An Intelligent Light Control System for Power Saving

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Abstract- **Saving energy has become one of the most challenging issues these days. The most waste of energy comes from the inefficient use of the electrical energy consumed by artificial light devices (lamps or light bulbs). This paper presents a system with detailed design for saving electrical energy by controlling the intensity of artificial light to a satisfactory level and getting use of the day light when possible with the best effort for energy saving. An improvement to daylight harvesting and controlled dimming systems is introduced while counting for over illumination cases. The idea behind is to control the venetian blinds or curtains in such a way to make use of the daylight if it is available. Otherwise, it uses the artificial internal building light. Controlling the amount of daylight passing inside is via controlling the opening angle of the venetian blinds while controlling the intensity of artificial light is by controlling the amount of power delivered to the lamp via Pulse Width Modulation (PWM) for DC lamps or clipping the AC wave for AC light bulbs. The system uses Controller Area Network (CAN) as the media of communication with the sensors and the actuators. The system is modular and can be expanded to span large buildings. The advantage of the design is that it gives the user a single point of operation which is the amount of desired light. The controller is responsible to determine a way to satisfy the amount of light desired with the least energy consumption. One of the major issues considered is the ease of installation and the low cost of the system components. The system shows a significant amount of energy saved and feasibility in practical implementation.**

***Index Terms*— Intelligent light control system, Energy saving, Daylight harvesting, venetian blinds control, Controller area network (CAN), Controlling light intensity.**

I. INTRODUCTION

Over the years, as the number of buildings and the number of rooms within building increases dramatically, it was difficult to manage the waste of energy due to the inefficient light control and illumination distribution. In addition, it is not practical to rely on the users to manually control the light to save energy. A lot of technology and sensors have evolved recently to manage the excessive energy consumptions like occupancy sensors (motion detector) which detect activity within a certain area. They provide convenience by turning lights on automatically when someone enters a room. They reduce lighting energy use by turning lights off soon after the last occupant has left the room. The disadvantage is that it doesn't count for the existing light in the room from other sources. In addition, it depends on the location of the user to trigger the internal sensor. Motion detectors are great but they are not sufficient.

Another way to save energy is using dimmers, which is a manual method to control the intensity of artificial light, although some dimmers save energy, they don't respond automatically if there is another source of light available inside the room.

Several studies have recorded the energy savings due to daylight harvesting. California Energy Commission's Public Interest Energy Research Program [1] proposed a research deploying on/off control but they didn't take into account the over illumination that is caused by daylight. Although it is cheaper to use on/off control, continuous dimmer will save a lot more energy with a reasonable cost. Daylight harvesting systems save electric lighting in the range of 20-60% [2]. Energy saving depends on the type of space where the control system is implemented. Daylight harvesting can be deployed whenever daylight is available; it works best in spaces with access to windows or skylights. Such spaces include offices, public buildings, and schools. Increasing energy saving by increasing the size of windows can cause over illumination that may be inconvenient for the occupants, causing them to deploy manual venetian blinds or other shading devices.

To design an effective method to save energy, it is necessary to understand the nature of light sources available. Natural light can be a direct or indirect sunlight (ambient light or reflected from object surfaces). Artificial light sources can be generated by delivering an amount of power (electrical) to standard light bulb. Other important factors are the location of the light source, the angle of incident of the light as well as the location of the photo-sensors and their alignments and calibrations. Finally the color of the light source can affect the sensors readings significantly [3].

A control method has been described in [4] to control the venetian blind angle. Y. Chen [4] has focused on the fuzzy controller and the double control loop, though a single control loop is enough as we don't care about the accuracy of the venetian blinds angle as we care about the amount of light exists. Some expensive solutions using MEMS (Micro Electronic Mechanical Systems) have been described in [5]. V. Viereck [5] has used micro mirrors to reflect back the extra undesired sun rays. Micro mirrors are expensive to be manufactured. Other researchers used wireless network for the light sensor communication [6]. Even though wireless sensors are easy to install and require no wiring, it is expensive and sensitive to noise.

