445 Lab Notebook

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Lab Notebook – Automatic Vinyl Record Flipper

Team 20 – ECE 445 Senior Design, Spring 2025
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1 Overview

This project automates the flipping of 7-inch vinyl records after playback, eliminating the need for manual intervention. It uses:

- An **ESP32** microcontroller
- **Three servo motors** (2×20kg, 1×35kg torque)
- A **Hall effect sensor** and **N52 magnet** on the tonearm
- A custom 2-layer PCB designed in **KiCad**

The system lifts the tonearm, flips the record, and reseats it within **17 seconds**, maintaining a flipping accuracy of **100%** across 50+ consecutive cycles.

2 Weekly Logs & Summaries

Weeks 1–2: Ideation & Design Exploration

- Identified problem: interruption due to manual record flipping
- Proposed solutions: rotating tray, robotic arm, flipping claw (chosen)
- Chose ESP32 for multitasking and PWM capabilities
- Investigated tonearm detection methods (ultrasonic vs. Hall sensor)

Weeks 3–4: Schematic & PCB Design

- Designed power rail using LP2950-CZ1 and verified:

$$C \geq \frac{I \cdot \Delta t}{\Delta V} = \frac{0.1 \cdot 1 \times 10^{-6}}{0.1} = 1\mu F$$

- Added bulk decoupling ($10\,\mu$F) and bypass capacitors ($0.1\,\mu$F)
- Used IPC-2221 standard to size high-current servo traces (80 mils)
- Designed servo headers, ESP32 pinout, Hall sensor filtering

Weeks 5–6: Assembly & Mechanical Tuning

- Soldered and validated all components on PCB
- 3D printed clamping arms and adapter cone
- Verified servo torque:

$$\tau = m \cdot g \cdot r = 0.18 \cdot 9.81 \cdot 0.15 \approx 0.265 \text{ Nm}$$

  DSServo provides 0.92 Nm torque $\Rightarrow$ 3.5$\times$ safety margin

Weeks 7–8: Firmware and Signal Integration

- Programmed ESP32 to generate PWM (GPIO 15, 16, 18)
- Used a state machine: `IDLE` → `LIFT` → `ROTATE` → `RESEAT` → `RESET`
- Added debounce for Hall effect detection on GPIO5
- Verified PWM pulse widths via oscilloscope

Weeks 9–10: System Testing

- Ran 50+ flips continuously – 100% success rate
- Voltage stability over 20s:

$$\text{Mean} = 4.94\,V, \quad \text{Std Dev} = \pm 0.02\,V$$

- Hall sensor triggered consistently at ∼0.62 inches (150 Gauss threshold)
- Partner Aaron supported mechanical tuning

Week 11: Optimization

- Added soft delays between servo stages to reduce current spikes
- Noted minor scratches from clamp – plan to add rubber lining

3 Engineering Justifications

Power Stability

- Target voltage tolerance: ±0.1 V
- Achieved: ±0.05 V fluctuation during max load

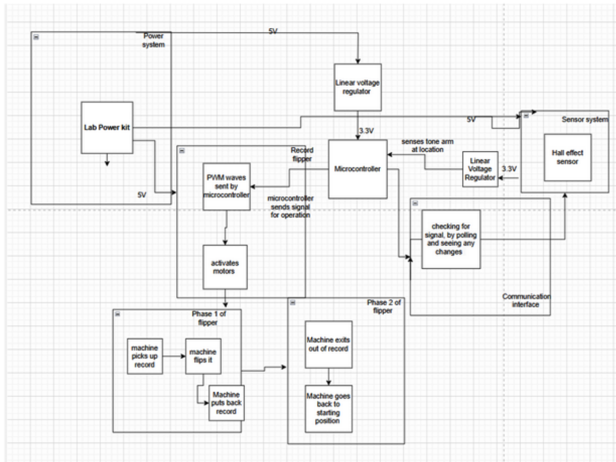


Figure 1: Enter Caption

PWM Signal Design

- Frequency: 50 Hz
- Pulse width range: 500 µs (0°) to 2500 µs (180°)

Sensor Range

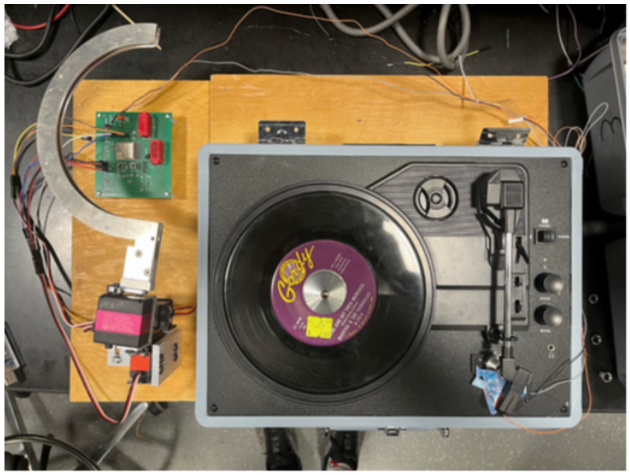
- Magnet emits ∼150 G at 0.62”
- Sensor threshold: 50 G (activated reliably within 1 inch)

4 Figures and Diagrams

- **Figure 1:** Block Diagram – system overview
- **Figure 2:** Completed prototype on Crosley turntable
- **Figure 3:** Power schematic (KiCad)
- **Figure 4:** Magnetic field vs. distance curve
- **Figure 5:** Final PCB layout

