MOTION SENSING GUITAR PEDAL CONTROLLER

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Abstract

This project proposal presents the design and implementation of a gesture-controlled guitar pedal board. The system integrates a microcontroller-based real-time wireless communication system that communicates whether pedals should be activated or deactivated based on a motion sensor. Two PCBs will be used: one transmitting the data read by the motion sensor and the other receiving the data and activating the chosen pedals. The transmitter PCB will include a microcontroller connected to a motion sensor and three LEDs (one representing each pedal), allowing the user to choose which pedals to activate via a hand or leg gesture. The receiver PCB will receive the pedal activation information and route the signal through the pedals and amplifier. Testing will determine real-time performance, accurate motion sensing, and reliable operation from the DC supply.

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1. Problem

Modern guitar effects pedals allow musicians to shape tone using parameters such as gain, delay time, and modulation depth. However, adjusting these parameters in real time often requires manual knob turning or additional expression pedals, which can interrupt performance flow. While some professional systems allow limited foot-based control, expressive lower-body motion is largely unused as a control input. Musicians performing live often move dynamically as part of their performance. Currently, these gestures have no direct interaction with the audio processing system.

1.1 Solution

A device that translates natural motion into real-time control of audio effects would enhance expressive capability without requiring additional manual adjustments. We propose a design of a two-part, PCB-based embedded system that integrates real-time signal processing with motion sensing to create a gesture-responsive multi-effects guitar pedal switching system. The sensing device detects when the user kicks near each LED indicator to switch pedal effects on and off, improving the flow of a guitarist's performance, as the upper body is already preoccupied. A pedal control device will wirelessly communicate with the sensing device to route the guitar's signal through the pedals as desired. An LED display attached to the sensing device will also help the guitarist track which pedal effects are on and off during the performance.
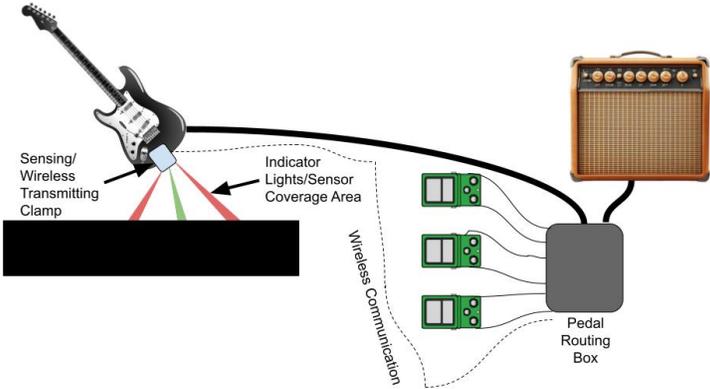
1.2 Visual Aid

Figure 1: Visual Aid of Guitar Pedal System Setup

1.3 High-Level Requirements

1. The system must be able to detect a user's foot within 20 cm of each pedal zone and register an effect toggle within 100 milliseconds of detection.
2. Each pedal zone must provide a clear visual indication of its on/off status using LEDs to ensure visibility under stage lighting conditions.
3. The device must process and output the corresponding audio effect with a total latency of no more than 10 milliseconds to ensure real-time performance suitable for live guitar playing.

