The Design of the Acoustic Wave Meter Transmitting Circuit

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Abstract. It is very important to design a good transmitter for acoustic wave guage, the performance of the transmitter directly decides whether the equipment can work properly or not, and the effective data can be got. The transmitter circuit structure of acoustic wave guage is introduced in this paper, including driving circuit design, power amplification circuit design and the transducer matching circuit design, and calculation of the transmitter output power. Finally, the actual measurement data is used to prove that the ultrasonic transmitter design is reasonable and practical.

1. Introduction

Acoustic wave meter is mainly divided into two types according to ultrasonic transmission mode: underwater acoustic mode and overwater mode. The principle of measurement is based on the propagation characteristics of ultrasonic wave in the medium and the reflection characteristics on the interface of different media, and it is realized by continuously measuring the distance between the ultrasonic transmitters to the sea surface.

Overwater acoustic wave meter installs the ultrasonic transducer (emitter) on the offshore platform, and the transducer launches the ultrasonic pulse from the platform to sea surface vertically, and receives the signal reflected from the sea surface. The transducer part of the water acoustic wave meter is usually installed above the water surface by the support. In the actual use, the transducer is easily affected by the wind and the bad sea condition, and then cause the error of the measurement data is caused by transducer vibration, so overwater acoustic wave meter is not often used.

The transducer of underwater acoustic wave meter is installed on the sea floor, launching the ultrasonic pulse vertically to the sea level and receiving the signal reflected from the sea surface. The underwater transducer is installed on the underwater balance device. Through the balance device, the transducer is balanced on the seafloor, and the pulse is emitted vertically to the sea level. The land device can control underwater acoustic transducer through seafloor armoured cable, and the armoured cable can protect the proper equipment for a long time, and the signal is attenuated due to the long distance cable transmission, when the wind brings air bubble, the bubble will consume the ultrasonic
energy, which makes the reflected wave energy weak. Therefore, when the transmitter circuit is designed, the power of the transmitter should be large enough [1, 2].

2. Circuit design

2.1. Circuit structure
The principle block diagram of ultrasonic emission circuit, as shown in Figure 1, is composed of driving circuit, power amplifying circuit, matching circuit and transceiver transducer.

![Fig 1. Ultrasonic emission circuit](image1)

The function of the driving circuit is mainly to provide enough voltage and electric current driving for the power tube, the function of power amplifying circuit is to amplify the power of signal, the function of the matching circuit is to make the output waveform of the transmitter have better frequency characteristics and improve the output characteristics of the transmitter, the function of the transceiver is to send the signal from the ultrasonic transmitter to the transducer, and the signal arrives at the sea level reflector and then the signal is received for processing on the shore.

2.2. Driving circuit design
The driving circuit is directly driven by CMOS transmission gate. The circuit diagram is as follows.

![Fig 2. Driving circuit](image2)

The selected chip is 74HC00, and the circuit structure of this chip is shown in Figure 2. Because the power amplifier is used in the MOS transistor D class amplifier, the D class amplifier is a quasi linear amplifier relative to the linear amplifier. Its main advantage is the high efficiency, and the efficiency of this kind of amplifier can be as high as 80%. In order to reduce the switching loss of the power tube, the switching speed of the power tube needs to be improved. It can be seen from the structure of the MOS tube that there is a parasitic capacitance between the gate source and the drain source, and the drive of the MOS tube is actually charging and discharging the capacitance, which means the drive circuit can provide a certain electric current. The quality of the driving circuit directly affects the reliability and performance of the power amplifier circuit. The switch tube opening instantaneous drive circuit should provide enough charging current to increase the voltage between gate and source of the MOSFET rapidly to the required value, ensure the switch tube can be opened quickly without high frequency oscillations in the rising edge, and ensure that the voltage between gate and source the MOSFET is stable, so that it can be connected through and can provide a maximum possible low resistance. The channel of resistance provides fast discharge for capacitance between gate and source of the MOSFET, so that switch tube can turn off [3, 4] quickly.
2.3. Power amplifying circuit design
The power amplifier is shown in the following diagram. The selected device is IRF640, IRF640 is the fifth generation HEXFET power field effect transistor of IR, which is made using advanced technology and it has very low conduction impedance. IRF640 features, coupled with fast conversion rates, and robust and durable HEXFET design, so IRF640N is super efficient and reliable power amplifier with a wide range of applications.

IRF640N has two kinds of encapsulation, one is patch installation (IRF640NS), the other is low-end through-hole installation (IRF640NL). The IRF640 of TO-220 package is generally applicable to the industrial and commercial applications of power consumption around 50W, low thermal resistance and low cost TO-220 encapsulation, IRF640 is widely used. The D2Pak encapsulated IRF640 is suitable for patch mounting. Compared with the existing other chip packages, it can be said that the power is the highest and the conduction impedance is the lowest. TO-262 is the through-hole installation version of IRF640, which is suitable for low-end applications. The TO-222 encapsulated IRF640N is selected in this circuit.

![Power amplifying circuit](image)

The maximum drain source voltage (VDS) of IRF640N is 200V, the maximum drain current (ID) is 16A, and the gate voltage range (VGS) is + 20V. The output power Po of the transmitter is required to be not less than 10W. In general, the power pipe and transformer will have a certain loss. In fact, the power of the power pipe should be designed to be 1.5Po about 15W. The power supply voltage VCC is 12V, and the drop of power tube is 2V, then the largest leakage current is [5].

\[
I = \frac{1.5 P_o}{V_{cc} - 2} = 1.5 A
\]

The maximum leakage electric current of the selected IRF640N meets the requirements.

