Science Arena Publications
Specialty Journal of Electronic and Computer Sciences
Available online at www.sciarena.com
2017, Vol, 3 (2): 24-37

Design and Implementation of Soccer Robot Control System

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Abstract: *One of the subjects that is highly regarded in robot soccer, is the robot control to chase the ball. Various control methods have already been proposed in this context that each has some advantages and disadvantages. This paper describes a new system for controlling a robot that is designed to comply with the latest RoboCup competitions rules to compete with other robots. In this design, the robot control system, have been investigated from both term of hardware and software modules. On the hardware side, we have used the latest technologies of electronic control equipments. In the software side also tried to use the best and fastest artificial intelligence models in decision-makers of the robot.*

Keywords: *RoboCup, Microcontroller, Sensor, Intelligent Operator*

INTRODUCTION

The idea of soccer player robots at first suggested by professor A.M in a paper named as "on seeing robots" in 1992. He also published a book and several papers on this topic.
Furthermore, in 1992 a group of Japanese researchers construct an interfacial intelligence laboratory to discuss topics related to interfacial intelligence. The idea of using football to improve growth of technology got a high attention in this laboratory [1]. Also several researches to investigate both technical and financial possibility of this idea and simulation of first generation of soccer player robots was done [2]. The results showed this project is viable.
In 1993 June, a group of researchers such as M.A, Y.K and H.K decided to compete their robots in a league which at first known as robots J-league. A few months later, several researchers from outside of japan wanted this competition to be international. Therefor the name of this league changed to robots' world cup and briefly as RoboCup [3].
Building a soccer player robot don't have a significant social an economic impact by itself, but this achievement is a great success in this field. This kind of project is known as turnoff project.
Important factors that must be considered while designing a soccer player robot model [4, 5, 6]:

1. Physical structure of robot must be based on RoboCup rules (such as diameter, height and ball capture area)
2. Movement of robot must be multi-directional or 2-dimensional while speed is acceptable.
3. The position of ball is determined by infrared search system, working of this system must be with high accuracy and less sensitive to disturbances.
4. The control system of robot must be fast enough with lowest delay. Also it must be possible to modify this system in both software and hardware parts.
5. It is necessary to have an energy source for several rounds of match.

The purpose of this paper is designing an electronic control system based on RoboCup rules for a robot which is going to be qualified for RoboCup competitions. In this paper hardware and software of control system is discussed. Advanced Micro controllers and interfacial intelligence model for decision making agents are discussed as hardware and software aspects, respectively.

Hardware systems:

In intelligent cases such as soccer player robots, the existence of a process system is inevitable. The main part of a processing system is CPU.

Since in soccer player robots, robot is responsible for decision and performance, a computer system is required for processing and decision making. One of the most common process systems are micro controllers which consist of a CPU, some memories and some contactors.

In order to use these micro controllers simply in contact with other hardware systems, it's necessary to design a printed circuit board to separate ports and install hardware parts on it. The numbers and specifications of each ports are extracted from micro controller data sheet [7] and circuit schematic is designed using these data. Circuit schematic and printed circuit board are shown in figures 1 and 2, respectively.

In the robot control system schematic, the ICSP junction is connected to programmer. The power junction is connected to power supply, and the AV_POWER junction has used for voltage reference determining in the A/D module. The other connectors are related to port A, port B, …, and port J.

