PROJECT PLAN FOR MODULAR AUDIO MIXER

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ABSTRACT

A detailed analysis of our project's requirements and intended timeline.

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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. The problems facing this situation are unique, and as such, they will require a unique solution.

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 outputs and will combine them into one output. The inputs will consist of several different interfaces to maximize the usefulness of the mixer. Each input will have a slider to adjust the volume. Our design will implement a mixture of analog circuitry and embedded controls in order to mix the input audio. The design will be cost-efficient, reliable, and also have a high degree of manufacturability.

DELIVERABLES

Our primary project deliverable is a functioning audio mixer prototype. For May 2015 we expect to have a box that meets most requirements, including clean audio mixing of up to four inputs. 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 strong enough to withstand damaging external forces.
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.

Non-Functional Requirements

1. The enclosure will include two 3.5 mm audio jacks, HDMI, and USB input ports.
2. Each input to the device will include a 7 segment display for volume and a dial for volume control. These will be connected to the Raspberry Pi.

PROPOSED SOLUTION CONCEPT

Circuit Design

Our design will consist 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 will use digital potentiometers in order to implement the volume controls. We will configure them 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 7 segment displays or an LCD.

We realize that our client may want to use the mixer to drive several different kinds of loads. As such, we will include a voltage buffer for the output so that the mixer is capable of driving low impedance loads, such as headphones. The buffer stage will dictate the active circuitry in the design. The simplest buffer stage design consists of an operation amplifier with the output shorted to the noninverting input. It may be possible to decrease cost or increase audio fidelity by using an alternative design. We will address this possibility later in the design phase of the project.

We will use OrCad PSPICE, a circuit simulation program, in order to test the functionality of our circuit. We will also use it to evaluate the fidelity of the system, by calculating figures of merit such as frequency response and Total Harmonic Distortion. Once we are satisfied with the circuit design, we can create a PCB design in Cadsoft Eagle. We will pick a manufacturer to fabricate our board, and then we will solder the components to the board for use in our prototype.

A preliminary design of our mixer is shown below. We have built this circuit on solderless breadboards in order to test it, and it functions correctly. A schematic of the basic circuit with two audio inputs is shown below.

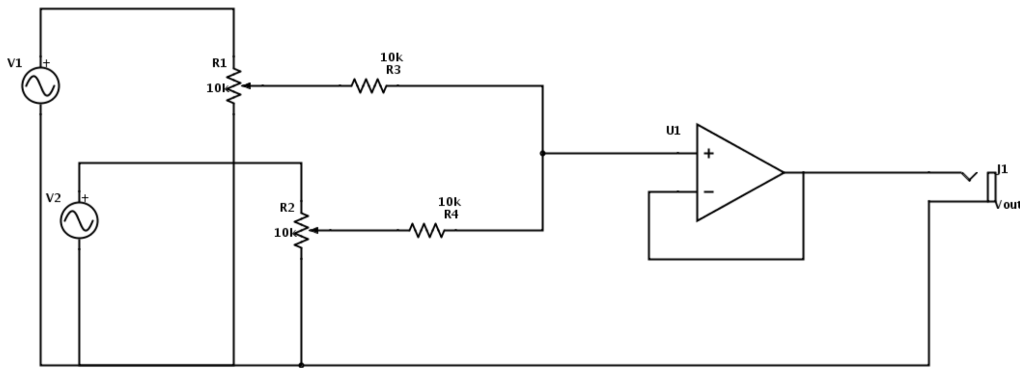

Figure 1: Preliminary Schematic

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 weigh no more than 20 lbs. The enclosure may be made out of metal, plastic, wood, or a 3D printable material. There must be a grounding strip or plate throughout the enclosure in order to route circuits safely. On the left side of the enclosure, there will be at least three 3.5 mm cable ports, but potentially as many as six cable ports. The top of the enclosure will display the main control center of the mixer; dials to manually adjust volume and master volume, hard switches to turn specific channels on or off, 7-segment displays to depict discrete levels of loudness to the user, and perhaps an LCD screen to guide the user through the Raspberry Pi functionality. The right side of the enclosure could have between one and three 3.5mm cable ports. The back of the enclosure may develop ports for the HDMI, USB, and Bluetooth adapters. We intend to design the enclosure using a 3D developer, such as AutoCAD Inventor. After designing the enclosure, we will search for a manufacturer or a 3D printer to fabricate the physical enclosure. The enclosure design will develop as our testing and market research continues.

