

Project Proposal

Problem

Sustained attention is increasingly difficult to achieve in modern digital environments characterized by constant notifications, multitasking, and on-demand connectivity. One widely adopted approach to addressing this challenge is the Pomodoro technique, a time-management method that structures work into focused intervals separated by short breaks. By encouraging intentional focus and regular rest, the Pomodoro technique has been shown to reduce mental fatigue, improve task engagement, and support healthier work habits.

Despite its simplicity and effectiveness, the implementation of the Pomodoro technique often relies on screen-based tools such as smartphone apps, browser extensions, or desktop timers. These tools require users to interact with the very devices that generate distractions, increasing the likelihood of interruption. Starting or checking a timer may expose users to notifications, messages, or unrelated applications, undermining the core goal of sustained focus. As a result, many users abandon structured focus techniques not because they are ineffective, but because they are difficult to maintain in real-world contexts.

The implications of this challenge extend beyond individual productivity. Difficulty maintaining focus contributes to stress, burnout, and decreased well-being. In academic and professional settings, fragmented attention leads to lower-quality work and inefficiencies. From a broader societal and cultural perspective, the over-reliance on screen-based productivity solutions reinforces unhealthy patterns of constant device engagement. There is a clear need for a more intentional, low-friction, and human-centered way to support structured focus practices - one that preserves the benefits of the Pomodoro technique while reducing dependence on distracting digital interfaces.

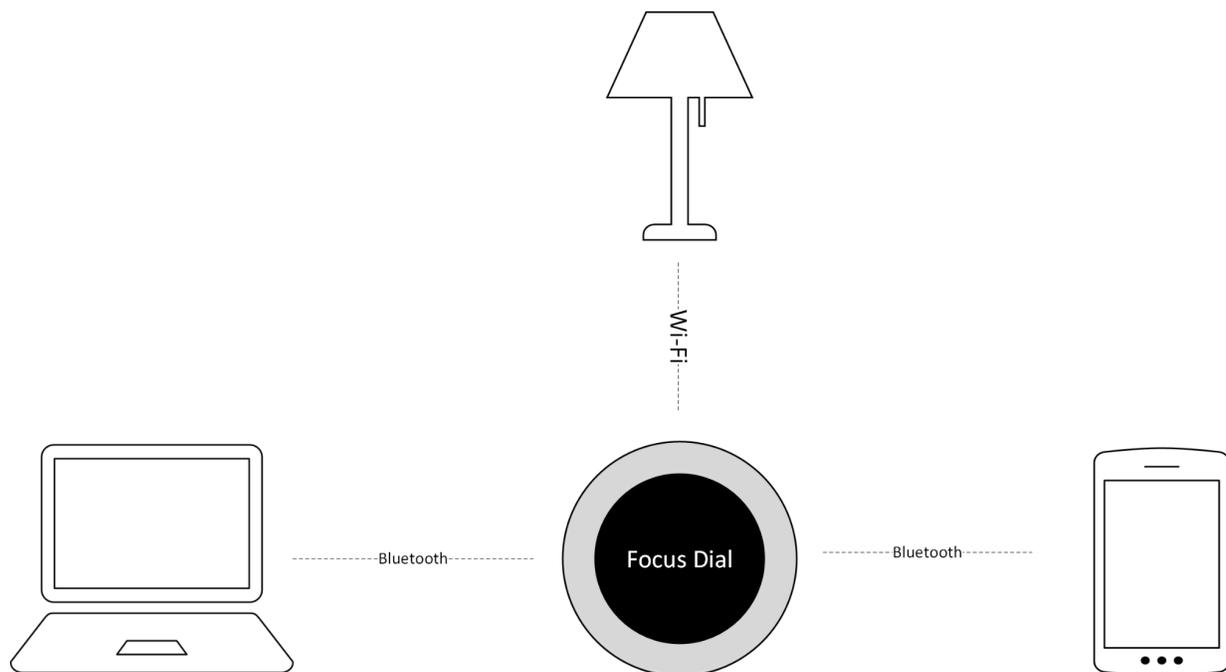
Solution

The Focus Dial is a standalone hardware device designed to support structured focus techniques, such as the Pomodoro method, without requiring direct interaction with digital connected devices. Rather than reinventing the concept of time-based focus, the project focuses on how users initiate, maintain, and conclude focus sessions through physical interaction. By turning a rotary dial, users can start a focus interval, adjust its duration, and transition into breaks using a deliberate action.

