PROJECT PLAN FOR MODULAR AUDIO MIXER

EE 491 | DEC1503

ABSTRACT

A general outline of the project's requirements and intended timeline. This project is advised by Josh Bertram, and is designed for Jay Becker.

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INTRODUCTION

Problem Statement

Our client, Jay Becker, has many different audio sources that he listens to. He only has one set of speakers by his computer. He needs a way to connect all of these audio sources with the speakers. His current setup consists of a 3.5mm audio source going into his computer, and the combined output goes out through his sound card to the speakers, a “daisy chain” configuration. This is not ideal because it requires that the computer to be on in order to use the audio from the 3.5mm source. Moreover, he would like to have more than two inputs available. He would also like more interface options, such as Bluetooth, HDMI, and USB, rather than just 3.5mm analog. Most of the audio mixers that exist on the commercial market are inadequate because they are geared toward professional audio recording, and not causal music listening. This gives us an opportunity to make a relatively simple, but unique product.

Objective

Our goal is to create an audio mixer that will solve our client’s problem. It will consist of an enclosure that takes multiple inputs and will combine them into one output. The inputs will consist of several different interfaces including analog 3.5mm, USB, and Bluetooth. Each input will have a knob to adjust the volume with a central LCD display. Our design will implement a mixture of analog circuitry and embedded controls aimed for simple controls with high quality audio. The design will be cost-efficient and reliable with room for future improvements or reproduction.

DELIVERABLES

Our primary project deliverable is a functioning audio mixer. For May 2015 we expect to have a box that meets most requirements, including clean audio mixing and volume control. By December 2015 we hope to have a functioning prototype that meets all requirements, including Bluetooth accessible and easy assembly for creating additional mixers. In addition to the prototype, we will also deliver all design schematic/files, and a simple user guide of which includes how to test the system.

SPECIFICATIONS

Functional Requirements

1. The audio mixer will provide near lossless audio quality.
2. The mixer will include a microcontroller that will provide input volume control among various other functions.
3. The enclosure will be durable enough to allow for easy storage and movement.
4. Our circuit design will be designed and fabricated onto a Printed Circuit Board.
5. The mixer will be capable of being plugged into a standard wall socket.
6. The device will be simple enough for a user of any expertise to use.
7. The enclosure will include two 3.5 mm audio jacks, HDMI, and USB input ports.

8. LCD or other Display for volume information.

Non-Functional Requirements

1. Minimize cost.
2. Design with manufacturability in mind.
3. Make the input interfaces as modular as possible.

PROPOSED SOLUTION CONCEPT

Circuit Design

Our design consists of an analog circuit to trim and mix the audio signals together. The circuit will be controlled by an embedded system, such as a Raspberry Pi. We are using digital potentiometers in order to implement the volume controls. We have them configured as voltage dividers, so that they attenuate the audio signals. The resistance of the digital potentiometers will be controlled by the microcontroller via a serial interface. The microcontroller will use shaft encoders to interface with the user to determine the volume level. When the user turns the knob to the right, the microcontroller will increase the volume. Conversely, the microcontroller will decrease the volume when the user turns the knob to the left. The main advantage of using a digital system over mechanical potentiometers is that we can control the volume via remote, such as a computer or smartphone app. Also, since the microcontroller keeps track of the volume, it can output a quantification of the volume level to an LCD.

We realize that our client may want to use the mixer to drive several different kinds of loads. As such, we have included a voltage buffer for the output so that the mixer is capable of driving low impedance loads, such as headphones. Our buffer stage design consists of an operation amplifier with the output shorted to the non-inverting input. We used a circuit simulation software called LTspice in order to simulate the circuit. This was critical in the design of the power supply because we had to make several design tweaks in order for the power supply to be robust enough for our needs.

We used Cadsoft Eagle to create a PCB design for our project. The printed circuit board measures about 6.5 inches wide by 4 inches long. We generated the Gerber files for our project, in order to have the PCB fabricated. The manufacturer that we chose was Advanced Circuits. They have a special deal for students so that we can have our board fabricated for just 33 dollars plus shipping. We have ordered our components from Digi-key and other vendors. As we receive them, we will assemble the PCB and create the prototype of our project.

