VERSATILE USB POWERED TURNTABLE

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Abstract

People enjoy vinyl music’s warm sound, user participation, and nostalgic feel, but the large physical size and seemingly immobile system requirements prevent vinyl turntables branching into digital music dominated realms. USB ports power many important everyday devices. A USB powered turntable increases record player adaptability, versatility, and portability thus expanding usable turntable scenarios. The manual turntable plays seven to twelve-inch vinyl at 33 1/3 or 45 rpm. It includes a stylus, magnetic phono cartridge, tonearm, 45-rpm adapter, motor, audio output, and several setting switches and knob for easy use.

Chapter 1:

Introduction

Recent years witnessed an analog music popularity rise, most particularly seen in a renaissance of vinyl record sales. Turntable sales also increased steadily over the past decade, with expected annual growth of 2% continuing through the year 2020. Amazon sold more turntables than any other single home audio product in 2015[1, 2]. The new vinyl and turntable era nostalgic wave caught hold and now many popular and recent music artists release vinyl record albums alongside digital music formats.

The rising trend and sales brought demand for newer innovative turntables. This includes one-device-plays-all sets playing cassette, radio, CD, digital, and vinyl; top of the line turntables providing the best quality sound; and portable devices usable off the grid complete with batteries and speakers. Typically a stationary music player, current turntable suppliers target realistic customer desires for superior quality sound while only beginning to address the portability and versatility customer needs. The vinyl size, play requirements, and power usage limit portability and versatility tremendously. Regardless, vinyl’s warm sound, hands-on play, and enjoyable music experience keep the format alive and prosperous [3].

Various turntable modifications improving sound, usability, functionality, and versatility still do not include a USB powered turntable. The limited standard USB power administers a tight turntable constraint and causes no market-available containing USB powered turntables. This project combines fundamental turntable functionality while producing a new and unique vinyl player; a turntable playable from electrical wall outlets, computer ports, and even portable USB battery chargers. The 1877 invented phonograph made electric during the 1940s, now plays analog music with more portability and versatility than ever before [4].

Chapter 2:

Customer Needs Assessment

Potential customers include analog music aficionados, record collectors and hobbyists, and vinyl music enthusiasts. Turntables play music in limited situations. These players do not have the adaptability and mobility most digital music players have today. Many music lovers, audiophiles, and regular individuals still enjoy and frequently prefer vinyl records over other digital formats [5]. Vinyl listeners currently enjoy records in a single, immobile location. The many situations with digital music exclusivity illustrate the vinyl music format versatility need and expansion potential. My several years' vinyl exposure including listening, collecting, and researching demonstrated the turntable mobility and versatility lack.

Requirements and Specifications

Two main sources derive the requirements and specifications list. The first concerns the underlying versatility and portability goals. Here, power source versatility and easily relocating the turntable to various environments identify the primary customer needs. The player must use USB power in all situations; albeit derived from several power sources: AC electrical outlets, computer USB ports, or portable USB chargers. Users can also quickly and easily move the turntable for listening in other environments without needing a pre-amplifier and large stereo system. Using headphones or a 3.5mm female audio jack compatible speaker, the user can listen to vinyl records anywhere they supply USB power. No longer tied to a single location, the flexibility enables listeners to enjoy vinyl in situations unavailable before such as outdoors and easily move the turntable to various locations ad libitum. The ability to play vinyl with or without an electrical outlet accomplishes the portability goal. The most common vinyl record formats include 12"/33 1/3 rpm Long Play (LP) albums and 7"/45 rpm Short Run (SR) albums. These two formats allow the play of all new vinyl records and most older records.

The second specification source addresses basic turntable requirements. Quality audio requires consistent and precise turntable rotation. Total harmonic distortion (THD) typically measures amplified sound quality. A very low THD maintains the original audio signal integrity [6, 7]. A desirable product implementation utilizes simple and inexpensive components. Using standard components streamlines system integration and lowers total cost.

Following USB 2.0 standards restricts the device to 5V, 500mA, and 2.5W power usage (see Table I). This major restriction limits potential functionality since the necessary functions of turntable rotation, audio amplification, and control all require considerable power. This challenge directly limits nearly all feature and design decisions. It determines the additional features and each component's criteria and specifications as this limitation forms the project foundation and cannot change. An initial system requirement included internal speakers, but the limited supply power eliminated this potential.

TABLE I

VERSATILE USB POWERED TURNTABLE REQUIREMENTS AND SPECIFICATIONS

Marketing Requirements	Engineering Specifications	Justification
1, 3, 4	USB powered per USB 2.0 specifications.	USB powers most everyday electronic devices. USB 2.0 compliance powers the player in nearly any environment.
2, 3	Contains total harmonic distortion (THD) <1% from the cartridge output to the audio turntable output over the audible frequency range 20Hz-20kHz.	Numerous amplifier options meet this THD criteria given today's audio amplifier capabilities [6, 7].
2	Vinyl rpm rotation errors ≤5% from rpm setting.	Sound quality requires accurate and consistent rotation. The myriad controllers and options available make this feasible.
3	Plays 7"-12" (SR and LP) vinyl at 33 1/3 and 45 turntable rpm.	This size and speed range plays most vinyl records available.
6	Adjustable output gain, audible with low impedance headphones.	The stylus supplies limited current and requires a buffer stage. Adjustable gain is needed for adequate customers.
5	Systems integrated and developed with existing components.	All required components have various options and alternatives available off the shelf. Using these simplifies integration and lowers cost.
4, 6	Includes tactile setting switches and knobs.	Easy use switches increase usability in myriad situations.
1, 3	Device size within 13"x13"x4"	Limited device size enables a mobile turntable easy to relocate to multiple environments.
5	Cost <$150	Low cost entices customers. Using currently available components improves cost.
1, 3, 4, 5	Output utilizes 3.5mm female audio jack.	This widely used standard output meets versatility needs.
4, 5	Stylus replacement requires no tools.	The main maintenance includes stylus replacement. No required tools allow easy use and replacement.

Marketing Requirements
1. Portable.
2. Quality sound output.
3. Versatile.
4. Easy use.
5. Low cost.
6. Amplification control.

Table 1 discusses requirements and specifications the project meets including marketing goals and how the project meets those requirements. Specifications focus on the portability, versatility, and functionality. Portability and versatility set the project apart from current market models and functionality meets basic turntable needs.

Chapter 3: Functional Decomposition

TABLE II
VERSATILE USB POWERED TURNTABLE DELIVERABLES

Delivery Date	Deliverable Description
4/28/17	Design Review
5/26/17	EE 461 demo
6/16/17	EE 461 report
4/20/18	EE 462 Individual Systems Check
5/18/18	EE 462 demo
5/25/18	ABET Sr. Project Analysis
6/1/18	Sr. Project Expo Poster
6/8/18	EE 462 Report

Table II lists deliverables and deadlines concerning project materials and milestone due dates during EE 461 and EE 462. The focus concerns demos, reports, systems checks, and deliverables.

