SkyLight Glass - Automated Windows that Mimic the Sun's Light without the Heat

Ben Farris, Paul Fedi, Blake Loeb, and William Tyback

Dept. of Electrical Engineering and Computer Science, University of Central Florida, Orlando, Florida, 32816-2450

Abstract **— This paper proposes a solution to the excessive energy use attributed to climate control in Florida. By reducing the amount of heat brought into the home the amount of energy used to regulate that home's temperature is also reduced. As a means of doing such, windows can be automated to prevent heat from the sun from entering the home. Unfortunately that is damaging to the circadian rhythm so it cannot be practically implemented on its own. Instead the product must also offer lighting that assists the circadian rhythm instead of harming it. This is done through color temperature mimicking lighting.**

***Index Terms* — PDLC Film, Light Temperature, Home Automation, Circadian Rhythm, Energy Efficiency.**

I. INTRODUCTION

Adequate cooling in the blistering summer heat is a considerable financial challenge for Floridians, and a substantial use of the energy generated by Florida Power and Light. In order to reduce the amount of energy used, it is necessary to find creative ways to reduce the amount of heat that enters Florida's residences and businesses.

One of the largest sources of heat in a Floridian building is sunlight that enters through the windows. Removing that heat allows the climate control system to use much less energy. By blocking the sunlight from entering, one is also creating a demand for additional light.

The infrastructure for additional lighting is already in place - all homes that are fitted with climate control are also fitted with electric lighting. Unfortunately using that lighting during the day is damaging to people's circadian rhythm.

An individual's circadian rhythm is the pattern to which they fall asleep, wake up, and stay awake on a consistent schedule. The color temperature of the light the individual sees is a major factor in regulating their circadian rhythm. Warm light ranges from orange to yellow hues and increases the production of melatonin: a hormone produced by the brain's pineal gland which facilitates sleep. On the other hand, cool light (blue to white hues) inhibits melatonin production. This is directly related to the time of day - cool light imitates sunlight which is the natural melatonin inhibitor. In the absence of natural light or by subtracting blue hues from artificial light, melatonin production is facilitated.

In order to preserve the circadian rhythm of human while also reducing the heat transmitted into a building through the windows, SkyLight glass mimics the color temperature of the sun based on time of day as well as modifying the transmissivity of the window to sunlight. The system also has a way to accommodate seasonal temperature variations. If the temperature outside is colder than the temperature inside, more light is allowed into the building to heat the interior.

SkyLight glass also offers users a number of other useful features. These features include: setting alarms, changing from summer to winter mode, setting a fixed color temperature, setting a fixed brightness, setting a static light transmissivity, and changing the default color temperature.

SkyLight Glass measures the outside light levels and inside temperature to determine the appropriate state of the film and attached light system based on the time of day and indoor environment.

II. RESEARCH

A. Polymer Dispersed Liquid Crystal (PDLC) Film

In order to control the amount of sunlight that passes through the SkyLight window, PDLC film is utilized. This film is laminated on a piece of glass and controlled via application of a constant voltage to the conductive coating in order for the device to exhibit a transparent state. The PDLC film requires a 60v 60Hz AC signal in order to transition between states. The transition time between states is between 30 to 50 milliseconds.

In PDLC, liquid crystals are placed inside of a polymer before the polymer is solidified. During the solidification process, a reaction occurs that causes the liquid crystals to form into molecular groups throughout the polymer. These molecules of liquid crystals, shown in Fig. 1., determine the state of the device. When a voltage is applied to the conducting layers, the liquid crystals align in the same direction: allowing light to pass through. When no voltage is present, the liquid crystals become randomly arranged: reflecting and scattering light as it attempts to pass through the polymer [1].

PDLC technology can be applied to both glass and film to achieve varying degrees of transmissivity. Both the glass and film variants may be cut into a variety of shapes in a wide range of dimensions. Variable transmissivity may be achieved by varying the magnitude of the voltage which increases or decreases the strength of the electric field. At lower voltages, the applied electric field is weaker which causes fewer liquid crystal molecules to align. In this state, the liquid crystals that are aligned to the electric field allow light to pass while the molecules that have not been influenced by the electric field continue to scatter and reflect light.

