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Self-Regulated Solar Lighting System

Mr. Ramesh C R[1], Prof.Lyla B Das[2]
[1] M.Tech Student, M130418EC, National Institute of Technology, Calicut
[2] Associate Professor, Department of ECE, National Institute of Technology, Calicut
[1]ramesh_m130418ec@nitc.ac.in, [2]lbd@nitc.ac.in

Abstract:* *Electricity is a prime concern in today's world. On observing the path through which we travel daily we can see that a lot of electricity is wasted by glowing sodium wafer lamps and even the traditional tube lights on the electric posts at unnecessary intervals. The self regulating solar system enters into action and exits from functioning depending upon the output from the Day/Night sensing unit. Once the unit indicates arrival of night then the system turns ON, the controlling unit thereafter controls the illumination level of the lamp depending upon the outputs of interruption detector, temperature sensor & real time clock. The system also contains an embedded temperature sensing unit that senses the temperature of the lamp module, thereafter preventing the operation of the lamp at undesirable temperature condition and hence increasing the life span of the LEDs a used in the lamp.

Keywords: *Solar Lighting System, Sensing Unit, Temperature, Interruption Detector, Real Time Clock*

Introduction

[1]Lighting systems, particularly within the public sector, are still designed per the previous standards of reliability and that they don't usually profit of latest technological developments. Recently, however, the increasing pressure associated with the raw material prices and also the increasing social sensitivity to CO2 emissions are leading to develop new techniques and technologies which permit significant cost savings and larger respect for the environment. The self-regulating lighting system designed here is capable and efficient in using the electricity available hence it increases the efficiency as well as decreases the consumption of electricity. The entire system functioning depends on the outputs from the various sensing units. The output from these sensing units are passed to the controlling unit implemented using the PSoC1 microcontroller[4] CY8C29466-24PXI. Here a simple sensing method is used for day/night detection using a potential divider network. The temperature of the LED lamp is monitored continuously so that if the permitted limit is crossed the illumination intensity is brought down so that the life span of the lamp is extended. The LCD display attached to the system expands the facility of imparting the status of the battery, lamp and its operating conditions to any person who wishes to view them. The real time operation of the system is achieved by incorporating the real time clock using DS1307 IC. The block diagram shown in Figure 1 provides the transparent outline of the system proposed here.

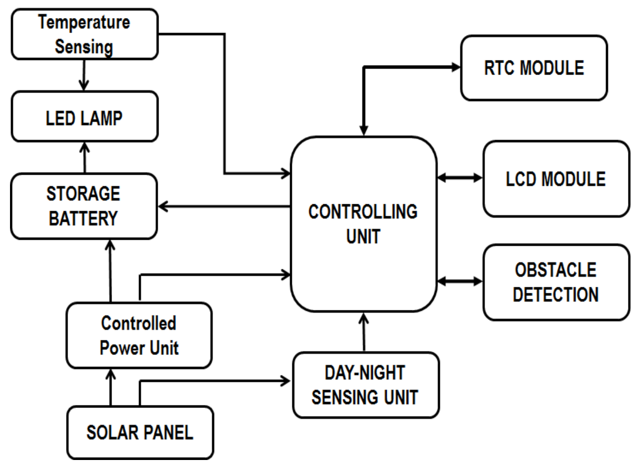

Figure (1): Block diagram of the proposed system

Controlling Unit

This section acts as core and essential for the automation of the product. The unit is implemented using PSoC1 CY8C29466-24PXI microcontroller from Cypress Semiconductors.

PSoC 1 CY8C29466-24PXI

The PSoC core[4] is a powerful engine that supports a rich feature set. The core includes a CPU, memory, clocks, and configurable GPIOs. These devices are designed to replace multiple traditional microcontroller unit (MCU)-based system components with one, low-cost single-chip programmable device. PSoC devices include configurable blocks of analog and digital logic, as well as programmable interconnects. This architecture allows you to create customized peripheral configurations that match the requirements of each individual application.

CY8C29466-24PXI, 28 pin PDIP package as shown in Figure 2 is a M8C CPU core powerful processor with speeds up to 24 MHz, providing a 4 million instructions per second (MIPS) 8-bit Harvard-architecture microprocessor. The CPU uses an interrupt controller with 17 vectors, to simplify programming of real-time embedded events. PSoC GPIOs provide connection to the CPU, and digital and analog resources of the device. Each pin's drive mode may be selected from eight options, allowing great flexibility in external interfacing. Every pin also has the capability to generate a system interrupt on high level, low level,

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and change from last read. Memory uses 32 KB of flash for program storage, 2 KB of SRAM for data storage, and up to 2 KB of EEPROM emulated using the flash.

