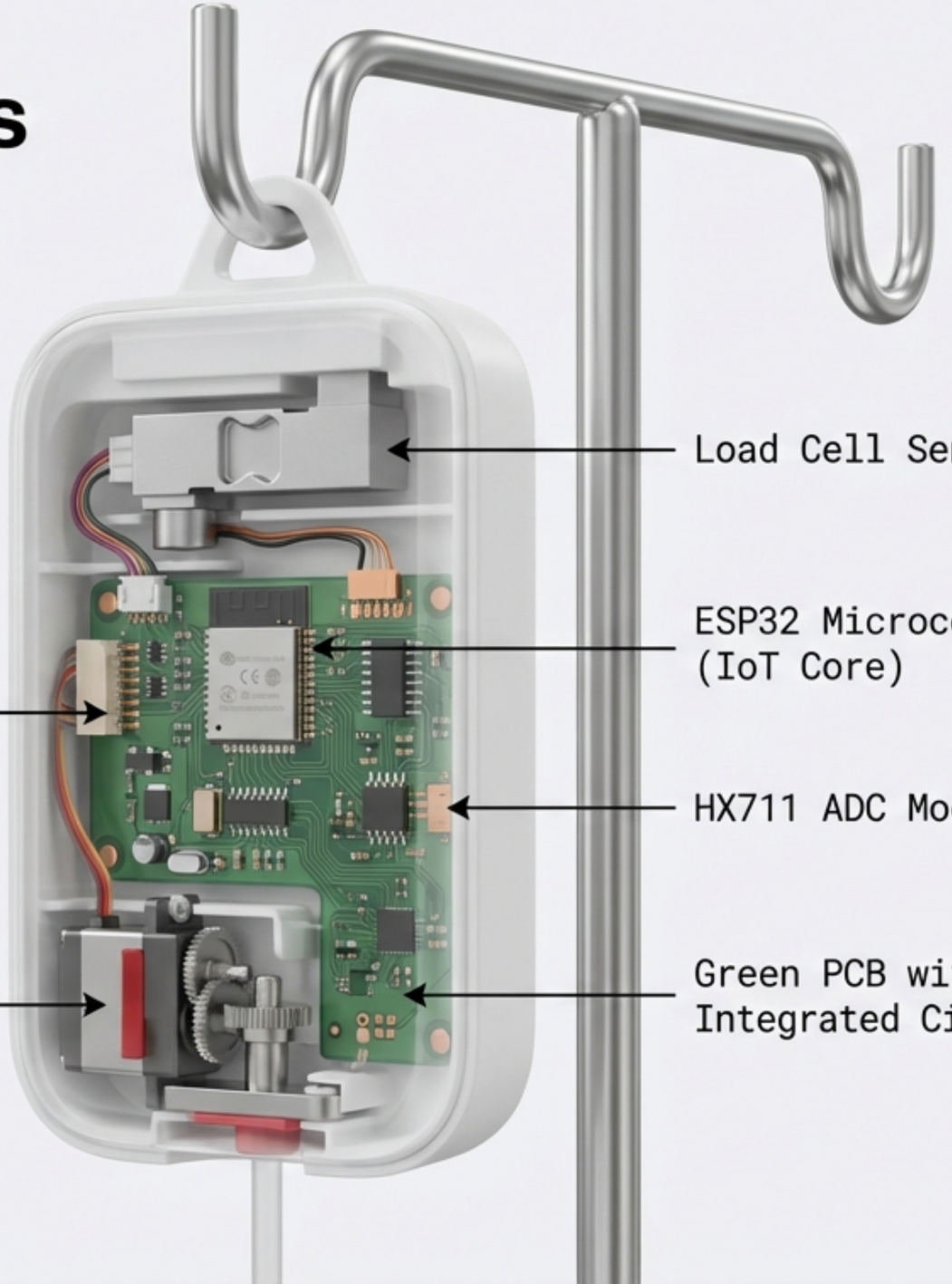
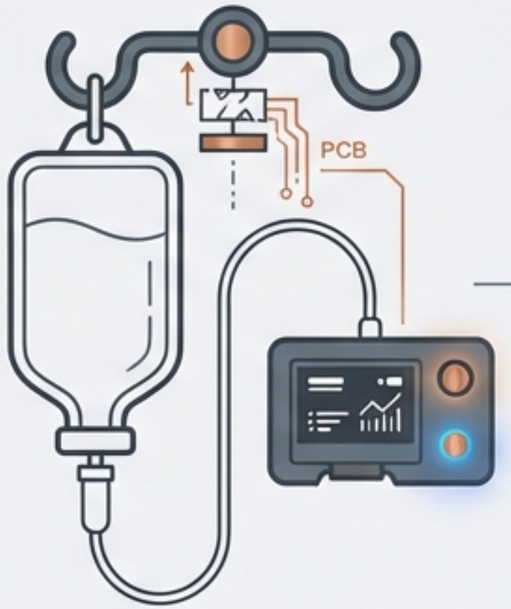
Drip-Sense: Autonomous IV Management System

Hardware Architecture, Circuit Design, and Manufacturing Strategy for an IoT Medical Edge Device.



The Device Definition: A Real-Time Medical Edge Node

EDGE DEVICE (PATIENT)



Continuous Weight Monitoring (Load Cell) + Local OLED Status

CONNECTIVITY (CLOUD)

ESP32 Data Transmission to AWS IoT Core / Firebase

CONTROL (SAFETY)

Closed-loop Actuator for Air Embolism Prevention

Core Utility: Transforming passive IV therapy into a networked sensor node.

