Automatic Record Flipper

ECE 445

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1. Introduction

1.1 Problem

Vinyl records have experienced a resurgence in popularity due to their rich, warm sound quality, physical ownership appeal, and artistic presentation. The global vinyl record industry, valued at $1.5 billion, is projected to grow by $900 million by 2030, demonstrating sustained consumer interest. However, despite the renewed demand, the inconvenience of manually flipping records disrupts the listening experience. While some enthusiasts consider flipping records a nostalgic part of vinyl culture, many listeners—especially those new to the format—find it inconvenient.

A 12-inch record can hold about 22 minutes of music per side, and a 7-inch single spinning at 33 RPM can only hold 6 minutes of music per side. This means listeners must frequently interrupt their experience to manually flip the record, which is particularly frustrating for shorter singles. Historically, automatic record-flipping mechanisms existed but were bulky, unreliable, and are now discontinued. Modern record players lack any equivalent automated solution, leaving users with an outdated and tedious manual process. This project aims to address this gap in modern record player functionality by designing an automatic record flipper that retains the analog charm of vinyl while enhancing convenience, making the experience more accessible and enjoyable without sacrificing the physical engagement of handling records between albums or singles.

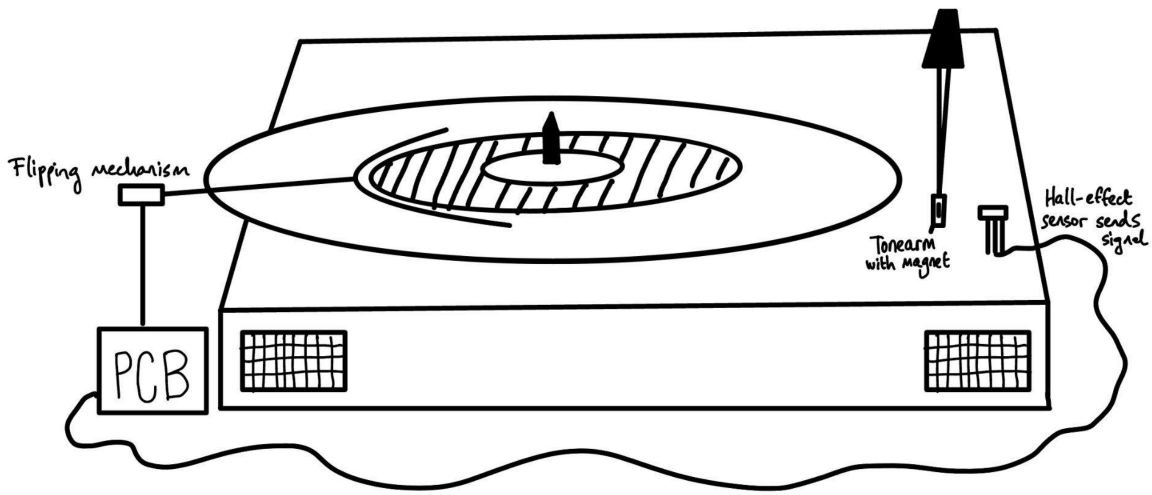
1.2 Solution

The proposed solution is an automatic vinyl record flipper that eliminates the need for manual flipping while maintaining the authentic experience of vinyl playback. The system will detect when the side of the record has finished playing and then automatically lift, flip, and replace the record onto the turntable within a controlled time frame. This allows seamless playback of the B-side without user intervention.

The device will use a Hall effect sensor positioned near the tonearm's rest position to detect when the tonearm (with a small magnet attached to it) has returned, indicating the record is ready to be flipped. Once the tonearm reaches this position, the sensor will send a signal to the microcontroller, triggering the flipping mechanism. The flipping process will be handled by three servo motors. The clamp servo moves in horizontally to grip the record with a horseshoe-shaped clamp. The lift servo raises the record off the platter, and the flip servo rotates the record 180° before the lift and clamp servos place it back down. Our implementation will be compatible with 7-inch records that play at 33 RPM.

