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Laser Pulse Code Detection System with Microcontroller using Pulse Repetition Frequency

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Abstract— **In this paper, we describe and enhance detection and tracking of laser guided weapon decoding system based on microcontroller. The system is designed to receive the reflected pulse through a 4-quadrant laser detector and to process the received laser pulses through an electronic circuit, which send data to the microcontroller for decoding laser signal reflected by the target. The laser seeker accuracy will be improved by the decoding system, which reduced the time of laser detection by reducing the number of received pulse to detect the code and generating a narrow gate signal to improve the anti-jamming ability. We implement a model of the laser pulse code detection (PCD) system based on Pulse Repetition Frequency (PRF) technique with two microcontroller units (MCU). MCU1 generates laser pulses with different codes and also communicates with switches to control which code is selected. MCU2 recognizes the laser code and locks the system at the specific code. The locked frequency can be changed in both MCUs by switches' selection. The system is implemented and tested in Proteus Software for laser code compatibility, laser code rejection. The concept is hardware implemented and used to evaluate the performance of 4-quadrant detector with laser PCD. The hardware system is tested for laser code compatibility, immunity to false laser codes, and laser code resolution. The system test results show that the system can detect the laser code with only three received pulses based on the narrow gate signal, and good agreement between simulation and measured system performance is obtained.**

Keywords— 4- quadrant detector, pulse code detection, laser guided weapons, pulse repetition frequency, ATmega 32 microcontrollers.

I. INTRODUCTION

4-QUADRANT detector is an optical sensor which is commonly used in alignment, free space optical communication, fiber optics measurements, and laser receiver decoder. Laser guided weapons (LGWs) are playing an important role with the growing demand for precision attack. As one of the guided munitions, semi-active laser (SAL) guided weapons are commonly used in the battlefield, and the development of the optoelectronic countermeasure was greatly strengthened in last two decades. On the humanitarian ground, everyone wants each and every warhead to hit only its specific target, and not the civilians [1]-[3]. Laser pulse code is an anti-jamming measure used in SAL guidance systems technology. The laser decoding system on the weapons receives and processes the pulse echoes reflected by the target surface, by which the trajectory of the weapon could be corrected and be led to the target.

The guided weapon has the capability to secure the target even if it is moving. The operation of LIDAR is functionally identical to conventional radar [4], [15]. Many patents are available in Pulse Code Detection (PCD) that describes the development of Pulse Repetition Frequency (PRF) detection and lock systems [5], [6], [16]. The target is acquired when LGW locates the echo and then tracks the direction from which laser echo with the highest intensity is received. It is common that a decoding system module was designed into a small or medium-scale integrated circuit (IC). And then, the IC was gradually replaced with technology developed by microcontroller unit (MCU). LGWs use laser pulses of a specific code, which produces laser beam echo from the target, including a certain gate window. LGW uses its onboard circuit to detect the echo. Usually, these codes are in the form of a counter of the PRF per second. Based on the detection of a lock pulse code, the tracking electronics circuit is commanded to track the target reflecting the laser beam energy with the locked pulse code. In this work, an MCU is used to primarily detect the locked pulse code and differentiate it from the jamming pulse code. The false pulse code may come from jammer, buildings, the reflections of trees, etc. or the sent cheating jamming pulse code to mislead the missile [7]-[9].

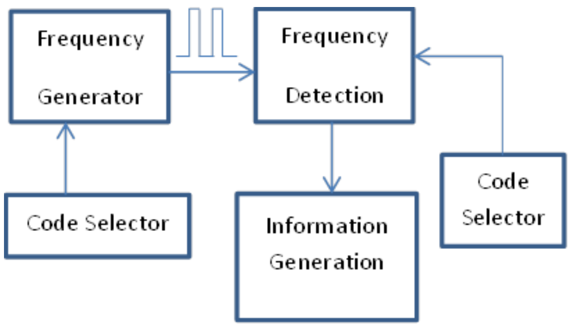

Fig. 1 Block diagram of PCD system

The command sequence is generated by the controller for the tracking purposes and communicates with the processing computer to load a negotiated code into the munition. The microcontroller is the important part in the processing circuit which controls and makes the decision for the component. The system is interfaced with the switches to select between different codes.

