Sunny Room

July 10, 2019
Dr. Craig Scratchley
School of Engineering Science - Simon Fraser University
8888 University Drive, Burnaby, British Columbia, V5A 1S6, Canada

RE: ENSC 405W/440 Design Specifications document for HESTIA

Dear Dr. Scratchley,

The purpose of this document shall be to specify the design for Sunny Room Inc's flagship product HESTIA which is a secure home automation solution using computer vision to replace existing light switches. This light switch of the future introduces autonomous occupancy detection and interaction with smart home devices to turn on/off/dim the lights while keeping data local and private.

The design outlined in this document specifies various sub-systems for HESTIA. Figures, tables, block diagrams, and circuits schematics are presented and described to illustrate all components of the system as well as appendices for the User Interface Appearance of the light switch and the IOS Mobile Phone Application and Test Plans. The development of the product includes an Alpha, Beta and Production phases which will act as deliverables for ENSC405W and ENSC440.

Sunny Room Inc is comprised of five senior engineering student at Simon Fraser University. Alexei Nevmerjitski, Philip Leblanc, Juan Decena, Rony Sheik, and myself Ryan Serkouh. Our team has been diligently and consistently meeting numerous times per week throughout this term to deliver HESTIA.

Thank you for your time in reviewing this design specifications document. Please direct any questions or comments to myself at hserkouh@sfu.ca.

Sincerely,

Ryan Serkouh

Chief Finance and Communications Officer - Sunny Room Inc.

Sunny Room

Design Specifications

HESTIA

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Abstract

This document specifies the design for HESTIA. Each sub-system of the device is detailed to guide, design, and test HESTIA from the proof-of-concept stage, the engineering prototype stage, and finally to the final product stage. The main parts of the system consist of the following:

- A physical light switch that serves to house the camera, capacitive touch sensor, processing unit, and power circuitry.
- A computer vision algorithm that will run on the processing unit to detect the occupancy of the room.
- A mobile application for users to control the light switch from anywhere within their home.

Note that the physical parts presented in this design only detail the proof-of-concept prototype that will continue to be used and updated in the final engineering prototype. As such, physical parts will also change as development continues towards a final product stage.

Table of Contents

List of Figures

Sunny Room

List of Tables

Glossary

Abbreviations	Term	Description (if needed)
CEC	Canadian Electrical Code	-
FOV	Field Of View	The field of view of the camera
FPS	Frames Per Second	-
ITO	Indium Tin Oxide	A transparent conductor
I2C	I-squared-C	Computer Bus
MCU	Micro Controller Unit	-
MVC	Model View Controller	-
MIPI	Mobile Industry Processor Interface	-
PL	Programmable Logic	Programmable FPGA Logic
PS	Programmable Software	-
PWM	Pulse Width Modulation	-
UML	Unified Modeling Language	-

UI	User Interface	**-**

1 Introduction

1.1 Scope

The document outlines the to date design specifications of Hestia, a smart light switch based on integrated computer vision, by Sunny Room Inc. The designs throughout the document are based on the most recent revision of the Hestia requirements specification document. The main systems and their associated subsystems will be presented as well as current component decisions selections were applicable. All designs are based on the current state of the R&D process with some portions subject to change as component selections are made based on simulations and prototyping.

UI is covered in the appendix of this document. It outlines the user interface for the mobile application for managing the system and the physical interface of the switch for manually using the device. Additionally, a test plan is also present in the appendix. It outlines the testing required to prove the functionality and quality of the final product.

Unless otherwise stated all designs are for the proof of concept stage of development.

1.2 Intended Audience

The intended audience for this document consists of the following:

- Members of Sunny Room Inc's engineering team responsible for the design and testing of the device.
- Members of the instructional staff of ENSC 405W/440 responsible for overview as required for completion of the course.

2 System Overview

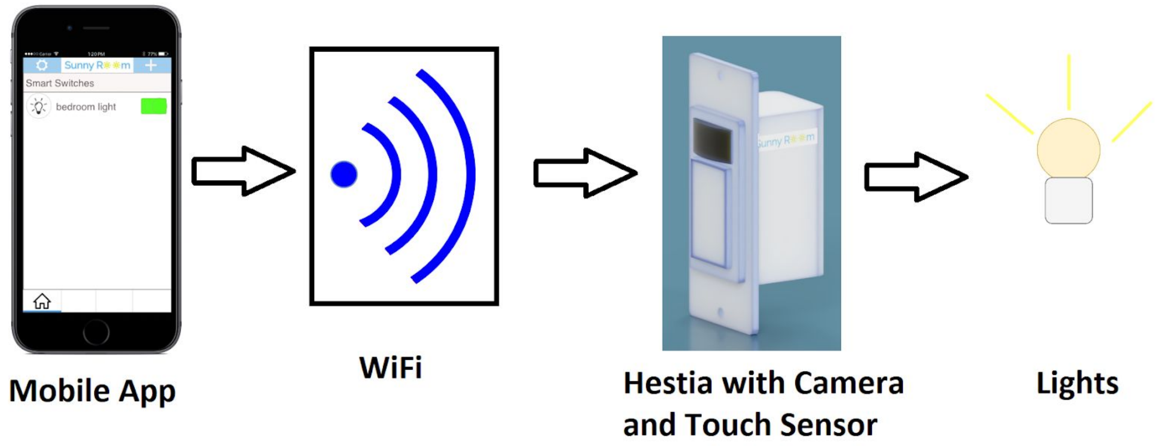

Figure 2.1: System Overview

Hestia is a direct replacement for a standard light switch as it enables automated powering based on occupancy not just movement. When installed the device will work right away turning off the lights when a room is found to be vacant and turn on the lights when occupancy is detected. Manual operation of the switch like a standard switch is also available with the use of a capacitive touch sensor in the front for toggling the light and allowing dimming functionality. In addition, a mobile application is available for personalizing the device functionality and toggling the device from anywhere on the home network.

3 Software Design

3.1 On-chip Software Design

There are multiple modules for the on-chip software as depicted in Figure 3.1.1. The inputs consist of MIPI data from the Camera, I2C data from the Capacitive Touch Sensor, and data packets from the Wifi receiver. The bootloader and main controller are used to generate the output . The main controller also regulates the dimming based on the capacitive touch sensor input. The output to the physical relay consists of PWM signal based on the AC frequency. These satisfy our on-chip software requirements and are to be delivered for the Prototype demo.

