Modular Desktop Audio Mixer Control

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Abstract

This project proposes a mixer control device in the form of a modular desktop panel. The product enables more physical interaction between a computer user and their computer's audio. A mixer panel generally consists of a base module and fader modules. The base module interfaces with the user's computer via USB. Fader modules can then be attached to the base module or to other fader modules. A computer application will serve as an interface between the hardware product and the computer's software mixer. The resulting mixer panel should be a hardware control interface of relatively low latency with one-to-one audio controls. Audio adjustments via the hardware product should be reflected in the computer's OS within a 5% margin of error- and vice versa. Audio control adjustments in both directions should meet 0.5 second latency. Our findings should reflect a precise and reliable product for effective audio control.

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1. Introduction

Modern desktop computers have generally revolved around a set paradigm for human-computer interaction: the keyboard and the mouse. However, analog control surfaces can be beneficial in interacting with the many analog-like controls present in a computer. With our project, we want users to be able to interact with a physical analog control for software volume mixers. These software volume mixers are prevalent in modern computing systems, shipping with the OS on Windows and Linux-based operating systems.

One of the main motivations of our project is the difficulty of accessing this mixer GUI. It is usually buried behind multiple menus. Power users might have music playing in the background, a call in the foreground, and application audio on top of that, which all need to be individually adjusted so that important details are heard. Gamers, who may frequently have full-screen applications occupying their screen, lose precious time when minimizing their game and searching for the volume mixer to turn down the loud voice call that they have in the background. The time spent doing so could be the difference between winning and losing their current match.

To address this shortcoming in user interface design, we propose a modular audio control panel that sits on a user's desktop, which can be physically interacted with to smoothly and easily change volumes of individual applications. Since the controls that we want to target are analog (volume controls for individual applications), the control surfaces that the user interacts with will be linear sliders. This allows for quick but granular control of the volume levels of various applications in the computer. To achieve this, the system will consist of at least two different types of modules. One type of module is a base station that connects to the computer. This module will control other modules, process the physical inputs and output signals from the other modules, and provide power to the other modules. The other necessary type of module are the fader modules. These modules contain a slider which the user can adjust. These modules connect to the base module, communicating slider position whenever the user changes the setting of a slider. We are designing the system so that the slider modules can be daisy-chained to give the user the freedom to choose the number of sliders to include in their setup. More details can be found in the Solution Components section.

If time permits, we also want to explore and implement audio output and post-processing through the device. The inclusion of a DSP chip will process the audio output from the system, which we want to use to implement an equalizer mode, which will temporarily switch the application volume controls to equalizer band controls, allowing users to dynamically adjust the sound profile. One of the target user bases for this feature are gamers: adjusting their audio profile on the fly facilitates listening for other players' footsteps by turning up the frequency range that footsteps reside in, giving them an advantage.
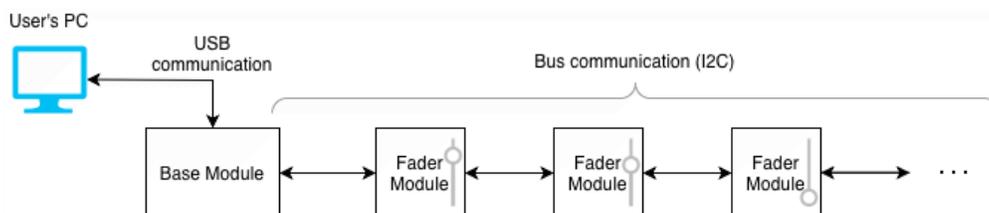

