DESIGN AND FABRICATION OF AUTONOMOUS MOBILE ROBOTS

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Abstract

In this project, some special purpose robots were built to compete in the Robocon 2008. The concept of mechanical engineering, electronic control and system thinking in the design and fabrication of automatic robots were combined and coordinated. These automated machines could pick some objects carry through a predefined path and place them at desired location. All these tasks have pragmatic applications in the industries in common repetitive works. As these robots were made for an International competition so main intention was precision and reliability rather than implementing audacious and cutting-edge ideas. The mechanical structure of all the robots was mainly made of aluminum. Steel was used in some places for structural strength and rigidity. Most of the motors were dc gear motors. The latest available advanced control mechanism incorporating microcontrollers, PWM, timers, counters, interrupts is used in this project. Apart from the robots for competition an additional experimental robot was fabricated to implement some new mechanical design concepts. The design and fabrication of these robots are good example of utilizing appropriate technology.

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Chapter 1

INTRODUCTION

As technology advances, it has been envisioned that in the very near future, robotic systems will become part and parcel of our everyday lives. Even at the current stage of development, semi-autonomous or fully automated robots are already indispensable in an incredible number of applications. To bring forth a generation of truly autonomous and intelligent robotic systems involves research and development on several levels, from robot perception, to control. And automatic control in industrial production is also increasingly becoming popular over the whole world. Autonomous and semi autonomous systems are familiar in most large scale production systems.

The increased use of intelligent robotic systems in current indoor and outdoor applications bears testimony to the efforts made by researchers on all fronts. Mobile systems have greater autonomy than before, and new applications abound — ranging from factory transport systems, airport transport systems, road or vehicular systems, to military applications, homeland security surveillance, and rescue operations. While most conventional autonomous systems are self-contained in the sense that all their sensors, actuators, and computers are on board, it is envisioned that more and more will evolve to become open networked systems with distributed processing power, sensors, and actuators. So the necessity of robot is increasing immensely in all sort of manufacturing process, from nanotechnology to larger production. At the early ages stationary robots were very popular and these were employed any particular state of production line.

A robot is a virtual or mechanical artificial agent. In practice, it is usually an electro-mechanical system which, by its appearance or movements, conveys a sense that it has intent of its own. Autonomous robots are robots which can perform desired tasks in unstructured environments without continuous human guidance. Different kinds of robots have different degrees of freedom. A high degree of freedom is particularly desirable in fields such as space exploration, where communication delays and interruptions are unavoidable.

A fully autonomous robot has the ability to

- Gain information about the environment.
- Work for an extended period without human intervention.
- Move either all or part of itself throughout its operating environment without human assistance.
- An autonomous robot may also learn or gain new capabilities like adjusting strategies for accomplishing its task(s) or adapting to changing surroundings.

To popularize robotics different competitions of mobile robots have been commenced throughout the world. ABU Robocon is one of the most prestigious contests in this arena. For this contest participants are supposed to fabricate both autonomous and manual robots. With a vision of taking part on that competition four robots were fabricated. These robots could move through a predefined path and grip and pick objects. Both design and fabrication of these robots were largely contingent on the available resources at local market and available machining facility. A severe devoid of proper motors needed for the definite jobs was faced. So, the motors were chosen at first from the second hand motor shop and then the machines were designed accordingly. The sensors were also made using own resources as they were not available. Moreover as these robots were built for a competition it had to meet so many constraints such as dimensional limitation, weight restraint, constraints on power supply etc. To meet the weight constraint light weight aluminum was used as key construction material. Other construction materials were mild steel used for strengthening; wood was used where strength was not a prime issue. As these robots were made for an international competition so precision and reliability was primarily emphasized rather than using audacious cutting-edge technology.

Autonomous robots were microcontroller controlled. Pulse Width Modulation, timers, counters, interrupts features of the microcontroller was used. PIC18F452 of Microchip technology was the brain of these robots. To compete in this contest four autonomous mobile robots were fabricated. H-bridge circuit along with electronic braking was used for motor controlling.

For ensuring the proper working of the robots and to understand their working efficiency, a game field was needed but unfortunately it was a very costly project to build such a game field. So, as the need for such a place was quite remarkable, some individual components of the game field such as the portion of the game field, some towers etc were built. The trial sessions were carried out on this mock field.

Apart from the robots for competition an additional experimental robot was fabricated to implement some new and advance mechanical design concepts. New design of slider and gripper was simulated on that robot. Name of all the four robots are SPSR (Six Point Scoring Robot), Carrier-bot, ScoutShip and X-bot.

Therefore, under such consequences, building such high-tech machines in this country to compete with the other much developed country's robots was reliant on the available appropriate technology largely. It was a tough job indeed but it helped to realize the real situation of the technology in Bangladesh which must be improved for the overall development of this country.

The objective of this report is to introduce the reader with the robotic system which comprises of both electrical and mechanical system design, be stated as establishing the foundations on which the design, control, and implementation of robotic systems are based. The second chapter of this report is intended to give the reader details overview of the mechanical systems of all the four robots. The third chapter highlights the major issues in the realm of robotic control systems. Chapter four is devoted to depict the test run results and chapter five is for conclusion and chapter six details outline of further development work is given.

Chapter 2

DESIGN AND FABRICATION

A mobile robot needs locomotion mechanisms that enable it to move unbounded throughout its environment. But there are a large variety of possible ways to move, and so the selection of a robot's approach to locomotion is an important aspect of mobile robot design. Among the several important systems that could be employed to manufacture a robot mechanical systems handles the structures, motion designing etc. Along with this it also requires some gripping actions. In the next few paragraphs involvements of mechanical engineering with the design and fabrication of robots SPSR, ScoutShip, Carrier-bot and X-bot would be described.

2.1 SPSR

The task of the SPSR (Six Point Scoring Robot) was to move a defined path and grip a polystyrene cube placed at the bowl top of the side tower and lift the block at a height above the rim of the bowl.

Figure 2.1: SPSR full view

2.1.1 Chassis Construction

The main chassis construction material was aluminum box pipe (channel stoke) taking into consideration the weight constraints. Aluminum was chosen because of its high strength to weight ratio and easily available in the local market. For the accommodation of the power supply, motors and circuit boards, some portion of the chassis was covered by thin aluminum plate.

The dimension of the base was determined by the size limitation of the machine starting zone and the position of the tower zone carefully. The base size was limited frontward because of this limitation. But this created probably the greatest

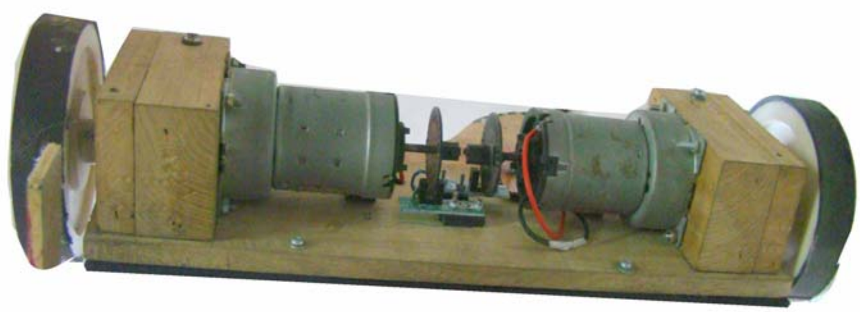


Figure 2.2 Drive motor mount

problem of severe unbalance of the machine. It was solved by compensating the overall longitudinal dimension of the machine.

Nylon was used as wheel construction material due its light weight, excellent abrasion resistance, high resilience, greater elasticity and elastic recovery, ease of machining and availability in local market. To increase the traction force rubber mat was used as tire. The dimension of the wheel was traded off between the motor torque available and stability of the structure. The bigger diameter wheels required higher torque from the motor and the stability decreased due to the raise of the center of gravity of machine. Smaller wheel diameter lingered the machine speed. If high speed motor was available wheel can be made of smaller diameter, contributing more to the stability of the machine and better control.

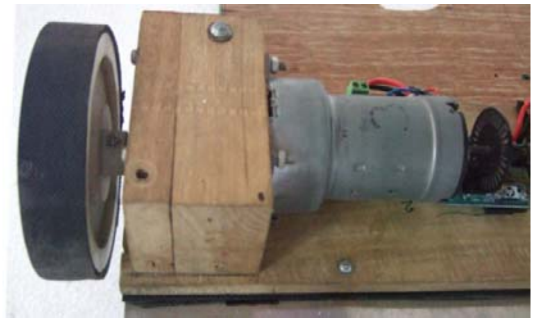


Figure 2.3 Drive motor with bearing housing

Motor mounting was a very crucial matter. A slight misalignment cause very high power loss. Two approach of motor mounting generally used, one is, placing the wheel in between two bearing and another is placing the bearing housing with the motor and letting the wheel overhanging. A comparative load distribution is shown in the figure 2.4. Placing bearing on either side of the wheel halved the radial load on each bearing but is it more prone to misalignment. Because when load applied to the structure its base tend to bend. Thus presence of a subtle amount of bending cause substantial raise of load on motor shaft. In case of overhanging wheel there is less possibility misalignment. Because bearings are enclosed in a single housing attached to the motor casing but due to single bearing whole load applied on the one set of bearing. But in contrast to that load with the load requirement due to the misalignment when bearings mounted on either side of wheel is much less. Single sided bearing mount require less space.

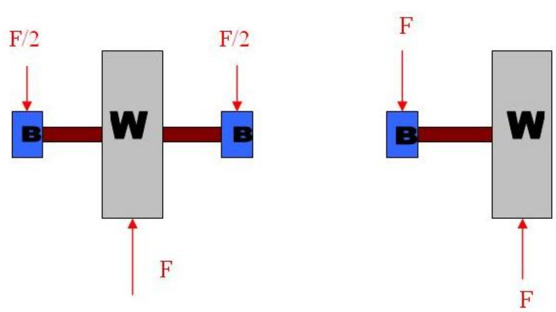


Figure 2.4 Effect of force for different bearing arrangement

In SPSR, two bearing separated by a distance enclosed in a casing was used. The housings for the bearings were made of wood which reduced the overall weight to greater extent but lead to dimensional inaccuracy. Sometimes with the change in atmospheric moisture wood tend to be swelled. But due to devoid of other light weight materials such as composites wood is the better alternative for this purpose.

