Design of Solar Energy Collecting & Controlling System

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Abstract. In this paper, the solar energy collecting and controlling system is designed to realize the function of solar mobile power. The system can be combined with the solar panels to achieve photoelectric conversion, packed in the knapsack or directly worn on the clothes to provide the function to charge the mobile intelligent terminals at any time. In the circuit, the input voltage from solar energy is stabilized by using LM317 regulator integrated chip. The XL4015E1 switching step-down chip is used to reduce the input voltage to reach the voltage range required for load charging. The constant current and voltage charging circuit is used to charge the lithium battery. Set the LED light to show the charging process and charging mode, control digital tube displays by the single chip STM8S103F3P6.

Introduction

As a source of energy for mobile power, solar energy has the advantages like convenient, environmental protection, energy saving, safety, long life and others. The design of solar mobile power, can be installed in the backpack or wear on the jacket and provide convenient charging, for work and play, etc.

The system designed that mobile charging power through the solar panels will be converted into light energy, in which case, mobile phones and other smart mobile terminals can be charged. One USB port can be charged directly to the phone, the output port can also access lithium battery energy storage, to achieve the absence of light conditions, there are current output. The choice of solar panels in order to meet the field like work, wearing etc.

The Design of System

In the design proposal of Figure 1, the solar panels generated current from light-electricity conversion through different locations, then make the current affected under voltage regulator circuit and step-down circuit, charging the smart mobile terminals like lithium batteries, mobile phones and others via constant current constant voltage charging circuit; at the same time feeding the single-chip, converting analog input signal into digital signals, then the converted digital signals will be scanned to control Nixie tube for voltage and current display.

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Figure 1. Block diagram of the design.
The Selection of Solar Panels

The selection of solar panels is the basis of the power supply circuit. The large plates usually are inconvenient to wear on clothes, for both of its area and cubage is too large, not enough to provide sufficient power by one piece of them, while the selection of small plates combined stack is more conducive to be wearable. Solar panels, which size in $49 \times 30 \times 3$ mm, open circuit voltage 6V, the maximum operating voltage up to 5.5V, the maximum operating current of 30mA, maximum power 0.16W, has been chosen for the system according to the requirements of charging load voltage. In order to meet the input voltage and current requirements of the charging load, eight panels of the same parameters for parallel combination have been chosen for the system, which have been measured that output voltage 6.8V, current 240mA, power up to 1.6W. The actual output voltage can be adjusted according to the charging load.

Design of Charge Controlling Circuit

Design of Voltage Regulator Circuit

As the solar panels will be affected by the strength of the sun in working, and there is large inner resistant in solar cell itself, which will cause output voltage instability and small output current. In order to protect the load, a regulator circuit to charge for lithium batteries or smart mobile terminals is needed. The design of regulator circuit design is as shown in Figure 2, solar panels produce unstable input voltage, as the capacitor has the characteristics of energy storing, the higher voltage leads to the capacitor charging, the lower voltage leads to the circuit power supply by the capacitor. The regulator circuit is designed to have the output voltage adjustable three-terminal integrated voltage regulator LM317 as the core, its output voltage range of 1.2V to 37V, which can provide 1.5A current to reach the required input voltage and current for the charging load. LM317 has the characteristics of output short circuit protection, over-current overheat protection, regulating tube safe working area protection and so on, especially the advantages of wide range of voltage regulation, better regulation performance, lower level noise and higher ripple rejection ratio.

Capacitor C1 is used to complete the work of filtering in circuit design. The more stable current filtered by the capacitor C1 will be sent to the Vin terminal (pin 3) of the three-terminal regulator IC LM317, which voltage output value can be changed by adjusting the tap position of R2. Capacitor C3 is used to filter the voltage of LM317 the ADJ (1 pin), so as to improve the quality of the output voltage. The role of D2 is to protect the current of C2 from flowing back to LM317 to cause damages, when the LM317 Vin pin (3 feet) voltage is lower than the 2-pin voltage. What’s more, the voltage reference between 1pin and 2 pin is 1.25V. In order to ensure the output performance of the regulator, R1 is set to less than 240 ohms, 200-ohm resistor is selected by the system, and changing the value of R2 can adjust the voltage regulator output voltage. D1 and D2 are used to protect the LM317, so IN4001 has to be selected.

