OCA Event Timer

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Abstract

In the framework of T2L2[1,2,3] project, OCA and CNES designed an ultra stable event timer[4]. It includes on a unique card, a vernier, a logic counter, a 100 MHz frequency synthesis and a module for communications and internal calibrations. It has a precision better than 2 ps, linearity below 1 ps and a thermal drift in the range of 0.5 ps per degree. The dead time between two consecutive events is 3 µs.

For the T2L2 ground operations both the start time and the return time of laser pulses are required and not only the differences between the events. In order to run properly the T2L2 project, it will be necessary to upgrade some of the laser stations in that way. A T2L2 questionnaire was sent to the ILRS community to identify precisely the needs of each station.

For these reasons it has been decided to develop from the studies of the space design an event timer dedicated for ground operations. It could have the same characteristics than the flight model even if it seems possible to increase the frequency of the vernier to reach a sub picosecond precision and to decrease the dead time below 1 µs.

Introduction

An event timer is a system able to get the time position of an event in the time scale of a clock. It can be consider as a counter driven by the clock which is the time reference. When an event occurs, the value of the counter is extracted and this value represents the arrival time of the event. The time origin of such an event timer has to be measured with a reference signal like a PPS. A time interval is computed from the difference between two arrival times. The most important characteristics of an event timer are: the precision, the linearity, the time stability and the dead time.

Ideally, the linearity error has to be good enough so that the precision of the timer do not rely on the position of the event in the time scale produced by the clock. A precision of few picoseconds requires then a linearity error in the range of one picosecond. The time stability $\sigma_x(\tau)$ permits to evaluate the performances of the instrument when the events are acquired during τ. In the framework of the laser ranging activities, this is an important characteristic to construct the normal point. In the frame of the time transfer this important to evaluate the noise introduce by the timer as compared to the noise introduce by the clocks. The start time and the arrival time can be measured from the same event timer if the dead time between two consecutive measurements is small enough. A dead time in the range of 3 µs permits to range ground targets at 500 m. This is a minimum requirement to be able to calibrate a laser station with an external ground target.

A first breadboard of the T2L2 space instrumentation was built at OCA in 2002. Since then, T2L2 project was accepted by CNES on the satellite Jason2. We started the development of the space instrumentation in mid 2005. Three models were built: a prototype, an engineering model and the flight model. The flight model is now ready

to be integrated on the satellite.

Description of the T2L2 event timer

The event timer is made with 4 distinct modules on a unique card (figure 1):

- A vernier having a time resolution of 0.1 ps
- Frequency synthesis @ 100 MHz controlled from an external 10 MHz clock signal coming from the DORIS system.
- Calibration module to improve the long term time stability
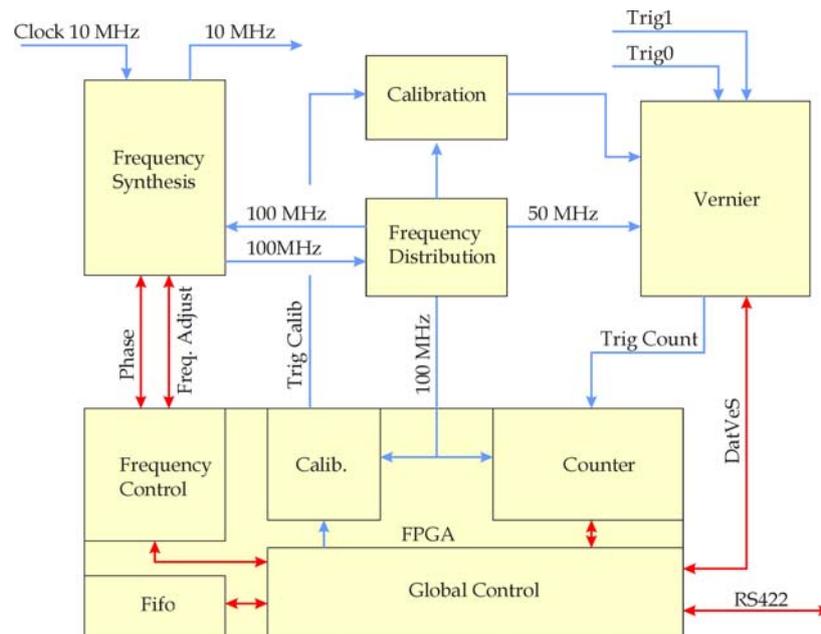- Digital module for communication through a RS422 serial bus

Figure 1 : Synoptic of the event timer.

The most important module is the vernier which give the arrival time of the event with a resolution of 0.1 ps. It is driven by the digital frequency synthesis module designed to translate the 10 MHz clock signal to 50 and 100 MHz. The global performances of the timer rely on these two modules. The calibration module permits to improve the long-term stability of the timer. It generates calibrated events that are timed by the event timer. The frequency synthesis is built from an ultra low noise quartz oscillator @ 100 MHz (ArElectronic) controlled with a Phase Lock Loop based on a digital phase measurement. Figure 2 gives the time stability specification of both the DORIS Oscillator and the ArElectronic oscillator. The PLL is tuned to get a frequency cut at 100 Hz with a damping factor of 3. The digital module is divided in 2 parts. The first one is a digital counter driven by the frequency synthesis signal. It gives the arrival time of the event with a time resolution equal to the period of this signal: 10 ns. The second one is the global control of the timer. It controls all the modules and the serial bus.

