Design of Solar Mobile Power with Industry Patent Analysis

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Abstract. Patent data shows that mobile power supplies are in urgent need of new technology solutions. Aiming at the demand and problems of mobile power, this paper proposes a safe, reliable and high-power solar mobile power supply design. The use of a folding solar panel can provide power for portable devices such as mobile phones, and has practical value. This design can improve the charging quality of mobile electronic devices.

1. Introduction
Mobile power is a portable charger that can be carried by individuals and can store electrical energy. It is mainly used for charging electronic products such as mobile phones. It is mainly used in applications where there is no external power supply. The main components of mobile power include batteries used for electrical energy storage, circuits that stabilize output voltage (DC-DC converters), and most mobile power supplies have chargers for charging their built-in batteries.

According to a recent study, The capacity of mobile power products which rated capacity was 10 000 m Ah was tested, it was found that the actual output capacity was below 65% of its rated capacity.

![Figure 1. Global patent technology.](image_url)
The figure above shows the number of published power technology technologies in various technology branches in the global patented technology. Among them, the main technology consists of H02J (more than 8,000 pieces), which is much higher than the number of patents in other technology branches. Other branches include F21V, H04M, H01R, G06F, H01M, A45C, F21Y, G07F, H05K. In terms of quantity, the IPC classification of mobile power technology is relatively simple, which reflects the relatively simple technology in this field.

The patented technology related to mobile power is mainly based on design. The shape of mobile power is still an important factor for consumers, and the internal technical characteristics of mobile power are relatively fixed, so consumers pay less attention.

Aiming at the demand and problems of mobile power, this paper proposes a safe, reliable and high-power solar mobile power supply design. The use of a folding solar panel can provide power for portable devices such as mobile phones, and has practical value. This design can improve the charging quality of mobile electronic devices.

2. Circuit structure design
Solar panels convert light energy into electrical energy and charge lithium batteries. At present, solar panels on the market have more polysilicon materials, and solar panels for mobile power sources generally have problems of small area, low power, and poor solar charging performance. In order to improve the performance, it is necessary to use a large-illuminated area and a high-power solar panel, which is inconvenient to carry, and the folding method is better, and the polycrystalline silicon flexible film material which is easy to fold can be selected. In summary, it is more appropriate to choose a 5 V, 7 W folded solar panel on the market, which can charge a larger capacity mobile power source.

According to the actual use environment of the lithium battery and the "dendritic" characteristics, the lithium battery charging and discharging circuit needs to increase the protection circuit. In order to achieve higher precision protection, it is often necessary to increase the voltage and current sampling circuit. Therefore, the system consists of input and output interface, lithium battery and protection unit, solar charge circuit unit, boost converter unit and PSoC system control.

![Figure 2. Circuit Structure Design](image-url)
PSoC is a programmable system-on-chip produced by Cypress Semiconductor that includes an 8-bit microprocessor core and a mix of digital and analog signals. The power is input through the Charge USB port and the battery is charged through the charge management circuit. When charging the device with this mobile power supply, the Boost boost circuit is used to boost the battery voltage and then output through the Output USB port. In order to improve the conversion efficiency of the system, synchronous rectification technology is required.

3. Circuit and key chip design

According to Figure 1, the charging circuit, the lithium battery protection circuit and the boosting circuit are respectively designed and analyzed.

3.1. Charging circuit

Solar mobile power is a new type of power source that converts solar energy into electrical energy and stores it in a battery, while having a movable nature [5]. Therefore, solar charging circuits are required to provide electrical energy, and charging circuits must consider efficiency and safety issues.

3.1.1. Charging circuit chip function design. The charging circuit is managed by a professional lithium battery chip CN3052, which is divided into pre-charge, turbulence, constant current and constant voltage charging stages. When the input AC adapter or USB power supply is powered down, the CN3052 automatically enters a low-power sleep mode where the current consumption is less than 3 A. When the input voltage is higher than the threshold, the CN3052 will release the sleep mode and start charging management. The modulated output voltage of the CN3052 is 4.2 V. If the battery voltage is lower than the threshold 4.1 V, the CN3052 automatically starts charging.

In order to extend battery life, the charging current needs to be strictly controlled. When the input voltage is greater than the VIN pin power low voltage detection threshold, the chip enable input CE pin is connected to a high level to start charging the battery:

$$I_{CH} = \left( \frac{V_{ISET} \times 900}{R_{ISET}} \right)$$

Where: $I_{CH}$ is the battery charging current; $V_{ISET}$ is the charging current setting terminal ISET pin voltage; $R_{ISET}$ is the ISET pin resistance, $R_{ISET}$ can use 2.7~3.6 kΩ resistor, which is R38 in the circuit of Figure 2, here choose 3.6 kΩ. When the battery voltage is lower than 3 V, the charger pre-charges the battery with a small current, which is modulated to 0.2 V, which is 50 mA; when the battery voltage exceeds 3 V, the charger charges the battery in constant current mode. At this time, $V_{ISET}$ is modulated to 2 V, $I_{CH}$ is 500 mA; when the battery voltage is close to 4.2 V, the charging current is gradually decreased, CN3052 enters the constant voltage charging mode; when the charging current is reduced to the charging end threshold, the charging cycle At the end, the charging state indicating terminal outputs a high level, and the threshold charging current is ended at 10% of the constant current charging current.

