COMP 3350: LED Modulation Project

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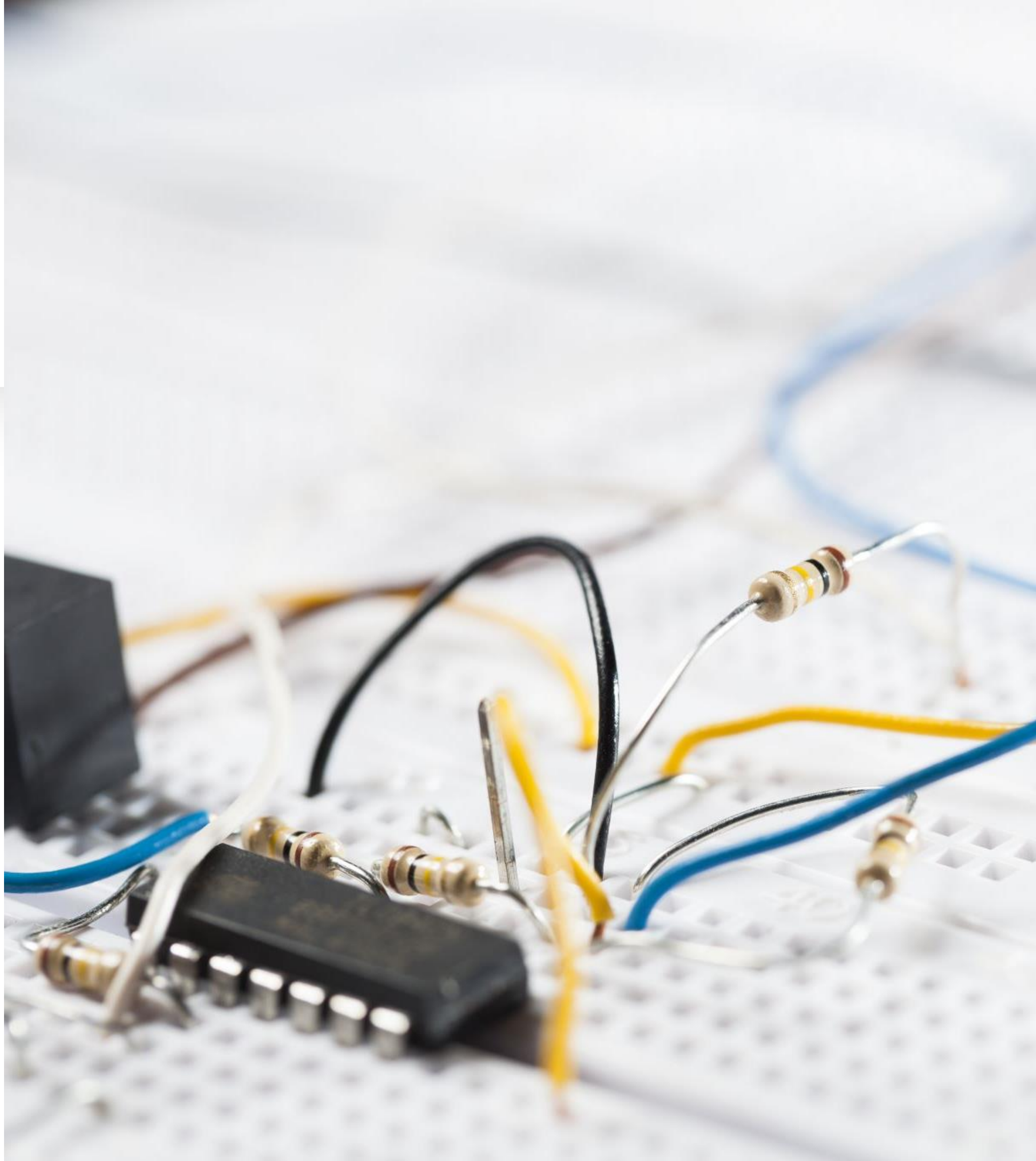
Introduction

- 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.



