1. PROBLEM STATEMENT

The market space for guitar pedals is diverse—even though only about 20 types of pedals exist [1], the differences between brands account for hundreds, if not thousands, of pedals on the market. Although Alternative Instrumentation's The Blackbox is one such pedal, its design focuses on ease of access, versatility, and robustness, allowing it (and the performers who use it) to stand above the rest.

1.1. Need Statement

Most guitar pedals in the contemporary design space function similarly in terms of user interface: usually, a large bypass switch in the center, several fine-tuning knobs, and occasionally an expression pedal operated by the user's feet. While this arrangement has its advantages, the performer has to bend down and take their hands off the instrument to adjust the strength of the effects, disrupting the performance. This problem compounds as the number of pedals on a user's setup increases, taking up precious minutes of performance time. Additionally, different pedals often include power supplies of varying voltages, requiring an aspiring musician to transform the input voltage to 9 V, 12 V, 18 V, and 24 V depending on their setup [2]. This cable management nightmare often forces new performers to sacrifice their time learning voltage regulations, money hiring a professional, or sound quality by ignoring impedance matching and feedback. Further, this voltage problem risks damaging components if done incorrectly, affecting the pedal's longevity.

1.2. Objective Statement

The Blackbox, engineered by Alternative Instrumentation, is an all-in-one modular system designed for a seamless user experience. It uses a digital microcontroller to emulate the effects of multiple pedals, allowing the performer to reorganize their effects chain and effect strength mid-performance. The Blackbox's user interface incorporates switches and pedals optimized to be controlled hands-free, including a powerful preset system that can adjust the effects chain (and its fine-tuned parameters) at the push of a button. Naturally, because the pedals are mostly software-controlled, the user can install new pedals from a connected device and use them immediately, sidestepping the complex setup process (and price point) necessary for a new physical pedal.

1.3. Background and Related Work

The most fundamental idea behind The Blackbox is a focus on many large foot-controlled pedals for performers to use, rather than the small, circular knobs used in most pedals today. Further, Alternative Instrumentation interviewed those in the local music scene in Starkville, MS to ascertain what effects consumers seek and problems they encounter when using guitar pedals. For instance, to implement greater control over effects, products called "Expression Pedals" allow one to strengthen or weaken a sound parameter smoothly with their foot. Most single or multi-effects (multi-FX) pedals average around 2–3 slots for an "expression input" (for instance, an envelope or filter), which could adjust multiple parameters concurrently with one input. An advantage of this approach is a smaller form factor; however, interviews showed compactness was not a top priority, instead being sound quality. Moreover, a problem with the knob-based approach is that performers cannot adjust their pedal's sound parameters consistently and effortlessly in the middle of a performance. Additionally, collecting multiple pedals of different varieties can be tedious and expensive for users. As for products that fill this niche, the Helix by Line 6 exists to fulfill the function of multiple pedals in an all-in-one product [3]. Even so, The Blackbox's inclusion of multiple expression inputs allows for unalloyed control over every facet of sound.

2. DESIGN REQUIREMENT SPECIFICATIONS

The following section details the design requirements placed on The Blackbox—marketing requirements, engineering requirements, constraints, and standards guide and define the design process.

2.1. Requirements

The Blackbox meets and exceeds the expectations of the performers who use it, including exceptional sound quality, intuitive operation, and a durable frame to protect the device from the conditions typical of a live performance. Marketing requirements communicate the design goals from the perspective of the end user, while engineering requirements communicate the design goals from the engineer's perspective.

2.1.1. Marketing Requirements

To the end user, Alternative Instrumentation communicates the following simplified marketing requirements for The Blackbox's design:

1. The Blackbox can be operated hands-free.
2. The Blackbox maintains high-quality audio at all times.
3. The Blackbox is durable against repeated use.
4. The Blackbox can perform multiple audio effects in sequence.

In addition to those marketing requirements, Figure 2-1 organizes any secondary design requirements into an objective tree, creating a hierarchy of goals and sub-goals.

