Middlesex University Dubai

CST3590 Final Year Project Report

Cost-Effective Record Player Design

Hamad Mohamed Asif

M00695912

Module Tutor – Dr Fehmida Hussain

Project Supervisor – Dr Sameer Kishore

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Abstract

Through the Vinyl Revival of the late 2000s came a massive increase in the sales of cheaper commercial turntables. This report details the design and implementation of a turntable meant to compete with these units. The background research regarding the working principles of a turntable is explored, including the various intricacies of its functioning. This information then serves as the basis for a design, which is then implemented as a prototype and tested to ensure proper functioning, with these tests being compiled in the report. The report closes with a reflective section on ways in which the turntable design could be improved.

Acknowledgements

I want to thank my friends for keeping me on the road to completion. We fought alongside each other for this.

I would like to thank my supervisor Dr Sameer Kishore for his enthusiasm in aiding me throughout this project. His passion for records mirroring mine reassured me that I had made the right choice in deciding to build this record player.

And lastly my father, for doing everything in his power to bring this project to fruition. I genuinely could not have done this without him.

Introduction

This report is an outline of the development process of a record player prototype. The primary motivation of this project lies in the Vinyl Revival phenomenon as described by Richter (2014), who notes a massive uptick in the sale of vinyl record pressings. This project aims to build a record player that can supplement the growth of the popularity of vinyl records by meeting the demand for good-quality record players. The report outlines the primary requirements that the project must meet; it then goes over the existing literature regarding the functioning of turntables in an effort to understand key design principles behind good record players; it then outlines the record player's design, the implementation of this design, and the testing of the implementation.

Literature Review

Preface

The final product of this thesis is a portable vinyl record player; to that end, several technologies from a diverse set of fields will be utilised, all of which will be listed below. The existing applications and literature regarding the intersection of these technologies with this thesis's product will therefore be reviewed. This is to provide a background and framework of understanding for the product itself and the decisions that go into designing and constructing it.

The following technologies as they intersect with the project will be explored:

- Record player cartridges and the mechanisms by which they work; namely Moving Magnet (MM) cartridges and Moving Coil (MC) cartridges
- Audio filters, and how they relate to the RIAA equalisation standard
- Record player drives; namely belt-drive and direct-drive

Cartridges

Record player cartridges are in essence electromechanical transducers that turn the kinetic energy of a needle's motion in a record groove into an electrical signal. Meyer (1958, cited in Enjoy the Music.com, no date) describes the construction of magnetic phono cartridges. The tip of the stylus is attached to a cantilever; the motion of the stylus is transferred to the cantilever, and since the opposite end of the cantilever is attached to a mechanism consisting of a magnet and a coil, an electric current is induced via electromagnetic induction. This current or signal represents the played back audio, which can be heard via amplification and a set of speakers.

The distinction between Moving Magnet (MM) cartridges and Moving Coil (MC) cartridges lies in which part of the magnet-coil mechanism the cantilever is attached to (Svetlik, 2021). In a Moving Magnet arrangement, the cantilever is attached to the magnet; the coil is fixed in place, so the motion of the magnet via the cantilever generates an electric current. In a Moving Coil arrangement, the opposite happens; the magnet is fixed in place while the coil is attached to the cantilever. The motion creates a similar signal, albeit with different preamplification requirements to a Moving Magnet arrangement given the relative positions of the coil and magnet in each arrangement.

Filters and RIAA Equalisation

One form of electronic circuit used frequently in audio applications is the filter circuit. Filters are used in signal processing to remove undesired frequencies in a signal while letting others pass. Carr (2000, p. 65) categorises filters by passband, meaning the band of frequencies that are filtered out by each circuit type. These categories are high-pass, low-pass, bandpass and notch filters. High-pass filters affect a signal by cutting off any frequencies below a certain threshold; Carr refers to this as the critical cut-off frequency. Since frequencies lower than the cut-off frequency are removed, frequencies that are higher are allowed to pass, hence the name 'high-pass filter.' Low-pass filters work in the exact opposite way; frequencies above the cut-off frequency are filtered out, and lower frequencies are allowed to pass through. Bandpass filters function differently; two cut-off frequencies are present, one as an upper limit and one as a lower limit. Any frequencies between these two cut-off frequencies are allowed to pass, while any frequencies within this range are filtered out. Lastly, notch filters are filters highly attenuated to a specific frequency; only the target frequency will be affected.

The importance of filters with regard to this project lies mainly in how they will be used to affect playback of vinyl records. Specifically, the phono preamplifier will use a series of filters that implement the RIAA equalisation curve specification for microgroove records.

Copeland (2008) describes the RIAA equalisation curve for microgroove records, which is a standard of equalisation employed by the Record Industry Association of America. He also describes it as being intended to serve as a global industry standard for cutting vinyl records, with RIAA officially announcing the standard in November of 1954.

Equalisation in this context as defined by the IASA is "the application of a frequency dependant boost or cut to the signal before it is recorded, and the inverse cut or boost on replay" (International Association of Sound and Audiovisual Archives, 2021). This equalisation can be done for any number of reasons; in the case of vinyl LPs specifically, RIAA equalisation is done to minimise the presence of lower frequencies and emphasise the presence of higher frequencies in the signal before cutting the record. This results in thinner grooves on the final record, which allows for longer-running recordings to be played back as more space on the record's surface is being made use of. The exact specifications of the RIAA equalisation curve will be discussed further below.

Record Player Drives

A key part of the functioning of turntables, or record players, is the rotation of the platter; the means by which that rotation is driven is the focus of this section.

A blog post by Fluance (2021a) lists two popular types of drive mechanisms: belt drive, and direct drive. Direct drive turntables have a motor where the shaft is directly attached to the platter (the platter being the surface on which the vinyl record is placed). This calls for a slower, more heavy motor as thirty-three rotations per minute and forty-five rotations per minute are both speeds under a frequency of one hertz. A belt drive turntable, on the other hand, has the shaft of the motor attached to the platter via a belt; using circumference ratio calculations, a smaller-circumference gear could be used on the shaft of a cheaper motor that runs at a higher rotation speed. The direct drive method, given the lower rotation speed, allows for less noise or vibration caused by things such as gear rotation. This in turn enhances playback of the record by minimising noise. A heavier, more stable platter on the other hand could dampen any potential noise caused by a belt-driven arrangement to the point where it is negligible.

Other classes of drive do exist, albeit with a lower apparent presence in mainstream turntable discussion. An article by Brinkmann Audio (no date) describes idler-wheel arrangements which make use of a gear or set of gears between the motor shaft and platter base or rim, an arrangement constructed using gear ratio calculations similar to belt drive mechanisms.

