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 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

Week 1–2 (Jan 22–Feb 2): Ideation & Design Exploration

- Identified the problem: interruption due to manual record flipping
- Proposed solutions: rotating tray, robotic arm, flipping claw (chosen)
- Chose initial ATMega microcontroller (later switched to ESP32)
- Considered tonearm detection methods (ultrasonic vs Hall sensor)
- Sketched preliminary mechanical design concepts

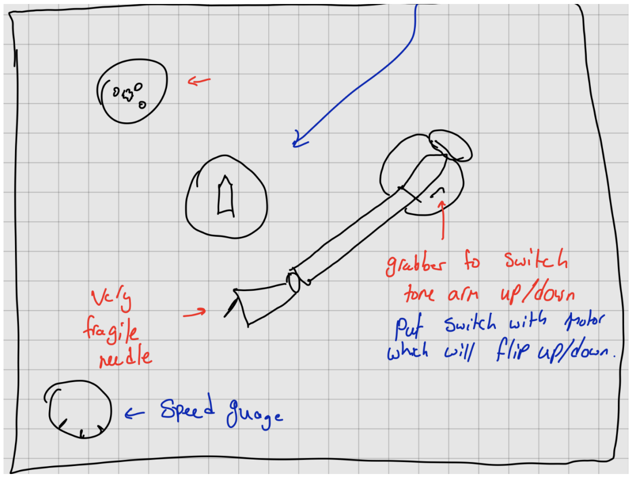

Figure 1: Sketch of preliminary proposed mechanical solution

Figure 2: Crosley vinyl player used as base for prototype testing

Week 3–4 (Feb 5–Feb 16): 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 capacitors to the schematic
- Designed headers and KiCad schematics

Week 5–6 (Feb 19–Mar 1): Assembly & Breadboard Testing

- Soldered and validated custom PCB
- Coordinated with mechanical shop on design tweaks

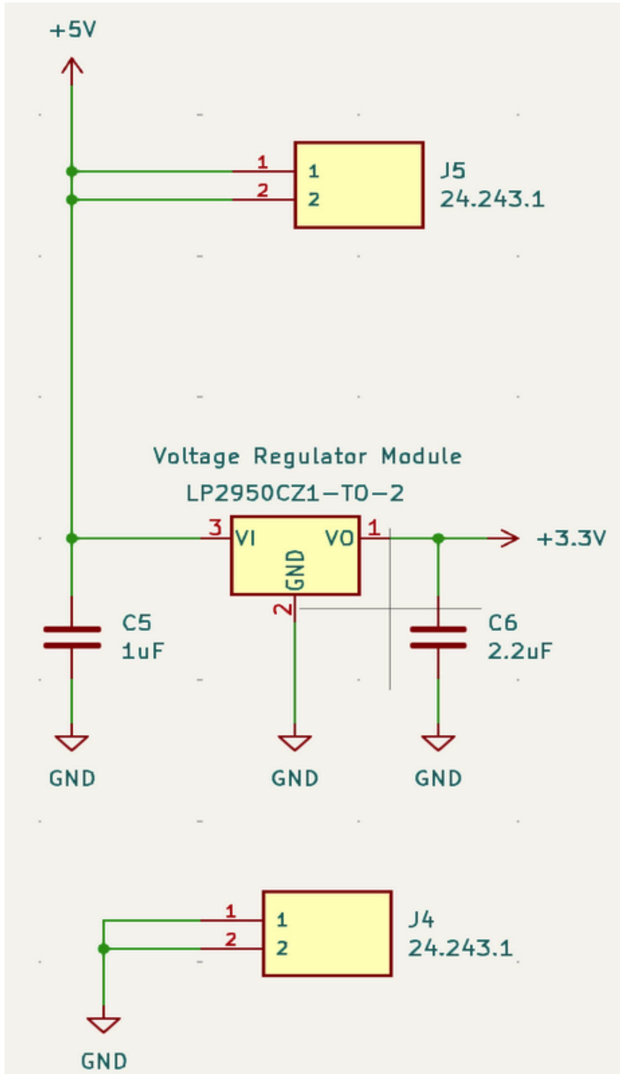

Figure 3: Power supply schematic with added 1 and 2.2µF capacitors

- Breadboarded servo system, verified 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 $\Rightarrow$ 3.5$\times$ safety margin