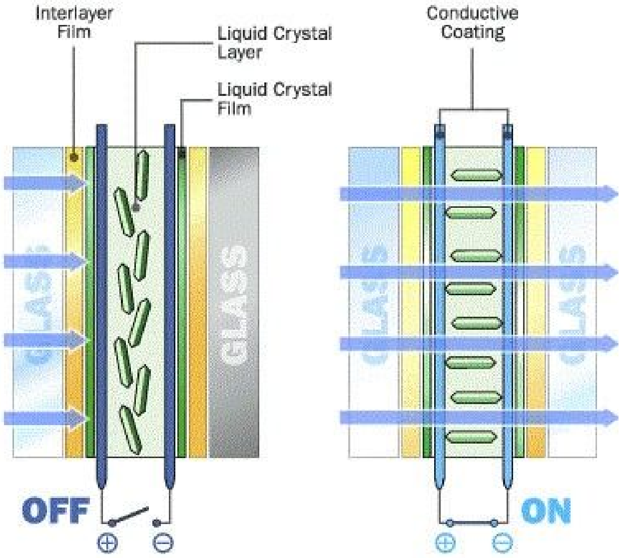


Fig. 1. PDLC film in the on and off states. [1]

The primary advantage of a PDLC device is its fast transition time between states. PDLC is also one of the most common smart glass and film technologies employed in the field: making acquisition of the material easier than other smart glass and film technologies. Another advantage of PDLC technology is its ability to block out up to 99% of ultraviolet radiation and a significant portion of infrared radiation. By applying this technology to a homeowner's windows and skylights, energy may be conserved as a result of the presence of cooler temperatures in the interior of the room or building the PDLC glass is attached to. Optimal results are obtained when paired with a photosensor or programmable device.

In the case of a photosensor, the PDLC glass or film is able to become opaque when sunlight is directly incident on the sensor and transparent otherwise. By using an embedded system on the PDLC device, the PDLC glass or film may be programmed to become opaque during hotter parts of the day while remaining transparent during others. If an embedded system is implemented in conjunction with the PDLC technology, there is also a possibility to access the Internet to obtain temperature information for the current area and adjust transmissivity based on this information.

B. Surface Mounted Device (SMD) LEDs

While the light emitting diode (LED) is considered a simplistic circuit element, SkyLight's design requires implementation of more sophisticated LEDs to achieve the range of intensities and color temperatures that are defined in the project's scope. The SkyLight LED requires variable intensity and color temperature to accommodate a variety of ranges that can simulate natural sunlight.

Before discussing the LED selection process that was undertaken, it is important to characterize the properties of light and how they affect an LED's output and differ from normal incandescent technology. The intensity of normal incandescent bulbs is correlated with how much power they consume (Wattage). Since LEDs dissipate very small amounts of power, the Wattage of an LED is not an accurate representation of its intensity. Instead, LEDs are measured using lumens which is the actual brightness emitted from a light source or LED. For example, a normal 60 Watt incandescent bulb is equivalent to 800 lumens. An LED of a similar lumen rating dissipates approximately 10 Watts of power. In this way, the efficiency of the LED light is highlighted: approximately 600% more efficient than its incandescent counterpart.

Another property of light that is fundamental to SkyLight's design is color temperature. Color temperature is defined as the temperature radiated from an ideal black-body by a light source of comparable color. Color temperature affects melatonin production in humans. As displayed in Fig. 2, orange and yellow colors ("warm") have a color temperature measured in Kelvin in the range of 2500K to 3500K while blue colors ("cool") range from 4500K to 5500K. At night when temperatures are considered "warm", melatonin production is facilitated by removing blue hues from the artificial light. During morning and afternoon hours, sunlight exhibits "cool" temperatures which inhibits melatonin production.

Color is normally defined by chromaticity coordinates represented by x and y on Fig. 2. Color temperature is used to determine the spectral power distribution of a blackbody radiator across these coordinates at a specific temperature in Kelvin. Correlated color temperature (CCT) of a non-ideal black-body radiator is determined by comparing the chromaticity coordinates of emitted light with an ideal black-body. In doing this, one value can be used to describe the color of light rather than two. This is the metric the lighting industry uses to describe LEDs.

