# Characterization of the Riga Event Timer A032-ET

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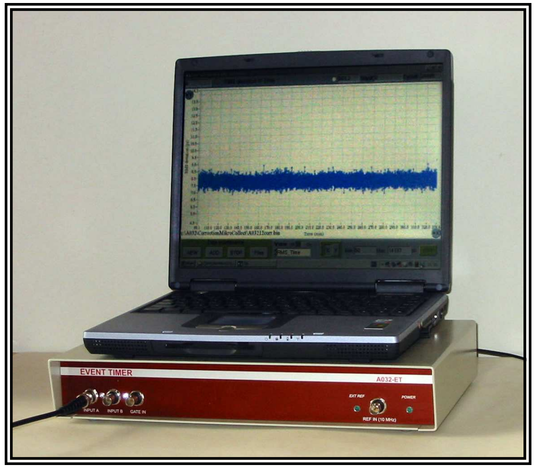


## The problem to be solved

Currently we are manufacturing several A032-ETs annually. The precision characteristics of each instrument must be certified before it is delivered to a customer. Taking into account an extreme precision of the instruments, there is a problem to evaluate these characteristics in a reliable way and without using of expensive test equipment.

As a rule, the precision characteristics of the Event Timers are specified by the precision of the measurement of time interval $T_j$ between two events. The error $\Delta T_j$ of the time interval $T_j$ measurement can be defined as :

$$\Delta T_j = B(t) + E(T_j) + \xi_j,$$

where: $B(t)$ – time-varying offset in the measurement;
$E(T_j)$ – non-linearity error that depends on a time interval $T_j$ ;
$\xi_j$ – unbiased random error.

These component values in the A032-ET specification are defined as follows:

$$B(t) < 1\,ps\,/\,^{\circ}C, \qquad E(T_j) < 1\,ps, \qquad \xi_j < 10\,ps$$

and are evaluated for each instrument before its delivering.

Errors caused by the reference frequency instability and trigger errors are not considered because the highest precision for A032-ET requires an external source of the reference frequency and normalised pulses for events presentation.

***How can we evaluate and grant these characteristics for each manufactured A032-ET?***

## Problem solution

To solve the problem we have developed methods using...

the next A032-ET properties:

1. full control from the computer, including the possibility to restart measurement, to open and close inputs;
2. common measurement node for both inputs; it excludes an offset for events, coming at the same input, and gives the minimal offset for events, coming at the different inputs.

and the special hardware and software means:

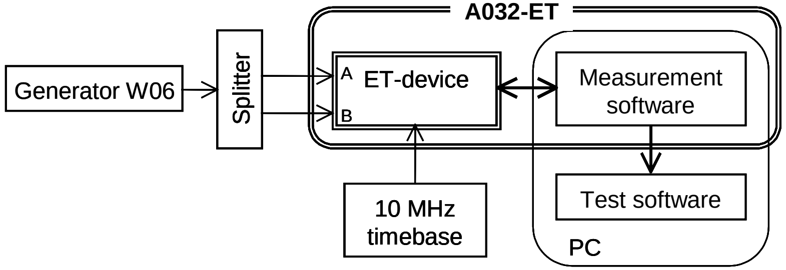
1. Self-made generator W06, which generates low-jittered periodic pulse sequence;
2. Special software to control the measurement process, accumulate and treat the measurement results for precision evaluation.

