Screamin' Green

Digital Guitar Pedals at the Systems Level

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Introduction

This paper describes the key considerations and building blocks for designing a Bluetooth controlled digital guitar pedal. A guitar pedal is a crucial component in the arsenal of any electric guitar player. It is used to modify and enhance the sound produced by the guitar. By transforming the traditional analog pedal into a digital form and integrating Bluetooth technology, the pedal can be easily configured and controlled via smartphones or computers. In this paper, we will explore the key considerations and building blocks that are essential in the development of this innovative piece of musical technology.

How it is Used

When you play an electric guitar, the sound it produces is initially in the form of an electronic signal. This signal is sent to an amplifier which increases its volume and power. Finally, the signal is converted into audible sound by a speaker.

A guitar effects pedal is typically placed between the guitar and amplifier. It takes the input signal from the guitar and modifies it, adding effects like distortion or delay, and outputs the altered signal to the amplifier. To ensure compatibility with the guitar and amplifier being used, the pedal must be designed accordingly.

To power the guitar pedal, a basic 9V DC supply, such as a wall adapter, is commonly used. Since the pedal does not provide any amplification, it consumes relatively little power.

User Interface

The user interface of a guitar effects pedal typically consists of buttons for selecting the desired effect type and a foot-pedal for applying the effect. However, our product eliminates the need for effect selection buttons. Instead, effects are selected via Bluetooth commands sent from a computer or phone.

Therefore, the user interacts with the pedal in two ways:

1. Using a phone app - This allows users to select the effect type, adjust settings to their preference, and even create custom effects by combining multiple effects.

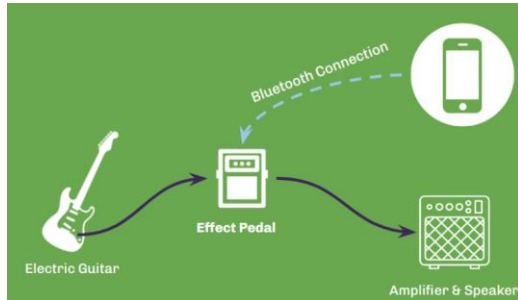2. Pressing the foot-pedal - This applies the selected effect.

Figure 1. Device Level Diagram

Inside the Pedal
As a digital effects pedal, the signal modification process occurs in the digital domain. Consequently, the circuitry of the pedal comprises three main sections:

1. Analog to Digital Interface
This section converts the incoming analog signal from the guitar into a digital signal that can be processed by the digital filtering section. A voltage buffer must be used so that the pedal and guitar don't interfere with each other in unexpected ways. After that, comes the key component of this section: the Analog to Digital Converter (ADC). For good sound quality, an ADC with a sampling frequency of more than 44.1 kHz and a word length of at least 16 bits must be used.

2. Digital Filtering
This section processes the digital signal using digital signal processing (DSP) algorithms to create the desired effect. It takes place on an SoC, which must be fast enough to perform complex mathematical operations on the signal without latency. It should also have Bluetooth compatibility to allow for control via another device like a smartphone. For example, the SoC used in this design is the nRF52840 by Nordic Semiconductor.

3. Digital to Analog Interface
This section converts the processed digital signal back into an analog signal that can be output to the amplifier and speaker, creating the final sound. The key component here is the Digital to Analog Converter (DAC). Ideally, the DAC should work at the same sampling frequency and have the same word length as the ADC. After that, the signal goes through another voltage buffer, which makes sure

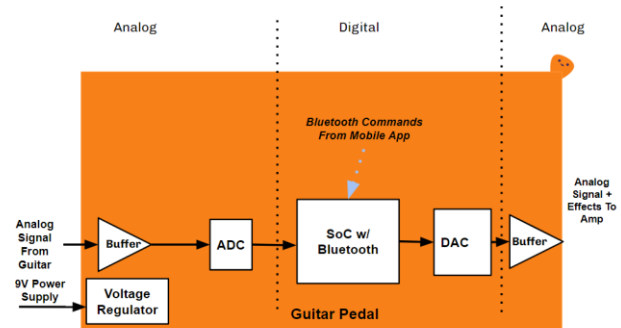the pedal and amplifier don't interfere with each other in undesirable ways.

Figure 2. Circuit Level Diagram

4. Power Supplies
The pedal is powered by a 9-volt DC supply, but the chips inside it require different voltages to function properly. Therefore, one or more voltage regulators are needed to convert the main supply to the voltages required by the internal components. To minimize power loss and heat generation, we can use a type of voltage regulator called Low Dropout Regulator (LDO) that can provide the required voltage with a minimal voltage drop. This ensures that the pedal operates efficiently without overheating.

References
1. Oppenheim, A. V., Willsky, A. S. (1997). Signals Systems (2nd ed.). ISBN-10: 0138147574
2. Proakis, J. G., Manolakis, D. G. (2006). Digital Signal Processing: Principles, Algorithms, and Applications (4th ed.). ISBN-10: 0131873741
3. Analog Devices. (n.d.). Filter Basics: Anti-Aliasing. Retrieved from https://www.analog.com/en/technicalarticles/guide-to-antialiasing-filter-basics.html