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Design of Wireless Charging System

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Abstract: This paper first discusses the design background of the wireless charging system, analyzes and studies the background environment of the design system of the wireless charging system, and puts forward the design scheme to design the wireless charging of the mobile phone which is more close to life and more popular for people. The design system of this mobile phone wireless charging system has very low power consumption requirements, and saving energy is its biggest feature, which is also a big advantage compared to other mobile phone wireless chargers. After testing and verification, the use effect of this product has completely met the design requirements of this time. Although this design has been completed, there is still much room for improvement in the function of the system, and many details can be further improved. It mainly includes improving and reducing material costs, and strives to use the lowest material cost and save money without affecting the use of mobile wireless charging systems. Continue to optimize the use of operational procedures and continue to test the hardware, find out the bugs that have not been found in the hardware, improve the system, and improve the accuracy and stability of the mobile wireless charging system.
Keywords: High efficiency, Line charging, Low power consumption

I. INTRODUCTION

With the popularization of digital products such as mobile phones and tablet computers, people gradually spend a lot of time on electronic products, so that the demand for charging is increasing day by day, the frequency of use of sockets and data lines is also increasing, and the problem of difficulty in charging is increasingly prominent[1][2]. Although wireless network applications are becoming more frequent, wireless charging has gradually entered the field of vision as an emerging technology. As wireless charging technology has just started, both attention and cooperation are quite immature, but it has very impressive applications prospect. The wireless charging technology will replace the complicated charging wires in the past, and the simple sensing technology can make people's life easier[3]. By combining the theoretical design with the actual operation, the battery and the receiving device can be simply placed on the charging platform to complete the charging of the receiving device. Moreover, the transmitted waveform is efficiently sensed by the coil, thereby completing real-time monitoring of the entire charging process. When to start charging, when to get rid of terminal charging, and when the power is full, this series of problems will be solved very effectively[4]. The development of wireless charging technology, with its humanized prompts, makes the system more popular for market application.

In the practical application of wireless charging of mobile phones, in September 2012, a mobile phone manufacturer with a wireless charging function caused a strong reaction from consumers. More understanding and attention to wireless charging technology, also introduced wireless chargers in public places such as restaurants, train stations, etc. And provide open use for the public, users only need to put wireless phones that support wireless charging in the wireless charging area of the mobile phone it can be charged; at present, various leisure places have begun to carry out wireless charging services[5][6]. In many areas of the United States, there are already many cafes and bookstores with wireless chargers installed; the commercialization of wireless charging technology really began to develop in 2010. In 2011, it has begun to receive attention and utilization from major electronics industries. An article in the American IT magazine "Connecting" predicted that wireless charging technology will be applied in the mainstream in the second half of 2013.In addition, HIS iSuppli, a US market research company, said that the market value of wireless charging systems was US$120 million in 2010, and then gradually developed. It is expected to generate a huge market of US$23.7 billion in 2015. Nowadays, countries have seen the huge potential of wireless charging technology and are vying to apply for patents for various wireless charging technologies. At present, Japan and the United States are highly competitive in the global market. These two countries are also currently global. Wireless charging technology is the two countries most concerned about. Nowadays, many giants in the technology industry have begun to develop vigorously. For example, Apple has applied this technology in the iPhone 8 and iPhone X, which is also launched by the company.

Compared with foreign countries, the domestic understanding of this new technology is still not enough, and the research intensity is obviously not big enough. At the beginning of this century, some people paid attention to this technology. It was also at this time that the research team began research on wireless charging technology. The wireless charging technology is derived from the inductively coupled non-contact power transmission technology. The domestic research of this technology is mainly in some of the top engineering colleges and universities and some home appliance manufacturing enterprises in China. Some companies and research teams have applied this technology to research and development products. The famous Haier Group has worked with a domestic university to apply this technology to many home appliances, even some large household appliances such as TV and kitchen appliances. Wireless power can be used. In terms of hand and charging applications, Haier Group has become a pioneer among other companies. The developed mobile phone wireless charger can realize one-to-many charging function. The wireless charger that Haier Group launched at the 2013 IFA exhibition can Charge four phones at the same time. ASUS's desktop computer M51AC can be used as a cradle to charge mobile phones with wireless charging. In addition, domestic smart chip manufacturers are also actively developing wireless charging layout. Lingtong has taken the lead in launching mass-produced wireless charging intelligent management chips. Holtek's wireless charging products have also passed WPC certification.