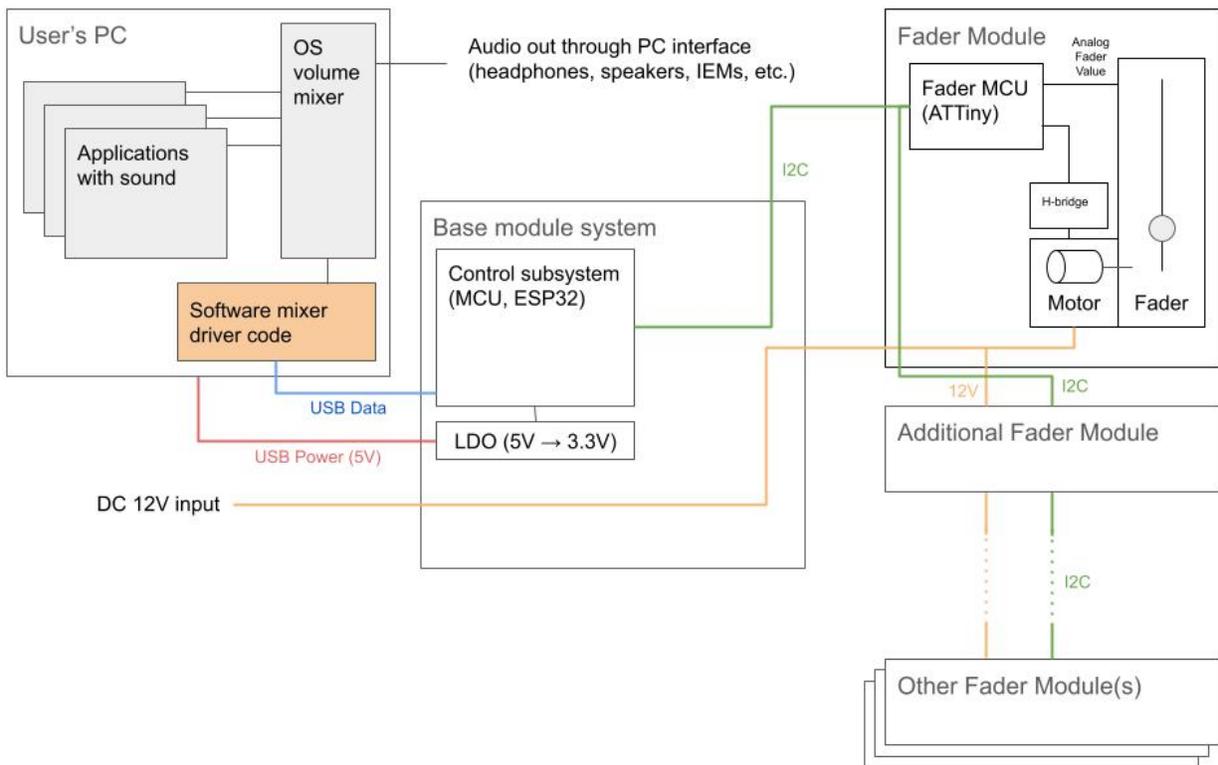Figure 1: Visual aid, physical layout of system

2. Design

Figure 2: Block Diagram of Product with Subsystems

2.1 Base Module

The Base Module forms the foundation of an Audio Mixer Control panel. The Base Module connects to the user's computer via USB and also accepts a 12V DC power input to drive the motor faders. The USB connection provides a data connection and 5V DC power for the module, which is stepped down via a regulator to the logic voltage of 3.3V, which can supply the ESP32 microcontroller.

The ESP32 microcontroller interfaces between the computer's software audio mixer configuration and connected Fader Modules. The Base Module has a series of Pogo pin connectors, through which its microcontroller transmits and receives data via I2C. A Fader Module can be connected via the Pogo pin with a magnetic closure. This enables quick but stable connections with Fader Modules for modular mixer setups. Modules can thus be chained to the base module and reconfigured with ease.

The Base Module additionally routes 12V power from an external source to attached Fader Modules over a Pogo pin in the series of pins, which will be used by the Fader Modules to drive the motorized fader. This is required because the motors could create a lot of noise if powered off of the same rail as the logic circuitry, which could cause microcontrollers to restart or display other erratic behavior. Additionally, this allows us to disregard the 500mA limit of the 5V USB connection. This 12V source must be able to handle a peak current of 3A to be able to drive multiple of the fader modules.

2.2 Fader Modules

Each Fader Module features a fader, a motorized linear slider that can be used to configure an audio setting. Fader Modules can be chained to a Base Module through Pogo connections, creating shared buses for data and power across the chain. These connections deliver 12V power necessary to operate the motor for each fader, along with I2C data lines for communication between the Base and Fader modules. As long as the modules are magnetically attached, the Pogo connections must maintain an electrical connection between each connected module; if there are small blips in the connection quality, the fader module could randomly restart, causing user confusion.

Each Fader Module has an on-board microcontroller, which uses the I2C bus for bidirectional communications. When a fader is manually adjusted, the microcontroller should forward these adjustments to update software mixer values on the computer. When the microcontroller hears that its Fader Module's assigned audio setting has been adjusted in computer software, it should update the fader's position via its motor. Thus, the microcontroller must distinguish between and respectively handle updates originating from computer software and fader movement to ensure synchronization between the computer and the Audio Mixer device. The microcontroller must be able to quickly send fader position information to the Base Module and also receive and execute fader positioning instructions to maintain low latencies that are crucial for a good user experience when adjusting analog interfaces.

