# 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

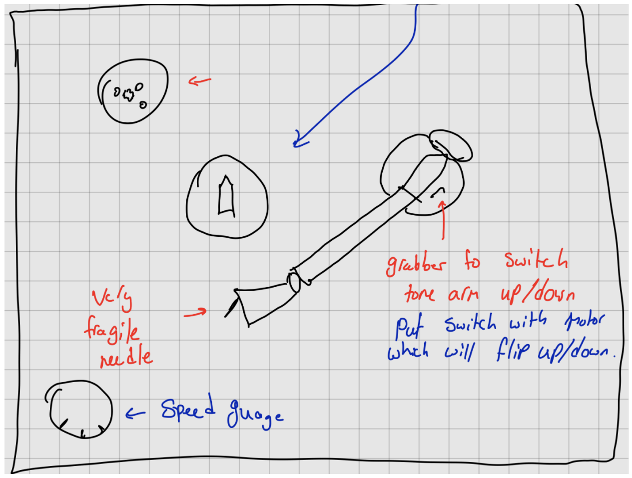


Figure 1: Sketch of preliminary proposed mechanical solution

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

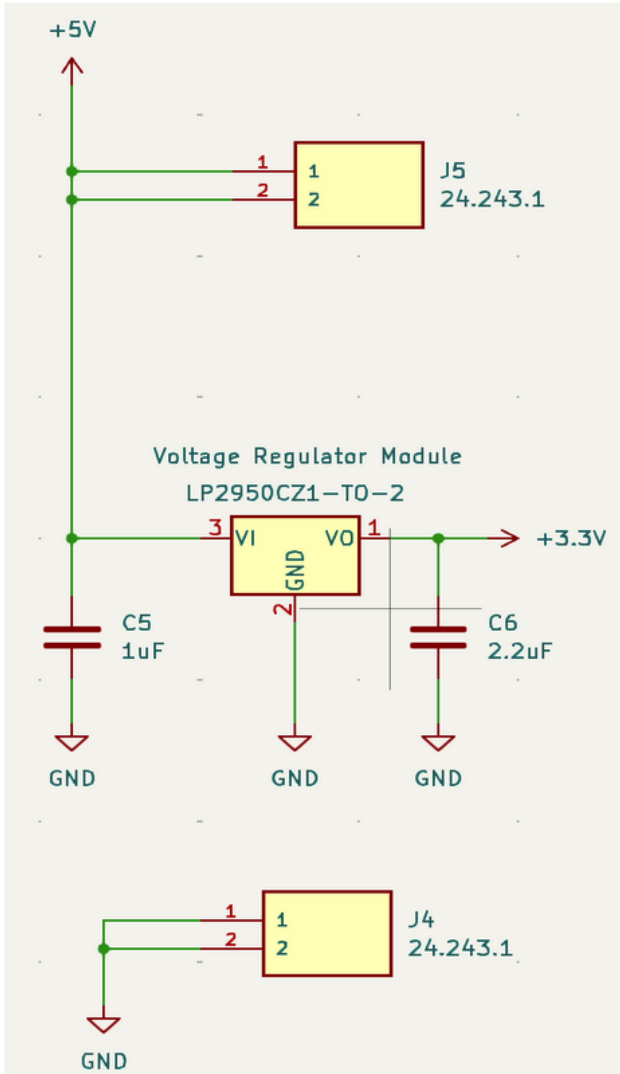


Figure 3: Power supply schematic with added 1 and 2.2µF capacitors

- 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

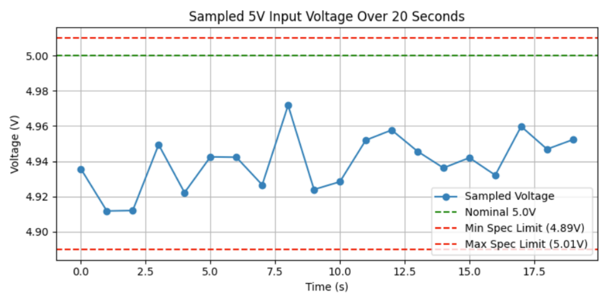


Figure 4: Voltage stability test: 4.94V ± 0.02V sampled over time

### 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

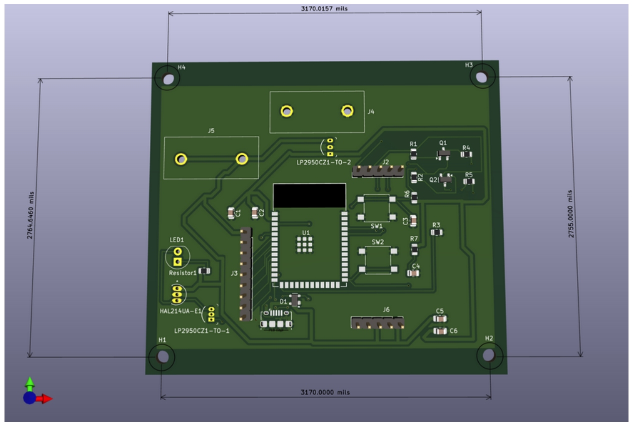


Figure 5: PCB layout 3D view for fourth round PCB order

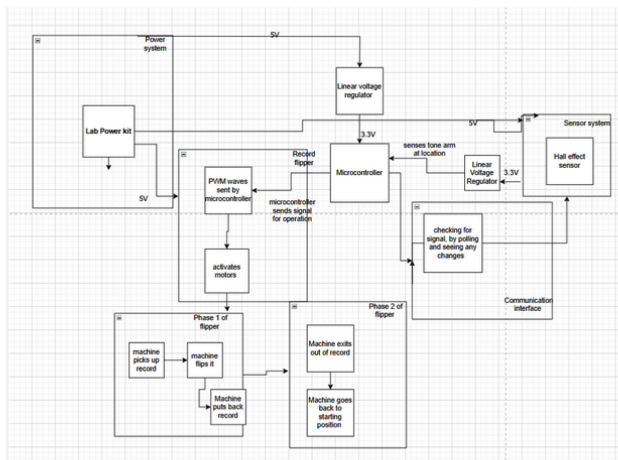


Figure 6: Final system block diagram showing modules and flow

## 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

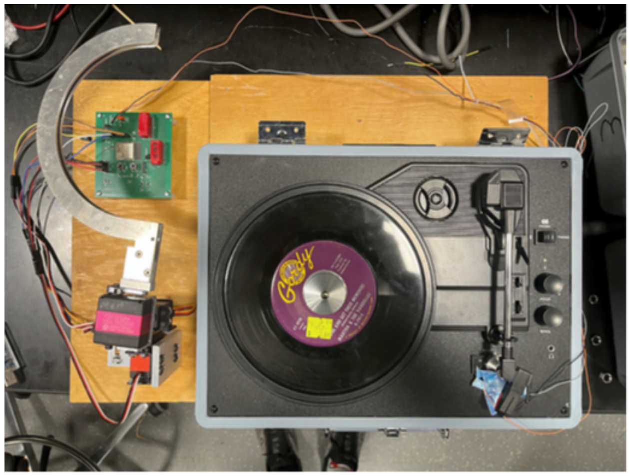

Figure 7: Completed prototype mounted on Crosley turntable

- 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× to reflect 270° physical range
- Clamp reseating misalignment ¡1mm using tapered cone

## 5 Ethics and Safety

- Followed IEEE 1100 and UIUC lab safety rules
- Wore PPE during soldering and hardware tests
- Transparent testing logs and data reporting
- Used N52 magnet with care to prevent finger pinching or circuit damage

## 6 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.

# 7 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 |