Multi-Purpose Device Controller

GROUP 36

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Members

Motivation and Background

- Recognized the demand for versatile controllers that can connect to multiple gaming consoles.
- Eliminate Stick drift: unintended and gradual movement of a gaming controller joystick, often caused by wear and tear on internal components, leading to challenges in precise control for players.
- Aimed to elevate the overall gaming experience by providing a reliable and responsive controller.
- Utilizing Bluetooth for a hassle-free connection, eliminating the need for cables and enhancing user experience.

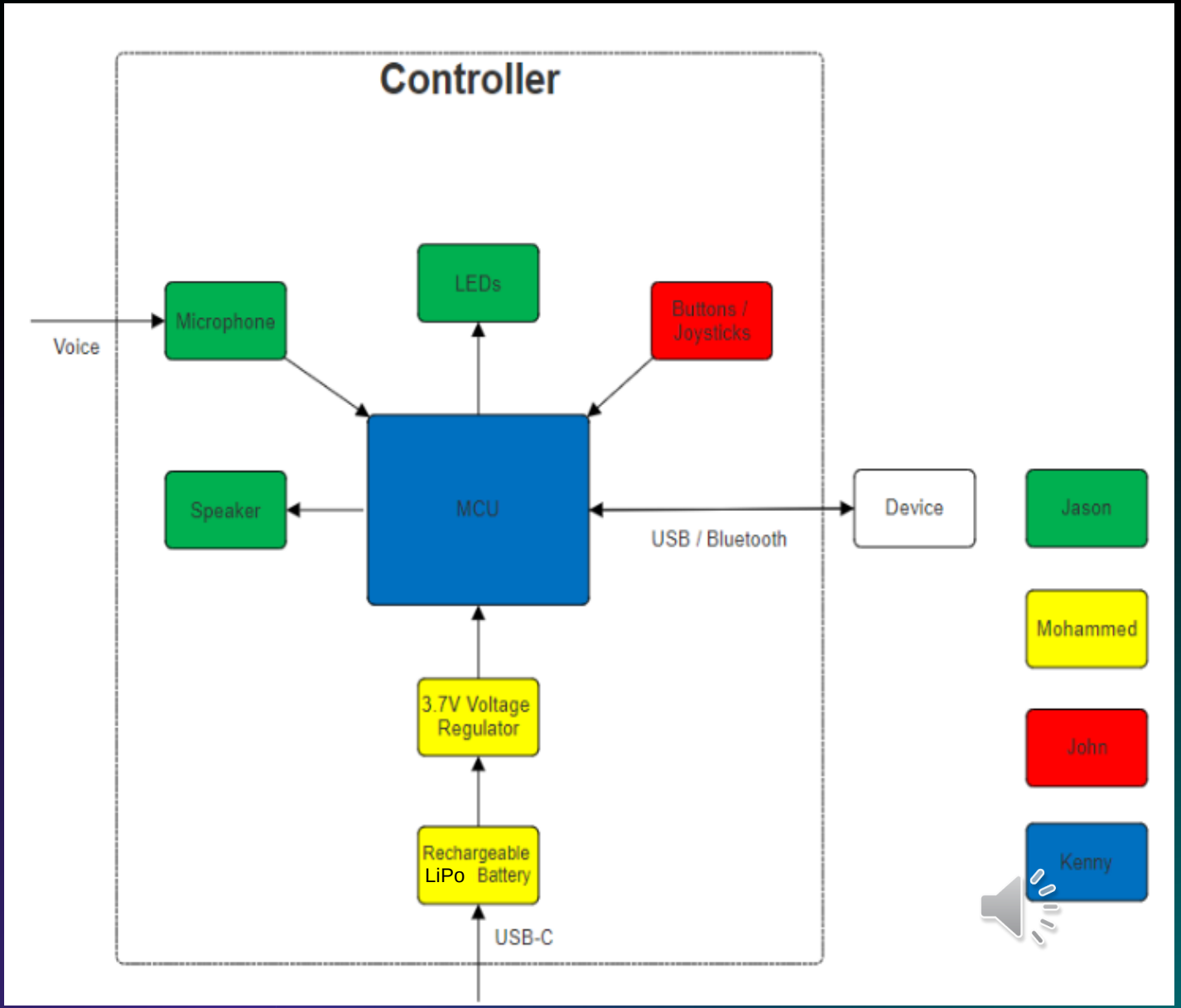
Goals and Objectives

- Goal
  - Design a durable controller with universal compatibility across multiple gaming platforms.
- Objectives
  - Eliminate Stick Drift:
    - Develop a controller with a Hall Effect joystick mechanism to effectively eliminate stick drift issues, ensuring precise and reliable input during gaming sessions.
  - Multi-Console Compatibility:
    - Create a controller that seamlessly connects to a variety of gaming consoles, providing users with a versatile gaming peripheral that adapts to their platform of choice.
  - Bluetooth Connectivity:
    - Implement Bluetooth technology to enable wireless connectivity, enhancing user mobility and reducing cable cl
      a more convenient gaming experience.
- Stretch Goals
  - Develop software enabling users to personalize controller settings and configurations.
  - Enhance compatibility across a broader range of gaming consoles.
  - Design a rubberized exterior to enhance grip and handling comfort.