Raspberry Pi Programming

The audio mixer will include a microcontroller such as a Raspberry Pi to perform various functions. The mixer will make use of digital potentiometers and dials connected through an i2c or SPI bus peripheral to control the volume for the individual audio inputs. The microcontroller will also be responsible for providing a display for the volume of each connected input device. This will allow for easier user interaction with the mixer. The use of a microcontroller also allows for expanded functionality in our design. Implementation of additional inputs will require only adding additional code for the input, volume control, and display. This will give us the freedom to expand our mixer throughout our design process and lead to unlimited potential. An example expansion to our device would be Bluetooth integration. With this feature, an app on a mobile device would allow the user to control our product from a distance. This demonstrates the expandability of our product.

STRENGTHS AND WEAKNESSES

Strengths

- The design of our product puts more focus on usability and functionality. Most items on the market have a certain amount of functions and cannot be expanded. Some devices will not allow expansion in the future either. Expandability is something we feel will satisfy our client and make our product more desirable.
- Our project also aims to allow easy interfacing for the user. If the user is not comfortable with using potential Bluetooth technology to interface with our device, they can still control the mixer manually. With the use of volume displays and easy to use dials, any user should be able to manage their input devices with little effort.
- Our design will aim to create a mixer that has full functionality with room for expansion, but will also be cheap for consumers. We believe that with the features we are looking to implement, we can give a user many options for audio mixing while keeping it within budget. With our design, there is also potential for creating a custom FPGA that could be produced cheaper than the Raspberry Pi bringing down costs even further.

Weaknesses

- Since there is a lot of flexibility in our project, it can be difficult to narrow down what we want to include and do the necessary research in advance. This allows for more creativity but we must make sure to include all of the necessary features in our design.
- Our design doesn't include optimization for each component in the design since we are delivering a product for our single client only. While this may not be desirable on the market of audio devices, it will satisfy the needs of our client and then some.

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. 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

The initial concept is to organize a flow of mastering multiple channels to a single output. In order to make this natural for the user, we will have vertical sections responsible for each input channel from the lower left region to the center region. Closer to the right side of the enclosure, the output channel(s) will be placed below the screen display for various Raspberry Pi information, and. A master channel, on the far right, will govern the entire system. Potentially, LED lights will depict volume levels or active channels.

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.

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 2: 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 3: Fall Schedule