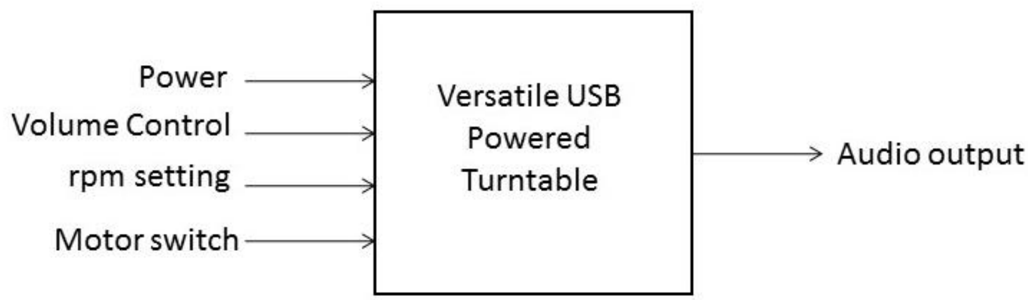

Figure 1: Level 0 Versatile USB Powered Turntable functionality block diagram.

Figure 1 displays the project level 0 block diagram listing system level inputs and outputs. Power and user settings determine the audio output.

TABLE III
VERSATILE USB POWERED TURNTABLE FUNCTIONALITY REQUIREMENTS

Module	Versatile USB Powered Turntable
Inputs	• Power: USB 2.0 compliant, 5 V DC. • Volume Control: variable analog input. • rpm setting: 1-bit digital input. • Motor switch: 1-bit digital input turning motor on or off.
Outputs	• Audio output: analog audio signal output, max $1V_{PP}$, 30 mA.
Functionality	Amplify audio input signal based on volume control settings and output the amplified signal to produce a 1W output signal [6, 8]. Control the turntable rpm based on user settings and input sensor data monitoring the motor rpm.

Table III breaks down the project level 0 block diagram describing inputs, outputs, and functions. The user set inputs, determines the tonearm cartridge audio signal amplification. The motor setting controls and regulates the turntable rotation.

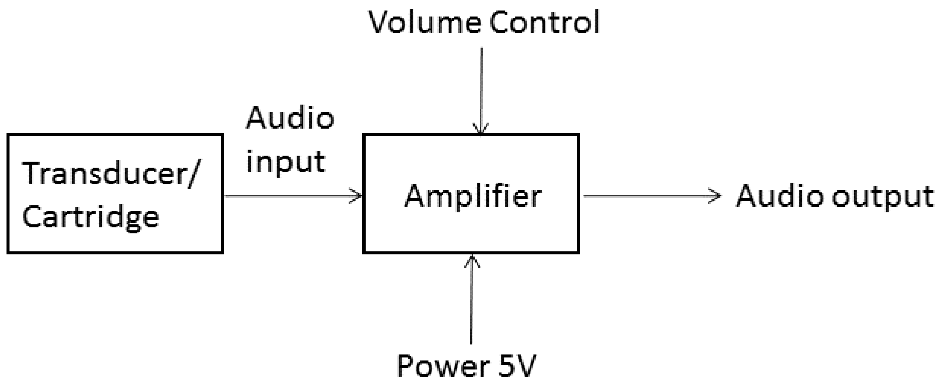

Figure 2: Level 1 Amplifier block diagram.

Figure 2 displays the amplifier level 1 block diagram listing inputs, outputs, and subsystem related components. The transducer/cartridge inputs the audio signal. User input controls amplification magnitude.

TABLE IV
AUDIO AMPLIFIER FUNCTIONALITY REQUIREMENTS

Module	Audio Amplifier
Inputs	• Power: USB 2.0 compliant 5 V DC. • Volume Control: variable analog input. • Audio input: analog audio signal input—1.3 V_{PP} [9] from magnetic cartridge/transducer with no current drive.
Outputs	• Audio output: analog audio signal output, max 1V_{PP}, max 30 mA.
Functionality	Amplify audio input signal based on volume control settings and output the amplified signal to produce a 30 mW output signal [6, 8].

Table IV breaks down the amplifier level 1 block diagram describing inputs, outputs, and functions. This amplification subsystem magnifies the tonearm signal current and modifies voltage using user settings.

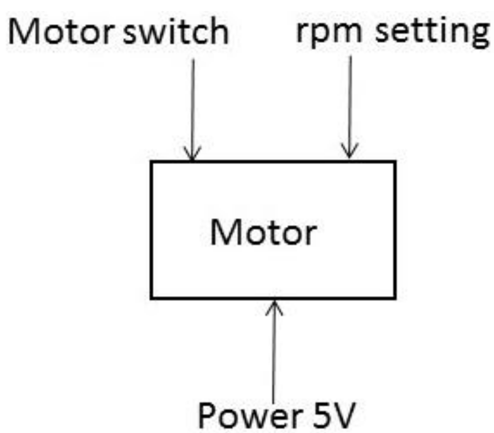

Figure 3: Level 1 Motor Control block diagram.

Figure 3 illustrates the motor control block diagram listing inputs, outputs, and related subsystem components. The user supplies the inputs necessary to determine on/off and rotation speed.

TABLE V

MOTOR CONTROL FUNCTIONALITY REQUIREMENTS

Module	Motor
Inputs	• Power: USB 2.0 compliant 5 V DC. • rpm setting: 1-bit digital input. • Motor switch: 1-bit digital input.
Outputs	• Motor power/control: motor control output
Functionality	Control the turntable rpm based on user settings and 5V input power

Table V deconstructs the motor control level 1 block diagram describing inputs, outputs, and functions. The motor, utilizes user settings for rpm regulation.

