MSL Technical Guide 8

Calibration of Stopwatches

Introduction

The measurement of time interval using a simple stopwatch or laboratory timer is an important parameter in many laboratory or industrial measurements, such as flow measurement, process timing, chemical measurement, and radiological exposure control.

Modern stopwatches, using quartz crystals as a time base, are probably more accurate than required for most of these measurements. However, to ensure reliable measurement, or for traceability requirements, it is important that the accuracy and functionality of these stopwatches are proven and checked regularly. This is particularly true when the application affects health and safety, or impacts significantly on productivity. For traceability, International Accreditation New Zealand (IANZ) has approved the use of the MSL talking clock for this purpose.

This technical guide describes the simple procedure required for the traceable calibration of a stopwatch using the MSL talking clock. The calibration is simple. However, this guide is intended to assist users with calculating an uncertainty of measurement, choosing a calibration period and to answer some of the questions often asked about the use of the talking clock for calibrations.

Figure 1. Photograph of a stopwatch.

The MSL Talking Clock

The MSL talking clock provides a convenient source of traceable time. The important feature of this clock is that it is connected to the New Zealand Time Standard and shows small variations in the delay of the signal during transmission.

The talking clock is available simply by phoning 0900 45678. There is a charge of 99c including GST for each call.

Every ten seconds the clock states the current New Zealand time and then broadcasts three “time pips” separated by one second. The time is correct at the start of the third “pip”. Each “pip” consists of a 150 ms burst of 1000 kHz tone. After one minute of time information the clock hangs up.

The Calibration Procedure

The calibration simply requires two calls to the talking clock. On the first call, the stopwatch is started at the beginning of the third "pip" while noting the time of day given by the clock. At some later time, a second call is made, the stopwatch is stopped on the third "pip", and the new time of day noted. The relative time error in the stopwatch is determined by dividing the difference between the time interval shown on the stopwatch and the time interval determined from the talking clock readings by the talking clock time interval .

For example, if the recorded talking clock times are 11:05 am on one day and 11:05 am on the following day, and the stopwatch records a time interval of 24 hrs 0 min 0.98 second, then the relative error in the stopwatch is

$$(86400.98 - 86400)\ \mathrm{s}/86400\ \mathrm{s} = 1.1 \times 10^{-5}\,.$$

Using a Stopwatch

When using a stopwatch, it is important to start the watch as close in time as possible to the start of the event and to stop it at the end of the event. In the case of hand timing using a stopwatch, the variation in the delay between the event and the actual recording of the time can be significant. This is true both for the calibration of the stopwatch and during its use.

There are two types of event commonly measured with stopwatches, and the delays are different for each type. The first type of measurement is timing an event where it is not possible to predict in advance when the event will occur. For example, in timing a running race the stopwatch must be started in time with the starter’s gun, but the exact time when the gun will be fired cannot be anticipated. In this situation, the delay between the start of the event and the starting of the stopwatch may vary by as much as one quarter of a second.

The second type of measurement is one where the event may be anticipated. For example, in a race the end of the race is a predictable event and the time of crossing the line can be anticipated. In this case, the variation in the delay between the end of the event and stopping the stopwatch may be closer to a tenth of the second. However, it is important to avoid over anticipating the actual event. When athletic events moved from hand timing to electronic timing, the electronic times were longer than the hand measured times. This is because of the tendency of the people doing the timing to anticipate the finish of the race.

Calls to the talking clock are another example of a measurement where the event can be anticipated. The three time “pips” allow the time to start (or stop) the stopwatch to be anticipated. By mentally counting “one” “two” “three” in time with the “pips” and starting the stopwatch on the count of “three”, it is possible to achieve a low error. Measurements that I made over 10 calls to the talking clock produced an uncertainty of around a tenth of a second. Note that this uncertainty included two events (both the starting and the stopping of the stopwatch).