Enclosure Design

The enclosure for our audio mixer will need to have many openings to place the various dials, levels, displays, and cables. It will be shaped similar to a simple box with a slanted top, for optimized viewing angle, and be light-weight. The enclosure may be made out of metal, plastic, wood, or a 3D printable material. On the left side of the enclosure, there will be three 3.5 mm input audio jack ports. The top of the enclosure houses the main user interface of the mixer; dials to manually adjust volume and master volume, and a LCD display to give the user information on the current settings for each channel. The right side of the enclosure contains a single 3.5 mm output audio jack, with room for additional outputs after the first prototype. A small, third-inch port in the back allows entry for a power cable. The enclosure is designed in Auto-Desk Inventor, and will be fabricated by a third party. However for the first prototype a simple junction box will be used. The main focus for the enclosure design is functionality, both a simple user interface and a rugged enough casing to protect the circuit components.

Raspberry Pi Programming

Our design includes a microcontroller to handle the translation from the user interface to the volume control circuits. Rotary Encoders (Volume Knob) are read from the microcontroller through interrupts, and translated into volume up, down, or mute commands. The controller then communicates with the respective Digital Potentiometer via serial and adjust the volume accordingly. Additionally the Controller interacts with the LCD display to show the user current volume settings.

Our first prototype involves using the Raspberry pi as our Microcontroller. This choice is unique in that the Raspberry Pi differs from the traditional microcontroller. At the cost of reduced Interrupt times and power efficiency, you gain a full working Linux Computer on a small chip. This allows for easier programming and upgrading of the chip. Although not currently in use, for the December Prototype we will take advantage of the USB and Audio Jacks on the Raspberry Pi. This will allow for simple, straight forward USB and Bluetooth integration.

STRENGTHS AND WEAKNESSES

Strengths

1. Our niche request for a low cost audio mixer allows for a straightforward project, we were able to focus on meeting and maximizing our functional requirements.
2. Extremely simple user interface consisting primarily of only Volume Knobs, additional usage of Bluetooth is entirely optional to the User.
3. Our current design leaves room for expansion. More unique input interfaces can be designed using the existing schematics. Additional expansion using the Raspberry PI for simple Bluetooth/USB which our team will be doing for December. Optionally after feature-Completion of the design a dedicated controller or FPGA/ASIC could be designed to replace the Raspberry Pi, greatly increasing the ability to manufacture.

Weaknesses

1. Our client requirements put a large amount of design choices and flexibility to our team. Although helpful we are required to narrow down and choose design related decisions over a large area, distracting from the main functional requirement.
2. Our design is for one customer for one use, although we try to make our code and hardware as reusable as possible, we lose robustness from our narrow client needs.

DESIGN ALTERNATIVES

Our design choice contains a mixture of analog and digital components. Alternative designs include an all-analog design and an all-digital design. An all-analog design would employ mechanical potentiometers, as opposed to the digital potentiometers. This would not allow the volume to be adjusted by remote. Moreover, there would be no digital display, such as an LCD or a 7 segment display. In the current design, we plan on using these displays to display volume levels and other information. In an all-analog design, we would have to employ physical markings near the knobs to display the volume levels.

Conversely, we could have also decided to use an all-digital design. This would consist of the audio inputs going into analog to digital converters in the microcontroller. The microcontroller would sample the audio signals at a high rate, and then use software in order to incorporate the mixing. The main advantage of using this setup is that you can add many digital signal processing effects to the audio, such as EQ settings. The drawback of this design is that it adds a great deal of complexity to the project, requiring hundreds of additional man hours and a lower audio quality. The main advantages that this design would provide are deemed not necessary for our client. He does not need the mixer to include advanced audio effects. He just needs something that can mix the raw audio signals and output a single to the speakers.

USER INTERFACE

Physical Interface

Our May prototype consist of a minimalist and user friendly interface. A central LCD displays current volume settings for the three input channels and the Master (Output) Channel. Each channel has a volume knob which can be clicked for mute. There is a small power switch on the right, with a small LED indicating above it to alert the user that the power supply is on and working.

Website or Mobile App

The client suggested that the mixer potentially have the ability to connect to the internet, and be controlled through a website interface. The site's layout would be identical in respect to location on the physical interface. After more research, the program MAX MSP could potentially help our client by employing a Graphic User Interface through MIDI channel technology. This program allows real time interaction of audio controls. If the client prefers to use his smartphone, or is away from his computer, we will develop an android/iOS application. These applications would allow him to adjust simple aspects of the mixer, such as the volume or the channel selection. Such updates and additions will be considered or implemented after the first prototype.

