High frequency pulse width modulator with resistance capacitance combination technology

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Abstract. Based on the important role of high frequency pulse power supply in the process of electro hydraulic beam processing, aiming at the particularity of the processing technology, an innovative scheme to realize the frequency modulation duty ratio is proposed. According to the high voltage high frequency adjustable pulse power requirements, design of control circuit and frequency generator, it is derived that element parameters meet the design requirements and the physical production, the use of power electronic equipment control experimental platform is built, the frequency signal waveform, voltage duty ratio, IGBT on-off control for a series of experiment. The experimental results show that the developed frequency pulse width modulator and drive circuit can drive the full bridge circuit of IGBT, and can control the light bulb (load) under the high frequency, and the rationality of the device and the design are verified.

1. Introduction

The characteristics of fluidic processing of electrochemical machining and water jet cutting, it is the electrolytic liquid into the conductive sealing head, through the holes at high speed by processing the workpiece position, coupled with the high voltage pulse electric current between the anode and the cathode electrode workpiece, "cutting" processing according to the principle of anodic dissolution. Because the current density distribution is limited by the range of the electro-hydraulic beam, the processing region only occurs within the beam range. In addition, the material reduction process is carried out in the form of ions, so this micro dissolution removal method makes the electro-hydraulic beam machining in the field of metal micro manufacturing has a broad application prospect.[1]-[3] The domestic development of electro stream machining relatively early in the Nanjing University of Aeronautics & Astronautics, Guangdong University of Technology, Dalian University of Technology unit etc..

Power supply is an important equipment of mask fluidic processing, is the key way to improve the machining accuracy and improve the surface quality of. Study on the domestic power unit many, for example: Harbin Institute of Technology special processing and electromechanical control research institute, China Institute of electrical engineering, Chinese Academy of Sciences Key Laboratory of power electronics and electric drive, China Academy of Engineering Physics and Southwest Institute of physics etc.. The gap between the pulse power supply and the pressure zone has a stirring function, which improves the flow state of the electrolyte in the gap, and the electrical conductivity tends to be
consistent everywhere. The pulse width is smaller, and then the stability, the machining gap can be smaller, and the nonlinearity can be enhanced.[4]-[6]

This topic is from the National Natural Science Foundation of China. In this paper, the design of high frequency modulator under high voltage is studied.

2. Design of control circuit and frequency generator for pulse power supply

In view of the particularity of fluidic processing power requirements, not only require a high voltage, and require a wide tunable frequency range, frequency generator needs development of 0-50kHz, and the pulse width adjustable. The control circuit of high voltage pulse power supply is shown in figure 1.

![Control circuit of high voltage pulse power supply](image)

As shown in Fig. 1, the SG3525 integrated PWM chip generates a signal pulse. After the pulse is sent to the drive circuit, the M57962 drive circuit generates an output voltage, and the IGBT gate is used to control the inverter circuit. [7] In addition to the data acquisition module of SG3525 frequency and duty ratio, the dead time of the AD conversion, and sent to the FPGA controller, the real-time information can be displayed on the screen TFT touch, the user can through the touch screen to set the parameters of.

SG3525 is a kind of excellent performance, complete function and general monolithic integrated PWM control chip is strong, it is simple and reliable and flexible and convenient use, the output driver for the push-pull output form, increase the driving capability; contains internal undervoltage lockout circuit, soft start control circuit, PWM latch, over-current protection function. Adjustable frequency, and can limit the maximum duty ratio.[8]

DC power supply Vcc (+15V) from pin 15 connected two, a way to input or gate; another way to the reference voltage regulator, to generate stable components as power supply. Oscillator pin 5 must be externally connected capacitor CT, pin 6 must be externally connected resistor RT.

The oscillator frequency is determined by the external resistance RT and the capacitor CT,

\[ f = \frac{1}{C_T (0.7R_T + 3R_D)} \]  \hspace{1cm} (1)

The design scheme of the RT=R1+R3, R1=1kΩ, R3 is an adjustable potentiometer, R3=0~100kΩ, and RT=1~101kΩ.

RD is the connection resistance between 5 feet and 7 feet, RD=R8=10Ω. The CT is connected with a capacitor 5 feet, 5 feet by switch with 103 ceramic capacitors (0.01μF), 104 capacitors (0.1μF).

Substituting R1, R3 and R8 into formula (1), then

\[ f = \frac{1}{C_T [0.7(R_T + R_3) + 3R_D]} \]  \hspace{1cm} (2)

PART A: 5 feet by switch with 104 ceramic capacitors (0.1μF)

\[ f_{\text{max}} = \frac{1}{C_T (0.7R_T + 3R_D)} = \frac{1}{0.1*10^{-6} (0.7 *1000 + 3 *10)} = \frac{1*10^7}{730} = 13698Hz = 13.7kHz \]

\[ f_{\text{min}} = \frac{1}{C_T (0.7R_T + 3R_D)} = \frac{1}{0.1*10^{-6} (0.7 *101000 + 3 *10)} = \frac{1*10^7}{70730} = 142Hz \]

The frequency of the sawtooth wave divided by 2 is the frequency of the output square wave, that is 71Hz - 6.85kHz.

