Implementing smart White LED Lightning system in buildings using 32-bit microcontroller.

Ramandeep Singh
Assistant Professor EECE department
ITM University
Gurgaon, India

Prithipal Singh
EECE department
ITM University
Gurgaon, India

Siddharth Lalit
EECE department
ITM University
Gurgaon,India

***Abstract*- Increasing user's comfort and reducing the wastage of our electricity power is the major objective of this paper. Current designs used in building are not successful in incorporating the occupant comfort for the user and use of the power efficiently at the same time. In this paper, we present a novel utility-based building control system that optimizes the trade-offs between meeting the user comfort and reduction in the cost of operation by reducing the excess usage of energy. We present an implementation of the proposed approach as an intelligent interior lighting control system that significantly reduces the energy cost. Today in our lighting system for institutes and offices either incandescent lamps or fluorescent tubes are being used. The luminous efficiency of fluorescent tube is 67 (lux) while that of an incandescent lamp is just 22 (lux). So LED panels are a very efficient alternative for them which have a luminous efficiency as high as 100 (lux). Although LED panels have initial cost but they repay it in form of their long lives. This new stage intelligent lighting system has main features like the use of sensor networks to optimize the trade-off between fulfilling different light preferences at different areas of building and minimizing the energy consumption using sensors and controllers. We further extend our approach to optimally exploit the ambient light using ambient light sensors and using dimming techniques. One of the ways to implement this holistic concept is illustrated in this paper that will result in an energy efficient system.**

***Keywords*- White LED down panels, PIR Sensors, Light Sensors, LPC2148 (ARM 7) microcontroller.**

I. INTRODUCTION

This paper concentrates on development of an efficient integrated lightning control system for a building which communicates with real world and help to save energy. This is achieved by using energy saving strategies in lightning system such as: (1) to replace the currently used fluorescent and incandescent lamps with energy efficient white LED down panels. (2) To integrate the day light with artificial lights to attain an optimal level of luminance in the area. (3) To switch OFF / ON the lights according to real time occupancy of the area [2]. Paper also shows results of an experiment conducted in which two identical rooms were selected. For ROOM-1 with White LED down panels with occupancy detection and day light adjustment, values of luminous intensity, current and power were observed, calculated and then compared with corresponding values of currently used CFLs in ROOM-2. The power consumption in ROOM-1 was observed to be a clear reason for the replacements of CFL'S with white LED down panels. One of the ways to implement this holistic concept in a building is illustrated in this paper that will result in an energy efficient system.

II. ARCHITECTURE AND BLOCK DIAGRAM

The controlling of White LED panels is done through 32-bit ARM 7(LPC2148) microcontroller [3]. Each microcontroller has a White LED panel connected to it through wires. Each White LED panels contain Light sensors to detect the ambient light intensity and PIR sensors (occupancy sensors) to detect human presence. All the data from these sensors is transmitted to the microcontroller that intelligently reads the data and compares them to control the light intensity of the LED panels. This basic idea how 1 LED panel is controlled by using a single microcontroller is proliferated to control the lighting system of whole building as shown.

Each 4 'x 1 'LED panel contains 2 sensors:

1) Light sensors
2) PIR sensors

Each sensor independently collects data and sends it to the microcontroller. For e.g. five such LED panels (LP) are designed for one room which are controlled by 1 ARM7 (LPC2148) microcontroller (RC). Each floor has 10 rooms, so 10 microcontrollers are used in each floor. A floor manager (FM) i.e. another ARM7 microcontroller is connected to these microcontrollers (RC) which manages the room controller. All the floor managers are then connected to a main server wirelessly so as to manage the whole lighting system. The data is transferred serially from one microcontroller to another. At server, the entire data base is collected, managed and controlled wisely so supervise the working of the system.