Background

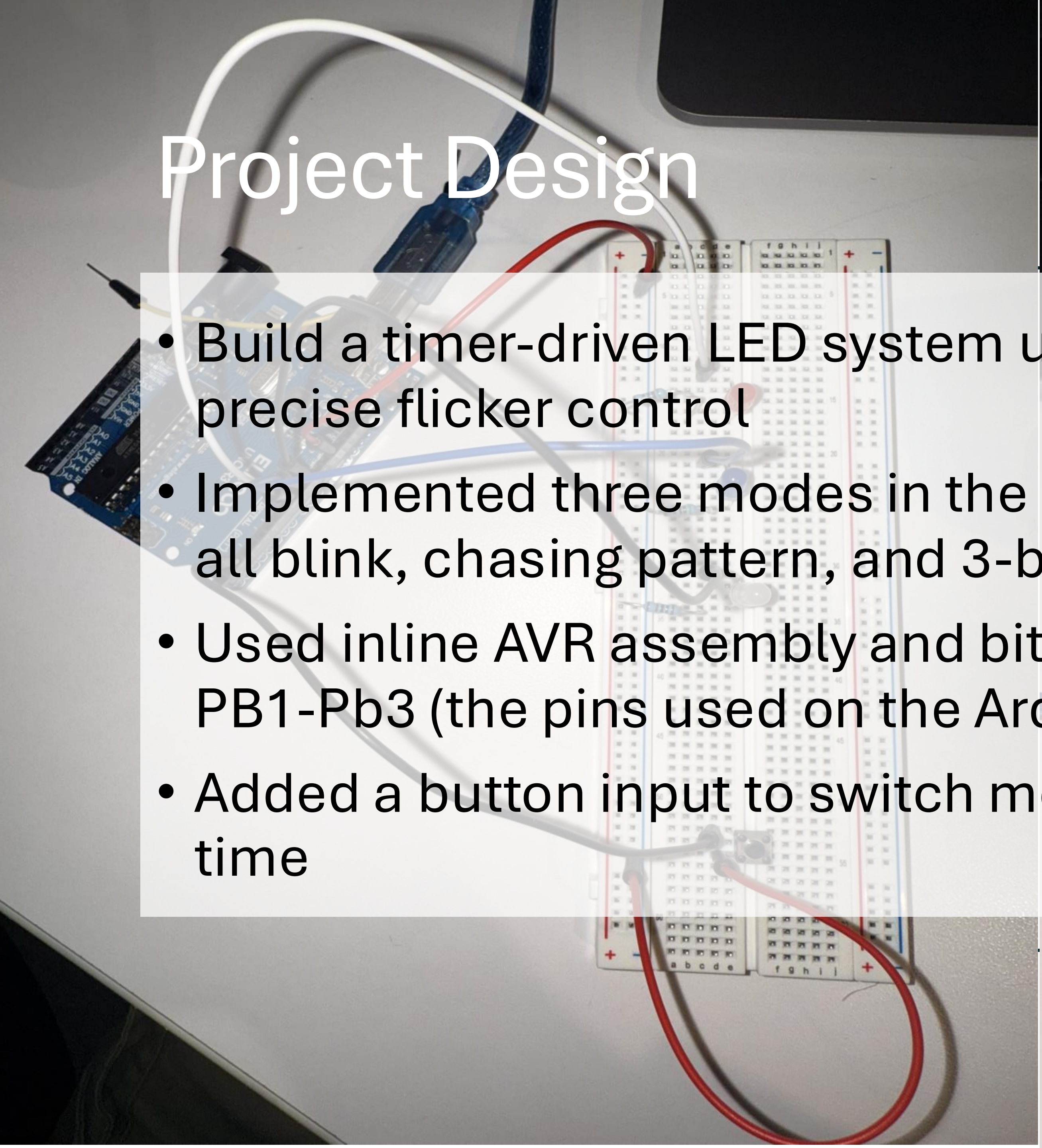
- The ATmega328P contains multiple hardware timers capable of generating precise timing events without CPU delay loops.
- Timer1, a 16-bit timer, is well-suited for generating stable modulation frequencies through CTC (Clear Timer on Compare Match) mode.
- We configured Timer1 to generate three flicker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

