Remote Wah Guitar Effect Pedal

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Introduction:

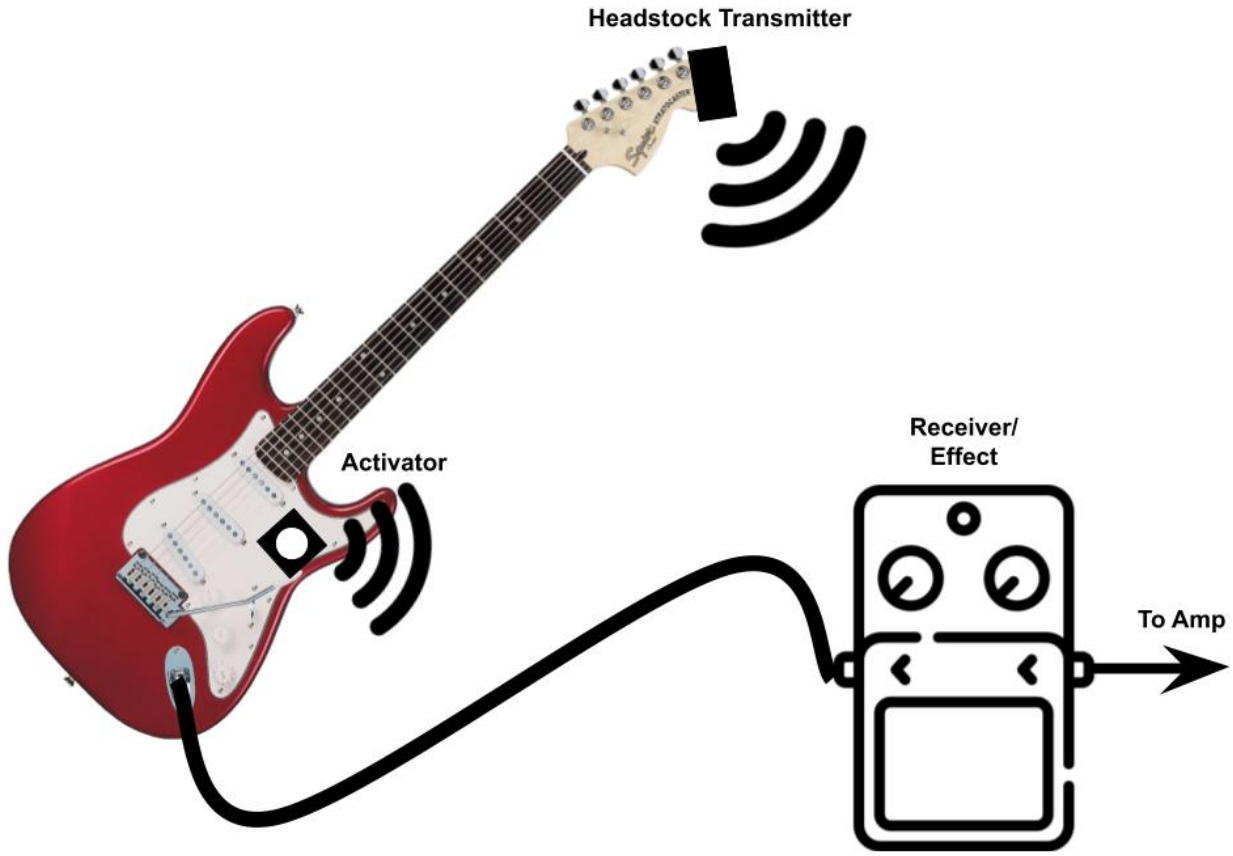
Problem:

Guitar and bass players have a wealth of effects pedals to choose from in order to modify the sound of their instrument, such as adding distortion, echo, reverb, etc. In most cases, the parameters for effects pedals are set by the player beforehand and turned on and off with a footswitch, or controlled by a foot treadle to modify a single parameter, such as the sweep of a high-Q bandpass filter in a wah pedal. However, this requires the player to remain fixed in place while using the effect, which can get in the way of the performance aspect of playing live music. It would be very convenient & expressive to have a way of controlling the parameters of certain effects while maintaining the ability to move around a stage unimpeded.