Specifications

Operating Time	5.6 Hours
Recharge Time	1.5 Hours
Charging	USB C
Connectivity	USB C / BLE
Bluetooth Range	10 Meters

Hardware Block Diagram



Comparison and Selection of Hardware

- MCU
  - ESP32
  - STM32F411
  - Arduino Nano RP2040
- Power Source
  - Lithium-ion
  - Lithium-polymer
  - Nickel-Metal Hydride
  - Power Bank
- Analog sticks
  - Hall Effect Joystick
  - Joystick
- LEDs
  - Adafruit 5050 RGB LED with Integrated Driver Chip
  - WL-SFTW SMT Full-color TOP LED

- Reasonings
  - MCU
    - ESP32 for ease of use and bluetooth capabilities
  - Power Source
    - Lithium-polymer for the size, power output and protection IC
  - Analog Sticks
    - Hall effect for the longevity
  - LEDs
    - Adafruit 5050 RGB LED with Integrated Driver Chip for price in bulk

MCU Comparison

Feature	ESP32	STM32F411	Arduino Nano RP2040
Processor	Dual-core Tensilica LX6 160/240 MHz	ARM Cortex-M4 100 MHz	Dual-core ARM Cortex-M0+ 133 MHz
RAM	520 KiB	256 KiB	264 KiB
Wireless Connectivity	Built-in Wi-Fi and Bluetooth LE	No (external modules needed)	Bluetooth LE only (external modules needed)
Analog Inputs	12-bit ADC with 18 channels	12-bit ADC with 16 channels	12-bit ADC with 2 channels
Digital Pins	34 GPIOs	32 GPIOs	30 GPIOs
Price	$5-$10	$5-$10	$5

MCU Selection: ESP32

- **Built-in Bluetooth**: Connect wirelessly to various platforms like PCs, tablets, and smartphones - no external modules needed.
- **Powerful Processing**: Dual-core CPU and ample RAM handle complex inputs and low latency for smooth gameplay.
- **Low Power Consumption**: Ideal for battery-powered controllers, extending playtime on a single charge.
- **Open-Source Friendly**: Large community and plenty of libraries & tutorials for easy development.
- **Cost-Effective**: Affordable option compared to dedicated gaming controller chips.
- **Future-Proof**: Support for latest Bluetooth LE standards ensures compatibility with upcoming devices.

Analog Stick Comparison

Feature	Hall Effect	Potentiometer
Rotary Mechanism	Magnetic Sensor	Resistive Wiper
Potentiometer	Non-Contact	Contact
Wireless Connectivity	Low	High
Longevity	Over 10 Million Cycles	500,000 – 1 Million Cycles
Cost	Higher	Lower

Analog Stick Selection: Hall Effect

- **Ditch the Drift:** No physical contact means eliminating stick drift, a common issue with traditional potentiometers.
- **Enhanced Durability:** Magnetic sensing resists wear and tear, extending controller life and reducing repair needs.
- **Greater Accuracy:** Higher resolution compared to potentiometers leads to smoother, more nuanced control.
- **Lower Latency:** Less physical interaction minimizes signal noise, potentially reducing input lag.

Battery Comparison

Feature	LP653042	AA Batteries	Battery Pack (1500mAh)
Capacity	1800mAh	2400mAh (combined)	1500mAh
Weight	46g	70g (approximate)	120g (approximate)
Cost	$10-$15	$2-$5 (batteries) + charger	$15-$20
Environmental Impact	Low (rechargeable)	High (disposable)	Moderate (rechargeable)
Temperature Tolerance	-20°C to +60°C	-20°C to +50°C	-10°C to +40°C
Safety Features	Over charge and discharge short circuit protection	None	May have some

Battery Selection: LP653042

- **Extended Playtime**: High capacity at 1800mAh ensures longer gaming sessions without interruption.
- **Reliable Performance**: Lithium-ion technology provides consistent power delivery throughout your gameplay.
- **Lightweight Design**: Weighs only 46g, minimizing controller weight for comfortable and fatigue-free play.
- **Rechargeable Convenience:** Eliminate the need for disposable batteries, saving money and reducing environmental impact.
- **Safety Features:** Built-in protection against overcharge, over-discharge, and short circuits for peace of mind.
- **Temperature Tolerance:** Operates reliably within a wide temperature range (-20°C to +60°C), suitable for various environments.

LED Comparison

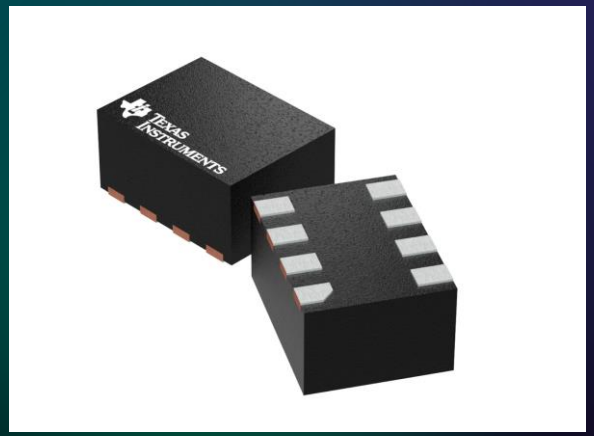
	Adafruit 5050 RGB LED with Integrated Driver Chip	WL-SFTW SMT Full-Color TOP LED
Voltage	5V	5V
Current	5mA	20mA Red, Green, Blue
Power	10 Watts	108mW (Blue), 108mW (Green), 72mW (Red)
Dimensions LxWxH	5.12 x 3.15 x 0.39 inches	3.5mm x 2.8mm x 2.1mm
Cost	$6.99 (10)	$0.50 (1)

