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An Embedded Approach for Motor Control Boards Design in Mobile Robotics Applications

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Abstract: In this paper the conception, the project, the realization and the test of a multi purpose board for motor control in robotics applications are presented. The main features of such a board are: the possibility of controlling CC motors as well as servomotors, using measures both from continuous (like potentiometers) and from digital (like encoders) sensors; the possibility of changing the control law, being contained in a microcontroller, by simply changing the C code of the programming; the possibility of serial communication, also via radio link, for control parameters changes and for data exchange with other boards or with a central unit.

Key–Words: DC Motor, Servo motor, Position control, Speed control, mobile robotics.

1 Introduction

In recent years the use of several cooperative mobile robots for many applications has been more and more investigated both from a theoretical point of view (planning and control techniques, modeling of the interactions, etc.) and from a practical one (fields of applications, robot design and sensors equipment for different uses, etc.).

In this field, a project related to the use of a *hybrid robot squad*, composed by a human and several different mobile robots, whose differences are in the mobility aspects (wheeled, legged, flying), sensors equipment and autonomy of decision and motion, for field analysis and monitoring is being carried on.

Within this project, the necessity of a standardization of the common parts of the robots has become evident in order to simplify both the robots design and their control.

One of the main common part is represented by the motor control, even if there are some differences between robot and robot. For example, some of them are provided by DC motors while some others works with servos, some of them use encoders for the wheels positions while others use potentiometers.

This necessity together with these small differences produced the idea of designing a multipurpose control board (or, to use an upto date terminology, an embedded control unit) to be used for all the wheeled robots in the squad.

With this in mind, the present work presents the results of the design and realization of such a device, able to communicate whit remote PC and to control mobile robots, for example using PID control laws. Such a device holds on all the components required for the sensors data acquisitions, the control (both logic and power sections) and the communications, with the possibility of using several types of sensors and motors without changing the hardware part but just acting on some switches and/or software sections, providing, at the same time, a standard for the communications.

The solution adopted makes use of a PIC microcontroller, used to generate a PM (Pulse Width Modulation) signal, used to control position and speed of DC motors or servos, to acquire sensors measurements and to communicate with other similar devices and with a central PC.

The design of the electronic board has been conducted in two different phases: during the first one the study of system requirements and the choice of the components have been performed; the second one addressed the development of the electric scheme of the circuit and the final realization of a prototypal board.

The modular solution together with the small dimensions requirements have produced a solution based on the design of two closely related boards divided into logical unit and power unit.

The whole design, in addition to the hardware development, has addressed also the software definition, both for the on board PIC and for the standard remote PC.

The prototype has been used on a mobile robot to test its functionalities and all its capabilities, giving very satisfactory results.

The present work is then organized as follows: in first section the hardware design and the prototype are presented; in second section the software is shortly illustrated, expecially for the PC section; some final considerations end the paper.

2 The hardware design

The design of the architecture for the electronic board requires, in general, a preliminary identification of the functional blocks needed starting from the analysis of the functionality desired for the board depending on the applications to whom it is devoted ([5] [1]).

In this case different contexts and different functions for mobile robots have been considered. In general, one or more boards can be used to move and control robots for environment exploration, for a safe trajectory definition and motion control, for the acquisition of measurements, through a set of on board sensors, and for receiving and exchanging data or commands from other robots or main central units.

For the applications we are interested to, the main requirements chosen to be implemented in the electronic system under development can be summarized as follow:

- move robot, implementing both a position control and a speed control;
- control DC motors;
- control servos;
- be able to talk whit a central PC by serial port;
- communicate with more boards on the same robot;
- convert analogic signals, obtained by sensors, into digital ones.

Additional requirements, always useful for any electronic board design, are the reduced board dimensions, in order to simplify its allocation on the robot, and a low cost of the components used.

The satisfaction of all the above specifications is described hereafter.

In order to exchange data with the external world the choices are a synchronous serial interface, based on a I^2C bus, and an asynchronous one, USART, to talk with a central PC, based on a RS232 standard. The communication with the central PC is allowed both through a wired connection and by a wireless one.

As far as the DC motor control is concerned, the choice of using a PWM technique has been adopted ([3], [4]).

With this system the speed of the motor is not regulated by a continuous voltage variation but changing the time during which the voltage is applied to the motor in the sense that a non symmetric square wave is generated, with the high level corresponding to the maximum of the input voltage and the low level equal to zero, such that the time, within each period, during which the signal is "high" can be changed. The low pass characteristic of the electric motor makes this solution very efficient. In fact, PWM technique allows to increase the efficiency at low speed, because the motor receives always all the voltage (even if for a short time).