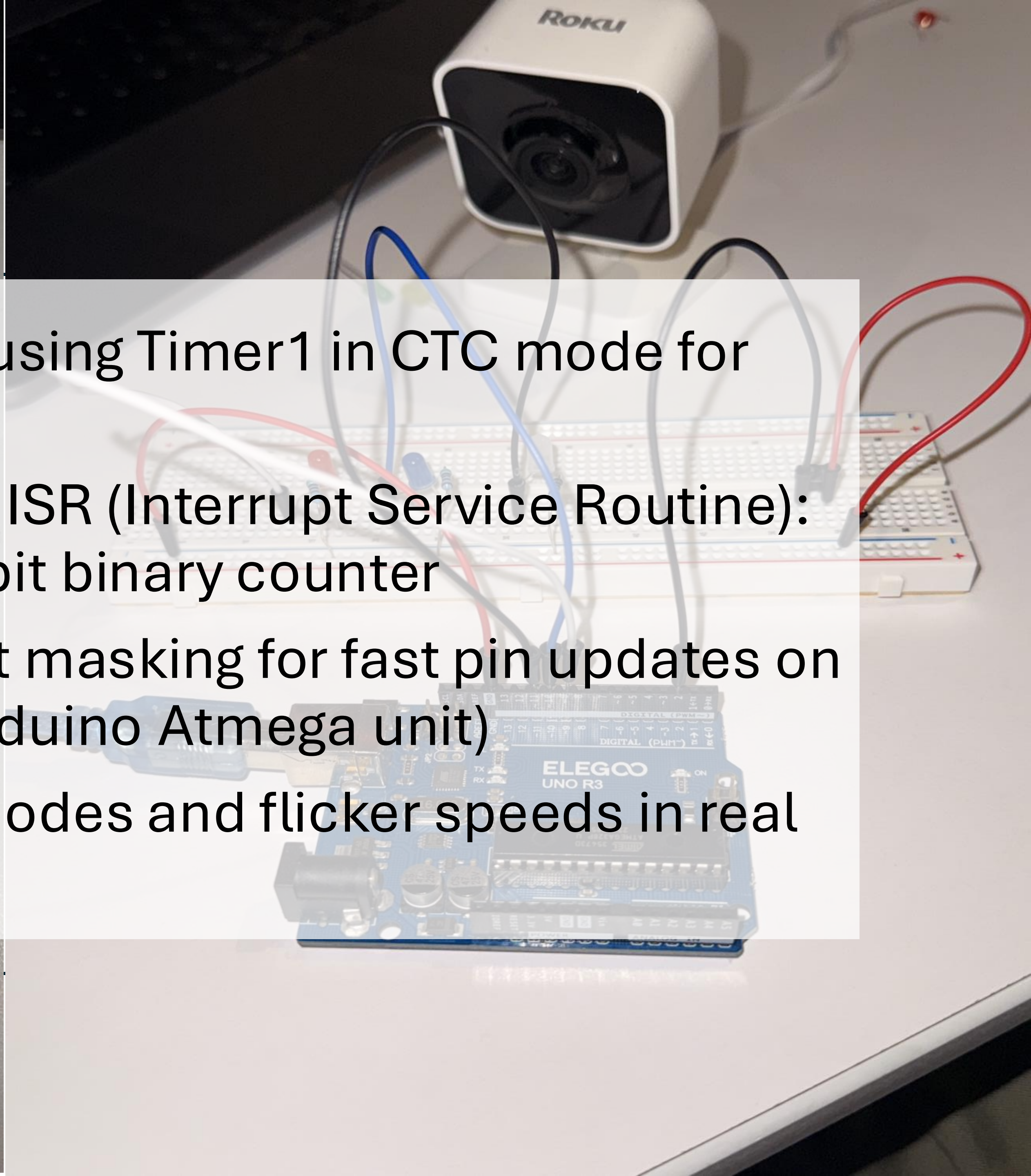
Contributions

- Designed a timer-driven LED modulation system using CTC mode.
- Implemented inline AVR assembly inside the interrupt service routine.
- Performed comparative testing on smartphone and Roku smart cameras.
- Documented modulation artifacts and detection delays caused by flicker.

