FIRE BIRD V

P89V51RD2
ROBOTIC RESEARCH PLATFORM
Hardware Manual

Designed By:

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FIRE BIRD V

HARDWARE MANUAL

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Notice

The contents of this manual are subject to change without notice. All efforts have been made to ensure the accuracy of contents in this manual. However, should any errors be detected, NEX Robotics welcomes your corrections. You can send us your queries / suggestions at info@nex-robotics.com

⚠ **Robot's electronics is static sensitive. Use robot in static free environment.**
⚠ **Read the hardware and software manual completely before start using this robot**

Recycling:

Almost all of the robot parts are recyclable. Please send the robot parts to the recycling plant after its operational life. By recycling we can contribute to cleaner and healthier environment for the future generations.

Index

1 Introduction

Thanks for choosing the Fire Bird V mobile robot platform. Fire Bird V will give you good exposure to the world of robotics and embedded systems. Thanks to its innovative architecture and adoption of the ‘Open Source Philosophy’ in its software and hardware design, you will be able to create and contribute to complex applications that run on this platform, helping you acquire expertise as you spend more time with them.

Safety precautions:

- Robot’s electronics is static sensitive. Use robot in static free environment.
- Read the assembling and operating instructions before working with the robot.
- If robot’s battery low buzzer starts beeping immediately charge the batteries.
- To prevent fire hazard, do not expose the equipment to rain or moisture.
- Refrain from dismantling the unit or any of its accessories once robot is assembled.
- Charge the NiMh battery only with the charger provided with the robot.
- Never allow NiMh battery battery to deep discharge.
- Mount all the components with correct polarity.
- Keep wheels away from long hair or fur.
- Keep the robot away from the wet areas. Contact with water will damage the robot.
- To avoid risks of fall, keep your robot in a stable position.
- Do not attach any connectors while robot is powered ON.
- Never leave the robot powered ON when it is not in use.
- Disconnect the battery charger after charging the robot.

Inappropriate Operation:

Inappropriate operation can damage your robot. Inappropriate operation includes, but is not limited to:

- Dropping the robot, running it off an edge, or otherwise operating it in an irresponsible manner.
- Interfacing new hardware without considering compatibility
- Overloading the robot above its payload capacity.
- Exposing the robot to wet environments.
- Continuing to run the robot after hair, yarn, string, or any other item has become entangled in the robot’s axles or wheels.
- All other forms of inappropriate operation.
- Using robot in areas prone to static electricity.
- Read carefully paragraphs marked with ⚠ caution symbol.

2. Fire Bird V P89V51RD2

Origins of the Fire Bird V

The Fire Bird V robot is the 5th in the Fire Bird series of robots. First two versions of the robots were designed for the Embedded Real-Time Systems Lab of Department of Computer Science and Engineering, IIT Bombay. Theses platforms were made commercially available form the version 3 onwards. All the Fire Bird V series robots share the same main board and other accessories. Different family of microcontrollers can be added by simply changing top microcontroller adaptor board. At present Fire Bird V supports ATMEGA2560 (AVR) and P89V51RD2 (8051) microcontroller adaptor boards. This feature makes Fire Bird V robots very versatile. User can also add his own custom designed microcontroller adaptor board

Figure 2.1: Fire Bird V Robots

Figure 2.2: ATMEGA2560 (AVR) and P89V51RD2 (8051) microcontroller adaptor board

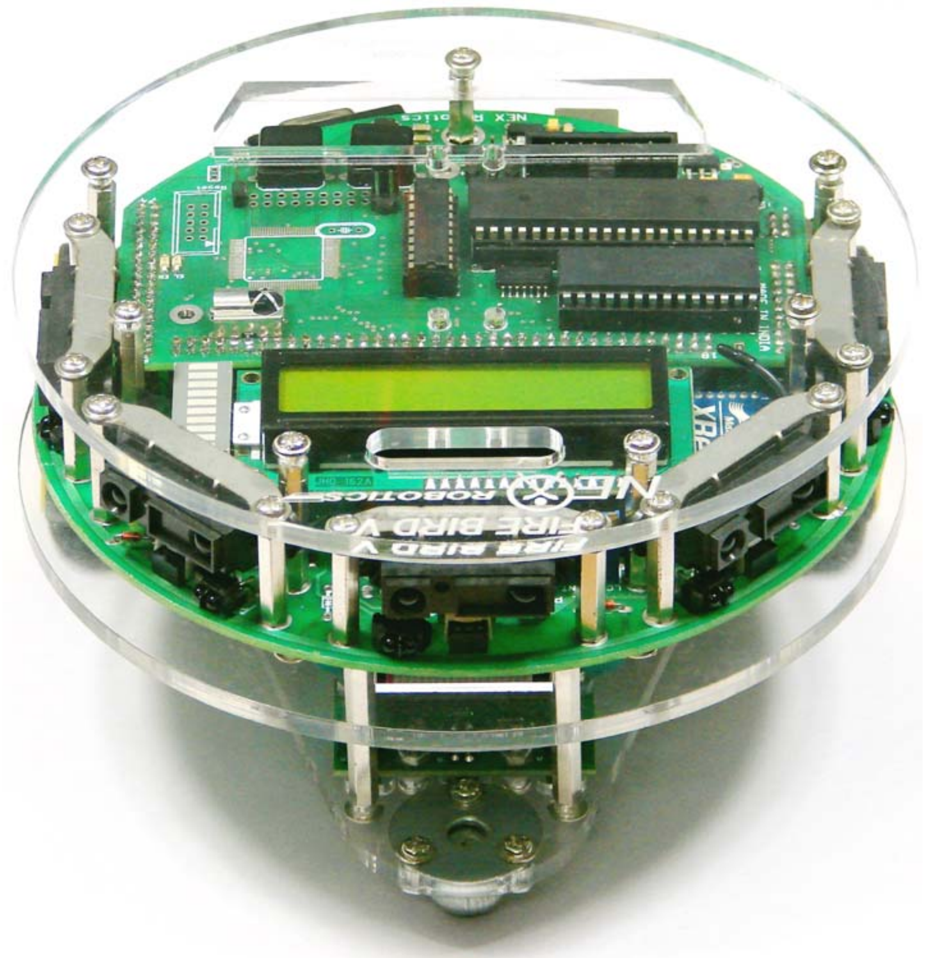

Figure 2.3: Fire Bird V P89V51RD2 robot

2.1 Fire Bird V Block Diagram:

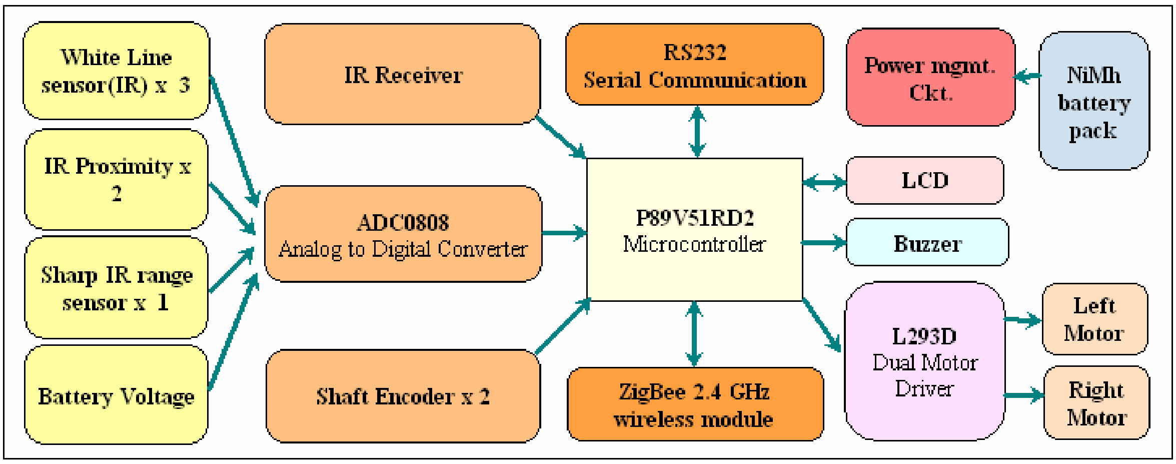

Figure 2.4: Fire Bird V P89V51RD2 robot block diagram

2.2 Fire Bird V P89V51RD2 technical specification

Microcontroller:
NXP P89V51RD2 (8051 architecture based Microcontroller)

Sensors:
Three white line sensors
One Sharp GP2D12C Infrared Range sensor with 80cm range
Three analog IR proximity sensors (TCRT5000)
Two position encoders (shaft encoders)
Battery voltage sensing

Indicators:
2 x 16 Characters LCD
Indicator LEDs
Buzzer

Control:
Autonomous Control
PC as Master and Robot as Slave in wired or wireless mode

Communication:
Wired RS232 (serial) communication
Simplex infrared communication (from infrared remote to robot)
Wireless ZigBee Communication (2.4GHZ)

Dimensions:
Diameter: 16 cm
Height: 10 cm
Weight: 1250 Gms.

Power:
9.6V, 2100mAh Nickel Metal Hydride (NiMH) battery pack and external Auxiliary power using battery charger.

Battery Life:
2 Hours while motors are operational at 75% of time

Locomotion:
Two DC geared motors in differential drive configuration and caster wheel at front as support
- Top Speed: 24 cm / second
- Wheel Diameter: 51mm
- Position encoder: 30 pulses per revolution
- Position encoder resolution: 5.44 mm

3. Using Fire Bird V Robot

In this chapter various components of the robot and there principal of operations are explained in brief. For more details user can refer to Chapter 8, which covers robot's hardware in detail. It is very important that user go through chapter 3 and 8 before starting to use robot.

3.1 Powering up Fire Bird V

Fire Bird V has onboard rechargeable 9.6V, 2.1Ah Nickel Metal Hydride battery which can power the robot for approximately 2 hours. In case experiments are to be performed for an extended period robot can also be powered by external, auxiliary power supply.

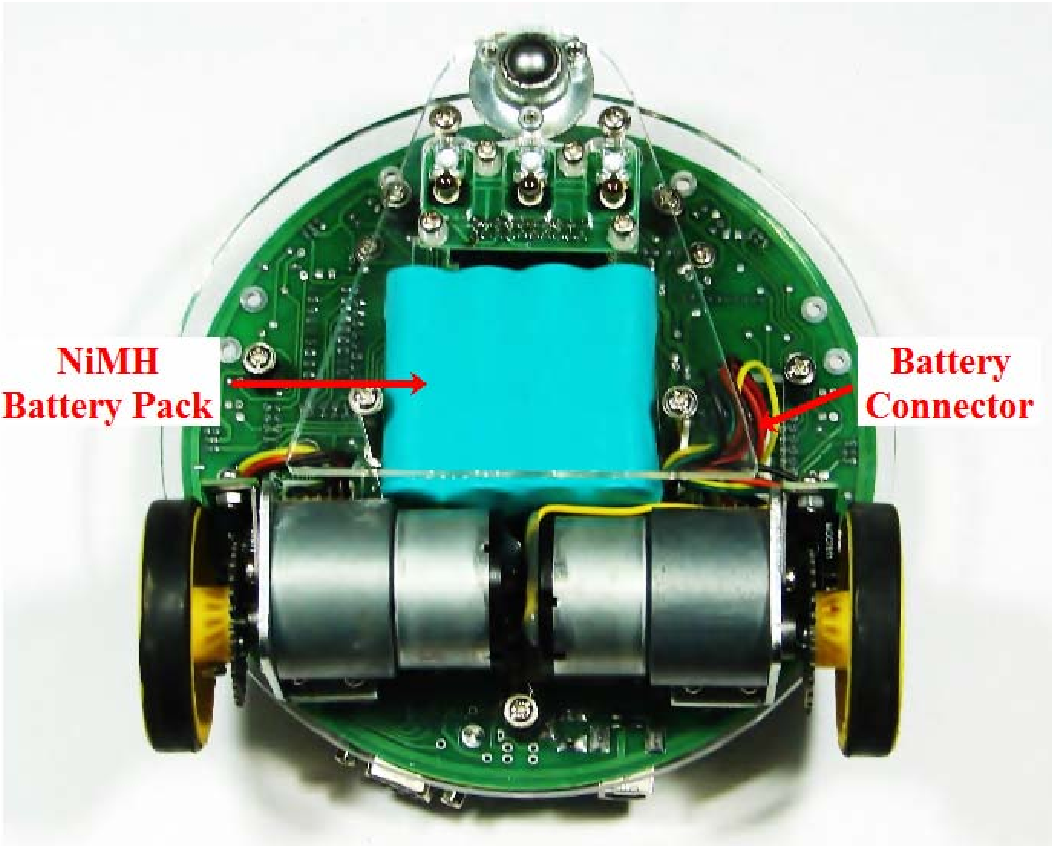

Figure 3.1: Connecting the battery on the Fire Bird V main board

For the safety during transportation, robot's battery is disconnected. Before connecting battery to the robot, make sure that power switch is moved towards back direction of the robot (AP). You need to charge the battery before first use. Refer to section 3.3 for battery charging. For running the robot on battery power or auxiliary power, refer to the section 3.4 and 3.5.

Note: There are two versions of the Fire Bird V P89V51RD2. First version was deployed in IIT Bombay. Second version has improved battery connector and sturdier battery charger. In order to maintain compatibility with the old version of the robot in the section 3.2 to section 3.5 both type of the chargers are covered.

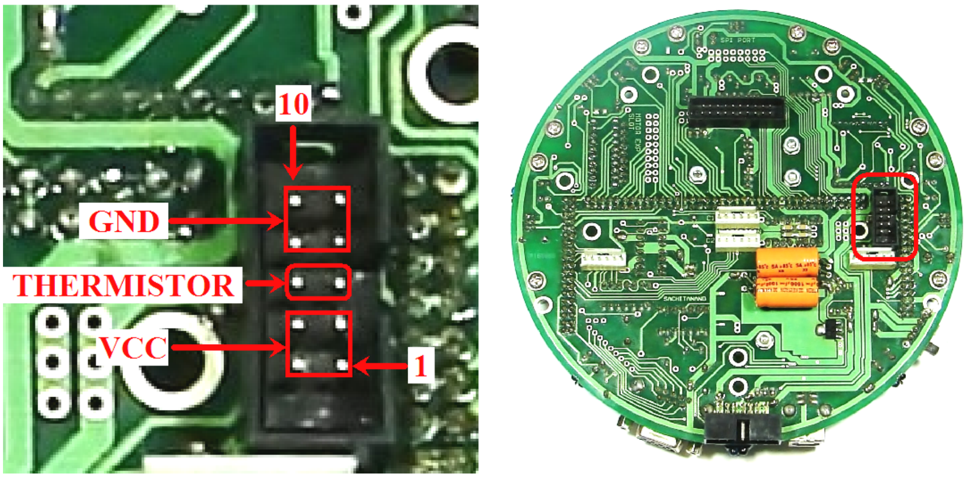

Figure 3.2: Battery Connector in the version 2

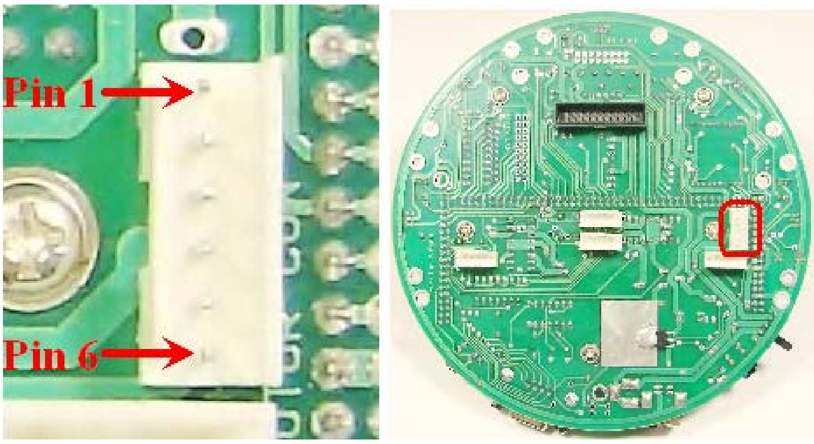

Figure 3.2B: Battery Connector in the version 1

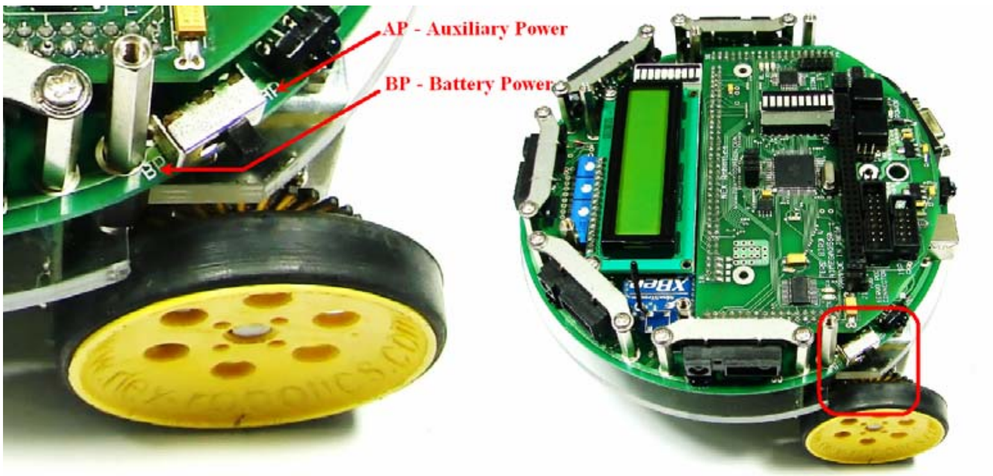

Figure 3.3: Power Switch

3.2 Power management system on the Fire Bird V

Fire Bird V is powered by 9.6V, 2.1Ah rechargeable Nickel Metal Hydride battery pack. When fully charged, battery pack gives 11.5V. When it is fully discharged, voltage drops to about 8.5V. Battery pack should not be discharged below 8V (1V per cell) to extend the battery life. Nickel Metal Hydride batteries must be recharged using smart charging circuit which follows the appropriate charging profile for the batteries. To avoid any damage to the batteries, only use charger provided with the robot.