LED Selection: Adafruit 5050 RGB LED

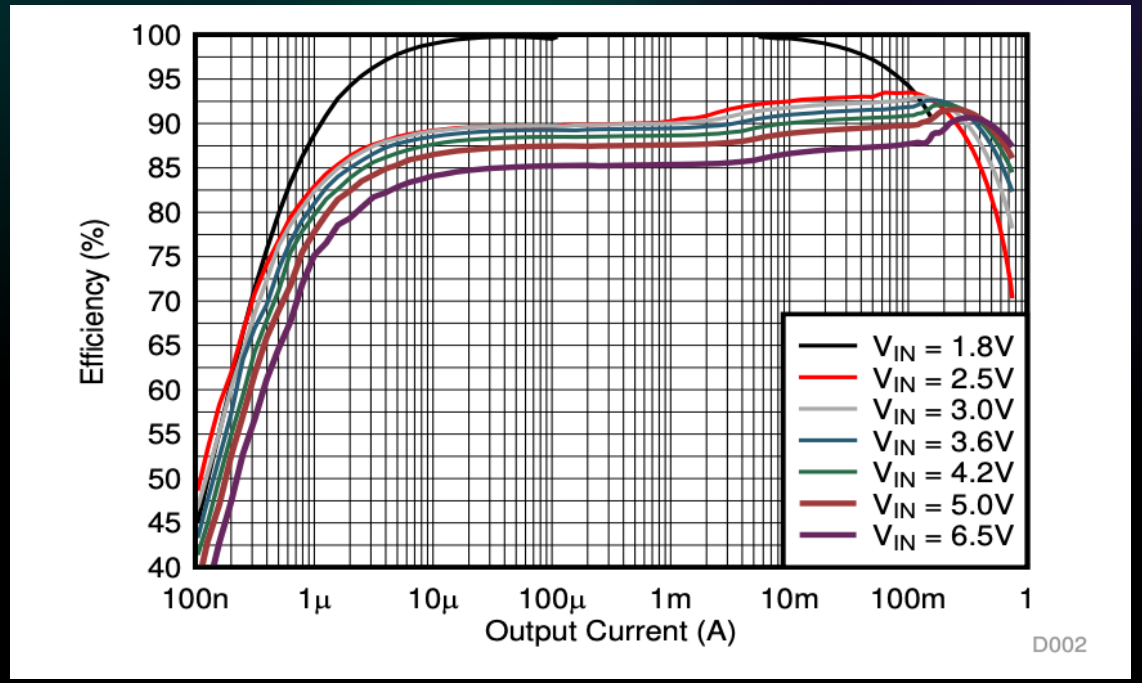
- **Addressable:** Able to set a color for each individual LEDs or all of them as a whole to indicate battery life, charging, connecting, or on and off
- **Bulk Shipping:** Comes in a pack size of 10, which is more cost effective in the long run
- **Power consumption:** runs on 10 watts, works in conjunction with our other components and the output of our battery

Voltage Regulator (TPS62840DLCR)

- 3.7v to 3v3
- high-efficiency step-down converter
- provides an output current of up to 750 mA
- Used to power all MCU peripherals except for LEDs

