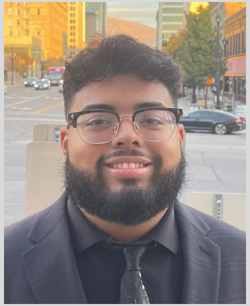
Advanced Breadboard

Group 20—CDR Presentation—Spring 2024

About Us

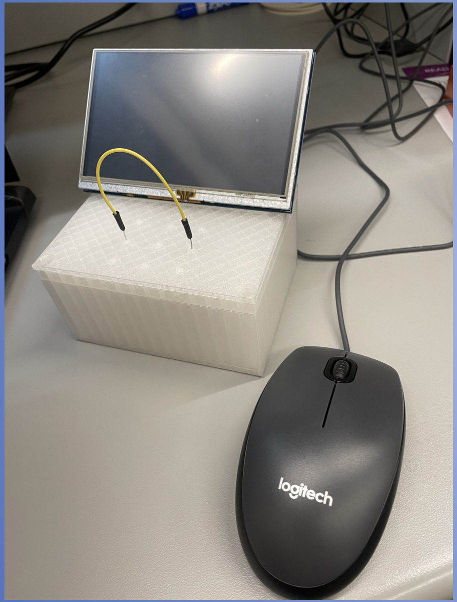


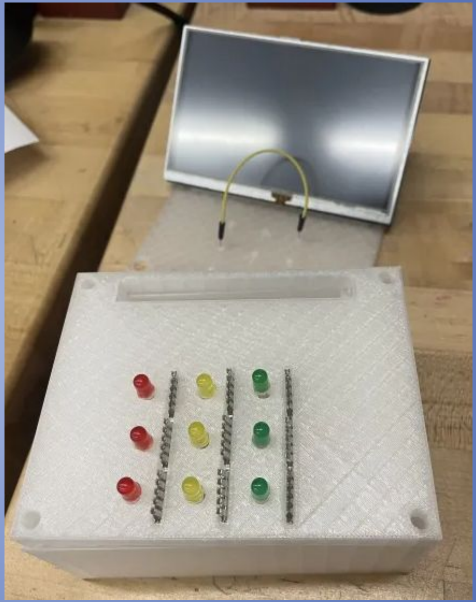
Cristian Gutierrez
Computer Engineering

Ammar Mubarez
Electrical Engineering

Sheridan Sloan
Computer Engineering

Introducing the New and Improved Breadboard





Introducing the New and Improved Breadboard

1. Draw schematic on GUI
2. Algorithm turns schematic into breadboard layout
3. LEDs light up on board
4. User places components on circuit
5. Current and voltage are shown

Motivation/Background

The idea for the project came from the team’s time in the Linear Circuits Labs. The correct use of the breadboard was integral to success in the laboratory.

- Understanding how to use the breadboard was straightforward, but applying it in practice proved to be more challenging than expected.

Two major challenges of using the breadboard were

- translating the schematic to a physical board
- debugging for components placed incorrectly. The first issue comes from connecting the idea of nodes in a schematic and nodes on the breadboard. Many mistakes come from a lack of understanding of nodes, especially when ground is involved. The second issue consumes a significant amount of lab time because open or short circuits can be hard to spot.

Labs are designed to give an application to theory, but unfortunately the majority of the time is spent trying to learn how to use the hardware.

Goal:

Redesigned breadboard with advanced features to assist students in learning how to use the breadboard

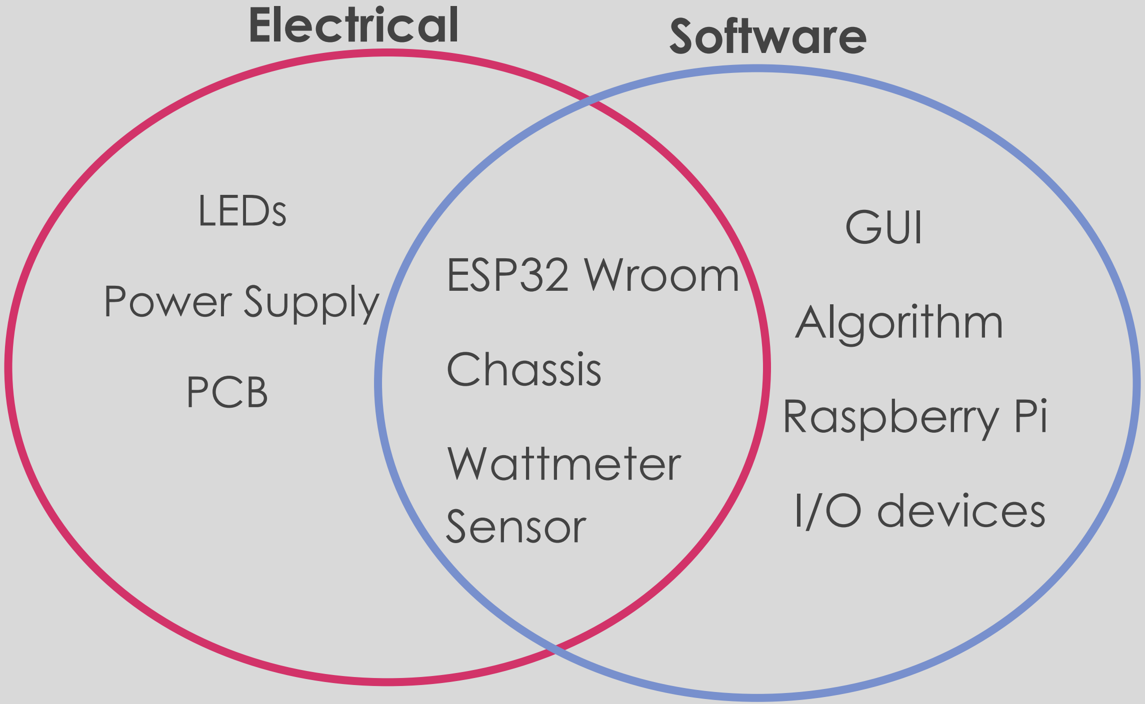
Objectives:

1. Schematic to breadboard wiring algorithm
2. LED activation for component placement
3. Open/short circuit detection

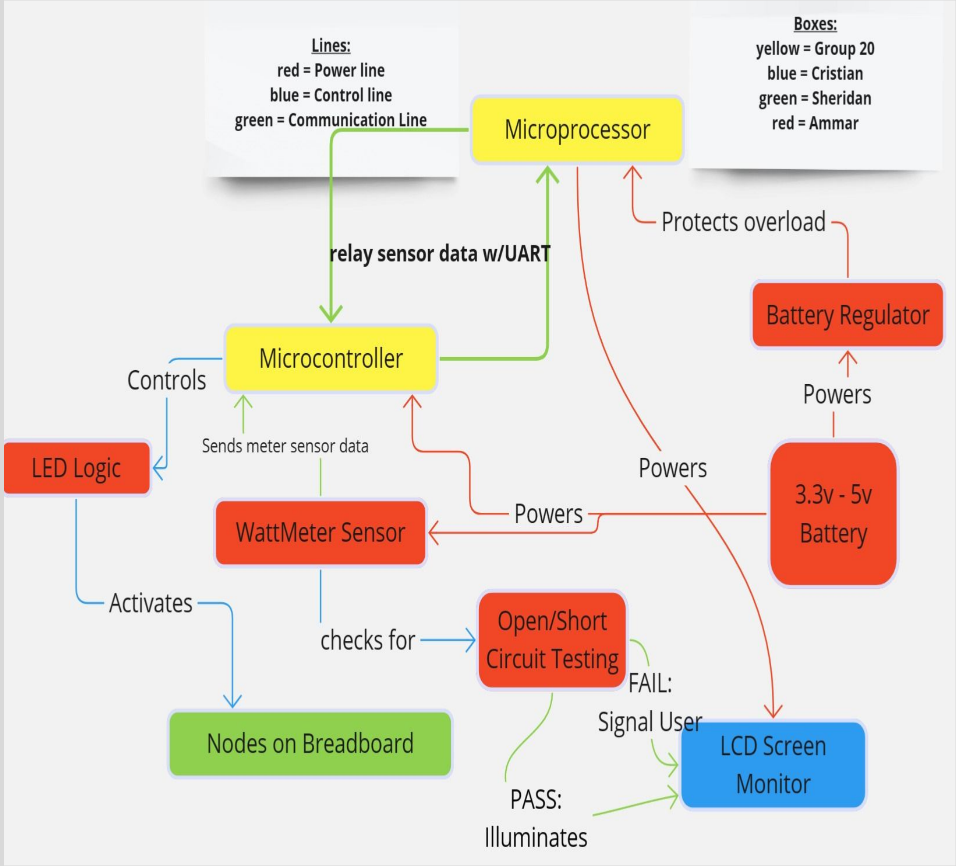
Engineering Specifications

Specifications	
Weight	< 10lbs
Size	Fit in two hands (Portable)
Computer Interface	ELECROW 5 Inch Touchscreen
Power Consumption	5W
Runtime for Software to Interact with Hardware (LED Activation or Sensor Data Retrieval)	< 10 Seconds
Open/Short Circuit Detection	>95% Accuracy
LED Activation Placement	>95% Accuracy
Battery Powered	Powers everything except the users circuit
PCB to GUI communication	Wired Connection
Cost	< $200

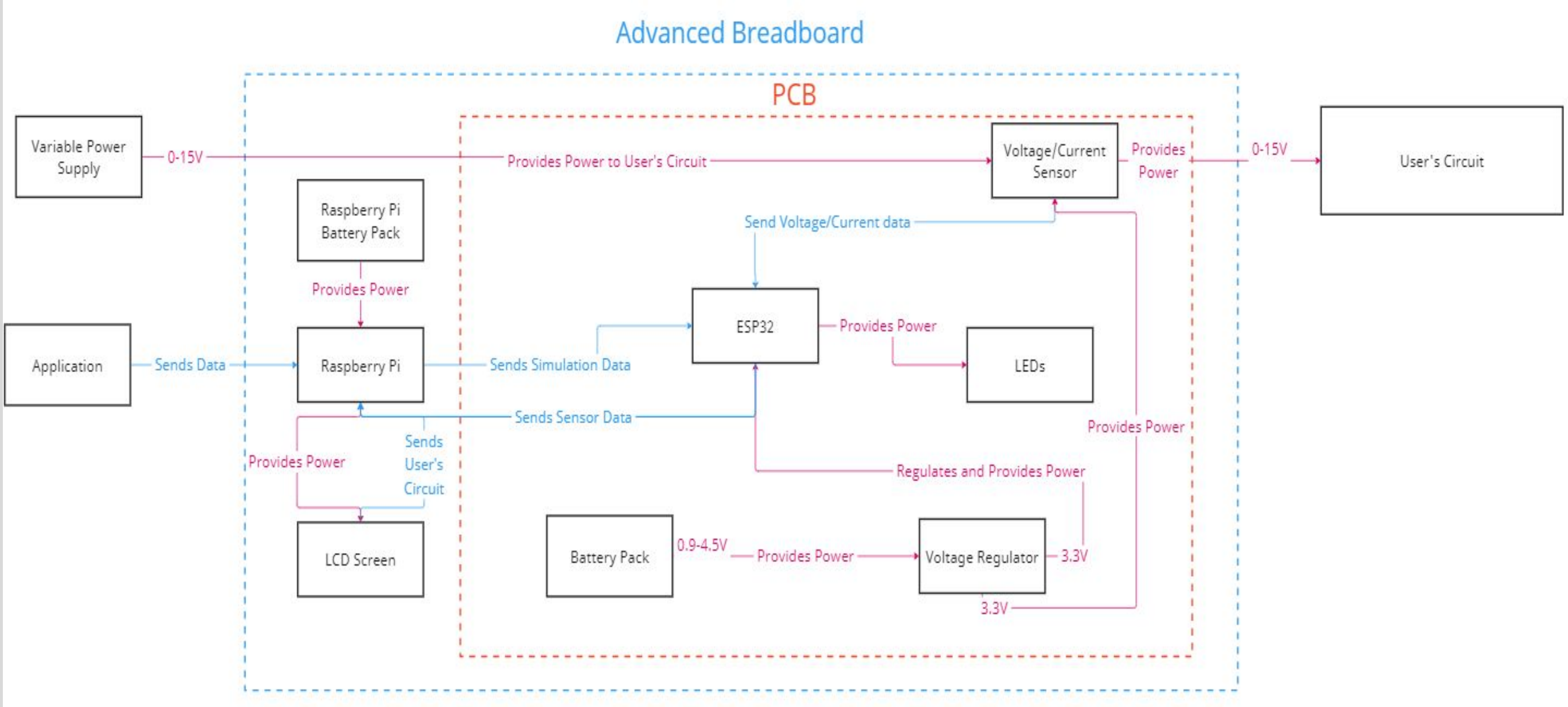
Main Elements

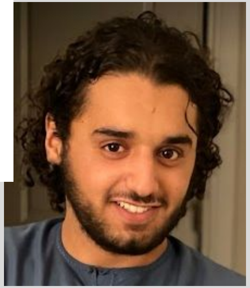


Hardware Overview



Hardware Subsystem Block Diagram

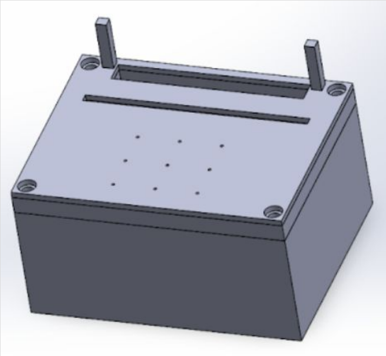




Breadboard Design

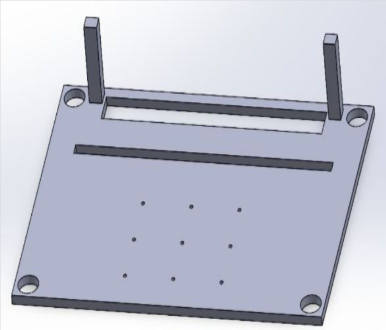
Technology Comparison:

Material	Melting/Burning Point	Ability to Manufacture	Weight
Glass	Very high	Very Low	Very high
Wood	Low	Low	High
Plastic	Medium	High	Low

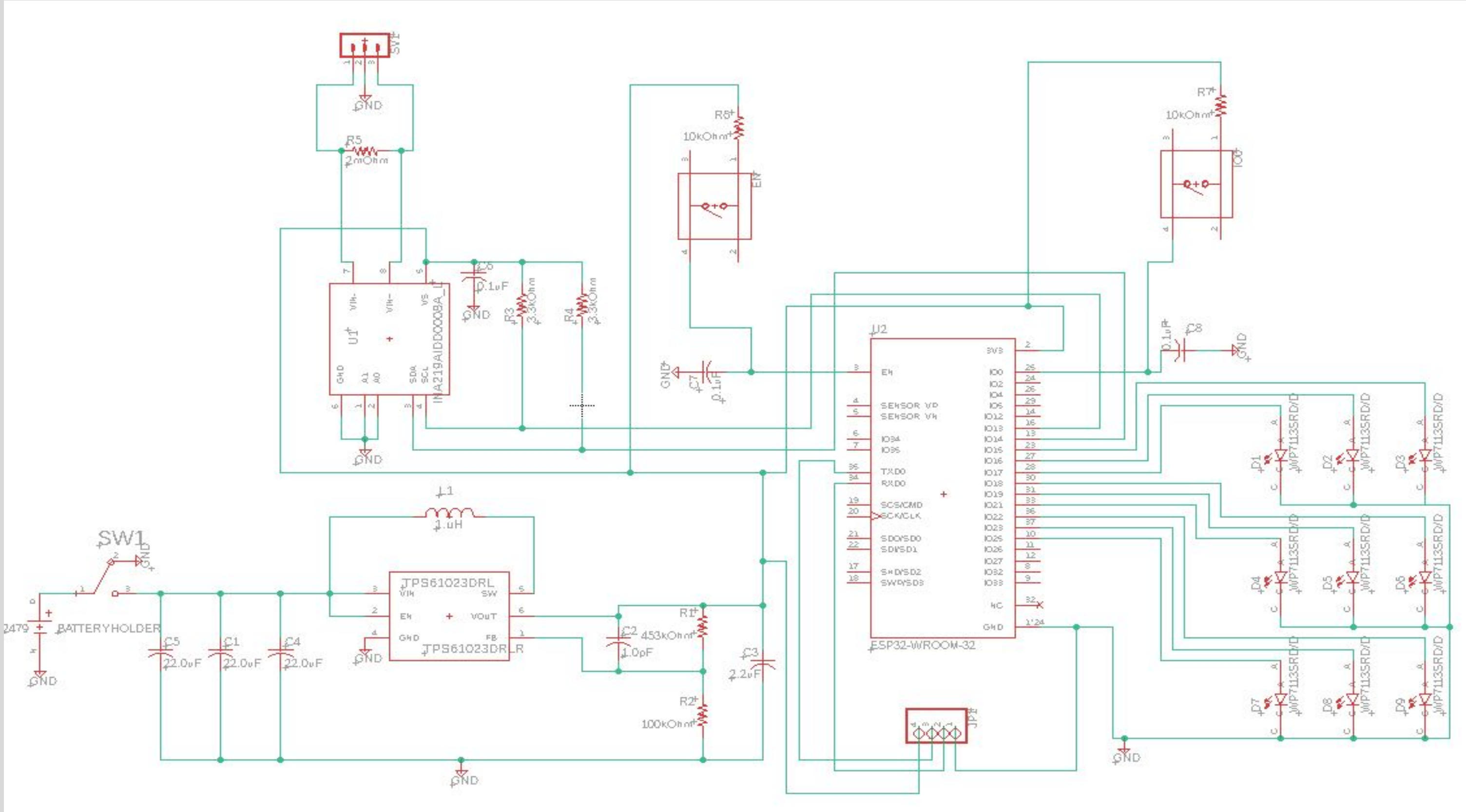


Part Comparison:

Plastic Type	Hardness (Shore)	Dielectric Constant	Melt Temperature
ABS	76	2.19-2.9	437F-473F
PLA	83	1.7-2.8	293F-320F
PETG	70	2.6	410F-455F



Overall Schematic



Voltage and Current Sensor

Sensors	INA219AID	INA260AIPW	INA233AIDGST
Cost	$2.70	$6.38	$4.22
Operating Voltage	3-5.5V	2.7-5.5V	2.7-5.5V
Sensing Voltage	0-26V	0-36V	0-36V
Accuracy	.5% Maximum Error	.15% Maximum System Gain Error	.1% Gain Error (Max)
Interface	I2C, SMBus	I2C, SMBus	I2C, SMBus, PMBus
ADC	Yes	Yes	Yes

Voltage:
Current:
Power:

Variable Power Supply

	Elenco XP-15K Power Supply	Korad KD3005D Power Supply	Matrix MPS-3206 Series
Cost	$34.99	$89.99	$69.99
Output Voltage	0-15VDC	0-30VDC	0-32VDC
Output Current	.3A @ 12V .2A @ 15V	0-5A	0-6A
Short Circuit Safety	Yes	Yes	Yes
Lead Time	1 Week	8 Weeks	5 days
Digital Display	No	Yes	Yes

Battery Pack

	Alkaline	Lithium-Ion	Zinc-Carbon
Capacity	850-1200 mAh	1150mAh	1100 mAh
Self-Discharge	2-3% per year	1-2% per month	.32% per month
Shelf-life	5-10 years	10-12 years	1-3 years
Temperature Performance	4-129°F	-4-130°F	23-113°F
Internal Resistance	High	Low	High

Alkaline Batteries

	Duracell AAA Batteries	EN91F3	ZEUS AA
Cost	$6.195	$3.22	$6.60
Quantity Needed	3	1	3
Voltage	4.5V Total	4.5V	4.5V
Capacity	3450mAh Total	2779mAh	3000mAh
Rechargeable	No	No	No
Lead Time	1 day	5-7 days	12 Weeks

Voltage Regulator

	TPS82150SILR	TPS613221ADBVR	TPS61023DRLT
Cost	$3.92	$0.58	$1.18
Frequency Switching	2MHz	500kHz-2MHz	1.2MHz
Input Voltage	3V-17V	0.9-5.5V	0.5-5.5V
Output Voltage	.9-6V- w	1.8-5.5V	2.2V-5.5V
Quiescent Current	20uA	6.5uA	<55uA
Maximum Output Current	1.2A	1.6A	3A
Efficiency	No	>90%	>90%
Size	3.0mm x 2.8mm x 1.5mm	2.90mm x 1.30mm	1.2mm x 1.60mm
Leaw dd Time	6 Weeks	6 Weeks	6 Weeks

LEDs

	LTST-C191KRKT	LTST-C171KRKT	WP7113SURDK
Cost of each	$0.25	$0.27	$0.35
Forward Voltage	2V	2V	1.95V
Viewing Angle	130 deg	130 deg	30 deg
Luminous Intensity	18.0-180.0mcd	18.0-54.0mcd	1300-2300mcd
Size	2.00mm x 1.25mm	1.40mm x 1.25mm	5mm
Lead Time	1 Week	1 Week	6 Weeks

Main processor

Microcontroller/Microprocessors	RAM	Pros for Project	Cons for Project
Raspberry Pi Zero W	512MB	Offers ample ram for the project.	Maybe overkill for a simple breadboard project.
Raspberry Pi 4B	2GB, 4GB, or 8GB	Provides plenty of RAM for complex tasks.	May be overpowered and more expensive.
ESP32	520KB SRAM	Suitable for basic circuit design tasks.	Limited RAM; may struggle with complex GUI.