Chapter 4: Project Planning

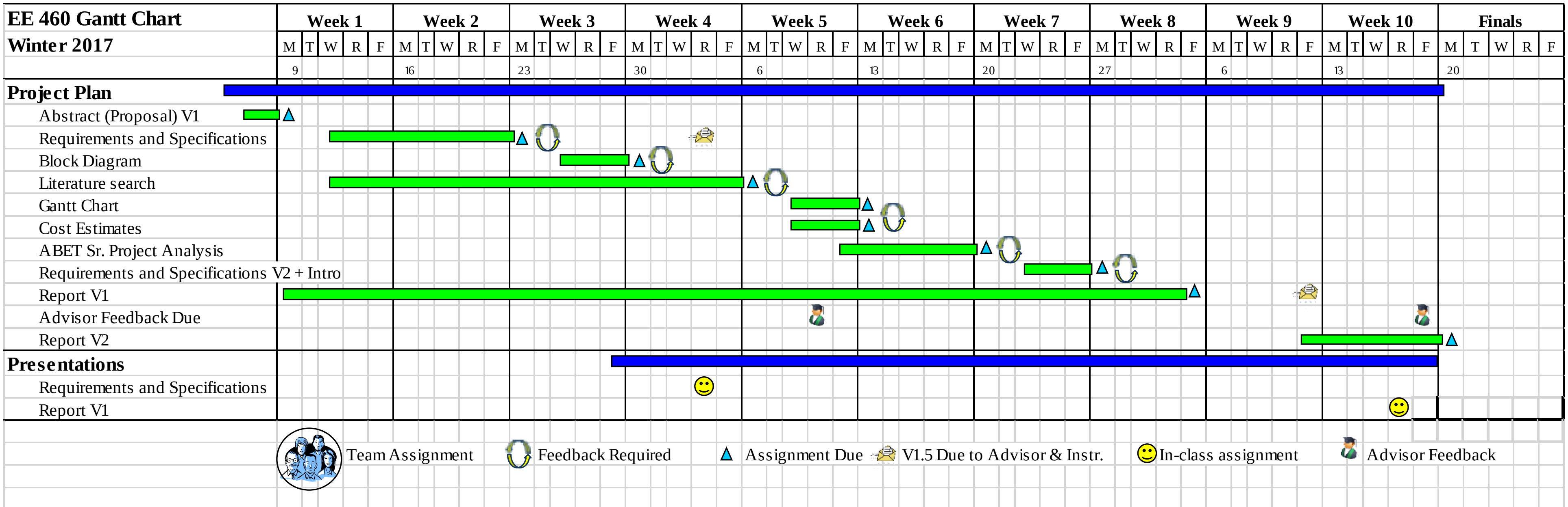

Figure 4: EE 460 Gantt Chart

This figure visually breaks down major course milestones, assignments, deliverables, and due dates. It includes task duration and suggested start time.

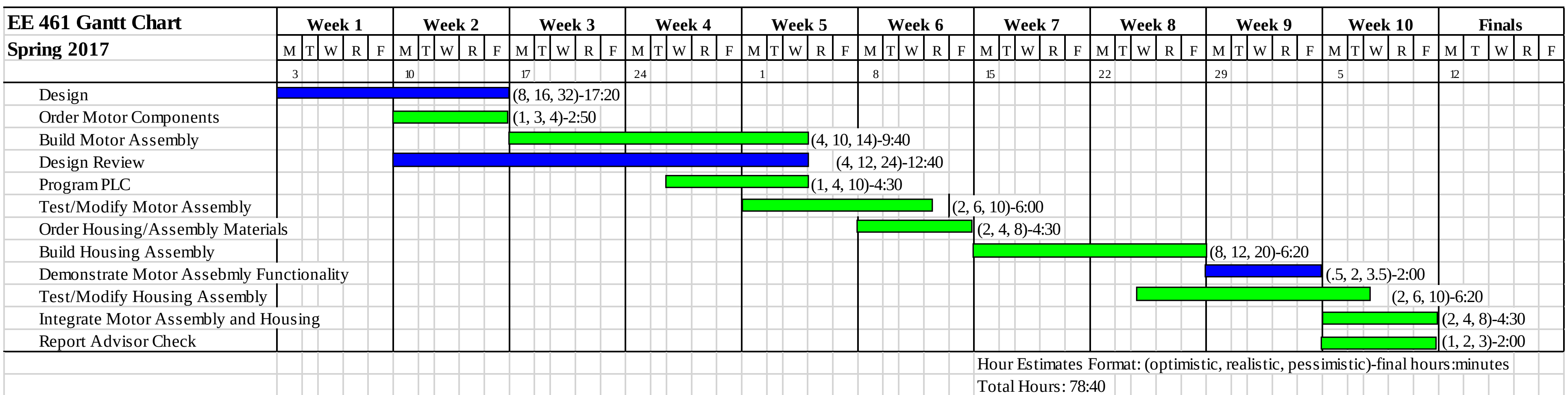

Figure 5: EE 461 Gantt Chart

Figure 5 illustrates EE 461 project tasks including design, motor assembly build and test, housing build and test, design reviews, and report updates.

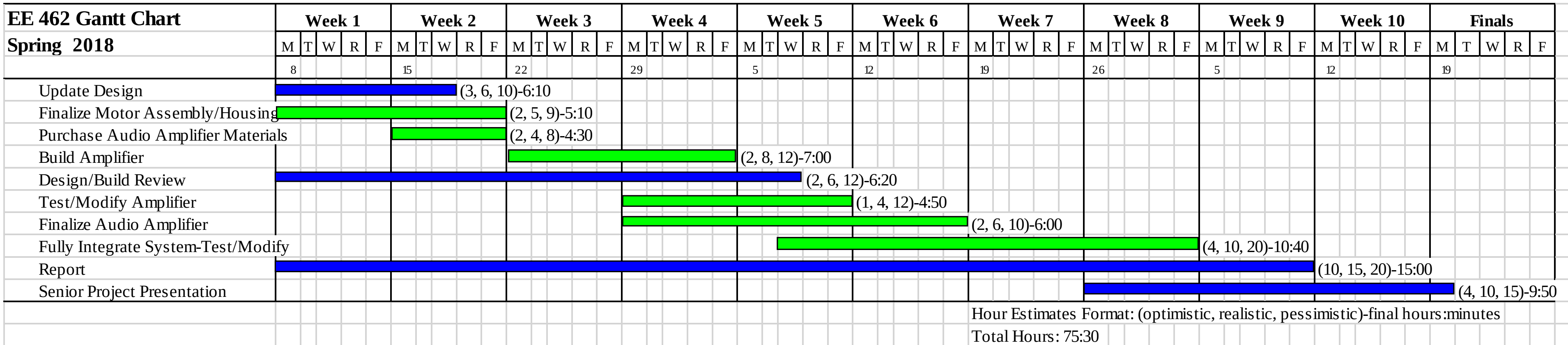

Figure 6: EE 462 Gantt Chart

Figure 6 reveals EE 462 project tasks including design updates, motor assembly and housing integration, amplifier build and test, final deliverables, and presentation.

TABLE VI

COMPONENT COST ESTIMATE, LABOR ESTIMATE, AND TOTAL COST ESTIMATE

Sub-Assembly	**Component**	**Cost ($)**	**Comments:**
Audio Amplifier	Adjustable Audio Amplifier	6	Op-amp.
	Miscellaneous	10	Amplifier small parts and pieces, namely wires, breadboard, potentiometer, knobs.
Housing/Assembly	Enclosure	30	Body enclosure holding most components.
	Turntable Platter	15	Vinyl rest platform.
	Miscellaneous	10	Housing assembly small parts and pieces, namely screws, nuts, bolts, washers.
Motor	Motor Package	14	Turntable rotation motor [9].
	Total Component Cost Estimate	85	
	Total Hours	154:10	Labor cost per hour: $28
	Total Labor Costs	4317	
	Total Project Cost Estimate	4402	

Table VI organizes cost estimates or materials and labor by component estimates. The table breaks down subassembly main component costs and labor estimates from the Gantt chart.

