

Report – Group 5: LED Modulation Project

1. Introduction

- This project implements an LED modulation system on the ATmega328P using a combination of hardware timers, interrupts, and inline AVR assembly. Our goal was to explore how different light-modulation frequencies interact with modern cameras. Such as smartphones and smart-home security systems and particularly how rolling-shutter sensors respond to flicker.

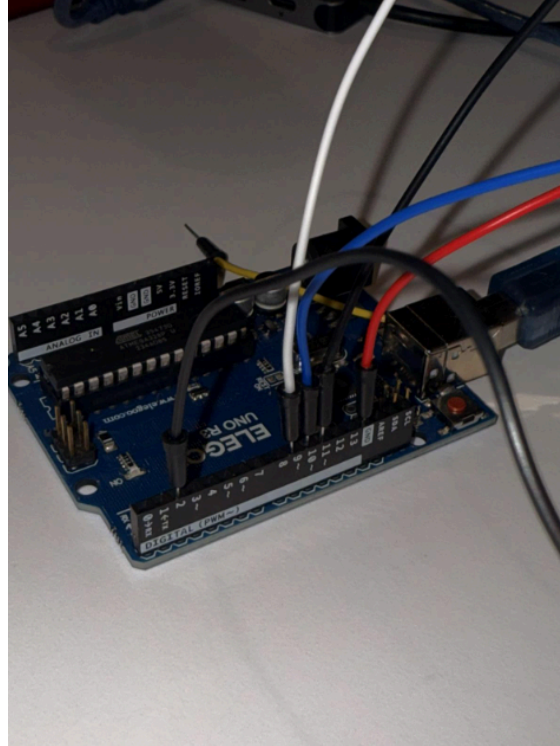
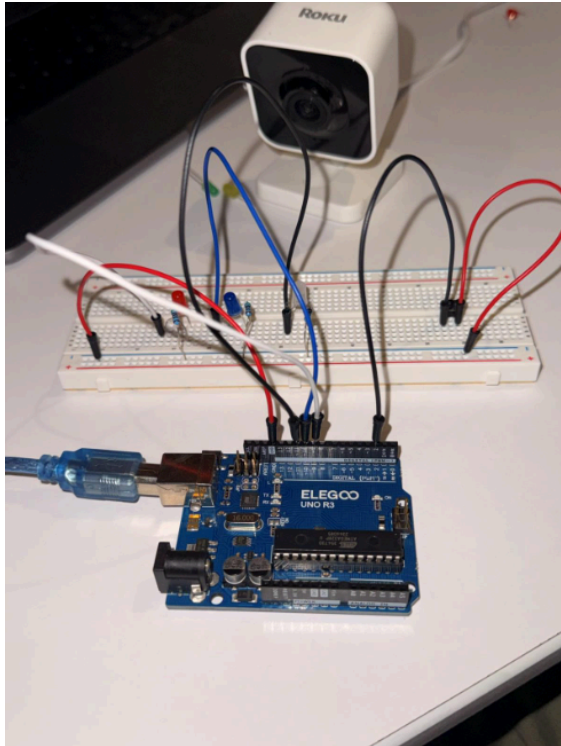
2. Background

- The ATmega328P contains multiple hardware timers capable of generating precise timing events without CPU delay loops. Timer1, a 16-bit timer, is well-suited for generating stable modulation frequencies through CTC (Clear Timer on Compare Match) mode. We configured Timer1 to generate three selectable flicker speeds (slow, medium, fast) and used interrupts to update LED states consistently, enabling us to evaluate how various camera systems react to controlled flicker patterns.

3. Contributions

- Designed a timer-driven LED modulation system using CTC mode.
- Implemented inline AVR assembly inside the interrupt service routine.
- Created three unique display modes: synchronous blink, chasing pattern, and a 3-bit binary counter.
- Performed comparative testing on smartphone and Roku smart cameras.
- Documented modulation artifacts and detection delays caused by flicker.

4. Project Design Process



6. Testing and Results

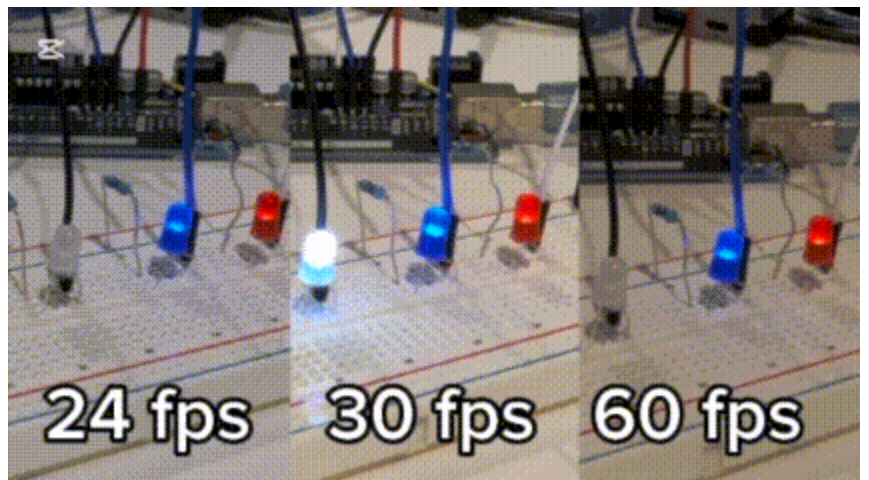
- As the camera frame rate increases from 24 \rightarrow 30 \rightarrow 60 fps, the recorded LED modulation becomes progressively more accurate, with 24 fps producing strong aliasing artifacts and 60 fps providing the most faithful representation of our timer-driven flicker patterns. Smartphone Camera:

Smartphone Camera:

- Fast flicker (2 kHz): Strong striping from rolling shutter.
- Medium (500 Hz): Pulsing bands.
- Slow (50 Hz): Normal blinking.

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[LED GIF](#)



Roku Smart Camera:

- High-frequency flicker affects exposure stability.
- Medium flicker causes pulsing artifacts.
- Motion/person detection occasionally delayed under unstable illumination.

7. Workload Distribution

- Alex: Assembly development, timer logic, hardware wiring
- Fredrika: Hardware wiring, presentation slides, report
- Noah: Smartphone testing, roku testing, report

8. Differences from Existing Projects

- Unlike existing online examples that either blink a single LED in pure assembly or demonstrate isolated Timer1 configurations, our project integrates timer interrupts, multi-LED control, inline assembly, and camera-oriented testing into one system designed specifically to study flicker effects on modern imaging devices

9. Conclusion and Future Work

We successfully implemented assembly-level modulation and documented camera behavior. Future extensions include IR LED testing, chirp modulation, and quantitative artifact measurement.

10. [GitHub Link](https://github.com/alexmkunneke-boop/Assembly-Programming-for-Atmega328-Output-Control-Embedded-Systems-/blob/main/ModulatedLED.ino)

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