Solution:

Our idea is that rather than using a foot treadle to control the filter sweep of a wah pedal, the range of the filter sweep is controlled by a sensor mounted to the headstock of a guitar/bass. This allows achieving the characteristic sweep sound of a wah by swinging your guitar up and down rather than using a foot treadle, which allows the use of the effect anywhere on stage (after you switch it on) and makes for an interesting visual accompaniment that is suited for live performance (it would look pretty cool). To further aid in freedom of movement, the effect will have the ability to be remotely activated via a button mounted to the body of the guitar within convenient reach of the player.

Visual Aid:



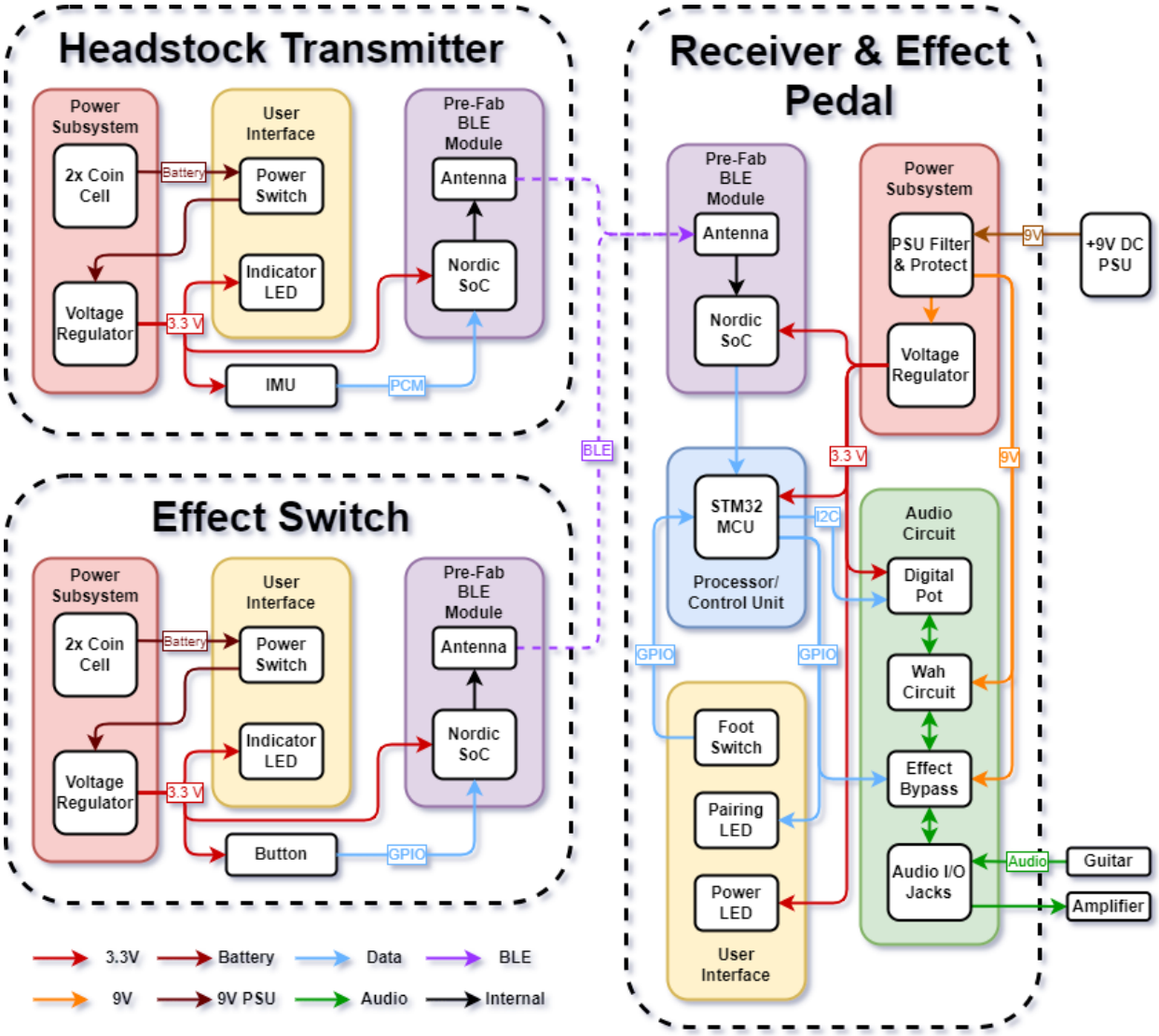
High Level Requirements:

In order to satisfy the core of our goals for this project, we should meet the following criteria:

- Successful linkage between receiver and transmitters to control circuit hardware, including switching effect on and off and controlling the filter sweep
- The receiver is able to process the raw transmitter IMU data into a usable digital potentiometer range
- The wah circuit is able to implement a suitably high-Q filter sweep across a broad range of the audible spectrum, namely 400 Hz to 2.5 kHz

Design:

Block Diagram:



Subsystems:

Subsystem 1: Headstock Transmitter

Overview:

This will be a small device mounted to the headstock of the guitar. It will include some sort of inertial measurement unit (IMU) to gather data about the motion of the guitar's headstock as it moves up and down. This data is then transmitted wirelessly to the receiver pedal through a prefabricated RF module. The transmitter will run off of commonly available button-cell batteries and include a simple power indicator LED and

an on/off switch that is activated before/after a performance, respectively. It should be housed in a small non-metal (probably 3D-printed) enclosure to allow transmission of RF signals, and should be attached to the headstock via an elastic strap. For simplicity, the transmitter will continuously send data to the receiver while it is on, however this can later be changed to sleep while the effect is off and transmit data only when the effect is on in order to save battery life.

Modules:

Power:

The power module adapts the power from two coin-cell batteries via a voltage regulator to supply 3.3 Volts to the Headstock Transmitter subsystem.

UI:

The UI will be used to turn power for the headstock transmitter on or off with a switch, as well as providing feedback on the state of the power switch in the form of an LED.

Prefabricated BLE:

The BLE is responsible for transmitting positional data to the pedal receiver. It will contain a nordic chip and a built-in antenna.

IMU:

The Inertial Measurement Unit measures the acceleration of the headstock to be transmitted to the pedal and interpreted for digital POT control.

Subsystem Requirements:

- BLE module is able to read and format IMU data correctly
- BLE module is able to link to receiver BLE module and transmit IMU data wirelessly
- Circuit must consume as small an amount of power as possible to preserve battery life

Subsystem 2: Effect Switch

Overview:

This will be our simplest subsystem, contained in a small non-metal enclosure that will attach to the guitar near the base of the instrument, ideally on the front where it can be easily reached by the musician's right hand while performing. The only sensor in

this subsystem will be an “ON” button accessible from the outside of the enclosure. This button will serve as the main switch to activate our project; it will communicate wirelessly with subsystem 3, the pedal, via a prefab RF module. Similar to subsystem 1, it will run off of commonly available button-cell batteries and include a simple power indicator LED. This subsystem will be working once it is able to toggle on and off our wah effect from a distance. This subsystem can potentially be expanded to toggle other pedals in addition to the remote wah if time permits.

Modules:

Power:

The power module adapts the power from two coin-cell batteries via a voltage regulator to supply 3.3 Volts to the Effect Switch subsystem.

UI:

The UI is used to turn power for the Effect Switch on or off with a switch, as well as providing feedback on the state of the power switch in the form of an LED.

Prefabricated BLE module:

The BLE is responsible for transmitting an on/off signal to the pedal receiver to control the on/off state of the effect. It will contain a nordic chip and a built-in antenna.

Button:

The button is used to determine if the effect is “on” or to be bypassed. The on/off state of the button will be transmitted to the Receiver & Effect Pedal subsystem.