Week 7–8 (Mar 4–Mar 15): Firmware Integration

- Programmed ESP32 for PWM output to control 3 servos (GPIO 15, 16, 18)
- Created state machine: `IDLE → LIFT → ROTATE → RESEAT → RESET`
- Debounced Hall effect sensor signal on GPIO5
- Verified PWM pulse widths using oscilloscope

Week 9–10 (Mar 18–Mar 29): Testing and Debugging

- Hall sensor output floated without pull-up resistor; added 10kΩ to 3.3V
- Sensor output stabilized at 3.3V (was dropping to 3V → false triggers)
- Observed 0V on GPIO37 when ESP32 powered by USB, 1.7V from VIN after flashing
- When microcontroller was unpowered, regulator outputted 2.1V (noise)
- Motors failed when ESP32 shared 5V rail → resolved by adding 10µF cap across 5Vin and GND
- Reoriented pink servo, observed 0–270° physical range despite 0–180° code range → scaled angle in firmware

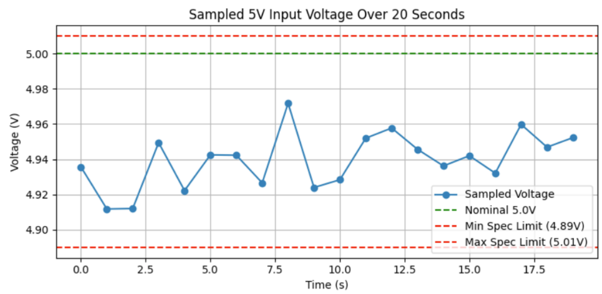

Figure 4: Voltage stability test: 4.94V ± 0.02V sampled over time

Week 11–12 (Mar 30–Apr 12): PCB Redesign and Optimization

- Reordered PCB (4th round) after updates to trace layout and headers
- Inserted soft delays between servo stages to reduce current spikes
- Implemented final clamping adjustments to minimize scratching

Week 13–14 (Apr 15–Apr 26): System Integration & Final Testing

- Assembled final prototype and verified full flipping sequence
- Flipping time: 17 seconds; 50+ flips with 100% success
- Final tweaks: Hall sensor trigger range, clamping force, and sequencing

3 Engineering Justifications

Power Stability

- Target voltage tolerance: ±0.1V
- Achieved: ±0.05V fluctuation under servo load

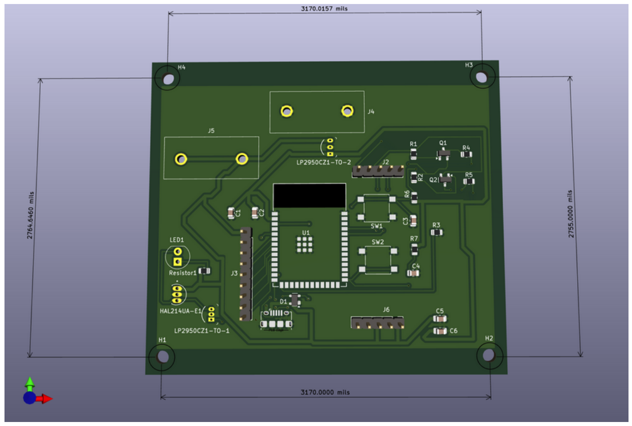

Figure 5: PCB layout 3D view for fourth round PCB order

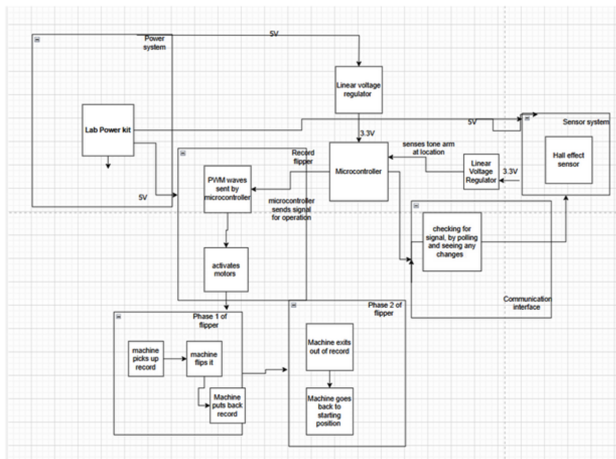

Figure 6: Final system block diagram showing modules and flow

PWM Signal Design

- 50 Hz frequency, 500–2500 µs pulse width range
- Smooth servo transitions verified with oscilloscope