Requirements Specification

Given that the product of this project is a variation of an existing product, the consumer-grade vinyl record player, the product must be able to function on similar terms as comparable products can. To this end, the following functionality must be guaranteed:

- **The turntable platter must be able to rotate at a steady 33 or 45 rotations per minute.** 33 rotations per minute is standard for 12-inch LP record pressings of entire albums, and 45 rotations per minute is standard for 7-inch pressings of singles; an inability to consistently rotate at this speed would cause distortions in the audio played back. In order for this to be achieved, the voltage supplied to the motor must be consistent in value to ensure the motor is powered properly. This will be done through the use of resistors in a voltage divider configuration and the voltage being constantly monitored throughout testing.
- **The tracking force or weight of the stylus must be adjustable.** This is necessary in order to tune the tracking force to the stylus's recommended tracking force range to optimise playback of audio and reduce the wearing-down of the record. This also facilitates the replacement of the cartridge with a different cartridge which may have its own tracking force specifications, should the user prefer it. To this end, a weight adjustment mechanism will be put in place on the tonearm; since the tonearm is what moves the cartridge, designing this mechanism so that it affects the tonearm's motion (and that its effect on the tonearm can be controlled by the user) ensures that this requirement is met appropriately.
- **The turntable must contain its own phono preamplifier circuit.** In order to minimise user effort and resources, the turntable must have its own phono preamplifier to produce a signal that standard consumer-grade audio playback devices can effectively work with. Whereas traditional record players consist of an elaborate motor control circuit and weight-adjustable stylus-tonearm array, one of the aims of this project is to improve portability by minimising the amount of additional or peripheral devices the user requires to use the unit. A phono preamplifier circuit is therefore to be designed and constructed as part of the turntable. To this end, operational amplifier ICs will be used in conjunction with capacitors, resistors and other electrical components; this will enable the construction of an RIAA filter preamp, the details of which are discussed in the literature review section.
- **The turntable must be powered with batteries.** This once more emphasises the portability aspect of the turntable, eliminating the need for an external power supply such as a mains-connected plug.
- **The turntable must be portable.** This requirement was outlined in the proposal, and referenced in the previous requirements. To this end the turntable must be light enough to carry, and house its own power source. The weight will be managed through the choice of parts and materials used in its construction, while the power supply requirement was addressed in the last point via batteries.

These are the minimum requirements that have been decided for this project to meet. The aim of meeting these requirements is ultimately to ensure the correct functioning of the turntable and that it performs as intended.

System Design Overview

Preface

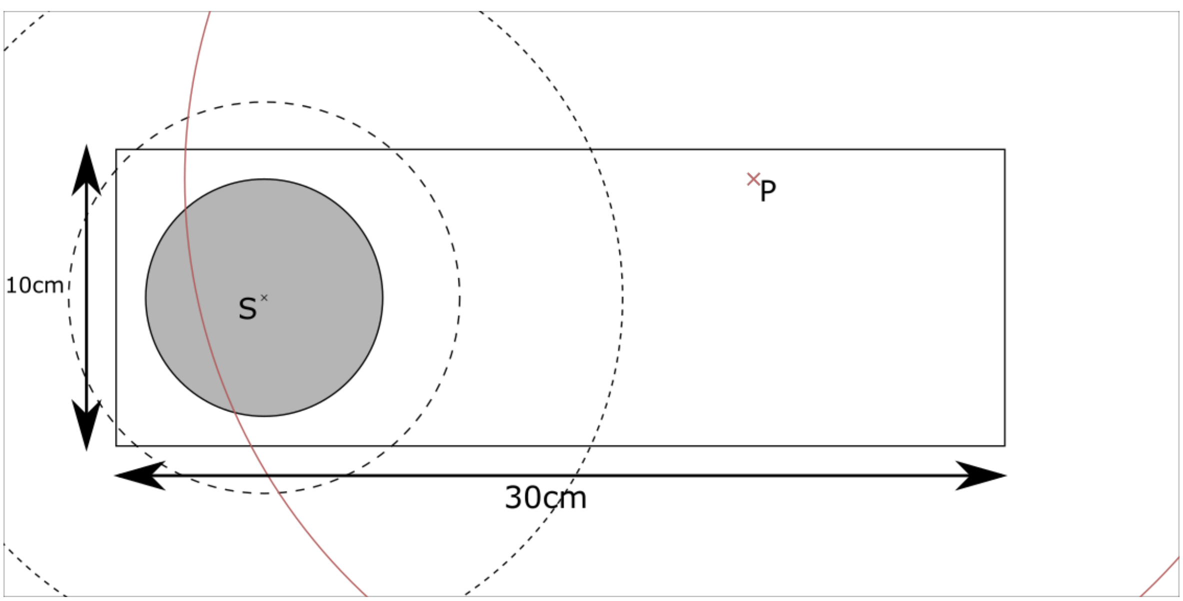
This section of the report will be an overview of the design of the product; this will include construction dimensions, layout and UI decisions, user-adjustable parameters, and developmental decision explanations for each. This breakdown of the product will happen in layers: from the top-most layer to the bottom-most layer.

Cartridge Alignment, Tonearm Mounting Distance and Effective Length

Before the tonearm length can be calculated, the concept of null points must be made familiar. The 'null points' are two points along the tonearm path where the stylus alignment is exactly at a right angle to the spindle. Multiple cartridge alignment systems exist with their corresponding null points, and this project will use the Baerwald alignment system as described by Vautier (2017). In the Baerwald alignment system, the null points are 66 millimetres and 120.9 millimetres away from the spindle respectively. That is, when the stylus is either 66 or 120.9 millimetres away from the spindle, if a circle of length *null point distance* and centre *S* is drawn, the cartridge alignment will be tangential to this circle. This alignment is done to make sure the cartridge is always perfectly aligned in the groove to minimise playback distortion, and calculating the tonearm pivot point geometry and tonearm length is key to this.

With null points explained, the calculation can begin.

Illustrated via the diagram below, the tonearm mounting distance is the distance measured between the turntable spindle (Point 'S' on the diagram) and the tonearm pivot point 'P'.



Top-down view of the record player showing the Spindle, Pivot, inner and outer null point radii and tonearm length

The red circle arc represents the path of the tonearm, whose centre is point P (the tonearm pivot point). The radius of this circle is the effective length of the tonearm from pivot to stylus tip. The two dashed circle arcs represent the radii of the null points.

The dimensions of the entire unit are 10cm by 30cm. The user controls have been omitted from this diagram for the sake of focus on the geometric calculations.

The distance 'PSD' of the pivot point from the spindle is 17cm. This distance was selected so as to leave room for the user controls.

Using Kearns's (2001) formula for overhang calculation, the effective tonearm length (including cartridge and stylus) would be as follows:

$$\text{Tonearm length} = \sqrt{PSD^2 + (N_i \times N_o)}$$

where N_i and N_o are the inner and outer null point distances respectively.

Plugging the values of PSD =17, N_i = 0.66 and N_o = 12.09, we have the following:

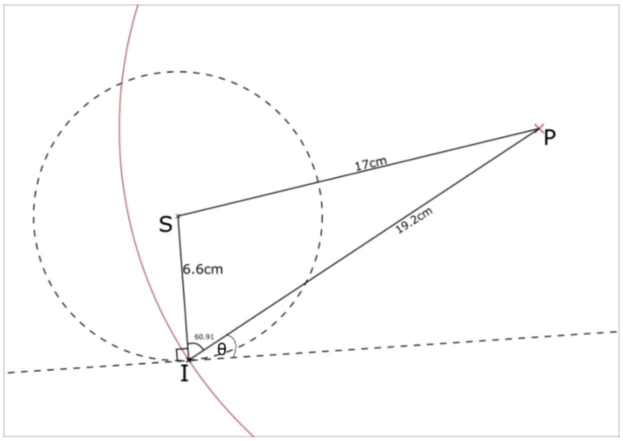
$$\text{Tonearm length} = \sqrt{17^2 + (6.6 \times 12.09)}$$
$$\text{Tonearm length} = \sqrt{289 + 79.794}$$
$$\text{Tonearm length} = \sqrt{368.794}$$
$$\text{Tonearm length} = 19.20401\ cm$$

Therefore, the effective tonearm length (shown as the radius of the red circle) is approximately 19.2cm.

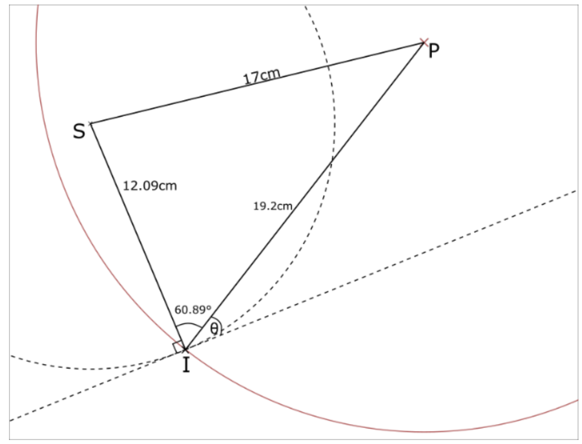
To verify the alignment angle, calculations will be done at both the inner and outer null points.

