S. Micloş[*], *I. Munteanu, D. Nicolae, C. Talianu*
National Institute of R&D for Optoelectronics INOE-2000, Bucureşti-Măgurele, ROMANIA

PORTABLE LASER RANGEFINDER STEERING BY MICROCONTROLLER

A portable laser rangefinder, capable to measure ranges up to 1,200 m, implies the measurement of time intervals ranging between some tens of ns and some tens of μs with an accuracy of less than 1 ns. Basically the measurement consists in accurately finding the time lapse between a start pulse generated by a transmitter and a stop pulse generated by a receiver. The realization of a such laser rangefinder raises some difficult problems. The first one is that a good temporal resolution is required to get a good ranging resolution and that means that both the transmitter and the receiver must be rapid. An other problem is that at measurements of range larger than 1,000 m the level of the reflected pulse current in the phodiode is of the order of the dark current, which has to be compensated, as well as the temperature offset of the photodiode (in order to keep the calibration). Another particularly difficult problems are related to the selection of an appropriate laser diode, having a sufficient optical power, but also the generation of very short rangefinding pulses, with very steep fronts. The authors used as emitter a high power pulsed laser diode CVD 193 from Laser Diode Inc. and build up for it a driving stage made up of a signal formatter that takes over the pulse sent by a microcontroller (that controls the whole rangefinder) and a switch based on a power high frequency MOSFET transistor 501N16A from DEI. The rangefinder is controlled by two PIC microcontrollers.

1. INTRODUCTION

A portable laser rangefinder, capable to measure ranges up to 1,200 m, implies the measurement of time intervals ranging between some tens of ns and some tens of μs with an accuracy of less than 1 ns. Basically the measurement consists in accurately finding the time lapse between a start pulse generated by a transmitter and a stop pulse generated by a receiver. There are several approaches to measure the very short time lapses, mainly used in nuclear electronics, that provide an accuracy of some tens of ps. The measurement of large (from hundreds of ns up to tens of μs) time lapses implies the use of other methods or to accustom some of the methods to measure the very short time lapses. There is no general approach to measure time intervals over a large range (from tens of ns up to tens of μs), as it is the case of a laser rangefinder. In our application

[*] miclos@inoe.inoe.ro; phone +4021 457 45 22; fax +4021 457 45 22; http://inoe.inoe.ro; 1 Atomiştilor Str., POB MG-5, Bucureşti-Măgurele 76900, ROMANIA

(portable laser rangefinder) the time intervals range from 160 ns (24 m) up to 8 μs (1,200 m), with an accuracy better than 1 ns over all the range. Other restrictions were: a low power consumption and a small amount of components (the rangefinder is portable).

The portable laser rangefinder, as may be seen in Fig. 1, is made up of the following units:

- the laser transmitter, which generates the rangefinding optical pulses
- the laser receiver, which receives the reflected optical pulses
- the short pulses measurement unit, which measures the time lapse between the generation and the reception of the laser pulse
- the control unit, which steers all the ranging process, using a PIC 16F873 microcontroller, and also the display of the results and of the status, using a PIC 16F627 microcontroller
- the electronic compass, which measures the azimuth and the elevation angles
- the LCD, which displays the measured range and the rangefinder status
- the power supply, important because the rangefinder is portable

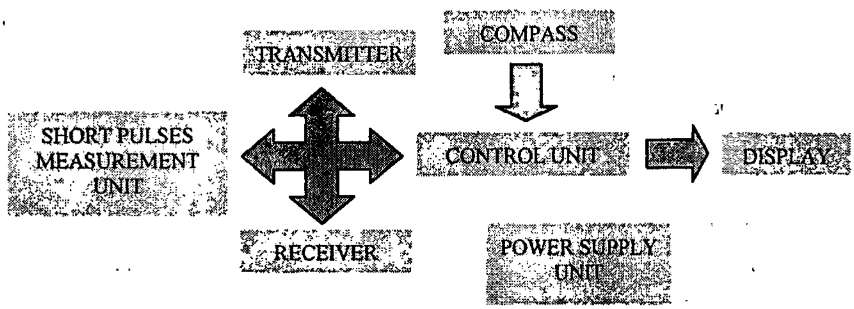

Fig. 1. Laser rangefinder schematic

2. CONTRIBUTIONS

2.1 The control unit

The rangefinder is build around two microcontrollers: one of them steers the rangefinder, while the other is only a LCD driver. The main microcontroller have the next functions:

- manages the input devices (two push-buttons)
- controls the laser transmitter and the laser receiver
- measure the time lapse between the START and STOP signals
- computes the range
- controls the second microcontroller (the LCD driver)
- controls the power supply unit
- receives data from the compass via serial communication interface
- sends data to an external PC via serial communication interface

The schematic of the control unit is shown in Fig. 2, except for LCD microcontroller driver, which is shown in Fig. 3.

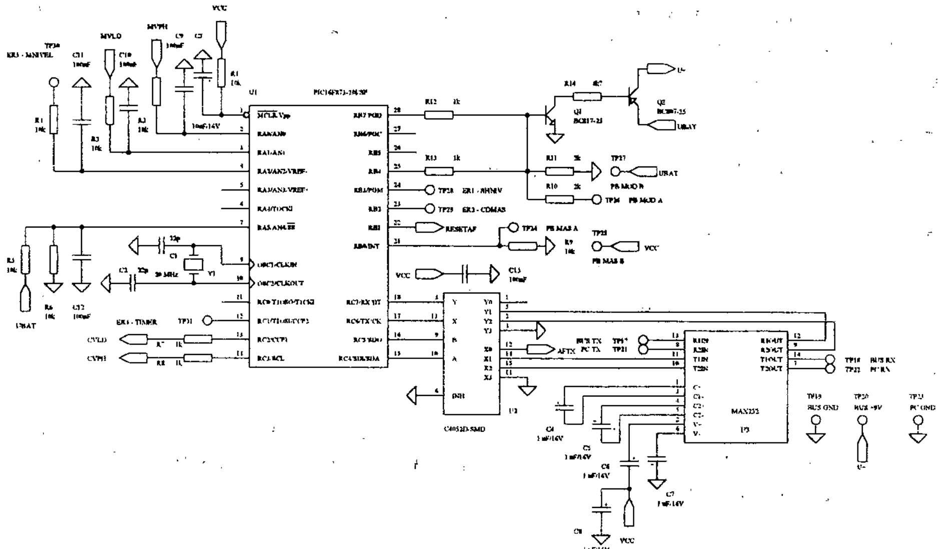

Figure 2. Control unit schematic

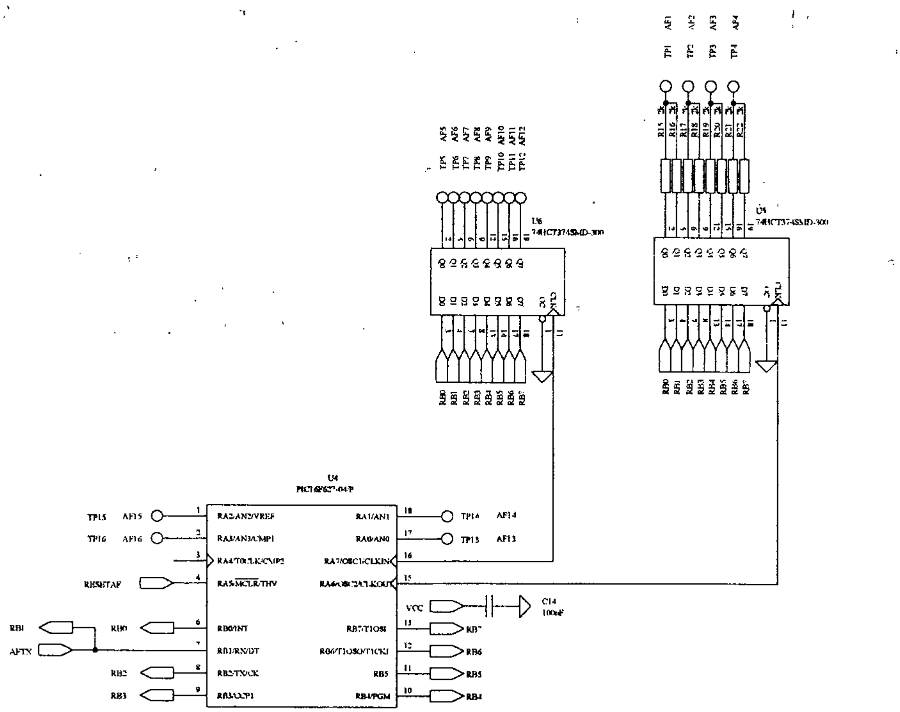

Figure 3. Control unit - LCD microcontroller driver

The management of the input devices (two push-buttons) is accomplished through the bits RB0 (push-button "Measurement") and RB4 (push-button "Mode") of the PORT B. As it is known, RB0 may be read by an interrupt. The time lapse is measured between two pulses TIMER entered on pin RC1, using TIMER2. All the calculations are done programmatically.

The power supply is controlled through signals CVLD (RC2) – MVLD (RA1) for the transmitter, CVPH (RC3) – MVPH (RA0) for the receiver and UBAT (RA5) for the general power voltage. As it will be seen in the next section, the voltages are controlled by measuring through analog/digital convertors of the microcontroller.