The user interface can be generated by PC serial interface and Proteus software comport interface. Fig. 1 shows the proposed PCD system block diagram. This paper can be organized as follows: in Section II, the proposed technique is discussed which includes code algorithms and important

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material used; in Section III, there are Proteus application and hardware implementation; in Section IV, there are simulations and results; and finally, conclusion is given in Section VI.

II. PROPOSED TECHNIQUE

The proposed laser PCD system is discussed in two parts. The first one includes hardware implementation with system materials used, and the second one includes algorithms software code.

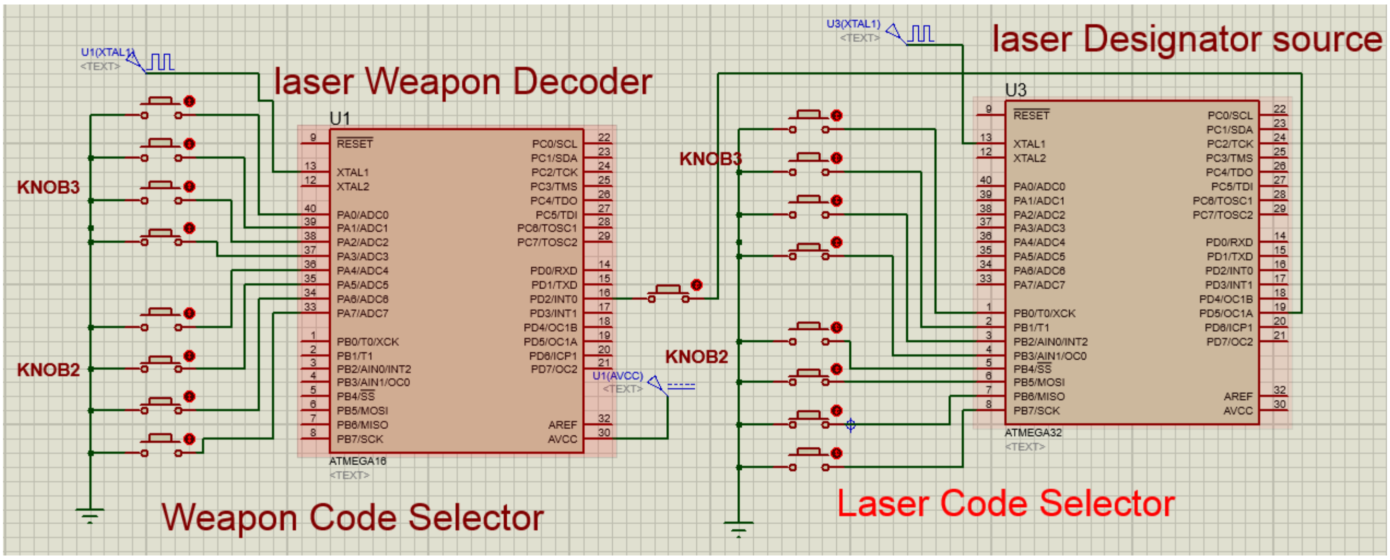

Fig. 2 Proposed schematics for laser PCD system

The system is implemented in ATmega32 microcontroller along with a real-time graphical display of two servo motors, one for yaw and another for pitch angles. Also, multiple code selection with the selector switches is modeled and implemented to produce different pulse codes to increase the efficiency of the system.

A. System Design

Two ATmega32 microcontrollers (MCU1/2) are used to simulate the laser coding and tracking system. MCU1 is used to generate laser pulse with different code which adjusted by the octal switch to model the laser pulse generated in the environment.