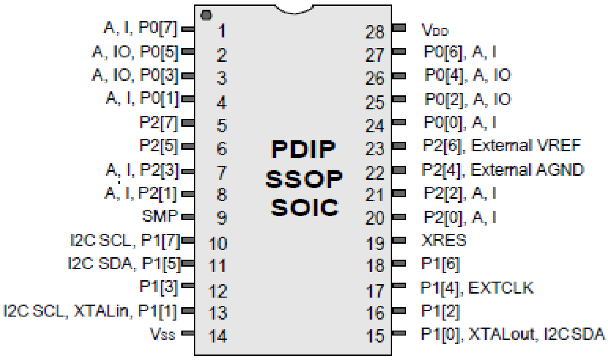

Figure (2): Pin out of CY8C29466-24PXI

Day-Night Sensing Unit

Normally, in solar home lighting system, solar lantern or solar streetlight, the load (the light) is switched on at dusk (evening) and switched off at dawn (morning). During daytime, the load is disconnected from the battery and the battery is recharged with the current from solar panel. For automating this process, the microcontroller needs to know the presence of the solar panel voltage to decide whether the battery should be in charging mode (dawn) or discharging mode (dusk). Here a simple sensing unit is built, using a potential divider formed around resistors, zener diode and transistor for the presence of panel voltage.

Controlled Power Unit

This unit facilitates the charging current to flow from the panel into the battery under normal conditions (dawn). Basically, there are two methods of controlling the charging current: series regulation and parallel (shunt) regulation. Here we have opted parallel regulation, the control circuitry allows the charging current to flow into the battery and stop charging once the battery is fully charged. Normally after full charged state, the charging current is through low-value, high-wattage resistor and which dissipates a lot of heat. But in our design, instead of wasting the charging current as heat, we have made it pulsed and applied to the battery to keep the battery topped-up. This keeps the overall current consumption of the solar controller low, ensures enhanced battery life-time and prevention against over-charging of the battery. The unit is realized using a power diode, relay and transistor.

Temperature Sensing

The unit ensures that the LED lamp doesn't operate at elevated temperatures. The unit is implemented using LM35 which provides analog voltage at the output proportional to the instant temperature of the LED lamp. The LM35 thus has an advantage over linear temperature sensors calibrated in º Kelvin. The LM35 does not require any external calibration or trimming to provide typical accuracies of ± 1/4º C at room temperature and ± 3/4º C over a full -55º C to +150º C temperature range. The LM35's low output impedance, linear output, and precise inherent calibration makes interfacing to readout or control circuitry especially easy[3]. If the temperature detected is above the first maximum limit then microcontroller step downs the illumination of the lamp to the minimum level and if it crosses the extreme limit, then the lamp is completely switched off even if there is need for light. This dynamic behavior ensures enhanced life-span of LED's and its operating characteristics.

RTC module

This unit consists of IC DS1307 serial real-time clock shown in Figure (3) which is a low-power, full binary-coded decimal (BCD) clock/calendar with 56 bytes of NV SRAM. It possesses a built-in power sense circuit that detects power failures and automatically switches to the backup supply. Timekeeping operation continues while the part operates from the backup supply. In the system, the time tracked together with other sensing modules configures our system to be operating at realistic environment with high precision. Here as shown in Figure (4), I2CHW User Module of CY8C29466-24PXI acts I2C Master to retrieve date and time from the DS1307 RTC.

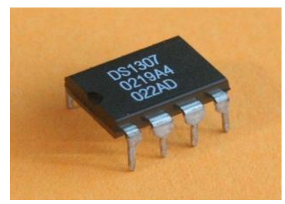

Figure (3): DS1307 RTC IC

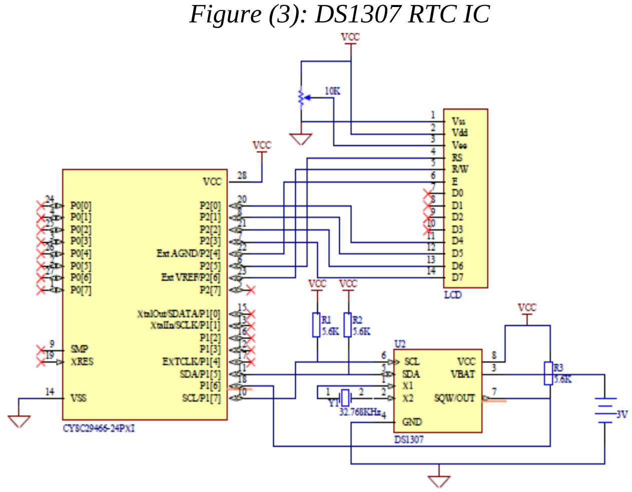

Figure (4): RTC interface with CY8C29466-24PXI[5]