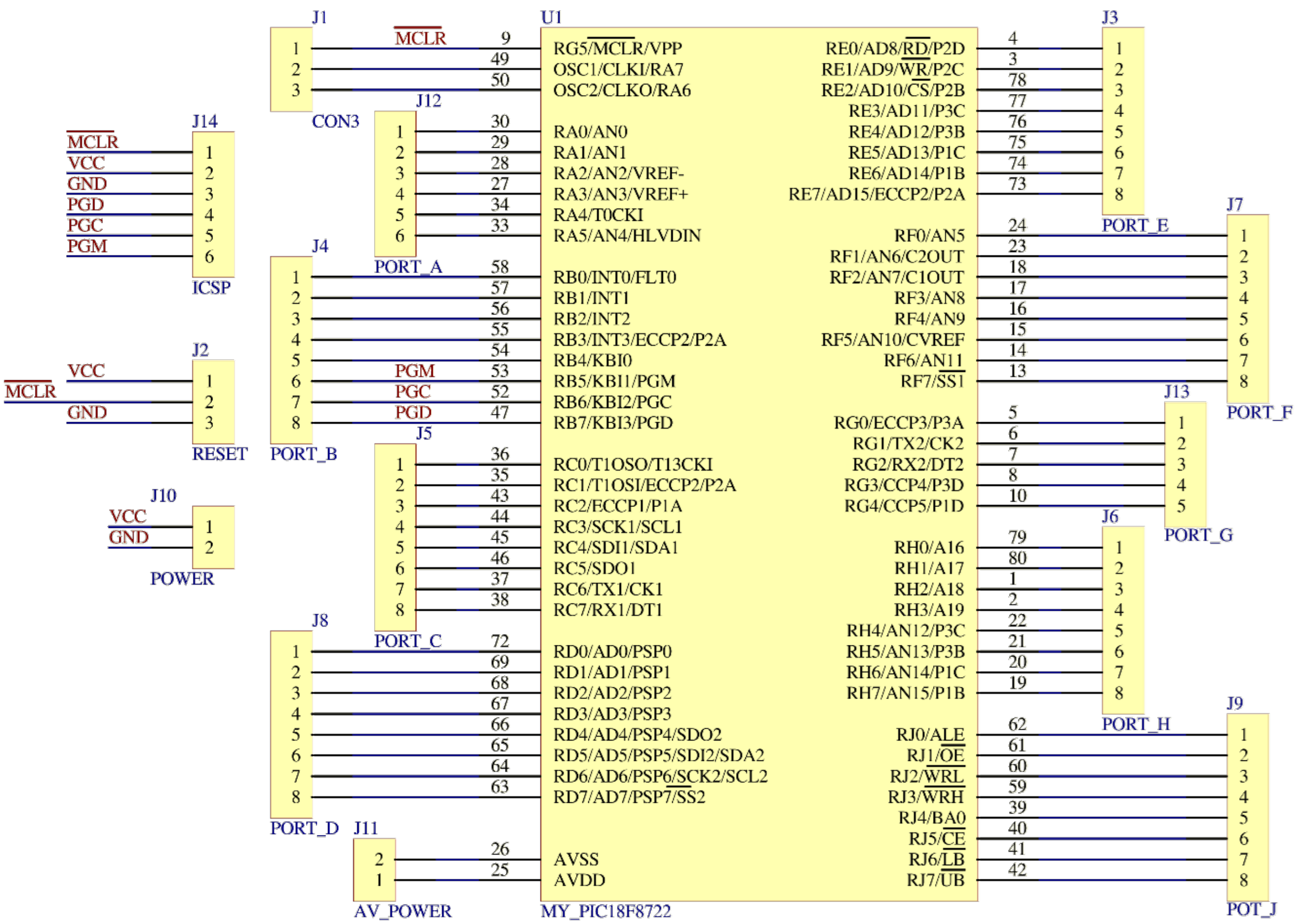

Fig 1 – The schematic of robot control system

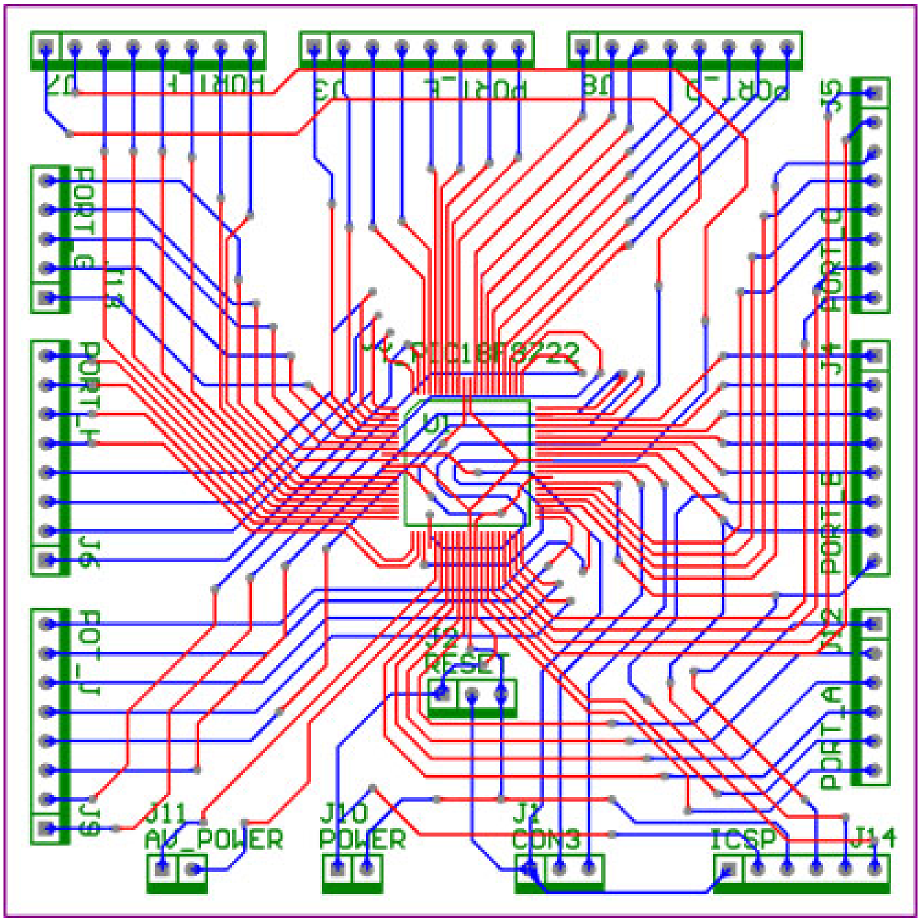

Fig 2 – The PCB of robot control system

The appropriate power supply for microcontroller, is a power supply with output voltage 5V and a stable current max to 500mA. In according to RoboCup rules [4], the Robot power supply must be in range of 12 to 15 volts, so it is necessary to design a voltage adaptor for microcontroller. For this job, a well-known voltage regulator, LM7805, has been used.

The LM7805 is shown in the figure 3 [8]. The circuit schematic for using LM7805 is shown in figure 4, So We would have a stable 5V voltage and maximum 1.5A in output.

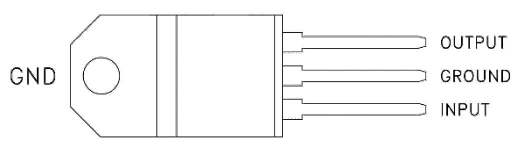

Fig 3 – The LM7805

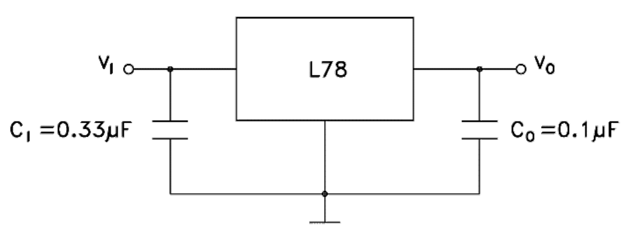

Fig 4 – The schematic circuit of The LM7805

In general, in electronic applications for creating motion and mobility, the electric DC motors are used. DC motors are divided into two main groups: traditional (with brush) motors and brushless motors.

In this robot, we used traditional DC motors, because of high power, and more flexibility in the rotor speed and direction changing. To achieve appropriate power-speed ratio, we used of a gearbox.

Important factors in the design of robot motion unit were determined as:

- Using 4 motors with the layout 45 degrees same as figure 5.
- Using traditional DC motors with gearboxes.
- Wheels diameters are 7cm.
- Each motor torque is 3 kg.cm and its speed ranges is between 450 rpm to 600 rpm.

