Ultrasonic therapy instrument based on intelligent neural network algorithm

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Abstract

Aiming at the shortcomings of low tracking accuracy and slow speed of the frequency tracking method of ultrasonic drive system, a frequency tracking method combining Fuzzy and DDS is proposed. The main control module controls the signal generation module to generate an ultrasonic excitation signal of a specific frequency, which is processed by the power amplifier circuit to obtain an ultrasonic drive signal, and the drive signal is added to the transducer load to output an ultrasonic signal with the same frequency as the drive signal. Frequency tracking and system protection modules are realized through closed-loop control. The ultrasonic output frequency is 1MHz, the output power is 0.6W to 2.1W, and the electro-acoustic conversion efficiency reaches 36%.

Keywords

Ultrasonic Therapy Device; Neural Network; Impedance Matching; Power Amplifier Circuit.

1. Introduction

The cause of chronic soft tissue injury as a common disease has not been determined yet. Science shows that the use of ultrasound therapy has a positive therapeutic effect on the treatment of different types of chronic soft tissue injuries[1-2]. Ultrasonic technology is widely used in industrial production, such as electronic packaging industry, ultrasonic processing industry, etc[2-3]. Generally, high-power ultrasonic equipment must have a matching circuit, but most of the current matching circuits use static matching circuits, and the research is carried out without any load on the system. Through the analysis of some of the current ultrasonic physiotherapy instruments, the main problem currently exists: the current matching circuit does not add any neural network algorithm, the adjustment effect is poor, and the output sound intensity is unstable. And most of them use static matching circuits, which are prone to static matching offset[4-5]. The frequency tracking speed is slow, the dynamic response ability is weak, and the system cannot maintain an automatic processing function of real-time adjustment parameters, and the system dynamic effect cannot be guaranteed[6-7]. When the energy conversion system dynamically matches the switching inductance, it is easy to lose the lock phenomenon, and the overall performance of the dynamic matching circuit of the energy conversion system is low[7].

2. Power system design

Figure 1 is the general block diagram of the ultrasonic therapy instrument. Ultrasonic therapy instrument based on intelligent neural network algorithm, which includes: power supply module, signal generation module, power amplifier module, impedance matching module, ultrasonic transducer, frequency automatic tracking module, main control unit, temperature

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control module, overcurrent and overvoltage Protection module, human-computer interaction module and concave piezoelectric ceramic sheet.