Flexible coupling was used for mounting the wheel with the motor shaft. A shaft with disparate end design was used. The solid end was attached with wheel and the hollow end held the motor shaft with some room for tiny adjustment of alignment while rotating.

2.1.2 Locomotion Mechanism

Front wheel drive was used that provide easier steering and controlling. Also the differential motion of the drive was obtained by using two independent drive motors. Differential motion facilitates moving in a curved path and veering.

In this case the alignment of the two motors was vital. Slight misalignment of the two motors and the designed wheel, leads to deviation from reaching the goal and as well as programming complexity. Maximum caution was taken during the manufacturing.

Rear wheels were supplanted by a caster. Casters were placed at the most rear portion to recover some balance. The forward movement of the machine seemed to be smoother than the backward movement which indicated that it would be better to fix the casters at the rear end of the machine and wheels at the front.

The using of caster has some drawback. The accuracy of reaching the destination for a robot largely depends on the initial positions of the casters used. So every time the casters are to be positioned on their desired situation to make the robots perform efficiently

2.1.3 Sliding System

This system was provided to pick blocks from different heights and to lift them to a definite height. The SPSR’s vertical limit was to pick and hold the block from the bowl placed at top of the tower of 750 mm height.

A sandwiched structure of two rigid Aluminum bar was used as a slider and was mounted on two circular guide ways of stainless steel, provided for the movement of the slider system along the vertical axis. The diameter of the circular guide was 19 mm and a 0.5mm clearance was provided between the slider and the guide.

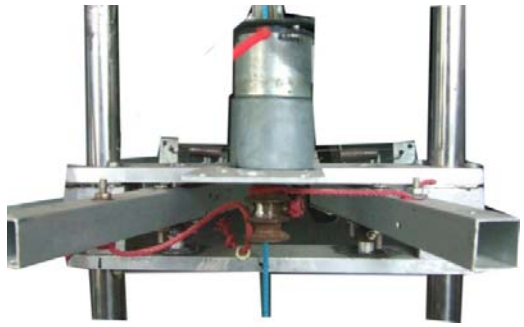


Figure 2.5 SPSR Slider

In this system two stainless steel pipes and circular slide ways were used to slide over the circular pipes. The sliding mechanism could be machined in built with another system such as gripping system or anything else. Sliders built of aluminum bars of two separate pieces. In between the bars wooden blocks and rubber pads were used as sandwich to ensure the surface contact. Circular pipes of closer diameter can also be used instead of wooden blocks.

Holes of diameter closer to the circular pipes are drilled on the aluminum bars. Through these holes circular guide ways were passed then these were supported by using wooden or aluminum blocks at the top and at the bottom. Usually at the top block the pulley was mounted through which the nylon string passed and is then winded on the aluminum pulley mounted on a motor. While the motor turns it winds strings on its coupled pulley and thus the slider lifted up, while motor turns in the opposite direction it loosens the string and the slider moves downward with the assistance of gravity force.

Advantages of two guide ways Slider

In comparison to the four pipe and pulley sliding system this system is far easier, handy, lighter and also reliable. The displacement of slider pulley is completely reduced in this type of system as it doesn’t use slider pulleys

Limitations of two guide ways Slider

The clearance between the guide ways and slider was very important. This clearance should be as less as possible. If the clearance was more the slide ways would get line contact rather than surface contact because of uneven loading. As a result guide ways exerts an opposite force on the slider causing the slider to be jammed. This increases the required motor power. So the clearance should be as small as possible.

For circular slide ways wooden piece is used as sandwich in between the aluminum bars to ensure surface contact. But if high quality woods are not used then the wooden sandwiches swell out with changing environmental conditions and cause extra amount of frictional forces. e.g. Changing moisture content in the environment etc. This makes the allowance selection difficult. This also limits the minimum clearance. So to ensure the desired clearance stainless steel pipe is suitable instead of wooden block.

2.1.4 Gripping System

In this robot gripper was used to hold a polystyrene cubic block. This gripper consists of channel stoke arm, medium torque motor, spring and a neutral plane for mounting motor and for attaching spring. The channel stoke of desired length was chosen and they were supported by bearing at a point. On the bearing support the channel stock could rotate freely. At one end of the channel stock it was spring loaded which provides necessary gripping forces and prevents the objects from slipping down from the grip of the robot. On the other end motor was equipped to drive the gripper system. The distance of the motor from the sliding axis was calculated such that the moment due to motor weight about sliding axis overbalances the moment caused by the gripping arm weight and the weight of the object which should be picked.

Figure 2.6 SPSR Gripper

Figure 2.7 Gripper motor close view

The motor was coupled with a two slot pulley where two set of string can wind simultaneously. The strings were connected to the end of the channel stock. So while the motor was rotating the string winds in the pulley thus creates a tension force in the end of the channel stock causing the gripper jaw to open. While the motor rotates in the reverse direction the tension force reduces on the string. The spring loaded on the front side of the gripper allows sufficient force to be developed to release and unwind the string. If the pulley diameter was big then the gripper can be opened and closed quickly. But the problem is the arms needed to remain in open condition without any power to the motor to protect the motor to be stalled. In that case the torque created by the spring force on the arms should be overbalanced by the motor starting torque. If the pulley diameter is very big then the motor resisting torque creates less resisting force on the wire, in that case the arms don't remain in full open condition and closes spontaneously when there is no power in motor. Thus the gripping system of string pulley gripper works.

2.1.5 Specifications of SPSR

The dimension of the Carrier Bot was 800x500x900 mm.

Sliding system was able to provide elevation of gripper: 100mm.

Power Supply: 12V and 6A.

PWM used.

Breaking System Used: Electronic Type.

Weight: 11 kg (with battery)

2.2 ScoutShip

"ScoutShip" was used to capture a polystyrene block from top of the central tower at a height of 1500 mm. Maximum dimension of an autonomous machine could be 1300mm. So it needed to ride on another machine and be carried to the tower and raised to desired height. Consequently it has only two motion**s,** forward movement and gripper actuation.

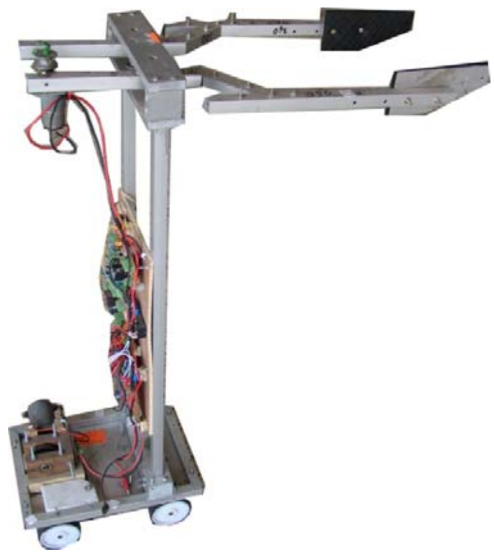


Figure 2.8 ScoutShip full view

2.2.1 Chassis Construction

This machine required only straight movement, no steering. So the single motor driven system was used. This was reliable as because there was nearly no scope of deviating from the target. Usually one single motor is not used to power only one wheel which would introduce slippage on the other while causing the robot to deviate from the actual destination. So power was transferred to one single shaft from the motor of which identical driving wheels were mounted on both ends. This ensures equal power distribution on both of the wheel and thus slippage was avoided.

Chain drive was used and motor was placed above the base of the machine in pursuit of stability as the base remained closer to the ground. Front wheels acted as idler.

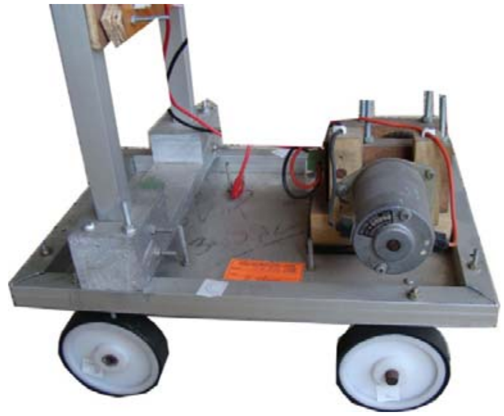
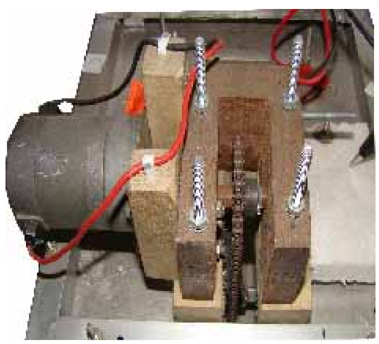


Figure 2.9 ScoutShip base

Base structure was constructed by Aluminum channel stoke. Aluminum has best in strength to weight ratio among available material. To facilitate battery mounting thin aluminum sheet was placed above the channel stoke structure.



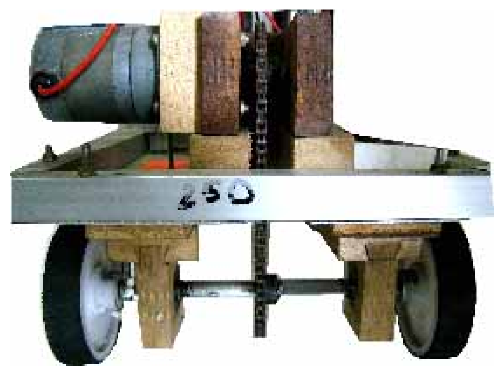


Figure 2.10 ScoutShip drive motor mount

Figure 2.11 ScoutShip Chain drive

2.2.2 Gripping System

Gripper employed for gripping a cubic polystyrene block, known as yellow butter cube. By its extended arm with rubber pad support could fairly grip the block. The arms were pivoted in a bearing support mounted on the wooden sandwich. The

spring was chosen of such that motor torque can keep the gripper open as well as arms can hold the object by the force exerted by the spring. The gripper was actuated by a small 12V DC motor of average torque.

