

Add-on box for old stereo systems

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1 Introduction

1.1 Objective

While online music stores and streaming services have significantly changed how people listen to music, many people still own large collections of CD and vinyl records, and prefer to enjoy them with existing stereo systems rather than purchasing digital copies. Though many of these old stereo systems are working properly, they lack modern features like remote volume control and equalization, making them inconvenient compared to newer devices. For example, a user sitting in sofa has to stand up and come close to the CD player to turn the volume knob.

Our goal is to bring user-friendly features to existing stereo systems, so users can play their existing music collections with their existing audio equipments, at the same time control volume, equalization, etc. wirelessly. In order to do this, we propose an USB powered low cost add-on box together with an iOS app. The add-on box will be inserted into the signal path of existing stereo system to route and alter the analog audio signal, and the iOS app will be used to control the add-on box wirelessly via Bluetooth. The combination will add wireless volume control, equalization, left/right balance, input selection and a sleep timer to the user's existing audio equipments. The add-on box will use RCA for inputs and output, so it will be compatible with most audio equipments on the market.

1.2 Background

Compared to the existing commercial wireless audio receivers that streams audio files, our device can satisfy the needs of those people who enjoy using the CD player or turntable. For example, those CD collectors can enjoy the modern features such as wireless control and equalizer without ripping their CDs into the digital files. Also, we expect our device to be relatively cheaper compared to other existing commercial wireless audio receivers.

1.3 High-Level Requirements

- Add-on box must be able to operate on 5V USB bus power.
- Add-on box must not significantly decrease input audio quality.
- Bluetooth connection between iOS app and add-on box must be stable and fast.

2. Design

The whole system contains two parts: the iOS app and the add-on box. The app serves as the user interface to control the functionality of the add-on box wirelessly via Bluetooth LE 4.0. The add-on box routes and processes analog audio signal to apply input selection, volume control, and equalization to the audio signal. It connects to other audio devices via RCA connectors, and is powered by 5V USB bus power through a micro USB connector.

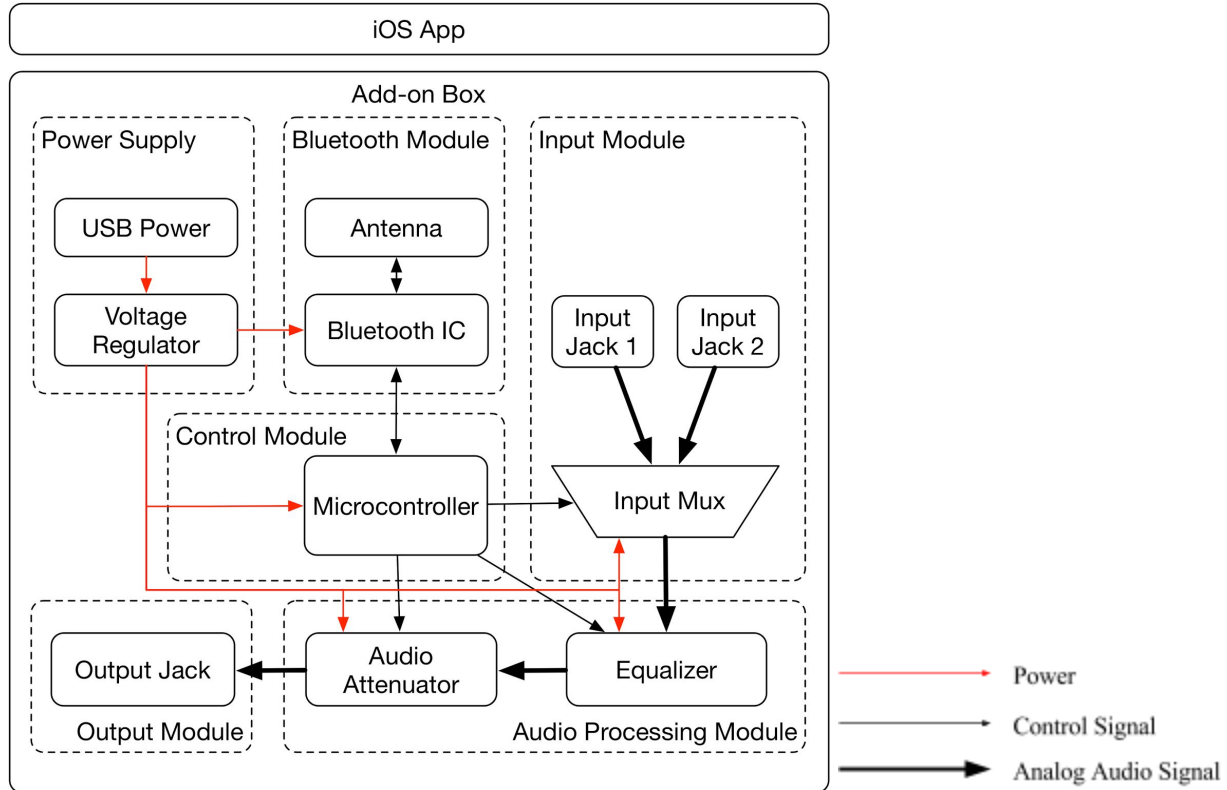


Figure 1. Block Diagram

2.1 Power Supply

USB power goes through a voltage regulator to the whole system.

2.1.1 USB Power

5V USB bus power will be drawn from a micro USB connector. Since USB phone chargers and micro USB cables are common accessories of smartphones and other electronic devices, they are very cheap and widely available. Using them as power source can reduce the cost of the project.