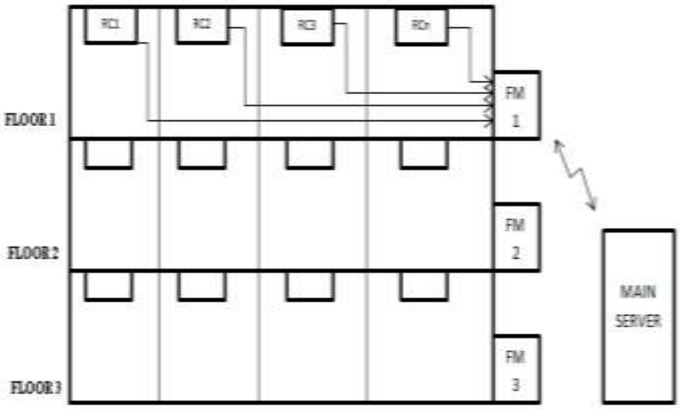


Figure 1. Building Plan

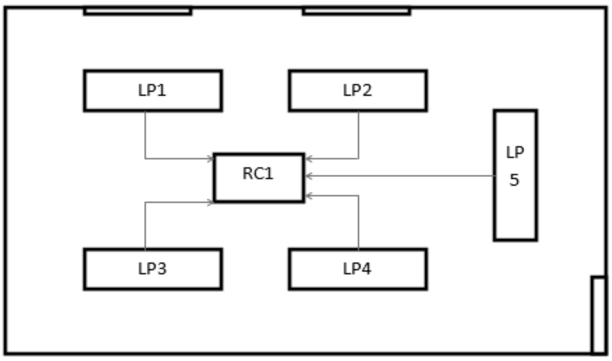


Figure 2. Room Plan

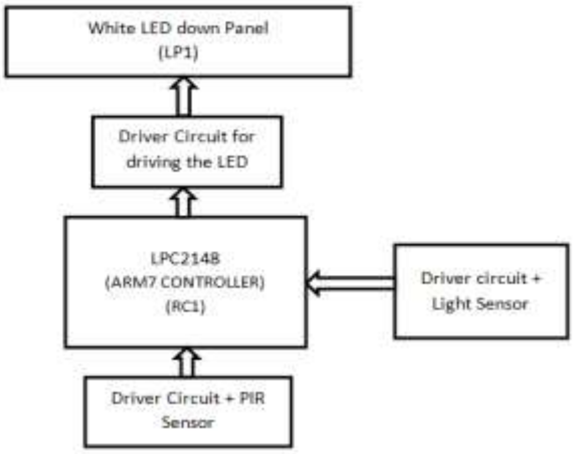


Figure 3. Block Diagram for a room controller interacting with one LED down panel.

III. WHITE LED DOWN PANEL

Even with the leaps and bounds that have taken place in power LEDs in recent years, a single device is rarely enough to provide all the light needed for general illumination. More than one LED will be needed if goal is to light a space formerly occupied by at the light bulb. Various white LEDs are arranged in a definite order to form a white LED down panel. Placing the LEDs in series guarantees that the same current flows through each device. In series combination, if any of the LEDs fail and create an open circuit, the entire white LED down panel goes dark. In addition, this configuration leads to highest output voltage, which translates into larger, more expensive circuit components and more requirements for safety. Thus, LEDs must be arranged in a series-parallel array. This arrangement has the advantage of using a lower output voltage and reducing the hazard of electric shock. If one LED fails open circuit, the other two branches continue to operate.

Fig 4: Square white LED panel of 12V.