2.3 Carrier Bot

Carrier-bot was used to carry ScoutShip on its platform to the desired place and raise that robot to the desired height. According to the theme one robot must have to carry another robot to the tower to score.

The locomotion system for this robot is same as that of the SPSR. Motors were mounted on the front end. Two casters were used to support the rear end. Encoders were equipped to ensure the straight travel and ensure the detection of the desired place. The drive system of this robot is capable of providing corrective measure if the drive system deviates from its path.

Figure 2.13 Carrier-bot base and slider

Figure 2.14 Close view of guide ways and slider

Sliding system of this robot may be called the combinations of two set of the two circular guide ways. Circular pipes of equal diameter were used to acquire surface contact in between the slider and supporting pipe. To rise the slider two sets of string instead of one was used to distribute the tension properly and equally over the slider. Each set of strings were connected with a shaft mounted with the power window motor, when power window motor rotated string wound the shaft and cause the slider upward movement. As the two independent motors were used for each slider so synchronization was difficult. Because of a subtle misalignment between these two sliders results the higher friction between circular guide ways and slider holes. It led to additional motor torque requirement and in more deteriorated case it cause motor stall. These four guide ways were supported by a wooden U shape structure. For the equal elevation of both the slider all four strings were set to equal length. A tiny deviation in string length causes slider tilting. So strings were essential to adjust after certain number of operations.

To facilitate its alignment with the destination tower a semicircular wooden guide was mounted at front end. Touch sensors were attached with this guide.

Figure 2.15 Carrier-bot full view

2.3.1 Specifications of Carrier-bot

The dimension of the Carrier Bot was   800x500x900 mm.

Sliding system was able to provide elevation of about : 800mm.

Power Supply: 12V and 6A.

PWM used.

Breaking System Used: Electronic Type.

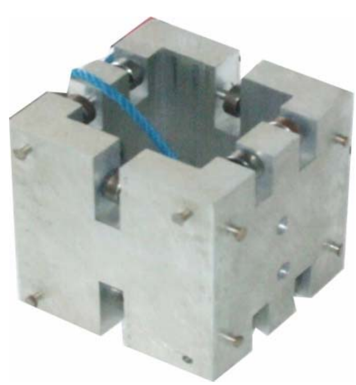
Weight: 13 kg (with battery)

2.4 X-bot

X-bot was an experimental project fabricated with the exploitation of high precision machining facilities. The objective of its fabrication was to simulate some advance mechanism that can be used on subsequent stages. New and advance mechanism was used for its gripper and slider construction. Stainless steel and mild steel was used as overall construction material. It was a rear wheel driven vehicle.

2.4.1 Sliding System

To surmount the drawbacks of two guide ways sliding system single supported slider system was built. Instead of using circular guide ways, rectangular slide ways was used and aluminum enfold rolled over the slide ways by means of tiny bearings having outer dia of 6mm. In between the collar and the guide ways there was about 0.75 mm clearance. It was very difficult to implement, but with high patience and perseverance it was done. There were necessary spaces on the enfolder to mount other systems like gripping system. The mounted systems like gripping system was hanged using nylon string over a support at top and then that string was wounded on a pulley. This pulley was driven by a power window motor to rise and lower that mounted system. Generally that system goes up using the tension forces created by the motor on the pulley and lowered by using gravity feed and loosening the tension on the string simultaneously.



On each front and back plane of the collar four bearing were used for load carrying purpose and on each side plane two bearings were used for supporting. Distance between two bearing shaft was set sufficient to withstand the moment caused by gripper weight. As the slider rolls over the bearing so its motions were extensively smooth.

Light weight aluminum was used as a construction material. The enfolder was formed from a rigid aluminum block of rectangular section. Machining process involved with this fabrication were milling, shaping and drilling respectively.

Benefits of Single guide way System

Several benefits of this type of systems are

- Weight is reduced as reduced number of support to slide.
- Improved stability rather than that of circular guide slide systems.
- Motor of less torque rating is required to drive the system.
- Less space is required to which is a feat of smaller and handy robots.

Limitations of Single guide way System

The limitations of this type of systems are:

- Due to continuous use of this system the channel stock and roller may wear out and thus increase the clearance which would lead to unstable situation.
- String and pulley used in this system is not reliable as there are possibilities for the string to miss the winding.

2.4.2 Gripping System

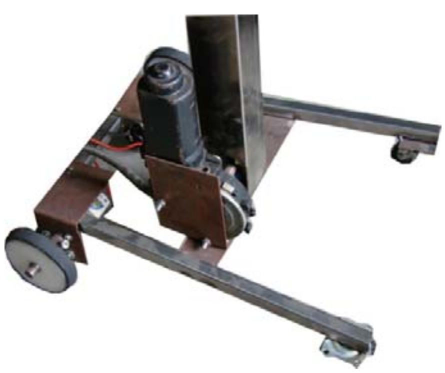
Gripper was designed on the basis of kinematic movement of the mechanical links. Strings-pulley systems were replaced by stainless steel links to provide the necessary gripping force. String pulley has some inherent intricacy such as for every operation it was necessary to check whether the string is rolling in right direction or not. As for incorrect rolling direction antithesis outcome were experienced. To overcome this hindrance kinematic links were used. By the kinematic link gripper actuation time requirement curtailed as motor need less amount of rotation than string-pulley. Kinematic links yield this gripper more reliability and strength with additional aesthetic value.

The figure 2.17 explains well the construction of this of gripper. There are three links of which the center one is coupled with motor which rotates with the motor. The movement of the center link incorporates the movements of the other two links. These two links are connected to the gripper jaws. So while motor rotates the gripper jaws actuate. Thus the gripping action took place. The designing of the link depends on the amount of gripping forces required.

Figure 2.17 X-bot Gripper

2.4.3 Chassis Construction

Chassis was built of stainless steel box pipe, welded to form a rigid structure. Because of its structural simplicity weight was reduced substantially. Screw joint and riveting were supplanted by welding joints. Casters were welded at front.



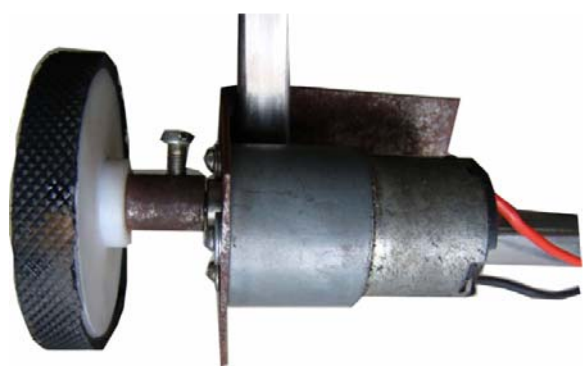


Figure 2.18 X-bot base

Figure 2.19 X-bot motor mount

Chapter 3

CONTROL SYSTEM

Control system comprises of the acquisition of sensor signals, analyzing these signals, making decisions based upon the signals and lastly actuating the manipulators according to the taken decisions.

The control system was consisted of electronic elements. It can be broadly classified into two categories. Such as:

i. Motor Control Circuit
ii. Microcontroller Circuit

The motor control circuit is designed to control the actuation of robot manipulators. Motor controller circuit was two relay operated H- Bridge. PWM (Pulse Width Modulation), timers, counters were also used in the motor control circuit.

PIC18F452 microcontroller was used as a brain of these robots. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor. In addition to all arithmetic and logic elements of a general purpose microprocessor, the microcontroller usually also integrates additional elements such as read-only and read-write memory, and input/output interfaces.

These complex circuits are generally incorporated with PCB's (Printed Circuit Board).Both design and fabrication of the PCB was done in the laboratory. Electrical drive was used in all the robots. All motors were operated by 12V DC source.

3.1 Motor Controller

Two type of motor control system used here:

- Open loop control
- Close loop or feedback control

3.1.1 Open loop Control

Open loop control means that electrical signals are send to an actuator to perform a certain action. There is no any mean for the controller to make sure the task was performed correctly and it often needs human intervention to obtain accurate result.

Gripper motor and slider motor control were open loop control system. These motors were controlled through precision time count.

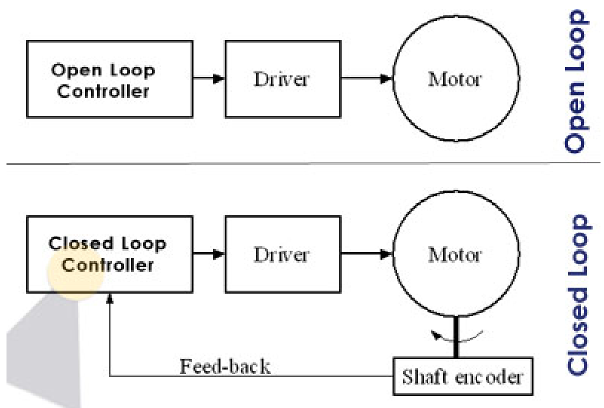


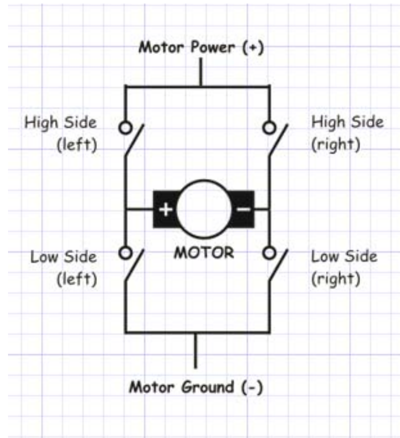
Figure 3.1 Open loop and close loop configuration

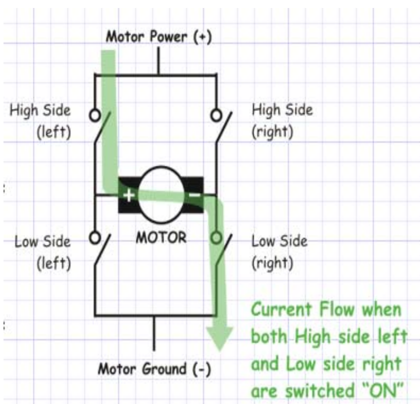
3.1.2 Close loop control

Close loop control system is feedback control system. A closed loop controller regulates the number of rotation required and the power delivered to the motor to reach the required velocity. Some means are essential for gaining information about the rotation of the motor through encoder, like the number of revolutions executed per second, or even the precise angle of the shaft. This source of information about the shaft of the motor is called "feed-back" because it sends back information from the controlled actuator to the controller Drive motors used feedback control system.