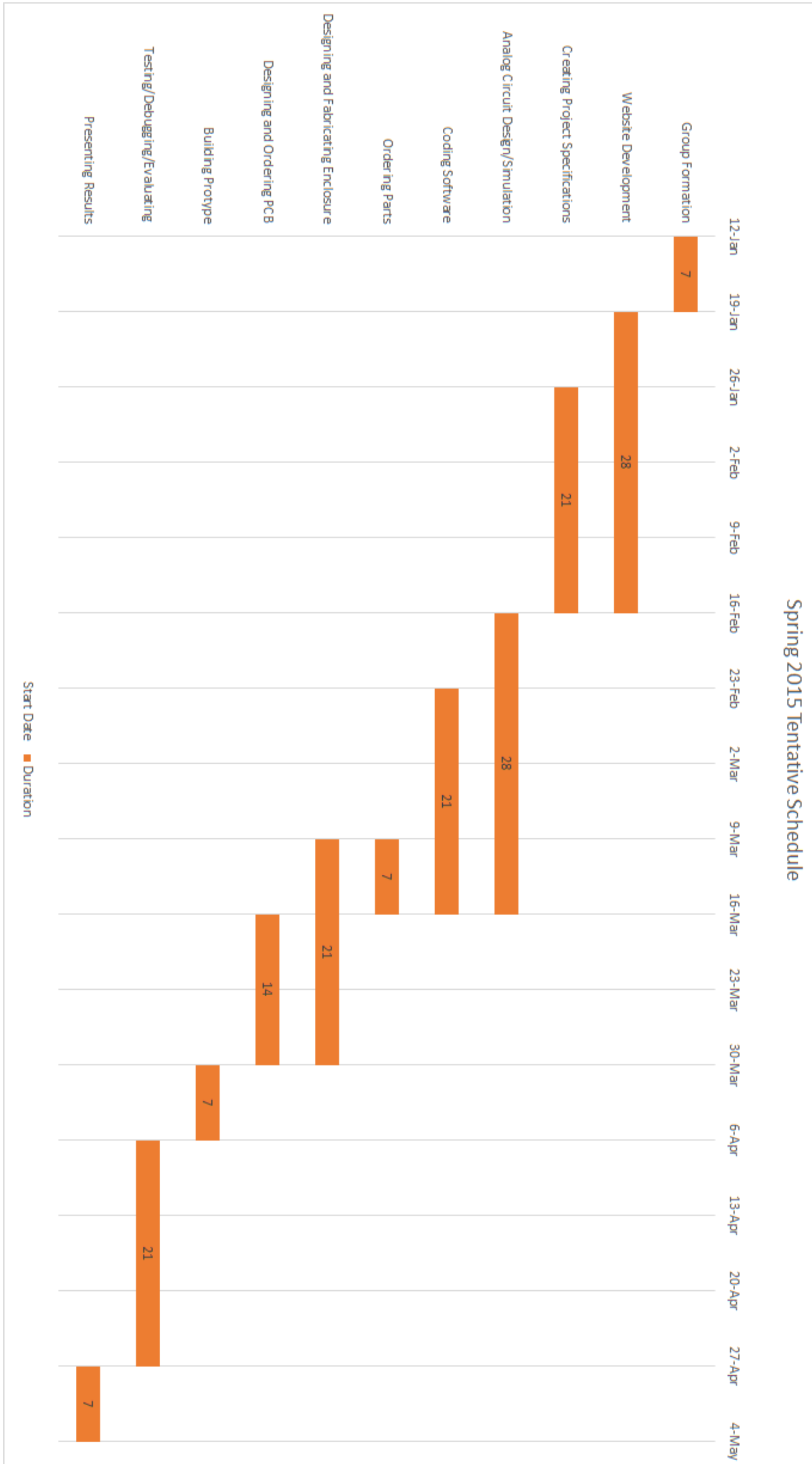

Figure 4: Spring Chart

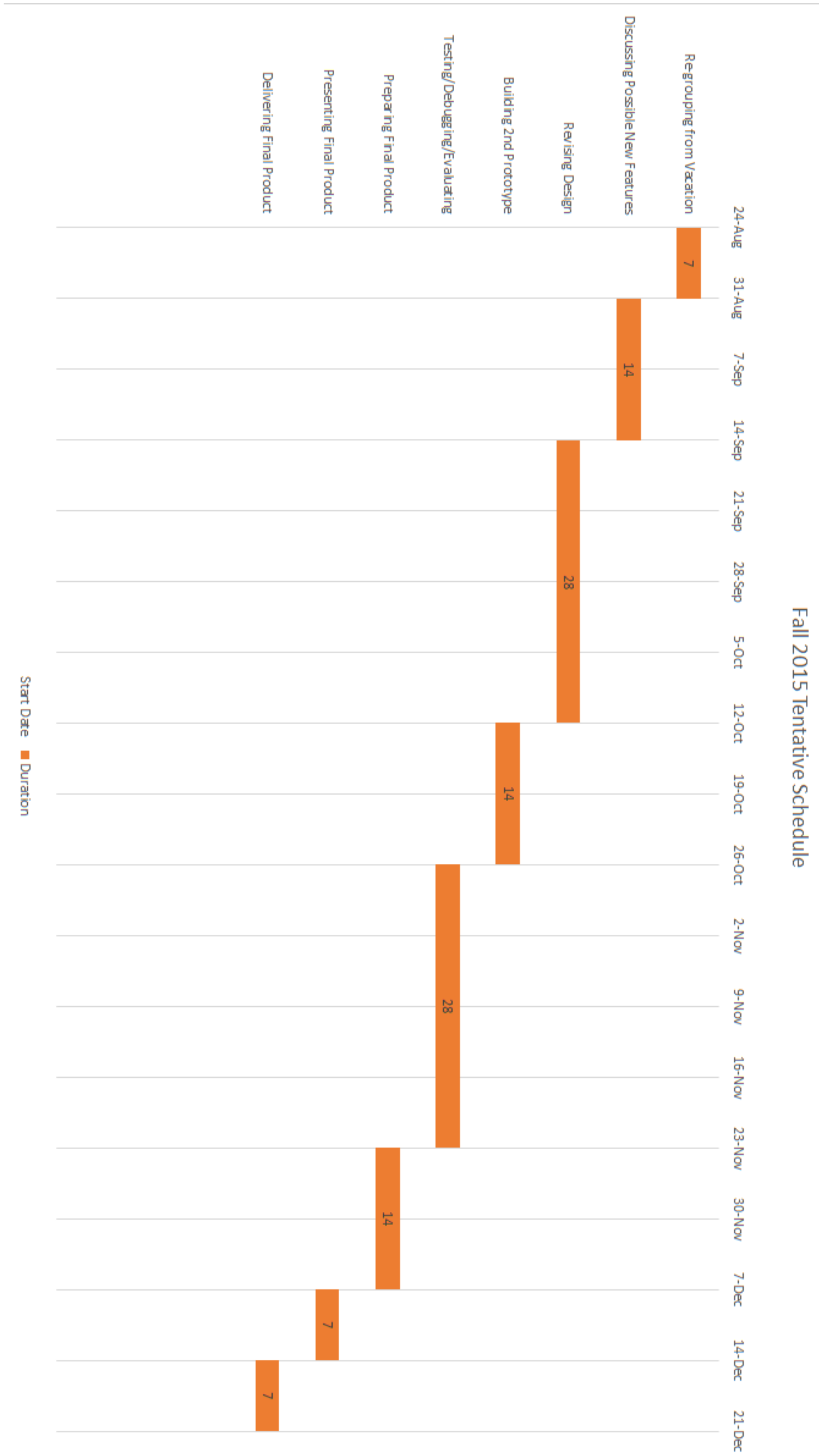

Figure 5: Fall Chart

COST CONSIDERATIONS

Component	Estimated Cost
Raspberry Pi	$30-$40
4 x 3.5 mm Female Jacks	$10
2 x Analog Audio to HDMI	$2-$20
2 x Analog Audio to USB	$2-$20
10 x Digital Potentiometer	$20
5 x Digital Display	$10-$50
5 x Rotary Encoder (Dial)	$10
4 x Switch	$5
Various Passive Circuit Components	$5
Enclosure Fabrication	$0-$50
PCB Fabrication	$10-$50
Raspberry Pi Power Supply	$10
Filtering Amplifiers/Transistors	$1-$20
Total = $125-$200	

Figure 6: Cost Table

MARKET SURVEY

There have been generations of audio mixers manufactured over the years, such as Behringer, Yamaha, or Mackie, 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 and efficient 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 on/off switches, as well as 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 where source PCB and enclosure fabrication. 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.