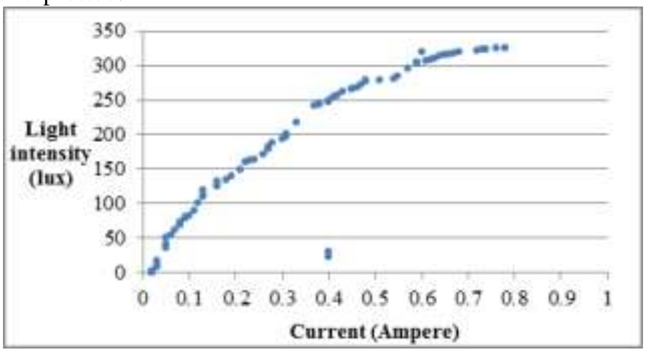
White LED down panel, shown in above figure, has a 4*6 series-parallel array i.e. it consists of 6 parallel branches with each branch having 4 LEDs in series. Voltage across each LED in series combination is 3volts resulting in grand total of 12 volts across each parallel branch of the white LED down panel. LED driver, being a current source, will force current I/6 current, I is the current drawn through the LED driver, through each parallel branch.

Fig 5: Back-side of the white LED panel showing series configuration.

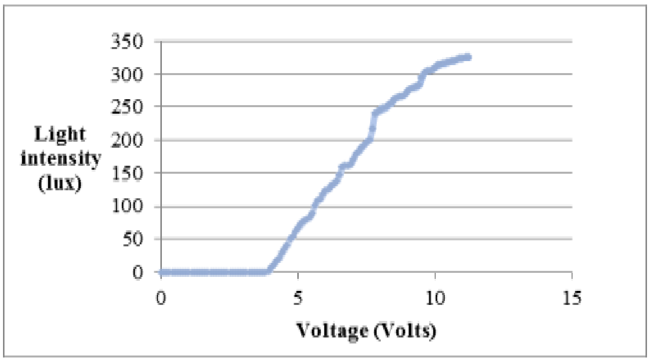
The figure 5 shows the series connection of four White LEDs on a single strip and showing black covering on each series connected LED. The black covering on each back side of the LED is the heat sink to avoid LED from large current flow or burning of the connection due to the high voltage.

A. Lux meter reading of white LED panel.

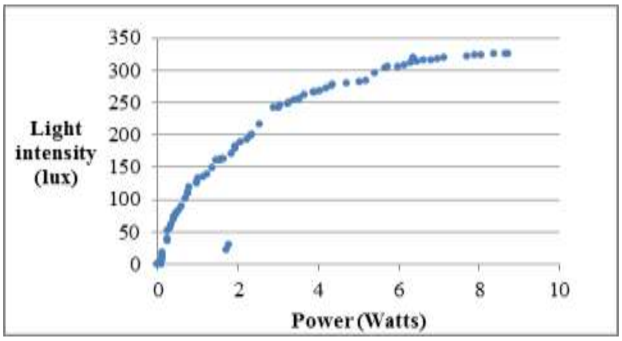
To calculate the light intensity radiated a single 12 volts white LED panel, a dark prototype room was selected. The LED panel was placed on top of the table 1meter from floor. The measuring instrument i.e. LUX meter is at 30 centimetres from the emitting surface of the panel and is directed towards it in the same plane. The colour of the walls is white. The temperature is normal room temperature at 300 kelvin. The lux readings of LEDs are measured at different values of current and voltages and then compared and plotted.



GRAPH I : Light intensity vs Current



GRAPH II : Light intensity vs Voltage



GRAPH III : Light intensity vs Power

From the graph 1 it is observed that lux reading increases with increasing values of current for smaller values but tends to go constant at higher values. The maximum light intensity of 326 (lux) is observed at 0.78 (A). In graph 2 values of voltage and light intensity are compared. The lux readings remain zero for the voltage values up to 3.7 (V). At this point the first lux reading is observed and is called pinch off point. From then the graph is linear voltage is directly proportional to light intensity. Since the graph is linear, we are able to implement PWM on these White LED panels. In Graph 3, the power consumed by the panel vs. light intensity is plotted. It is observed that the light intensity is more at less power and it becomes constant at high power input.