These will be done using trigonometry.

Shown below are diagrams for the cartridge's alignment at the null points:



Inner null point alignment angle



Outer null point alignment angle

In each diagram, the point 'I' is the actual null point that the stylus tip passes through; the dashed line is a tangent to the radius 'SI', and PI and PS are 19.2cm and 17cm respectively.

Using the cosine rule, the angle PIS is found.

In the inner null point case, the calculation would be as follows:

$$\text{Angle PIS} = \cos^{-1}\frac{19.2^2 + 6.6^2 - 17^2}{2 \times 19.2 \times 6.6}$$

$$\text{Angle PIS} = \cos^{-1} 0.486\dot{1}$$

$$\text{Angle PIS} = 60.9147°$$

In the outer null point case, the calculation would be as follows:

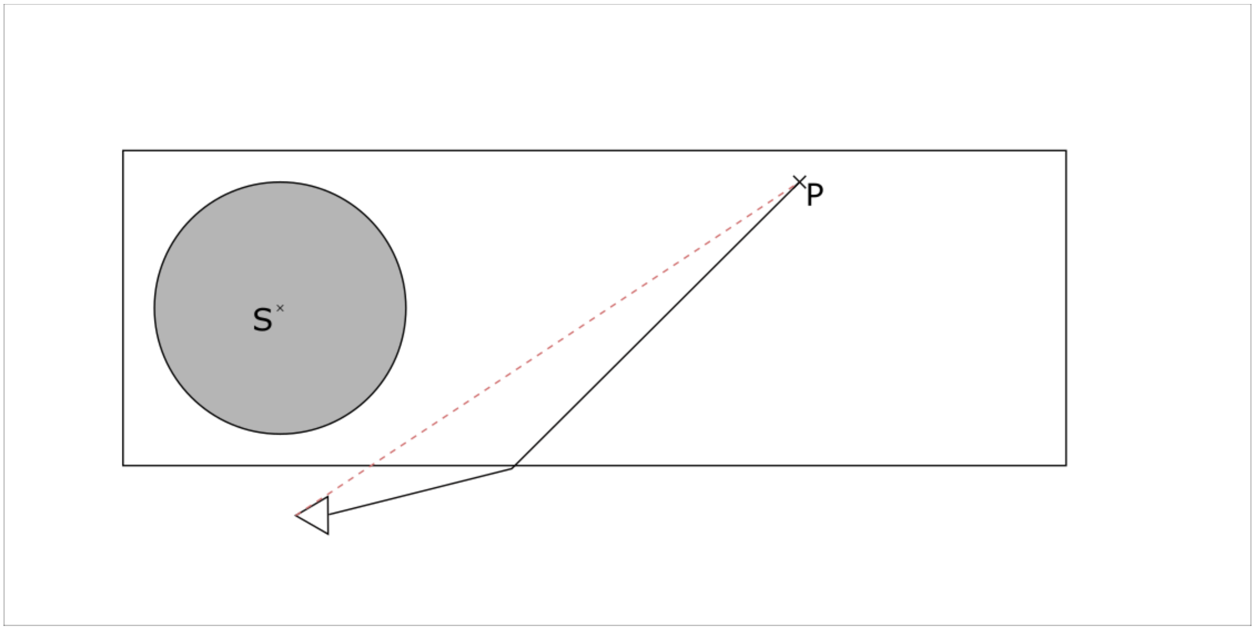
$$\text{Angle PIS} = \cos^{-1}\frac{19.2^2 + 12.09^2 - 17^2}{2 \times 19.2 \times 12.09}$$

$$\text{Angle PIS} = \cos^{-1} 0.4863870365$$

$$\text{Angle PIS} = 60.8966°$$

In both cases, the angle PIS is approximately 60.9 degrees, with the value deviating between each null point by less than 0.02 degrees. The calculated tonearm length is therefore within an acceptable margin of error.

As mentioned earlier, the cartridge can only be considered aligned when its angle of alignment is tangential to the null points, i.e., an angle of 90 degrees; however, the calculated value is 60.9 degrees. This is where the angle θ comes into consideration; this angle is the amount by which the cartridge must be offset in order to be properly aligned. The diagrams and calculations thus far have assumed that the stylus's alignment is at 0 degrees relative to the tonearm; if the tonearm is modified such that a bend is present to offset the cartridge's alignment by θ degrees, the cartridge will be perfectly aligned. Given that the calculated angle PIS is approximately 60.9, the offset angle θ is $90 - 60.9 = 29.1°$. Therefore, the final tonearm will appear more like the following diagram:



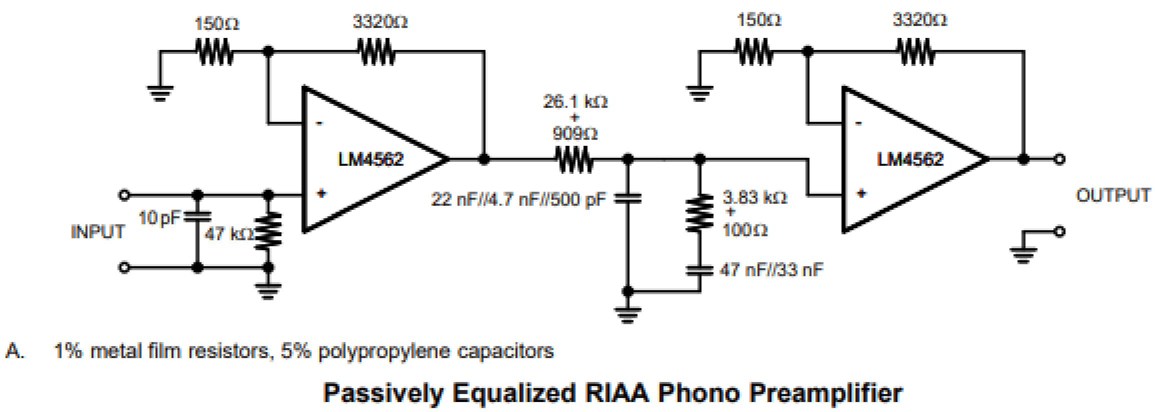
In this diagram, the tonearm is bent to accommodate the cartridge offset; the red dashed straight line depicts the original effective tonearm length of 19.2cm.

Circuitry

The circuitry for this project will consist of 3 main circuits:

- The preamplifier circuit
- The motor control circuit
- The power and recharge circuit

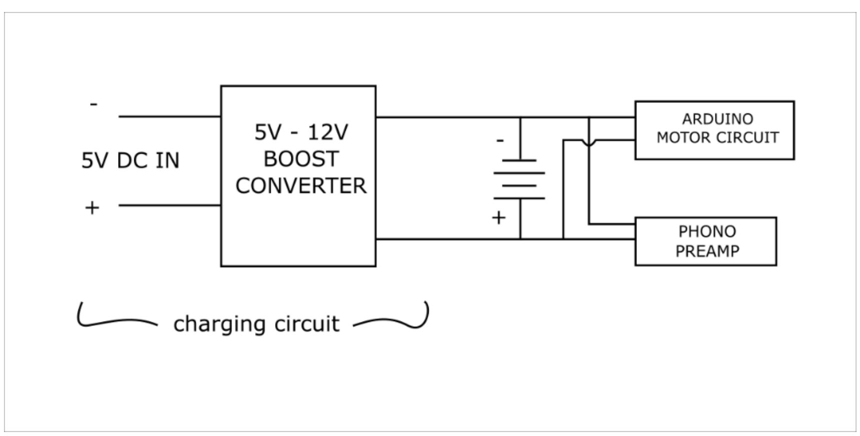
The preamplifier circuit will make use of the LM4562 operational amplifier IC. This particular op-amp IC was chosen because of its low total harmonic distortion + noise value (0.00003% according to its datasheet) as well as its use in hi-fidelity audio circuits in general (Texas Instruments, 2013). One possible preamplifier circuit implementation is shown below:



Preamplifier circuit diagram (Texas Instruments, 2013)

This implementation of a phono preamplifier uses resistors and passive equalisation to meet the standard RIAA curve discussed previously. This circuit will be implemented twice; one for each stereo channel. Each output will then be amplified using a stereo amplifier circuit with a potentiometer, to allow the user to control the listening volume.

