Solar-Powered Traffic Light

ECE 445 Project Proposal - Spring 2022

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Team 20

1 Introduction

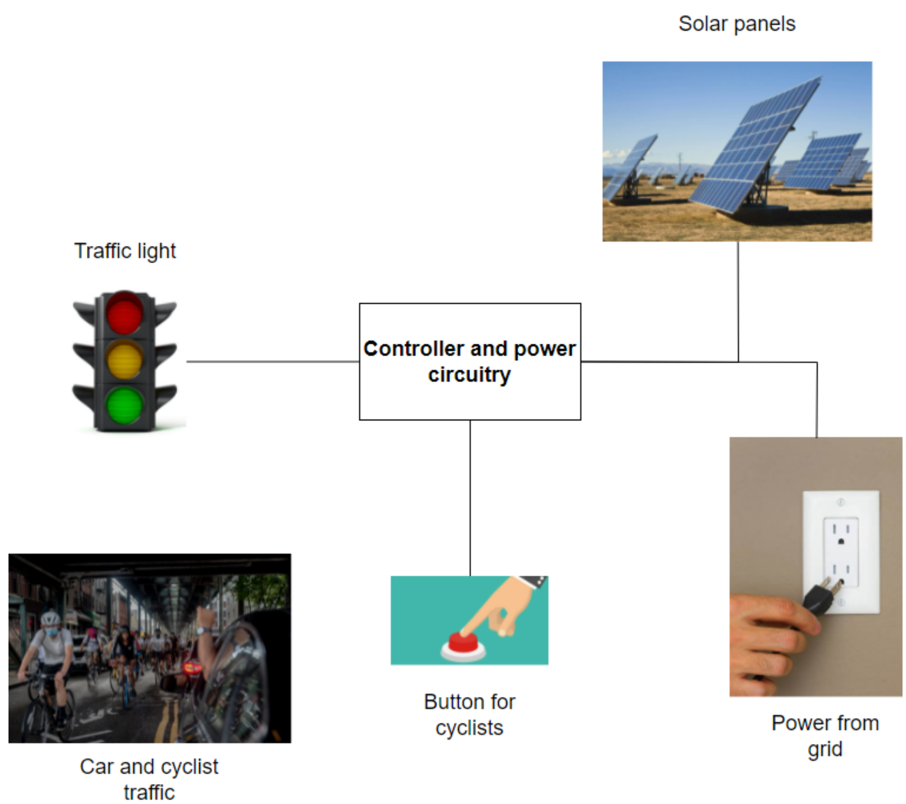
1.1 Problem

Traffic lights are integral to our society, despite their relative lack of innovation over the years. The most significant change has been the switch from incandescent bulbs to LEDs in an attempt to reduce the power consumption of this necessary device. However, this has also led to an increase of light pollution due to the cooler, more intense light emitted by LEDs.They can cause extreme glare and pose a danger to drivers at night. Additionally, the issue of bicyclists and vehicles sharing the road can create many awkward or dangerous situations due to the lack of separation.

1.2 Solution

We propose a solar-powered traffic light system that will reduce light pollution and solve the issues of drivers and bicyclists sharing the intersection. The system will be solar powered to minimize utility power used during the day. Connection to the grid will be necessary for operation at night or when solar conditions are suboptimal. At night, PWM circuitry will dim the LED modules. This not only reduces light pollution, but also lowers utility consumption at night. In the case of adverse weather conditions, the system will not dim the lights to ensure proper visibility.