The complete T2L2 space instrument includes four more cards, two for the detection, one for the computer and memory and one for the power supply. It also includes an optical module made with an avalanche photodiode provided by PESO [5]. All these modules are gathered in a compact aluminium box (figure 3), which is placed inside the satellite payload. The instrument is completed with a detection module located

outside the satellite and very close to the Laser Ranging Array provided by ITE inc.
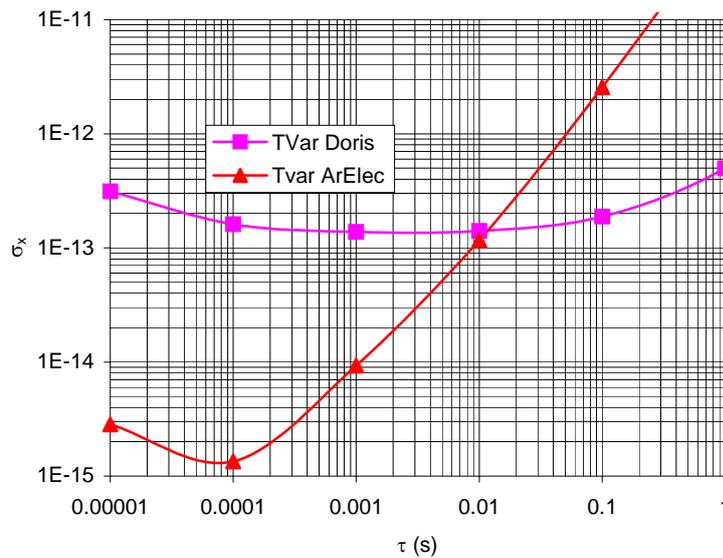

Figure 2 : Time stability of both the local oscillator and the external oscillator

The global characteristics of the event timer are:

Input frequency	10 MHz sinus 0 dBm
Event input	2 inputs, ECL level
Local oscillator	100 MHz; noise floor : -165 dBc
Logical frequency	100 MHz
Dynamic	5.7 years
Vernier period	20 ns
Vernier resolution	0.1 ps
Vernier precision	< 2 ps rms
Vernier linearity	< 1 ps rms
Vernier Time Stability	< 30 fs over 1000 s
Vernier Thermal sensitivity	< 1 ps/°C
Vernier Magnetic field sensitivity	< 1ps /100 µT
Calibration Precision	0.9 ps rms
Freq synthesis stability	$\sigma_X = 0.2 \times 10^{-12} \ \tau^{-1/2}$ s @ $\tau_0 = 40$ ms
Communication	RS422 @ 1 Mbits
Continuous rate	7000 Hz
Dead time	3 µs
Memory	2 frames
Size	220 x 180 mm²
Power consumption	15 W

Figure 3 : *T2L2 Electronic instrumentation. The electronic card (in the center of the photography) is the event timer. A part of the Geiger photo detector can be seen on the left side.*

T2L2 ground instrumentation

For the T2L2 ground operations, both the start time and the return time of laser pulses are required and not only the differences between the events. In order for the T2L2 project to run properly, it will be necessary to upgrade laser stations in that way. A T2L2 questionnaire has been sent to the ILRS community to identify precisely the needs of each station. The questionnaire will help us to define the specifications and the design of the event timer: communication, size, number of entry, input frequency, etc.The event timer designed for T2L2 is not dedicated for T2L2: it will also be perfectly well suited for laser ranging. The timer could have the same characteristics than the flight model even if it seems possible to increase the frequency of the vernier to reach a sub picosecond precision and to decrease the dead time below 1 µs.

Conclusions

With an expected improvement of one order of magnitude as compared to existing time transfer techniques, T2L2 will allow the calibration of various existing radiofrequency time and frequency transfer systems like GPS or TWSTFT, and comparisons of cold atomic clocks at a level never reached before. Both the characterizations of the engineering model and the first measurement of the flight model allow us to be confident about the whole performances of the project. The T2L2 space model could also be used in the future in the framework of some interplanetary projects like TIPO [6] (One way laser ranging in the solar system) and Astrod [7] (Astrodynamical Space Test of relativity using optical devices) or LATOR.

Figure 4 : *laser ranging network : Event timer status in September 2006. In yellow laser station requiring an upgrade ; in green, compatible laser station (from the questionnaire)*

For a ground application, the performances of the event timer are at least one order of magnitude better than the performances of the other sensitive elements in the chain: laser – photo-detection. The short dead time between two consecutive measurements (that could be below 1 µs for the ground design) could permit to envision a laser station with only one timer and one photo detection system that will allow a direct accurate laser ranging measurement without any external calibration.

References

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