Simple underwater wireless communication system

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Abstract

The system uses the ultra-low power MSP430F449 MCU as the control core, and uses the infrared wireless communication, achieving a simple underwater wireless communication. The entire system consists of 3 parts, the land-based unit, the electrical unit and the submarine model. The land-based unit uses the ASK modulation to achieve wireless communication with the submarine model. The submarine model receives and decodes signals, then communicates with model unit via infrared light waves. The motor unit receives the infrared signals and keeps the floating and diving of the submarine model by controlling the suspension. The system realizes the controlling of the submarine model to achieve various forms of movement when the antenna is 3 meters above the water. The distance error, time error and speed error all meet the requirements. The whole system operates simply and functions well.

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Selection and/or peer-review under responsibility of [CEIS 2011]

Keywords: underwater, wireless, communication system

1. Project Design

1.1 Theoretic analysis

The system consists of the land-based unit, the submarine model and the electrical unit. The land-based unit modulates the control signal with carrier wave of working frequency of 507KHz by ASK modulation, and it is sent to antenna after operated by subsequent power amplifier; the submarine model sends the signal received by coil through
amplification, detection, reshaping, decompiler PT2272, SCM, and finally to infrared transmitted module; the electrical unit receives infrared signal and decodes it, for control work of electric motor.

1.1.1 Radiating circuit analysis of land-based unit

The land-based unit transmits signal, working at a frequency of 507KHz and electromagnetic wavelength of 591.7m. Because it is requisite that the length of antenna is 10m, which for less than 1/4 of wavelength(λ), namely 147.9m, the decline of signal in transmitting procedure is very large. In order to enhance the transmitting power of antenna, it usually uses C-class amplifier of high frequency to amply the power of signal. As for ASK modulation, requirement of amplitude is not rigid when using relatively nice method of demodulation, and it directly connects with antenna of L-sharp after through matching network.

1.1.2 Radiating circuit analysis of the submarine model

Receiving device applies antenna, parallel connects a capacitance with resonant frequency of 507 kHz. The value of inductance L=11.7μF, and the value of the capacitance C=8.4nF. Receiving signal transforms to digit signal after amplifying, detecting and reshaping.

1.1.3 The electrical unit

When stepping motor rotates, phase current declines with the increase of frequency by reverse electromotive force, which declines the moment. Precision of normal stepping motor is $3\sim5\%$ of stepping angle. By adapting method of three-phases and six-beats, error can be constrained below 2%, satisfying requirement of design.

1.2 Choice of instrument

1.2.1 Selection and introduce of SCM

Because of the small volume of submarine and the inconvenience of changing batteries under water, the system uses low power consumption SCM MSP430F449 of TI. MSP430F449 is applied in broad fields with characters such as low power consumption, dependable working system, abundant peripherals, and convenience of debugging.

1.2.2 Selection and introduction of power amplifier chip

System design using ASK modulation. Power amplifier chip is TI's current feedback operational amplifier OPA561. The chip output current is high; Put the chip when welding sheet metal to the adapter board bottom connected with heat sink of the shed heat easily.

1.2.3 The selection and introduction of rectifier chip

On decoding ASK modulated signals, rectification is applied to acquire the digital signal. The system adopts the TLC372 Dual Differential Comparator by TI. TLC372 is a low-power comparator. Its input impedance is high so it is unnecessary for a buffer. Extra-low input offset voltage diminishes the noise of transited wave output to the lowest.
1.3 The demonstration of design scheme

1.3.1 The selection of coding and decoding method

Design No.1
The wireless communication system consists of coding and decoding. It is realized by serial port correspondence. The block schematic diagram is as below:

Fig.1.1.Block schematic diagram of design No.1 in wireless communication

Design No.2
The communication system consists of coding chip PT2262 and decoding chip PT2272. The power consumption is low. Despite that the communication channel capacity is not big, the reliability of data transmitting increases. The block schematic diagram is as below:

Fig.1.2.Block schematic diagram of design No.2

All factors considered, Design No.2 meets the design requirements that it is adopted.

1.3.2 The selection of generating methods of operating signals

Plan A Direct Digital Synthesizer (DDS)
When a positive edge of reference frequency arrives, the phase accumulator increases by one according to the length of frequency control word K, which result searches the sine table. After D/A converting and filtering, bear the final output waves. The DDS frequency band is wide but the output signals of D/A are cascaded which need a filter to rectify.

Plan B Output the PWM from internal timer A of MSP430F449
The timer consists of the timer, the capture/comparator, and output unit. To realize the wanted signals, set timer A at increasing counting mode (mode 7) and the capture/comparator register 0 to control the period of PWM waves. The output signals are then filtered to remove high order harmonics.
Both plans considered, plan B is used to produce the working signal.

1.3.3 The selection of modulation method

While AM modulation is low on the anti-interference capability and FM modulation circuit complicated, ASK modulation is the best choice for the modulation-demodulation circuit is easy and the power cost is low.

2. The realization of the system

2.1 Hardware design

2.1.1 Circuit block diagram

The circuit block diagram to the system is shown below:

![Fig.2.1. The whole block diagram of the system](image)

2.1.2 The design of each function module

The continental rise unit consists of modulation and the amplifier.

A. Modulation part
The continental rise unit controls the analog switch CD4051 by using the output of PT2262, thus realize ASK modulation.

B. Amplifier Part
In order to increase the transmission power of the antenna, adopt two-stage amplification. Former amplifier use current feedback OPA561 to drive the latter amplifier, the latter stage amplifier adopts C class resonant amplifiers.

The submarine consists of receiving amplification, demodulation and infrared emission.

A. Receiving Amplification Part
The coil iron inside the radio kit work as receiving antenna. The design adopted AD620 as the former amplifier and LM6171 as the latter amplifier.

B. Demodulation Part
The circuit is made up of diode circuits and capacitance resistors. In the figure2.5, diode D2 compensates for D1 conduction pressure drop. The TLC372 Hysteresis loopback comparator can effectively avoid the leaping and wobble. Decoding part adopts PT2272
- L4 as decoding chip.
C. Infrared Emission Part
Chip PT2262-1R consists of the carrier oscillator, encoder and transmission unit. Motor unit consists of infrared decoding part and motor driver.
D. Infrared Decoding Part
The infrared receiver needs one pre-amplifier to ensure the input signal amplitude of PT2272 is big enough to be correctly demodulated.

2.2 Software Design

2.2.1 Software Design Thought

Continental rise unit, motor unit and submarine these three parts adopt microcontroller as the control core to maintain the accuracy of the data transfer. Flow charts as follows:

2.2.2 Software design cautions

Msp430 pins are prone to coupling interference, therefore right when entering interruption, interruption should be disabled and unused pins set as output state. The land-based unit sends signals consecutively to reduce error to the least. Delay is used to compromise to the infrared speed limit of identification.

3. Test and analysis

3.1 Test methods and results

Test method: When the distance between water surface and antenna is within 1m, control the moving mode and direction of the submarine. Increase the distance.
The results: The longest effective distance is 3m. The error is within 2%. The moving directions and depth can be controlled.
In the test, rulers and stopwatches introduces reading error. The step degree of motor is 1.5 degrees which affects the stability of level rotating.

3.2 Further improve the design

Amplifier 2SC9018 max output power is 0.5W which largely limits the transmitting power of land-based unit. OPA561 did not actually amplifies current which should be modified. Furthermore, without proper containers, the size is a little beyond requirements.