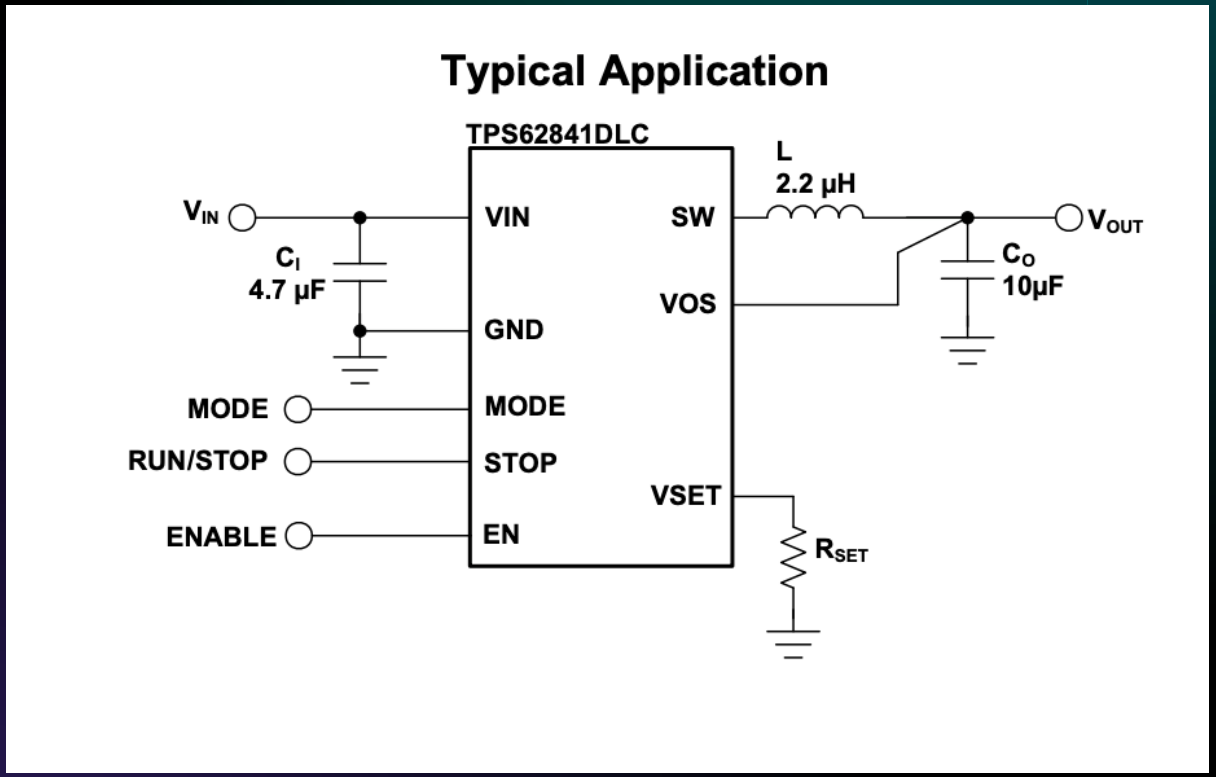


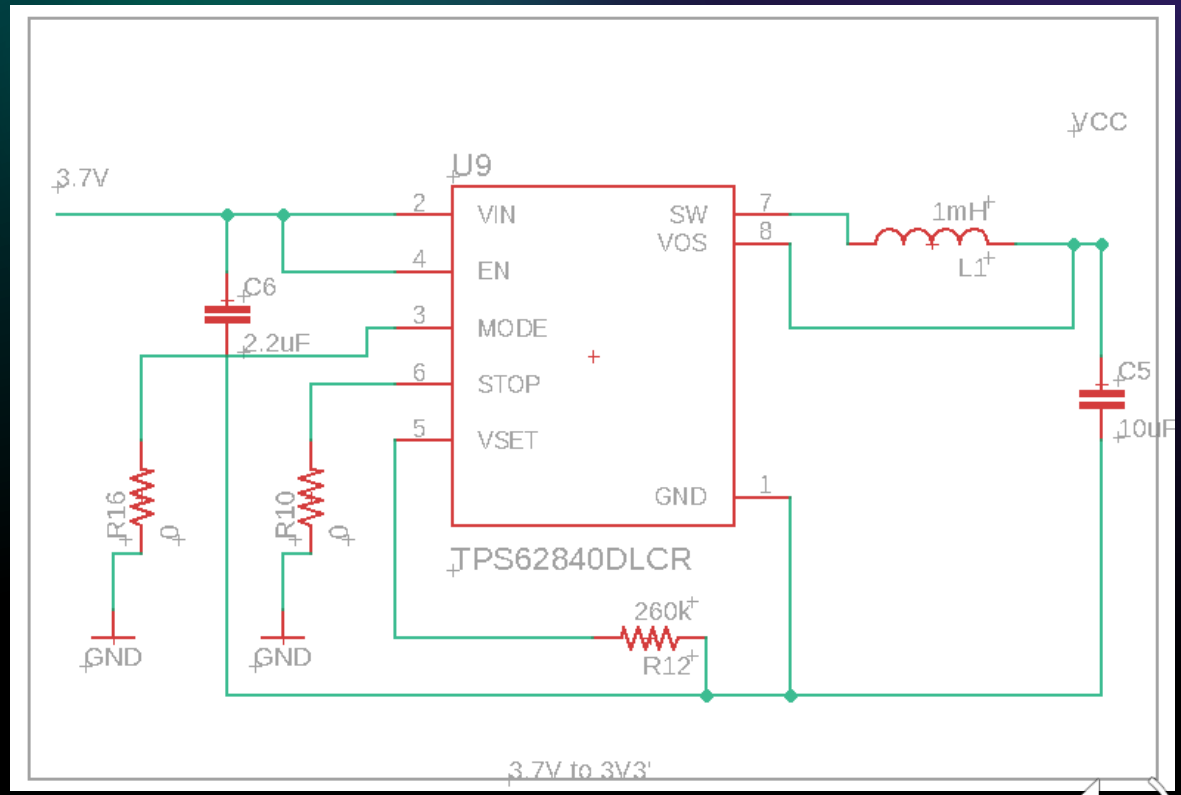
Efficiency Graph



Voltage Regulator Circuit

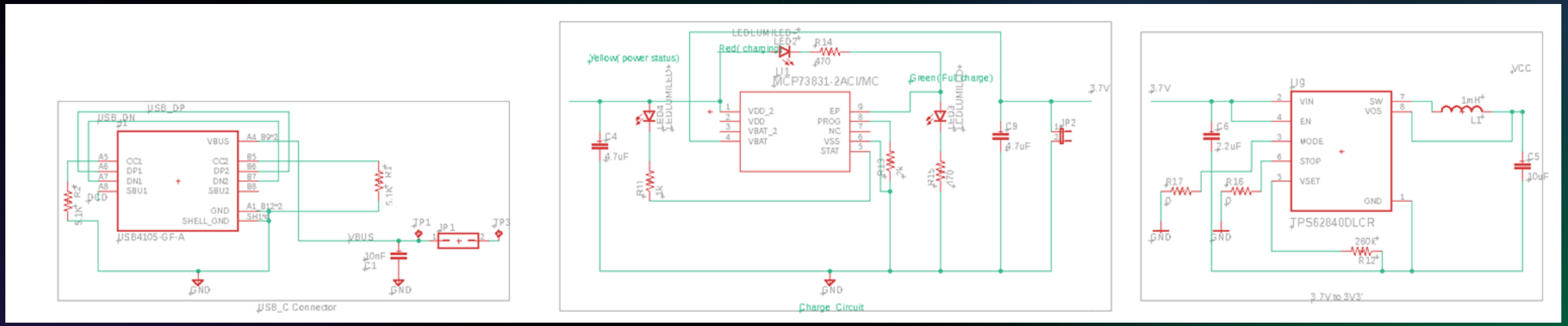
Typical application circuit vs used circuit in our PCB





