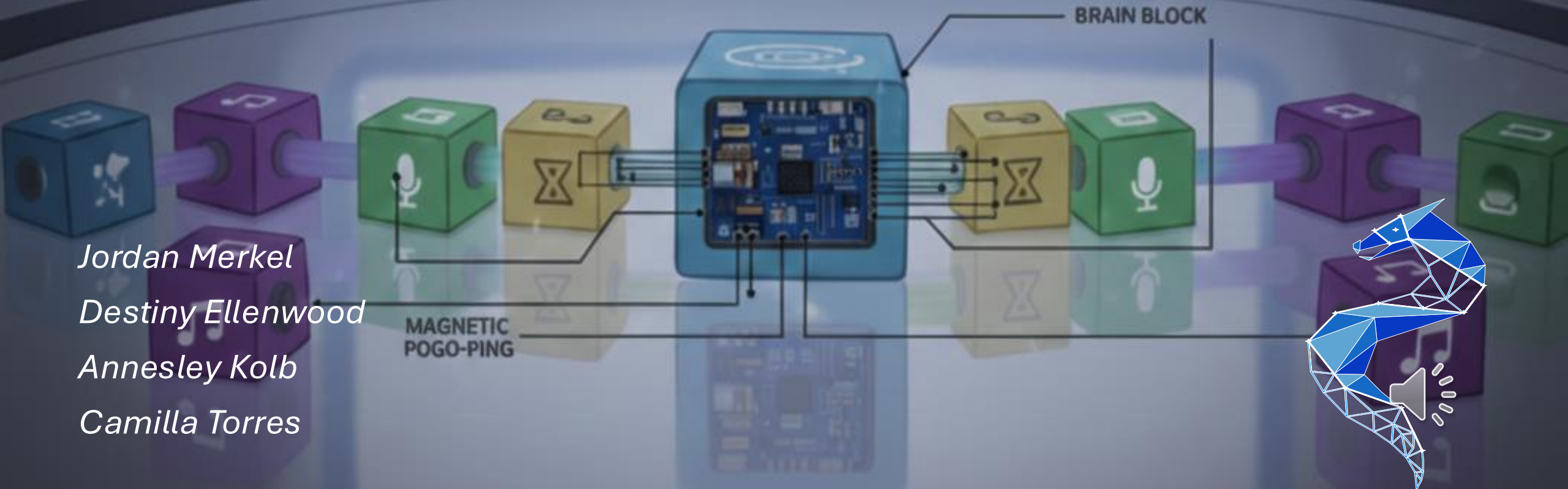


Blocks o' Code (v3)

Sponsored by Dr. Mike and Dr. Weeks

*Jordan Merkel
Destiny Ellenwood
Annesley Kolb
Camilla Torres*



The Team



Jordan Merkel

Computer Engineering



Destiny Ellenwood

Computer Engineering



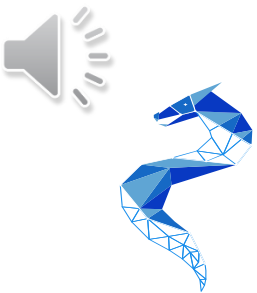
Annesley Kolb

Electrical Engineering



Camilla Torres

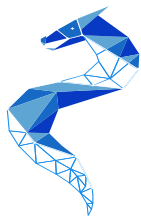
Electrical Engineering





Team Member Roles

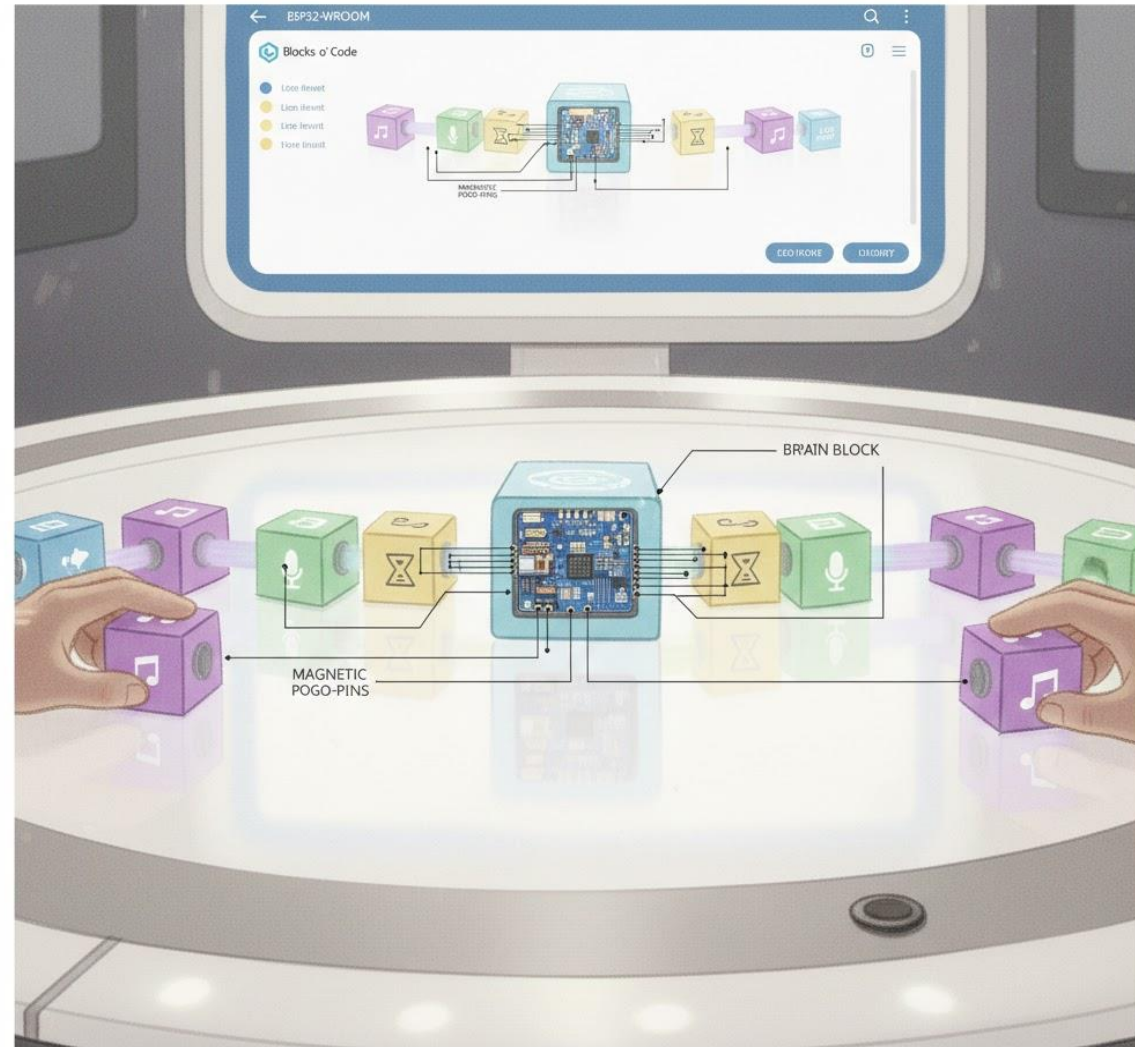
Team Member	Primary Responsibilities
Jordan	Project Lead, Fullstack Software Integration, Firmware development, UI/UX Design, Network Architecture
Camilla	PCB Design, Power Distribution, PCB Assembly & Testing
Annesley	PCB Design, PCB Assembly & Testing, CAD modeling
Destiny	Firmware development, reliability & hardware/software validation.



Project Overview

What is Blocks of Code?

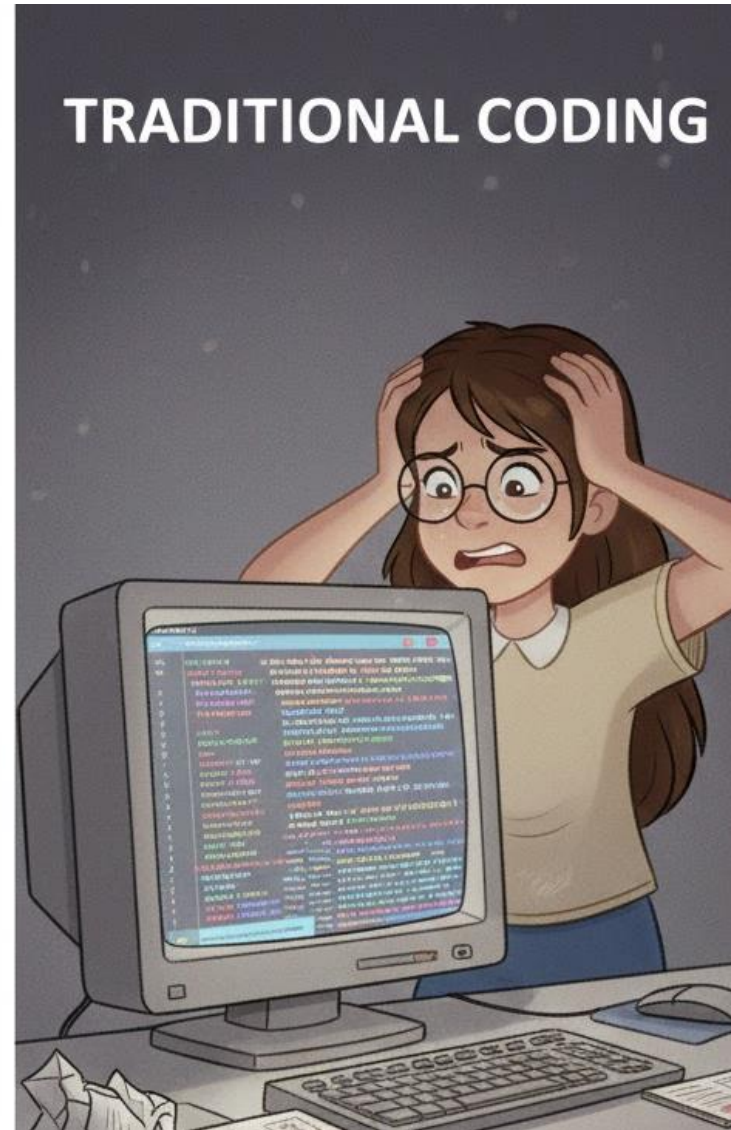
- Physical coding system for teaching programming
- Designed for kids and beginners
- Uses magnetic blocks to build programs
- No typing or traditional coding required
- Creates real-world outputs like lights and sound
- Makes learning interactive and hands-on