Chapter 5: Project Design

The motor chosen is a turntable replacement motor used in most mid to low range belt drive turntables. This motor's benefits include variable speed, consistent rotation speed, and no required feedback. Reasons for using this without feedback are discussed in Chapter 7. A small IC is included with the motor package that determines the speed. The IC regulates the total voltage sent to the motor thus regulating the speed. Shown in Figure 7 below, the switch connecting motor pin 3 and 4 controls the motor speed. An open or closed switch pertains to 33 1/3 or 45 rpm respectively. Tables VII-XI show the motor current and rpm testing results under various conditions.

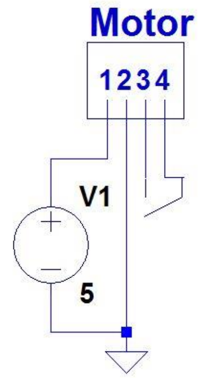

Figure 7: Motor Schematic

TABLE VII
MOTOR CURRENT—NO LOAD

Input Voltage	Current 33 1/3 rpm (mA)	Current 45 rpm (mA)
5V	15.1	17.7
9V	15.2	17.9
12V	15.3	18.1

TABLE VIII
MOTOR CURRENT—SIMULATED HIGH LOAD

Input Voltage	Current 33 1/3 rpm (mA)	Current 45 rpm (mA)
5V	125	130
9V	130	140
12V	200	220

TABLE IX
MOTOR CURRENT—TYPICAL LOAD

Input Voltage	Current 33 1/3 rpm (mA)	Current 45 rpm (mA)
5V	30	33

TABLE X
MOTOR CURRENT—PEAK IN RUSH CURRENT

Input Voltage	Current 33 1/3 rpm (mA)	Current 45 rpm (mA)
5V	81	80

TABLE XI
OUTPUT RPM AND RPM ERROR

rpm Setting	Actual rpm	% Error
33 1/3	33.9	+1.7%
45	45.8	+1.77%

As Table VIII illustrates, even under heavy load when the motor draws the most current, the limit of 500mA is not reached, passing the USB power requirement. Table VII and VIII data show no major difference between using 5V, 9V, or 12V. More voltage only draws more current and increases the output torque. The significant mechanical advantage between the motor and turntable platter, requires little torque, allowing a 5V input. The motor and belt assembly is shown in Figure 8. The lower motor voltage eliminates a voltage converter need. Table XI data collection utilized a Crosley portable turntable which will be used for the mechanical assembly and enclosure for the system. As such, total output rpm to the turntable platter was measured, meeting requirement three from Table I. This unit specifically uses a belt driven system. Belt driven system advantages over direct drive include lower necessary torque and higher vibration reduction. A USB port to terminal block break out supplies power to the motor as shown in Figure 9.

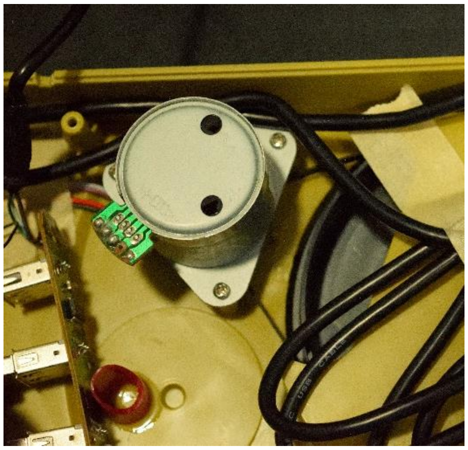

Figure 8: Motor and belt assembly

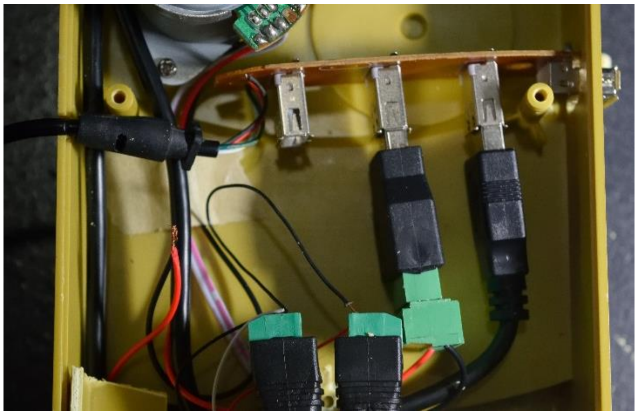

Figure 9: USB hub distributing power

Further product research found a USB powered pre-amplifier. A pre-amplifier is the typical method to amplify the low cartridge signal to a usable line level signal. For this project's purposes, the line level signal is used as the audio output. Here the Behringer U-Phono UFO202 product is used (Figure 10). This cheap, off the shelf device fulfills many design requirements needs, including audio output, THD, adjustable volume, and an existing product [10]. This device's capabilities go beyond the requirements and are discussed below. The input connection to the pre-amplifier is done via RCA terminal connectors shown in Figure 11 for both the left and right audio channels from the cartridge output. The pre-amplifier controls the volume output level with an adjustable knob. Figure 12 shows the output connection and the volume control.

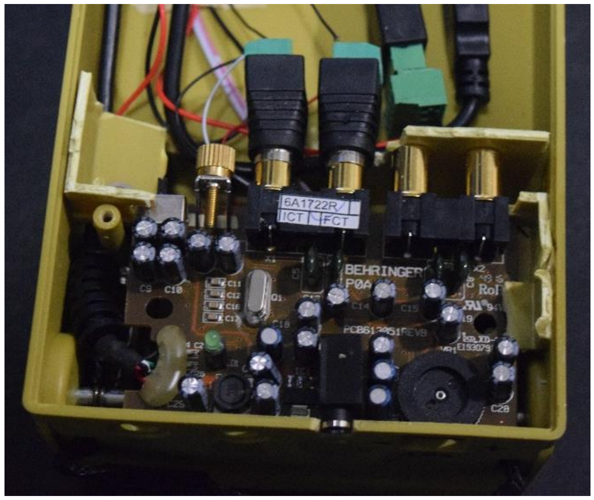

Figure 10: Pre-amplifier

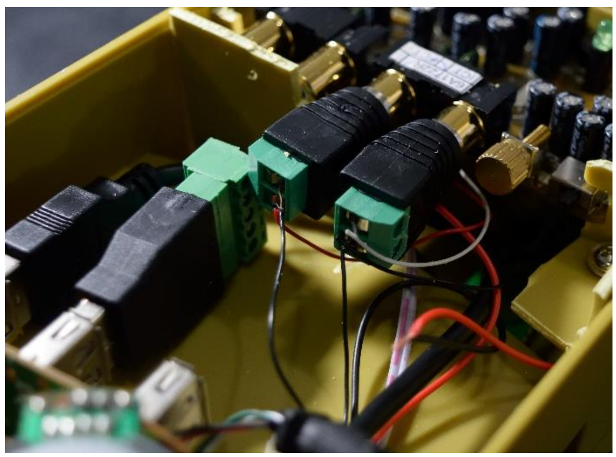

Figure 11: RCA connectors

Figure 12: Audio output and volume control knob

Minimal changes to the utilized Crosley chaise were made. The changes include mounting the USB hub (Figure 9) and pre-amplifier (Figure 10) and locating the input and output connections to the turntable. The motor mount and assembly, turntable platter, and tone arm assembly were not modified and used as is.

