Instrumentation for Creating KHz SLR Timing Systems

Yu. Artyukh, E. Boole, V. Vedin

Institute of Electronics and Computer Science
Riga, LATVIA
E-mail: artyukh@edi.lv

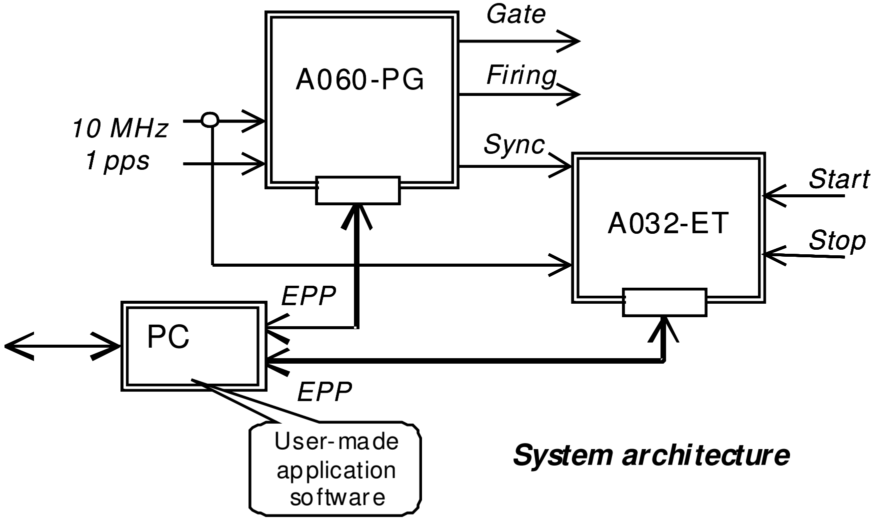
~51 ms Time of Light Flight from Canberra

*"We think, that kHz systems will be the future SLR standard;
We assume that SLR stations switch to kHz in next years;
This is not a very easy task, but it can be done! …"*

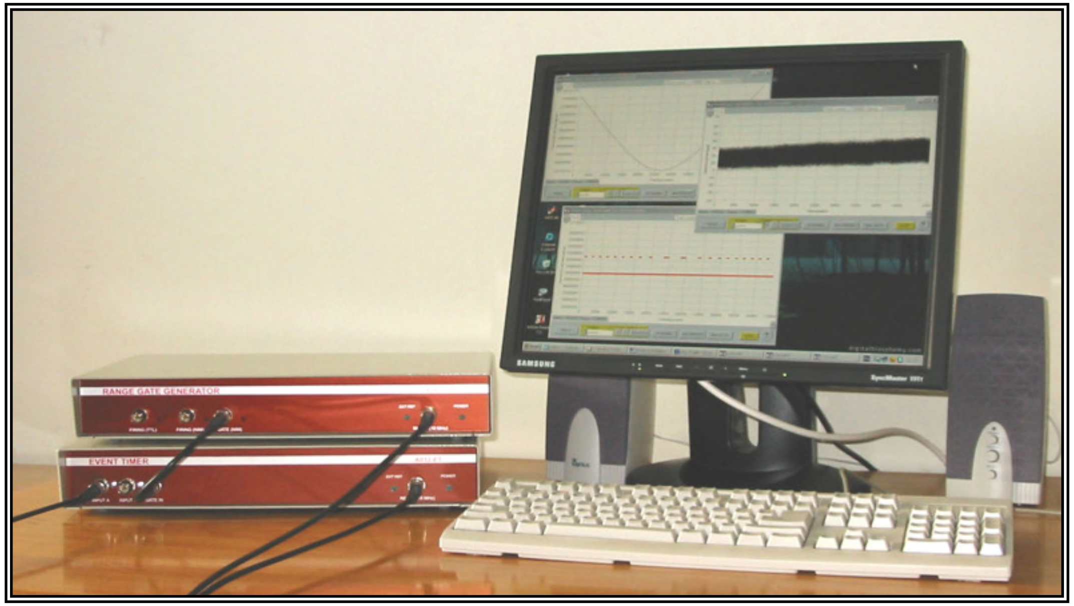
From "G. Kirchner. Goals of the Graz kHz Meeting"
(Graz, October 2004)

The instrumentation provides basic tools for SLR Timing System operating at repetition rate up to KHz.