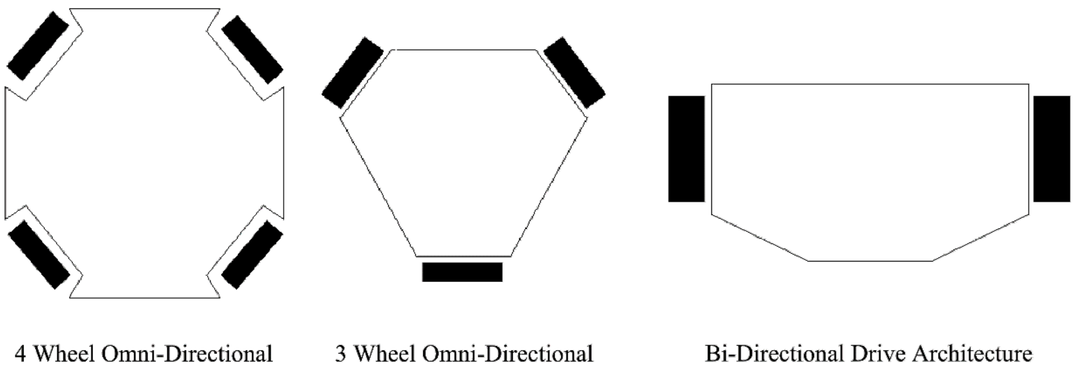

Fig 5 – The motor layout

In general, to control the current of electric motors, the H-bridge circuit is used. The H-bridge circuit composed of four transistors. To select the appropriate transistors, the motor current and voltage, and to the input signal frequency must be considered. In this job, we used L6203 to control the motors. The L6203 key features are [9]:

- High efficiency
- Internal logic supply
- Operation frequency to 100 kHz
- TTL compatible drive
- Supply voltage up to 48
- Total RMS current up to 4A
- 5A MAX current peaks
- Cross conduction protection
- Thermal shutdown
- $R_{DS(ON)}$ = 0.3 Ω (typical value at 25°C)

We can use of this device by a circuit same as figure 6. The pins 5 and 7 are inputs. The pin 11 is Enable, and the pin 10 must be connected to the ground.

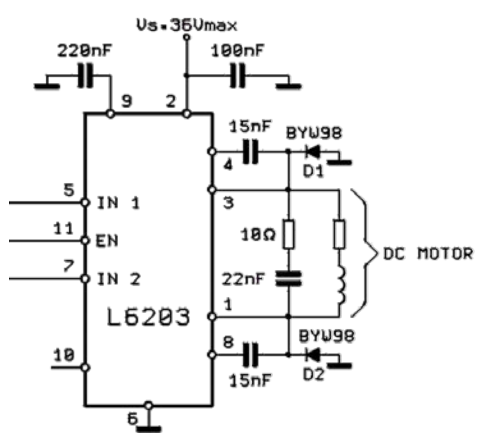

Fig 6 – The circuit schematic of L6203 implantation

For each motor, we must use an individual L6203. The supply circuit, and the robot motion unit are implemented together on a printed circuit board that shown on figure 7.

In figure 7, the pins SENSPOWER and MCUPOWER are connected to ball detection sensors and microcontroller, respectively. The pins M1, M2, M3, and M4 are connected to motors. The MCON junction pins are separated, and connected to the L6203s inputs. This junction, is the microcontroller output.