1.3 Visual Aid



1.4 High-level Requirements List

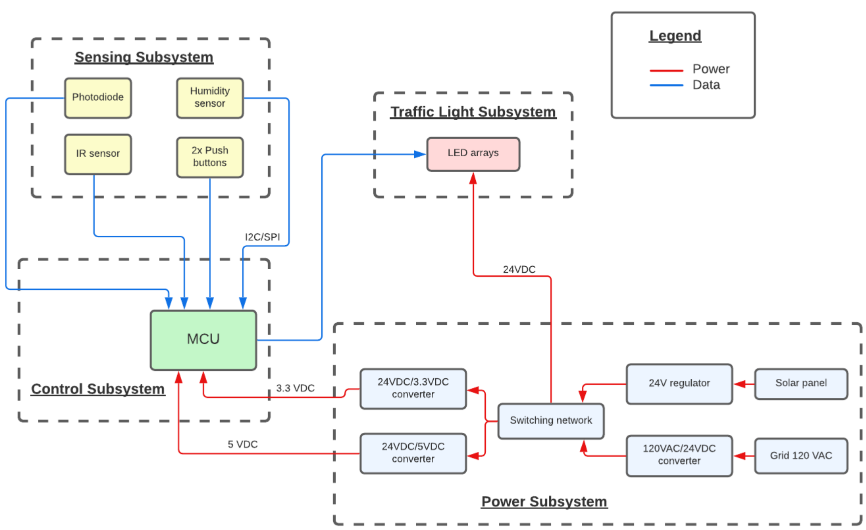
- A single traffic light bulb uses about 15 watts of power [1]. In order to limit light pollution and reduce consumption of utility power, the light modules will operate with less power when it is sufficiently dark outside (assuming clear weather). Should the power saved over an expected lifespan of about 20 years be non-negligible (and the other two requirements are met), we can conclude that this system is a success.

- The system must be able to switch between solar and utility power without causing a power failure. This is especially important when switching to utility power at night. Maximum voltage transients and switching time must not exceed 2.4V and 20ms respectively. This can be tested using an oscilloscope in the lab.

- The system will be able to efficiently adjust the light patterns and lengths of operation to increase the efficiency of traffic. Bicyclists and pedestrians will be able to press one of two buttons to trigger the bicycle and walk signs for them to safely cross the intersection. For example, assuming a walking pace of 3 miles an hour and a lane width of 20 feet [2], the walk signal must be on for a minimum of 15 seconds to ensure everyone crosses.

2 Design

2.1 Block Diagram



2.2 Subsystem Overview & Requirements

2.2.1 Power

Solar Panel

Main power will be supplied by a solar panel with an output voltage of 18V

Requirement 1: The solar panel must provide up to 100W.

Requirement 2: In full sunlight, the panel will generate 18V±5% when loaded.

Utility

If the solar panel is not able to provide enough power, the entire system will switch to being powered by 120VAC utility power.

Requirement 1: Must provide stable 120VAC±5%.

Switching Network

This system will switch the power input seamlessly between solar and utility. It will prioritize using solar power, and will switch to utility power if solar power drops below a threshold of 50W.

Requirement 1: Switching between the two sources must not interrupt normal operations.

Requirement 2: Switching transients must not exceed 2.4V.

Requirement 3: Switching time must not exceed 20ms.

Power Converters

Various converters will be utilized to ensure proper voltage levels for the lights, microcontroller, and sensors. The solar panel's output will be regulated to 24V with a step-up/step-down DC-DC converter. 120VAC utility power will be converted to 24VDC, which will further be stepped down to 5V and 3.3V.

Requirement 1: The 24V DC-DC converter at the solar output and 120V to 24V AC-DC converter at the grid output must both provide 24V±10%.

Requirement 2: The 24V to 5V converter must provide 5V±5%.

Requirement 3: The 24V to 3.3V converter must provide 3.3V±5%.

2.2.2 Sensors

Buttons

The buttons will be used to determine if there are bikes or pedestrians waiting to cross the street. Realistically, the wires carrying the button signals would be 20+ feet long, so a 24V signal will be used to reduce noise interference from voltage drops and ensure signal integrity. An opto-isolator circuit will be used to transmit the 24V signal to the microcontroller.

Requirement 1: Buttons must be rated for at least 24V and 0.1A.

