The Model A032-ET of Riga Event Timers

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Abstract

The Event Timer A032-ET is an advanced version of the earlier model A031-ET of Riga event timers. As compared to this model, the A032-ET offers better single-shot resolution (<10 ps RMS) and is adapted to KHz SLR, supporting continuous measurement at the mean rate up to 10 KHz. At the same time it satisfies basic demands of conventional (low-rate) SLR. In this paper the principles of operation and basic features of the A032-ET are considered. Typical test results concerning the evaluation of single-shot resolution, linearity and offset drift are presented.

Introduction

Riga Event Timer A032-ET was designed in 2005 as an advanced version of the previous model A031-ET [1] with the main aim to adapt it to KHz SLR and improve its operating characteristics. As a result the following additional features of the A032-ET have been achieved:

- Continuous measurement at mean rate up to 10 KHz;
- Client-Server interaction supporting full remote control from the Client;
- Increased single-shot resolution (better than 10 ps RMS);
- Decreased "dead time" (not more than 60 ns);
- Built-in online programmable Stop pulse gating.

At the same time the A032-ET satisfies basic demands of conventional SLR at repetition rate up to tens of Hz and remains affordable at price. A032-ET is already known for some part of users. In particular, during one year after its designing about 10 instruments were delivered to different SLR stations. In this paper the principles of operation and basic features of the A032-ET are considered in more detail.

A032-ET main features

The A032-ET is a computer-based instrument that precisely measures epoch times when events (input pulse comings) occur. There are two alternative modes of the A032-ET operation that are tailored to the high-rate SLR and conventional low-rate SLR respectively:

- **"True Timer"** provides continuous (gapless) measurement of events at high (up to 10 KHz) mean measurement rate, allowing bursts up to 16 MHz. This mode suits well to measure Start and Stop events that come at the separate inputs (either *A* or *B*) of the A032-ET in any order.
- **"Multi-Stop Counter"** provides cyclical measurement of events that come at the separate inputs of the A032-ET in the strict order: in every cycle at first the A032-ET measures a single Start event coming at the input *A*, and then – a user-defined number of Stop events (up to 12,000) coming at the input *B*. The Stop events can be measured with online programmable gate delay.

Such measurements are performed with 7-9 ps RMS resolution in practically unlimited range. Extreme low measurement non-linearity (<1 ps) is supported.

A032-ET architecture

Like the most of virtual instruments, the A032-ET performs its measurement functions partly by hardware means and partly by software means. The measurement software provides interfacing with a user program via TCP/IP based network according to the well-known “Client/Server” scheme. The application program using TCP/IP service utilities can control the A032-ET and receive measurement data from it for further specific-application processing.

In terms of the Client/Server architecture the A032-ET can be considered as a combination of a specialised timing device (ET-device), and a specialised Server (ET-server) dedicated both to managing the ET-device and primary processing the timing data obtained from it (Fig.1).

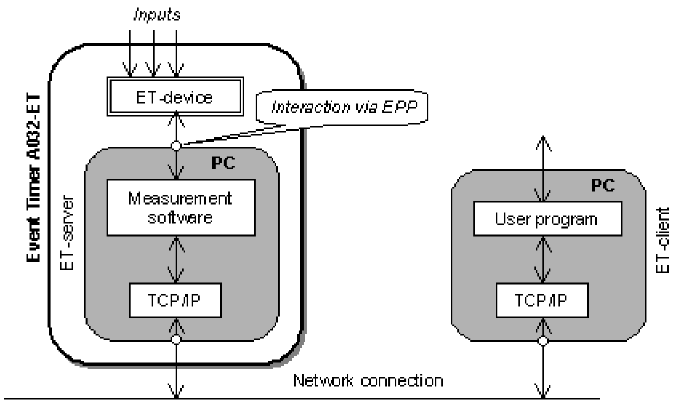

Figure 1. *Network architecture of the Event Timer*

In this case the ET-client is a PC on which user runs his application, using the specific ET-server resources via network. In many cases a single PC under MS-Windows can serve as both the ET-server and the ET-client although a separate PC for the ET-server is preferable to achieve the highest operating speed.

Principles of operation

The A032-ET performs the measurement of input events in two stages. At first, the ET-device transforms every input event into single 80-bit timing data block (TD-block) and sequentially accumulates such blocks in a buffer FIFO memory. Each TD-block contains the clock counter data (39 bits) and interpolating data (40 bits) about the time of event incoming, as well as one-bit mark specifying the input (either *A* or *B*) providing the measured event. The interpolating data are presented initially in an intermediate redundant form and need further an additional processing by the ET-server.

