CONTROL SYSTEM INTERFACE OF SCANNING SONAR FOR MOBILE ROBOTS

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Keywords: Mobile robot, Ultrasonic range-finder.

Abstract: In this work, a simple, low-cost and reliable electronic module for coupling of an ultrasonic range-finder with a mobile robot's microprocessor system is presented. A software filter for correct reading of the ultrasonic data is presented as well. Due to the software filter, a shielding of robot and sonar's electronic modules is not required. In this way compactness and low price of the device construction were achieved.

1 INTRODUCTION

Ultrasonic range-finders, referred also as sonars, are known as robust and cheap distance measurement devices suitable for various applications (Corrion et al., 1996), including gathering of information from environment for real-world modeling as well as for navigating in mobile robotics (Borenstein et al., 1996; Cao and Borenstein, 2002; Noykov and Manolov, 2004). Ultrasonic range-finders don't depend on the lighting and brightness of surfaces, even if they are influenced by the matter in which the objects are made; they don't depend on smoke, and they don't need cumbersome equipment (Corrion et al., 1996). These devices provide relative distance measurements between them and surrounding obstacles located within their angular detection range, also called "sonar detection cone". The time elapsed between the transmission of a wave and the reception of its echo allows the computation of a range reading *r*.

The current market suggests a variety of ultrasonic range-finders. As is reported in (Borenstein et al., 1996), the ultrasonic range finders, based on *POLAROID* ranging modules, are the most widely found in mobile robotics literature. The base series of *POLAROID* ultrasonic ranging systems is described in (Borenstein et al., 1996; Polaroid Corp., 1991; Polaroid Corp., 1981). It includes transducer and two electronic modules: *ranging circuit board* and *experimental demonstration board*. This ultrasonic ranging system is low cost and its parameters satisfy the requirements of the most applications in mobile robotics (Borenstein et al., 1996). It is able to measure ranges from 0.9 feet to 35 feet with resolution 0.1 feet. The *ranging circuit board* (RCB) controls both the transmit and receive operating modes of the transducer. The *experimental demonstration board* (EDB) is designed especially as a user interface to the RCB. The EDB contains all the necessary electronic circuitry to convert the transmit/receive time interval into a figure indicating distance, in feet, and present it on a three digit light emitting diode (LED) display. The block diagram of the EDB, given in (Polaroid Corp., 1981), is shown in Fig. 1. The output of the EDB is a three digit display (9) with a numeric output range of 0.9 to 35.0 in increments of 0.1 feet. The multiplexed display is controlled by a three-digit binary counter (8) with strobed digit-select lines *DS1, DS2, DS3.* It uses a single binary-coded decimal (BCD) to-7-segment decoder (11). Unfortunately, this multiplexed display output does not allow direct coupling with external microprocessor system. For this purpose, an additional interface circuitry is required. Such interface equipment, given in (Ciarcia, 1980), was manufactured and tested in Laboratory of Mobile Robotics LAMOR, ICSR-BAS. Unfortunately, it was established that this interface circuitry did not work properly.

Noykov S. and Manolov O. (2005).
CONTROL SYSTEM INTERFACE OF SCANNING SONAR FOR MOBILE ROBOTS.
In *Proceedings of the Second International Conference on Informatics in Control, Automation and Robotics - Signal Processing, Systems Modeling and Control*, pages 245-250
DOI: 10.5220/0001164302450250

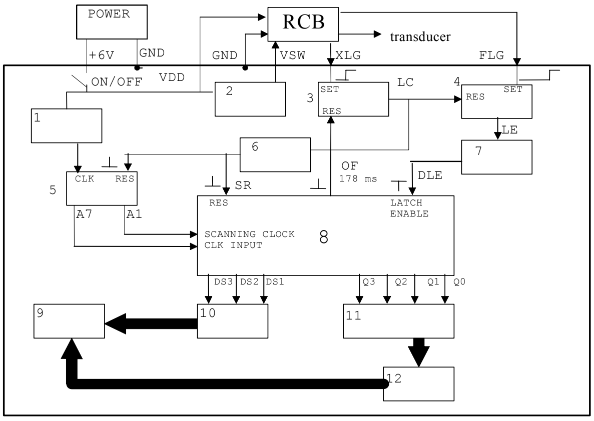

Figure 1: Block diagram of the Polaroid Experimental Demonstration Board

In this work, hardware and software devices, which enable an external microprocessor system to read correctly the information from a *POLAROID* ultrasonic ranging system, are presented.