B. Driver Circuit for White LED down panel.

The each GPIO (General Purpose Input Output) pin of the LPC2148 microcontroller can safely supply or sink a maximum of 4(mA) current. It would be difficult for GPIO pins to drive a high current LED DRIVER. So, it is not recommended to directly supply current to a LED of 20(mA) or a white LED. Thus, the matrix form of LEDs mounted on the square panel cannot be directly linked to the GPIO pins of the LPC2148 microcontroller. So, it is not recommended to connect the white LED down panel directly to the GPIO pins of the LPC2148 microcontroller. But, a single LED of 2(mA) or 5(mA) can be connected directly to the GPIO pins of the LPC2148 microcontroller.

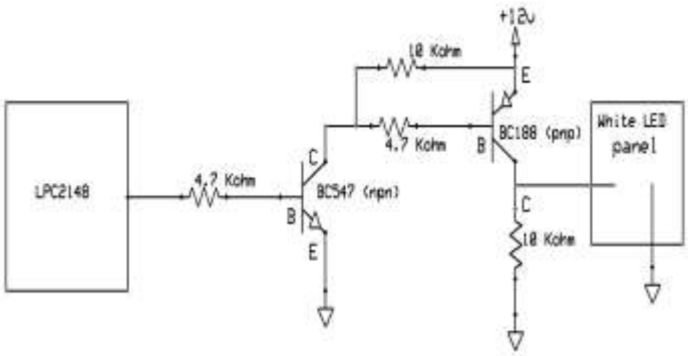


Fig 6: Schematic diagram of the transistors circuit as the intermediate module.

The figure 6 shows the basic schematic diagram of the intermediate circuit between the LPC2148 microcontroller and the white LED down panel. This schematic diagram has been drawn on the Express SCH software.

The figure shows the use of LPC2148 as the controller whose GPIO pin is connected to the base (B) of the NPN (BC547) transistors and the output of this transistor is at collector (C), connected to the input base (B) of the PNP (BC188) transistor. The output of the intermediate circuit is taken at the collector (C) terminal of the PNP transistor, connected to the positive terminal of the white LED down panel. The three terminals i.e. emitter (E) of the NPN transistor, collector (C) of the PNP transistor and the negative terminal of the white LED down panel in the above figure, are connected to ground.

According to the schematic diagram, when LPC2148 microcontroller pin is at high, the connection between the emitter and collector terminal of the PNP transistor goes open circuit. So, the output at collector terminal of the PNP transistor goes low i.e. 0(V) due to the open circuit of PNP transistor. Similarly, when the same pin of the microcontroller is at low, the connection between the emitter and the collector terminal of the NPN transistor goes closed circuit and the output at the collector terminal is observed high i.e. +12 (V).

IV. INTEGRATING DAYLIGHT WITH ARTIFICIAL LIGHTS

As stated earlier one of the strategy to save energy is to integrate the day light with artificial lights to attain an optimal level of luminance in the area.

This is achieved by using (1) Light sensors for sensing and (2) Exploiting an inbuilt feature PWM of LPC 2148 for dimming of lights.

A. *Using Light Sensors for sensing ambient light.*

A light sensor is an electronic device which detects and measures amount of light to which it is exposed and converts it into digital form (counts) and gives output via two wire I^2C bus for serial interface. Light-to-digital device includes on-chip photodiodes, integrating amplifiers, Analog to digital converter, accumulators, clocks, buffers, comparators, and an I2C interface on a single IC. The photo diodes used are responsive to visible light and their output current is boosted by amplifier which is simultaneously converted to digital value using ADC providing up to 16 bit resolution. The digital value is then written into data registers.
The ARM7 (LPC2148) controller reads the register and calculates the luminance in lux.