At a high-level, the Focus Dial externalizes the Pomodoro workflow into a physical object. The rotary dial allows users to select predefined focus and break intervals or customize session lengths, while visual, haptic, and ambient feedback communicate progress and state without demanding attention. For example, an LED ring can indicate time remaining through color or gradual animation, and subtle haptic feedback can signal the end of a focus session or

the start of a break. This design reduces cognitive load and minimizes interruptions, aligning more closely with the original intent of the Pomodoro technique.

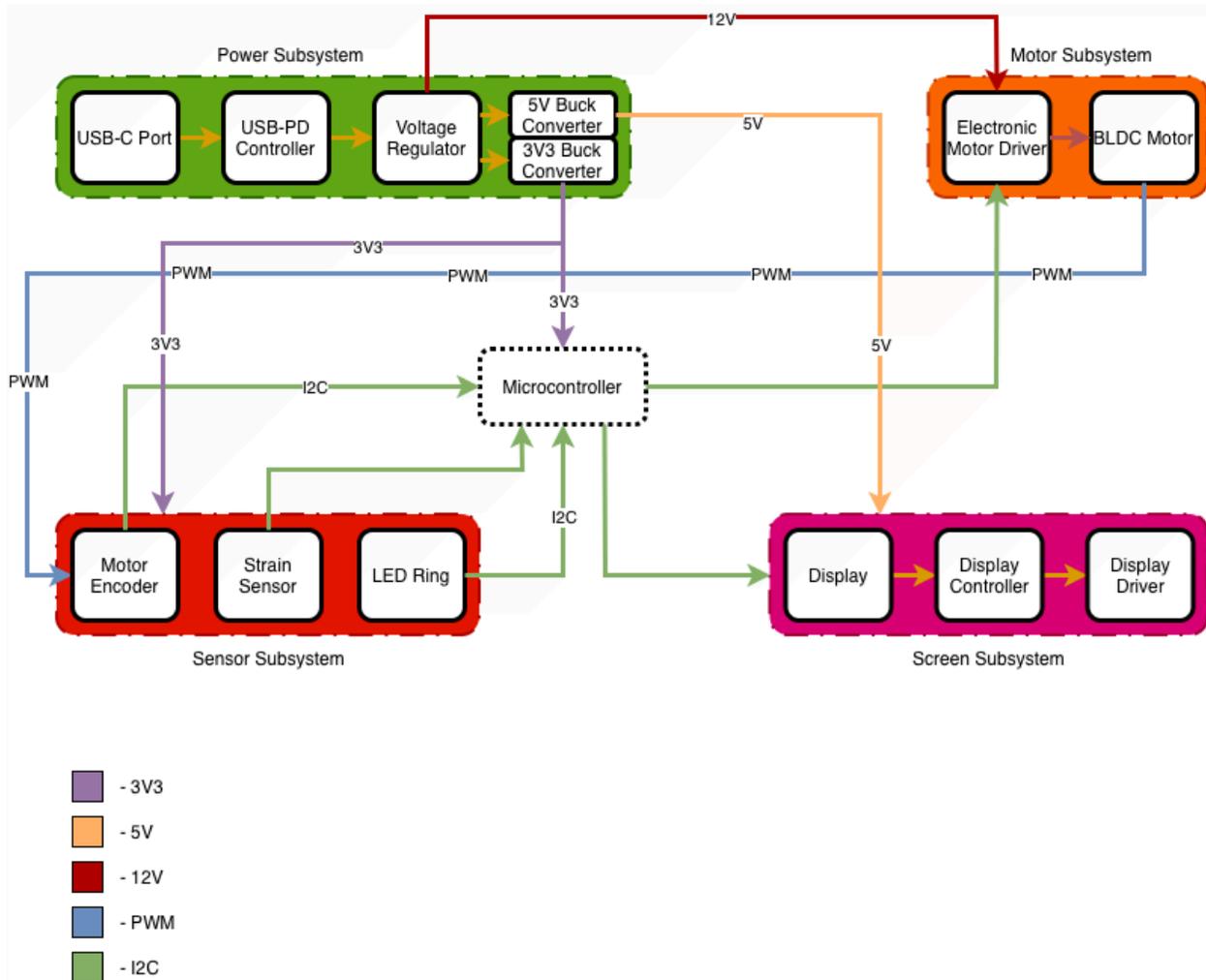
In implementation, the Focus Dial consists of an embedded system that integrates tactile input, local processing, and wireless communication. The device synchronizes focus states with connected phones or computers to activate Focus Mode or Do Not Disturb automatically during work intervals. Optional integration with IoT devices - such as smart lighting - extends the Pomodoro concept into the physical environment, reinforcing focus through ambient cues. Importantly, the system is designed to function primarily offline, prioritizing privacy and reliability while offering a concrete, hardware-driven evolution of time-based focus techniques.