Subsystem Requirements:

- BLE module is able to read and format button press correctly
- BLE module is able to link to receiver BLE module and transmit button data wirelessly
- Circuit must consume as small an amount of power as possible to preserve battery life

Subsystem 3: Receiver & Effect Pedal

Overview:

This will be the main heart of the project, it will contain our primary PCB and microcontroller. This subsystem is functionally divided into an analog half and a digital half. The analog half will include the wah effect & bypass circuit that the guitar is routed

through. A large part of the classic sound of wah effects has to do with the particulars of which inductor is used to create the peaking filter, so this part is best left analog. It also avoids any latency in the guitar signal since the audio path remains completely analog. The digital half will receive and process the Effect Switch on-button and Headstock Transmitter IMU data into useful control signals that control the analog half. This includes processing the raw IMU data into a useful range that controls a digital potentiometer, which in turn controls the sweep of the analog filter in the wah effect side. This sweep must be calibrated by a footswitch, which is configured before the performance to allow for any range of motion of the guitar to generate a useful sweep of the wah. The range of the sweep will be formatted to control a digital potentiometer, which will interface to the MCU with I2C, thus the MCU has to process the IMU data into a range that controls the digital potentiometer across its full sweep. The button data will also be processed into a control voltage that switches signal relays/analog muxes to either activate or bypass the wah effect.

Modules:

Power:

The power module filters and adapts the power from a +9 Volt power supply via a PSU filter and voltage regulator to supply 3.3 Volts to the Receiver & Effect Pedal subsystem.

UI:

The UI module is used to calibrate the received IMU data to ensure a usable sweep. The footswitch will be used to initiate calibration and set positional limits. A pairing LED indicates if the pedal is in pairing mode or paired to the transmitter, and a power LED indicates if the pedal subsystem is on or off.

Prefabricated BLE:

The BLE is responsible for receiving and interpreting signals from the Headstock Transmitter and Effect Switch subsystems to control respectively the expression of the effect as well as its on/off state.

Audio Circuit:

The audio circuit will feature the “Wah” effect circuit but with the potentiometer being digital to control expression by interfacing with the control unit. The bypass will enable or bypass the “Wah” effect. An input and output ¼” jacks will be used to connect the circuit’s input to an instrument and output to an amplifier/speaker.

Control Unit:

The control unit will be responsible for interpreting signals received by the BLE to enable/disable the bypass, calibrating the POT sweep, and control the digital POT value for pedal expression.

Subsystem Requirements:

- Microcontroller is able to receive and interpret data sent from our two transmitting subsystems
- Wah pedal effect will be off/bypassed until turned on by the Effect Switch subsystem sending activation signal
- IMU data is able to be converted into potentiometer values that accurately mimic the wah pedal effect
    - Footswitch on the pedal allows for on-the-spot calibration of what range of IMU data will correspond to the limits of the wah

Tolerance Analysis:

An important consideration for all wireless devices is their power consumption, as batteries have a limited amount of time to supply power before they run out. In order to ensure the usefulness of our project, we must conduct a power budget analysis for each of our wireless transmitters, and take care to use designs and components that minimize power consumption. This will be derived from balancing the energy capacity of our coin cell batteries to the worst-case current consumption specifications of the components we use, plus an extra margin for error in order to ensure performance up to a given point . Thus we can calculate

$$T_{on} = \frac{E_{battery}}{\sum I_{n,max} * c_{error}}$$

and determine which batteries and parts to use for a desired on time.

Another critical factor in the success of our project will be in making sure that the sweep of our wah filter is within an appropriate range to be useful musically. We must be able to process the IMU data into a range that results in a sweep that is sensitive enough to span an audibly useful range and not under- or overshoot this range. Our sweep will be determined by mapping the acceleration data from the IMU to corresponding resistance values in a digital pot that align with the sweep of a mechanical pot housed within a conventional wah unit. The sweep can then be

measured with a spectrum analyzer to measure the frequency response of the wah over a range of digital potentiometer values.

Ethics:

In keeping with ethical guidelines outlined by IEEE and ACM, consideration for the safety of the end user is our highest priority. We will ensure to include safety features and redundancy in our designs, mostly in our power supply designs, to ensure that there is minimal/inconsequential risk involved in using our project. We will also be sure to follow any standards and regulations that apply to the designs we make. RF frequency spectrums are tightly regulated by the FCC, and thus we have chosen to use RF communication protocols and modules that are well-defined and approved to avoid any conflict with other communications. We also strive to meet standards that are commonplace in the field where our project will operate, such as in the operation of our receiver pedal off of standard 9V center-negative power supplies commonly used for other effects pedals. Finally, we will ensure the quality of our designs through seeking criticism and advice not only through mandatory design reviews, but by seeking the guidance and advice of others with experience in the scope of our project.