Output voltage α √ light intensity

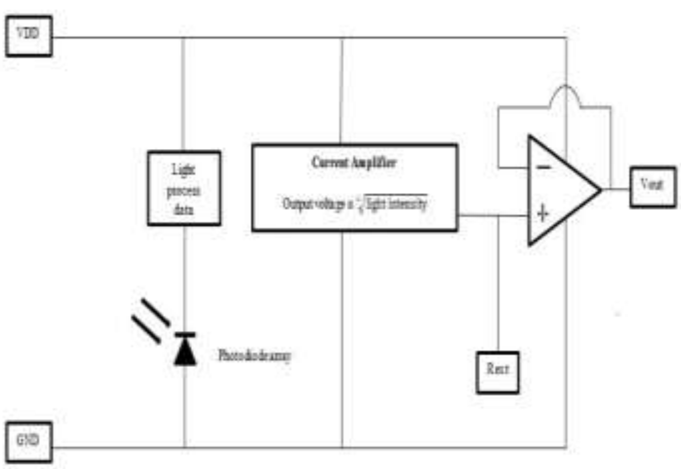


Figure 7 . Block diagram to show the functioning of a light sensor

In figure 7 the Vdd supplied is 1.8 – 3.3 (V) and Rext is 100 (kΩ). Communication between ARM7 (LPC2148) and IC is accomplished through a fast two wired I^2C serial bus interface compatible both the ARM7 and IC. The digital output of the device is inherently more immune to noise when compared to an analog interface. The final converted digital output is used by ARM7 controller to perform the dimming operation of LED panels using pulse width modulation technique.

B. *Controlling the dimming of lights: PWM technique.*

PWM is a modulation technique in which the width of digital pulses of signal is varied according to the amplitude of analog signal [1]. Duty cycle is defined as the percentage of the ratio of the ON time to the total time i.e. ON + OFF time, in a fixed period of time.

$$\text{Duty cycle} = \frac{\text{ON time}}{\text{Total time}} * 100$$

PWM technique is a widely used digital technique used for dimming of LED down panels. This is accomplished by keeping the LED off for a longer period than it is on.

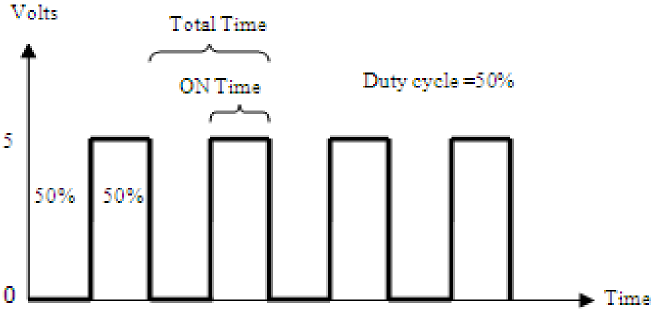


Fig 8: waveform of 50% duty cycle.

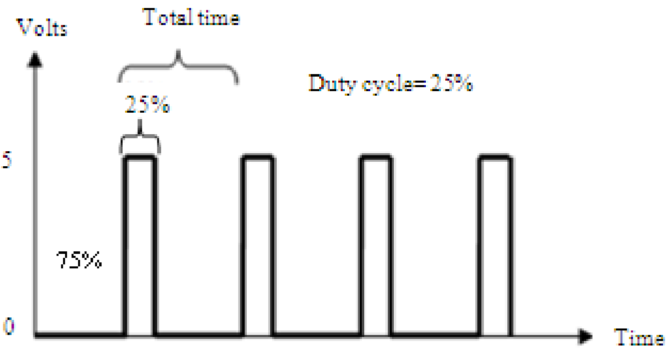


Fig 9: Waveform of 25% duty cycle.

These strobes are for such short times that human eye could not detect them. The longer is led is kept on the brighter it appears to the observer.
For example if the LED is kept off for 80% time the light intensity as observed by the observer will be 20% of its maximum. One of the important features of this technique is the wide dimming range offered by it. The minimum brightness level that could be achieved is 0.01 times of its maximum level thus offering a ratio of 100:1 dimming ratio.