3.2 H- Bridge Motor Controller

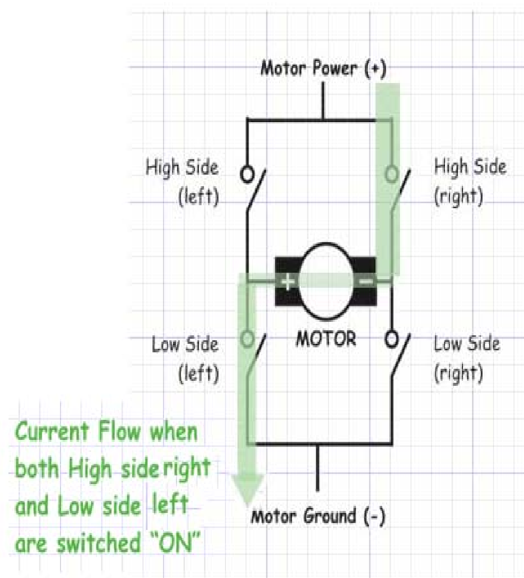
H bridge circuit uses four switches. SPDT relays were used as switch. The relay coils were energized by ULN2003 IC to control the direction of the motor. Practical circuits are comprises of other components such as diodes to mitigate the effect of back-emf.





If Upper Left side relay and Lower Right side relay are turned on, the right lead of the motor will be connected to ground, while the left lead is connected to the power supply, Current starts flowing through the motor which energizes the motor in the forward direction and the motor shaft starts spinning.

If Upper Right side relay and Lower Left side Relay are turned on, the converse will happen, the motor gets energized in the reverse direction, and the shaft will start spinning in that way.



Overall operation is shown below:

High Side Left	High Side Right	Lower Left	Lower Right	Quadrant Description
On	Off	Off	On	Motor goes Clockwise
Off	On	On	Off	Motor goes Counter-clockwise
On	On	Off	Off	Motor "brakes" and decelerates
Off	Off	On	On	Motor "brakes" and decelerates

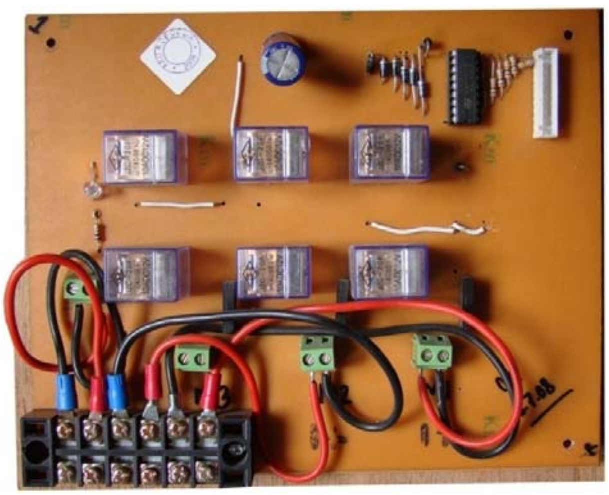


Figure 3.2 Motor controller circuit board

3.3 Microcontroller

A microcontroller (also MCU or µC) is a small computer on a single integrated circuit consisting of a relatively simple CPU combined with support functions such as a crystal oscillator, timers, and watchdog, serial and analog I/O etc.

PIC18F452 is used as a main intelligence in autonomous robots. A microcontroller is a computer-on-a-chip with both input, output and with in built timers and counters. It is a type of microprocessor emphasizing self-sufficiency and cost-effectiveness, in contrast to a general-purpose microprocessor (the kind used in a PC). In addition to all arithmetic and logic elements of a general purpose microprocessor, the microcontroller usually also integrates additional elements such as read-only and read-write memory, and input/output interfaces.

Microcontrollers are frequently used in automatically controlled products and devices, such as automobile engine control systems, office machines, appliances, power tools, and toys. By reducing the size, cost, and power consumption compared to a design using a separate microprocessor, memory, and input/output devices. The PIC18F452 microcontroller is a CMOS FLASH-based 8-bit microcontroller packs that features a 'C' compiler friendly development environment, 256 bytes of EEPROM, Self-programming, an ICD, 2 capture/compare/PWM functions, 8 channels of 10-bit Analog-to-Digital (A/D) . Detail information of PIC18F452 is enclosed in the appendix.

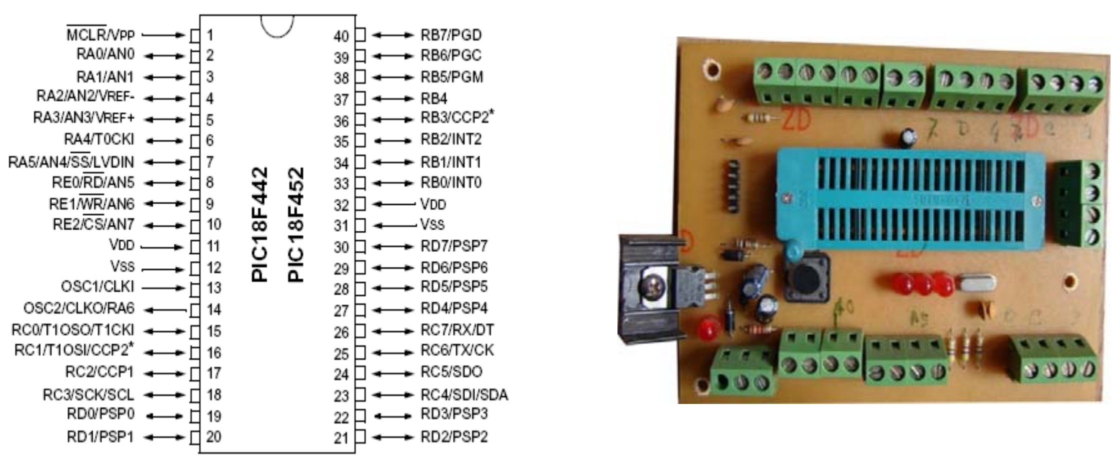


Figure 3.3 Microcontroller circuit board

3.4 Pulse Width Modulation

PWM (Pulse Width Modulation) is the term used to describe using a digital signal_to generate an analogue output signal. This was used to control the average power to a load in a motor speed control circuit.

It can generate a continuously variable analogue output without using any other integrated circuits by smoothing the PWM signal using a capacitor. Using analogue circuits to generate accurate signals that don't drift is a difficult task so PWM is very effective and cheap.

It works by changing the average voltage level and this is done by generating a constant frequency signal but one where the pulse width is changed (or modulated).

The digital signal when it is at its extremes i.e. normal - it generates the maximum of 5V when the output is high and the minimum of 0V when the output is low. To generate a 2.5V signal then it need to make the signal on for half of the time and off for the rest and then take the average.

Examples of PWM from the PIC Microcontroller

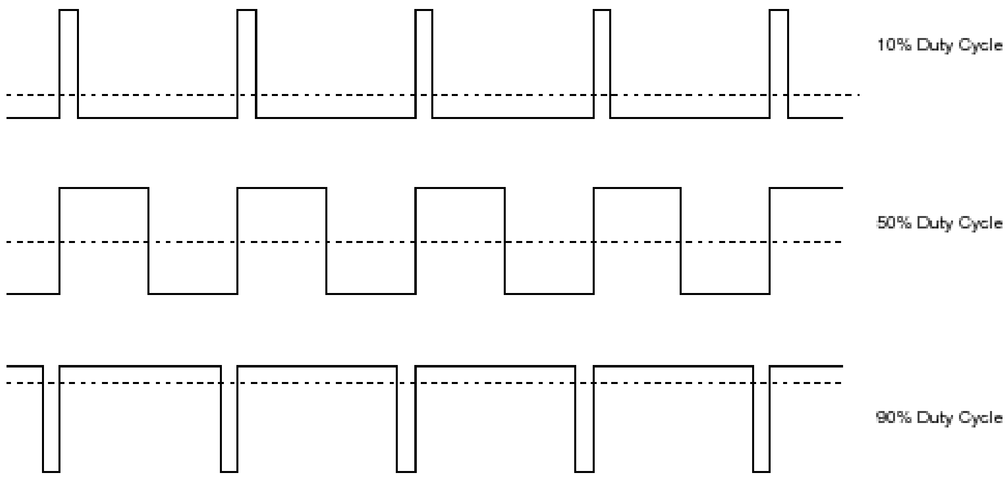


Figure 3.4 Pulse width modulation

In the diagram the digital signal (solid line) is at a constant frequency while the pulse width is changed (modulated). The dotted line represents the average signal (if the digital signal is converted to an average). The duty cycle represents the amount of time that the signal is high compared to the amount of time that the signal is low.

3.5 PWM with PIC Microcontroller

The circuit of autonomous robots is fully controlled by the micro-controller PIC18F452. PIC18F452 provides a prospective feature of PWM. With the help of various kind of registers PWM signals can be produced by the micro-controller. The speed of the drive motor is controlled by this way. All of the robots use the PWM technology for maintaining the different speed. For instance, SPSR uses different speed while accelerating or decelerating. Another feature of the SPSR is the two actuating wheel's speed can be separately controlled. All of these are done by PWM technology provided by PIC18F452.

PWM signal of this microcontroller is exerted from the CCP1/RC2 pin.