The display controller (in fact the other PIC microcontroller) is reset through the signal RESETAF (RB1) and all the data that has to be displayed is sent coded via serial communication interface (RC6).

The compass is read via the same serial communication interface (RC7) as the communication with the external PC (RC6 and RC7). A multiplexer (C4052) separates these users of the serial interface.

2.2 The power supply

Here are presented the high voltage power supplies of the rangefinder : in Fig. 4 the transmitter power supply and in Fig. 5 the receiver power supply.

The laser transmitter supply works as it follows:

The combination FET - transistor ensures a low output impedance, which is necessary because the amplifier stage has a low input impedance.

Because the rangefinder is built around a microcontroller which has a PWM output and also an A/D convertor, it is possible to use a performant high voltage source using a minimal number of components (Fig. 4). The supply is of type FLY BACK.

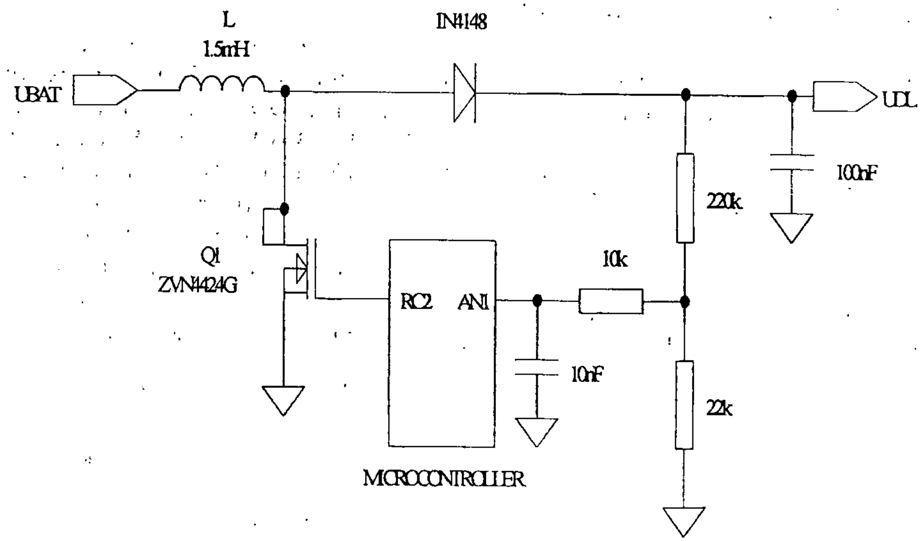

Figure 4. Laser transmitter high voltage supply schematic

For the receiver, the schematic is similar.

When Q1 is ON the inductor L is charging with energy, which is then transfered into the capacitor C when Q1 is OFF. The DC voltage from the output is measured and the value compared to the reference modulates in width the command impulse of the FET Q1. So the reaction loop is in fact hardware/software, using the microcontroller.