1. *STRATEGIES TO IMPLEMENT PWM IN CASE OF LPC2148 (ARM7) MICROCONTROLLER USING INBUILT PWN MODULE*

```
void PWM(void)
{
 PINSEL1=0x00000400;     // to select pin PO.2 for PWM5
 PWMTCR=0x00000002;      // resets PWM function  of timer
 PWMPR=0x00000000;       // prescalar register    disabled
 PWMMCR=0x00000002;      // resets on PWM0
 PWMPCR=0x00002000;      // enables PWM5
PWMMR0=0x000000ff;
PWMTCR=0x00000009;       // enables PWM
 PWMLER=0x00000021;      // latch new match entries
while(1)                 // infinite loop
 {
   PWMMR5=0;    // set PWM5 duty cycle at fixed freq
   PWMLER=0x00000021;
   delay(9);
```

```
  PWMMR5=255   // set PWM5 duty cycle at fixed freq
  PWMLER=0x00000021;
  delay(1);
 }
}
int main()
{
 PWM();                          // calling PWM
 delay(1);                       // calling delay function
 while(1);                       // disable infinite loop
}
```

The above code shows the implementation of the PWM on the LPC2148 microcontroller, by NXP using Keil micro-vision4 software. In the PWM coding implementation, we have to initialize inbuilt PWM registers [7] of the LPC2148 microcontroller. We define a function *void PWM();* in which all the inbuilt registers [7] of the PWM module are initialized to perform a specific task. In *void PWM();*function, PWM output 5 (PWMMR5) is taken to observe the Pulse Width Modulation of the LPC2148 microcontroller as the other PWM output channels share their pins as UART0 and UART1 (PWM1, PWM3, PWM4, PWM6) and PWM2 shares with IRQ EINT2 and can also be configured as the GPIO pins. So, PWM5 output channel is left which shares pin P0.21 with only general purpose input output (GPIO) pin. The while(1) loop defines the infinite loop which keeps on executing the PWM5 to give the Pulse Width as the output on pin P0.21. In while(1) loop, PWMLER (Pulse Width Modulation Latch Enable Register) is declared after the initialization of PWMMR5 as it enables the new PWM match values [7].

2. *STRATEGIES TO IMPLEMENT PWM IN CASE OF LPC2148 (ARM7) MICROCONTROLLER USING GPIO PINS*

```
void main()
{
 IODIR0=0x000000ff;   // configuring port 0
 IODIR1=0xffffffff;   // configuring port 1
 IOCLR0=0xffffffff;
while(1)
 {
  IOSET1=0x00000000;
  b=IOSET1;
  delay(9);
  IOCLR1=b;
  IOSET1=0x00000001;
  b=IOSET1;
  delay(1);
  IOCLR1=b;
  }
 }
```

In this, we have implemented the PWM using GPIO (General Purpose Input Output) [6] [7] pins of LPC2148 to observe the output waveform in the logic analyzer of Kiel micro-vision4 software. It has two ports i.e. P0 and P1 and defines the 4 basic registers that are:-

TABLE I : Description of GPIO registers[7].

NAME	DESCRIPTION
IOPIN	GPIO Port Pin value register reads the current state of GPIO configured port pins.
IODIR	GPIO Port Direction Control Register controls the direction of each port pin individually.
IOSET	GPIO Output Set Register controls the state of output pins.
IOCLR	GPIO Output Clear Register clears the state of the output pins in IOSET.

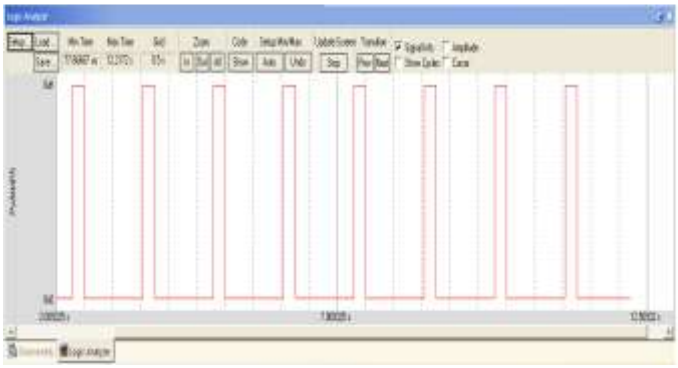


Fig 10: PWM5 waveform on the logic analyzer of 10% duty cycle implemented using inbuilt module of LPC2148.