The MCU2 is used to decoding the output pulse from the first microcontroller by receiving it at the interrupt pin as input for simulation purpose. There are two cases; the first case: when the code is the same with the locked code at the second one, the LED will be illuminated, and the other case: when the code is different from the locked code in the second one, the LED is OFF.

Two Crystals with 16 MHz are used to generate TIMER1, which is used to generate laser pulse for the MCU1. With this value, pulse width can be produced with several frequencies, and the other one is used with the MCU2 to generate the gate for the decoder to distinguish between the locked pulse with it, and the pulse is sent from the first one.

From the status of the LED that we can know, if LED is ON the laser code is the same; if LED is OFF laser code is different.

For simulation purpose, we used switched to control the output code from the MCU1 (laser designator) by changing the switched position we can produce different PRF code. The MCU2 also has switches to simulate the locked code on the receiver. With this variety of codes, we can simulate system to test its ability to recognize the true and false code. An oscilloscope is used to measure the pulse width and frequency of the specific PRF from microcontroller one and also to measure the gate produced by the second microcontroller.

TABLE I COMMUNICATION PROTOCOL BETWEEN SWITCHES AND CONTROLLER

Octal switches	Terminal display	Function
(1,1)	50ms	ATmega Pin 18,19
(1,2)	50.800ms	ATmega Pin 18,19
(1,3)	51.600 ms	ATmega Pin 18,19
(1,4)	52.200 ms	ATmega Pin 18,19
…………	…………	…………
…………	…………	…………
(8,8)	100.800ms	ATmega Pin 18,19

B. Code Algorithm

Most of the programming techniques are operating in interrupt mode. Fig. 4 shows algorithm code for PRF generation. This code generates signals with different PRFs according to code switch selector, and pulse width is equal to 500 ns at pin 18,19. By default, it generates 20 Hz signal and has an ability to switch between codes.

Fig. 4 shows the flow diagram for frequency detection and information generation code algorithm for detecting PRF and information coming from different parts of the system including yaw/pitch angles of the servo motor. It also locks the system at different PRFs. At the start, the system is initialized and locks at 20 Hz. Then, all interrupt priorities are set at high priority except for Timer1 interrupt which is low priority interrupt. Pulses from the first controller come at interrupt I_0 at pin 16. It keeps on measuring the time between two pulses and calculates frequency. Timer1 is used to measure time period.

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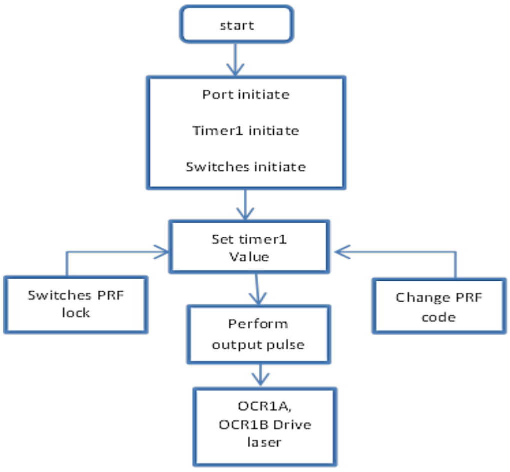

