Applied Research on the Guidetech GT668 SLR-1 Event Timer in Satellite Laser Ranging (Postprint)

Authors: Pi Xiaoyu, Ju Qinghua and Pi Xiaoyu, Tang Rufeng, He Lijuan, Zhang Haitao

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Abstract

In high-repetition-rate satellite laser ranging systems, the laser pulse time-of-flight is obtained by separately measuring the epochs of the main pulse and echo pulse using an event timer. To adopt an event timer with higher repetition rate and higher precision, the GT668SLR-1 event timer from Guidetech was applied to the 1.2m telescope laser ranging system at Yunnan Observatories, Chinese Academy of Sciences, its architecture and principle were analyzed, and experiments including measurement of fixed signals generated by a signal generator, ground target ranging, and satellite ranging were conducted using it. The processing results of the collected data met the accuracy requirements for laser ranging, thereby demonstrating that the GT668SLR-1 event timer can be used as the time measurement unit for satellite laser ranging systems.

Full Text

Application Research of the Guidetech GT668SLR-1 Event Timer in Satellite Laser Ranging

Pi Xiaoyu[1], Ju Qinghua[1], Tang Rufeng[1], He Lijuan[1], Zhang Haitao[1,2]
[1]Yunnan Observatories, Chinese Academy of Sciences, Kunming 650011, China
[2]University of Chinese Academy of Sciences, Beijing 100049, China Email: pixiaoyu@ynao.ac.cn

Abstract

In high-repetition-rate satellite laser ranging (SLR) systems, the flight time of laser pulses is obtained by an event timer that separately measures the epochs of transmitted and received pulses. To employ a higher-frequency, high-precision event timer, the GT668SLR-1 event timer from Guidetech was integrated into the 1.2 m telescope SLR system at Yunnan Observatories, Chinese Academy of Sciences. This paper analyzes its structural principles and validates its performance through tests measuring fixed signals from a signal generator, ground target ranging, and satellite ranging. The processed results demonstrate that the data acquisition meets the precision requirements for laser ranging, confirming that the event timer can function as the time measurement unit in an SLR system.

Keywords: Event timer; Satellite laser ranging; High repetition rate; Ranging data processing

1. Introduction

Satellite Laser Ranging (SLR) calculates the distance between a ground observation station and a satellite by precisely measuring the round-trip time interval of laser pulses [1]. In recent years, kHz laser ranging technology has emerged as a new method that increases observation data volume by raising the ranging frequency, thereby improving standard point precision and benefiting precise satellite orbit determination [2]. This represents a key development direction in laser ranging.

Traditional SLR systems used time interval counters to measure laser pulse flight time. However, in kHz ranging, the limitations of time interval counters became apparent, leading to the development of event timers [3]. An event timer records the precise arrival times of pulse leading edges—designated as the start (transmitted) and stop (received) epochs—with the difference between them representing the laser pulse flight time.

Following the demand for event timers in kHz ranging, numerous companies and universities began developing these instruments, including PET4 (Dassault), A032-ET, and A033-ET (Latvia). The proliferation of kHz laser ranging systems has been facilitated by instruments like the A033-ET, which offers high measurement precision, low time jitter, and a maximum operating frequency of 12 kHz [4]. To accommodate even higher frequency event measurements, the GT668SLR-1 event timer test board from Guidetech was evaluated for integration into the Yunnan Observatory' s 1.2 m telescope kHz SLR system.

2. GT668SLR-1 Event Timer

2.1 Performance Specifications

The GT668SLR-1 event timer is based on a new Time Interval Analyzer (TIA) series circuit board. The system comprises a test board, PCI/PXIe chassis, and control software that can communicate with external SLR software for programming configuration. The instrument features multiple programmable trigger output ports and integrates a time interval analyzer to record the precise epochs of input signal events. Here, an "event" is defined as a voltage transition across a set threshold in either direction.

Compared with the previously used A033-ET model, the GT668SLR-1 offers superior time resolution and significantly improved dead time. The single-shot time resolution reaches approximately 0.9 ps with a sampling rate of 4 Ms/s, while supporting 2 to 34 input/output channels as required by the user. The test board' s integration with the communication chassis provides substantial performance improvements.

Performance comparison between GT668 and A033-ET

Timer Model	A033-ET	GT668
Time Resolution	<5 ps	0.9 ps
Maximum Frequency	12 kHz	2.9 GHz
Dead Time	50 ns	-

2.2 Instrument Structure and Workflow

[Figure 1: see original paper] GT668 test board

[Figure 2: see original paper] GT668 global view

The GT668SLR-1 event timer test board consists of several main modules: input module, measurement logic, clock module, and control logic. The measurement and clock modules maintain synchronization. Input signals from detectors undergo preprocessing in the input module before being sent to the measurement logic for time interval measurement. The control logic manages these modules and processes measurement outputs for delivery to the user.