Physical Construction & Form Factor

Exploded View

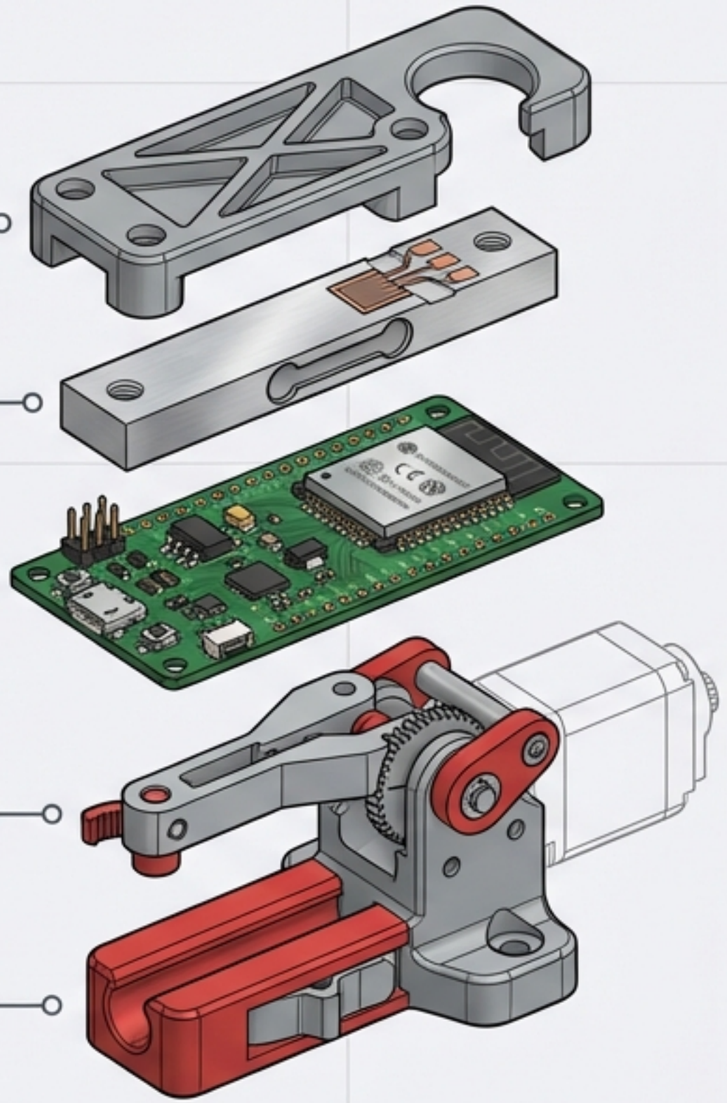
Integrated Plastic Hook
(Custom 3D print design)

5kg Load Cell
(Aluminum bar with strain gauges)

PCB Carrier Board
(Green circuit board with ESP32 and components)

Servo Actuator Linkage
(Mechanical arm for pinching)

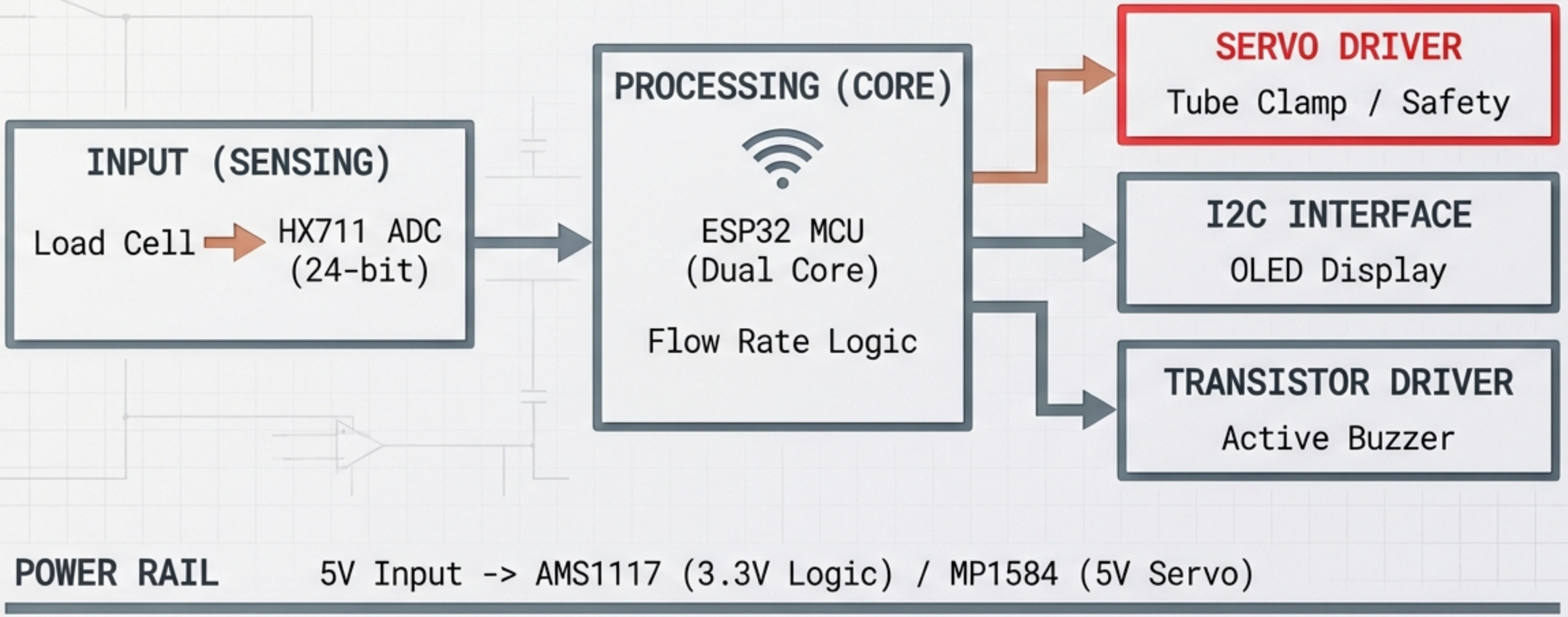
Tube Clamp Mechanism
(Where the IV tube sits)



