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Study of Energy-saving Solar Street Lamps Based on S3C2440

Yongqiang Zhang*, Yanshuang Zhou, Cheng Feng

School of Information Engineering, Handan College, Handan, Hebei, 056001, China,
zyqhdc@163.com.

With the rapid development of solar photovoltaic devices and high power LED device technology, the use of solar energy street lamps is much more extensive. However, there is no reasonable use of electricity generated by solar energy, it wastes a portion of the energy. Traditional solar energy street lamps have problems such as low control accuracy, poor anti-interference ability, high cost and so on. This paper proposes a new scheme to utilize this electrical energy using LEDs based on S3C2440 in the street lamps system. This design cannot only control the street lamps intelligently, but also realizes energy conservation and environment protection.

1. Introduction

Although the current solar street lamps popular in the market can satisfy the basic need of lighting, there is a large degree of energy waste during the day due to the ineffective utilization of energy. For example, the luminance of the street lamps remains constant and fails to quickly adjust according to the surrounding environment, causing huge power loss and waste (C.Y. Fu (2013)). Therefore, it is urgently required to design a kind of solar street lamp system that realizes energy conservation. In this paper, a design of a solar street lamps system is proposed which uses the Samsung microprocessor S3C2440 as the microcontroller. Using a microcontroller allows the system to control the energy application and adjust the luminance of the lamp automatically.

In order to adjust the luminance of the street lamps, a new lamp is designed which contains several Light Emitting Diodes (LED) with every LED controlled respectively to adjust the luminance of the whole lamp. In this paper, the lamp is designed to have 3 LEDs.

2. The design of the overall circuit

The principle of the solar street lamp system is as shown in figure 1; the solar power circuit uses the photovoltaic battery and a super capacitor as energy conversion and storage system.

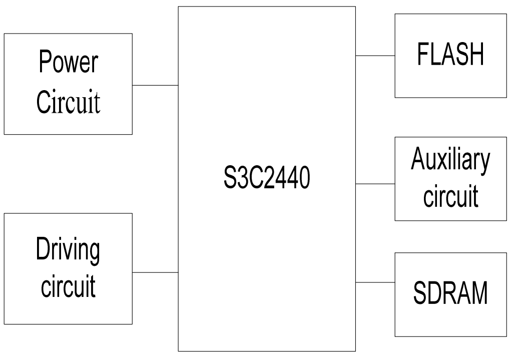

Figure 1: The diagram of the overall circuit

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The whole system is divided into the driving circuit, power circuit and auxiliary circuit of ARM. The single lamp includes three LEDs, and the luminance of the lamp can be adjusted by controlling the number of working LEDs (L. Chen and X.Y. Zhang (2014)). The drive circuit uses the constant current LEDs to guarantee the stability of electric current and the luminance of the LEDs.

2.1 The design of the power supply circuit

As shown in Figure 2, BT1 is photovoltaic cells, C0 is a super capacitor, and they provide power for the MCU and LEDs. R6 and R10 are divider resistances, R7, R8 and R9 are current limiting resistances, and C1 is a filtering and voltage stabilizing capacitor. Q1 controls the conduction and shutoff to Q0, and the emitter of Q0 is connected to the power of the MCU to control its switch.

When the sun shines during the day, the photovoltaic cells generate electricity, and store power to the super capacitor C0 through the diode D. The diode guarantees the current in the super capacitor does not go back into the photovoltaic cells. Simultaneously, potential at point A would rise, and the base electrode of transistor Q1 is at a high level (K. Zhang (2011)). Then Q1 conducts, and potential at point V1 is low, so the triode Q0 switches off and energy stored in the super capacitor cannot be sent to the S3C2440, which couldn't be in use without power supply, and so the street lamps are out of use.

When night falls, there is less sunlight and electricity generated by the photovoltaic cells begins to reduce. Potential at point V0 decreases, so Q1 is shut off, energy stored in the super capacitor raises the potential at point B, and Q0 is opened (L.X. Cheng (2013)). Then S3C2440 is powered, street lamps are lit up, and then the whole street lamp system commences operation.

