ATTACHMENT A

STOPWATCH CALIBRATION

Introduction

The international standard for evaluating the accuracy of quartz watches is given in ISO 10553:2003 "Horology – Procedure for evaluating the accuracy of quartz watches". The procedure designed for quartz watches with an indicated accuracy of less than ±30 seconds per annum involves taking measurements over three days with a three day stabilisation period before and a twenty four rest period before the next stabilisation/test period. With three separate three day test periods the total measurement period for this test phase is 66 days and this is followed by a temperature simulation test program over thirteen days. As a typical stop watch may have an indicated accuracy of 6ppm i.e. about 0.5s per day such a test is not appropriate for competition stopwatches apart from being too expensive.

The calibration test method given below was suggested by the Centre for Sports Technology London and their permission to use their work is gratefully acknowledged.

Procedure

Determine an appropriate verifiable source of UTC time. This could be from a talking clock provided by the local telephone service, your computer or a GPS timer. The detailed procedure that follows is for a telephone service. Guidance for using other systems follows.

Reset the timer being checked to zero.

Whilst listening to the time on the telephone, start the timer at the third of a set of strokes or when the timing source reaches a full minute. Note the time. For long periods using the telephone time service, it is helpful to choose to start the clock when a full minute is reached at the third stroke.

When the required time has elapsed, stop the timer.

Where long intervals of time are involved, the telephone may be replaced and the call made again near to the time needed. The telephone will, in any case, disconnect automatically after a maximum of one minute in Australia but at different intervals elsewhere. Note that these days there is usually a charge for the telephone time service.

Repeat the test at least three times but preferably four or more times for each time interval so that the calculated standard deviation of the mean of the errors will be reasonably accurate.

Record the time recorded by the timer for each of the tests.

It would also be acceptable to compare a timer against another timer that has been calibrated professionally and is traceable back to a national or international standard. This could be a photo-finish timing system. Both timers would be started and stopped simultaneously, and the times compared. As stated above preferably five or more separate readings would be taken at the maximum time interval at which the timer being calibrated records the time in 1/100ths of a second.

Calculations

The error is the difference between the stopwatch reading and the reference time interval. Record the error of the time for each test interval including the sign of the error, "+" or "–". Calculate the mean and the standard deviation for each time interval. The mean time difference from the timing interval should not exceed the equivalent of 1 second per day. If the time difference exceeds this amount then return the watch to the supplier if it is under warranty. If the warranty has expired do not use the watch for competition timing. The standard uncertainty for the mean time is the calculated standard deviation for the mean time interval divided by $\sqrt{n}$ where n is the number of readings taken at the time interval. This is essentially the standard deviation of the difference between the start and stop reaction times. In the following uncertainty calculation a value of 0.050s has been used. The actual value obtained from the measurements should be used. The standard uncertainty value obtained should not exceed 0.010s. If it does exceed that figure then the whole test procedure and particularly the start / stop procedure should be reviewed or a different tester used.

Uncertainty (Precision and Accuracy)

The UK Speaking Clock is stated to be accurate to 5 ms and is corrected as necessary, twice a day, by reference to the NPL atomic clock.
These values for accuracy refer to the difference between the time given by the Speaking Clock and the 'true' time, as indicated by the NPL Clock. Over shorter intervals, provided the going rate of the clock is constant, errors should be pro-rata.

In other countries the speaking clock accuracy may be less as it will depend on the delay added by the telephone service as this can be variable as the information is possibly routed differently each time you call for a "time". As an estimate the delay might be taken as 15 milliseconds and a semi-range of 15 milliseconds might be achievable in Australia.

Using a programme from Dimension 4 it is possible to synchronise your PC's clock for Windows-based operating systems using a suitable source server preferably as close to your computer as practicable to minimise the number of routing nodes. The synchronising frequency can be set by you. Also note

that the network delay is determined by a one-way measurement that assumes that the send and return paths are the same. Due to the vagaries of the software clocks and the internet connection the errors are likely to be of the same order as for the talking clock but it is a cheaper option certainly in Australia.

A GPS timer might also be used as the source timer if it has been synchronised with an UTC source. However as cheap GPS receivers are generally primarily concerned with position the time display could be delayed by a variable amount.

The uncertainty of the time recorded will depend upon:

- variations in the speed of reaction of start and stop of the user (you will recall that the standard adjustment of stopwatch manual times for races 400m and less for comparing with automatic times is +0.24 s to allow for operator reactions);
- at least one digit with digital timers;
- the constancy of the speaking clock or other timing reference going rate.

An uncertainty budget for the calibration using the talking clock in Australia is given below.

UNCERTAINTY BUDGET FOR AN ELECTRONIC STOPWATCH CALIBRATED AGAINST A TALKING CLOCK IN AUSTRALIA

Component number	Uncertainty component	Nominal Value	Type	Uncertainty comment	Distribution	Standard uncertainty	Variance
1	Speaking clock accuracy	15 ms	B	Uncertainty is independent of timed interval = 8.66 ms	Rectangular	0.00866	0.0000750
2	Start/stop error	50 ms	B	sd of difference in reaction times	Normal	0.05	0.0025
3	Digitisation error stopwatch	10 ms	B	Resolution is 0.01 s	Rectangular	0.002887	8.333E-06
4	Timebase variations – i.e. crystal oscillator frequency.	Assume 10 ppm	B	For 100 s = 0.001 s	Rectangular	0.00057735	3.333E-07
						Combined standard uncertainty	**0.051**
						Uncertainty 95% CI	**0.102**

It can be seen that the largest effect by far on the uncertainty of measurement is operator start / stop error cf. its standard uncertainty (0.050ms) with the combined standard uncertainty of 0.051ms.

Start / stop errors will vary from person to person. For one person the errors will tend to be constant either always early or always late so there is a cancellation effect.

Mechanical watches and clocks going rate most probably will vary with temperature, the degree to which the watch is wound and physical movement of the watch particularly rotational. Mechanical timers must always be handled with great care, be full wound before use and be kept at constant temperature. These old technology timing devices should no longer be used for competition timing.

With electronic timers, the time-base is provided by a quartz crystal oscillator. These oscillators are selected for their stability and constant frequency, though they can be affected by temperature. Significant temperature variations cannot occur over short periods since the crystal is physically located within the clock or watch. If the frequency is constant over the calibration period a valid calibration can be carried out using periods much longer than the periods the watch is used to measure. Since as shown above the significant errors listed above are mostly constant and give rise to a constant-time uncertainty in the measured time, the longer the calibration period, the smaller the calibration uncertainty expressed as a percentage of the measured time. Therefore it is recommended that the calibration test interval be 24 hours or the maximum time at which the timer reads to 1/100ths of a second with the time being read and recorded to 1/100ths of a second. Federations are advised to purchase digital watches that continue to time in 1/100ths of a second even if the hour's digit returns to zero after 10 hours.

A summary of the results achieved in the testing should always be kept in the Federation Equipment Manual recording the "errors" indicated for future reference.

Check the results of the measurements against the acceptability criteria for the timer being calibrated.