PWM MOTOR DRIVE CIRCUIT WITH WIRELESS COMMUNICATION TO A MICROCOMPUTER FOR SMALL PLAYING SOCCER ROBOTS

EWALDO L. M. MEHL, ANDERSON C. ZANI, JACKSON KÜNTZE, VILSON R. MOGNON

Departamento de Engenharia Elétrica, Universidade Federal do Paraná.
Centro Politécnico, Caixa Postal 19011, CEP 81531-990, Curitiba - PR
E-mails:
mehl@eletrica.ufpr.br
zani@eng.eletrica.ufpr.br
jackson@eng.eletrica.ufpr.br
vilson@eng.eletrica.ufpr.br

Abstract— Experimental research in robotics and artificial intelligence (AI) can be achieved at low cost with small robots designed to play soccer games without human intervention. This article describes the motor drive circuitry of micro-robots to robot-soccer tournaments, using pulse-width modulation and a wireless UHF communication system. Although the circuits use conventional topologies, it is shown that a complex robotic drive system can be easily build using off-the-shelf electronic components and achieves high performance. The system is intended to be used as an educational project, gathering undergraduate students to a challenging task. The aim of the article is also to propose that other engineering institution can design their own micro-robot teams, with a multiplicative effect in electronics education

Keywords— Drivers; Robots; Robotics; Educational Aids

1 Introduction

Micro-Robot soccer tournaments are becoming a very common activity in university engineering programs worldwide. The original ideal of setting-up small robots to play soccer was from Prof. Jong-Kwan Kin, at the Korean Advanced Institute of Science and Technology (KAIST) in 1996. The purpose of those tournaments is to encourage research in multi-agent robotic systems and achieve practical implementations of robotic systems, and several competitions continues to merit serious attention. International tournaments are being organized by the Federation of International Robot-soccer Association (FIRA) [1] and the Robot World Cup Initiative (RoboCup) [2]. While soccer game is used as a standard problem where a broad-range of efforts will be concentrated and integrated, competition is only a part of FIRA and RoboCup activities. The main challenge is to foster AI and robotics research by providing a standard problem where a wide range of technologies can be integrated and examined, as well as being used for integrated project-oriented education. In fact, in addition to encouraging research activities, robot soccer has a significant educational outreach component. One exciting by-product of the robot soccer initiatives is the quality of undergraduate participation. Several teams are being set up by undergraduate students; this suggests that the principles of robotics electronics and AI are now sufficiently understood such that talented undergraduates can comprehend and apply them to a challenging task.

Figure 1 shows the basic set-up for micro-robot soccer tournaments. In FIRA's rules each team has three self contained robots (7.5 cm x 7.5 cm x 7.5 cm) in a 130 cm x 150 cm arena, with an orange golf ball serving as the miniature soccer ball. There is also with FIRA an 220 cm x 180 cm arena, with five players in each team. In RoboCup's rules, each team has five robots and the field is 152.5 cm x 274 cm; the robots can have any shape, but each robot must fit inside an 18 cm diameter cylinder. Teams can place one or more cameras above the playing field and the robots must have wireless communication to the controlling computers. The system must be completely autonomous, that is, human operators are allowed only to press a key upon the referee command, to start and stop the "match". The robots have color-coded marks on the upper surface, so the vision system can identify each robot individually.

2 Building Micro-Robots

Building the small robots to the soccer tournaments demands work in multiple areas of electronics. Besides the dimensions of the robots must fit in the rules, the robots must be self-powered and should make complex movements controlled by a remote computer. Although both FIRA and RoboCup rules allow the installation of cameras inside each robot, most teams prefer to have a centralized approach, using only one camera with global vision of the field [3]. This article describes the circuit of a PWM controlled dual motor drive system, that communicates to a microcomputer via a UHF transceiver, used in a micro-robot soccer team with centralized vision system. Each micro-robot uses two small DC motors, with reduction gears, that achieves high velocity and mobility.