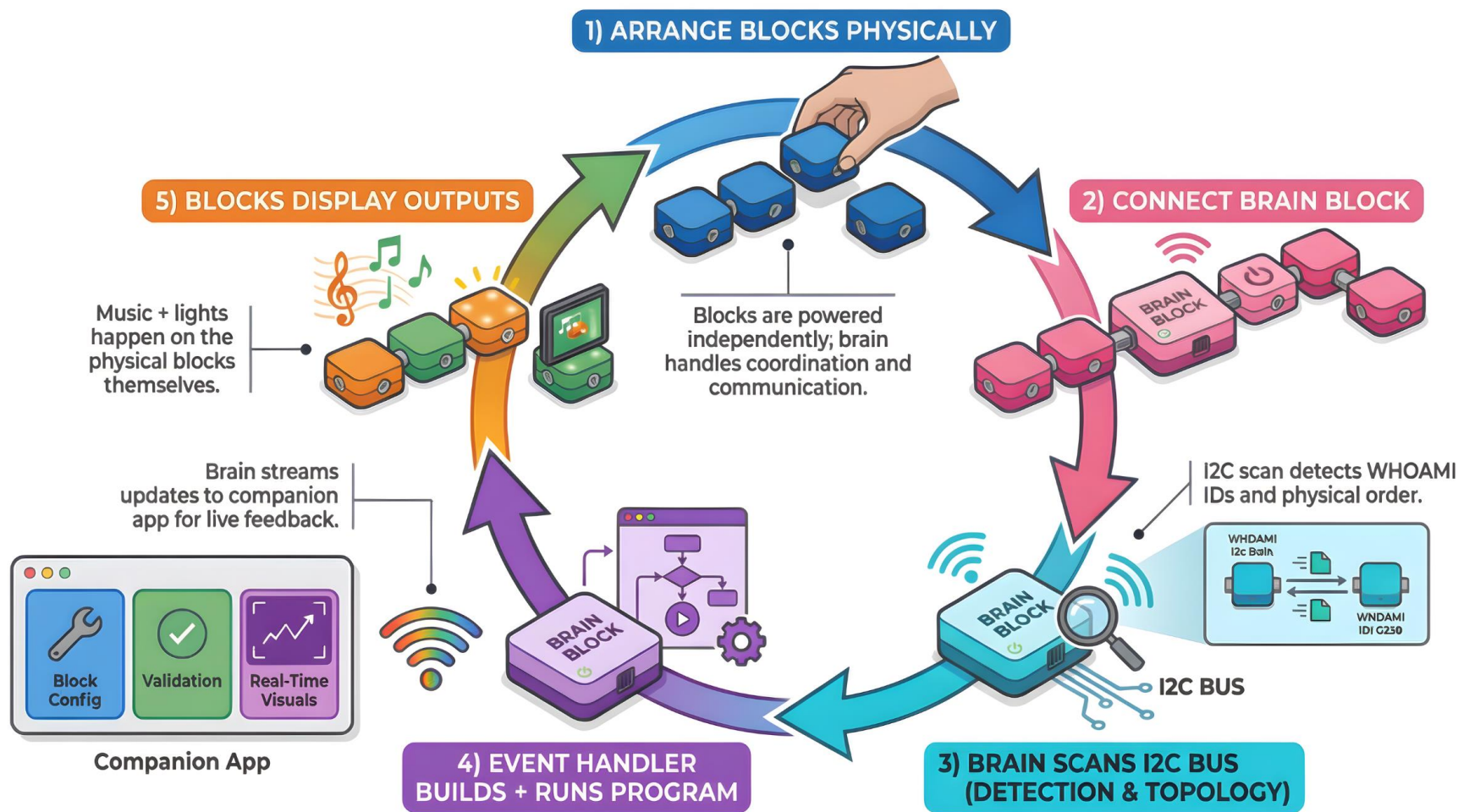
Problem and Motivation

- Complex Syntax
- Unclear Cause-and-Effect
- Limited Accessibility



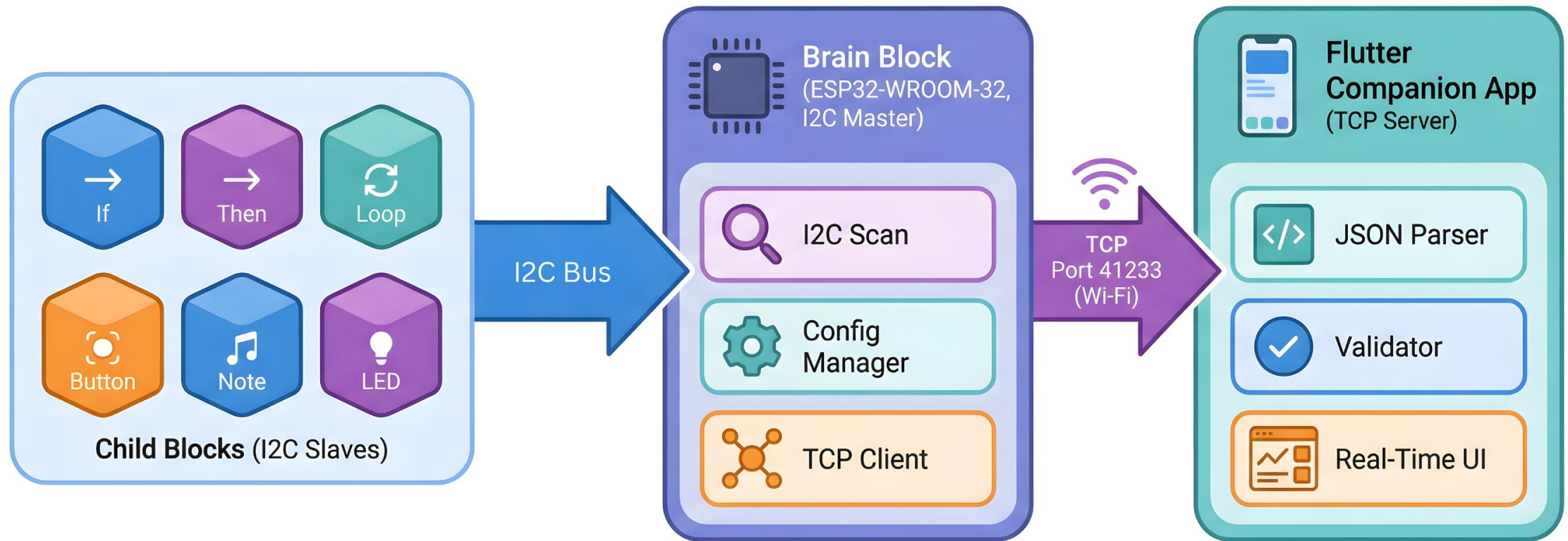


End-to-End Interaction Flow



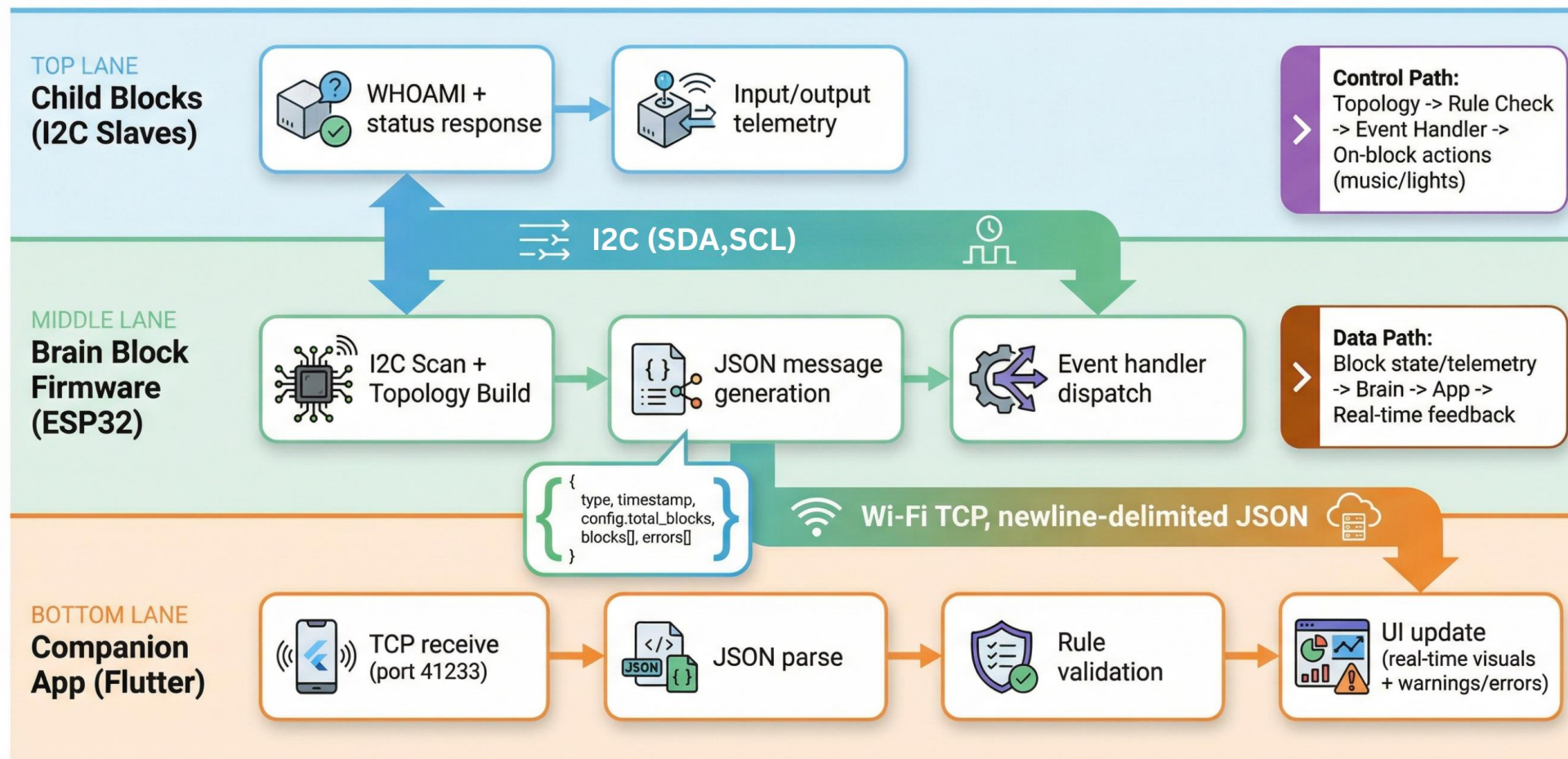


System Architecture





Data/Control Flow



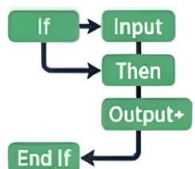


Configuration Rules



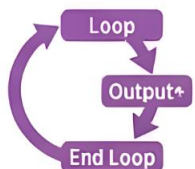
Brain Block Rule

Brain block is required and must be at index 0.