The Measurement Uncertainty

The terms in the previous section largely determine the measurement uncertainty you can achieve in a calibration with respect to the talking clock. The only other large term is the resolution of the actual stopwatch being used. For electronic stopwatches this is usually 1/100 of a second, but for long times the resolution may only be one second. For example, the watch shown in Figure 1 can time intervals up to 23 minutes 59 seconds with a resolution of 1/100 of second, but for intervals longer than this the watch only reads time with a 1 second resolution.

Table 1 shows a complete uncertainty analysis for a stopwatch. The first two terms in the table are insignificant in the final uncertainty, but are included for completeness and to establish traceability. The calculation is for a random start and anticipated stop type of measurement. The stopwatch resolution is 1/100 of a second.

Table 2 shows the uncertainty for some different combinations of stopwatch resolution for a random start and stop measurement and a predictable start and stop measurement. Most other measurements will fall somewhere between these two extremes.

Table 1. A complete uncertainty calculation for a stopwatch assuming a 0.01s resolution, and a random start and anticipated stop type of measurement.

Source of Uncertainty	Standard Uncertainty (seconds)	Effective Degrees of Freedom
Traceability of the Cs clock of the national time standard	41×10^{-9}	60
Variability of the delay in the phone lines (measured at MSL)	0.02	9
Starting and stopping the stopwatch when calibrating it with the talking clock.	0.10	9
Starting stopwatch in the measurement	0.25	9
Stopping the stopwatch in the measurement	0.10	9
Resolution of the stopwatch = 0.01 s. Rectangular distribution, so use 0.005/√3.	0.0029	5000
Combined standard uncertainty	**0.29**	
Expanded uncertainty	**0.61**	
Effective degrees of freedom	**15**	
Coverage Factor	**2.13**	

Table 2. Measurement uncertainty for different combinations of stopwatch resolution and reaction times.

Stopwatch Resolution (seconds)	Reaction Times for the Measurement Start and Stop (seconds)	Expanded Uncertainty (seconds)
0.01	0.1	0.36
0.01	0.25	0.76
1	0.1	0.66
1	0.25	0.94

Determining a Time between Calls

Once the uncertainty of measurement is known and the desired accuracy of the calibration is determined, it is possible to calculate the shortest time interval between calls to the talking clock. The graph in Figure 2 shows the time required between calls to the talking clock versus the accuracy required from the calibration for stopwatches with 0.36 second and 0.94 second uncertainties.

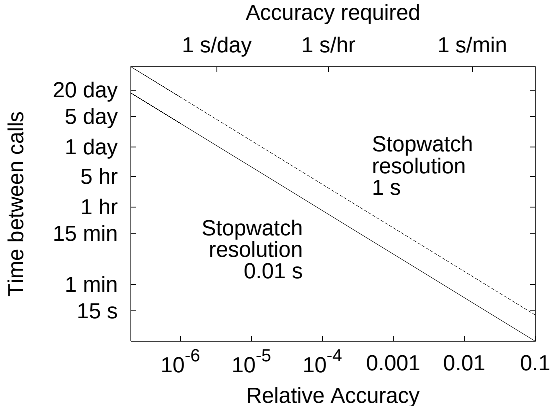

Figure 2. Graph showing the time required between calls to the talking clock versus the accuracy required from the calibration for the first and last uncertainties shown in Table 2.

Common Talking Clock Queries

To synchronise the spoken time messages with the true time, the talking clock only answers every ten seconds. This means that it can take up to nine seconds to answer a call, which, if you are expecting a machine to answer, can seem like a long time.

The MSL talking clock has been run on the same phone number since 1989 and there is no intention to change it. Twice in the last ten years, some fault in the phone system or in the clock has stopped its operation for a short time of less than an hour. However, MSL receives many queries from people who use the clock as a reliable time source and think that it has suddenly stopped working. The main reason for this perception is usually the installation of a new telephone system at their place of work (or even a change to the software on the exchange) so that 0900 calls are prevented. In these situations the 0900 number appears to ring normally but is never answered. It is usually possible for the bar to be removed for particular numbers if requested.

Prepared by Tim Armstrong, June 2004.

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