Fig. 3 Flow diagram for PRF generation

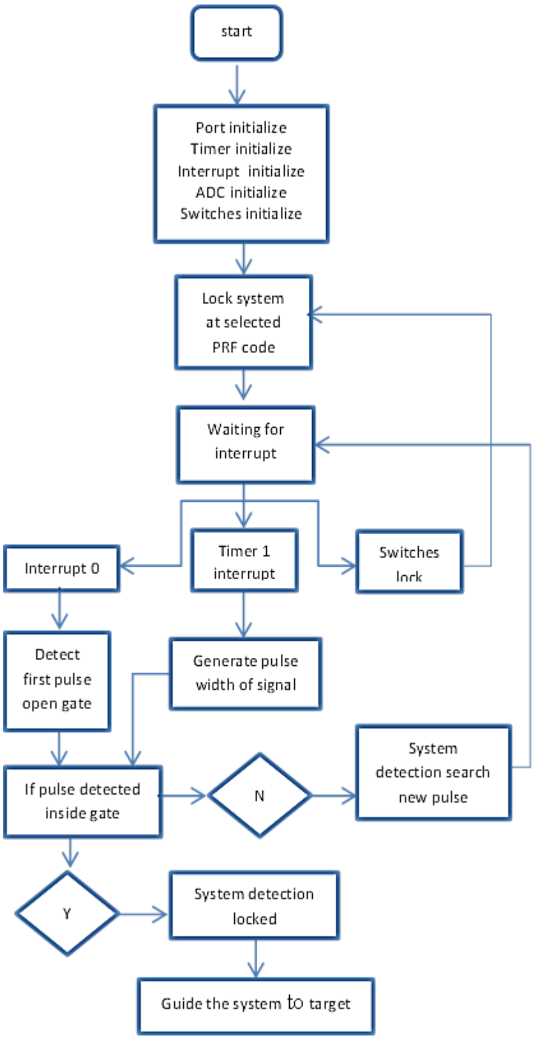

Fig. 4 Flow diagram for freq. detection and information generation

Timer 1 prescalar is adjusted to 1:64, which prevents the timer overflow in low PRFs measurement. The used crystal is 16 MHz, which produces one step per clock (CLK) equal 4usec, if the timer period requested value is 90000usec the

OCR1A= 90000/4=22500=0x57E4-1=0x57E3.

The following C code statements are used to calculate PRF:

```
timer value = (TMR1H*256 + TMR1L) ;
time period = (timer value /312500) ;
frequency = (1/ (time period));
```

where TMR1H is timer1 high byte register and TMR1L is timer1 low byte register.

If PRF detected is equal to PRF locked, it turns LED status ON; Otherwise, it turns LED OFF. Analog to digital conversion (ADC) interruption is used to convert input analog voltage to digital voltage and map it to -90° to +90° yaw/pitch servo motor gimbal angle. The weapon's line of travel and its longitudinal axis are defined as Yaw angle. The pitch angle is the angle between the horizontal plane and weapon's longitudinal axis [10], [11].

Timer1 interrupt is used to generate a 30-μs pulse with PRF equals to PRF of the input signal at interrupt pin. Timer1 is used with 1:64 pre-scaler to decrease the number of overflows.

A serial interrupt is used to display locked PRF, detected PRF, yaw/pitch angles, and also, locked PRF can be changed using code selector switches [10],[12].

To enhance the performance of anti-jamming, we put a gate signal to select the right laser pulse in the decoding system and producing a fixed interval code in the laser target designator.

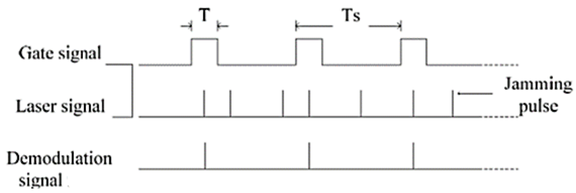

Fig. 5 The schematic diagram of the modulation waveform

As shown in Fig. 5, gate signal is a generated signal equivalent to the signal of laser pulse which is transmitted by the laser designator. It has the same period as the laser radiation. The decoding seeker received the reflected laser radiation from the target and any other laser radiation. Based on the gate signal pulse width, the system rejects jamming signal and locks real signal. The wider the gate pulse width is, the higher interference occurs. So, to minimize the laser pulse gate, reduce the jamming effect and increase the system sensitivity, only three input pulses are used to identify the laser code, and this is done based on the seeker module software code.

III. HARDWARE IMPLEMENTATION

Fig. 6 shows the block diagram of the proposed design concept of the laser PCD and recognition device. The design is configured with the 4-quadrant detector QP50-6SD2 from the first sensor, microcontroller programming card with ATmega32, a laser diode (LD) required to simulate laser target designator. The driver of the laser diode is controlled by a microcontroller-based embedded circuit.

