UNIVERSITY OF ILLINOIS

ECE 445

Adaptive Lighting

Design Review

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Introduction

Motivation

Lighting accounts for a substantial portion of energy consumption in homes and offices worldwide. More importantly, a lot of artificial lighting in use is not necessary, as there might be lighting in use well beyond the required intensity for a given activity, or lights are on when people are not present. In this project, we attempt to implement a system that will not only reduce energy consumed from lighting by using accurate occupancy sensing, but also provide a more pleasing lighting experience that utilize feedback in achieving optimal lighting intensity and color.

Objectives

We propose an adaptive lighting system that responds to the environment in outputting the optimum desired color temperature and intensity of light on a given surface. A light sensor unit will be set on a table or the area to be illuminated. These sensors will wirelessly transmit to a microcontroller which will control ceiling-mounted LEDs. The feedback from the sensors will keep the desired color and intensity at the area of interest, so that if there is sufficient sunlight, the LEDs need not consume as much power. Occupancy sensors will be mounted near the light and will only turn on the light when a person is detected in the area.

Benefits

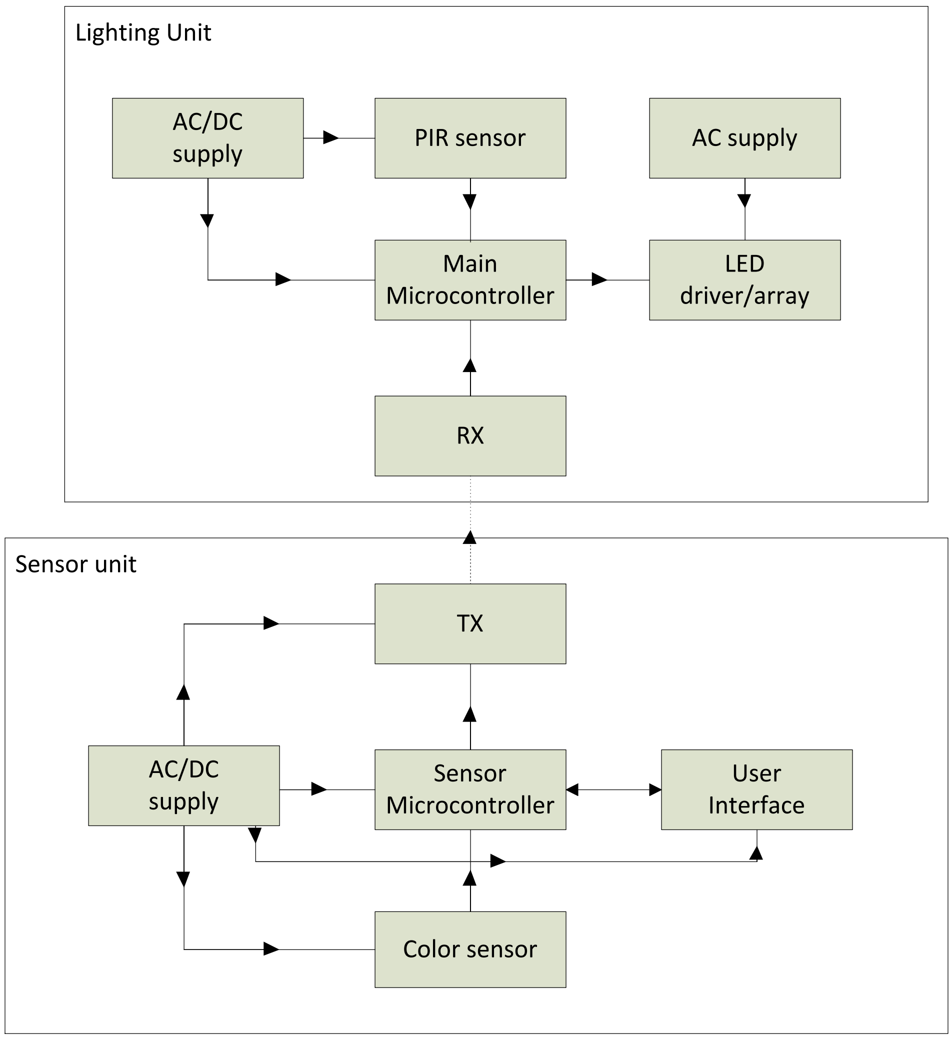
- Reduce lighting energy consumption
- Provide a more pleasing lighting experience
  - By using feedback from the color sensor, the system can more accurately render desired colors
  - The system could potentially be automated to render colors for appropriate mood such as being set to produce warmer colors at night

Features

- User sets desired color temperature and intensity using switch buttons and an LCD screen interface.
- System accurately senses color intensity for the location, and the main controller adjusts intensities for color channels until the desired setpoint is detected.

- Occupancy sensors will be used to detect if a person is present in a section of the room to switch the light for that section.
- An accessible on/off switch for the light.

Design



Block Descriptions

Color sensor

We will be using a TAOS TCS3200, programmable color light to frequency IC to detect the color temperature and intensity of incident light. The output of the color sensor is a square wave with 50% duty cycle, whose frequency is directly proportional to received light intensity. The sensor has an 8x8 array of photodiodes with 16 photodiodes having red filters, 16 having green filter, 16 having blue filters, and 16 having no filter. Only one color channel of output can be selected at a time using two control pins. The output frequency can be scaled from 600 kHz two

120kHz or 12 kHz. The supply voltage of the chip should be 5V ± 10%. The sensor has a dark frequency of 2 kHz. So for each color channel, the minimum wait time to receive each color channel is $T_i = \frac{1}{2\text{kHz}} = 0.5\text{ ms}$. So the total minimum wait time to read data from all four channels is $4T_i = 2\text{ ms}$.