2 THE SCANNING ULTRASONIC RANGE-FINDER

In the *LAMOR Lab, ICSR – BAS,* the mobile robot *LAMOR-1TV* has been created for experimental research and education. *LAMOR-1TV*, shown in Fig. 2, is described in (Noykov and Manolov, 2004). *LAMOR-1TV* is a mobile mini-robot with differential steering. *LAMOR-1TV* has a length of 400 mm, a width of 260 mm and a height of 220 mm. As part of sensor subsystem of the robot, a scanning ultrasonic range-finder (shortly sonar) was developed. The sonar is based on an ultrasonic ranging system from the base series of *POLAROID*. To enable scanning, the transducer of the sonar is mounted on the axle of a stepper motor. The home angular position of the sonar's transducer is 0º, i.e., the sonar's transducer is directed to the robot's front in its home position. The scanning range of the sonar is 244.8º, starting from -122.4° to +122.4° in the horizontal surface. The minimum scanning angle step of the sonar is 1.8º. The described in the next section interface module IM is used for coupling of the sonar with the *LAMOR-1TV* microprocessor system.

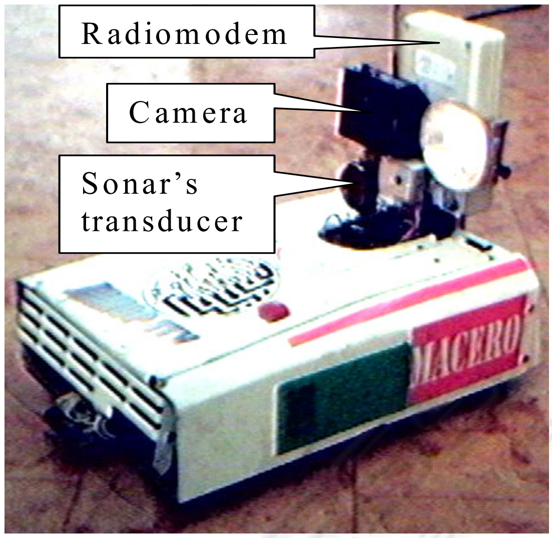

Figure 2: The mobile mini-robot *LAMOR-1TV*.

3 INTERFACE MODULE FOR CONNECTION OF AN ULTRASONIC RANGING SYSTEM TO AN EXTERNAL MICROPROCESSOR SYSTEM

The suggested in (Ciarcia, 1980) interface circuitry was modified and new interface module for coupling of an ultrasonic ranging system from the base series of *POLAROID* with an external microprocessor system was developed. The block diagram of the

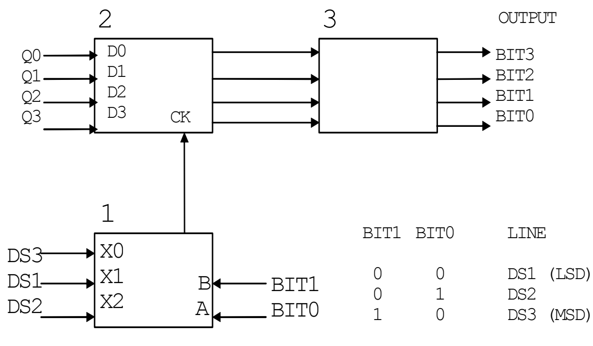

Figure 3: Interface module for connection of an ultrasonic ranging system POLAROID to an external microprocessor system: block diagram