Below is a simplified diagram for the overall wiring of the circuit to the power supply:

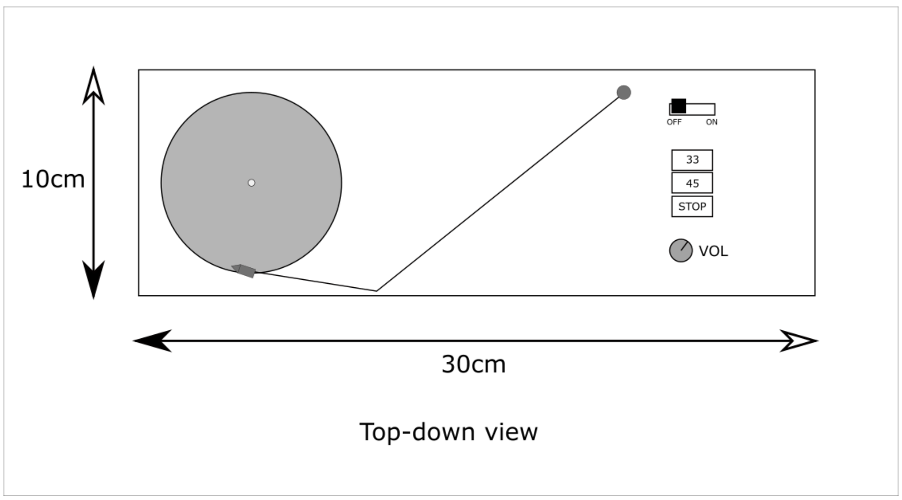


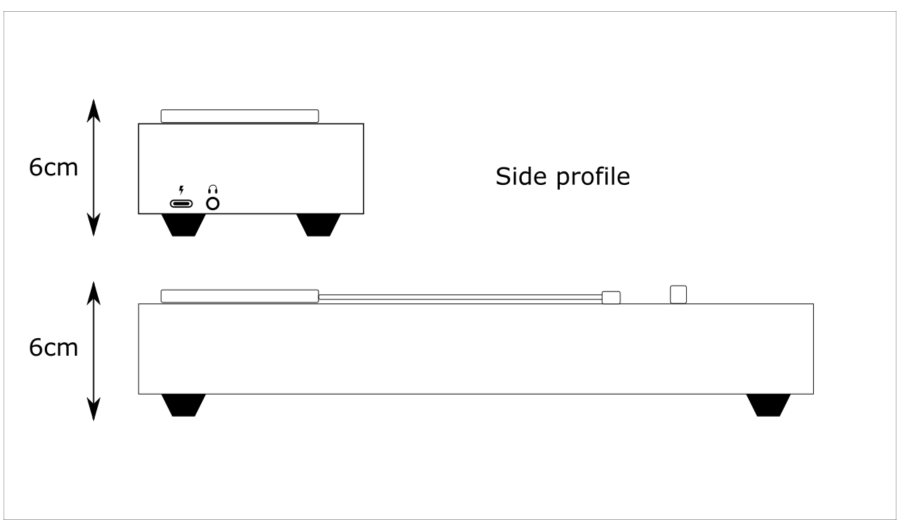
The battery featured in the above circuit is a series-connected array of 18650 Lithium-ion batteries, whose combined voltage will reach 12 volts. Lithium-ion batteries were selected because of their ability to be recharged, which is an essential factor in the portability of this record player. Additionally, it is to be noted that a virtual ground will be constructed by splitting the battery supply. This is done to ensure the op-amp circuit has its required dual supply in order to function properly.

The motor circuit consists of an Arduino Nano controlling a brushless DC motor using pulse-width modulation. This will allow it to control the speed of the motor more precisely, minimising irregular playback. A 7805 voltage regulator IC will be used to regulate the battery's 12V supply down to the Arduino's required 5 volts.

Anticipated Construction

The dimensions and user interface will be as shown in the following diagrams:





The user interface contains only 4 main elements, not including the tonearm.

The 33 and 45 buttons correspond to the motor rotating the platter at 33RPM and 45RPM respectively. The STOP button stops the motor from rotating, and the volume knob controls the output volume from the headphone jack shown in the side profile diagram. A type-C USB port is used to charge the device via a standard mobile phone charger or type-C USB cable.

The turntable itself, platter and case will be made of acrylic. The platter will be a 1-centimetre-thick disc of acrylic, and the walls of the case will be built with acrylic sheets. Acrylic was selected because of its price, availability and durability, as well as its ability to dampen vibrations when in contact with vinyl records (Fluance, 2021b).

Implementation

Preface

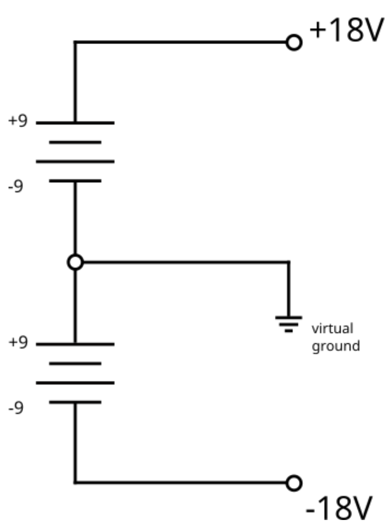
This section will outline the implementation of the turntable. The first iteration of the turntable's construction will be explored, and supplemented through the use of diagrams and photographs documenting the construction. The construction process will be explored via a breakdown into sections; each section will represent a component or aspect of the turntable's physical composition.

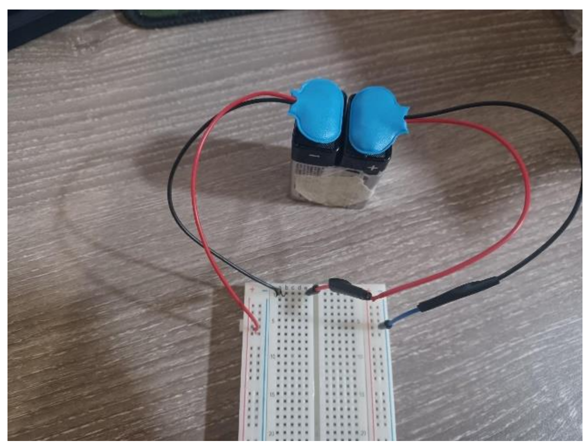
Additionally, the equipment used to test and benchmark the turntable build will be explored.

Preamplifier Circuit

The preamplifier circuit design proposed in the System Design Overview section was built and tested. To power the preamplifier circuit, a pair of 9-volt batteries were connected in series with the midpoint between the circuit serving as the virtual ground or reference voltage for the op-amp.

The batteries were connected in the following configuration:





The positive and negative 9 volts are connected to the power rails on either side of the breadboard. The virtual ground is between the batteries on the middle rail.

