TELKOMNIKA, Vol. 11, No. 6, June 2013, pp. 3279 ~ 3284
e-ISSN: 2087-278X

Implementation of Waste Battery Energy Collection System

Li Chao*, Yi Bo-nian
Wuhan University of Technology, Wuhan, Hubei, China
*Corresponding author, e-mail: curio.lichao@gmail.com

Abstract

In this energy collection system, it uses Boost and Buck circuits. If the input voltage is too low, low power supply chip will be active, making the charging voltage at an appropriate range. In order to measure the input voltage, output voltage and the current, high-precision chips are used, cooperated with 32-bits-high-speed CPU to make sure the output voltage stable. This system has a perfect over-current, over-voltage protection function. The system uses the high efficient switch power supply.

Keywords: *boost, buck, DC/DC transform, overcurrent protection*

1. Introduction

Restricting power consumption is now a major issue in society. Every year, there are many waste batteries dropped. The battery will be discarded when their internal resistor becomes higher and the output voltage is too low. In fact, this waste battery has limited power that can be recycled. In this paper, we introduce the implementation of waste battery energy collection system. This system has the ability to use the battery to its limits. This system use boost and buck circuit, with overcurrent protection. It is easy to handle and safe to use. The overall cost is also very low.

2. System Solution

The function block of the system is illustrated in Figure 1.

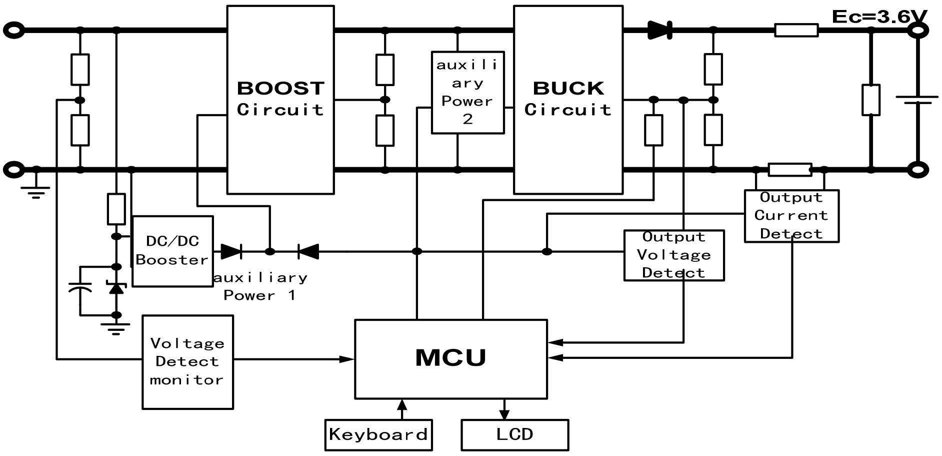

Figure 1 Function Block of the System

In order to better gather electric power [11], the implementation of the system use two-level direct- current convert circuit. A boost converter followed by a buck circuit. The schematic

Received January 19, 2013; Revised April 10, 2013; Accepted April 24, 2013

is shown in Figure 1. There is another boost circuit of DC-DC, which provides energy for the MCU and other external circuit, in case that the input voltage is too low.

The first level boost circuit is active when the input voltage is too low to provide energy for the whole circuit. It boosts the voltage and then the buck circuit lower the voltage to the appropriate range. When the input is too high, the first level boost circuit is inactive and the input is directly into the second level buck circuit. This circuit is well designed for variety of input range. Thus it is very easy for power gathering and convert.

The system use 32Bit high performance MCU-STM32F103RCT6. High precision INA AD623, which is used for voltage and current detection. The power gathered first is processed by the CPU and then light the circuit on.

3. The Circuit Design and Calculation of the Power Gathering Charger

3.1 The Design and Analysis of the DC-DC Boost Convert [7, 8, 9]

According to the real situation, the system should be well working under rather low input. But if the input voltage is too low, even lower than the threshold of the chip, it won’t work properly. But our system uses a novel approach in which a chip named NCP1400A is used to boost the lower voltage to a higher level. Thus can let the input voltage into a very low range. NCP1400 is a boost switch voltage regulator which has a rather low active voltage. Its input voltage can be as low as 0.8V, and the output is stably 6V, the voltage of which can be used to let the circuit work normally. If the voltage vibration is active, the chip can get power automatically from its output. This part of circuit like a pump power is a necessity in the system. The schematic of the circuit is illustrated in Figure 2.

