Compact Event Timing and Laser Fire Control Device for One Way Laser Ranging

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Abstract

We are presenting the design, construction and performance of the compact control circuit, which can be used as an event timing unit and time laser fire control unit in one way ranging experiments. The main design goals were to construct compact device, which can measure time epochs with resolution of hundreds picoseconds and which can control the time of laser fire with resolution of 100 nanoseconds. The unit is controlled by 10 MHz and 1 pps signals from local time base.
The electronic board is designed using SMD technology; the precise voltage stabilizer is included. The external power of 4.5 to 9 Volts 0.5 A DC is required. The input signals receivers accept TTL (1 pps) and NIM (Event) signal levels via SMA connectors. The epochs are determined using coarse counter and time interpolator. The coarse counter determines both the epoch of laser fire and received pulses with resolution of 100 nanoseconds, it is based on programmable gate array. The time interpolator by Acam provides the epoch of received pulses resolution of hundreds of picoseconds. The unit is controlled by microcontroller made by Microchip, it communicates through standard serial line - RS232 using ASCII characters. The user friendly controlling application for the device was developed. Maximum measurement rate exceeds 100 Hz.
The device was tested in our lab and complete set of measurement were produced. The timing unit was compared to Pico Event Timer (P-PET2k) and the epoch timing resolution of the device is 130 picoseconds rms, the warm up characteristics does not exceed ~160 ps/K, the warm up time is one hour. The long term stability is as low as 10 ps/hour and the non linearity is below +/- 125 ps.
The device may be simply integrated to any SLR (or similar) system, it is compact, easy to control and friendly to use hence it satisfies the requirements variety range of experiments. The device was mainly designed for one way laser ranging of the Lunar Reconnaissance Orbiter and similar experiments.

Introduction

The main design goals were to construct event timing module with timing resolution of 100 ps and dead time less than 100 μs. The device can be calibrated witch 1pps signal. The timing unit must be able to generate programmable laser fire control signal, which enable to control the epochs of laser fire with resolution of 100 nanosecond. These properties allow using the timing unit in one way laser ranging experiments and applications.
The device can be included in Satellite Laser Ranging stations, which will be participated in Lunar Reconnaissance Orbiter (LRO) project. The LRO will orbit the Moon and the timing unit can trigger the laser in advance known epochs and the real laser fire will be measured to provide one way range measurements between the Earth based station and LRO to better than 10 cm precision [1].

Block diagram

The timing unit is based on Time-to-Digital converter (TDC-GP1), which was developed by Acam company [2]. This chip can measure only time intervals. To keep the generous purpose of the timing unit it is possible to run the unit in two different modes. The first is measuring of epochs (event timing mode) and second is measuring of time intervals start - stop. The block diagram of timing unit is shown in Figure 1. The input signals receivers of Event respectively Start, Stop and reference clock signal are based on fast comparators. The input signal of the comparators are NIM for event, TTL for stop (calibration of the timing unit) and 1 volt Vpp for reference clock of 10 MHz.

The coarse counter is implemented in programmable logic device form Lattice company with name ispLSI1032 for more information see [3]. It provides 10 MHz counter and gives the resolution of the generated laser fire and epochs of 100 ns.

The Time-to-Digital converter (TDC-GP1) from Acam company makes the resolution of the entire timing unit. As it was said this chip only time intervals start - stop measure. From this reason the last bits of epochs are derived from time intervals from received event and a first rising edge of the reference clock.

