Low Power Consumption Design for Wireless Charging Self-Starting System

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***Abstract*—The self-starting function with low power consumption of the wireless charging system is designed and implemented. The MSP430F5529 is used to carry on AD sampling to the circuit in order to realize the self-starting function, which effectively reduces the power consumption of the control system. The super capacitors are used to store electrical energy, which controls the DC-DC conversion through the TPS63020 chip. The ripple of the output voltage is less than 76 mV, which effectively reduces the power consumption of DC-DC conversion circuit. The experimental results show that the power utilization rate of wireless charging reaches more than 85%, which ensures the stability of the output voltage and reduces the power consumption of the system.**

Keywords*—*wireless charging, self-starting, low power consumption

I. INTRODUCTION

At present, the charging method of electronic products is divided into wired charging and wireless charging. Wired charging has problems in that the charging device is prone to wear and is prone to sparks. Wireless charging can achieve high dynamic charging flexibility and reduce the impact stability of the power grid[1-4], and wireless charging also solves the problem of wired charging in terms of security maintenance[5-8]. In 2007, Professor Marin Soljacic of the Massachusetts Institute of Technology proposed the working mode of electromagnetic resonant wireless charging, which realized long-distance transmission under the condition of ensuring relatively high transmission efficiency. The performance of electronic products' DC-DC converter circuits directly affects the operating efficiency of electronic products[9-10]. Today, DC-DC (DC-DC converter) is widely used in remote and data communication, computer, office automation equipment, industrial instrumentation, military, aerospace and other fields, involving all walks of life in the national economy. As IC chip integration continues to increase, DC-DC converter circuits are required to achieve a small ripple function[11-14], while conventional DC-DC converters have low power conversion rates and large size, which is not suitable for small circuit systems.

This paper uses the case study[15-16], taking the electric trolley as an example, through charging for 1 minute, the charging efficiency, DC-DC conversion efficiency, output voltage stability and self-starting function of the wireless charging self-starting system are studied. Experiments show that the system realizes the self-starting function of the system while ensuring low power consumption and stable output voltage.

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II. SYSTEM COMPOSITION

The system consists of two parts: a wireless charging transmitter and a wireless charging receiver. The system uses the MSP430F5529 single chip microcomputer as the micro-control processor of the wireless charging transmitter. The 5V/1A power supply is provided by the DC stabilized power supply for the single chip microcomputer and the XKT412 wireless charging module transmitting coil. The MSP430F5529 single chip microcomputer controls the on/off of the relay in order to realize the power-on and power-off of the wireless charging transmitter. The system block diagram is shown in Fig.1.

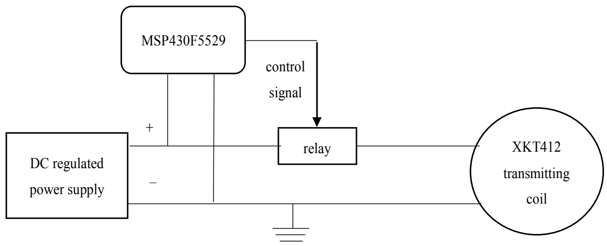

Fig.1 Wireless charging transmitter system block diagram

The system uses the MSP430F5529 single chip microcomputer as the wireless charging receiver micro-control processor, and uses the super capacitor as the energy storage system. The wireless charging receiver charges the super capacitor through the XKT412 wireless charging module receiving coil When the voltage of the super capacitor reaches 1.8V of the working voltage of the TPS63020, the power of the super capacitor is stabilized by the DC-DC conversion circuit to output 5V voltage for the MSP430F5529 single chip microcontroller and system. When the single chip microcontroller starts normal operation, it continuously samples the AD of the system. When the sampling voltage meets the self-starting condition, the single chip microcontroller starts the system operation. The block diagram of the wireless charging receiver system is shown in Fig.2.