The entire flipping sequence will be timed to complete within 20 seconds, ensuring the tonearm can be repositioned onto the record without interference. A custom PCB will integrate the microcontroller with necessary motor drivers and sensor inputs to synchronize movement and provide stable operation. This system provides an automated, reliable, and non-intrusive solution for vinyl enthusiasts who want to enjoy uninterrupted listening while preserving the physical charm of record handling when changing albums or singles.

1.3 Visual Aid



1.4 High Level Requirements

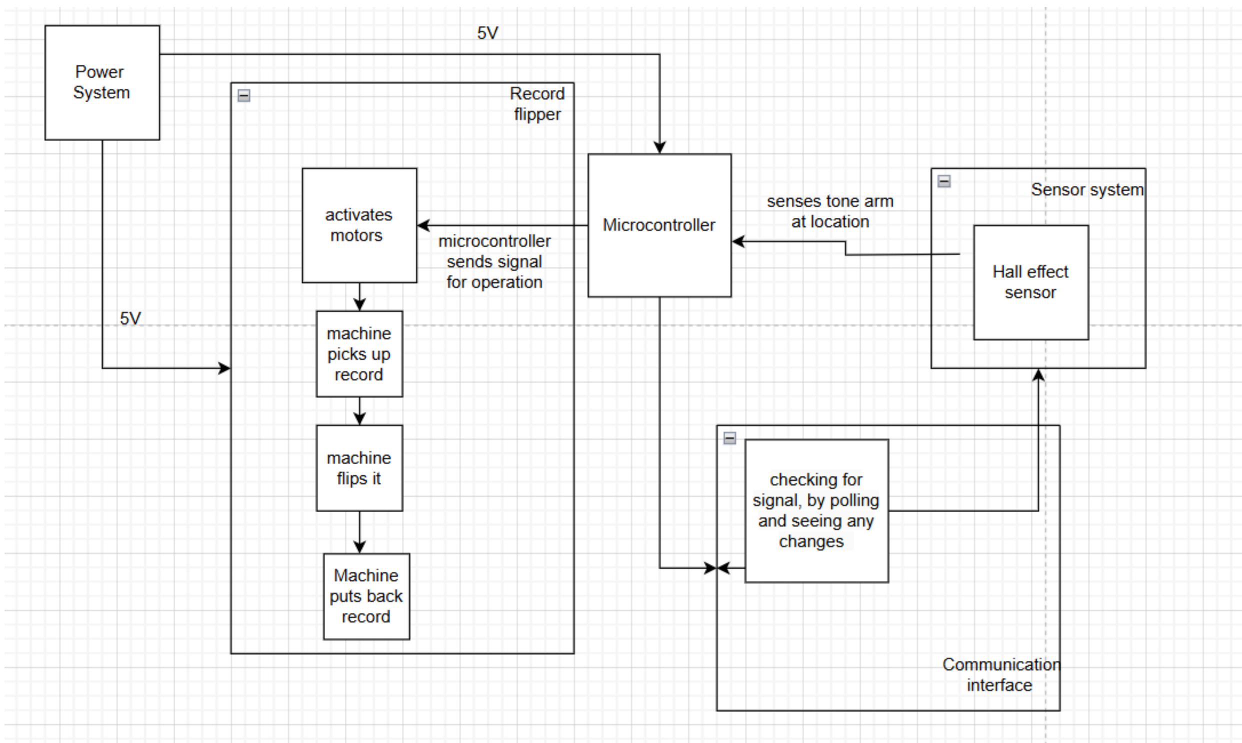
- **Flipping Accuracy and Reliability:** The flipper must successfully grip, lift, rotate, and place back the record with a success rate of at least 95% over 50 consecutive flips. Any misalignment, dropping, or improper placement of the record must be minimized to ensure consistent playback.