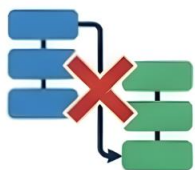
If Sequence Rule

If → Input → Then → Output+ → End If



Loop Sequence Rule

Loop → Output+ → End Loop



Sequence Isolation Rule

If/Loop sequences should not interleave.

Validation Output

! Error (must fix)

- ✗ Missing Brain Block
- ✗ Brain Block not at index 0
- ✗ Invalid If sequence
- ✗ Invalid Loop sequence

Warning (advisory)

- ⚠ Interleaved If and Loop sequences



Receive JSON → Parse → **Validate** → UI feedback



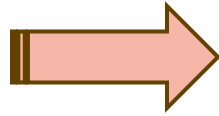


Goals and Objectives



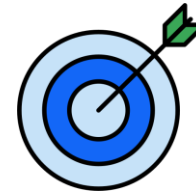
Basic Goal

- Magnetic contact-based block-to-block communication.
- Low-latency I2C (100kHz) keeps commands fast and reliable.
- At least 15 functional blocks with clear visual indications.



Functional Goal

- Brain detects connected blocks in milliseconds and syncs topology to the companion app.
- App mirrors actions instantly for guidance, status, and playback.
- Magnetic contact pads for data and power; low-power design for extended runtime (e.g. ≥ 60 min active).



Stretch Goal

- Real-time visualization on PC/tablet.
- 3D-printed block enclosures.
- OLED/ e-paper on-block displays.
- Voice input blocks



Success Criteria

- System validates 3+ sequence types (e.g. If/Then, Loop, LED Color Flash) and supports configurations with 15+ blocks.
- Peripherals such as lights, sound, and UI provide immediate feedback for valid and invalid sequences.
- App mirrors actions in real time for guidance and playback. 
- Battery life: ≥ 60 min active runtime; durable, repeatable connections.





Engineering Specifications

Specification	Target	Measured	Verification
Gateway block – MCU	ESP32- WROOM-32, 240 MHz, Wi-Fi	—	Functionality test
Display- hardware	2.8" TFT SPI, 240x320, 14-pin, touch	—	Power-on + SPI; logic analyzer
Display- block UIs	TFT shows block-type-specific interfaces (e.g. numpad for note/input, animations for feedback)	—	Power-on + SPI; logic analyzer
Addressable LED strips	WS2812B; chainable	—	Power-on + data line; oscilloscope
LED matrix	4x4 RGB WS2812B	—	Power-on + scan; oscilloscope
Speaker	0.3 W into 8 @ 3.3V	—	Oscilloscope + SPL meter
Power module – Battery	200 mAh L-ion, 3.3V/5V	—	Charge/discharge test
Contact resistance	≤ 150 m per interface	—	4-wire ohmmeter
Block topology sync to app	≤ 200 ms	_ms	Logs; oscilloscope; logic analyzer
Maximum chain length	≥ 15 blocks (I ² C @ 100 kHz)	_blocks	Logic analyzer (I ² C decode); repetition test
Active runtime	≥ 60 min	_min	Timer to battery cutoff
End-to-end latency	≤ 50 ms	_ms	Oscilloscope; logic analyzer

*Highlighted = Demonstratable specification





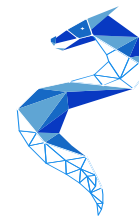
Hardware Selection

Hardware selected

Peripheral	Part/description	Purpose
MCU	ESP32-WROOM-32 (Espressif)	Wi-Fi, I ² C master/slaves, processing
Display	SPI TFT LCD touch (HiLetgo)	2.8" UI/feedback on blocks
LED matrix	4x4 RGB WS2812B	Grid visual feedback
Addressable LED	WS2812B strip (BTF-LIGHTING)	Block identification/configuration feedback
Speaker	Same Sky (CUI) CMS-2580-05SP	Audio feedback
Amplifier	LM386 (TI)	Drive speaker from MCU

Connector options comparison

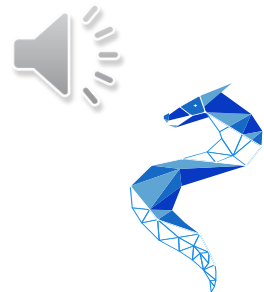
Option	Pros	Cons	Choice
Board-to-board/header	Inexpensive, widely available, simple for prototyping	Exposed pins (not child-safe), bend easily, need precise alignment	No
ADuM1201 (magnetic coupling)	Contactless, no exposed metal, touch-safe, dust-resistant	Higher cost and complexity, lower efficiency, tuning required	No
Magnetic pogo-pin (Mill-Max 858-22-004-10-011101)	Snap alignment, power +data, compact, gold-plated for reliability	Alignment sensitive	Yes





Software Selection

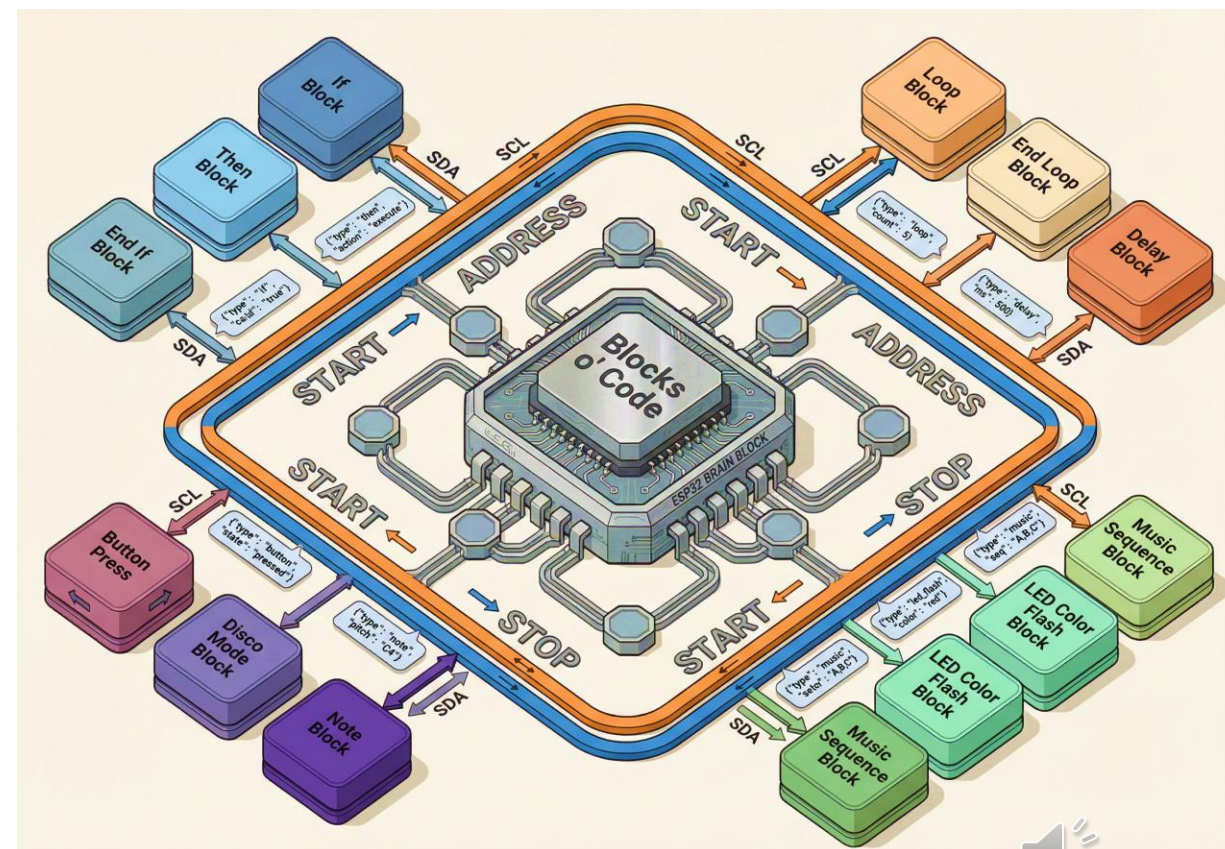
Layer	Selected Tool	Role	Justification	Alternatives Reviewed
Version Control System	Github	To host the project repository, manage branches for hardware and software teams, and track changes.	Enables collaborative development between group; provides a centralized "source of truth" for code and system diagrams.	Bitbucket / GitLab: Less community support and fewer integration tools for our specific workflow.
Embedded Framework	ESP-IDF	To develop the firmware for the ESP32-WROOM-32.	Provides full access to wireless connectivity, RTOS support, peripheral drivers	Arduino IDE: Lacks advanced multi-threading, less compatible with MCU, not great for real-time systems
Application Framework	Flutter	To build the Companion App that connects to the ESP32-WROOM-32.	Cross-platform performance, C-like programming language, good response time	React Native: Slower bridge performance for real-time data streaming Unity: Great for 3D visuals, but excessively high overhead.