When liquid crystal and LED technology was first invented and considered for application in smartphones, computers, and other electronic devices, the color temperature that these lights emitted was neglected. Standard computer and smartphone screens were assigned a color temperature that is similar to broad daylight. This has a negative impact on the human circadian rhythm as developers of these technologies have discovered. People who are on their devices late at night often have a hard time falling to sleep because of the constant exposure to color temperatures associated with broad daylight. [2]

This has led to advances in algorithms and filters to subtract certain hues from the light of electronic devices to mimic natural light at specific hours of the day to facilitate proper melatonin production and normal circadian rhythms. LEDs can achieve differing color temperatures in multiple ways. The method that was selected for SkyLight involves using an LED strip with SMD technology. On the 3528 strip, there are two sets of LEDs with two different color temperatures. One of the LEDs has a warm color temperature around 3000K and the other LED has a cool temperature around 6000K. By activating them both at once, an intermediate color temperature is achieved and variable color temperature required by SkyLight may be demonstrated.

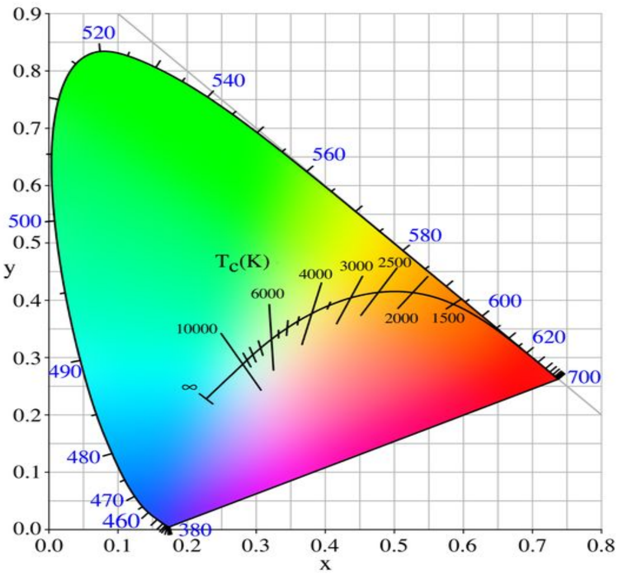


Fig. 2. Color Temperature and Chromaticity Spectrum. [3]

Another requirement of the SkyLight system is to modify the intensity of the LEDs. This is achieved through pulse width modulation (PWM). In PWM, the LED is quickly turned on and off depending on the duty cycle of the PWM signal. This is done at such a quick rate that the human eye cannot detect when the LED turns off or on. Instead, the apparent intensity of the LED is reduced or increased.

To integrate the LEDs into the SkyLight system, a PWM signal is sent from the microcontroller to the SMD LED strip. To control the rate at which the LEDs are turned on and off, two bipolar junction transistors are used for each channel of the LED: one for the "warm" color temperature and the other for the "cool" color temperature. By programming the microcontroller to send a PWM signal to the LEDs by using analogWrite(), a value of 0 through 255 is assigned to correspond to particular duty cycles. Based on the current duty cycle, the intensity of the LED is adjusted. For instance, a value of 0 corresponds to a 0% duty cycle and the LED strip is off. A value of 191 corresponds to a 75% duty cycle and the LED strip is activated but not at full intensity. This method is illustrated in Fig. 3. using a 5v square waveform.

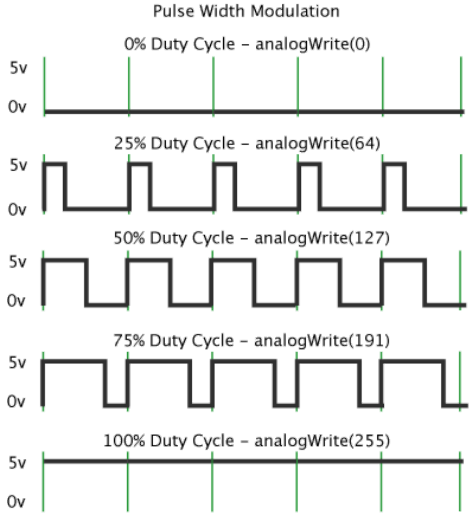


Fig. 3. PWM Duty Cycles for the 3528 SMD LED strip [4]

Based on the time of day, the color temperature and intensity of the LEDs is modified by the microcontroller's program. If sunlight is directly impinging on the window, the window becomes opaque and the LEDs turn on. Based on the time of day, the color temperature and intensity is adjusted. For instance, in the middle of the day with direct sunlight hitting the window, the LEDs emit cool light (5000K to 6000K) at full or near full intensity. When the sunlight is not directly impinging on the window during the day, the window becomes transparent and the LEDs are dimmed or turned off.