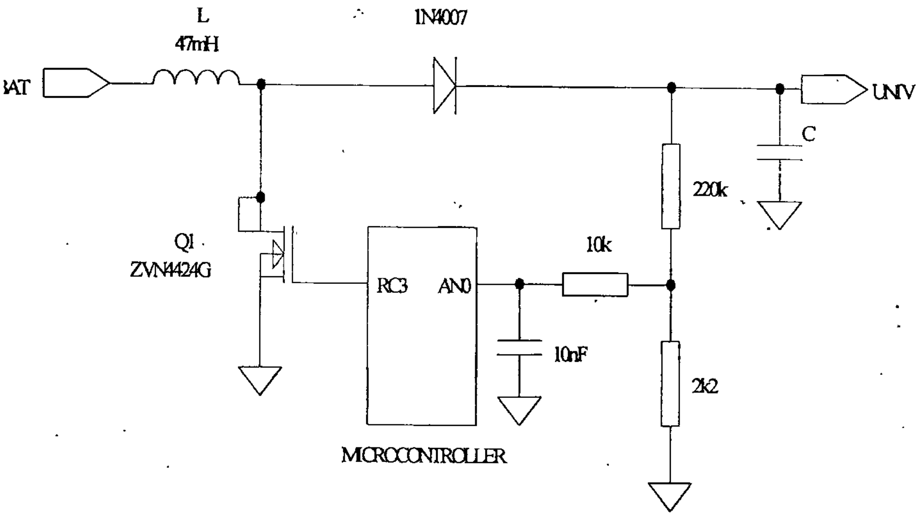

Figure 5. Laser receiver high voltage supply schematic

2.3 Short pulses measurement

It is possible to use a time-amplitude conversion followed by a stretcher and then followed by an analog-digital conversion. Still it is a problem: in order to measure with an accuracy better than 1 ns it is necessary a 15-bit A/D converter, that means a resolution of 100 μV per channel and a broom less than 30 μV. Such a broom can be obtained (the rangefinder uses a microcontroller driven by a 20 MHz clock) only using a large number of components, meaning a large volume and a large power consumption. Because this alternative was inacceptable, we opted for a solution in which the measured time is expanded by a factor of 240, so that the time range is shifted from 100 ns - 10 μs to 24 μs -2.4 ms. This time range may be measured by the internal 16-bit timer/counter of the microcontroller, so that fundamentally the measurement has an accuracy given by a clock of 5MHz: $\pm\frac{1}{2f_{osc}} = \pm 100\,\text{ns}$. Taking into account that we did an expansion by 240, the theoretical accuracy of measurement is 240 times better: $\pm\frac{100\,\text{ns}}{240} = \pm 0.42\,\text{ns}$, that is an accuracy of distance measurement of : $\pm\frac{100\,\text{ns}}{240}\cdot\frac{0.15\,\text{m}}{\text{ns}} = \pm 6.25\,\text{cm}$.

The schematic of the short pulse measurement unit is shown in Fig. 6.

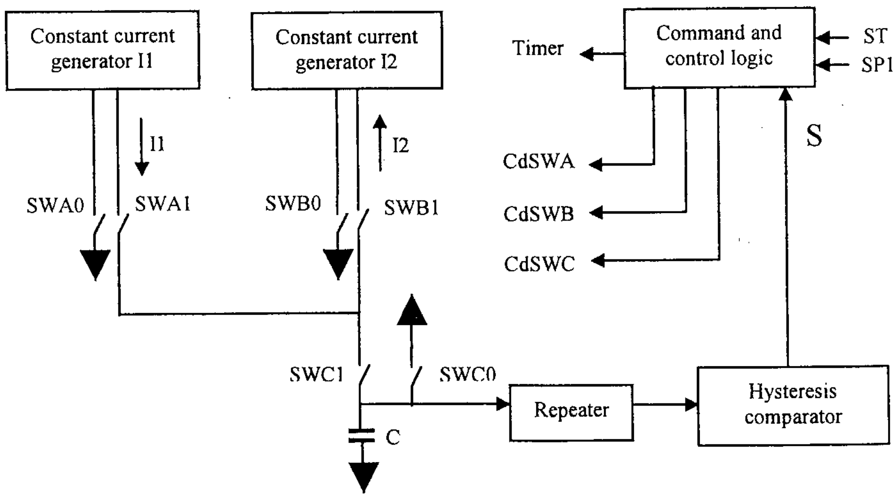

Figure 6: Short pulses measurement unit schematic

In the stand-still state the block "Command and control logic" ensures that the analogic switches SWA0, SWB0 and SWC0 are in the state ON (closed) so that the storage capacitor C is discharged and the generators I1 and I2 have the output put to the ground through the resistor ON (typically some tens of ohms) of the corresponding analogic switch.