- **Flipping Time Constraint:** The entire flipping process, from detecting the tonearm at rest to placing the flipped record back on the turntable, must be completed within 20 seconds to ensure minimal disruption to the listening experience. The tonearm must be able to return to the record without interference immediately after this time frame.

- **Tonearm Detection and Triggering Precision:** The Hall effect sensor must correctly detect when the tonearm has reached its resting position and trigger the flipping mechanism with at least 98% accuracy. False positives or negatives must be minimized to prevent premature or failed flips.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 Power System

This subsystem houses the power system that will power the entire system in order to function properly. The power system will be able to power the entire operation of the project without causing harm (i.e. short or burn any components during operation). The power system will be powering the motors used to flip the vinyl record, the microcontroller which controls the entire operation of the project, and the Hall effect sensor which will scan for the moment to begin operation. The subsystem will deliver a constant DC voltage to the entire system at a voltage level compatible with all other subsystems whilst not causing any damage.

2.2.2 Record flipper system

This subsystem will handle the flipping of the vinyl record, in which it will do three steps. The system will first receive a signal from the microcontroller to begin operation. Once it receives a signal, it will use a grabber attached to motors which will grab onto the record, completing the first phase of operation. In the second phase of operation, the flipper system will then move up and flip the record, out of range from any obstruction which may impede the process. The flipper will then put back the record in the correct position, using Servo motors. Once the record is flipped and is in the proper position, the record player will automatically begin playing the vinyl record via the pre-installed auto-stop and auto-start functions.

2.2.3 Sensor system

This subsystem will consist of a Hall effect sensor near the location of the tone arm's resting position when the tone arm is done reading the vinyl. It will be situated right above the tone arm and will be able to detect when the tone arm is finished playing via a magnet that will be attached to the top of the tone arm. When the sensor detects that the tone arm is in its resting position, it will emit a voltage signal to the microcontroller, telling it the tone arm is in its resting position and that the record flipper system is ready to be activated. The flipper will activate itself and flip the vinyl after receiving the signal from the microcontroller.

2.2.4 Microcontroller system

This subsystem will be the brains of the entire project's operation, it will receive and send signals to each of the components to instruct them when to begin operation and know when a component has finished operation. The microcontroller will act as the method of communication between each component and will be able to make the component operation transition smoothly. The operation of the project would follow a linear order, where the Hall effect sensor attached to the tone arm will send a signal to the microcontroller, which will then be transmitted to the vinyl record flipper to begin operation. Once the vinyl record player has finished operation, the auto-start function built into the record player will automatically begin playing the other side of the vinyl record.

2.3 Subsystem Requirements

2.3.1 Power System

The Power system will be sending out to the entire system a nominal voltage of 5V with a variance of ± 0.1V. How this will contribute to the design is it will be the driver that our system needs in order to function. From being sent out to our microcontroller that will be outputting power to it. We also are outputting power to the motors that will also be needing a voltage that is around 5V as well. For this subsystem, we will be using a **linear DC voltage regulator** from the lab kits provided which will produce enough voltage for the entire project's system to function correctly.

2.3.2 Record flipper system

This system's importance is it will contribute to the flipping accuracy and also flipping time constraint of our design. The system will house three (**Tower Pro MG996**) servo motors that will each need to draw a voltage of about 4.8-6V which our system's power system will provide. We will also need to make sure that the clamp will provide enough force and support to lift and hold our vinyl record, which for reference the vinyl will weigh about 120-150 grams. We also need to make sure the force of the clamp will not damage the record, so as not exceeding the 150 grams of force. From looking at the datasheet of the servo motor, we can determine that the motors do indeed have enough power (9.4 kg-cm torque at 4.8V) to handle flipping the vinyl record and complete the intended operation for the record flipper subsystem.

