Luxury IR/RF Controller

THE PROBLEM

A luxury audio manufacturer was shipping premium amplifiers and DACs with an inexpensive off-the-shelf television remote.

The remote worked. But it was the first thing a customer touched after unboxing a product that cost tens of thousands of dollars. It undermined the entire experience.

WHAT WE DESIGNED

- CNC aluminum enclosure
- Floating volume dial on concealed ball bearings
- Optical quadrature encoder for rotation sensing
- Four tactile buttons with laser-etched icons
- Dual-mode control: IR and RF
- USB-C rechargeable with three-month battery life

The client provided a reference remote they admired. We were asked to take that intent and deliver a production-ready product tailored to their ecosystem.

THE MECHANICAL DESIGN

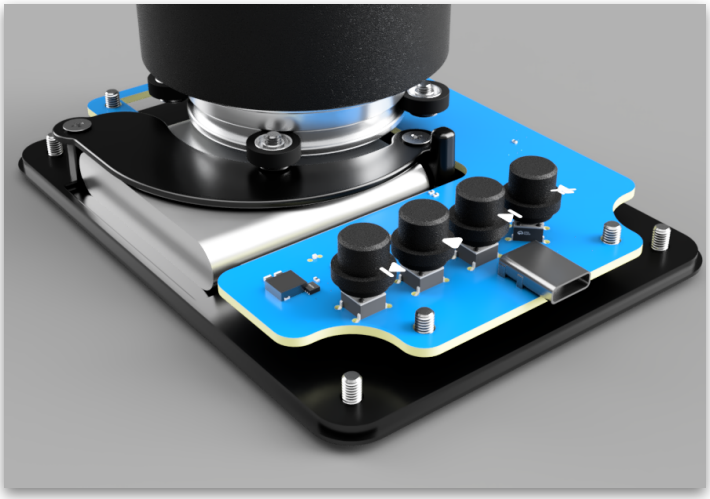
The floating dial had to feel effortless and precise. It rides on concealed rubber ball bearings inside a machined aluminum race. The optical encoder sits beneath, reading quadrature signals from a slotted disk.

Every tolerance mattered. Too tight and the dial binds. Too loose and it wobbles. The bearing preload, encoder alignment, and enclosure fit all had to be resolved together.

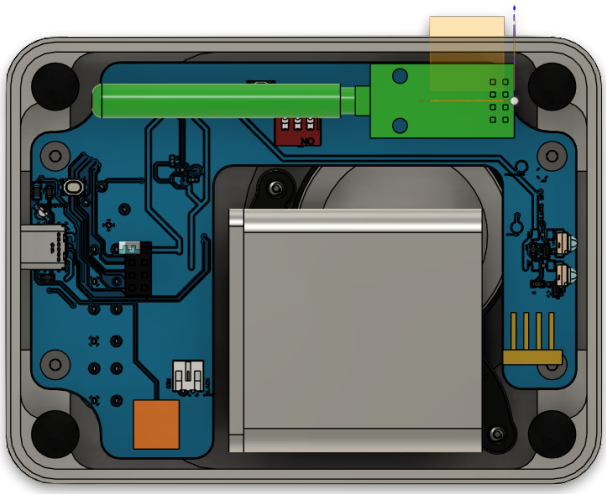
POWER ARCHITECTURE

The optical encoder required always-on IR emitters and photodetectors. Initial standby draw was tens of milliamps — incompatible with a three-month battery target, so we added an ultra-sensitive accelerometer wired to the ESP32 RTC wake pins. The system sleeps at microamp levels until the user picks it up. Buttons also wake directly.

CNC aluminum enclosure with floating dial, tactile controls, and USB-C charging.



Internal assembly: concealed ball bearing race, optical encoder, and custom PCB.



Li-ion cell, encoder assembly, RF module, and battery management integrated within the enclosure.

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RF THROUGH A SEALED ENCLOSURE

The controlled products also had suboptimal receiver antenna placement, requiring unusually strong transmission from a device designed to block it.

We iterated through:

- PCB trace antennas
- Chip antennas
- Wire antennas with enclosure tuning
- Dedicated PCB transmitter

REVERSE ENGINEERING THE PROTOCOL

The original remote manufacturer refused to share the RF and IR protocols so we reconstructed it from scratch for compatibility with the existing product line.

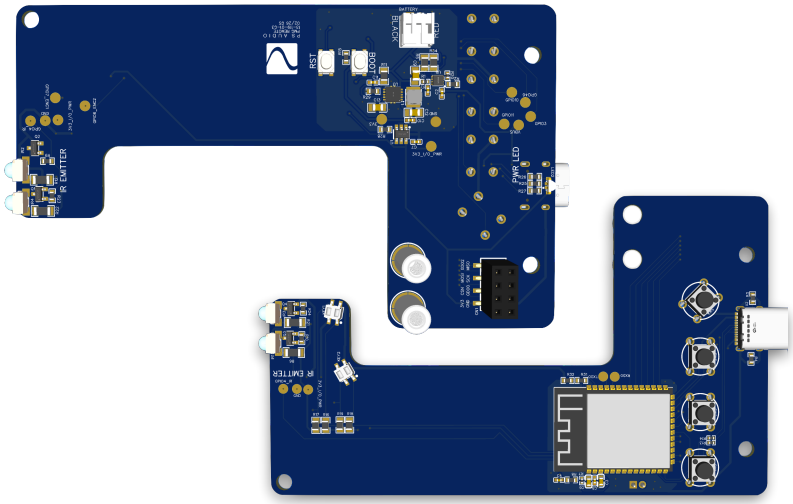
- Disassembled the original remote
- Probed microcontroller outputs
- Captured baseband pulse trains
- Used SDR to demodulate the RF transmission
- Reconstructed the modulation scheme in firmware

The IR command structure was replicated independently. Full protocol compatibility achieved without manufacturer documentation.

CONFIGURATION WITHOUT COMPROMISE

The initial request was a physical DIP switch for product code selection. Functional, but inconsistent with the premium surface.

- Hidden RGB LED near USB-C port
- Long-press button combinations for mode entry
- Software-selectable product type and code set



ESP32 (for control only), IR emitter array, accelerometer, battery management, and RF module header.

Button detail: laser-etched icons, tactile switches, and USB-C charging port.