In the moment when the transmitter sends a START impulse (a TTL impulse with a width of 50 ns and rise/fall edges of about 2 ns) the switch SWC0 opens and the switch SWC1 closes. Meanwhile the switch SWA0 opens and the switch SWA1 closes. Thus the current I1 begins to charge the capacitor C.

At the moment of the emergence of the impulse SP1 (STOP1) generated by the receiver (a TTL impulse with a width of 50 ns) the "Command and control logic" opens the switches SWA1 and SWB0 and closes the switches SWA0 and SWB1, so that the capacitor C begins to discharge with a constant current I2 while the constant current generator I1 turns into the stand-still state (with the output to the ground).

At the moment when the switch SWB1 turns from the state OFF to the state ON the capacitor C is charged with a voltage U_C proportional to ΔT_1, where ΔT_1 is the time lapse between START and STOP (in fact is exactly the time lapse to be measured). The capacitor will be discharged by the current $|I_2|$ during a time interval $\Delta T_1 = k \cdot \Delta T_1$. Therefore ΔT_1 was expanded by a factor k, which is in our case 240.
Synchronously with the signal SP1 (STOP1) the Timer output turns from logical "0" to logical "1", which makes the microcontroller (initially programmed to work in the TIMER mode) to store the momentary value (N1) of the 16-bit counter (input Capture/Compare). When the capacitor C is discharged the hysteresis comparator switches and makes that the switches SWC0 and SWB0 closes and the switches SWC1 and SWB1 opens. So both constant current generators are reset to the initial state and the capacitor C is discharged through the resistor ON of the switch SWC0 and maintained discharged till a new measurement.
Synchronously with the signal SP2 (STOP2) the Timer output turns into logical "0", which makes the microcontroller to store the momentary value (N2) of the 16-bit counter. Immediately after the signal SP1, the microcontroller was programmed to store on the falling edge. Therefore the lapse ΔT_1 was expanded to the value $\Delta T_1 = k \cdot \Delta T_1$, which is stored as a value $N = N_2 - N_1$.

2.4 The laser transmitter

The rangefinder laser transmitter have to accomplish some requirements:

- generate a current pulse of 30 A with a width of about 100 ns and edges of about 1 ns
- protect the laser diode

The laser rangefinder transmitter mainly consists (Fig. 7) of four functional blocks:

- laser diode and its MOSFET driver
- MOSFET gate driver
- START signal formatter
- high voltage power supply

The operation of the laser transmitter is as it follows. In the stand still state the capacitor C charges at the voltage UDL through R1, R2 and D1. When the transmitter receives a command from the microcontroller, the gate driver switches the MOSFET (Q1) into the state ON and begins the discharge of the capacitor C through the laser diode and the resistors R2 and R3. The current through the monitoring resistor R3 actually forms the START impulse, which is however formed in amplitude by the two NAND gates.

