

A simple and cheaper solution to calibrate microcomputer time base with NIST totalizer method

Uma solução simples e mais barata para calibrar a base de tempo do microcomputador com o método totalizador NIST

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ABSTRACT

Normally, laboratories that need traceability of time quantity in measurements, find high cost and complex infrastructure to collect traceable time measurements and automation software. This paper shows the calibration of microcomputers in LNMRI laboratory, using a simple method proposed by Special Publication NIST 960-12, with a unique reference counter with an external time base by the CSAC cesium frequency standard and a virtual stopwatch that can be download on the internet. The totalizer method is a simple way to calibrate time offset dt/t , and the results show that the microcomputers can be used how a time base reference in measurements that required dimensionless fractional time uncertainty until microseconds for a second.

Keywords: Traceability, Totalizer method, Microcomputer, Time offset.

RESUMO

Normalmente, os laboratórios que precisam de rastreabilidade da quantidade de tempo nas medições encontram alto custo e infraestrutura complexa para coletar medições de tempo rastreáveis e software de automação. Este artigo mostra a calibração de microcomputadores no laboratório do LNMRI, utilizando um método simples proposto pela Publicação Especial NIST 960-12, com um contador de referência exclusivo com base de tempo externa pelo padrão de frequência de césio CSAC e um cronômetro virtual que pode ser baixado no Internet. O método totalizador é uma maneira simples de calibrar o deslocamento de tempo dt / t , e os resultados mostram que os microcomputadores podem ser usados como uma referência de base de tempo em medições que requerem incerteza de tempo fracionário adimensional de até microssegundos por segundo.

Palavras-chave: Rastreabilidade, Método Totalizer, Microcomputador, Time offset.

1 INTRODUCTION

The Instituto de Radioproteção e Dosimetria (IRD) is the national reference to standardize quantities of Ionizing Radiation, and the Observatório Nacional (ON) is the reference in Time and Frequency. Both of Institutes have this delegated mission, in the interest of Country, by Instituto Nacional de Metrologia, Qualidade e Tecnologia

(INMETRO) that is the Legal Authority in Metrology in Brazil, officially recognize by BIPM with that mission. In this way, the research to solutions in Ionizing Radiation and Time and Frequency Metrology is its priority of the group.

Thus, with a long history, in 1912, with 16 representatives, including Brazil, was created the BIH (International Bureau of Time) [1].

In 1921, at the 6th metro convention, the Bureau International des Poids et Mesures (BIPM) extended the scope and responsibilities in other fields of action and the advisory committee for electricity (CCE, and currently CCEM) was created [2].

In 2005, the CCTF (Time and Attendance Advisory Committee), the working group was created where the main objectives are to develop and propose standards for specific documentation. Its provide discussion forums, to interact with BIPM on issues related to International Atomic Time (TAI) and to encourage, facilitate and provide help for the direct comparison between primary frequency patterns and the construction of new standards [3].

Currently, Brazil participates in the CCTF as an official observer through the National Observatory (ON / MCTIC), through the designation of the National Institute of Metrology, Quality, and Technology (INMETRO / MDIC) [4].

The details of the time quantity history show that the time traceability in measurements is not quite trivial, because the cost of apparatus is so not attractive, and the instruments accessories to collect data require more infrastructure in software and training to development.

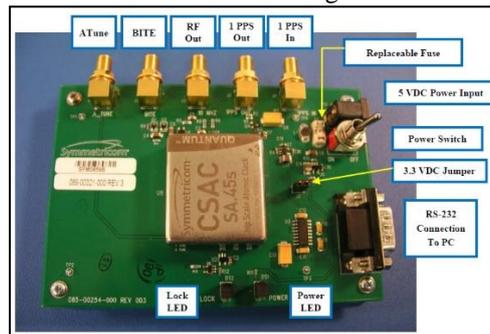
So, was proposed a simple way to traceable the internal time base of the microcomputers, for specific applications, based on a known method, and cheaper to calibrate lots of microcomputers in a laboratory net, where a unique setup can transfer traceability.

2 MATERIALS

The time and frequency standard CSAC (Chip-Scale Atomic Clock) is a reference generation system with 1 PPS outputs in 5 V and 10 MHz in alternating high square wave. The system has low power consumption less than 125 mW and is manufactured in the standard board where the chip contains a TCXO internal quartz oscillator and the CSAC module with a cesium 133 source, the same chemical element of the definition of the second in the SI. The laser camera for detecting the transition of 9,192,631,770 cycles per second, in miniature configuration, which controls the quartz operating point.