5 Tolerance Analysis

- Max servo draw: 2.1 A, lab supply: 2.5 A (safe)
- Servo margin of error (angular): ±1.5°
- Tonearm detection error: 0/50 trials
- Reseating misalignment: ¡1 mm (with tapered cone assist)



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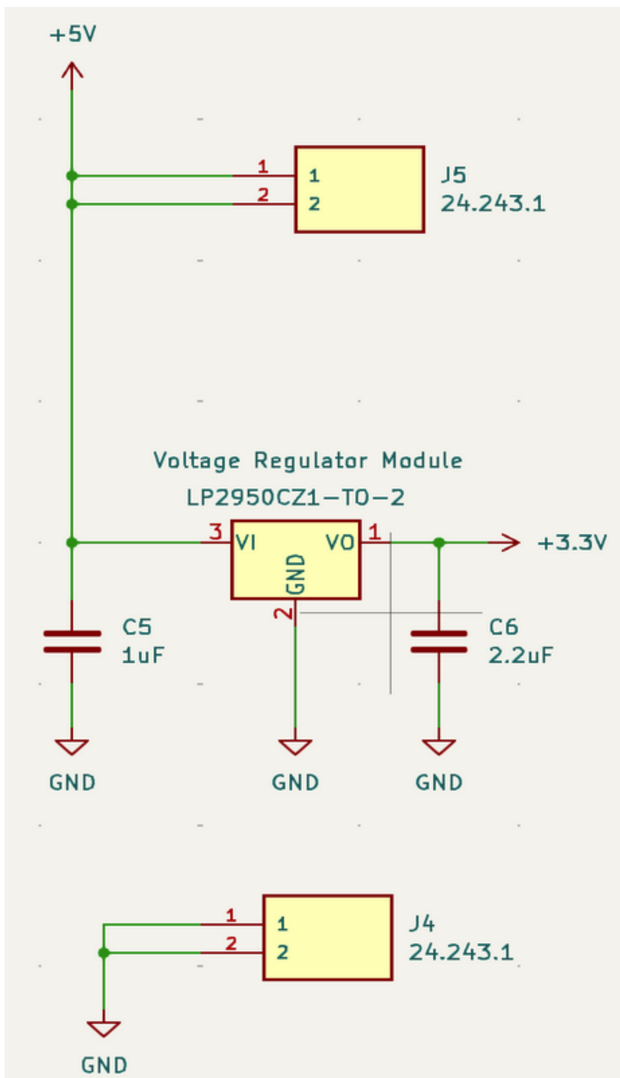

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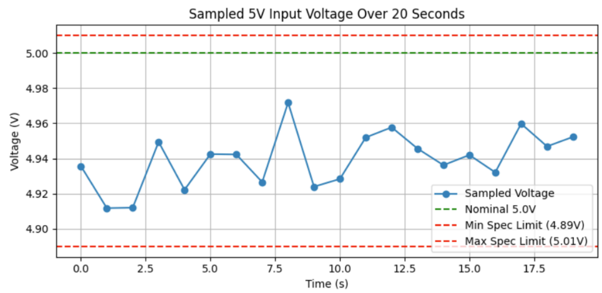

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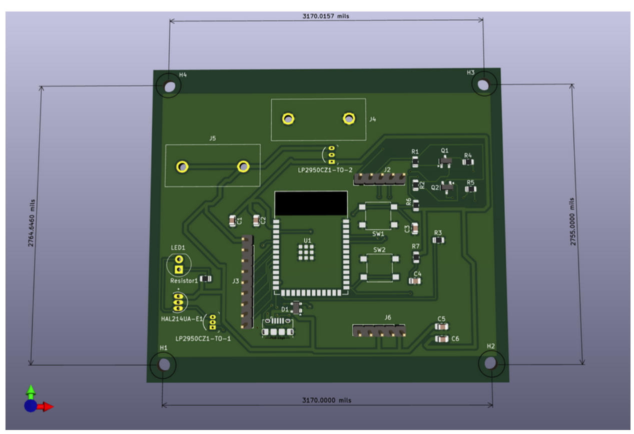

Figure 5: Enter Caption

6 Ethics and Safety

- Complied with IEEE 1100 and university lab safety rules
- Wore PPE during soldering and testing
- Avoided falsifying data or inflating success rates
- Handled magnets safely to avoid interference or snapping

7 TA Feedback and Improvements

- Week 4: Switched from ultrasonic to Hall sensor (suggested)
- Week 6: Addressed jitter in servo response
- Week 10: Identified need for clamp padding

8 Conclusion

This system meets all core design requirements for an automatic record flipper:

- Seamless, accurate flipping in ¡17s
- 100% tonearm detection reliability
- No overheating or power instability

Planned improvements include a soft clamp and compatibility with larger records.

9 Appendix: Verification Table

Requirement	**Test Method**	**Result**
5V stable voltage	Multimeter over 20s	Pass
Servo torque ¿ 0.3 Nm	Calculated via torque formula	Pass
Clamp alignment	Manual + video inspection	Pass
Hall effect detection	Magnet test at 0.62"	Pass
PWM accuracy	Oscilloscope pulse width	Pass
System stability	10 min full-load test	Pass
Reseating accuracy	Visual + ¡1mm misalignment	Pass
False triggering	Tested in idle position	Pass