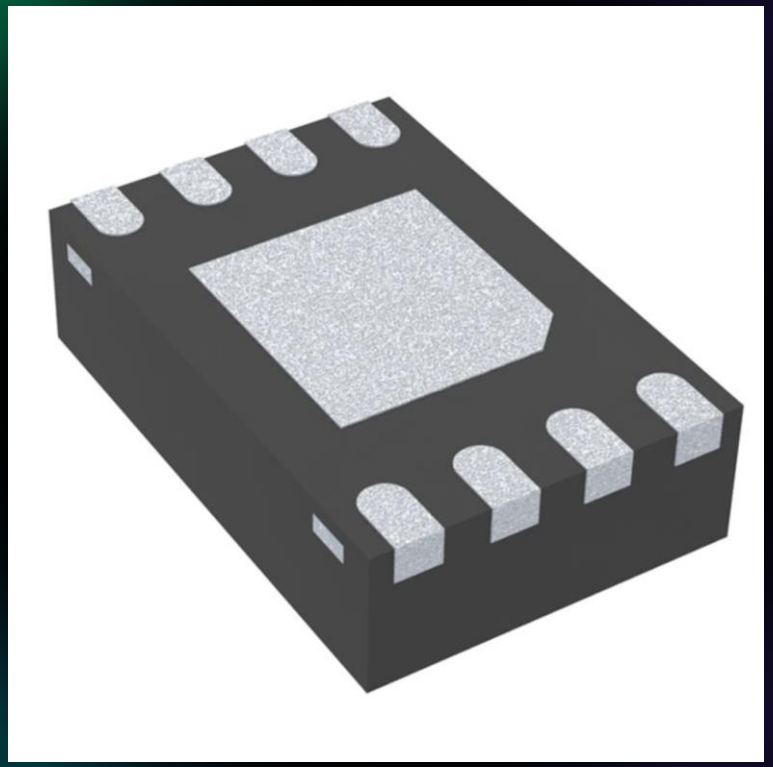
Power regulation schematic

- UCB-C CONNECTER
- CHARGING CIRCUIT
- VOLTAGE REGULATOR

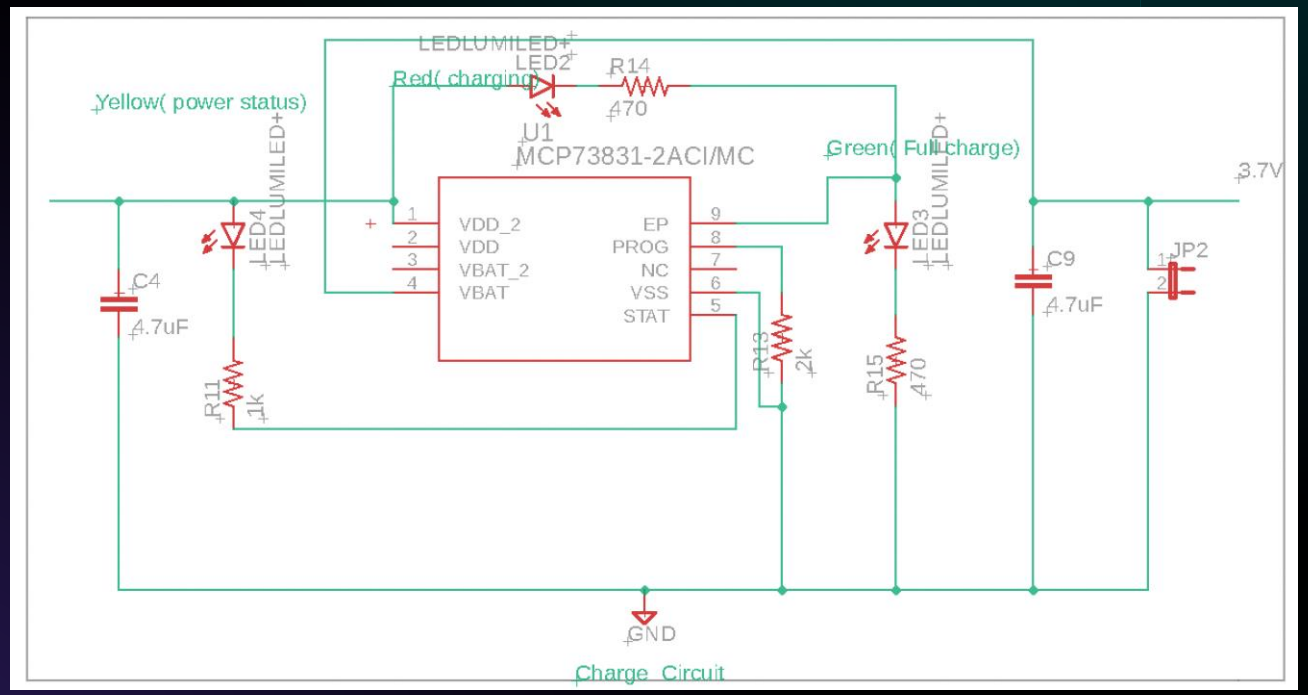


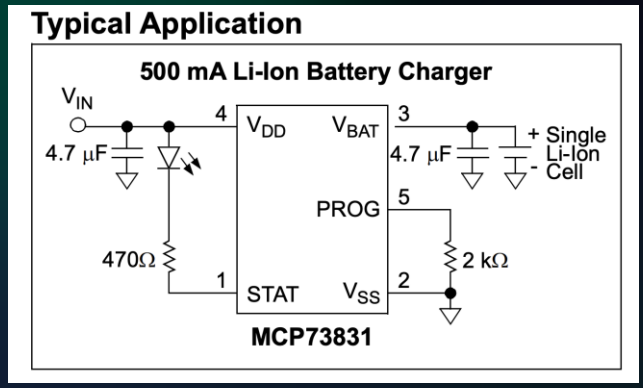
Charging Circuit (MCP73831/2)

- Programmable Charge Current: 15 mA to 500 mA
- Charge Status Output (LEDs)
- High-Accuracy Preset Voltage Regulation: + 0.75%



