Modular Light Control

Team 44 - Ibrahim Odeh, Rohan Tikmany, Konrad Woo
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TA: Amr Martini

1 - Introduction

1.1 - Objective

Smart light systems can take time, expertise, and much money to install. This is why we devised a modular, wifi-capable sensor system solution to control zonal lights. The system will be easy to install with no professional help required and minimal effort applied. It should be able to detect movement and presence with the help of a PIR sensor and microphone and change specified lights accordingly.

1.2 - Background

If you've ever been in a room with motion sensing lights, you may be familiar with how frustrating it can be when the lights turn off whilst you're still occupying the room. You have to periodically stand up, move around, possibly even wave your arms, and go back to where you were. What if the room is very large and you want to control a set of lights in a certain portion of the room where the switch is far away?

Other systems require a hefty initial investment and effort to install or are limited by having the sensor mounted on the switch itself. Our system will be able to address these issues by being cost effective and not requiring any major rewiring other than replacement of switches. The modularity of the sensors and the ease of mounting (using 3m double sided tape) will allow for the sensors to be at any location. Our system will also be able to group multiple sensor units to one or more switches using an app based user interface. Once setup, the system will be passive with no required human intervention.

1.3 - High-level Requirements List

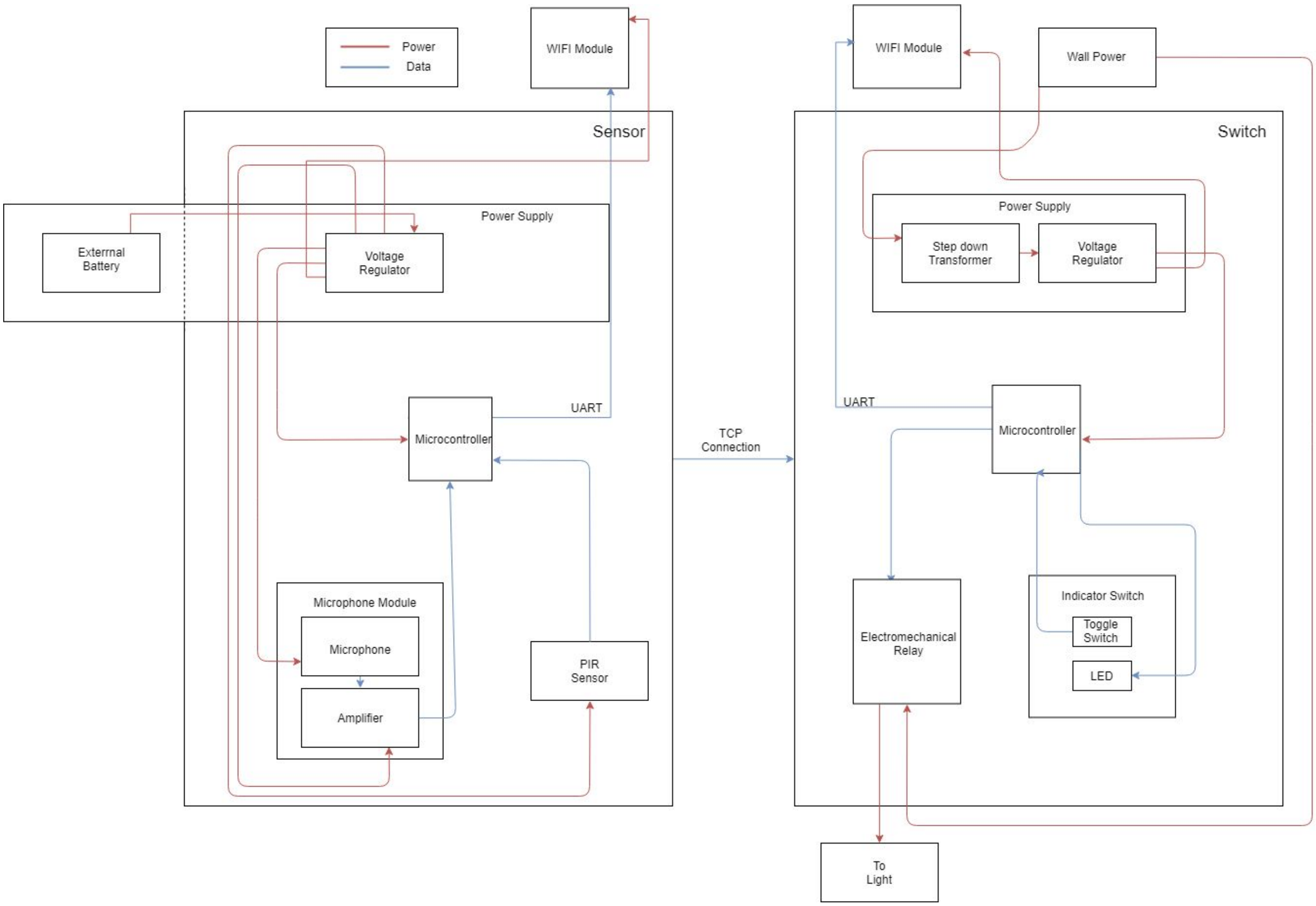
- <u>Modularity</u> to add and adjust new components with ease and minimal setup