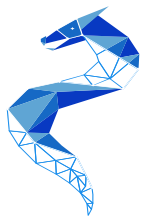
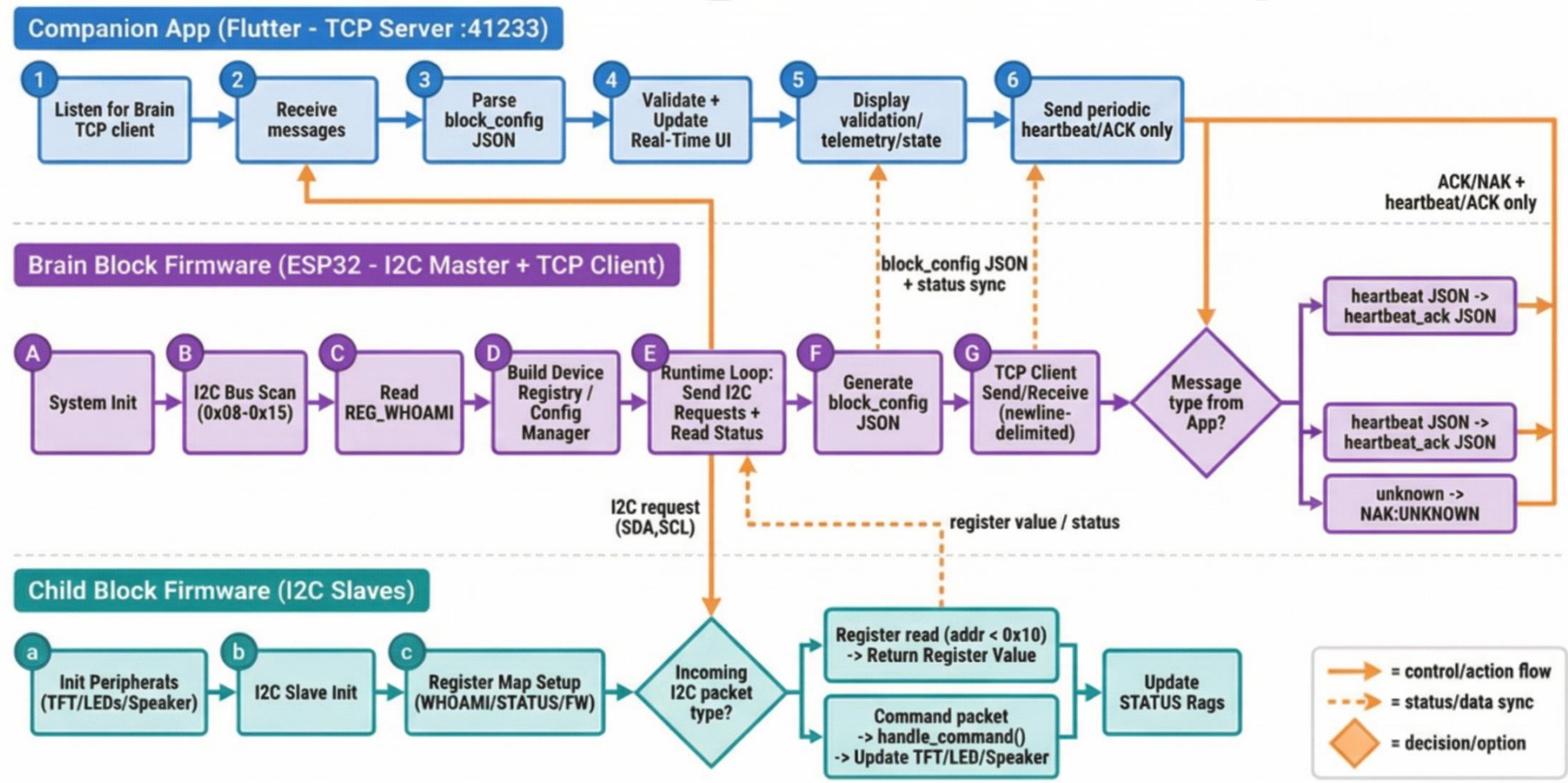
Software Design

Layer	Role
Companion App	User interface. Design programs (block flow), see live state, send commands to the Brain. Connects via Wi-Fi.
Brain Block	Controller. Finds Child blocks over I ² C, runs programs, sends commands to blocks and status to the app.
Child Blocks	Peripherals. Execute actions (lights, sound, display) and report identity and status over I ² C.





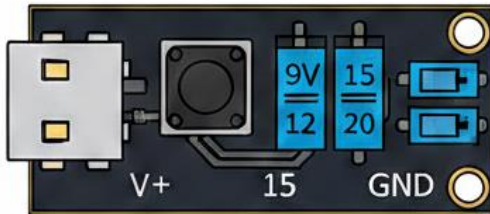
Software Block Diagram





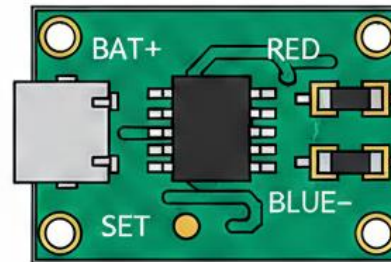
Power System Selection

PD trigger



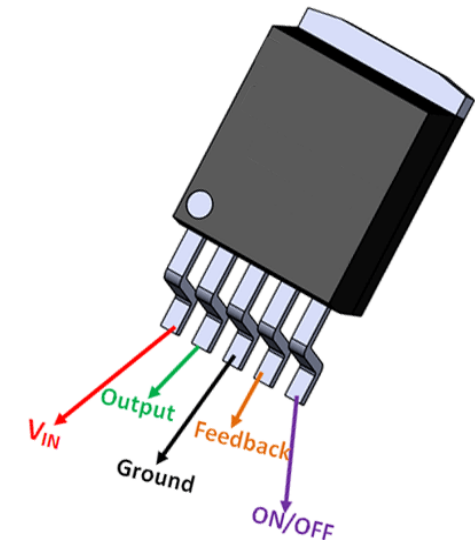
Provides safe and controlled CC/CV charging for our 2-cell lithium-ion battery pack.

TP5100



Negotiates 9V from a USB-C power adapter to supply sufficient voltage for 2S battery charging.

LM2576

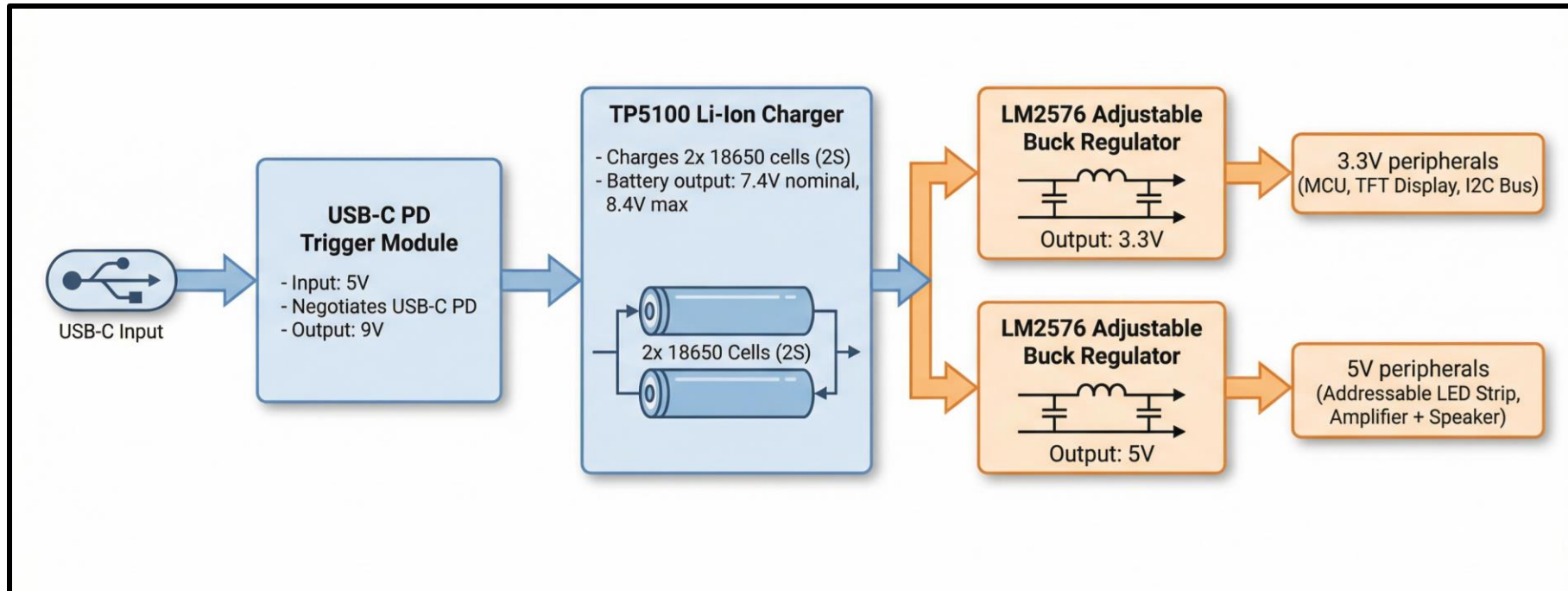


Steps down and stabilizes the battery voltage to provide a consistent, safe supply for the system electronics.