C. Sensors

The team wanted to design a seamless system that helps the user save energy under many varying circumstances and also aid maintain a healthy sleep pattern. In order to accomplish this tasks, there were a few hurdles required to overcome this problems. The team opted for utilizing a temperature sensor, to gain a metric that enables the system to respond to the surroundings. Also, a light sensor to be able to measure the light intensity in order to adjust the indoor brightness to better simulate the outside conditions indoors.

The temperature sensor was initially designed with Florida's summer weather conditions in mind. However, there is a brief time where our system becomes counterproductive, if maximizing energy savings is one of our goals. This time is the winter, when the temperature is cold enough that a heater is required in order to heat the household, it might be best to simply allow the sunlight to come in and naturally heat the property.

There are many different temperature sensors available in the market. Our main concern is to simply be able to detect the temperature that is accurate within a few degrees fahrenheit and must do this while maintaining a thru hole construction and be low cost. The team, decided to go with TMP36, for its simplicity. This device, exceeded the basic requirements for the team. Having only three pins, this device is given a source, ground and the third pin is connected to one of the analog-to-digital converters that our ATmega328P contains.

Aside from the low cost of this device, the simplicity and accuracy aided the design greatly. Once, connected to our MCU the team can easily get a reading that is proportional to a temperature in degrees Celsius that can easily be converted to Fahrenheits and then utilized for our needs.

As mentioned, the system also needed to able to automate many tasks for a user to work seamlessly. An important aspect is the simulation of artificial lighting to match outside lighting conditions coherently indoors. A way to do this, is simply to detect the intensity of the light outdoors and derive a scheme that will correlate those conditions inside. Hence, the light sensor.

The ability to deliver a product in time was important and without much experience the team opted to avoid components that could cause problems in the production stage. Hence, the team decided to utilize a phototransistor that was very low cost but also provided flexibility. This device can be paired with a resistor to vary its resolution.

Once set in place, the team simply reads for the variation in light intensity which translates to a varying current which can be measured using an analog-to-digital converter from our MCU. Once, this metric is gained the system uses a scheme to translate intensity that is reading in a cohesive manner to simulate similar conditions indoors.

D. Microcontroller

In order to bring our entire system together we needed a robust microcontroller capable of handling all of our necessities. Our team was concerned with building a PCB that could be easily assembled in house to avoid any delays from failures. Thru hole construction facilitated this principle, reducing the number of choices.

Additionally, the unit needed to be capable of driving at least two PWM signals for controlling the LEDs, while having at least three analog-to-digital converters to acquire data from our sensors. During the process of selection the team looked at many options, including microcontrollers that contained embedded RF chips which initially seem like a great plan except that it added a whole new level of problems that the team wanted to avoid.

Finally, the team went with the ATmega328P because not only did it satisfy all of our requirements but it went above and beyond. This microcontroller is utilized in some Arduino prototype boards, providing a huge sense of relief for the team because of the extensive catalog of documentation for many different tasks. At the time of development this device came in handy, since the team was able to experiment with many of the subsystems and incorporate many of the building blocks right from there gaining confidence for time of development of our own PCB.

ATmega328P provides 6 PWM pins, 6 analog-to-digital converters, as well as TX/RX pins. The latter is an extremely important part of making our entire system function as intended. Even though, this microcontroller satisfy many of our needs, it only lacks wireless communication. Having RX/TX pins allows for a Bluetooth module to be added and enable that functionality. This is how an user will utilize the system.

Everything considered, the ATmega328P satisfied all of our requirements while maintaining a low cost but offering simplicity and thru hole construction that aided the moment of manufacturing thus cutting production time greatly.

E. Bluetooth

There aren't many options to connect microcontrollers to Android phones without adding additional peripherals to the phone. The two main protocols supported by the Android phones are Bluetooth and the Internet. Since internet devices require network connectivity and are generally less secure than bluetooth, bluetooth became the method of choice for SkyLight Glass to connect to Android devices.

One of the key deciding factors in bluetooth modules is the ability to use the ATmega328P's serial communication. It dramatically reduces the complexity of the software on both the Android side and the ATmega328P side.

Bluetooth itself is used to adjust the settings of the SkyLight Glass, to correct the time of the SkyLight Glass, and to receive temperature from the SkyLight Glass.

Settings adjusted by the Android device through bluetooth include setting alarms, changing from summer to winter mode, setting a fixed color temperature, setting a fixed brightness, setting a static light transmissivity, and changing the default color temperature.

