Event Timer A033-ET: Current State and Typical Performance Characteristics

Artyukh Yu., Bespal'ko V., Boole E., Vedin V.

ABSTRACT

The main results of experimental evaluation of precision characteristics (conventionally considered as well as new ones) for the Event Timer A033-ET are presented in this report. These results allow to suppose that the A033-ET really provides the measurement precision and rate that altogether seem sufficient for both routine and advanced KHz SLR.

1 Introduction

The Event Timer A033-ET represents the latest model of Riga event timers intended for SLR. It has been developed as an advanced version of the previous model A032-ET [*Bespal'ko V., et al.*, 2008] that is well known in SLR community. As it was announced at the 16th ILRS Workshop [*Artyukh Yu., et al.*, 2009], the A033-ET became commercially available from 2010, and up to now 10 units of this device have been manufactured and carefully tested. Consequently, significant statistics have been accumulated to reliably specify the A033-ET typical performance characteristics

Generally the A033-ET and A032-ET are closely related instruments in terms of general architecture and functionality. The main difference concerns the A033-ET precision which has been considerably improved, making the A033-ET one of the highest precision event timers commercially available. In this paper we'll focus on specification of the actually obtained precision characteristics.

2 A033-ET precision characteristics

2.1 Single-shot RMS resolution

We consider the single-shot RMS resolution as the main parameter specifying the practicable A033-ET precision and define that as the standard deviation of instrumental error in asynchronous measurement of time intervals between events. The commonly used way to specify the actual value of the single-shot RMS resolution for particular instrument is direct repetitive measurement of time intervals between events defined by a periodic test pulse sequence. For that we used low-jitter (RMS<1 ps) crystal clock oscillators with period of test pulses which is virtually incommensurable with internal clock period of the timer. The evaluated in this way single-shot RMS resolution typically is in the range 2.5-3.0 ps (Fig.1).

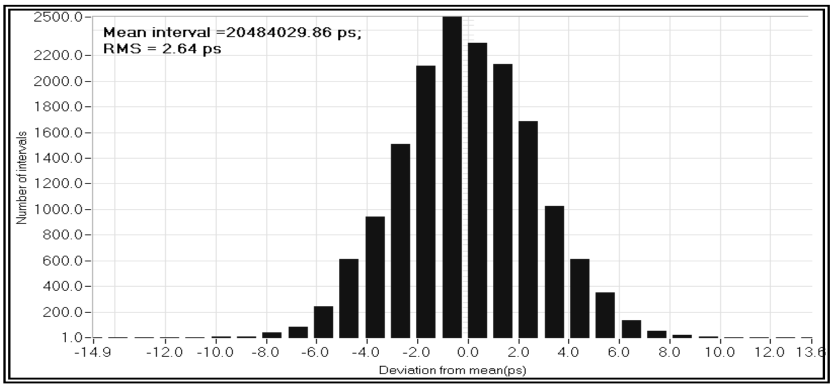

Figure 1. Histogram of time intervals measured by the A033-ET

It should be noted that the A033-ET offers the best resolution under stable measurement conditions. In particular, natural fluctuations of the ambient temperature result in a slight long-term instability of the practicable resolution (Fig.2).

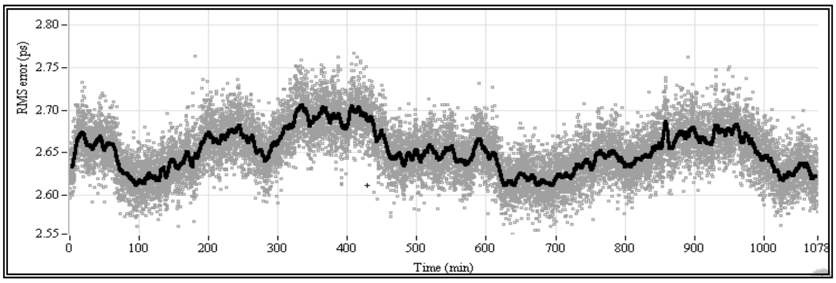

Figure 2. RMS resolution vs. time under ambient temperature variation in the range ±2.5 ^{0}C

As can be seen, such instability is quite acceptable to support the measurement for long without recalibration.

The A033-ET supports the above resolution at relatively high (for such high resolution) measurement rate: up to 20 MSPS for bursts of up to 2 600 events, and up to 12.5 MSPS for bursts of up to 16 000 events. As for the maximum average rate of continuous measurement, it is limited mainly by the hardware interfacing with PC. For PC under MS Windows it is not less than 12 KSPS but can be increased by using the operating systems better adapted to real-time applications.