High-Level Requirements

1. The system shall initiate, modify, or terminate a focus session within 1 second of a user's rotary input, ensuring low-friction interaction that does not interrupt or distract the user from their task.
2. The Focus Dial shall accurately track and display focus and break intervals with a timing error of no more than ± 1 second per 30-minute session, supporting reliable implementation of structured techniques such as the Pomodoro method.
3. The device shall maintain continuous operation for at least 8 hours of active use, enabling users to complete multiple focus sessions throughout a typical work or study day without interruption.

Block Diagram



Subsystem Overview

Power Subsystem

The Power Subsystem is responsible for converting external power from the USB-C port into stable voltage rails required by the rest of the system. The system explicitly requests a 12 V power profile from the USB-C Power Delivery source via the USB-C PD controller. This 12 V rail serves as the primary system supply and is distributed to high-power loads while also feeding dedicated buck converters that generate regulated 5 V and 3.3 V rails. These lower-voltage rails supply the Microcontroller, Motor Subsystem, Sensor Subsystem, and Screen Subsystem. By isolating power negotiation, conversion, and regulation into a dedicated subsystem, the design ensures reliable operation, protects sensitive electronics from voltage fluctuations, and supports the system's overall requirement for consistent, low-latency user interaction.

Microcontroller (Control) Subsystem

The Microcontroller Subsystem acts as the central control unit of the system. It receives input data from the Sensor Subsystem via I2C and PWM signals, executes control logic, and generates output control signals to the Motor Subsystem, LED Ring, and Screen Subsystem. The microcontroller operates on the regulated 3.3V rail and serves as the primary integration point between all subsystems. Its role is essential for interpreting user input, managing timing and state, and coordinating feedback across visual, haptic, and motor outputs.

Sensor Subsystem

The Sensor Subsystem captures physical user input and system state information. It includes the motor encoder, strain sensor, and LED ring. Sensor data is transmitted to the Microcontroller via I2C and PWM interfaces operating at 3.3V logic levels. This subsystem enables accurate detection of rotary input and applied force, which directly supports intentional, tactile user interaction. The LED ring also provides visual feedback driven by the microcontroller, reinforcing system state without requiring screen interaction.

Motor Subsystem

The Motor Subsystem provides haptic response through a BLDC motor controlled by an electronic motor driver. The motor driver receives PWM control signals from the Microcontroller and is powered by the 12V rail generated by the Power Subsystem. This subsystem enables physical feedback and resistance, enhancing the tactile nature of the interface and supporting the project's goal of distraction-free, non-screen-based interaction.

Screen Subsystem

The Screen Subsystem provides visual feedback to the user through a display, display controller, and display driver. It receives control and data signals from the Microcontroller and operates primarily on the 5V power rail. The display presents contextual information such as system status and timing, complementing the LED and haptic feedback mechanisms. This subsystem allows the system to communicate state information clearly while remaining secondary to tactile interaction.

Subsystem Requirements

Power Subsystem Requirements

The Power Subsystem enables all other subsystems to function by providing stable, regulated voltages.

Block Contribution

This subsystem directly supports the high-level requirement for reliable, low-latency system operation by ensuring uninterrupted power delivery to all components.

Interfaces (Quantitative)

Input: USB-C PD input, nominal 12V

Outputs:

- $12V \pm 5\%$ to Motor Subsystem
- $5V \pm 0.1V$ to Screen Subsystem
- $3.3V \pm 0.05V$ to Microcontroller and Sensor Subsystem

Required Characteristics

- Must supply $\geq 2A$ at 12V continuously to support motor operations
- Must supply $\geq 1A$ at 5V for display and peripherals
- Must supply $\geq 600\text{ mA}$ at 3.3V for logic and sensors
- Voltage ripple must be $< 50\text{ mV}$ peak-to-peak on all rails

Microcontroller (Control) Subsystem Requirements

The Microcontroller Subsystem coordinates all sensing, control, and feedback functions.

Block Contribution

This subsystem fulfills the high-level requirement for responsive and accurate user interaction by processing sensor input and generating control outputs within tight timing constraints.

Interfaces (Quantitative)

Power: $3.3V \pm 0.05V$

I2C:

- Clock frequency: 100-400 kHz
- Logic levels: 3.3 V

PWM:

- Frequency: 1-20 kHz
- Duty cycle resolution: ≥ 8 -bit

Required Characteristics

- Must process input-to-output control logic with $< 10\text{ ms}$ latency
- Must support at least 3 PWM outputs simultaneously
- Must maintain I2C communication error rate $< 1\%$ under nominal conditions

Sensor Subsystem Requirements

The Sensor Subsystem captures user input and provides visual state feedback.

