Light Activated Window Blinds System

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Abstract

This project develops a prototype light-activated window blind system aimed at addressing the inconvenience posed by unreachable windows. Motivated by the desire for an autonomous solution to regulate sunlight and privacy, the project involved integrating various electronic components, including a DC motor, H-bridge, 5V relay, Texas Instrument's MSP430 microcontroller, and a photo diode setup. The project included connecting a light sensor, relay, H-bridge and prototype with the analog to digital conversion module of the MSP430. Results highlighted the device's great overall performance, along with challenges encountered during construction, such as resistor selection and motor control. Looking ahead, future improvements entail implementing user calibration for light sensitivity and integrating distance sensors for automatic blind positioning. This project not only enhanced microcontroller skills but also holds practical implications for everyday use.

1. Introduction

This project originated from a common inconvenience in apartments: windows out of reach. While these windows receive sunlight, their operation poses a challenge due to the labor involved in reaching them. Automating the process, where the window responds to sunlight during the day and provides privacy by closing at night, would greatly enhance convenience and functionality.

Given this idea, the motivation to start a project for a prototype for a light activated blind system that operated completely autonomously emerged. In order to make this happen, several different electronics must be utilized such as a dc motor to lift the blinds, an H-drive to change the direction of the motor, a 5V relay to turn on and off the motor, Texas Instrument's MSP430 microcontroller to process the light information and a photo diode setup to measure the light conditions.

2. Theory

A solid grasp of the theory behind photodiodes, 5V relays, and H-bridges is essential for understanding this project.

Photodiodes are the main component of any light detection system. A photodiode is a semiconductor device that transforms light energy into electrical current through a process known as the photoelectric effect [Das (2023)]. Comprised of a P-N junction, typically made of materials like silicon, it operates by absorbing photons emitted by incident light. When photons strike the semiconductor material, they can excite electrons from the valence band to the conduction band, generating electron-hole pairs. The built-in electric field within the P-N junction then separates these charges, with electrons moving towards the N-side and holes towards the P-side. This separation creates a flow of electrons, constituting a photocurrent, which is proportional to the intensity of the incident light. By connecting the photodiode to an external circuit, this photocurrent can be measured. Thus, the photodiode serves as a light-to-electricity converter, enabling the detection and utilization of light in a circuit such as this project.

A 5V relay is used to activate and deactivate the motor on the system. A 5V relay functions as an electromechanical switch, employing an electromagnet and a set of switch contacts to control electrical circuits [n.d.]. When a voltage is applied across its coil, the coil generates a magnetic field that attracts a ferromagnetic armature, causing the switch contacts to change their state. Typically, this action closes the normally open (NO) contact and opens the normally closed (NC) contact, effectively switching the relay's connection between circuits. This allows low-power control signals, such as those from microcontrollers or sensors, to command high-power devices like motors or lights. Upon removal of the voltage across the coil, the magnetic field dissipates, releasing the armature and returning the switch contacts to their resting state.

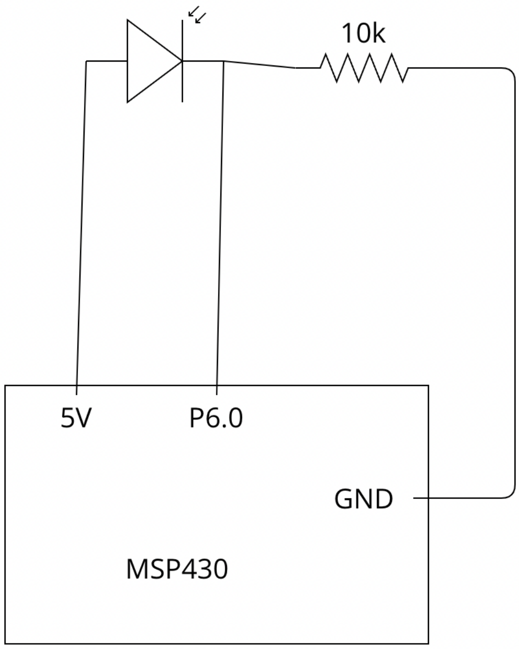

Figure 1: A representation of the light sensor using a photo-diode

Finally, an H-bridge is essential for control the directionality of the circuit. An H-bridge is a circuit used to control the direction and speed of a DC motor [Wiki (n.d.)]. It consists of four switches arranged in an "H" configuration, with the motor placed between the switches. By toggling specific combinations of these switches, the direction of the motor can be controlled.