PART B: 5 feet by switch with 103 ceramic capacitors (0.01μF)
The frequency of the sawtooth wave divided by 2 is the frequency of the output square wave, that is 710Hz – 68.5kHz.

3. experimental test

The experimental platform device is shown in figure 3. On the left side of the black knob control knob input AC voltage, can produce 0~220V continuously adjustable single-phase AC DC rectifier through the tunable 0~311V filter module, and then through the adjustable square wave single phase square wave inverter module 0~311V.As shown in Figure 3, SG3525 PWMA and PWMB signals through the M57962 chip and generates a control signal to the single-phase full bridge (pulse), the control signal is connected to the IGBT driving circuit of G (Shan Ji), IGBT to achieve the on-off action.[9]～[10]

3.1 frequency signal waveform testing

As shown in Figure 2 and figure 3, the self checking end of the oscilloscope is used to complete the calibration, to ensure that the oscilloscope is in its normal working state and to prepare for testing the PWM control chip. The 2 probes of the oscilloscope are connected to W1 (measuring feet of PWMA) and W2 (measuring feet of PWMB). Adjust the resistance value of the R3 potentiometer, set the parameter, use the oscilloscope to test the signal of the 11 pin (PWMA) and the 14 pin (PWMB) of the two ports of SG3525, and measure the waveform, as shown in figure 2.

As shown in Fig. 3, at the sampling frequency of f=50kHz, the PWMA and PWMB signals are two equal frequency, opposite phase waveforms, which are in line with the experimental expectation.

By formula (1) and formula (2) and its deduction, we can see that this design has been continuously adjusted from 71Hz~68.5kHz through the tolerance linkage scheme. In the power electronic control experimental device, the processing voltage is set to 200V, and the driving signals of 20kHz, 30kHz, 40kHz and 50kHz are generated by SG3525, The voltage and frequency relation broken line diagram is shown in figure 3.
The voltage 200V, the frequency of driving signal is increasing, we can see that square wave is 
not deformed, waveform stability, provide a reliable guarantee for driving circuit of pulse.

3.2 duty cycle test

Test conditions: the capacitor shift is adopted 103 (0.01 μF), and then the formula is calculated by 
formula (1) and formula (2), and the frequency range of the square wave is between 710Hz-68.5kHz. 
Set frequency f=10kHz, determine the duty cycle, pin 2 voltage, voltage divider circuit resistance 
corresponding table, as shown in table 1. The line diagram of the voltage duty cycle is shown in figure 
4.

As can be seen from table 1 and Figure 6, by adjusting the resistance of an adjustable 
potentiometer R2, the duty cycle is continuously increased and can be changed between 0%~50%. 
However, as the voltage increases further, the duty cycle no longer increases and peaks appear. 
SG3525 the maximum duty ratio of the theoretical value is 49%, plus dead time 1%, two output add 
up to 100%, the actual test results in line with expectations for the next stage of implementation of full 
bridge continuous adjustable driver IGBT made the necessary preparations.

3.3 experimental test
Developed a frequency pulse width modulator and a driving circuit in power electronic control apparatus, driving signal generated by the SG3525 50kHz, 200V, 225V, tested in 250V, 275V, 300V voltage, by rotating the duty ratio (10%, 20%, 30%, 40%, 50%) button, the realization of the IGBT G tube feet the on-off control, load (light bulbs).

To adjust the duty ratio adjustment knob to \( f = 50 \text{ KHZ}, D = 50\% \) of the state, in a voltmeter clearly shows the current voltage is 203 v, after half an hour of fatigue test, load (lamp) to work, also recorded a 50% signal on the oscilloscope waveform. To adjust the duty ratio adjustment knob to \( f = 50 \text{ KHZ}, D = 10\% \) of the state, in a voltmeter clearly shows the current voltage is 206 v, after half an hour of fatigue test, load (lamp) to work, also recorded a 10% signal on the oscilloscope waveform.

The latter brightness bulb was significantly higher than that of a in the former and brightness of the bulb, because in the peak (200V) under certain circumstances, the mean voltage and duty ratio is proportional to the duty cycle to reduce the average voltage drop, voltage across the load is reduced, the brightness of the bulb becomes dark.

4.  Conclusion

Found in the experiment found that further continue to improve the voltage between 285 v and 290 v, rotating duty ratio control, found that can be achieved from dark to light bulb, but back knob doesn't switch off the light bulb, that is to say, can no longer be valid and reliable control IGBT G feet. The next step is to conduct a further study on the above problems.

By adopting the cascade method of resistance and capacitance combination, the capacitor tap position can be selected through the dial code switch, and the adjustable potentiometer can be used to adjust the resistance, so the frequency band can be dynamically adjusted and expanded easily. A frequency pulse width modulator and a drive circuit are developed to realize the on-off control of IGBT G pin and the load (light bulb) on the power electronic control experimental device.

Acknowledgments
This work was supported by National Natural Science Foundation of China(No.51575113)

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