The system circuit is interfaced with a reasonable selector changes to control laser pulse codes [13].

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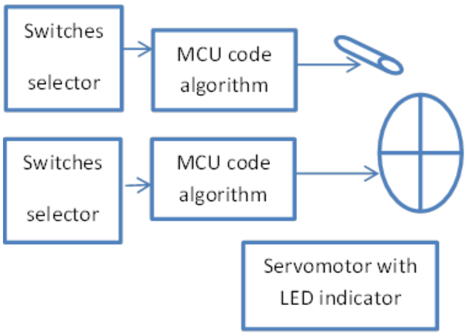

Fig. 6 Block diagram illustrating the design concept

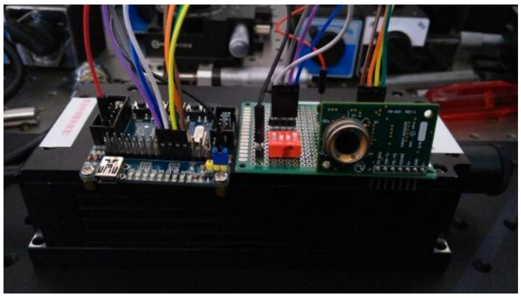

Fig. 7 Photograph of the laser pulses code detection device prototype

Fig. 7 shows the photograph of laser PCD device prototype. The hardware prototype was done and assembled to test laser PCD and recognize between different laser pulses. The system consists of QP50-6SD2which is used to bias the QD from ±4.5 V to ±18 V to put it in working mode, microcontroller programming Card working at +5 V, LD working with +5 V and MCU driver and selector switches.

IV. SIMULATION AND RESULTS

Proteus virtual system modeling (VSM) is commonly used in simulation purpose [14], [17],[18]. Its spatial features include the availability of simulating components, and a microcontroller helps to test the system virtually before making the final project. Using Proteus Transient analysis tool, frequency, and width of different waveforms and signals can be analyzed with very high precision and accuracy.

The first part was to model pulsed laser in a simulated environment. For this purpose, ATmega32 microcontroller generates pulses with 30-µs pulse width and PRF of different wavelengths according to code select switches. From Fig. 6, we can see the pulsed laser model output on the Proteus VSM simulation at microcontroller PIN 18,19.