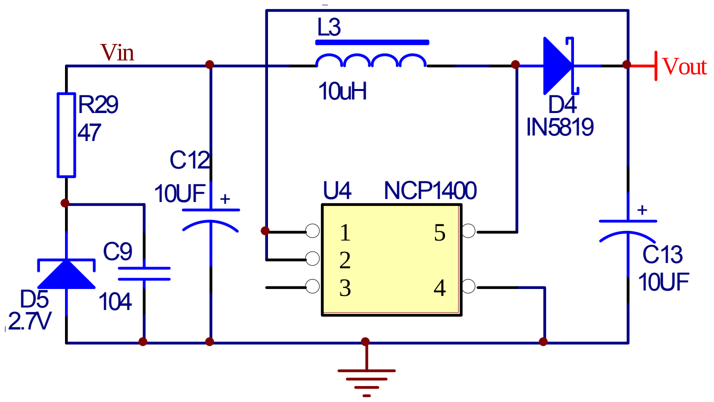

Figure 2. Schematic of NCP1400

The datasheet of NCP1400 provides enough information for the design .

3.2. The Design and Analysis of Boost Circuit

The boost circuit in the mesh circuit is to boost the very low voltage so that the whole other circuit can work normally [5, 6, 7]. The schematic of the circuit is shown in Figure 3

The boost circuit is based on the specific pulse width modulation chip TL494 whose active voltage is very low, the control pattern of which is rather simple. The output is based on the PWM pulse width in the feedback loop. The TL494 can supply itself. The circuit in Figure 2 supply for the active voltage, and the output of TL494 then supply itself. The output of the boost circuit is connected to a SCR. When the whole circuit is powered on, the output of boost circuit is very low so it can not active the SCR, thus the voltage rises without any load. When the voltage reach a threshold, then the SCR will be active and the Buck circuit can get input.

When the input voltage is high, the TL494 will not work, the output of the boost circuit will direct to the input of the buck circuit. In this way, the power loss in the circuit will be reduced. We choose 75N75 which has only a 11mΩ switch on state resistor as the switch tube in the boost circuit. It can significantly reduce the power loss in the circuit. The related parameters are calculated as follows:

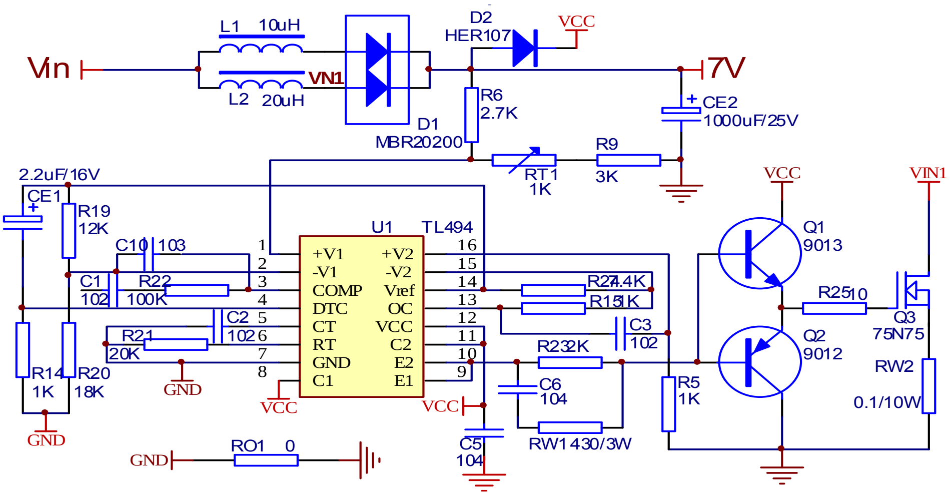

Figure 3. Schematic of TL494

The parameter of inductor:

$$L = \frac{V_{on}\times D}{f\times I_C\times r} \qquad r \approx 0.4 \qquad (1)$$

Where the pulse width $D = \frac{V_o - V_{IN}}{V_o}$. When $f = 50\text{Hz}, V_o = 7V, I_c = 2A$, we can get L = 96uH , but we rather set it to 120uH .

3.3. The Design and Analysis of Buck Circuit

The first level boost circuit boost the lower input to 7V and then output to the buck circuit. The schematic of the buck circuit is shown in Figure 4. The buck circuit use a specific chip LM3458 to adjust the voltage to a appropriate range and then charge the battery. The LM3458 has the character of fast response, high control precision, and simple external component. The precision of the output voltage is decided by designator FB. The output of this chip is decided by both hardware and software. In Figure 4, resistor R4, R5, R6 consist of the feedback resistor net while Vout is the output, Vfb is the feedback input, Vda is the digital control input. Then the voltage is:

$$\frac{V_{out}-V_{FB}}{R_4} + \frac{V_{DA}-V_{FB}}{R_6} = \frac{V_{FB}}{R_5} \qquad (2)$$