Since it is wanted to be able to carry out a control in speed and in position, the measurements usually are acquired by a potentiometer or an encoder; then, the board is designed for reading both continuous and digital signals. Moreover, the board must have input and output ports usually used to acquire data or to drive components, including at least an ADC.

The full devices coordination and control together with the motor control law are chosen to be performed by a microcontroller, the PIC18F452, a 40 pin microcontroller produced by Microchip, because it seems to be particularly adapted to the requirements of the board, in terms of dimensions of ROM and RAM and in term of calculation power, and it has all the necessary resources, it's available at a low cost, and have a package of small dimensions. This device does not incorporate an internal oscillator and needs therefore of an external system of oscillation to be connected to generate the clock. The device implements nearly the totality of the I/O peripheral offered from microcontrollers. The PIC18F452 integrates also a 10 bits AD converter. The conversion module makes use of one converter for 8 multiplexed analogic inputs. The USART peripheral (Universal Synchronous Asynchronous Receiver Transmitter) is used for serial interfaces. The PIC18F452 has five I/O ports and two CCP modules (Capture/Compare/PWM), each of them using a 16 bit register. The PWM modality permits to generate a square wave with fixed amplitude and different duty-cycle.

For the serial communication between PIC and PC, implemented according to a RS232 protocol, two components have been chosen; the first, to be used for the wired communications, is a MAX232N produced by Maxim, and the second, for the wireless communications, is a radio modem ER400TRS. The MAX232 has two channels for the bidirectional RS232 communication; it requires only +5V for RS232 transmission standard. The ER400TRS is a digital transmitter-receiver device, working by frequency modulation, able to transmit using RS232 standard; it needs 5V as input voltage, it is simple to be programmed, it's

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possible define the communication speed and, without obstacles, it has an operational range up to 250 m.

The functional blocks are depicted in the following logical scheme 1.

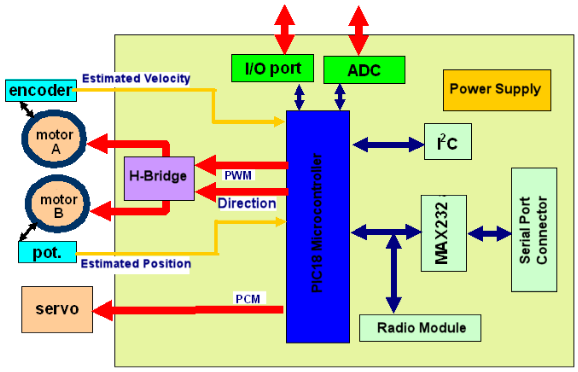

Figure 1: Functional blocks of the board

The final full electric scheme has been divided in two schemes: the logic one, with the microcontroller and all the directly required components, and the power one, with the power circuits for driving the motors.

The choice is due to the necessity of making the elaboration board independent from the power one, since it can be possible to immagine that, if the characteristics of the motors change so much to be needed a power circuit replacement, the modularity of the full realization produces a simple substitution of the power board with the same standard without any other change.

Moreover, this division helps to reduce the dimensions.

In the first board all the components for the corrected feed of the two DC motors have been installed; the most important among them is the IC L298N, by ST, together with all the required components as in its datasheet.

The input signals for the L298N comes from the logic board, i.e. the one with the microcontroller, which generates the reference signals to drive the motors; the output signals from L298N are directly connected to the two 6 pin motors connectors.

Since the measures, as previously discussed, can be acquired from an (incremental or absolute) encoder or from a potentiometer, a switch has been added in order to choose the type of device. A 14 pins connector allows all the input-output communications with the logic board, with the motors and with the sensors.

The second board is the logic one, whose core is the microcontroller PIC18F452. The power section is constituted by two voltage regulators, the IC L7805 and the IC L7806; the clock section is based on a 20 MHz quartz oscillator, connected to ports OSC1 and OSC2 of the PIC (pin 9 and 10). The PIC MCLR port is connected to the reset button, mainly used to restart the PIC in order to load new programs on the PIC through the PC serial port. In fact the PIC software is provided by a sort of bootstrap routine that allows to load new programs at the startup.

The IC used for the interface is the MAX232, that converts TTL/CMOS signal to RS232 standard. MAX232 is interposed between connector DB9 and lines RC6/RC7 of the PIC, in order to adapt the levels of serial line (0-12 V) to the ones of the PIC (0-5 V).

In the same mode, also the IC ER400TRS is connect to RC6 and RC7 PIC lines to carry out the wireless serial connection with the PC.

