Collection Method of Arbitrary Laser Echo Based on STM32

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Abstract. When LiDAR measures the water depth, in most cases the echo signal is more complex, with more backscattering, and it is difficult to observe different parts of the waveform separately, especially the underwater echo signal. Therefore, this paper uses an STM32 controller to design a signal generator to send out pulse signals, which act on the detection device PMT in the LiDAR detection system to control the start and stop of the PMT receiving channel. By adjusting the frequency, duty cycle, and other parameters of this signal generator, the arbitrary part of the waveform can be collected, and the waveform is not disturbed. Using the STM32 instead of a traditional signal generator can reduce system power consumption and load capacity.

1. Introduction
In recent years, LiDAR has been mostly used for near-coastal terrain detection [1-2], and most of the detection waveforms in the bathymetric system are multi-channel detection, including surface channel, shallow water channel, and deep water channel [3]. Usually, the laser is shot into the complex environment underwater with a wavelength of 532nm, because the 532nm laser belongs to the blue-green light, blue-green light can be shot to the bottom of the water. As the bottom reflection signal is absorbed by various energy in the water body [4], the echo signal is relatively weak, so a new high-sensitivity detector photomultiplier tube PMT that can detect nW-level signals and respond very quickly is used to detect the weak light from the underwater channel [5]. For underwater channels, when the detecting device receives the bottom echo signal, there will usually be interference from other backscattered underwater signals. Therefore, Guo, K (2018), et al. [6] used Gaussian waveform decomposition to reduce backscattering; Wang, XK (2018), et al. [7] used the decomposition of Gaussian and wavelet methods to process the waveform backscatter. But this all belongs to the processing of the waveform by the later software algorithm. So, this paper designs a signal generator based on STM32 (STMicroelectronics32), using the signal generator to send out pulse signals, acting on the PMT (Photo Multiplier Tube), and starting and stopping the underwater detection channel. Arbitrary part of the waveform can be collected by adjusting the parameters, and the waveform is not disturbed. This design is of great help in testing equipment before system integration.
2. Methods

2.1. Gated PMT control

PMT has high sensitivity and fast response and is usually used for the detection of extremely low light [8-9]. Gated PMT is divided into NN normally open type and NF normally closed type, given the gating signal to control it to open or close. The specific work start-stop state depends on the pulse width and repetition frequency of the given gated signal. When the gated PMT works, after the detection surface receives weak incident light, it passes through the internal light-emitting cathode, collecting electrode, electron multiplier, and electron collector, and finally converts light energy into electrical energy to complete photoelectric conversion.

![Figure 1. PMT structure schematic](image)

This paper uses Hamamatsu Photon’s H11526-20NF PMT. To realize the gated function requires a certain signal. The signal has a certain relationship with the working state of the PMT. The specific relationship is shown in Figure 2:

![Figure 2. NF normally closed type](image)

The maximum gated input signal frequency that the gated PMT can accept is 10KHz, with a minimum period of 100us and an amplitude voltage of 3.5V-5V. The minimum duty cycle that the traditional signal generator can set is 0.1%, corresponding to a pulse width of 100ns.

2.2. STM32 Microcontroller

STM32 series microcontrollers are ARM (Acorn RISC Machine) processors based on the CortexM3 core introduced by ST. The controller used in this paper is STM32F103ZET6, which has a complete clock module and a system clock up to 72 MHz, and our research group at Guilin University of Technology used this type of controller in the previous work [10]. The implementation of the signal generator in this paper requires a timer module to generate PWM (Pulse Width Modulation) waveforms.
2.3. Trans-impedance Amplification Circuit

The chip used in the trans-impedance amplifier circuit in this paper is LTC6268, which has low noise, a low input bias current of 3pA, and a bandwidth of 300Mhz. The specific module design diagram is shown in Figure 3.

![Figure 3. Trans-impedance amplifier circuit design](image)

2.4. Design

In this paper, the internal RC oscillator of the chip is used to generate the clock. Compared with the external clock, the internal clock has the advantage of quick start-up and can quickly generate the target waveform. The internal clock through the internal prescaler and the clock frequency can reach the highest frequency of 72MHz after frequency division. According to equation (1), the output pulse frequency can be calculated:

$$f = \frac{T_{\text{clk}}}{(\text{arr} + 1) \times (\text{psc} + 1)}$$

Where $f$ is the target pulse frequency, arr is the auto-load value, psc is the prescaler coefficient, and $T_{\text{clk}}$ is the timer clock frequency. The gated PMT module operates normally after power is applied and the corresponding pulse signal is input, and the 532nm incident laser is photoelectrically converted to output the corresponding current signal. Since the echo signal in actual detection is weaker and lower in energy, and the subsequent modules require a certain voltage signal, a trans-impedance amplifier circuit is required. The current signal after gated PMT photoelectrically conversion is converted into a voltage signal and amplified for subsequent echo signal analysis. The specific system design diagram is shown in Figure 4.