On this basis any specific SLR timing system can be created mainly through developing application software. Sample Program (source code written in *C)* defines device-specific software functions which can be directly built in the user-made software to interact with the hardware.



System architecture



Content of the instrumentation:

- Event Timer A032-ET
- Range Gate Generator A060-PG
- Demo Software
- Sample program in C

Availability: starting in 2007

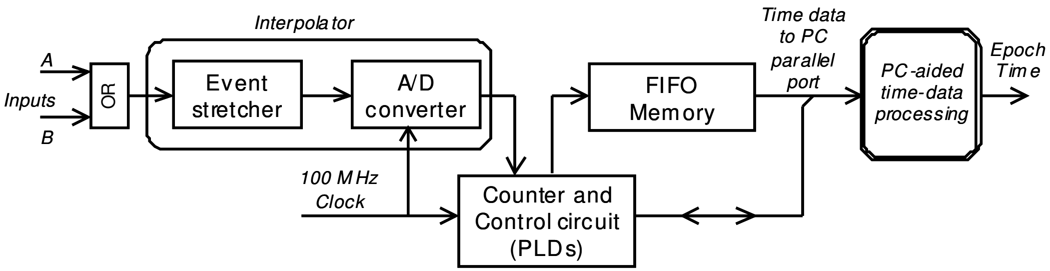
Verified system potentialities:

- Repetition rate 7 Hz to 4 KHz
- Single shot RMS resolution <10 ps
- Range gate delay 1 to 335 ms
- Advanced laser firing to fully prevent transmit/receive overlap

SYSTEM COMPONENTS

1. Event Timer A032-ET

Schematic block diagram



Digital clock supports Epoch Event Timing up to ~1.5 hr with 10 ns LSD resolution. Interpolating measurement increases the resolution up to 7-8 ps RMS.

Exceptionally small "dead time" (60 ns) provided by the advanced interpolating technique allows sequential measurement of START and STOP using single-channel hardware structure.

Special feature of the A032-ET is the performing of measurement functions partly by software means. For this reason the A032-ET always uses certain computing resource.

Key specifications

Event Timing

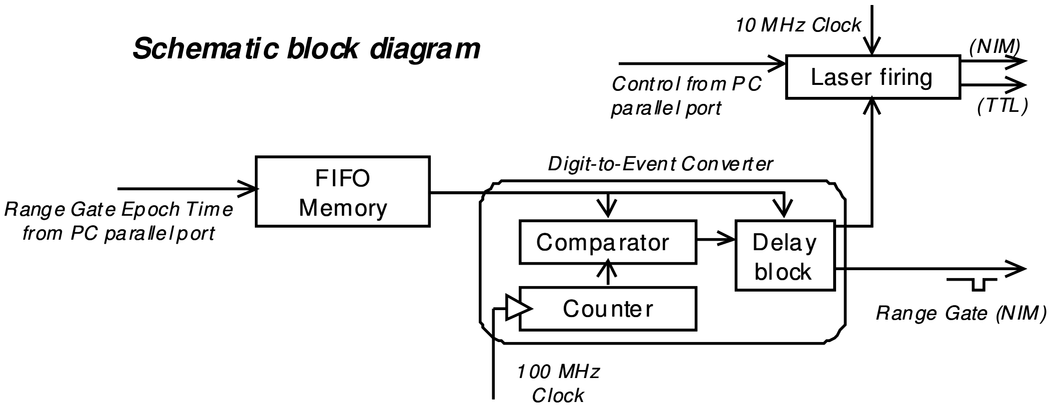
Two NIM inputs (for START and STOP pulses)

Single-shot RMS resolution	<10 ps
Dead time	60 ns
Non-linearity error	<1 ps
Offset temperature stability	<0.5 ps/^{0}C
FIFO depth	12,000 time-tags
Mean measurement rate	up to 10 KHz
Burst rate	up to 16 MHz

In stand-alone applications the instrument provides wider capabilities than the above ones.