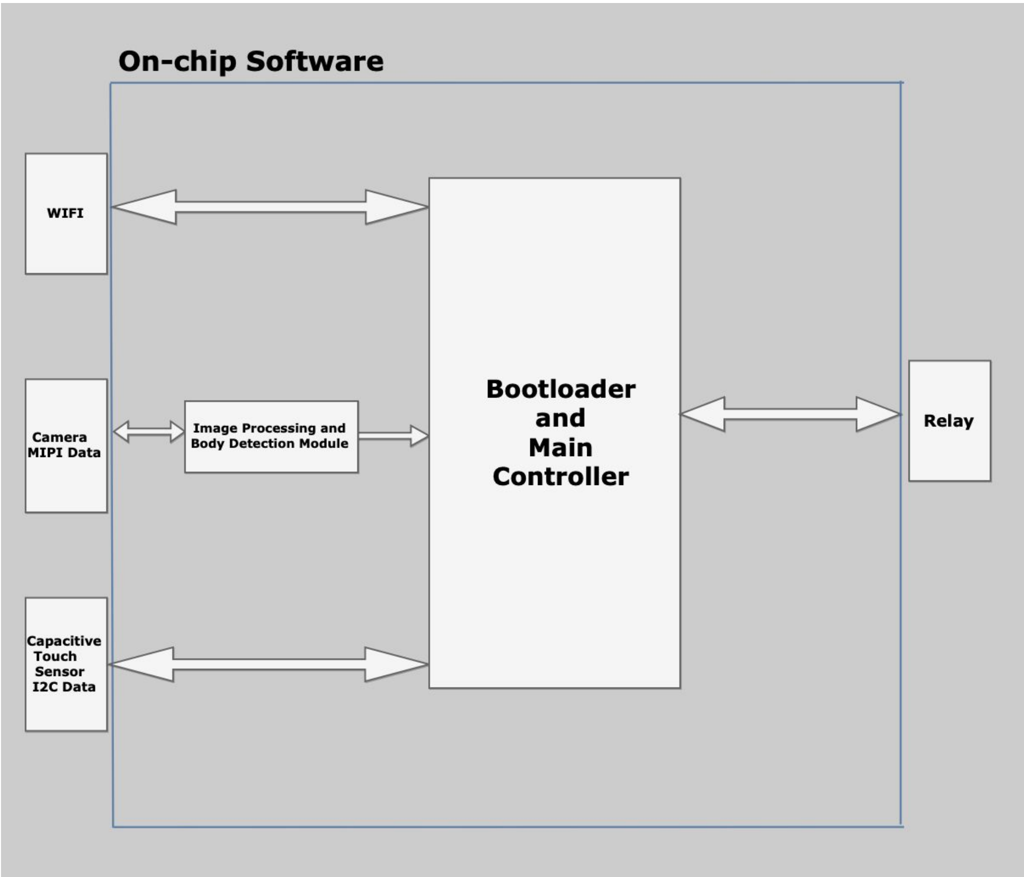

Figure 3.1.1 : Block Diagram for the On-Chip Software Modules

Figure 3.1.2 below shows the detailed Image processing steps. The images captured by the camera used to detect the body shape. The method is called the cascade object detector and it uses the Viola-Jones algorithm and a train classification mode for object detection [1]. Once the captured frame is received from the camera, significant features are extracted from the image to locate and match a specified object. The trained model to be used then locates full human body shapes as well as half body shapes (upper and lower) [2]. A result is then output to the main controller with the room occupancy status.

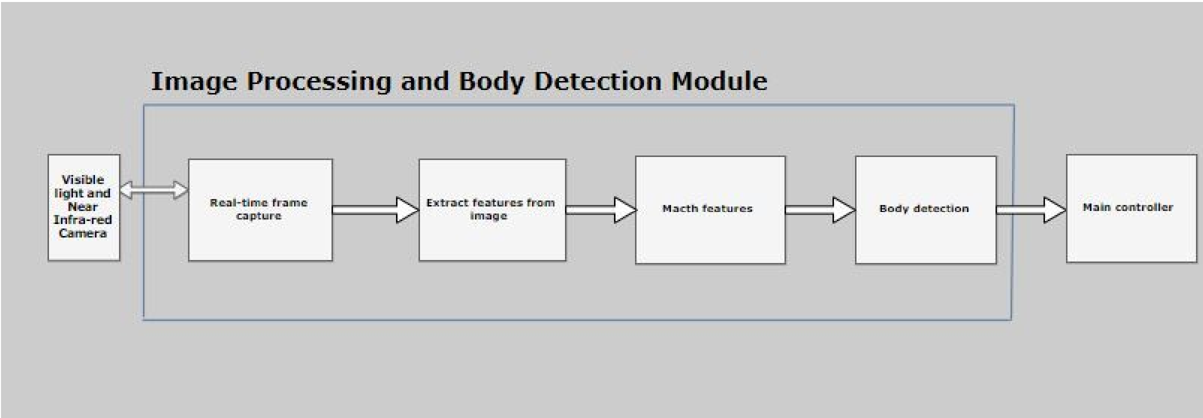

Figure 3.1.2 : Block Diagram for the Image Processing and Body Detection Module

The Haar-Cascade algorithm [3] will be used for the human body shape detection from the processed image from the camera MIPI data.

3.2 Mobile Application Design

3.2.1 IOS Model-View-Controller Design

The IOS mobile application to control the HESTIA light switch is the second main software component of the system.
The user shall be able to control and display the light switch setting using the application. The user shall also be able to create an account and login to the application for security purposes. After successful login, the main page of the application shows the user each switch available with options to turn on/off/dim the light.

The figure below depicts the three software modules for the mobile application. First, the VIEW module to show a user-friendly interface of the room name and the switch status. Second, the CONTROLLER to deal with user actions about turning on/off/dim the light and select the switch status that the interface displays. And last, the MODEL to interact with the wifi module data including both the light switch status. These satisfy our Mobile Application software requirements and are to be delivered for the Prototype demo.

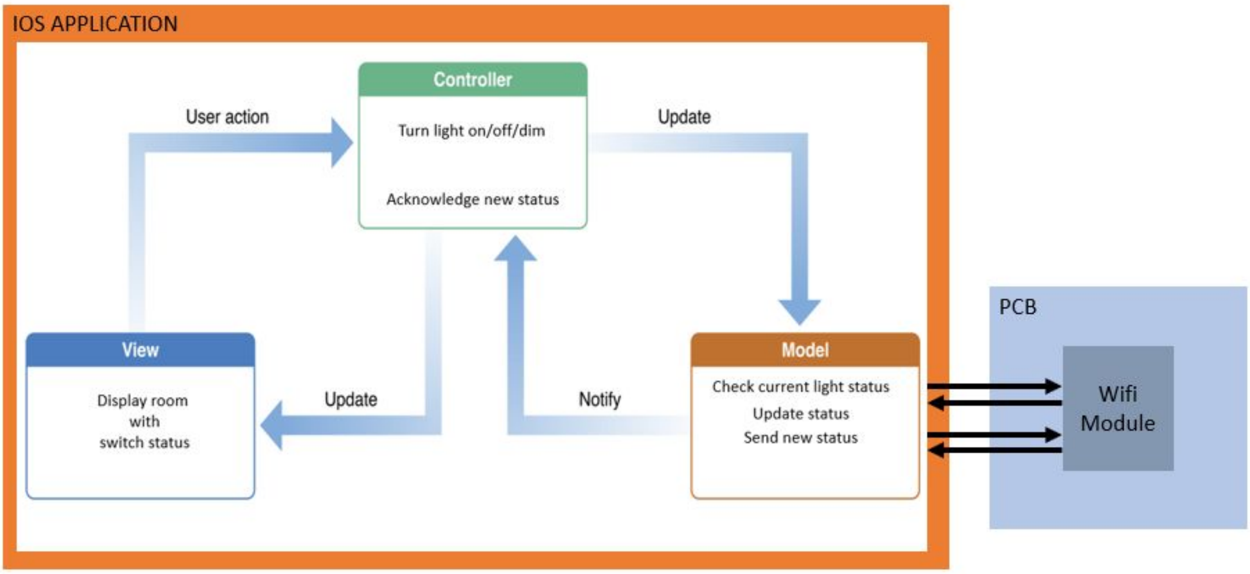

Figure 3.2.1 : MVC Model for the implementation of the IOS application "HESTIA"

3.2.2 Sequential UML Design

Figure 3.2.2 below describes the sequence followed once the user launches the application for the first time:

1) Application Launch.

2) The Login/Create new account Page is displayed.

3) The user presses the Creates an account button.

4) The Create New Account page is displayed and the user fills out the information. The info is saved locally initially, then a call to update the online database is made.

5) The user is sent back to the login page to enter their User Name and Password. The login info is checked by the online database and sent to the main page if the info is correct, or an error displays.