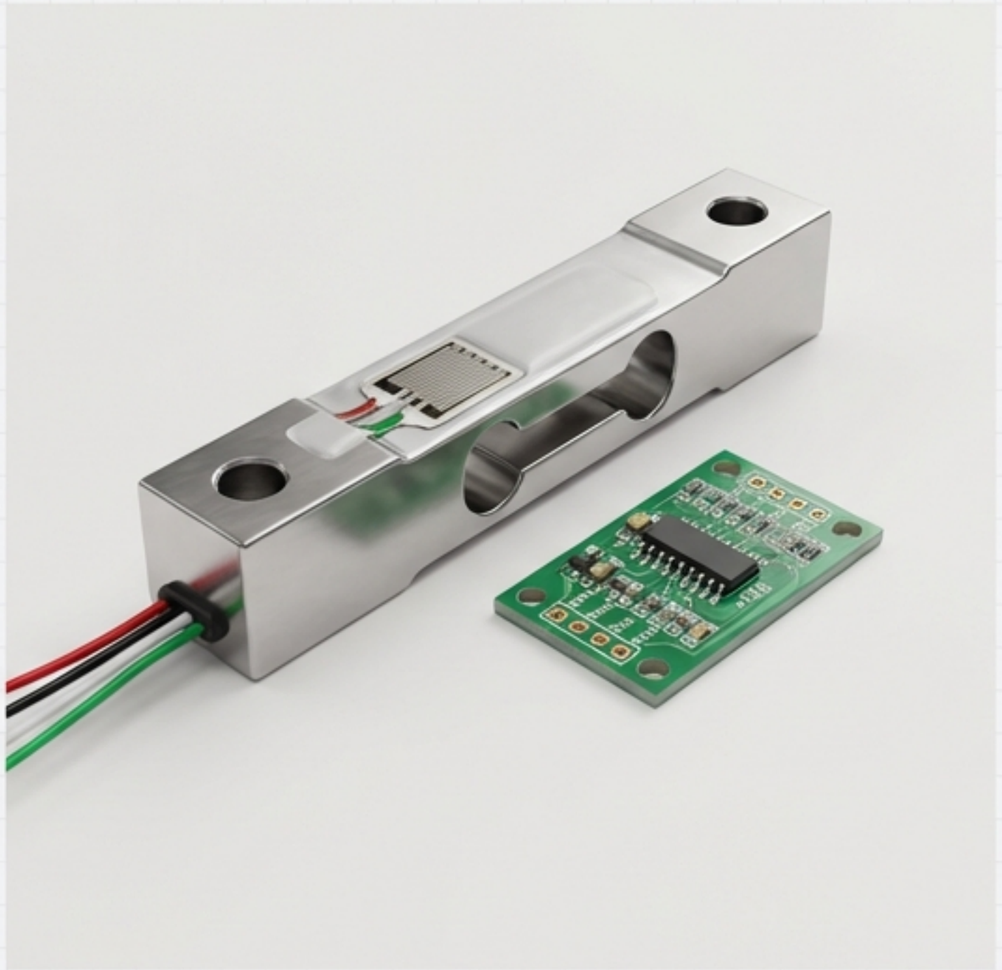
Engineering Goals

- Plug-and-play installation
- Minimal wiring complexity
- Modular replacement

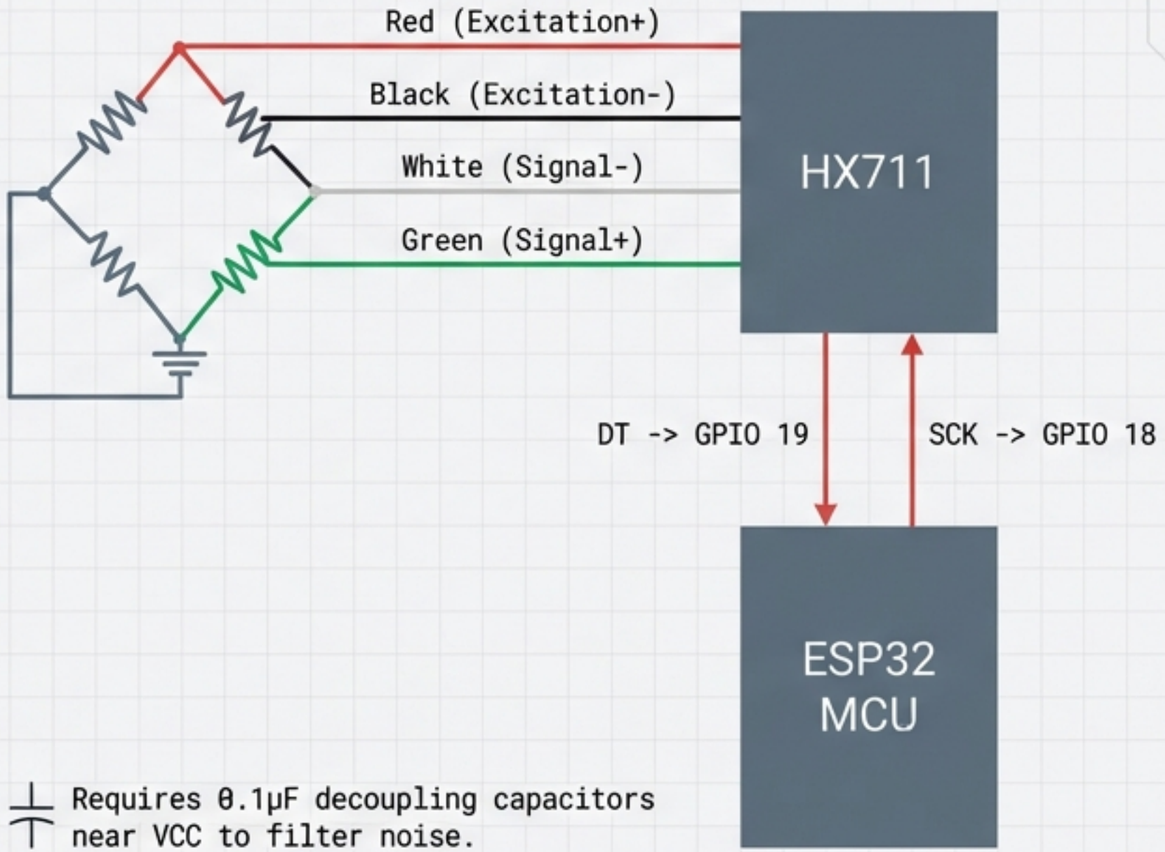
Hardware System Architecture



Sensing Subsystem: Precision Fluid Measurement



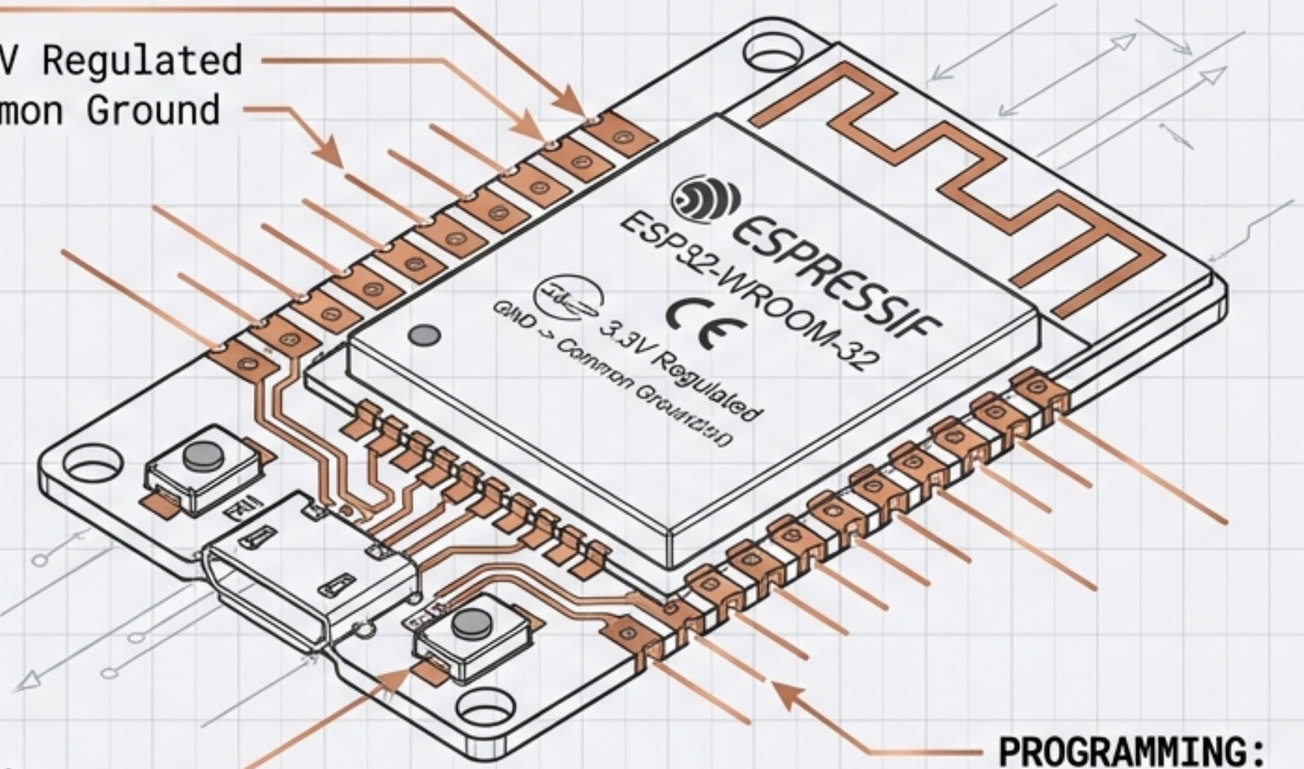
Wheatstone Bridge Interface



Requires 0.1µF decoupling capacitors near VCC to filter noise.

Processing Core: ESP32 Implementation.

POWER:
VCC -> 3.3V Regulated
GND -> Common Ground



Component Choice:
ESP32-WROOM-32

Why:
- Dual-core, Integrated WiFi/BT, Robust PWM.