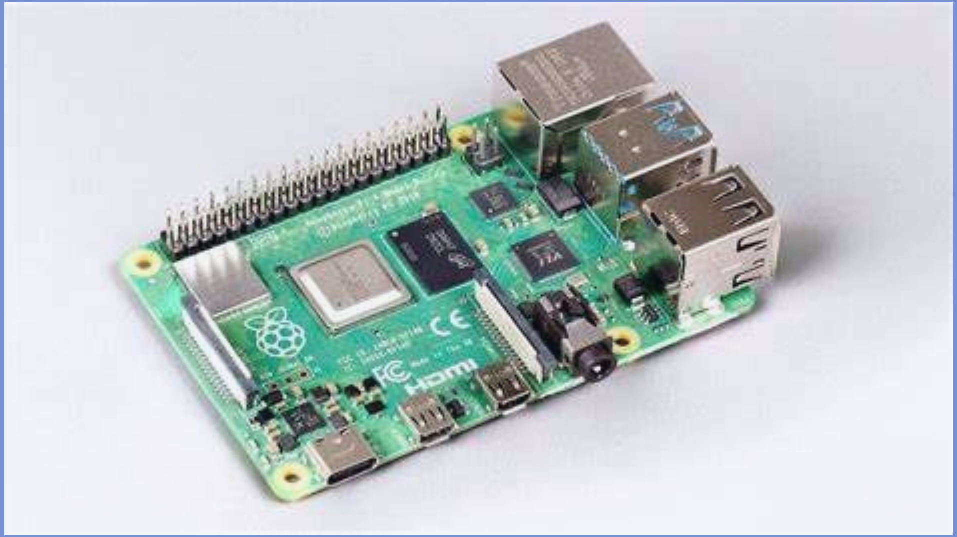
Table 3: *Project-Specific Comparison.*

Main processor

Microcontroller/Microprocessors	Pros for Project	Cons for Project
Raspberry Pi Zero W	Offers a full Linux environment.	Higher power consumption compared to ESP32
Raspberry Pi 4B	Powerful, suitable for a wide range of tasks.	High power consumption may need active cooling.
ESP32	Extremely power-efficient and portable/	Limited computational capabilities compared to Pis

Table 4: *General Aspect Comparison.*

Main processor

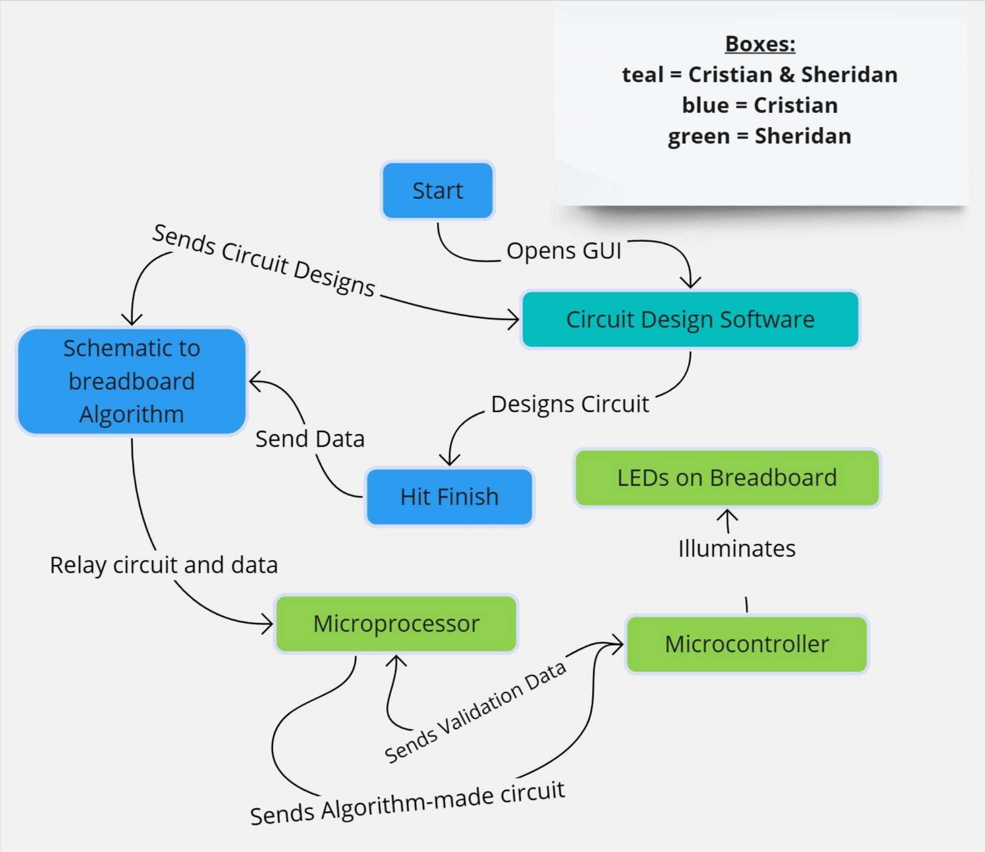


ESP32

- Has enough available GPIO pins
- Has libraries for the Digital Wattmeter Sensor
- Can communicate with the Raspberry Pi 4
- Cheap and easily accessible
- Useful with Arduino IDE