[Figure 3: see original paper] GT668SLR-1 event timer structure

User inputs are pulse signals from detectors [5]. The input module first filters and conditions these signals, which then pass through analog-to-digital conversion into a prescaler. After prescale division, signals corresponding to user-selected channels are processed. Channel selection is implemented through software commands and hardware multiplexers [6].

The measurement logic core is the Time Interval Analyzer, which works in conjunction with the ARM processor. The TIA calculates precise signal delays by utilizing delay units to create variable delays between two input signals and statistically analyzing these delays. The clock module, primarily composed of a phase-locked loop, synchronizes the measurement clock with an external reference signal—either Coordinated Universal Time or a 1PPS (Pulse Per Second) signal from GPS. The module can also perform self-calibration using an external clock. The accuracy of the external reference clock is critical as it determines the overall measurement precision of the timer system.

The control logic manages all modules through register read/write operations commanded by the ARM processor. Measurement logic outputs are processed by the control logic and sent to the user interface according to instructions. The system is sensitive to rising edges of input signals, with input signal lines employing 50Ω impedance matching.

The entire event timer module is primarily controlled through embedded Windows-based software. To ensure measurement time synchronization with UTC, the program must first synchronize the external GPS clock with the instrument’ s internal clock signals, as deviations exist between them. This is accomplished by sending commands from the PC to the clock module’ s phase-locked loop to align the GPS 1PPS signal with the internal clock.

3. Testing and Results

The primary objective of testing was to verify the instrument’ s suitability for SLR operations, focusing on whether measurement data accuracy meets requirements under various application scenarios [7-8]. Data precision refers to the standard deviation of the data, with the most intuitive representation on statistical histograms being the concentration degree of non-noise data points. While acquired points form a line on the time axis, specific precision must be determined through data processing [7].

Testing was conducted sequentially with fixed signals, ground target ranging, and satellite ranging, evaluating the instrument from functional configuration and performance perspectives.

3.1 Fixed Signal Measurement

Initial ground signal tests focused on verifying instrument functionality and basic performance, particularly maximum sampling rate and input signal sensitivity. Signals were generated by a laboratory signal generator to simulate satellite ranging pulses [9], adjusted to appropriate levels using an oscilloscope, and then input to the event timer. The PC received output data from the test board.

Instrument settings configured input triggering on positive rising edges, with output format as event epoch data. Input signals were continuous pulses with frequencies in the MHz range and voltages from 0 to 5 V. Tests were conducted with signals connected to either Channel A or B on the test board’ s native system platform.

[Figure 4: see original paper] Stable signal sampling and processing result

The data acquisition results demonstrate that the test board successfully captured high-frequency inputs at the MHz level, validating its basic functionality. While the sampling rate significantly exceeds that of the A033-ET, effective utilization of this high sampling rate will be a focus during system integration.

3.2 Ground Target Ranging

Ground target ranging involves transmitting laser pulses to a fixed-distance ground target and receiving the return signal to calculate the distance based on the time difference between transmission and reception. The experimental configuration matched standard SLR systems except for the target, with time synchronization from GPS and input signals from detector output circuits. The precision requirement for ground target ranging is 1.5 cm.

Data acquisition software was rewritten to incorporate time synchronization functionality. After synchronization, data collection commenced.

[Figure 5: see original paper] O-C result of ground target sampling data

Processed data achieved precision meeting the 1.5 cm requirement, demonstrating performance comparable to the A033-ET instrument level.

3.3 Satellite Ranging

Satellite ranging represented the primary testing phase, with a precision requirement of 1.5 cm. The instrument was integrated into the SLR system, and measurements were conducted for various satellites including LAGEOS, Ajisai, and Beacon-C.

[Figure 6: see original paper] Ranging sampling data of SLR-LAGEOS

For LAGEOS, processed data achieved 1.5 cm precision, meeting practical requirements.

[Figure 7: see original paper] Ranging sampling data of SLR-Ajisai

Ajisai measurements also achieved 1.5 cm precision after processing, satisfying experimental requirements.

[Figure 8: see original paper] O-C result of SLR-Beacon-C ranging

Beacon-C measurements achieved the required experimental precision.

[Figure 9: see original paper] O-C result of SLR-Compass-I5 ranging

Similarly, Compass-I5 measurements met the specified precision requirements.

4. Conclusion

This paper described a series of tests conducted on the GT668SLR-1 event timer test board for SLR data acquisition. The test board' s structure and working principles were analyzed, and experiments including fixed signal measurement, ground target testing, and satellite ranging were carried out. The results verify the test board' s primary functions and its suitability for satellite laser ranging applications. The acquired data precision meets SLR requirements, and the instrument can be deployed for operational satellite laser ranging work.

The chassis-based design offers flexible expandability, facilitating future multi-channel event timer applications.

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Note: Figure translations are in progress. See original paper for figures.