

Research and application of time relay calibration device

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Abstract

This paper introduces the design principle and application of time interval measuring instrument. A simple calibration device basing on the powerful data processing ability of single chip microcomputer, has strong data processing capability for time relay is designed Which solves the traceability problem of various types of time relays, and realizes the automatic calibration of time relays, the uncertainty of measurement process is analyzed and studied. Not only be used to calibrate the time relay, but also be used for testing industrial digital electronic detonators and other initiating explosive devices.

Keyword

single chip microcomputer
Time relay
electronic detonator
initiating explosive device
uncertainty

I. INTRODUCTION

Time relay is widely used in delay time control of automatic control circuit, its design principles are different. There are generally four types of time relays.

For example, power on delay type, power off delay type, on delay type, off delay type, etc. Nowadays, although there are time relay delay time detector, digital electric stopwatch, digital millisecond meter, time interval measuring instrument and other equipment with time relay contact on-off time interval detection function^[1].

However, in the process of measurement and calibration, different tooling is loaded to calibrate different types of time relays. The operation mode is complex, error prone, low efficiency and low measurement accuracy. The purpose of automatic calibration cannot be achieved.

The device has excellent promotion value, not only be used for the calibration of time relay, but also be used for testing industrial digital electronic detonators and other initiating explosive devices.

II. MEASUREMENT PRINCIPLE

The measurement principle of timing test system is shown in Figure 1.

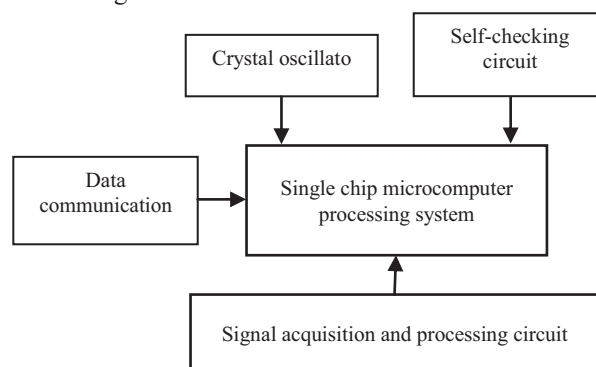


Fig. 1. measurement principle block diagram

According to JJF1282-2011 calibration specification for electronic time relay, calibration device of time relay is studied. The device can calibrate the delay time of time relay.

Test system is mainly composed of signal acquisition and processing circuit, single chip microcomputer processing system, crystal oscillator, self checking circuit, display output, etc.

III. DESIGN IDEAS

A. Calibration of power-on delay time relay

Calibration of power-on time delay type time relay, As shown in Figure 2. It is mainly designed based on the function of closing action time of a switch, when the S switch is closed, start timing, normally closed contact, S

switch off stop timing ,normally closed contact^[2].

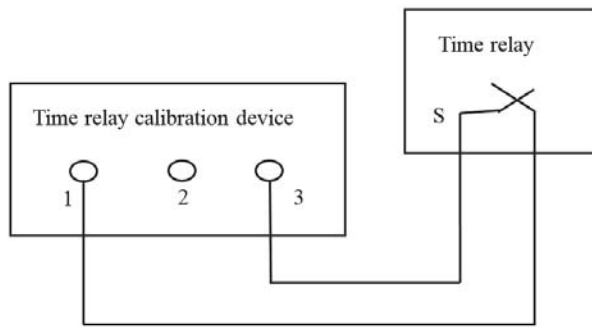


Fig. 2. Calibration diagram of power-on delay

B. Calibration of power-off delay time relay

Calibration of power-off delay time relay, it is mainly designed with the function of the disconnection time difference between the two switches, start timing when S1 switch is off, power on switch, S2 switch off stop timing , normally closed contact, is shown in Figure 3.

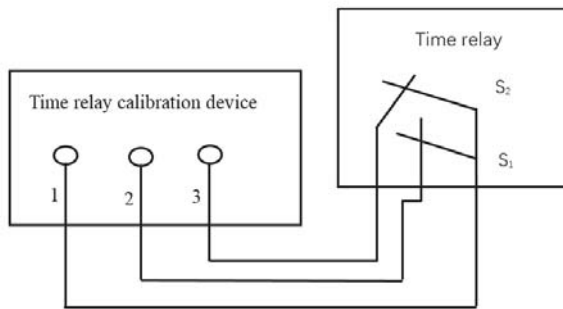


Fig. 3. Calibration diagram of power-off delay time

C. Calibration of on-delay time relay

Calibration of on-delay time relay, the calibration of on-delay time relay is mainly designed based on the function of closing action time of a switch with additional on conditions. The delay does not start when only the relay control power is turned on, only when an additional signal is switched on again, or an electronic time relay that starts delay only after a certain line is connected^[3].