3. Apparatus

3.1 Light Sensor

Figure 1 illustrates the conversion of the photo-diode into a light sensor by configuring the input to the MSP430 alongside a 10kΩ resistor. When connected to a 5V source and exposed to bright light, the photo-diode produced a voltage reading of 3-4V, detected by the MSP430. Conversely, in darkness, the voltage dropped to approximately 2.4V. This change was significant enough for easy detection via the analog to digital converter accessible through P6.0 on the MSP430.

The MSP430's programming was adjusted to accommodate the differenc in voltage for the system to respond appropriately. In Figure 2, the initialization of the analog to digital conversion module and the utilization of microcontroller pins are illustrated. Additionally, the system establishes a state of 1 when lights are off and 0 when they are on, preventing unintended actions that could damage the motor system.

Figure 3 demonstrates when the ADC12MEM0 register reads above 2457, indicating bright conditions, the microcontroller executes two operations. These operations involve activating an LED for testing (via "P1OUT = BIT0") and changing the device's state.

```c
int main(void)
{
    WDTCTL = WDTPW + WDTHOLD;   // stop watchdog timer

    P6DIR = 0x0;   // motor direction control from light
    P2DIR |= BIT2; // motor drive CCW
    P2DIR |= BIT4; // motor drive CW
    P1DIR |= BIT0;  // light for testing
    P4DIR |= BIT0; // turn on motor

    int state = 1;  // is 1 if lights off, is 0 if lights on
    // set up adc12
    ADC12CTL0 = ADC12SHT02 + ADC12ON;   // sampling time and ADC12 on
    ADC12CTL1 = ADC12SHP;               // sampling signal sourced from the sampling timer instead of sampling input signal
    ADC12CTL0 |= ADC12ENC;              // ADC enable
    P6SEL |= 0x01;                      // P6.0 allow ADC on pin 6.0
    ADC12MCTL0 = ADC12INCH_0 + ADC12REFON; // ADC12INCH_0 selects A0 panel and ADC12REF0 sets ref voltage to 5V
```

Figure 2: The initialization of all variables used in programming of the MSP430

```c
while (1)
{

    ADC12CTL0 |= ADC12SC;          // start sampling
    while (ADC12CTL1 & ADC12BUSY);// while bit ADC12BUSY in register ADC12CTL1 is high; wait

    if (ADC12MEM0 > 2457){          // 2457 is 3V
        P1OUT = BIT0;
        state = open(state);       // lights on - open the blinds
        __delay_cycles(1500000); // delay

    } else {
        P1OUT = ~BIT0;
        state = close(state);       // lights off - close the blinds
        __delay_cycles(1500000); // delay
    }

}
```

Figure 3: The programming for the light sensor for the MSP430

The state changes by triggering the 5V relay, providing instructions to the h-bridge and facilitating blind opening. Similarly, the reverse operations occur when the ADC12MEM0 register reads below the specified threshold, signaling dark conditions and prompting blind closure.

3.2 Relay

The relay logic operates using the 3.3V pin for power and is grounded on the MSP430. Utilizing P4.0 on the microcontroller (as shown in Figure 4), this pin serves to toggle the switch. The switch, in turn, governs the flow of the 5V power source on the MSP430 to the H-bridge by connecting to the normally open (NO) pin. When P4.0 is triggered, the normally open pin closes to the COM pin, enabling current to flow to the H-bridge, thereby activating it. This activation occurs when there's a change in the system's state, triggered by the activation or deactivation of the light sensor.