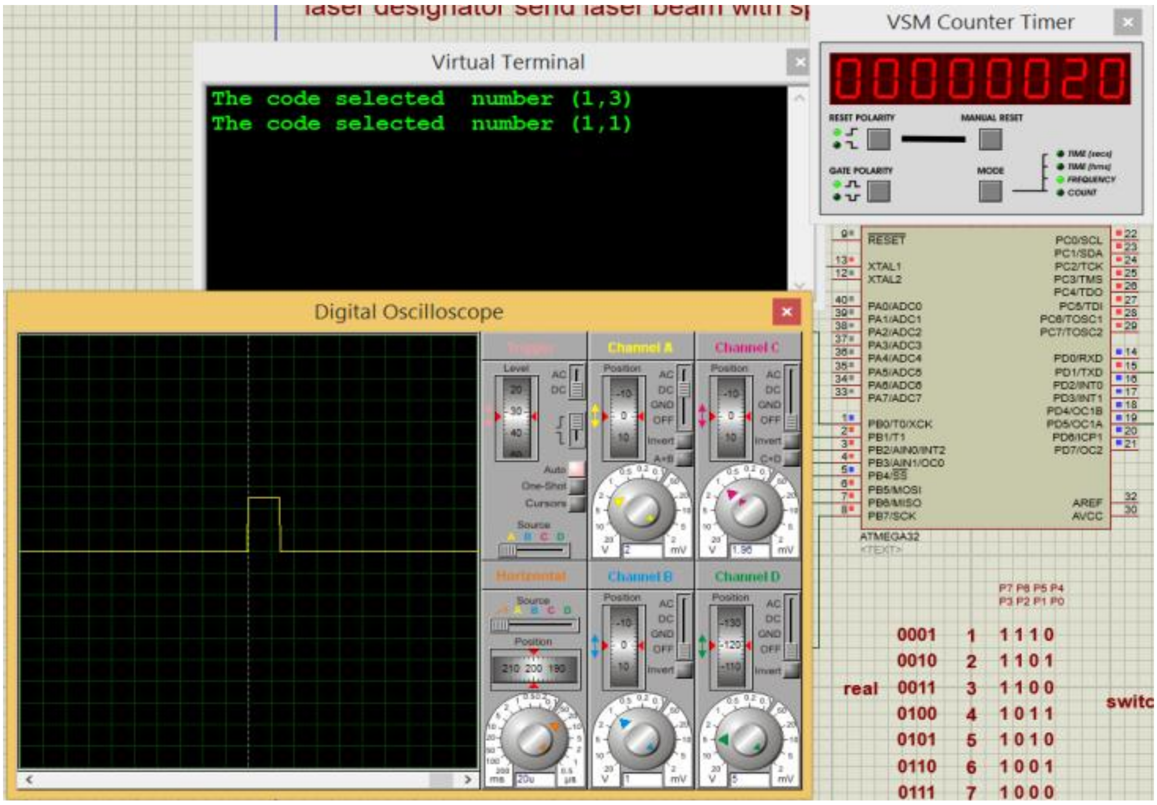

Fig. 8 Laser pulsed model pulse width

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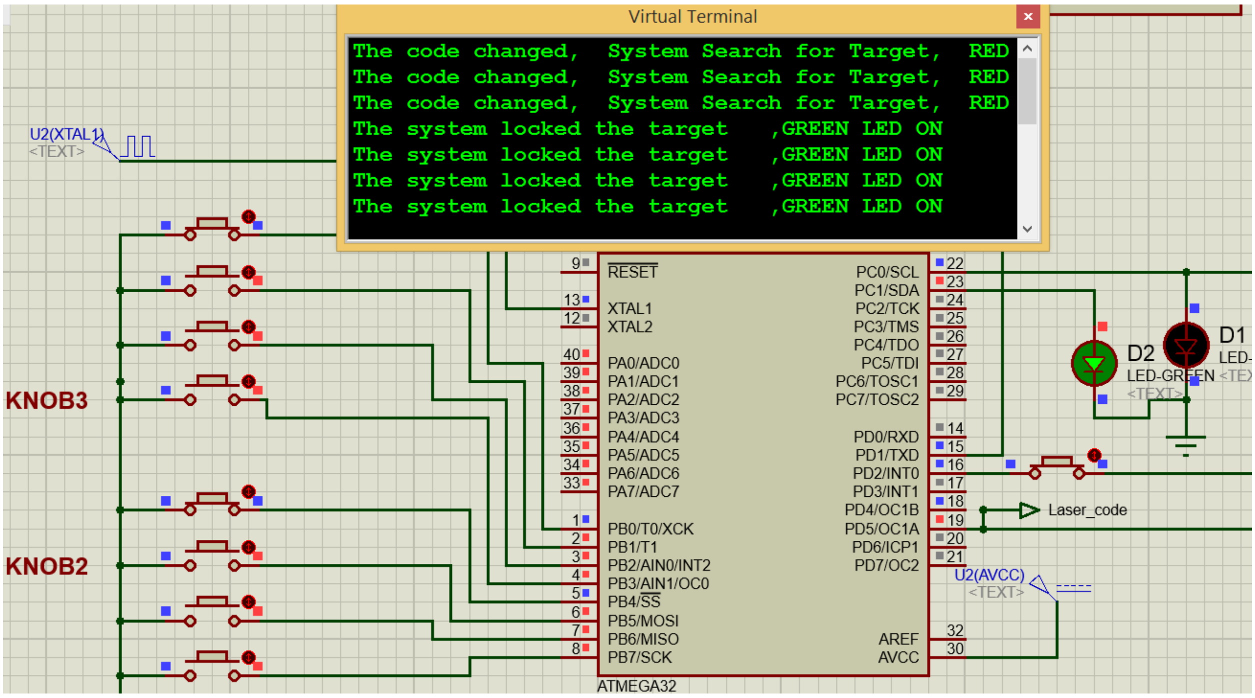