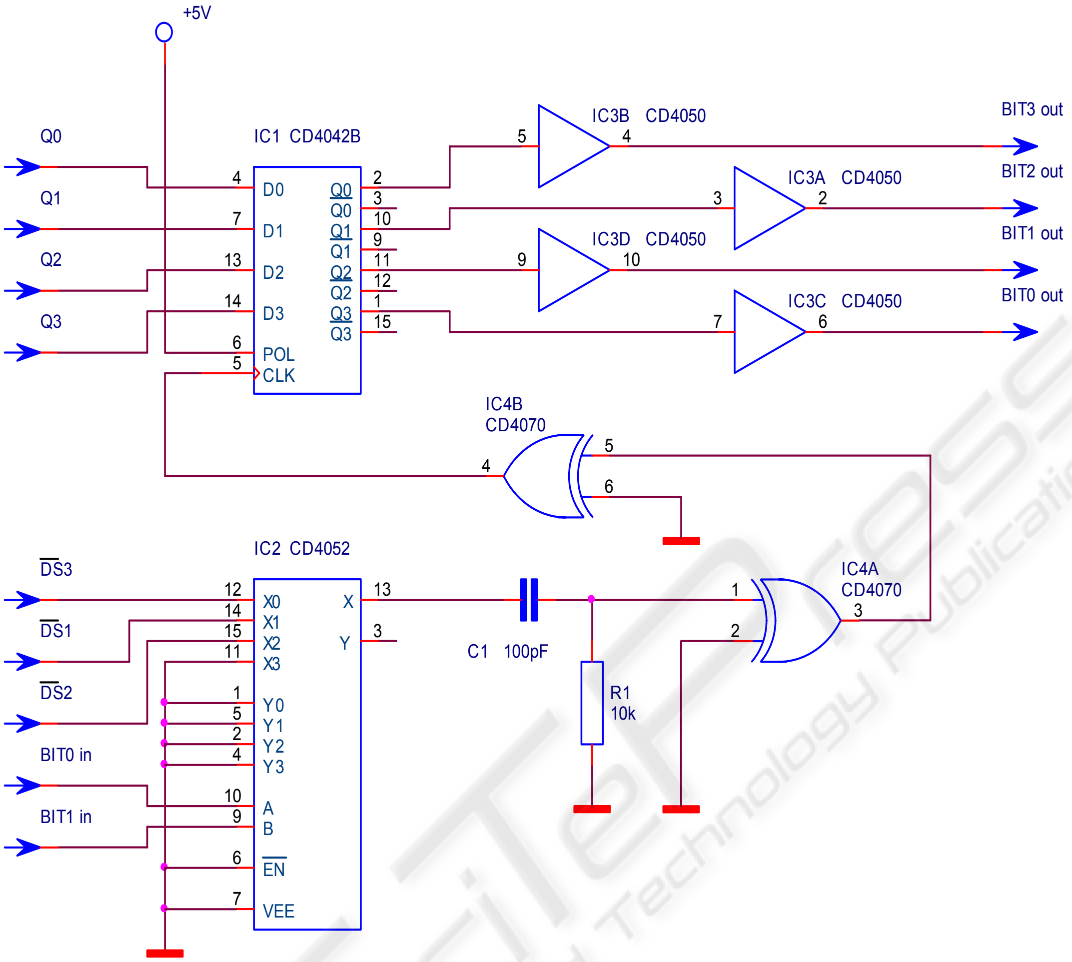

Figure 4: Interface module for connection of an ultrasonic ranging system *POLAROID* to an external microprocessor system: schematic diagram

interface module (IM) in Fig. 3, its schematic diagram in Fig. 4, and its timing diagram in Fig. 5, are shown.

