Coat Hanger Light Switch Controller
Design Review

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ECE 445 Project Proposal - Fall 2017
10/5/2017
TA: Kexin Hui
1. Introduction
1.1 Objective
The drive to reduce one's carbon footprint is steadily increasing in the US and across the world. However, it is often difficult for people with busy schedules to take time to make their life more sustainable. A simple way everyone can reduce their carbon footprint is by turning off lights in the home when they are not in use, but often times it is easy to rush out in the morning without remembering to turn anything off. On average, every kilowatt hour of energy produces 1.222 lbs of CO2 [1]. Just one 60 watt bulb someone forgot to turn off would produce 0.659 lbs of CO2 in 9 hours. This number, though seemingly small, can easily grow to have a serious impact on the atmosphere when accounting for the number of lightbulbs left on in each home as well as the number of homes that sit empty during a weekday across the globe.

1.2 Background
Our goal is to make it easy to reduce CO2 emissions by automating an easily forgettable task. To achieve this, we will use a coat hanger to detect when a user removes an item, such as a purse or coat, from the hanger and turn the lights off one minute after the removal has been detected, giving the user plenty of time to leave their home and still be able to see their way out.

The coat hanger will communicate with any light switches that are connected to it, indicating to stop the current to the outlet/light fixture. This way, the user only has to take their belongings with them, and the hanger will do the rest. Automating this task will ensure that it gets accomplished.

1.3 High-Level Requirements
- Light switch and hanger must be able to connect wirelessly.
- After removal of object, light must turn off after a short delay to allow for user exit.
- Light switch control must be able to be restored to use as normal in case the object is not returned to the hanger.
- Apparatus must be functional in test environment: a battery powered lamp with light switch control. The purpose of the test environment is to prevent electrocution.
2. Design
2.1 Block Diagram
The hanger and light switch fixture are designed to be completely modular such that the light switch fixture can be placed within a fixed radius of the home and still be controlled by the hanger wirelessly. For this to be achieved, this project will require two independent control units and two independent power sources. The pressure detector, delay circuit, and communication element will allow the Hanger unit to signal the Fixture unit to turn off the light after a fixed time. The Reset component of the Light Fixture unit will allow the light to be operated as normal even if there is not an object on the Hanger fixture.

![Block Diagram]

Legend:

- Voltage Regulator
- Digital Signal
- Power
- Z-Wave Communication
- House Current

Figure 2.1.1: Block Diagram

2.2 Physical Description
For this project, the electronics should fit into a standard sized coat hanger. The pressure detector will be placed on the underside of the "hook" portion of the hanger so as to register the mass of whatever is on the hanger.
1. Pressure Detector: under "hook" part of hanger
2. Circuit housing for additional elements
3. LED Indicator for battery level
4. Delay Circuit
5. Communication element
6. Hanger LED
7. Power (battery)

Figure 2.2.1: Physical Design
2.3 Hanger
2.3.1 12V Battery
For the hanger, we have selected a 12V Alkaline battery (Energizer A23) to properly power the Delay Circuit.

Output: Power (55mAH per 12V / 2 in parallel with a 20 kΩ .48mA draw will reach 6 V (functional bottom) in 230 hours of up/broadcasting time, which should satisfy the requirements below. [19]

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification (12/50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Must last 10-20 days</td>
<td>1. Leave battery in for 10 days without loss of functionality. (3)</td>
</tr>
<tr>
<td>2. Must have 1.5-3.3 V potential to power the communication element.</td>
<td>2. Output voltage will be measured with a standard Hewlett-Packard DMM as available in the lab.(3)</td>
</tr>
<tr>
<td>3. Must be replaceable by a standard consumer (easily removed/inserted)</td>
<td>3. Have multiple people with no knowledge of project try to replace battery. (3)</td>
</tr>
</tbody>
</table>

2.3.2 Battery Status LED (Hanger)
This LED will indicate when the voltage from the battery is at 60% capacity or 7.2 V, showing the user when it is necessary to change out the battery in the hanger itself.

Inputs: Power, signal from communication device.