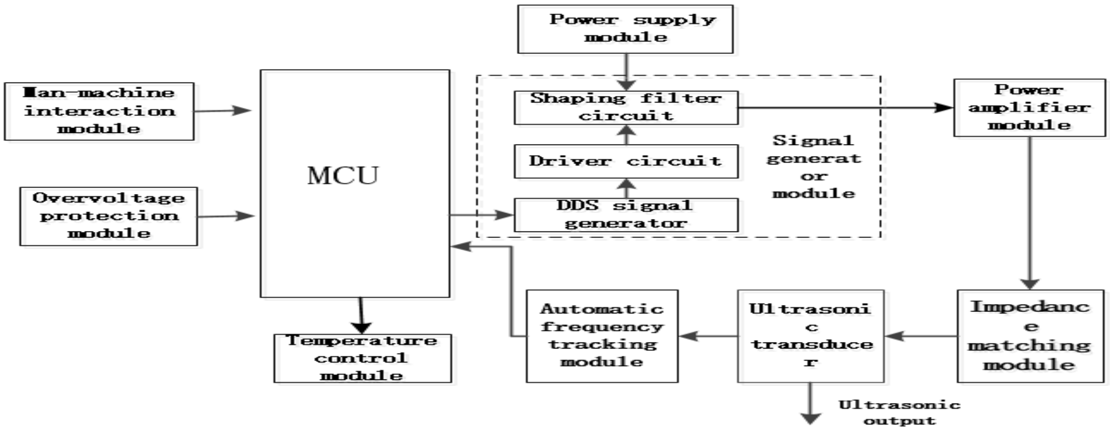

Figure 1 The general block diagram of the ultrasonic therapy instrument

2.1. Power module

Power supply module, the power supply module has three voltage formats: power amplifier module power supply (12V), signal generator power supply (5V), main control unit (3.3V). The 12V rechargeable lithium battery boosts the 12V voltage to 48V through the boost boost module, and directly supplies power to the power amplifier module; considering that the voltage drop from 12V to 3.3V is too large. The signal generating circuit converts the 12V voltage into 5V through the linear voltage regulator chip LM7805 for power supply; uses the voltage regulator chip AMS1117 to convert the 5V voltage into 3.3V to power the main control unit. AMS1117 is a forward low-dropout regulator with an output voltage of 3.3V, with low cost and simple circuit design. The charging part uses the QI standard wireless charging module to wirelessly charge the entire ultrasonic therapy device. The battery uses a 12.6V 1800mAh rechargeable lithium polymer battery pack. The volume of the polymer lithium battery pack is only 45 cubic centimeters, which further simplifies the volume of the physical therapy device.

2.2. Signal generation module

The signal generation module includes DDS signal generator, shaping filter circuit and driving circuit. The AD9833 chip is connected to the main control unit through a serial bus, and the pins of the main control unit are configured to SPI bus mode to cooperate with AD9833 for data transmission. The main control unit adopts a low-power STM32L151 main controller. The AD9833 chip generates a 2MHz square wave through the low-power STM32L151 main controller. The drive circuit uses a D flip-flop to divide the 2MHz square wave generated by the DDS signal generator. A more stable 1MHz square wave is reshaped by a shaping filter circuit. The concave piezoelectric ceramic sheet outputs an adaptively adjustable ultrasonic wave with a frequency of 1MHz and an intensity of 0W/cm2 to 1W/cm2.

2.3. Impedance matching network

Impedance matching module, used to realize dynamic adjustment of matching inductance. For conventional static circuit matching, the frequency of the transducer is prone to drift. The impedance matching module uses a BP neural network module with a neural network intelligent algorithm to achieve dynamic adjustment of the matching inductance.

As shown in Figure 2, the impedance matching module is mainly composed of five modules: data detection module, data preprocessing, BP neural network training, BP neural network prediction and BP neural network controller. The ultrasonic transducer first collects input parameters through the data detection module, and preprocesses the parameters, mainly

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normalization processing, and then through neural network training, the weight of the network is constantly adjusted, and the inductance value is predicted, and then through the BP neural network The controller outputs the dynamic matching inductance, and adjusts the reactance angle of the reactor in real time according to the size of the dynamic inductance, thereby changing the voltage and current at both ends of the transducer. This cycle continues to realize the dynamic adjustment of the matching inductance.

The intelligence of BP neural network module is to adjust the weight of the network in real time, so that any input can get the desired output. The training method is to conduct neural network training for each set of data samples, starting from the first layer of the network and calculating layer by layer until the output layer.

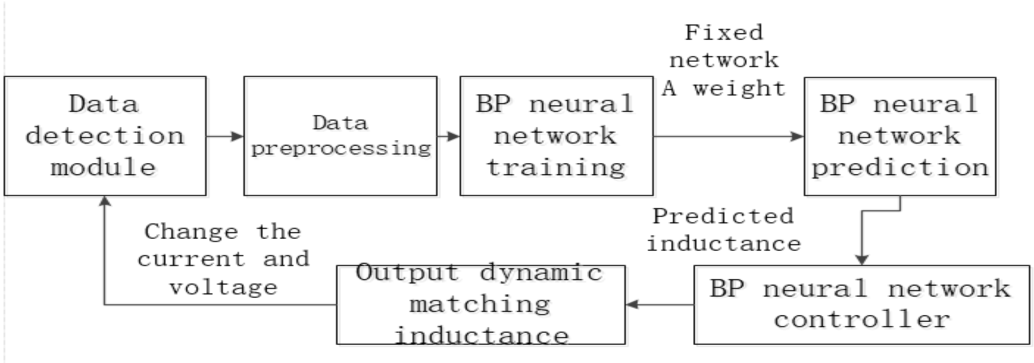

Figure 2 Meter Impedance matching module

The specific steps of BP neural network module are as follows:

The first step is to obtain the input parameters of the neural network through the data detection module. Since the size of the matching inductance is related to the internal parameters of the ultrasonic transducer, the five main variables that cause the change of the internal parameters of the transducer are used as input parameters, which are the temperature of the transducer, the ultrasonic frequency, and the voltage across the transducer. The value, the current value at both ends of the transducer and the depth of the concave piezoelectric ceramic sheet into the sink, and the output parameter is the dynamic inductance value.