Power management block on the Fire Bird V performs following functions.

1. Battery voltage monitoring
2. Battery current sensing*
3. Battery low warning in case battery is below critical level
4. Regulated supply for onboard payload.

* Current sensing is an optional accessory.

Battery low threshold value is factory set at 8V. Battery low threshold value can be adjusted by turning potentiometer which is shown in Figure 3.4. Robot will start giving beeping sound when battery is critically low and needs recharge.

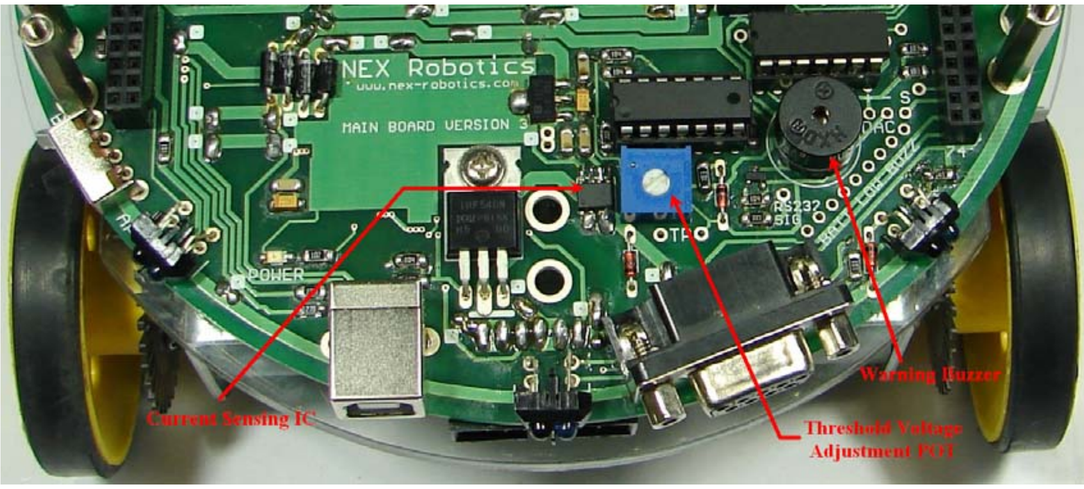

Figure 3.4: Power Management section on the main board, Version 2

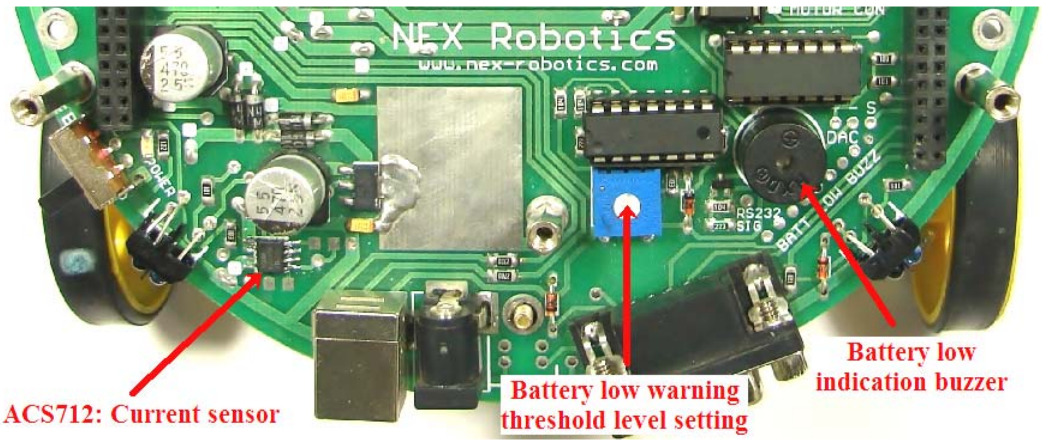

Figure 3.4B: Power Management section on the main board, Version 1

3.3 Battery Charging

Fire Bird V is powered by 9.6V, 2.1Ah NiMH rechargeable battery. NiMH charger provided with the robot will charge the battery in 4.5 hours. Battery has built-in thermistor for monitoring battery temperature during battery charging.

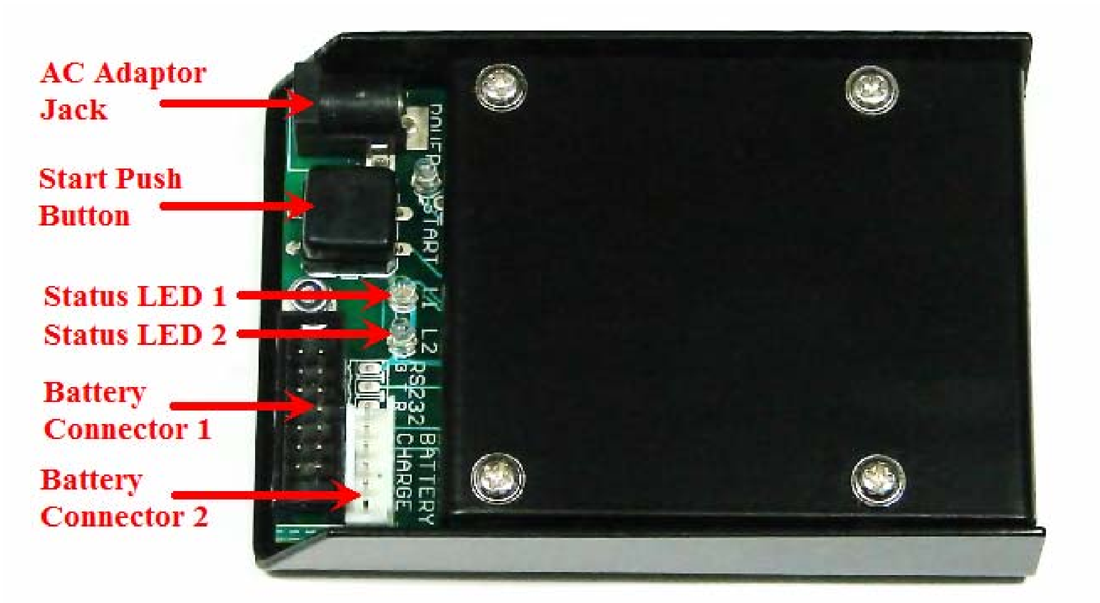

Figure 3.5: Smart NiMH battery charger version 2 for Fire Bird V

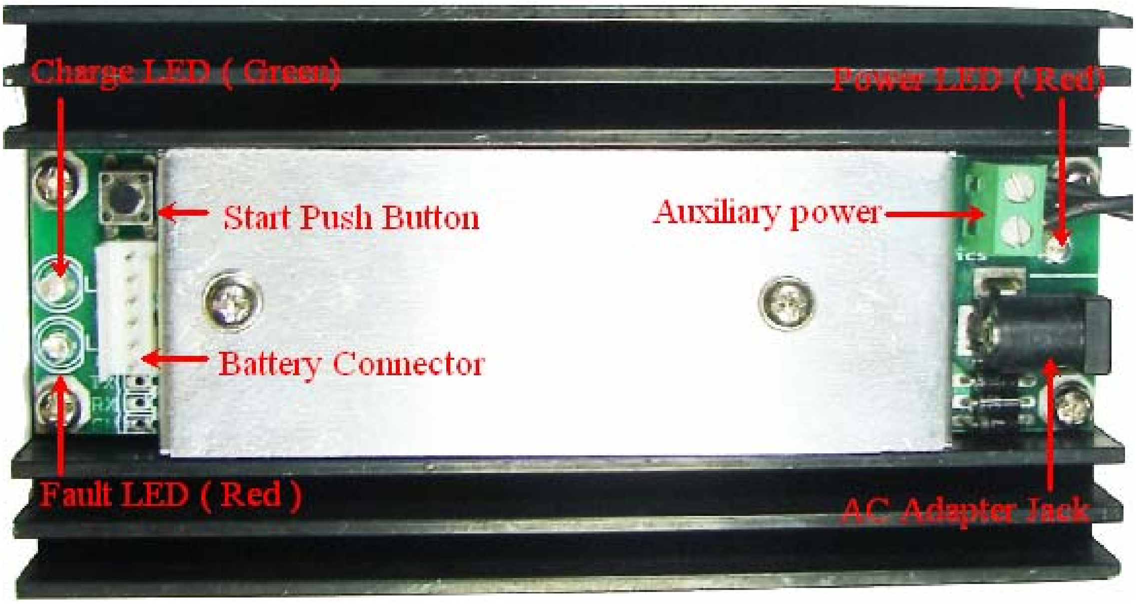

Figure 3.5B: Smart NiMH battery charger version 1 for Fire Bird V, Version 1

Figure 3.5 shows the smart battery charger for Fire Bird V robot. Battery charger checks state of battery before initiating the charging process. If battery is deeply discharged it preconditions the battery before starting full charging cycle. While charging the battery, by looking at battery voltage, current and temperature it selects optimal charging algorithm.

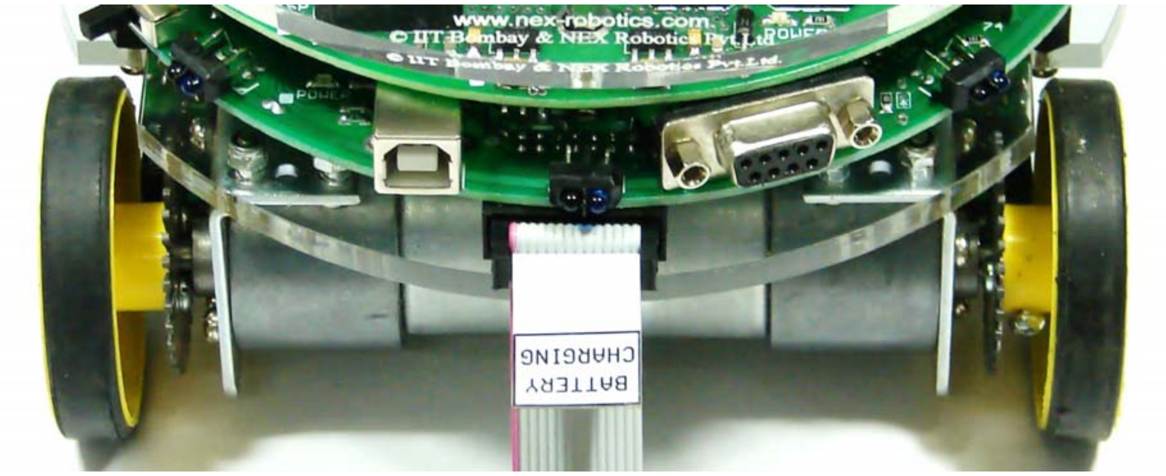

Figure 3.6: Connection for battery charging, Version 2 with robot Version 2

Figure 3.6 B: Connection for battery charging, using Battery charger version 2 with robot version 1

Battery Charging procedure for battery charger version 2:

1. Turn off the robot.
2. Connect AC adaptor in the mains. Connect AC adaptor’s output to the battery charger’s “AC Adaptor jack” connector as shown in figure 3.5 and turn on the adaptor. Battery charger’s power LED will turn on and red and green LEDs will blink twice.
3. Insert one end of the connector which is marked with the label “Battery Charging” in to the socket which is located at the back side of the robot as shown in the figure 3.6. Insert the other end of the connector in to “Battery Connector 1” of the battery charger as shown in the figure 3.5. To start the battery charging, press button marked with “Start

Push Button”. After a small delay green LED will turn on which indicates battery is being charged.

4. When battery is fully charged red and green status LEDs will blink alternately.
5. If there is any fault then charger will give different types of LED indication to indicate nature of fault. Refer to table 3.1 for interpretation of the LED status.

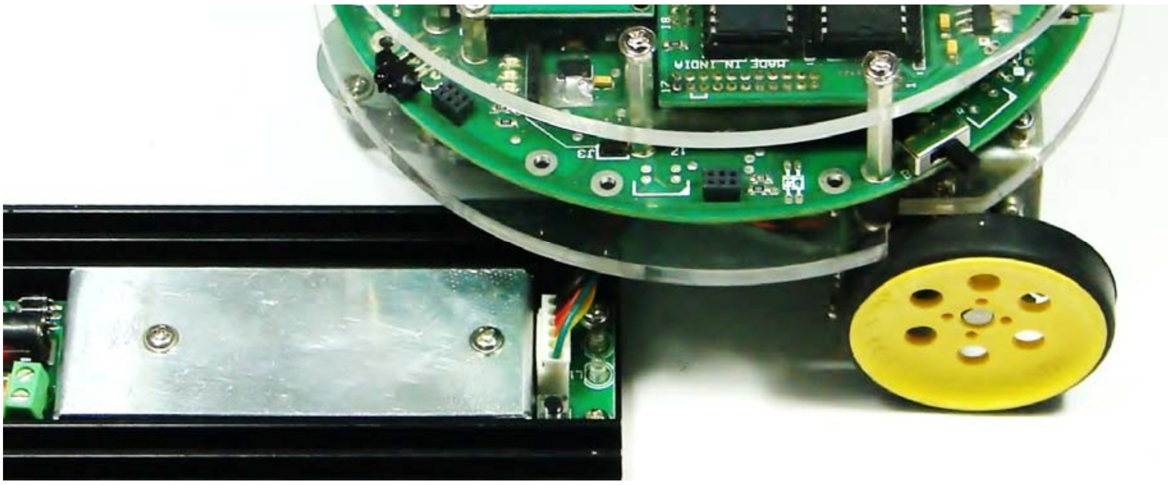

Figure 3.6C: Connection for battery charging, Version 1

Battery Charging procedure for battery charger Version 1:

1. Turn off the robot, disconnect battery connector from the main board.
2. Connect AC adaptor in the mains. Connect AC adaptor’s output to the battery charger’s “AC Adaptor jack” connector as shown in figure 3.5 and turn on the adaptor. Battery charger’s power LED will turn on and red and green LEDs will blink twice.
3. Insert Battery connector in the Battery Connector shown in the figure 3.5B. To start the battery charging, press button marked with “Start Push Button”. After a small delay green LED will turn on which indicates battery is being charged.
4. When battery is fully charged red and green status LEDs will blink alternately.
5. If there is any fault then charger will give different types of LED indication to indicate nature of fault. Refer to table 3.1 for interpretation of the LED status.

Indicator LEDs		**Battery Status**	**Charger Status**
Green	Red		
On	Off	Voltage < 11.4 V	Battery is getting charged
Off	Off	Charger idle	Charger is in idle state. Press “Start push button” to start charging
Off	On	Fault	Charge termination due to over current
On	On	Fault	Charge termination due to timeout
Alternate blinking		Fully charged	Battery is fully charged

Table 3.1 Battery charging indicator LED status

Note:

- If fault condition occurs, then wait for some time till battery is cooled down and start recharging again after some time. If problem persists then replace the battery.

- While battery is being charged robot will not turn on irrespective of the position of the power switch.

3.4 Powering the robot on battery power

To turn on the robot on the battery power, make sure that battery is connected to the robot and move the power switch towards forward direction (BP) as shown in the figure 3.3

3.5 Powering the robot on auxiliary power

Usually robot is powered by onboard battery. In order to do experiments for longer duration with out worrying about the battery getting low, robot can be powered by external power source which is also called as auxiliary power source. Auxiliary power source provides regulated 12V, 1Amp. Supply to the robot.