2 Design

2.1 Block Diagram
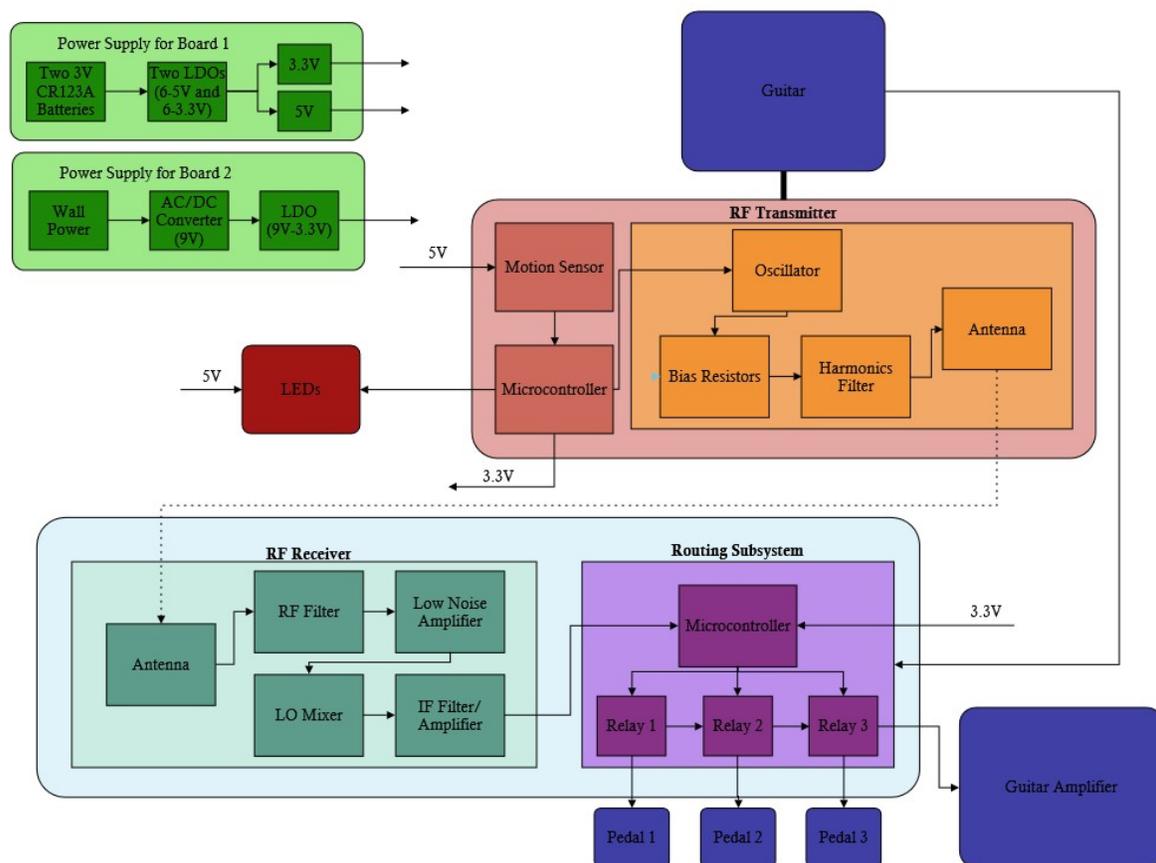
2.2 Subsystem Overview

2.2.1 Power Management Subsystem

Both PCBS (one for transmitting/sensing and one for receiving/routing) will need consistent DC power supplied to operate. The transmitting/sensing PCB will be battery powered by two 3V CR123A batteries

in series. These batteries provide a maximum discharge current of 1500mA, which is more than enough to accommodate the entire PCB. The PCB will also contain two linear dropout regulators, one to step down to 5V and one to step down to 3.3V. The 3.3V Rail will power the microcontroller and the wireless communication circuit. The 5V rail will power the IR sensors and the LEDs. The receiving PCB will be powered by wall power with an AC/DC converter. The 9V DC coming from the converter can be sent through a linear dropout regulator to 3.3V to supply the relays, microcontroller, and wireless communication system on the receiving/routing PCB.

Requirements for Power Management Subsystem:
- Battery Power for Lighting/Sensing/Transmitting PCB
    - Must support ≥ 30 minutes of consistent use while voltages stay within ± 5% of their intended values.
    - Must have reverse polarity protection (a Schottky placed at the battery terminal).
    - Low Idle Current: The regulators must draw less than 200µA when the system is inactive.
- Wall Power For Receiver/Signal Routing PCB
    - Must support consistent use while voltages stay within ± 5% of intended voltage values (3.3V).

2.2.2 Sensing Subsystem

The sensing subsystem consists of a GP2Y0A21YK0F analog distance sensor that can be found on amazon. This sensor emits infrared light and outputs an analog voltage proportional to the distance of an object from the sensor in the range of approximately 10–80 cm. In the context of the guitar pedal system, the sensor is mounted above each pedal zone, oriented downward toward the foot. When a foot enters the detection zone, the voltage output rises, allowing the microcontroller to detect the presence of the foot. The analog voltage output interfaces with the STM32 microcontroller's ADC input, providing real-time data for decision making.

Requirements for the Sensing Subsystem:

- Must detect a foot at a distance of 10–80 cm with an output voltage that varies linearly enough for threshold detection.
- Must respond to a moving object within 50 ms to maintain low-latency effect toggling.
- Output voltage must be compatible with a 3.3 V ADC input
- Must operate continuously at 5 V ± 0.25 V without thermal drift affecting detection accuracy.

2.2.3 Lighting Subsystem

The lighting subsystem provides visual feedback to indicate the on/off status of each pedal. Each pedal zone is equipped with an RGB LED, controlled by the microcontroller based on signals from the sensing subsystem. The STM32 microcontroller will be compatible with the WS2812 RGB LED strip which can also be soldered onto our PCB. This subsystem ensures performers can clearly see which effects are active, satisfying the high-level requirement for visual feedback.

