**Design of the High Accuracy Ultrasonic Flowmeter Based on TDC - GP22**

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**Abstract:** Inorder to solve the high precision ultrasonic wave heat meter measurement of heat, on the basis of the principle of ultrasonic heat meter flow measurement, using the TDC - GP22 which is produced by ACAM company in Germany, it is a chip to realize high precision measurement of temperature and time based on digital conversion technology of low power consumption and high precision measurement. Issue will choose the STM32F103 chip with low power consumption MCU as the core which is produced by ST Microelectronics (ST) company, completed the system hardware, software design, realized the high precision, low power consumption and low cost of ultrasonic heat meter design, after a lot of flow measurement results show that the heat meter with high accuracy and can meet the requirements of heat meter industry standard grade 2, so it has a broad application prospect.

**Key words:**Ultrasonic wave;Heat meter; TDC-GP22；STM32F103；Low power；High precision

**Introduction**

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Mechanical and electromagnetic calorimeter seriously affect water quality, resulting in inaccurate measurements and short life. And with the develop of ultrasonic flow measurement technology ultrasonic heat meter, ultrasonicheat meter overcomes the defectsabove the two types ofheat meter [1]. I use the time difference method principle, the choice of ultra-low power STM32F103 microcontroller with high-precision timing chip TDC-GP22, designed a long life, high precision, low power consumption and low cost ultrasonic heat meter. It is the use of a pair of ultrasonic transducers send and receive ultrasonic signals, by timing chip TDC-GP22 measured ultrasonic wave in the medium and the downstream propagation time difference countercurrent indirect estimates velocity and flow [1-2]. Finally, the K coefficient of flow and temperature difference calculated by integrating the heat.

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**Measuring Principle**

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To calculate heat, we choosethe method of K coefficient, it is calculated as follows:

 (1)

Wherein, Q is heat, k is the thermal coefficient, ΔT is the temperature difference between the import and export of water, F is the flow rate flowing through the heat meter.

Heat coefficient K is changing if the heating water flow under different pressure and temperature, Pressure within the allowable range changes had little effect on the heat transfer coefficient K, in fact, the heat meter is put inside pipe, The pressure of this case is almost constant, So you just need to control the variable temperature, coefficient of heat from the table to find the corresponding coefficient of heat. That is to say, to be able to accurately measuring pipeline import and export of water temperature and water flow to become the top priority of the thesis [3].
Ultrasonic Heat energy table (Ultrasonic Heat meter) is based on the measured water temperature difference and flow integral and calculate the Heat energy supply users [4]. Flow measurement of indirect measurement method, with the aid of a pair of ultrasonic transducer to measure ultrasonic propagation in the well and spread in the under time difference and the flow rate, and then according to the water flow with velocity formula is derived out flow [5]. Temperature measurement part is connected by pin the PT3 and PT41kΩresistance of capacitor discharge time determined, the capacitance will be respectively to discharge the reference resistor and PT1000.

The flow calculation is indirectly calculated by using the jet lag. The ultrasonic heat meter has different structure and the measuring accuracy is also different, according to the different positioning of the ultrasonic transducer in the pipes, can be divided into direct type, oblique type and reflection type structure [4]. After reading literature analysis contrast, reflective structure induced no change in the direction of flow measurement accuracy is not enough at the same time, the structure of flow of the pipe to the same as the ultrasonic transmission in the pipe, and reduce the error, and ultrasonic transmission distance is long enough, so it provides more accurate measuring conditions for the time difference method.

Ultrasonic heat meter flow measurement principle is shown in figure 1.



Fig1. Ultrasonic heat meter flow measurement schematic

Assuming that measuring pipe diameter is D, straight line between A and B ultrasonic transducer of length is L, ultrasonic transducer and the distance between the reflection column is S, water flow rate is V, ultrasonic velocity is C [6].

From transducer A to B, the ultrasonic transmission (downstream) Time:

 (2)

From transducer B to A, the ultrasonic transmission (countercurrent) Time:

 (3)

The ultrasonic transmission process in smooth flow and flow under the time difference :

 (4)
 Speed ultrasonic velocity in water is about 1500m / s, far greater than water, so the equation simplifies to:

 (5)

Final flow rate can be obtained:

 (6)

Instantaneous flow:

 (7)

Where K is the flow rate correction factor.