Fig. 9 Pulsed laser model with the receiver laser bomb model

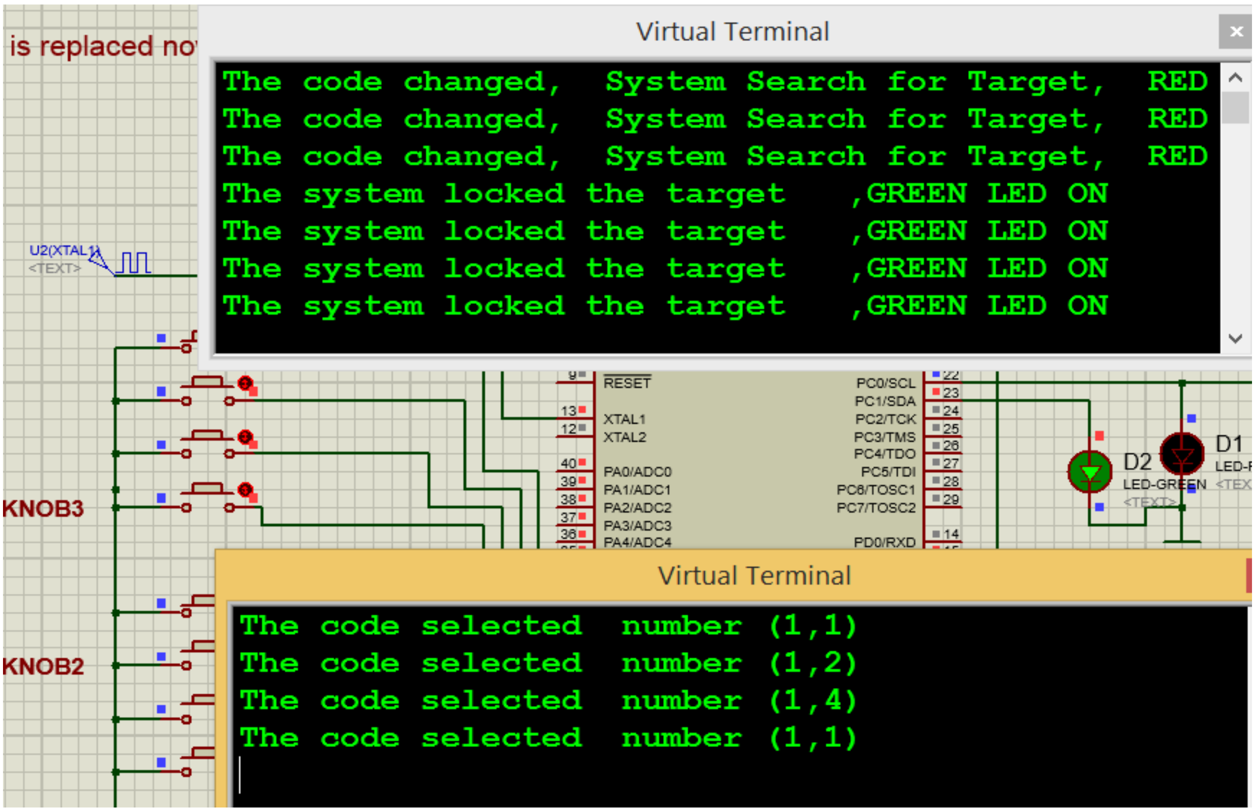

Fig. 10 The virtual terminal output with different inputs

From Fig. 9, we can see the pulsed laser model with the optical receiver laser model including indicator LED for the system which did not lock the target, and the RED LED is on when the system forgets the target and starts the search again.

When the system locked the target, the GREEN LED is ON.