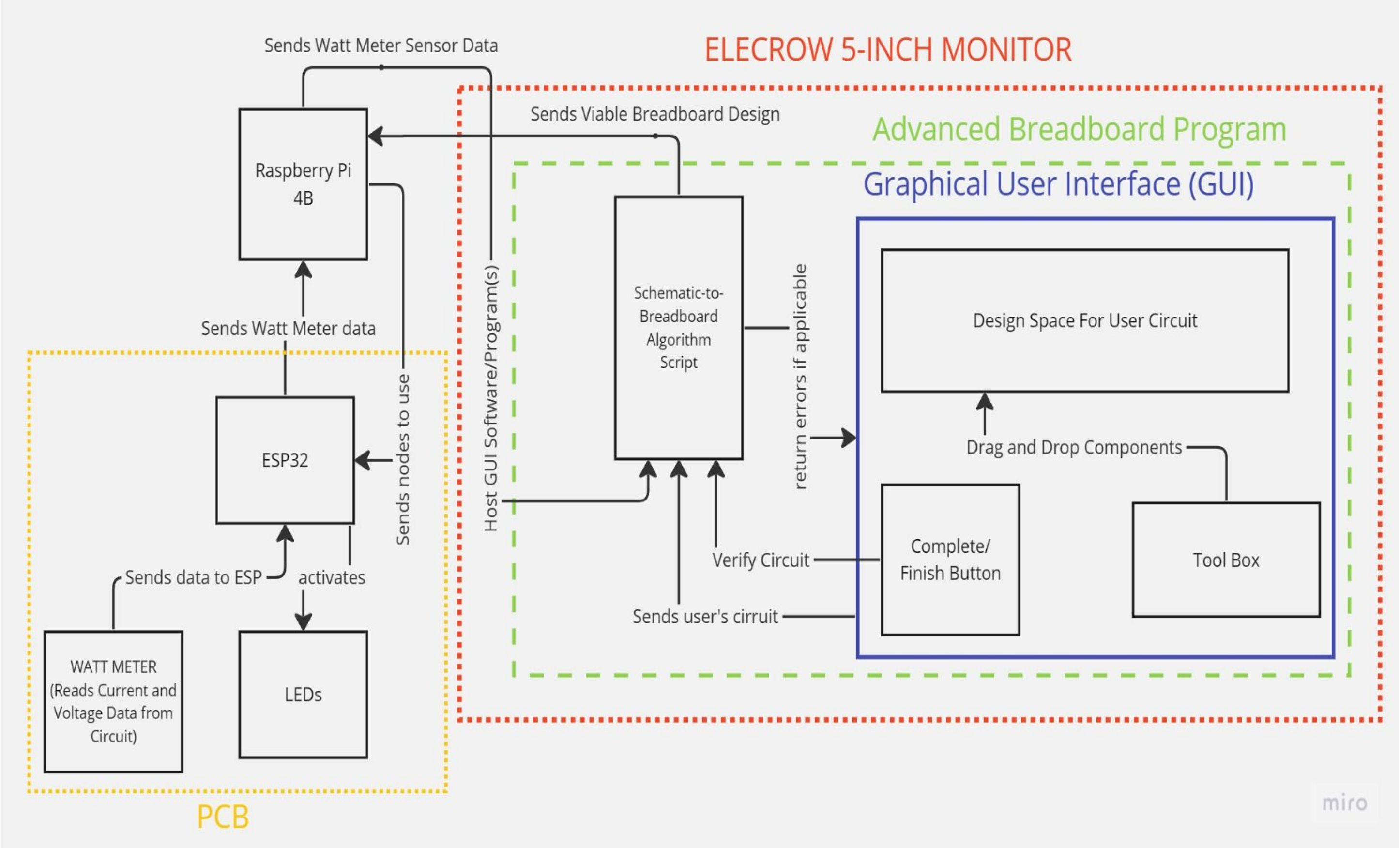
```
void loop(void) {
  //digitalValue = digitalRead()
    Serial.print("BusVoltage:   ");
    Serial.print(ina219.getBusVoltage_V(), 2);
    Serial.println("V");
    Serial.print("ShuntVoltage: ");
    Serial.print(ina219.getShuntVoltage_mV(), 3);
    Serial.println("mV");
    Serial.print("Current:      ");
    Serial.print(ina219.getCurrent_mA(), 1);
    Serial.println("mA");
    Serial.print("Power:        ");
    Serial.print(ina219.getPower_mW(), 1);
    Serial.println("mW");
    Serial.println("");
    delay(1000);
}
```

Software

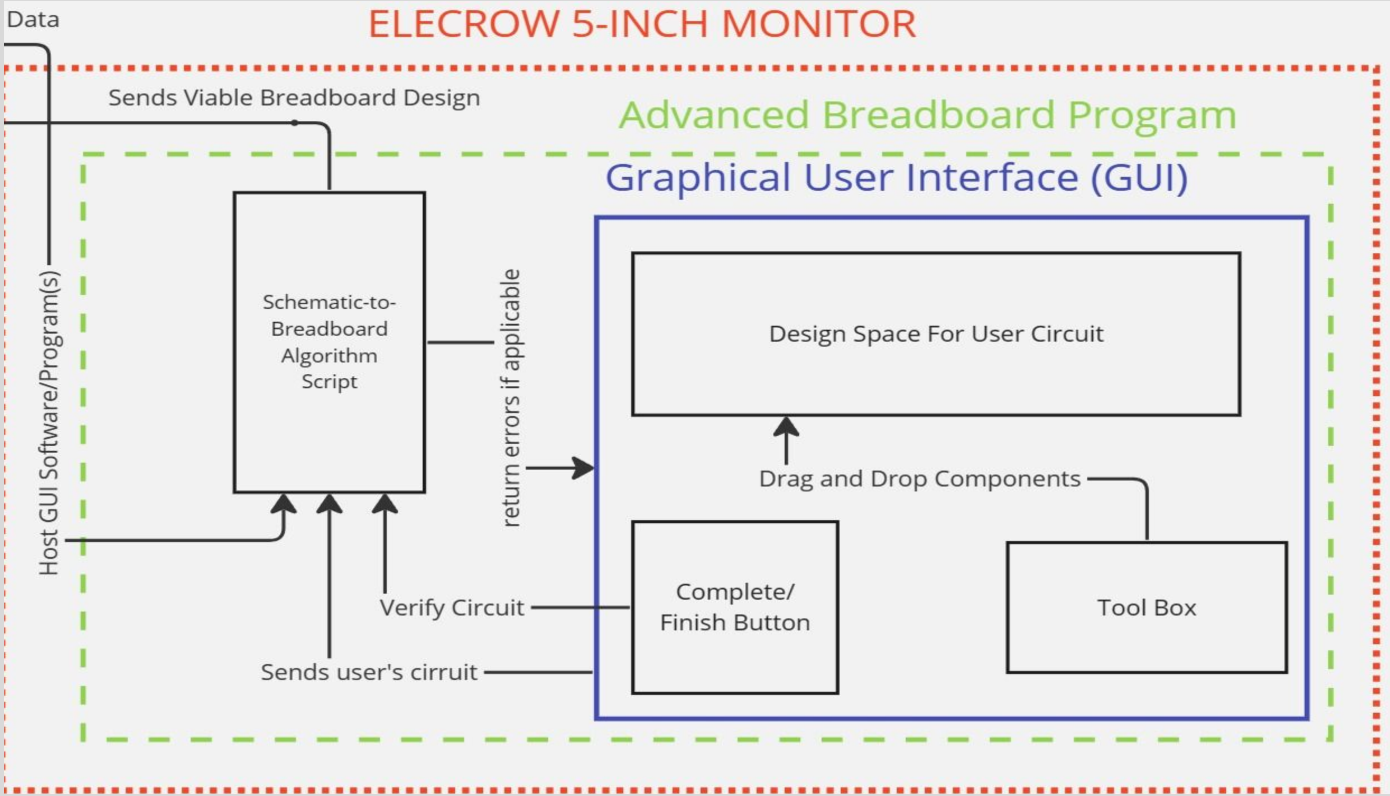


Boxes:
teal = Cristian & Sheridan
blue = Cristian
green = Sheridan
Start
Opens GUI
Circuit Design Software
Sends Circuit Designs
Schematic to breadboard Algorithm
Designs Circuit
Send Data
Hit Finish
LEDs on Breadboard
Illuminates
Relay circuit and data
Microprocessor
Microcontroller
Sends Validation Data
Sends Algorithm-made circuit