Once the instructions are issued to change the device's state from the light sensor, the 5V relay must be activated to power the H-bridge. The procedures for opening and closing the blinds both follow the same sequence: activate the relay, operate the motor, introduce a delay, and then deactivate the relay (as depicted in Figure 5). To activate the relay, P4.0 on the microcontroller is utilized. Subsequently, a delay of approximately 6,000,000 cycles ensues. The duration of the delay for closing is slightly shorter than for opening, owing to the force of gravity operating on the blind. This delay duration was determined

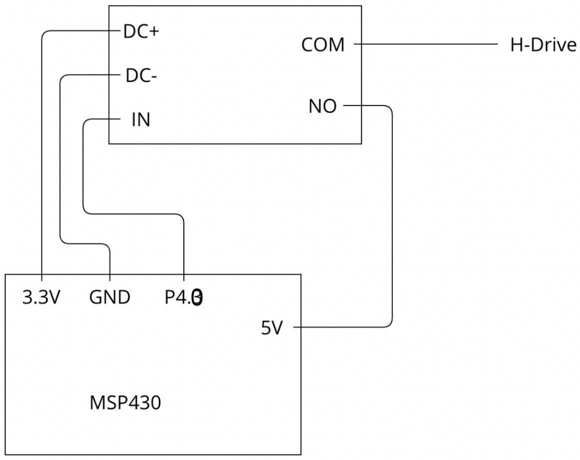

Figure 4: The circuit utilized for the relay of the MSP430

```
int close(int state) { // CW
   if (state == 0){
        P4OUT = BIT0;  // activate relay for power
        P2OUT = ~BIT2; // drive the motor one way
        P2OUT = BIT4;
        __delay_cycles(6000000);
        P4OUT = ~BIT0; // deactivate relay for power
   }
   return 1;
}

int open(int state) { // CCW
    if (state == 1) {
        P4OUT = BIT0; // activate relay for power
        P2OUT = BIT2; // drive the motor one way
        P2OUT = ~BIT4;
        __delay_cycles(6200000);
        P4OUT = ~BIT0; // deactivate relay for power
    }
    return 0;
}
```

Figure 5: The functions used to open and close the blinds and establish the state of the system

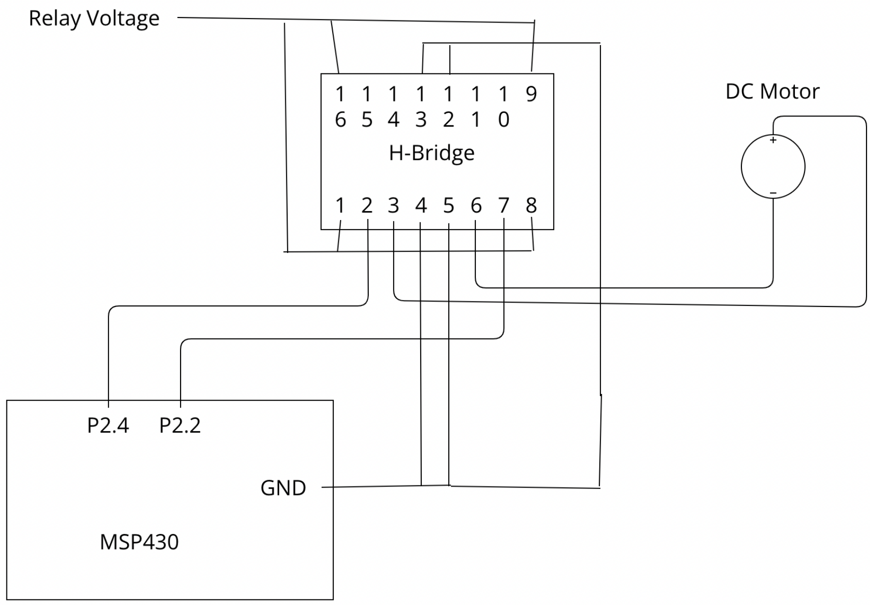

Figure 6: The circuit configuration through powering the DC Motor via and H-bridge

through iterative testing to suit the prototype's dimensions. However, an enhancement to this project could involve integrating a sensor to detect when the window reaches its upper and lower limits, thus automatically shutting off the relay.

3.3 H-bridge

When the H-bridge is energized via points 16, 1, 9, and 8, it directs power to the DC motor, enabling it to rotate either clockwise or counterclockwise, depending on the specific pin configuration of P2.2 and P2.4 (as depicted in Figure 6). Microcontroller pin inputs are routed through points 2 and 7 of the H-bridge, subsequently powering the DC motor through points 3 and 6. By altering the pin configurations, points 3 and 6 switch the roles of the 5V power source and the ground, thus dictating the motor's direction. For instance, if P2.2 is set to true while P2.4 is false, the motor rotates counterclockwise, thereby opening the blinds on the prototype (refer to Figure 7). Conversely, to close the blinds in the clockwise direction, P2.2 should be false and P2.4 true.