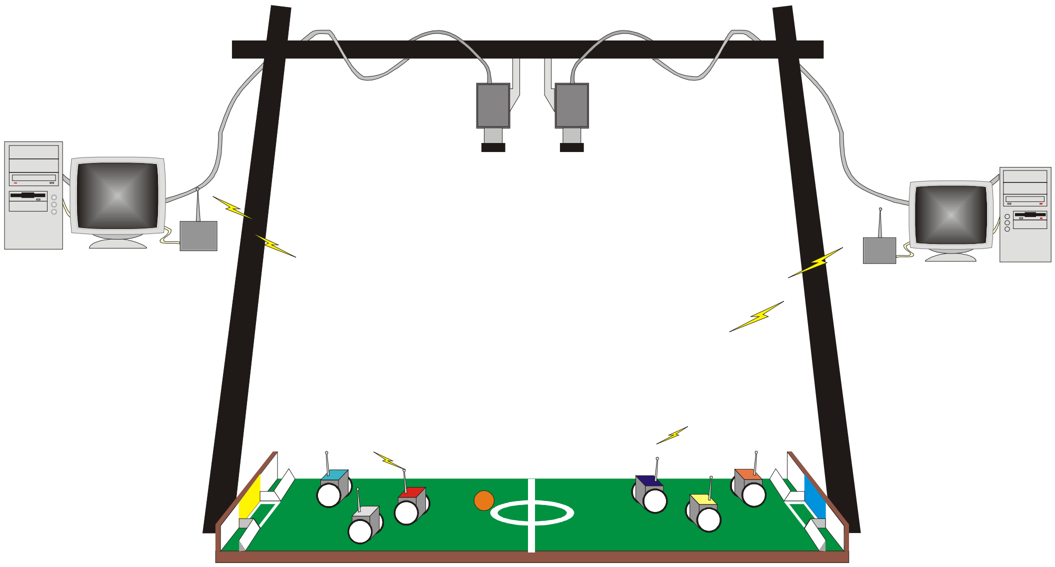

Figure 1: Set-up for the micro-robot soccer games.

Figure 2 shows the overall block diagram of the system. Communication from the computer is carried out by a digital UHF radio transmission module, operating at 433.92 MHz. At each robot there is a radio receiver module, and digital data is handled by a microcontroller that generates width-modulated pulses (PWM) to a pair of DC micro-motors. The motors are mounted in an opposed position, in a wheel-chair arrangement, that allows the robot to have high mobility. Each robot has it's individual digital address, so the software running in the microcomputer can control several robots with only one UHF transmission

3 Communication Protocol and Transmission Module

The transmission system requires that each robot can be individually commanded to stop or run forward or backward at different speeds. The robot must be also able to spin around it's own axis, setting the motors to turn the wheels in opposite directions. As a result, a serial communication protocol was established, using two sets of 8-bits words, capable of individual addressing to each robot's wheel. The first word sets up the robot individual identification; the second word addresses the speed and direction of each motor. Table I shows the communication protocol: each motor uses 4 bits of the second octet, one bit for the motor's direction and three bits used for the motor's speed.

Table 1: Communication Protocol

First Word							
b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Robot Identification							

Second Word							
b_1	b_2	b_3	b_4	b_5	b_6	b_7	b_8
Direction	Speed			Direction	Speed		
Motor 1				Motor 2			

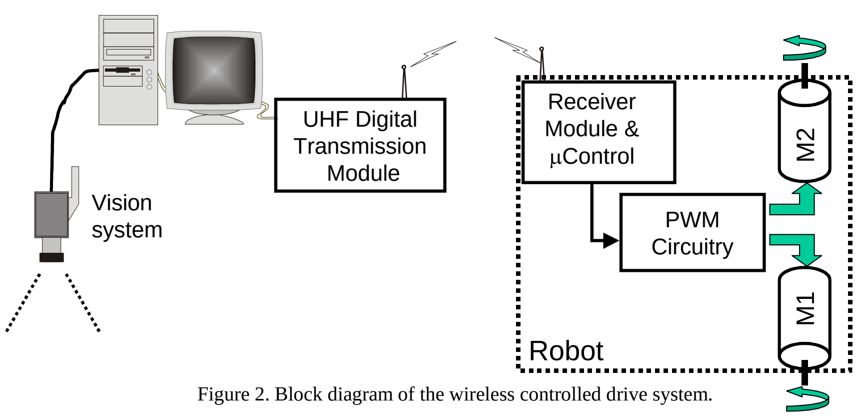

Figure 2. Block diagram of the wireless controlled drive system.