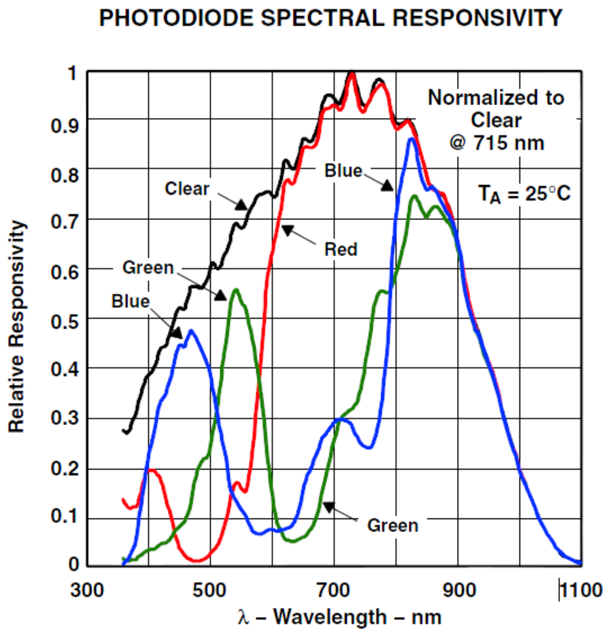


Figure 1: Spectral responsivity of color sensor taken from datasheet [6].

This IC was chosen over others for its simplicity of use. However, one drawback is the responsivity of the blue and green sensors in the 700-1000 nm range. While this wavelength range is beyond the response from our LEDs, the external light sources (i.e. sunlight) will have significant spectral energy in this range. A filter will be used to block the spectrum above 700 nm.

According to the datasheet [6], the sensor saturates at a saturation irradiance of 1266 $\mu W/cm^2$ for 640 nm incident light. We will have to test that saturation does not occur at reasonable ambient lighting intensities. However, saturation of the sensors in bright daylight is expected, and it is reasonable that the LEDs should be off in this state.

The IC will be directly connected to the sensor microcontroller and will get its supply power from the microcontroller.