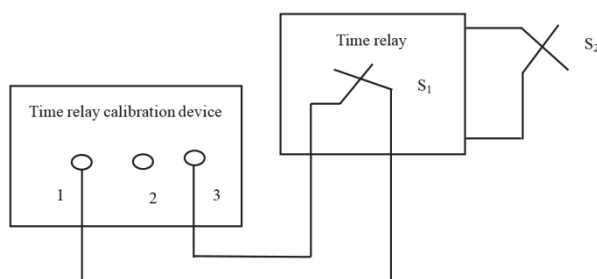


Fig. 4. calibration diagram of on-delay

D. Calibration of disconnect time delay relay

Calibration of disconnect time delay type time relay, it is mainly designed with the function of closing action

time of a switch with additional opening conditions, the relay is disconnecting an external signal, or an electronic time relay that starts delaying after a certain line. The control power supply of the relay is continuously switched on during the whole delay cycle^[4].

As shown in Figure 4, the relay is connected to the control power supply, when accessory condition switch S2 is off, switch S1 (normally closed contact) is on. The normally closed contact is closed to start timing, and the switch S1 (normally closed contact) is disconnected to stop timing.

E. Test of industrial digital electronic detonator

As shown in Figure 5, we delay the initiation time by setting the tested industrial digital electronic detonator,after completing the identification and detection of digital electronic detonator through network communication,then send the initiation command of digital electronic detonator^[5].

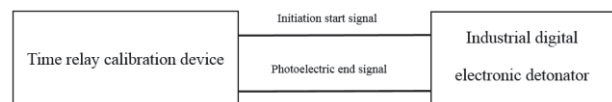


Fig. 5. Test diagram of industrial digital

Measuring the time interval between sending initiation command start signal and initiation end signal,the test of digital electronic detonators is generally completed in a safe blasting box.The industrial digital electronic detonator tester is connected to the blasting box through photoelectric sensor, and connected with it through the data line interface.

The time interval generator outputs the standard time interval, calibrates the industrial digital electric detonator electric parameter tester, and calculates the delay measurement error.

According to the industry standard, the technical requirements for industrial digital electronic detonator products are as follows.

The delay time is not more than 150 ms and the maximum allowable error is not more than ± 1.5 ms.

The delay time is more than 150 ms and the maximum allowable error is less than $\pm 1\%$.

The maximum allowable error of the calibration device for the electric parameter tester of the industrial digital electronic detonator shall at least satisfy the following requirements^[6].

when the delay time is less than 150 ms, the maximum allowable error of the measuring standard instrument is ± 0.05 ms.

when the delay time is more than 150 ms, the maximum allowable error of the measuring standard instrument is $\pm 0.02\%$.

IV. SYSTEM DESIGN

The timing test system is mainly composed of front-end signal generation and conditioning module, time measurement circuit module and MCU control

module. The time measurement circuit module is realized by CPLD. The structure of the timing test system is shown in Figure 6.

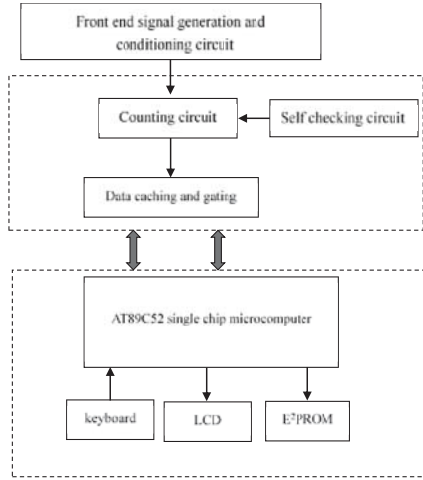


Fig. 6. structure diagram of timing test system

The essence of front-end signal generation and conditioning module measuring time relay is to quickly and accurately measure the hourly interval between multiple adjacent pulses through timing method.

As shown in Figure 7, the existing program-controlled DC power supply output voltage regulation speed is slow (generally in tens of Ms Level), can not quickly set up the set-up voltage. Based on the existing program-controlled DC voltage, the device can increase the MOS switch control output, and can set up the set-up voltage quickly (in tens of microseconds level).