The main research purpose of the thesis is to build on the reaearch of a large number of literatures to learn about wireless charging technology at home and abroad, and to use the relevant knowledge of electromagnetic induction principle to design a charging system suitable for ordinary mobile phones and to sort out the preliminary design. The main research contents are as follows: (1) The design of the transmitting end of the wireless charging system, including the selection according to the performance of the main control chip, the design of the coupling mechanism connected to the transmitting end, and the design of the protection circuit; (2) The design of the receiving end of the wireless charging system , including selection according to the performance of the main control chip, the design of the coupling mechanism connected to the receiving end, and the design of the protection circuit; (3) functional verification of the wireless power supply system, including the function of the transmitting end and the parameter test, the load test of the receiving end and Protect functional tests and analyze the test results.

II. WIRELESS CHARGING SYSTEM

A. The principle of wireless charging system

The principle of the wireless charging system is mainly operated by magnetic induction technology and magnetic resonance technology. Magnetic induction technology is based on two principles we understand: the principle of magnetic coupling and the principle of LC resonance. A closer comparison will reveal that magnetic resonance technology is based on these two principles, but only requires higher frequencies for the transmitter and receiver. Resonance requires that the transmitter and receiver frequencies be the same and both operate at the resonance point.

The current field is generated by the transmitter coil, and the magnetic field current energized by the other coil generates a physical phenomenon called "electromagnetic induction" near the wireless charging. The impact of the magnetic resonance coil can be arranged in a line, which can extend the distance of the power supply. The induced electromotive force is generated because the conductor cuts the magnetic flux in a closed loop to change the magnetic flux, and then we can reason that if the conductor is closed into a loop, a current will be formed in the conductor under the action of this electromotive force. It is through this principle to give the coil a constantly changing magnetic flux, the corresponding current will be generated in the coil, and then the current will be rectified into DC to charge the device. The feasibility of this scheme is very high. The electromagnetic induction wireless charging transmits energy through the magnetic field, and the effective energy that the equipment can receive is as high as 70%. It has the function of fully charging and closing, which reduces the unnecessary energy consumption. Moreover, as research deepens the effective acceptance rate of energy is increasing.

B. Structure of the wireless charging system

In terms of system design, the three parts of the transmitting system, the receiving system and the power monitoring system form a wireless charging system. The wireless charging system mainly uses the principle of electromagnetic induction to transmit energy through the transmission of the coupled coil. The wireless charging technology generally uses two magnetic coils, the primary coil is built in the charging base to provide an alternating electromagnetic field, and the other coil is built in the device that needs to be charged to receive energy to complete the charging, so the two coils together form a wireless Charging system. In this design, the transmitting system adopts SGD5011 as the main control chip. The chip is simple in operation and complete in function; the receiving system adopts SGD5121 chip, and the circuit design is also flexible.

III. SYSTEM HARDWARE DESIGN

A. Transmitting chip

The transmitter chip also has many features, in which the built-in power stage of the chip uses low-resistance NMOS FET technology to ensure high efficiency and low power consumption of the chip. At the same time, AD demodulation is built in, and its peripheral devices are reduced in order to make the chip more flexible. In order to more clearly define the charging state of the charger, it is also equipped with a light-emitting diode (LED) indication, and the chip can also automatically detect the load and automatically control the power. It is usually powered by 3.0V to 5.6V, which makes it easy to use universal USB 5V or battery power, making it easier to carry and select the power supply. Flexible peripheral programming and configuration for easy adjustment of different coil parameters. It also has the feature of automatically selecting the rate of scanning the receiver to achieve the purpose of reducing power consumption during standby. The chip also offers features such as overtemperature protection (OTP), undervoltage protection (UVLO), and overcurrent protection (OCP). In summary, in order to facilitate installation and flexibility, this design selects this chip as the main control chip of the transmitting end, as shown in Figure 1.