![Figure 2. Voltage regulator circuit.](image-url)
Buck and Constant Voltage Regulator Circuit Design

Since the average input voltage of the selected solar panel can reach 6V, and the charge input voltage of the lithium battery and the mobile phone is lower than the input voltage generated by the solar panel, it is necessary to set the step-down circuit. The selected XL4015 is a switching step-down DC-DC converter chip, which in detail is a built-in single-chip high-voltage, high-frequency, high efficiency, high current, high reliability, high Cost-effective integrated circuits. Fixed switching frequency is 180KHz, in case of which the size of external components can be reduced to facilitate the design of EMC. The operating mode is TTL compatible. The integrated buck chip has excellent linear regulation and load regulation, the input voltage is 8 ~ 36V, the frequency is 144 ~ 216KHz. Conversion efficiency can reach 85% to 95%; the working temperature is between -40 ~ 125℃. The chip integration includes the reliability modules of short-circuit protection, over-temperature protection, over-current protection and others.

DC Buck is to convert a higher solar panel DC voltage to the required voltage value, where the step-down converter is designed as VIN = 7V, VOUT = 5V, INOUT = 0 ~ 4A. Only several peripheral devices are needed to constitute a high-efficiency step-down circuit to achieve the effects of less external components and low ripple.

Constant Current and Constant Voltage Charging Circuit Design

As the constant current charging method has been accepted during the whole process, a great deal of damage has been occurred to the lithium battery, this subject would firstly charge the battery quickly in constant current, the charging current is about 212.5mA, until the battery voltage rises to 4.25V ± 0.05V then transfers to the next stage: constant voltage charging. During the constant voltage charging, the current will increase gradually while time went by. Until the charging current reduced to 0.1mA, which means lithium battery has been charged to the rated capacity of 93% to 95%, then basically can be thought that lithium battery charging reached saturation. If continued to charge, the charging current will gradually reduce to zero. It will be benefit to preserve the battery capacity to fully charge the lithium battery. There are three different colored LED lights’ instructions in charging process, what’s more, the over-voltage and over-current protection have been designed in case that the damage will be caused when the battery is over charged. And the charging circuit will use USB interface to charge mobile phones, flat panels and other smart mobile terminals.

Design circuit shown in Figure 3: The LM317 regulator, LM358 amplifier and XL4015 have constituted a control circuit of constant voltage and constant current. LM358 has the following main features: Internal frequency compensation, unity gain bandwidth (about 1MHz), DC voltage of about 100dB of high gain; Wide supply voltage range: single power supply range is 3-30V, dual
power supply range of ±1.5 ~ ±15V; the ideal output current amplitude of constant current source will not be changed by the load, the environment, time or other factors. LM358 is used to form a dual constant current source, which output current amplitude relative change will not exceed 0.3%. The design of the lithium battery charging circuit includes two parts, which are: 1. The battery charge control circuit; 2. The battery charge status and the electric quantity detection control circuit. The charge control circuit, which can be also seen as the charge circuit of lithium battery, is used to control the step-down circuit and the voltage stabilizing circuit mentioned above to reach the charging voltage of the lithium battery. And in the battery power detecting circuit, by setting different colored LED lights to detect the charging amount: The blue indicator lighted, means the charging process is working; while the green indicator light, blue light off, means the battery is full. Stop charging when the logic circuit controls to cut the charging circuit off.

Figure 4. Constant current constant voltage charging circuit.

Digital Tube Display Control Circuit Design

It is used to control digital display circuit by STM8S103 single-chip. The controller has a three-stage pipeline Harvard architecture and extended instruction set, plus that the flash program memory can provide 8K bytes of capacity. The single-chip will receive the voltage through the buck regulator, then convert the analog signal into a digital signal for data processing, after that use the two function keys of C programming circuit control circuit, which are: Switch button (to select whether to display voltage and current values) and Key switch (to display the values of the input voltage, output voltage, output current, output power and turn display).

System Testing

After the completion of the system, the test data is as follows:
(1) The output voltage is about 6.8V in no-load circuit. The current was 240 mA.
(2) Adjust the output voltage into 4.2V, after the connection to the lithium battery, the blue LED lighted on PCB board, since the beginning of the lithium battery has not been full.
(3) Adjust the output voltage into 5V, after connecting the USB and mobile phone, which can be seen that the phone can be charged normally.
(4) As the circuit size is small, which can be made into a wearable system for mobile phone charging.
If changing the digital tube into a liquid crystal display, more functions such as temperature, time and compass can be provided, in which case the display can be more abundant, but the total cost will increase then.

References

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