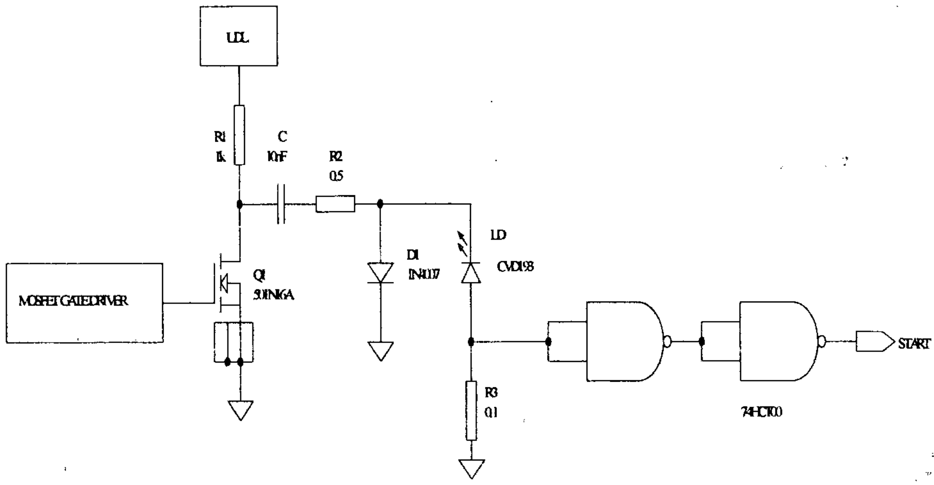

Figure 7. Laser rangefinder transmitter shematic

2.5 The laser receiver

The rangefinder laser receiver have to accomplish some requirements:

- storage of the temporal information
- protection of the diode against reflections from targets closer than 25 m
- response to an input power of order of nW (because of the measuring range: 25-1200 m), comparable to the dark current
- extended range of operating temperature (-30 ... +40 °C)

The solution commonly used for receivers, that is to compensate the dark current taking into account the temperature range (requirement d) can't be used because the variation of the dark current is greater than 15 nA and the compensation is no longer effective. A solution of compensation with the temperature measurement would be costly (as number of components, volume, power consumption).

We adopted a solution of coupling to the amplifier stages in AC, where the dark current - slowly variable - has no more importance.

As it may be seen in Fig. 8, the photodiode is biased from the high voltage source through an analog switch. This is necessary in order to protect the photodiode against the reflectionsfrom targets closer than 25 m. So the photodiode is biased with a delay of about 160 ns after the light pulse was emitted.

The light pulse converted by the photodiode into a current pulse and then by the resistor R into a voltage pulse is amplified by two stages of amplification.

The output pulse of the second amplifier stage passes through a discriminator using a tunnel diode followed by a width and amplitude formator, which generates a TTL impulse (STOP) with a width of about 50 ns and an edge of about 2 ns (the jitter is

lower than 100 ps). Simultaneously, the output pulse of the second amplifier stage passes through a stretcher, is then amplified and is output as an impulse ASTOP, with a width > 10 μ s, which is sufficient that the A/D converter of a microcontroller accomplish the conversion.
The signal ASTOP is necessary to determine the reflection quality (high, medium, low or no reflection).

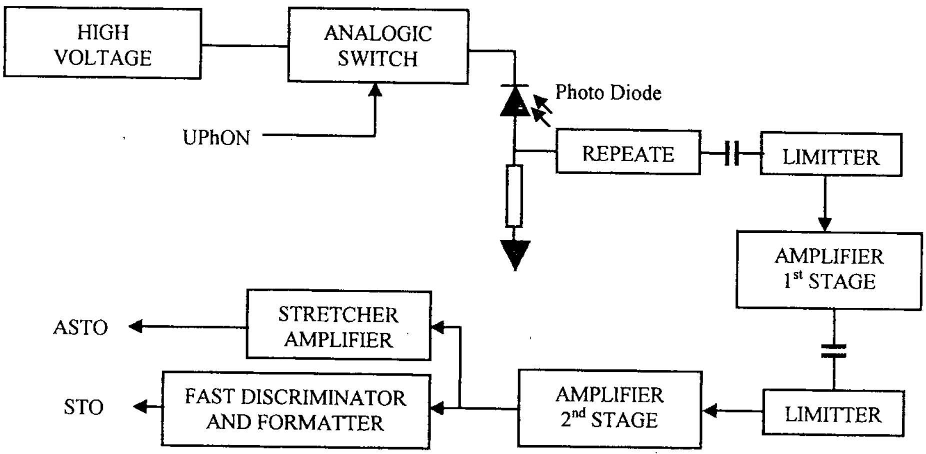

Figure 8. Laser rangefinder receiver shematic

3. REFERENCES

[1.] John B. Peatman, *Design with PIC Microcontrollers*, Georgia Institute of Technology, Prentice Hall Engineering, 1998

[2.] David Benson, *PIC Microcontroller Applications Guide*, Wanda Benson Square 1 Electronics, 2001

[3.] Roger Stevens, *PIC Microcontroller Serial Communications*, Wanda Benson Square 1 Electronics, 2001