Particular methods and means are intended for the experimental evaluation and specification of each mentioned component of the measurement error and are reviewed as follows:

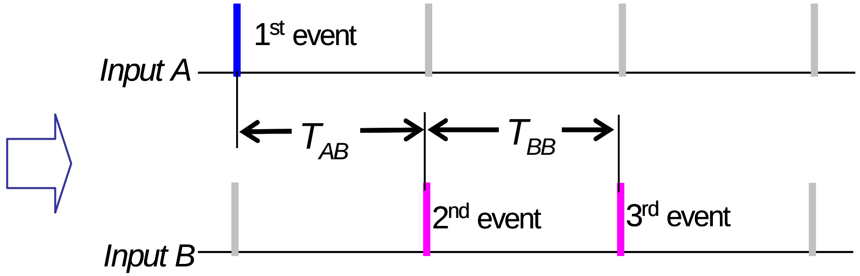
1. Stability Test (evaluation of the offset drift)
2. Linearity Test (evaluation of non-linearity errors)
3. Resolution Test (evaluation of random errors)

## Stability test - evaluation of the offset drift …

**In our case the offset is a systematic error in time interval between two events if and only if they arrive at the different inputs of the ET-device. The test is dedicated to monitor an offset variation during long time at permanent or slightly changing ambient temperature.**




**Test setup for stability monitoring**



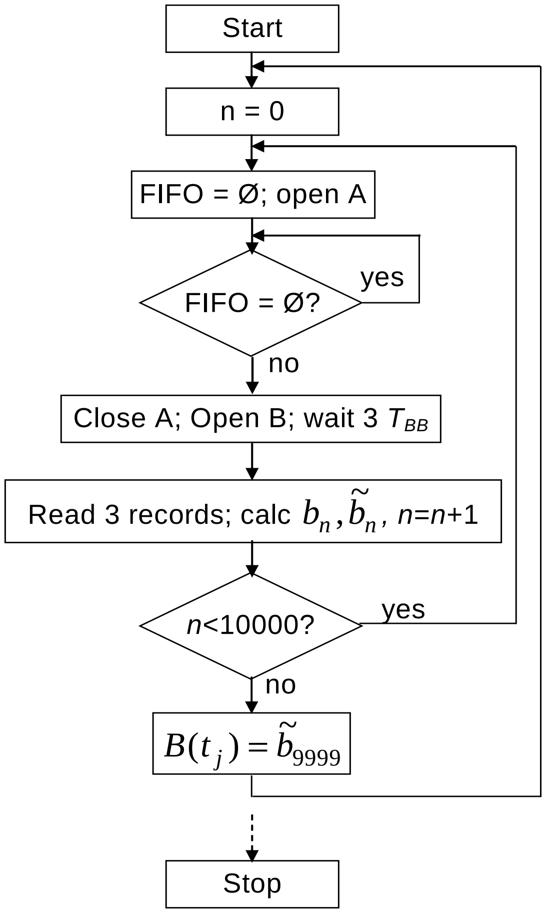

**Event sequences at ET-device inputs**

Under these test conditions the time interval $T_{AB}$ is measured with some offset, but the time interval $T_{BB}$ – without any offset. Therefore the offset in the time $t_j$ can be defined by a difference:

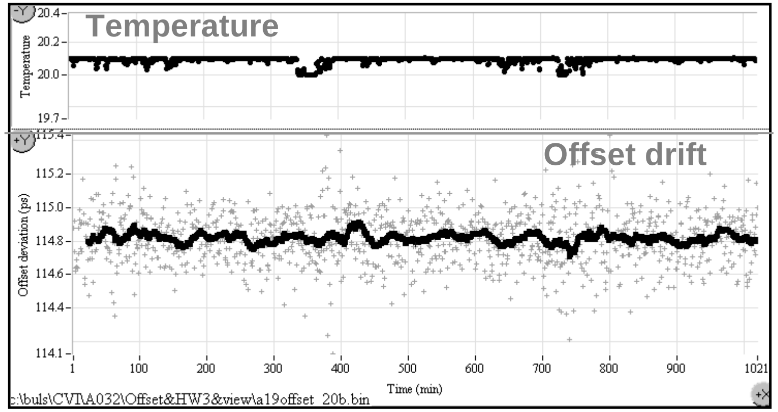
$$b_j = T_{AB} - T_{BB}$$

The long-term instability of the generator W06 does not affect on the offset estimation, but the test signal jitter and random errors of event measurement affect. Typically such errors dominate over offset drift. Taking into account that the offset drift is a slow process the sequential single estimates $b_j$ can be averaged to minimize the evaluation error.