The second step is data preprocessing. In order to reduce the absolute error, data preprocessing is performed before the normalization process, and the input and output data of the network are restricted to (0,1) or interval (-1,1) through transformation.

The third step is the normalization of sample data.

The fourth step is the training of BP neural network. The training purpose of BP neural network is to fix the weight of the network. Cross-input a large number of samples of different categories, through a large amount of learning of multiple sample data, continuously adjust the weights, reduce the error, adjust the weight of the network to minimize the error, and fix the weight of the network.

The fifth step, the prediction of the neural network, is to predict the matching inductance value through the BP neural network. After BP neural network training, the weight of the network has been determined. Test whether the trained sample data has good generalization ability. If the error of the training sample is small, but the test sample error is large, indicating that the generalization ability is relatively poor, then proceed to the first step until the neural network is good Predictive effect.

2.4. Power amplifier module

The power amplifier module is used for DDS signal amplification and drives the DDS generator to generate signals that can drive the ultrasonic transducer. DDS adopts AD9833 chip, DDS has

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the advantages of low cost, low power consumption, high resolution and fast conversion time. Since AD9833 output excitation signal strength is not enough to drive the ultrasonic transducer, it is necessary to amplify the power of the excitation signal. The ultrasonic excitation signal is processed by the logic chip 74HC74D for frequency division filtering, and then sent to the gate drive chip UCC27525 for subsequent amplification. The amplified ultrasonic drive voltage signal can reach 40V, which can directly drive the ultrasonic transducer to work. The main control unit generates PWM waves to control the enable terminal of the gate driver to achieve indirect control of the ultrasonic output power.

2.5. Protection circuit

The software flow of over-temperature protection and DDS signal generator can obtain the system temperature through calculation by collecting the voltage at both ends of the thermistor, and compare it with the threshold temperature to judge whether it is over-temperature. The DDS signal generator calculates the corresponding frequency control word according to the required output frequency, determines the storage location of the control word, and sets the output waveform and signal amplitude.

3. Frequency tracking module

Because the frequency tracking method of conventional phase-locked loop technology is easy to lose lock, and the frequency of ordinary fuzzy control lacks self-integrated dynamic response capability, it cannot maintain an automatic processing function of real-time adjustment parameters in the system, and the tracking speed is slow, which cannot be guaranteed. System dynamic effects.

In order to solve the above pain points, an automatic frequency tracking technology based on Fuzzy neural network is proposed. The automatic frequency tracking technology based on Fuzzy neural network is based on some problems of the fuzzy controller and the phase-locked loop technology itself, and the intelligent frequency tracking technology of the neural network algorithm is introduced into the fuzzy control. The automatic frequency tracking module mainly includes: voltage and current acquisition, phase detector, Fuzzy neural network controller. First, the phase detector is used to collect the voltage and current signals at both ends of the transducer in real time to obtain the phase difference e and the rate of change of the phase difference. Then input the phase difference e and the rate of change of the phase difference into the Fuzzy neural network controller. The specific working steps of the Fuzzy neural network controller are as follows:

The first step is to determine the input and output signals of the Fuzzy neural network controller. The phase difference e is the rate of change of phase difference as the input of the fuzzy neural network controller. The adjusted phase difference E is used as the output, and then the neural network algorithm is used to map the input and output.

The second step is fuzzification and determination of membership functions. Fuzzy the input and output variables of the controller, use MATLAB fuzzy control toolbox and neural network algorithm to jointly adjust the input and output parameters, which is simple and convenient to operate. The membership function adopts Gaussian fuzzification function.