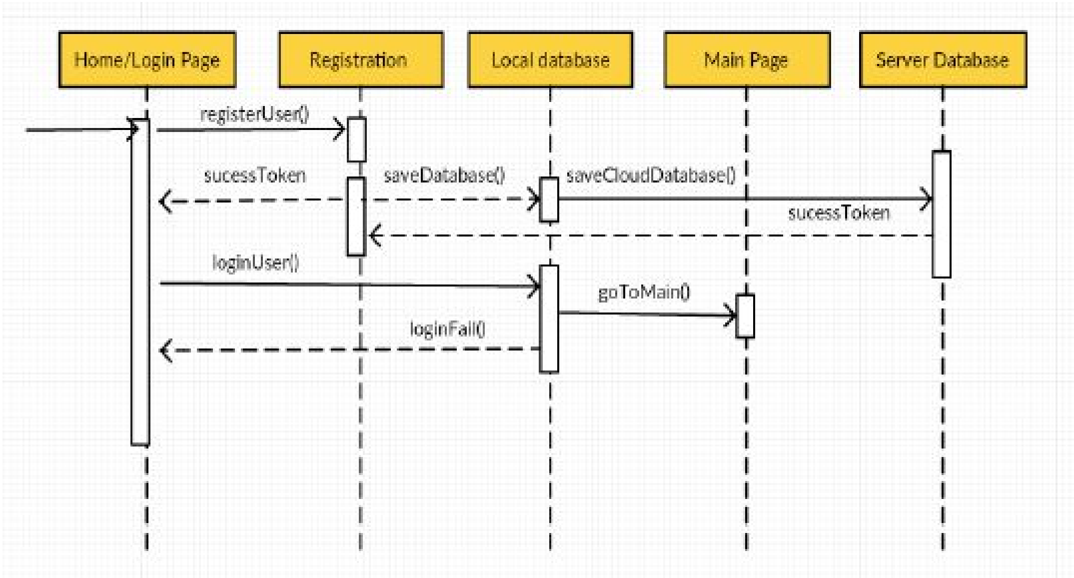

Figure 3.2.2 : Sequential diagram of first time launching the application “HESTIA”

Figure 3.2.3 below describes the sequence followed once the user launches the application if he already registered an account:

1) Application Launch.

2) The device’s local User Defaults is checked to validate whether the user is already logged on or not. If the user is not already logged on, the login page is displayed.

3) A token is saved in the device’s User Defaults for future auto-login functionality.

4) If the login information passed is incorrect, an error message displays. Otherwise, the user is directed to the Main Page.

6) The user can add a light switch and connect to it on the Main Page.

7) The user can go to the Settings page, the About page, or the Tutorial page on how to add a light switch.

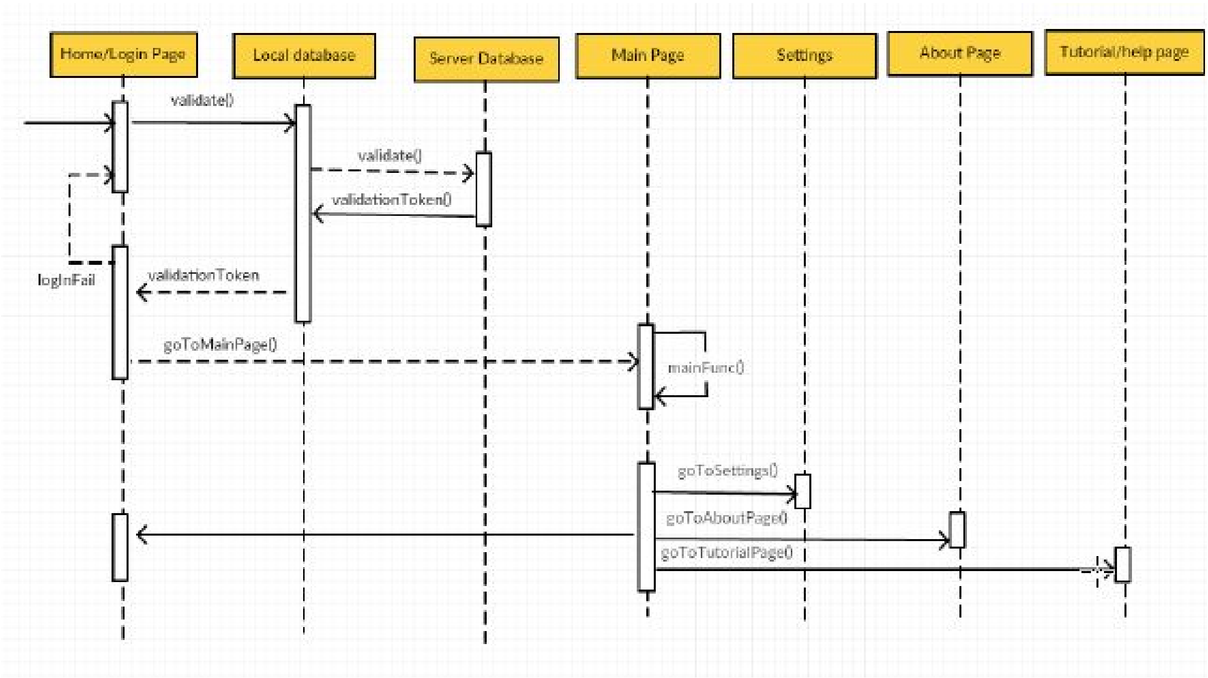

Figure 3.2.3 : Sequential diagram for normal login after opening the "HESTIA" application

3.2.3 Cloud Database Design

The cloud database uses NoSQL. Figure 3.2.3.1 illustrates the structure of the database. A unique object ID is associated with each user as well as a unique user email for login purposes. Figure 3.2.3.1 also shows the data type of each variable in the database.

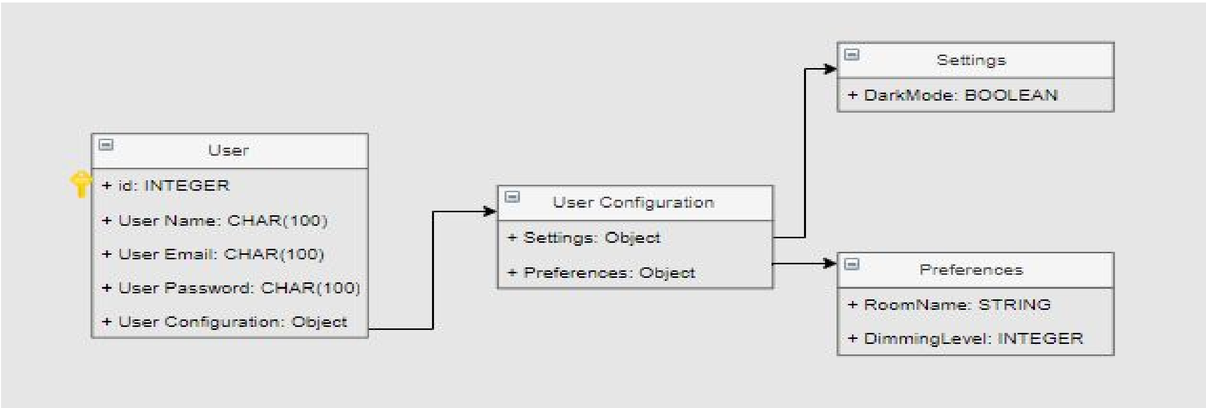

Figure 3.2.3.1 : System cloud NoSQL database structure

Figure 3.2.3.2 below shows what an instance of a JSON object would be for a particular user:


```
{
    "_id": "59eag8gb734d1d17c8S42jul",
    "Username": "John Smith",
    "UserEmail": "johnsmith11@gmail.com",
    "UserPassword": "dd1235dss",
    "userConfiguration": {
            "Settings":
                {
                    "DarkMode": "True"

                },
            "Preferences": [
                {
                    "RoomName": "BedRoom"
                },
                {
                    "DimmingLevel": "80"
                }
            ]
     }
}
```


Figure 3.2.3.2 JSON Object instantiated on the Database

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4 Hardware Design

4.1 Dimming Circuit Design

Modern dimming circuits use both a triac and a diac and dim the lights by changing the amount of time that energy is supplied to the load. Although some may believe that current dimming circuits work through lowering the voltage through the load, this is not actually the case. As of the writing of this document, it is planned to implement a slight modification of the standard dimming circuit to meet REQ-5.1.2 and REQ-5.2.1 through REQ 5.2.6. This modification is split into two parts.