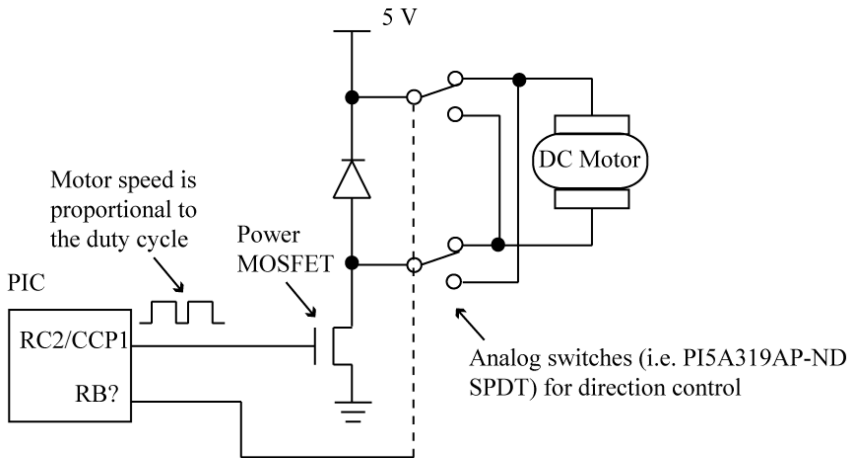


Figure 3.5 MOSFET driver circuit

The registers and variables associated with the PWM are stated below:

- CCPR1 (Capture/ Compare/ PWM)
  - CCPR1L (Low Byte)
  - CCPR1H (High Byte)
- CCPR2
  - CCPR2H
  - CCPR2L
- CCPR2H
- PR2 (Period Register)
- TMR2_PRE
- CCP1CON
- CCP2CON
- Oscillator speed.
- Duty Cycle
- PWM period

In Pulse Width Modulation (PWM) mode, the CCP1 pin produces up to a 10-bit resolution PWM output. Since the CCP1 pin is multiplexed with the PORTC data latch, the TRISC<2> bit must be cleared to make the CCP1pin an output.

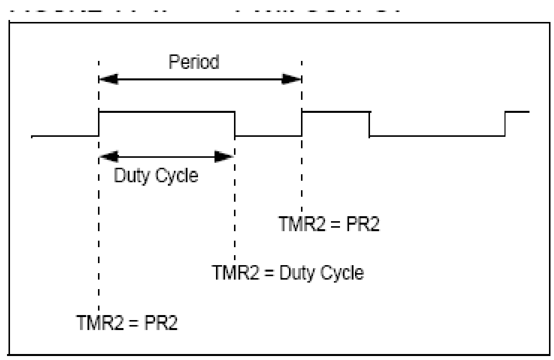


Figure 3.6 PWM output

A PWM output has a time-base (period) and a time that the output stays high (duty cycle). The frequency of the PWM is the inverse of the period (1/period).

The PWM period is specified by writing to the PR2 register. The PWM period can be calculated using the following formula:

PWM Period = (PR2+1) * 4 * TOSC * TMR2_PRE

PWM frequency is defined as 1 / [PWM period].

The PWM duty cycle is specified by writing to the CCPR1L register and to the CCP1CON<5:4> bits. Up to 10-bit resolution is available. The CCPR1L contains the eight MSbs and the CCP1CON<5:4> contains the two LSbs. This 10-bit value is represented by CCPR1L:CCP1CON<5:4>. The following equation is used to calculate the PWM duty cycle in time:

PWM Duty Cycle = (CCPR1L: CCP1CON [5:4])*TOSC*TMR2_PRE

The maximum PWM resolution (bits) for a given PWM is given by the equation.

$$\text{PWM Resolution (max)} = \frac{\log\left(\frac{FOSC}{FPWM}\right)}{\log(2)} \text{bits}$$

The following steps should be taken when configuring the CCP module for PWM operation:

1. Set the PWM period by writing to the PR2 register.
2. Set the PWM duty cycle by writing to the CCPR1L register and CCP1CON<5:4> bits.
3. Make the CCP1 pin an output by clearing the TRISC<2> bit.
4. Set the TMR2 prescale value and enable Timer2 by writing to T2CON.
5. Configure the CCP1 module for PWM operation.

3.6 Timers

Timer is another useful feature used in microcontroller. In PIC18f452, there are 4 timers. The different timers can be set as different bit mode. As an example, Timer0 can be set as 8 bit mode or 16 bit mode. The prescaler value of the timer sets the accuracy of the timer. The timer is usually used to measure the signal period. Each timer needed a clock pulse for the timing. These clocks can be divided into 2 divisions:

- Timer with internal clock
- Timer with external clock

Following Timers are used for disparate operations.

Timer0

The Timer0 module has the following features:
• Software selectable as an 8-bit or 16-bit timer/ counter
• Readable and writable
• Dedicated 8-bit software programmable prescaler
• Clock source selectable to be external or internal
• Interrupt-on-overflow from FFh to 00h in 8-bit mode and FFFFh to 0000h in 16-bit mode
• Edge select for external clock

Timer1

The Timer1 module timer/counter has the following features:

• 16-bit timer/counter (two 8-bit registers; TMR1H and TMR1L)

• Readable and writable (both registers)

• Internal or external clock select

• Interrupt-on-overflow from FFFFh to 0000h

• RESET from CCP module special event trigger

Timer2

The Timer2 module timer has the following features:

• 8-bit timer (TMR2 register)

• 8-bit period register (PR2)

• Readable and writable (both registers)

• Software programmable prescaler (1:1, 1:4, 1:16)

• Software programmable postscaler (1:1 to 1:16)

• Interrupt on TMR2 match of PR2

• SSP module optional use of TMR2 output to generate clock shift

3.7 Interrupt

An interrupt is an event in hardware that triggers the controller to jump from its current program counter to a specific point in the code. Interrupts are designed to be special events whose occurrence cannot be predicted precisely (or at all). The controller has many different kinds of events that can trigger interrupts, and for each one the controller will send the execution to a unique, specific point in memory.

Under normal operation, the microcontroller starts execution at program memory location 0. When interrupts are in use, two additional addresses in program memory have special meaning. When an interrupt occurs, the processor will jump the program counter to one of two interrupt handlers, which are specific locations in program memory. The high-priority interrupt handler starts at program memory location 0x8 and the low-priority interrupt handler starts at program memory location

0x18. Normally, there is not enough space to store your complete interrupt handling code in these locations, so a goto instruction is often used to branch somewhere else in the program memory.

Interrupts generally have a "priority;" when two interrupts happen at the same time, the higher priority interrupt will take precedence over the lower priority one. Thus if a peripheral timer goes off at the same time as the reset button is pushed, the processor will ignore the peripheral timer because the reset is more important (higher priority).

Interrupts shows generally 3 kinds of execution process:

- Rising edge interrupt
- Falling edge interrupt
- Change mode interrupt

In PIC18F452, INT0, INT1, INT2 are the interrupts which were used either in rising mode interrupt or falling edge interrupt, while all RB port can be used as a interrupt port as change mode. In the change mode, either change of the state from zero to one or one to zero will cause interrupt. On the other hand rising edge and falling edge will call the interrupt function (ISR) when the rising edge and falling edge occurs respectfully in the input.

The registers used in the interrupts are:

- INT0IF
- INT0IE
- RBPU
- INTEG0
- IPEN
- GIE
- GIEH
- GIEL

3.8 Shaft Encoder

A shaft encoder is an electro-mechanical device used to convert the angular position of a shaft or axle to an analog or digital code, making it an angle transducer.

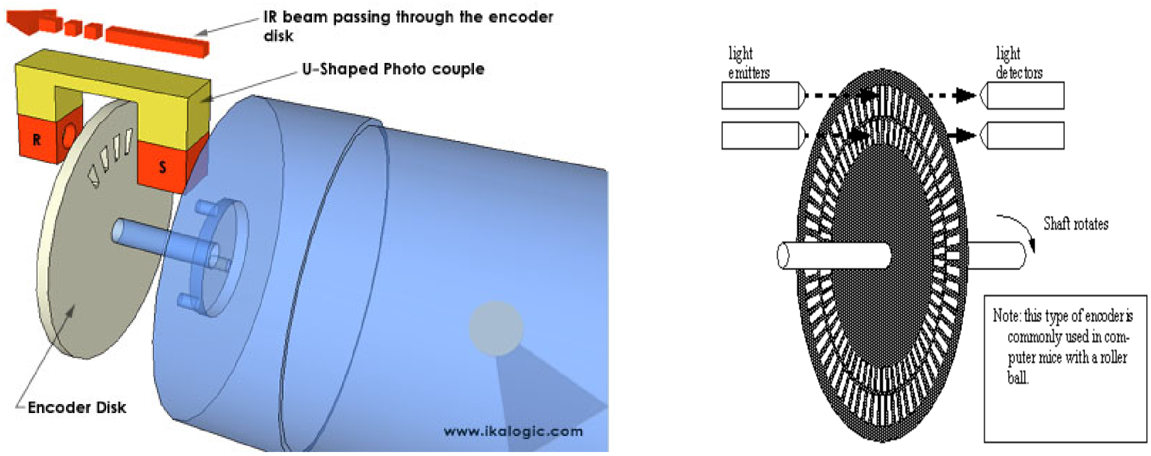


Figure 3.7 Shaft Encoder

They are not sufficient to locate a certain absolute position of the motor shaft. The materials for the completed shaft encoder consist of the encoder wheel, IR emitter/detector, black plastic film canister, and a cable tie. The wheel is attached to the rear of the motor shaft. The optical sensors are mounted on a small piece of board with a couple of other components. This type of encoders is called incremental, because they can only count the number of segments passed from a certain starting point.

When the wheel attached at the rear side of the motor moves, it block the optical sensors emitter and receiver. By blocking like this, controller system can recognize this state. Thus the moving path can be measured by counting these state positions. There was a gear train in the motor to increase the motor torques. When the encoder wheel which attached at the rare side of the motor shaft rotates 30 rotations the motor shaft will move just one rotation. Again, there are 26 divisions in the motor-wheel.

So the Resolution of the motor = $(360^o) / (26*30) = 0.46$ degree.