Requirement: The micro USB connector must provide stable $5V \pm 5\%$.

2.1.2 Voltage Regulator

Most of the chips we are implementing require around 3.3V power on voltage, so we are going to use 5V to 3.3V linear regulators. Also, we are going to make sure that the regulators don't decrease the quality of the audio signal.

Requirement 1: Voltage regulator must provide stable $3.3V \pm 5\%$.

Requirement 2: Voltage regulator must not induce audible noise within 20Hz - 20000Hz to the analog audio signal.

2.2 Bluetooth Module

This module manages communication with the iOS app.

2.2.1 Bluetooth IC

The Bluetooth IC is responsible for communicating with the iOS app via Bluetooth and send user commands to the microcontroller. It acts as a BLE peripheral device.

Requirement: The IC must support Bluetooth Low Energy 4.0 communication with an iOS device.

2.2.2 Antenna

A 2.4GHz on board antenna will be connected to the Bluetooth IC. We will optimize the layout and impedance matching for best performance.

Requirement: The antenna must provide stable connection to the iOS device within 30ft.

2.3 Control Module

This module processes commands from user and control the whole add-on box accordingly.

2.3.1 Microcontroller

The microcontroller intercepts user command received by Bluetooth IC and sends corresponding control signals to input mux, equalizer and audio attenuator.

Requirement 1: The microcontroller must be able to communicate with Bluetooth IC.

Requirement 2: The microcontroller must be able to send control signals to input mux, equalizer and audio attenuator via GPIO.

2.4 Input Module

This module receives audio signals from RCA connectors and route them to the Audio Processing Module.

2.4.1 Input Jacks

2 pairs of RCA connectors can receive stereo analog audio signals from 2 different audio sources like CD players or turntables as long as the audio source provides RCA output. The input jacks can also receive audio from 3.5mm jacks via an adaptor.

Requirement: Input jacks must be firm and hold the attached RCA cables well.

2.4.2 Input Multiplexer

This analog multiplexer selects which input signal to send to the audio processing module.

Requirement: The input mux must not generate audible clicking noise when switching inputs.

2.5 Audio Processing Module

This module applies volume control, equalization and left/right balance to the audio signal. Parameters are set by the user using the iOS app.

2.5.1 Equalizer

The equalizer alters the sound signature to user's preference by boosting/attenuating certain frequency bands of the analog audio signal. We plan to develop our own analog equalization circuit with variable parameters. The user will be able to adjust bass/treble using the iOS app and hear the result instantly.

Requirement: The equalizer must be able to be digitally controlled by the microcontroller.

2.5.2 Audio Attenuator

The audio attenuator chip adjusts the volume of the analog audio signal. It also alter the left/right balance by adjusting volumes of left and right channel independently.

Requirement 1: Audio attenuator must be able to adjust volumes of left channel and right channel independently.

Requirement 2: Audio attenuator must be able to attenuate volume to -60dB or lower with at most 1dB steps.

2.6 Output Module

This module outputs processed audio signal.

2.6.1 Output Jack

Similar to the input jacks, the output jack exports the processed audio signal to any device that accept RCA input. Devices that accept 3.5mm input can be connected via an adaptor.

Requirement: Output jack must be firm and hold the attached RCA cables well.

2.7 iOS App

The app will be the only user interface to control the functionality of the add-on box. It acts as a BLE central device and transfer commands to the add-on box.

Requirement 1: The app must be compatible with iOS 10.0 and higher.

Requirement 2: The app must be compatible with all iPhones and iPads which support Bluetooth LE 4.0.

2.8 Risk Analysis

- Since our device is expected to be wirelessly controlled through the iOS App, we need to make sure that the app is able to adjust parameters of the audio signal appropriately. The compatibility of our device with the iOS App will significantly determine the overall performance of our project.
- The design of the bluetooth antenna can be a significant risk to the performance of our device. First of all, we need to guarantee that the connection between the antenna and bluetooth is stable enough to send our commands to the device through the bluetooth.

Since the primary objective of our project is to wirelessly control the stereo system, the range of the antenna needs to be determined according to the antenna trace dimensions. Secondly, the impedance of the antenna varies with different frequencies, which will cause additional power in our device. Since we are only using the 5V USB Port as the power supply, we need to be cautious about the power loss in the antenna during the meantime.

3. Ethics and Safety

Incorrect connection of audio cables, like connecting two outputs together, may cause short circuit and potentially overheat and fire. We must inform users clearly on how to safely use the product by providing instructions of how to connect the cables correctly and warn users the danger of not doing so. Otherwise, this product should be relatively safe because we only deal with low power analog audio signal. The product doesn't process any power amplified signal.

Few potential ethics issues might affect the project. During our development, we are committed to follow the IEEE code of Ethics. We will instruct users on how to safely use the product according to the IEEE code of Ethics, #1: "to accept responsibility in making decisions consistent..." [1]. When we are programming our iOS application, we might cite and imitate some online source code. We assure that proper citation would be included in our project which is consistent with IEEE code of Ethics, #7: "..... credit properly the contributions of others" [2].

4. Reference:

- [1] Ieee.org, "IEEE IEEE Code of Ethics", 2017. [Online]. Available: <http://www.ieee.org/about/corporate/governance/p7-8.html>. [Accessed: 7-Feb-2017].
- [2] Ieee.org, "IEEE IEEE Code of Ethics", 2017. [Online]. Available: <http://www.ieee.org/about/corporate/governance/p7-8.html>. [Accessed: 7-Feb-2017].