3.4 Prototype

To replicate the functionality of my home blinds, I devised a pulley system operating on a cable that could be manipulated by coiling and uncoiling string on a spool (refer to Figure 7). The process began with constructing a window frame using cardboard, hot glue, and tape. Next, I affixed the motor and spool to the frame, which was straightforward thanks to the motor's offset configuration, allowing me to insert it into a hole in the side of the frame. Then, I connected the spool to the motor using tape and set up a pulley system with the string. This setup ensured that the blinds could be raised and lowered effectively, mimicking the functionality of my home blinds.

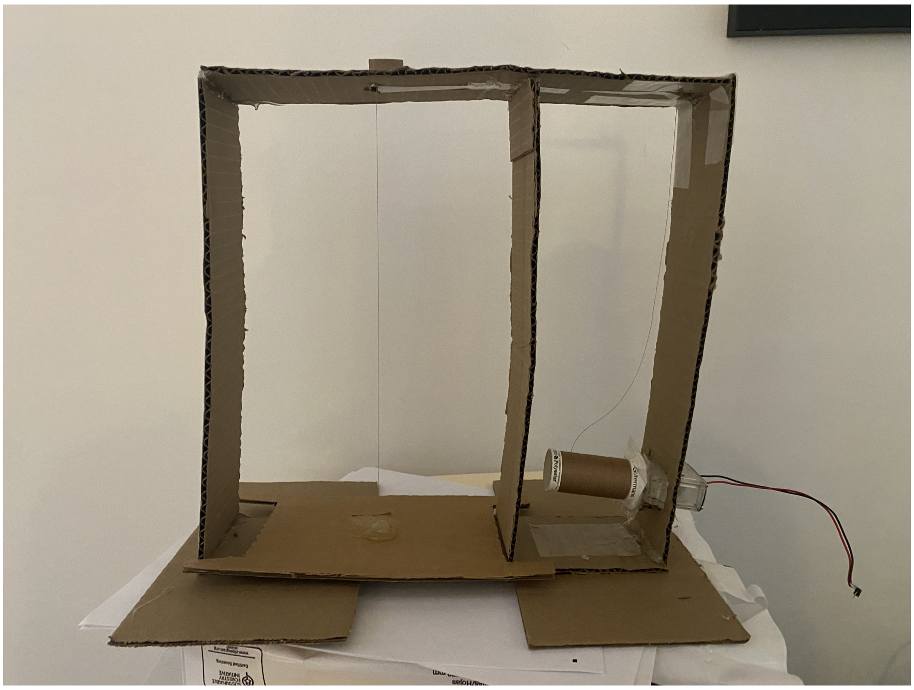

Figure 7: The cardboard prototype for my window blinds system

4. Results

The device demonstrated great performance overall. However, the cardboard blind occasionally encountered issues such as getting stuck on the frame during opening and closing, posing a potential risk to the pulley system on the prototype.

Several challenges emerged during the device's construction, notably determining the appropriate resistor size to generate a large voltage difference from the photodiode for distinguishing light and dark conditions. Initially, a 1 MΩ resistor was employed, however with inconsistent results. It was later realized that the circuit functioned sporadically due to connections formed by pushing the metal ends of the photodiode together. Through iterative testing, a 10 kΩ resistor created a significant voltage difference that was not accidental.

Moreover, creating a mechanism to stop the motor's operation was very difficult. Initially, the plan did not involve utilizing a 5V relay. However, the team recalled a circuit used of a past personal coffee machine project that was built, which employed a relay for device control, which provided a solution. Incorporating a relay was effective in facilitating motor control, which resolved this challenge effectively.

5. Discussion

The overall outcome of the project was pleasing, although some challenges were encountered during the prototype development phase. In future iterations, a sturdier pulley system using a wooden frame to elevate a fake cardboard blind would be a more optimal setup.