Figure 3.7: Robot Powering via Battery and Auxiliary supply, using battery charger version 2 for robot Version 2

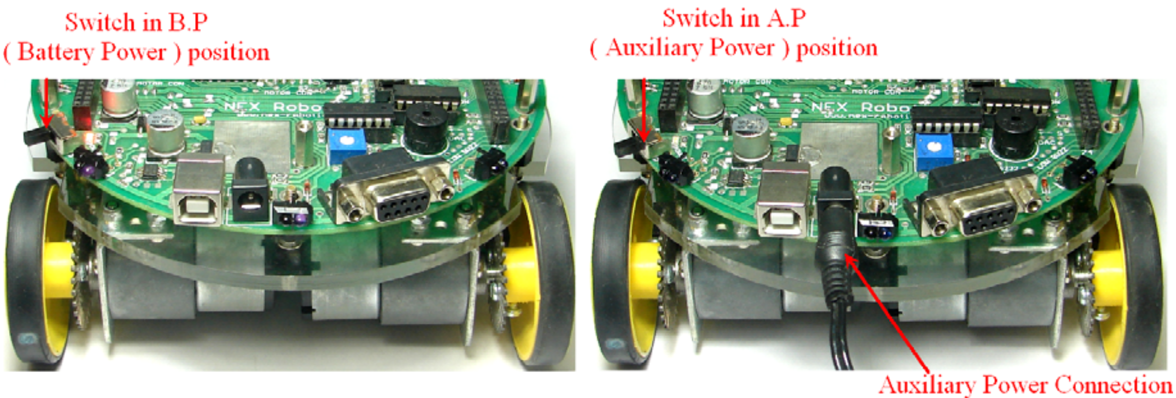

Figure 3.7B: Robot Powering via Battery and Auxiliary supply, using battery charger version 1 or battery charger version 2 on robot version 1

Figure 3.7C: Auxiliary power cable for battery charger version 2 accompanying robot version 1

To turn on the robot on the Auxiliary power use following steps:

1. Disconnect the battery by removing the battery connector from the main board which is located at the bottom side of the robot.
2. Move the power switch to the BP (refer to figure 3.3).
3. Insert the connector marked with the "Auxiliary Power" in the connector which is located at the back side of the robot as shown in the figure 3.7. Connect the other end of the connector to the "Battery Connector 1" on the battery charger (refer to figure 3.5) Connect the AC adaptor to the battery charger unit and turn on the power.
4. Now to turn on the robot move power switch towards "AP" (backwards) (figure 3.3).

⚠**Warning:**

Do not connect auxiliary power while battery is connected to the robot. In such case robot will either run on the battery if switch is in Battery Power mode ("BP" or forward direction) or in auxiliary power mode ("AP" or backward direction). Robot will not turn off.

For Version 1: Do not connect AC adaptor jack in the auxiliary power socket. Excess of voltage form the adaptor can damage the robot.

3.5B Battery Maintenance

Fully charged NiMh battery will get completely discharged with in a week. Always charge battery before use. If battery is charged after for about a month in the first charge it can deliver only 1/3rd power of its rating. To restore battery to its full potential again, perform at least 2-3 charge discharge cycles.

To ensure long life charge battery at least once a week and discharge it till robot starts giving battery low warning. Charge battery again. Repeat this cycle for atleast 2-3 times. For faster battery discharge load "Motion_Control_Simple" program which is located in the "Experiments" folder in the documentation CD. Loading the program on the robot is covered in the chapter 4 in the hardware manual or chapter 2 in the software manual.

3.6 Motion control

FIRE BIRD V robot has two DC geared motors for the locomotion. The robot has a top speed of 24cm/second. These motors are arranged in differential drive configuration. I.E. motors can move independently of each other. Front castor wheel provides support at the front side of the robot. Using this configuration, the robot can turn with zero turning radius by rotating one wheel in clockwise direction and other in counterclockwise direction. Position encoder discs are mounted on both the motor's axle to give a position feedback to the microcontroller.

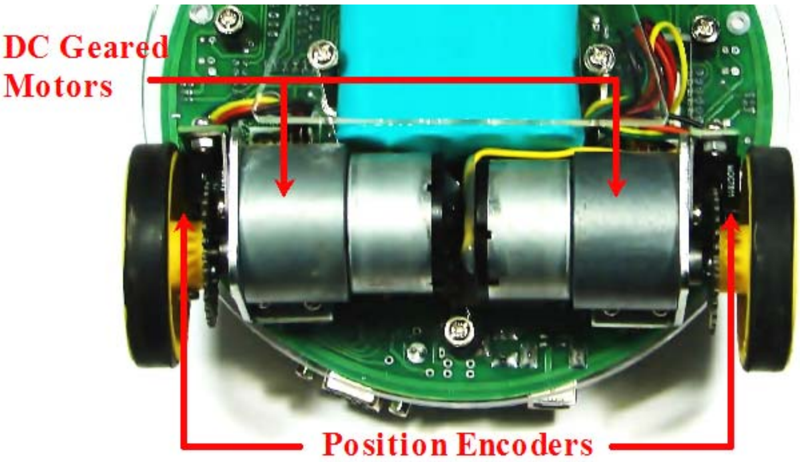

Figure 3.8: Motion Control

Robot's motors are controlled by L293D motor driver IC from ST Microelectronics. To change the direction of the motor, appropriate logic levels (High/Low) are applied to L293D's direction control pins. Velocity control is done using pulse width modulation (PWM). Single L293D can drive 2 DC motors. Fire Bird V has onboard two L293D ICs to drive four DC motors. Each channel of the motor driver IC can provide current up to 600mA to drive motor.

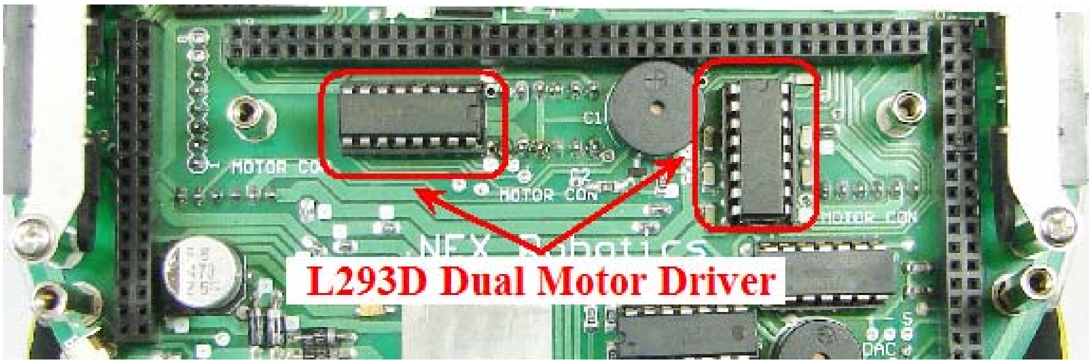

Figure 3.9: Motor Drivers

Pulse Width Modulation for velocity control:
Pulse width modulation is a process in which duty cycle of constant frequency square wave is modulated to control power delivered to the load i.e. motor.

Duty cycle is the ratio of **'T-ON/ T'**. Where **'T-ON'** is ON time and **'T'** is the time period of the wave. Power delivered to the motor is proportional to the **'T-ON'** time of the signal. In case of PWM the motor reacts to the time average of the signal.

PWM is used to control total amount of power delivered to the load without power losses which generally occur in resistive methods of power control.

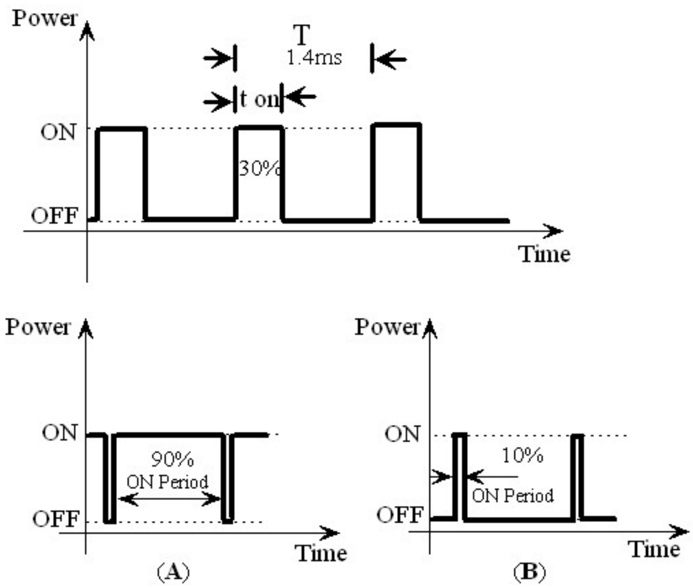

Figure 3.10: Pulse Width Modulation (PWM)

Above figure shows the PWM waveforms for motor velocity control. In case (A), ON time is 90% of time period. This wave has more average value. Hence more power is delivered to the motor. In case (B), the motor will run slower as the ON time is just 10% of time period.

For the Fire Bird V P89V51 RD2 version, logic level for the motor direction control is given in the table 3.3.

Microcontroller Pin	Function
P1.3 (CEX0)	Pulse width modulation for the left motor (velocity control)
P1.4 (CEX1)	Pulse width modulation for the right motor (velocity control)
P1.0	Left motor direction control
P1.1	Left motor direction control
P1.2	Right motor direction control
P3.4	Right motor direction control

Table 3.2 Motion control pin functionality

DIRECTION	**LEFT BWD (LB) P1.0**	**LEFT FWD(LF) P1.1**	**RIGHT FWD(RF) P1.2**	**RIGHT BWD(RB) P3.4**	**PWM**
FORWARD	0	1	1	0	As per velocity requirement
REVERSE	1	0	0	1	As per velocity requirement
RIGHT *(Left wheel forward, Right wheel backward)*	0	1	0	1	As per velocity requirement
LEFT*(Left wheel backward, Right wheel forward,)*	1	0	1	0	As per velocity requirement

SOFT RIGHT*(Left wheel forward,, Right wheel stop)*	0	1	0	0	As per velocity requirement
SOFT LEFT*(Left wheel stop, Right wheel forward,)*	0	0	1	0	As per velocity requirement
SOFT RIGHT 2 *(Left wheel stop, Right wheel backward)*	0	0	0	1	As per velocity requirement
SOFT LEFT 2 *(Left wheel backward, Right wheel stop)*	1	0	0	0	As per velocity requirement
HARD STOP	0	0	0	0	As per velocity requirement
SOFT STOP (Free running stop)	X	X	X	X	0

Table 3.3: Logic table for motor direction control

We can see all the commands given on the Bargraph LED display which is located at the top right side on the robot. Figure 3.11 shows the location and function of indicator LEDs related to motion control.

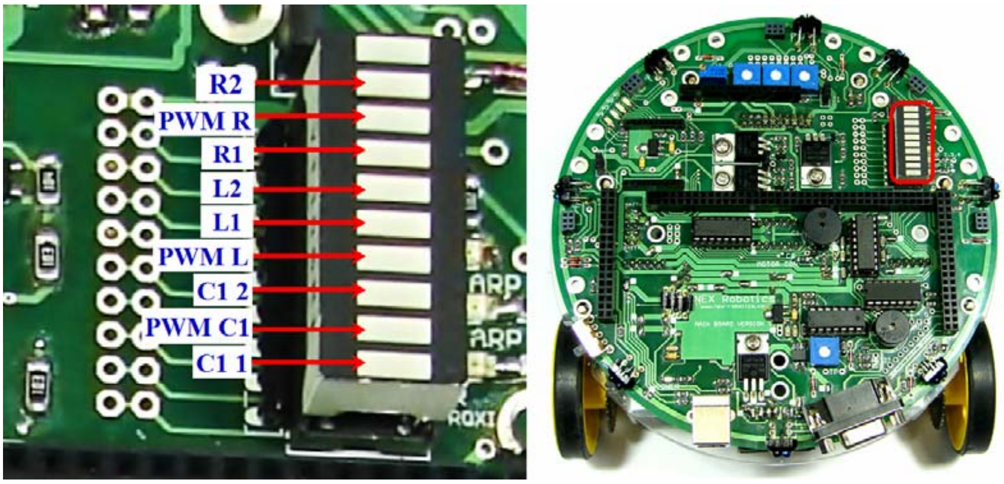

Figure 3.11: Motion status LED indication for P89V51RD2 microcontroller adaptor board for Fire Bird V

Important:
Auxiliary power can supply current up to 1 Ampere while Battery can supply current up to 2 Ampere. When robot is on auxiliary power and robot changes is direction suddenly from forward to backward or vice versa, it will cause large current surge and robot's microcontroller might get reset. This will happen repeatedly and you might think that problem is in the software. To avoid this problem use stop command for at least 0.5 second before changing direction. This problem will not occur when robot is on battery power and battery have sufficiently charge. But still it is a good practice to stop robot for 0.5 seconds before changing the direction to increase the life of the motor.

3.7 Position Encoders

Position encoders give position / velocity feedback to the robot. It is used in closed loop to control robot's position and velocity. Position encoder consists of optical encoder and slotted disc assembly. When this slotted disc moves in between the optical encoder we get square wave signal whose pulse count indicates position and time period indicates velocity.

Optical encoder MOC7811 is used for position encoder on the robot. It consists of IR LED and the photo transistor mounted in front of each other separated by a slot in the casing. When IR light falls on the photo transistor it gets in to saturation and gives logic 0 as the output. In absence of the IR light it gives logic 1 as output. A slotted encoder disc is mounted on the wheel is placed in between the slot. When encoder disc rotates it cuts IR illumination alternately because of which photo transistor gives square pulse train as output. Output from the position encoder is cleaned using Schmitt trigger based inverter (not gate) IC CD40106.

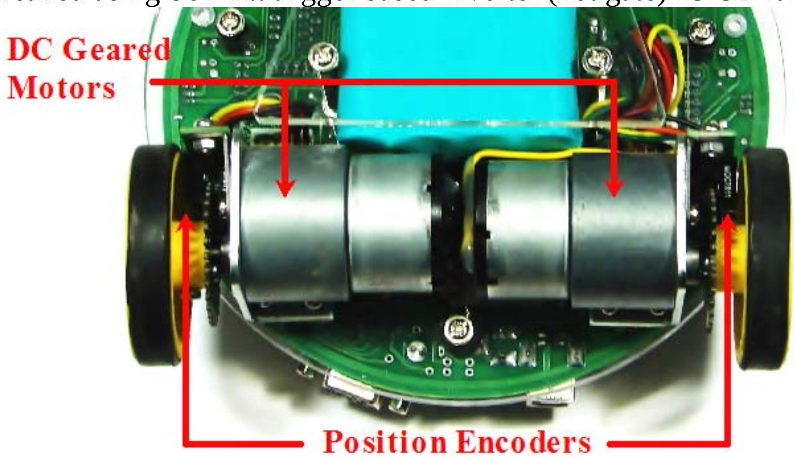

Figure 3.12: DC geared motors and position encoders

Figure 3.13: Position encoder assembly

Calculation of position encoder resolution:

Case 1: Robot is moving forward or backward (encoder resolution is in mm)

Wheel diameter: 5.1cm
Wheel circumference: 5.1cm * 3.14 = 16.014cm = 160.14mm
Number slots on the encoder disc: 30
Position encoder resolution: 163.2 mm / 30 = 5.44mm / pulse.

