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Source:

Verification regulation of time interval measuring instrument with digital indication (trial usage)

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Prepared by	Approved
Quality Systems Group of 23rd ITTC	23rd ITTC 2002
Date	Date

Calibration of Chronometers with Digital Indication

PURPOSE

This working instruction can be applied to the calibration of a time interval-measuring instrument with digital indication with a measuring range larger than 10 ns on new products, also for products in the use and after repair.

WORK INSTRUCTION

1. Introduction

Chronometer with digital indication means a time interval measuring instrument with numbers for indicating the time interval measuring value.

The fundamental principle of these chronometers is that the unit time (time base), the accuracy of which is known, is used to measure the time interval. The measuring results are recorded and displayed by an electronic counter. The selected time base is generated by division or doubling of the frequency of a quartz crystal oscillator .

The principle block-diagram is shown in Fig. 1.

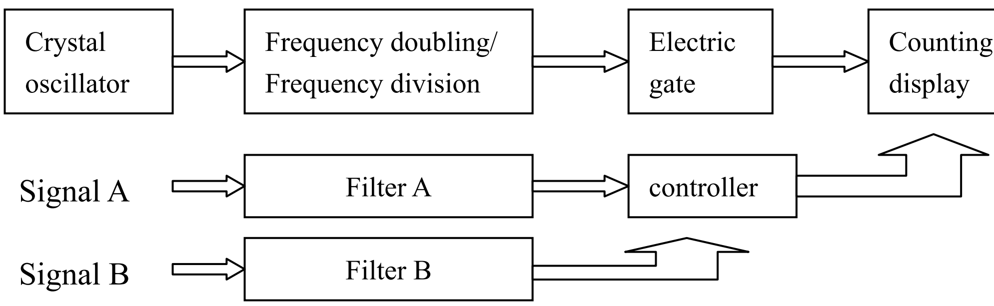


Fig. 1 Fundamental diagram of the time interval measuring instrument with digital indication

These **chronometers** are used for the following measurements:

- time interval between two electronic pulses (rising or falling edge)
- time of one single electronic pulse
- time interval between closing and (or) opening of two mechanical contacts
- duration of closing or opening for a single mechanical contact
- time interval between the actions of a single electronic pulse and a single mechanical contact

2. Technical Requirements

2.1 Interior Crystal Oscillator

Frequency fluctuation: $10^{-6} \sim 10^{-10}$
Accuracy of frequency: $10^{-5} \sim 10^{-9}$

2.2 Time Interval Measuring

Time base: 10ns ~ 100ms
Measuring range: 10ns ~1d
The measuring error may be calculated by the following formula

Measuring error = $T \times$ accuracy of the frequency of crystal oscillation + trigger error + τ_0
Where:
T measured time interval
τ_0 selected time base during measuring

3. Calibration Conditions

3.1 Environmental Conditions

3.1.1 Environmental temperature: can be between 10 ℃ ~30 ℃. The temperature variation should not exceed ±2℃ during the calibration.
3.1.2 Relative humidity: (65±15)%
3.1.3 Power supply: ~Voltage(1±10%)V
3.1.4 No strong electro-magnetic interference

3.2 Standard equipment for calibration

3.2.1 Standard time interval generator
3.2.1.1 It has two outputs. The signal pattern should be:

- The interval of two positive and (or) negative electronic pulses
- single positive or negative electric pulse width
- the interval between the open circuit and (or) the short circuit of two output terminals
- the duration of the open circuit or the short circuit of the single output terminal

3.2.1.2 The rise or fall time of the pulse must be less than one-fifth of the minimum resolution of the calibrated **chronometer**.
3.2.1.3 The range of the output time interval should meet the measuring requirements of the calibrated **chronometer**s.
3.2.1.4 The error of the output time interval should be less than or equal to one-tenth of the measuring error of the calibrated **chronometer**s.
3.2.2 Reference frequency standard
This can be a highly stable crystal oscillator or an atomic frequency standard. The frequency fluctuation and the frequency accuracy must be ten times higher than the relevant indexes of the calibrated **chronometer**.
3.2.3 Frequency Standard Comparator
Able to compare the functions and the technical indexes for realizing the calibration of the crystal oscillation index of the calibrated **chronometer**.
3.2.4 Electronic counter
Able to measure the frequency in the range from 1 Hz to 10 MHz.