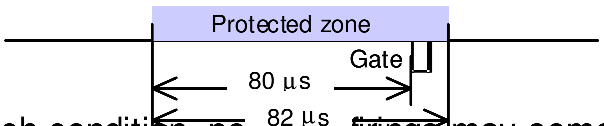
Reference: *The Model A032-ET of Riga Event Timers. Presented on this Workshop*

2. Range Gate Generator A060-PG



25-bit comparator control provides Range Gate Epoch Time up to 335 ms with 10 ns LSD resolution. Additional 7-bit controlled interpolation (based on MC100EP196 chip) increases LSD resolution up to 80 ps.

Each firing is generated so that it never can occur within protected zone around any gate being generated. This zone has 82 µs duration and begins 80 µs before the gate occurrence.



To provide such condition, periods of firings may sometimes be incremented, resulting in certain reduction of average firing rate.

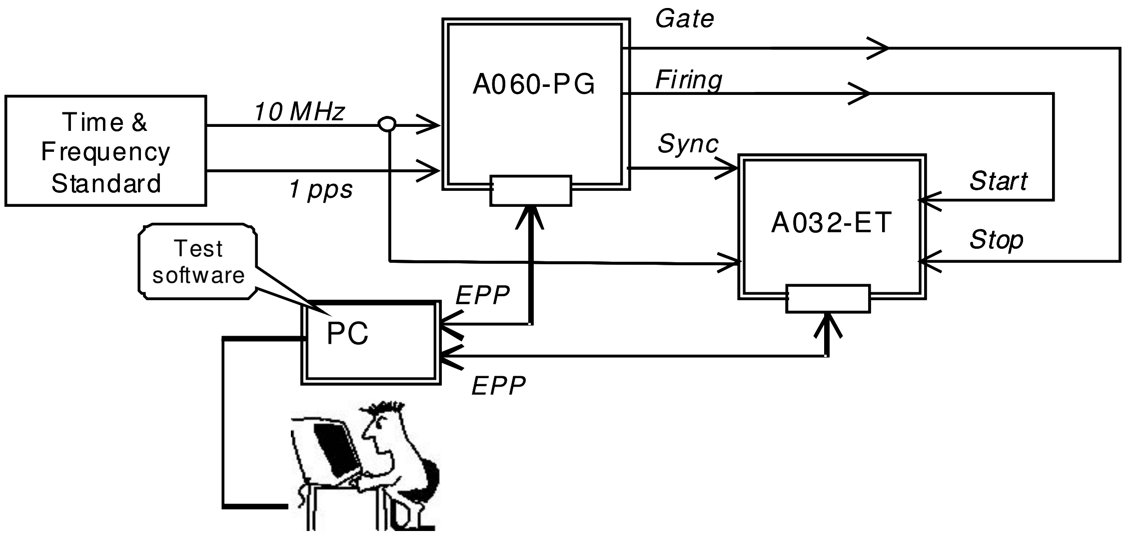
Key specifications

Range Gate Generation	
Gate output	NIM pulses
Gate width	40 ns
Gate delay	100 µs to 335 ms
Setting resolution (LSD)	80 ps
Non-linearity (RMS)	<100 ps
Mean rate (max.)	10 KHz
FIFO depth	16,000 events
Firing pulse generation	
Two outputs (NIM and TTL)	
Period (nominal)	100 µs to 167 ms
Setting resolution (LSD)	0.64 µs
Special feature	protection from Receive/ Transmit overlap

In stand-alone applications the instrument provides wider capabilities than the above ones.

EVALUATION OF THE SLR TIMING SYSTEM POTENTIALITIES

Test Setup



Each firing simulates *Start* and each generated gate simulates the corresponding *Stop*

The test software is created in LabWindows/CVI and executes under MS-Windows XP.