This virtual ground was then used as the reference voltage for the initially proposed preamplifier circuit, which when attempted failed to produce any output. The reason for this may be due to the complexity of the circuit as it was being built – it was built on a breadboard, with the connecting wires crowding together, making discerning the path of the circuit a challenge. In addition to this, some of the breadboard wires likely were not in contact with the breadboard rails. This may have caused a break in the circuit, thus preventing it from working.

To simplify the design, a different preamplifier circuit design was selected, once again from the datasheet. The diagram below illustrates this circuit:

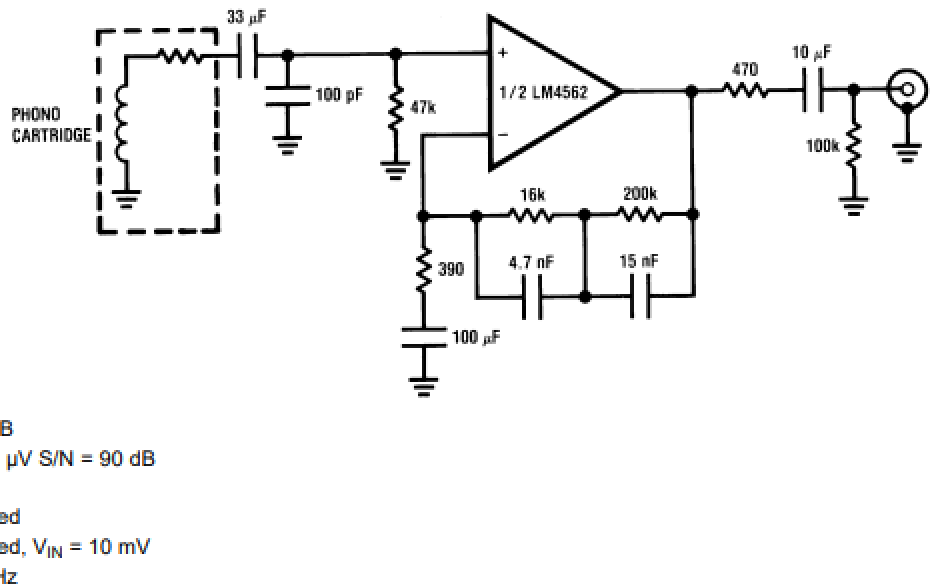
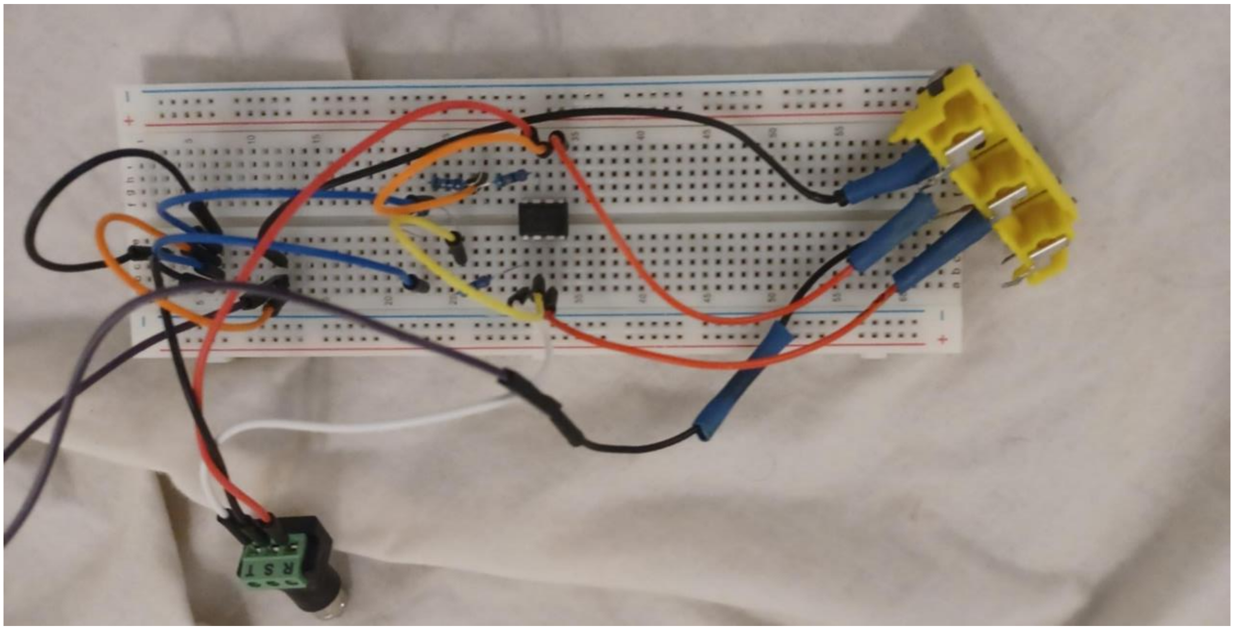


Figure 126. RIAA Preamp

RIAA Preamp circuit schematic; Texas Instruments (2013)

This design made use of only one op-amp per channel as opposed to the original design's two op-amps per channel. As a result, fewer IC chips were used since one single IC contains two op-amps, thus simplifying the circuit.

One feature to be noted in both phono preamplifier designs is the use of a 47kOhm load resistor at the amplifier's input, signifying that it is to be used with a Moving Magnet cartridge. Paul McGowan (2017) highlights the importance of a load resistor for a phono preamplifier, and specifies the values needed by a Moving Magnet cartridge as opposed to a Moving Coil cartridge. Each cartridge type has different output voltages, with 47kOhms typically being used to apply an appropriate load to match a Moving Magnet cartridge's output. This is to be taken into consideration since the cartridge used in the implementation is a Moving Magnet cartridge, explored in its own subsection in this implementation chapter.



Pictured above is the implemented preamplifier circuit with the LM4562 IC used in the first iteration of the turntable. This was tested used a Denon DP-30L to provide a driving signal; the RCA connectors received input from the turntable, and the TRS connector carried the output of the circuit to a pair of headphones.