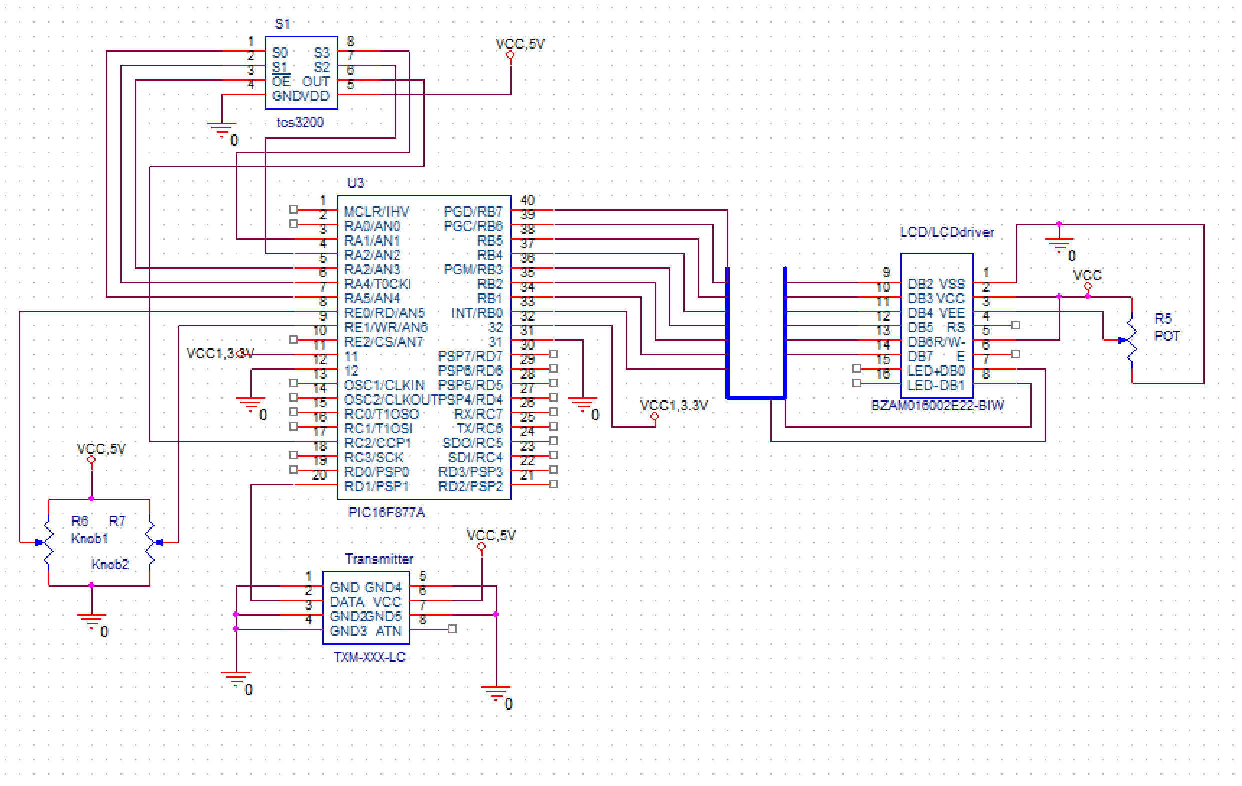


Figure 2: Sensor Puck Design

Sensor microcontroller

This controller will connect to the color sensor output and the transmitter. It will scale the frequency variations from the color sensor to determine the measurement for the color intensity. This data will be sent wirelessly to the main controller to perform the processing for lighting. Since the sensor unit will be located on the surface to be illuminated, it is also the logical place for the user interface. We chose a PIC16 since it has sufficient memory, and an internal clock speed of 60 MHz will be sufficient for reading the frequency values from the color sensor, which will have a maximum frequency of 500 kHz. The microcontroller will receive 5V DC power from an AC/DC converter.

Transmitter

We will use a Linx receiver-transmitter pair which operates at a carrier frequency of 434 M Hz. The transmitter will connect to the sensor microcontroller and will transmit the sensor data to the receiver. This allows for the sensor to be placed in a convenient location such as on the table, without a wire running directly to the light. The module will receive 5V DC from an AC/DC converter. Since the sensor unit processes the user interface, and the user expects the light should change immediately after a button press, we should transmit at a reasonable high rate that will be determined through testing.

User interface

This is the primary interaction of the user with the system, and will be located on the sensor unit. The interface will allow the user to select from a setpoint from the two parameters of intensity and color temperature. There will be two knobs (potentiometers) to adjust the correlated color temperature and intensity. There will also be a button for initiating the calibration procedure.

The intensity can be varied from 0 to 100%. The correlated color temperature can be varied from 3000K to 6500K, though it is yet to be will be determined if this range is attainable. An LCD screen will display the value that the user has selected. The module will receive 5V DC from an AC/DC converter.

The LCD will have a 16x2 character grid, and will display as follows:

I	N	T	E	N	S	I	T	Y	:	1	0	0	%		
		C	O	L	O	R		T	:	6	5	0	0		K

Receiver

The Linx receiver will be connected to the main microcontroller that controls the lights, and will be mounted in the lighting enclosure. The module will receive 5V DC from an AC/DC converter.

Main microcontroller

The main microcontroller will interface receive data from the sensors and control the LED array. It will connect to the receiver module, the PIR sensor, and the LED driver. It will read the serial data from the receiver(s) and process it. This includes processing both the sensor data, and the setpoints from the user interface, and a calibration command.

It will also process the output from the PIR sensor and will use this to switch the light on an off. It will determine the PWM duty cycle for each of channels of the LED arrays. This will be located near the LED array to provide PWM output.

For our microcontroller, we chose a Texas Instruments TMS320F28027, since this chip is specifically designed for driving LEDs. It has 16-bit PWM resolution, 64KB for program memory, and 12 KB for data RAM. The microcontroller has a V_{dd}=3.3V and will be powered by an AC/DC converter with a nominal value of 3.3V.