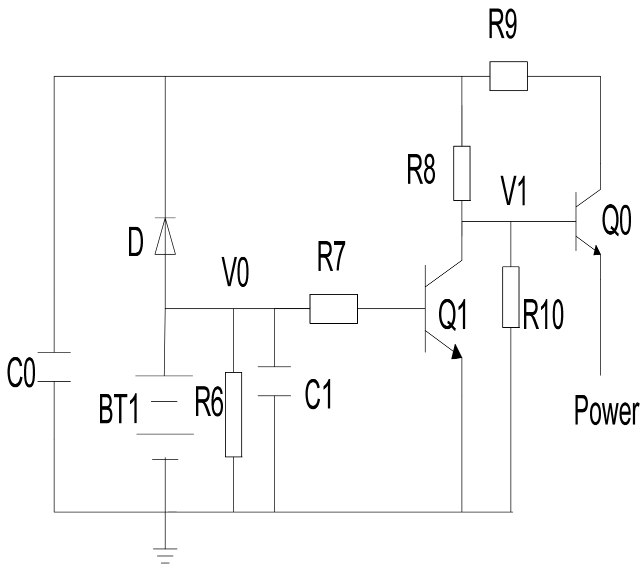

Figure 2: Power circuit diagram

2.2 The design of the LED driver circuit

The level of electrical output directly from S3C2440 struggles to drive the LED street lamps because of their high luminance, therefore in the paper a drive circuit was designed as shown in Figure 3.

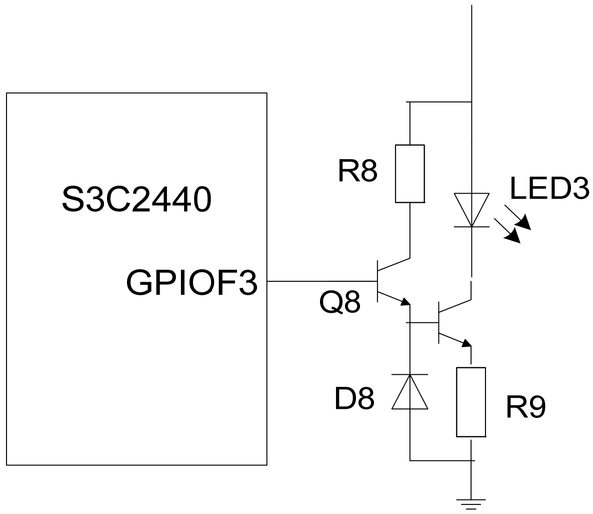

Figure 3: Led drive circuit

Figure 3 is a drive circuit for a constant current LED. The base of Q7 is connected to MCU PX (X = 1, 2, 3), and D1 is a Zener diode connected on the base of Q3 as a source of constant pressure. Due to the stable base bias, collector current Ic is stable. According to Ic = (VZD - VBE varies)/R10, even if the voltage source VDD changes, Ic will not change, which could guarantee the stability of current and brightness.

2.3 System function realization

In this paper, the operating state of solar street lamps in a 24 hour period was analyzed from the aspect of rational utilization of energy. Its working process can be divided into three stages:

(1) From 18:00 to 20:00 in the afternoon, the road dimmed gradually and darkness was coming, so solar street lamps began to operate. It's not necessary to be too bright. Its luminance was marked as level L.

(2) From 20:00 to 24:00 at night was the darkest period in the day. The luminance of street lamps should be adjusted to the maximum value, marked as level S.

(3) From 00:00 to 3:00 in the morning, there were few pedestrians, so the luminance of lamp could slightly decrease to a value marked as level I.

(4) From 3:00 to 5:00 in the morning, the need of luminance of lamps is lower. It is marked as level L.

Based on the analysis above, it could be concluded that the solar street lamps must be controlled by intelligent controlling technology to be adjusted automatically. The algorithm of the MCU to control the luminance of the LEDs is shown in Figure 4.

As shown in the algorithm, the program runs automatically after the MCU is powered on. When sending high electrical level output, GPIOF3 drives LED1 to glow, and the luminance of the street lamps reaches level L. After 2 hours, GPIOF4 and GPIOF5 send high level output at the same time to drive LED2 and LED3 to glow. At this point, the luminance of the street lamps reaches level S. Consequently, the street lamps are extinguished completely when GPIOF3, GPIOF4, GPIOF5 send low electrical level output at the same time.