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification (6/50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Must turn on when the associated battery is running below 60% voltage capacity or 7.2 V.</td>
<td>1. Put dead battery in place of full battery and visually confirm LED output. (4)</td>
</tr>
<tr>
<td>2. Must be visible from 3 meters away.</td>
<td>2. Visually confirm LED visibility by standing 3 meters away while being able to see the LED illuminated. (2)</td>
</tr>
</tbody>
</table>

Figure 2.3.2.1: Requirements and Verification

Figure 2.3.2.2: Hanger LED Circuit Schematic
2.3.3 Delay Circuit
The delay circuit will be located on the hanger component between the pressure detector and
primarily transmitting communication element. This will delay the signal to turn off the light by an
amount of time so as to not turn out lights before the user leaves the house. [5][6][7][8]
\[ \tau = R \times C \] 
we chose a variable resistor of 100k Ohms and a capacitor of 1000 \( \mu \)F so that the
base time to take the capacitor to fully charge would be 100s. This is in range of the time we
want, 60s, and since the resistor has a range from 10 ohm to 2M ohm[10], we will be able to
easily adjust it to the appropriate time. Given our calculations, this appropriate resistance will be
140k ohms. The diode behind the relay is included to reduce the effective EMF from the relay.

Input: 12V power (alkaline battery), analog signal (pressure circuit)
Output: Delayed signal

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification (10/50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Delay: Should delay signal for <strong>50 - 70</strong> seconds</td>
<td>1. <strong>Delay:</strong> A cell phone timer will be used to measure the time duration between replacing an empty hook on the bar it hangs from and the test fixture turning off (the test fixture being a simple circuit representing a standard household 120V/60Hz AC power source, light switch, and standard light bulb). (5)</td>
</tr>
<tr>
<td>2. Voltage: Should output a voltage of <strong>1.5 - 3</strong> V</td>
<td>2. <strong>Voltage:</strong> Output voltage will be measured with a standard Hewlett-Packard DMM as available in the lab.(2)</td>
</tr>
<tr>
<td>3. Robustness: Should never output more than <strong>3</strong> V to protect communication circuit</td>
<td>3. <strong>Robustness:</strong> The performance of the circuit will be tested by repeatedly signalling the circuit with intermittent high and low voltage. The output will be monitored to never exceed 3V so as to protect downstream circuitry. (2)</td>
</tr>
</tbody>
</table>
2.3.4 Pressure Detector

The pressure circuit will provide main functionality for the Coat Hanger Light Switch by providing the signal into the Delay Circuit to start the process of communicating with the light switch to turn off.

**Input:** 5V  
**Output:** Logical True (>1V), Logical False (<1 V)  
**Calculations:** 0.4 P2P V, 16 MHz

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification (7/50)</th>
</tr>
</thead>
</table>
| Pressure detector will activate when an item is placed on the hanger, and will not send a signal if there is nothing placed on the hanger. | **Sensitivity:** Should provide a logical TRUE signal when experiencing **less than .3-6kg** of weight [1] [2] and a logical FALSE when experiencing more than the threshold. (5)  
**Repeatability:** Should perform correctly at threshold weight when removing and
Push button
(kg resistance provided by mechanical springs)

Fig. 2.3.4.1: Pressure sensing circuit
2.4 Light Switch
2.4.1 Z-Wave Light Control

There are three components of our Z-Wave light control: The GE Z-Wave 960-Watt CFL-LED Indoor In-Wall On/Off Rocker Switch, a Raspberry PI 3, and a Z-Stick. The GE Z-Wave 960-Watt CFL-LED Indoor In-Wall On/Off Rocker Switch requires a Z-Wave hub to operate, which we will implement using a Z-Stick and a Rasberry PI. This apparatus of the Z-Stick and the Raspberry PI can be placed anywhere in the home up to 100ft away from the Z-Wave device, and is plugged into the wall, and will recieve RF signal from the communication device. The Raspberry PI will be using Home Assistant, an open source Python project designed to control Z-Wave technology.

Input: RF output from communication device
Output: Light Control

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification (15/50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upon receiving input from the communication device, the Raspberry PI will send a signal via the Z-Stick to the Z-Wave Rocker Switch, turning the lights off.</td>
<td>Python program compiles and runs successfully. (5) Visually verify that the signal to the Z-Wave Rocker switch is successfully executed by observing light turning off. (10)</td>
</tr>
</tbody>
</table>

Figure 2.4.3.1: Requirements and Verification

Figure 2.4.1.2: FSM for Z-Wave Technology
2.5 Risk Analysis

The communication element will pose the greatest risk to the successful completion of our project. We have tentatively selected LPWAN as our method of communication, since the low power and local network seem ideal for the project [3]; however, other options available may be simpler, and we may be complicating the circuit by selecting this method. Consistent communication between the two devices is another part of the risk, as the behavior of our devices should be always repeatable. If the communication device does not consistently relay information from the coat hanger to the light switch, the project will not be completed.
2.6 Tolerance Analysis