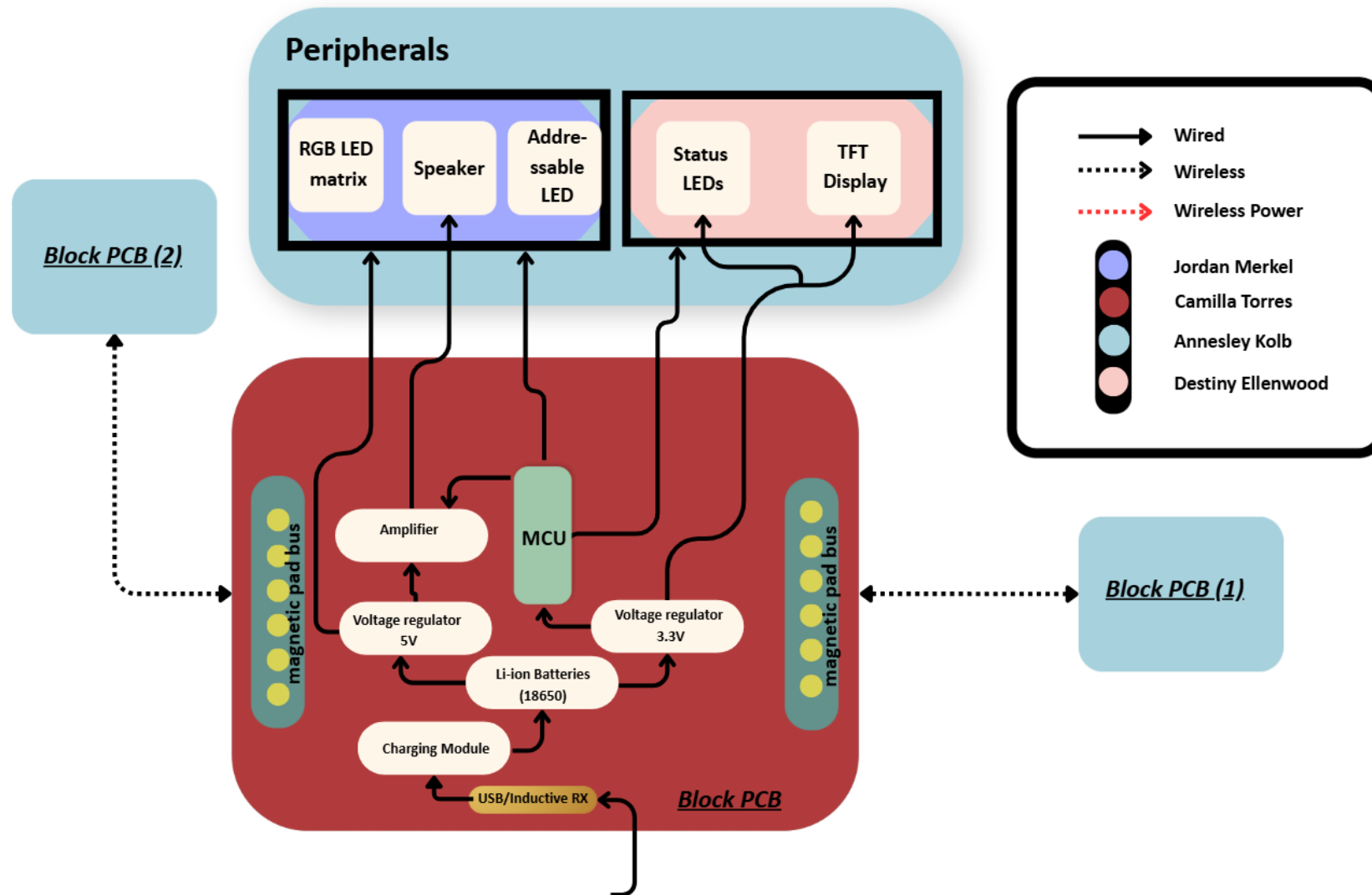


Power Architecture



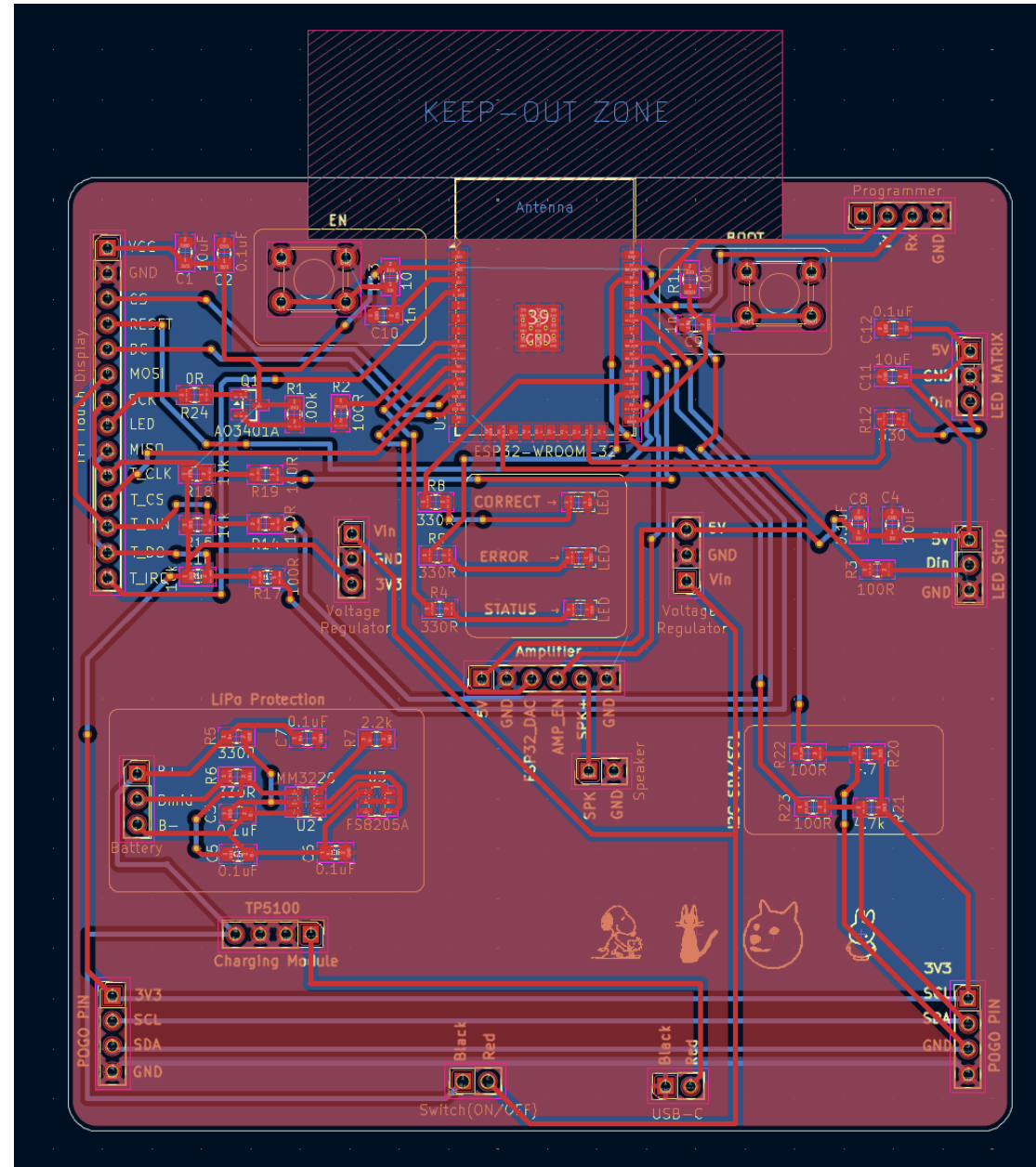


Hardware Block Diagram



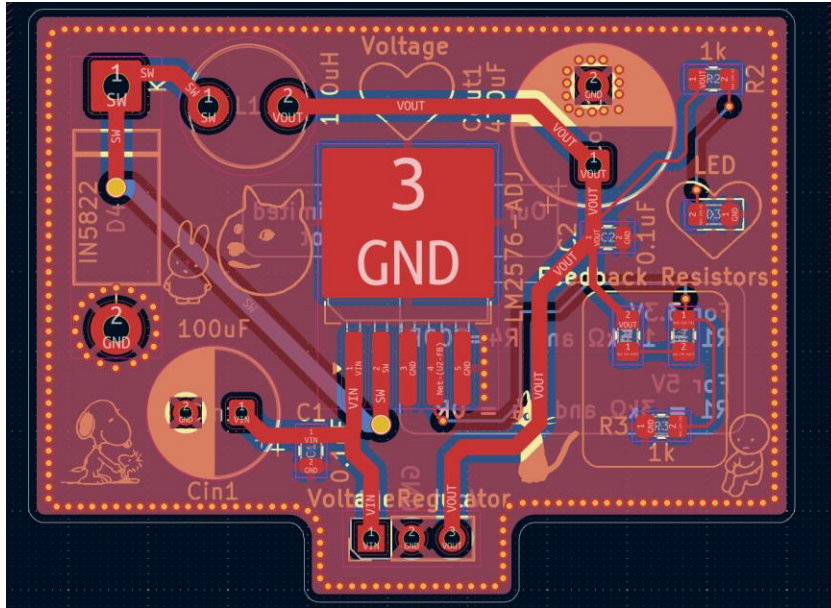


PCB Layout

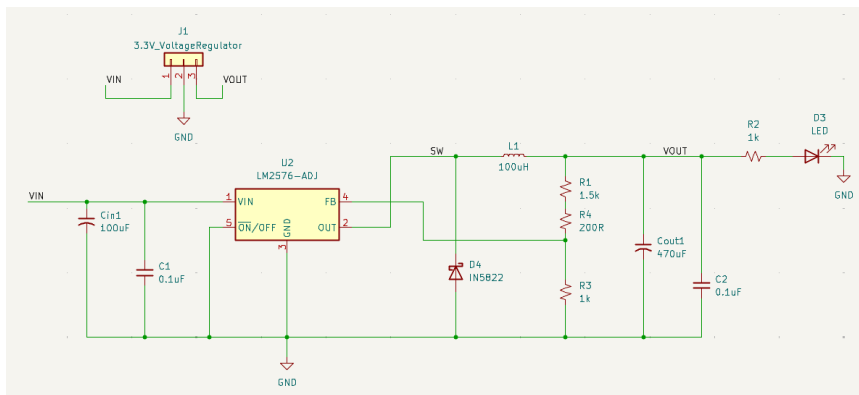




Layout



Schematic



Voltage Regulators

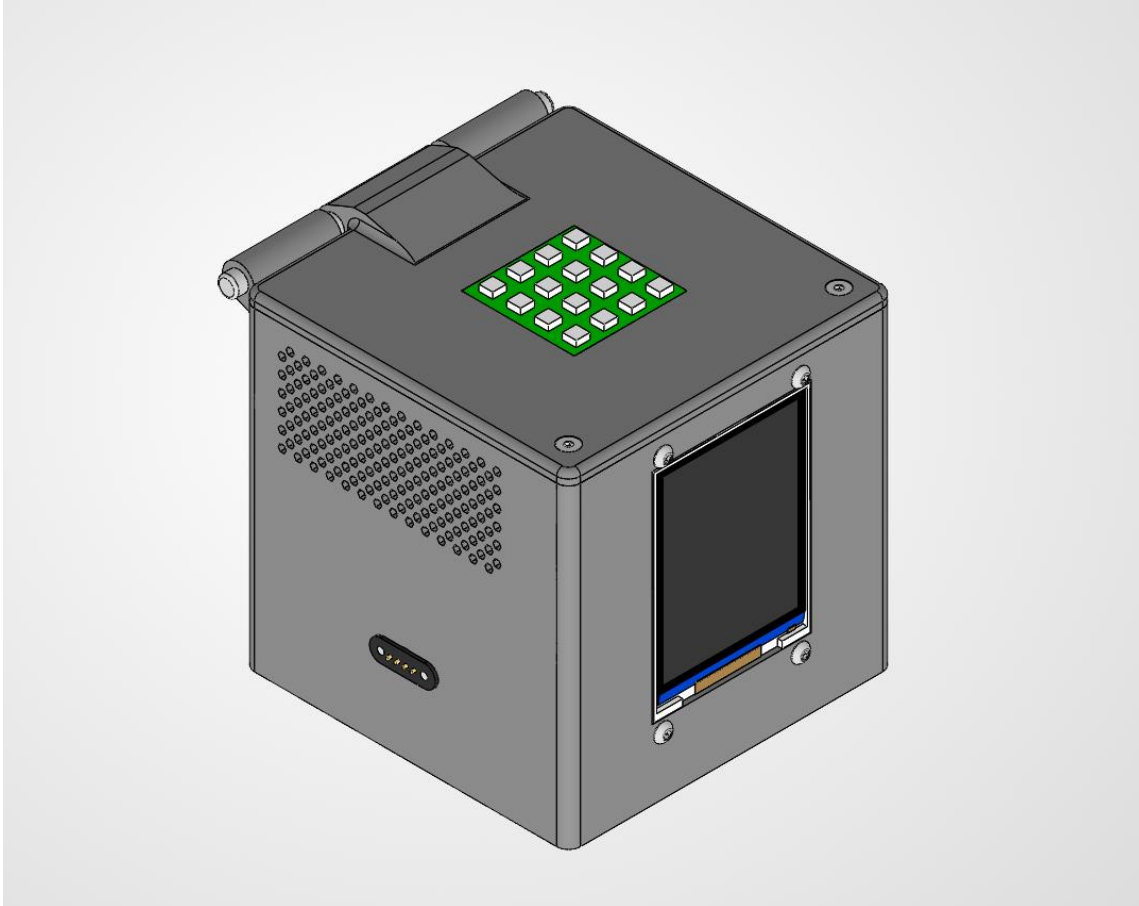
For 3.3V: $R1 = 1.5k\Omega$ and $R4 = 200R$