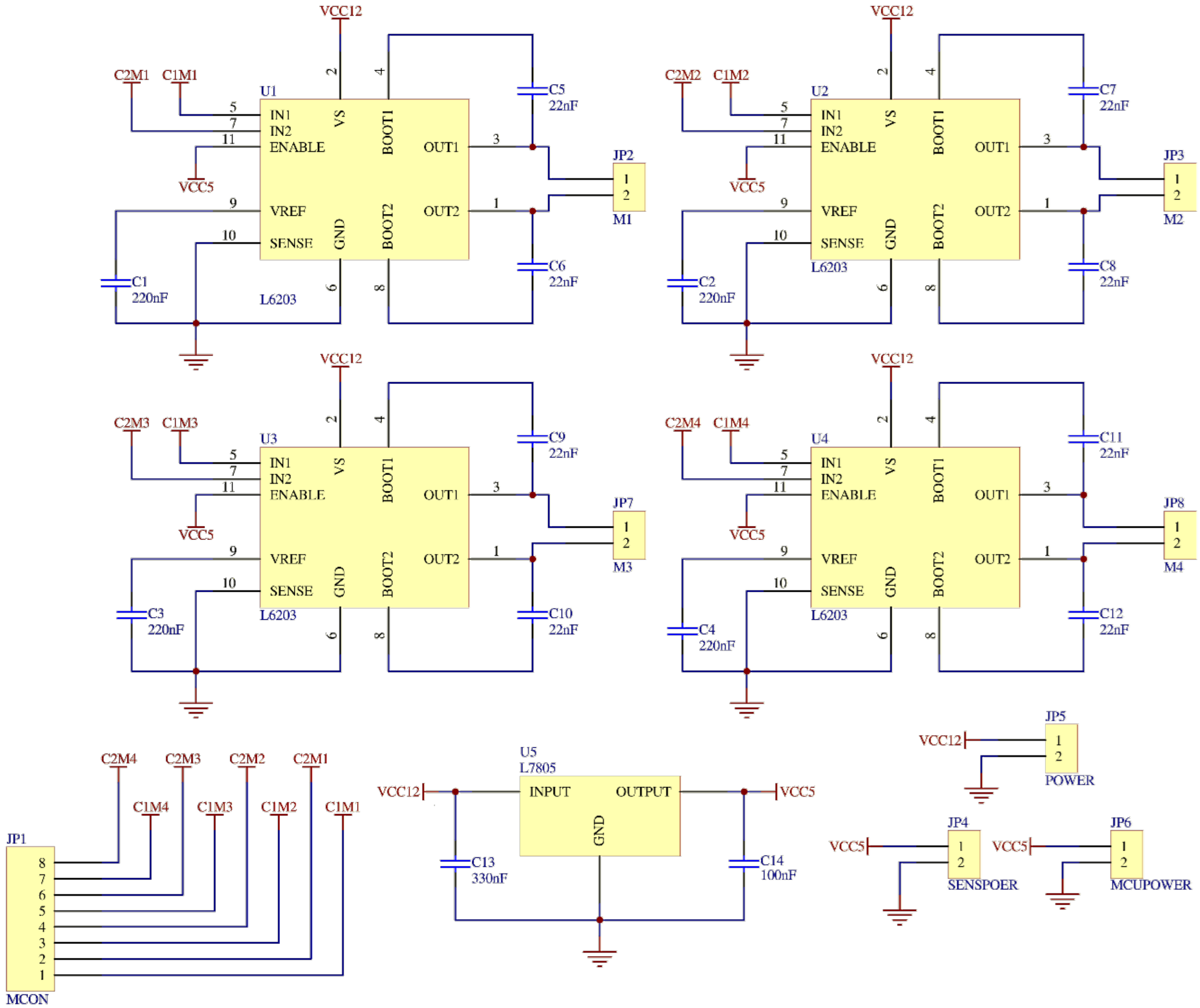

Fig 7 – The schematic of robot motion system and robot supply circuit

Since each motor consumes 0.5 Amps, so a 12V-3Ah Li-ion battery would can supply the robot more than one hours. The POWER pin would have connected to battery bank.

The PCB of this robot is shown in figure 8.

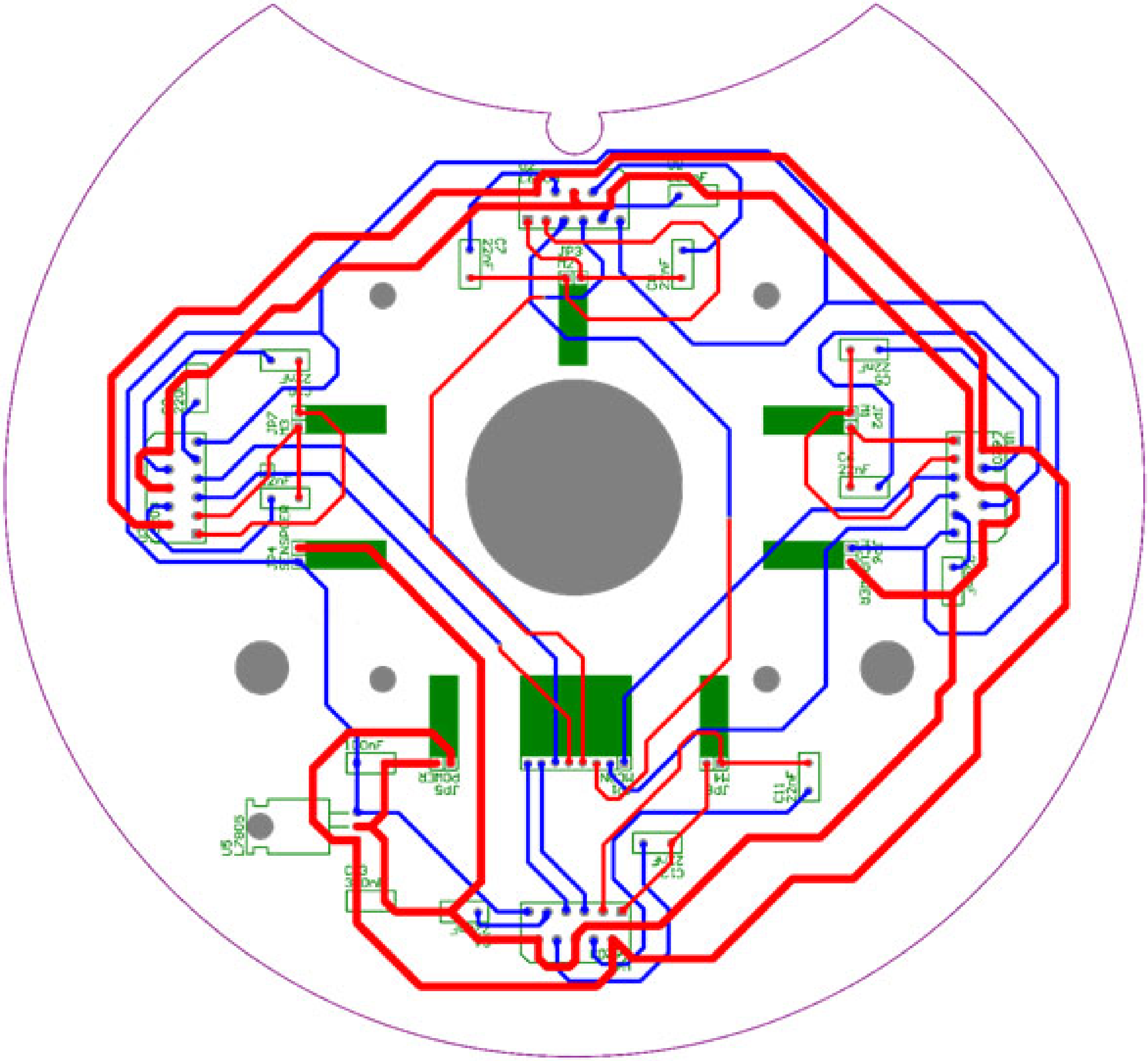

Fig 8 – The PCB of fig 7

Because of RoboCup rules [4], the ball must radiate infrared rays. So we must design a system to detect these rays and determine the ball location. To design this system, we used an infrared sensor, named GP1UX511QS [10]. By installing the 16 sensors in around of the robot, that any sensor has an angle about 22.5 degrees from its beside sensors. By using this sensors, the robot can detect the ball location.

This infrared rays have a frequency about 1.2 kHz [4], so the sensor output signals are step shaped. To resolve this problem, a low pass RC filter is connected on the output of each sensor. The cut off frequency of each filter is set to10 Hz. The infrared ray detector schematic is shown in figure 9. Its PCB schematic is shown in figure 10.