Table XII shows which subsystem helps ensure each Table I engineering specification is met in the final product.

TABLE XII
PERFORMANCE SPECIFICATION ALLOCATION

Subsystem	**Specification**
Motor Assembly	1, 3, 4, 6, 9,
Housing Assembly	6, 7, 8, 9, 10, 11
Audio Amplifier	1, 2, 5, 6, 9, 10

One feature enhancement not listed in the design requirements is the digital recording ability. When the unit’s USB is connected to a computer, it functions as a recording device and transfers the analog audio media to any desired digital format.

A second additional feature is the additional USB port on the unit. This supplies power and data to any connected device. A practical option is a Bluetooth transmitter. The Bluetooth transmitter shown in Figure 13 enables wirelessly playing audio on a Bluetooth connected device such as a speaker or headphones. All three additional features help increase the products goals of versatility and functionality.


Figure 13: Bluetooth transmitter and external USB port connection

Chapter 6: Testing and Design Verification

Testing and design verification involves validating power consumption, rpm speed, rpm consistency, size requirements, functionality, and audio tests. The most stringent requirement is the power consumption to comply with USB 2.0 standards. Many other tests contain simple measurements or pass/fail requirements. Table XIII below lists the design requirements, tests completed, and associated results.

TABLE XIII

SPECIFICATIONS TESTS AND RESULTS

Engineering Specifications	**Test(s) and Results**
USB powered per USB 2.0 specifications.	The components drawing power are motor, pre-amplifier, and any externally connected USB connected device. Under typical load, the motor draws 33 mA. The pre-amplifier draws 100 mA maximum [10]. The Bluetooth module draws 30 mA maximum. This leaves a factor of safety of over 200%.
Contains total harmonic distortion plus noise (THD) <1% from the cartridge output to the audio turntable output over the audible frequency range 20Hz-20kHz.	The pre-amplifier's THD is 0.05% typically.
Vinyl rpm rotation errors ≤5% from rpm setting.	Table XI shows the rotations error less than 1.8%.
Plays 7" and 12" (SR and LP) vinyl at 33 1/3 and 45 turntable rpm.	The device plays both SR and LP vinyl at the respective speeds.
Adjustable output gain, audible with low impedance headphones.	The output delivers adjustable, usable to any low impedance device whether headphones, a powered speaker, or a Bluetooth transmitter.
Systems integrated and developed with existing components.	All components used are previously existing components.
Includes tactile motor and setting switches.	Switches are easy to set and identify.
Device size within 13"x13"x4"	Product's size is 11" x 4" x 3"
Cost <$150	$31.82 Crosley turntable $11.99 Motor $29.99 Pre-amplifier $2.39 USB hub $3.99 USB terminal $12.48 Bluetooth transmitter + $0.87 RCA connector = $93.53
Output utilizes 3.5mm female audio jack.	Product uses 3.5 mm female audio jack.
Stylus replacement requires no tools.	Product stylus replacement does not require tools.

Chapter 7: Design Alternatives

Various solutions were considered for each subsystem before the finalized solutions were determined. Potential motor drivers and rotation systems included a PWM controlled DC motor both with and without tachometer feedback. The frequency oscillation from the PWM signal caused hesitation as the magnetic interference would be significant, but it is an easy way to control and regulate the motors speed. After reviewing various mid to low level turntables utilizing DC motors with regulating IC’s, it was determined, feedback was not necessary. The load applied to the system is very consistent not requiring regulation for any audibly noticeable difference in quality. It was expected the motor would need a voltage of 9V or 12V for the supply and thus a DC-DC step-up converter necessary. Since 5V worked fine in testing, one is not needed.

Initially, an instrumental amplifier was chosen for the audio amplifier [7]. It contained adjustable gain, dual channels, low THD, and designed for audio applications. After measuring the cartridge output as in Figure 14, it was determined an amplifier in this style was unnecessary and did not suit the needs. A simple application of an op-amp is more suitable, practical, and easily integrated. With voltage amplification to high levels not required, a single supply op-amp was chosen.