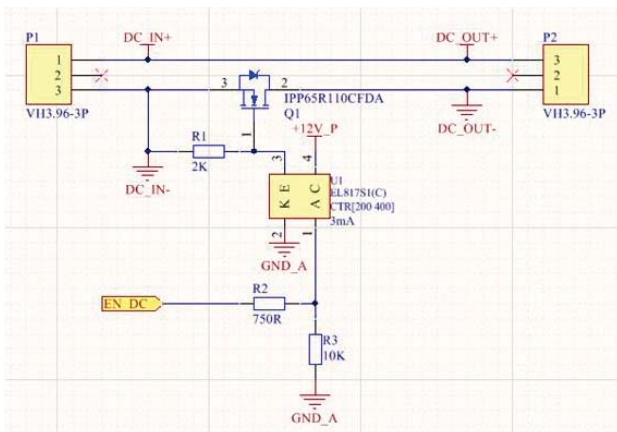


Fig. 7. Quick Power Supply schematic diagram

- P1 is the variable DC input.
 - P2 is variable DC power output Q1 is Mos for switching on and off DC signal.
 - R1 is MOS discharge resistance (adjustable switching speed).
 - U1 is optocoupler for isolating control signal.
 - EN_DC is DC output enable signal.
 - TTL level, high level effective.
- As shown in Figure 8, the trigger circuit is ready to work, timing circuit module, between the start and end of

the counter, the time scale pulse enters the corresponding counter through the counting circuit, the counter starts counting. When the contacts are momentarily connected, the first shaping circuit outputs a single pulse as the counting on signal of the first single pulse as the counter, when the contacts are disconnected, the generated signal passes through the single pulse output by the shaping circuit as the counting end signal.

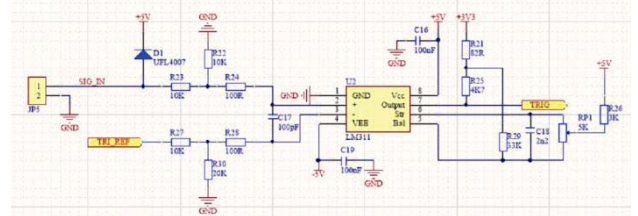


Fig. 8. Trigger circuit

At the same time, send a counting end signal to the single chip microcomputer for inquiry. The counting circuit mainly counts the pulse of contact delay, the number N counted by the counter multiplied by the cycle T of the clock pulse is the time interval between contact delays^[7].

The time interval data is stored in each counter respectively before the instrument is reset, the single chip microcomputer gates the counter and collects data. The self-test circuit is mainly moved in by serial, move out the register in parallel and output pulse signal to the counter for counting, so as to detect whether the counting circuit can work normally.

After the measurement is completed, the front-end time measurement count ends, when the single chip microcomputer detects the transmitted signal, it will gate the counting results and collect the data, the collected data is calculated and saved, and then displayed by LCD controlled by keyboard.

V. TEST DATA ANALYSIS

In order to verify the metering characteristics of the time relay calibration device, In this paper, SF2001-1 stopwatch calibrator is selected as the verification standard.

Table 1. test data time relay

Test point	Measured value (s)						average value	standard deviation
	one	two	three	four	five	six		
100ms	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.10000	0.00000
1s	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	0.00000
10s	10.00000	10.00000	10.00000	10.00000	10.00000	10.00000	10.00000	0.00000
100s	100.00000	100.00000	100.00000	100.00000	100.00000	100.00000	100.00000	0.00000
1000s	1000.00000	1000.00000	1000.00000	1000.00000	1000.00000	1000.00000	1000.00000	0.00000

The standard has been traceable and qualified by the superior measurement organization for many years and has good stability. From 1ms to 9999 s, according to different time bases, select any test point for 100 ms, 1 s, 10 s, 100 s and 1000 s for calibration.

The test data are shown in Table 1. According to the test data, within the measurement range from 100 ms to 9999

s, the maximum allowable error of the time relay calibration device designed in this paper is better than $1 \times 10^{-6}T$, Maximum allowable error and stability of calibration device. All can meet the requirements of measurement standards in calibration specifications.

VI. APPLICATION

A. testing of initiating explosive devices

In initiating explosive device test, the detonation velocity of explosives has always been considered as an important index to measure the performance of explosives. How to accurately measure the detonation velocity of explosives has practical guiding significance in scientific research, high-quality production and rational use.