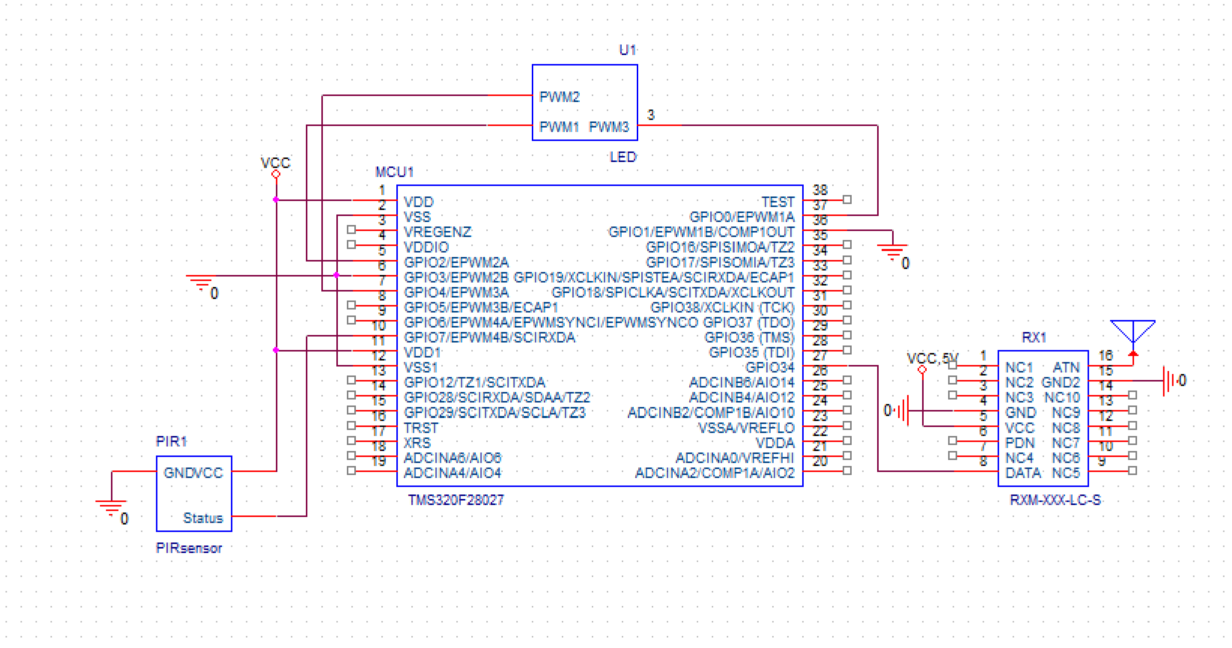


Figure 3: Main Microcontroller Design

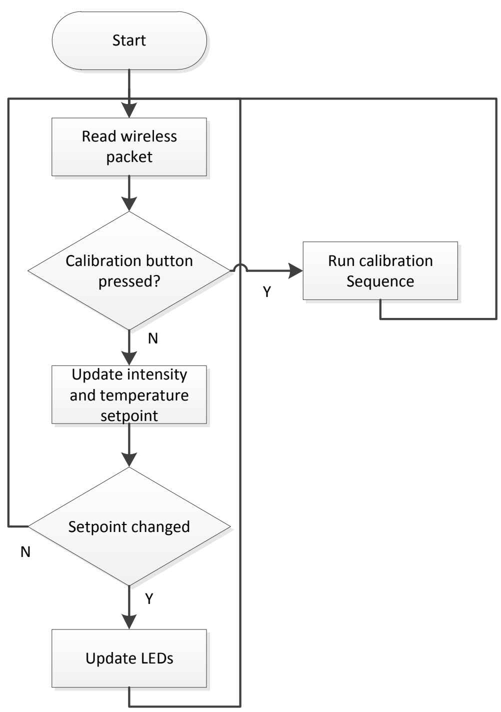


Figure 4: Program flow for main microcontroller

LED Driver/Array

We plan to use 9-3W RGB LED modules, where each module has a red, green, and blue LED. To ensure safe and precise operation, the LEDs will need to be current-limited. We will connect each of the color channels of the LEDs in a series “string” which will be driven by the driver circuit as described below. So there will be 3 such driver circuits in total.

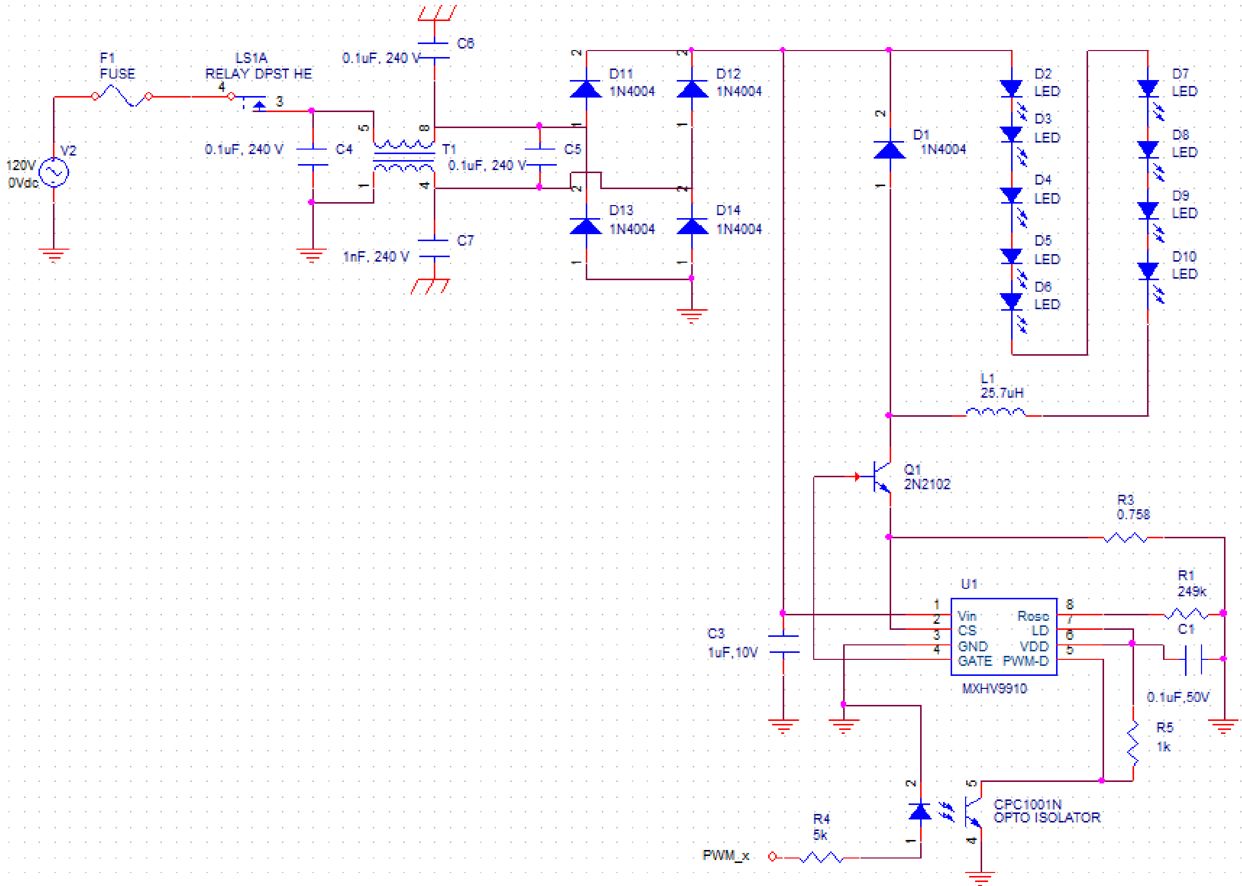


Figure 5: LED Driver Circuit

The 9910 IC is an LED driver capable of driving multiple high power LEDs. LED dimming will be accomplished by setting a pulse width modulated signal to the PWM_D pin with a low frequency such as 500 Hz. For PWM operation, the PWM_D signal is connected to the VDD pin. When enabled, the rising edge of the internal clock turns on the gate driver of external power MOSFET, causing the inductor current to ramp up. When the voltage of the current sense pin (CS) of the IC exceeds a threshold the gate drive signal becomes low and the external MOSFET turns off. This causes the current to through the inductor to decay until the next rising edge of the clock. Thus the current is regulated.