Obstacle Detection Unit

The PIR Sensor used in the system is a pyroelectric device that detects motion by measuring changes in the infrared levels emitted by surrounding objects. This motion can be detected by checking for a high signal on a single I/O pin. The sensor combines advantages of single bit output, smaller in size making it easy to conceal, compatibility with all types of microcontrollers and operates with an input voltage range from 5V to 20V with <100uA current draw. Due to its mode of detection, here we use it for both human and vehicle detection.

LED Lamp

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It is configured with 16, 1W ultra bright white LED's making a load of 16W which operates with an input voltage of 12V and current of 1.332A. The final encapsulated LED lamp is shown in Figure (5)

Figure (5): Encapsulated LED Lamp

LCD Module

This part of the system serves as an alternative of GUI application to read the battery voltage, operating status and system performance. The module used here 16X2 LCD shown in Figure (6) is based on HD44780 controller. The backlight feature of the LCD makes it readable even in low light conditions. The LCD is used here in 4-bit mode to save the microcontroller's port pins. Usually the 8-bit mode of interfacing with a microcontroller requires eleven pins, but in 4-bit mode the LCD can be interfaced to the microcontroller using only seven pins.

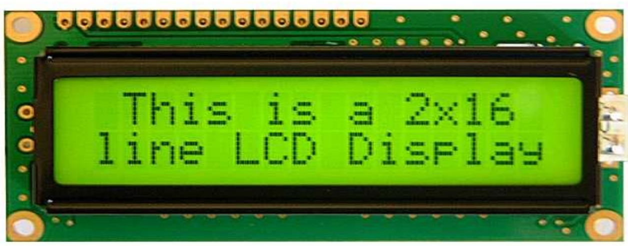

Figure (6): 2X16 LCD Module

Working of the Proposed System

On power-on of the system, the microcontroller reads the battery voltage and displays the status of the battery in the LCD. It monitors the input signal from the dusk-to-dawn sensing unit and activates the load or charging relay accordingly. As V_{REF} of the ADC is VCC (5V), the input voltage to the ADC cannot exceed +5V. A battery level indicator circuitry[10] is used to scale down this voltage from 0V-12V to 0V-5V.

When the solar panel voltage is present, the microcontroller is configured to display message 'CHARGING' on the LCD. During charging, the battery voltage is continuously monitored. When the voltage reaches 14.0V, the microcontroller interrupts the charging current by energising the relay, and starts a 2-minute timer. During this stage, the LCD shows "battery full." After 2 minutes, the relay reconnects the panel to the battery. This way, the charging current is pulsed at the intervals of five minutes and the cycle repeats until the panel voltage is present.

When the panel voltage falls below the dusk-to-dawn senses it and is given to the microcontroller and if the battery level within the safe limit the controller activates the load in the level 1(4W) and message "LOAD IN L1" is displayed. After 2 minutes, the illumination is upgraded to level 2(4+4 = 8W) and message changes to "LOAD IN L2" again after 2 minutes the illumination goes to the highest illumination level 3(4+4+8 = 16W) and message changes to "LOAD IN L3".In this mode, the microcontroller monitors for low battery, RTC limit and temperature of the LAMP module. If the temperature exceeds the first limit, then the illumination is scaled down to level 1 and displays the message "HIGH TEMPERATURE".

After 5 minutes the illumination again switches back to level 3 if the battery level, RTC limit and temperature limit are below the limits. If the RTC indicates that the sleep time (midnight) has arrived then the illumination goes to level 1 else remains at level 3 itself. If the temperature is still high then the illumination scales to level 1.When the battery voltage drops below 9 volts, the microcontroller turns off the load and displays the message "BATTERY LOW" and enters to a lock mode. The system comes out of the lock mode when the dusk-to dawn sensor receives the panel voltage (the next morning).