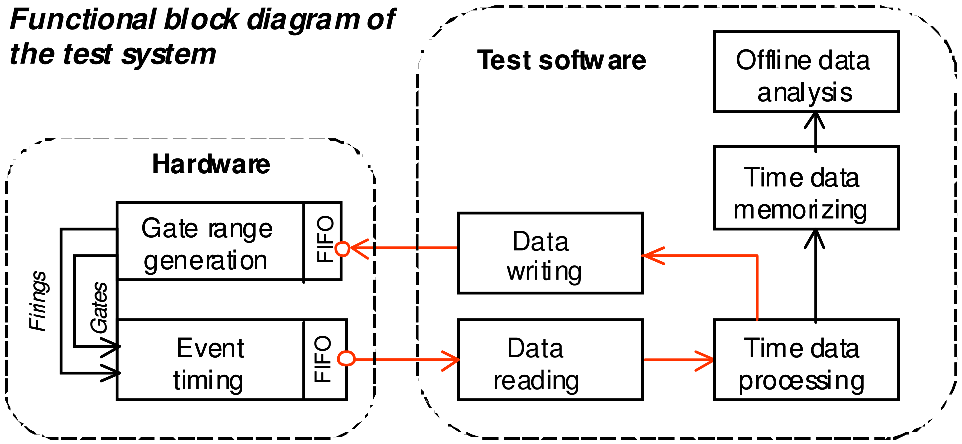
The test setup simulates the ranging of various satellites at different repetition rate by calculating Range Gate Epoch Time for each measured Start. Output data analysis is used to evaluate the system capabilities under various test conditions.

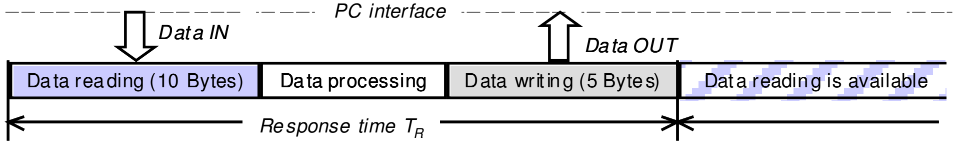
Experimental investigations were focused on simulation of laser ranging of LEO satellites (such as CHAMP) forasmuch as this represents an extreme case for evaluation of the system capabilities in possible real applications (the higher orbit, the less problems for the system operation).

EVALUATION OF THE SLR TIMING SYSTEM POTENTIALITIES

General performance limitations

Functional block diagram of the test system





The total time of data block reading/writing via EPP lies in the range from 0.025 to 0.15 ms and depends mainly on the used operating system

The response time T_R is a system parameter that defines both the SLR maximum repetition rate and allowable minimum of satellite range.

If the response time accidentally exceeds the range, correct system operation becomes impossible. In such cases the test program restarts the measurement, resulting in some gaps (15-20 ms) in continuous measurement process.

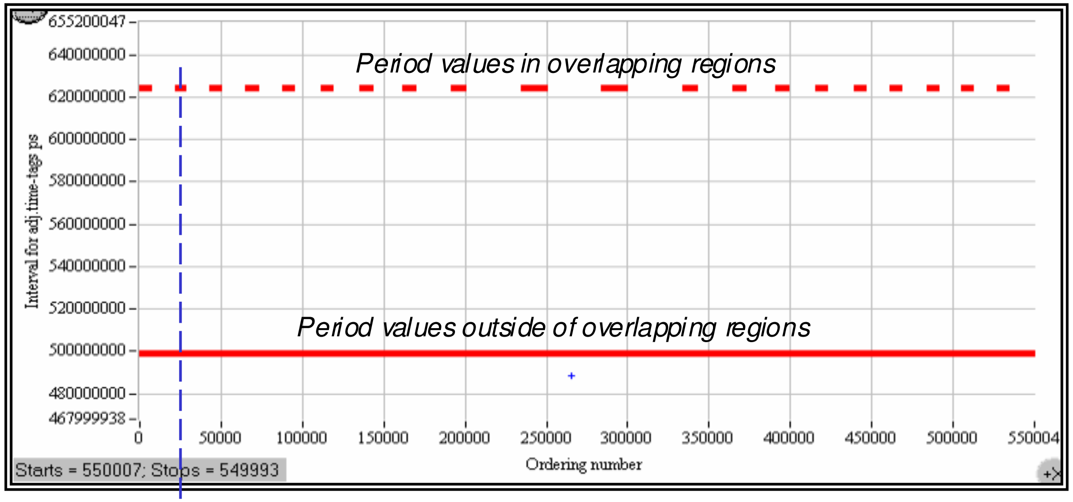
Actual response time depends on the complexity of specific software and its implementation (in many respects – depends on the operating system). For the test software under *Windows XP* the response time significantly varies cycle-to-cycle due to particularities of this operating system not well suited for real-time applications.