The PWM frequency is very small compared to the converter switching frequency, but it is still sufficiently large such that flickering in the LEDs cannot be seen. However, this will need to be verified during the testing of the driver.

In order to keep the LED current from ever reaching the peak rating of 350 mA, we would like the maximum current to ripple with a peak value less than 350 mA. So with a nominal current value of 300 mA a percentage ripple of 20% will lead to a ripple of +/-30mA, which is sufficient to meet the constraint.

According to the data sheet the sense resistor is sized by the following equation:

$$R_{sense} = \frac{V_{csth}}{[1+(0.5r_{iout})]I_{LED}} = \frac{0.25V}{[1+(0.5)(0.2)]\ 300\times10^{-3}A} = 0.758\Omega$$

Where V_{csth} is the internally set current sense threshold of 250 mV, r_{iout} is the percentage ripple through the inductor.

The power dissipation in the sense resistor is given as

$$P_{Rsense} = R_{Rsense}I_{LED}{}^{2} = (.758\Omega)(0.3A)^{2} = 68.2\text{ mW}$$

The resistor to ground for pin 8 sets the switching frequency of the device. According to the data sheet, for 80kHz operation, a 250 kOhm resistor should be connected from to the Rosc pin to ground.

According to the datasheet [1], the "maximum duty cycle must be restricted to less than 50% in order to prevent sub-harmonic oscillations and open loop instability."

The LED string voltage will be $9V_f = 9(2.5) = 22.5V$. The maximum duty cycle is given as

$$\mathrm{D}_{\max} = \frac{\mathrm{V}_{LED,string}}{\mathrm{V}_{in}}$$

Setting $\mathrm{V}_{in} = 50V$ results in $\mathrm{D}_{\max} = 0.45$.

The converter maximum on-time is $T_{ON} = \frac{D}{f} = \frac{0.45}{80kHZ} = 5.625\mu s$

Thus the inductance required as specified by the formula in the datasheet [1] is

$$\mathrm{L} = \frac{\left(\mathrm{V}_{in}\text{-}\mathrm{V}_{\mathrm{LED,string}}\right)t_{on}}{(\text{Ripple }\%)(\mathrm{I}_{LED})} = \frac{(50\text{-}22.5)(5.625\times10^{-6})}{(20)(0.3)} = 25.7\mu H$$

The LD pin is connected to ground because PWM mode as opposed to linear dimming is being used.

An estimate of the power dissipated in the LED system at full load is (3W*9) = 27 W. The total driver circuit maximum expected power sums to 0.0982W. So the total expected power for the LED system is 27.1 W.

The luminous flux for the three color channels are 60, 55, and 20 lumens for the red, green, and blue LEDs respectively. Therefore the total luminous flux of the light will be the number of fixtures times the sum of the flux of each of the LEDs. Therefore the maximum possible luminous flux that can be obtained with this light is 9(60+55+20) =1215 lumens. By comparison a typical 60 W incandescent outputs 840 lumens. So our system should yield sufficient lighting for desktop use.

In order to achieve color mixing to achieve white light we will use a diffuser. We could use a two side drafting film or frosted window film. A rectangular cubic enclosure capable of holding 3 arrays of 9 LED's each. At 14.5 x 7.5 mm for 9 LEDs this corresponds to a minimum surface area of 9.79 sq. cm = 1.5 sq. in. An aluminum enclosure of dimensions 7x9x2 in. will provide adequate space for the LED drivers, wiring, microcontroller, PIR sensor, and power supply. The enclosure itself will act as a heat sink perhaps with addition of silicone thermal compound.

PIR sensor

This passive-infrared sensor will be used to detect the presence of a person in the area to be illuminated. It will be connected directly to pins on the main microcontroller. It will be mounted near the LED to detect a person from above. The PIR sensor should accurately detect the presence of a person in a particular section of the room. The LED lighting enclosure will be mounted together with the PIR occupancy sensor and the main microcontroller.

The PIR sensor we have has two slots in it; each slot is made of a special material that is sensitive to IR. The lens used here is not really doing much and so we see that the two slots can 'see' out past some distance (basically the sensitivity of the sensor). When the sensor is idle, both slots detect the same amount of IR, the ambient amount radiated from the room or walls or outdoors. When a warm body passes by it first intercepts one half of the PIR sensor, which causes a *positive differential* change between the two halves. When the warm body leaves the sensing area, the reverse happens, whereby the sensor generates a negative differential change. These change pulses are what is detected.

Control Algorithm

A calibration procedure will be needed to map each color temperature to a color mixture. Color mixtures are determined by the duty-cycles for each of the LEDs.

Our algorithm will take as control variables intensity and correlated color temperature (CCT) setpoints. These setpoints will be transmitted from the sensor microcontroller.