2.2 Non-inearity errors

There are two kinds of non-linearity errors in event timing. The integral non-linearity error represents a systematic error in event measurement that depends on the position of measured event over interpolation interval. Stand-alone specification of the integral non-linearity errors can be important mainly for the case of synchronous measurements when the measured events are located in some fixed areas of interpolation interval. In this case results of their measurements can be biased by these errors. For asynchronous measurements the integral non-linearity errors are not of particular interest since they get in the total instrumental error as its random-like component, limiting the single-shot resolution. Statistical method for such error evaluation is offered in [*Artyukh Yu., et al.*, 2008]; in our case applying this method allows to define the A033-ET integral non-linearity with sub-picisecond precision (Fig.3).

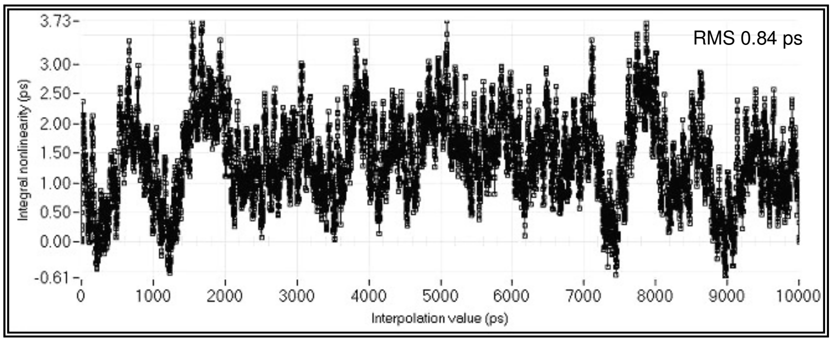

Figure 3. Integral non-linearity error over 10 ns interpolation interval

On average these errors are specified by the value of their standard deviation, representing significant component of single-shot RMS resolution. Typically the A033-ET integral non-linearity RMS error is less than 1 ps directly after device calibration. In this case the actual integral non-linearity decreases the the timer’s RMS resolution by 25-30% approx. Note that for Riga event timers the integral non-linearity considerably depends on the calibration quality that has been significantly improved as compared to the previous instrument.

Unlike the integral non-linearity error, the interval non-linearity error is a systematic error in measurement of time interval between adjacent events, depending on the value of this interval. Mostly specification of the interval non-linearity error may be important for the case of measurements of time-intervals varied in a wide range. However, the A033-ET provides negligible interval non-linearity errors (peak-to-peak value less than ±0.2 ps approx) in a wide range of time intervals. Exceptions represent very small time intervals (close to the timer’s dead time) where the errors can be a little greater.

2.3 Single-input offset drift

The A033-ET has a single-channel configuration. This means that all events provided by either input of the timer's hardware are measured sequentially in the same manner and by the same means. Owing to this there is no any noticeable error in time intervals between measured events when these events come at only one input. However there is some offset drift in measurement of a single event coming at this input (so called Single-input offset drift). Outwardly, it is seen as long-term instability (phase deviation) of the internal time-base relative to the external 10 MHz reference frequency, depending mainly on the ambient temperature variation. Typically the A033-ET single-input offset drift does not exceed 2 ps/^{0}C (Fig.4).

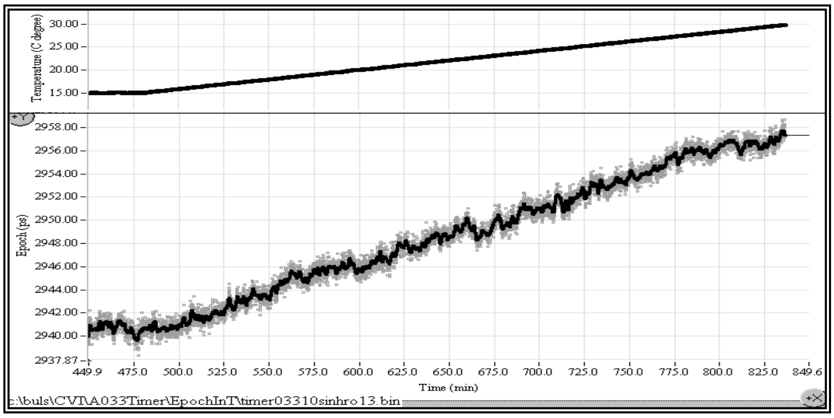

Figure 4. Single-input offset drift in line with slow linear changing of ambient temperature from 15 to 30 ^{0}C

Generally such offset drift is not too important for the applications related to the time interval measurement, except for very long time intervals during which the ambient temperature can be significantly changed.