4. Subject and method of the calibration

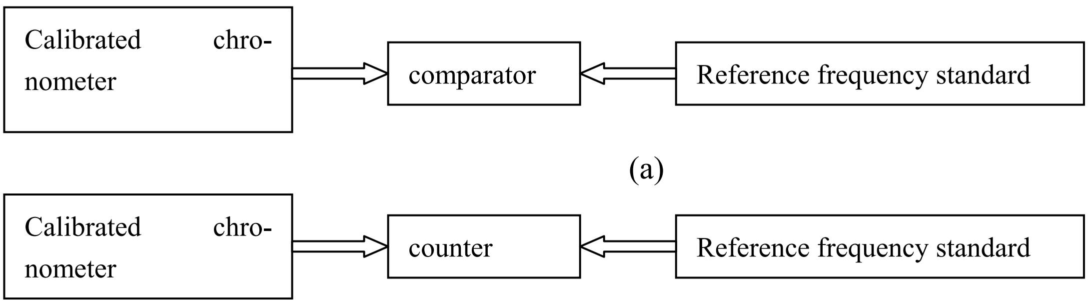
4.1 Examination of the exterior and during normal working

4.1.1 The calibrated **chronometer** should not have any mechanical damages, which could affect the normal use of the instrument. All the control switches should work easily and reliably.

4.1.2 Switch the current on. A standard time interval is deliberately given by a standard time interval generator for checking the variety of functions in the measuring range of the calibrated **chronometer.**

4.2 Calibration of the interior crystal oscillation

The connection of the instruments is shown in Fig. 2.



(b)

Fig. 2 Connection diagram of the instruments for calibrating the interior crystal oscillation

If the accuracy of the frequency measurement can meet the calibration requirement when the gate time of the electronic counter is 10s, the version shown in Fig. 2 (b) may be selected for the calibration. The reference frequency standard can be used as the input of the external standard for the electronic counter.

4.2.1 Calibration of the frequency fluctuation

After the **chronometer** has been warmed up according to it's specification the measurements can be started. One measurement per hour, totally N times ($N = 4$, 8 or 24). The measuring sample time can be taken as 10s.

Three values each time. The frequency fluctuation value can be calculated the formulae (1) or (2).

$$S = \frac{\bar{f}_{max} - \bar{f}_{min}}{f_0} \qquad (1)$$

$$\bar{f} = \frac{1}{3}\sum_{i=1}^{3} f_i$$

where:

f_i measured value of each sample by use of the electronic counter.

f_0 nominal value of the output frequency for the calibrated crystal oscillation.

Or: $S = \overline{y_{\max}(\tau)} - \overline{y_{\min}(\tau)}$ (2)

$$\bar{y}(\tau) = \frac{1}{3}\sum_{i=1}^{3} y_i(\tau)$$

where:

$y_i(\tau)$ average relative frequency deviation directly measured using a comparator of the frequency standard.

4.2.2 Alignment of the frequency accuracy

To ensure the reliability of the calibration result during the process the accuracy of the crystal oscillation must be restricted to a value less than one-tenth of the frequency fluctuation value.

The frequency accuracy may be calculated by formula (3) using the data of the frequency fluctuation calibration.

$$A = \frac{\left|\bar{f} - f_0\right|_{\max}}{f_0} \tag{3}$$

If the result of the calculation is better than the required accuracy, the crystal oscillating frequency need not be adjusted. Otherwise it must be aligned.

When being adjusted the sampling time can be taken as 10s and only one measurement is sufficient. The frequency accuracy may be calculated by formula (4):

$$A = \frac{\left|\bar{f} - f_0\right|}{f_0} \tag{4}$$

The crystal oscillation frequency must be aligned to the same order as that of the frequency fluctuation. However, the accuracy ought to be noted on the the calibration certificate.

If the calibrated **chronometer** does not have an output of the crystal oscillation, the calibration of the crystal oscillation norm can be carried out on the basis of the method given in the Appendix 2.

4.3 Calibration of the measuring error

4.3.1 Selection of the calibration values and the error calculation.

The measurement begins at the minimum value, followed by a series of values ten times greater each time and then ends with the maximum value.