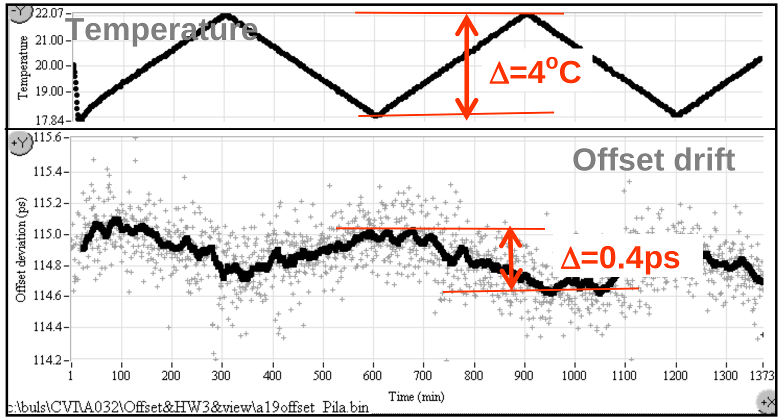
## … evaluation of the offset drift




Offset monitoring procedure




Offset at stable ambient temperature = 20 °C

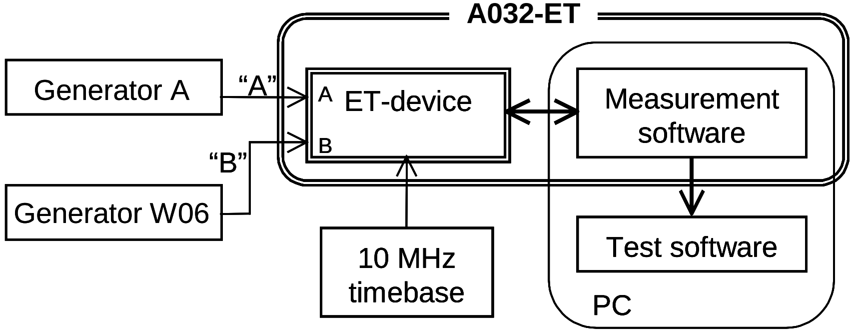



Offset at varied ambient temperature

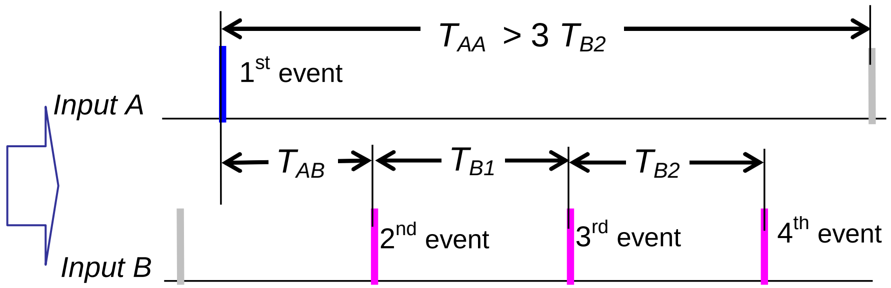
RMS error of the evaluation is about 0.2 ps. In addition a moving averaging of 25 such offset values is applied to detect the offset drift more distinctly.