One important tolerance we must maintain is the battery status LED circuit for the hanger. A vital part to this circuit is the 7.2V diode, which determines when the status LED will turn on. Since a battery is considered 'dead' when it reaches 60% of its capacity, it is important that the diode functions properly. The part we are looking at has a +/- 5% tolerance level, which would create a range between 7.56V and 6.84V. Potential problems that could arise from this is battery level getting lower than functional but the LED not lighting appropriately. To solve this problem, once we receive the 7.2V diode, we will use the function generator and DMM to test the specific tolerance of the diode. If it is too low, we will need to replace the diode. If it is too high, we may not replace it as 7.2 is the minimum voltage.
### 3.1 Cost

Our fixed development costs are estimated to be $30/hour, 8 hours/week for 10 weeks and 2 people:

\[
2 \times \frac{\$30}{hr} \times 2.5 \times \frac{8 \text{hr}}{\text{week}} \times 10 \text{ weeks} = \$12,000
\]

<table>
<thead>
<tr>
<th>Part</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assorted resistors, capacitors, wires, small Zener diodes, transistors (est.)</td>
<td>$10.00</td>
</tr>
<tr>
<td>7.2 V Zener Diodes (2)(amazon)</td>
<td>$0.60</td>
</tr>
<tr>
<td>A23 12V Alkaline 23-A replacement battery 23AE GP - 5 Pack (amazon)</td>
<td>$4.75</td>
</tr>
<tr>
<td>Momentary N.O. Push Button Switch (Amazon)</td>
<td>$0.52</td>
</tr>
<tr>
<td>6V Coil Electromagnetic Relay (Amazon)</td>
<td>$0.92</td>
</tr>
<tr>
<td>.3kg spring (Home Depot)</td>
<td>$0.70</td>
</tr>
<tr>
<td>Hanger/Light Switch (Home Depot / Walmart)</td>
<td>$5.03</td>
</tr>
<tr>
<td>Raspberry Pi 0 W (Amazon) and asst cables, power, display</td>
<td>$34.99</td>
</tr>
<tr>
<td>ZStick (Amazon)</td>
<td>$44.95</td>
</tr>
<tr>
<td>ZWave Compatible Switch (Amazon)</td>
<td>$30.60</td>
</tr>
</tbody>
</table>

*Figure 3.1.1 Cost Analysis*
### 3.2 Schedule

<table>
<thead>
<tr>
<th>Week</th>
<th>Kate</th>
<th>Birgit</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/2/2017</td>
<td>Finish Design Review/Review design with machine shop</td>
<td>Finish Design Review/Get complete parts list</td>
</tr>
<tr>
<td>10/9/2017</td>
<td>Order parts and design light switch schematic</td>
<td>Design hanger schematic</td>
</tr>
<tr>
<td>10/16/2017</td>
<td>Start light switch PCB</td>
<td>Start hanger PCB</td>
</tr>
<tr>
<td>10/23/2017</td>
<td>Finish PCB and order</td>
<td>Finish PCB and order</td>
</tr>
<tr>
<td>10/30/2017</td>
<td>Receive parts and assemble</td>
<td>Receive parts and assemble</td>
</tr>
<tr>
<td>11/6/2017</td>
<td>Assembly and testing</td>
<td>Assembly and testing</td>
</tr>
<tr>
<td>11/13/2017</td>
<td>Extensive communication test</td>
<td>Light switch tests for manual control</td>
</tr>
<tr>
<td>11/20/2017</td>
<td>Catch up(break)</td>
<td>Catch up(break)</td>
</tr>
<tr>
<td>11/27/2017</td>
<td>Bug Fixing</td>
<td>Bug fixing</td>
</tr>
<tr>
<td>12/4/2017</td>
<td>Prepare final report</td>
<td>Prepare final presentation</td>
</tr>
<tr>
<td>12/11/2017</td>
<td>Present</td>
<td>Present</td>
</tr>
</tbody>
</table>

*Figure 3.2.1: Schedule Table*
4 Ethics and Safety

There are several potential safety hazards in our product. One major safety concern is that the light switch directly interacts with the house current, which contains up to 120 V. This could easily electrocute a user if not correctly implemented. To prevent this, we will house our light switch control unit inside the conventional light switch casing for protection against electrocution.

We are responsible for not causing harm to users of our product. If a user plugged in a life support device into an outlet that was controlled by a light switch that communicated with our coat hanger, it could have devastating consequences. This would go against the IEEE code of ethics #9, as we could be injuring someone [2]. To avoid this situation, we would put a warning on the product if it were to go to market warning that a user affixing our device to a light switch that controls an outlet should consider what they use the outlet for and to avoid installing it where it could turn off a critical device. Another safety concern related to this same IEEE code is taking the hanger outside. This is not advised, as if a user is doing something light-critical and another person triggers the pressure detector, they could injure themselves. To combat this, there will be a warning on the hanger itself stating not to take it outside the home without disabling its functionality.
References