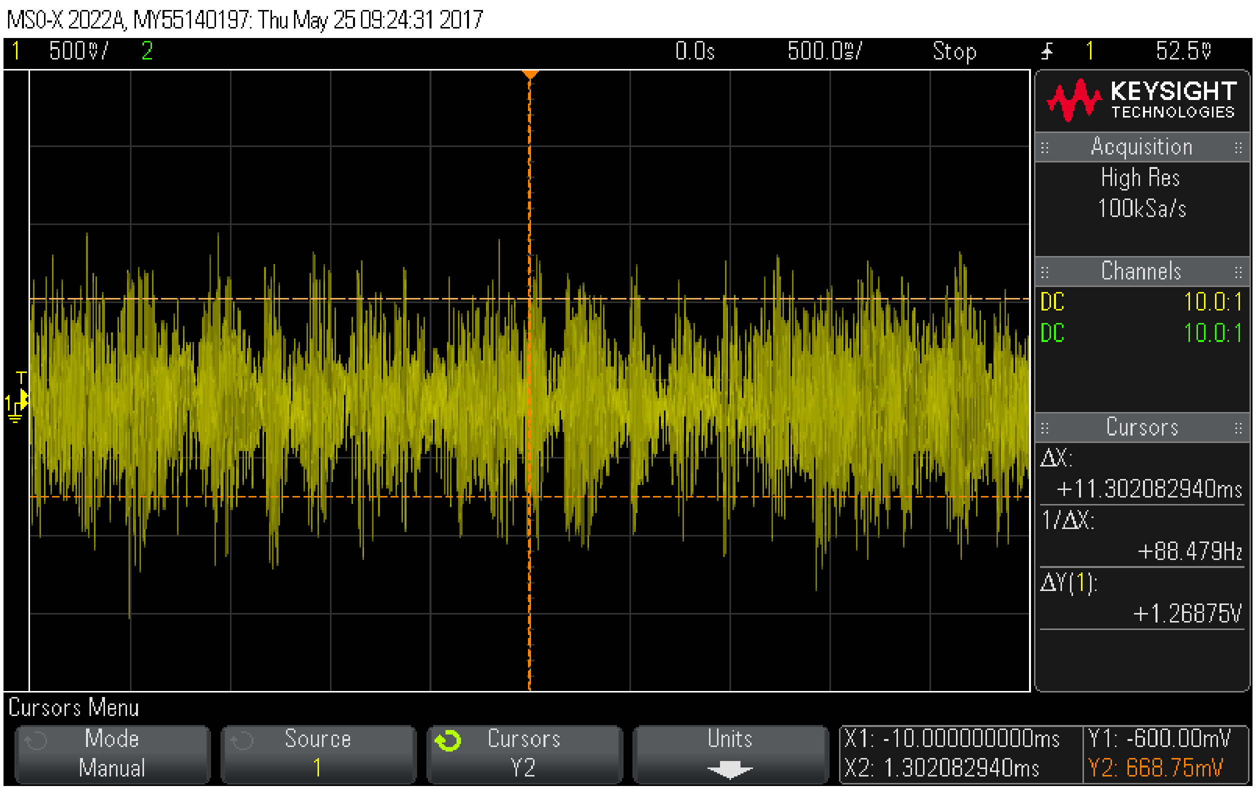

Figure 14: Unloaded Cartridge Output Playing Record

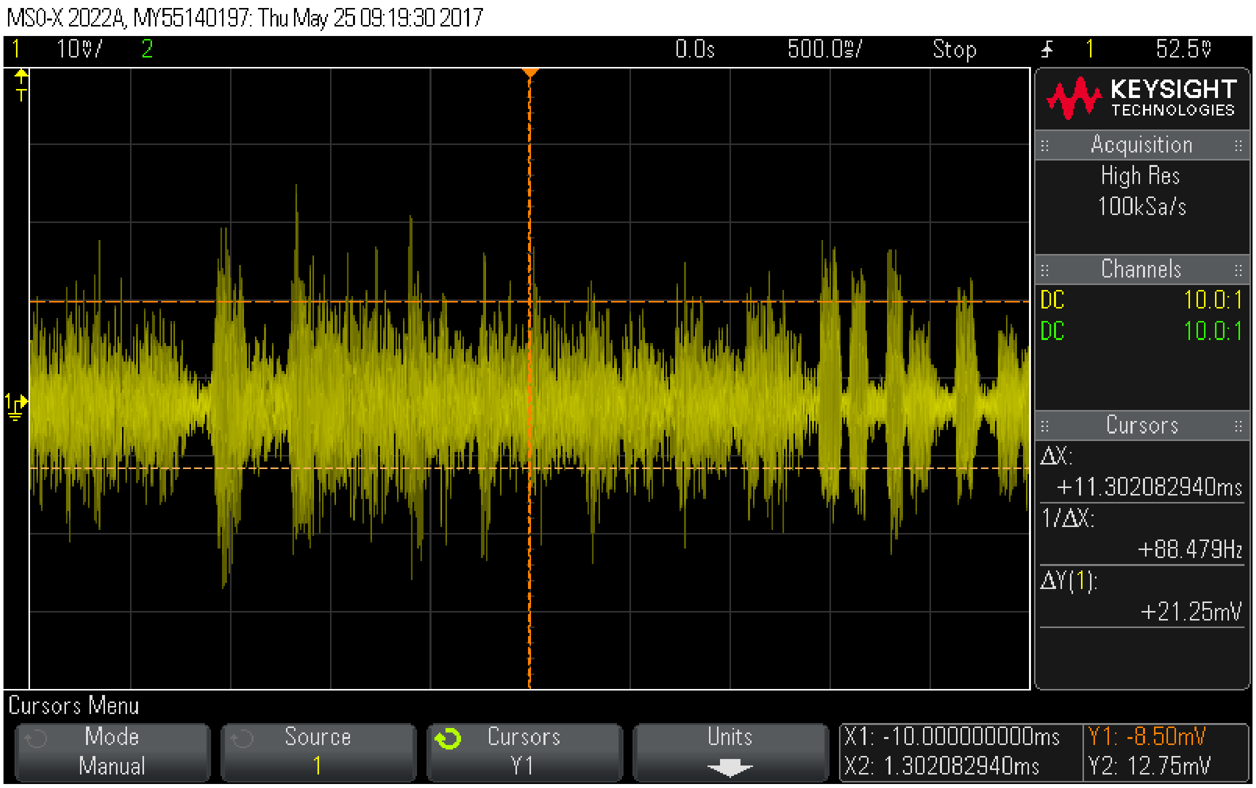

Figure 15: Cartridge Output Playing Record Across 100kΩ

Figure 14 shows the unloaded cartridge output from the transducer when playing a typical record. Figure 15 shows the output across a 100kΩ load under similar conditions. Using these figures and the general peak voltage of 1.2V and 22mV for Figure 14 and 15 respectively, an estimate for the cartridge series resistance, r_S, can be made shown below.

$$\frac{1.2V_{PP}}{0.022V_{PP}} = \frac{r_S\Omega}{100k\Omega} \qquad \rightarrow \qquad r_S = \frac{1.2V_{PP} \times 100k\Omega}{0.022V_{PP}} = 5.5M\Omega$$