## Linearity test - evaluation of non-linearity errors …

**A032-ET needs about 60 ns for single event measurement. During this "dead time" new events are not logged. But even after this time there is some damping transient, which affects on a next measurement. This effect depends on the time interval from the previous measured event. The linearity test is dedicated to define this dependence.**




**Test setup for nonlinearity measurement**




**Event sequences at ET-device inputs**

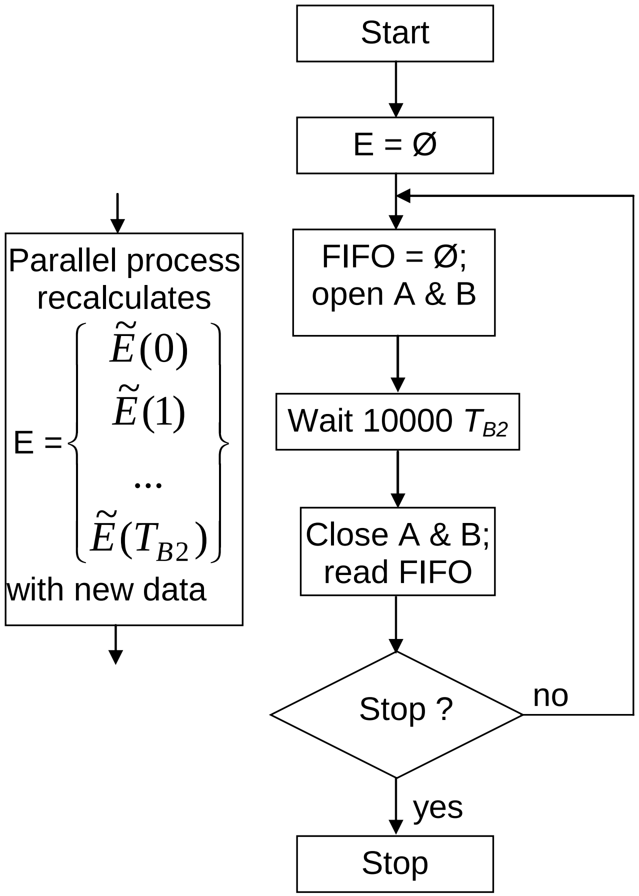
Generator A is a NIM pulse generator without special requirements to its precision and stability. It generates a pulse sequence with period a little greater than three periods of test signal.

As the result for any event at the input A we have at least 3 events at the input B and the interval $T_{AB}$ is changing in the range from the "dead time" value up to the W06 period.

In such quads the events 1, 3 and 4 are not affected by the transient process, but the event 2 is affected. Taking into account the short term stability of W06 the nonlinearity error will be defined by difference:

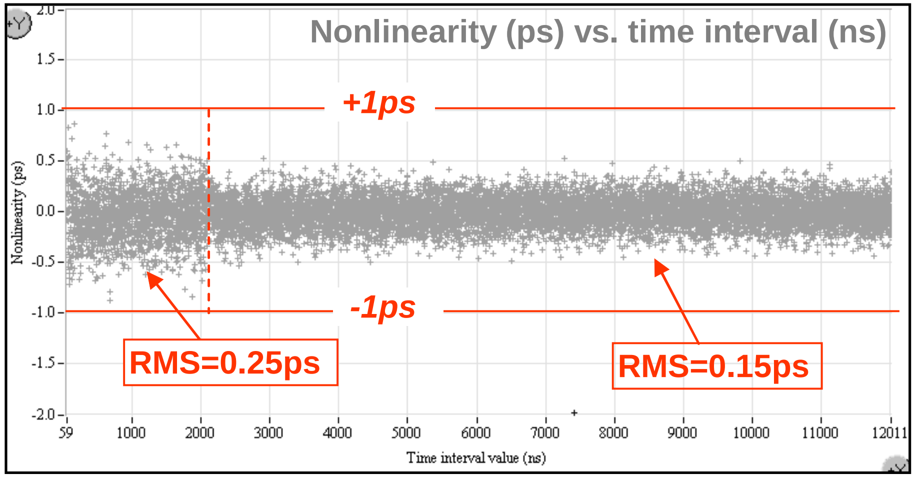
$$E(T_{AB}) = T_{B1} - T_{B2}$$

## … evaluation of non-linearity errors




**Nonlinearity test procedure**

The measurement software of A032-ET provides a digital correction of ET-device non-linearity. However, as shown below, it cannot correct initial nonlinearity completely, leaving slight, noise-like non-linearity.