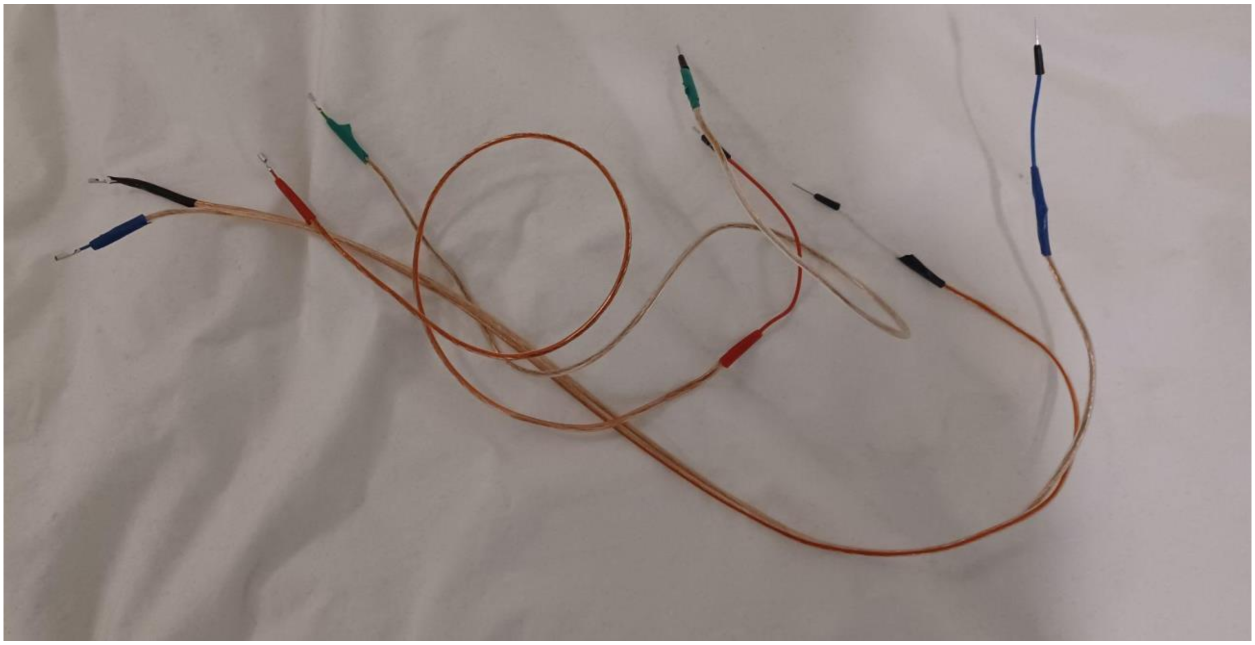
Cartridge

The cartridge selected to be used in this project was the Audio Technica AT-3600L moving magnet cartridge. This cartridge was selected for two main reasons – the first being its affordability, costing approximately 25 US Dollars (LP Gear, no date) and the second being its ubiquity and ease of acquisition. This makes the AT-3600L an ideal choice with which to build a prototype record player. Its moving magnet mechanism necessitates the use of a 47kOhm load resistor on the phono preamplifier circuit, as mentioned in the preamp subsection.

Below is an image of the cartridge itself, sourced from the LP Gear product page (no date):

Audio Technica AT3600L cartridge

In addition to the cartridge, custom headshell cables were soldered to lengths of speaker wire: this functioned as a tonearm cable to carry the signal from the cartridge to the preamp circuit. They are shown below:

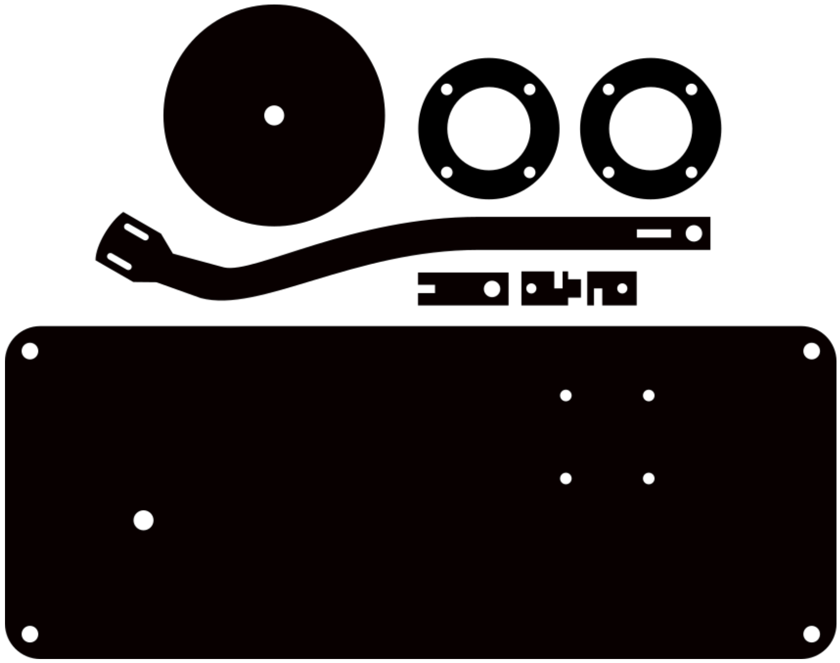


Body Construction & Counterweight Mechanism

The body of the record player is made from acrylic, which was precisely laser-cut to make the necessary parts for the player's physical mechanisms. Acrylic as a material was selected because of its ability to be laser-cut into the desired shape, as well as its sound reduction qualities as noted by Harun et al (2012). This property of acrylic to dampen vibration makes it a prime material to mitigate any unnecessary vibration caused by the motor or any nearby vibration source which would affect the sound reproduction by the stylus.

Expanding more on the ability to laser-cut acrylic, a schematic was designed to be cut out from acrylic: these cut parts would be assembled into the body of the record player which would carry the circuitry, tonearm array and motor, and also serve as the tonearm tracking force adjustment mechanism.

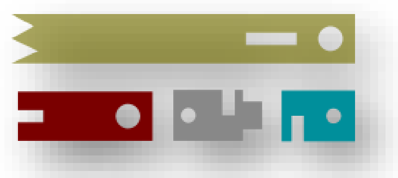
Below is the laser-cutting schematic, created as a .svg vector graphics file but rendered in this report as an image (the schematic has since been updated; pictured is the first iteration of the turntable's acrylic laser-cutting schematic):

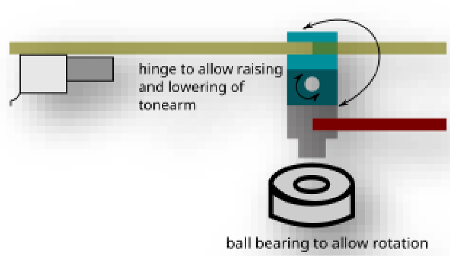


Record Player Schematic, first iteration

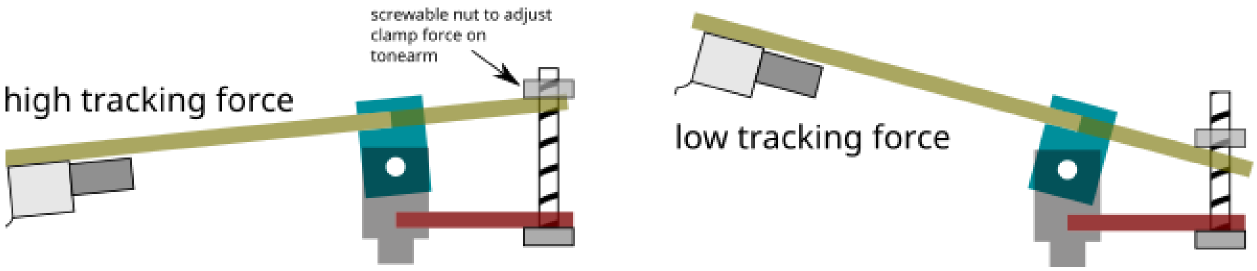
The pictured schematic diagram features the following parts in clockwise, starting from the top-left: the platter, which is attached to the motor and upon which the record is meant to be placed; the ball bearing brace for the tonearm pivot point; the tonearm itself featured in a typical S-shape; the base plate for the record player upon which the other parts such as the tonearm and motor would be mounted. The three small parts in the middle are the tonearm mechanism.

The diagrams below illustrate the functioning of the tonearm's raising and lowering, as well as the operation of the tracking force mechanism.