F. Control

SkyLight Glass contains devices that operate at three dramatically different voltages and both DC and AC. This means that different methods of control must be used for different devices.

Transistors cannot be used for everything because transistors do not tend to cooperate well with AC. Relays are an alternative. They use an electromagnet to open and close a physical circuit. This circuit is separate from the original, and does not need to share a ground.

Unfortunately Relays cannot be used for everything as Relays are incapable of being universally used in SkyLight Glass as well. They are not capable of having a frequency response because of the time it takes to physically open and close the circuit. Unlike electricity, newtonian physics is very slow.

Because of this, both transistors and a relay should be used. While there are other methods of control, these two are common, effective, work nicely at ATmega328P logic levels, and achieve all of SkyLight Glass' goals.

Transistors are used to control the 24vDC LEDs. They are configured as Common Emitter Amplifiers. A Relay is used to control the 60vAC PDLC Film. The Relay is actually activated by a MOSFET, making Transistors a universally vital part of the SkyLight Glass design.

III. Implementation

A. Overall Approach

SkyLight Glass was created as a series of subsystems that were eventually integrated into the whole of the system. Initially it was various hardware components tested via breadboard. Afterwards various hardware systems were made from those component and tested individually on a breadboard. Those systems include: Smart Film, LED, External Devices, and Power.

After being rigorously unit tested on a breadboard individually the subsystems were merged onto a single breadboard model. This breadboard model was tested using an Arduino UNO which utilizes the same ATmega328p as the final SkyLight Glass. After the circuit had been carefully debugged and optimised the breadboard model acted as a base for the PCB design.

At the time of construction all software was disposable and made only to test hardware functionality. After the PCB was fully constructed the software aspect was concurrently developed both for the ATmega328P and the Android mobile device.

B. Subsystem Design and Test

SkyLight Glass consists of four major hardware subsystems: the Smart Film subsystem, the LED subsystem, the External Devices subsystem, and the Power subsystem.

The Smart Film Subsystem consists of two main hardware components: the Smart Film and the Relay. The relay takes a digital pin from the ATmega328P as an input and either closes or opens the Smart Film's connection to power as an output. Doing so causes the Smart Film to be either transparent or opaque.

The LED subsystem consists of the color temperature LED strip, two bipolar junction transistors, and two resistors. The bipolar junction transistors are configured as common emitters and the resistors connect the base pin of the transistors to two digital pins. The pins output a PWM frequency which controls the brightness of each LED color.

The External Devices subsystem consists of two sensors and the HC-05 bluetooth module. The sensors are a phototransistor which acts as a light sensor and a temperature sensor. Both of the sensors use analog inputs; the phototransistor uses a resistor while the temperature sensor does not.

The Power System is how power gets delivered to each subsystem. The LEDs and Smart Film use the included power supplies at 24vDC and 60vAC respectively, while the ATmega328P uses 5v from a lm7805 voltage regulator connected to a 9v power supply. This is done to avoid heat dissipation problems that happen when directly regulating 24vDC to 5vDC.

It should be noted that the External Devices subsystem is physically distant from the Smart Film Subsystem because of EM interference that the inductor on the Relay could potentially cause.

C. Microcontroller and System Interaction

The ATmega328P interacts with the subsystems through pins. The bluetooth module connects to two digital pins, the relay connects to one digital pin, the LEDs connect to two analog pins, the light sensor connects to an analog pin, and the temperature sensor also connects to an analog pin.

The software that drives the ATmega328P is based around the serial interface, the Time.h library, and the TimeAlarms.h library in the Arduino environment.

Every time serial data is available a software interrupt runs the function “serialEvent()”. That reads four bytes sent by an Android device which are read as a long integer and then masked to interpret their meaning. The first byte contains information about the nature of the request and the following bytes contain the details. For instance, the first byte could indicate that the SkyLight Glass is being moved into manual mode, and the remaining bytes would specify each LED’s PWM value and the smart film state.

If the SkyLight Glass is not in manual mode and is instead in automatic mode the color temperature of the LEDs will update every minute. Every hour has a stored color temperature and the current color temperature is calculated based on a weighted average of the current hour’s and next hour’s color temperature. Updating every minute is done through a software interrupt provided by the TimeAlarms.h library through the Alarm.timerRepeat() function. The brightness is determined by the value outputted from the light sensor so that the brightness inside matches the brightness outside, emulating an open window.