Once, the system enters into sleep time then the illumination remains at level 1 and depending on obstacle detection using PIR sensor the illumination is raised to level 3. In this mode also the battery level is monitored in case of fall off battery voltage the system enters to lock mode. In order to avoid the false switching during raining times, in addition to day-night sensing unit here the RTC module values are also simultaneously monitored. Even if the sensing unit indicates a night arrival, if the time is below 06:45pm then switching or load doesn't gets turned ON. Similarly to turn OFF the load at day arrival, even if the sensing unit indicates, the load will be turned OFF only if time crosses beyond 06:15am.

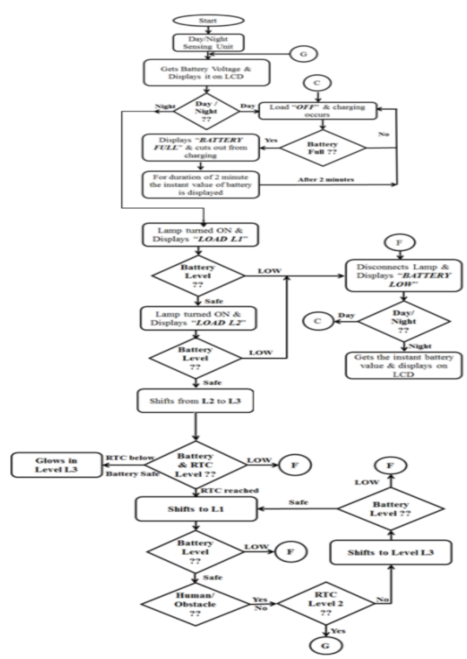

Figure (7): Flowchart showing working of the system

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Power Distribution Design

Solar Power Generation[6]

The used single solar panel of standard 20 Watt / 24 volts can deliver a power of 20Watt per hour, under full uniform sunshine. Knowing that the sun shine vary during the day, the effective sun power of one day is equal from 4 to 6 hours of a maximum measured at midday. Since this maximum at midday is not the same every day, it should be taken in consideration, that more or less heavy cloud reduces the possible power. To calculate the energy it can supply to the battery, multiply Watts by the hours exposed to sunshine, then multiply the result by 0.85 (accounts for natural system losses). Hence, for the solar panel of 20W in 5 hours of sunshine,

Energy deliverable = 20 x 5 x 0.85 = 85Wh.

Since, the output of the solar panel is 24V, here batteries of 12V/7.5Ah are usedin series for storing the charge.

Power distributed from battery[6]

For technical reasons, it is not recommended to empty a battery more than 70%. Hence, the usable capacity of individual battery is around 63Wh, what match to the produced electrical energy of 68Wh to 102Wh. Here we need power for the following requirements;

1. One LED lamp - 16W
2. Automation circuitry - 2.5W

Hence a total of 18.5W is required, so the current battery is capable of providing this required energy for 3 hours and 40 minutes.

Result and Outcomes

Result

The proposed product was implemented successfully and was tested for functionality under real time environment considering the realistic nature of time and it was proved that the product is suitable for real time implementation. Figure (8) shows the final prototype of the system/product developed.

Figure (8): Prototype of the system

Features

On the run of product development we realised some of the features proposed would result in unwanted power consumption. The tested OK features of the product are;

- A 20W solar power and 24V, 14Ah battery system supports the functioning of the entire product.
- RTC module lies as the backbone of the entire system function, ensuring the product operation more realistic.
- PIR sensor based obstacle detection alone was implemented due to its capability to detect both humans and vehicles.
- Temperature sensing of LED lamp was embedded, so that safe operation of the lamp was ensured with low probability for damage of the LED if operated at elevated temperatures.
- Automatic charging and monitoring facility incorporated to the storage batteries thereby ensured enhanced battery life-time and avoids dry run condition.
- LCD display system enables any customer to obtain details regarding the standalone and run-time status of the system.
- Overall peak power consumption of 18.5W provides light more than the current traditional tube lights and even a 60W CFL light.

Future Scope

For the product developed if some more enhancements are done, it is expected to be a remarkable economic product in today's market.

1. Networking a few similar modules modifies the system to be used as a security system when, at midnight times, the lamp can be switch to lower illumination level and save energy meanwhile on any intrusion auto-glowing to the highest brightness with some alarm facility that awakes the residents.
2. The current load power can be increased to 30W so that the system could be an alternative for the sodium lamps and halogen lights.
3. If a video capturing system is incorporated, the single pack serves to be very advantageous in the market.
4. Incorporating ultrasonic sensors with the capability to estimate distance of the obstacle enables more accurate and appropriate needy switching of the lamp.

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