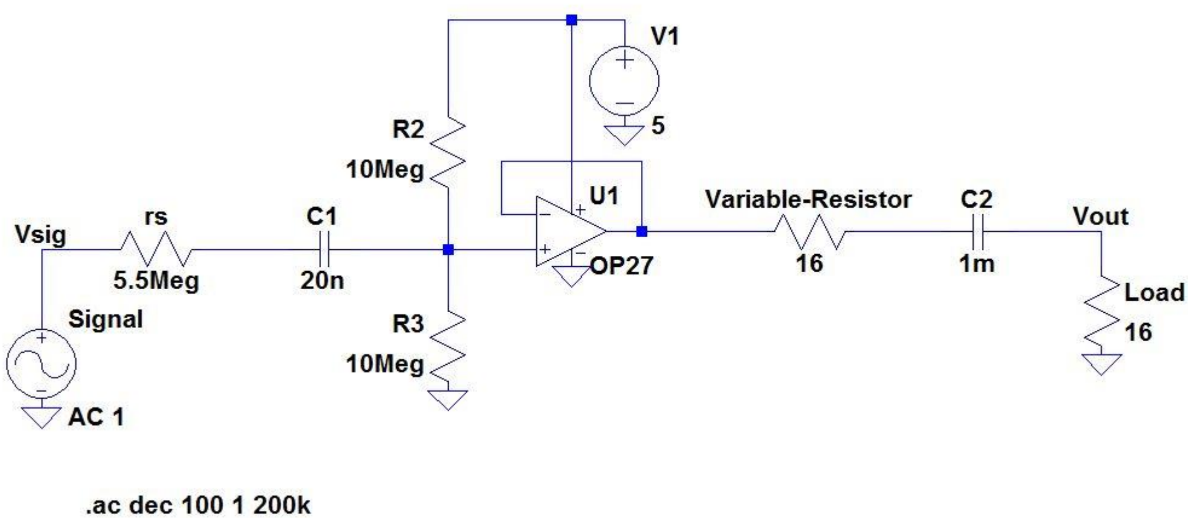

Figure 16: Audio Amplifier Schematic

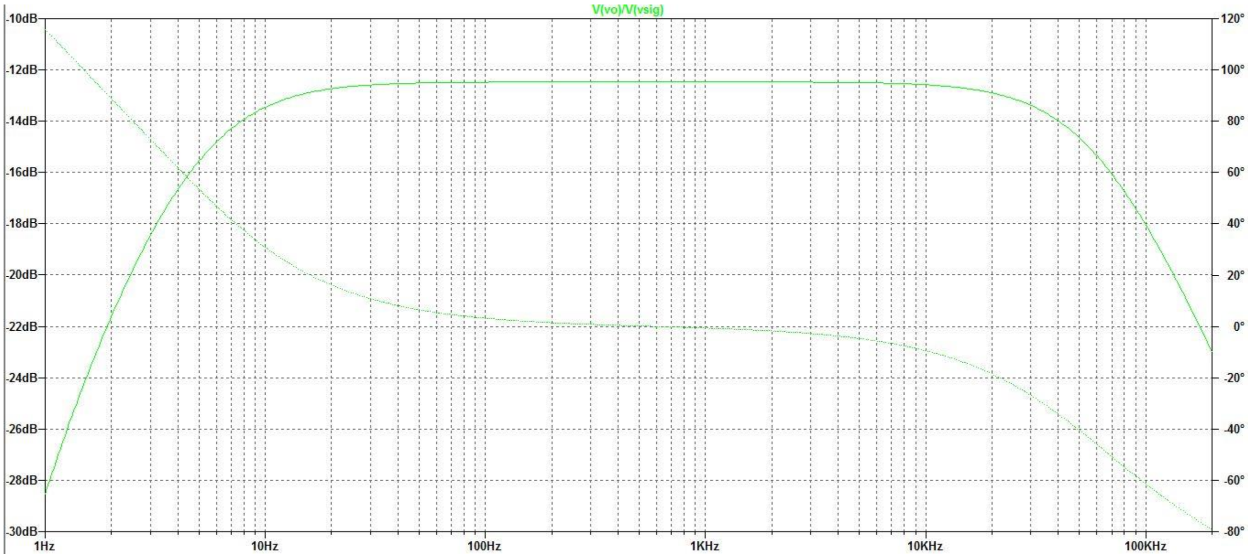

Figure 17: Audio Amplifier Frequency Response—1Hz to 200kHz

Figure 16 above shows the schematic for the audio amplifier and the designated component values. Figure 17 displays the frequency response plot for the corresponding schematic. As desired, the response is nearly linear in the 20Hz to 20kHz audible range. The first stage consisting of r_S, C_1, R_2, and R_3, isolates the AC component of the cartridge signal and centers it between 0V and 5V. This allows single power supply usage direct from USB. The second stage op-amp is configured as a buffering voltage follower. The cartridge's limited current output necessitates the op-amp to supply the necessary output current. The final stage with the variable resistor, C_2, and the load, adjusts the overall gain reduction, and passes only the AC to the output. A typical headphone load of 16Ω is used.

Further figures, tables, and descriptions on the design solutions are discussed in Chapter 5.

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Appendix A. Senior Project Analysis

1. Summary of Function Requirements:

USB ports power many important everyday devices. A USB powered turntable increases record player flexibility, versatility, and portability which expands usable turntable scenarios. The manual turntable plays seven and twelve-inch vinyl at 33 1/3 or 45 rpm. It includes a stylus, magnetic phono cartridge, tonearm, 45-rpm adapter, motor, audio output, and several setting switches for easy use. If connected to a computer, the project can be used as a recording device.

2. Primary Constrains:

Following USB 2.0 standards constrains the voltage, current, and power usage to 5V, 500mA, and 2.5W, respectively (see Table I) [14]. This major restriction limits potential functionality since much power usage goes to the necessary functions of turntable rotation, audio amplification, and control. This challenge directly affects and limits nearly all decisions and options. It determines the additional features and each component's criteria and specifications as this limitation forms the project foundation and cannot alter. An initial system requirement included internal speakers, but the limited supply power eliminated this potential. It also limits component selection. Each subsystem's components must meet the total power criteria eliminating many solutions if the power requirement conflicts.

3. Economic:

The human capital includes myself, advisors, mentors, vendors, and colleagues. Advisors and mentors aid, knowledge, experience, and advice concerning future steps, approaches, and solutions on the project systems and troubleshooting. Vendors provide component and product information and specification, allowing better component selection. Colleagues advise and illuminate potential solutions.

Financial Capital occurs in obtaining components and required resources. Component acquisition requires proper financial capital. Each component impacts real capital and depletes the stock reserve with component purchase and usage. All products, components, and goods use Earth's natural capital resources such as the metals and plastics used in the chips, motor, control circuits, and wires [15]. Component delivery requires energy used in transportation, packaging uses cardboard and paper made from trees, and the energy that sustains myself and workers directly and indirectly invested in the project stems from the Earth.

The largest cost accumulates at the onset of the project during the design, built, test, and integration. Most human capital usage occurs during this time and constitutes a significant project cost percentage. Benefits accumulate at each successful subsystem completion. Every subsystem addition adds functionality and meets more customer needs including sound output, motor control, and volume control.

Estimated component costs total $89 and estimated project costs total $4406. I pay project costs concerning component acquisition and labor. The project profits benefit myself—the designer—and any other stakeholder in the design and product development should any exist by the project completion. Each turntable sold produces $125 revenue [16]. Higher production causes lower component cost and lower product cost, increasing project earnings and profit. Products emerge after meeting proper consumer tests and exist for decades under proper care and minimal component replacement. Approximately every 2000 hours of play requires a stylus replacement, and every fifteen years requires a belt replacement. Other components last the life of the product [17].

Project completion time includes 155 hours for design, build, and test for each subsystem and the complete system integration. Future project improvements include better design aesthetics of the product increasing consumer appeal, expanded functionality such as internal Bluetooth compatibility, and increased durability

4. If manufactured on a commercial basis:

As a new and unique product in the turntable market, the USB powered turntable potentially holds a 1% market share. Recent US turntable sales projects approximately 56,000 devices sold domestically each year by all manufacturers [1]. A 1% market share yields an expected 560 units per year manufacturing rate. The typical manufacturing cost totals $100 for each device and sold at a $125 purchase price. The proposed device's potential annual profit then comes to $14,000 for expected typical manufacturing costs. The minimal operating cost totals $0.12 every 400 hours of play [18].