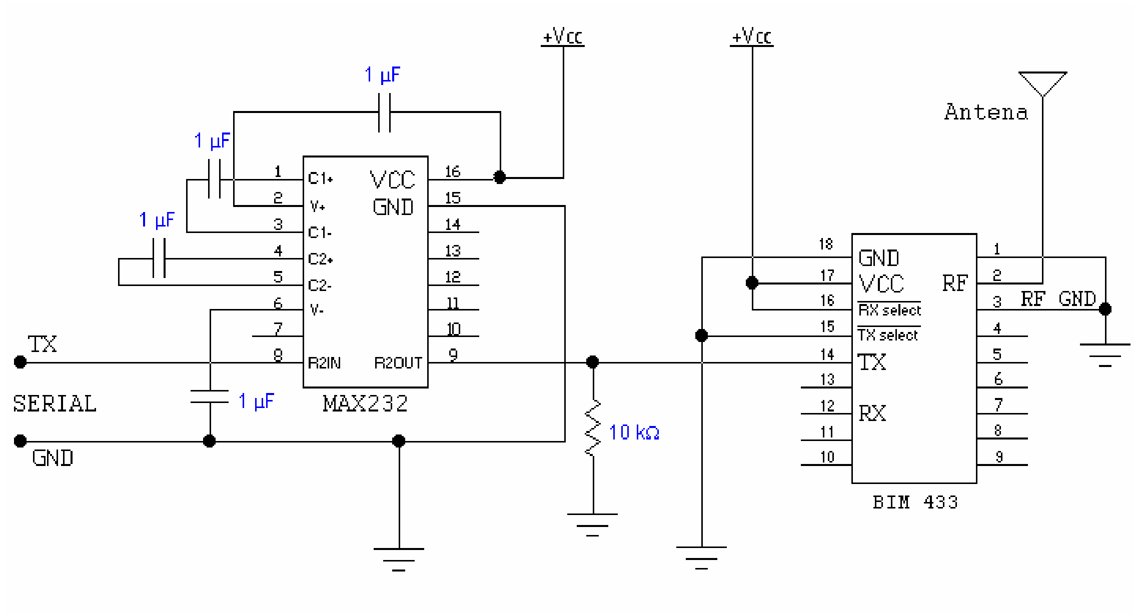

Figure 3: Circuit diagram of the transmission module, connect to the serial port of the controlling computer.

The circuitry of the transmission module is shown in Figure 3. The main component is a miniature radio module model BiM-433 (Radiometrix, UK), capable of half duplex data transmission at speeds up to 40 kbit/s over distances of 30 meters "inbuilding" and 120 meters open ground and operating at 433.92 MHz [4]. The BiM-433 module has a TTL input, so a MAX232 serial-to-TTL converter was used as interface to the microcomputer serial port. At the present state of the project, there is no need for feedback communication from the robots to the computer; as a result the BiM-433 module connected to the computer serial port is wired up as a transmitter, and the module in each robot is set up as a receiver. In the future the same radio module can be set to operate at half-duplex mode, achieving two-way communication between each robot and the computer. The UHF signal of the transmission module is broadcasted to all robots through a small helical antenna, because the distance between the transmitter and each robot is only a few meters.

4 Robot's Module and PWM Drive Circuit

Each robot has a circuitry according to Figure 4. Data is received by a BiM-433 UHF module wired as a receiver, with a small helical antenna inside the robot's plastic frame. The BiM-433 module outputs TTL pulses, that are then processed by a PIC16F84 8-Bit microcontroller and generates width-modulated pulses (PWM) to a pair of DC micro motors. The PIC microcontroller has a set of switches that is configured to the robot's individual identification. As a result, one can have a "spare robot" that can be easily programmed to substitute a defective player during the game (rules specifies that a damaged robot can be substituted during a stoppage in play). The program in the PIC internal Frash/EEPROM memory first verifies if the received address is the same of the robot and, if true, decodes the data in width-modulated pulses according to the desired speed to drive the desired motor. Motor interface is achieved through a double-H-bridge-IC, model L293D, that drives the two DC motors. This arrangement is also used by other teams [7] [8], but using different brands of microcontrollers; in this aspect, the using of a PIC microcontroller showed remarkable advantages in power consumption and simplicity [9].