The first part of the circuit is meant to only detect the zero crossing points of the Mains line and then send these points to the processing unit. This is possible by having the input to the following circuit be stepped down and rectified mains voltage.

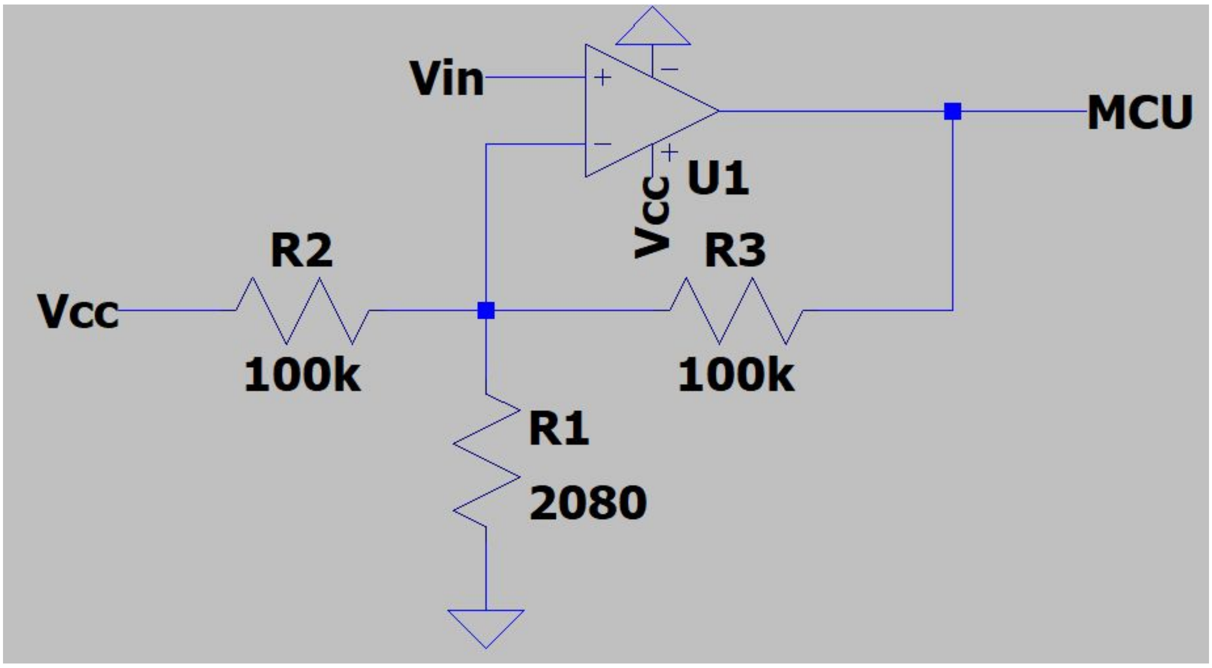

Figure 4.1.1: Dimming Circuit Part 1, Zero-Crossing Circuit

When choosing which specific Op-amp to use, there were not very many constraints to follow. Our chosen Op-amp is as follows:

Manufacturer	Part Number	Notes
Microchip	MCP-6541	4µs propagation delay Supply Voltage 1.6V - 5.5V Push-Pull output

Table 4.1.1: Op-amp Specification

As a note, we have also included hysteresis with a higher voltage,V_H, threshold of 0.2V and a lower voltage,V_L, threshold of 0.1V. The math for the resistor values is as shown below based on reference designs by TI[4].

$$R_3/R_2 \; = \; V_L/(V_H - V_L) \; = \; 0.1/(0.2 - 0.1) \; = \; 1 \quad \text{(eq.1)}$$

$$R_1/R_2 \; = \; V_L/(V_{CC} - V_H) \; = \; 0.1/(5.0 - 0.2) \; = \; 0.0208 \quad \text{(eq.2)}$$

$$R_2 = R_3 = 100K\Omega \, , \; then \; R_1 \; = \; 100K\Omega \, * \, 0.0208 \; = 2.08K\Omega \quad \text{(eq.3)}$$

The second part of the circuit receives information from the MCU, and directly controls the opto-DIAC as shown below:

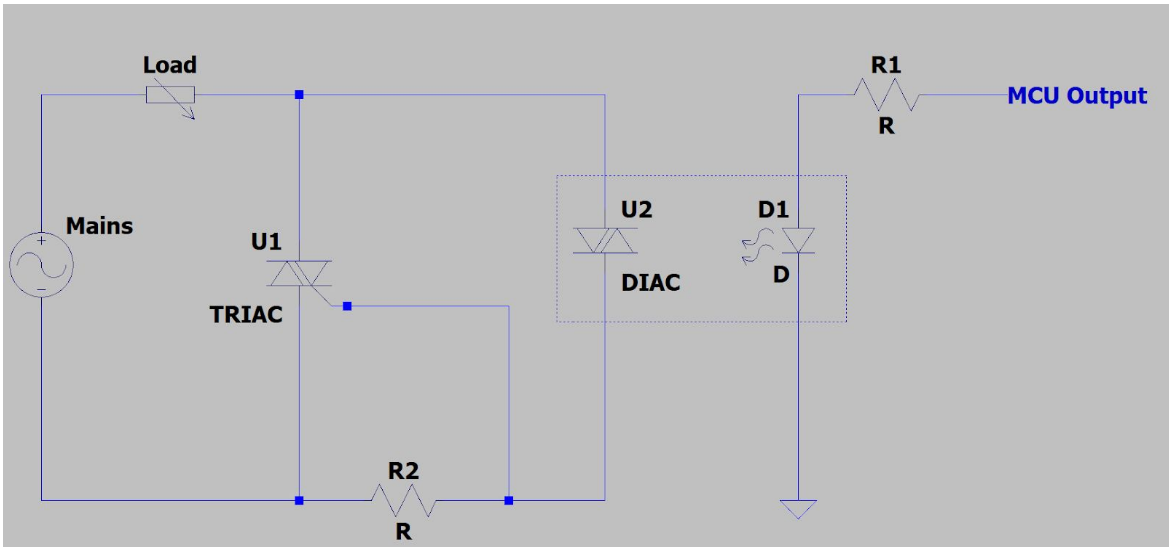

Figure 4.1.2: Dimming Circuit Part 2, Light Dimming Circuit

For the TRIAC, we have chosen to use the BT134-600. When looking for possible options for this part of the circuit, our main concern was whether or not the parts would be able to handle loads connected to the Mains line.

Manufacturer	Part Number	Notes
NXP Semiconductors	BT134-600D	3V3 Supply Voltage Scroller Functionality I2C Address: 0x1C 400 kHz clock

Table 4.1.2: TRIAC Specification

Lastly, for the Opto-DIAC, we have chosen to use the MOC-3021. Similar to the TRIAC, our main concern for this part was whether or not it would be suitable to use when connected to the Mains line of a home.