The third step is the formulation of fuzzy rules. In the MATLAB fuzzy toolbox, formulate fuzzy rules.

The fourth step is the training of Fuzzy neural network controller. The Fuzzy neural network controller has a tutor-style self-learning ability. It adopts a four-layer structure of input layer, middle layer, inference layer and output layer. The training method is to conduct neural network training on each data sample, starting from the first layer of the network. Layer

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calculation, up to the output layer, through a large amount of learning of multiple sample data, adjust the size of the phase difference, and change the current at both ends of the transducer.

The fifth step is the adjustment of the fuzzy neural network controller. After the fuzzy rule training, the phase difference and the first derivative of the rate of change of the phase difference are used as the input of the data preprocessing. After the trained Fuzzy neural network controller, the phase difference is adjusted to change the two ends of the transducer. The current loops in this way until the phase difference is zero, so that the signal output frequency and the input frequency are gradually kept consistent, and the frequency is automatically tracked.

The sixth step is to build a Simulink simulation model based on the Fuzzy neural network controller through the MATLAB fuzzy toolbox and Simulink simulation platform. Experiments have proved that the frequency tracking speed of the automatic tracking module with Fuzzy neural network controller can reach 0.12ms, which improves the frequency tracking speed of the system and improves the working efficiency of the ultrasonic therapeutic apparatus.

4. MCU

The MCU uses a low-power STM32L151 microprocessor to detect the sampling resistor voltage through ADC, program the PID algorithm to control the ultrasonic output intensity and display the current working state of the device, scan the button to determine the output ultrasonic intensity, and display the current position through the LED light Stalls.

5. Experimental results

The Fuzzy neural network module improves the system frequency tracking speed, solves the loss of lock phenomenon when the transducer system dynamically matches the switching inductance, and improves the overall performance of the transducer system's dynamic matching circuit. The frequency automatic tracking speed can reach 0.12 ms, which improves the frequency tracking speed of the system and improves the working efficiency of the ultrasonic therapy instrument. The ultrasonic power meter is shown in Figure 3. The test waveform is shown in 4, the waveform has no distortion and the effect is obvious.

Figure 3 Sound power meter

The test waveform is shown in 4, the duty cycle of the excitation signal is 50%, and the frequency is 2MHz. The frequency of the driving sine wave is 1MHz, and the waveform has no distortion, indicating that the device works stably.

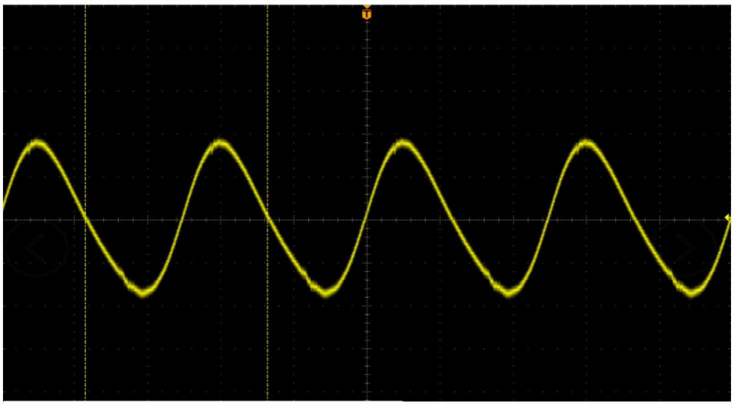

Figure 4 The test waveform

6. Conclusion

This paper proposes an automatic frequency tracking technology based on fuzzy neural network, which enables the output frequency of the ultrasonic power source to track the resonant frequency of the transducer in real time. The Fuzzy neural network is added to the frequency tracking module to make the dynamic matching accuracy high, and the frequency automatic tracking speed is fast, which solves the volatile lock phenomenon when the transducer system dynamically matches the switching inductance, and improves the overall performance of the dynamic matching circuit of the transducer system . It solves the pain points of slow tracking speed and weak dynamic response ability of ordinary fuzzy control, and the easy locking of phase-locked loop technology.

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