Case 2: Robot is turning with one wheel rotating clockwise while other wheel is rotating anti clockwise. Center of rotation is in the center of line passing through wheel axel and both wheels are rotating in opposite direction (encoder resolution is in degrees)

Distance between Wheels = 15cm

Radius of Circle formed in 360^0 rotation of Robot = Distance between Wheels / 2
= 7.5 cm

Distance Covered by Robot in 360^0 Rotation = Circumference of Circle traced
= 2 x 7.5 x 3.14
= 47.1 cm or 471mm

Number of wheel rotations of in 360^0 rotation of robot
= Circumference of Traced Circle / Circumference of Wheel
= 471 / 160.14
= 2.941

Total pulses in 360^0 Rotation of Robot
= Number of slots on the encoder disc / Number of wheel rotations of in 360^0 rotation of robot
= 30 x 2.941
= 88.23 (approximately 88)

Position Encoder Resolution in Degrees = 360 / 88
= 4.090 degrees per count

Case 3: Robot is turning with one wheel stationary while other wheel is rotating clockwise or anti clockwise. Center of rotation is center of the stationary wheel (encoder resolution is in degrees)

In this case only one wheel is rotating and other wheel is stationary so robot will complete its 360^0 rotation with stationary wheel as its center.
Radius of Circle formed in 360^0 rotation of Robot = Distance between Wheels
= 15 cm

Distance Covered by Robot in 360^0 Rotation = Circumference of Circle traced
= 2 x 15 x 3.14

= 94.20 cm or 942 mm

Number of wheel rotations of in 360^0 rotation of robot
= Circumference of Traced Circle / Circumference of Wheel
= 942 / 160.14
= 5.882

Total pulses in 360^0 Rotation of Robot
= Number of slots on the encoder disc / Number of wheel rotations of in 360^0 rotation of robot
= 30 x 5.882
= 176.46 (approximately 176)

Position Encoder Resolution in Degrees = 360 /176
= 2.045 degrees per count

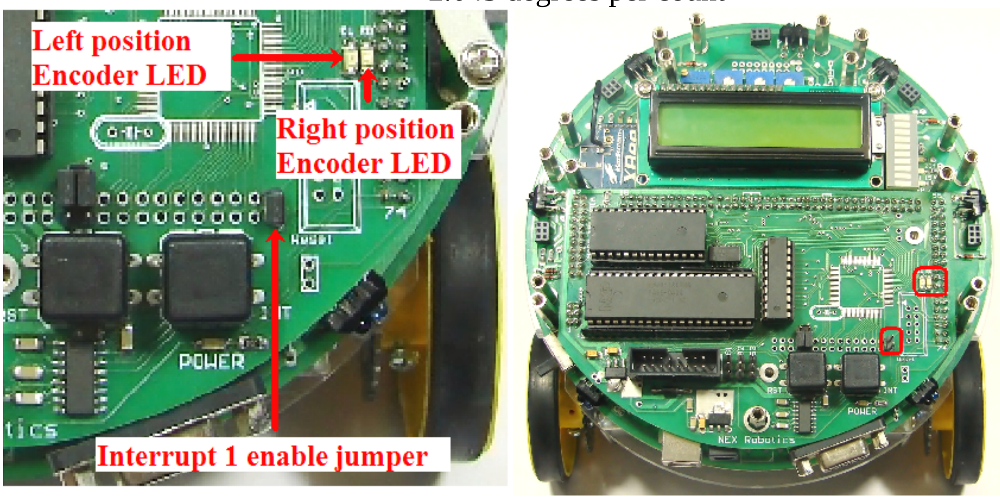

Figure 3.13: Jumper to enable left position encoder and position encoder LEDs on the P89V51RD2 microcontroller adaptor board

Pulses coming from the position encoders are indicated by two LEDs on the P89V52RD2 board as shown in figure 3.13

Important:
On the P89V51RD2 microcontroller board for Fire Bird V robot left encoder is connected to Interrupt 1 while right encoder is connected to Timer 1 input pin of the P89V51RD2 microcontroller. To enable left position encoder "Interrupt 1 enable" jumper needs to be connected, which connects output of the left position encoder with the Interrupt 1 of the microcontroller. For more details refer to chapter 8.

3.8 Sharp IR range sensors

For accurate distance measurement, robot uses Sharp IR range sensors. The robot can be fitted with five IR range sensors as shown in figure 3.14. Sharp IR range sensors consists of narrow IR beam for illumination and CCD array, which uses triangulation to measure the distance from any obstacle. A small linear CCD array is used for angle measurement. When light hits the obstacle and reflects back to the linear CCD array. Depending on the distance from the obstacle, angle of the reflected light varies. This angle is measured using the CCD array to estimate distance from the obstacle. It gives same response to different colored objects as measured distance is function of the angle of reflection and not on the reflected light intensity. Figure 3.15 shows the internals of the sensor. Figure 3.16 explains how change in the distance from the obstacle can be measured by measuring angle of reflection of light beam from the obstacle. Since sensor measurement is based on triangulation and not on intensity of the reflected light it is immune to disturbance caused by ambient light.

Sensor gives out analog voltage corresponding to angle of reflection. Relationship between the angle of reflection and output voltage is not linear because of trigonometry involved. Also these sensors can not cover initial range of 0 to some distance depending on the type of sensor. It is known as blind spot distance. In this range sensor gives incorrect readings. Table 3.4 gives information about sensing range and the blind spot distance for each sensor.

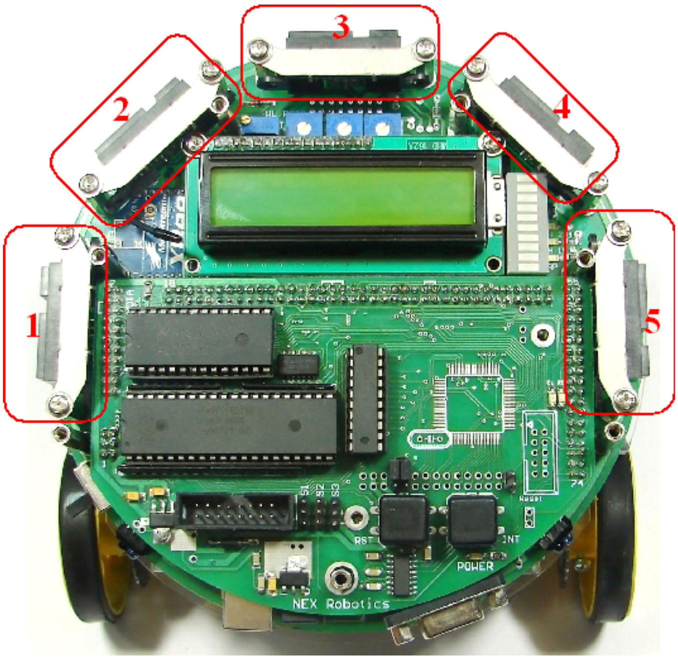

Figure 3.14: Sharp Sensors mounted on Fire Bird V

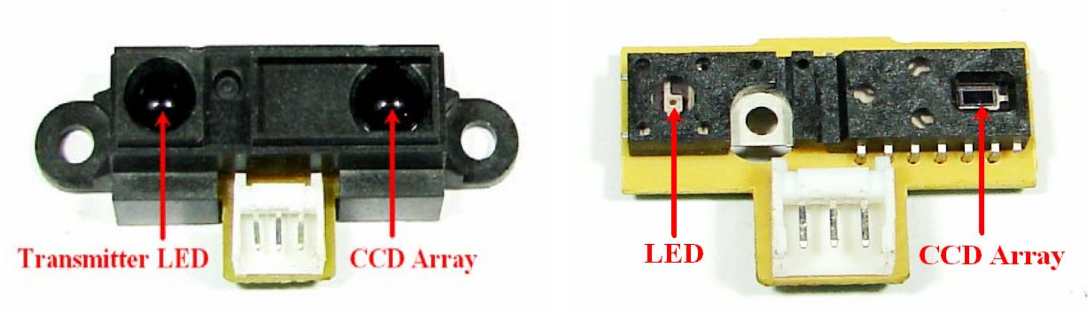

Figure 3.15: Infrared Range finder sensor and its inside view

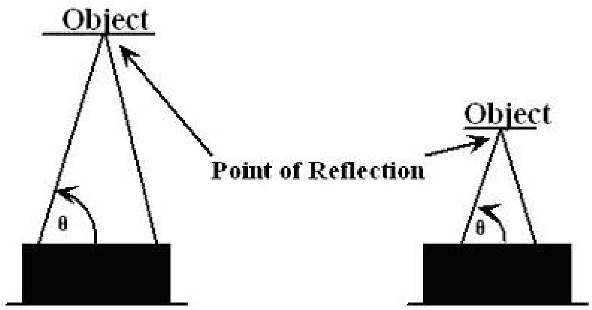

Figure 3.16: Distance measurement based on angel of reflection

Fire Bird V supports three types of IR range sensors from Sharp Microelectronics.

GP2D120 GP2D12 GP2Y0A02YK

Figure 3.17: Sharp IR Range sensors for Fire Bird V

Sensor	Range	Blind Spot
GP2D120X	30cm to 20cm	4cm to 0cm
GP2D12	80cm to 10cm	10cm to 0cm
GP2Y0A02	150cm to 20cm	20cm to 0cm

Table 3.4: Sharp IR Range sensors coverage

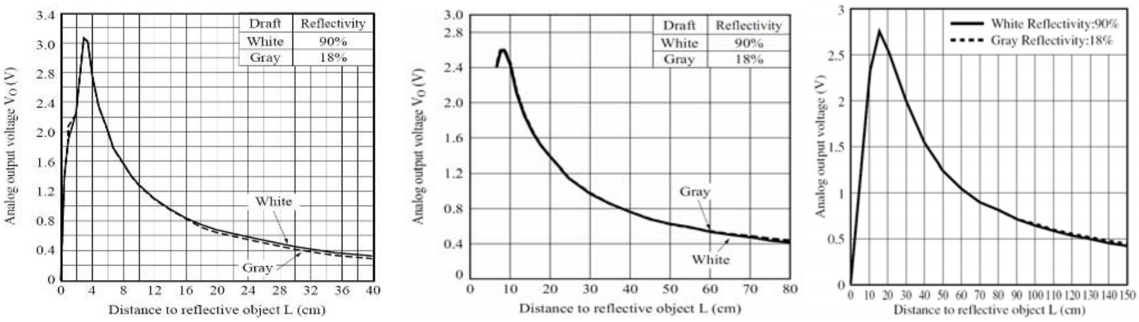

Figure 3.18: Distance Vs. Output voltage of GP2D120, GP2D12 and GP2Y0A02YK

Figure 3.18 shows the typical output character of the GP2D120, GP2D12 and GP2Y0A02YK sensors. In these graphs X axis represents distance from the obstacle and Y axis represents the output voltage. The sensor's output characteristic is slightly logarithmic in nature hence to get the distance in millimeters we have to use following formulas.

Distance in mm for GP2D120 = 10.00*((1.00/ ((0.001240875*(float) ADC value) + 0.005)) – 0.42)

Distance in mm for GP2D12 =
(int)(10.00 * (2799.6 * (1.00 / (float)((double)(ADC_Value)^(double)(1.1546)))));

Figure 3.14 shows locations of the Sharp IR range sensors on the robot. Each sensor consumes about 30mA current. If a sensor emits some signal and senses any object based on the reflected signal then it is known as active sensor. If many robots in the same field are using active sensors such as Sharp IR range sensors, IR proximity sensors or ultrasound sensors then they will interfere with the sensors of the other robots.

To prevent this interference from occurring Fire Bird V can switch all of its active sensors on and off. This means that many Fire Bird series robots can work in same field without causing interference with other Fire Bird robot's sensor. Many robots can synchronize when particular sensor should be turned on or off over wireless communication using ZigBee wireless modules. Another advantage of this feature is that robot can turn off these sensors when not in use to conserve power.

Note: For more details about the sensor interfacing, turning on /off the sensors, refer to section 8.3 in the chapter 8. It also shows the jumpers for the bypassing the MOSFET switches. You can also check weather particular sensor is on or off by looking at the LEDs which are located just right side of the bar graph LED display.

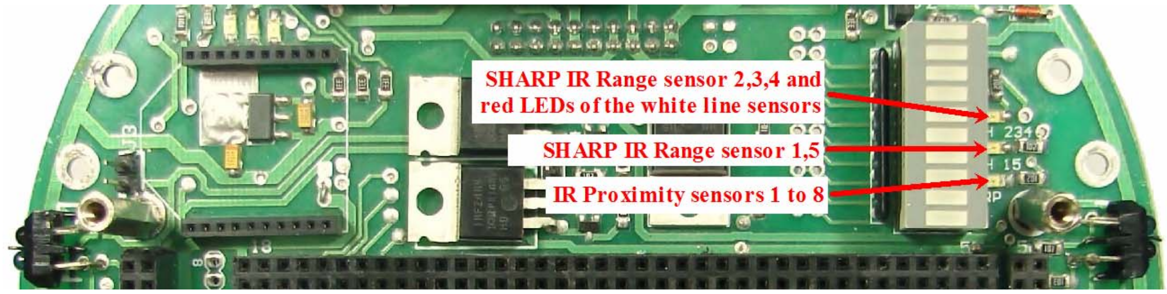

Figure 3.19: Sensor status indicator LEDs

Important:
Fire Bird V P89V51RD2 supports only one IR Range sensor (3ensor 3). In order to connect sensors 2 and 3 small modification needs to be done on the P89V51RD2 microcontroller board. To do these modifications refer to the section 8.3.3 from the chapter 8.

3.9 Infrared proximity and directional light intensity sensors

Infrared proximity sensors are used to detect proximity of any obstacles near the robot. Directional light intensity sensor gives intensity of the light in particular direction. IR proximity sensor consists of IR LED and IR photo diode. When obstacle comes within sensing range IR photo diode detects reflected light of the IR LED. To reduce interference with ambient light photo diode is cased in material which allows only IR light to pass. While sensing obstacle in order to eliminate interference due to ambient light, reading should be taken while IR LED is on and off. By comparing these two values effect of ambient light can be nullified. To detect directional light intensity, IR LED is turned off and light intensity at photo diode is measured. Fire Bird V has eight IR proximity sensors. IR LEDs of all these sensors can be turned on and off by MOSFET Q3. To turn on IR LEDs permanently J4 needs to be shorted. Refer to table 8.4 for more details.

In the absence of the obstacle there is no reflected light hence no leakage current will flow through the photo diode and output voltage will be around 5V. As obstacle comes nearer, more light gets reflected and falls on the photo diode and leakage current flowing through the photo diode starts to increase and voltage across the diode starts to fall.

When IR proximity sensors used in conjunction with Sharp IR Range sensors, IR proximity sensors covers sensing range in which Sharp IR Range sensors have blind spot. IR proximity sensors working together with Sharp IR range sensors covers range from 0 to maximum range of the Sharp IR sensor without having any blind spot.

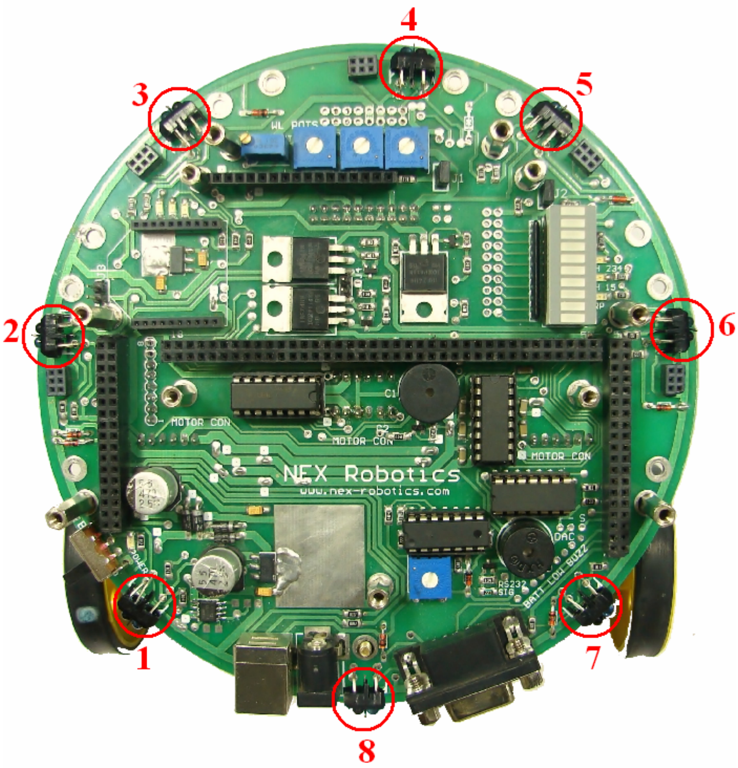

Figure 3.20: Eight IR proximity sensors on Fire Bird V

Note: Fire Bird V P89V51RD2 only supports IR proximity sensor number 3, 4 and 5.

3.10 White Line Sensor:

White line sensors are used for detecting white line on the ground surface. White lines are used to give robot sense of localization. White line sensor consists of a highly directional phototransistor for line sensing and red LED for illumination. Due to the directional nature of the phototransistor it does not get affected with ambient light unless it is very bright.