Manufacturer	Part Number	Notes
Fairchild Semiconductor	MOC-3021	Off-state Output Terminal Voltage: 400V Peak Repetitive Surge Current: 1A

Table 4.1.3: Opto-DIAC Specification

4.2 Capacitive Touch Module Design

The touch module is one of the least involved parts of the system. Although it is one of the only two methods of manual user input for the system, it essentially only becomes a substitute for the standard light switch, as stated in REQ-5.3.1. For this product, we have decided to create our own capacitive touch module after researching into their functionality, as it would provide us with much more customizability. To create our system, we have chosen our materials as follows.

For the conductive surfaces, we plan to have two separate sections throughout the length of the touchpad, fulfilling REQ-5.3.3. Specifically, we have decided to use copper tape. After looking into the many types of conductors used for similar applications, we came across two main competitors: copper (commonly found in trackpads), and products coated with Indium Tin Oxide (commonly found in touch screens). Until further developments, we have chosen to use copper tape over ITO.

	Copper Tape	Products coated with ITO
Pros	Cheap ($0.40 CAD/ sq inch) Available Easier to cut/customize size	Transparent
Cons	Not transparent	Very expensive (~$7.20 CAD/sq inch) Harder to customize size

Table 4.2.1: Pros and Cons of Conductor Material

For our dielectric, we found that there were many possible options, but we narrowed it down into using either acrylic or glass. Until any further developments, we have chosen to use acrylic for our purposes as these two would provide us with our desired appearance and feel.

	Acrylic	Glass
Pros	Significantly more durable than glass Lower costs Can apply scratch resistant films at later stages	Scratch Resistant
Cons	Easier to scratch	Not as durable More expensive

Table 4.2.2: Pros and Cons of Dielectric Module

Lastly, we have decided to use an existing IC (AT42QT2120) to detect touches. These touch signals are then sent to the MCU, and according to other inputs, providing manual control the current state of the lights, fulfilling REQ-5.3.1.

Manufacturer	Part Number	Notes
Atmel	AT42QT2120	3V3 Supply Voltage Scroller Functionality I2C Address: 0x1C 400 kHz clock

Table 4.2.3: IC Specification

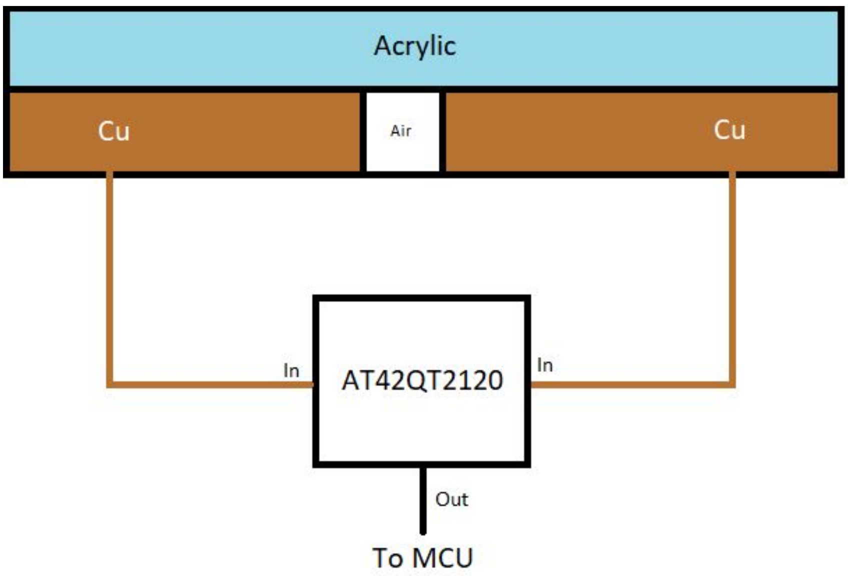

Figure 4.2.1: Cross-Section of Touch Screen with Rough IC Functionality

4.3 Camera Unit

The camera module used will be a NoIR Raspberry Pi compatible camera with a wide angle lens offered as a combo package by SainSmart. The NoIR camera contains no infrared filter and is therefore able to capture the near IR region and within the visible light region. Combined with an IR illuminator and the camera will be able to pick up usable image data even in low light conditions to meet REQ-5.1.1 and REQ-5.4.2. The camera is a 3.3V module to comply with REQ-5.4.1. The FOV of the camera is 165 degrees and falls short of REQ-5.4.5 but can be modified with a new lens if 165 degrees is too little and the requirement is not modified. The frame of the camera support 640x480 pixels at 60 frames per second as required by REQ-5.4.3 and 5.4.4.

Manufacturer	Part Number	Notes
SainSmart	101-40-186	N/A

Table 4.3.1: Camera Module Specification

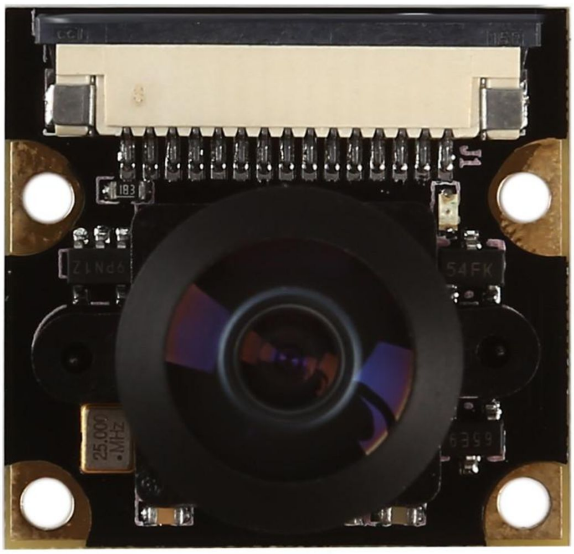

Figure 4.3.1: Camera Module[5]

4.4 Power Regulator

Main power source will come from the rectifier at above 5.1V into the regulator circuit. Voltage will be stepped down for all rails using a buck regulator. Current ratings for the regulators will be decided upon after simulations and testing with working firmware. This part is for engineering prototype development.

Rail	Purpose	Max Current Requirement
Rectified Input (>5V1)	Host voltage for powering power regulators	3A
3V3	GPIO	TBD
5V	CPU Core,Zero Cross Reference Voltage,Misc Power	TBD
1V8	PLL, I2C	TBD

Table 4.4.1: Power Regulator for Prototype

4.5 Full Bridge Rectifier

Rectifies the AC voltage to DC voltage to run power regulators. Forward voltage at the max current rating of 3A is 1.1V and 2 diode drops places the pre rectified voltage at a minimum of 7.3V after the transformer. This accounts for a 100mV ripple on the rectified voltage after the bulk capacitor.

Manufacturer	Part Number	Notes
SMC Diode Solutions	UG3KB60GTB	Through Hole Vf =1.1V @ 3A (per pin)

Table 4.5.1: Diode Specification

4.6 Transformer

Main power input for the device will be the AC mains wiring, as required by REQ-5.5.1 through REQ-5.5.4, at 120Vrms which is stepped down to 5.16Vrms minimum, roughly 7.3V peak, before being fed into the rectifier. A current rating of 3A is required for the transformer's output side. This is a temporary part picked for testing, cheaper part should be found. This part is for engineering prototype development.

Manufacturer	Part Number	Notes
Triad Magnetics	F-16X	6.3V output @ 115V input 3A output current rating Temporary part

Table 4.6.1: Transformer Specification

4.7 Crystal

As the CPU has not been decided on the crystal shall be omitted until then. Consideration will need to be put into selecting the correct crystal oscillator to generate the required clock frequency for the final chip choice. Additional PLL circuit will be implemented if a bare CPU will be used instead of a SoC. This part is for engineering prototype development.