Charging circuit





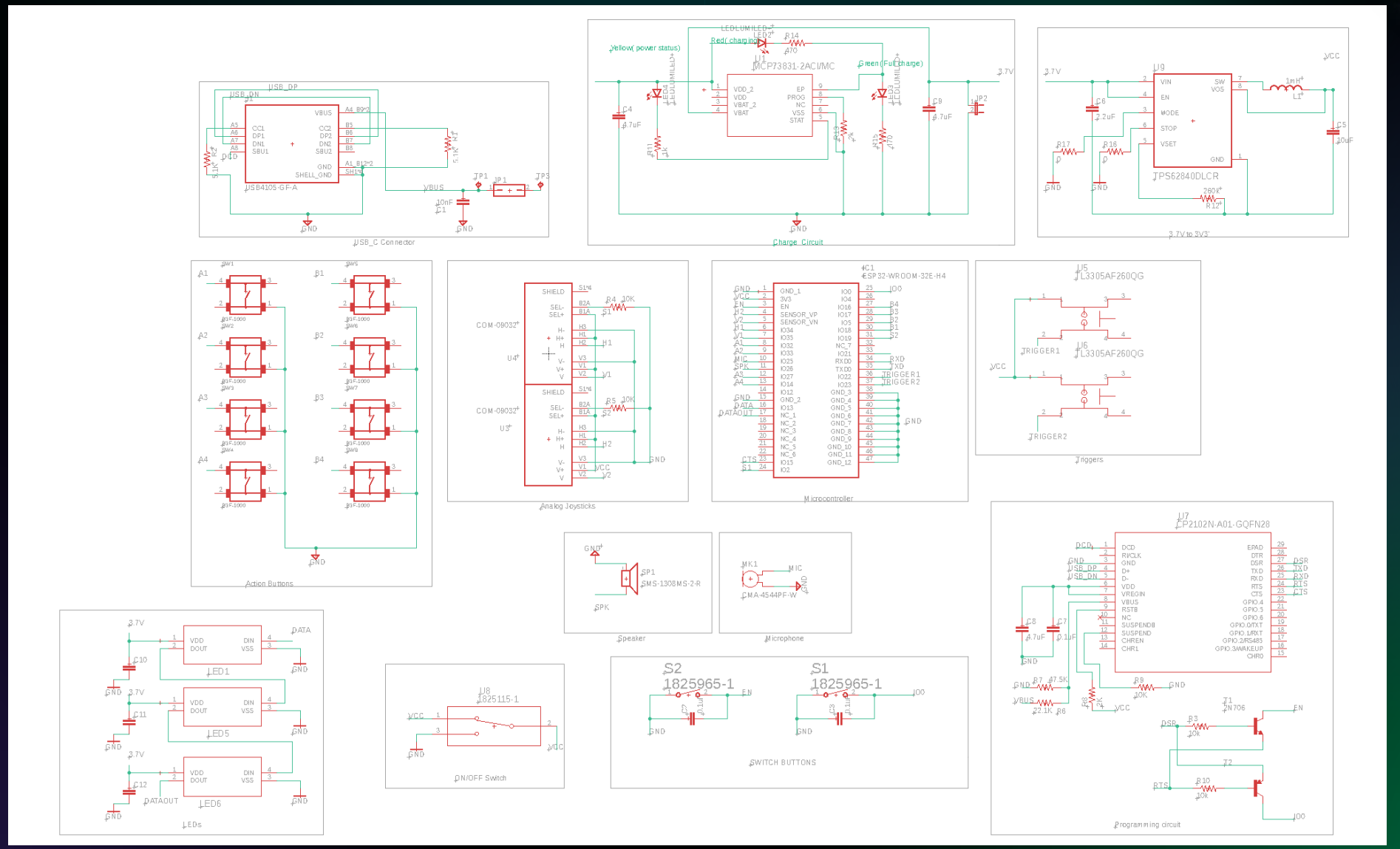
$$I_{REG} = \frac{1000V}{R_{PROG}}$$

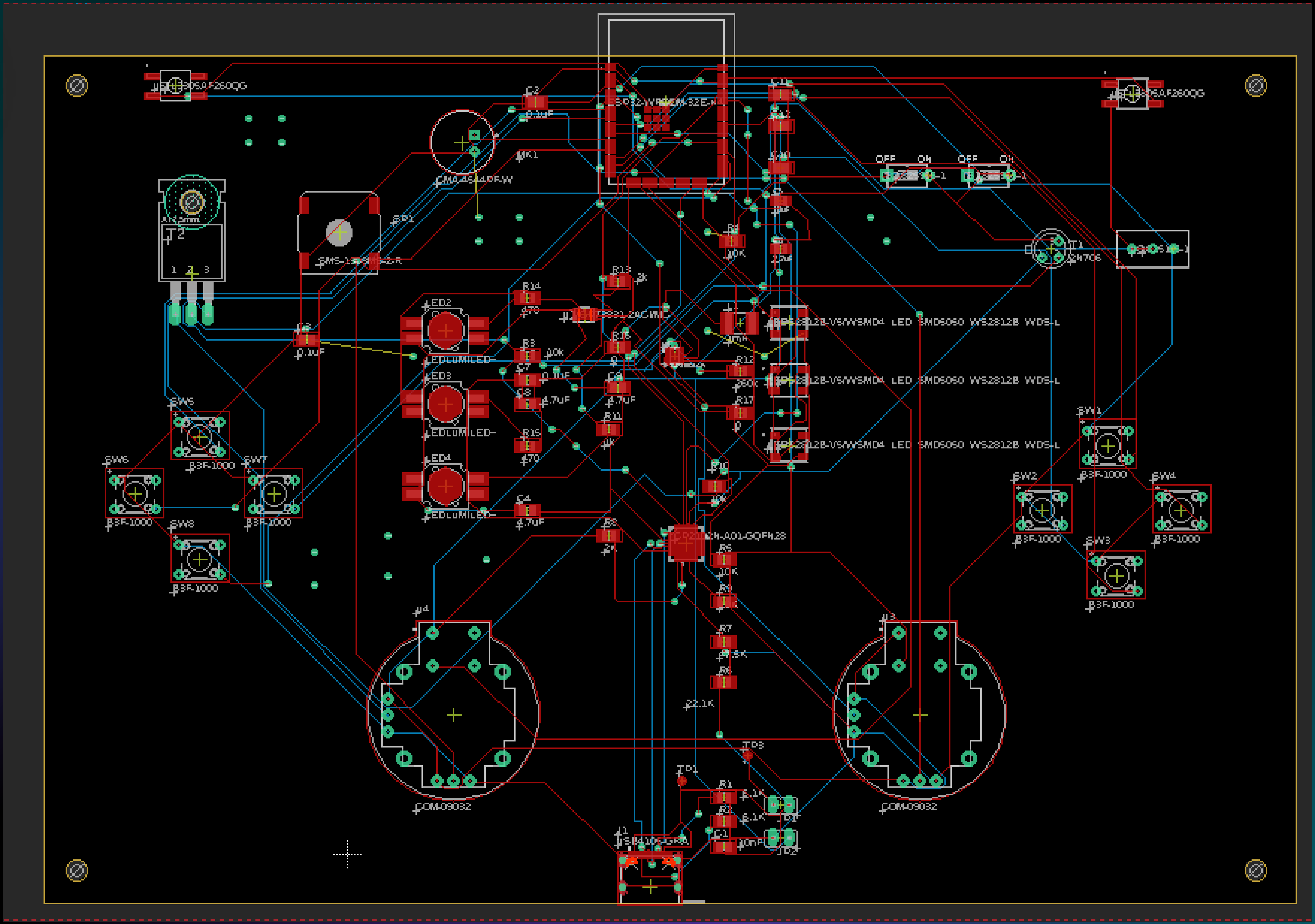
Where:

R_{PROG} = kOhms

I_{REG} = milliampere

- PCB Schematic




OFF
ON
OFF
ON
SW1
SW2
SW3
SW4
SW5
SW6
SW7
SW8
B3F-1000
LED2
LED3
LED4
COM-09032
R14
R13
R3
R15
C4
4.7uF
0.1uF
10K
22.1K
470

Feature	BLE (Bluetooth Low Energy)	Wi-Fi	Radio Frequency
Latency	Low	Moderate to High	Variable
Power Consumption	Low	High	Moderate
Range	Up to 10 meters	Up to 30 Meters	Variable
Compatibility	Broad (smartphones, PCs, tablets)	Moderate (PCs, some consoles)	Variable
Cost	Lower	Higher	Variable
Security	Built-in security features	Requires additional security measures	Variable

Wireless Comparison

Wireless Communication Software Selection: BLE

- **Low Latency:** Enjoy responsive gameplay with minimal input lag.
- **Power Efficiency:** Extends battery life for longer gaming sessions without frequent charging.
- **Wide Compatibility:** Connects to various devices like PCs, tablets, and smartphones offering platform flexibility.
- **Secure Communication:** Built-in security features protect data privacy during gameplay.
- **Simple Integration:** Requires less complex hardware compared to other wireless protocols.
- **Future-Proof:** Supports latest Bluetooth LE standards for broad device compatibility.
- **Low Cost:** Enables affordable controller design without sacrificing performance.

NimBLE

- Enables ESP32 to communicate wirelessly with BLE-enabled devices.
- **Low Power Consumption**: Essential for gaming controllers, prolonging battery life.
- **Compatibility:** Works seamlessly with ESP32.
- **Comprehensive API:** Facilitates BLE functionalities.
- **Security:** Ensures data protection during wireless communication.
- **Flexibility:** Customizable BLE profiles to suit gaming controller requirements.

Connection Test

Output | Serial Monitor

Message (Enter to send message to 'ESP32 Dev Module' on 'COM3')

New Line | 115200 baud

```
entry 0x400805f0
The device with name "ESP Gaming Controller" is started.
Now you can pair it with Bluetooth!
ets Jul 29 2019 12:21:46

rst:0x1 (POWERON_RESET),boot:0x13 (SPI_FAST_FLASH_BOOT)
configsip: 0, SPIWP:0xee
clk_drv:0x00,q_drv:0x00,d_drv:0x00,cs0_drv:0x00,hd_drv:0x00,wp_drv:0x00
mode:DIO, clock div:1
load:0x3fff0030,len:1344
load:0x40078000,len:13964
load:0x40080400,len:3600
entry 0x400805f0
The device with name "ESP Gaming Controller" is started.
Now you can pair it with Bluetooth!
```

Add a device

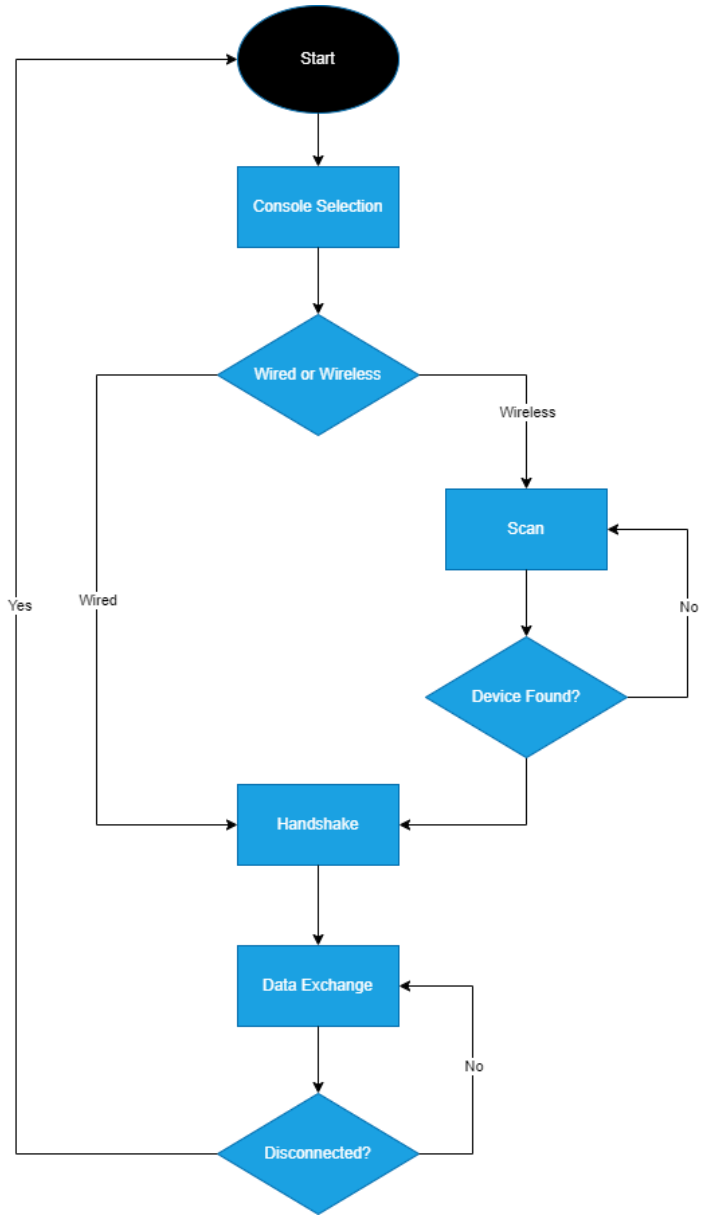
Your device is ready to go!