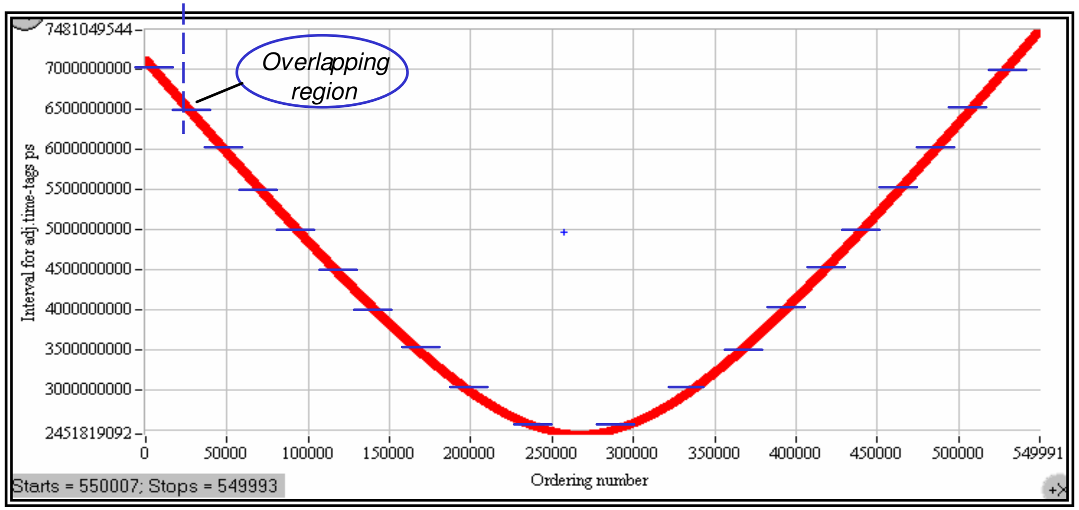
In our tests the mean response time was about 0.25 ms, resulting in the maximum repetition rate of 4 KHz. The maximum response time was about 1 ms and directly corresponds to the allowable minimum of satellite range.

In real KHz SLR systems the time data processing is more complicated than that for the test setup. For this reason it is preferable to use the real-time operating systems to reduce the response time as far as possible.