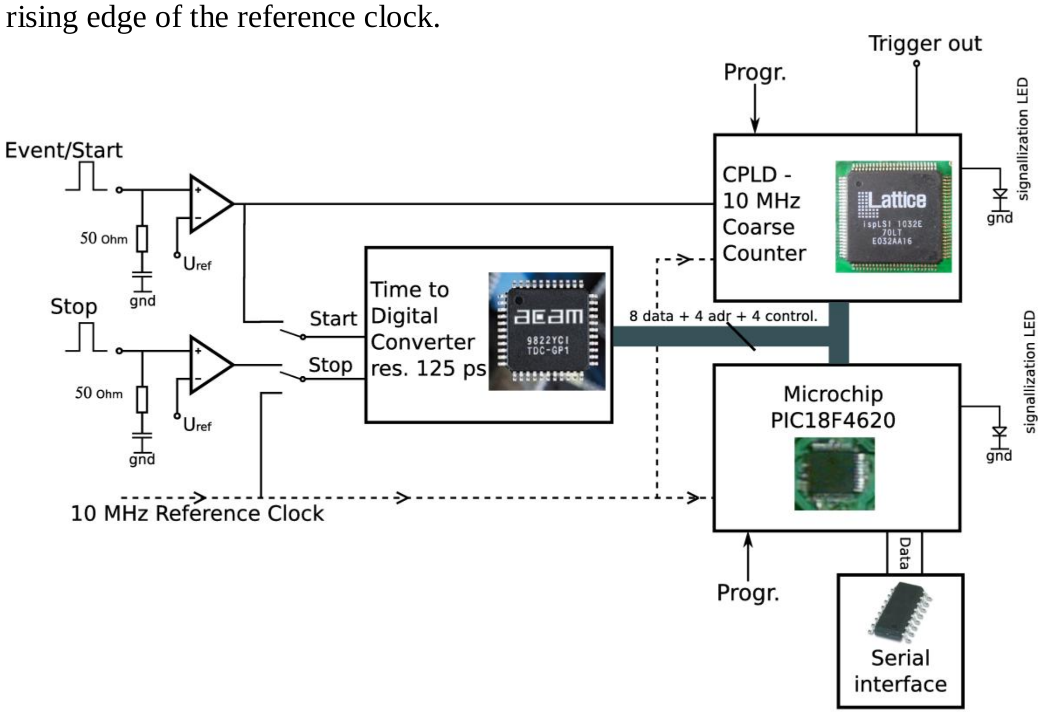

Figure 1. The block diagram of the timing unit

As a control heart of the timing unit a microcontrollers PIC18F4620 was chosen , which is produced by Microchip company [4]. It is 8 bit powerful RISC controller with 64 kb program memory and 3986 bytes of RAM memory. The advantages of all PIC18 microcontrollers are namely, high computational performance at an economical price and low power. Those devices incorporate a range of features that can significantly reduce power consumption during operation and big advantage is also In Circuit Serial Programming (ICSP) via two pins. The device can be set and driven by computer through standard serial line of 19200b and 8N1 configuration.

Prototype of the device

Very important was to develop the device from cheap and ordinary components. The entire board is designed using SMD technology and power consumption is about 200 mA at 5 volts. The board includes DC/DC converter, which enables to power the device with voltage from 5 to 9 dc volts. The signals 10 MHz reference clock, event and TTL (calibration – 1pps) can be connected via SMA connectors, see Figure 2, which are located on the front panel of the timing unit. There are also signalization diodes, which give the visual information of power on, connected reference clock, receiving of events and generating of trigger signal for fire of the laser.

Figure 2. The front panel of the timing unit.

On the back side of the device are power supply connector and serial line communication connector, see Figure 3. The back panel of the timing unit.Figure 3. The entire device is pretty small 16x9 centimeters in size and 3.5 centimeters of height.

Figure 3. The back panel of the timing unit.

To control the timing unit the demo software can be used. It includes all feature of the device. That mean the timing unit can be programmed with in advance known epochs, which can be uploaded in ascii file to the device. In consequence the device can measure epochs of events and the program can read the epochs and save them in file. The timing unit can be also calibrated using this demo software and the calibration 1pps signal. The window of the demo software can be seen in

Figure **4**.

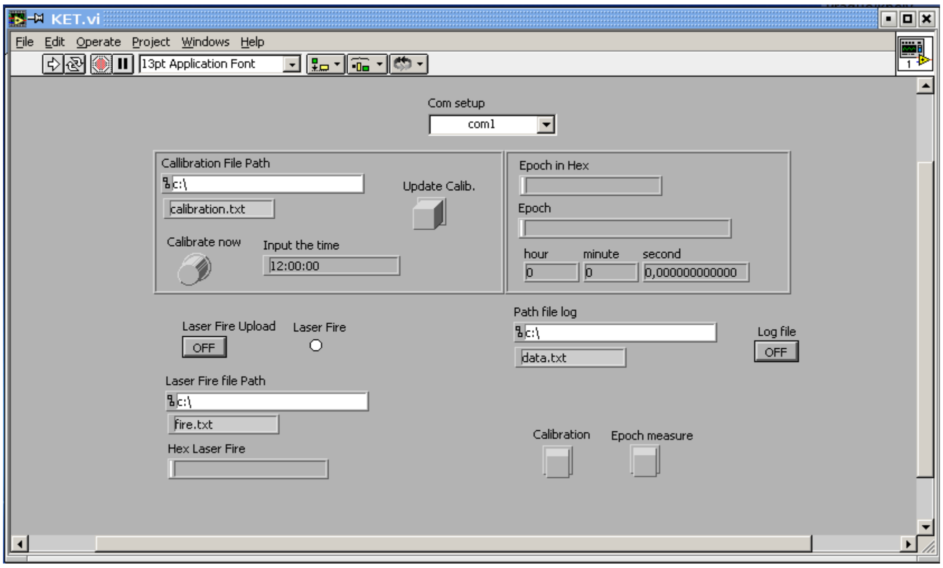

Figure 4. The demo software for work with the timing unit.