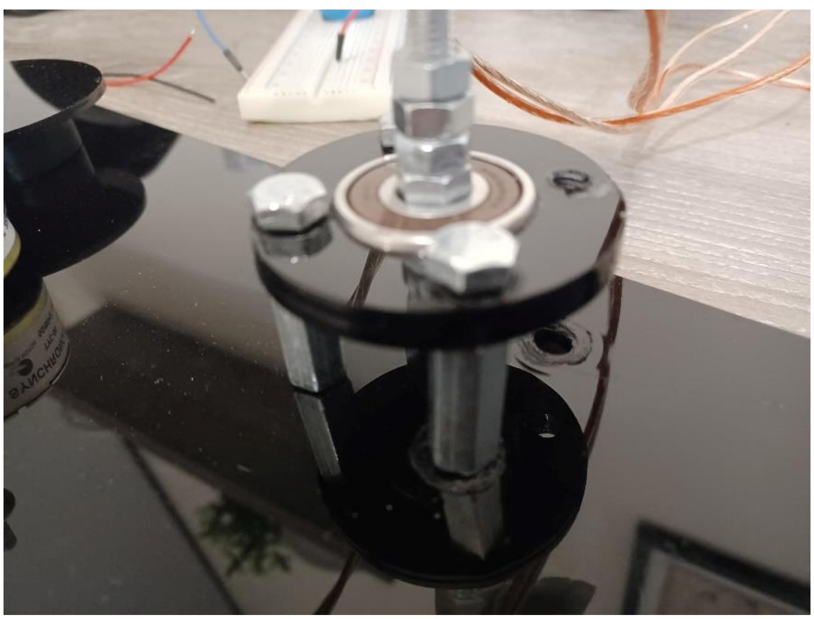


Each part of the mechanism is highlighted in a different colour; the yellow represents the tonearm, the grey and blue represent the parts of the tonearm's raising/lowering hinge, and the red is the mounting brace that enables the weight to be adjusted. Note the hole on the far-right end of the tonearm and how it is mirrored in the red piece. Through this hole, a bolt is threaded and secured, and a nut on the opposite is screwed on, on top of the tonearm. Thus, the red and yellow parts are clamped in a loose vice-like grip, and their distance from each other is determined by how far down the bolt the nut is screwed. Further illustration is provided in the following diagram, which illustrates the high tracking force and low tracking force positions of the nut-bolt weight adjustment mechanism.
The bottom part of the grey piece that juts out is inserted into the inner hole of the ball bearing and fixed there, allowing the entire tonearm array to swivel side-to-side, allowing the tonearm to trace its path down the record from the outer rim to the centre.



As pictured above, the higher up the bolt the nut is threaded, the more room there is for the stylus to dip forward; conversely, the tighter the nut is threaded down the bolt, the less freedom there is for the stylus to dip down and it is thus forced upward, reducing its effective downward force or weight. This simple nut-bolt mechanism thereby effectively acts as a counterweight. This mechanism was devised partly due to the inconvenience caused by conventional counterweights; they work via micromovements along the tonearm to fine-tune the weight similar to a seesaw. If this balance or positioning of the counterweight is offset, the tracking force will have to be recalibrated, whereas with this mechanism, the nut position along the bolt is not likely to be affected by smaller movements.

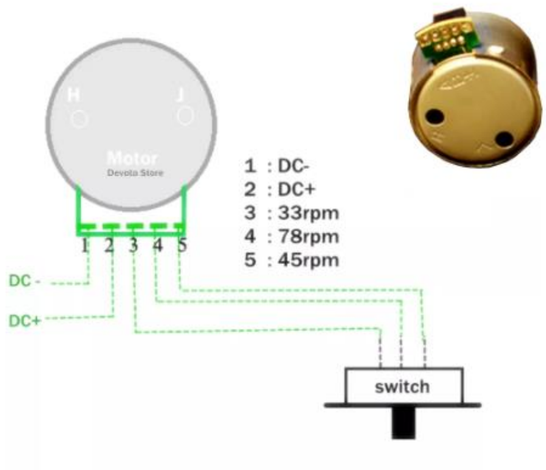
The pivot braces were constructed after measuring the outer and inner diameter of the ball bearings procured for the project's use; the ball bearing thus fit the brace, and the entire array was mounted onto the four holes on the base plate. Note the four corresponding holes in the braces.



Pictured above is the ball bearing fitted into the braces, which are then mounted to the base plate. The long nuts used to affix the braces raise the entire ball bearing array up, allowing any overhang of the tonearm array that juts through below the ball bearing to rotate free of obstruction.

Motor circuit

The motor circuit initially aimed to make use of an EG530SD-3F motor. Below is the pinout diagram for the motor (AliExpress, no date).



Upon first operating the motor, it had a high RPM output estimated to be in the several thousands, but further use of the motor revealed that it lacked the necessary torque to start rotating while bearing the weight of the platter and record.

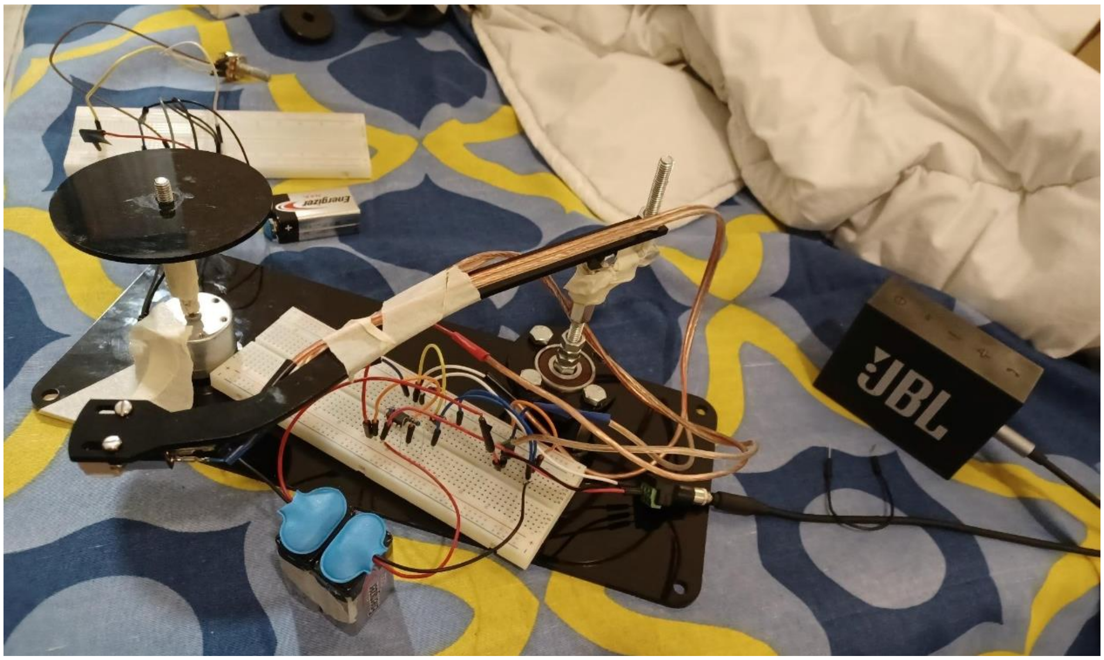
This then led to the acquisition of the second motor, the Chancs TYC-50 which is a higher-torque but lower RPM motor specified to be 30 RPM (Amazon, no date).

To the right is an image of the TYC-50 motor. Having resolved the issue of torque, the RPM also fit with a 10-percent margin of error for the requisite 33 rotations per minute specified earlier. This made the TYC-50 the best possible choice for this first iteration of the record player's design. The platter is mounted onto the motor shaft, and the motor is then placed in the appropriate position on the acrylic base plate of the record player.

The motor is finally powered by a 9-volt battery separately from the phono preamplifier batteries.

Final record player prototype

With the build complete, the final record player prototype is visible below:



The audio here is played out through the speaker on the right of the image. The separate battery sets for the phono preamp and the motor are also visible.

Testing, Evaluation, Results

Preface

This chapter explores the various testing methods used to evaluate the record player. This will cover both intended testing methods that ultimately failed to be conducted and the methods that were conducted to evaluate the record player.

Phono Preamp testing

The first test conceived was to measure the Total Harmonic Distortion of the phono preamplifier. Shmilovitz (2005) notes down two possible definitions of Total Harmonic Distortion The definition used for the purposes of this project is the second definition he notes; THD or Total Harmonic Distortion is “the harmonic content of a waveform is compared to the waveform’s rms value”, RMS standing for Root Mean Square (the square root of the mean of the squares of the wave’s amplitudes).