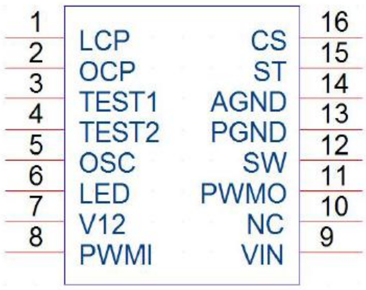

Figure 1 Transmitter chip

B. Receiving chip

The characteristics of the receiver chip, such as the built-in power stage using low-resistance NMOS FET technology, ensure the high efficiency and low power consumption of the chip. Among them, AD demodulation and fewer peripheral components make communication more reliable and flexible. The same receiving chip as the transmitting terminal main control chip can also indicate the charging status and the battery status, and accepting the automatic connection of the chip application avoids the complicated debugging process. The chip also offers features such as overtemperature protection (OTP), undervoltage protection (UVLO), overcurrent protection (OCP), and short-circuit protection (SCP). The quiescent current in the chip is kept below 6uA, which provides a good protection function for the battery. The pin description is shown in Figure 2.

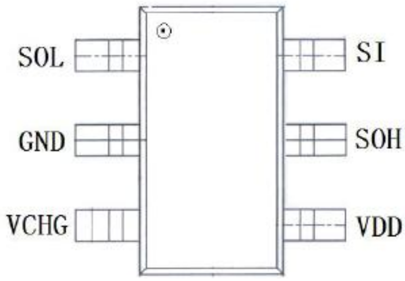

Figure 2 Receiver chip

C. Transmission circuit principle

In the design process of the circuit, it encountered many difficulties. After several times of debugging, it was found that the C4 capacitor needs to adopt a polyester capacitor with a withstand voltage of 100V or more when connecting the circuit. This is also an advantage of the small capacity and small capacity of the polyester capacitor. In designing the transmitting coil, a plurality of wire windings are used in order to reduce the resonance internal resistance, and the corresponding size and shape are wound according to the receiving end coil size. In order to reduce the influence of parasitic inductance on the capacitance, the position of the capacitor is as close as possible to the chip, and the traces to the VIN and AGND of the chip are short and thick. The two pads of the C4 capacitor and the two pads of the L1 coil are as close as possible. One of the C5 capacitors is connected to the L1 coil, as close as possible to the L1 pad, and the other C5 is placed as close as possible to the R10 ground pad. The D1 diode is as close as possible to the SW and PGND of the chip. The trace is as short and thick as possible for the stability of the entire structure and the reduction of other factors.

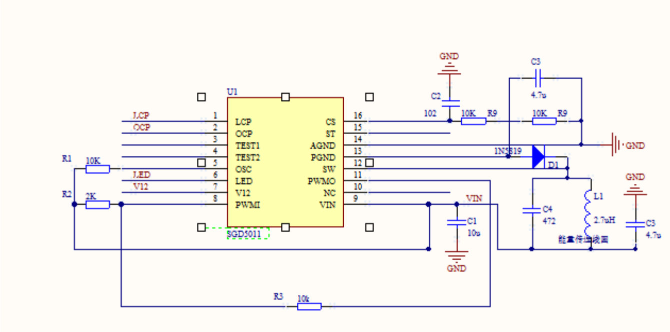

Figure 3 Schematic diagram of the transmitting circuit

D. Receive circuit principle

When designing the receiving circuit, in order to avoid the influence of other unnecessary factors, the position of the C1 capacitor is also selected as close as possible to the chip. In the design, because the frequency of the C1 capacitor is too high, the high-frequency ceramic capacitor is selected. The lead of the battery to the VDD and GND of the chip should be as short and thick as possible. If the lead is too long, the capacity of the C1 capacitor needs to be increased. What needs to be specially mentioned is that when the receiving coil is designed, the receiving coil is smaller than the number of turns of the transmitting coil, and in order to reduce the influence of other factors, a plurality of windings are used.