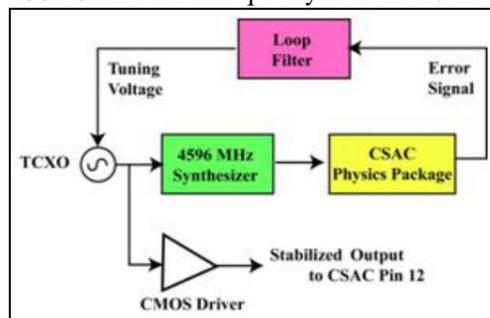
The system comes with control software and RS-232 serial interface to the user, multi-connector board for parameter configuration, the possibility of synchronization and external discipline via another reference standard or GPS, offset adjustment and monitoring of operational data such as temperature, laser operating point, drift and other parameters necessary for the operation of the equipment. Figure 1 below shows the overview of the board and the CSAC module.

Figure 1 – Circuit board for mounting the CSAC module [5]



The main output signal of the CSAC is provided by the TCXO quartz oscillator, which is continuously compared and corrected by the hyperfine frequency of the cesium atoms which is 9,192,631,770 Hz. Figure 2 shows the block diagram of the CSAC.

Figure 2 – CSAC Time and Frequency Pattern Block Diagram [5]



AUTOMED is the name of the multiplexer, which is the automatic time interval measurement system used in the Time Service Division (DISHO), one pulse per second (1 PPS) time and frequency standard. The system uses an universal time interval counter SR620 to measure the difference between the pulses of 1 PPS, a switching module of the various 1 PPS signal inputs, a microcomputer for signal processing and a graphical interface for user interaction.

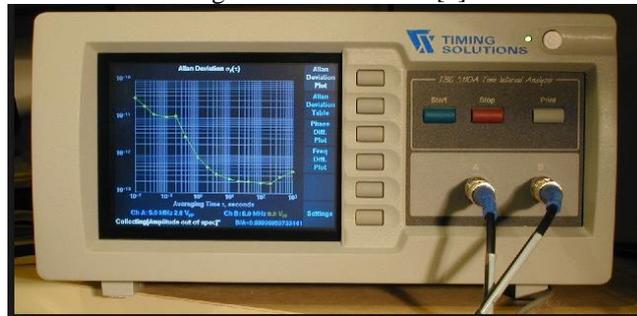
The measurements are performed with time intervals $\tau_0 = 60$ s for each measured standard, the time difference sampling of each measured standard is in 60 s intervals. The

standard was compared with the reference 1 PPS signals of the Brazilian Atomic Time Scale (UTC(ONRJ)) and the T130 (cesium standard used in the calibration laboratory).

The system has two dedicated calibration channels, CAL01 and CAL02, and time difference data is stored in .txt files in a folder on a data server.

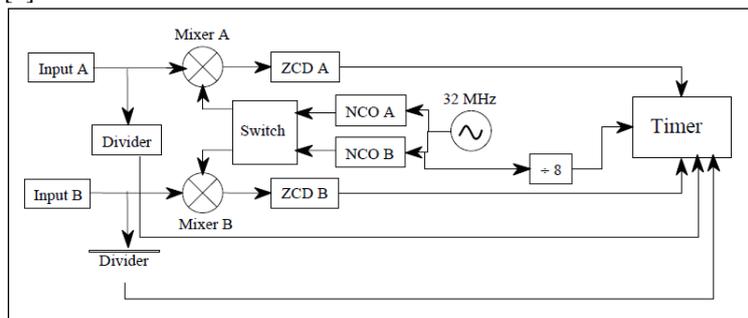
The TSC5110A is a meter that uses the time difference technique with dual DTDM mixer [6], of frequency signals provided by time and frequency patterns. The system receives the input signals on channels A and B, one of the respective channels being the frequency reference and the other channel for the equipment to be tested (DUT), figure 3.

Figure 3 – TSC5110A [6]



Measurements can be performed at $\tau_0 = 1$ s (1 sample per second) and $\tau_0 = 10$ ms (100 samples per second). The equipment display allows plotting the Allan deviation data (frequency stability), phase and frequency measurements of the standard under test with respect to the reference. The collected data is transfer to the microcomputer via serial port (1 sample per second) and stored in .txt format, ordered by MJD on each measurement day. The collection of 100 samples per second is done through TCP-IP cable and stored in a .txt format file. The block diagram is shown in Figure 4.

Figure 4 – Block diagram of the phase data acquisition in the dual-mixer time difference measurement method - DTDM [6]



The same frequency signals at inputs A and B are combined with a reference offset (mixer) to eliminate the influence of the offset fluctuation of the two inputs, and the contribution of the reference signal is canceled in the process of treating the output signal.

The PM6681 is a counter totalizer that was utilized with CSAC time base to calibrate the microcomputer's time base. There is an internal time base of rubidium oscillator, an external input of 10 MHz, where the CSAC was connected. Figure 5 shows the PM6681.

