Design of Induction Heating Power Supply Based on CD4046

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Abstract: In view of the complex control of small induction heating power supply, a small induction heating power supply based on CD4046 is designed in this paper. The power supply adopts the method of controllable rectification and power adjustment to adjust the power. This paper presents a detailed design of the control circuit and driver based on CD4046 integrated PLL. The prototype test results show that the structure of the power supply is consistent and reliable, and the induction heating effect of small workpiece is good.

1. Introduction

Induction heating has been widely used in metallurgy, machining, national defense and other fields because of its advantages of precise heating, environmental protection and energy saving. In order to further to understand the principle of induction heating and related circuit designed, this paper analyzes the circuit of CD4046, and analyzes the setting of dead time of driving signal and phase compensation.

2. Principle of Main Circuit

The essence of induction heating power supply is a frequency conversion inverter, which converts the rectified direct current into a specific frequency of AC, and passes into the heating slot to achieve the heating of a specific workpiece.Therefore, the core of the induction heating power supply is the design of the inverter.Because the heated parts are different, their inverting frequencies are different, but their basic components are not changed, including a control circuit, inverting the main circuit, inverting the drive circuit, and necessary protection circuit.

In the process of sensory heating of workpieces, due to the differences of separate workpieces, the power requirements are also different when heating. Appropriate heating power plays an important role in the heating quality of workpieces. At the same time, selecting the appropriate power is also conducive to energy saving and emission reduction.Therefore, a good power regulation scheme is especially critical for induction heating power supply.Since the induction heating power supply is essentially an inverter, it can be utilized to power regulation on the DC side or the inverted side. [1, 2]

3. Circuit Design

The small induction heating sample power supply with input voltage of 220V/50Hz and output voltage of 0-400V is intended. Maximum output power is 2KW, the power supply operating frequency is 5kHz~15kHz, and the efficiency is more than 80%.

As showed in Figure 1. The topology of induction heating power supply is designed for this purpose. The AC 220V voltage is input, the rectification voltage is obtained after the bridge controlled rectifier circuit is rectified, the large capacitance group of the filter is stabilized to an approximate voltage source, and the load circuit is supplied after the inversion of the inverter to a specific frequency AC voltage to achieve induction heating.Inverter and bridge controllable rectifier circuits are controlled by control and protection circuits to achieve specific frequency, precise power output of inverted voltage. This design also joins a display and monitoring circuit based on single-chip computer [3].

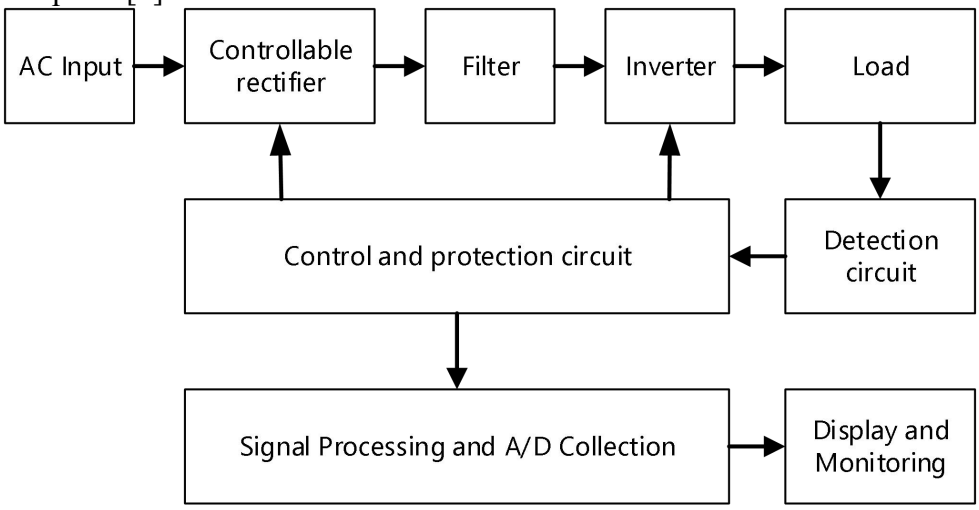

Figure 1: Power structure diagram.

3.1.CD4046 Circuit Design

The circuit diagram of CD4046 module is illustrated in Figure 2. C2, R11, R12 and VR3 in the figure jointly determine the oscillation frequency of CD4046. R1, C1 and R2 are the external oscillation capacitance and resistance of CD4046.