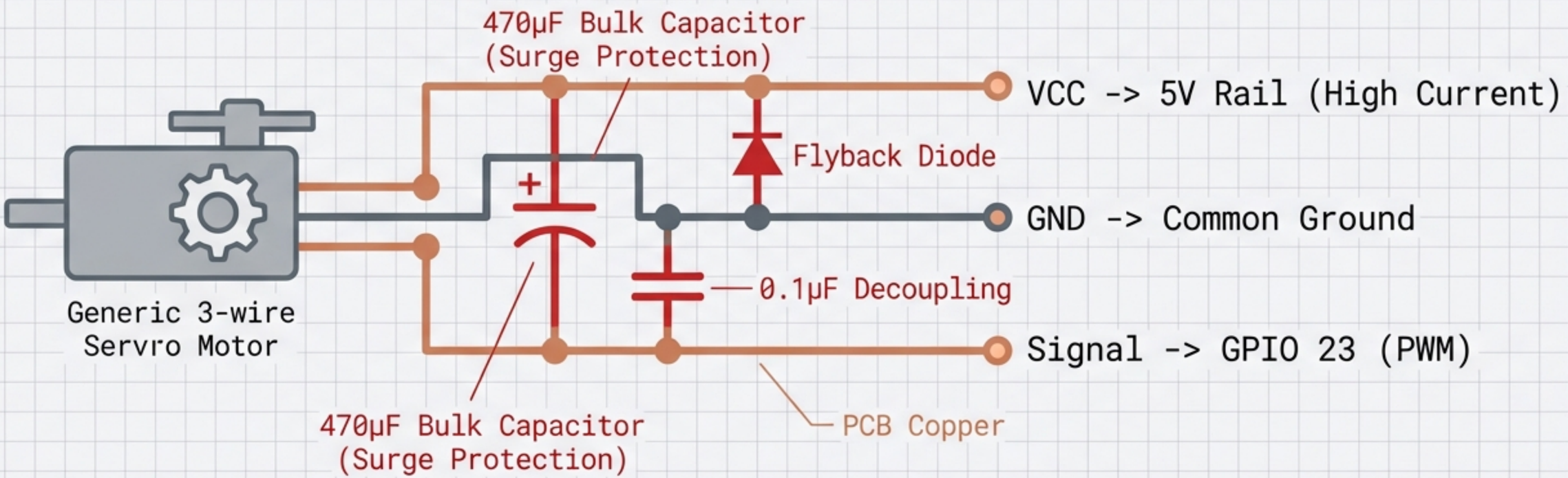
BOOT LOGIC:
EN -> 10k Pull-up
GPIO0 -> 10k Pull-up (Flash Mode Control)

PROGRAMMING:
UART0 (TXD/RXD) -> USB Bridge (CP2102/CH340)

POWER RAIL

5V Input -> AMS1117 (3.3V Logic) / MP1584 (5V Servo)

Actuation & Safety Layer: The Auto-Cutoff Mechanism.

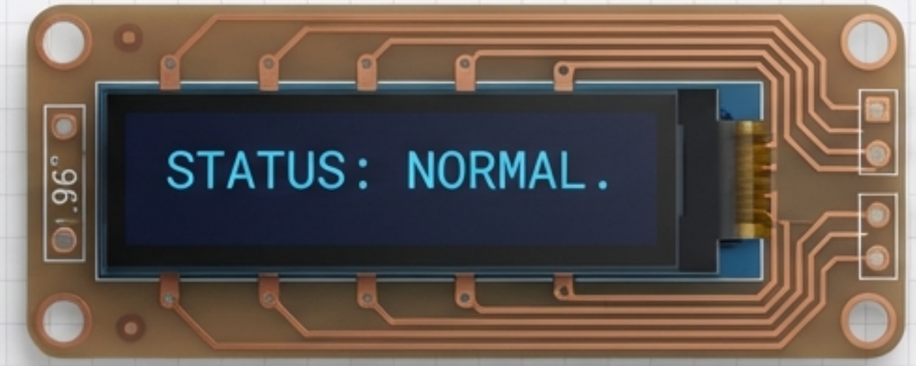


Function: Mechanically pinches IV tube to prevent air embolism.

User Interface & Feedback Systems.