EVALUATION OF THE SLR TIMING SYSTEM POTENTIALITIES

1. Simulation of CHAMP laser ranging at 2 KHz repetition rate





Period of laser firing vs. cycle number

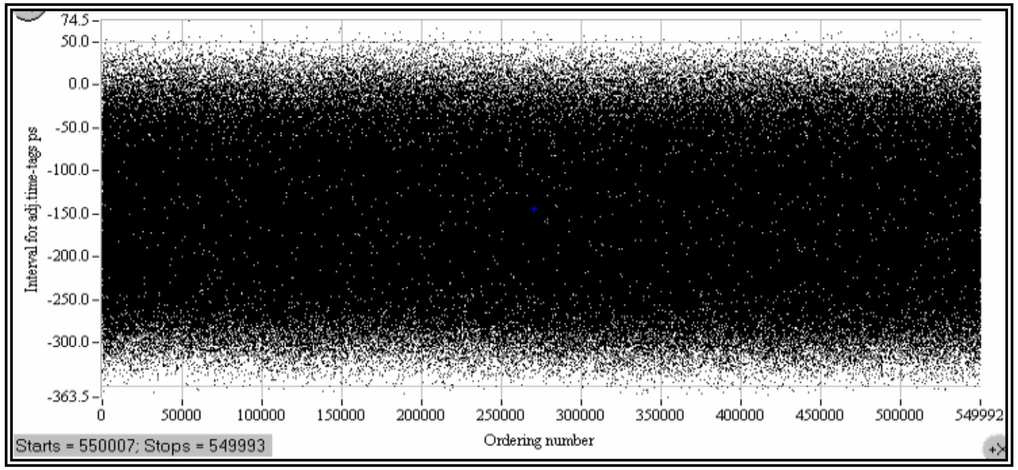
Nominal repetition period is 499.2 µs. Actual average period is increased up to 502.157 µs (by 0.59%) due to incrementing of some periods (~2.4% of total number) by 0.125 ms to avoid transmit/receive overlap.

Measured range (TOF) vs. cycle number

550,000 readings obtained continuously during 275 seconds of the CHAMP pass simulation. Satellite range: from 2.45 to 7.48 ms

EVALUATION OF THE SLR TIMING SYSTEM POTENTIALITIES

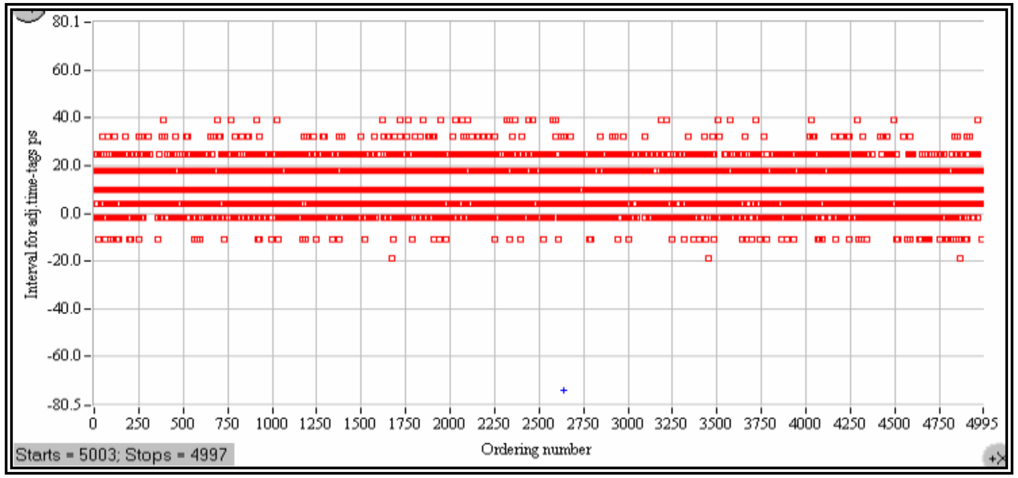
2. Simulation of CHAMP laser ranging at 2 KHz repetition rate



Difference between the measured TOF and TOF defined for RGG with 80 ps LSD (in conformity to the best RGG resolution).

In this case there is maximum non-linearity in Range Gate generation (RGG interpolation delay varies in full 10 ns range).

RMS of difference variation (78.8 ps) characterizes the RGG accuracy.



Difference between measured TOF and TOF defined for RGG with 10 ns LSD.

In this case there is not noticeable non-linearity in Range Gate generation (RGG interpolation delay is not being changed).

RMS of difference variation (8.9 ps) characterizes mainly the single-shot RMS resolution of TOF measurement.

Conclusion

Our team works in the area of SLR timing system development and production over many years. We always do our best to meet the current demands for such systems from various potential users in view of their both present and future needs.

Currently we present our latest product at this workshop, presuming that KHz SLR is of vital interest for many ILRS partners. It seems that this product offers sufficient performance for such applications and can be useful for creating new KHz Timing Systems.

Special thanks to Dr. Kirchner for his assistance and promotion of our latest designs. His well-known achievements concerning the KHz SLR at Graz station in many respects stimulated our research in this area.