VALIDATION TESTING

Our primary test to ensure that the prototype audio mixer is valid will be the frequency response. Using software and equipment provided by Iowa State we can set up an efficient logarithmic sweep of the audible frequencies. We will need to use other audio equipment in order to set up an acceptable standard for signal loss, but generally we want a linear, minimal delayed response, with constant amplitude at all frequencies in the audible range.

RISK AND FEASIBILITY ASSESSMENT

The basic prototype is very feasible, our most difficult constraints will be keeping cost down and the schematic simple in order to promote manufacturability. The biggest risk area comes from our circuit's noise. Unforeseen interference could come from the power supply or Raspberry Pi into our audio circuit, or perhaps the components we select will have non-linear behavior that our buffer amplifiers cannot handle. Hopefully by carefully selecting components and making sure to isolate our input and output loads we can minimize noise, in addition to selecting parts specifically designed for audio. If we wish to eventually convert the circuit to all PCB and microcontroller (no Raspberry Pi) we will face more design issues, pursuing this will only come into effect after a successful initial design in May.

BREAKDOWN STRUCTURE

Project Schedule

We have created a schedule so that we stay on track in the development process. Below are the schedules and Gantt Charts for the spring and fall Semesters.

Spring 2015 Tentative Schedule			
Tasks	**Start Date**	**Duration (days)**	**End Date**
Group Formation	12-Jan	7	19-Jan
Website Development	19-Jan	28	16-Feb
Creating Project Specifications	26-Jan	21	16-Feb
Analog Circuit Design/Simulation	16-Feb	28	16-Mar
Coding Software	23-Feb	21	16-Mar
Ordering Parts	9-Mar	7	16-Mar
Designing and Fabricating Enclosure	9-Mar	21	30-Mar
Designing and Ordering PCB	16-Mar	14	30-Mar
Building Protype	30-Mar	7	6-Apr
Testing/Debugging/Evaluating	6-Apr	21	27-Apr
Presenting Results	27-Apr	7	4-May

Figure 1: Spring Schedule

Fall 2015 Tentative Schedule			
Tasks	**Start Date**	**Duration (days)**	**End Date**
Re-grouping from Vacation	24-Aug	7	31-Aug
Discussing Possible New Features	31-Aug	14	14-Sep
Revising Design	14-Sep	28	12-Oct
Building 2nd Prototype	12-Oct	14	26-Oct
Testing/Debugging/Evaluating	26-Oct	28	23-Nov
Preparing Final Product	23-Nov	14	7-Dec
Presenting Final Product	7-Dec	7	14-Dec
Delivering Final Product	14-Dec	7	21-Dec