The used unconventional method of event timing supports both high precision and high speed. Specifically, using the 100 MHz internal clocks the method provides each single measurement with <10 ps RMS resolution during 60 ns only. This gives the maximum available rate of event timing about 16 MHz. At this rate the applied FIFO memory is able to accumulate up to 12,000 TD-blocks. An additional attractive feature of this event timing method is that it leads to the relative simplicity of hardware implementation (Fig.2). At the next stage the ET-server reads TD-blocks from the FIFO memory and processes them to obtain the corresponding time-tags in a unified form. Further these time-tags are sent to the ET-client via network.

The ET-device is flexibly controllable and applies two different procedures of TD-

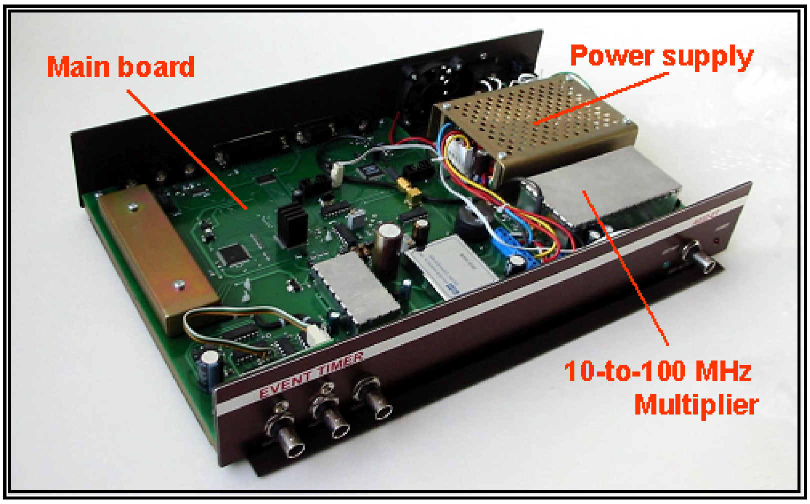

Figure 2. *Hardware design*

block accumulation in the FIFO memory and TD-block reading by the ET-server for two operation modes respectively

In the **"True Timer"** mode the ET-device provides continuous event measurement during practically unlimited time. To do that, the ET-device continuously accumulates TD-blocks in FIFO memory in order of measured event incoming. Concurrently with this process, the ET-server continuously monitors the current state of the FIFO memory with some user-defined period to detect the state when the amount of TD-blocks exceeds the user-selectable value (204, 102, 50, or 25 TD-blocks). The rest of the FIFO memory capacity is used to damp possible bursts of input event intensity. When the specified FIFO state is detected, the ET-server takes out the defined amount of TD-blocks from the ET-device, processes them and sends the corresponding time-tags to the ET-client. Such procedure is being cyclically repeated. In this way continuous event registration goes together with cyclical timing data processing and sending the time-tags to the ET-client via network. The mean rate of such continuous measurement is limited mainly by the available speed of TD-block reading and processing by the PC of the ET-server. Typically (although it may depend on the actual performance of the PC) the total time of single TD-block reading and processing on average is about 0.1 ms, resulting in the maximum mean measurement rate about 10 KHz.

In the **"Multi-Stop Counter"** mode the ET-device provides cyclical measurement of events. In the beginning of each cycle the A032-ET measures a single Start-event coming at the Input *A* of the ET-device, and only then - a number of Stop-events (up to 12,000) coming at the Input *B*. In this case the ET-device accumulates TD-blocks in the FIFO memory during some user-defined waiting period, starting from Start-event registration. During this time the ET-server processes TD-blocks, which are read from the ET-device in previous cycle, and sends the corresponding time-tags to the ET-client. Then the ET-server stops the event registration, reads the accumulated TD-blocks (but not more than the user-defined amount) and starts the next similar cycle. The waiting period can be defined in a wide range with a 1 ms step.

During the waiting period the ET-server can receive a command from the ET-client to restart the measurement with modified gate delay. In this way online cycle-to-cycle controllable gating is possible. However it should be taken into account that the real network may produce some unexpected delays for data exchange, resulting in episodic loss of synchronism in such interactive operation at a high (more than tens of Hz) repetition rate of measurement cycles.

