Full Play: A Modern Record Player

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24-671: Electro-Mechanical Systems Design Senior Capstone

Mechanical Engineering
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Problem Description

Vinyl turntables are an antiquated medium for playing music. They lack the usability of newer technologies, specifically modern digital media. The album is split onto two sides of the record, forcing users to manually flip the record to complete the experience. Our goal is to create a mechatronic system to solve this problem.

Despite being an old technology, there has been a massive resurgence in the popularity of turntables over the last decade, as shown in Figure 1. Turntables have now become a must have for any devoted music aficionado.

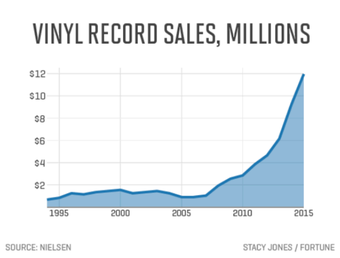


Figure 1 - Historical Vinyl Record Sales[1]

Customer Needs & Specs

In order to obtain our customer needs, we sent out and conducted a survey on several CMU students and WRCT employees – a Carnegie Mellon radio station. After reviewing our market research and survey results, we developed the following customer requirements and needs:

CUSTOMER REQUIREMENTS:

1. The system must not scratch the record
2. The record must not be damaged during the flip
3. It should be easy to place the record into the turntable
4. The system must not be too large
5. Flip should not take too long
6. The system must be aesthetically pleasing and have a classy finish

TARGET SPECFICATIONS:

We determined some marginal and ideal specifications our final design should meet shown in Table 1 below.

Metric #	Need #	Metric	Importance	Units	Marginal Value	Ideal Value
1	4	Unit size	High	Inches	20” x 20” x 20”	16” x 16” x 16”
2	5	Flip time	High	Seconds	20 s	5 s
3	6	Aesthetic Design	Medium	Subjective		
4	3	Time taken to place Record	Medium	Seconds	10 s	2 s
5	1, 2	Visible or Audible damage to Record	Highest	# of scratches	0	0

Table 1 - Target Specifications

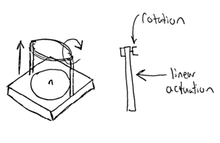
Concept Generation & Selection

We broke down out project into 6 subsystems and designed various methods to solve each problem. We then came up with the following combinations of concepts shown below. We analyzed our concepts with respect to certain metrics i.e. safety, aesthetic, size, etc. to arrive at our concept design.

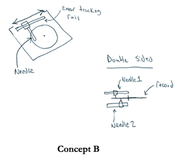
SUB-FUNCTIONS					
Record Spinning	Needle	Flip	Microcontroller	Actuators	Position Tracking
Direct Drive	Rotational	Lift and Flip	Arduino	Pneumatic	Line Tracker
Belt Driven	Linear Tracking	In Plane	Rasberry Pi	Servos	Camera / Computer Vision
Edge Drive		Double Tracking	Photon	Stepper Motors	Motor Encoders

Concept	Color
A	
B	
C	

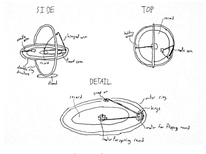
Table 2 - Combinations of Concepts



Concept A



Concept B



Concept C

Concept Description

OVERALL DESIGN

Our concept design features the record suspended in the air by two rings, similar to a globe.

A. The first ring is vertical and attaches to a sturdy base at the bottom.

B. The second ring is horizontal and attaches halfway up the first ring.

The record is held in plane with this horizontal ring by two arms that snap together, fixing it in place. These arms can flip, allowing the record to flip in plane so that the second side can be played. The needle attaches to the horizontal ring and swings out over the record. This idea provides a unique and aesthetic design and a simple and quick flip.