Software Subsystem Block Diagram



Main Program Software



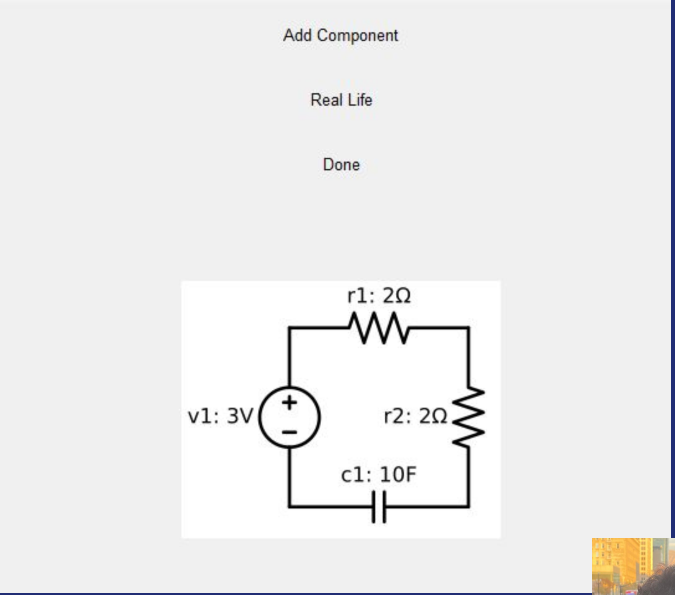
GUI

The GUI comes in a fully packaged individual application (.exe) and inside it provides two main modes:

Free Scale

- Free Scale allows the user to make practically any type of basic circuit in whatever shape and size they want. In this GUI, users may also adjust the orientation and value of each of their components. Upon finishing they will receive a list the connections made

Example Circuit on Free Scale

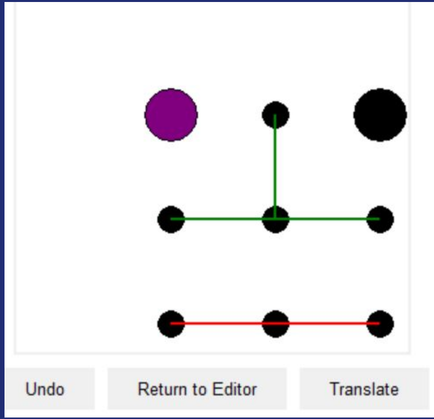


GUI

"Real Life"

- Real life allows users to make a much smaller circuit on a breadboard grid representative of the actual custom breadboard made by us. The user may then translate that circuit into a real life circuit as represented by the LEDs in the nodes inside the breadboard.

Example Circuit on Real Life



Wire color represents component.
Larger dots represent power/ground

GUI Development Specifics

- The majority of the code was ran, compiled, and tested/developed in **VS Code**
- It is entirely written in **Python**
- Main libraries: **Tkinter, PIL, Wand, and SchemDraw**

A Deeper Look (Interface Kit)

Feature	Tkinter	PyQt	Kivy	wxPython
Complexity	Low	Moderate to High	Moderate	Moderate
Ease of Use	Easy for beginners	Steeper learning curve	Moderate, with a focus on touch apps	Good for traditional desktop apps
Flexibility	Basic, suitable for simple applications	Highly flexible with more features	Highly flexible, good for mobile apps	Flexible, suitable for complex apps
Look and Feel	Native look on most platforms	Native via Qt, customizable	Modern, customizable, suitable for touch interfaces	Native look on most platforms
Use Case	Simple desktop applications	Advanced desktop applications, commercial use requires a license	Cross-platform mobile and desktop apps	Complex desktop applications
License	Python Software Foundation License	GPL (free) or commercial license needed for proprietary applications	MIT License	wxWindows Library Licence
Community & Support	Good, due to being a part of standard library	Very good, large community and resources	Good, especially in mobile and interactive applications	Good, established community

A Deeper Look (Circuit Drawing Tools)

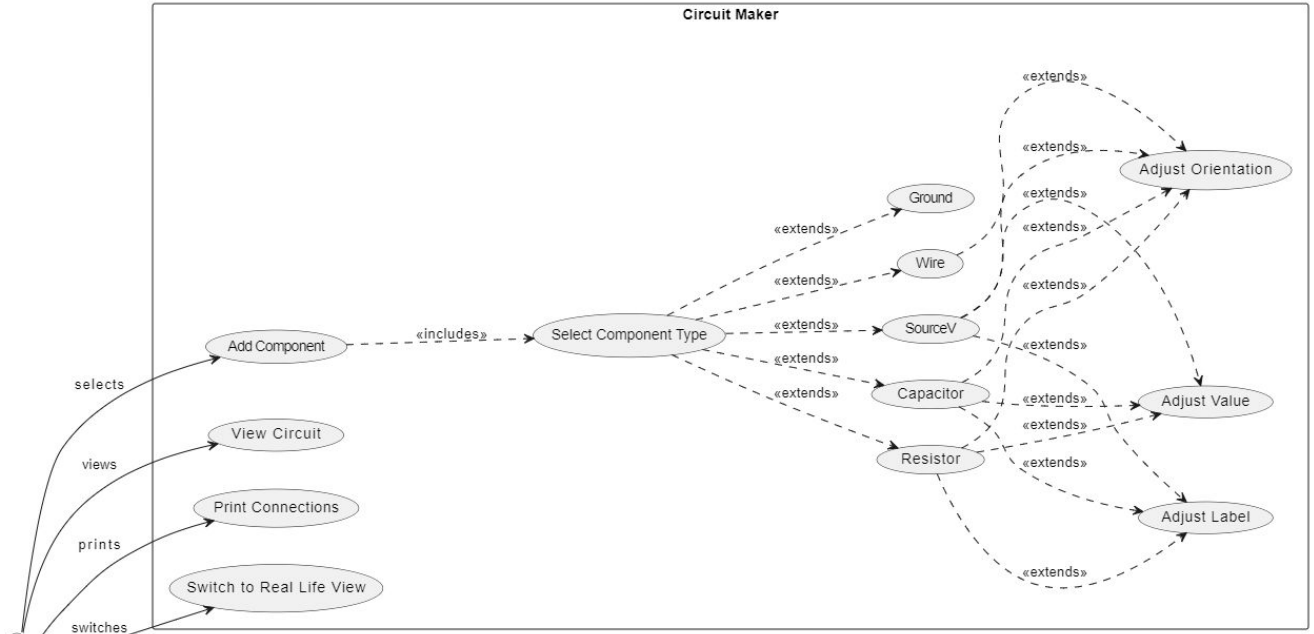
Feature	SchemDraw	PySpice	Matplotlib (for circuit visualization)
Purpose	Drawing electrical schematics	Simulating electronic circuits	General plotting library used for visualizing circuits among other plots
Ease of Use	Easy for basic schematics	Moderate, requires understanding of SPICE	Moderate, requires additional setup for schematics
Key Features	- Simple API for drawing schematics	- Circuit simulation using SPICE engine	- Highly customizable plots
	- Supports drawing resistors, capacitors, inductors, etc.	- Supports analysis like AC/DC, transient, and noise	- Can be used to plot simulation results
	- Customizable component styles	- Python interface for circuit description	- Requires creative use for schematics
Integration	Standalone for schematics	Can be integrated with other Python libraries for analysis and visualization	Often used alongside other libraries
License	MIT	GPLv3	Matplotlib license (PSF-based)
Use Case	Creating electrical circuit diagrams	Circuit simulation and analysis	Visualizing data, including circuit simulation results
Community & Support	Moderate	Good, especially among electronics and simulation communities	Very good, widely used in various fields