V. IMPLEMENTING PIR SENSOR

This feature is again a very interesting feature and contributes a major part of energy savings as people move out of their places keeping the lights turned on or forget to switch them off. In any such cases when the area is not occupied the lights will automatically switch off and if the person moves in to that area the lights will be switched on. This is done by sensing the occupancy or human detection by using PIR sensors. A PIR sensor is a sensor which is able to detect motion by using infrared radiations. It is also called as a Passive Infrared sensor or Infrared motion sensor. A PIR sensor is made of a pyro electric sensor. A pyro electric sensor detects levels of radiations around it. It is assumed that every living body emits some level of radiations. We are not interested in level of radiations rather we want to detect presence of such radiations. The sensor is split into two halves which are connected to each other through a wire in such a manner that if there is no detection of radiations, the output is a LOW signal. As soon as it detects any variations or movement of a radiated body from one half to another it outputs the signal as HIGH [8]. A pyro electric sensor is made of a crystalline material which when exposed to infrared radiations generates electric charge. The changing radiations changes voltages generated measured by the amplifier. The sensor is attached with a Fresnel lens which focuses the radiations into the crystalline material. The varying radiations that fall on this crystal generate the voltage which is indicated by the amplifier.

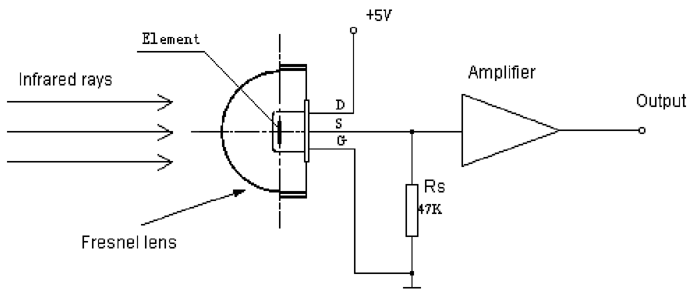


Figure 11. Working of a PIR sensor

TABLE II: Specifications and dimensions of PIR used [8].

Model	D203B
Encapsulation type	TO-5
IR Receiving Electrode	2×1mm, 2 elements
Window Size	5×3.8mm
Spectral Response	5-14µm
Transmittance	≥75%
Signal Output [Vp-p]	≥3500mV
Sensitivity	≥3300V/W
Detectivity (D*)	≥1.4 ×108 cmHz1/2/W
Noise [Vp-p]	<70mV
Output Balance	<10%
Offset Voltage	0.3-1.2V
Supply voltage	3-15V
Operating Temperature	-30-70ºC
Storage Temperature	-40-80ºC

A. Connecting PIR sensor to LPC2148 (ARM7) microcontroller

The PIR module contains a 3 pin connector with power supply pins and output pin. Pin-1 in supplied with 3-5 (V) Dc supply and Pin-3 is GND. Whenever the device detects a motion or change in radiations level, it outputs as HIGH signal to the pin-2. The HIGH output generated by the module is 3.3 (V) Dc. This voltage level is not enough for the microcontroller to detect. So to power up the output to 5 (V) Dc we use a driver circuit which converts the 3.3 (V) Dc to 5 (V) Dc by using 2 BJTs in cascaded structure. The output pin of the PIR module is connected to the base of the NPN BJT which supplied with 5(V) collector supply. The emitter output acts a base input for the second PNP BJT. Thus the output of the circuit is 5 (V) which is connected to port 2 of LPC2148 (ARM 7) microcontroller.