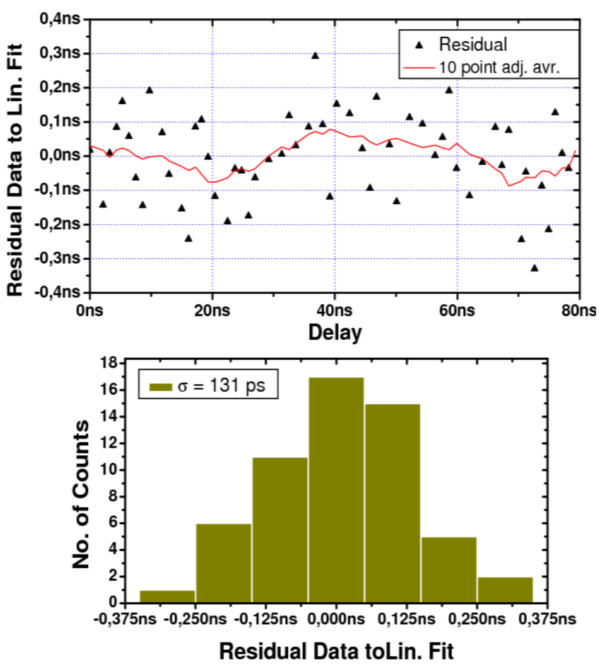

Figure 5. The first graph shows the residual data to linear fit, the adjacent averaging over 10 points was applied. The second graph illustrates the histogram of residual data, with standard deviation of 131 picoseconds.

Tests of the timing unit

At first the timing linearity of the device was investigated. The timing unit was driven from 10MHz reference clock, which was derived from GPS receiver. From the reference clock the epochs were generated and preciously delayed with Stanford delay line. The results were fitted with linear function and the residual data to linear fit were computed, the graph is in Figure 5. The results are uniformly spread with peak to peak of ±100 picoseconds of adjacent averaging. The histogram of residual data has been plotted with 131 picoseconds of rms.

Next important characteristic of the device is warm up characteristics. The warm up characteristics were measured in both regimes, event timing and time intervals measurement. The entire timing unit was closed in box and the temperature sensor was glued to the TDC-GP1 chip. First the devices (power supply, GPS receiver, Stanford pulse generator) were more then one hour switched on to warm up. Then the timing unit was connected to a power supply and the epochs/time intervals were measured. As a source of events the programmable output from GPS receiver was used and the repetition rate of 100 Hz was set. Graph in Figure 6 illustrates the warm up characteristic of the timing unit in event timing regime. Each point represents average over 255 samples. The start temperature was 23.4 °C and it increased up to 38.4 °C, which gives the temperature change of 15 °C. The time has changed about 2.5 ns during 1500 s. It gives the change of 167 ps/°C.