The block diagram of the interface module (IM) includes three blocks. Block 1 includes three-input demultiplexer (IC2) and logic circuits for a strobe signal generating (IC4). Block 2 includes a 4-bit lach (IC1), and Block 3 includes an output buffer (IC3). When the MSD (most-significant digit) of the LED display is energized, the DS3 line is low. The data on Q0 thru Q3 at this tame form the BCD value of that number. Similarly, when DS2 goes low, the data lines will hold the second digit value. IC2 is a 4-to-1-line demultiplexer with the three digit strobes as inputs. A 2-bit TTL compatible parallel output from the reading external microprocessor system determines which of these channels is routed though the multiplexer. To get DS1, the LSD (least significant digit), the input code to the EDB interface would be 00. A binary code of 10 would set channel 3, allowing DS3 to go through. A summary of the codes is given in the table showed in Figure 2.2a. When we have selected which digit we want to read by setting the proper multiplexer-input code, that digit value will be latched into IC1 and available as a BCD value to the reading external microprocessor system. IC3 buffers the CMOS voltage levels of the EDB to the TTL level required by some microprocessor systems. To obtain the distance indication, it is necessary to add the three values:

$$\text{DISTANCE} = (\text{MSD})*10+(2^{nd}\text{ digit})*1+(\text{LSD})*0.1$$

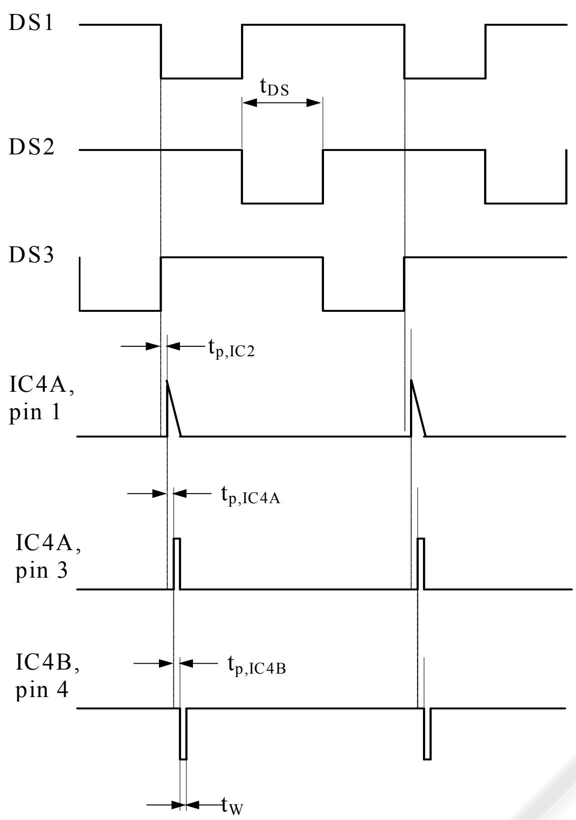

Figure 5: Interface module for connection of an ultrasonic ranging system POLAROID to an external microprocessor system: timing diagram

4 THE SOFTWARE FILTER FOR CORRECT READING OF THE SONAR INFORMATION

During preliminary experimental gathering of information from laboratory environment by the mobile robot *LAMOR-1TV*, equipped with the presented in Section 2 sonar, we found that the robot's microprocessor system did not read sonar data correctly, due to the mutual influence of the electromagnetic fields of the near located circuit boards of the robot, circuit boards of the sonar, IM, and stepping motors. Instead of shielding, we developed a software filter for correct reading of the sonar information by the robot's microprocessor system. The objectives that we had to achieve were compactness and low price of the construction.

Initially we accomplished number experimental readings by the sonar. Afterwards we analyzed the stored in robot's memory sonar information, read by robot's microprocessor system. It was found that this information contained alternated sequences of correctly and wrongly received data. The durations of these sequences were analyzed. Afterwards, on the basis of obtained results, a software filter was developed, and implemented as executable code, written in the on-board EPROM memory of the robot.

The algorithm of the software filter is represented in Fig. 6. The calling subprogram requires LSD, 2nd digit, and MSD of sonar data from the called subprogram consecutively. The called subprogram reads the data of required digit repeatedly. To validate the read digit, a coincidence of 100 consecutive readings is required. After the read digit is validated, the called subprogram sends it to the calling subprogram. A single reading takes 34 μs; therefore 100 consecutive readings take 3.4 ms. In the best case (i.e., in case without wrongly read data) the acquiring of all three sonar digits will take 3*3.4=10.2 ms. We found that in the worst case the acquiring of all three sonar digits will take 19.1 ms.

