Research on Frequency Tracking Technology of High Frequency Induction Equipment

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Abstract. With the development of luxury cruise ships and large offshore platforms, the use of high-frequency electromagnetic heating power sources to replace fireworks for thin steel plate leveling is a new development trend in the shipping and offshore industries. The technical difficulty of high-frequency induction power supplies is frequency track. The frequency tracking circuit in this article uses CD4046 as the core, which not only realizes frequency tracking but also realizes the dead time setting, ensures that the power supply can realize frequency scanning and maximum frequency tracking, and ensures that the circuit always works in resonance or quasi-resonance state, The output is more efficient at this time.

1. Introduction
During the construction of the luxury cruise liner, there are a large number of thin plate (4-10mm) welded structures. The buckling strength of the thin plate is relatively small. The longitudinal and transverse shrinkage stress generated by welding can easily cause local instability of the steel plate, resulting in wave deformation and "exposed ribs" Phenomenon"[1]. The control of welding deformation in thin plate processing is a key technology in the processing of luxury cruise ships [2]. In order to level the thin plate deformed by welding, the traditional method often uses manual pyrotechnics to level it. The method of artificial fireworks has the problems of slow leveling speed and low efficiency, a large amount of harmful gases and particulates will be generated during the leveling process, and there are problems such as greater safety hazards [2]. In 2009, Mark Wells of EFD Group proposed that the traditional heat correction method is usually used for steel plates with a thickness greater than 8mm. For steel plates with a thickness of less than 8mm, the Terac induction heating system can effectively reduce deformation.

The application of electromagnetic induction heating technology to ships and offshore platforms is a new type of technology. The main principle is to invert the power frequency electricity into high frequency, low voltage and large current single-phase alternating current through rectification. The high-frequency single-phase alternating current generates an alternating magnetic field on the surface of the steel plate and then generates an eddy current in the workpiece. The eddy current makes the workpiece heat up rapidly, thereby achieving the purpose of heating and leveling.

At present, the cutting-edge technology in the field of electromagnetic induction heating is mastered by companies such as EFD in Norway and Miller in the United States. Among them, EFDI's Terac25/40SM system is widely used in the flattening of thin plate welding deformation of ships and
offshore structures. Due to the high technical threshold of large-area thin plate electromagnetic induction heating leveling equipment, its resonance frequency can reach more than 20kHz, and cables of different lengths and workpieces of different materials require the equipment to adaptively adjust the frequency to the best resonance point. At present, few domestic manufacturers can fully localize key technologies and equipment. This article takes the key technology of induction heating equipment—frequency tracking as the starting point for research.

2. Principle and realization of frequency tracking

2.1. cd4046 Component Introduction
CD4046 is a phase-locked loop with a voltage-controlled oscillator and a high-speed silicon gate CMOS devices. The circuit comprises a linear voltage-controlled oscillator (VCO) and two common Different phase comparators (PC1,PC2) input from signal input amplifiers and common comparators, the input signal can be directly coupled to a large voltage signal or electrically connected in series Capacity is indirectly coupled to small voltage signals. Self-bias input circuit keeps small voltage signalsIn the linear range of the input amplifier. Using a passive low-pass filter, then4046 constitutes a second-order phase-locked loop (PLL). Using linear operational amplifier technology, Can achieve excellent linearity.

2.2. cd4046 working principles

From Fig 1, CD4046 contains two phase comparator, a voltage controlled oscillator and two additional parts, namely the input signal source follower and regulator tube, the comparator there are two common input end (3) and 14 feet, "signal input" can directly match with large signal, and can indirectly through the series capacitor connected to the small signal. The self-bias circuit can adjust the small vo
ltage signal in the linear region of the amplifier. The phase comparator 1 is an xor gate that generates a digital signal (2 pins) and maintains a 90" phase shift (requiring a 50% duty cycle of the input signal) at the center frequency between the "Signal input" and the "phase comparator input" signals. Phase comparator 2 consists of four side flip-flops and 3-state output circuits controlled by logic gates, generating digital error signals (13 pins) and phase pulse output (1 pin), and maintaining strict synchronization between "signal input" and "phase comparator input" signals, generating zero phase shift (independent of duty cycle). Therefore, phase comparator 2 is used in this paper.