4.8 Illuminator

A single 3W infrared LED running off of the 3V3 rail will be used to allow for illumination under low light conditions to aid in meeting REQ-5.4.3. The module used has a photoresistor that will detect when the light level falls below a threshold before turning on the illuminator so as to not waste power lighting the room when not required. A custom solution should be explored for lower power consumption.

Figure 4.8.1: LED illuminator[6]

4.9 Processor

This part will be selected after simulation and testing on working firmware to determine required processing power. The choice of processor will be limited to one with 5V core voltage as to not require changes to regulator voltages. This part is for engineering prototype development.

5 Conclusion

The preceding document provides an in-depth look into the modular subsystems that together constitute HESTIA. It details several aspects such as:

- The implementation of each subsystem and other implementation alternatives
- Justification for the implementation chosen of each subsystem
- Justification for the parts chosen to create each subsystem and other potential alternatives
- How each of these subsystems function independently and their role in the system
- How different subsystems interact with each other to create HESTIA

From this point on, this document will also serve as a thorough technical guideline throughout HESTIA's implementation phase, clearly outlining achievable milestones for our PoC, Engineering, and Manufacturing Prototypes. At the end of ENSC 440, we hope to have taken considerable steps into pushing HESTIA as the newer, high-tech standard of light switches found in every household.

Lastly, all members of Sunny Room Inc. understand that the development cycle is not always as clear-cut as it is made out to be in this document; that changes are likely to be made as feedback is received, unforeseen problems arise, and new technologies made available. Consequently, this Design Specifications Document is a dynamic document, with all major releases being archived and revisions being noted in the Revision History section.

6 References

[1] Object Detection Using Image Processing
https://arxiv.org/pdf/1611.07791.pdf

[2] opencv
https://github.com/opencv/opencv/blob/master/data/haarcascades/haarcascade_fullbody.xml

[3] OpenCV-Python Tutorials, “Face Detection using Haar Cascades”
https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_objdetect/py_face_detection/py_face_detection.html#face-detection

[4] Comparator with Hysteresis Reference Design
http://www.ti.com/lit/ug/tidu020a/tidu020a.pdf

[5] No IR Wide Angle FOV160° 5-Megapixel Camera Module
https://www.sainsmart.com/products/noir-wide-angle-fov160-5-megapixel-camera-module

[6] 2 Pcs Infrared LED Light Board Module, 3W 850 IR High Power Night Vision Infrared Illuminator with Adjustable Resistor for Raspberry Pi Camera Night Vision Module
https://www.amazon.com/Infrared-Illuminator-Adjustable-Resistor-Raspberry/dp/B07FM6LL3V/ref=sr_1_13?keywords=infrared+led&qid=1561088757&s=gateway&sr=8-13

[7] “Section 14 - Protection and Control.” Canadian Electrical Code, CSA Group, 2018, pp. 166–175.

[8] “Part 940: Evaluation of tactile and haptic interactions.” Ergonomics of human-system interaction, ISO – International Organization of Standards, 2017
https://standards.globalspec.com/std/1085241/iso-9241-410

[9] “Part 420: Selection of physical input devices” Ergonomics of human-system interaction, ISO – International Organization of Standards, 2011

[10] “Part 400: Principles and requirements for physical input devices” Ergonomics of human-system interaction, ISO – International Organization of Standards, 2007

A User Interface and Appearance Design Appendix

A.1 Introduction

In the design of everyday things, engineers strive to make their product as intuitive and easy-to-use as possible, because beautiful interfaces attract customers. The purpose of this appendix is to detail the user interface and the appearance design for the HESTIA light switch, with justification for design decisions made by the engineering team. For our prototype we are using a Raspberry Pi 3B in order to simplify the process of setup since in a final version of this product, the end-user will have to install the device in their home by turning off the electricity via the correct breaker and connect neutral, live and ground wires. If the end-user is uncertain about the electrical setup of their home they should consult an electrician. The appendix is divided into the following sections:

1. **User Analysis:** outlines the required user knowledge and restrictions with respect to the users' prior experience with similar systems or devices and with their physical abilities to use the proposed system or device.
2. **Technical Analysis:** analysis takes into account the "Seven Elements of UI Interaction" (discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints). Analysis encompasses both hardware interfaces and software interfaces.
3. **Engineering Standards:** outlines specific engineering standards that apply to the proposed user interfaces for the device or system.
4. **Analytical Usability Testing:** details the analytical usability testing undertaken by the designers.
5. **Empirical Usability Testing:** details completed empirical usability testing with users and/or outlines the methods of testing required for future implementations. Addresses safe and reliable use of the device or system by eliminating or minimizing potential error (slips and mistakes) and enabling error recovery.

A.2 User Analysis

The user would be able to use this light switch just like any other existing light switch (simply by touching it) as HESTIA is meant as a replacement for existing light switches in homes. We do not expect HESTIA to have many differences in constraints or restrictions compared to products already available on the market. As a note, Sunny Room Inc. has decided to follow the cultural and physical constraints of our target home automation market. For the first release of HESTIA, the constraints that will be adhered to are those found in Canada and the USA. Differences that will have to be taken into account when expanding to other regions would include but are not limited to dimensions, colour, and the location of the ON/OFF positions.

The main difference in usability will be that the user can use a mobile application to control their light, and even with this, there are existing products on the market. The user will need a smartphone in this case, and be familiar with installing mobile applications on their phone. Since the light switch is equipped with a computer vision algorithm, the goal would be that the user will not have to physically touch or use the mobile application (except during setup). In addition, the video data is kept internal to the device, so the user experiences maximum privacy.

A.3 Technical Analysis

A.3.1 Light Switch User Interface

The capacitive touch module does not have a very complex user interface and allows for easy discoverability. As previously stated, HESTIA is meant to replace light switches in existing homes. Therefore, it would be reasonable for customers to assume correct functionalities: the same switch has control over the same lights, the high position is related to brightening up the room, the low position is related to dimming the room. The light switch interface and its ranges of operation will be available online. It will also be included in every purchased package. Visual feedback will of course come in the way of the lights in the room changing states.

There are a few supported actions for HESTIA which depend on where an action was detected. Current plans include having the touch module split up into two different sections: high and low. For simplicity in explaining device behavior, several terms were defined. A touch is defined as a finger (or any other conductive material) completing the parallel plate capacitor for a length of time no shorter than 0.05 seconds, and no longer than 0.25 seconds. A hold is defined as a touch that lasts longer than 0.25 seconds. The supported actions and the appropriate response are summarized in the table below:

Action	Lights Action
No Touch, or Hold	Keep the current state
Touch High	Brighten the lights one level (if applicable)
Touch Low	Dim the lights one level (if applicable)
Hold High	Brighten the lights as much as possible
Hold Low	Dim the lights as much as possible

Table A.3.1.1 : System Response Outline

In cases users produce unintended touches on the capacitive touch sensor (Ex. Holding high while touching low), the system will respond only to the most recently initiated actions as described in the table above.

Additional ways to improve the new user experience are also being implemented. As depicted on figure A.3.1.1, it is planned to ink a marker on the touch module to differentiate between the High, and Low sections. This marker can be created with something as simple a permanent marker, but other methods such as visible etching on the back side of the dielectric or even physical valleys are being considered. We also plan to include an LED for verifying Wi-Fi connection.

As a side note, the option of having the touch module itself light up using LEDs as another source of user feedback is being considered. The brightness of the touch module will have varying degrees of brightness depending on the current status level. However, this will likely require the use of a transparent conductor (such as ITO) and a more transparent dielectric. As of now, there are no plans to implement this for the first release of HESTIA other than on the mobile application.