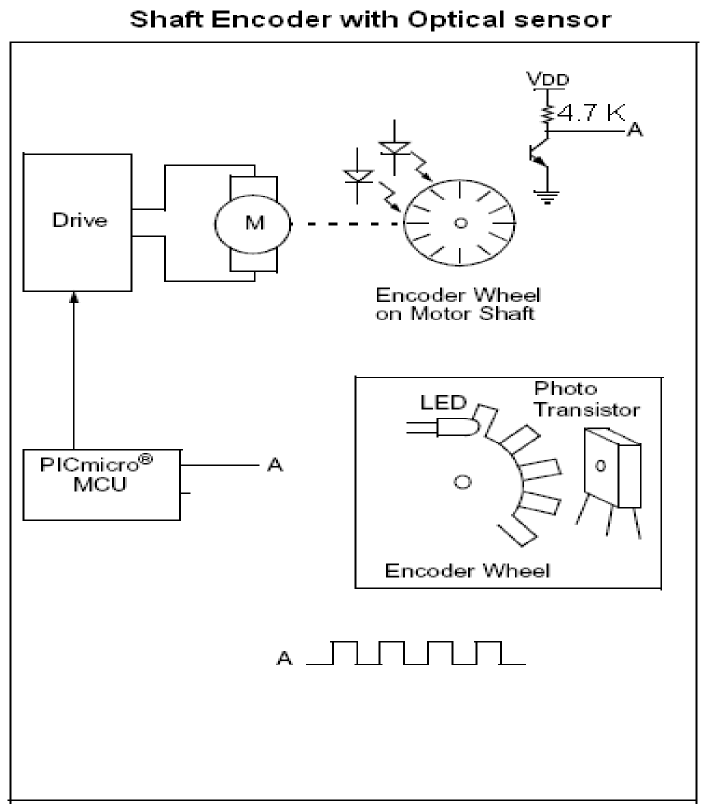


Figure 3.8 Shaft encoder working principle

Shaft encoder digital data was interfaced with microcontroller through Timer/Counter feature. Timer was used to count the rotation of the shaft encoder rather than measuring the time. For two independent drive motors Timer0 and Timer1 was used.

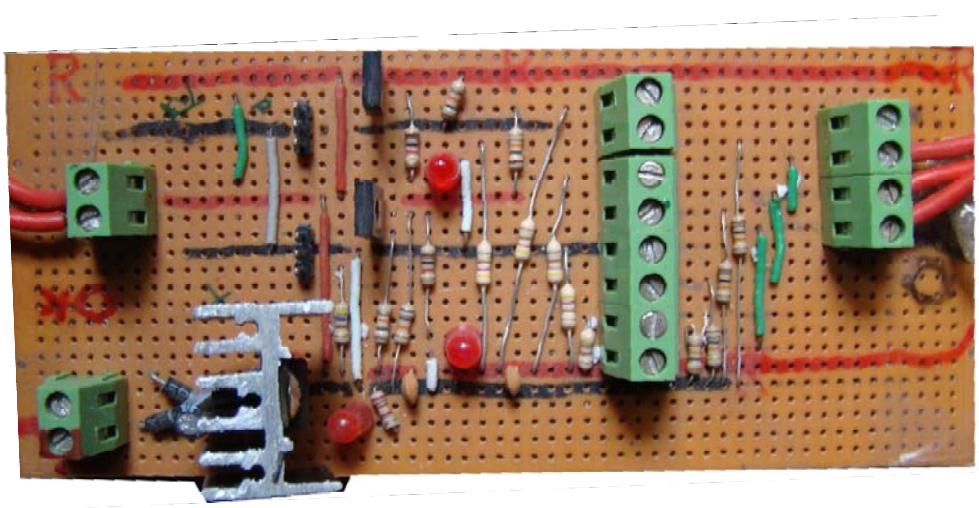


Figure 3.9 Encoder interface circuit

3.9 Robot Operation Sequence

3.9.1 SPSR operation

The SPSR was a DC motor driven robot. The SPSR waits in the starting zone until the start switch was pressed. After starting it moved at a constant speed for 1500 mm. The distance was measured by counting the number of rotation of the wheel using an encoder. While the microcontroller PIC 18F452 executed the specified number of rotation, it sent signal to the controller it stopped the motor to take a 90 degree turn.

After turning, the SPSR traveled another 500 mm to reach the scoring tower. The speed was controlled using the PWM of the microcontroller. At this stage the robot moved forward and waits for a light impact with the side tower. The impact was sensed using touch switches mounted on the guide firmly attached in front of the SPSR.

After the light impact the driving motor stopped, else it would move for an extra 2 seconds using the timer, to reach the destination. When the SPSR reached the side tower it actuated the gripper to grip the polystyrene block and then the slider was pulled upward so that the block is lifted above the rim of the bowl.

3.9.2 ScoutShip Operation

ScoutShip was DC motor driven robot that maneuvered straight ahead. The robot waited until the Start switch was pushed. As the switch was pressed it started to move forward and rode on the Carrier-bot, another robot. The locomotion time was set using the Timer sub-system of the PIC 18F452 microcontroller. After stopping the drive motor it expanded its gripper arm and waited until it reached the central tower being carried by the Carrier-bot. As it got the Butter (cube) it closed it gripper arm to grasp the Butter.

3.9.3 Carrier-bot Operation

As the switch was pressed it starts from sleep mode. It started moving after the ScoutShip board on it. There were two touch sensors to sense the ScoutShip. It then advanced some distance straight as the both motors for the two wheels were given power. Here At certain point in its way it had taken a turn by switching off power to one motor. As it reached somewhere near the tower the duty cycle of PWM was decreased slowly to slowed down the Carrier-bot.

Then power was given to the slider power window motor to raise the ScoutShip until the touch sensors for the vertical limit of sliding mechanism give the interrupt signal to the control unit. Then further advancement was made to grip the cube. The perfect position of the Carrier-bot was ensured by using a mechanical guide and three touch sensors. After gripping the cube the ScoutShip was raised somewhat to elicit the score. This time of gripping was predetermined in the controller.

Carrier-Bot

Figure 3.10 Carrier-bot and ScoutShip in operation

Chapter 4

PERFORMANCE ASSESSMENT

In this chapter test run results of all the four robots will be discussed. Precision and reliability of each machine along with common troubles which were faced will also be delineated.

4.1 SPSR

SPSR was a simple but robust machine and it was assigned to score six points in the game field. Its reliability was almost 100%. In the trial, it never failed to reach the destination and pick the polystyrene block (Butter).

Its only deficiency was its slow speed. Due to the dearth of high-speed motor in the local market its wheel rotation was only 62 rpm. It took ten seconds to start from the sleep condition following the predefined path and capture the block. Most of the team used DC motors of speed more than 1000 rpm in an average for all of their machines. So they required only three seconds to complete the task. It speed was used to reduce instantly by electronic braking system instead of decelerating gradually resulting short scoring time. In the competition maintained its consistency and elicited six points for the MECH.BUET team.

4.2 ScoutShip

Scout-ship rode on the Carrier-Bot and was carried to the central tower, then it captured the scoring block. So its performance was greatly contingent on the performance of the Carrier-Bot. To accomplish its own task it was reliable, very stable, the chance of tilting while ridding on another machine was totally eliminated by keeping its center of gravity in its lower portion. As an extra safety locking mechanism was introduced in the Carrier-Bot.

Scout ship was constructed as lighter as possible so that it becomes easier for the carrier to lift at a height of 500 mm. The time between starting and actuating the gripper was set by trial to combine and coordinate with the activity of the Carrier-Bot.

As communication between these two machines was not done, so it took some ancillary time after reaching the destination to ensure the arrival.

4.3 Carrier-Bot

The Carrier-bot was assigned to carry and lift the scout-ship to a particular height. To carry the load the structure became very complex and it got the highest weight among all the machines.

In the trials it was a very reliable and stable machine. It successfully followed a path of 5500mm with two turns, reached the destination and lifts the scout-ship to the desired height. There were number of sensors to ensure straight movement, reaching of destination, and lifting at the particular height. Its main deficiency was its time requirement to accomplish the task. The carrying and lifting were done at separate time interval. Lifting started after completion of traveling of the Carrier-bot. This had taken some extra time.

Lifting of the Scout-ship before reaching the destination would make the system unbalanced in braking due to the raise of the center of gravity. Another problem was to keep the source voltage consistent and operate four motors simultaneously, two motors for drive the machine and another two for lifting. And very common problem was the slow motor speed. High speed motor could mitigate the time requirement.

For lifting, nylon string was employed. Nylon has inherent problem like high creep rate and it elongates with time under constant load. So it became slack and needed to be adjusted after some trials.

4.4 X-Bot

Its advance gripping system and slider worked very well.

These robots were very sophisticated and cutting edge technologies were used in the robotic circuitries and control systems to make them smarter and quicker. These robots could calculate its path and could advance about a fraction of a millimeter if required with high degree of precision. The robots were fully autonomous and microcontroller controlled, so there was no chance of error in the control.

Chapter 5

CONCLUSION

The industrial world is showing an escalating trend towards automated systems. To design and manufacture the robots to compete in an international contest was a perfect opportunity for us to learn and apply sophisticated technologies of control systems.

With consistent dedication and perseverance we have achieved the ability to implement locally available resources to challenge the robot teams from highly developed countries. The design work required a great deal of time and concentration. Through these processes we have achieved the knowledge of kinematics, stability of a mechanical system, space management, selecting appropriate manufacturing process and how to make a system reliable.

To design each and every part of the robots, the limitation of resources was kept in mind always. The machining and assembling works were also difficult as it was not a precise industrial product. Several sessions of test runs were performed before packing up the robots.

This robot making task helped a lot to improve the sense of reality in manufacturing a real component. Difficulties at different points showed that the design of a machine should be done in such a way so that it can fulfill the end requirements with least difficulty at maximum efficiency.

This project relates the interconnected knowledge which is essential in practical field to work with people from different disciplines. To plan, organize and work as a team was an exciting and valuable experience.

In manufacturing process the automation system lead to increase productivity, reduce labor cost, improve product quality and uniformity. And other important things are remote control, power amplification and worker safety.

As a developing country like Bangladesh, application of robot building technology will be conducive to pave the way of industrialization. We strongly believe that this effort of ours will set the trend in the studies related to automation and robotics in our university.