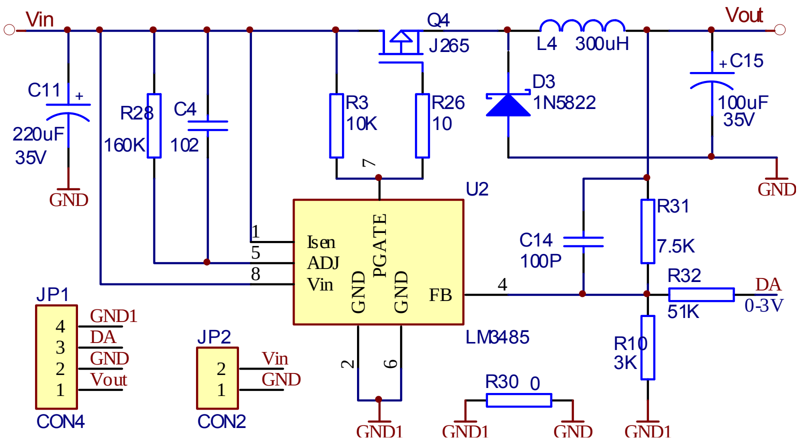

Figure 4. Schematic of Buck Circuit

So in order to adjust the output, you just need to change the input voltage on FB and resistor R5. But in order to precisely control the output, we add a voltage detection circuit. We use a DA to sample the output and compare it to the expected one, so we get an offset. We then add this offset to the DA output so that the offset will be reduced. In this way, the output will be more equal to the expected one.

According to Equation (1) and the condition $V_{FB} = 1.24V$, we can get $R_4 = 3.3K\Omega, R_5 = 1.5K\Omega, R_6 = 15K\Omega$. If the MCU adjust the output of DA, then the chip will respond to this change and change its output. There is a SBD connected to the output. Its function is to protect the current from the battery.

3.4. MCU Controlling and Detection Circuit [1, 2, 3, 4]

The core of the system is the STM32F103 ARM. The chip has internal 12bit AD and DA, which guarantee the high precision of controlling and sampling and reduce the cost at the same time. As to get the high precision of controlling and sampling, we use a high precision, low temperature drift chip INA AD623. The circuit is shown in appendix. We also use low temperature drift, rather stable resistor Kang copper wire. All these components can significantly guarantee the precision and stability.

3.5. Analysis the System Efficiency

The power consumption of the system is mainly in the switch power regulator and auxiliary power regulator. The power loss is made up of active component loss and inactive component loss. Inactive component loss occurs when the boost inductor operate under a high frequency. Active component loss consist of switch tube loss, drive loss, switch loss and controlling loss. The controlling circuit will cut down the useless part to reduce power consumption when the circuit operate stably. The power loss of switch power regulator is mainly on the MOS and its drive. But due to the correct choose of MOS, the on-state resistor is very small, even when the current reach to the limit, the circuit still consume a little. The above mentioned analysis is based on the condition that the drive signal is standard square wave, but in reality, when the switch tube is between the state of on and off, due to the unsharp rising or falling signal, the MOSFET will be in the state of amplifying area, in which state, the power consumption will be large. So to improve the quality of the drive signal is efficient way to upgrade the system efficiency. The auxiliary power also use the switch power supply, the schematic of which is shown in appendix 2. Compared with linear power, the switch power supply can improve the efficiency up to 30%, upgrading the overall system efficiency at the same time. The software of the system also takes the power consumption into consideration. The CPU is switching between working and idle state, which significantly reducing the power consumption.

4. Software Design

The software play a major part in the system. The software provide the basic function like screen showing the result of some parameters, keys to monitor the system. We also add PID algorithm to our system. Compared with hardware PID, software PID is more easy to use because you just need to change the three parameters or use some genetic algorithm to automatically change them to the perfect one. Using PID can make the system more stable. We also use the digital filter to process the sampling signal, improving precision and accuracy. The program flow chart is illustrated in Figure 4.

5. System Measurement

5.1. Test Instrument

1. Dual channel oscilloscope : TDS1002
2. Four and a half bit universal meter : FLUKE 15B
3. Current meter :STS10 5A/10A

5.2. Test Method and Result Analysis

5.2.1. Test Method

(1) Rs = 100ohm, Es is in the range 10-20V, series a current meter with the battery. Set the step 2V. Measure the current when Es is changing. The result is shown in Table 1. Then compare them with (Es - Ec) / (Rs + Rc).

(2) Set Rs = 100ohm, input voltage 2V, series a current meter with the battery, and then gradually reduce the input. At this time, watch the result on the current meter, when it reach zero, we can get the lowest input is 1.2V.

(3) Set Rs = 0.1, series a current meter with the battery. Gradually set Es from 0 to the large value, watching the current meter at the same time. When it reach 1.1V, the value on the meter is larger than zero, that is to say, the minimum value of Es is 1.1V.

(4) Set Es = 0V, series a current meter with the battery. measuring the discharging current .