If the measuring range of the **chronometer** is divided into sub-ranges, the calibration value at the lowest sub-range can be selected according to the above mentioned method. For the calibration only the maximum values of the other sub-ranges need to be taken.

The measurement must be done three times for each calibration value. The arithmetic mean value will be taken as the measuring value.

The measuring error can be calculated by formula (5):

$$\Delta T = \overline{T_i} - T_0 \qquad (5)$$

$$\overline{T_i} = \frac{1}{3}\sum_{i=1}^{3} T_i$$

where:

T_i value which is measured every time.

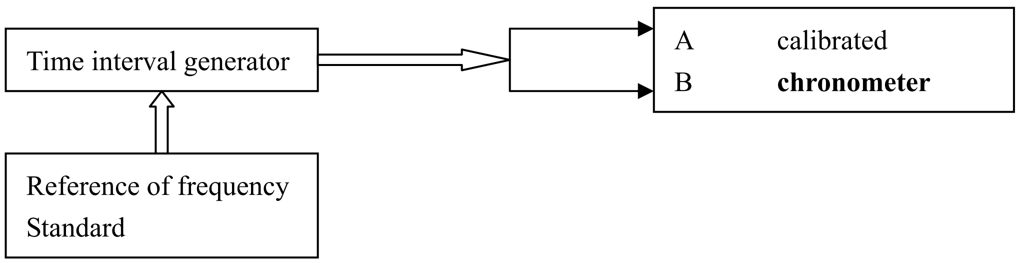
T_0 given value of the standard time interval generator.

4.3.2 Measuring of the time interval of the electronic pulse

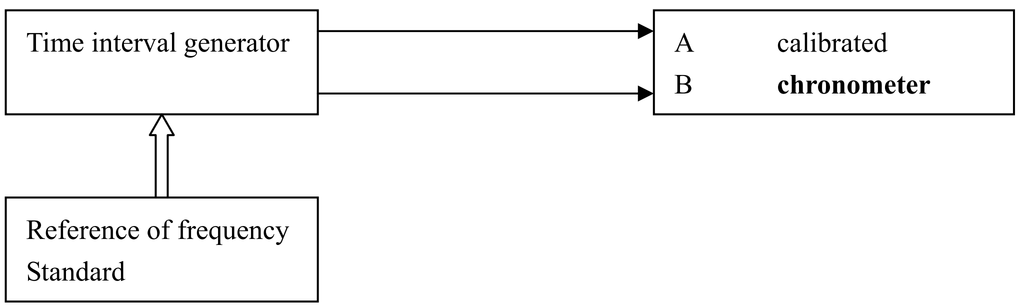
The connection of the instruments is shown in Fig. 3.

4.3.2.1 Pulse Width Measurement of the Positive Pulse

The single positive electronic pulse signal is given by the time interval generator and at the same time is sent to the A and B input terminals of the calibrated **chronometer**. The trigger slope of A channel (start-up channel) is set to be positive; the trigger slope of B channel (stop channel) is set to be negative.



(a) for single pulse measurement



(b) for twin pulse measurement

Fig. 3 The instruments connection diagram of the time interval measure for the electric pulses

4.3.2.2 Pulse Width Measurement of the Negative Pulse

The time interval generator gives a single negative pulse signal. The trigger slopes of A and B input channels of the calibrated **chronometer** are set to be negative and positive respectively.

4.3.2.3 Time interval measurement of two positive electronic pulses

The time interval generator gives a single positive pulse signal in two traces. The start-up signal is put on A channel of the calibrated **chronometer**. The stop signal is put on B channel. The trigger slopes of both channels are set to be positive .

4.3.2.4 Time interval measurement of two negative electronic pulses

The time interval generator gives a single negative pulse signal in two lines. The start-up signal is put on A channel of the calibrated **chronometer**. The stop signal is put on B channel. The trigger slopes of both channels are set to be negative.