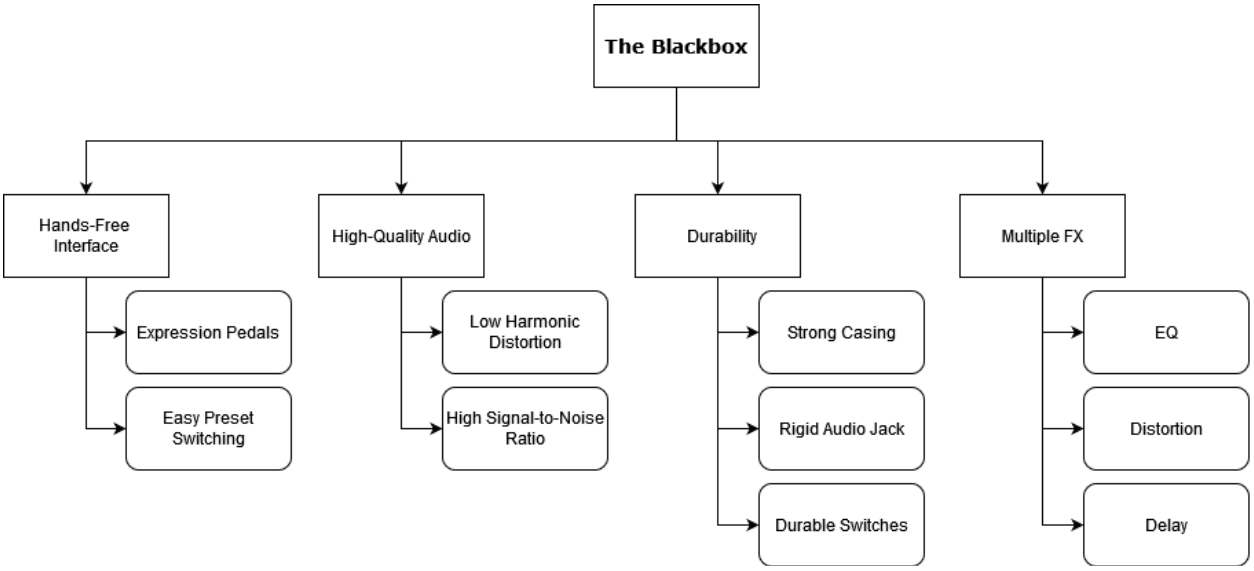

Figure 2-1: Objective Tree

2.1.2. Engineering Requirements

Table 2-1 lists the engineering requirements The Blackbox meets to guarantee it can perform all of its marketed features.

Table 2-1: Engineering Requirements

Marketing Requirements	Engineering Requirements	Justification
1	The force necessary to activate a footswitch is ≤ 3 lb.	Ensuring that the activation force is 3 lb or less allows users to easily switch between sounds without requiring excessive effort, which supports hands-free operation and general ease of use.
1,4	The response time for a footswitch's effect is ≤ 25 ms.	Maintaining a response time of 25 milliseconds or less minimizes any noticeable delay during live performances, enabling live, seamless transitions between sound effects or audio adjustments.
2	The pedal has a minimum signal-to-noise ratio of 60 dB.	60 dB is considered a "good" SNR for consumer equipment, so it represents a minimum for professional audio equipment [4].
2	The pedal limits unintentional audio distortion to < 1% THD.	By limiting total harmonic distortion (THD) to less than 1%, the pedal ensures that any unintentional audio distortion remains inaudible to the listener, thereby preserving the clarity of the sound being processed [5].
2	The pedal can interface with standard 120 V wall outlets.	Ensuring compatibility with 120 V wall outlets allows the pedal to be powered through standard electrical sources likely to be available for most performance setups.
3	The pedal withstands a minimum force of 250 lb without lasting deformation or loss of function.	By designing the pedal to withstand a force of at least 250 lb (about 50 lb higher than the average weight of an adult man), the product ensures long-term durability and reliable performance even under heavy foot pressure or accidental impacts during use [8].
3	The pedal operates without issue within a temperature range of 0°F to 125°F.	Ensuring the pedal operates effectively within a temperature range of 0°F to 125°F guarantees that it will perform reliably in a variety of environmental conditions, making it suitable for both indoor and outdoor use across different climates.
Marketing Requirements: 1. The Blackbox can be operated hands-free. 2. The Blackbox maintains high-quality audio at all times. 3. The Blackbox is durable against repeated use. 4. The Blackbox can perform multiple audio effects.		