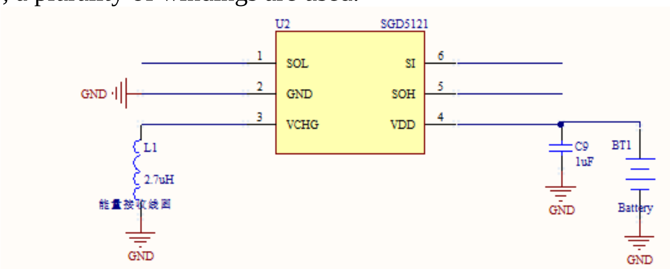

Figure 4 Receiver circuit schematic

IV. COUPLING MECHANISM DESIGN OF MOBILE WIRELESS CHARGING SYSTEM

The coupling mechanism, the two coils used for electromagnetic conversion energy transfer, is a vital part of this design. The coupling mechanism plays a decisive role in the stability of the overall system. The details of the coupling coil design are for the whole The speed of the system's transmission of energy and the normal working ability of the system are directly loud. The main purpose of this design is to apply to mobile phones, so the starting point of the coil design is inseparable from the small size, the use of lightweight materials and significant transmission effects. Nowadays, the most common coil design of wireless charging system is made of Litz wire or thin copper wire, which directly increases the production cost of the coupling mechanism, makes the production work more complicated, and improves the difficulty of assembly. In order to solve these problems fundamentally, this paper envisages a coil structure, which not only reduces the cost of production, but also makes the manufacturing process simpler, can directly complete the production, and also solves the shortcoming of the uniform winding of the coupling mechanism. The practicality of the coupling mechanism has been upgraded to a higher level, and the entire system is very compact and fits well with the mobile phone. This section will use simulation to analyze various factors that affect the coil transmission efficiency of the coil structure, mainly from the aspects of coil shape, coil size, and coil distance.

The main problem of the line width design of the coil is the size of the current carrying capacity of the coil and the strength of the skin effect, and whether the size of the internal resistance of the coil meets the requirements of the system. The maximum current that passes through the safe range of the coil is called the current carrying capacity of the coil. The skin effect means that when there is alternating current in the conductor, there is a non-uniform current in the conductor, and the current is concentrated on the surface layer of the conductor, so that the current actually passing through the inside of the conductor is reduced, thereby causing an increase in the resistance of the wire. In order to reduce the skin effect of the conductor, we have abandoned the use of thick copper wire and the use of multiple strands of thin copper wire. The resistance of the coil refers to the size of the resistance of the coil itself. The resistance of the coil will affect the transmission capacity of the coil. The smaller the resistance, the higher the transmission efficiency. When designing the coil structure, in order to make the coils transmit efficiently and minimize the influence of other interference factors, it is better to use multiple board superposition methods. Every detail of the coil design has a great influence on the transmission efficiency of the coil and the self-inductance of the coil, so the design is to consider all the problems. Since the coupling mechanism of the wireless charging system of the mobile phone has a large limitation, it is limited by the area and the like, and the inner size of the coil cannot be too small, so the line spacing at the time of wiring is preferably set to be small, and the smaller the better.

The mutual inductance between the coils becomes smaller as the vertical distance and the horizontal distance between the coils increase, and increases as the coil self-inductance increases. Since the vertical distance of the mobile phone wireless charging system generally does not change much, the horizontal distance of the center of the coil is also more important for the mutual inductance of the coil. Therefore, many companies have studied many ways to increase the transmission efficiency of the coil to align the coils to reduce the horizontal distance of the coil center. Therefore, there should be a simple and conspicuous text prompt on the surface of the transmitting end of the charging system to prompt the user to place the receiving device directly above the transmitting end. In this design, only the center point of the two coils is in the same axis. Happening. When the vertical distance and horizontal distance of the coil are fixed, it is necessary to pay attention to the influence of the self-inductance of the coil on the mutual inductance. The relationship between the self-inductance of the coil and the mutual inductance of the coil is obtained through simulation. In order to increase the mutual inductance of the coil, we should increase the mutual inductance as much as possible. The large coil is self-inductive until the transmission efficiency between the coils meets the requirements.

V. CONCLUSION

This paper first discusses the design background of the wireless charging system, analyzes and studies the background environment of the design system of the wireless charging system, and puts forward the design scheme to design the wireless charging of the mobile phone which is more close to life and more popular for people. System design. The design system of this mobile phone wireless charging system has very low power consumption requirements, and saving energy is its biggest feature, which is also a big advantage compared to other mobile phone wireless chargers.

After testing and verification, the use effect of this product has completely met the design requirements of this time. Although this design has been completed, there is still much room for improvement in the function of the system, and many details can be further improved. It mainly includes improving and reducing material costs, and strives to use the lowest material cost and save money without affecting the use of mobile wireless charging systems. Continue to optimize the use of operational procedures and continue to test the hardware, find out the bugs that have not been found in the hardware, improve the system, and improve the accuracy and stability of the mobile wireless charging system.

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