Block Contribution

This subsystem supports the high-level requirement for intentional, tactile interaction by enabling precise detection of rotary motion and applied force.

Interfaces (Quantitative)

- Power: 3.3V
- I2C:
 - Data rate: ≥ 100 kHz
- PWM (encoder):
 - Pulse resolution sufficient to detect ≥ 24 detents per rotation

Required Characteristics

- Encoder must detect rotational changes with $\geq 95\%$ accuracy
- Strain sensor must resolve force changes of $\leq 5\%$ of full scale
- LED ring must support update rates of ≥ 30 Hz for smooth feedback

Motor Subsystem Requirements

The Motor Subsystem provides controlled mechanical motion and haptic response.

Block Contribution

This subsystem enhances the user experience by providing physical feedback, reinforcing system state without visual distraction.

Interfaces (Quantitative)

- Power: $12V \pm 5\%$
- Control:
 - PWM input from Microcontroller
 - PWM frequency: ≥ 10 kHz

Required Characteristics

- Motor driver must handle $\geq 2A$ peak current
- Motor response time must be $< 50ms$ from control input to motion
- Must operate without inducing voltage droop $> 5\%$ on shared rails

Screen Subsystem Requirements

The Screen Subsystem communicates system information visually.

Block Contribution

This subsystem supports the high-level requirement for clear system state awareness while remaining secondary to tactile interaction.

Interfaces (Quantitative)

- Power: $5V \pm 0.1V$
- Data interface from Microcontroller (SPI/I2C equivalent):
 - Refresh rate: $\geq 30 FPS$

Required Characteristics

- Display must update within 100 ms of state change
- Must remain readable under standard indoor lighting conditions
- Must not exceed 500 mA current draw during peak brightness

Tolerance Analysis

Risk Identified: Voltage Droop on the 3.3V Rail During Motor Actuation

A primary risk to successful system operation is voltage droop on the 3.3V rail when the Motor Subsystem draws high transient current from the 12V rail. Sudden current spikes can propagate through the power distribution network, potentially causing microcontroller brown-out or sensor communication errors.

Feasibility Analysis

Assume:

- Peak motor current: 2A at 12V
- Buck converter efficiency: 90%
- Total 3.3V load: 600 mA
- Allowable voltage drop: $\leq 50mV$

Required output power at 3.3V: $P = 3.3V \times 0.6A = 1.98W$

With adequate bulk capacitance C near the 3.3V rail, transient voltage drop is approximated by:

$$\Delta V = \frac{I \cdot \Delta t}{C}. \text{ For a transient of } 10 \text{ ms and allowable } \Delta V = 50 \text{ mV}, C = \frac{0.6A \times 0.01s}{0.05V} = 0.12F.$$

By distributing multiple decoupling capacitors totaling $\geq 120mF$ near the microcontroller, voltage stability can be maintained. This analysis demonstrates that the design is feasible with standard power-conditioning techniques.

Ethical and Safety Considerations

As engineers, we are ethically responsible for designing systems that prioritize user safety, privacy, and well-being. The Focus Dial project involves embedded electronics, wireless communication, and direct user interaction, making ethical considerations relevant during both development and use. These responsibilities align with the IEEE Code of Ethics, which emphasizes protecting public welfare, and the ACM Code of Ethics, which highlights minimizing harm, respecting privacy, and ensuring transparency.

A key ethical concern is user well-being. While the device is intended to improve focus, excessive or intrusive feedback could increase stress or promote unhealthy work habits. To avoid this, the system provides subtle, non-disruptive feedback through haptics and ambient lighting rather than aggressive alerts. Another major concern is privacy. Wireless communication is limited to local Bluetooth and Wi-Fi connections, and the system does not collect, store, or transmit personally identifiable data. This design choice minimizes privacy risks and aligns with ethical principles of user autonomy and informed consent.

During development, ethical risks include inadequate testing or overstating system capabilities. These risks are mitigated through thorough validation of electrical, software and communication components and by clearly documenting system limitations. Open-source software and external resources are used responsibly and cited appropriately.

Potential safety risks include electrical faults, overheating, and unintended motor activation. These risks are mitigated by operating at low voltages (less than 12V), incorporating voltage regulation, current limiting, and isolating high-power components from low-voltage logic. Wireless communication adheres to FCC Part 15 regulations for unlicensed devices in the 2.4 GHz band.

From a broader perspective, the Focus Dial promotes healthier focus habits and reduced digital distraction, supporting societal well-being and productivity. Its local, energy-efficient operation minimizes environmental impact and avoids reliance on cloud infrastructure. Overall, the design balances technical functionality with ethical responsibility, safety, and respect for users.

Project References

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