The time set by Bluetooth command and kept using the Time.h library. If the SkyLight Glass is unplugged it will need to have the time set again. Alarms are also set through Bluetooth command and implemented via the “alarmRepeat()” function.

The films status is either determined by direct user control (manual mode) or by temperature. If the temperature is equal to or above the user specified desired temperature the film will be on. Otherwise the film will be off.

D. Overall System

The overall system was initially tested using a breadboard model. Each input and output was tested in conjunction with the other parts of the system to confirm that the overall system would meet our requirements and specifications. Several problems arose from integrating all of the subsystems together. The current draw from the

LEDs would cause the sensors, which use analog pins, to give inaccurate results. This was corrected using capacitors and limiting resistors to isolate the LED subsystem from the rest of the systems. Another issue that arose was the need for a clock on the microcontroller since SkyLight uses PWM signals. This was initially overlooked since most of the testing on the breadboard was done using the development board.

When the SkyLight system’s overall schematic was generated, the PCB was designed and fabricated. The PCB uses a through-hole design. This design choice was selected because it provides the most flexibility, the least amount of cost from the PCB manufacturers, the least overhead time, and decreased chance of having to reorder a PCB due to a component failure. If a component is damaged or found to be faulty, all that needs to be done is to remove the component via soldering and replace it with a working component. This saves considerable time considering it requires one to two weeks to have a PCB fully fabricated. The cost is also severely reduced since all of the individual components were purchased separately at discounted rates.

Upon receiving the PCB, it was readily apparent that the system required a clock to send appropriate signals to the microcontroller to get correct outputs. Initially, the MCU was always tested on the development board instead of built separately on the breadboard. This created a problem: when the PCB arrived, none of the outputs worked. Since a through-hole approach was used, it was relatively easy to add a working clock to the MCU’s appropriate pins illustrating the power of the through-hole approach.

E. Software Logic and Control

The SkyLight system sections the day into five segments as follows:

1. 7 AM - 11 AM [Morning]
2. 11 AM - 2 PM [Midday]
3. 2 PM - 6 PM [Afternoon]
4. 6 PM - 11 PM [Evening]
5. 11PM - 7AM [Night]

Throughout the day, the SkyLight system will adjust the transmissivity of each window and the LEDs on the inside based on the intensity of light impinging upon the window. The LEDs will also adjust based on the time of day and the current state of the smart film. There are preset modes for users to select and also adjustable modes so that the user can pick based on their preferences. Fig. 4 illustrates an example environment with possible windows that SkyLight system will be attached to.

Window	**1**	**2**	**3**
Morning	Off	Off	On
Midday	Off	Off	Off
Afternoon	On	On	Off
Evening	On	Off	On
Night	Off	Off	Off

Table 1. Smart film tates based on time of day

Window	1	2	3
Room	Living Area	Master Bed	Kitchen
Morning	High, 6500K	High, 6500K	Off
Midday	High, 6500K	High, 6500K	High, 6500K
Afternoon	Low, 4750K	Off	High, 4750K
Evening	Medium, 3000K	Low, 3000K	Medium, 3000K
Night	Low, 3000K	Off	Low, 3000K

Table 2. LED states based on time of day

Table 1 and Table 2 demonstrate the states of the smart film and LEDs over the span of 24 hours as seen from the conceptual operational environment in Fig. 4 for three particular windows. As the sun moves from east to west, certain windows have light directly impinging upon them which results in the smart film becoming opaque and the LEDs turning on to acomodate for the lack of natural light.

Depending on the time of day, the color temperature and intensity of these LEDs change to mimic the natural light's color temperature on the outside. It is assumed that windows that do not have light directly impinging upon them are transparent. However, this setting can be overwritten manually by the user. If a user desires extreme energy efficiency, SkyLight provides an energy efficiency mode that will keep the film opaque for a majority of the day to keep temperatures on the inside cool thus preventing the interior systems from running needlessly.

SkyLight, despite being designed with Central Florida in mind, is equipped to deal with colder outside temperatures. In this case, the user often desires for windows to be open during the day to heat the interior of the building: preventing the interior heating unit from running longer than needed. During winter months, the sun often sets earlier than during the summer months. In future SkyLight versions, the team hopes to program the system to handle this slight offset in the day and night cycles. Ideally, the user should be able to set their country or region to best determine how the LEDs and smart film should react. Expanding the film to wider regions ensures success of the SkyLight system worldwide.