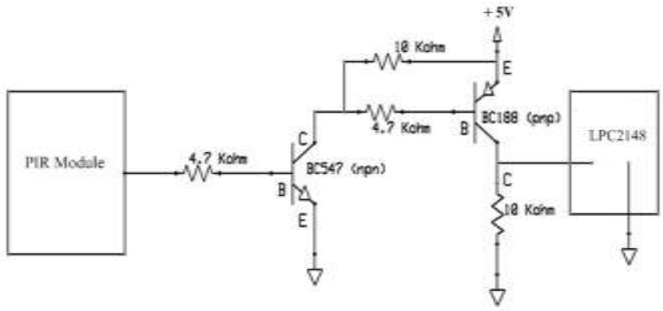


Figure12. Driver Circuit used with PIR sensor

A. Strategies to implement PIR code in case of LPC2148 (ARM7) microcontroller

```
void main()
 {
 long unsigned int temp;

IODIR0=0x00000000;   // configuring port 0 as input
IODIR1=0xffffffff;   // configuring port 1 as output
IOCLR1=0xffffffff;
  temp=IOPIN0;
  while(1)
   {
    if(temp==0x00000001)
       delay(500);  // wait for PIR sensor to respond
        if(temp==0x00000001)
         {
              IOSET1=0x80000001;   // LED panel ON
          }
       else
         {
       IOCLR1=0xffffffff;   // LED panel OFF
         }
     else
       {
       IOCLR1=0xffffffff;   // LED panel OFF
         }
    }
}
```

In this way, we have implemented the code for detection of human using PIR sensors. The registers used are general purpose input/output registers of LPC2148 microcontroller [7]

TABLE III : Description of GPIO registers [7].

NAME	DESCRIPTION
IODIR	GPIO Port Direction Control Register controls the direction of each port pin individually.
IOSET	GPIO Output Set Register controls the state of output pins.
IOCLR	GPIO Output Clear Register clears the state of the output pins in IOSET.

VI. CONCLUSION

Integrating light sensor with PIR sensors to control the dimming of white LED down panels by using PWM technique to a 32 bit microcontroller is achieved. Expanding this controlling feature to the whole building will definitely reduce energy wastage .The implementation of this holistic concept of intelligent lightning system will help in green building design with low carbon footprints and thus harmonious to nature.

ACKNOWLEDGMENT

The authors are highly grateful to their respective organisations for their help and support.

REFERENCES

[1] Hongming Yang, Tim C. W. Schenk, Ashish Pandharipande, "Enhanced Illumination Sensing Using Multiple Harmonics for LED Lighting Systems", IEEE TRANSACTIONS ON SIGNAL PROCESSING, VOL. 58, NO. 11, NOVEMBER 2010.

[2] Luigi Martirano, "Lighting systems to save energy in educational classrooms", DIAEE – Electrical Engineering Area Rome, Italy.

[3] Hui Ren,Kai Zhou, Zhen Li,Hui qin Wang," Research and realization of new stage lighting control system", 2011 Fourth International Joint Conference on Computational Sciences and Optimization

[4] A.B. Sebitosi and P. Pillay"White LEDs for rural lighting"

[5] Narendra B Soni,member IEEE and P. Devendra"The transition to LED illumination: A case study on energy conservation".

[6] Chapter 16: PWM, LPC214X user manual by NXP (founded by Philips).

[7] Chapter 8: GPIO, user manual by NXP (founded by Philips).

[8] PIR Sensors

Ramandeep Singh is currently working as an assistant professor in EECE department in ITM University, Gurgaon. He received his M.E. in embedded systems from BITS-Birla Institute of Technology and Science in 2009. He completed his B.Tech in Electronics and communication from GTBIT-Guru Tegh Bahadur Institute of Technology, IP University in 2007. He got 100% scholarship in his M.E. Program from Philips Semiconductor, Bangalore.

Prithipal Singh is currently a final year undergrduate student in ITM Univerity, Gurgaon in EECE Department.

Siddharth Lalit is currently a final year undergrduate student in ITM University, Gurgaon in EECE Department.