For 5V: $R1 = 3k\Omega$ and $R4 = 0R$





Exterior Enclosure



Front View



Back View

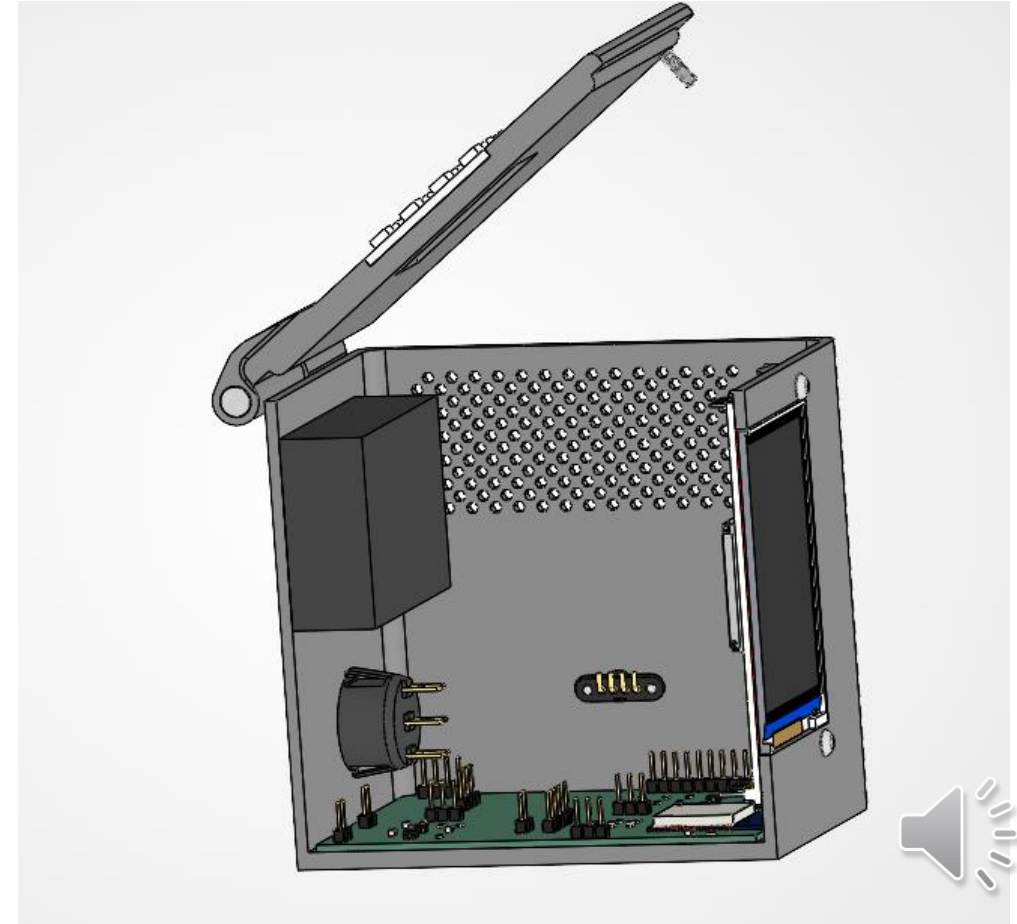




Interior Enclosure



Left Side View



Right Side View

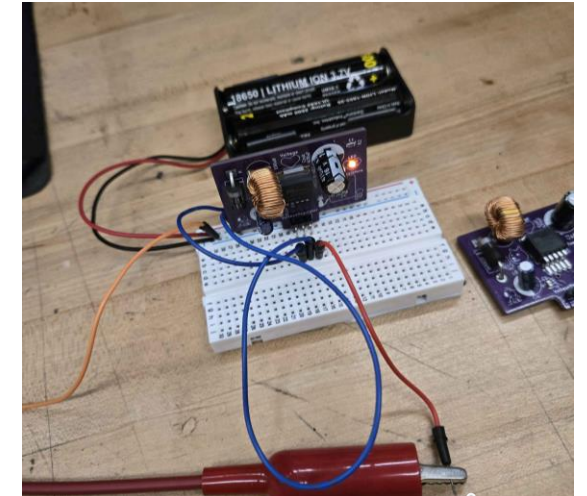
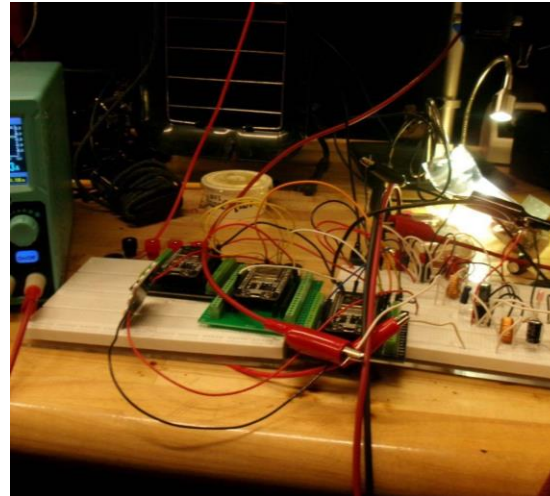
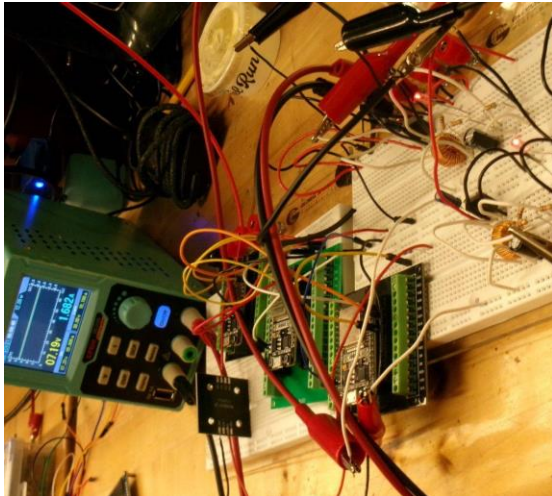