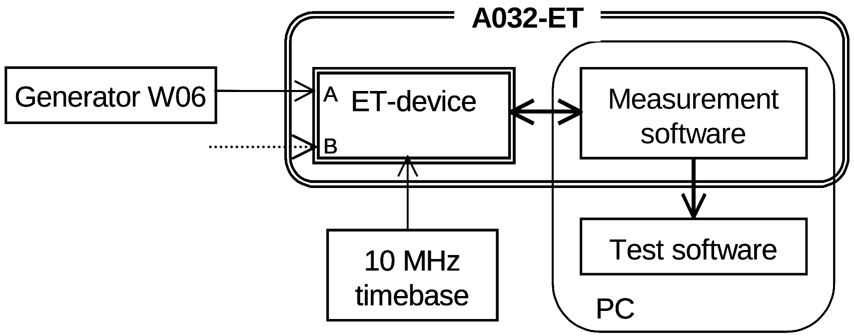

**Typical result of the linearity test**

This result is obtained from 500 millions measurements (~ 7900 initial estimates for each 1 ns increment). Such statistics has been collected during 9 hours of continuous test.

## Resolution test …

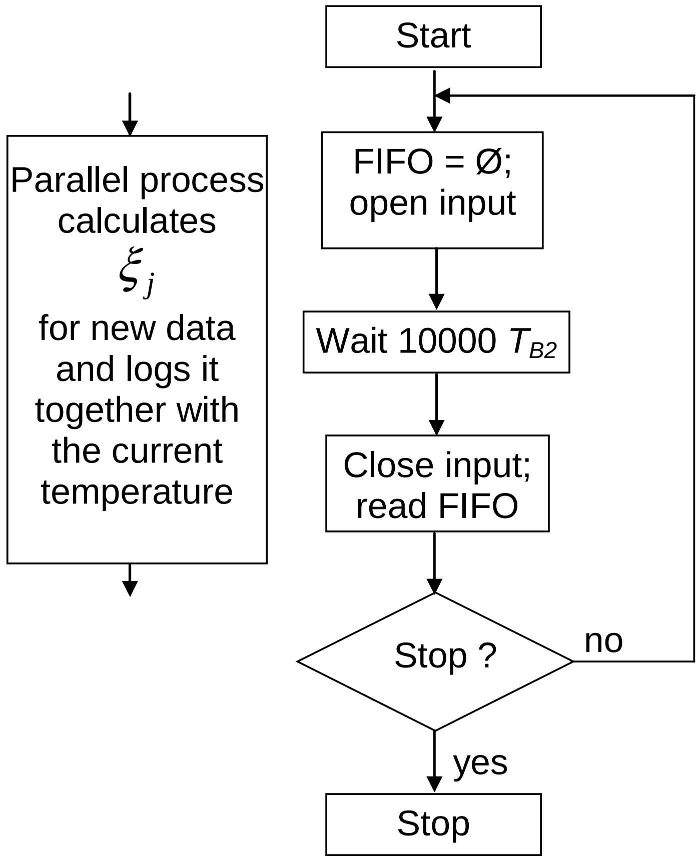
**The Event Timer precision usually is characterized by the "single-shot RMS resolution". This test is dedicated to monitor the RMS resolution and the ambient temperature during the long time.**

The simplest way to specify the RMS resolution is to perform direct repetitive measurement of the test signal that has a jitter much smaller than expected random errors produced by the instrument.