As shown in figure 2, the chip of TDC-GP22 has a PICOS-TRAIN which is based temperature measurement unit. It can provide high precision, low power consumption of temperature measurement. The chip to realize temperature measurement is based on the pin PT3 and PT4 connected on a 1KΩresistor to capacitance discharge time, the capacitance will be respectively to discharge the reference resistor and PT1000. 23 and 24 pin connected to measure the precision of 0.004℃for platinum resistance temperature sensor PT1000 [7]. High precision of the TDC time to digital conversion to the capacitor discharge time accurately recorded, measurement accuracy can reach 2 us. According to the formula:

 (8)

Where TN is the measured resistance of the discharge time, Tref is discharge time for the reference resistor, Rref is a reference resistance value, RN is the measured resistance value. Then DSP digital processor, according to the ratio of discharge times the resistance ratio can be obtained, and the result is stored in the register. STM32 microcontroller via SPI communication interface to read the measurement results.
 We can obtain the corresponding temperature according to the compensation formula :
  (9)
 Wherein R\_Ratio is the resistance ratio.
 Because of the single chip temperature measurement scheme is adopted to avoid the conventional constant current source circuit and control circuit, improve the stability and precision of the circuit, and resistance and base resistance is connected on the same charge and discharge capacitance, overcome the influence of temperature drift of resistance measurement, realize the measurement of resistance [8].

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Fig2.TDC-GP22 peripheral circuit

**The Hardware Design of AHeat Meter**

Power system adopts B2405-3 w and AMS1117-3.3 V chip, chip to convert voltage 24 V to 3.3 V voltage, power supply voltage for each chip. System with self-check function, the system can enter the self-inspection after initialization procedure, system failure is detected, the corresponding fault indicator light is lit up, at the same time a buzzer alarm prompt. Ultrasonic transducer and temperature sensors and TDC - GP22 is linked together. Through the SPI interface connected to the STM32 microcontroller. STM32 microcontroller through the SPI communication interface connection analog-to-digital conversion module, LCD through the I/O port connection. Heat meter hardware system is shown in figure 3.

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Fig3. heat meter hardware structure

**The Software Design Of The Heat Meter**

System software is mainly to complete the single chip microcomputer control of TDC - GP22 and according to the above formula is derived to TDC - GP22 measured ultrasonic transmission time and the measured pipe into the data calculated by monitoring the return water temperature. Ultrasonic heat meter processes as shown in figure 4.



Fig4.ultrasonic heat meter of the main program flow chart

With the aid of TDC-GP22 can simply to measure temperature and time. Through the SPI interface, single chip microcomputer to measure instruction to the TDC-GP22, then according to the instruction of TDC-GP22 can automatically measure the resistance from capacitor charging time and the ultrasonic transmission time, finally through the results registers to store the results. After completion of the above process, MCU receives the interrupt request signal from the TDC-GP22, finally MCU to complete the processing of the measurement result.

TDC-GP22 receives and configuration from STM32F103 microcontroller control signals, including the clock setting, measurement mode, channel number and calibration Settings, and so on, and then initialize [10]. The FIRE-UP pin of chip TDC-GP22 launch ultrasonic wave trigger signal after receiving START pin, TDC control unit began to count, when the FIRE-DOWN pin of the TDC-GP22 receive back to the ultrasonic trigger signal, a time cycle is complete. After the first wave test is completed, the comparator automatically back to zero point for the next measurement.

**Test And Result Analysis**

Because of the heat meter calibration is more complex, therefore the TDC - GP22 ultrasonic heat meter test data and standard instrument for temperature test data are compared, the results are shown in table 1.

Table 1 temperature test results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Entrance to the standard temperature（℃） | Export standard temperature（℃） | True temperature difference（℃） | According to difference in temperature（℃） | Error（℃） |
| 89.673 | 48.962 | 40.711 | 40.73 | 0.019 |
| 65.705 | 52.318 | 13.387 | 13.410 | 0.023 |
| 57.283 | 52.071 | 5.213 | 5.220 | 0.007 |

Flow test was conducted in the heat meter calibration device, flow testing in accordance with the level 2 table flow sensor test accuracy formula.