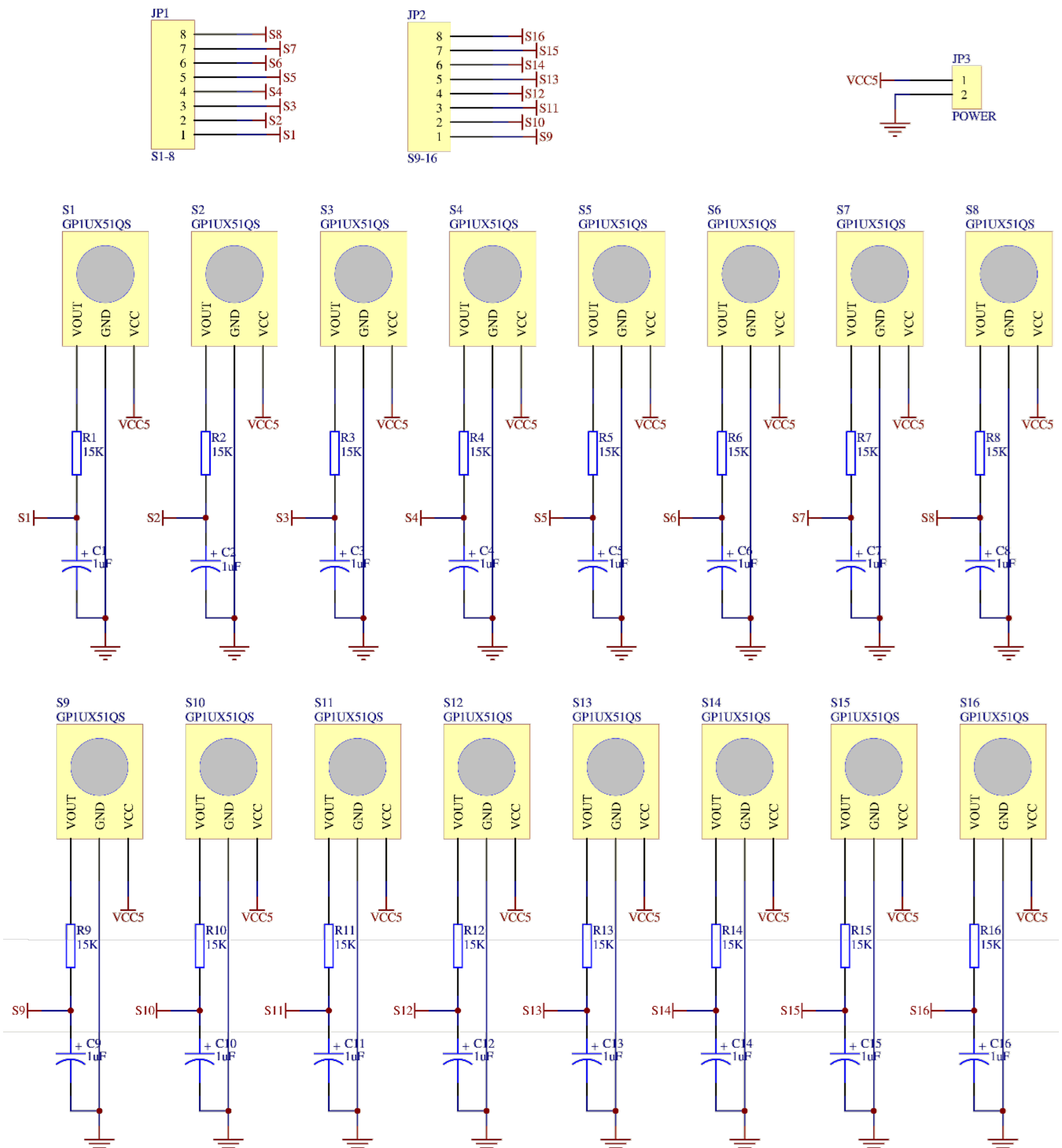

Fig 9 – The infrared ray detector schematic

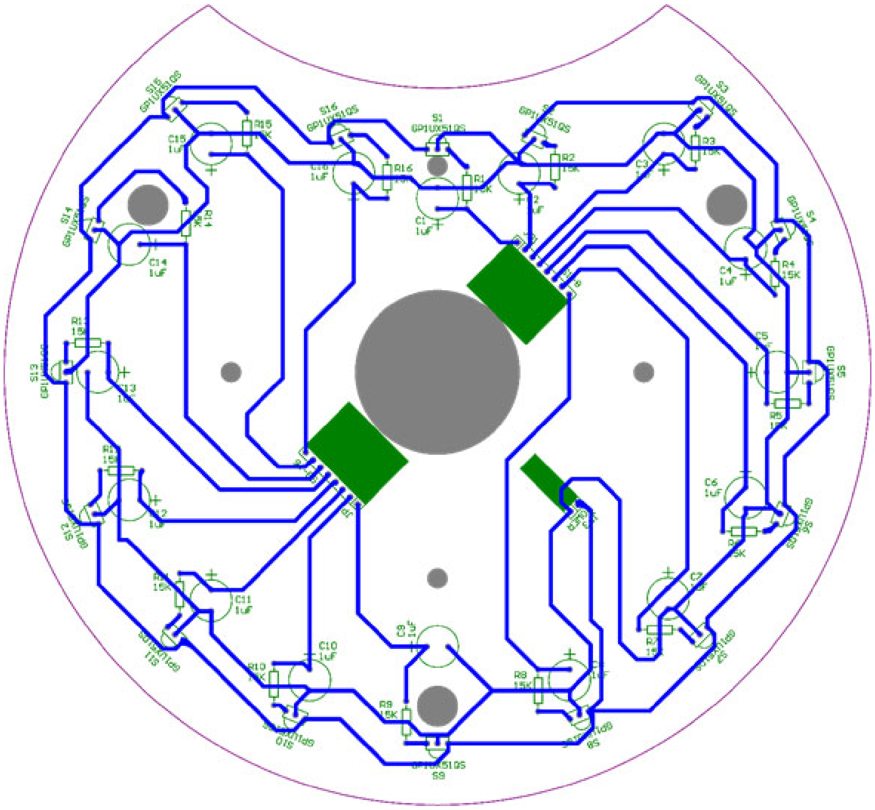

Fig 10 – The PCB of fig 9

Software processes

In order to control the speed of robots, the pulse width modulation (PWM) has been used. In this method the required mean voltage for electronic systems such as electro motors can be provided by changing the duty cycle of a square wave signal with arbitrary frequency.