![Figure 4. System design diagram](image)

3. Programming

This paper is based on the STM32F103ZET6 controller to generate the PWM pulse waveform, the program implemented by the Keil MDK5 platform. The core of the PWM waveform output module is
the configuration of the general-purpose timer, the specific configuration is as follows: a) Initialize and enable timer clock, GPIO (General Purpose Input Output), and AFIO (Alternate function Input Output); b) Set pin output mode; c) Initialize timing function and set \( arr, psc \); d) Initialize PWM mode of the channel, select timer pulse width modulation mode.

After completing the timer configuration, adjust and modify the \( arr \) and \( psc \) values according to equation (1) in 2.4 to adjust the PWM output signal frequency and duty cycle.

4. Experiment and analysis
Firstly, the traditional signal generator is used to output the pulse signal, and the waveform is captured using the oscilloscope. Combined with the existing hardware controller and the corresponding upper computer programming software, the STM32 is completed to output the same pulse signal as the traditional signal generator, and the waveform is captured using the oscilloscope. Then the experiments are compared separately.

4.1. Waveform generation by signal generator
Using a traditional signal generator to set the output waveform, adjust the frequency of 10KHz, the duty cycle of 0.1%, and amplitude of 3.5V, the output waveforms acquired by using an oscilloscope are shown below.

In Figure 5 above, (a) indicates a pulse width of 100ns and (b) indicates a period of 100us.

4.2. Waveform generation by STM32
Using the STM32 controller to set up the output waveform, the controller pins were connected to the oscilloscope by BNC to DuPont cable, and the waveforms were collected as shown in Figure 6.
In Figure 6 above, (c) indicates a pulse width of 100ns and (d) indicates a period of 100us, which is the same as the result in Figure 5.

4.3. Comparison
As shown above, comparing the waveforms generated by the traditional signal generator and the STM32 controller, the pulse width and period are the same; In terms of amplitude, the amplitude of the traditional waveform generator is relatively stable, and the STM32 controller is relatively fluctuating. The reason is that the PWM waveform output comes with a small oscillation, and the pulse width is only 100ns, the waveform amplitude needs to be restored to the zero value as soon as it stabilizes. Overall comparison of the waveform output of the traditional signal generator and the STM32 controller, the former is relatively stable, and the latter has small oscillations, both of which meet the control signal requirements of the gated PMT.

4.4. Experiment
Based on the previous analysis, build an experimental platform. NF gated PMT is off without signal when there is no gated signal input. When other conditions such as laser energy are the same, use traditional signal generators and STM32 controllers to provide gate control signals for NF-type PMT.

4.4.1. Signal generator provides gated signal experiment
As shown in Figure 7 below, (e) is the overall experimental diagram of using a signal generator to provide gated signals for PMT, and (f) is the corresponding waveform diagram.

Figure 6. Waveform generation by STM32

Figure 7. PMT experiment (with signal generator)
4.4.2. STM32 provides gated signal experiment

As shown in Figure 8 below, (g) is the overall experimental diagram of using STM32 to provide gated signals for PMT, and (h) is the corresponding waveform diagram, which is the same as the result in Figure 7.

![Figure 8. PMT experiment (with STM32)](image)

As shown above, under the same other conditions, the output of waveforms by the traditional signal generator and the STM32 controller is used as the gated signals to control the start and stop of the NF gated PMT. The detected laser signals are the same, which proves The STM32 controller can be used as a signal generator. In the bathymetry experiment, the controller can be used to set the relevant parameters to achieve arbitrary part of the waveform collectible.

5. Conclusion

This paper innovatively proposes to use the controller in the LiDAR integrated control system to output pulse signals to control the start and stop of the PMT. The advantage of this is that the working state of the PMT in the detection module can be controlled according to the needs, and arbitrary part of the waveform can be observed, and the waveform has no interference, the feasibility of the method in this paper is proved through experiments. And using the controller to achieve the output of the gated signal reduces the load and power consumption that would be added by using a traditional signal generator.

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