2.3. Determination of parameters
Linear VCO(4-pin) produces an output signal, the frequency of which is related to the input voltage of
VCO and the value of C of capacitance connected to the lead end and the resistance value of R1 and R2. And the output frequency range \( F_{\text{min}} \sim F_{\text{max}} \) satisfies the following formula:

\[
\begin{align*}
    f_{\text{min}} &= \frac{1}{R_1(C_1+32pF)} \\
    f_{\text{max}} &= \frac{1}{R_2(C_1+32pF)} + f_{\text{min}}
\end{align*}
\]  

R1=100k\Omega, R2=64k\Omega, and C1=1nF were calculated according to the demand. At this time, the minimum frequency was 15KHz and the maximum frequency was 25KHz, that is, when the control voltage of 9 pins varied from 0-5V, the output frequency varied from 15K-25KH, and when the control voltage of 9 pins was 2.5V, it was 20khz.

Low pass filter is an important part of PLL and its time constant limits the frequency of tracking input signal. The rate of change also limits the range of capture. In addition, the loop filter can help prevent noise and voltage from interfering with the normal operation of the loop. This is because the capacitance stored on the loop filter can help quickly recapture signals lost due to noise spikes or other transient effects. If the time constant is too long, the loop tracking will cause excessive delay and too small in the rapidly changing input frequency, and the loop tracking the rapidly changing input signal will cause abnormal changes in the output frequency of the VCO. Generally, R3=470\Omega, R4=47\Omega, C4=0.1uF. The best working condition is resistance to resistance R4 of 10% to 30% of resistance R3.

3. The realization of phase shift function

The 7 pins of CD4046 will output a sawtooth wave of the same frequency as the OUTPUT of VCO. The following waveform can be obtained by comparing the sawtooth wave with the comparator LM393:

Fig.2 Phase shift simulation circuit diagram.
Waveform 1 is the 4-pin output waveform of CD4046, waveform 2 is the sawtooth waveform of 7-pin output of CD4046, and waveform 3 is the waveform obtained by comparator LM311.

As shown in the figure above, the phase difference is proportional to the comparison voltage by changing the resistance of the potentiometer.

The figure above shows a comparison of waveforms before and after the phase shift.

4. Dead zone time setting

Using CD4538 dead band time Settings, the second piece of CD4046 output waveform as CD4538 input, each has a rising along the output a pulse width for $T = RC$ wave, when the need for dead zones of 4 us, set up $R = 4 \, k \, \Omega \, C = 1 \, \text{nf}$
As shown in the figure below: using CD4538 dead band time Settings, the second piece of CD4046 output waveform as CD4538 input, each has a rising along the output a pulse width for $T = RC$ wave, when the need for dead zones of 4 us, set up $R = 4 \, \text{k} \, \Omega \quad C = 1 \, \text{nf}$

As shown in the figure below:

Waveform 1 is the output of the second block CD4046, and waveform 2 is the output of the 7 pins of CD4538. The two are combined with the obtained waveform 3, that is, the waveform after adding the dead zone time.

5. Result of experiment

Waveform 1 through 4 respectively represent the output and reverse of the first block CD4046 and the output and reverse of the second block CD4046.

6. Conclusion

Based on the advantages of several frequency-tracking phase-shifting PWM control schemes and the characteristics of integrated phase-locked loop CD4046, this paper proposes a new frequency-tracking phase-shifting PWM control circuit based on CD4046, analyzes the working principle of the circuit in detail, and gives the calculation method of circuit parameters. The phase-shifting range of the circuit is $0^\circ$-$180^\circ$, which meets the requirements of power output regulation. Compared with other frequency tracking phase-shifting PWM control circuits, this circuit has the advantages of simple circuit, stable and reliable operation, etc.

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