2.4 Input-to-input offset drift

When the events come at the different inputs some offset in time interval measurement appears. It is caused by a difference between internal propagation delays of input signals before coming to the common measurement unit. These delays slightly vary with the ambient-temperature change, causing certain offset drift (so called Input-to-input offset drift) and corresponding long-term instability in time interval measurements. Outwardly, it is seen as long-term deviation of systematic error in time interval measurement between Start and Stop events coming at the different inputs A and B of the event timer respectively.

The A033-ET input-to-input offset drift typically is about of 0.1 ps/^{0}C (Fig.5), i.e. it is much less than the single-input offset drift due to partial compensation of two similar offsets.

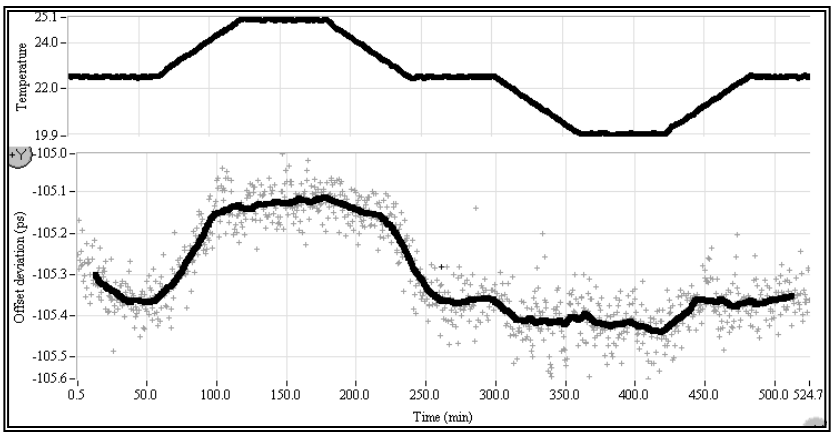

Figure 5. Input-to-input offset drift in line with slow linear changing of ambient temperature from 20 to 25 ^{0}C

Actually this offset is tangible only during warming-up the timer's hardware after power-up.

3. Summary

As the Table 1 below suggest, the model A033-ET, in comparison with the previous model A032-ET, is distinguished by considerably advanced precision concerning different essential aspects of its specification.

Table 1. Precision comparison

Model	*Resolution*	*Integral error*	*Interval error*	*Single-input offset drift*	*Input-to-input offset drift*
A032-ET	7 – 8 ps	<2 ps	<1 ps	N/A	<0.4 ps/^{0}C
A033-ET	2.5 – 3 ps	<1 ps	<0.2 ps	<2 ps/^{0}C	<0.1 ps/^{0}C

In principle even better measurement precision is possible but its achievement leads to much higher production cost. However the Riga event timers have been always conceived as commercially available instruments which have an attractive price/ performance ratio. In this case currently we have come to the conclusion that single-shot RMS resolution of them should be limited by 3 ps approx. to achieve relatively simple and inexpensive technical solution.

Newertheless, it seems that the A033-ET currently offers resolution and measurement speed that are quite sufficient for the most of ground-based SLR stations that provide both routine and KHz SLR. Taking that into account, currently we focus our research activity on advancing of other important performance characteristics of Riga event timers, such as their reliability, friendliness and hardware simplicity [*Artyukh Yu., et al.*, 2011].

Acknowledgements

This paper reflects the research results that were obtained in frameworks of the R&D project No. 2DP/2.1.1.1.0/10/ APIA/VIAA/084 co-sponsored by the European Union.

References

Bespal'ko V., Boole E., Vedin V., 2008. The Model A032-ET of Riga Event Timers// Proceedings of the 15th International Workshop on Laser Ranging, Canberra, Australia, 2008, Vol.2, pp. 321-326.

Artyukh Yu., Bespal'ko V., Boole E., 2008. Non-linearity errors of High-precision Event Timing.– Automatic Control and Computer Sciences, Vol. 42, Nr. 4(68), pp. 191-196.

Artyukh Yu., Bespal'ko V., Boole E., Vedin V., 2009. Advances of High-precision Riga Event Timers// Proceedings of the 16th International Workshop on Laser Ranging, Poznan, Poland, 2009, Vol.2, pp. 398-403.

Artyukh Yu., Bespal'ko V., Boole E., Stepin V., Stepin D., Vedin V., 2011. Main Directions of Riga Event Timer Development and Current Results (these Proceedings).

Correspondence

Yuri Artyukh
Institute of Electronics and Computer Science, 14 Dzerbenes Str., Riga LV-1006, LATVIA

e-mail: artyukh@edi.lv