Chapter 6

SCOPE OF FURTHER WORK

Though very sophisticated technologies were used in these robots but still have some areas for improvements. These development works can be on both Mechanical and Electrical sites.

Electrical system developments:

- Ultra-sonic Sensor
- Vision Sensor
- Line Follower
- Advanced Motor control Circuit

Mechanical system developments:

- Material
- Motor
- Pneumatic control
- Use of Vacuum pump
- Omniwheel

6.1 Electrical System Development

6.1.1 Ultrasonic Sensor

In these robots to ensure destination reached touch switches were used. Although these switches work well but have some deficiencies. For instance, machine need to approach for light impact with the destination. There always some possibility of mechanical damage during mild collision, and sometimes has devoid of accuracy. These hurdles could overcome by using ultrasonic sensors.

Ultrasonic sensors may be used for detection of blocks, measuring the distance and targeting the desired post. The Ultrasonic Distance Sensor measures the distance or presence of a target object by sending a sound wave above the range of hearing at the object and then measuring the time it takes for the sound echo to return. By knowing the speed of sound, the sensor can determine the distance of the object from the transducer element.

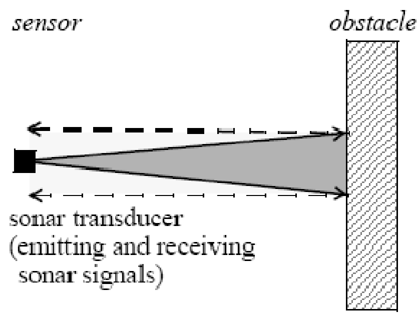


Figure 6.1 Ultrasonic sensor

The Ultrasonic Distance Sensor is available in two different output types:

- Ultrasonic Sensor with Analogue Voltage Output
- Ultrasonic Sensor Digital Output

The sensor gives a voltage output proportional to the distance after the distance (time) is measured. The sensor's scaling is fixed, where 0 VDC represents a target at 152.4 mm and 10 VDC a target at 1524 mm, with a proportional voltage change in between those two endpoints. After the distance (time) is measured, the sensor transmits the distance as binary data on the RS232 output.

6.1.2 Vision System

To detect an object vision system is the best alternative. With the vision system exact position, shape, color of the desired object can be determined. Thus robots can be made more reliable on reaching the desired goal.

Many of today's vision and recognition applications require the extraction of pertinent image features in real time, without necessarily having to acquire and process the whole image as traditional image processing systems do If these Robots have this kind of Vision sensor it can have ability to sense any thing on the fields. Robot can also sense opponent robots by vision sensors and can block them.

During the past years, several optical sensors have been developed, which are capable of performing on-chip pre-processing tasks at the pixel level that dramatically simplify the extraction of the desired information. First implementations aimed at functionalities such as light adaptation and spatio-temporal filtering, properties similar to those found in the biological retina. The most recent generation of vision sensors introduces a variety of fundamentally new properties. They process the image information in a pixel-parallel way and can be programmed to represent process and extract the relevant image features, in real time.

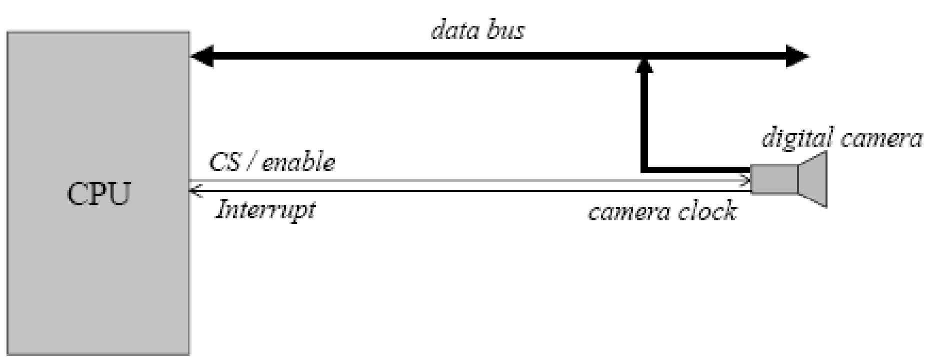


Figure 6.2 Camera interface

In recent years we have experienced a shift in camera sensor technology. The simplest camera interface to a CPU is shown in Figure 6.2. The camera clock is linked to a CPU interrupt, while the parallel camera data output is connected directly to the data bus. Every single image byte from the camera will cause an interrupt at the CPU, which will then enable the camera output and read one image data byte from the data bus.

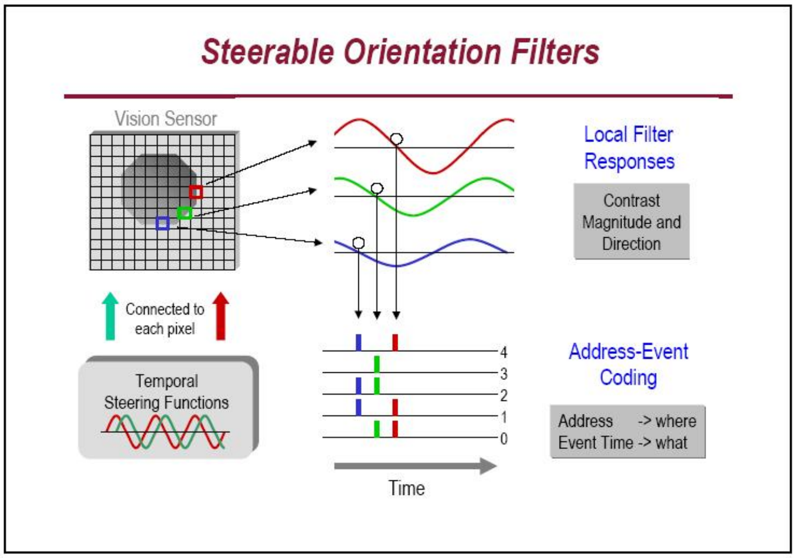
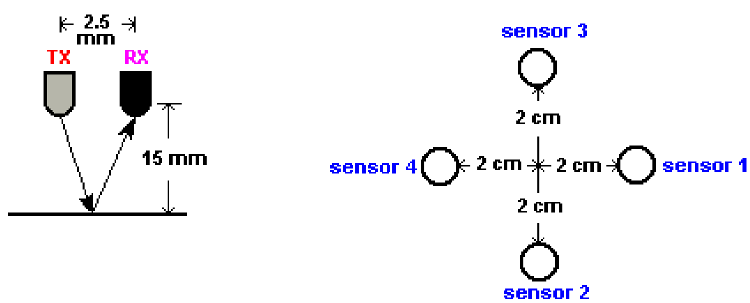


Figure 6.3 Vision system

6.1.3 Line follower

Now-a-days, the Line-following mechanism is widely used in robot locomotion. Especially in the Robocon competition game fields generally equipped with grid lines which make the application of line-follower more convenient to reach the destination.



Position of sensors, left hand side is side view and right hand side is top view.

This technology may be employed for better positioning of the robots. In these robots line follower was tried to implement but due to dearth of sensors in the local market that attempt was not fruitful. Previously manual alignment was used or defined path was followed by counting both the drive motor rotation, with the line follower that could be done in a effective way. Line follower robots are most effective way to ensure that the robots will reach their target.

6.2 Mechanical System Development

6.2.1 Material

In design and fabrication of the robots basically aluminum was the main material. Sometimes mild steel was also used when strength is the concern. Aluminum has the best strength weight ratio among the monolithic metals and material available in local market.

In robot building weight has always been a matter to be concerned, so to lessen the weight; use of composites can be a very good option. Some composites have specific strength (ratio strength to density) almost ten times greater than that of aluminum. Those materials also hold high specific modulus. So weight could be minimized to a great extent.

6.2.2 Motor

The DC motors mounted on the machines were very slow and behaved unpredictably. Most of the motors were collected from rejected textile machinery and marine ships. If high-speed lightweight motors could be collected, the machine′s working cycle would be reduced. Servomotors provide easy control of speed. For higher speed, torque and better control BLDC motors can also be used.

6.2.3 Pneumatic Control System

In pneumatic control system high-pressure air could make the system faster and more reliable than conventional motor driven system. This control can be employed for faster gripper and slider operation with higher efficiency. It could also be used to assist the electrical drive system.

Pneumatic Control consists of follows equipments

- Air Compression
- Compressed Air Conditioning
- Compressed Air Drying
- Air Distribution
- Air Circuit Construction
- Pneumatic Cylinders
- Air Motors
- Directional Control Valves
- Flow Controls
- Sensors
- Physical Principles
- Circuit Presentation and Analysis
- Step-Counter Circuits
- Cascade Circuits
- Combinational Circuits

6.2.4 Vacuum pump

When machines maneuvered at a high speed it tends to skid on the slippery floor. This problem can be avoided by using vacuum pump. Vacuum pump mounted close to the ground suck air during robot maneuvering and creates higher traction and avoids skidding.

6.2.5 Omniwheel

The casters had possessed some erratic behavior. If initially it was not aligned properly with the robot direction, causing deviation in the robots maneuvering. This caster alignment problem can be totally eliminated by using Omni wheel.

Figure 6.4: Omniwheel

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APPENDIX

Theme of Robocon 2008

Robocon, short for **Robotic Contest,** is an interesting game- cum- intellectual exercise for budding engineers and their enthusiastic instructors, determined to innovate and create machines to produce desired results. Participation in it is an end-to-end competitive experience from concept design of a system of robots programmed to perform according to rules of the game played on a precisely created challenging field and to score a victory beating the competitors; all this according to a Theme declared by the Host Country.

Last year the competition was organized in India. The contest theme is based on Indian mythology related to Lord Krishna (a Hindu deity) and the festival of Dahi-Handi, celebrated annually in northern part of India. Born as a prince and brought up into a cowherd family, **Krishna** is often referred to as "**Govinda**".

As children, **Govinda** and his friends used to raid kitchens in search of milk, butter (Makhkhan) and cheese (Paneer). They also used to tease young girls (Gopis) carrying pots (Matka) filled with water, milk, butter, or cheese on their heads.