4.3.3 Action Time Measurement of the mechanical contacts

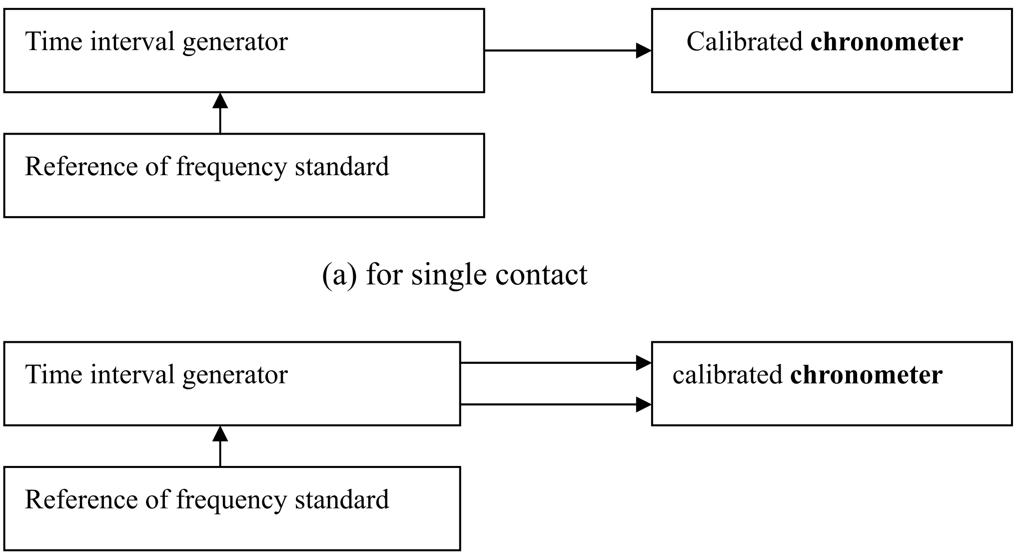
The connection of the instruments is shown in Fig. 4.

4.3.3.1 Duration Measurement of the closing for one contact

A single start signal (short circuit) given by the time interval generator, connected to the relevant measurement input terminal of the **chronometer**.

4.3.3.2 Duration of the opening for a single contact

The single turn-off signal (open circuit) given by the time interval generator is put onto the relevant measurement input terminal of the **chronometer**.



(b) for two contacts

Fig. 4 The instruments connection diagram of the action time measurement of the mechanical contacts

4.3.3.3 Measurement of the time interval for closing between two contacts

The time interval generator gives single start signals as two outputs, one is the start-up signal and the other is the stop signal. Both of them are connected to the relevant measurement input terminals of the **chronometer** respectively.

4.3.3.4 Measurement of the time interval for the turn-off of two contacts

Single turn-off signals given by the time interval generator one after another are connected to the relevant measurement input terminals of the **chronometer** respectively.

5. Treatment of the calibration results and calibration period

5.1 Treatment of Calibration Results.

For chronometers which meet the requirement of this working instruction, a calibration certificate will be supplied: For the ones which do not meet the requirement, an advice note of the calibration result should be supplied with the items which do not comply being pointed out.

5.2 Calibration period

The calibration period of the chronometer is one year

APPENDICES

Appendix 1
Contents and format of the calibration certificate

A. Calibration of the internal crystal oscillation
1. Frequency fluctuation
2. Accuracy of frequency

B. Calibration of the time interval measurement
1. Pulse width measurement of the positive pulse
2. Pulse width measurement of the negative pulse
3. Time interval measurement between two positive pulses
4. Time interval measurement between two negative pulses
5. Duration measurement for closing mechanical contacts
6. Duration measurement for opening of mechanical contacts
7. Time interval measurement for closing of two contacts
8. The time interval measurement for opening of two contacts

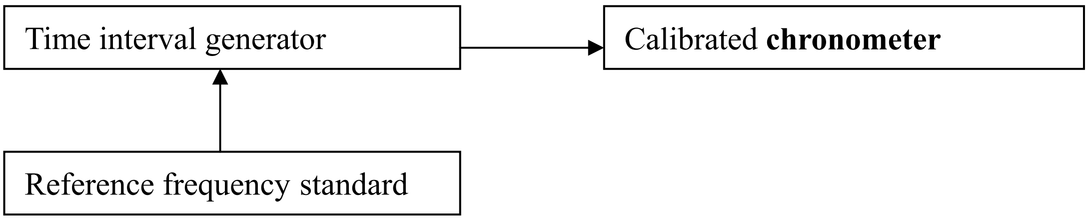
Each item of the calibrated data is given on the basis of the following table.