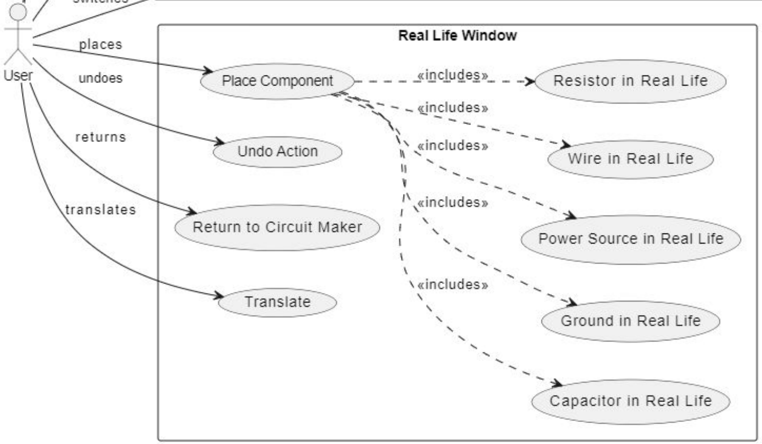
Translational Algorithm

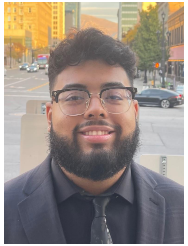
"Real Life" Mode comes with the option to translate your real life circuit, so how does it work?

- The breadboard represented by a 3x3 dot grid in the real life mode, stores the coordinates and connections of each component placed into the circuit. Which is then sent to the esp-32 in the format of matrix to dissect.