ESP Gaming Controller

Done

Software Flowchart

- Power On
- Initialization
- Connection Type Check
  - Wired: Skip to step 4.
  - Wireless
    - Discovery
- Connection Initiation
- Data Exchange
- Disconnect



Comparison and Selection of Software

- Programming Language
  - C
  - MicroPython
  - Arduino C++
- Connections
  - Bluetooth Low Energy
  - Wi-Fi
  - Radio Frequency

Language Comparison

Feature	C	MicroPython	Arduino C++
Performance	High	Moderate	Moderate
Hardware Access	Direct	Limited	Moderate
Memory Management	Manual	Garbage Collection	Semi-Automatic
Community and Resources	Vast	Growing	Very Large
Error Handling	Manual Checks	Automatic	Semi-Automatic
Portability	High	Limited	Moderate

Language Selection: C

- **Direct Hardware Access:** Control peripherals like buttons, joysticks, and sensors with precise timing crucial for gameplay.
- **Efficiency and Speed:** Compiled language minimizes overhead, maximizing responsiveness and minimizing latency for smooth gameplay.
- **Wide Toolchain Support:** Abundance of open-source compilers, debuggers, and libraries readily available.
- **Mature and Stable:** Long history and active development ensure reliability and compatibility.
- **Large Community & Resources:** Benefit from the shared knowledge and experience of many developers.
- **Future-Proof:** Widely used in professional game development and embedded systems.

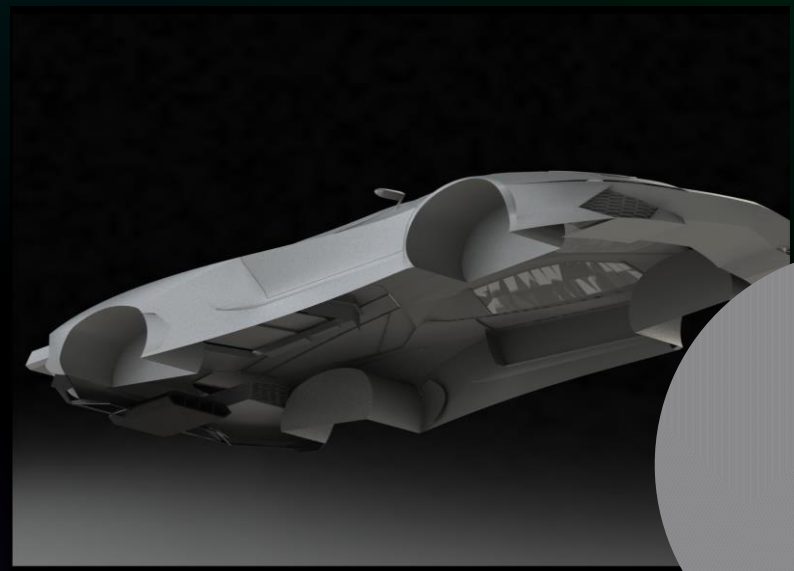
Accuracy Techniques

- **Polling**
  - Polling involves continuously checking the state of each button or input at regular intervals.
  - Provides a straightforward implementation for detecting input, ensuring responsiveness in gameplay.
- **Dead zone**
  - Dead zones are regions around the center position of joysticks where no input is registered.
  - Implemented to filter out small unintended movements or inaccuracies in the joystick's resting position.
  - Improves the user experience by making the joystick feel more stable and responsive, especially in games requiring precise control.

Budget and Bill of Materials

Parts	Quantity	Price ($)
MCU	1	4.50
Hall Effect Joysticks	2	1.35
USB-C Connection Port	5	6.32
Push Buttons	10	0.25 – 0.90
Custom PCB	5	23.26
Rechargeable Li-Po Battery	1	10
Addressable LEDs	3	7.45
Programmable Circuit	1	7
Speaker	1	3.71
Microphone	1	0.43
Subtotal		207.59

- Total budget $600
- Spent roughly $208
- Remaining $392
- Final component will consist of 3D printed encasing which will house the PCB and some internal hardware components.



Division of Work

Tasks	Primary	Secondary
PCB Design	Mohammed	Jason
Component Specification and Ordering	Jason	Mohammed
Analog Sitck and Button Calibration	John	Kenny
Bluetooth Connectivity	Kenny	Jason
Microcontroller Programming	Kenny	John
Hardware Assembly	Everyone	N/A
Battery Regulation	Mohammed	Jason