Figure 5 – PM6681 [7]



Beyond that, a PC stopwatch was free downloaded by the internet and installed to extract the behavior of the internal time base of microcomputer, through the totalizer method. Figure 6 shows the user's interface.

Figure 6 – PC Chrono [8]



3 METHODS

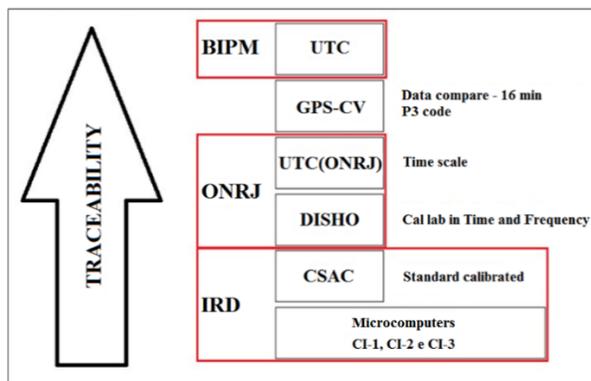
3.1 CALIBRATING A CSAC (CHIP SCALE ATOMIC CLOCK) TO REFERENCE THE PM6681 COUNTER

The calibration of Time and Frequency standard CSAC was necessary to get traceability of 10 MHz signals to counter system Fluke PM6681, that is the reference system to the calibration of the microcomputer time base, through the PC stopwatch.

The BIPM traceability is guaranteed through the UTC(ONRJ) time scale compared to UTC(BIPM), and the calibration of the CSAC standard in the Observatório Nacional (ON) laboratory of the Time Service Division (DISHO). As the UTC(ONRJ) time data are continuously compared every 16 minutes through a Common View GPS system - CV, code P3, and through the results of UTCr(BIPM) - UTC(ONRJ) with weekly frequency

and UTC(BIPM) - UTC (ONRJ) published monthly, according to figure 7. The microcomputers were calibrated by the NIST totalizer method [9] with the stable time base CSAC.

Figure 7 – Traceability of microcomputer set CI-1, CI-2, and CI-3 of Instituto de Radioproteção e Dosimetria – IRD to Bureau International of Weight and Measures – BIPM through the Observatório Nacional – ON



3.2 CALIBRATING A MICROCOMPUTER INTERNAL TIME BASE

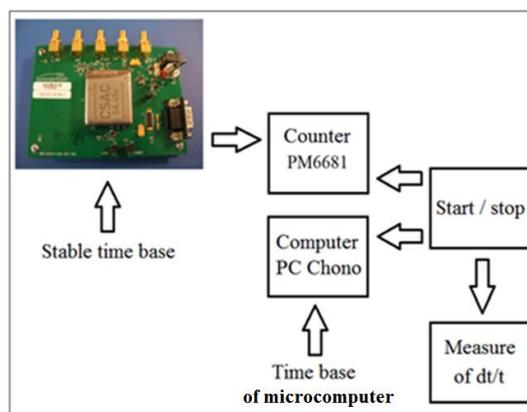
In the calibration of the time base of the microcomputers of the CI-1, CI-2 and CI-3 assemblies, the totalizer measurement method [9] was used, comparing the totalized count from a digital microcomputer timer (PC stopwatch) available for free download on the internet, with resolution in hundred seconds. This program is powered by the time base of the microcomputer, in addition to the totalized count of the PM6681 reference counter powered by a stable cesium 133 (CSAC) time base. As the counting time increases in both systems, the microcomputer time base deviation behavior will appear relative to the reference system and the simple subtraction between the values will give the information of the delay or forward behavior of the second generated by the system microcomputer in relation to the stable time base.

Due to components of influence that could impact the PC stopwatch measurements, the most obvious being the execution of routines in the microcomputer's processing and the ambient temperature, the two were duly circumvented. For processing, it was defined that the count measurement would be performed in parallel to a continuous measurement of a data acquisition program to simulate the operational condition in the processing of the system during the entire counting period. Regarding temperature, the microcomputers are in a laboratory with a temperature in the range of 20 ± 1 °C. Thus, the deviation in the value presented should represent within a range, the behavior of the time base of the microcomputer in operation, which is the measure of interest.

Count intervals of 86 400 s (1 day), 172 800 s (2 days) and 259 200 s (3 days) were tested. The 3-day counting value would be chosen for calibration due to the influence of the operator start / stop in this interval being smaller [10], but due to obtaining good reading statistics, 1 day was chosen due to the greater ease of measurement in relation to the period of 3 days. This method only provided an estimate of the behavior and should not be confused with the characterization of a time base that would require another arrangement and output signal from the microcomputer. This method provided essential information in programs fed by the internal time base of a microcomputer, measuring successive time intervals and short measurement time intervals, integration times or long period counting, and has no offset information of the time that is the case of the present work. The traceability of the time that is also essential in the metrology of measured quantities as a function of time.