Given additional time, my primary focus would be implementing user calibration for the device. This feature would enable users to adjust the light sensitivity according to their environment, eliminating the need to manually alter the timing for blind movement within the software.

To enable user adjustment of light sensitivity, the development of a function controlled by two buttons within the software would be necessary. These buttons would allow users to incrementally increase or decrease the voltage threshold for blind operation. This would be user accessible by integrating a LCD display to visualize the sensitivity on a scale of 0 to 100. Up and down buttons would facilitate easy adjustment of the sensitivity scale.

To eliminate the need for manual software adjustments based on blind dimensions, two distance sensors could be integrated. To detect proximity, one sensor, could be positioned beneath the blind, and another on the bottom of blind facing upwards to the frame. These sensors would automatically stop the relays when the blind approaches within 1cm distance. Integrating these sensors would enable operation of the system without requiring software modifications for each installation.

6. Conclusion

Through the development of this project, valuable skills in microcontroller usage were acquired. Firstly, proficiency was developed in establishing light detection systems using a photo diode and the analog-to-digital conversion module. Additionally, mastery was attained in configuring an H-bridge to drive a motor and control of its directionality Moreover, this project holds practical significance and could benefit daily life for many individuals. Constructing it allowed me to contribute to the creation of a product, that scaled up, has real-world applications. In summary, this experience provided both learning opportunities and enjoyment, fueling enthusiasm of the team to pursue further microcontroller projects in the future.

References

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Das, N. (2023, August). Photodiode - a beginner's guide. https://www.build-electronic-circuits.com/photodiode/

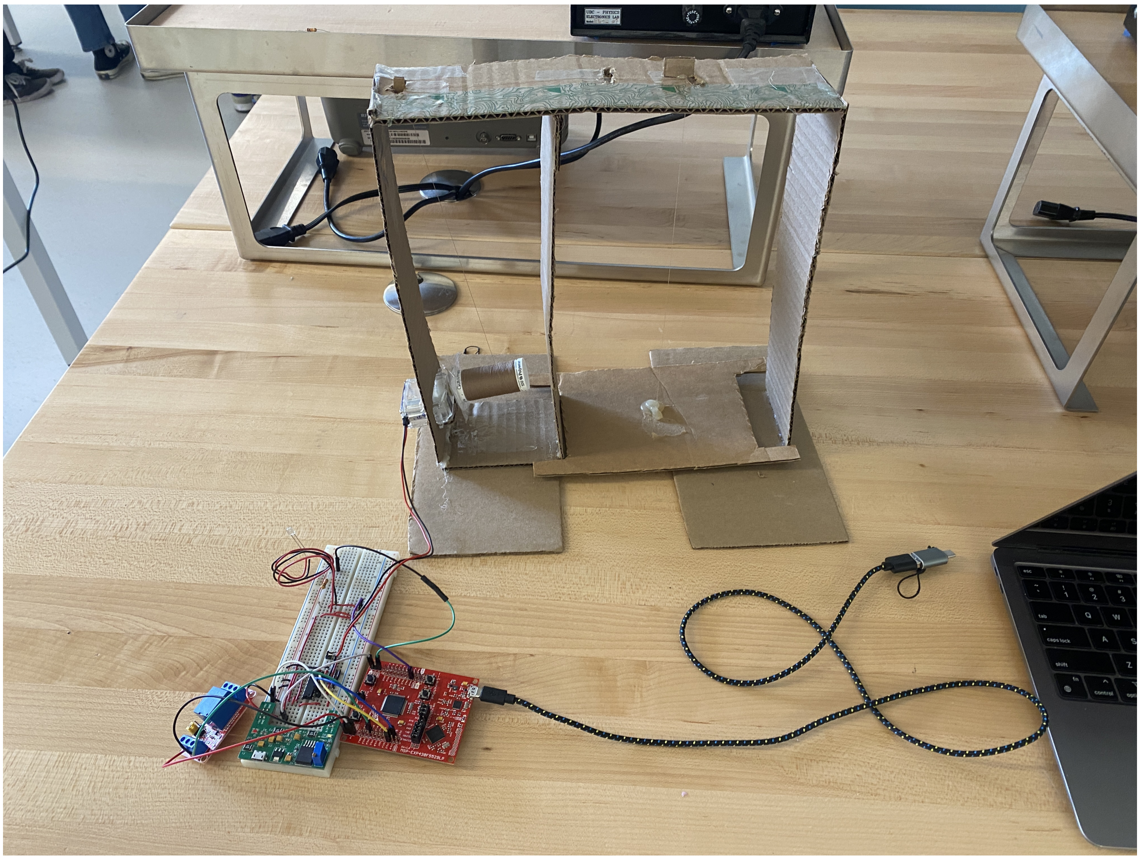
Wiki, C. t. E. (n.d.). Sn754410 quadruple half-h motor driver. https://erace.fandom.com/wiki/SN754410_Quadruple_Half-H_Motor_Driver