2.2. Constraints

The Blackbox has several constraints imposed on it, including a weight limit, available budget, and cost associated with the design. These constraints impact the type of material Alternative Instrumentation has and the time that's put into this design. All design constraints are outlined in Table 2-2.

Table 2-2: Engineering Constraints

Type	Name	Description
Economic	Time	Alternative Instrumentation is given a few months to design three working sub-systems by December 2024 and a fully integrated product by May 2025.
Economic	Cost	The Blackbox has a $1000 budget.
Environmental	Durability	The Blackbox is capable of withstanding at least a 250 lb. weight limit [8].
Material	Sustainability	The Blackbox is made of strong materials, allowing for a long product life.
Technical	Complexity	The Blackbox has at least three usable effects in its chain.
Usability	Instruction Manual	The Blackbox has a user-friendly instruction manual.
Health and Safety	Electric Shock	The Blackbox's enclosure protects the user from high voltages and current sources.

2.3. Engineering Standards

Table 2-3 lists engineering standards that The Blackbox adheres to. These standards exist to ensure safe operation, device reliability, and interconnectivity between other pedals.

Table 2-3: Engineering Standards

Specific Standard	Standard Document	Specification/Application
IP-54	International Electrotechnical Commission Standard 60529	Protected against dust and water splashes from any direction.
Federal Communications Commission Part 15	Code of Federal Regulations Title 47, Subchapter 1A	Portable RF devices do not cause harm to humans or the environment.
Federal Communications Commission Part 15	Code of Federal Regulations Title 47, Subchapter 1B	The device does not cause any harmful interference and accepts any interference received.

2.3.1. Ingress Protection Standards

The Blackbox follows the IEC's IP-5X and IP-X4 Standards for ingress protection. Its enclosure is both dust-protected, limiting dust ingress to an amount that will not interfere with operation, and water-protected against splashing from any direction. These standards are rigorously tested under criteria specified in the document IEC 60529.

2.3.2. FCC Compliance Statement

The FCC RF (Radio Frequency) Emissions Regulations specify three criteria for portable RF sources (where portable is defined as any device not fixed to its location) within 20 centimeters of the body of a user. The Blackbox's Specific Absorption Rate (SAR) shall have RF emitting sources within the frequency range of 100 kHz to 6 GHz, inclusive. This standard is enforced to ensure that human and environmental exposure is kept within safe limits. Devices operating in distances between 0.5 cm and 20 cm from the human body must not exceed an available maximum time-averaged power of 1 mW and must operate in the frequencies of 0.3 GHz to 6GHz to use said power condition. [6]

Further, any receivers operating in the range of 2000–2020 MHz are required to accept RF interference in the 1995-2000 MHz band so long as it is from a lawful source. Moreover, wireless operations occurring in the ranges of 512–608, 614–763, 775–793, and 805–806 MHz are subject to agreements among the USA, Mexico, and Canada. The Blackbox must accept interference from, and cause no interference within, these frequencies. Operation in the 1695–1710 MHz, 1710–1755 MHz, 1755–1780 MHz, 1915–1920 MHz, 1995–2000 MHz, 2000–2020 MHz, 2110–2155 MHz, 2155–2180 MHz, 2180–2200 MHz, 3450–3550 MHz, and 3700–3980 MHz bands is also constrained by similar political agreements with Canada and Mexico [7].

Public safety information bands operate in the 758–787 MHz bands; however, licenses can be permitted to operate in certain derivative ranges. Additionally, Wireless Communications Services communicate with radio and satellite in the 2305–2320 or 2345–2360 MHz, and 2320–2345 MHz respectively, where the last band can be licensed to operate [7].

2.4. REFERENCES

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