Requirements for the Lighting Subsystem:

- Each LED must be visible under stage lighting.
- Must update within 50 ms of pedal detection.
- Must operate at 3.3 V logic levels and draw current compatible with the microcontroller outputs.

2.2.4 Wireless Communication Subsystem

The wireless communication subsystem enables the two STM32 microcontrollers to exchange pedal states in real time using an RF transmitter and receiver. The microcontroller connected to the sensing subsystem encodes pedal activation/deactivation as digital pulses using on-off keying (OOK) at 433 MHz and transmits them wirelessly to the receiver connected to the microcontroller that is part of the routing subsystem. Each pedal's state is represented by a distinct pulse sequence, ensuring proper communication between the transmitter and receiver. This subsystem contributes directly to the high-level requirement for real-time detection and feedback, allowing pedal activations to trigger LEDs and audio effects with minimal latency.

Requirements for the Wireless Communication Subsystem:

- Must communicate all pedal states simultaneously over a distance of at least 1 meter, suitable for a typical pedalboard layout.
- Must correctly encode and decode which pedals are to be activated/deactivated.

2.2.5 Audio Signal Routing Subsystem
The signal routing subsystem will consist of three 3.3V electromechanical relays. Each relay will have the input and output of a guitar pedal connected to it and will receive a logical 1 or 0 from the STM32 to turn it on and off. The three relays will be connected in series, and will start in the off state. Since we have a wall power supply for this subsystem, the relays will be non-latching to reduce complexity.

Requirements for Audio Signal Routing Subsystem:

- Must correctly open and close each relay depending on the logical signal given from the STM32.
- Must reproduce a clear audio signal when none of the pedal effects are activated.

2.2 Tolerance Analysis

A potential risk in the power subsystem is the thermal dissipation of the voltage regulator when stepping down from 6 V to 3.3 V, particularly because the regulator's heat must be dissipated through the limited area of the PCB. Excessive heat could lead to thermal shutdown or reduced reliability, violating the requirement for continuous, stable operation.

Assume the 3.3 V subsystem draws a maximum current of:

$$I_{load} = 250 \text{ mA}$$

The regulator must drop:

$$V_{\text{drop}} = V_{\text{in}} - V_{\text{out}} = 6 - 3.3 = 2.7 \text{ V}$$

Power dissipated in the regulator:

$$P_{\text{dissipation}} = V_{\text{drop}} \cdot I_{\text{load}} = 2.7 \cdot 0.25 = 0.675 \text{ W}$$

Assuming a regulator thermal resistance to ambient through the PCB of:

$$\Theta_{JA} \approx 80 \text{ C/W}$$

The expected junction temperature at $T_A = 40$ C ambient:

$$T_J = T_A + P_{\text{dissipation}} \cdot \Theta_{JA} = 40 + 0.675 \cdot 80 \approx 94 \text{ C}$$

This is below typical maximum junction ratings (125–150 °C), but it leaves little margin for higher ambient temperatures or increased current draw.

3. Ethics

As engineers, we are responsible for designing safe, reliable, and socially responsible devices. Our motion-sensor guitar pedal system will be built with consideration for user safety, accessibility, and fairness. We will ensure that the device does not pose hazards to performers or audiences, avoids misuse of laser or infrared components, and respects privacy (no cameras or audio recording will be used beyond the user's guitar input). Additionally, we will document all limitations and instructions clearly to prevent misuse.

3.1 Safety

The primary safety concerns for this project include electrical safety, mechanical integrity, and heat management. Low-power, eye-safe LEDs or infrared modules will be used, positioned to interact with the user's foot only, with housing and shielding to prevent stray light from escaping the enclosure. The enclosure will be sturdy, with no sharp edges, and foot-placement areas will withstand repeated stepping. Heat-generating components such as voltage regulators and op-amps will be properly rated, with heat dissipation considered in PCB layout and enclosure design. Bench testing and stress testing will be conducted before live use to ensure user safety.

3.2 Societal Impact

The motion-sensor guitar pedal project has primarily positive societal impacts, including increased accessibility for musicians with limited hand mobility and the demonstration of modern embedded systems in an educational setting. Potential negative impacts are minimal but include the possibility of distraction from bright LEDs. These risks are mitigated through user instructions and proper labeling to ensure the device contributes positively to musical performance.

4. Conclusion

This project proposes a motion-sensor guitar pedal system designed to provide intuitive, hands-free control of multiple effects by the guitarist. The system integrates sensing, processing, visual feedback, and communication subsystems to ensure accurate detection, real-time response, and clear feedback for the performer. By meeting the defined high-level requirements, the design will result in a reliable and user-friendly device that enhances the musical performance experience.

References

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