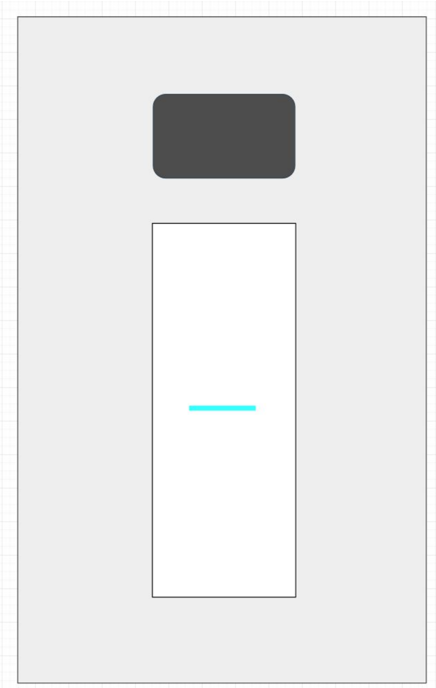

Figure A.3.1.1: Light Switch Interface Sketch (not to scale)

A.3.2 Mobile Application User Interface

The user interface of the mobile application will be kept as simple and intuitive as possible with well-labeled and minimal amounts of buttons. The app will consist of the initial sign up/login page when opened for the first time. Once an account is created the main page only has two buttons, one for settings and one for adding a light switch with a step-by-step guide to connect to wifi and any other setup required. The sketches below provide more detail about the app user interface.

A.3.2.1 Creating a user account and signing in to the Application

The user shall be able to download the IOS application HESTIA from the “App Store”. The user shall then sign in or create a new account if it is their first time using the application by entering their email and password. Upon a failed login, an error message will be displayed and the user will be prompted to try again or recover their password via email.

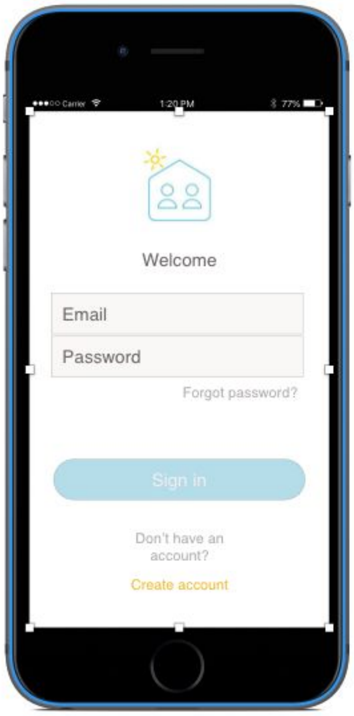

Figure A.3.2.1.1: Signing in

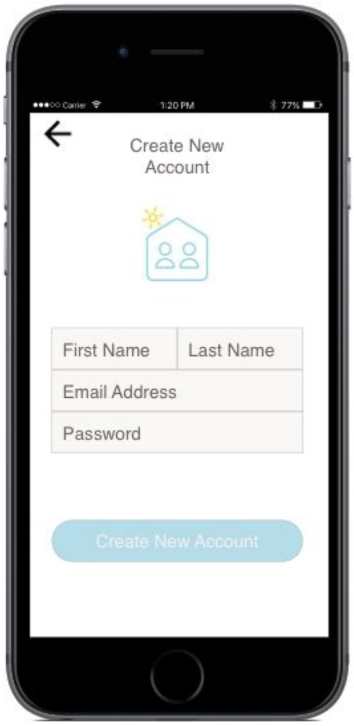

Figure A.3.2.1.2: Creating account

A.3.2.2 Main page

Upon login, the user is directed to the main page which allows the user to:

- Add a light switch with the + button on the top right
- View preferences for the app with "gear" button on the top left

Once a light switch is added, the user can click on the light switch to:

- Rename the light switch. For example, rename the light switch to "bedroom light".
- Turn on/off/dim a certain light switch.

The user can also use the preferences page to:

- Enable "Dark mode" for the application which turns the screen black instead of white.

Figure A.3.2.2.1: Main Page

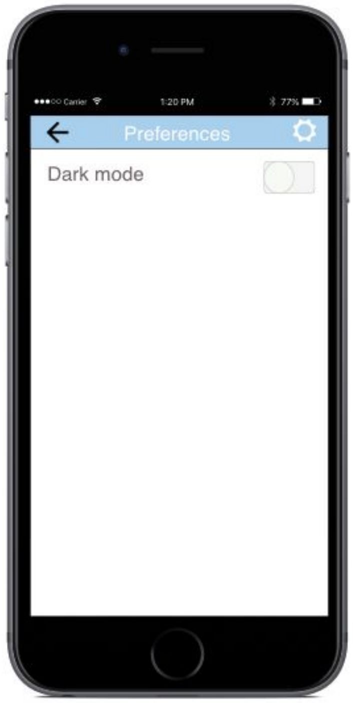

Figure A.3.2.2.2: Preferences Page

A.4 Engineering Standards

The HESTIA system is meant to be a replacement for light switches and thus not related to the lighting installation themselves. As such, the HESTIA system is mostly unrelated to Section 30 of the CEC. However, for this same reason, it is required to adhere to several rules in section 14 of the CEC. The User-Interface related rules are listed below, but it should be noted that the HESTIA system consists of many parts and are not only subject to the ones listed below [7]

Rule	Brief Description
14-010	Protective and control devices required
14-402	Disconnecting means required for fused circuits
14-408	Indication of Control Device Positions
14-410	Enclosure of Control Devices
14-416	Control Devices Used Only for Switching
14-500	Operation of Switches
14-506	Connection of Switches

Table A.4.1.1: CEC Rules for HESTIA

Although we were not able to find any specific standards set for a touch screen interface, we have found very useful references in terms of how to approach the evaluation of Human-System Interaction [8], Selection of Physical Input Devices [9], and Principles and Requirements for Physical Input Devices [10].

A.5 Analytical Usability Testing

For the analytical usability testing, the engineering team shall test the buttons on the physical light-switch and on the mobile application.

A.5.1 Light-switch

Once powered on:

1. The light-switch shall be in a ready-to-connect-to-wifi state
2. The camera and machine vision algorithm shall be initialized and can automatically turn on the light when someone is present in the room
3. The touch module shall function as described in Table A.3.1.1 : System Response Outline

A.5.2 Mobile Application

1. The mobile application shall display the product name and company logo on start up
2. The signup/login should work as expected, displaying a prompt if the email or password is incorrect
3. The main page shall be intuitive with a preference “gear” button and + button to easily navigate to the settings page or adding a device setup page respectively
4. The settings page has a dark mode for changing the colour scheme of the app to dark
5. The add page has a step-by-step instructions for connecting the light switch to your wifi and naming the device
6. If the device is not powered on the mobile app won’t detect the device when it searches

A.6 Empirical Usability Testing

In this section, the engineering team describes use cases to test on end-users with no prior knowledge of the system, to provide feedback on our UI. As they are completing these tasks users will be asked to think out loud and tell the team what they like and do not like. In testing with real users, the team can determine potential problems in order to address safe and reliable use of the device. By having robust firmware to handle the three inputs to control the light switch (touch module, mobile application, and machine vision algorithm) this would eliminate potential errors.

A.6.1 Scenario 1: Machine vision detecting if person is in a room

In this scenario we want to test our occupancy detection algorithm. The assumptions we are making for this algorithm are the following: the camera will have the doorway in it's FOV and there is only one entrance to the room.