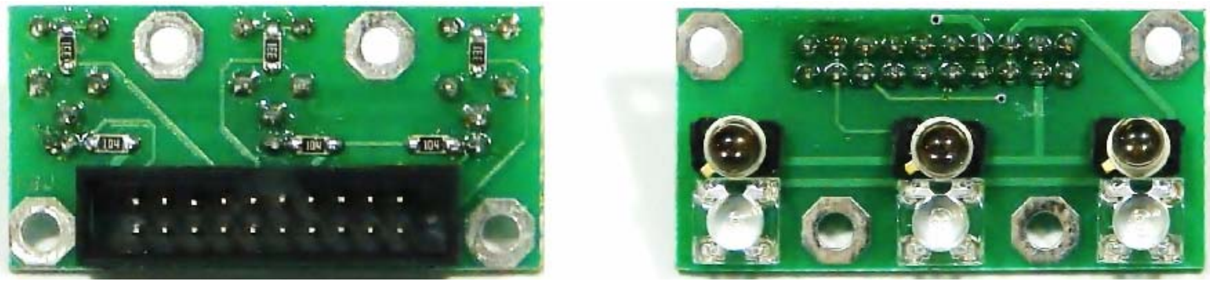

Figure 3.21: White line sensor

Figure 3.22: White Line sensor

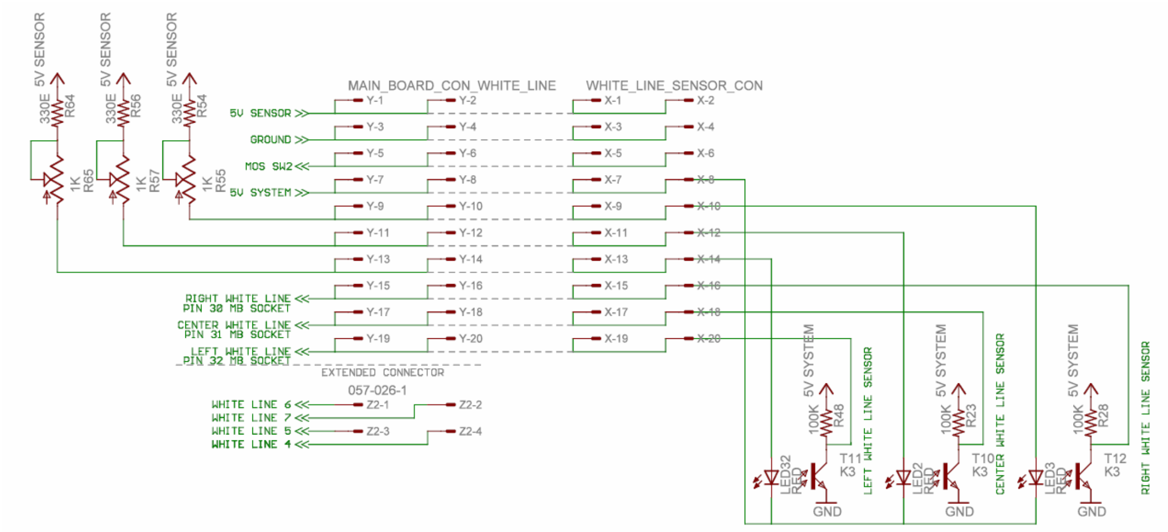

Figure 3.23: Schematic of the white line sensor

When the robot is not on a white line, amount of light reflected is less hence less leakage current flows through the photo transistor. In this case, the line sensor gives an output in the range of 2 volts to 5 volts. When the sensor is on a white line, more light gets reflected resulting in considerable increase in the leakage current and sensor's output voltage falls to 0.15 to 0.8 volts.

Power to the red LEDs is controlled by MOSFET which can be turned Off to extend robot's battery life. This feature is also very useful in advanced methods of line following in which reflected light intensity from the surface is measured while red LEDs are on and off to nullify the effect of the ambient light on the sensor reading. To turn on red LEDs permanently put jumper on J4. J4 controls power to the red LED of white line sensors 1, 2 and 3 and Sharp sensors 2, 3 and 4. Refer to the table 8.4 for more information on jumper settings. In case of Fire Bird V P89V51RD2 based robot these sensors are permanently enabled.

White line Sensor	ADC channel number
Left	ADC channel no. 4
Center	ADC channel no. 5
Right	ADC channel no. 6

Table 3.5 White line sensor connections with ADC in Fire Bird V P89V51RD2

White Line sensor calibration

By using trimming potentiometers located on the top center of the main board, line sensors can be calibrated for optimal performance. Line sensors are factory calibrated for optimal performance. Using these potentiometers we can adjust the intensity of the red LEDs of the white line sensor. Sensitivity adjustment is needed when color contrast between the white and non-white surface in a white line grid is sub-optimal. In such cases the sensors can be tuned to give maximum difference between white and non white surfaces. You can also turn on and turn off IR LEDs and take sensor readings at the same place and nullify the effect of the ambient light.

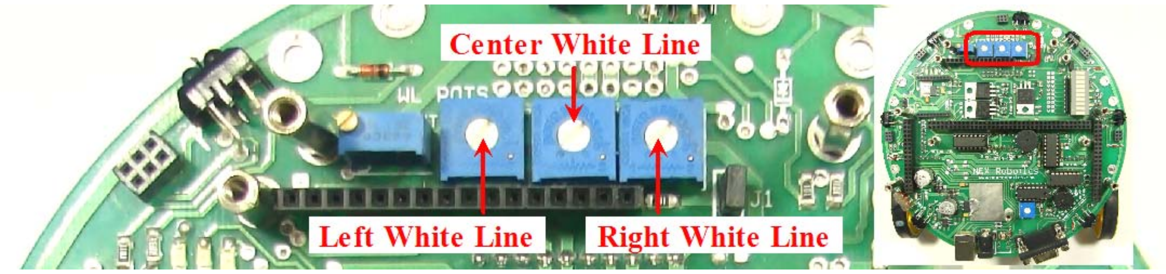

Figure 3.24: Potentiometers for white line sensor calibration

3.11 LCD Interfacing

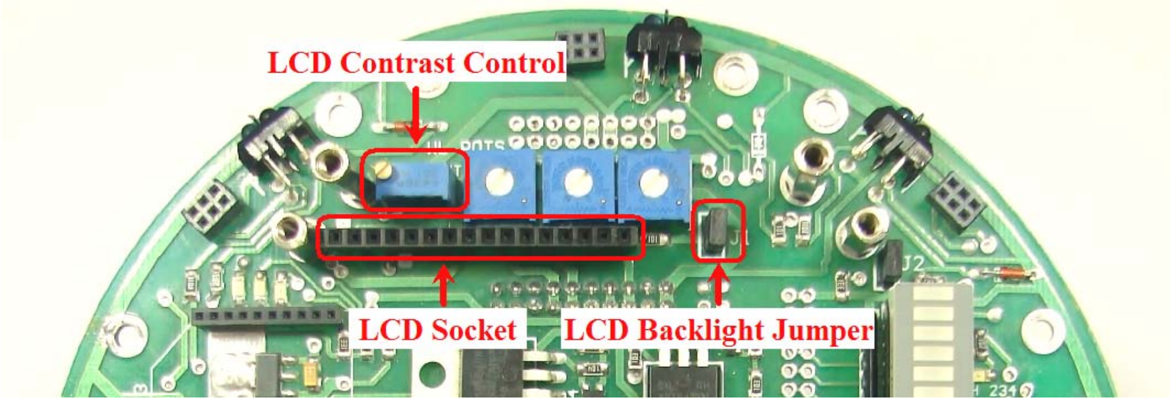

Figure 3.25: LCD socket and other settings

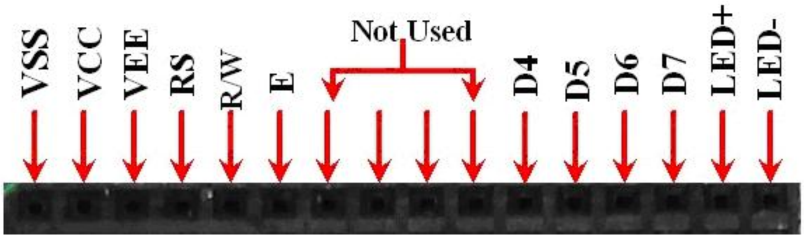

Figure 3.26: LCD socket pin connection

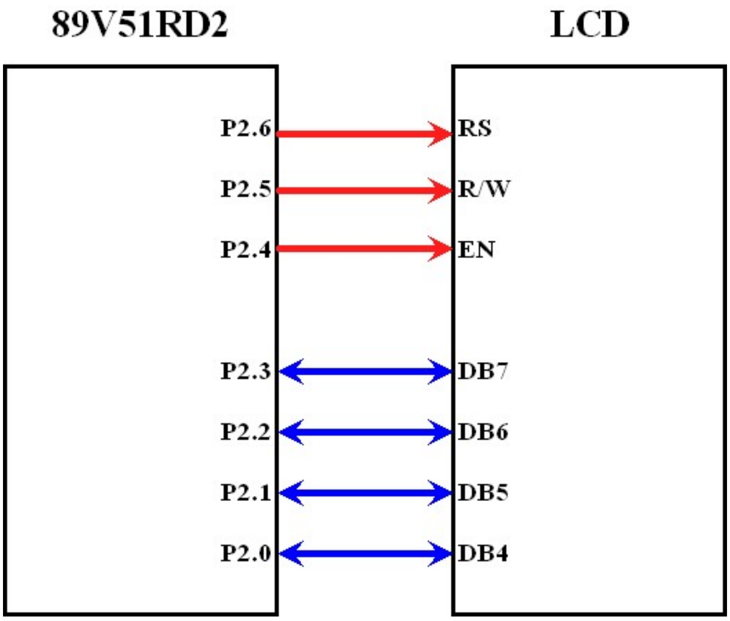

Figure 3.27 LCD interfacing with the microcontroller

Microcontroller	**LCD PINS**	**Description**
VCC	VCC	Supply voltage (5V).
GND	GND	Ground
P2.4	EN (Control line)	Enable
P2.5	-R/W (Control line)	-READ /WRITE
P2.6	RS (Control line)	Resistor select
P2.0 to P2.3	D4 to D7 (Data lines)	Bidirectional Data Bus
	LED+, LED-	Backlight control

Table 3.6 LCD Pin mapping and functions

Normally to interface LCD with the microcontroller requires 3 control signals and 8 data lines. This is known as 8 bit interfacing mode which requires total 11 I/O lines. To save number of I/Os required for LCD interfacing we can use 3 control signals with 4 data lines. This is known as 4 bit interfacing mode and it requires 7 I/O lines. We are using 4 bit interfacing mode to reduce number of I/O lines. In this mode higher nibble and lower nibble of commands/data set needs to be sent separately. Figure 3.27 shows LCD interfacing in 4 bit mode. The three control lines are referred to as EN, RS, and RW.

The EN line is called "Enable" and it is connected to PORT 2’s 5th pin (P2.4). This control line is used to tell the LCD that microcontroller has sent data to it or microcontroller is ready to receive data from LCD. This is indicated by a high-to-low transition on this line. To send data to the LCD, program should make sure that this line is low (0) and then set the other two control lines as required and put data on the data bus. When this is done, make EN high (1) and wait for the minimum amount of time as specified by the LCD datasheet, and end by bringing it to low (0) again.

The RS line is the "Register Select" line and it is connected to PORT 2's 7th pin (P2.6). When RS is low (0), the data is treated as a command or special instruction by the LCD (such as clear screen, position cursor, etc.). When RS is high (1), the data being sent is treated as text data which should be displayed on the screen.

The RW line is the "Read/Write" control line and it is connected to PORT 2's 6th pin (P2.5). When RW is low (0), the information on the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading from) the LCD.

The data bus is bidirectional, 4 bit wide and is connected to PORT2 (P2^0 to P2^3) of the microcontroller. The MSB bit (DB7) of data bus is also used as a Busy flag. When the Busy flag is 1, the LCD is in internal operation mode, and the next instruction will not be accepted. When RS = 0 and R/W = 1, the Busy flag is output on DB7. The next instruction must be written after ensuring that the busy flag is 0.

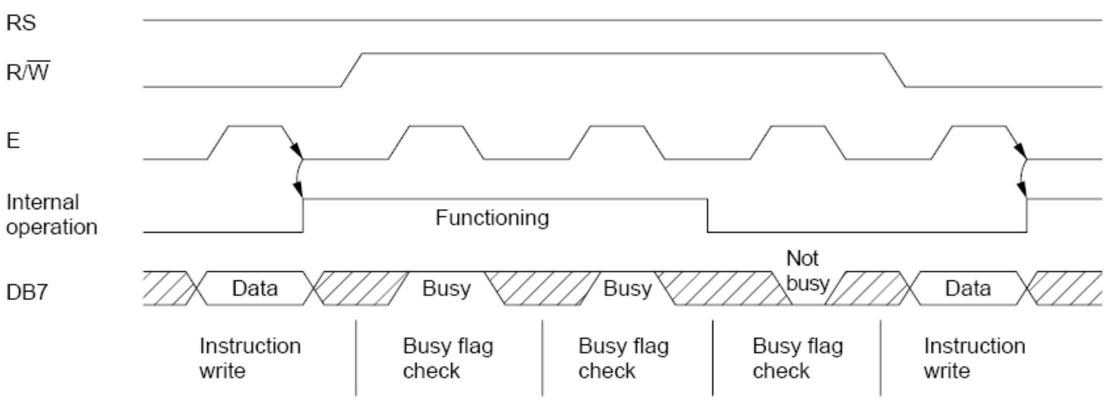

Figure 3.28: LCD Timing Diagram.

3.12 Buzzer

Robot has 3 KHz piezo buzzer. It can be used for debugging purpose or as attention seeker for a particular event. The buzzer is connected to PORT 2 at the 7th pin (P2.7).

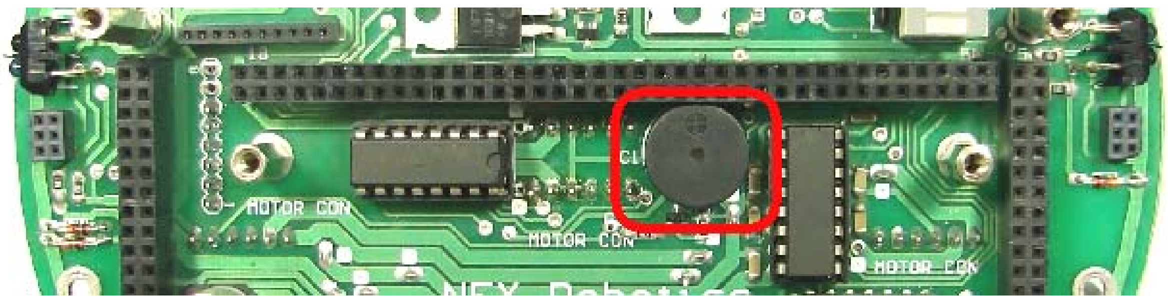

Figure 3.29: Buzzer

4. Loading Firmware on Fire Bird V

Programming Fire Bird V P89V51RD2 Robot

Fire Bird V P89V51RD2 robot programming involves two steps. First step is to write and compile the code and generate the "*.hex" file. Second step is to load this "*.hex" file on the microcontroller using Flash Magic software provided by NXP (formerly Phillips)

We are going to use Keil-U-Vision (Version 3) software for writing the code for the microcontroller. We can also use any other open source or proprietary software supporting P89V51RD2 microcontroller. Fire Bird V CD contains free version of the uVision 3 software. You can also download latest version from http://www.keil.com/dd/chip/3711.htm and click C51 Evaluation Software

4.1 Steps for writing program in uVision3

Figure 4.1

Step 1: Start with Keil-U-Vision

Go to project and start new project.