2.3.3 Sensor system

This subsystem will consist of a sensor that will be located right above the tone arm and will be able to detect when the tone arm is at its rest position to signal the flipper to begin operation. From the data sheet, it is apparent that the sensor **PK87881** contains three pins, one for V_{DD} (supply voltage), one for the GND (ground), and lastly, one for the V_{OUT} (which is for the output voltage). The sensor system will be powered by the power system, receiving the nominal voltage of 5V which will be attached to the V_{DD} pin of the sensor. Once the sensor has received a strong enough magnetic signal (around 150 Gauss), the output voltage (V_{OUT}) will match that of the input voltage (V_{DD}). We plan on attaching a disc shaped $\frac{3}{8}$ $inch$ diameter, $\frac{1}{4} inch$ thick grade N52 magnet to the tone arm, which will act as the signal emitter for the Hall effect sensor to know when the tone arm is at its resting position. The magnet will emit a magnetic field of 151 Gauss when it is within $\sim\ 0.62\ inches$ from the sensor, and anything below that distance will result in a higher magnetic field, meaning that the sensor will be activated. We do not have to worry about any higher magnetic field, as the sensor does not have a maximum operating limit of magnetic field per the datasheet. For the magnet, we propose to use the PO - P1315208 Bob Wallace, 3/8 x 1/4 Neodymium Magnet (available in the ECEB workshop store) which should have a weight of approximately 0.01 lbs, light enough to be attached to the tone arm without hindering its performance. In the end, we hope to have the Hall effect sensor receive a signal from the tone arm's magnet which will then send a signal to the microcontroller, telling it that the tone arm is at its resting position and to begin the operation for the record flipper since the tone arm will no longer be in the way of the flipper's operation, not hindering it.

2.3.4 Microcontroller system

The microcontroller that we will be using is the **ATmega328P** which will be powered through the system's power system, with the microcontroller having an operating voltage of 2.7V to 5.5V. It will also need to be able to handle response times quickly and efficiently, we expect the moment our tone arm gets to position, the signal will be received and sent out in our system in under 2 seconds.

2.4 Tolerance Analysis

A major risk in our automatic flipping mechanism is accurate reseating of the flipped record onto the platter spindle (the small metal spike that fits in the central hole of the record). If the record's centre hole is not aligned with the spindle, the record would not be ready for playback after being flipped as it would not be positioned on the platter, resulting in possible damage to the record player stylus and record itself.

The spindle diameter is $\mathbf{d_s = 7.143mm}$ with ISO F7 tolerance (meaning it will remain within a few hundredths of a millimetre) and the 7-inch record hole diameter is $\mathbf{d_h = 7.3mm \pm 0.025mm}$. Under nominal conditions (using the mid-value of the record hole), the nominal clearance between the record hole and the spindle is

$$\Delta d = d_h - d_s = 7.3mm - 7.143mm = 0.157mm.$$

This results in a radial clearance available on each side of the spindle of:

$$\Delta r_{max} = \Delta d / 2 = 0.0785mm$$

So we need to limit our misalignment to Δr_{max} of 0.0785mm.

Our horizontal clamping mechanism is actuated by servo motors. We will use the Tower Pro MG996, which typically has an angular positioning error of around ±1°. This angular error produces a linear (lateral) displacement at the point of contact between the clamp and the record. Assuming the horizontal clamp contacts the record at a distance R from the record's center, then, a servo angular error $\Delta\theta$ (in radians) produces a linear error:

$$\Delta x = R \sin(\Delta\theta)$$

Using small-angle approximations, we can see that this is approximately equal to

$$\Delta x = R \sin(\Delta\theta) \approx R * \Delta\theta$$

A 7-inch record has a diameter of 174.75mm ± 0.79mm. So we can say $R \approx 87.375mm.$

$$\Delta x = R * \Delta\theta = 87.375mm * 0.01745 \text{ radians} = 1.5247 \text{ mm}.$$

This horizontal error in clamping is too large and far exceeds our allowed tolerance of 0.0785mm. A conical (cone-shaped) spindle can amplify small offsets near its tip so that even a 1.52 mm error is reduced to less than 0.0785 mm when the record finally seats.