Step 1: Walk into the room and the light turns on
Step 2: Walk out of the room and the light turns off

A.6.2 Scenario 2: Using the touch module

Step 1: Dim the light
Step 2: Increase the brightness
Step 3: Turn off the light
Step 4: Turn on the light to full brightness

A.6.3 Scenario 3: Using the mobile application

Step 1: Signup using email and password
Step 2: Login
Step 3: View settings and try dark mode
Step 4: Go back to main page and add light-switch / connect to wifi
Step 5: Turn off light using app
Step 6: Turn light back on

A.7 Conclusion

Designers of everyday things need to put an exceptional amount of effort to cater to the common-person in order to have a beautiful, reliable, and safe user interface. In this UI and Appearance Design Appendix the team described the design of the product and how a user can interact with it. Currently, the team has ordered parts and begun setting up the Raspberry Pi to begin prototyping. In the following weeks, the team is set to complete the PoC touch module, camera module with on-chip computer vision algorithm, and a mobile application. Using the Raspberry Pi, a PoC firmware will be made to handle inputs from these three modules to control a light, and demo these capabilities with instructional personnel from Simon Fraser University.

B Supporting Test Plans Appendix

B.1 Test Plan

The following is the test plan to be used as a guide while testing during product development. The plan is separated into two distinct groups based on whether it is a software requirement or a hardware requirement. Both sections differ in some aspects and testing methodology. All tests shall be performed in their earliest stages of development based on the staging below:

C - proof-of-concept/Alpha stage

P - Engineering Prototype/Beta stage

F - Final Product/Production Stage

Please note that each test shall be completed in all subsequent stages as well, and be marked off as passed before moving on to the following stage.

B.1.2 Software

The software testing shall be conducted in using the following strategies:

- Unit/Module Test: After writing each software file, it shall be tested for basic functionality and anticipated error cases including expected vs. actual and corner cases.
- Integration Testing: There shall be three major integration tests with each one conducted prior to each release for demonstration per phase(Alpha - Beta - Production). Integration tests shall be thorough to ensure robustness, and expose possible systemic risks.
- Acceptance Test: A final test shall be conducted prior to the release for demonstration for each phase(Alpha - Beta - Production). The approach taken to formulate this test relied on putting the end-user at the center because representing and understanding the final audience is primordial to the success of the product. Table B.1.2.1 details the software acceptance test plan for the features implemented using software.

Software Acceptance Test			
Date Completed:		**Test Engineer:**	
Test	**Stage Tested (C/P/F)**	**Pass/Fail**	**Comments**
APP: Connect to the Light Switch	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
APP: Turn on/off/dim the Light Switch and update status on app	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
APP: Create user and save it to the cloud	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
APP: Integrate with Google Home API to turn on/off/dim light	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
On-chip: Detection of human body shape	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
On-chip: Detection of lower human body shape	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	
On-chip: Detection of upper human body shape	**□C** **□P** **□F**	**□Pass □Fail** **□Pass □Fail** **□Pass □Fail**	

On-chip: Detection of upper human body shape	□**C** □**P** □**F**	□**Pass** □**Fail** □**Pass** □**Fail** □**Pass** □**Fail**	

Table B.1.2.1: Software Acceptance Test Plan

B.1.3 Hardware

Labels are applied based on their relevant sections within the body of this document and based on the formatting below:

Test name (document section.subsection.test number)

The procedure are for each test and their passing criteria are outlined after each table.

Hardware Test Plan			
Date Completed:		**Test Engineer:**	
Test	**Stage Tested(C/P/F)**	**Pass/Fail**	**Comments**
Zero cross low level (4.1.1)	☐**C** ☐**P** ☐**F**	☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail**	
Zero cross input noise rejection (4.1.2)	☐**C** ☐**P** ☐**F**	☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail**	
Zero cross functionality (4.1.3)	☐**C** ☐**P** ☐**F**	☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail**	
Triac Functionality (4.1.4)	☐**C** ☐**P** ☐**F**	☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail**	
Touch Functionality (4.2.1)	☐**C** ☐**P** ☐**F**	☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail** ☐**Pass** ☐**Fail**	

Guard Channel Functionality (4.2.2)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Proximity Sensor Functionality (4.2.3)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Camera Voltage ripple(4.3.1)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Camera FOV (4.3.2)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Rectified current max (4.4.1)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Rectified ripple (4.5.1)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	
Illuminator functionality (4.8.1)	☐C ☐P ☐F	☐Pass ☐Fail ☐Pass ☐Fail ☐Pass ☐Fail	

Table B.1.3.1: Hardware Test Plan

Procedures for each test are mentioned below based on their test name, section numbering and test numbering. As well the pass criterion for each test is noted after each procedure.

4.1.1 Zero cross low level:

Input a slow ramp from 5V down to 0V with ramp rates of 1s, 5s and 0.1s and Vcc of 5V +/- 10%. Scope the input signal and the output signal with a trigger on the output signal at 50%.

Pass Criterion : Output of the opamp triggers a high at 100mV +/- 10%

4.1.2 Zero Cross input noise rejection:

Input a steady voltage at 100mV +/- 10% with 50mV peak sinusoidal noise injected into the signal and Vcc of 5V +/- 10%.. Scope both input signal and output signal with a trigger on the output signal at 50%.

Pass Criterion: The scope should not trigger after 10s of run time.

4.1.3 Zero Cross functionality:

Input a 60Hz sinusoidal with 5V peak to the input and Vcc of 5V +/- 10%.. Scope the input and the output with a trigger on the output signal at 50%.

Pass Criterion: Output goes low when the input is below 100mV +/- 10% and high when the input is above 200mV +/- 10%.

4.1.4 Triac functionality:

Drive the digital side of the DIAC isolator with a 5V +/- 10% signal with a dummy load on the AC side. Scope the load voltage and the digital signal.

Pass Criterion: The TRIAC circuit powers the load when the digital signal is high and turns off before the AC signal reaches 0V.

4.2.1 Touch Functionality:

Configure the IC for standalone mode. Connect one of the key pins to the copper tape electrode. Perform a touch on the dielectric above the electrode. Repeat for all 6 general input pins.

Pass Criterion: The appropriate output lines are driven high when there is a touch made and driven low when the touch is removed.

4.2.2 Guard Channel Functionality:

Configure the IC for standalone mode and connect an input pin to an electrode. Afterwards, connect the guard channel pin to an electrode surrounding the electrode connected to the input pin. Perform a sweep of touches throughout the dielectric above the electrodes.

Pass Criterion: The appropriate output lines are only driven high when the touch is sufficiently far away from the guard channel electrode.

4.2.3 Proximity Sensor Functionality:

Configure the IC for standalone mode and connect the proximity sensor to the electrode. Do not perform a touch, but instead place a finger in close proximity to the dielectric.

Pass Criterion: When the finger is in close proximity to the areas above an electrode, the proximity output pin is pinged high, and driven low when moved away from the dielectric.

4.3.1 Camera voltage ripple:

Power the camera using a voltage of 3.3V +/- 10% while aimed at a test pattern. Compare outputs at 3.3V and 3.3V +/- 10%.

Pass Criterion: Picture quality does not change within the voltage range.

4.3.2 Camera FOV:

An object at 1m away from the camera will move from the center of the imaging frame to either horizontal extents until the center is no longer within the frame. The angle from the center of the object to the camera lens center will be measured.

Pass Criterion: The angle measured is greater than 80 degrees.

4.4.1 Rectifier current max:

A dummy load will be put on the output of the rectifier and increased up to 3A current draw.

Pass Criterion: The circuit survives up to 3A current draw.

4.5.1 Rectified ripple:

A dummy load will be placed at the output of the rectifier and bulk capacitor to simulate a 3A current draw.

Pass Criterion: The ripple is less than 100mV.

4.8.1 Illuminator functionality:

The camera and illuminator will be placed in a dark room and turned on. An object will be placed at 3m from the camera and illuminator.

Pass Criterion: The silhouette of the object is identifiable.