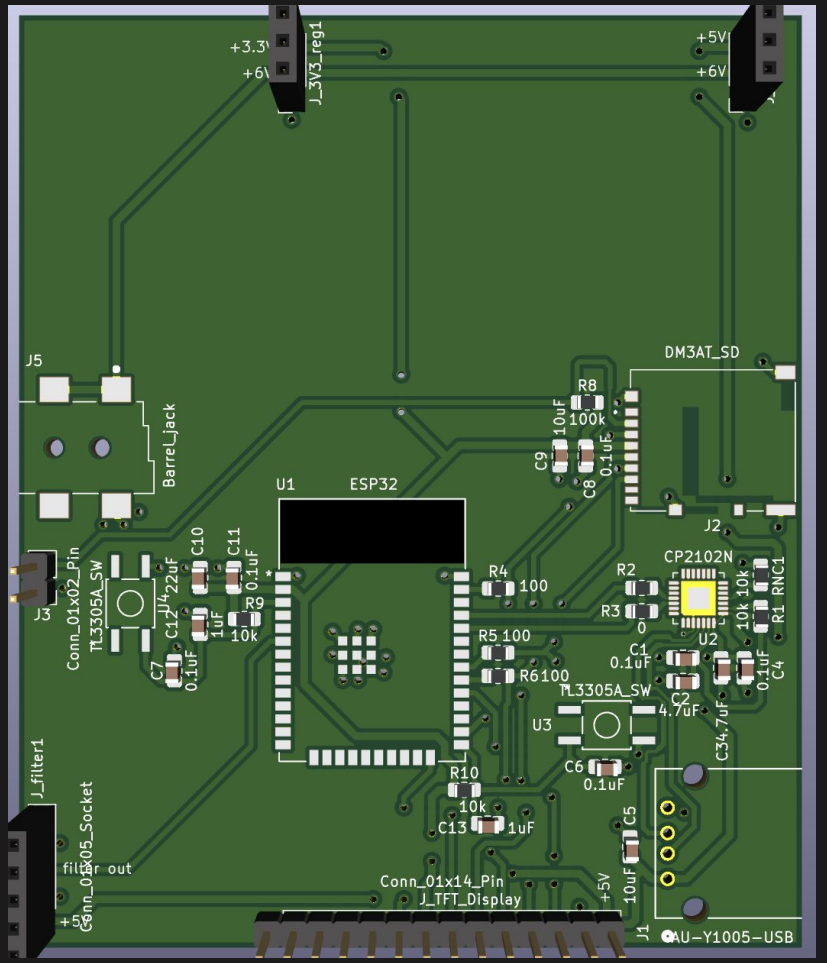
Main PCB Schematic



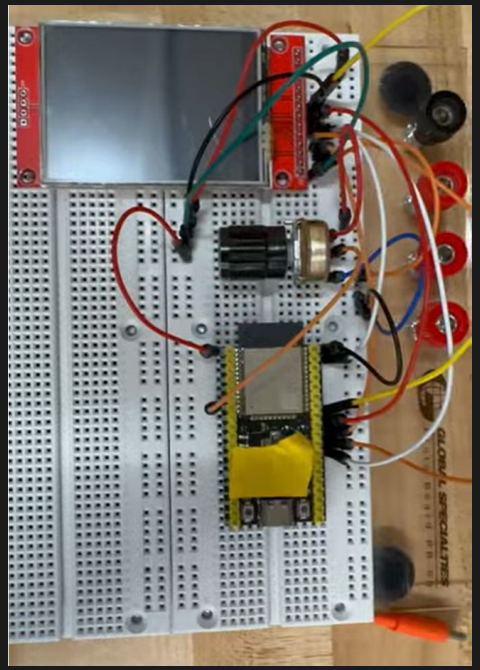


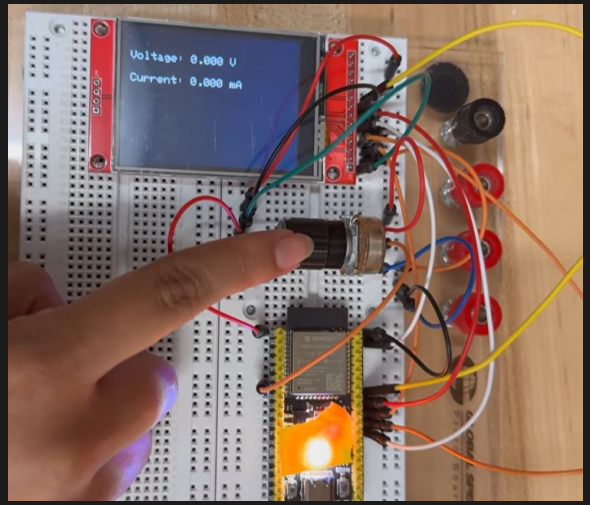
Main PCB Layout





Prototyping and Testing



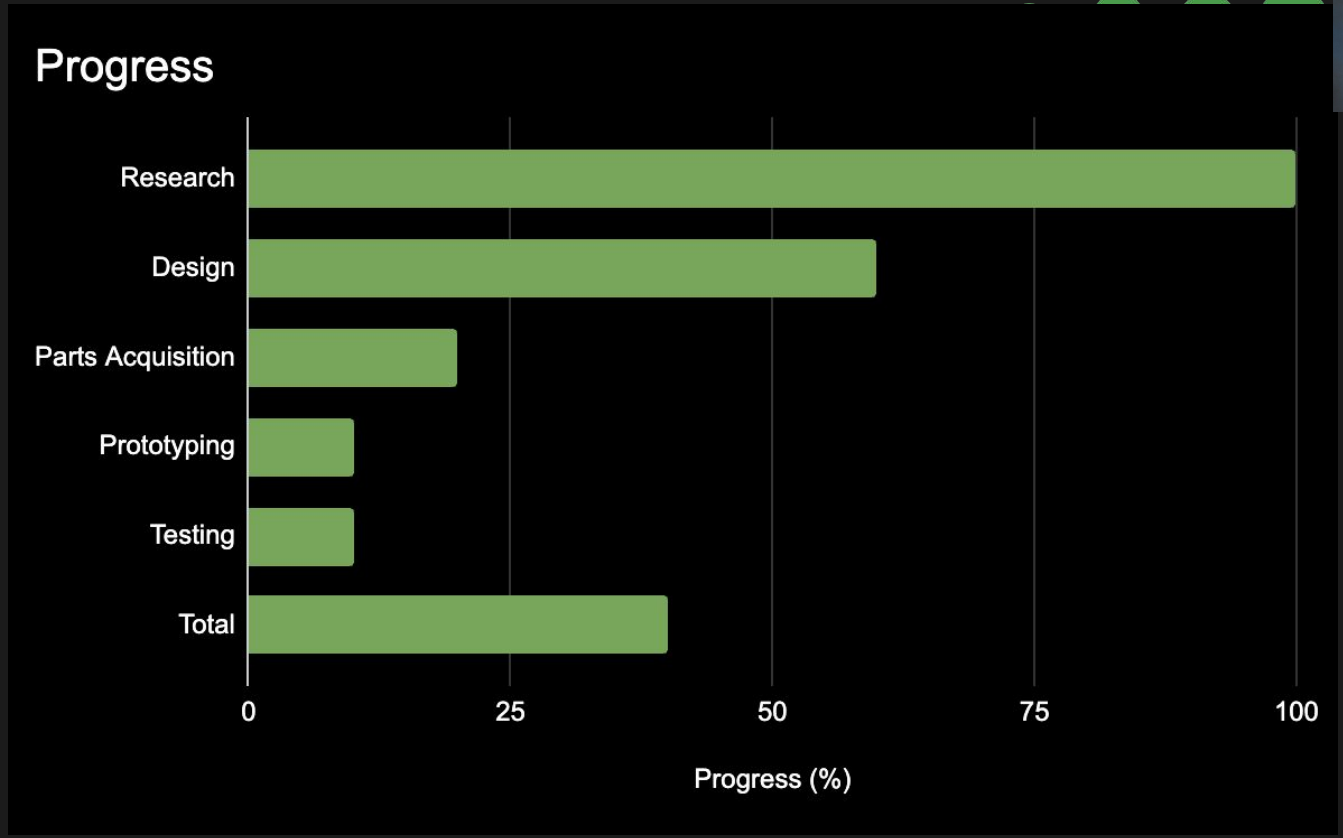


Budget

Component Part Name	*Quantity*	*Unit Price (USD)*	*Total Price (USD)*
Core Circuit Components			
MicroSD Card Breakout Board+	2	$7.50	$15.00
ESP32 Dev Kit	1	$10.00	$10.00
ESP32-WROOM-32E-N4 MCU Module	2	$4.84	$9.68
LM22680 Regulator IC	4	$4.84	$19.36
OPA141AIDR	4	$2.61	$10.44
DM3AT-SF-PEJM5	2	$2.85	$5.70
Additional Components (resistors, capacitors, etc.)	–	–	$61.81
AXUV20HS1 Opto Diode	2	$627.06	$1254.12
PCB's	4	–	$163.07
Additional Components			
2.8" TFT Resistive Touch Shield (LCD Display	3	$24.95	$74.85
Total			
Grand Total	–	–	$1,624.03

Total spent: $1,624.03
Total budget: $3,000

Project Progress



Future Plans

- Prototype and test PCB boards
- Test the connections with the X-ray machine
- Plot the dose-rate on the LCD successfully

Thank you