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In this paper, a new logical low cost design is introduced to save electrical energy taking into consideration the daylight over illumination using CAN bus as the media for communication. CAN is a message based protocol, designed specifically for automotive applications, but it is also widely used for industrial as well as manufacturing applications. The high noise immunity of the CAN bus and its robustness give the system the ability to be expanded all over the building, it gives the user a single point for operation and made the system modular. The rest of the paper is organized as follows. The system model is presented in Section II. Section III introduces our experimental work and simulation. Finally, Section IV presents the conclusion.

II. SYSTEM MODEL

A. Main System Components

As shown in Fig. 1, the system is composed of two sets of photosensors, blinds actuator (servo motor), internal artificial light, an operating point and the main controller. All components communicate via a CAN bus. The photosensors are used to measure the room and daylight illumination. The room-photosensor should be placed in such a way that it avoids direct light from light sources and at the same time it picks up light from the task surface. Typical location for the room-photosensor is the ceiling above the task surface. The daylight-photosensor can be placed outside the venetian blinds to pickup daylight intensity level. Both room- or daylight-photosensor can be a group of photosensors and by taking the average among the entire group a better precise readings can be obtained. The venetian blinds actuators are used to control the blinds angle to pass daylight or to block it. The light intensity required is adjusted via the operating point unit. The internal light source can be a DC or AC light bulbs. DC light bulbs are usually controlled via PWM signals to deliver a specific amount of power without wasting any energy in passive resistors. AC light bulbs are controlled via thyristors to clip a part of the AC wave and hence deliver the specified amount of energy required for the desired illumination. The main controller communicates with the other components via the CAN bus.

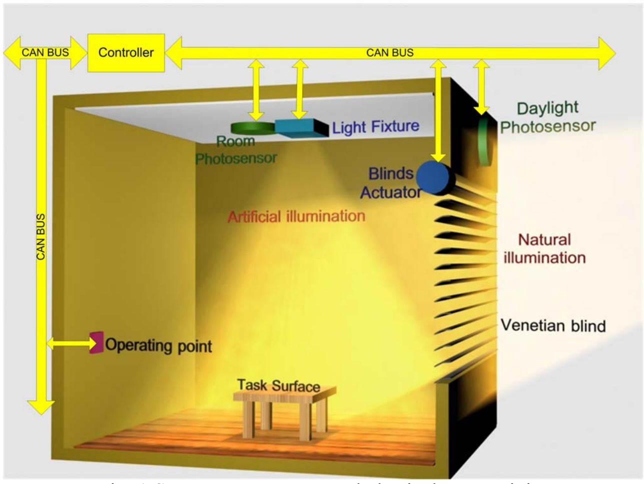

Fig. 1 System components and physical connectivity

B. System Operation

Fig. 2 shows the block diagram of the control loop. The controller and logic process blocks are responsible to collect all the incoming environment variables including light intensity outside the room (daylight), light intensity inside the room (lamp) and finally the user input. The controller will process all the inputs and will be responsible to provide the best solution to illuminate the room with the least possible power consumption. For example, if the user wants to increase the room illumination, the controller will first check how much light can be obtained from the daylight. If it is enough even for small contribution, the controller will start to open the venetian blinds to bring a part of the daylight inside. If the daylight contribution is not enough to satisfy the user requirements, the controller will partially use the artificial light (light bulb) as an assistant source to satisfy the desired light level. The controller will act as the decision making block. Moreover, the controller will be handling all CAN messages. Venetian blinds motor control block is responsible to adjust the venetian blind angle; it contains a controller and a motor driver amplifier to supply power to the motor.