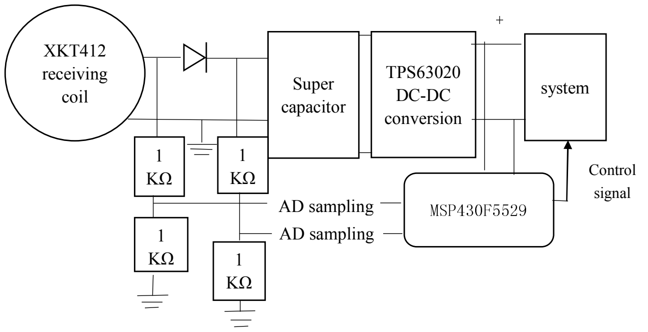

Fig.2 Wireless charging receiver system block diagram

III. Subsystem Design

A. Wireless Charging System

- *The of Advantages of the XKT412 Wireless Charging Module*

In order to achieve high efficiency wireless charging, the wireless charging module must be required to have high current and high power utilization. The XKT412 wireless charging module has a simple circuit. The maximum charging current that can be obtained under the 5V/1A power supply is >0.85 A, and the energy utilization rate is extremely high.

- *The spacing between the charging coil and the receiving coil*

When the power supply of 5V/1A is supplied, the experimental data of the charging current when the voltage across the capacitor U<0.9Vcc is measured by changing the interval between the charging coil and the receiving coil is shown in Table Ⅰ.

TABLE I. Relationship Between Power Utilization Efficiency of Charging Coil And Coil Spacing

Coil spacing	1 mm	2 mm	3 mm	4 mm	5 mm
Voltage and current supplied	5V 1A	5V 1A	5V 1A	5V 1A	5V 1A
Charging voltage	5V	5V	5V	5V	5V
Charging current	0.67A	0.86A	0.86A	0.56A	0.2A
Power utilization efficiency	67%	86%	86%	56%	20%

By measuring the experimental data, when the charging coil and the receiving coil are separated by 2~3mm, the electric energy utilization rate of the XKT412 wireless charging module can reach more than 85%, and the electric energy utilization rate is extremely high.

B. Energy Storage System

- *Super Capacitor Breakdown Voltage*

Since the power supply voltage is 5V, in order to prevent the breakdown capacitance when the capacitor is charged, the system selects a super capacitor with a breakdown voltage of 5V to store the electric energy[17].

- *Super capacitor capacity*

According to the capacitor charge and discharge formula,

$$U(t) = Vcc(1 - e^{\frac{-t}{RC}}) \quad (1)$$

when the capacitance voltage U = 0.9 Vcc, t = ln10 RC ≈ 2.3 RC. After measurement, the wireless charging receiving end circuit resistance R ≈ 2.5 Ω, in order to study the charging effect of the system for 1 minute, the system selects a super capacitor with a capacity of 10F, that is, the capacitor can be charged to 4.5V at t ≈ 57.5s[18-21].

C. DC-DC Conversion System

- *TSP63020 Chip*

In order to make full use of the power, the DC-DC converter circuit must have high efficiency and low power consumption. TI's TPS63020 chip has an efficiency of up to 96%, automatic conversion buck-boost mode, wide input voltage range (1.8~5.5V), adjustable output voltage in the range of 1.2~5.5V, small quiescent current, over temperature, over voltage Protection and other advantages. The pin diagram of TPS63020 is shown in Fig.3.

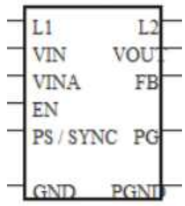

Fig.3 TPS63020 pin diagram

- *DC-DC conversion circuit*

The DC-DC conversion circuit is based on TI's TPS63020EVM. Based on this, the inductor is modified to reduce the interference of the circuit and the layout is adjusted to reduce the interference of the circuit.