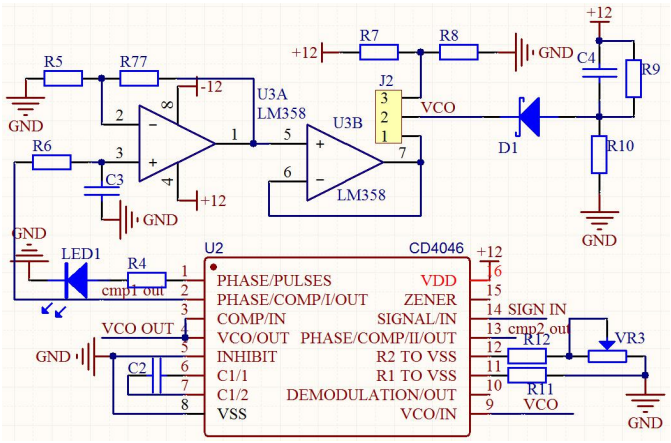

Figure 2: CD4046 module circuit.

Since the design power frequency is 10kHz and 5KHz, the maximum frequency is set at 15 kHz, the minimum frequency is 5 kHz, and C2 is 10nf. The calculation results show that R11 is 200K, R12 is 10K and VR3 is 100k. The purpose of adding VR3 is to manually adjust the frequency range to ensure that the resonance frequency within the frequency range. C3 and R6 in the figure determine the cut-off frequency of the low-pass filter, that is, the maximum frequency permitted to pass without attenuation. The in-phase proportional amplifier circuit composed of an operational amplifier can improve the gain [4].

3.2.Current Phase Detection and Compensation Circuit

The current phase detection circuit is shown in Figure 3, which includes current transformer detection circuit, phase shift compensation circuit and zero crossing comparison circuit. Zmct103c current transformer is used for current detection, which is small in size, suitable for small power and small current detection, and can be installed on the printed circuit board.

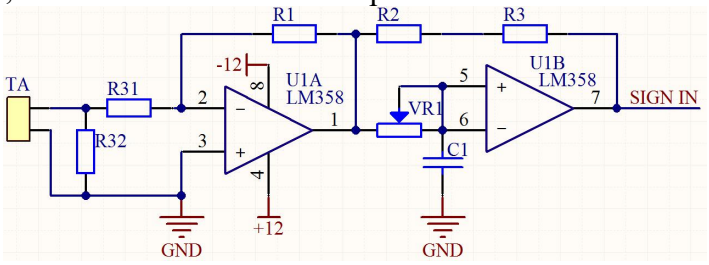

Figure 3: CD4046 module circuit.

3.3.Design of Driving Pulse Circuit

The drive circuit of full bridge inverter is illustrated in Figure 4. It is composed of two parts: one is a push-pull output structure, which is composed of two-stage triode to provide power and PWM wave required for driving; the other part is the isolation circuit, which is composed of an isolation transformer. In the figure, the capacitors in C10, C11, C12 and C13 circuits are isolated. Its purpose is to isolate the DC, and the second is to provide the restart voltage of the transformer. Because the magnetizing voltage of a transformer is related to the PWM duty cycle, the magnetic core of a transformer may be saturated if there is no isolating capacitor. R19, R22 is the gate resistance of MOSFETs, which is usually several to ten ohm. Their purpose is to amend the steepness of the control pulse and to prevent oscillation. When the gate resistance increases, the on time of MOSFET increases, the switching loss increases, and the MOSFET heats up seriously.

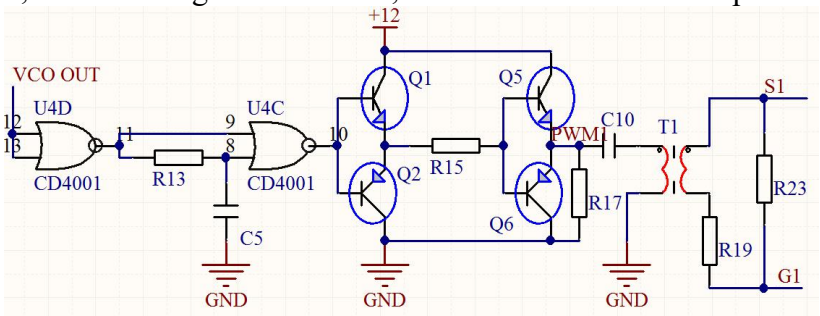

Figure 4: Transformer drive circuit.

The reason why this circuit has the function of producing dead time is caused by the addition of RC structure. Due to the influence of RC charging and discharging, the potential at one end of or no gate input changes. With the continuous capacitor charging, the potential of 8 pins in the above

figure will gradually increase from 0. When the or no gate input is low level, when there is no RC charging and discharging structure, it is equivalent to a non gate structure, and the output will be high level. However, due to the addition of RC, the 8-pin potential in the figure will be low level and the output will be high level before the capacitor charging reaches the high level voltage required by COMS. However, when the capacitor continues to charge and the voltage at both ends of the capacitor exceeds the high-level potential required by COMS by 4.5V, that is, the 8-pin in the figure is high-level, then or no gate output will be low-level. The width of the dead zone can be changed by adjusting the relationship between RC charge discharge period and input PWM period [5].