Standard value T_0	Measured value $\overline{T}_i$	Error ΔT

Appendix 2

Calibration of the crystal oscillator standard if the chronometer does not have an output of the crystal oscillator frequency

The connection of the instruments is shown in the following Fig.



The functions of the **chronometer** are measured by use of the electronic pulse. The time interval generator gives the pulse width of the single pulse or the interval between two single pulses.

The given time interval may be supposed to be T_0. The time unit corresponding to the minimum display position of the **chronometer** is τ_0. Then the value of T_0 must meet the following formula:

$$\frac{\tau_0}{T_0} \le \frac{1}{10} v$$

where:

v frequency fluctuation of the internal crystal oscillator of the **chronometer**.

1. Calibration of the frequency fluctuation

After the **chronometer** has warmed up according to the working instruction the measurement can be started. One measurement is taken per hour, in total N times (N = 4, 8 or 24). The frequency fluctuation value can be calculated by use of formulae (1):

$$S = (y_i)_{max} - (y_i)_{min} \qquad (1)$$

$$y_i = \frac{T_i - T_0}{T_0}$$

where:

T_i measured value every time.

2. Alignment of the frequency accuracy

If the result of the calculation using the data from the frequency fluctuation measurements satisfies the following formula, the alignment of the crystal oscillator frequency is not needed.

$$10S \ge |y_i|_{\max} \ge S \qquad (2)$$

else: open the cover of the **chronometer**, adjust the frequency of the crystal oscillation till it meets the requirement of formula (2). This time the value of $|y_i|_{\max}$ need only be calculated for one measured value after the alignment.

If the crystal oscillator frequency cannot be adjusted or although it can be adjusted but the requirement of formula (2) cannot be met, $|y_i|_{\max}$ must be stated in the calibration report as the frequency accuracy.

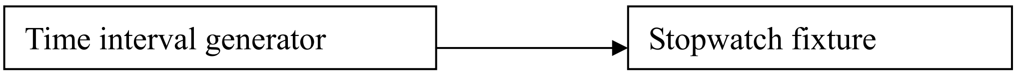
Appendix 3

The calibration of the crystal-oscillator stopwatch

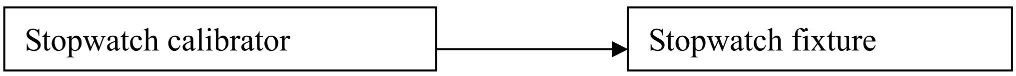
A crystal-oscillator stopwatch belongs to the type of instruments for the time interval measuring with digital indication based on its working principle and display. Owing to the particularity and uniqueness of its measuring principle, the general-purpose items in the main body of this working instruction cannot completely meet the requirements for the calibration of the crystal–oscillator stopwatch. For this reason a stopwatch fixture i.e. a mechanical hand that starts and stops the stopwatch by use of an electromagnetic pulse should be used in the standard calibration equipment. The standard time interval generator must possess the corresponding function or a calibrator for this special use may be used.

If the crystal-oscillator stopwatch does not have an output of the crystal oscillator frequency, the interior crystal oscillator need not be calibrated. Only the measuring error of the time interval and the daily difference should be calibrated.

The connection of the instruments is shown in the following Figure:



Or



1. Calibration of the measuring error

The calibration values are selected as 1s, 10s, 1min and 1h.

Three measurements should be carried out for the first three measuring values. The arithmetic mean of their measurement values may be taken. For the last case, two measurements can be performed. Take the arithmetic mean value of its measurement value.

The measuring error can be calculated by use of the formula (5) in the main body of this working instruction.

2. Calibration of the daily difference

The daily difference means the measuring error when the time interval is taken as one day. For the normal stopwatch no one will measure such a long time interval. But the crystal-oscillator stopwatch also posses the display function of hour, minute and second. So the requirement of the index of the travel-time – “daily difference” similar as watch and crystal clock is required.

The calibration of the daily difference is the same as that of the calibration of the measuring error. The crystal-oscillator stopwatch measures the time interval, the standard time interval generator gives only one time. The calculation of the error is the same as above.

The daily difference can also be calibrated by use of an instantaneous measuring device for the daily difference.

3. Format of the calibration certificate for crystal-oscillator stopwatch

See the table below.

Standard value T_0	Measuring value $\overline{T_i}$	Error $\Delta T = \overline{T_i} - T_0$
1s 10s 1min 1h		