Visual Output

Helvetica Now Display

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Protocol: I2C
SDA -> GPIO 21
SCL -> GPIO 22
Pull-ups: 4.7kΩ
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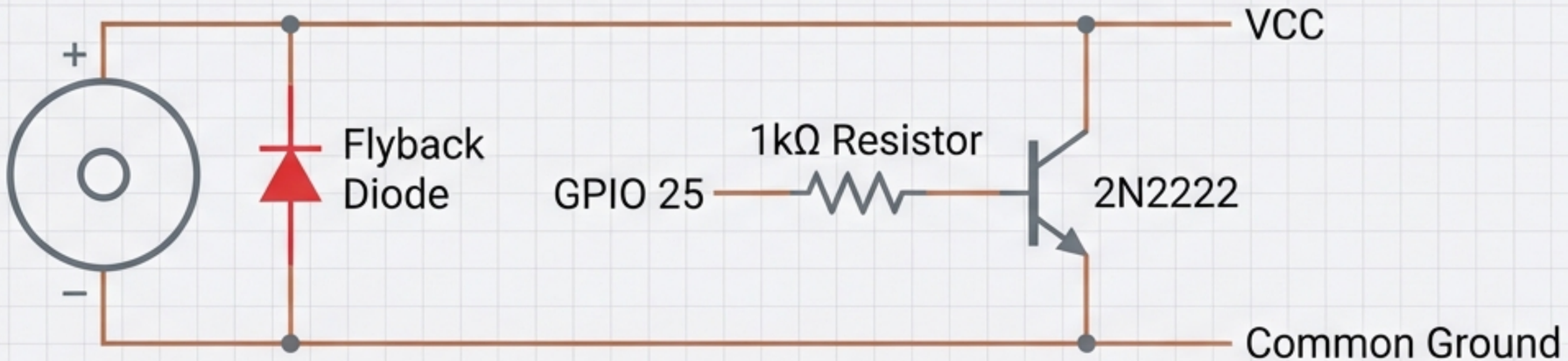
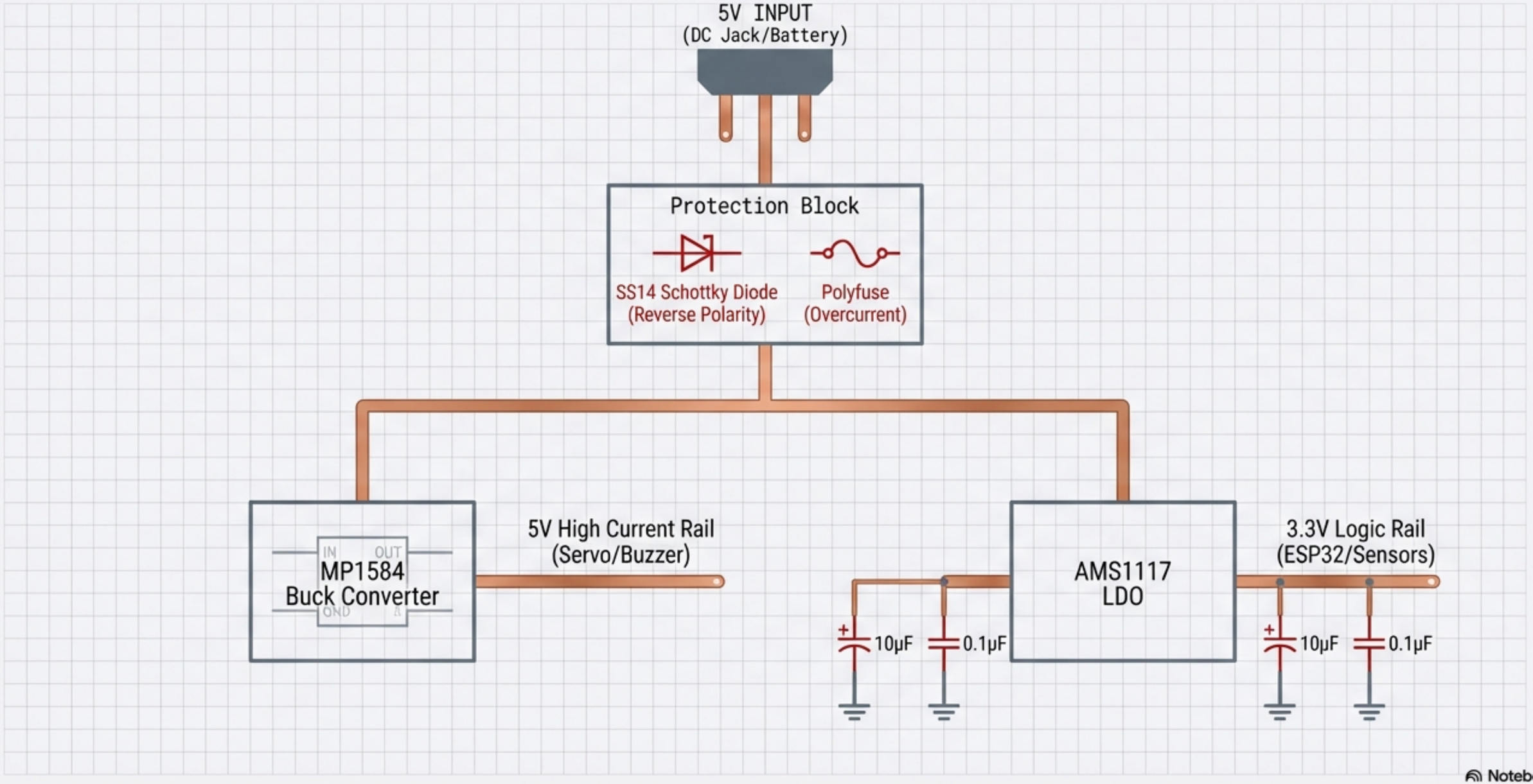
Audio Output

Helvetica Now Display

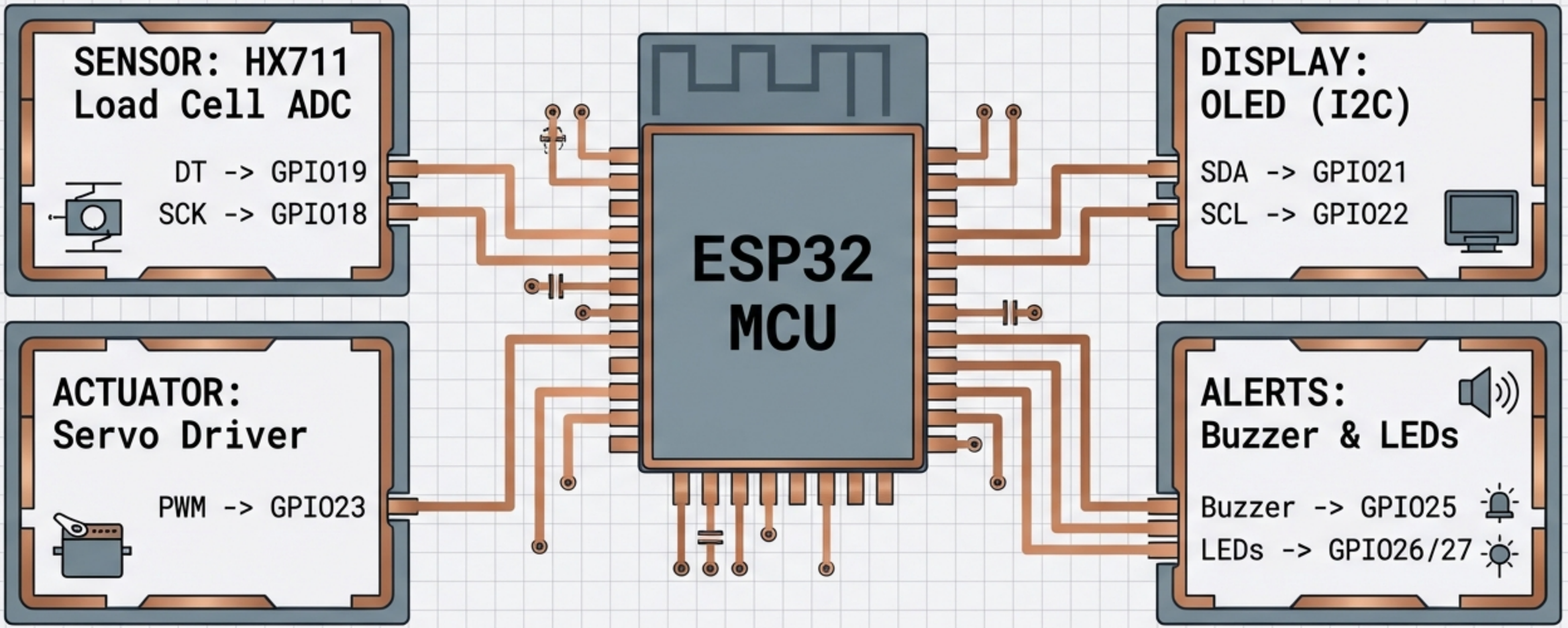


Active Buzzer for High-Priority Alerts.