Figure 2: Fall Schedule

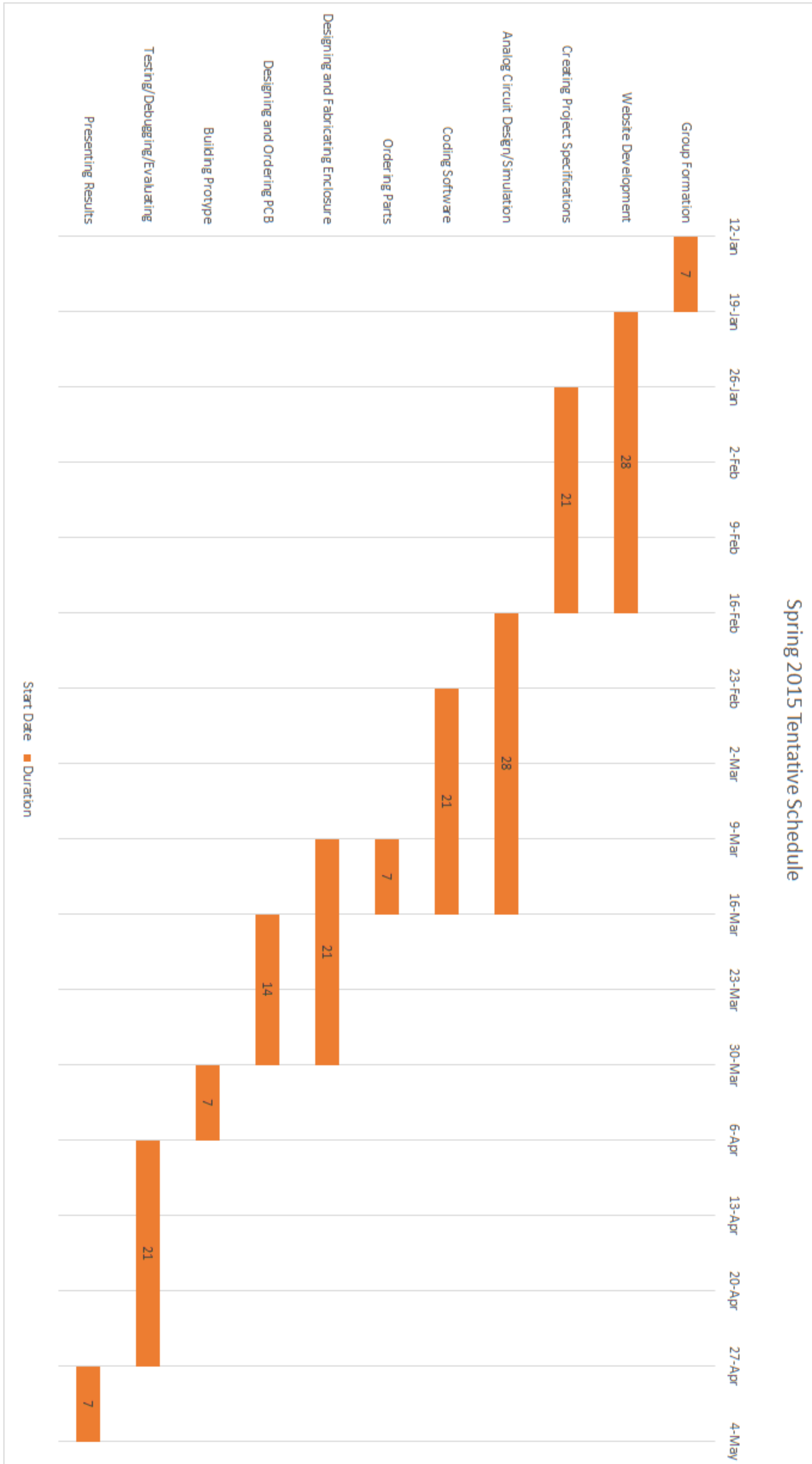

Figure 3: Spring Chart

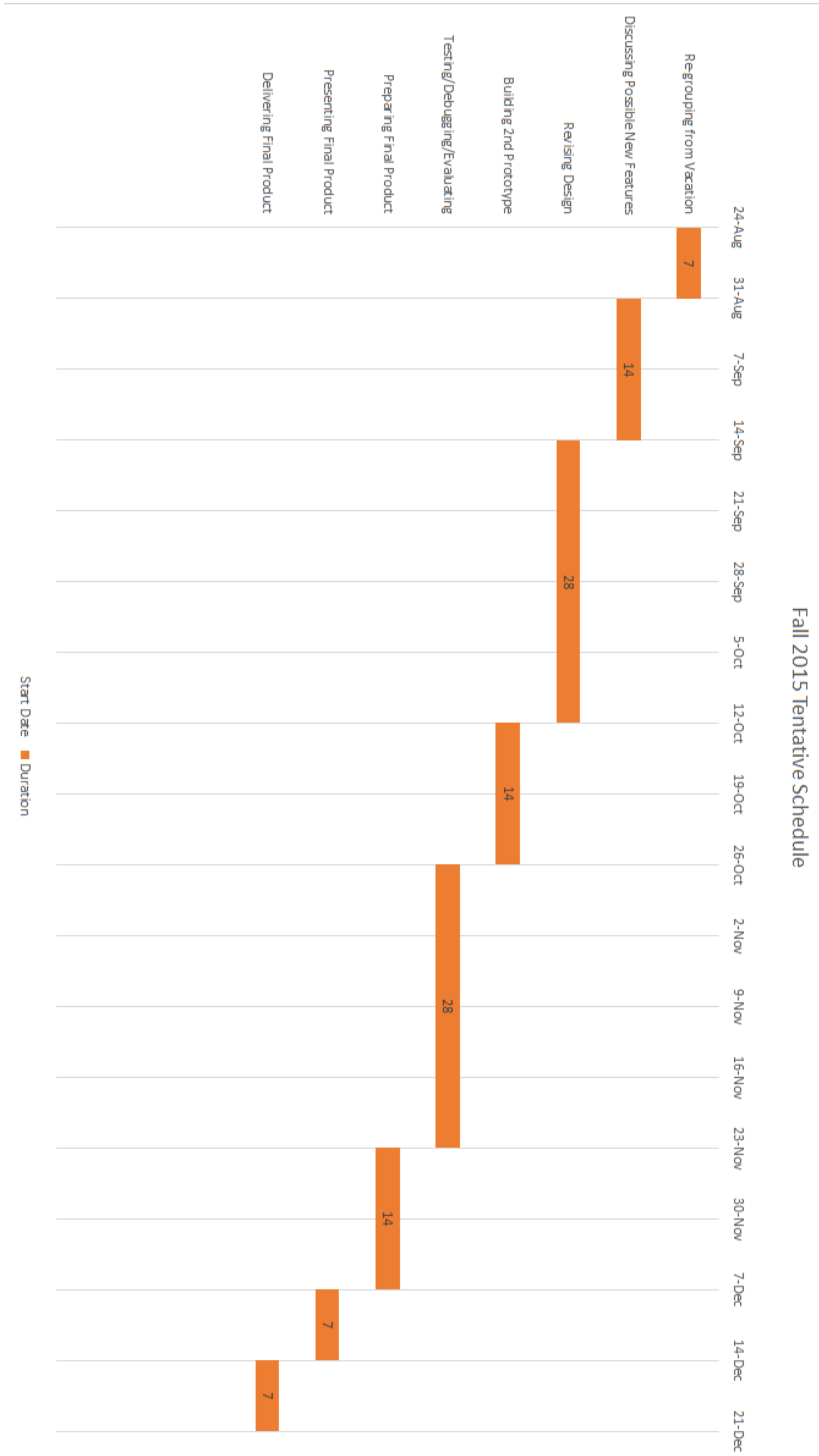

Figure 4: Fall Chart

COST CONSIDERATIONS

The basic cost break down of our project is as follows (Complete breakdown is found in the Design Documents under the BoM).

1. 50$ - Circuit components (Resistors, Power Supply etc.)
2. 40$ - Raspberry Pi
3. 40$ - PCB Fabrication
4. 40$ - User Interface Components (Knobs, Jacks, LCD)
5. 25$ - Prototype 1.0 Enclosure Fabrication
6. ?? - Prototype 2.0 Enclosure Fabrication (*Quotes under consideration*)
7. **195$ - Total Cost**

MARKET SURVEY

There have been generations of audio mixers manufactured over the years, such as Yamaha, but the same theme arises: expensive, large, and complex. This may seem attractive to professional sound studios looking to produce state-of-the-art audio tracks, but our client asked for something more customizable. Audio mixers at market now commonly use USB connections, and are much more expensive than a few hundred dollars. Our design aims to cover multiple input options: audio jack, USB, HDMI, or Bluetooth, while reducing cost as well. We want to deliver a modular audio mixer that can adapt, and be user- friendly. Using the Raspberry Pi, we will be able to meet many customizable needs. The audio mixing market could potentially benefit from an analog/digital combination, low-cost modular mixer. The market research survey will be an ongoing process throughout our product's development.

CONCLUSION

The design of a simple, low-cost audio mixer would help the audio market that traditionally only had high cost mixers for production and performance. Our project fits for a casual consumer or business interested in mixing a limited number of audio signals into a limited number of outputs. We will provide a box with simple, intuitive user interface that effectively mixes required signals for 3.5mm audio, USB, HDMI and eventually Bluetooth. Our interface will contain volume control dials with a digital display of current volume levels. Our end goal includes a compact mixer that has minimal (undetectable from the human ear) noise or signal loss. We also hope to keep the cost below 200$, however this is dependent on which features are chosen, as well as PCB and enclosure fabrication cost. With a mostly functioning prototype delivered in May 2015, we hope to improve upon that to meet all and exceed some requirements for the December 2015 prototype. With a simple, low cost and Bluetooth capable design, we could provide benefits to a lacking area of consumer audio mixers.