2.3 OS Integration

A dedicated application running on the computer forms the OS-side of the Audio Mixer interface. Through the USB connection with the Base Module, this program will maintain synchronization between the software settings and the physical fader positions.

When a Fader is moved, the application will receive the Fader-side update and utilize Windows APIs to update the OS mixer values. Likewise, when a user updates an audio setting on the computer's UI, the application will broadcast the update to the setting's corresponding fader (if assigned).

The program should also be used to configure the settings controlled by each Fader Module through a graphical user interface (GUI). This GUI will display each Fader Module actively connected to the device and allow the user to assign an audio setting for each Fader. Addition or removal of Fader Modules from the system will be instantaneously reflected in the GUI. The fader-setting configuration should be transmitted to and maintained by the Audio Mixer hardware.

2.4 Tolerance Analysis: Motor Fader Voltage Drop Across Modules

We want to analyze the voltage drop across multiple modules to make sure that we can support multiple motors actuating at once. According to the data sheet, the motor fader RSA0N11M9 draws a max current of 800mA at 10V DC [3]. Since motors draw the most power when starting, we can convert this to an effective resistance of 12.5 Ohms. A standard Pogo pin can transmit 2A continuous, 3A burst current, while the contact resistance is 50 mΩ [4]. From this, if we assume that 3 faders are trying to start moving at the exact same time, each fader would draw 12 / 12.5 = 0.96 amps of current, or a combined 2.88A. This is under the 3A burst current that the Pogo pin can carry, and if required, the design can have multiple Pogo pins to carry the 12V line to increase the current capacity. To calculate the drop from the contact

resistance, we can do as follows: The Pogo pin between the base and the first fader module is carrying 2.88A, so the voltage drop over the Pogo pin is 0.144V. Between the first and second fader module, the current is 1.92A, therefore the voltage drop is 0.096V. Between the second and third fader, the current is 0.96A, therefore the voltage drop is 0.048V. Combined, at the third fader, the voltage drop is 0.288V, which should not be an issue. Also, if such a situation arises where many faders need to start at exactly the same time, we can program the microcontroller to stagger the start times of the potentiometers by milliseconds, which should prevent multiple motors from drawing startup current at the exact same times, at the expense of some unperceivable latency.

5. Conclusion

5.1 Ethical considerations

This product, though an interface for enhancing existing audio controls, must uphold several ethical considerations. Privacy is particularly paramount in the computer application component of the product, with ACM principle 1.6 underlining "informed consent for automatic data collection, and to review, obtain, correct inaccuracies in, and delete their personal data" [1]. When designing the OS component of this product, we must ensure that the product solely interacts with audio controls with the user's knowledge, and maintain that the design will forgo any collection or storage of any data as intended.

We must additionally take measures to mitigate potential health risks for this product in accordance with IEEE's Code of Ethics I Part 7- "to hold paramount the safety, health, and welfare of the public" [2]. Potential hazards of this product include pinch points on the faders and the magnetic module interconnects, as well as mild magnetic interference to medical devices (like pacemakers) from these magnetic interconnections. The design of the device's body should prevent any extrusions that increase pinch risk or guard against accidental access to pinch points. We must moreover post clear notice of these risks for the product's users, i.e. via warning labels. Through the design process of the product, we must take careful notice of any warnings attached to hardware components and ensure that the product informs users of these warnings.

By IEEE I Part 5, we must also be "honest and realistic in stating claims or estimates based on available data" [2]. A successful audio mixer product must uphold our success criteria, and thus the performance metric claims within these criteria. We are responsible for ensuring transparency in the latency and accuracy of audio control features through measurements collected by replicable means. Under this code, we will also remain receptive and responsive to feedback for this device and "seek, accept, and offer honest criticism of technical work" [2].

References

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[2] IEEE, "IEEE Code of Ethics | IEEE," *Ieee.org*, 2020. https://www.ieee.org/about/corporate/governance/p7-8

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[4] "1.00 Pogo Pin Connector P08824SH1," *Ccpcontactprobes.com*, 2026. https://www.ccpcontactprobes.com/en/product/794-mm-pogo-pin-694-mm-working-height-p08824sh1 (accessed Feb. 14, 2026).