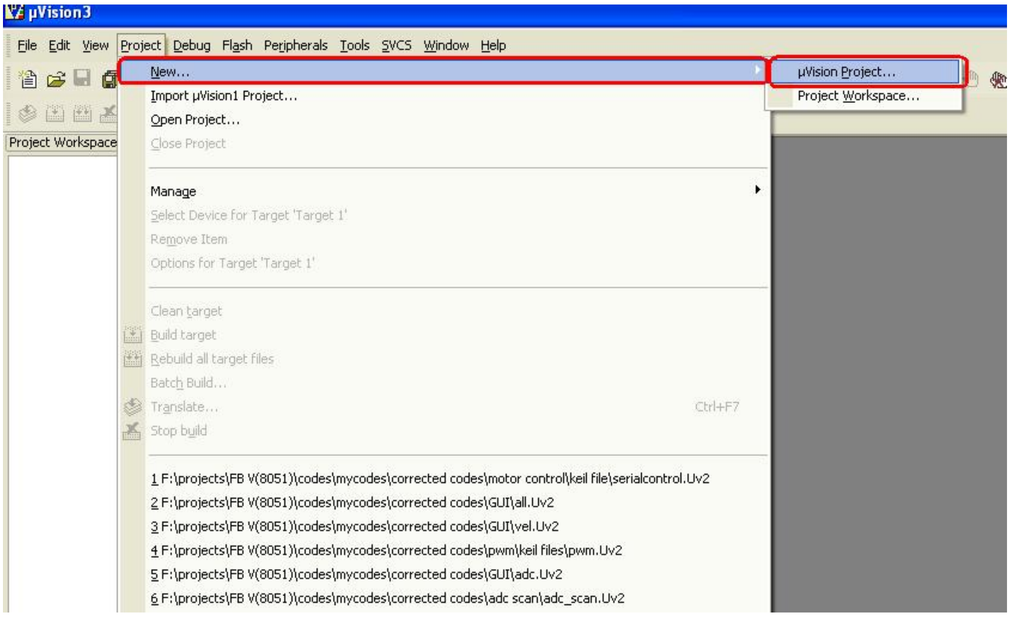

Figure 4.2

Step 2: Name your project and save it in your project folder. (always create new folder for new project)

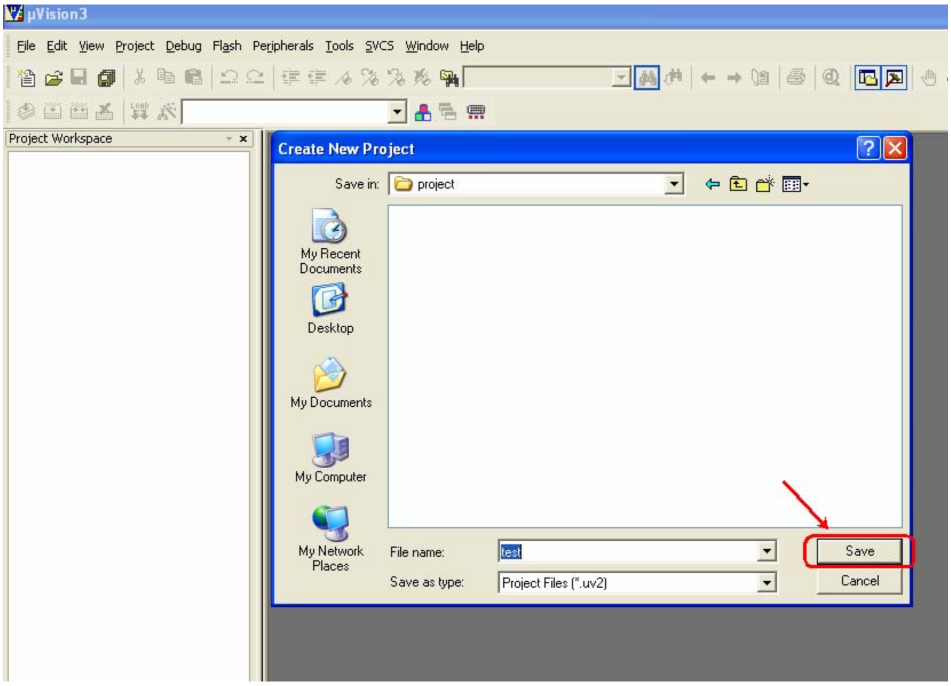

Figure 4.3

Step 3: A dialogue box will open asking you to select your device used. Select the appropriate device for e.g. P89V51RD2.Then click OK. P89V51RD2 can be found in the NXP (founded by Philips) directory.

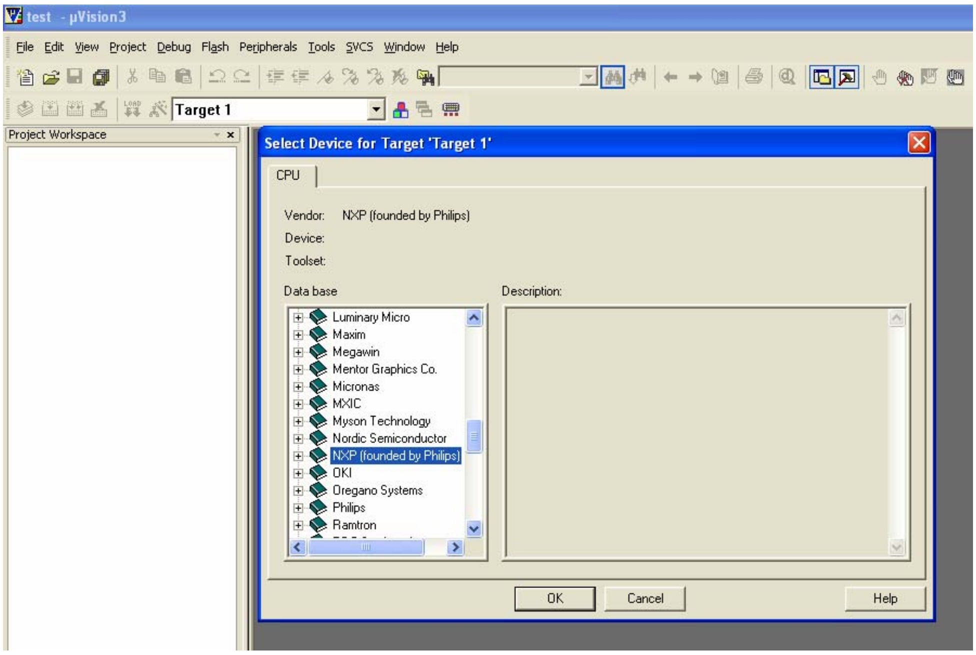

Figure 4.4

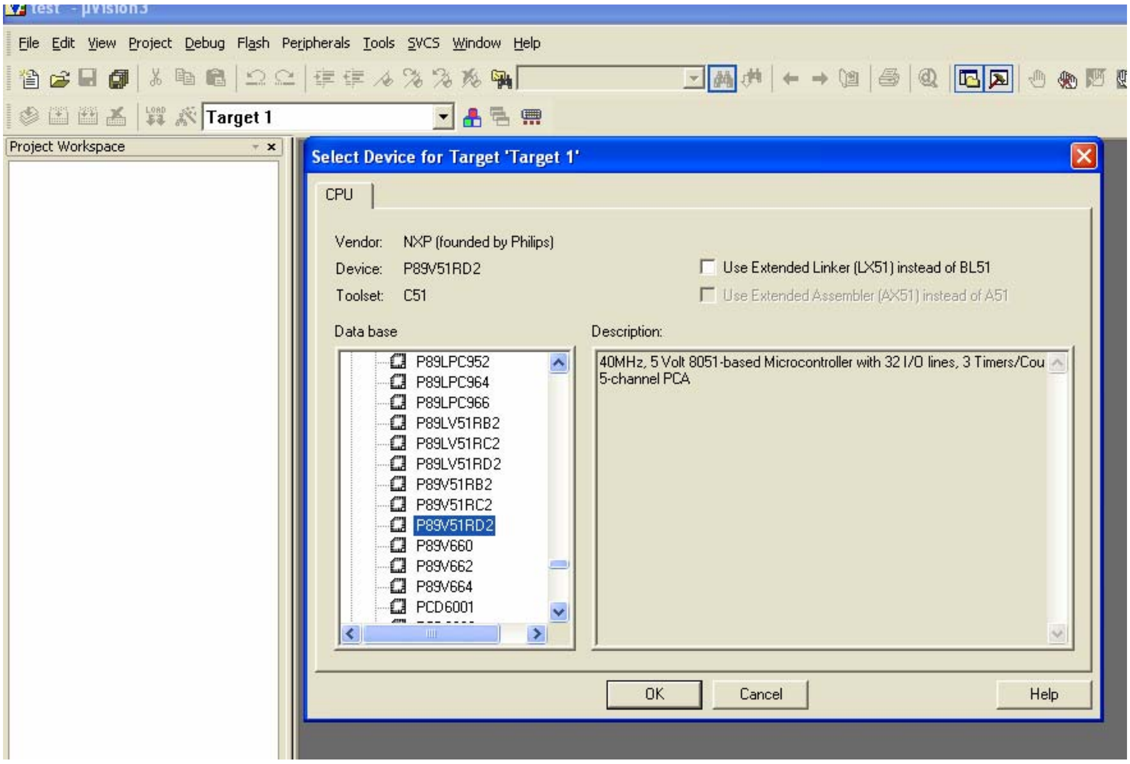

Figure 4.5

Step 4: Next it will ask you if you want to add the A51STARTUP code. Say “NO”,

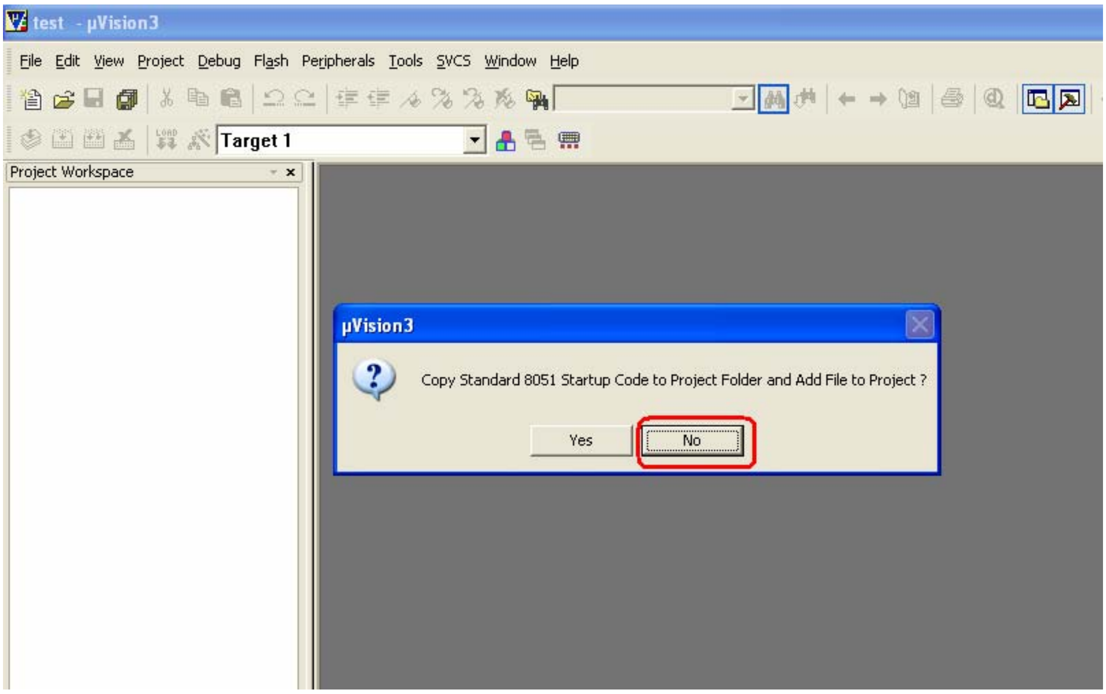

Figure 4.6

Step 5: In the Project Workspace right click on 'Target 1' and select options for target as shown. A dialogue box to choose different options will open.

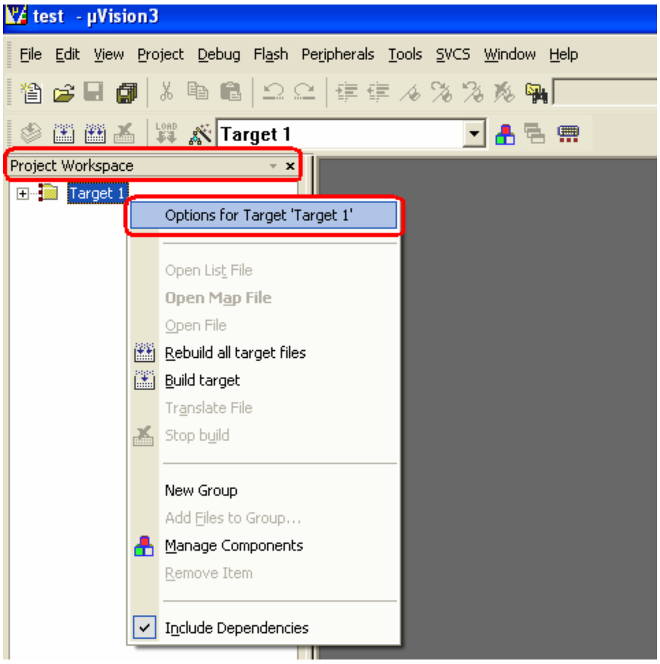

Figure 4.7

Step 6: Click on the the 'Target' tab. Enter the frequency of the crystal. For FIRE BIRD V its 11.0592 MHZ.

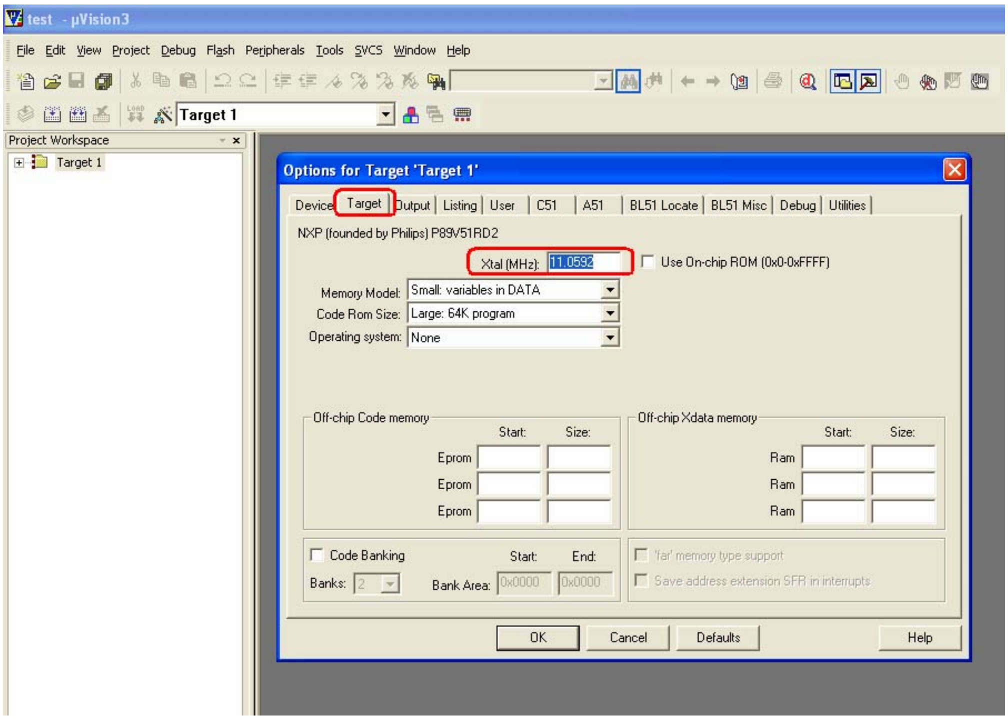

Figure 4.8

Step 7: Go to the output tab and tick on the file to create HEX-file. Then click OK to save your options. Other tabs can be left with the default options.

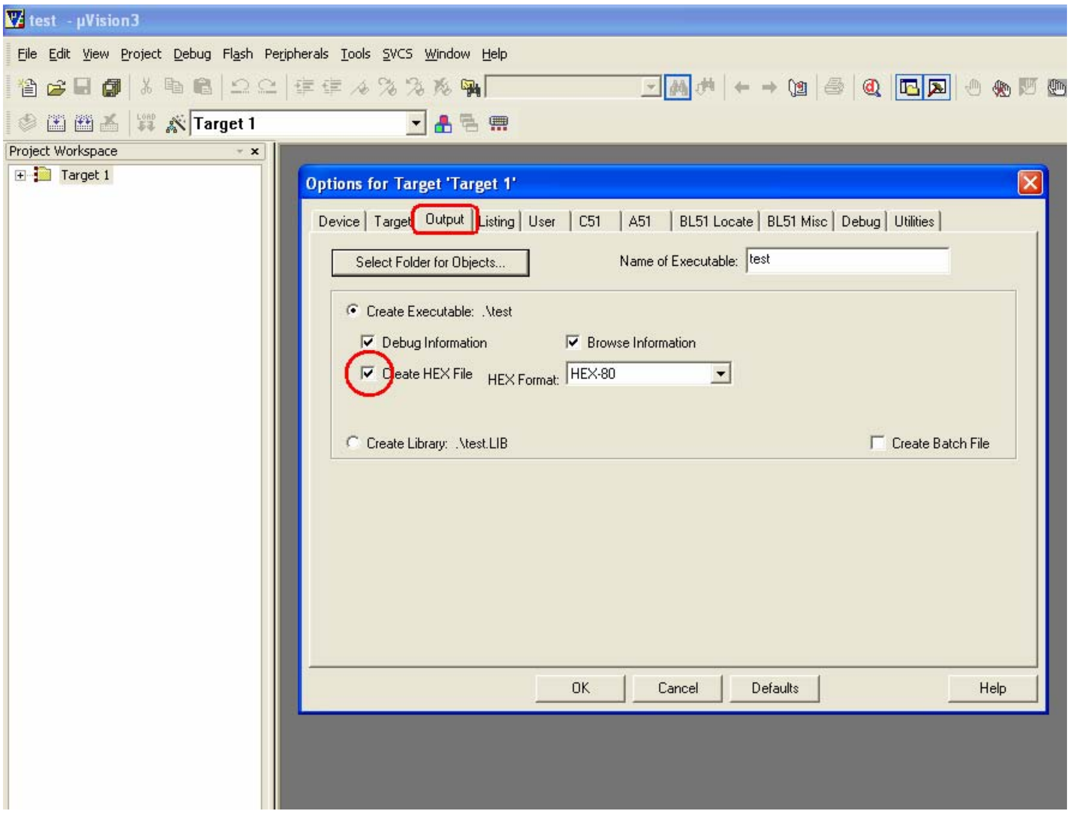

Figure 4.9

Step 8: After this is done, open a new file and save it with the project file as a C file i.e. with the extension ".c".