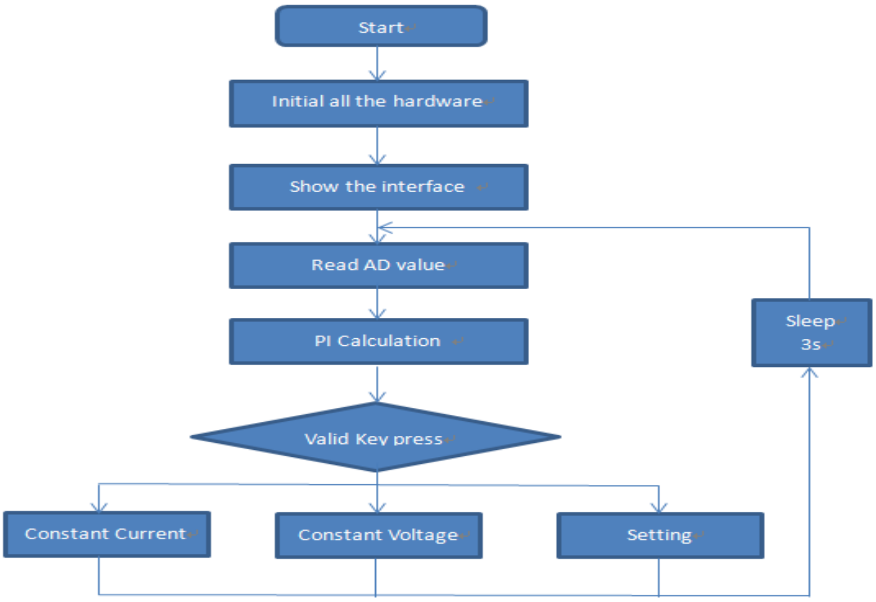

Figure 5. Chart Flow of Program

5.2.2. Result Analysis

Table 1 is the test result of our system. Es is the input voltage. Rs is the resistor in parallel with the the charging battery. Icmax is the charging current, and Vomax is the output voltage.

Table 1

	Es(V)	Rs(ohm)	Icmax（A）	Vomax(V)
1	0.8	0.1 ohm	0.009	3.601
2	1.0		0.014	3.601
3	1.2	1 ohm	0.125	3.613
4	1.5		0.728	3.671
5	2.0		1.15	3.714
6	2.5		1.38	3.736
7	3.6		1.52	3.753
8	10.0	100 ohm	0.072	3.601
9	12.0		0.087	3.602
10	14.0		0.145	3.615
11	16.0		0.167	3.619
12	18.0		0.175	3.617
13	20.0		0.187	3.602

We can see that when the Es is changing between 10V and 20V, the charging current are all larger than (Es - Ec) / (Rs + Rc).

From the measurement result, we can conclude that our system has a rather low input active voltage, and the performance will be better when the input voltage is upgraded. It has high precision, low ripple wave. It is really an wonderful charger.

6. Conclusion

Compare the theoretical analysis with the test result, we can conclude that our system get much satisfactory result. Our design uses high performance switch power control chip TL494, and use both hardware and software feedback. PID algorithm and digital filter both significantly improve the system performance. The auxiliary power supply also use switch power, further improving system efficiency. The intelligent load detection circuit can intelligently control circuit state, guaranteeing safety.

References

[1] JI Li. Power measurement and data transmission based on STM32 chip. *Automation & Instrumentation*. 2010.

[2] H Liu, B Fan. Study of Control System of Multiple Step Motors Based on STM32. *Measurement & Control Technology*. 2010 .

[3] YH Wang, W Xu, LP Hao. *STM32 family of ARM Cortex-M3 microcontrollers principles and practice*. Beihang University Press. 2009.

[4] ZXQXL Shiguang, RYQ Biao. Design of electric power data acquisition system based on STM32. *Electronic Measurement Technology*. 2010.

[5] GA Rincon-Mora, N Salamina. Low-dropout voltage regulator incorporating a current efficient transient response boost circuit. US Patent 6,046,577. 2000.

[6] Ride-through energy boost circuit DL Drinkwater - EP Patent 0,340,787. 1993.

[7] AJ Stratakos, RW Brodersen, SR Sanders. High-efficiency low-voltage DC-DC conversion for portable applications. 1998.

[8] RL Steigerwald. Dual output DC-DC converter with independently controllable output voltages - US Patent 4,628,426, 1986.

[9] T Mathews. Switching regulators demystified. 2000 - 67.215.231.165

[10] Han Yang. A Pedagogical Approach for Modeling and Simulation of Switching Mode DC-DC Converters for Power Electronics Course. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(6): 1319-1326.

[11] Aryuanto Soetedjo. Modeling of Maximum Power Point Tracking Controller for Solar Power System. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 2012; 10(3): 419-430.