УДК 681.175, 681.118.1

J. Horský[1],J. Horská[2]

[1] *Czech calibration society*
[2] *Czech metrology institute*

STOPWATCH AND TIMER CALIBRATIONS WITH INTERNET REFERENCE SIGNAL

This paper described very simple calibration of stopwatches or timers made with internet time services as reference standard.

Keywords: *Stopwatch ,Timer, Calibrations internet time service.*

Performance of the problem

Millions of stopwatch and timers calibration are provided and it is usually costly and time consuming services of calibration labs. Traceable in house calibration is important for many stopwatch users.

Formulation of the article purpose

This paper described very simple calibration of stopwatches or timers made with internet time services as reference standard.

Summaries

Described calibration can be made everywhere, where internet or radio broadcast time services are available.

Foreword

Stopwatches and timers are instruments used to measure time interval, which is defined as the elapsed time between two events a stopwatch or timer simply measures and displays the time interval from an arbitrary starting point that begins at the instant when the stopwatch is started. Although stopwatches and timers measure time interval, they do so by using a frequency source. Frequency is the rate of a repetitive event, defined as the number of events or cycles per second. A time base oscillator (sometimes called a clock or reference oscillator) produces the frequency signals used by the stopwatch or timer to measure time intervals. The time base oscillator serves as the reference for all of the time and frequency functions performed by the device. The most common frequency used by quartz time base oscillators is 32 768 ($=2^{15}$) Hz.

Stopwatches

Stopwatch and timer calibrations are perhaps the most common calibrations performed in the field of time and frequency metrology

Stopwatches can be classified into two categories, mechanical and digital. In a traditional mechanical stopwatch, the power source is a helical coil spring. The time base is usually a balance wheel that functions as a torsion pendulum. In digital stopwatches the time base is a quartz crystal oscillator that usually has a nominal frequency of 32 768 Hz.

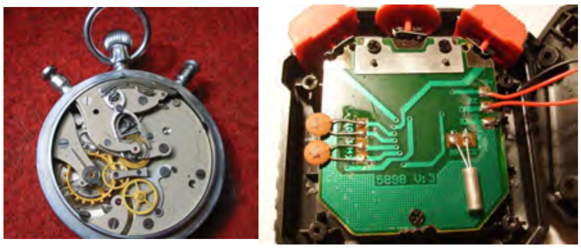

Fig. 1. Mechanical and digital stowatch interior

32 768 Hz stopwatch Crystals

Initial frequency tolerance for crystal frequency is 10ppm, 20 ppm. 50 ppm and 100 ppm. 100 ppm in frequency is 18s/day and can be important for longer time measurements. Aging is the systematic change in frequency over time due to internal changes in an oscillator. Aging is the systematic change in frequency over time due to internal changes in an oscillator. Because of their slow aging rate, stopwatches tend to produce very repeatable results over long periods of time the small changes in frequency due to aging are usually insignificant. This makes it possible for a laboratory to allow long intervals (perhaps exceeding one year) between calibrations. The small changes in frequency due to aging (5 ppm/year) are usually insignificant. This makes it possible for a laboratory to allow long intervals (perhaps exceeding one year) between calibrations. As can be seen in the fig. 2, the flat portion of the performance curve is near room temperature (23 °C), and drops off as the temperature increases or decreases.