Project Design

- Build a timer-driven LED system using Timer1 in CTC mode for precise flicker control
- Implemented three modes in the ISR (Interrupt Service Routine): all blink, chasing pattern, and 3-bit binary counter
- Used inline AVR assembly and bit masking for fast pin updates on PB1-Pb3 (the pins used on the Arduino Atmega unit)
- Added a button input to switch modes and flicker speeds in real time



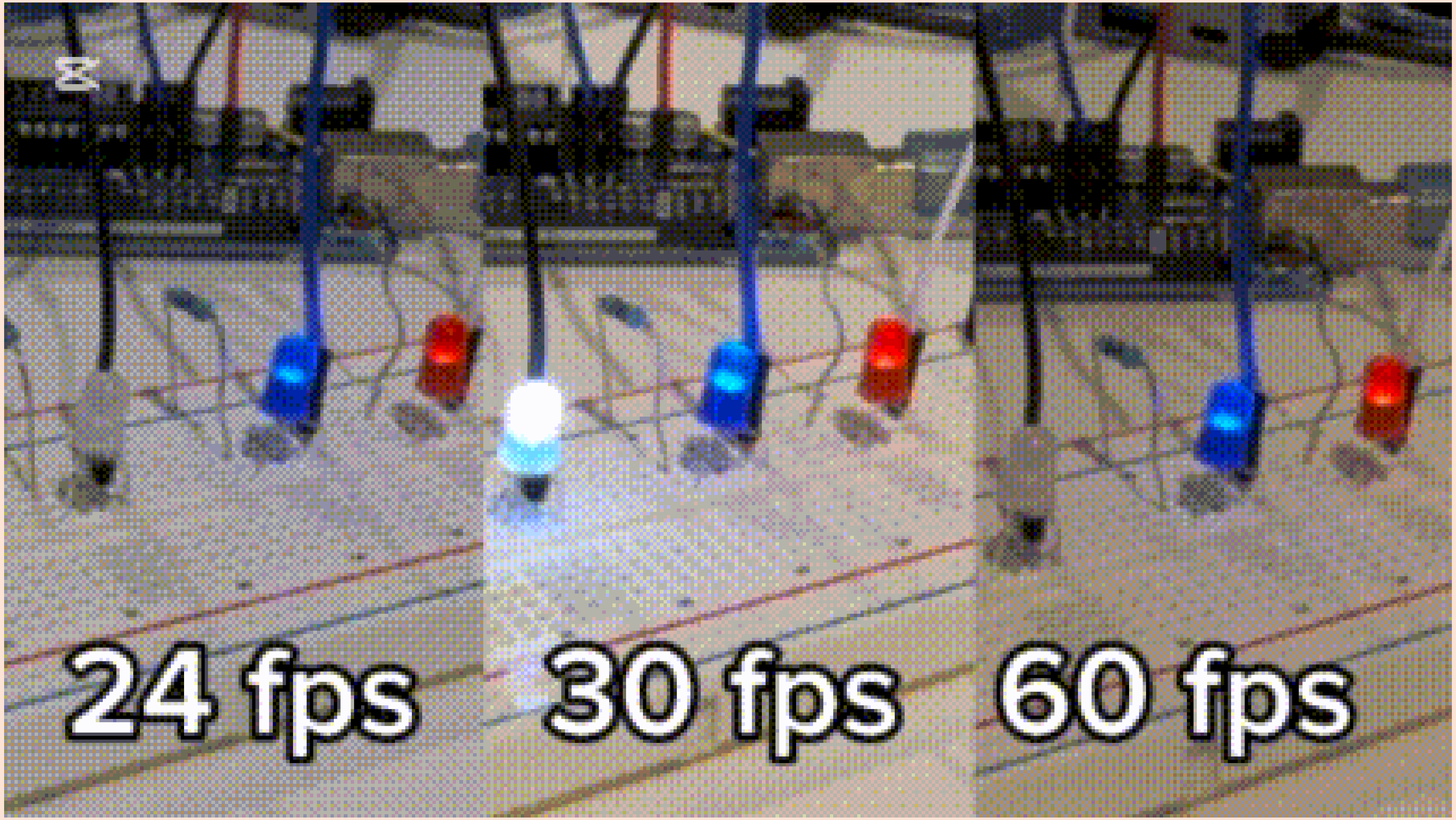


Results and Testing

- As the camera frame rate increases from 24 → 30 → 60 fps (Frames Per Second), the recorded LED modulation becomes progressively more accurate, with 24 fps producing results simulating what the human eye sees, and 60 fps providing the most reliable representation of our flicker patterns.