The correlated color temperature (CCT) is defined as the Kelvin temperature at which an ideal blackbody would radiate with a spectral peak wavelength matching that of the light source of interest.

We will use a common standard for measuring color and intensity. The CIE 1931 chromaticity space defines a color using two coordinates x and y. A similar color space uses the coordinates X, Y, and Z and there is a direct mapping between chromaticity coordinates x,y and tristimulus coordinates X,Y, and Z. This mapping to the CIE XYZ tristimulus space can be accomplished by the equations

$$x = \frac{X}{X+Y+Z}$$
$$y = \frac{Y}{X+Y+Z}$$
$$z = \frac{Z}{X+Y+Z} = 1 - x - y$$

In order to convert the sensor data to control variables, there needs to be a mapping between the sensor data for each of the color channels and the above coordinates.

Configuring Color Sensor to Measure Color Temperature

We need to calculate a mapping between the color sensor output and chromaticity measurement. We will use the calibration procedure described by [7]. This calibration needs to be done only once for the entire system. A chroma-meter will be used to measure the chromaticity values (in CIE XYZ coordinates) for 5 measurements: once for each of the LED colors at full brightness while the others are off, once with all at full brightness, and once with all sources off.

Calibration RGB settings and corresponding measurements

R_{PWM}	G_{PWM}	B_{PWM}	Chroma-meter reading	Sensor Reading
100	0	0	Xr, Yr, Zr	Rr, Gr, Br
0	100	0	Xg, Yg, Zg	Rg, Gg, Bg
0	0	100	Xb, Yb, Zb	Rb, Gb, Bb
100	100	100	Xmax, Ymax, Zmax	Rmax, Gmax, Gmax
0	0	0	Xmin, Ymin, Zmin	Rmin, Gmin, Gmin

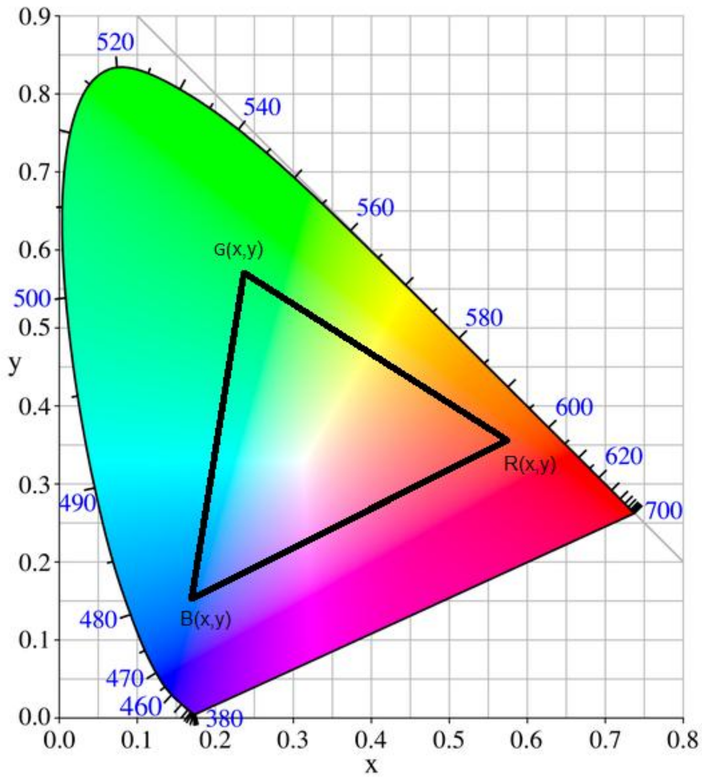


Figure 6: Possible color gamut shown as a triangle on CIE XYZ map

The X,Y,Z measurements for each of the individual colors can be mapped to the (x,y) color space and the triangle formed by them represent the gamut of colors that can theoretically be attained by mixing.

The maximum and minimum measurements are not needed directly for calibration, but may be used in further analysis.

The matrix M is the linear mapping between the sensor values $(\mathrm{R_s}, \mathrm{G_s}, \mathrm{B_s})$ and the tristimulus measurement (X, Y, Z).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \mathrm{m}_{11} & \mathrm{m}_{12} & \mathrm{m}_{13} \\ \mathrm{m}_{21} & \mathrm{m}_{22} & \mathrm{m}_{23} \\ \mathrm{m}_{31} & \mathrm{m}_{32} & \mathrm{m}_{33} \end{bmatrix} \begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix}$$

Given the matricies

$$C = \begin{bmatrix} X_r & X_g & X_b \\ Y_r & Y_g & Y_b \\ Z_r & Z_g & Z_b \end{bmatrix} \quad T = \begin{bmatrix} R_r & R_g & R_b \\ G_r & G_g & G_b \\ B_r & B_g & B_b \end{bmatrix}$$

The matrix M can be obtained by the relationship $M = CT^{-1}$.

Mapping Tristimulus Values to LED Output

Similar to the sensor calibration, the mapping between the tristimulus measurement (X, Y, Z) and PWM output (R, G, B) can be calculated using these measurements by setting

$$T = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

If $N = CT^{-1}$, then

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = N^{-1} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}$$

Since the values of (R,G,B) for the PWM duty must range from 0 to 1, we will scale the matrix N accordingly.

The error will be determined as the difference in the (X,Y,Z) coordinates between the color setpoint and the perceived color from the sensor. This error will be used to drive the LED to the new value.