- <u>Zonal Lighting</u> through grouping of sensors and switches

- <u>User Interface</u> to control groupings and policies and to add new sensors

2 - Design

2.1 - Block Diagram



2.2 - Functional Overview & Block Requirements

2.2.1 Microcontroller

The microcontroller we chose is the ATMega328P. The microcontroller will be communicating with the Wi-Fi module using UART protocol. The other functions of the microcontroller for the different parts are as follows:

1. For the sensors, the microcontroller will convert the analog outputs from the PIR sensor and the amplified microphone output to a digital form using its internal A/D converter.

2. For the slave switch, the microcontroller will control the signals to the electromechanical relay (EMR) and the LED based on what communications/signals it receives from the WiFi module and the toggle switch.
3. For the master switch the microcontroller will use the WiFi module to communicate with a front end application to control the settings of the system. It will also receive communications from the sensors, and, based on the programmed protocols, will trigger switches by communicating with them over WiFi.

Requirement 1: The microcontroller must be nested in an IC socket on both sensor and hub assemblies to allow for simpler debugging and replacement.

Requirement 2: The microcontroller must be capable of processing the inputs from the PIR Sensor and microphone and send readings over WiFi if the thresholds have been reached with a maximum delay of 2 seconds.

2.2.2 Indicator Switch

The indicator switch will function as a manual override for the lights and will also provide visual feedback representing the condition of the lights.

2.2.2.1 LED

The LED will be used as an indicator as to whether the lights connected to the switch are ON or OFF.

Requirement 1: Must sync up with the light status.

Requirement 2: The LED must be visible from a minimum of 1 m away.

2.2.2.2 Toggle switch

The Toggle switch will be used as a manual override to control the lights. The switch will be connected to the ATMega which based on the signal input will control the lights.

Requirement: Must toggle the condition of the light irrespective of presence of humans

2.2.3 Step Down Transformer

This will be used in the switch assembly to take the wall voltage and step it down so the voltage regulators can further lower it to feed the microcontroller and WiFi module.

Requirement 1: Must be able to take 120V ± 6V and step down to at least 40V ± 10V.

Requirement 2: Must be of decent size to fit into switch box such that the switch assembly will not protrude more than 2.5" from the wall.

2.2.4 Voltage Regulator

The voltage regulator assembly will accept the step down transformer voltage and will channel lower voltages to the respective components.

Requirements: Single input, 4 ±1V output for 328p, 3.3 ±.3V output for wifi module.

2.2.5 WIFI Module

We will be using wifi modules that will interface with the atmega controllers on the sensor board and the switch board using UART. We intend to use a module with a PCB trace antenna to communicate between the microcontrollers. Since the wifi module may take up too much power on the sensor board and kill the battery too quickly, we will power the wifi module on and off as necessary, only using power when the sensors need to communicate the presence of somebody in the room.

Requirement 1: Must be able to interface with the atmega to read proper sensor data

Requirement 2: Must be able to communicate this sensor data through wifi to the receiving module in the switch.

2.2.6 Electromechanical Relay

The relay will be used to operate the high-voltage lights based on a low-voltage control signal generated by the microcontroller.