Precision characteristics

Although, in fact, the A032-ET measures the separate events, its precision is specified for time interval between two measured events. In this case the total measurement error ΔT_j for time interval T_j represented by difference of any two time-tags can be expressed as follows:

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

where:

$B(t)$ – time-varying offset in measurement;

$E(T_j)$ – non-linearity error that depends on the value of measured time interval;

ξ_j – unbiased random error.

Specific values of these components of measurement error are evaluated for each instrument. Let’s consider some typical examples of such evaluations.

Single shot RMS resolution

The A032-ET provides the best RMS resolution (standard deviation of the error ξ_j) directly after ET-device calibration. Then the resolution may slightly degrade under time-varying temperature conditions (Fig.3).

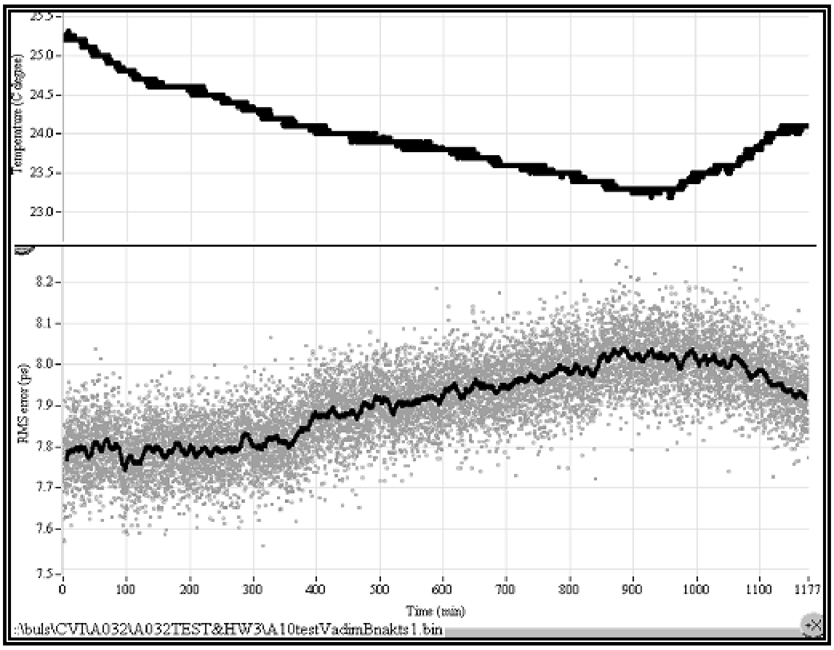

Figure 3. *Ambient-temperature and RMS resolution vs. time*

As can be seen, initially the RMS resolution is about 7.8 ps. During the next 15 hours the ambient-temperature is gradually changed for 2°C, resulting in decreasing of the RMS resolution down to 8 ps (about 0.1 ps/°C).

Linearity

There is some damping transient in electrical circuits responsible for event measurement. If such transient is not completed by the beginning of the following measurement it will be performed with some error. This error depends on the time interval between previous event and event currently measured, causing non-linearity in event measurement.

The A032-ET corrects such non-linearity but cannot exclude it completely, leaving slight, noise-like residual non-linearity in the range up to 2000 ns. This non-linearity appears as errors, which are particular and constant for every 1 ns step of time interval incrementing (Fig.4). In the range exceeding 2000 ns the non-linearity is negligible.

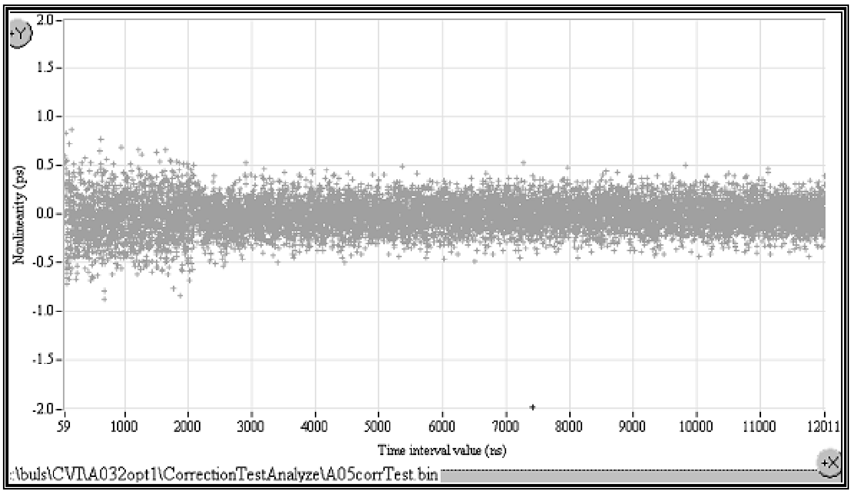

Figure 4. *Typical result of non-linearity error testing*

As can be seen, the maximum non-linearity does not exceed ±1 ps. However such estimate is overstated by reason of the additive evaluation errors (these errors are directly present in the range from 2000 ns). Actually the non-linearity is much smaller.