3.1.2. Charging circuit design. The solar mobile power charging circuit is shown in Figure 2. When the solar power is on, the red LED4 lights up and charging. When the charger charges the battery, the charging status indicating pin is pulled low by the internal switch, indicating that charging is in progress, the transistor 3904 is turned off, the green LED 3 is on, and the red LED 2 is off, indicating that charging is in progress. When the charging is completed, the pin is in a high impedance state, and the transistor 3904 is turned on. Due to the action of R34, the green LED 3 is off, and the red LED 2 is on, indicating that charging is completed.
3.2. lithium battery protection circuit

The CR6002D chip is a lithium battery protection chip that is simple, efficient, and cost-effective on the market. When overcharge, overcurrent, and overdischarge occur, the chip will automatically stop charging or discharging, which will protect the lithium battery. The chip has high integration and simple peripheral circuit structure.
3.3. boost converter circuit

After the solar charging circuit, the output voltage is generally 4.2 V, which is low. In practical applications, a boost circuit is needed to regulate the output voltage and output current.

3.3.1. Boost circuit chip function design. Different chips can be used to boost according to the maximum input/output current required by the user. For example, the PT1301 chip provides a maximum output current of 300 mA; the CN5136 chip provides a maximum output current of 500 mA; the CP6209 chip can provide a 5 V, 1.5 A output, with the PT1301 as an example. The PT1301 chip is a step-up DC/DC converter with a startup voltage of less than 1 V and a small size and high efficiency. It is controlled by an adaptive current pulse width modulation mode. The output voltage is set by two external resistors, high efficiency. The low quiescent current at the microampere level allows the battery to last longer.

The output voltage of the circuit is controlled by the feedback input terminal FB pin. The voltage of the pin is generally obtained according to the output voltage division, as shown in the solar boost circuit of FIG. The output voltage $V_{out}$ can be calculated by the resistors $R_{40}$ and $R_{41}$ as follows:

$$V_{out} = \left(1 + \frac{R_{40}}{R_{41}}\right) \times 1.25 \text{ V}$$

Where $V_{out}$ is the output voltage. The choice of resistor value affects multiple circuit parameters and needs to be balanced in output voltage, quiescent current, and anti-interference. Here, $R_{40}$ is 1.8 MΩ and $R_{41}$ is 553 kΩ. At this time, $V_{out}$ is about 5.3 V. Because there is a voltage drop during charging, the design output voltage is slightly larger than 5 V, and the quiescent current is calculated according to the formula $I=1.25 \text{ V} R_{41}$.

3.3.2. Boost circuit design. The boost circuit is shown in Figure 4. The output current can be adjusted by changing the value of $R_{41}$. The larger the $R_{41}$ resistance, the smaller the output current. The choice of inductors and Schottky diodes in the circuit has a large effect on conversion efficiency; the choice of inductor and output capacitor affects the ripple of the output voltage. The voltage ripple is caused by voltage fluctuations, which are easy to generate interference such as harmonics, which will reduce the conversion efficiency and reduce the ripple during circuit design.

![Figure 5. Solar boost circuit](image-url)
The actual circuit components are selected as follows: Schottky diode (forward voltage drop is about 0.2 V), 20μH (r<0.5Ω) inductor, tantalum capacitor, can improve circuit conversion efficiency and reduce power supply ripple. The BM2302 FET is used as a load switch.

4. Programming and experimental results

The programming was developed in PSoC Designer™, a proprietary development environment for PSoC. PSoC Designer™ is an integrated development environment for customizing, configuring, and programming PSoC family devices. Depending on the needs of the project, you can configure analog and digital peripherals, write code, and debug to create the required PSoC applications.

After the system is powered on, enter the main program. If an external power supply (USB port or adapter) is detected, the charging management subroutine is entered; if an external load is detected, the discharge management subroutine is entered; if a button is pressed, the capacity display and status display are performed. In addition, during the whole charge and discharge process, the battery voltage/current, discharge voltage/current, temperature, etc. are continuously detected to process abnormal events in time; if there is no operation, the low-power state is entered, waiting for wake-up.

When the power input is detected at the input, the default charging mode is entered. The system first biases the AD of the on-chip sampled voltage and current. If the voltage is lower than the voltage of the constant current charge, the system enters the precharge mode, at which time the charge current is limited to 100 mA. When the battery voltage reaches the normal charging voltage, the battery is subjected to constant current charging, and the charging current is 1 A. After the constant current charging is completed, the constant voltage charging mode is entered, that is, the termination mode, and the charging current is continuously detected. If the charging current is less than the minimum constant voltage charging current, the PWM signal is turned off, the charging status flag is updated (full charge state), and the entire charging process is completed, as shown in FIG. The battery voltage should be continuously measured in each charging mode. To avoid the measurement error caused by the battery voltage falling back when charging is stopped, delay measurement and third-order average filtering are needed to improve the measurement accuracy and anti-interference ability. When not charging, the measurement voltage uses sixth-order IIR filtering because the system has sufficient CPU resources.

Under normal working conditions, when the battery voltage is greater than the allowable discharge voltage, adjust the PWM signal to keep the output voltage at +5 V constant voltage discharge. The output current is continuously monitored during continuous discharge. When the output current is less than a given threshold or the battery voltage is lower than the discharge cutoff voltage, the discharge is stopped, and the discharge end or overdischarge flag is set.

The output waveform of the solar mobile power supply is shown in Figure 5. After boosting, the voltage rises from 0 to about 5 V. Because of the voltage drop across the load, the no-load voltage is slightly greater than 5 V, which is about 5.3 V.
Figure 6. Solar mobile power output waveform

5. Conclusion
The solar mobile power circuit design consisting of a charging circuit, a lithium battery protection circuit, a boosting circuit, and a PSoC control chip adopts a larger power folding solar panel, taking into consideration the charging efficiency of the solar energy, the life of the lithium battery, and safety, boost efficiency and output power quality issues, while having the advantages of simple structure and low cost, is a green and safe energy solution.

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