Power Management Strategy.

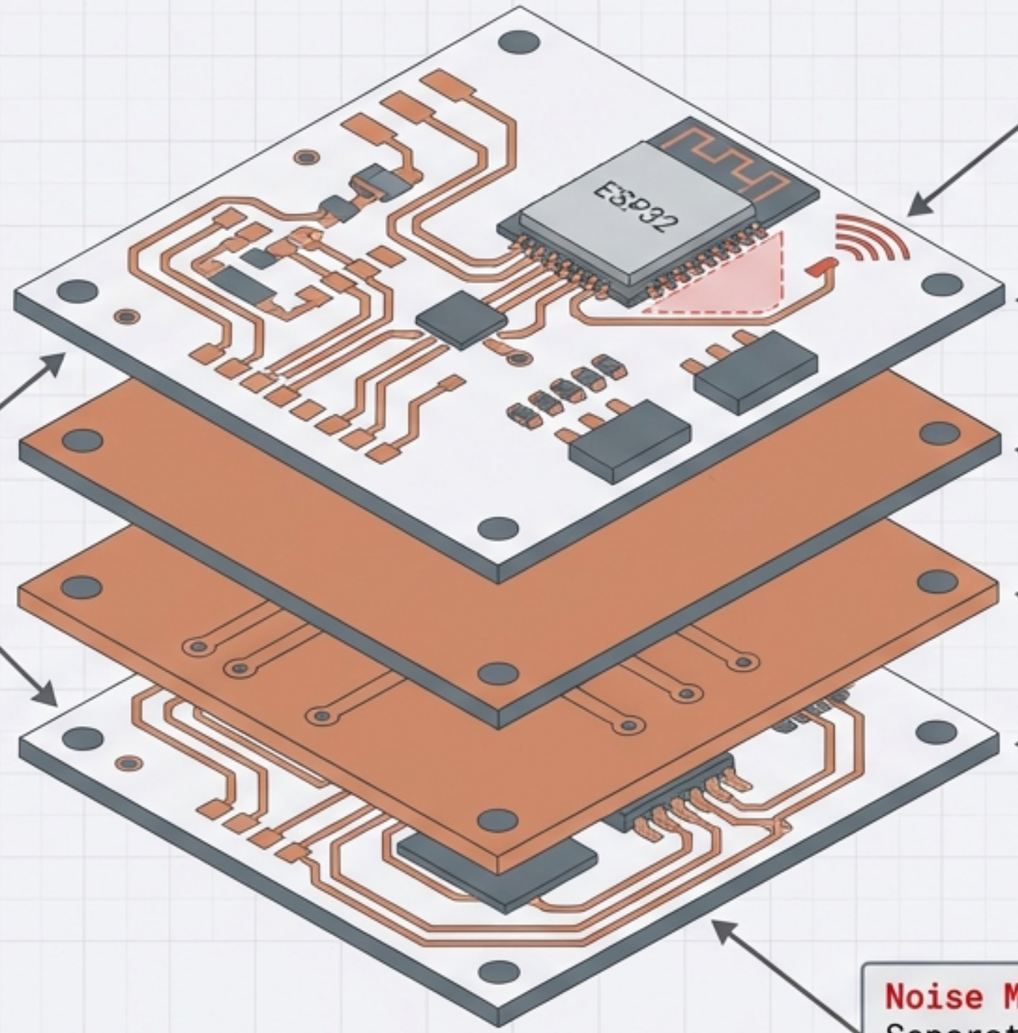


Critical Schematic Integration.



⚠ **CRITICAL:** Common ground reference required for all subsystems.

PCB Design Strategy & Stack-up



RF Safety:
Antenna keep-out zone under ESP32

Layer 1: Top Signals (High Speed / RF)

Layer 2: Ground Plane (Solid, Unbroken)

Layer 3: Power Plane (3.3V / 5V Distribution)

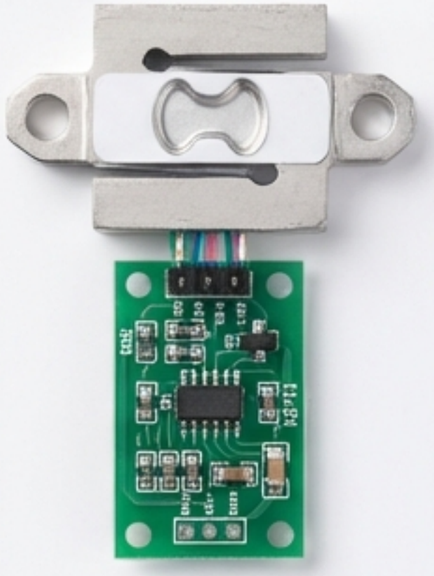
Bottom Layer
Layer 4: Bottom Signals

Analog Isolation:
Keep Load Cell traces short; separate analog ground

Noise Mitigation:
Separate 5V servo power traces

Bill of Materials (BOM) & Unit Economics.