The PIC18F452 generates on ports RC1 and RC2 (pins 16 and 17) the signals required to generate the PWM, while control signal are generated on ports RB1-RB5 (pins 35-38). The RB6 and RB7 ports are used to drive the servo motors. Each of them, together with the two power lines (6V and ground) are linked to the two 3-pins connectors for each of the servos.

Lines RC3 and RC4 (pins 18 and 23) are present on the connector devoted to the I^2C communication. The eight RD0-RD7 lines can be used in order to connect additional sensors. For example, it is under development a new version of such control boards with three accelerometers and three gyro mounted on board to provide absolute localization of the device.

Finally, the board contains also two 20-pin connectors that reply PIC signals. They can be used in the test phase or to send all signals generates by the microcontroller to other boards.

The following figures 2 and 3 depict the prototypal realizations of the power board and the logic one respectively.

The figure 4 depicts a small robot, equipped by the present control boards, used for experimental navigation tests in our Laboratory[1]

3 The software design

In the standard realization, the control law implemented on the board is a classical PID control. The PID parameters, i.e. the three gains K_P, K_D (or τ_D) and K_I (or tau_I) can be changed also through the serial connections, more interesting when performed from the wireless one.

The implemented software regards the servos control, the DC motor control, and finally the neces-

[1]Systems Laboratory, directed by Prof. S. Monaco

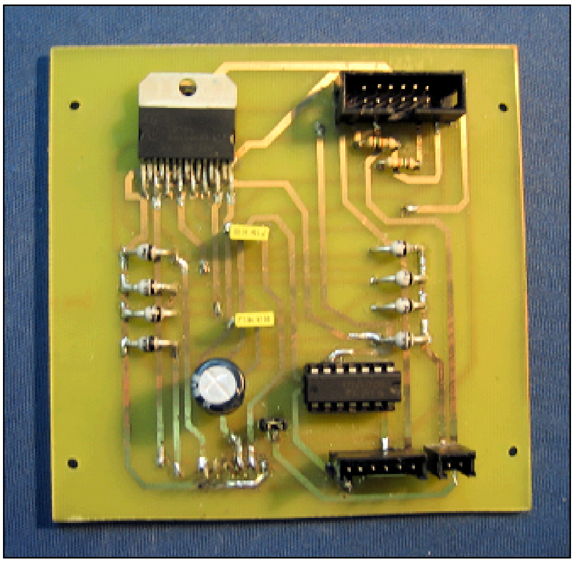

Figure 2: Power control board 10×10 cm.

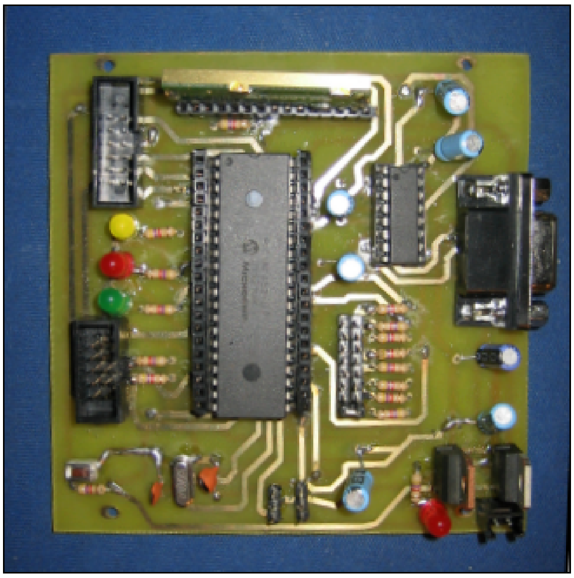

Figure 3: Control logic board.

sary software for the communication with the central PC.

A Matlab interface for the remote PC has been produced for the development phase in order to

- communicate the different commands;
- modify the parameters of the PID control;
- choose whether implement a speed control or a position control;
- plot sensors data;
- elaborate signal from the PIC.

The interface is also necessary for selecting the device to be controlled when several equivalent robots are working together.

Clearly, such operations are supposed to be performed by a supervising program or, using a suitable protocol under development, by other units.

The possibility of bidirectional data connections between control board and remote PC allow one to perform heavy computations (like path generations, minimizations, map construction and so on) on the PC and to communicate the results to the robot.

Working with the graphic interface, once that the PC serial port for communication has been chosen, one can select speed or position control and the PID parameters to be used. Moreover, the reference signals (desired speed or position) are sent to the control board.

The figure 5 represents the graphic interface results during a speed control test.