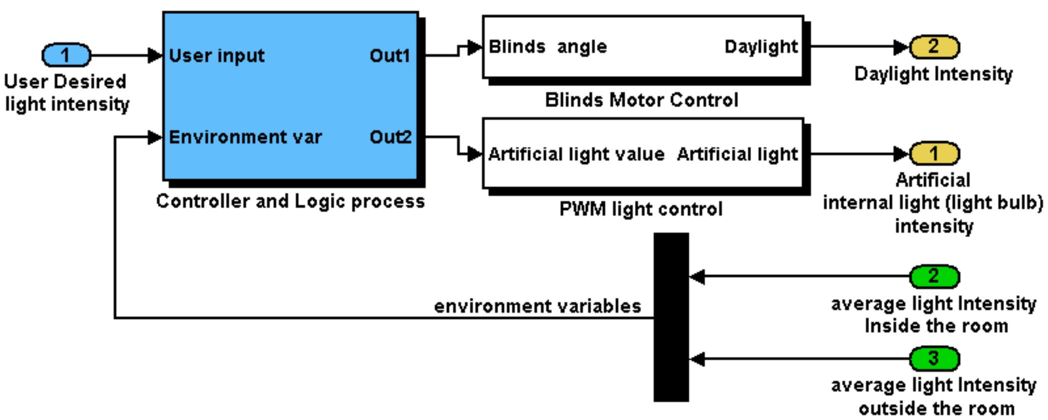

Fig. 2 System control loop

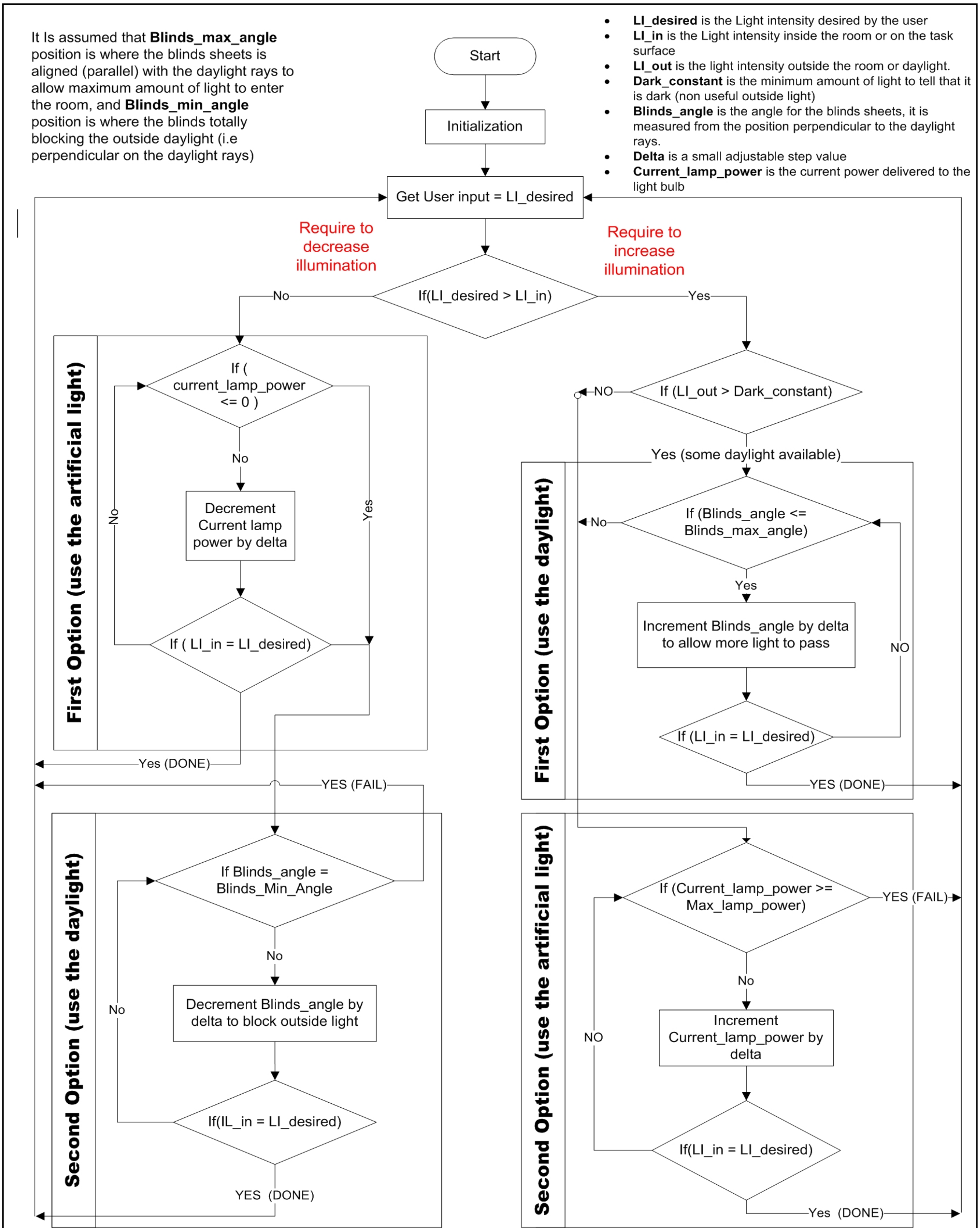

Fig. 3 Flow Chart

The PWM light controller block is responsible for providing power to the light bulb to obtain specific illumination.

C. Process Flow

To adjust the amount of light inside a room, we have two options: the venetian blinds angle to bring light from outside (daylight) and the artificial internal light source. Of course the artificial light is the least we want to use. The daylight is the most we want to use. Following the flow chart shown in Fig 3 we have two scenarios. First scenario is when the user wants to increase the intensity of light inside a room. The user will adjust the set point as desired. The controller will compare the amount of daylight outside the room with the Dark_constant[1]. If some light is available outside, the controller will start to open the venetian blinds until the intensity inside the room reaches the set point (user satisfactory light level). If the amount of daylight is not enough, the artificial internal light will be used (use the lamps) in such a way to satisfy the amount of light desired. The second scenario is to decrease the amount of light inside a room. The controller in this case will check if there is any artificial light used, if so, it will start to decrease the amount of light by decreasing the power going to the lamps till the desired intensity is reached. If the lamps are totally turned off and still the desired intensity is not satisfied, the controller will start to close the venetian blinds. If both reach the minimum value, the controller will stop at this stage[2]. Since the system is a closed loop system, at any instant if the daylight intensity changes, the system will respond accordingly by closing or opening the venetian blinds or turning on-off the Internal light obeying the system rules of saving the maximum energy possible. The venetian blinds zero position varies according to the average direction of the daylight. The blinds 90 degree position allows the maximum amount of daylight to pass, and the blinds zero degree position is the total shading (blocking) position as shown in Fig. 4. The venetian blinds zero position can be controlled via ray tracking to keep track of the zero position.