4. Actual Test and Analysis of Power Supply

4.1.Circuit Board Design

According to the layout shown in the figure, the whole PCB board can be divided into three parts: one is the control part composed of IC, the other is the rectifier part, and the third is the power part composed of MOSFET and the isolated drive of transformer. The duty cycle of CD4046 is 50%. The input signal of CD4046 phase detector 1 must be the square wave with a duty cycle of 50%. Then the "capture" range of CD4046 is the largest, and the square wave with a duty cycle of 50% is generated by VCO.

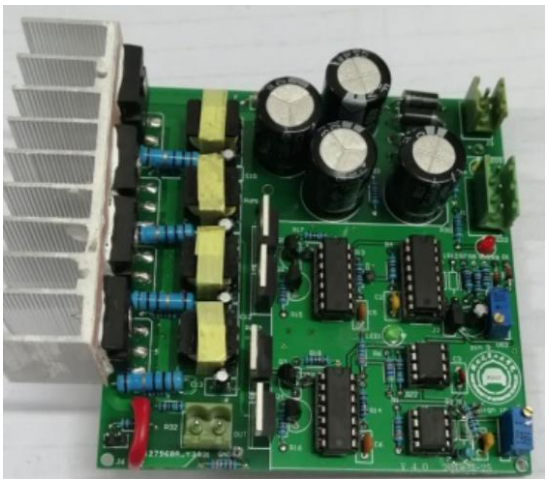

Figure 5: Layout of control and power components.

4.2.Analysis of Voltage Waveform at both Ends of Heating Coil

The actual waveform of coil current is shown in Figure 6 when the coil inductance is very small, and the waveform of coil after increasing the coil inductance is shown in Figure 7. By comparing the actual waveforms of the trivial induction heating prototype in Figure 6 and Figure 7, we can see that the coil current waveform is not a theoretical sine wave when the inductance is very small. It can be seen from the characteristics of the inductor that the resistance of the inductor is not only related to the quantity of the inductance, but also to the frequency of the alternating current. The maximum frequency of the power supply is fixed in the design. Therefore, when the inductance of the heating coil is very small, the coil inductance has negligible effect on the current, which can not restrain the sudden change of the current, which leads to the appearance of the above waveform [6].

Figure 6: Actual waveform of coil current when coil inductance is very small.

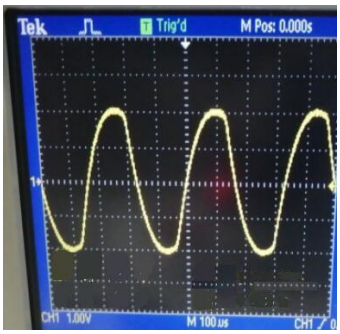

Figure 7: Coil waveform after increasing coil inductance.

In the MOSFET on time, the driving circuit can not maintain a high level, and the driving waveform will slide down in the later stage of conduction, which is caused by the insufficient driving ability of the drive circuit. In order to make MOSFET turn on reliably, the first method is to improve the driving voltage, so as to improve the driving ability. Another method is to improve the isolation capacitor of the isolation transformer. After the increase of the isolation capacitance, the capacitor can store part of the energy, so as to increase the driving ability and reduce the slip of the driving waveform.

5. Conclusion

Heating and quenching in industry has traditionally been the core technology of workpiece heat treatment, and induction heating technology is the key and difficult point in this field. In recent years, the way of industrial heating has changed from traditional heating to energy-saving and efficient induction heating.

This paper first presents the research background, development status and heating principle, and then analyzes the load connection form and power regulation scheme. The main inverter circuit adopts full bridge series resonant circuit structure based on MOSFET. DC side phase-shifting full control rectifier is selected for power regulation. Then, this paper briefly introduces the main components of the induction heating power supply, and makes a detailed design and calculation of the control circuit based on CD4046 integrated PLL and the main circuit of resonant bridge series resonance. Then the load matching problem is briefly introduced. Finally, this paper analyzes the waveform and debugging difficulties in design and debugging, and proposes solutions. After debugging, when the bus voltage is about 20V and the current is about 3a, the small workpiece can be heated to about 100℃ in 2 minutes. The prototype test results show that the structure and control

strategy of the power supply is stable and reliable, and the induction heating effect of small workpiece is good.

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