Sensor Range

- Magnet field ∼150 Gauss at 0.62”
- Sensor threshold 50 Gauss – activates reliably within 1 inch
- Weak magnet issue mitigated with resistor pull-up and consistent power

Voltage and Signal Integrity

- Pull-up resistor (10kΩ) fixed sensor output instability
- 10µF cap resolved power instability when sharing supply

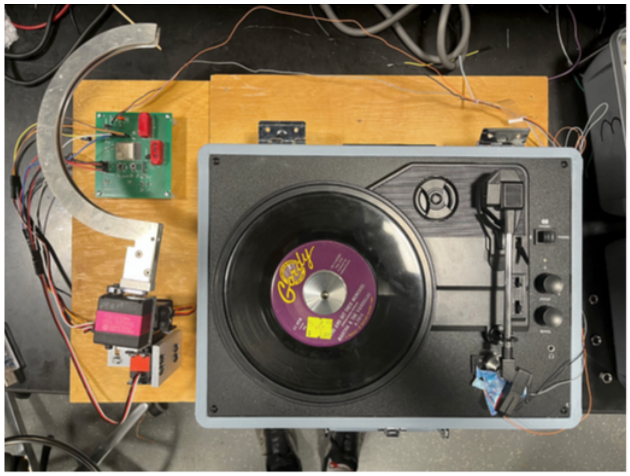

Figure 7: Completed prototype mounted on Crosley turntable

- GPIO37 behavior dependent on USB vs VIN supply path

4 Tolerance Analysis

- Servo current draw: 2.1A, lab supply: 2.5A
- Angular error tolerance: $\pm 1.5^\circ$
- Sensor detection error: 0 in 50 trials after fix
- Pink servo angle scaled $1.5\times$ to reflect 270° physical range
- Clamp reseating misalignment ¡1mm using tapered cone

5 Conclusion

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

- Seamless flipping process under 17 seconds
- 100% tonearm detection reliability with Hall effect sensor
- Robust power delivery and no random motion glitches

Future improvements: soft clamp rubber lining and support for 12-inch records.

6 Individual Contribution Summary

My individual contributions to the Automatic Record Flipper project span all subsystems, from mechanical and power system design to integration, testing, and schematic/PCB development. I proposed the project concept, conducted tolerance analysis to ensure mechanical accuracy during flipping, and redesigned the 45 RPM adapter to improve record seating, and programmed the setup. I also designed the round 4 PCBs.

On the electrical side, I contributed to the initial buck converter design for voltage regulation using LM2596 modules and implemented reverse polarity protection. When component sourcing became an issue, I led testing of the 5V bench supply and confirmed its adequacy, leading to the removal of buck converters and simplifying the system. I validated this with resistor load testing and confirmed current delivery with help from course staff.

For control, I programmed PWM generation on the ESP32 using Arduino IDE, verified servo actuation via the dev board and signal generators, and designed fallback testing plans using a simplified fourth PCB revision. This ensures continued progress in the event of hardware failures.

I resolved 45+ DRC errors across our initial PCB, collaborating with teammates to replace invalid footprints, reassign nets, and manually modify KiCad footprints to pass manufacturing review. I also created final Gerber files and confirmed audit success through PCBWay's tools.

Throughout the course, I emphasized modular testing, worked to align our project with the IEEE Code of Ethics, and maintained team coordination for integration and demonstration planning.

7 Ethical Reflection

Our project adheres to the IEEE Code of Ethics through its emphasis on user safety, realistic performance evaluation, sustainable design choices, and collaborative teamwork. We minimized risk by automating a manual flipping task and verified design claims through testing and analysis. We reused an existing record player platform rather than designing from scratch, reducing electronic waste. Our process was transparent, feedback-driven, and inclusive, ensuring shared credit and responsibility among team members.

8 Appendix: Verification Table

Requirement	**Test Method**	**Result**
5V stable voltage	Multimeter over 20s	Pass
Servo torque ¿ 0.3 Nm	Torque equation	Pass
Clamp alignment	Manual inspection	Pass
Hall effect detection	Magnet test at 0.62"	Pass
PWM accuracy	Oscilloscope	Pass
System stability	10-min full-load test	Pass
Reseating accuracy	Visual ¡1mm misalignment	Pass
False triggering	Idle state verification	Pass