The PIC18F8722 micro controller consist of 5 CCP module which can be used as PWM signal generator for robot motors. Since robot movement system consist of 4 motors, so 4 of these modules are structured as PWM performance

One of two timers (timer 2 or 4) of microcontrollers is required for each CCP module to perform in PWM case (for other cases such as abduction and evaluation one of two timers (timer 1 or 3) is required). Although it is possible to use one timer for all CCP module.

Suppose that CCP1 module structured in PWM case and timer 4 allocate to that, the output compare with stability of periodicity of PR4. When these two values become similar, the output of CCP1 module returns to first step and timer reset to zero. During this process whenever the value of timer 4 equal the stability of CCPR1L, the output of module become zero.

Based on microcontrollers datasheet, in order to allocate timer 4 to all CCP modules, 0x48 in the basis of 16 put into T3CON. Clock signals for each timer is provided from microcontroller itself, while passed through a pre-amplifier. When 0x7D put into T4CON which is related to timer 4 structure, pre-amplifier adjusted to 4 and timer start working.

The period of PWM signal can be calculated by following formula:

$$PWM\ Period = [(PR4) + 1] \times 4 \times T_{OSC} \times \text{pre amplifier}$$

Therefore, if PR4, the clock frequency of microcontroller and the value of pre-amplifier are set to 66, 32 MHz and 4 respectively, the produced PWM frequency is 33.5 µs or 30 KHz approximately.

The duty cycle of PWM signal can be calculated by following formula:

$$PWM\ Duty\ Cycle = (CCPR1L{:}\,CCP1CON < 5{:}4 >) \times T_{OSC} \times pre \text{ amplifier}$$

The register CCP1CON used in order to structure the CCP1 module. This module structured in PWM case by allocating the 0x0C to it, in the basis of 16. Besides that, 4th and 5th bits set to zero. The duty cycle of PWM signal can be tuned by allocating a value to CCPR1L register between zero and the value allocated to period PR4. For example, if register CCPR1L set to 20, the active interval of PWM signal become 10 µs or the duty cycle become 30% in another word. Since the value allocated to 4th and 5th bits is zero, therefore the value of register CCPR1L is multiplied by 4.
The configuration of other CCP modules are built as well. Each module has a register CCPxCON for configuration and a register CCPRxL for duty cycle, which letter 'x' is replaced by the number of CCP module.
The output of CCP modules has been placed in several ports of microcontroller. Based on datasheet, the output of CCP modules has been shown in table 1. This bases must be configured as output. Therefore, each port has a TRIS register which this registers for C and G ports will be TRISC and TRISG, respectively. When each TRIS register set to zero, the corresponding base arranges as output.

Table 1. output of CCP modules

Output			**module**
Pin no.	**bit**	**port**	
43	2	C	CCP1
35	1	C	CCP2
5	0	G	CCP3
8	3	G	CCP4
10	4	G	CCP5

Therefore, all bases of CCP module arrange as output if TRISC register and TRISG register set to 0xF9 and 0xE6 values, respectively.
Note that electric motors have two feed wire. One of them receive PWM signal and the other one set to 0 or 1. The rotation direction of motor adjusted by changing this constant signal. Digital ports provide this constant signal by occupying the 0 to 3 bits of E port. The duty cycle must be complement while the rotation direction of motor changes.
The connections between movement systems and central controller arrange as shown in figure 11. As told before, there is two control signal for each motor, one of them is connected to the PWM signal source and the other is connected to the constant signal. Also the movement system provides the feeds for the center controller of robots, MCUPOWER from mean board of movement control connect to the power from the microcontroller board.