**Test setup for resolution check and monitoring**

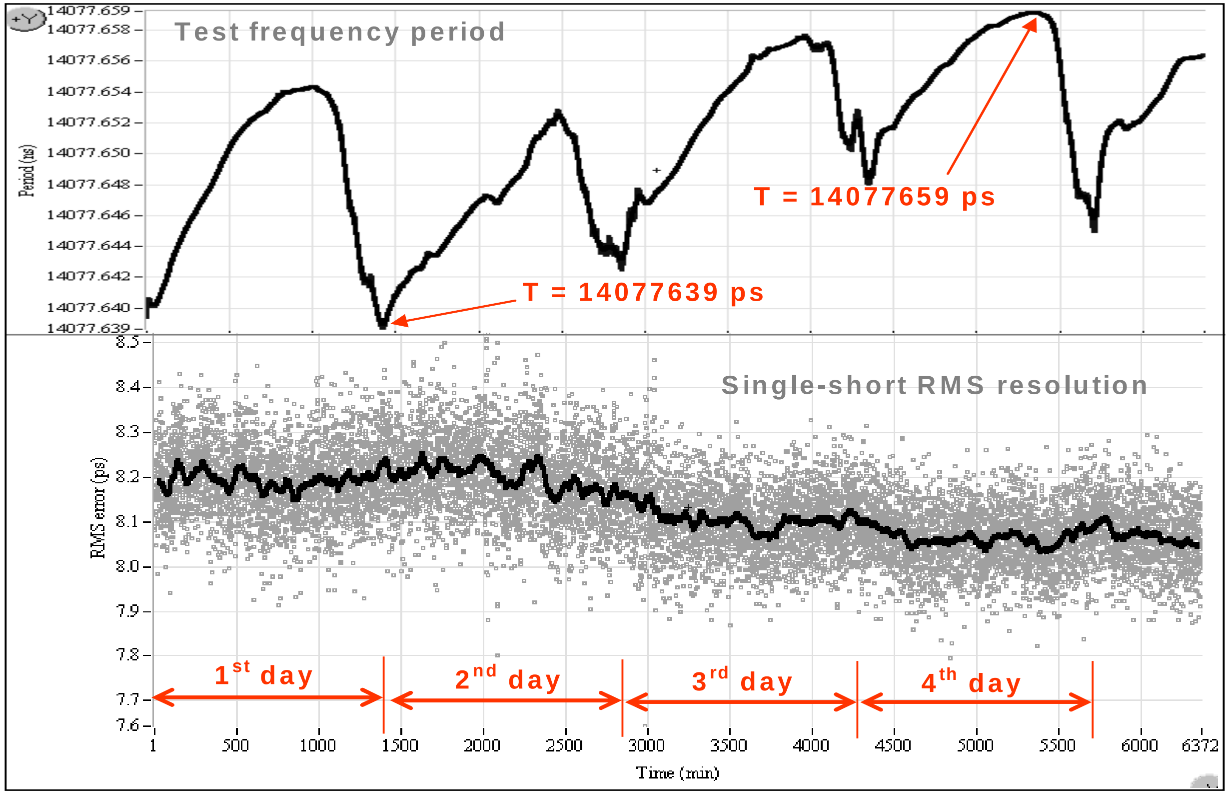
The Generator W06 provides low jitter (<2 ps RMS) test signal and its period (14077.4… ns) ensures nearly uniform event distribution within the interpolation interval.




**Resolution monitoring procedure**

## … resolution test in stabile ambient temperature

The test result, when the ET-device is placed into incubator with stable temperature. The test generator W06 is outside the incubator and the test frequency varies by 4 diurnal cycles.