Performance Requirement

- In a given day, the energy consumption of the device should not exceed the total savings due to decreased lighting use. The energy consumed by the entire system—including lighting—should be less than 80% of the energy usage without the system in place.
- The range between the transmitter and receiver should be at least 10 m.
- The brightness of our lighting system will need to be comparable to conventional interior lighting. A goal of at least 840 lumens at full brightness is desired.

- Power requirements:

Estimates of power consumption of integrated circuits are based on average current draw from datasheets and the supply voltage, as summarized in the table below.

	Vsupply (V)	Isupply (A)	Power (W)
Color sensor	5	1.40E-03	7.00E-03
LCD driver	4.5	2.50E-02	1.13E-01
LCD backlight	5	3.00E-03	1.50E-02
Linx transmitter	5	3.00E-03	1.50E-02
Microcontroller	5	2.00E-05	1.00E-04
Sensor Total Power			**1.50E-01**
Microcontroller	3.3	6.20E-02	2.05E-01
PIR sensor	5	6.00E-05	3.00E-04
Linx receiver	5	3.00E-03	1.50E-02
Light Controller Power			**2.20E-01**

The total power without the LEDs will be approximately 0.330 W. The power of the LED system totals to 27.1 W. For our system to be economical, the reduction in energy due to the system in a day should exceed the total power consumed by the entire system without the LEDs or 24hr(0.330W) = 7.92 Wh, which should be easily attainable.

Testing and Verification

Component Testing

RGB Color Sensor Testing

The first step of our testing procedure will be to determine how effectively our sensor is able to measure the light produced by our bulbs and whether the measurement of each of the three channels (i.e. red, green and blue) are within the parameters required. We will test the sensor with individual red, green and blue LEDs and compare the results with a commercial chroma meter or spectrometer.

Wireless Communication Testing

Since our system will be utilizing wireless communication, we will need to check that is the ideal placement of all devices within the system. We will verify that serial data can be sent with from one microcontroller to another with the RF chips, by sending packets. We will then place the transmitter at various distances and locations and verify what percent of packets are received.

User Interface Testing

We will also need to test our user interface and make sure the design we create is dynamic enough to incorporate any user needs. This will include testing our LCD screen and work around with user setting to see if the design is able to handle any and all user demands. First, we will test that we can send data from the microcontroller and it will display correctly on the LCD screen.

Occupancy Sensing Testing

As our system includes motion sensing technology we will have to evaluate our motion sensors and see whether it responds to movements. We will also have to take into account edge cases where there may be single occupancy in the room and set appropriate clock time so as to make this efficient and remove the need for continuously moving for the lights to remain on. We will test the performance by observing the percentage the sensor correctly detects a person.

Testing Procedures

Requirement	**Verification**
1. The sensor module outputs a digital intensity measure that is linear with respect to the intensity of the source, with a nonlinear error that is less than 10%.	We will vary the irradiance of each color channel of the LED by slowly sweeping the duty cycle of the PWM from 0% to 100%. We will then observe the sensor output using the microcontroller for the corresponding color and record the output. After analyzing the results, we should observe a linear trend and the corresponding nonlinear error.
2. The sensor does not saturate under normal lighting conditions.	We will place the sensor in the ECE 445 lab, in various parts of the room and check that it does not saturate.
3. PIR module should accurately detect motion. a. The voltage input to the PIR sensor is at least 4.5V for proper operation b. The maximum distance to be sensed is adjustable between 3 to 7 meters. c. The delay time between sensing can be 5 to 200 seconds.	a. When the PIR sensor is connected to the supply, the measured voltage always exceeds 4.5V. b. We will test that the sensitivity potentiometer on the PIR module behaves as specified in the data sheet, and accurately detects when a person moves by at a walking pace with a distance of less than 3m from the sensor when set to the lowest sensitivity, and at 7m when set to the highest sensitivity. c. We will verify that the delay time for motion sensing can be adjusted between 5 to 200 s as stated in the data sheet by timing how long before the data output goes low after we stop

	moving.
4. There is a proper communication link between the main microntroller and the sensor unit. a. The main microcontroller receives the correct setpoints from the sensor microcontroller. b. Able to transmit data as far as 10 meters at 98% packet delivery ratio, which is reasonable for the practical use in a room.	a. After a communication link is established, we will send setpoint data, and see if it can be received and read properly. Then we send sensor data and see if this is received as well. Finally, we send a calibration command and see if it can be received as well. b. The PIC controller will send 1000 packets of fake sensor data and we will check if the TI controller successfully received more than 980 packets.
5. LED driver circuitry functions properly a. The LED input voltage V_{in} should range from 45-55 V before connecting to the LED driver (open circuit voltage) for proper operation. b. The driver should also be able to provide 350mA for the green and blue LEDs and 400 mA for the Red LED. c. LED power must be linear with respect to PWM duty cycle.	Testing procedure: a. A DMM will be used to measure the open voltage of the output of the transformer and rectification stage, without a load connected. b. After the entire circuit is connect and PWM is set to maximum duty cycle an ammeter will be used to measure the current through the LEDs and this should correspond to 350 mA and 400 mA c. We will use the DMM to measure both the voltage and the RMS current to verify that the power is linear.
6. LEDs give proper light output. a. The light output of the LEDs should be at least 840 lumens at the maximum power setting b. The output light intensity is linear with PWM duty cycle.	a. A lux meter will be used to measure the luminous flux. b. A meter will be used to measure the irradiance at several PWM duty cycles. The irradiance measured should have a linear relationship with the duty cycle.
7. The voltage input to the TI microcontroller should be less than 2.97-3.63 V for working operation.	After connect the power supply to the microcontroller with PIR sensor and receiver module, the supply voltage V_{dd} should be in the range 2.97-3.63.