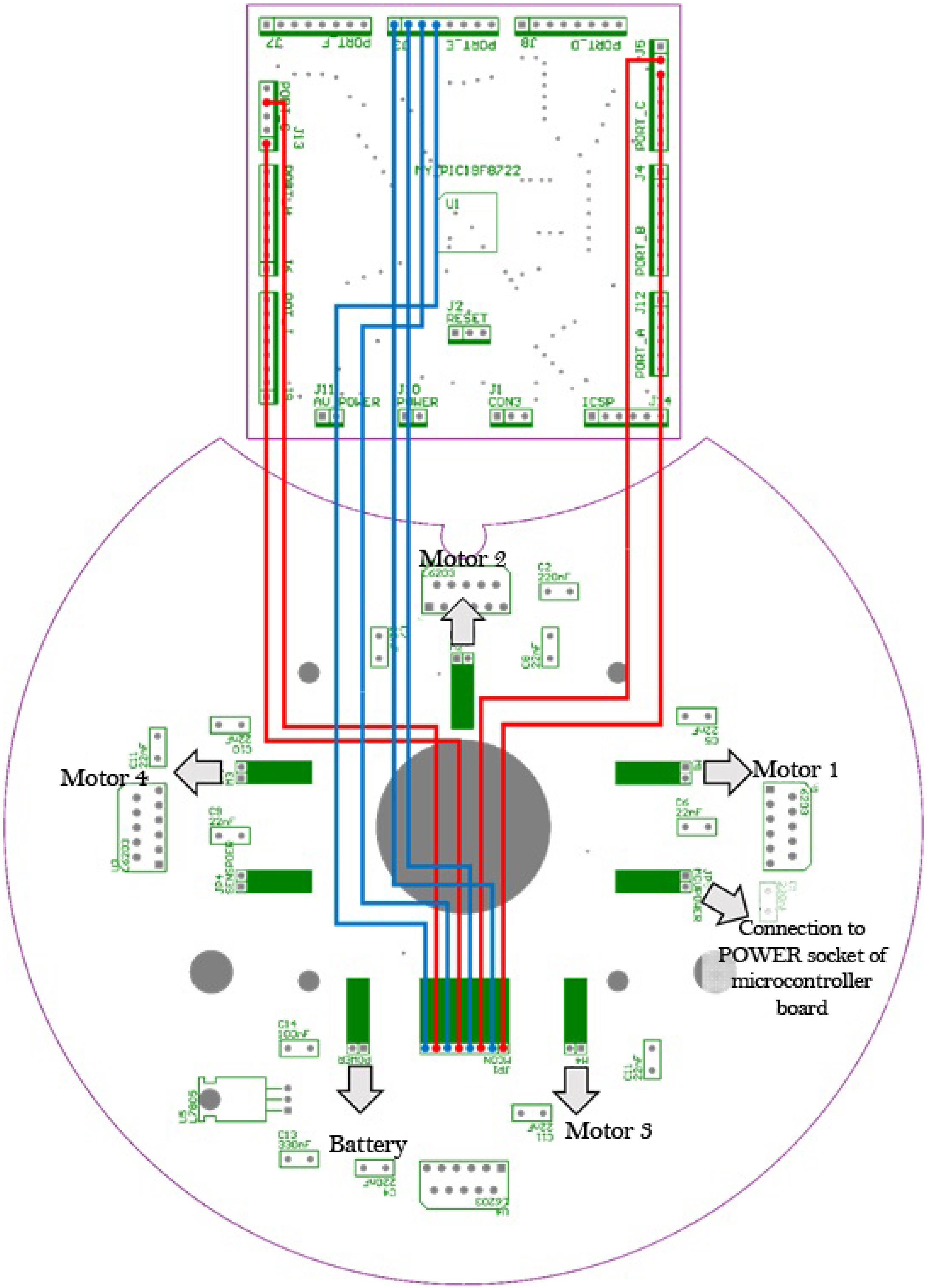

Fig 11 - The connections between movement systems and central controller

As told before, the search system for infrared waves has 16 outputs related to 16 censors. When infrared waves of ball radiate to censor, the corresponding output will be a value between 0 and 5 V. based on datasheet of GP1UX511QS receiver, the more powerful received waves have lower censor output (near 0). As shown in figure 12, the arrangement of censors shows that the angle between them is 22.5 degree. Therefore, each censor can be shown by a vector with angle of 22.5 and magnitude of received waves. The summation of these vectors for each censor will specify the position of ball.

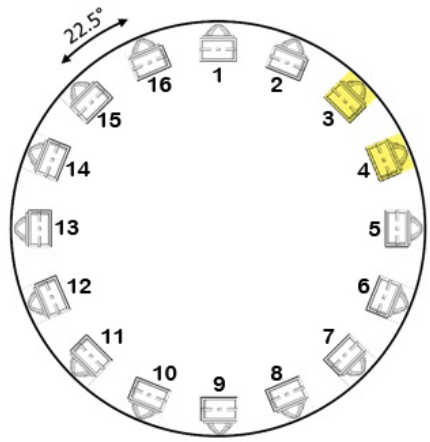

Fig 12 – The infrared sensors

Since the nature of these outputs are in analog form, an analog to digital converter is needed to convert these values to digital form and make them readable for micro controller. ADC converter in PIC18F8722 micro controller has the accuracy of 10 bits and able to read 16 input channel. The robot microcontrollers have 3 registers, ADCON0, ADCON1 and ADCON2. For ADC module 5:2 bits of ADCON0 used to select one of 16 input channel. When the zero bit of ADCON0 is set to 1 ADC module receive the voltage from selected input channel and the operation is started.

When the conversion operation is terminated, the corresponding digital value is placed in the pair of ADRESH: ADRESL registers. At the end of operation, the ADCON0<1> is erased. Other registers such as ADCON1 and ADCON2 used for adjusting reference voltage, number of input channel, signal selection and voltage attaining time. Based on datasheet the 0x00 and 0xBE in the basis of 16 are assigned to ADCON1 and ADCON2. The input channel for ADC module, such as CCP modules output, distributed among microcontroller ports. Based on micro controller datasheet, the input channels of ADC module are shown in table 2.

Table 2.

input			channel
Pin no.	bit	port	
30	0	A	AN0
29	1	A	AN1
28	2	A	AN2
27	3	A	AN3
33	5	A	AN4
24	0	F	AN5
23	1	F	AN6
18	2	F	AN7
17	3	F	AN8
16	4	F	AN9
15	5	F	AN10
14	6	F	AN11
22	4	H	AN12
21	5	H	AN13
20	6	H	AN14
19	7	H	AN15

At the end, the connection between search system and central controller will be as shown in figure 13. Also, there is a connection between POWER in PCB of censors and SENSPOWER in the PCB of movement control system in order to provide censors feed.