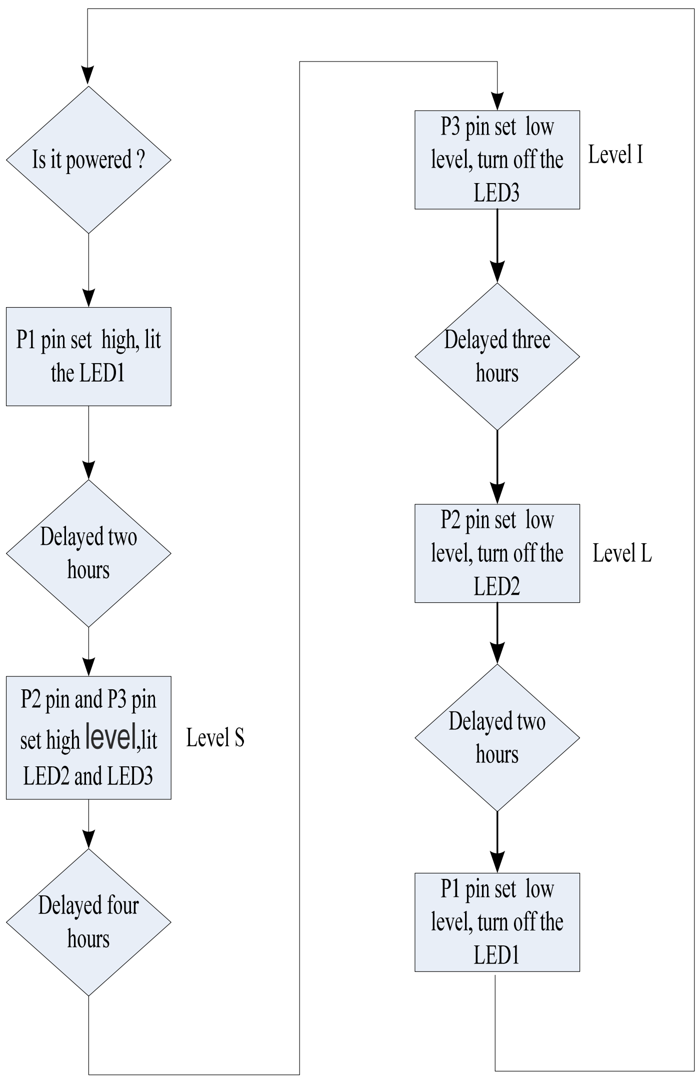

Figure 4: Control algorithm flowchart

3. The choice of device

3.1 The choice of processor

In the Intelligent controlling chip market, S3C2440 is famous with its small size, simple packaging format, simple welded operation, perfect function and smaller power consumption: it is regarded as the best choice. With the help of S3C2440, it is possible to adjust the luminance of street lamps automatically and to achieve the energy conservation goal. Once S3C2440 starts to work, it would keep working intelligently with less maintenance.

This manual describes Samsung's S3C2440A 16/32-bit RISC microprocessor. Samsung's S3C2440A is designed to provide hand-held devices and general applications with low-power, and high-performance micro-controller solutions in a small die size. To reduce total system cost, the S3C2440A includes the following components: separate 16KB Instruction and 16KB Data Cache; MMU to handle virtual memory management; LCD Controller (STN & TFT); NAND Flash Boot Loader; System Manager (chip select logic and SDRAM Controller); 3-ch UART, 4-ch DMA; 4-ch Timers with PWM; I/O Ports; RTC; 8-ch 10-bit ADC and Touch Screen Interface; Camera interface; IIC-BUS Interface; IIS-BUS Interface; USB Host; USB Device; SD Host & Multi-Media Card Interface; 2-ch SPI; and PLL for clock generation.