The motors are mounted in an opposed position, that allows the robots to have high mobility. The DC motors are high-efficiency models 2230-003 from Faulhaber Minimotor (Switzerland), equipped with gearheads. The power supply of the robots requires that the players run without interruption through the length of the game. Although the rules states that the games consist of the first half, break, and the second half, each of 10 minutes, normally the total length of the game is longer because of timeouts. In addiction, the DC motors requires high currents due to inertial movement and also because it is very common that the motors are suddenly stopped in an "obstruction" by an opponent player. As a result, two separate power supplies were used: for the motors, a set of four nickel-metal-hydrate rechargeable batteries delivers approximately 4.8 V, with 1000 mA.h capacity; for the PIC microprocessor and the BiM-433 UHF module, 5 V supply is obtained from a

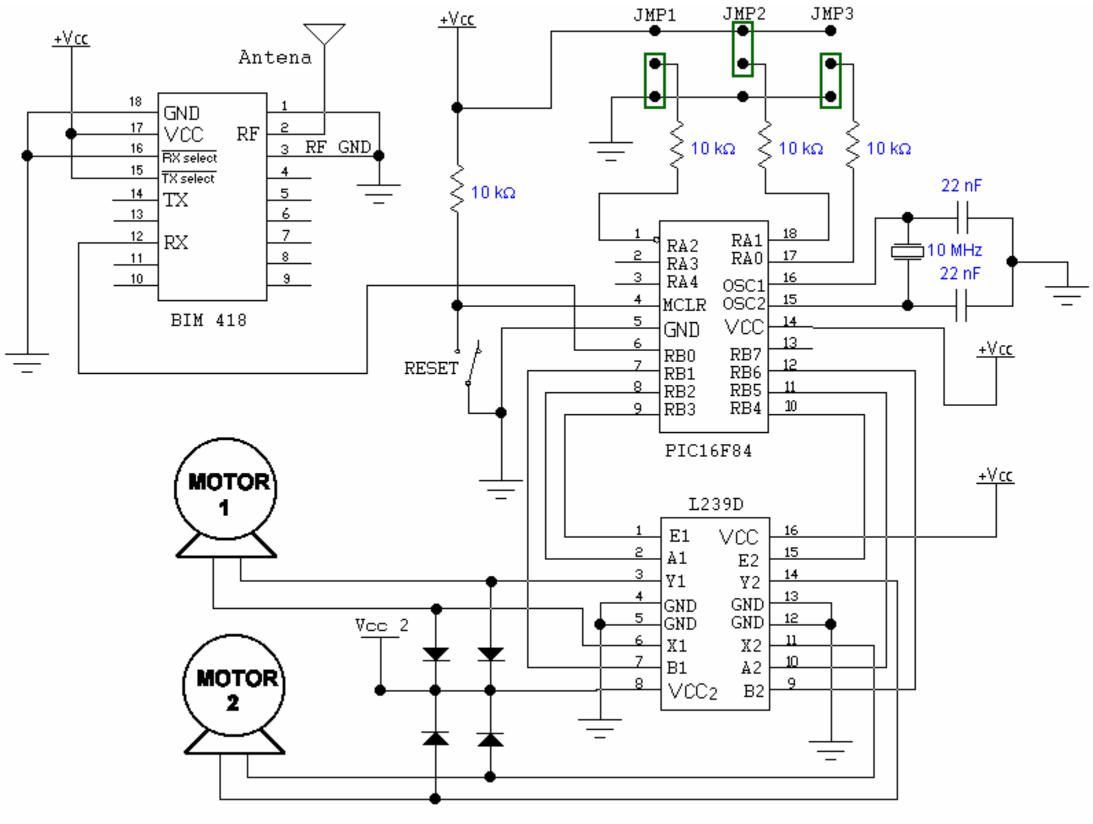

Figure 4: Circuit diagram of the robot module, showing the PWM drive system of the two DC motors.

small 9 V battery and a LM7805 regulator (not shown in Figure 3). If a single power supply was used, it was seen that the battery voltage can drops below 3 V during motor's "obstruction", and as a result the program inside the PIC microprocessor stops running.