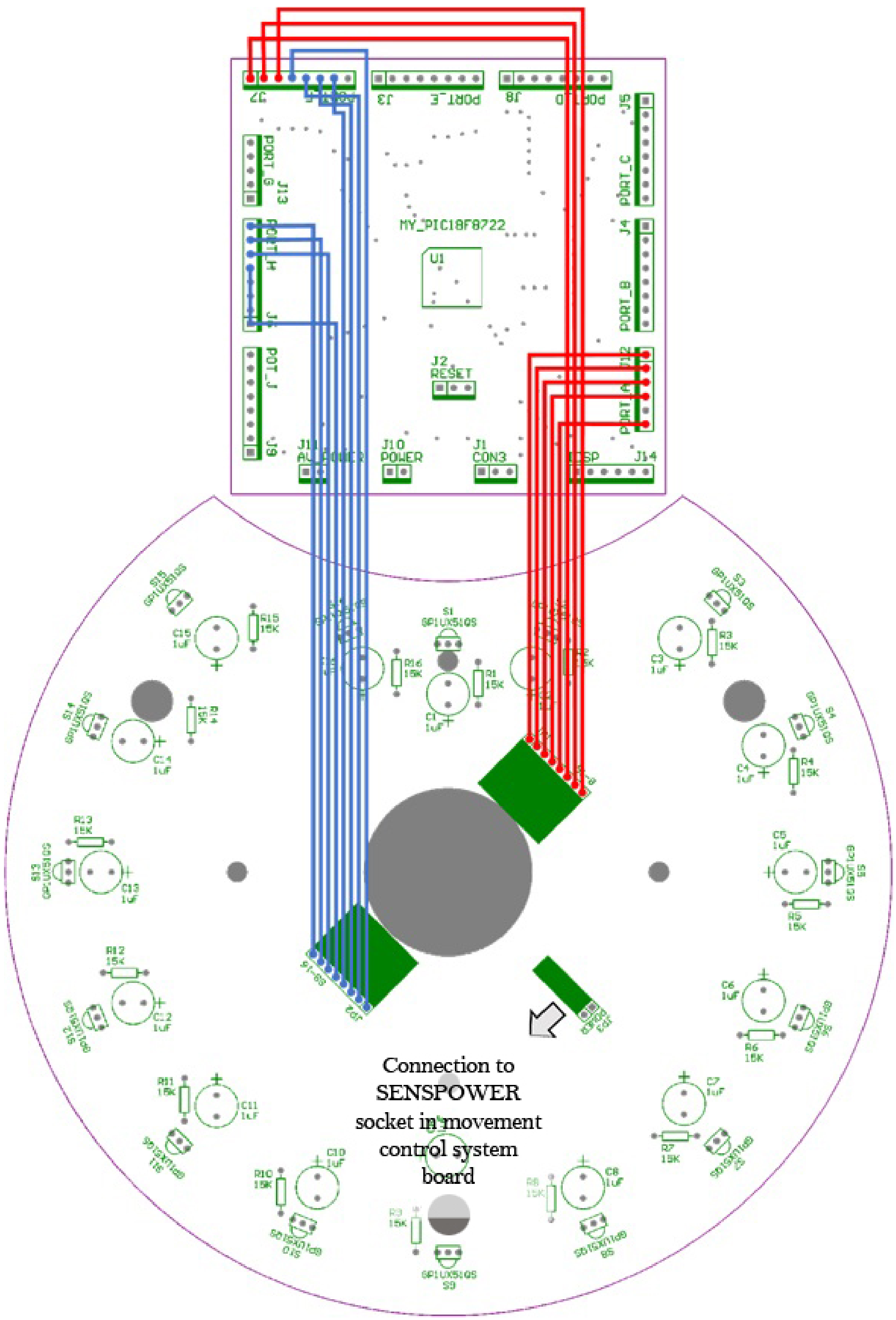

Fig 13 – The connection between search system and central controller

Several models are invented in order to configure intelligent agents. One popular model is simple action agents. The basic of these intelligent agents is responding to any environmental changes. These agents usually have a status-action table. The other popular model, shown in figure 14, is action agents by internal status. This agent behaves like simple action agent. The only difference between two agents is that the second agent change its status by predicting changes in environment as a result of its actions.

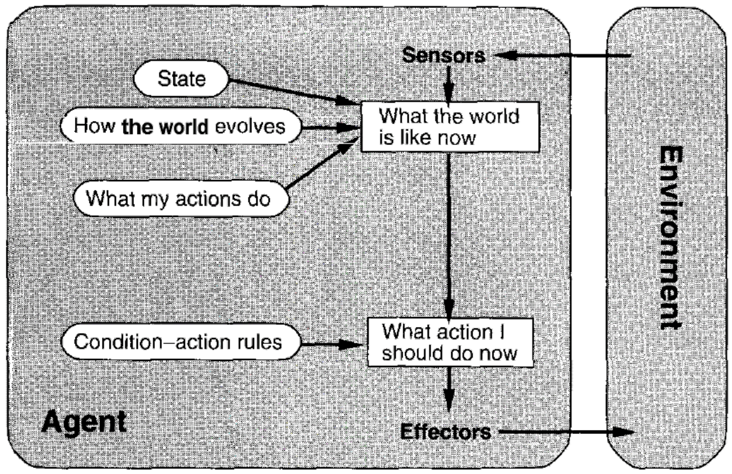

Fig 14

The action agents by internal status, choose their new status by using their previous status and environment. Then using status-action table and new status to command actuators. When the agent action is complete, it looks for a new status to match changes that previous action exerts to system.

Conclusion

Conclusion and recommendation

One of the most powerful aspects of this robot is the advanced processing core. PIC18F8722 microcontroller is one of the newest microcontroller from PIC18 group which is made by Microchip Company. PIC18 group of microcontrollers are the most advanced controllers among 8 bit micro controllers in comparison with other groups produced by Microchip Company.

Numerous input and output bases, lateral facilities and high processing speed are valuable properties of this microcontroller. These properties enabled robot to be upgradable in all aspects. The performance and reaction of robot remained fast while processor was busy (processing trigonometric calculation).

Most of robots in RoboCup competition use AVR microcontrollers with low processing speed, few lateral facilities and few input and output bases. Therefore encounter some problems such as continues breaks, low reaction speed, limitation in censors and other software installation (because of few bases).

Search system for infrared waves is another powerful aspect of this robot. This system uses GP1UX511QS receiver for infrared waves. These receivers have a high application in control systems such as television, because of their sensitivity and accuracy. Using 16 number of these censors enable robot to trace the ball accurately even in an environment exposed to high disturbances and sunlight.

The reason of this high accuracy is a modulation filter inside their structure which is able to distinguish between ball waves and disturbances

By analyzing the RoboCup competitions, it was found all robots use normal infrared sensors which have a structure like LED. Since Theses sensors act in inactive mode and their structures is simple, they affected by disturbances easily. Also, the limitation in input channel of ADC converter cause them to use just 8 sensors for the search system. These items make the opponent robot to be really slow and inaccurate.

Therefore, the search system for infrared waves is enough to solve any problem. Although the break frequency of the filters of selected sensors is 38 KHz and sensors with 40 KHz such as TSOP1140 are better. But this problem doesn't have a significant effect on accuracy.

Sometimes robots forced to rotate (such as accident with opponent robots), this issue cause the robot to refine the position of ball. It is necessary to design a navigating system to determine the angle of opponent goal, a compass sensor is required for this system. Since we have several empty port, designing of this system is possible.

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