We can create a cone whose apex is sharp (a point) at the top and which widens continuously until its base is exactly the spindle's nominal diameter (7.143 mm). When the record's centre hole drops onto this cone, any lateral mis‑alignment is converted into a vertical drop along the cone. Because the record's inner edge is only 0.0785 mm away from the cone (in the perfectly centred case), we can think of the cone as providing a mechanical advantage (the ratio between a horizontal offset and the vertical distance needed to correct it) of roughly

$$M = \Delta x / \Delta r_{max} \approx 1.52 / 0.0785 \approx 19.4.$$

For a cone with a half–angle φ the mechanical advantage is

$$1 / \tan \varphi$$

So to cancel out a 1.52 mm error down to 0.0785 mm we require

$$1 / \tan \varphi \geq 19.4$$

$\tan\varphi \leq 0.0785 / 1.52 \leq 0.0516$

$\varphi \leq \arctan(0.0516) \approx 2.95°$

So the cone's half angle is around 2.95 degrees. Because the base of the cone must be the spindle's diameter, its radius is:

$r_{base} = d_s / 2 = 7.143mm / 2 \approx 3.57$ mm.

For a cone the height is related to its base radius and half–angle by:

$h = r_{base} / \tan\varphi = 3.57 / \tan(2.95°) = 69.28mm.$

So our dimensions for the cone on the spindle will be the following:

- Half-angle = 2.95 degrees ≈ 3 degrees.
- Cone height = 69.3 mm ≈ 70 mm.
- Cone base diameter = 7.143 mm.
- Apex = a point (very small)

This cone will "funnel" the record's centre so that even if the record comes in with a 1.52 mm error, the self‑centering action will reduce the final mis‑alignment to no more than 0.0785 mm, keeping the record safely on the platter.

3. Ethics and Safety

3.1 Safety

Our project design incorporates a linear DC voltage regulator, and due to the presence of risks associated with overheating and potential fires due to said regulator, we've decided to adopt a set standard of safety when handling the power subsystem component of the overall design. For our project, we will be implementing the 1100 IEEE Emerald Book standard for handling the powering and ground electronic equipment, which should provide adequate guidelines for a safe and robust power system, reducing downtime, failures and electrical hazards which may be present in the project.

Throughout the creation, testing, and finalization of the project, we will be adhering to the University of Illinois' laboratory safety guidelines which prioritize proper handling of electronic components and safe usage of said material. As part of Illinois' safety guidelines, we will be conducting all laboratory work with the proper personal protective equipment (PPE) and ensure proper storage of all project components in the storage area allocated for the team for this semester.

3.2 Ethics

We assert that this team will maintain intellectual and ethical honesty in our endeavors. In accordance with IEEE code (IEEE), section 1, parts 1-6, we will not by any means cut any corners and we will use the most accurate data we note down. If any behaviors happen that would benefit the individual, team, or project but also hinder the progress of society, they will be discarded in favor of honest work towards the betterment of society. Specifically noting down, we will “seek, accept, and offer honest criticism of technical work, [acknowledge] and correct errors, [be] honest and realistic in stating claims or estimates based on available data, and [credit] properly the contributions of others”, to quote the IEEE code of ethics.

4. References

1. IEEE. "IEEE - IEEE Code of Ethics." www.ieee.org, https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed 12 February, 2025.