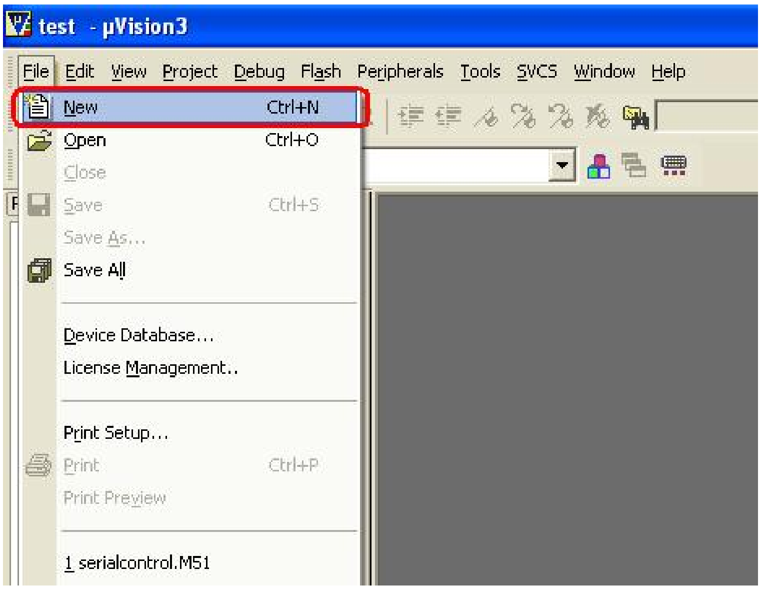

Figure 4.10

Step 9: Add this file to the project by Right-clicking on “Source Group” and choosing to add files to group. Select the appropriate ‘.C’ file to be added.

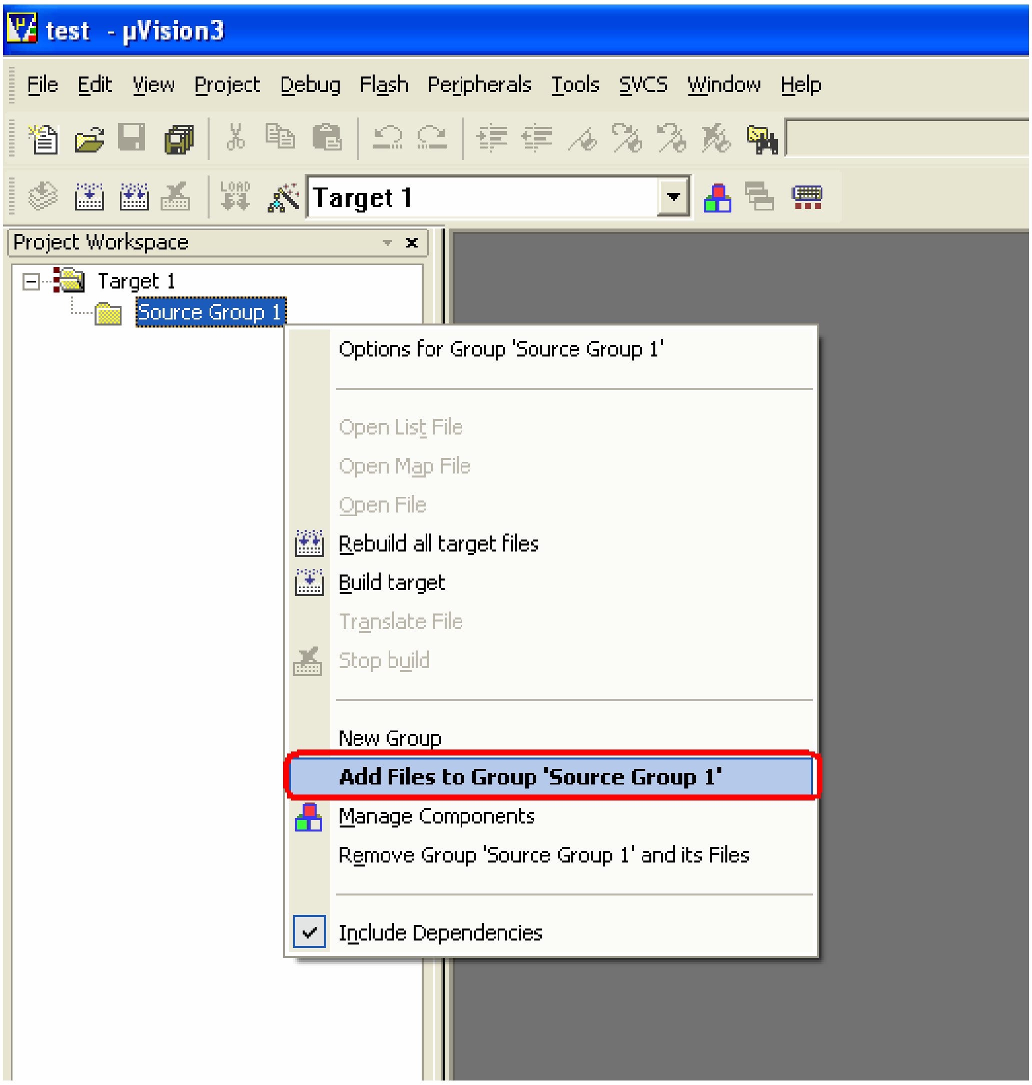

Figure 4.11

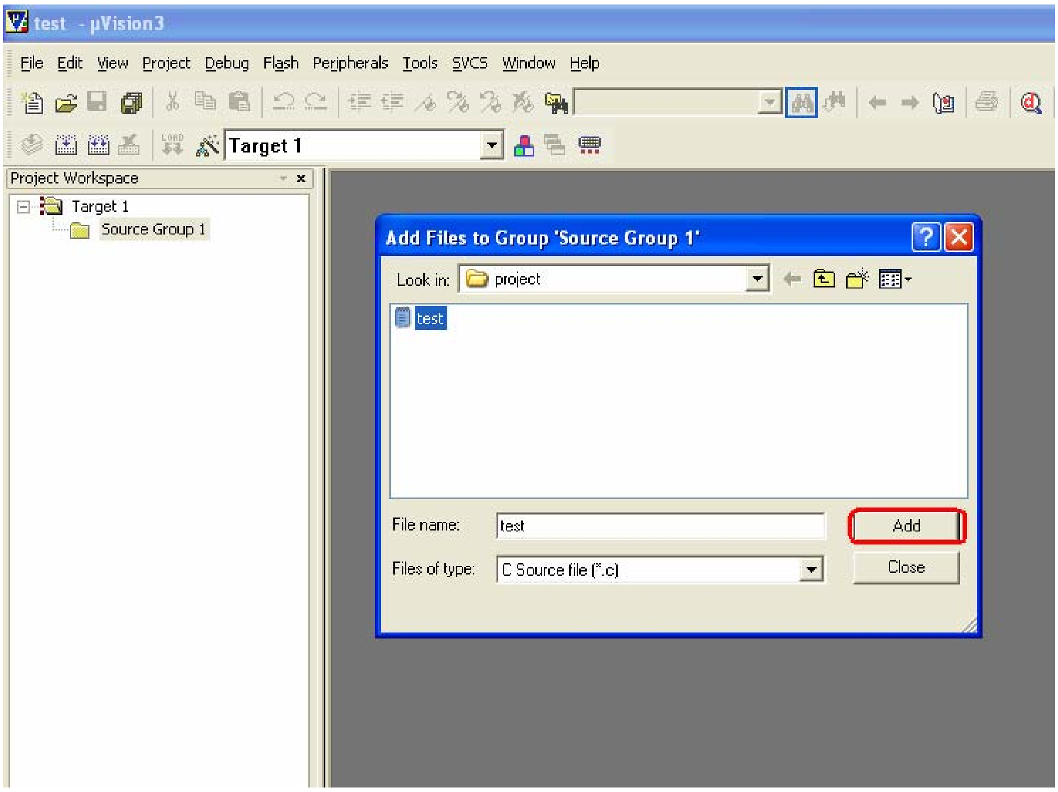

Figure 4.12

Step 10: You can write macros and save them with an ".h" extension and add them to your project files. Write your 'C' code and save the file.
Add (write): #include <intrins.h>
Add (write): #include "p89v51rx2.h"

Add (write): #include "lcd_array_disp.h" If you want to display Data of LCD display. It is covered in chapter 6 in the software manual.

Copy file: 'p89v51rx2.h' from the folder 'Experiments' from the documentation CD and paste it in your existing project folder before building target.

If you want to display Data of LCD display Copy file: 'lcd_array_disp.h' from the folder 'Experiments' from the documentation CD and paste it in your project folder before building target.

Note: A declaration with the following syntax **#include** <intrins.h> would direct the compiler to look for the **.h** file in its own parent directory whereas the syntax **#include "**intrins.h**"** would direct the compiler to search for the **.h** file in the parent directory where the current project is stored. Therefore the double quotes **" "** are used to declare the files specific to the Microcontroller chip and its peripherals where as < > are used to declare more generic files which are compatible with multiple chips

Copy following code in your ‘C’ (#include <intrins.h> and #include "p89v51rx2.h" are already written in the ‘C’ file)

```
//code for buzzer beep

#include <intrins.h>
#include "p89v51rx2.h"

sbit buzzer=P2^7;  //buzzer = 1; buzzer off, buzzer = 0; buzzer on,

// function for giving a delay of ms milliseconds
void delay_ms(unsigned int ms)
{
unsigned int i,j;

for(i=0;i<ms;i++)
for(j=0;j<53;j++);

}

void main (void)
{

while(1)
{
buzzer=0;               //switch ON the buzzer
delay_ms(100);          //give delay of 100 milliseconds
buzzer=1;               //switch off the buzzer
delay_ms(100);
}
}
```

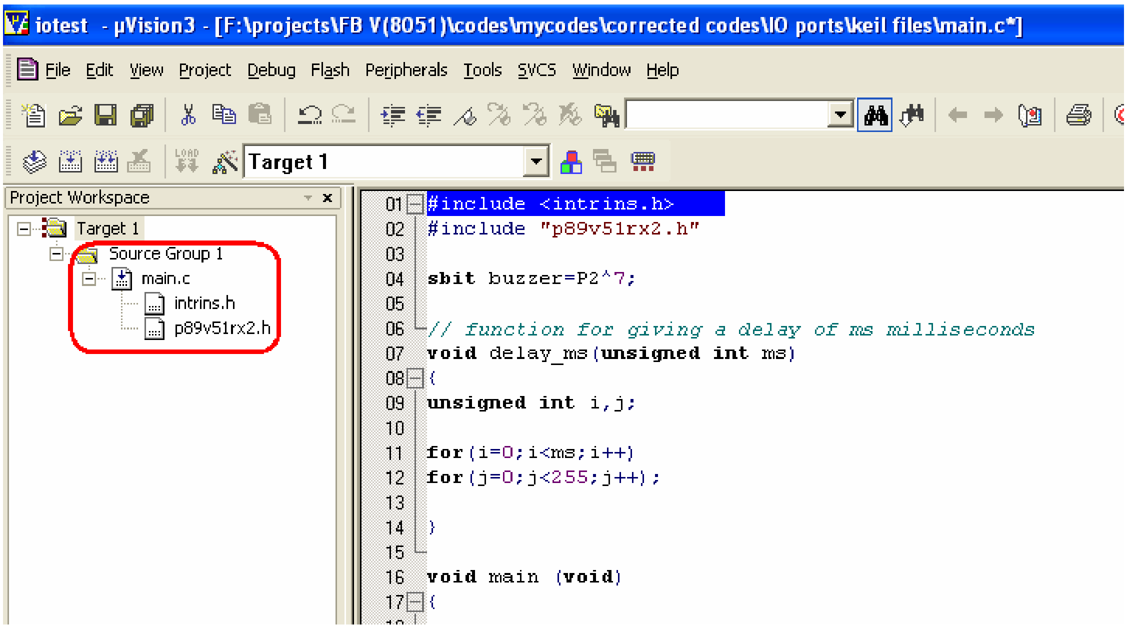

Figure 4.13

Step 11: Now click on the “Project” tab and choose to “Build Target” as shown.

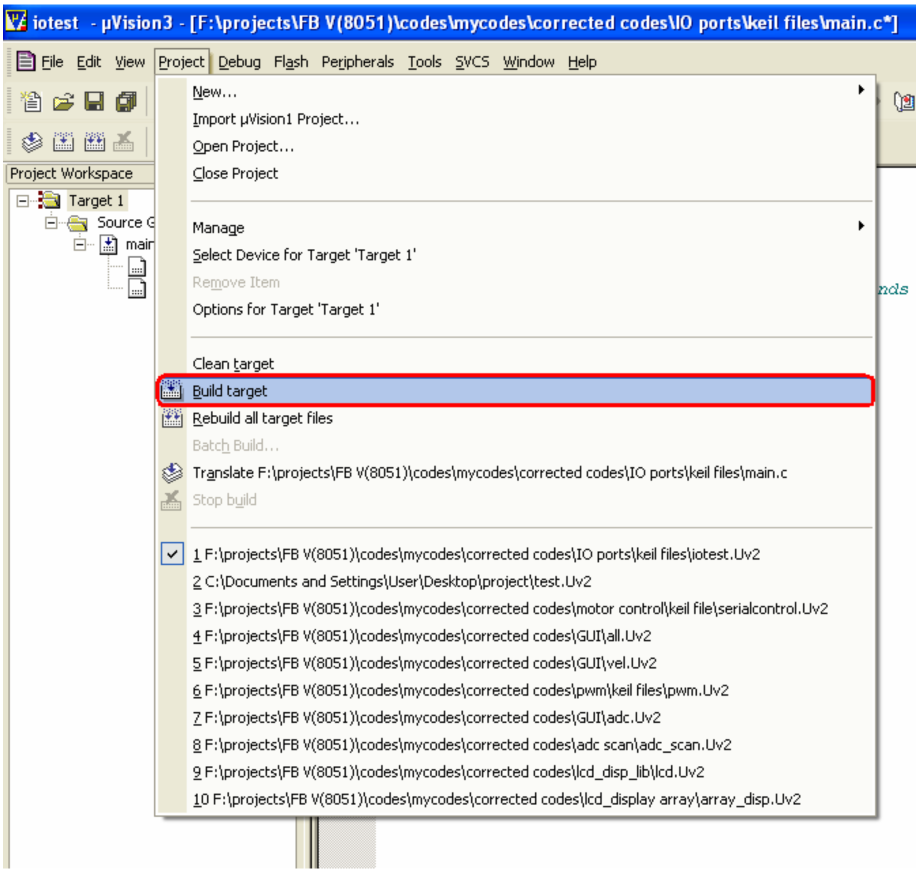

Figure 4.14

- Check for any errors in the 'Output Window'.
- If there are no errors then 'Hex' file will be created and stored in the Project folder.
- You can then download this file onto your microcontroller using the In System Programming (ISP) software i.e. using flash tools like Flash Magic or FLIP or parallel programming as supported by your microcontroller.

Note: Use 'rebuild all target files' option if you are including multiple header files

⚠**Warning:**
You need to set jumpers to select wired RS232 option between wired RS232 and Wireless communication options before loading hex file on the robot.

Make sure that jumper is configured to enable RS232 serial communication. Jumpers should be in the position as shown in the Figure 2.15.