Adjusting the ratio of the resistance across the feedback port FB changes the output voltage. According to the TPS63020 data sheet:

$$R_1 = R_2\left(\frac{V_{OUT}}{V_{FB}} - 1\right) \quad (2)$$

And the system sets the output voltage V_{out}=5V, R_2=200Ω, and calculates R_1=1.8MΩ. The schematic diagram of the DC-DC converter circuit is shown in Fig.4. The layout of the PCB component of the DC-DC converter circuit is shown in Fig.5.

The output voltage is measured by an oscilloscope and the output voltage ripple is less than 76mV.

D. Control System

The MSP430F5529 single chip microcomputer is a 16-bit ultra-low-power microcontroller with 128KB of flash memory, 8KB of SRAM, 63 programmable I/O lines, four 16-bit timer/counters, and a wide range of interrupt sources. The low power mode combination is suitable for use in battery-powered products, and it is a reduced instruction set (RISC) structure, powerful, rich on-chip resources, fast operation, and the small size and weight of the microcontroller Light, has obvious advantages for low power systems[22-28].

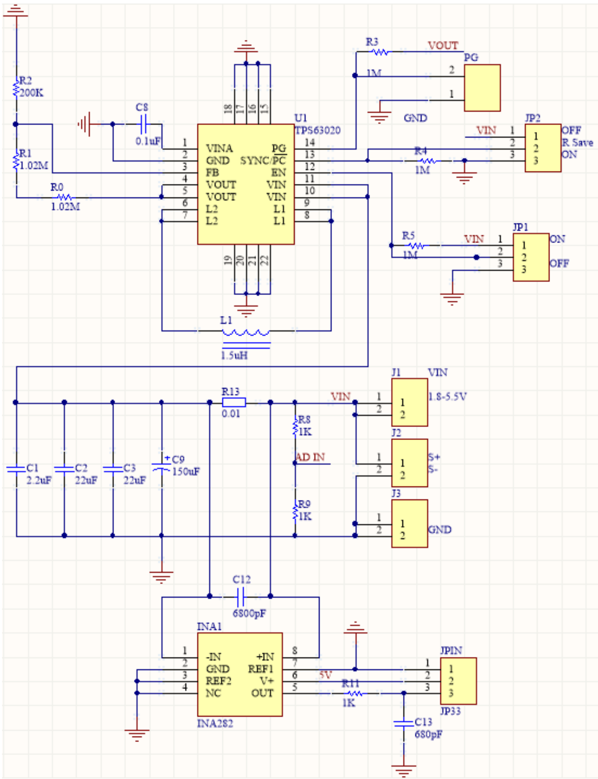

Fig.4 DC-DC conversion circuit schematic

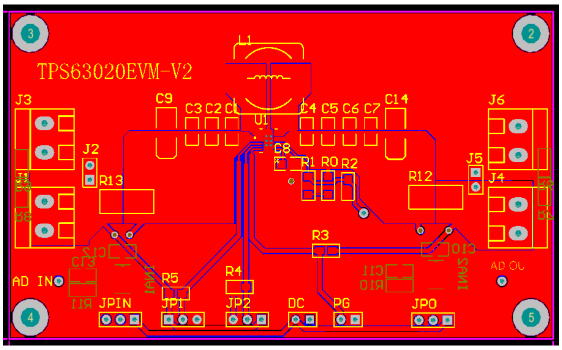

Fig.5 DC-DC converter circuit PCB component layout

IV. SELF-STARTING PRINCIPLE

The system can trigger the self-starting function in two situations. The first one is to power off the wireless charging transmitter, and the other is to reach the Vcc of the super capacitor voltage.

A. Hardware Circuit

The MSP430F5529 single chip microcomputer determines whether self-starting is performed by separately sampling the voltage across the capacitor and the voltage across the receiving coil of the XKT412 wireless charging module. The system uses a diode to separate the XKT412 wireless charging receiving coil and the super capacitor. The positive pole of the diode is connected to the output coil of the XKT412 wireless charging module, and the negative pole of the diode is connected to the super capacitor. Therefore, the voltage U_1 of the positive terminal of the diode is the receiving coil voltage of the XKT412 wireless charging module. The diode negative terminal voltage U_2 is the voltage of the capacitor. In order to prevent the AD sampling voltage from penetrating the MSP430F5529, the system uses two 1KΩ resistors for voltage division sampling. When the sampling voltage of the positive terminal of the diode is 0 or the voltage of the negative terminal of the diode is Vcc/2, the MSP430F5529 starts the system. The sampling principle is shown in Fig.6.