Although more than a hundred different speeds can be programmed, limitations in the control software makes possible to use only three speed levels at the moment. The motors has no-load speed of 9600 rpm, reduced to about 500 rpm through a 18:1 spur gearhead. Tests showed a final speed of over 1 m/s, that is quite high for the vision system to handle. As a result, the speed of the robots is limited at the present stage of the project to reduced values, using pulses of low duty cycle. In the future, with improvements on the camera and vision system, higher speeds can be obtained simply by re-writing the PIC internal program.

At the moment the circuitry does not includes a feedback feature to allow the microcontroller to act in the presence of robot's obstructions. This is achieved via the camera and vision system, that can detect that a specific robot is not moving or moving not accordingly to the commands. However, in a future version of the robot's circuitry, an optical system can be assembled in each wheel of the robot, making possible to implement a local feedback control.

5 Conclusions

The circuitry of both the transmitter and the robot module are straightforward and were built using common components. The use of pre-assembled digital radio modules makes possible to overcome the problems commonly associated in designing high-frequency circuits. In addition, the use of PIC microcontrollers as data handlers both in the transmission and receiving stages established a circuit that can be easily re-programmed for other applications and can cope with future improvements in the project.

The system was designed and constructed totally by undergraduate students, under the supervision of the university staff. The project enrolls students from electrical engineering and computer engineering, because the challenge has both a hardware and a software aspect. At the first moment the idea of small robots playing soccer seems to be a merely toy for grown-ups, but in fact invites the students to put in practice several theoretical aspects of engineering. In that aspect, the PWM drive system presented in this article can be seen as an educational tool for teaching power electronics and drive control techniques.

A robot soccer game is a very interesting activity to undergraduate students, and can also lead to more sophisticated research to graduates. Applications of automatic machine vision system can be foreseen in a wide range of fields, from industrial systems for automatic inspection, to guidance systems for handicapped persons. Both FIRA and RoboCup initiatives has rules that can be changed from time to time, introducing additional difficulties and limitations to the game. As a result, each team has to keep pace with technical evolutions, and achieve constant improvement in performance

References

[1] http://www.fira.net *Online documents*.

[2] http://www.robocup.org *Online documents.*

[3] Sun-Gi Hong, Tae-Dok Eom, Choon-Young Lee, Min-Soeng Kim, M. Sugisaka, and Ju-Jang Le, "Designing a Soccer-Playing Robot Team based on the centralized approach", *Proceedings of the Micro-Robot World Cup Soccer Tournament*. Taejon, Korea, pp.119-123, June, 1997.

[4] "Low Power UHF Data Transceiver Module", Radiometrix Ltd., October 1997. *Data sheet*.

[5] "PIC 16F8X 8-Bit CMOS Flash/EEPROM Microcontrollers", Microchip Inc., 1996. *Data sheet*.

[6] "DC-Micromotors series 2230 ... S with Precious Metal Commutation", Faulhauber Minimotor SA, 1999. *Data sheet*.

[7] Wei-Min Shen, Jafar Adibi, Rogelio Adobbati, Bonghan Cho, Ali Erdem, Hadi Moradi, Behnam Salemi and Sheila Tejada. "Building Integrated Mobile Robots for Soccer Competition", *IEEE International Conference on Robotics and Automation* (ICRA '98), Leuven, Belgium, May 1998.

[8] Sukhan Lee and Javier Bautista, "Motion control for micro-robots playing soccer games", *IEEE International Conference on Robotics and Automation* (ICRA '98), Leuven, Belgium, May 1998.

[9] Anna Helena Reali Costa and Renê Pegorato, ´Construíndo robôs autônomos para partidas de futebol: o time Guaraná", *Controle e Automação* (Revista da Sociedade Brasileira de Automática), vol.11, no. 3, pp. 141-149, Sept./Dec. 2000.