D. Expandability

As shown in Fig. 5 the system can be looked up as a group of power saving unit. Every unit is responsible for a specific zone within the building. Every unit is composed of the controller, a group of sensors, actuators and user console as described earlier. Basically we assumed that every power saving unit controls a single zone. However due to the fact that all sensors and actuators use the CAN bus, it is possible to connect all power saving units together. In this architecture all units can communicate together and all units can be controlled from different operating points via the CAN bus. Moreover, all building lighting can be controlled from building management center through a computer graphical interface. It gives the ability for a single operator to control and monitor the energy waste for the whole building.

CAN bus can be used up to a certain limits in length, to expand the Bus to cover more length, a repeater or CAN-to-CAN interface can be used.

Fig. 4 Different Venetian Blinds Angles

[1] This constant define the minimum amount of light to tell if it is dark outside or not, if the photosensor reading is below the Dark_constant it will not be worthy to open the blinds.

[2] it means that there is a leakage of light and is uncontrollable.

E. Fault Tolerance and Reliability

Since some buildings have no physical boundaries between zones, an illumination from one zone can affect other zones. An advantage of using the CAN bus is that a zone which is controlled by a single power saving unit can also take into account the other units sensor data. Due to the fact that all the sensors are connected to the CAN network it is possible for one unit controller to request readings from other zone sensors without any physical modifications for the wirings. In addition, the CAN bus gives high fault tolerance for the proposed system. In case of a failure for any of the sensors or actuators, the system can recover itself and rely on other sensors in the network.