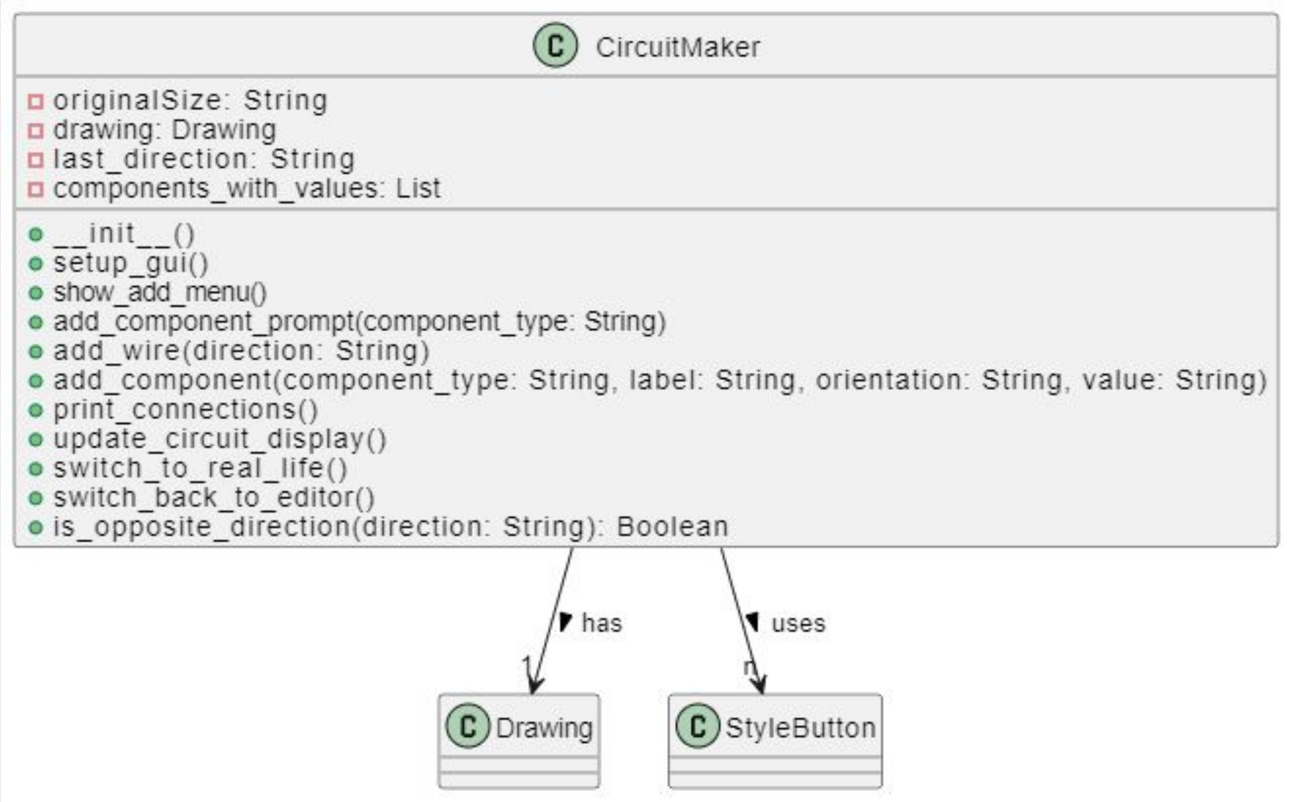
Use Case Diagram



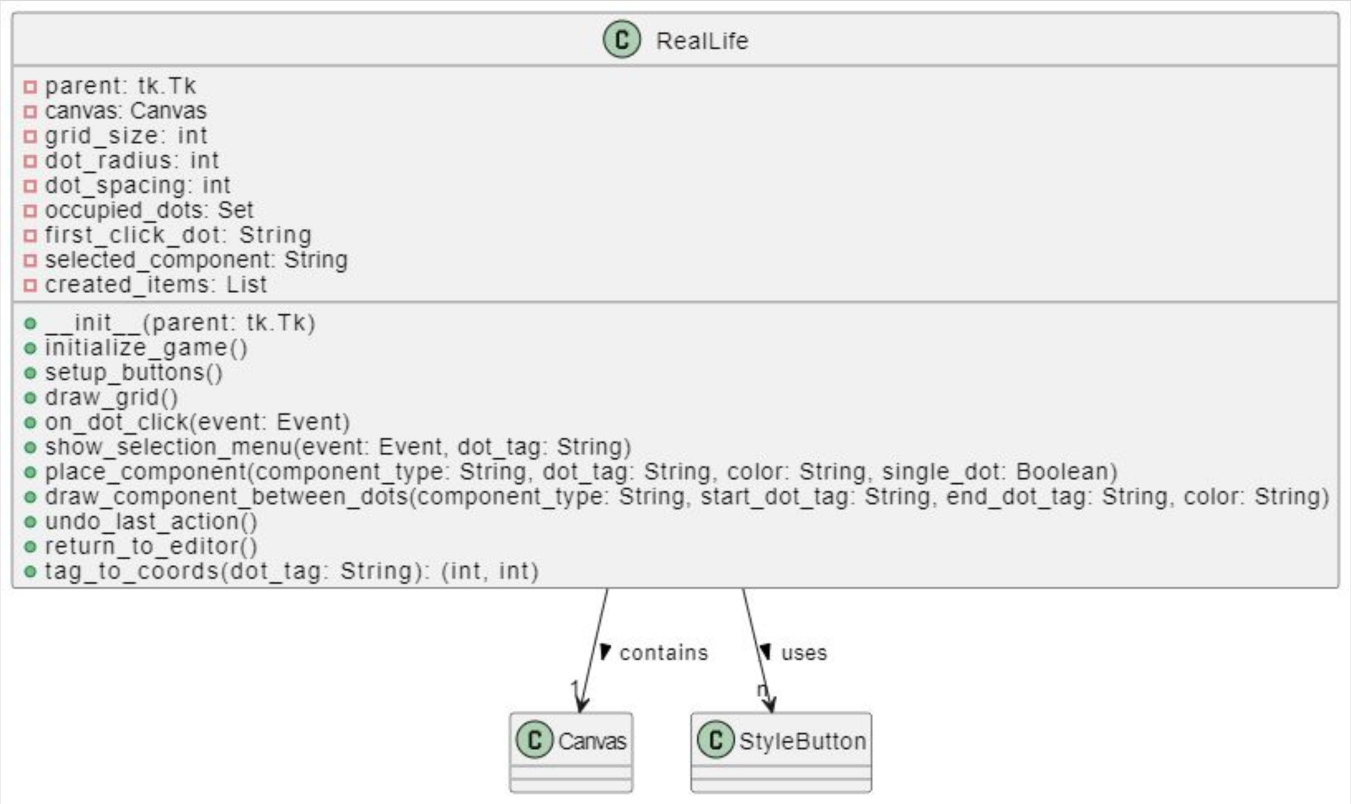




Free Form Mode Class Diagram

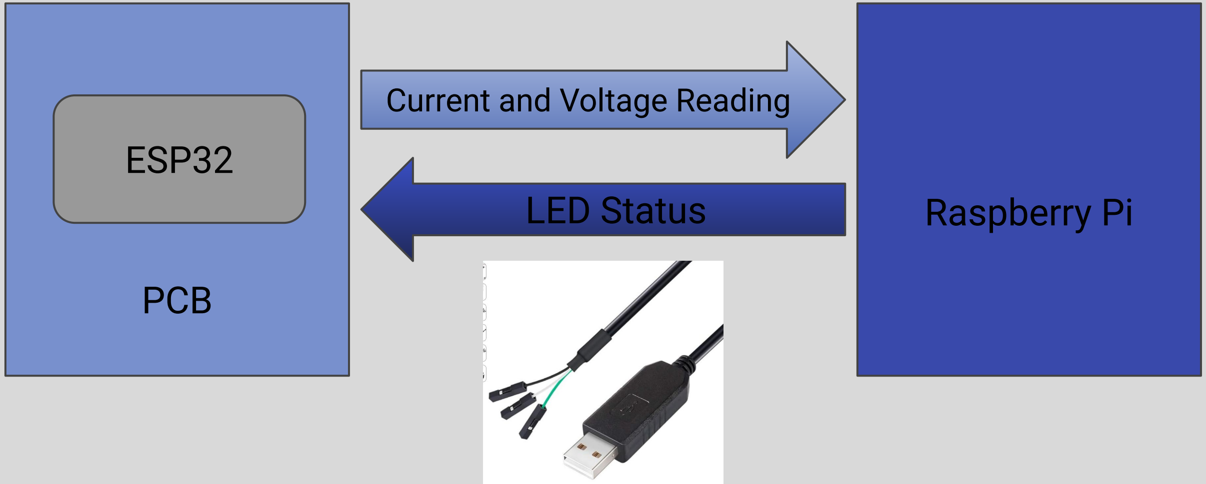


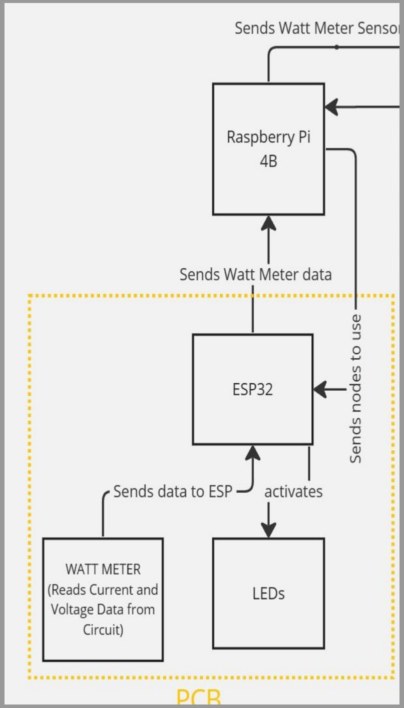
“Real Life” Mode Class Diagram



PCB Communication

- ESP32 will be on the pcb
- This will communicate with the raspberry pi using serial comms
- Pi to esp will give commands for the led
- Esp to pi will give voltage and current readings





Administrative Content

Budget

Work Distribution

Progress

$182.96

Current Dollars Spent

Budget

Purchased

- Raspberry Pi 4B
- ESP32 MCU
- ELECROW Monitor
- I2C Digital Wattmeter (Current/Voltage Sensor)
- 5MM Red LED
- Voltage Regulator
- Battery Holder
- ABS White Filament
- Clear ABS Filament
- ESP32 Development Board
- HDMI to microHDMI converter
- Surface Mount Resistor 0.1 Ohm

To Be Purchased

- PCB
- Power supply for user circuit
- Serial usb to Tx Rx connection
- Solder material

Work Distribution

CpE1	CpE2	EE
Software Designing	Esp 32 Programming	Power Supply Design
Algorithm Creation	Raspberry Pi UART Setup	Wiring Diagram
GUI Development	LED Communication	PCB Design
Raspberry Pi Manipulation	Sensor Communication	Short/Open Cir. Detection

Progress

Design Testing Completed

Software Implementation

Algorithm Creation

GUI Development

Cristian

Esp 32 Programming

Raspberry Pi UART Setup

Sensor Communication

Sheridan

Power Supply Design

PCB Design

Short/Open Cir. Detection

Ammar