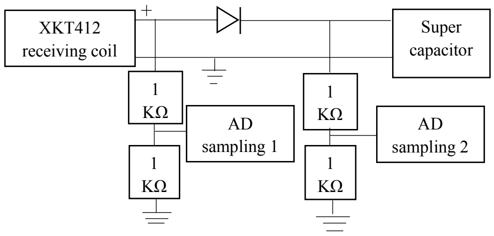

Fig.6 Sampling schematic

B. Software programming

After the MSP430F5529 is powered, the voltage sampling is continued. To prevent the judgment error, the MSP430F5529 starts the system operation when the self-start condition is satisfied for 5 consecutive times, and the MSP430F5529 stops sampling and enters the low power state. The block diagram is shown in Fig.7.

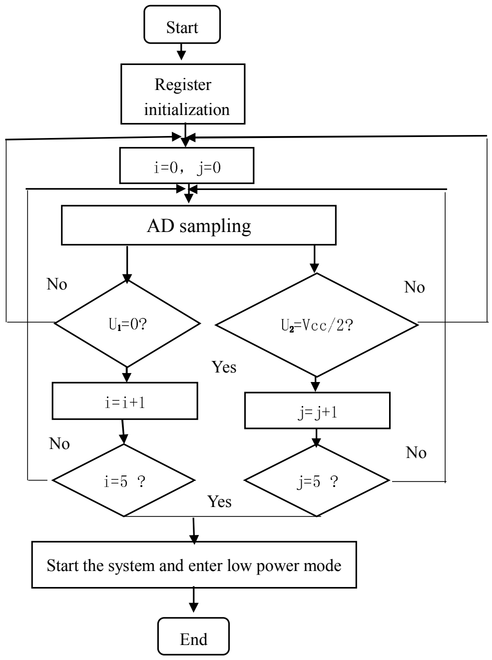

Fig.7 Block diagram

V. SYSTEM DEBUGGING

The system is tested by charging a small electric car for 1 minute. The wireless charging receiving coil is mounted on the electric car and spaced 2.5 mm from the wireless charging transmitting coil. The wireless charging transmitter is supplied with a 5V/1A power supply, and the wireless charging transmitter's MSP430F5529 starts timing and drives the relay to energize the wireless charging transmitting coil. The wireless charging receiving coil starts to charge the super capacitor. When the voltage across the capacitor reaches 1.8V, the DC-DC converter circuit stably outputs 5V voltage and the ripple is less than 76 mV, and the wireless charging receiver starts working. When the timer is turned off for 1 minute, the wireless charging transmitter transmits the relay to the microcontroller, and the wireless charging receiver detects the end of charging and drives the car.

VI. Conclusion

In this design, the wireless charging self-starting system supplies power to the XKT412 wireless charging module through the 5V/1A power supply. The wireless charging transmitting coil and the wireless charging receiving coil are separated by 2~3mm for charging the super capacitor. The obtained charging current is greater than 0.85A, and the power utilization rate is greater than 85%. The super capacitor discharges 5V voltage through the DC-DC conversion circuit, and the output voltage ripple is less than 76mV. The system uses the MSP430F5529 low-power single chip microcomputer as the system control chip and uses the TPS63020 chip to design the DC-DC conversion circuit, which can effectively reduce the power consumption of the system circuit. In practical applications, the 5V/10F supercapacitor can be replaced with a 5V/500F supercapacitor. In the future, the system can be applied to electronic products such as sweeping robots, which will further reduce the size of the charging device and increase the service life of the charging device, especially the self-starting function will improve the overall performance of the product.

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