III. EXPERIMENTAL WORK AND SIMULATION

The system is implemented using a small hardware model for a room with a horizontal venetian blind. Two sets of DC light bulbs installed at the center of the ceiling and two photo-resistances are used as the light sensors. The venetian blind is controlled via PWM Servo Motor HS-422 from HI-tech, it costs around $13 and it comes with the controller and amplifier build in. Due to the compact size of the servo motor, it can be mounted directly inside the venetian blinds top case. PIC18F458 microcontroller is programmed to act as the main controller (Node 1) while the smaller version of PIC microcontroller as PIC18F2480 (costs $4.27) can be used for the actual production. One of the photo-resistances (Node 2) is installed at the center of the ceiling inside the room and the other photo-resistance (Node 3) is installed outside the room. The photo-sensors are mounted inside a short tube to sense the illumination reflected from a specific direction. Both photo-resistances are connected to a simple voltage divider circuit to obtain voltage variation from resistance variation. The voltage level which represents the illumination level is digitized via an ADC (analog to digital converter) and kept ready to be requested by the main node. A DC light bulb is used in the experimental work and is derived with MOSFET transistor IRF640. The light bulb intensity is controlled by varying the duty cycle signal (PWM control) generated from the microcontroller and connected to the MOSFET Gate pin.

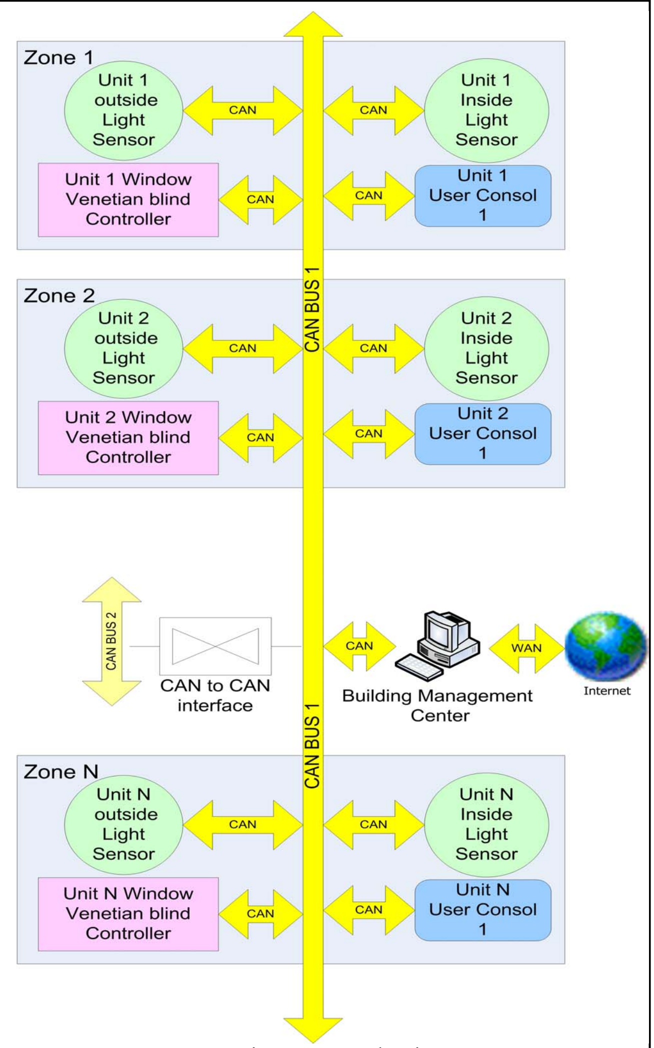

Fig. 5 Zones and Units

Node 1 will act as the master and the other nodes will act as the slaves. Node 1 will keep pooling Node 2 and 3 to obtain the light level inside and outside the room respectively. Node 4 is responsible for receiving CAN messages from Node 1 and converting it into PWM signal to control the artificial illumination (lamp). Node 5 is combined with Node 1 to control the blind angle via the servo motor. In addition, the operating point is directly connected to Node 1. MCP2551 (costs $0.89) is used as the transceiver. It also provides a buffer between the CAN controller and the high-voltage spikes that can be generated on the CAN bus by outside sources. The circuit diagram of Node 1 is shown in Fig. 6. It is assumed in the experimental work that Node 1 is directly controlling the servo motor and directly connected to the user input. Two terminal resistances are used to terminate the CAN bus at the near and far ends. Pin RC6 and RC7 are used to communicate to a PC via RS232 to monitor the different variables.