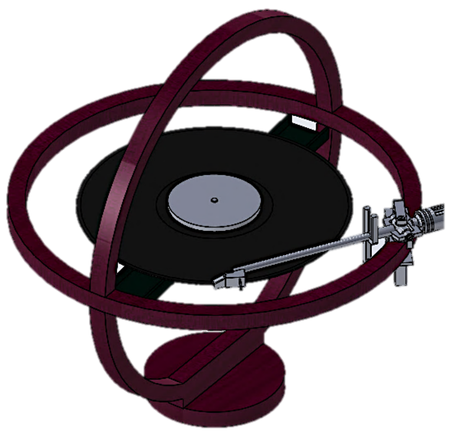


Figure 2 – Isometric View of CAD Model

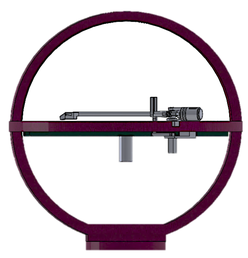


Figure 3 – Side View of CAD Model

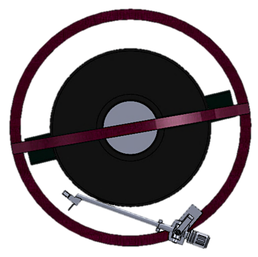


Figure 4 – Top View of CAD Model

NEEDLE SUB-ASSEMBLY

Our Needle assembly utilizes of a DC motor with encoder and a servo. The mechanism consists of CNC and 3D Printed parts to link up the motors and needles.

- The DC motor serves to measure the angular position of the needle in order to detect that the needle is at the end of the record and sends a signal to our code to move the needle and flip the record
- The servo is used to raise and lower the needle to prevent damage to the record while placing and removing

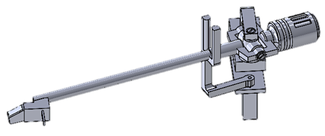


Figure 5 – Isometric View of Needle Assembly

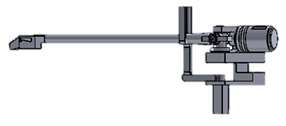


Figure 5 – Side View of Needle Assembly

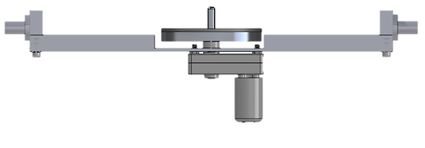
OUR PAST PROTOTYPES











Results and Analysis

We conducted various tests on our final design and prior prototypes and iterations of the turntable. Two of the imperative tests regarding the functionality of the turntable were the levelness of the record and the spinning speed.

LEVELNESS OF RECORD

The levelness of the record is significant in our design particularly after it has been flipped as it will impact the audio quality of our record player and it may also cause scratches on the record impacting it’s safety. Figure 6 illustrates the data taken from a digital level.

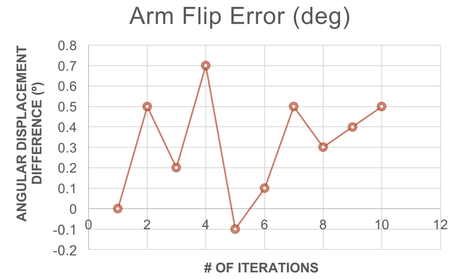


Figure 6 – Digital Level Measurement Data

SPINNING SPEED

We tested our spinning speed by utilizing 3 methods:

- **Encoders:** Our motors had built in encoders in order for us to determine the number of ticks per second and determine speed
- **Tachometer:** We used a tachometer to ensure that we are consistently moving at 33 rpm
- **PID:** We implemented a PID controller to determine our settling time and ensure we are consistently at 33 rpm even when noise is added to the system.

Final Prototype Testing

DEFLECTION ANALYSIS

We ran a simulations on SolidWorks and measured the deflection of the record while spinning and determined the value was negligible to impact the audio quality

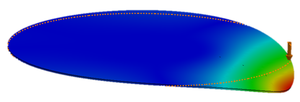


Figure 7 – SolidWorks Simulation of Deflection

Distance from Center (in)	Simulation Deflection (in)
6	0.00307
5	0.00135
4	0.00046
3	0.00008
2	0

Table 3 - Record Deflection Measurements and Analysis

USER SURVEY

We conducted a user survey to determine the time taken for the flip and needle actuation to determine the ‘ideal’ value to set the time taken to actuate the needle and flip the record to maximize the aesthetic and ’wow’ factor of the turntable.

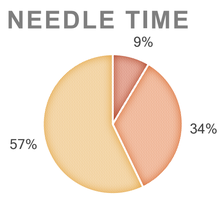


Figure 8 – User Survey for Needle Time

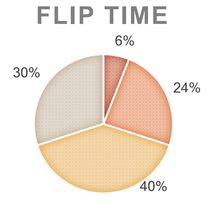


Figure 9 – User Survey for Flip Time

Conclusion

Our final prototype managed to accomplish all the tasks and fulfil the customer requirements that were set. Our turntable effectively and reliably plays both sides of the record without scratching the record. The audio quality of the record player is also reasonable.

Our turntable attempts to beat our competitors by bringing in new users into the Vinyl world by providing them a luxurious and tech-savvy device at an affordable price.