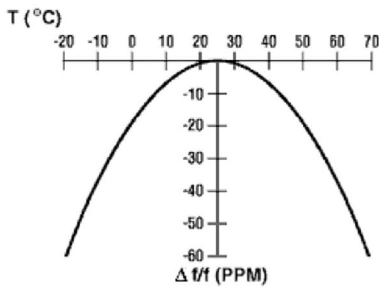

Fig. 2. Crystal temperature characteristic

Uncertainty Due to Human Reaction Time

Mental chronometry is studied using the measurements of reaction time (RT). Reaction time is the elapsed time between the presentation of a sensory stimulus and the subsequent behavioral response. *Simple* reaction time is the motion required for an observer to respond to the presence of a stimulus. For example, a subject might be asked to press a button as soon as a light or sound appears. Most important source of uncertainty in measurement wit stopwatch is human reaction time. To understand the effect of human reaction time on stopwatch and timer calibration uncertainties, a study can be made. Mean RT for college-age individuals is about 160 milliseconds to detect an auditory stimulus, and approximately 190 milliseconds to detect visual stimulus. The mean reaction times for sprinters at the Olympics were 170 ms for males and 190 ms for females. We can use many internet programs for this measurements, as is:
http://www.humanbenchmark.com/tests/reactiontime/,
http://www.topendsports.com/testing/reaction-timer.htm.,
http://getyourwebsitehere.com/jswb/rttest01.html,
http://www.mathsisfun.com/games/reaction-time.html *or*
http://www.bbc.co.uk/science/humanbody/sleep/sheep/.

The Direct Comparison method for calibration indicates that the average (mean) reaction time of the operator can be either negative (anticipating the audible tone) or positive (reacting after the audible tone), also shows that in addition to the average reaction time having a bias, the data is somewhat dispersed, so both elements of considered in a complete uncertainty budget.

Fig. 3. BBC reaction time test

Calibration NTP

Network Time Protocol (NTP) synchronizes clocks of hosts and routers in the Internet. NIST estimates 10-20 million NTP servers and clients deployed in the Internet and its tributaries all over the world. Every Windows/XP has an NTP client.

The NTP architecture, protocol and algorithms have been evolved over the last two decades to the latest NTP Version 4 software distributions.

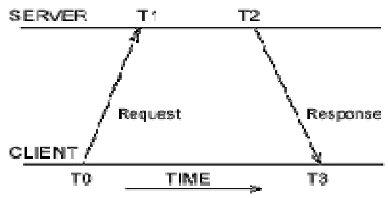

Fig. 4. The NTP protocol basic algorithm

Regardless of the long development of the NTP protocol is the basic algorithm remains the same (fig. 4). The client sends a query to which inserts the current value of their time (timestamp) T_0. Server receives the query at time T_1 and T_2 will respond in time. Answer client arrives in time T_3. It should be emphasized that the values of T0 and T3 refer to the client's local clock, while the values of T1 and T2 to the clock server. Knowledge of all four time data, the client computes δ total transmission time (delay) and mean shift their time to the server θ_0 (offset). Calculation θ_0 is based on the assumption of symmetrical delays in both directions. The actual value of θ lies in the specified interval. This way the client receives one sample containing three values: offset - likely shift hours delay - the time of signal transmission, uncertainty interval offset dispersion - the stability of clock server (the server sends data in response). Each such sample contains values randomly affected immediate network conditions.

Primary (stratum 1) servers synchronize to national time standards via radio, satellite and modem.

Secondary (stratum 2) servers and clients synchronize to primary servers via hierarchical subnet.

Clients and servers operate in master/slave, symmetric and multicast modes with or without cryptographic authentication. Multiple servers/peers provide redundancy and diversity:
http://support.ntp.org/bin/view/Servers/StratumTwoTimeServers or ntp.vc.ukrtel.net, ntp.campus-rv.net.

SP TimeSync

SP TimeSync is a program with multilingual interface which lets you synchronize your computer's clock with any Internet atomic clock (time server). It uses a high precision network time protocol (NTP) which provides accuracy of several milliseconds depending on the characteristics of the synchronization source and network paths Base SP TimeSync user interface is in **English**, but currently it also supports **Ukrainian and Russian.**

SP TimeSync's "Difference is a "refined" time difference. It involves complex calculation which allows the exclusion of the time taken by the NTP server to process your request. Although it's impossible to completely eliminate the "Delay" in this calculation, its influence is greatly reduced. The maximum possible synchronization error does not exceed one-half of the roundtrip delay. But this is the worst case error. The actual precision is several times better.