The Simulation carried out on two phases, the first phase using Matlab to simulate the process flow as a standalone system without considering CAN. A CANoe simulator is used in the second phase simulation, CANoe is a simulator used widely by automotive industries to analyze the CAN messages and calculate the latency time. Our system works efficiently at low baud rates. Thus, low cost components can be used to build the proposed system. A 64kbps is tested and found enough for a few power saving units. Fig. 7 shows an example where the user requires 500 LUX. In Fig. 7(a) an amount of 250 LUX is available from the daylight, so the controller decides to use the internal light to assist the daylight with a contribution of 50%. Fig 7(b) shows that the daylight increased to 750 LUX, so internal light is totally turned off and the venetian blinds are used to protect from over illumination. The system response is shown in Fig. 8.

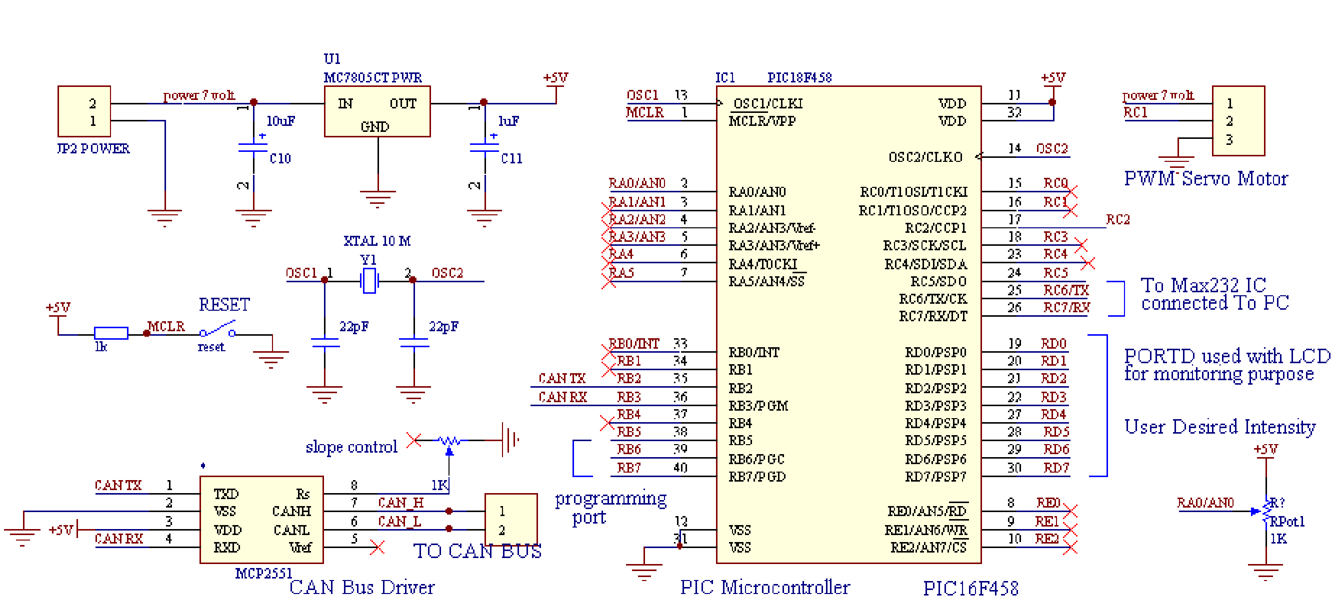

Fig. 6 Node 1 Circuit diagram

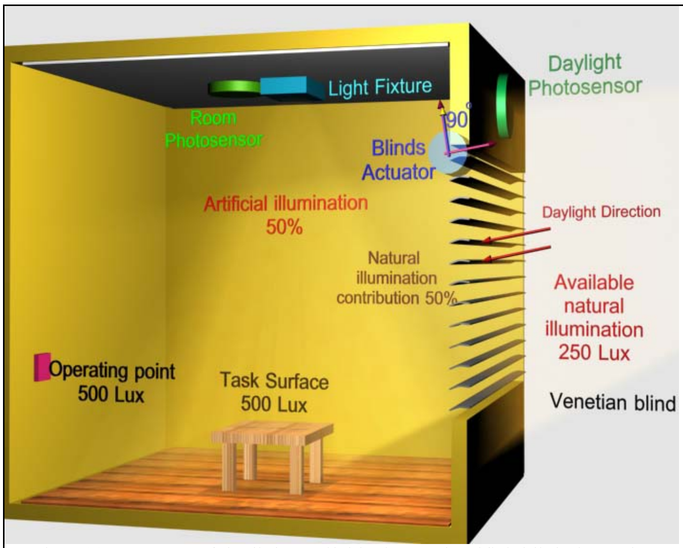

Fig. 7(a) 250 LUX of daylight available, internal artificial light is used at half power.