Figure 8 shows the arrangement for measuring the time base of microcomputers by the totalizer method [9].

Figure 8 – Totalizer method for measuring dt/t of the microcomputer in relation to the stable time base CSAC



4 RESULTS

In order to calculate the uncertainty of the PC chronometer, the recommendations of NIST [9] according to table 1, based on the recommendations of ISO GUM [12], were followed.

Table 1 – Uncertainty of the microcomputer timer (PC) used in the CI-1, CI-2 and CI-3 microcomputers calibrated with the CSAC standard

Uncertainty	Magnitude (ms)	Method	Distribution	Standard uncertainty (ms)
Human reaction time	27	Type B	Rectangular	16
Human reaction time Standard deviation	10	Type B	Normal (k=1)	10
Synthesizer precision	0	Type B	Rectangular	0
Totalize counter resolution	0	Type B	Rectangular	0
1/2 Stopwatch resolution	5	Type B	Rectangular	3
Stopwatch - Standard uncertainty	1.05	Type A	Normal (k=1)	1.05
Combined uncertainty				19
Expanded uncertainty (k=2)				38

Note: the values 0 in the table are considered of negligible influence

The uncertainty components considered were the uncertainty of the series of measurements of the time offset (dt/t), the uncertainty of the timer PC and the uncertainty of the CSAC standard used as a reference for the counter PM6681. Due to the stability characteristic of the CSAC standard in relation to the microcomputer, this component of uncertainty was neglected because it would present the negligible relative result in the order of magnitude of the measurement performed in the microcomputer where: (sensitivity coefficient = 1)

$$u_{(dt/t)_{\text{Microcomputer}}} = \sqrt{\left(u_{(dt/t)_{1 \text{ day}}}\right)^2 + \left(u_{(\text{Stopwatch})_{\text{PC}}}\right)^2} \quad (1)$$

$u_{(dt/t)_{1 \text{ day}}}$ – uncertainty of type A of the series of 03 measurements of 1 day (~ 86 400 s);

$u_{(\text{Stopwatch})_{\text{PC}}}$ – uncertainty of type B of the stopwatch PC;

Where:

$$u_{(dt/t)_{1 \text{ day}}} = \frac{\left(\frac{\text{Standard deviation of time offset (seconds) of 1 day}}{\sqrt{\text{number of measure days}}}\right)}{\text{Average of time offset (seconds) of 1 day}} \quad (2)$$

$$u_{(\text{Stopwatch})_{\text{PC}}} = \frac{(\text{Combined uncertainty of PC stopwatch})}{\text{Average of time offset (seconds) of 1 day}} \quad (3)$$

The dt/t measurements or time offset of microcomputers [9] were performed in ~ 1 day of totalization on each of the systems, with 3 measurements, and LabVIEW program running in cycle mode, to simulate the normal operating condition. During the whole measurement period, the temperature in the room remained around $20 \pm 1 \text{ }^\circ\text{C}$ and the results for the dt/t in the CSAC according to table 2.

Table 2 – Results for the dt/t of the CI-1, CI-2, and CI-3 microcomputers according to ISO GUM recommendations [12] with the reference standard stable time base CSAC

Standard	CI-1 k = 2,0 (s.s⁻¹)	CI-2 k = 2,0 (s.s⁻¹)	CI-3 k = 2,0 (s.s⁻¹)
CSAC cesium	$(16,2 \pm 0,6) \text{ E-06}$	$(-14,0 \pm 0,8) \text{ E-06}$	$(32,7 \pm 1,1) \text{ E-06}$

5 CONCLUSIONS

Firstly, it is important to say that in this paper, was used a CSAC how to reference time base, but the internal rubidium oscillator of the PM6681 counter is sufficient to traceable the time measurements in totalizer method related to microcomputers. This setup was made because of the intent to demonstrate a configuration with an external time base more accurately.

Secondly, after the internal time base calibration, the virtual stopwatch can be used to measure any process, in microcomputer, notebook or tablet calibrated.

Thirdly, all results of dt/t time offset were tens of microseconds for seconds, and when the application needs have been between of this range, the microcomputer will be a good solution to get the standard time interval to software applications.

Fourthly, it is extremely important to say that in this paper don't characterize the time base of microcomputers with frequency stability or time stability, but solely calibrate in relation to stable time base with the time interval and the uncertainty of the reference CSAC, being much minor than the microcomputer time base, providing a secure reference measure.

Interest future works could be made with characterization in frequency stability or time stability of the microcomputer's time base.

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