5 IMPLEMENTATION

In (Noykov and Manolov, 2004), we proposed a modified method for occupancy grid map building by a mobile robot and a scanning ultrasonic range-finder. The map building process consists of two phases: 1) Gleaning of information from environment, and 2) Sonar data processing. For sonar data processing the proposed modified method combines: 1) statistical approach for probability sonar model building; and 2) application of the fuzzy logic theory for sonar data fusion. For experiments, the mobile robot *LAMOR-1TV*, equipped with the scanning sonar, is used. The experimental laboratory environment is presented in Figure 7. The experimental laboratory environment is characterized by two book shelves A and B, with rough surfaces, which may cause a smooth sonar echo, and two walls C and D, with flat surfaces, which may induce multiple reflections. The environment involves also a stationary cylindrical object E. The executed robot path is depicted by dotted line. Successive positions, where the robot stops and collects information from environment by scanning range finder, are O_1, O_2 ... O17. They are labelled by stars. The robot is shown in its both start position O_1 and end position O_{17}.

The algorithm for gleaning of information from environment by moving mobile robot and scanning ultrasonic range finder is as follow:

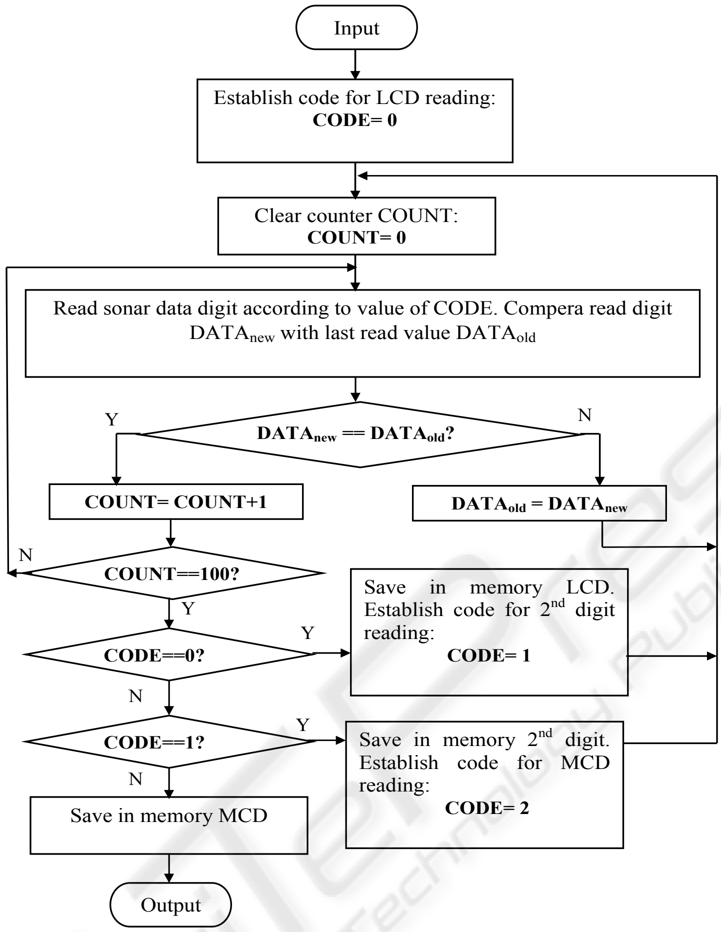

Figure 6: The algorithm of the software filter.

1) The robot stops in the point $O_к$. The sonar rotates in its end right angular position (-122.4°) and takes a measurement r_i^k . The counter is established i= 1.
2) The counter is incremented, i= i+1. The sonar rotates one step to the left and takes a measurement r_i^k .
3) Step 2 repeat while sonar reaches its end left angular position (+122.4°).
4) The sonar rotates in its home position (0º) and the robot goes to the next path point, O_{k+1}.
5) Algorithm 1) - 4) repeated while the robot reaches the end of the planned path.