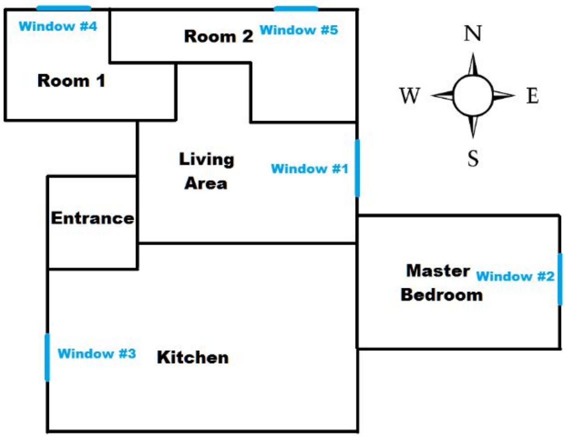


Fig. 4. Conceptuality Operational Environment

IV. Conclusions

A. Current Draw

Current draw from the MCU pins became a much larger issue than the SkyLight team initially thought. SkyLight Glass' MCU, the ATmega328P, can only tolerate around 5ma drawn from any particular pin. We discovered that while the ATmega328P will still operate under conditions where a current larger than 5ma is drawn from any particular pin, it becomes impossible to use the internal analog to digital converters. These converters are integral to both the temperature sensor and the light sensor, so it is imperative that the SkyLight Glass have less than 5ma from any particular pin at a time.

Unfortunately the SkyLight Team learned this the hard way. The PN222A Bipolar Junction Transistors that they initially used to control the LEDs only have a current gain of 220, meaning that microcontroller outputs roughly 220 times less than the LEDs draw, which, as it turns out, is more than 1.1a at max power. Since .005*220=1.1, the analog to digital converters would give wildly inconsistent readings.

While MOSFETs would have an incredibly larger current gain, it became very difficult to find non-bootleg MOSFETs. Bootleg MOSFETs that the SkyLight Team was able to acquire had very poor frequency responses and were unable to correctly utilize PWM to control the brightness of the LEDs. Some of them also had incorrect turn-on voltages which lead to difficulty activating them with the ATmega328p which uses 5v logic.

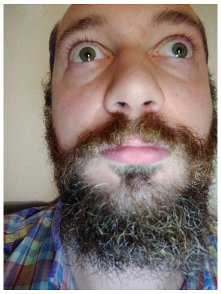
Instead of using MOSFETS the SkyLight Team ended up continuing to use the BJTs. This still left the team with the original problem: BJTs drew way too much current. Thankfully this overlapped with another issue: the LEDs were much too bright. By using a large resistor from the base pin of the transistor to the digital output pin of the ATmega328P. This reduced the current draw significantly and allowed the integrated analog to digital converters to work concurrently with the LEDs.

B. Microcontroller Clock

As mentioned previously, the PCB initially could not function due to the lack of a microcontroller clock. The microcontroller was always tested using a development board which has a clock circuit element built in. To rectify this issue, a two terminal clock was soldered onto the ATmega328P's 9 and 10 physical pin which are denoted as crystal pins in the literature. While this corrected the issue, PCBs for the next version of the SkyLight window will consist of a MCU with a clock attached to the appropriate pins.

The clock is especially important for SkyLight as the project uses pulse width modulation to control the LED states. The LEDs are quickly turned on and off using PWM signals. These PWM signals for digital circuits utilize a counter. This counter is incremented at regular intervals by connecting directly to the MCU's clock. Without one, the MCU's PWM signals are unable to be generated.

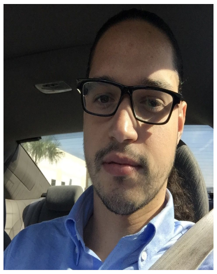
Biography



Blake Loeb is a Senior at UCF who expects to graduate in August 2017 with a degree in computer engineering. He works as a research assistant for Dr. Gou on the Phantom Lung Project automating the manufacturing of artificial lungs. Please do not publish any pictures of Blake Loeb. For committee use only.

Ben Farris is a Senior at UCF who expects to graduate in August 2017 with a degree in Computer Engineering. He currently works at Lockheed Martin.

Paul Fedi will be obtaining his BSEE in August 2017. He hopes to find employment as a systems engineer for the navy or airforce or as an educator for mathematics and science.



William Tyback is graduating in August 2017 with a degree in Computer Engineering. He currently works at Leidos as a software engineer facilitating solutions along a very talented team. He expects to go into industry and begin working immediately after graduation.

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