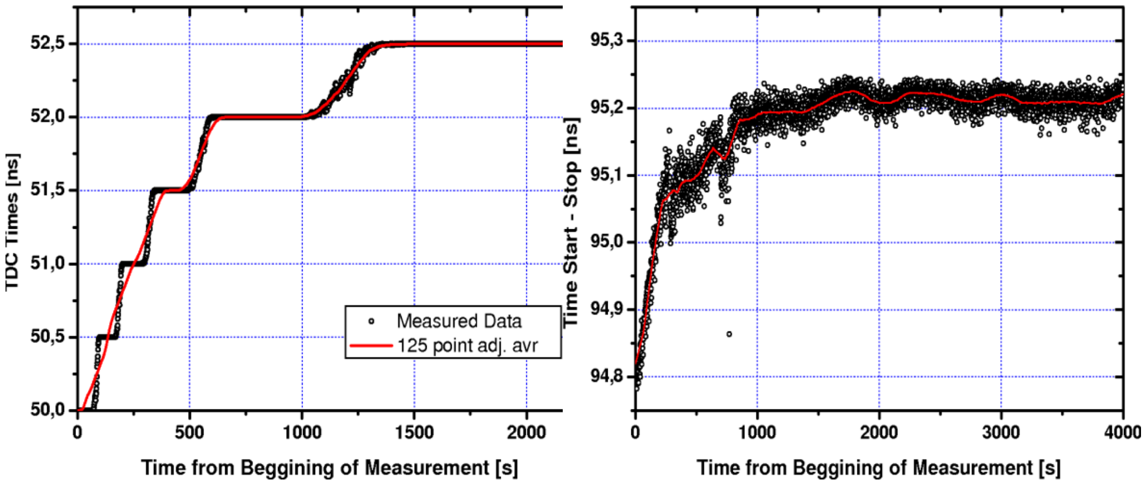

Figure 6. The first graph shows the warm up characteristics of the timing unit in event timing regime. Each point represents average of 255 samples. The second graph shows the warm up characteristics of timing unit in start - stop regime. Each point represents average of 255 samples.

Completely different results have been obtained in start - stop regime. The start temperature was 26.6 °C and in the end of the measurement it was 37.0 °C, which gives the temperature change of 10.4 °C. As a source of time intervals the Stanford digital pulse generator was used. The measured time intervals were averaged through 255 samples and a graph was plotted (see Figure 6). The average value of measurement has changed by 400 ps over 2000 seconds. It gives the change of 38 ps/°C.

The both regimes has been measured over 2000 sec in event timing regime and over 4000 sec in time intervals measurement to investigate the long term stability. The repetition rate was set to 100 Hz and averaging over 255 samples was applied. The results are shown in Figure 7, y-axis represents time, which was obtained from epochs or time intervals.

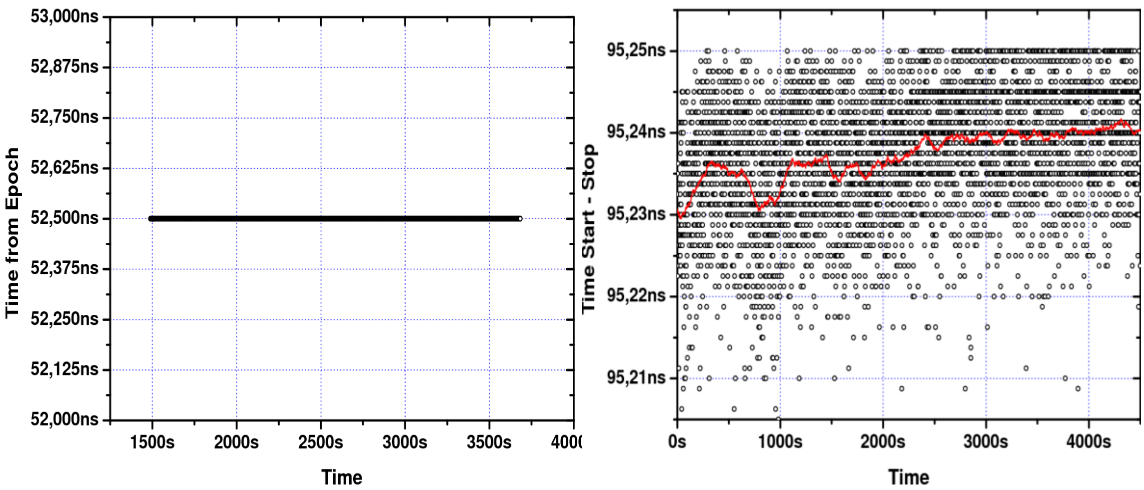

Figure 7. The first graph shows the long term stability of event timing. Each point represents average over 255 points. The second graph shows the long term stability of time intervals measurement. Each point represents average over 255 points and adjacent averaging over 100 points was applied.

Conclusion

By here the development of the event timing and time of laser fire device was presented. The timing unit is based on three chips, time interpolator - time to digital converter TDC-GP1, Complex programmable logic device (CPLD) ispLSI1032 and microcontroller PIC18F4620 which controls the entire timing unit. The timing unit can operate in two modes. The default mode is the event timing, which is realized by a counter which overflows every 30.5 hours. The second is the time intervals measurement of maximum 7.6 μs. The input signal pulses of TTL, NIM can be used. The whole signals can be connected using SMA connectors. The complete set of programs were presented and discussed. This work provides the set of measurement - linearity measurements, warm up characteristics and long term stability. The foreseen application of the timing unit is Lunar Reconnaissance Orbiter project and the unit can be used in one way ranging experiments.

References

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