Light Dependent Resistor

The light dependent resistor (LDR) is responsible for detecting the presence of sunlight and sending a signal to the MCU. The LDR's resistance can range from a few hundred ohms in a bright environment to over one mega ohm in complete darkness. A simple voltage divider circuit will be used to correlate the light level to voltage level.

Requirement 1: Must be able to sense visible light (400nm to 700nm).

Humidity

The humidity sensor is used to detect adverse weather conditions and turn off the PWM light dimming if it is on. This ensures proper visibility of the traffic lights.

Requirement 1: The sensor must have either a I2C or SPI output.

Infrared

The infrared sensor is used to detect vehicles and send a signal to the microcontroller.
Requirement 1: Must be able to detect the presence of a vehicle from a distance of at least 10ft.
Requirement 2: All components in this section must function properly from temperatures -8°F to 91°F (-22°C to 33°C). These temperature points were supplied from the National Weather Service and are the coldest/hottest monthly averages in Illinois from the past decade [3].

2.2.3 Control

Microcontroller

The microcontroller will take data from the various sensors and control the PWM as well as the timing for the traffic lights.
Requirement 1: Microcontroller must respond to sensor input within 50ms.
Requirement 2: Maintain state information and respond with appropriate control signals
Requirement 3: Must support either I2C or SPI communication, analog inputs, and PWM outputs.

2.2.4 Traffic Light System

Traffic Lights

For our traffic light system we will be constructing them out of high power LEDs, which we will have to design an additional PCB board for or get a sample of real traffic lights to use in our project
Requirement 1: The LEDs must be visible from 150 ft for drivers to see them in bright conditions, most modern traffic lights are 400-1000 lumens so we aim to be in this range[4].

Pedestrian/Bike Lights

The pedestrian/bike light will turn on to indicate whether pedestrians/bikes can cross the intersection. When this light is on the traffic light should be red.
Requirement 1: Light up when pedestrians/bikes want to cross the intersection.

2.3 Tolerance Analysis

The main issue we will run into this project is creating a 24V input switching network. We will need to ensure there is no delay/outage in our traffic lights when switching between grid power and solar power. Putting multiple 24V capacitors in parallel will limit the voltage drop and be able to provide power during the switching time. Using an oscilloscope, we can verify the transient voltage will be less than 2.4V and switching speed less than 20ms.

3 Ethics and Safety

The team will strive to adhere to the IEEE Code of Ethics. Since we are designing a product for use in traffic, we must ensure "the safety, health, and welfare of the public" and to "disclose promptly factors that might endanger the public or the environment." [5]

One of the dangers to this project is the bike and pedestrian buttons. Since they will be using 24V to transfer signals, the enclosure must be properly grounded or insulated to minimize risk of electric shock. Additionally, only the ground wire will be extended to the physical switch so that no accidental short circuits will occur.

We will also follow Section 4.1.1 "Relationship between Signal Timing and Traffic Control Design" of the U.S. Department of Transportation's guidelines for the traffic signal design process [6]. In order to provide the highest level of service to its users, the team will tune the system. Visibility, vehicle detector position, and minimum green time are some of the parameters that we will experiment with.

References

[1] City of Yakima, “Led Traffic Signals.” [Online]. Available: https://www.yakimawa.gov/services/streets/led-traffic-signals

[2] Wikipedia, “Lane.” [Online]. Available: https://en.wikipedia.org/wiki/Lane

[3] National Weather Service, “Climate.” [Online]. Available: https://www.weather.gov/wrh/Climate?wfo=lot

[4] Leotek, “Il6 - p3 Series Ultra Low Power 12” Traffic Signal Module 10-28vdc Incandescent Look Ball.” [Online]. Available: https://leotek.com/wp-content/uploads/ULP_IL6-P3_8inch-and-12inch_10-28Vdc_Signal_Ball_Spec_Sheet_12-14-18.pdf

[5] IEEE, “IEEE Code of Ethics.” [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html

[6] U.S. Department of Transportation, “Traffic Signal Timing Manual.” [Online]. Available: https://ops.fhwa.dot.gov/publications/fhwahop08024