Offset drift

All events coming at either input of the ET-device are measured sequentially in the same manner and by the same means. Owing to this there is no any noticeable offset in time intervals between measured events when these events come at the same input. However when the events come at the different inputs it results in some offset. The offset is caused by a difference between internal propagation delays of input signals before their coming to the common measurement unit. These delays slightly vary with the ambient-temperature change, thus causing certain offset drift and corresponding long-term instability in time interval measurements.

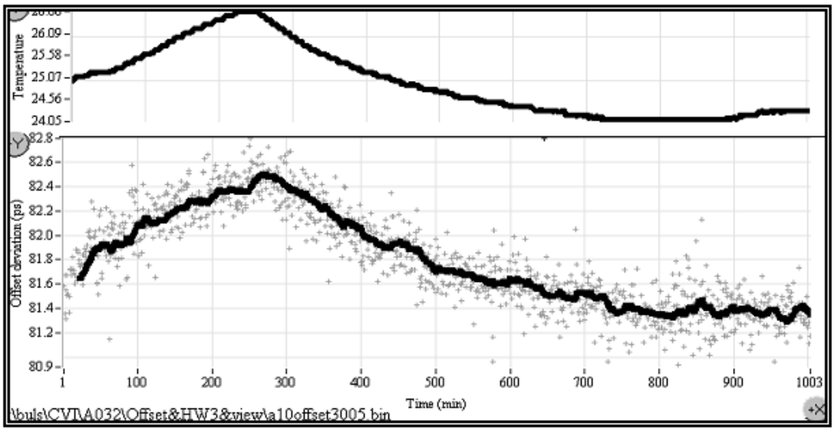

Figure 5. *Ambient-temperature and offset vs. time*

As can be seen from the example shown in Fig.5, the offset variation is directly related to the temperature variation, indicating in this case the offset temperature stability about 0.48 ps/°C. Generally this parameter value depends on the specific operating conditions.

A032-ET summary specification

Generalizing the test results that have been obtained at least for 15 units of the A032-ET, the following summary specification can be stated:

Inputs (BNC): INPUT A INPUT B SYNC IN TRIG IN REF IN	NIM pulse (falling edge; >5 ns width) NIM pulse (falling edge; >5 ns width) TTL pulse (rising edge, 1 pps) TTL pulse (rising edge) 10 MHz (>0.5 V p-p)
Single-shot RMS resolution	<10 ps
Dead time	60 ns
Non-linearity error	<1 ps (<3-5 ps for time intervals less than 100 ns)
Offset temperature stability	<0.5 ps/^{0}C after warm-up
Warm-up time	2 hours
FIFO depth	12,000 time-tags
Measurement rate (True Timer)	up to 10 KHz continuously
Stop pulse gating (Multi-Stop Counter)	online programmable via network (10 ns LSD, 60 ns to 167 ms range)
Control	fully remote control from a user program via the network
Application interface	over TCP/IP
Hardware interface	via PC parallel port supporting EPP mode
Server software	MS-Windows based
Accessory software	DEMO application software
Hardware dimension, weight	375x60x233 mm (desktop); 3.0 kg
Power supply	100-240 VAC

It should be pointed that the A032-ET is a custom instrument manufactured in a limited quantity and only on request. For this reason such instruments may differ from one to another in some details. Additionally it should be taken into account that the measurement rate may depend on the actual performance of the user's PC and network.

Additional notices

The A032-ET is currently available in the following configuration:

- ET-device;
- Server software A032.1 that provides **"True Timer"** mode;
- Server software A032.2 that provides **"Multi-Stop Counter"** mode;
- DEMO Client software (including source codes in *C*) that illustrates the manner in which the user can create own specific application.

Optionally the Sample program (source code in *C*) is available. This program defines the device-specific software functions to communicate with the A032-ET hardware via PC Parallel Port. These functions can be directly built in the user software when the user desires to create fully integrated timing system.

References

[1] http://ilrs.gsfc.nasa.gov/docs/timing/Event-Timer-A031-ET.pdf