Testing -Regulators

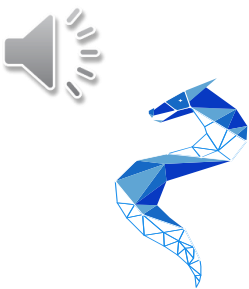
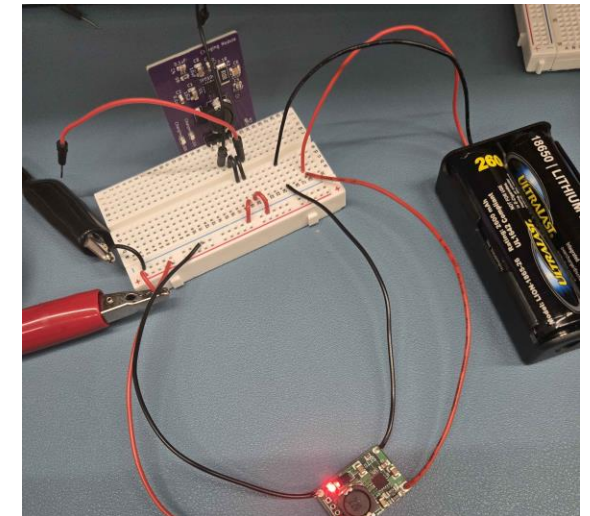
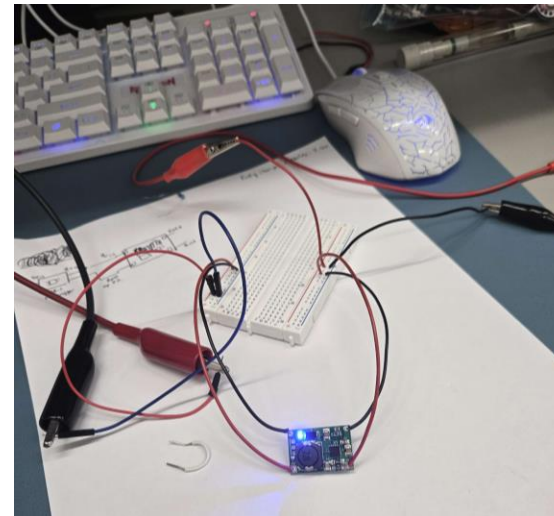
Tested with:

- Electronic Load
- Power supply and 18650 batteries



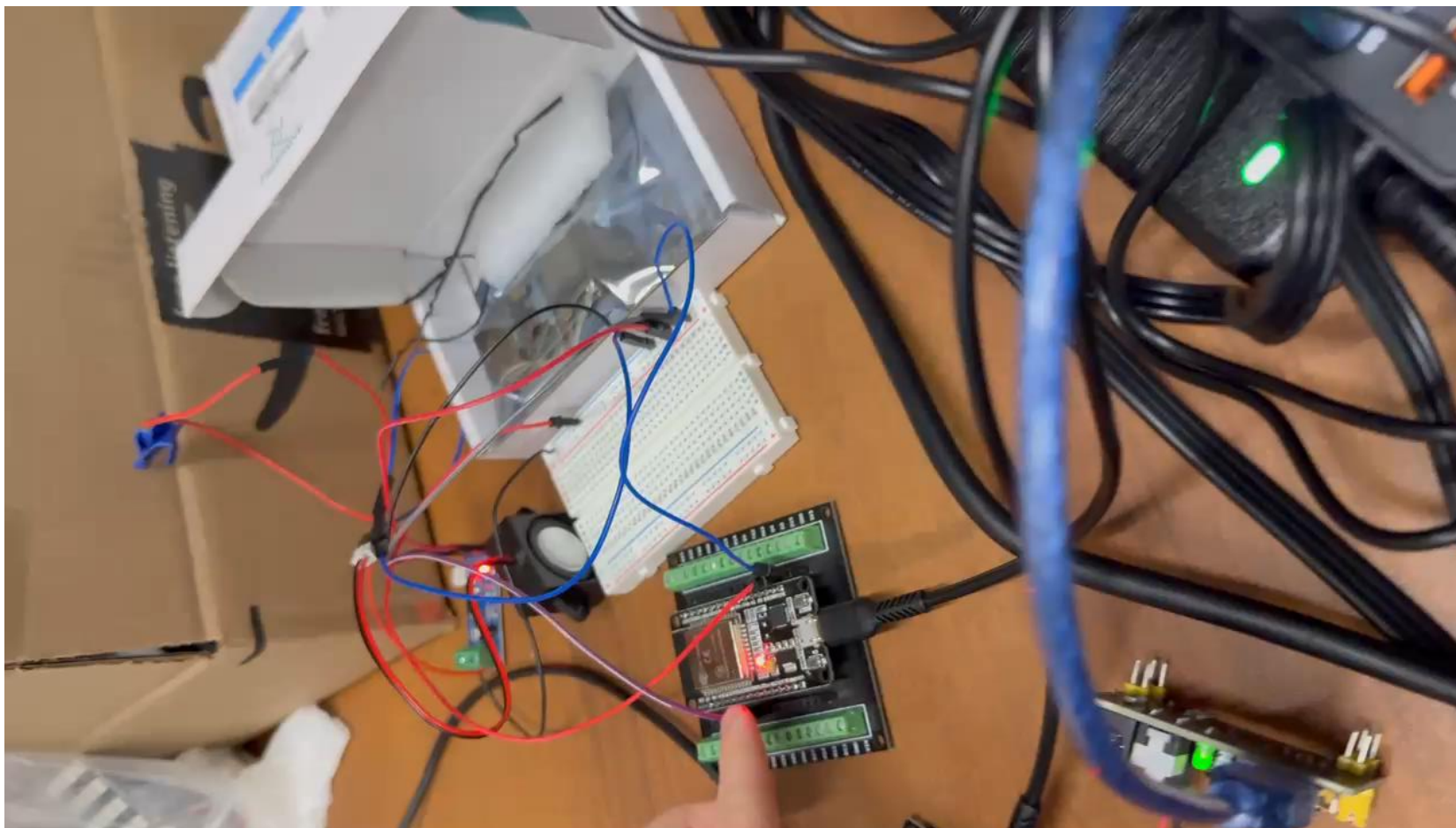


Testing - Charging





Testing – amplifier + speaker





Testing – Wi-fi Connection + Integrity

Stress Test:

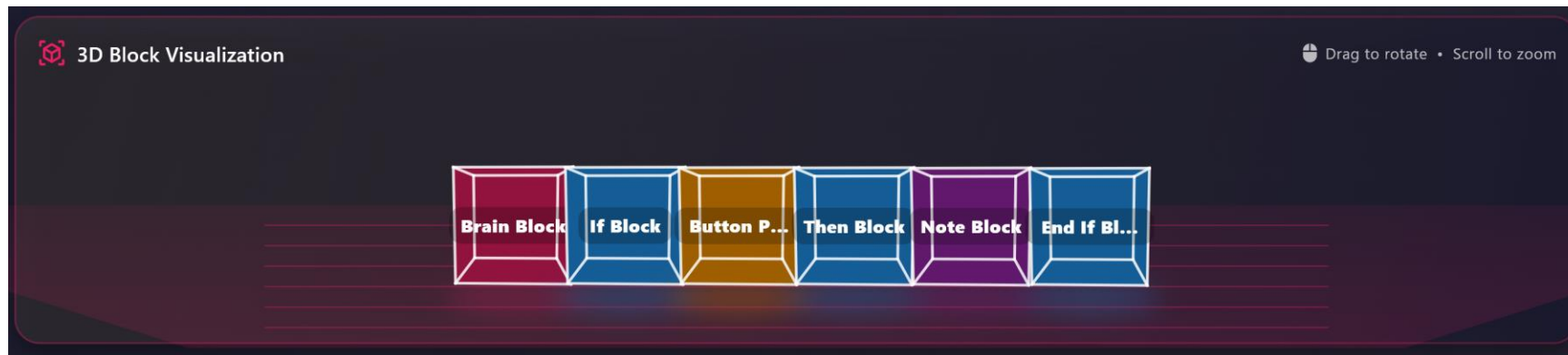
- App sends packets at a fixed rate (10 msg/s)
- Packet includes timestamp, sequence number, and payload to simulate network traffic
- Ran for 1 minute

Metric	Result
Sent	542 (10/s)
Received	665 (12.3/s)
Errors	0
Loss % (Sent-Received)/Sent*100	-22.9%

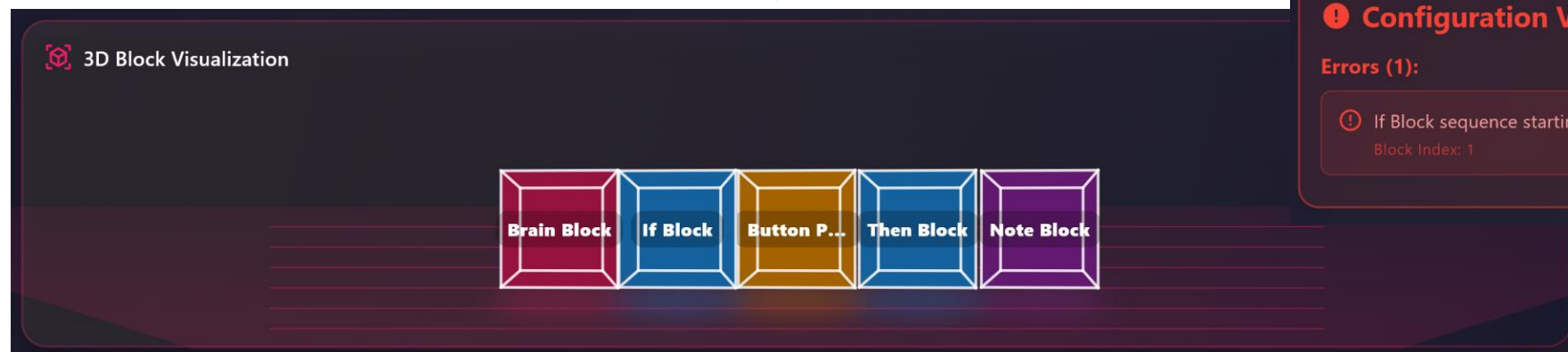




Testing – JSON Generation + Parsing



Remove 1 block



❗ Configuration Validation

Errors (1):

- ❗ If Block sequence starting at position 1 is not properly terminated with End If Block
Block Index: 1





Performance Evaluation and Results -

Hardware

- Regulated power rail validated with electronic load, bench supply, and 18650 battery input
- Charging path tested and confirmed stable operation during charge and discharge scenarios
- Amplifier and speaker integration verified with successful audio output
- Additional peripheral bring up verified: TFT UI, addressable LEDs, and LED matrices functioning

Firmware

- I²C communication validated across Brain (master) and Child blocks (slaves)
- Device identification flow validated via REG_WHOAMI and registry/config updates
- Command handling verified for peripheral control paths (LED/audio/display actions)
- JSON configuration generation from firmware verified for app synchronization
- Runtime flow supports real-time command/response with stable status updates

Companion App

- TCP server communication with Brain validated with successful message exchange
- JSON parsing and configuration validation workflow verified end-to-end
- UI updates confirmed live configuration/status messages
- Stress test completed (1-minute, fixed packet rate) with 0 reported errors.