This measurement was to be done using either an oscilloscope or a Total Harmonic Distortion multimeter, which allow for precise THD values to be recorded. This THD value would be recorded for signals of the following frequencies: 20Hz, 50Hz, 100Hz, 200Hz, 500Hz, 1kHz, 5kHz, 10kHz, 15kHz, 20kHz. These readings would be repeatedly taken over multiple rounds to ensure the values are not anomalous, and the total harmonic distortion would therefore be established using this data. The various frequencies at which readings are taken are meant to evenly be distributed across the frequency spectrum. This ensures that whether the reading at a specific frequency was higher or lower than at other frequencies, it would be recorded and taken into account when calculating the final THD of the preamplifier circuit.

Due to time constraints and the lack of availability of an oscilloscope with the sufficient resolution to measure fine enough levels of the THD, this test was not conducted. In its stead, the preamplifier circuit was listened to by human ears and rated subjectively and arbitrarily based on user feedback. The results acquired were as follows:

The phono preamplifier circuit exhibited significant amounts of distortion in the signal. Though the source audio signal itself was discernible, the noise ultimately distorted the signal too greatly for it to be considered clean enough for consumer use.

This distortion may have been due to the battery configuration used to power the op-amp IC. As noted in the article Virtual Ground Circuits (2015), using two batteries in such a simple configuration can result in exacerbated DC offset at the output if one battery discharges faster than the other. With no use of buffers or ways to stabilise the power supply, this discrepancy in the powering of the op-amp causes it to function poorly and distort the output signal greatly as a result. Another issue may have been due to naturally occurring electromagnetic interference; because the cables and op-amp were left unshielded, ambient electromagnetic waves may have interfered with the signal causing more distortion.

Motor Testing

Testing the motor of the record player would be done to ensure two things: the speed of rotation, and how consistent that rotation is. One method with which this rotation speed could be measured and fine-tuned is through the use of a stroboscope-like mechanism.

Strobe Disc (Hudson HiFi, no date)

Featured above is the Strobe Disc from Hudson HiFi, which employs the use of the stroboscope effect via mains electricity-powered lights. Given that mains electricity is fixed at either 50Hz or 60Hz, the appropriate markings on the edge of the disc should therefore appear to stay still via the stroboscope effect If the record player platter is turning at the right speed.

The Strobe Disc was ultimately never acquired, which meant that it could not have been used to test the rotation speed of the motor. The only testing done as a result of this was to use a multimeter to see if the motor was receiving consistent power; it was assumed that given the motor was given a consistent voltage supply, the output RPM would therefore stay consistent. Following that rationale, what was conducted was the following testing method:

A new 9-volt battery was used to power the motor continually for fixed periods of time at regular intervals. The battery's voltage is measured in the interval between periods of being powered, and the results are compiled in the following table:

Time in minutes	0	2	4	6	8
Voltage across battery	9.04	9.01	8.97	8.95	8.90

The data collected form testing shows that for shorter periods of time, the overall voltage drop is within a margin of 0.1 volts. From this, it can be inferred that the rotation speed of the motor remained largely unaffected or otherwise indiscernible.

Counterweight Mechanism

The testing of the counterweight mechanism is perhaps the simplest in this project – using a tracking force gauge (which is essentially a fine mass scale with a degree of accuracy to the nearest 10 milligrams) the nut is threaded up and down the bolt, and its weight on the tracking force gauge recorded.

What inhibited the testing of the counterweight mechanism was a mismeasurement while creating the laser-cutting schematic for the counterweight mechanism. As a result of mismatched size, the base of the tonearm could not steadily fit onto the ball bearing platform; this caused an irregularity in the position of the tonearm, making its tracking weight constantly vary as a result of improper balance. The test could therefore not be reliably conducted.

Conclusion

This report on the record player prototype covered the background and motivation for this project, the objectives the project undertaking was required to meet, the design, implementation and finally the testing of this prototype. This conclusion to the report serves to summarise the course of the project's undertaking, as well as reflect on the possibility of future designs as well as improvements to the methodology employed through the building of this prototype.

With regards to future designs and advancements on this current iteration, the laser cutting schematic may definitely be improved. Mismeasurements as well as areas of the turntable where parts could be supported and simplified more have been made note of.

In addition to this, the noise and distortion in the phono preamplifier circuit can be remedied via buffering the power supply and properly rectifying the positive and negative power rails; this will improve grounding in the circuit, leading to a lower total harmonic distortion overall. Additionally, a printed circuit board (PCB) could be designed and the circuit components mounted onto it, making the preamp circuit more compact.

Though this project may have been obstructed at several points, the successful production of a working prototype proves that the requirements can be met; the way in which they are met can be refined through studying the methodology of this project's first iteration and noting its mistakes and successes.

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Appendix

Middlesex University Dubai

Research Ethics Screening Form for Students

Middlesex University is concerned with protecting the rights, health, safety, dignity, and privacy of its research participants. It is also concerned with protecting the health, safety, rights, and academic freedom of its students and with safeguarding its own reputation for conducting high quality, ethical research.

This Research Ethics Screening Form will enable students to self-assess and determine whether the research requires ethical review and approval before commencing the study.

Student Name: M00695912		Email:hm945@live.mdx.ac.uk
	Research project title: A Portable Cost-Effective Record Player Design Without Compromising Quality	
	Programme of study/module: BEng Computer Systems Engineering, CST3590	
Supervisor Name:Dr. Sameer Kishore		Email:s.kishore@mdx.ac.ae

Please answer the following questions to determine whether your proposed activity requires ethical review and approval		
1. Will the research 'involve human participants,' with or without their knowledge or consent? *('Human participants' is a wide phrase including, but not limited to, observation, questionnaires, interviews (online and hard-copy), focus groups, social media platforms, etc., visual recordings (e.g., photos, video), audio recordings (e.g., digital, tape), or other human data/materials (e.g., blood, saliva, tissues or other human samples). It also includes yourself in cases where you, as the researcher, are planning to conduct research on yourself or to be involved in the same way as other participants in the project)*	☐ Yes	☒ No
2. Will the research involve animals or animal parts?	☐ Yes	☒ No
3. Will the research involve any activity that might cause damage or present a significant risk to society? *(e.g., to precious artefacts or the environment)*	☐ Yes	☒ No
4. Is the research likely to put you or others to any risks other than considered everyday risks? *(e.g., risk of physical or psychological harm, engagement in illegal activities, working in a foreign country, travel risks, working alone, breaching security systems or searching the internet for data about highly sensitive topics such as sexual abuse, terrorism, etc.)*	☐ Yes	☒ No
5. Will the research include digital information/data from the internet, social media platforms, Apps, or smart devices with or without users' knowledge or consent, and/or could it lead to users being identified?	☐ Yes	☒ No
6. Will the research require approval to access any data? *(e.g., access data through individuals and/or data through an external organisation(s))*	☐ Yes	☒ No
7. Could anyone involved in the research have a potential conflict of interest or lack of impartiality?	☐ Yes	☒ No
8. Will your project involve working with any substances and/or equipment that may be considered hazardous to you or others?	☐ Yes	☒ No

9. Will the research involve discussion of sensitive topics? *(e.g., sexual activity, drug use, national security etc.)*	☐ Yes	☒ No
10. Will the outputs from your research (e.g., products, reports, publications, etc.) likely cause any harm to you, others, or to society; or have legal issues?	☐ Yes	☒ No

If you have answered 'Yes' to ANY of the above questions, your application requires ethical review and approval prior to commencing your research. Please complete the 'Application for Ethical Approval for Research Projects for Students' form

If you have answered 'No' to ALL of the above questions, your application may not require ethical review and approval before commencing your research. Your research supervisor will confirm this below.

Student Signature: Date: 13th December 2021

To be completed by the supervisor:

Based on the details provided in the self-assesment form, I confirm that:	
The study does not require ethical review and approval	☑
The study requires ethical review and approval	☐

Superivsor Signature: Kishore …………………… Date: 30/12/2021