Requirement 1: Must be able to withstand 113-125VAC, the typical wall voltage threshold.

Requirement 2: Must be triggerable based on the Atmega328p's output voltage.

2.2.7 Passive Infrared Sensor

The ZRE200GE PIR sensor will be used to identify human presence. It will be fed 3 ± .3V and will output an analog signal to the sensor board's microcontroller. There will be blinders or a convex Fresnel lens applied to limit the viewing angle.

Requirement: On a 9 foot ceiling, the sensor must be able to have a detection radius of 7 ± 2 feet.

2.2.8 Microphone Module

The microphone module will be our second sensor which will be used in conjunction with the PIR sensor to decide whether to trip the light in its assigned zone or not.

2.2.8.1 Microphone

An ICS-40180 surface mount electromechanical microphone which will be used in conjunction with the readings of the PIR sensor to detect human activity/presence.

Requirement: Microphone must be able to detect man-made noises ranging from 60Hz to 10kHz and must run on a current below .2mA.

2.2.8.2 Amplifier

We will need an amplifier to take the microphone output and amplify the signal to an analog voltage that is readable by the atmega. The digital addressability of the ADC will require a voltage range of 0-5V for the best possible granularity of the voltage input. The amplifier should operate from low human vocal ranges of ~80Hz to upper frequencies of human hearing ~10KHz.

Requirement 1: The amplifier should be able to extend the microphone output range to 0-5V.

Requirement 2: The amplifier must have a passband over the frequency range from 80Hz-10kHz.

2.2.9 Battery

The battery we are planning to use is a 9V battery because of its higher voltage, its ease of voltage regulation, and its longevity for our purposes.

Requirement: Ability to power the sensor for a month.

2.4 - Risk Analysis

The biggest obstacle we will encounter in this project will be the communications between each of the boards. The entire network of sensors and switches will require synchronization between each of the wifi communications boards, and these boards must be able to communicate with our microcontrollers. We must be able to boot the proper wifi information onto these wifi control boards, and we must ensure that the boards can be updated with certain protocols through wifi. Requiring several “chains of command” through these wireless communications could create a series of comms problems that may prove difficult to pinpoint and debug.

3. Ethics and Safety

The electromechanical relay in our device will be connected to wall outlet power through one of its pins and will be conducting this wall power in its active state. This will pose a safety risk during our own testing procedures and during installation by any consumer. We would like to market this device as easy to install, but we will make the shock hazards abundantly apparent and will encourage support by others more familiar with the dangers for those who are entirely unfamiliar with rewiring electronics in order to maintain #1 of the IEEE code of ethics - “to disclose promptly factors that might endanger the public” [1]. We intend to include descriptions of proper safety practices regarding mains power with our product, and we will approach our design and test using the same safety practices. We will be following the OSHA standards for power safety [2]. Our ground and power rails on our device will be clearly marked so that polarities are not switched. When rewiring the circuitry, the power to the device will be off. In testing, we will use a ground-fault circuit-interrupter and insulating gloves to ensure no significant electric shock. We will use the “one hand rule” with one hand in pocket when working with the relays and transformers [3].

Since our device connects the modules through wifi, an ethical and safety concern arises with the possibility of unauthorized users who would be able to gain access to the network and control the lights manually and/or retrieve the sensor data to detect a person’s presence in the building in order to use this information for malicious intent, directly infringing upon #9 of the IEEE code of ethics - “to avoid injuring others, their property, reputation, or employment by false or malicious action”[1]. In order to prevent this, we will have identifying data associated with the sensor boards that will be encrypted along with the data read from the sensors, and this ID will be required for the switches to act upon the given command. We strive to take advantage of the utility of wifi while also accounting for the associated safety concerns.

References

[1] Ieee.org, "IEEE IEEE Code of Ethics", 2019. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: Feb 7, 2019].

[2] osha.gov, “Occupational Safety and Health Standards Subpart S: Wiring design and protection”, 2019, [Online]. Available: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.304. [Accessed: Feb 7, 2019]

[3] UC Irvine, “High Voltage Electrical Safety Program”, 2015, [Online]. Available: https://www.ehs.uci.edu/programs/safety/hvoltageAppendixB.pdf. [Accessed: Feb 7, 2019]