A program, written in the EPROM of the on-board microprocessor control unit, carries out the immediate servicing and control of the *LAMOR-1TV* sensors and motors. This program accomplishes also the communication with external PC through RS232 interface, where the high-level robot control program is written in C. The high-level robot control program enables the user to program the robot's path, co-ordinates of the positions, where the robot must stop and collect information from environment, scanning angle step of the sonar, etc. Range finder data are collected in the robot's frame of reference by scanning a space around the robot's instant position O_i, passed to the external PC, and stored there into a text file.

One of the experimentally obtained cell maps of the environment from Figure 5 is presented in Figure 8. The occupied cells are labelled by thick black crosses and small points label the indeterminate cells. It can be seen, that: 1) regardless of the different roughness of the object surfaces, the thicknesses of the object contours are approximately equal; and 2) the wrong measurement results due to multiple reflections are rejected.

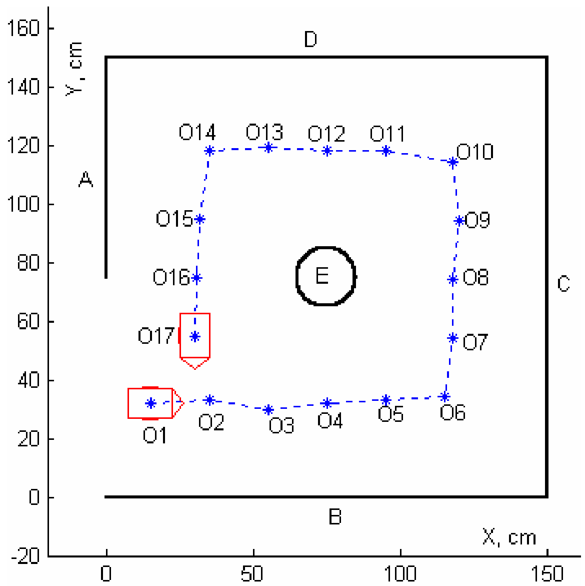

Figure 7: Gleaning of information from environment by moving mobile robot and scanning ultrasonic range finder: experimental laboratory environment and robot path.

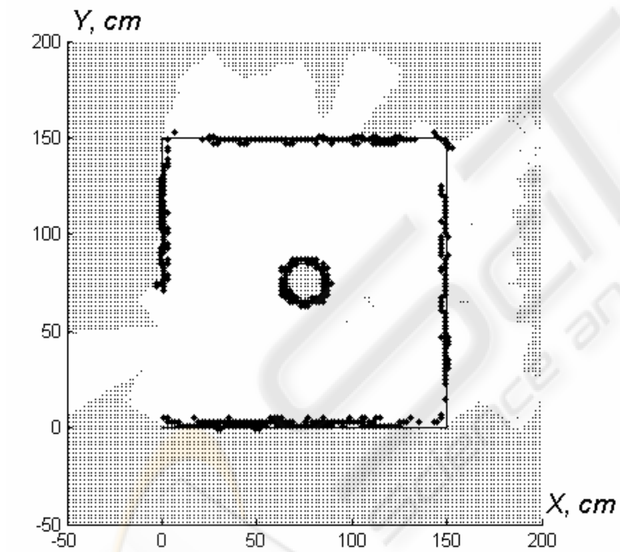

Figure 8: An experimentally obtained integrated occupancy grid map of the environment, represented in Figure 7. The empty cells are leaved by white; thick black crosses label the occupied cells; and small points label the indeterminate cells.

6 CONCLUSION

In this work, hardware and software devices, which enable a robot's microprocessor system to read correctly the information from scanning sonar, based on a *POLAROID* ultrasonic ranging system, are presented. The interface includes a simple, low-cost and reliable electronic module for coupling of the ultrasonic ranging system with the robot's microprocessor system, and a software filter for correct reading of the information passing between them. Due to the software filter, a shielding of robot and sonar's electronic modules is not required. In this way compactness and low price of the device construction were achieved.

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