A common practice in rural India is to suspend these pots (containing Cheese, Butter and Milk) from beams high in the ceiling out of reach of cats.

During the day when the men were busy in the fields and the women folk busy with outdoor chores, the naughty and adventurous **Govinda** along with his band of friends

“The Objective of Robocon 2008”

Two opposing teams (a Red team and a Blue team) will operate Manual machines and Autonomous machines and attempt to get at the pots of butter placed at a height and remove the large cube of Butter (Makhkhan) from the bowls. A few of the machines would also attempt to “Steal” the Earthen Pots (Matkas) containing balls of Cheese (Paneer) being carried by the Young Girls (Gopis). Points are earned when the Butter is removed from the Bowls placed at a height.

Points could also be earned when a Pot and/or Cheese is transferred to a Basket. The team which picks up all the three butter cubes directly from the bowls and holds them in the air will be declared “GOVINDA” (the winner) and the game will be over.

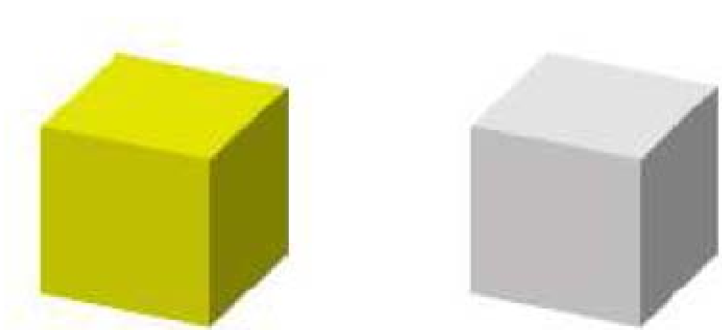
If no team becomes “GOVINDA”, the team which accumulates more number of points within the specified time of three (3) minutes will be declared as the winner.

Definition of words and their representation in the game:

Words in bracket are translation in Hindi language

1) Butter (Makhkhan)

Butter is represented by a 200 mm cube of low density polystyrene painted Yellow for the Central Bowl. For the Side Bowl, the cube is of the same size and is painted White.



2) Earthen Pot (Matka)

A hollow thin walled cylindrical Pot made up of light weight plastic material with a wide mouth on the top.

3) Cheese (Paneer)

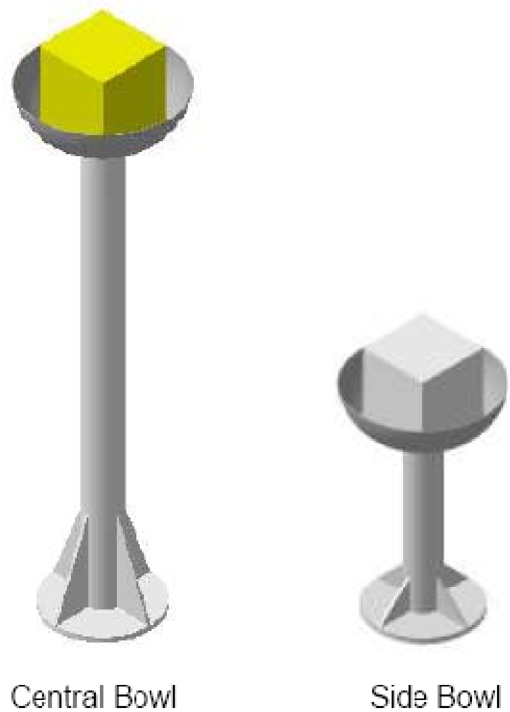
The Cheese is represented by a light weight miniature basket ball which rests on the mouth of the pot with most of it visible above.

4) Central Bowl (Handi)

This Bowl is placed in the centre of the game field. Yellow colored Butter cube is placed in it.

5) Side Bowl

There are two (2) Side Bowls, one in each half of the game field. White colored Butter cubes are placed in these Bowls.



The Game Field with various Objects:

The game is played on a game field (sized 14500 mm x 13000 mm), which is surrounded by a 100 mm high and 30 mm wide wooden wall. The floor of the game field is made of 2 mm thick vinyl sheet. The field consists of a Manual Area in pacific blue color, an Autonomous Area in green color and Common Areas colored red and blue for respective team.

Manual and Autonomous Areas

The Manual machines can move freely in the Manual Area but cannot enter the Autonomous Area. The Autonomous machines can move freely in the Autonomous Area but cannot enter the Manual Area.

The Autonomous Area is H-shaped (overall size 9500mm X 8000mm) and surrounded by a wooden wall of 50 mm height and 30 mm in width. There is a grid of lines in the Autonomous Area and these lines are made of 30 mm wide White, non-shiny tape.

Manual machine Start zone

Manual machine Start zone is a square (1000 mm x 1000 mm) and is located in the Manual Area. There are two (2) Manual machine start zones. One, colored red, is for the Red team and the other, colored blue for the Blue team.

Central Bowl

Central Bowl is in the centre of the game field. The Bowl is fastened to the top of tower. The Butter cube with Yellow color is placed in this Bowl. The top surface of this cube is at a height of 1500 mm from the floor of the game field.

Side Bowls

There are Two (2) Side Bowls in the Autonomous Area. Bowls are fastened to the top of towers. Each of these Bowls carries one White Butter cube. The top surface of these cubes is at a height of 750 mm from the floor of the game field.

Butter

Each butter will be made up of a 200mm cube of low density polystyrene. The butter cube painted Yellow will be placed in Central Bowl and the butter cube painted White will be placed in each Side Bowls. The weight of each Butter cube is 130g (± 20 g).

Machines

Autonomous machines

1. The entire set of Autonomous machines of a team should fit within a cube of 1000 mm before the game begins and when the machines are in the Autonomous Start zone.

2. Each autonomous machine's size and form may undergo a change during the game, but each machine should fit into a cube of 1350mm thereafter. Each machine should fit into a 1350mm cube whose bottom is entirely touching the field and no portion of the machine should penetrate this imaginary cube during a match.

3. The number of Autonomous machines is limited to three (3) maximum and to be used throughout the contest

Power Supply for Machines

1. Each team shall prepare its own power supply for all its machines.

2. Voltage of the electric power supply for machines shall not exceed 24V DC.

3. A Power supply that is considered dangerous or unsuitable by the Contest Committee shall not be permitted.

Weight

All Manual and Autonomous machines including their power sources, cables, remote controller and other parts of each machine shall be weighed prior to the competition. The total allowable weight of all machines and above accessories for each team to be used throughout the contest must not exceed 50 Kg. The total weight of 50kg doesn’t include spare batteries with the same shape, same weight and voltage.

Microcontroller

General Information of PIC18F452

- DC - 40 MHz osc./clock input
- 4 MHz - 10 MHz osc./clock input with PLL active
- Priority levels for interrupts

Peripheral Features

- High current sink/source 25 mA/25 mA
- Three external interrupt pins
- Timer0 module: 8-bit/16-bit timer/counter with 8-bit programmable prescaler
- Timer1 module: 16-bit timer/counter
- Timer2 module: 8-bit timer/counter with 8-bit period register .
- Timer3 module: 16-bit timer/counter
- Secondary oscillator clock option - Timer1/Timer3
- Two Capture/Compare/PWM (CCP) modules.
- CCP pins that can be configured as:
- Capture input: capture is 16-bit, max. resolution 6.25 ns (TCY/16)
- PWM output: PWM resolution is 1- to 10-bit, max. PWM freq. @: 8-bit resolution = 156 kHz 10-bit resolution = 39 kHz

Analog Features

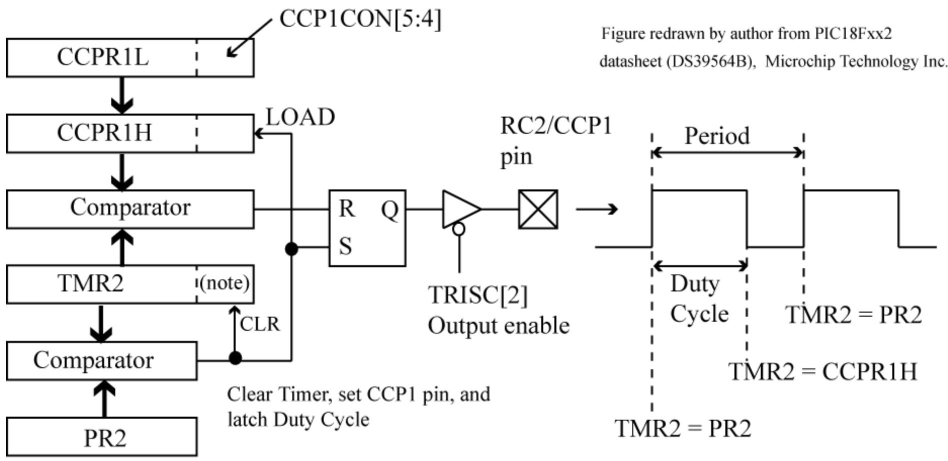
- Compatible 10-bit Analog-to-Digital Converter module (A/D) with:
- Fast sampling rate
- Conversion available during SLEEP

Special Microcontroller Features

- 100,000 erase/write cycle Enhanced FLASH program memory typical
- 1,000,000 erase/write cycle Data EEPROM memory
- Programmable code protection

Pulse width Modulation

PWM capability is provided through the use of Timer2 and the CCPR1 Registers as shown in figure below:



Note: 8-bit timer is concatenated with 2-bit internal Q clock or 2 bits of the prescaler to create 10-bit time-base

The PR2 register sets the period of the generated square wave, while the CCPR1H register provides the duty cycles. A match of the PR2 register and TMR2 values sets the CCP1 pin high, clears the TMR2 register, and transfers the CCPR1L value to CCPR1H to fix the duty cycle. A match of TMR2 with CCPR2H resets the CCP1 pin, thus terminating the high portion of the square wave. Both PR2 and the duty cycle are extended to 10 bits of precision; the PR2 register by using the 2 bit internal Q clock or 2 bits of the prescaler and the duty cycle by using the CCP1CON[5:4] bits as the lower 2 bits of the 10 bit duty cycle value.

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