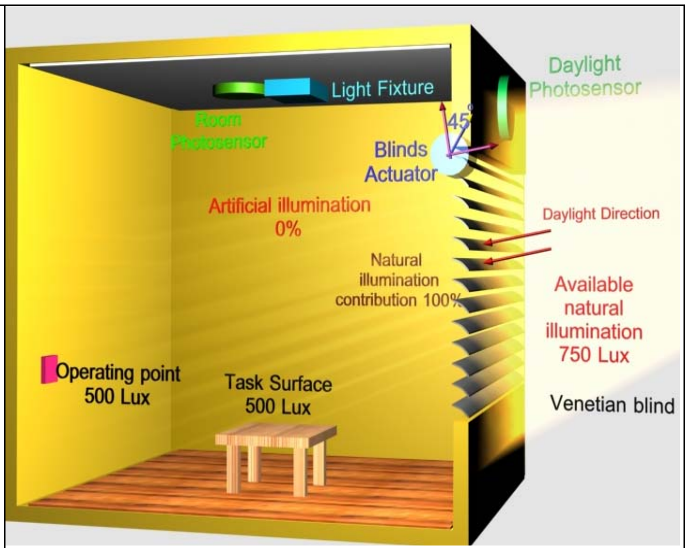

Fig. 7(b) 750 LUX of daylight available, Blinds used to protect from daylight over illumination.

Usually a business day starts at 8 am in the morning when it is required to increase the illumination to 500 LUX as recommended by IES [7]. In the early morning, daylight starts to increase gradually to reach its peak at 12 pm, and then starts to decrease gradually. In the early morning and late evening energy consumption is the maximum because the intensity of daylight is not enough to satisfy the user needs. The Energy saved is the area of the intersection between the set point and daylight curve. The over illumination is successfully blocked by means of the venetian blinds. The daylight curve is a function of many parameters like the calendar day and the current month. It also depends on whether it is a cloudy day or a sunny day. Finally the direction of the window[3] can significantly affect the amount of daylight that can be used.

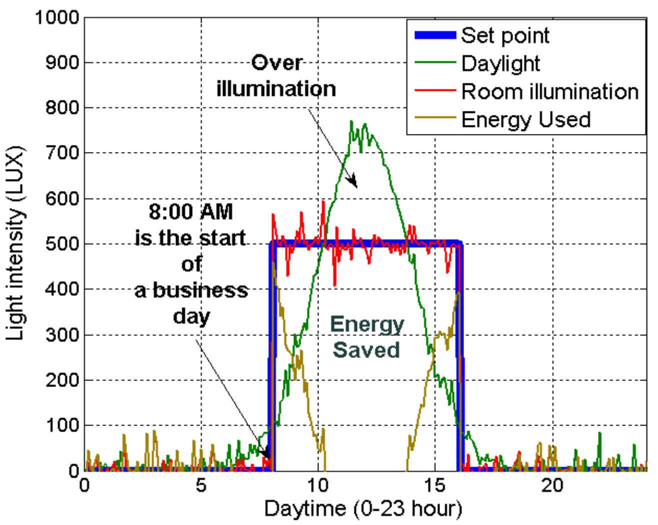

Fig. 8 System response

[3] If the window is facing the East, then more daylight is available in the morning compared to if it is facing the west.

IV. CONCLUSION

In this paper, we have presented an intelligent power saving system using CAN. A logic method is introduced to control venetian blind angles for using the daylight while still protecting the users from over illumination. The proposed schemes are verified by practical implementation using an actual hardware model as well as by computer simulation.

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