2. Statista. (n.d.). LP sales in the United States. Statista. Retrieved February 12, 2025, from https://www.statista.com/chart/7699/lp-sales-in-the-united-states/

3. GlobeNewswire. (2024, August 8). Vinyl records business report 2023-2030: Market to grow by $900 million; Growth of collectible and limited edition vinyl releases spurs dynamics. GlobeNewswire. Retrieved February 12, 2025, from https://www.globenewswire.com/news-release/2024/08/08/2927039/0/en/Vinyl-Records-Business-Report-2023-2030-Market-to-Grow-by-900-Million-Growth-of-Collectible-and-Limited-Edition-Vinyl-Releases-Spurs-Dynamics.html

4. Quora. (n.d.). *Did people who bought vinyl singles get sick of having to stand in front of the record player and flip each record over after the song was done to hear the B-side and then have to change the record to hear the next?* Quora. Retrieved February 12, 2025, from https://www.quora.com/Did-people-who-bought-vinyl-singles-get-sick-of-having-to-stand-in-front-of-the-record-player-and-flip-each-record-over-after-the-song-was-done-to-hear-the-B-side-and-then-have-to-change-the-record-to-hear-the-next

5. Atmel. ATmega48A/PA/88A/PA/168A/PA/328/P datasheet. ATmega328P. 2020. Retrieved 13 February, 2025, from https://ww1.microchip.com/downloads/en/DeviceDoc/Atmel-7810-Automotive-Microcontrollers-ATmega328P_Datasheet.pdf

6. Honeywell. (2015, October). Low Gauss, Bipolar Digital Hall-effect Sensor ICs: SS41 (PK 87881) Datasheet. Honeywell. Retrieved February 12, 2025, from https://prod-edam.honeywell.com/content/dam/honeywell-edam/sps/siot/en-us/products/sensors/magnetic-sensors/bipolar-position-sensor-ics/common/documents/sps-siot-bipolar-digital-hall-effect-sensor-ic-installation-instructions-ss41-pk87881-6-en-ciid-50342.pdf?download=false

7. K&J Magnetics, Inc. (n.d). Magnetic Strength Calculator. K&J Magnetics, Inc. Retrieved February 12, 2025, from https://www.kjmagnetics.com/magnet-strength-calculator.asp

8. Applied Magnets Superstore, (n.d) N52 Neodymium Magnets 3/8 in x 1/4 in Rare Earth Disc. Applied Magnets Superstore. Retrieved February 12, 2025, from

https://appliedmagnets.com/n52-neodymium-magnets-3-8-in-x-1-4-in-rare-earth-disc/

9. Audio Karma, (n.d) Turntable centre spindle size/thickness? Audio Karma. Retrieved February 13, 2025, from https://audiokarma.org/forums/index.php?threads/turntable-centre-spindle-size-thickness.515619/

10. RECORD INDUSTRY ASSOCIATION OF AMERICA, INC. (October 16, 1963) STANDARDS FOR STEREOPHONIC DISC RECORDS. Retrieved February 13, 2025, from http://www.aardvarkmastering.com/riaa.htm

11. Interalloy Australia. (n.d) Tolerance Tables. Retrieved February 13, 2025, from http://www.interlloy.com.au/wp-content/uploads/2015/04/Tolerances2015.pdf

12. Physics department, University of Connecticut. (n.d) Critical Bandwidths and Just-Noticeable Differences. Retrieved February 13, 2025, from https://www.phys.uconn.edu/~gibson/Notes/Section7_2/Sec7_2.htm#:~:text=Between%20these%20two%20mechanisms%2C%20the,is%20about%200.5%25%20or%200.005

13. Wikipedia. (n.d) Phonograph record. Retrieved February 13, 2025, from https://en.wikipedia.org/wiki/Phonograph_record

14. ServoDatabase. (September 16, 2025) TowerPro MG996R Servo Specifications. Retrieved February 13, 2025, from https://servodatabase.com/servo/towerpro/mg996r

15. IEEE Xplore. (May 24, 2006). 1100-2005 - IEEE Recommended Practice for Powering and Grounding Electronic Equipment. Retrieved February 13, 2025, from https://ieeexplore.ieee.org/document/1638205