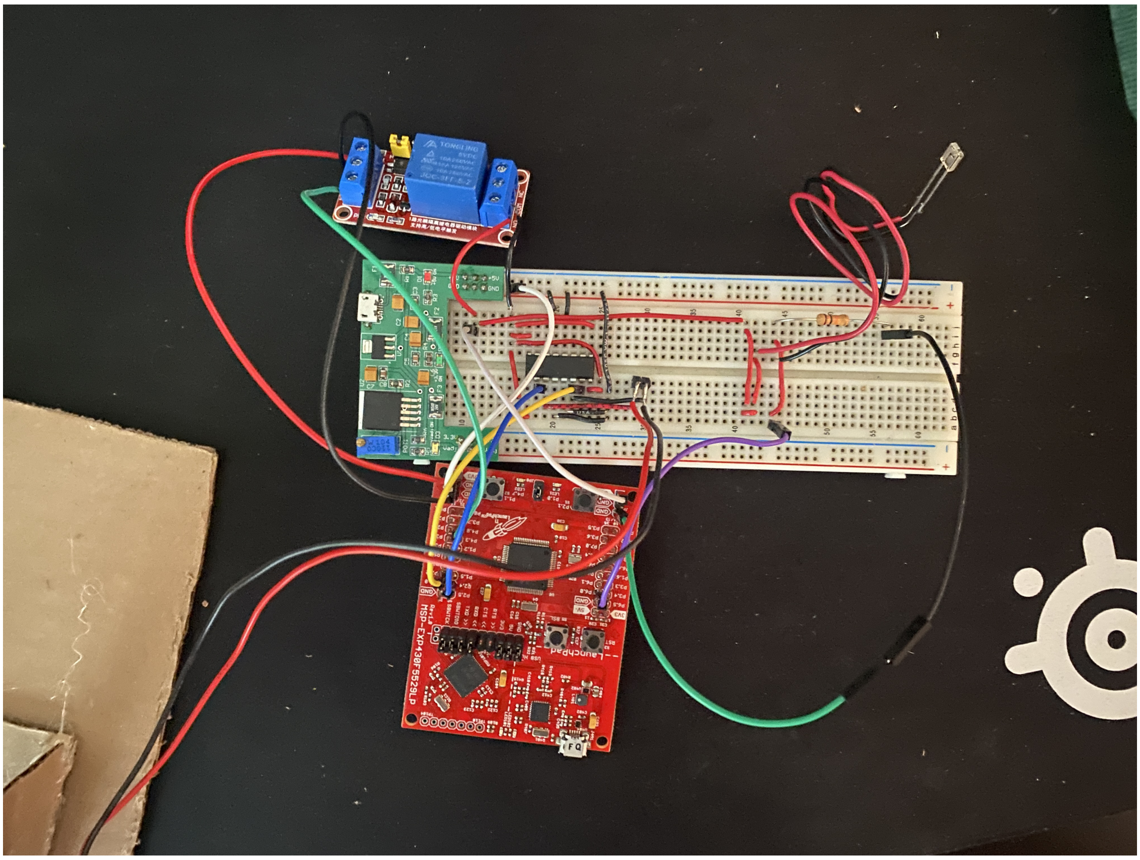
A. Appendix

A.1 Materials Used

- MSP 430 Microcontroller
- DC Motor
- H-drive
- Photo diode
- $10K\Omega$ resistor
- Wires
- Cardboard, hot glue and wire
- 5V Relay

A.2 Images of Full Project





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