  (10)

Among them, the qp for common flow, subject to choose the 20 nominal diameter test tube, reference CJ128-2007 industry standards, DN20 corresponding qp value is 2.5 m3/h, test results under the condition of 50℃, such as in table 2.

Table 2 flow test results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Flow reference point（m3 /h） | The cumulative flow real value（m3） | The cumulative flow display value（m3） | Relative error（％） | Accuracy（％） |
| 0.035 | 0.0041521 | 0.004173 | 0.5034 | 2.429 |
| 0.057 | 0.0050372 | 0.005072 | 0.6909 | 2.877 |
| 0.130 | 0.0107065 | 0.010803 | 0.9098 | 2.385 |
| 0.521 | 0.4718315 | 0.471914 | 0.0175 | 2.096 |
| 2.073 | 0.0954719 | 0.095512 | 0.0420 | 2.024 |

Test results show that the ultrasonic heat meter measurement data is accurate, the measured data and the reading of the calibration system differs little, to less than 0.03℃temperature error has broken the traditional measurement accuracy. Through the actual test of heating pipes, we found that based on TDC-GP22 ultrasonic heat meter measuring accuracy is higher, the error is small. Under the rules of environmental test, reached the industry standard CJ128-2007 for level 2 tables in the measurement accuracy requirements. At the same time, through the test and estimate system power consumption, heat meter dormant when the current is less than 4.7 uA, average working current is less than 8.5 uA, the average power consumption is less than 0.09 mW. Comparison results of document [9]: test and estimate the system power consumption, testing time for 1 s/time, sleep time for 999 ms, the average power consumption of about 0.13 mW, heat meter in the state of work maximum current shall not exceed 36 uA, dormant when the current is not more than 6.5 uA. Above all, the author not only design of ultrasonic heat tables on the precision of the measurement had the very big enhancement, but also with low power consumption.

**Conclusion**

The author in view of the social needs, and some problems of the heat meter on the market, we adopt the reflection type structure, using the method of time difference principle, combining Acam company makes heat meter timing chip dedicated GP22 designed a new ultrasonic heat meter high precision low power consumption. Experimental data show that the ultrasonic heat energy table has good measurement results, and solved the short service life of the traditional heat meter, high cost, power consumption and high measuring accuracy, the disadvantage of low effectively reduced the difficulty of system design, suitable for a wide range of promotion and a broad application prospect.

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**Reference**

1. S. H. SHUO, Z. LIU and J. SUN: The Study of errors in ultrasonic heat meter measurements under caused by impurities of water -based on ultrasonic attenuation [J]. Journal of Hydrodynamics, vol. 27(2015) No1, p.141.
2. M. YANG, L. ZHANG and SIMON C K: Gabor feature based robust representation and classification for face recognition with Gabor occlusion dictionary [J]. Journal of Pattern recognition, vol. 46(2013) No7, p.186.
3. C. Liang, T. Yuan: Ultrasonic heat meter based on TDC-GP2 [J]. Instrument technique and sensor, vol. 16-17(2010) No10, p.14.
4. W. T. Ju: Design and development of ultrasonic heat meter [D]. Zhejiang: zhejiang university, (2008).
5. X. N. Wang, L. H. Sun and C. Song: Correction algorithm of time difference method ultrasonic heat meter measurement flow [J]. Modern manufacturing engineering, vol. 36(2013) No6, p.101.
6. Q. Yong: Design and development of ultrasonic heat meter [D]. Nanjing: nanjing university of science and technology,( 2014).
7. Y. Xiong: Based on TDC-GP21 high-precision low-power ultrasonic heat meter design [J]. Journal of measurement and control technology and instrument, vol. 9(2015) No7, p.61.
8. H. J. TIAN, J. Zhang: High accuracy intelligent temperature measurement system based on RDC design [J]. Journal of manufacturing automation,vol. 2(2015) No12, p.139.
9. J. Hou, W. J. Zhang: Based on TDC-GP2 a new type of ultrasonic GP1 high precision timer heat energy table [J]. Journal of shenyang architecture university, vol. 24(2008) No1, p.167.
10. Y. P. Mei, M. J. Zhang: The application of TDC-GP21 in ultrasonic heat meter [J]. Instrument technique and sensor, vol. 15(2012) No 95, p.39.