5.Environmental:

Large environmental impacts occur during component acquisition and integration. Each component uses natural resources and energy for manufacturing, processing, shipping, and compiling into the subsystem. Components themselves use materials in plastics, metals, polymers, and fibers during the manufacturing process and component distribution causes pollution and waste product creation [15]. Shipping uses energy and causes unavoidable air pollution. Product packaging uses many plant byproducts in paper and cardboard. The project harms component manufacture areas, mining areas, lumber areas, refinery areas, and air quality both directly and indirectly and harms animals and ecosystems in or near those areas [19].

6. Manufacturability:

This project presents no significant manufacturing issues or challenges. The project does not design new components, but instead integrates existing components into a new product which requires no new component knowledge and human capital. The large vinyl size causes a large enclosure and allows the workers much room during product assembly. The small amount and simplicity of components promotes quick and easy production [20]. The component selection criteria during design requires ease of compatibility of all needed components. This may limit the options available but allows easier manufacture.

7. Sustainability:

Maintaining the finished product does not present major issues. Minimal maintenance includes stylus replacement every 2000 hours [17]. The product uses limited resources including metals, plastics, and paper products. Using only necessary components in the devices improves sustainability. Upgrades to the project include better aesthetics and enhanced functionality like more play speeds, internal speakers, and increased durability. These upgrades increase the cost and require more power usage making an external or additional battery necessary.

8. Ethical:

The project design utilizes Ethical Principlism, including non-maleficence, beneficence, autonomy, and justice. The design utilized doing no harm in ensuring no copied or misused intellectual property. The design focuses on building a good beneficial product, not simply one that did not abuse others' designs. Analysis and research determined potential customers and customer needs inspiring the Requirements and Specifications (see Table I). Meeting these requirements ensures a successful and beneficial product. The product does not discriminate any individual or party during design, build, testing, manufacture, or sale. Although the design focused on certain customer needs, all persons and groups contain equal purchase rights. Autonomy includes myself during design, build, and test; manufactures as no parties coerced any unwilling products; customers as they utilized free-will in product purchase; and peers and advisors as they supplied feedback willingly.

The product utilizes the IEEE Code of Ethics by:

1. Applying safety first for project entirety concerning all relevant parties.
2. Circumventing conflicts before they occurrence and handling conflicts which arose.
3. Not misrepresenting and reporting accurate data.
4. Rejecting bribery and avoiding potential situations involving bribery.
5. Grasping the utilized technology fully before implementation and applying it adequately.
6. Employing appropriate limitations and completing tasks only if properly qualified.
7. Correctly citing all sources, information, and knowledge gathered from others.
8. Fairly treating all involved directly and indirectly under any circumstances and situations.
9. Applying non-maleficence in conditions and steps.
10. Uplifting those connected with myself and the project.

9. Health and Safety:

Design safety concerns include the component and subsystem assembly and subsystem integration. Precautionary measures take place during processes using tools and soldering equipment. Many test phases utilize analysis equipment and mitigate safety hazards with appropriate personal protective equipment and caution including safety glasses and proper training [21]. Project use poses few serious safety hazards and avoiding improper usage eliminates risks. The product and its design utilizes UL, CSA, and VDA associated safety criteria and the manufacturing process follows OSHA protocol which further reduce product use and manufacturing safety risks.

10. Social and Political:

Social and political issues related to the project include project resource designation and project resource consumption. The design and manufacture uses resources in the components themselves and the component acquisition. The project effects those in areas where the raw resources originate and those located in component manufacture areas. The direct stakeholders include customers and vendors. The indirect stakeholders include those located near raw resource areas, distributors, shippers, and turntable competitors. Not all stakeholders benefit equally. Some contribute little regarding indirect involvement such as distributors and shippers who benefit only during product success but not harmed regardless. More direct stakeholders such as component vendors and manufactures benefit greater from a better product as this causes more manufacture and vendor component sales and usage. Indirect stakeholders receive no benefits if not purchasing the product but still incur harmful environment impacts including pollution and nature resource depletion.

11. Development:

Throughout the project I improved my research and project planning skills immensely. I grasped much during conception, requirements and specifications, block layout, and stage planning. These demonstrated new areas to me and proper documentation and planning requirements. System integration also taught me much. Looking at each system separately and the entire integrated system pushed my knowledge greatly. It forced me to think from multiple angles continuously and evaluate design solutions and constraints. I explored new areas concerning audio specifications, audio amplifiers, appropriate wave levels, and audio control [6, 8]. I increased motor integration and control feedback experience requiring encoder and various control techniques knowledge [9, 12]. Mechanically, I learned thinking at the product development standpoint regarding packaging and physical component layout. This required not only knowing how the components connect together but how they are placed and mounted.

Appendix B. User Guide

Play Vinyl Record

1. Connect turntable USB A male connector to any USB powered port. Examples include electrical outlet adapter, computer USB port, and portable USB battery charger.
2. Open turntable using tab on side of turntable.
3. Place record on turntable platter using supplied 45 rpm adapter if necessary and close turntable.
4. Connect desired device to audio jack.
5. Set appropriate speed setting.
6. Switch on motor.
7. Remove stylus cover
8. Gently set stylus on record.
9. Adjust volume as desired.

Play Vinyl Record Via Bluetooth Transmitter

1. Follow steps to Play Record.
2. Ensure Bluetooth Transmitter is charged or connect Female Micro USB port on transmitter to Female USB A port on turntable.
3. Turn on receiving Bluetooth device and set to discover or connecting mode.
4. Press and hold large center “Play” button on Bluetooth transmitter until transmitter and receiver have connected.
5. After devices have connected, use both the volume knob on the turntable and the volume buttons on the transmitter to control audio volume.

Record Vinyl Audio

1. Connect turntable USB A male connector to computer USB port.
2. On computer, open desired recording software (e.g. Audacity or GarageBand) and ensure recording input is set to USB device.
3. Follow steps 2-7 of “Play Record.”
4. Adjust the input sensitivity of the recording program to achieve desired sound quality.
5. Begin recording on software program.
6. Immediately place stylus on record.
7. Once first side has completed playing, stop the recording, flip record over, resume recording, and replace stylus on record.
8. Headphones can be used on turntable to monitor the playback/recording.

Appendix C. Troubleshooting Guide

Turntable does not spin:

1. Ensure device is properly powered.
2. Verify motor switch is in the "on" position.
3. Ensure nothing is jamming the turntable platter. If unsure, turn off motor and disconnect power. Manually turn platter. It should spin with relatively low resistance.
4. If turntable platter freely spins, reconnect power and turn on motor. Listen for motor sound. If you can hear the motor, the belt has likely fallen off the motor pulley. Remove bottom panel and reconnect belt by gently stretching it over the motor pulley.

Volume is very low:

1. Ensure device is properly powered. If device is not receiving adequate power some internal devices might operate normally while others do not function
2. Remove any externally connected USB device.
3. Utilize volume knob.