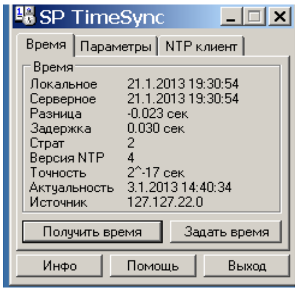

Fig. 5. Program SP TimeSync's panel

Dimension 4

Is the fastest and easiest way to synchronize your computer's clock if you're running a Windows-based operating system. Dimension 4 uses a low level internet protocol, called SNTP, to connect with special purpose Internet Time Servers that have been keeping the rest of the web on-time for the last 20 years. These time servers typically have direct access to their very own time source, or they are connected directly to other Internet Time Servers that do. At an interval you specify, Dimension 4 connects to one of these Internet Time Servers, which you get to choose from an exhaustive list built directly into Dimension 4 (fig. 1). The Time Server then sends the correct time back to your computer, where Dimension 4 uses sophisticated algorithms to correctly adjust your computer's clock to with-in a few milliseconds of the real time. Synchronize your PC's clock to within milliseconds of "real" time.

For SNTP, that either means that the server isn't working correctly or it means that firewall and/or virus software on the client machine is blocking UDP traffic.

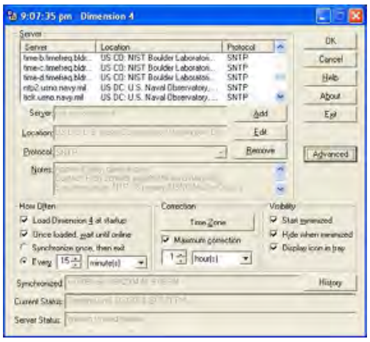

Fig. 6. Program Dimension 4 panel

Calibration methods

There are three generally accepted methods for calibrating a stopwatch or timer:

- the direct comparison method,
- the totalize method,
- the time base method.

The first two methods consist of time interval measurements that compare the time interval display of the DUT to a traceable time interval reference. In the case of the direct comparison method, the time interval reference is normally a signal broadcast by an NMI, usually in the form of audio tones. In the case of the totalize method, the time interval reference is generated in the laboratory using a synthesized signal generator, a universal counter, and a traceable frequency standard. The third method, the time base method, is a frequency measurement. It compares the frequency of the DUT's time base oscillator to a traceable frequency standard.

The Time Base Method

The time base measurement method is the preferred method for stopwatch and timer calibrations, since it introduces the least amount of measurement uncertainty. Because the DUT's time base is measured directly, the calibration technician's response time is not a factor. Unfortunately it needs expensive and special standards and it is why is not described here.

The Totalize Method

The totalize method partially eliminates the measurement uncertainty from human reaction time, but requires two test instruments: a calibrated signal generator, and a universal counter. Unfortunately it needs expensive and special standards and it is why is not described here.

The Direct Comparison Method

The direct comparison method is the most common method used to calibrate stopwatches and timers. It requires a minimal amount of equipment, but has larger measurement uncertainties than the other methods. The direct comparison method requires a traceable time-interval reference. This reference is usually an audio time signal, but in some cases a traceable time display can be used. The audio time signals are usually obtained with a shortwave radio or a telephone. Since time interval (and not absolute time) is being measured, the fixed signal delay from the source to the user is not important as long as it remains relatively constant during the calibration process. It might be tempting to use a time display from a radio controlled clock or from a web site synchronized to UTC as a reference for stopwatch or timer calibrations. As a general rule, however, these displays are not acceptable for establishing traceability. Nearly all clock displays are synchronized only periodically. In the period between synchronizations they rely on a free running local oscillator whose frequency uncertainty is usually unknown. And of course, an unknown uncertainty during any comparison breaks the traceability chain. For example, a low cost radio controlled clock that receives a 75 kHz signal from PTB radio station DCF is usually synchronized only once per day. The DCF receiver's clock presents similar problems. It synchronizes to UTC (DCF) one day if the web browser is left open. However, between synchronizations it keeps time using the computer's clock, which is usually of poorer quality than a typical stopwatch, and whose uncertainty is generally not known.

Calibration Procedure for the Direct Comparison Method

Near the top of the hour, dial the phone number (or listen to the radio broadcast) of a traceable source of precise time. Start the stopwatch at the signal denoting the hour, and write down the exact time. After a suitable time period (depending on the accuracy of the stopwatch), listen to the time signal again, and stop the stopwatch at the sound of the tone, and write down the exact stopping time. Subtract the start time from the stop time to get the time interval, and compare this time interval to the time interval displayed by the stopwatch. The two time intervals must agree to within the uncertainty specifications of the stopwatch for a successful calibration. Otherwise, the stopwatch needs to be adjusted or rejected.