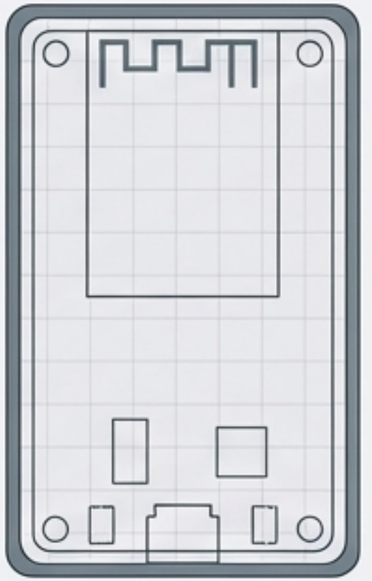
ESP32 Dev Board:
₹550



Load Cell + HX711:
₹200

Servo Motor:
₹150

Power Modules:
₹150



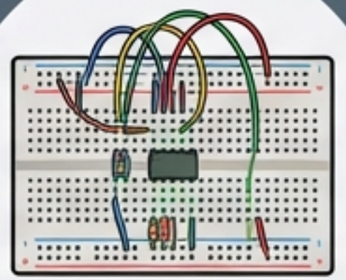
Housing/PCB:
₹800

Total Prototype Cost: ~₹2,800 INR

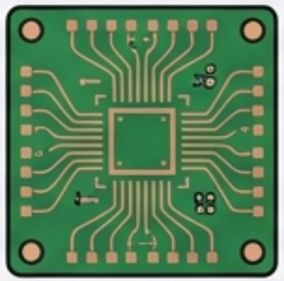
* Pricing based on local Indian suppliers (Robu.in / Robocraze).

Development Roadmap: Prototype to Production.

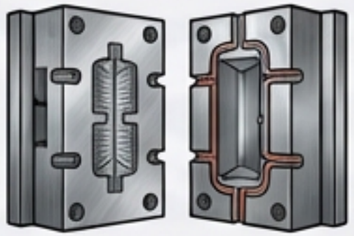
PHASE 1: RAPID PROTOTYPE



PHASE 2: ENGINEERING PROTOTYPE



PHASE 3: PRODUCTION HARDWARE



PHASE 1: RAPID PROTOTYPE

Proof of Concept,
3D Printed Case

PHASE 2: ENGINEERING PROTOTYPE

Custom 4-Layer PCB,
EMI Shielding

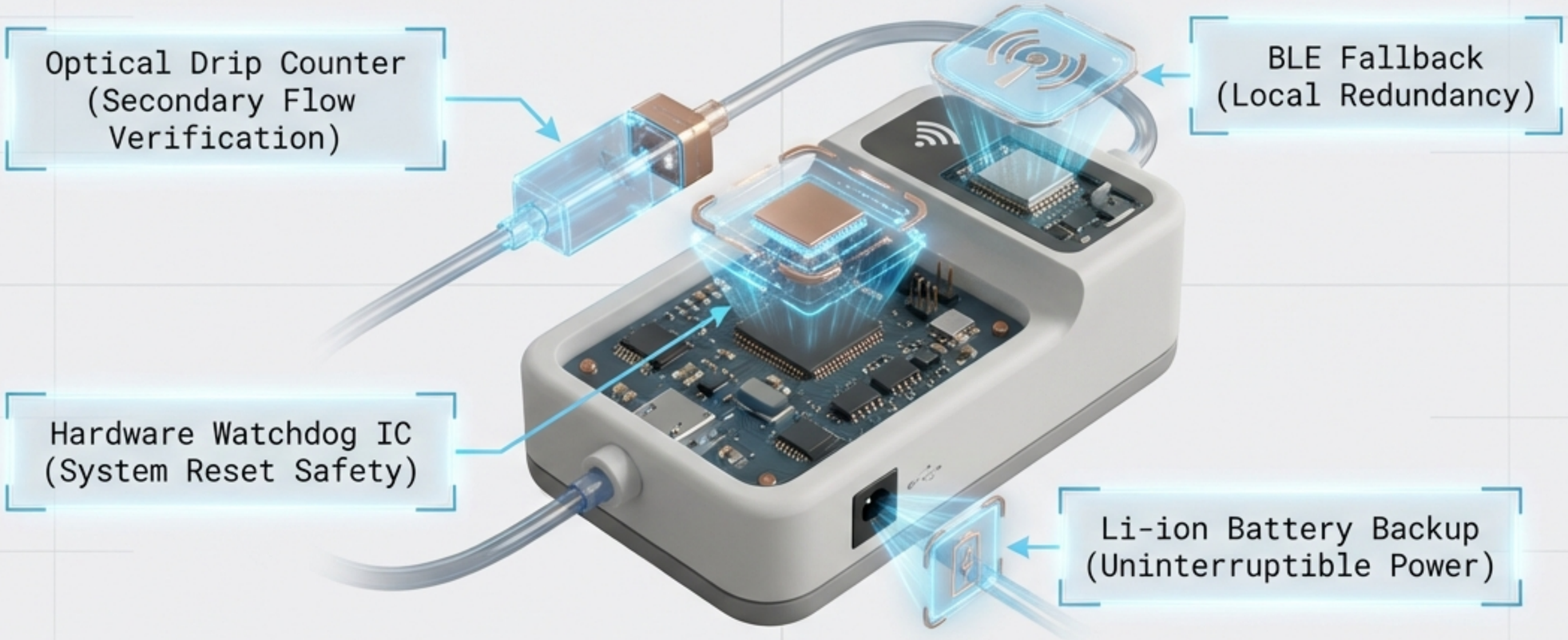
PHASE 3: PRODUCTION HARDWARE

Certified Assembly,
ISO 13485 Compliance

Key Engineering Challenges & Mitigations.

	CHALLENGE	ENGINEERING MITIGATION
	Sensor Drift	Software calibration mapping & averaging.
	Power Noise (Servo)	Decoupling capacitors & separate buck converter rail.
	Tube Clamp Wear	High-torque servo & reinforced mechanical linkage.
	Medical Safety	Use of isolated power adapters & redundant sensors.

Path to Clinical Deployment: Recommended Upgrades



A scalable, modular architecture ready for ISO 13485 clinical trials