Difficulty, Problem, and Proposed Solution -

DIFFICULTY

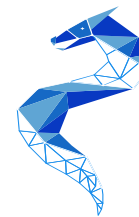
- PCB interconnection
- 3D Block Enclosure
- Custom TFT UI development
- 3D App visualizer

PROBLEM

- Serial port recognition
- Layout and footprint constraints
- Latency and multi-feature UI integration complexity
- Model behavior not ideal

PROPOSED SOLUTION

- Replace MCU
- Reprint modified enclosure and re-evaluate and make documentations
- Build a modular LVGL UI pipeline and optimize timing/task priorities to reduce latency and meet real-time behavior
- Learn more about Flutter 3D animations





Budget - Prototype

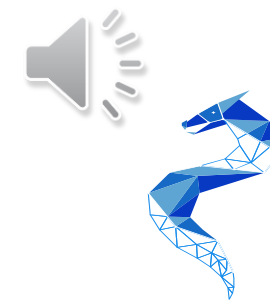
Item	Qty	Manufacturer	MPN	Supplier	Supplier P/N	Unit Price (USD)	Ext. Price
ESP32-WROOM-32 (MCU)	15	Espressif Systems	ESP32-WROOM-32-N4	Digi-key	B0CDRLRYJB	\$6.56	\$98.04
18650 lithium-ion cell batteries	30	Ultralast	N/A	Ace Hardware	UL1865-26-2P	\$19.99	\$299.85
TP5100 (charging module)	15	DKARDU	JK-US-386	Amazon	B09TKNFB3W	\$9.99	\$29.97
Type-C Female Chassis	20	Coliao	687117711298	Amazon	B0D813FX3J	\$8.99	\$8.99
SPI TFT LCD Display Touch Panel	1	HiLetgo	3-01-1433	Amazon	B073R7BH1B	\$16.39	\$16.39
4x4 RGB WS2812B LED Matrix (5 Pcs)	2	GODIYMODULES	N/A	Amazon	B0F59HC7PT	\$10.99	\$21.98
0.96" SSD1306 128X64 OLED SPI LCD Display	10	HiLetgo	3-01-1234-YB-AU-1PC	Amazon	B01NOKIXI6	\$6.99	\$69.99
1602 I2C LCD Display	5	Hosyond	N/A	Amazon	B0BWTFN9WF	\$11.99	\$23.98
WS2812B IC RGB Addressable LEDs (300 ft)	2	BTF-LIGHTING Technology Co., Limited	WS2812B5M60LW67	Amazon	B01CDTEID0	\$29.99	\$59.98
Discrete LED 0805 (Red)	15	ams-OSRAM USA INC.	LS R976-NR-1-0-20-R18	Digi-Key	475-LSR976-NR-1CT-ND	\$0.15	\$2.25
Discrete LED 0805 (Blue)	15	Würth Elektronik	150080BS75000	Digi-Key	732-4982-1-ND	\$0.19	\$2.85
Discrete LED 0805 (Green)	15	ams-OSRAM USA INC.	LG R971-KN-1-0-20-R18	Digi-Key	475-LGR971-KN-1CT-ND	\$0.15	\$2.25
Same Sky (CUI) CMS-2580-05SP (speakers)	4	Same-Sky	CMS-2850-058SP	Digi-Key	2223-CMS-2850-058SP-ND	\$2.13	\$8.52
PAM8302A (Amplifier)	5	JESSINIE	PAM8302	Amazon	B0BG2F3LMP	\$9.95	\$9.95
MAX98357A (Amplifier)	4	GODIYMODULES	MAX98357A	Amazon	B0DPJRLMDJ	\$6.88	\$13.76
Adafruit I ² S MEMS Microphone (SPH0645LM4H)	3-4	Adafruit	SPH0645LM4H	Adafruit	SPH0645LM4H	\$6.95	\$27.80
Mill-Max 85B-22-004-10-011101 (POGO pins)	15	Mill-Max Manufacturing Corp.	85B-22-004-10-011101	Digi-Key	ED11072-ND	\$8.49	\$127.35
						Total:	\$823.90





Budget – Manufacturer Level

Item	Qty	Manufacturer	MPN	Supplier	Supplier P/N	Unit Price (USD)	Ext. Price
ESP32-WROOM-32 (MCU)	30	Espressif Systems	ESP32-WROOM-32-N4	Digi-key	BOCDRLRYJB	\$6.56	\$196.80
18650 lithium-ion cell batteries	30	Ultralast	N/A	Ace Hardware	UL1865-26-2P	\$19.99	\$599.70
TP5100 (charging module)	30	DKARDU	JK-US-386	Amazon	B09TKNFB3W	\$9.99	\$299.70
Type-C Female Chassis	40	Coliao	687117711298	Amazon	B0D813FX3J	\$8.99	\$359.60
SPI TFT LCD Display Touch Panel	15	HiLetgo	3-01-1433	Amazon	B073R7BH1B	\$16.39	\$245.85
4x4 RGB WS2812B LED Matrix (5 Pcs)	20	GODIYMODULES	N/A	Amazon	B0F59HC7PT	\$10.99	\$219.80
WS2812B IC RGB Addressable LEDs (300 ft)	4	BTF-LIGHTING Technology Co., Limited	WS2812B5M60LW67	Amazon	B01CDTEID0	\$29.99	\$119.96
0805 SMD Book	2	SMT Books and Assortment	N/A	Amazon	B0B2WZ9XD7	\$34.90	\$69.80
Same Sky (CUI) CMS-2580-05SP (speakers)	15	Same-Sky	CMS-2850-058SP	Digi-Key	2223-CMS-2850-058SP-ND	\$2.13	\$31.95
LM386 (Amplifier)	10	Texas Instruments	LM386MMX-1/NOPB	Mouser	926-LM386MMX-1/NOPB	\$9.95	\$99.50
Mill-Max 858-22-004-10-011101 (POGO pins)	30	Mill-Max Manufacturing Corp.	858-22-004-10-011101	Digi-Key	ED11072-ND	\$8.49	\$254.70
Filament for 3d printing (transparent){	5	TECBEARS	JWDE-PETG-TP-1KG	Amazon	JWUS-PETG-TP-1KG-TB	\$13.99	\$69.95
Total:							\$2,567.31





Progress and Plan for Completion

Progress to Date

- ✓ All peripherals implemented in firmware
- ✓ Child Blocks $\leftrightarrow$ Brain Block $\leftrightarrow$ App communication
- ✓ Block "WHOAMI" identification + 3D real-time visualization
- ✓ PCBs acquired and being assembled
- ✓ 3D enclosure initial print and redesign

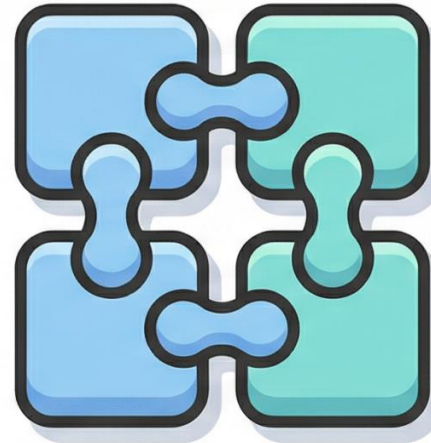
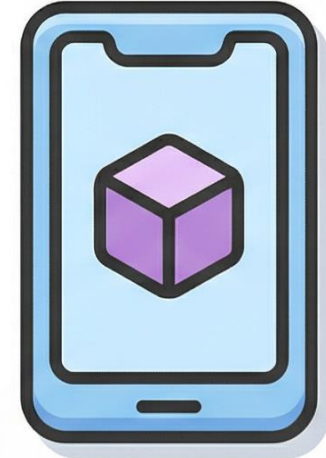
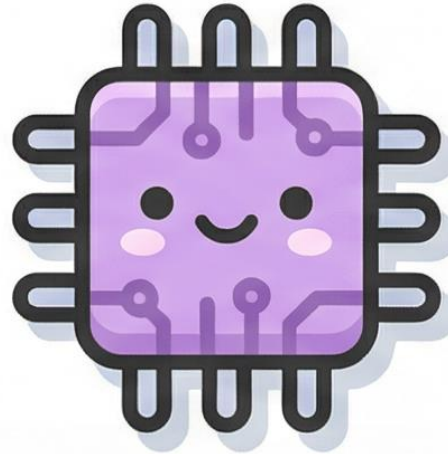
Plan for Completion

-  **Early March (Midterm Demo):** 3 block configuration + live app visualization
-  Buildout firmware for each block and create central event handler
-  Finalize 3D Enclosure
-  Full PCB acquisition + assembly
-  User Testing + Feedback
-  Prepare Final Demo and Presentation



Thank You!

Questions?



Backup slides



Test Methodology -

Test strategy

- Component / block level – Per-block hardware (TFT UI, LEDs, speaker, pogo pins, rails); power on and continuity.
- Subsystem - I²C discovery and topology; power along chain; Wi-Fi link to companion
- System – Full 15-block chain; app sync via Wi-Fi with brain block; end-to-end validation.

Instrumentation

- Logs (serial monitor) - Firmware and app behavior, timing, topology sync.
- Oscilloscope – Voltage rails, timing, latency.
- Logic analyzer - I²C decode, protocol, chain length.

Pass/fail criteria

- Pass – result meets or exceeds the target in the Engineering Specifications table
- Fail – Results outside of spec → document, investigate, fix, then retest
- No partial pass – Each spec is either met or not