2.4. Acoustic transducer selection
Transducer is the key component of acoustic wave meter. It is an energy converter that converts an alternating signal into an acoustic signal in a certain frequency range or converts the signal in the external sound field into an electrical signal.

In this circuit, a piezoelectric ultrasonic transducer is used in this circuit, the transducer is composed of a piezoelectric chip, a wedge, a joint etc. Each part has an important role. The first is the piezoelectric chip: the probe of the transducer is made by a piezoelectric chip, and the piezoelectric chip is excited by the emission pulse to produce vibration, and the acoustic pulse can be emitted. When ultrasonic waves act on wafers, the deformation induced by forced vibration of wafers can be converted into corresponding electrical signals, which is the process of ultrasonic emission and reception. The vibration frequency and the working frequency of the piezoelectric wafer depend mainly on the thickness of the wafer and the propagation speed of ultrasonic wave in the wafer material. In order to get higher frequency and make wafer work in resonance state, the thickness of wafer is usually selected at 0.5 times wavelength. The wafer is more brittle, easy to damage. For the smooth surface of the surface, a hard protective film made of an alumina layer is attached to the front of the wafer. This is the protective film. There is a wedge in front of the inclined probe chip. The
longitudinal wave emitted by the chip is shot to the surface of the specimen by the set wedge, and the wedge is made of organic glass. In order to improve the ultrasonic emission of the probe, the wafer is often used in the resonance state, which makes the vibration not easy to stop, and it is difficult to form narrow pulses. Therefore, damping blocks are often mounted on the back of the wafer to increase the vibration damping of the wafer, and absorb the ultrasonic waves generated on the back of the wafer.

Considering the performance of the ultrasonic transducer, the size of the installation and the field test, the piezoelectric ceramic disc is selected, and the radial / thickness coupling vibration mode are used as the oscillator of the ultrasonic transducer. The basic natural frequency of a disc type piezoelectric vibrator is:

\[ f = \frac{a}{2 \lambda H} \sqrt{\frac{Y_p}{2(1 + \mu)\rho}} \]  

In the formula, \( Y_p, \mu, \rho \) is the young's modulus, Poisson's ratio and density of the piezoceramic, the \( H \) is the thickness of the disc, and the \( a \) is the basic characteristic value of the disc piezoelectric vibrator, which is the function of \( \frac{H}{R} \). The basic characteristic value can be determined by looking up the characteristic curve of the disc piezoelectric vibrator.

The axial vibration mode of disc piezoelectric vibrator is not axial translational motion like circular piston. Its directional characteristics can be approximately expressed by the following formula.

\[ R_\theta = \frac{2J_1(K_Z R \sin \theta)}{K_Z RS \sin \theta} \]

\( \theta \) is the angle between the observation direction and the main beam direction, \( K_Z \) is the wave number of the air medium, and \( R \) is the disc radius.

Fig 4. is the axial displacement distribution of disc piezoelectric vibrator.

The vibration energy of the piezoelectric vibrator is concentrated in the center of the disc radiant surface. Therefore, for the same structure size, the directional characteristics of the disc piezoelectric transducer are better than the directional characteristics of the piston type piezoelectric transducer. In order to determine the structure size of the disc piezoelectric vibrator, the radius \( R \) of the disc piezoelectric vibrator is estimated by calculating the beam width formula of the piston type piezoelectric vibrator. Assuming that the working frequency of disk piezoelectric oscillator is 200 KHz, the wavelength of several mid waves is about 7mm. If the transducer beam width of 3, while the radius of \( R \) of circular piezoelectric vibrator should be at least equal to
The piezoelectric ceramic material PZT-5 is chosen as the vibrator of transducer. Its parameters are \( \mu \approx 0.33 \), proportion \( \rho = 7.75 \text{(kg/m}^3) \), Young's modulus

\[
Y_F = 8.13 \times 10^{10} \frac{N}{m^2}
\]

\[
f = \frac{4.47}{2\pi \times 0.007} \sqrt{\frac{8.13 \times 10^{10}}{2 \times (1 + 0.33) \times 7.75 \times 10^3}} \approx 200 \text{(kHz)}
\]

In the launching state, the measured value of the optimum resonant frequency of the transducer is approximately equal to calculated value. Performance indicators selected by the above parameters: emission sensitivity: 76dB, receiving sensitivity: -78db, impedance: 50 Omega, side lobe: -24.6db, open angle: 3°, diameter: 7cm, resonant frequency: 200 KHz, Q: 14.

3. Application of acoustic wave meter

This circuit has been widely used in acoustic wave meter now, and the effect is excellent. In the field measurement and application, the acoustic transducer is placed at the bottom which is more than ten meters, the distance between the land based host and the transducer is up to 1000 meters, and up to 1500 meters in some places.

The transmitter is converted to acoustic signal through the transceiver, and the transmitter is transmitted to the sea and air medium to reflect the signal to the acoustic transducer, and the transducer converts the acoustic signal to the electrical signal through electricity. The cable is transmitted by the echo analyzer, and the desired displacement signal is processed through the receiving circuit. The acoustic wave gauge is installed in the South China Sea, Beihai Sea and the East China Sea. The actual installation and measurement data are shown below in Figure 6 and figure 7.
In practical application, the ultrasonic transmitter plays a very important role in the acoustic wave meter. The lack of transmitting power causes the echo signal to be too weak and cannot be measured correctly. Because the transmitting power is large enough, the acoustic transducer can be deployed far away from the shore, which is a better observation position. Only the cable and transducer are deployed on the seabed and the rest of the electronic parts are on the shore, the failure rate of the equipment is greatly reduced, the acoustic wave meter is widely used [7-9].

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