Smartphone Camera

- Fast flicker (red light/ 2 kHz): Shows strong striping from rolling shutter
- Medium (blue light/500 Hz): Pulsing bands
- Slow (white light/50 Hz): Normal blinking

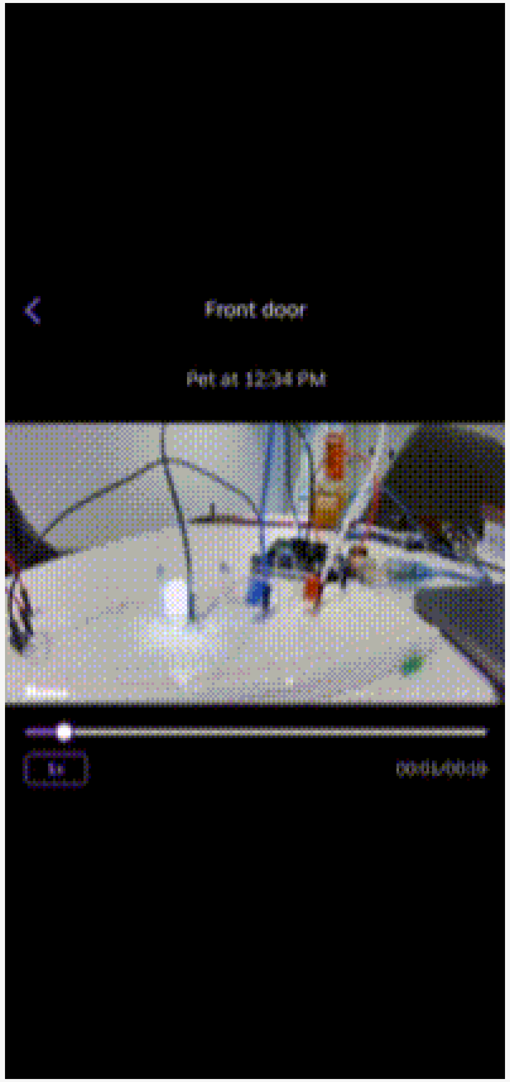


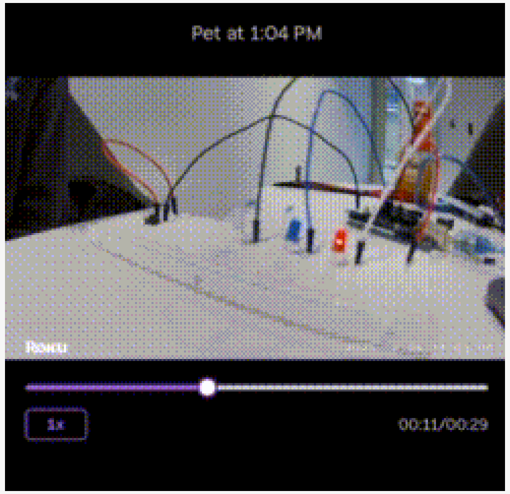
Roku Smart Camera

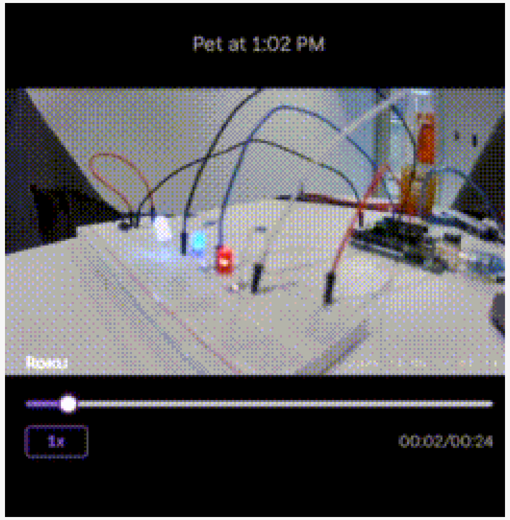
-The LED is blinking faster than the camera can sample each frame evenly.

-As a result, the camera sometimes records the LED when it's ON and sometimes when it's OFF.

-This creates a slow, rhythmic bright–dim–bright–dim effect in the video, even though the LED isn’t actually pulsing at that speed.







Conclusion and Future Plans

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