8. The tristimulus values measured by the microcontroller match that of a commercial meter with an error of less than 2%.	After initial calibration, we will measure the tristimulus values as they appear on the LCD with various settings on the LEDs. We will record these measurements with those from the chroma meter, and determine the percentage error.

Tolerance Analysis

The RGB light sensor is the most critical part of the system. For our system to behave properly, the RGB sensor needs to have a precision so that the lighting can closely track the desired illumination. We will test the light sensor against a commercial photometer for various color mixtures. We will test that the output we get from our sensor after analog to digital conversion should match that of a quality commercial meter with an error of less than 10% for the frequency spectrum of interest. For our LED strings we aim to have a current of 300 mA through each string. A tolerance of about +/- 15mA should be acceptable to control light color. A resistor attached to the LED string in series will tell us the amount of current being drawn.

Cost and Schedule

Cost Analysis

Labor

Person	Rate	Hours	Total	Total x 2.5
Jered Greenspan	$35/hr.	200	$7000	$17,500
Madhav Khanna	$35/hr.	200	$7000	$17,500
Sichao Wang	$35/hr.	200	$7000	$17,500
			Total	$52,500

Parts

Part	**Part Number**	**Price**	**Quantity**	**Total**
Color Light to Frequency Converter	TCS3200	2.44	1	2.44
RF transmitter	TXM-433-LC	3.95	1	3.95
RF receiver	RXM-433-LC-S-ND	13.56	1	13.56
PIR sensor	sku023606	2.71	2	5.42
LED driver IC	MXHV9910	0.75	3	2.25
RGB LEDs	Vollong H01RGB00302	4.95	9	44.55
LCD (16x2)	Hitachi HD44780	15.95	1	15.95
PIC microcontroller	PIC16F877A	2.80	1	2.80
TI microcontroller	TMS320F28027	5.65	1	5.65
Diode	1N4004	0.30	5	1.50
Power switch	H61923001	5.87	1	5.87
Transformer	DP-241-7-24	22.45	1	22.45
Pushbuttons		0.25	1	0.25
AC/DC converters		5.00	2	10.00
potentiometer		0.50	1	0.50
Resistors		0.02	15	0.30
Capacitors		0.20	5	1.00
750 uH inductor		2.00	1	2.00
Enclosure for LED light		5.00	1	5.00
Enclosure for sensor unit/user interface		5.00	1	5.00

Parts = $150.44

Grand Total = Labor + Parts = $52,650.44

Schedule

6-Feb	Finish proposal	All
	Design control system logic	Jered
	Search for LED parts	Madhav
	Select microcontroller	Sichao
13-Feb	Select LED and driver parts	Madhav
	Select microcontrollers	Sichao
	Simulate the control algorithm	Jered
20-Feb	**Design Review**	
	Test PIR sensor	Jered
	Test color sensor	Sichao
	Design LED driver circuit	Madhav
27-Feb	Test RF link between two microcontrollers	Jered
	Build LED driver circuit and test	Madhav
	Build simple user interface	Sichao
5-Mar	Program microcontroller to control LED dimming and color mixing	Jered
	Calibrate LEDs with known color temperature setpoints	Sichao
	Test interface between components	Madhav
12-Mar	Test user interface	Jered
	Program control system on microcontroller	Sichao
	Integrate all system components	Madhav
19-Mar	**Spring break**	
26-Mar	**Mock-Up Demo**	
	Prepare for mock-up presentation	Madhav
	Collect power consumption data	Jered
	Calibrate overall system	Sichao
2-Apr	**Mock-Up presentations**	
	Test motion detection performance	Madhav
	Test color mixing performance	Sichao
	Analyze energy savings	Jered
9-Apr	Prepare for final demo	Sichao
	Begin writing first half of written report	Madhav
	Begin writing second half of written report	Jered
16-Apr	Prepare for final demo	Madhav
	Continue writing written report	Jered
	Final testing for demo	Sichao
23-Apr	**Final Demo**	
	Prepare a final presentation	Sichao
	Revise second half of report	Madhav
	Revise first half of report	Jered
30-Apr	**Presentation**	

Ethical Considerations

The IEEE Code of Ethics [5] mandates that its members commit themselves "to be honest and realistic in stating claims or estimates based on available data." As we will be doing testing to determine the power consumption of our device, we will also be comparing the consumption with that without our device in place. It is therefore important that we do not overstate our claims.

Citations

1. "MXHV9910 Offline High Brightness LED Driver." Clare. August 2011. Web 21 Feb 2012. http://www.clare.com/home/pdfs.nsf/0/713EA18902B59CCF85257566004FAD55/$file/MXHV9910.pdf.
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4. Color Adaptive Lighting, ECE 445 Senior Design Project, Fall 2011.
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7. "Closed Loop Chromaticity Control: Interfacing a Digital RGB Color Sensor to a PIC24 MCU" AN1257. Microchip. [Online]. Available: http://ww1.microchip.com/downloads/en/AppNotes/01257A.pdf.