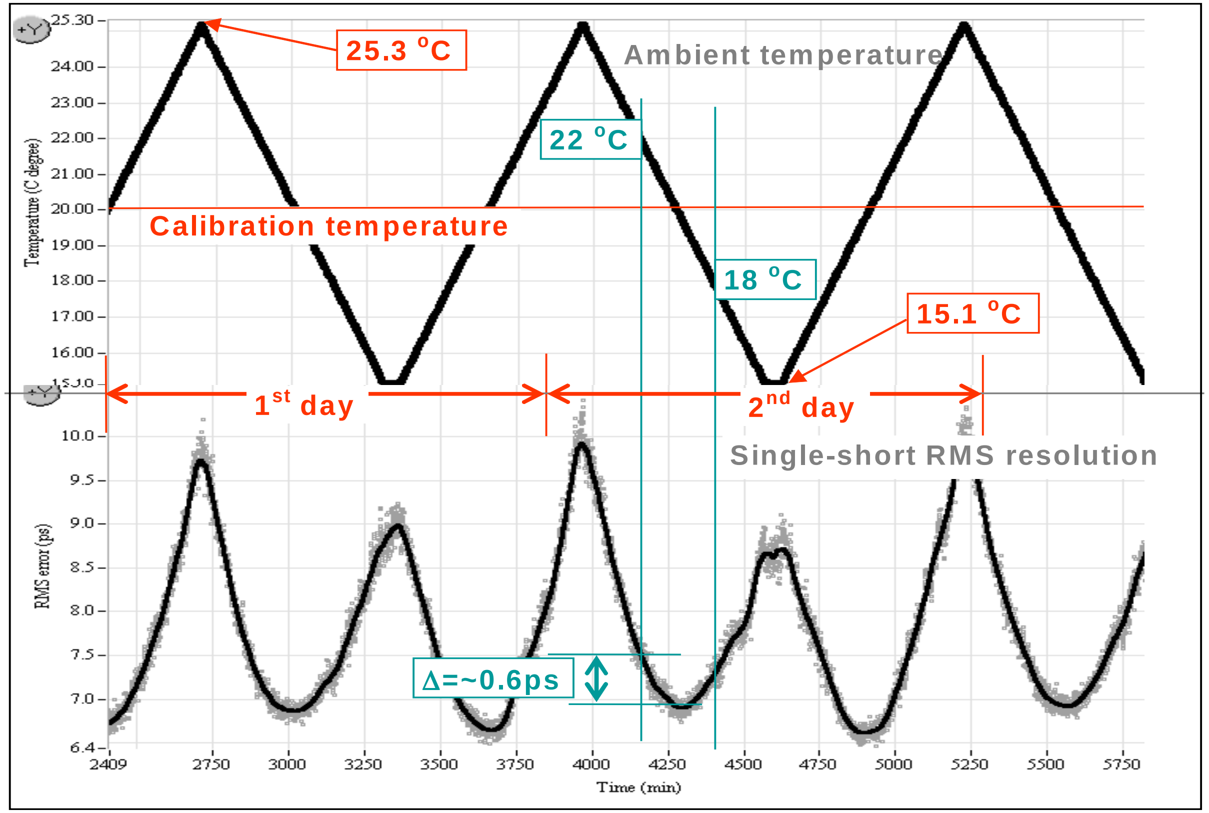



**Resolution variation during 4.5 days at permanent ambient temperature**

The slight (+/- 0.1 ps) change of RMS resolution can be observed. Probably this is caused by a change of test signal jitter, which cannot be separated from the monitored resolution.

## … resolution test at essential variation of ambient temperature

The test result, when the temperature inside the incubator varies in the range ±5˚C. The calibration was done when the temperature was 20˚C.




Resolution vs. time under ambient temperature variation

The resolution degrades in line with any temperature variation (negative or positive) from the temperature when the calibration was done. But such degradation is not too large (0.6 ps approx.) if the temperature variation is relatively small (less than ±2˚C)

## Conclusions

1. Practicable precision of the Riga Event Timer A032-ET is completely specified by three basic parameters:
   - offset stability;
   - nonlinearity;
   - single-short RMS resolution.

2. The methods of reliable evaluation of these parameters are developed and successfully applied. The distinctive features of the methods are:
   - differential test measurements to minimize the impact of test signal instability upon the test results;
   - full automation of the tests and using of very large statistics to minimize the evaluation errors;
   - there is no necessity of complex and expensive test instrumentation.

3. It is shown that long-term instability of the A032-ET precision parameters is caused mainly by ambient temperature variation.

4. Although currently the test methods are applied for the A032-ET testing, they also can be used for testing other event timers with similar architecture.