• Around 1.2 V internal, 1.8 V/2.5 V/3.3 V memory, 3.3 V external I/O microprocessor with 16 KB I-Cache/16 KB D-Cache/MMU

• External memory controller (SDRAM Control and Chip Select logic)

• 3-ch UART (IrDA1.0, 64-Byte Tx FIFO, and 64-Byte Rx FIFO) / 2-ch SPI

- 4-ch PWM timers & 1-ch internal timer
- 130-bit general purpose I/O ports / 24-ch external interrupt source
- Power control: Normal, Slow, Idle and Sleep mode
- RTC with calendar function

With these features S3C2440 is the obvious choice as the controller of the whole street lamp system. It has low cost and high performance to ensure an economic and practical solution and its feature of erasing repeatedly could ensure that the user can modify the program for many different time slots to realize the intelligent control in different environments according to actual conditions. It also has rich interfaces to facilitate expansion.

3.2 The choice of energy storage device

In this paper, a super capacitor is selected as the energy storage device. It has great advantages explained below.

Firstly, it is convenient for the application to charge in have a minimized charging time. Super capacitors could be used repeatedly in the same way as secondary batteries, such as lead-acid ones. When energy stored in a super capacitors runs out, it could be recharged. Usually, with traditional secondary batteries, such as nickel metal hydride batteries, it is necessary to charge for several hours. However, the charging time of for super capacitors is very short, and the users would only wait for a moment.

Secondly, it could be used repeatedly, and it could even be used for the whole of a user's life. Differing from traditional batteries, where the charging and discharging damages the electrode, super capacitors could charge and discharge over 10,000 times. As a result, users could use it for life (X.H. Wang and Y.L. Jiao (2015)).

Lastly, super capacitors are less influenced by environment temperature in normal use. Generally speaking, super capacitors can keep working normally in the range 35-75 ^{o}C. In the unfortunate environment, such as critical high or low temperature, its ability to resist bad environment temperatures is much greater than traditional batteries. Therefore, for military and aviation applications as well as in bad conditional regions, super capacitors could provide superior superior performance role.

Super capacitors could be used as the solar energy storage system due to their long charging and discharging cycle-life, high reliability and completely maintenance-free nature. Also, it does not have a negative impact on the environment and the users so provides a kind of healthy energy. Therefore it is a wise choice to apply super capacitors in the solar energy field.

3.3 The choice of lamps

With the photosynthetic efficiency and brightness of white LEDs increasing rapidly, the applications of LEDs are rapidly expanding from the traditional, such as navigation signs, road signs and so on, to lighting applications. LEDs are ever increasing in popularity (Y.Y. Zhang (2013)), and regarded as the third generation of lighting products contributing toward energy conservation and environmental protection.

High brightness white LEDs used for lighting systems have these advantages as follows:

• Their service life is long. The service life of LEDs could reach l00, 000 hours, while the life of incandescent light bulbs is generally not more than 2,000 hours, even the life of fluorescent lamps is only about 5,000 hours.

• Their efficiency is high. Compared with traditional incandescent light bulbs, the first generation of lighting source, the power consumption of LEDs is only 10-20 %.

• They are a kind of product of more environmentally friendly than their predecessors. Compared with fluorescent lamps, the second generation of light sources, LEDs do not contain mercury and with no stroboscopic effects, they are regarded as environmentally friendly.

• They have low temperature resistance. LEDs could be used between 40-70 ^{o}C.

In addition, LEDs are direct current supply devices and can easily be used in direct current systems, such as solar power products. Nowadays, there are many manufacturers of LEDs and related products, and it is easy to meet the needs of various users. In this paper, LEDs were chosen as the lighting device for solar street lamps.

4. The feasibility of the design

In this paper, the parameters in the energy circuit could be calculated completely, and the drive circuit is well established. So the parameters in the drive circuit can be accurately determined. The algorithm program of S3C2440 was run successfully on the development board. The experimental data in Table 1 shows that it can supply enough current to S3C2440 to ensure system stability and reliability.

Table 1: Battery Charging Experiment Data

Time	Battery voltage (V)	Charge current (A)
9:00	11.82	5.12
10:00	12.56	6.40
11:00	13.06	7.48
12:00	13.20	7.89
13:00	13.42	8.47
14:00	13.61	8.61
15:00	13.51	6.52
16:00	14.16	4.92
17:00	13.70	2.62

5. Conclusions

Due to the deficiency of solar street lamps on the market at present, this paper puts forward a new design of solar street lamp based on S3C2440. This design could provide intelligent control as well as energy conservation and environmental protection. The design has been verified as feasible and lays a solid foundation for the future design of solar street lamp systems.

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