Through the developed time interval measuring instrument, it can realize the rapid and accurate test of the action time of various products in the civil explosive industry, such as detonator, detonator, electric detonator, explosive, igniter and so on.

The photoelectric conversion circuit uses light as the medium to transmit electrical signals. After photoelectric conversion, the collected electrical signals are amplified, filtered and level converted. After photoelectric conversion, there may be some noise in the output voltage signal, which needs to be suppressed.

The photoelectric sensor designed in this way is generally used to test the detonator. For the test of Nonel Detonator, the other end needs to be a sound sensor, and the test of Nonel Detonator can be realized through the acoustic electric conversion circuit. For the test of explosives and electric detonators, one end is the current trigger circuit and the other end is the sound sensor trigger circuit^[7].

The design of the calibration delay time of the industrial digital electronic detonator simulator is shown in figure 6

The program memory control module is connected with the high precision time interval measuring instrument as the delay start signal, and the delay time is set. After verifying the password is correct, the start signal starts to time, the delay time ends, and the energy storage capacitor starts to discharge, the analog bridgewire circuit has an instant initiation capacitance current, and the analog bridgewire resistance is connected in parallel with a high-precision time interval measuring instrument to turn on the delay end signal or trigger the end signal through a photoelectric sensor, high precision time interval measuring instrument and industrial digital electronic detonator electric parameter measuring instrument simultaneously measure delay time, calculate delay time error.

B. calibration of time parameters of automatic detection system for fire emergency lamps

According to GB17945-2010 fire emergency lighting and evacuation indication system, the automatic detection system tester of fire emergency lamps is the equipment for detecting the lighting system of fire emergency lamps. The emergency conversion time of fire emergency lighting system shall not be greater than 0.5 s, and that of

the system used in high-risk areas shall not be greater than 0.03 s.

This requires that the emergency time of the tester of the automatic detection system of fire emergency lamps is better than that of the fire emergency lighting system. The emergency conversion time of the tester of the automatic detection system of fire emergency lamps is calibrated by using the developed time interval measuring instrument.

For the calibration of emergency switching time, one end is connected with the start switch (solid-state relay). Using the switching response speed characteristics of the solid-state relay, when there is a sudden power failure, trigger the timing start circuit and start the start signal. The other end is connected with a photosensitive triode. When the emergency light is on instantaneously, the timing end circuit is triggered to start the end signal.

VII. UNCERTAINTY

For example, taking 10s measurement point to analyze the source of uncertainty of time relay calibration device, The allowable error limit of stopwatch calibrator, Uncertainty component caused by inaccurate time base of calibration device and measurement repeatability.

A. Uncertainty component introduced by allowable error limit of stopwatch calibrator

According to the technical indicators of the stopwatch calibrator, the maximum allowable error of the time interval: $\pm (1 \times 10^{-7} \times T_0 + 3 \mu s)$, which is qualified after verification and evaluated according to class B. Assuming uniform distribution and inclusion factor k be equal to 2, uncertainty is equal to $2.3 \mu s$.

B. Uncertainty introduced by inaccurate time base of calibration device

Since the time relay calibration device in different verification points, it is necessary to select different time bases for measurement. If the time base of the selected 10s point is 0.001 s and the half width of the interval is 0.0005s, according to the class B evaluation method, assuming uniform distribution, k be equal to 2, uncertainty is equal to 0.29 ms.

C. Uncertainty component introduced by measurement repeatability

Under the specified conditions, use the stopwatch calibrator to make 6 repeated measurements on the calibration device at 10 s, testing data are shown in Table 1. According to class a evaluation, the standard uncertainty introduced is calculated by Bessel formula, uncertainty is equal to 0.02 ms.

D. Synthetic standard uncertainty

The above standard uncertainty components are not related to each other, so the synthetic standard uncertainty is equal to 0.3 ms.

E. Extended uncertainty

Take k be equal to 2, Extended uncertainty be equal to

0.6 ms.

VIII. CONCLUSION

This paper designs a simple time relay calibration device according to JJF1282-2011 electronic time relay calibration specification, which is from 0.1 ms to 9999 s, maximum allowable error: $\pm (1 \times 10^{-6}T + 0.1 \mu\text{s})$, accuracy of crystal oscillator frequency is better than 1×10^{-6} .

The test data results show that the measurement range and maximum allowable error of the instrument can meet the requirements of the measurement standard in the specification.

It can be used to calibrate the delay error of time relays such as power on delay type, power off delay type, upper delay type and lower delay type, and can also be used for the test of industrial digital electronic detonators and other initiating devices.

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