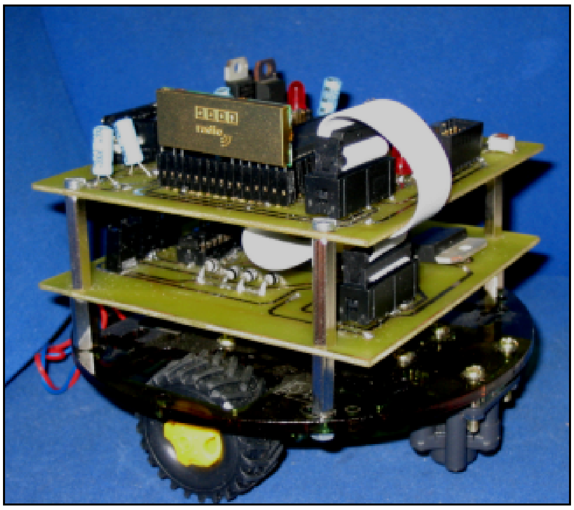

Figure 4: The control boards at work.

The following figures 6 and 7 represent the control and output signals for the case of an implemented position control and for a velocity control one, both in the case of DC motor and encoder measurement feedback.

4 Conclusion

In this paper the design of an electronic device for motors control in mobile robotics applications has been presented. This device represents a multipurpose, easily configurable, component that can be used for several different applications, also away from mobile

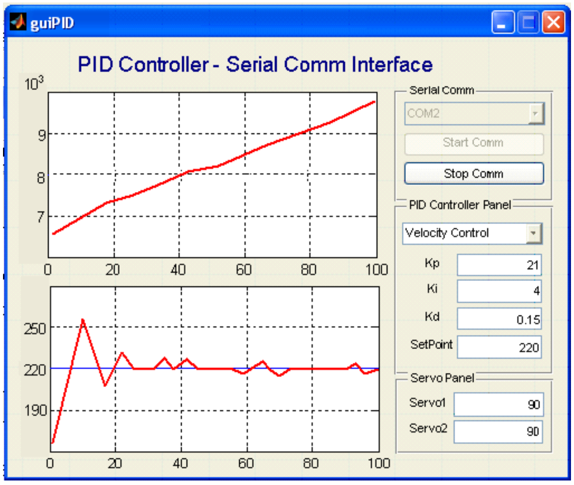

Figure 5: PC graphic interface: results of a speed control.

robotics.

The electronic components, the circuits and the physical realizations have been discussed.

A large part, larger than what seems in this short exposition, involved the software development in its two main parts: one regarding the PIC programming, with the control law implementation together with the sensors interface and the communication sections, the other regarding the communications and the interface for the PC with the main remote commands and the sensors data visualization.

The communications can be performed using different channels and standards: I^2C, wired RS232 and radio RS232.

The implemented control law is a classical PID one, whose parameters can be changed also while working.

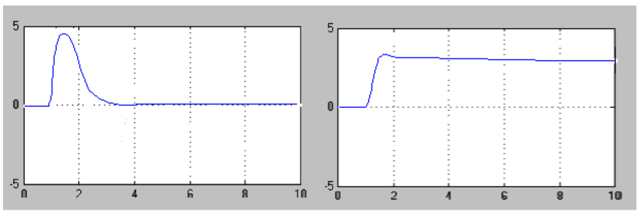

Figure 6: Control and output signals: position control with optimized parameters K_P=0.9, K_I=0.85, K_D=0.02.

The prototypal realization is based on two electronic boards, one for the logic and control section, the other for the connection with motors (including the power section) and sensors.

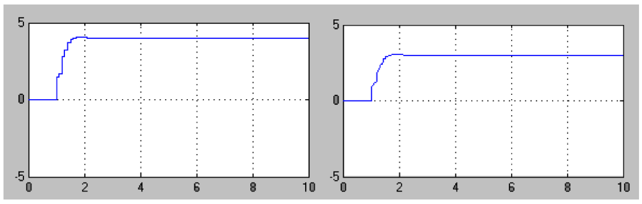

Figure 7: Control and output signals: velocity control with optimized parameters K_P=1.2, K_I=0.56, K_D=0.01.

This device is being used to standardize the motion control and the communications in an application, under study in the Systems Laboratory of our Department, of a network of mobile robots.

In this context, it is under study a development of such a device which includes also some additional sensors built on (as accelerometers and gyros) to provide absolute localization.

The configuration adopted makes the definition of the control and the measurements independent from the actual motor or sensor used.

Moreover, the modularity and the expansibility of such a device (some ports present in the controller have been left unused for further expansions) makes it interesting for several different applications.

Clearly, several different improvements can be performed, expecially in the software part, affecting the performances of the device. However, the importance and the interest of the present work is in the power of the idea and the feasibility of such an embedding device, proved also by some tests performed, whose results have been shortly reported.

5 ACKNOWLEDGMENTS

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