Advantages of the Direct Comparison Method

This method is relatively easy to perform and, if a telephone is used, does not require any test equipment or standards. It can be used to calibrate all types of stopwatches and many types of timers, both electronic and mechanical.

Disadvantages of the Direct Comparison Method

The operator's start/stop reaction time is a significant part of the total uncertainty, especially for short time intervals. Table 1 shows the contribution of a 300 ms variation in human reaction time to the overall measurement/

Table 1

The contribution of 0,3 s variation in reaction time to the measurement uncertainty

seconds	Uncertainty (%)
10	3
600 (10 minutes)	0,5
3600 (1 hour)	0,05
21600 (6 hours)	0,017
43200 (12 hours)	0,0083
86400 (1 day)	0,0042

As Table 1 illustrates, the longer the time interval measured, the less impact the operator's start/stop uncertainty has on the total uncertainty of the measurement. Therefore, it is better to measure for as long as practical to reduce the uncertainty introduced by the operator, and to meet the overall measurement requirement. To get a better understanding of the numbers in Table 1, consider a typical stopwatch calibration where the acceptable measurement uncertainty is 0.02 % (2.10^{-4}). Therefore, we need to extend the time interval so that human reaction time becomes an insignificant part of the measurement.

Uncertainties of the Direct Comparison Method

The Direct Comparison Method has three potentially significant sources of uncertainty that must be considered: the uncertainty of the reference, the reaction time of the calibration technician, and the resolution of the DUT.

Uncertainty of the Traceable Time Interval Reference

If the radio signals listed in Table 6 are used as a reference instead of a telephone signal, the arrival time of the signal will vary slightly from second to second as the length of the radio signal path changes, but not enough to influence the results of a stopwatch or timer calibration.

Conclusions

Traceable calibration of the stopwatch or timekeeping devices is now available everywhere with virtually no cost with low uncertainty, but it is necessary to choose the longest period of calibration (cheap stopwatch with a resolution of 0.01 s typically offer measure up to 48 hours, expensive with a resolution of up to 0.001 100 hours. Some cheap stopwatch measure does not allow measurement for a long time, but practically all digital stopwatch can work and watch mode, it is possible to use this mode when calibrating (preferably with fotomethod sensing data reference clock and UUT stopwatch simultaneously). The purpose of calibration of digital stopwatch is mainly to determine whether it can at the usual time of measurement applied reference oscillator frequency deviation stems, therefore, the main result of the calibration stating that stems systematically late or ahead of and is given for the selected time interval, such as the hour or day.

List of literature

1. Stopwatch and Timer Calibrations, National Institute of Standards and Technology Special Publication 960-12,

2. IAAF Calibration and Testing Manual edition 2010, International association of athletics federations (IAAF)

3. Technical Guide 8 , Calibration of Stopwatches, Measurement Standards Laboratory of New Zealand.

Поступила в редколегію 7.02.2013

Рецензент: д-р техн. наук, проф. И.В. Руженцев, Харьковский национальный университет радиоэлектроники, Харьков.

КАЛИБРОВКА СЕКУНДОМЕРА И ТАЙМЕРА ЭТАЛОННЫМ ИНТЕРНЕТ-СИГНАЛОМ

Ю. Хорский, Я. Хорска

В статье описана очень простая калибровка секундомеров и таймеров, производимая с помощью эталонной интернет-службы времени.

Ключевые слова: *секундомер, таймер, калибровка, служба времени*

КАЛІБРОВКА СЕКУНДОМЕРУ І ТАЙМЕРУ ЕТАЛОННИМ ІНТЕРНЕТ-СИГНАЛОМ

Ю. Хорський, Я. Хорська

В статті описано дуже просте калібрування секундомірів і таймерів, що виконується за допомогою еталонної інтернет-служби часу.

Ключові слова: *секундомір, таймер, калібрування, служба часу.*