Now different scenarios can be imagined depending upon the value of detected PRF at the receiver and locked PRF on the laser pulsed model. The system can be switched to a number of different codes, but for simulation purposes the system is tested for two PRFs, 10 Hz and 10.8 Hz. So, four different cases are studied.

One of the cases is when detected frequency at interrupt pin is 10 Hz and system is also locked at 10 Hz. As locked PRF equals detected PRF, so status green LED turns ON, and red LED turns OFF as shown in Fig. 6. Similarly, in the second case, if we select switches to code 2 on the receiver, the system becomes locked on 10.8 Hz, and status green LED switches OFF and red LED switched ON.

In the third case, if the select switch is on, the PRF generated is now 10.8 Hz and hence detected PRF and locked PRF both become 10.8 Hz, and status green LED switches ON and red LED switched OFF.

In the last case, if we select switch to code 1 on the receiver, the system is locked at 10 Hz. Now, detected PRF is 10 Hz and locked PRF is 10.8 Hz. As both are different, the status green LED turns OFF and red LED is turns ON.

Fig. 10 shows the virtual terminal output with different

inputs from selected switches. When select switch is '1' at both laser and receiver, it shows the value of detected and locks system to 10 Hz. When selecting different code, the system forgets the target and starts to search again.

In the case where the system locked the target, it starts to process data and makes a calculation to detect laser position of the reflected beam, and then sends digital OCR1A, B data to move servomotor YAW and PITCh in order to word the target.

TABLE II
PRF CODE COMPATIBILITY TESTS

PRF code setting on designator(ms)	PRF code setting on seeker(ms)	System locked status
50	50	System locked
50.800	50.800	System locked
51.600	51.600	System locked
52.200	52.200	System locked
…………	…………	…………
…………	…………	…………
100.800	100.800	System locked

TABLE III
PRF CODE REJECTION TESTS

PRF code setting on designator(ms)	PRF code setting on seeker(ms)	System locked status
50	60	Searching mode
50.800	70.800	Searching mode
51.600	91.600	Searching mode
52.200	51.600	Searching mode
…………	…………	…………
…………	…………	…………
100.800	50.800	Searching mode

Table II shows the PRF computability test for the system including laser designator model with laser seeker model.

Different PRF codes were programmed in the laser seeker and the laser designator device using selector switches which are used to change code with different code outputs according to the table test requirements. We can show the compatibility between two models with the same values.

Table III shows the PRF rejection test for the system including laser designator model with laser seeker model. We can show that there is no compatibility between two models with different values.

TABLE IV
PRF CODE RESOLUTION TESTS

PRF code setting on designator (ms)	PRF code setting on seeker (ms)	System locked status
50.001	50	System locked
50.002	50	System locked
50.003	50	System locked
50.100	50	System locked
50.005	50	System locked
50.006	50	Searching mode
100.007	50	Searching mode

Table IV shows the PRF rejection test for the system including laser designator model with laser seeker model.

The test was performed by programming the same PRF code in the laser designator and seeker unit and reaction of seeker checked. The PRF code was increased in ventures of 1.0 µs and the seeker reaction recorded for each incremental setting. For time interim contrast of >5.0 µs, seeker was seen to change from following to securing mode demonstrating out-of-lock condition. The outcomes are abridged in Table IV.

V.CONCLUSION

In this paper LIDAR, PCD system is developed using PRF Code. Based on the detection of a true code, the tracking electronics are commanded to track the object reflecting the laser energy with the true pulse code. Under different situations, the simulated results are obtained depending upon the locked PRF, detected PRF and switch selector commands given. We have status green LED ON to distinguish true pulse and red LED ON in the false pulse. Also, we get real-time output and input data for the yaw/pitch angle of the servo motor. Also, the 50-µs gate signal is generated at pin 18 of the microcontroller, which anticipates the incoming PRF signal at interrupt pin 16.

The system is tested and simulated for the system PRF code compatibility, rejection, and resolution. Mainly test the PRF code compatibility of the seekers.

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