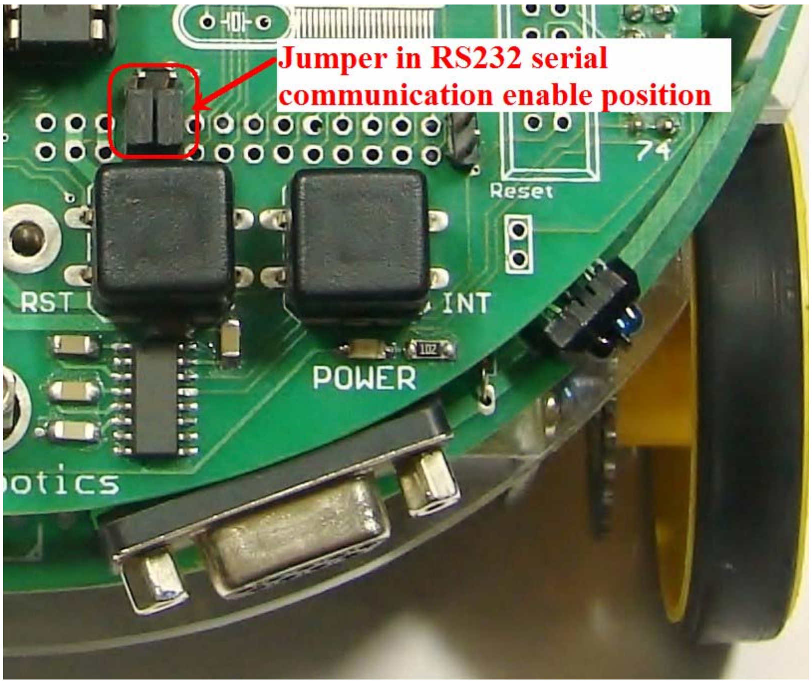

Figure 4.15: Enabling RS232 communication

4.2 Loading the generated Hex file on the microcontroller using Serial Port

Figure 4.16

Flash Magic is Windows software which allows easy access to all the In System Programming (ISP) features provided by the devices.

These features include:
• Erasing the Flash memory (individual blocks or the whole device)
• Programming the Flash memory
• Reading Flash memory
• Reading the signature bytes
• Reading and writing the security bits
• Direct load of a new baud rate (high speed communications)
• Sending commands to place device in Boot loader mode

Flash Magic provides a clear and simple user interface to these features

Step 1: Go to '*Flash Magic'* Icon, it will open the main window as show below.

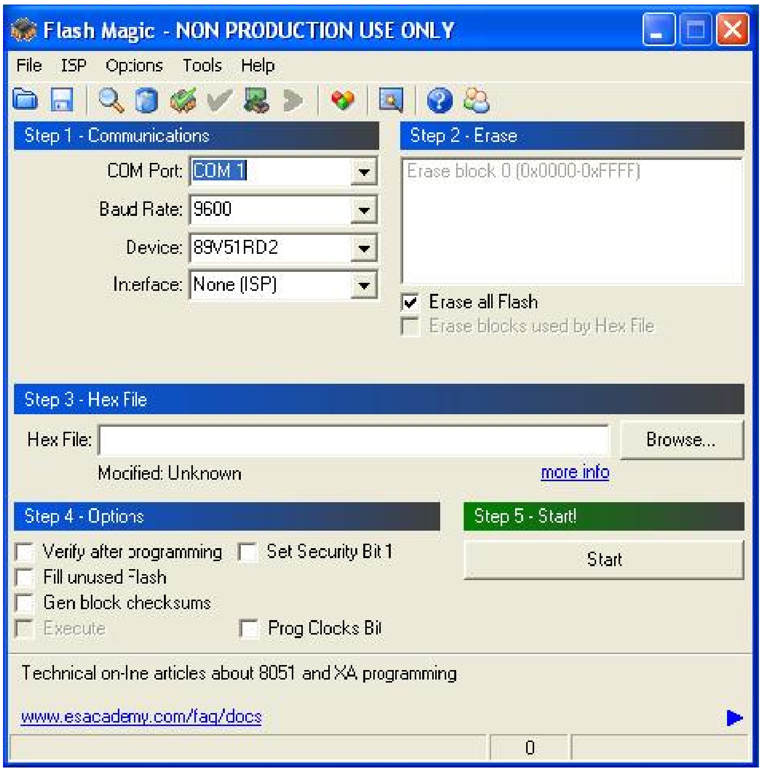

Figure 4.17

In main window you can see five types of sections.

- Communications
- Erase
- Hex File
- Options
- Start

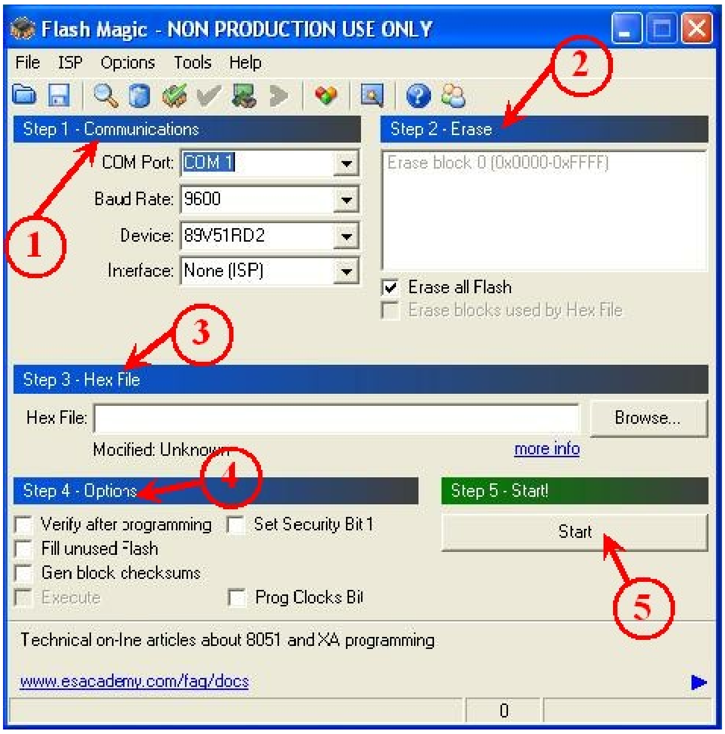

Figure 4.18

Step 2: Go to "*Option*" in the toolbar, and select first menu '*Advance options*.'

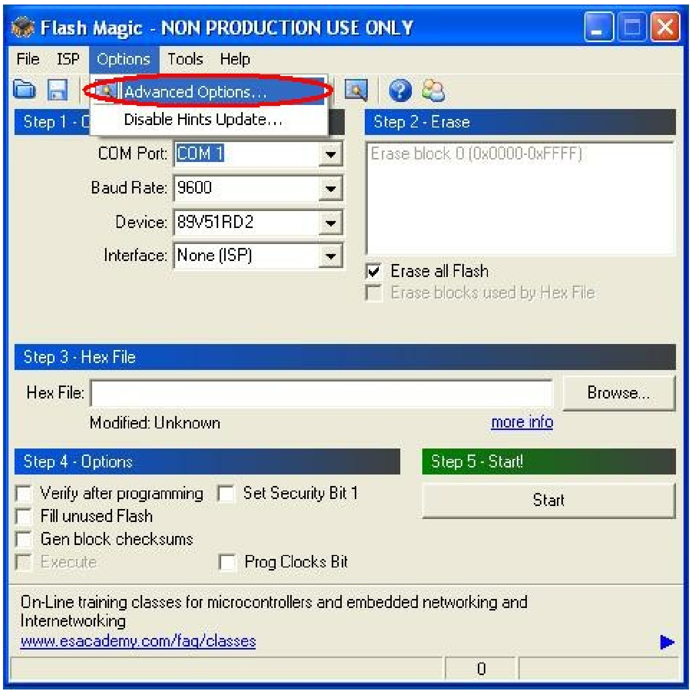

Figure 4.19

It will show you extracted window with many options.

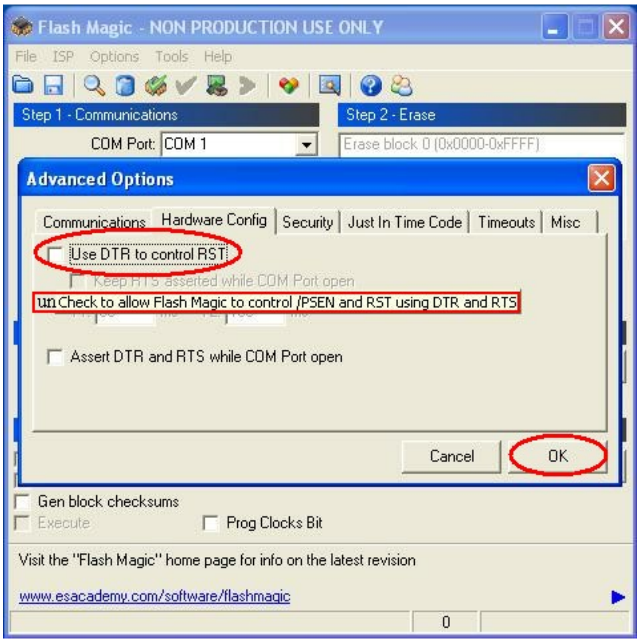

Figure 4.20

Uncheck the box which is highlighted to don't allow Flash Magic to control PSEN & RST using DTR & RTS.

Step 3: Now go for Communication selection, select '*COM 1*' from '*COM PORT*' Option if you are using serial port. If you are using USB to serial converter from NEX Robotics then find out COM port number with the help of documentation provided with the USB to serial converter.

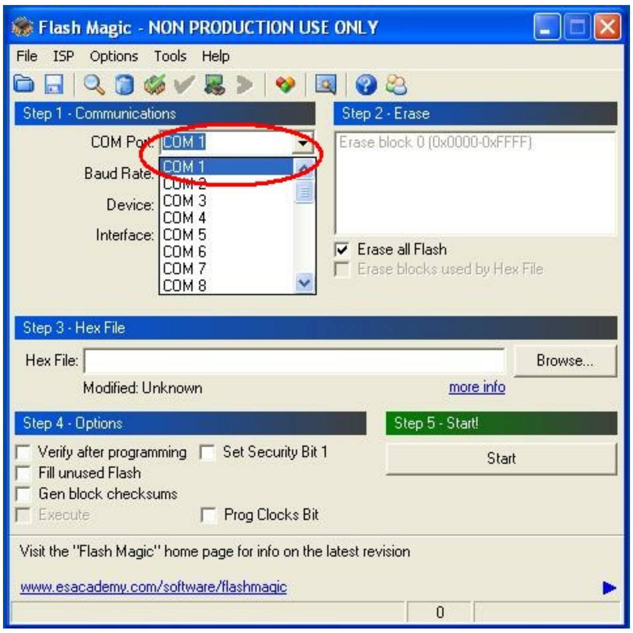

Figure 4.21

Select '*Baud Rate*' 9600 from Baud Rate option.

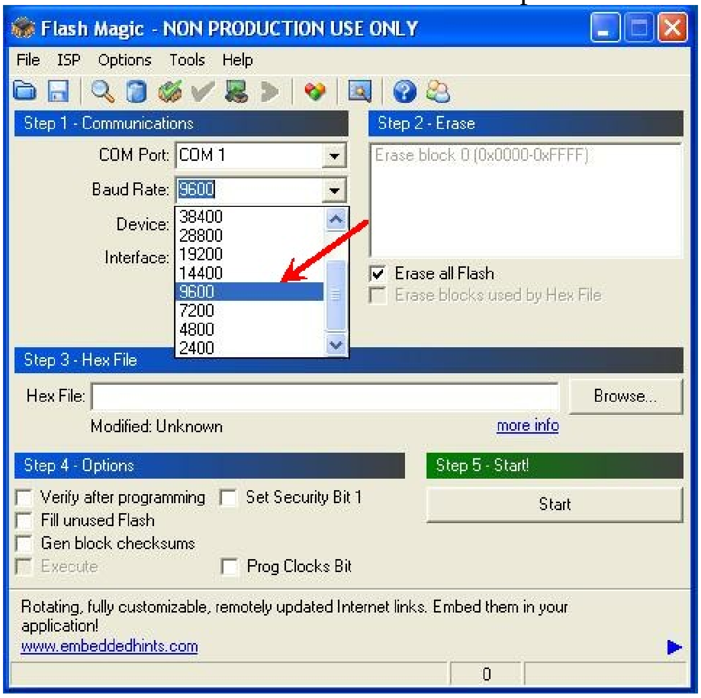

Figure 4.22

Select proper Device '*89V51RD2*' from Device option.

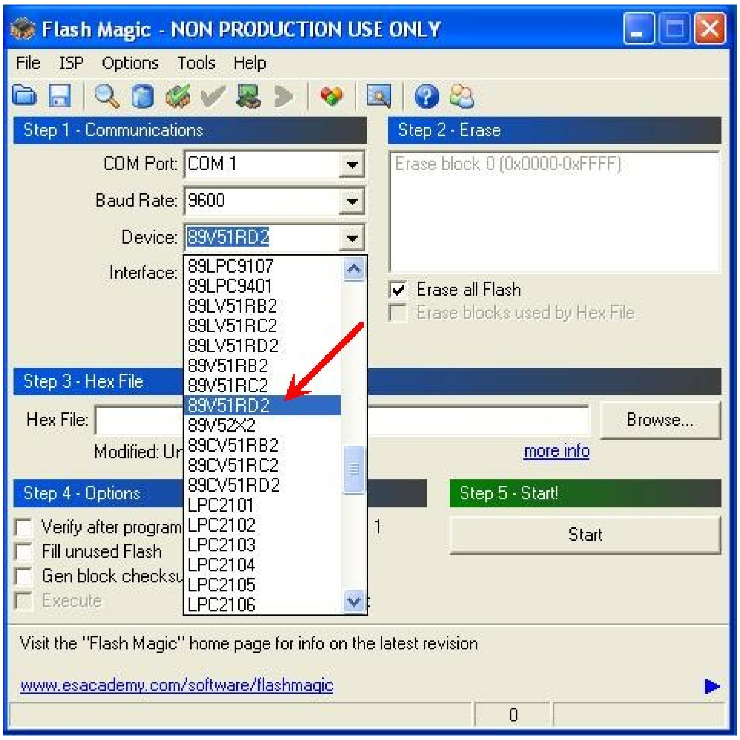

Figure 4.23

Step 4: Go to ‘*Erase*’ section for erasing the all ‘*Flash’* or Blocks used by ‘*HEX File’*

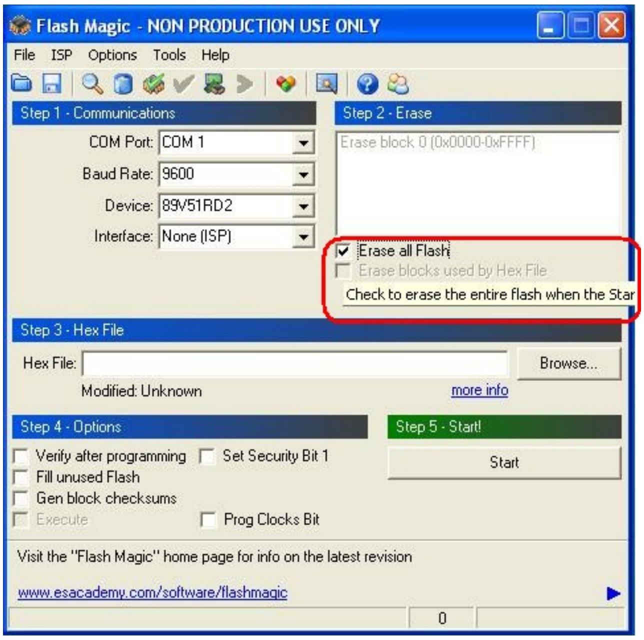

Figure 4.24

Check on the check box to Erase all Flash.

Step 5: Go to ‘*HEX File*’ section click ‘*Browse’* to select proper Hex file which is to be loaded into Fire Bird V P89V51RD2 Robot.

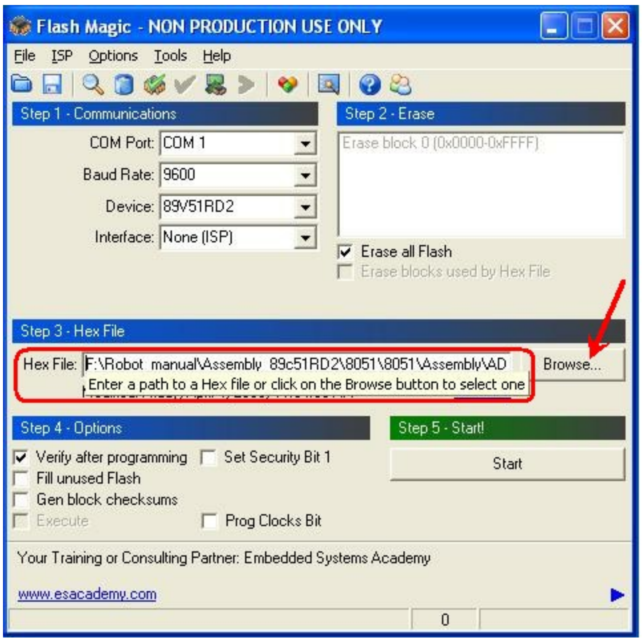

Figure 4.25

Step 6: Go to '*Option*' section to select *'Verify after programming'* option. This will verify hex file after loading.

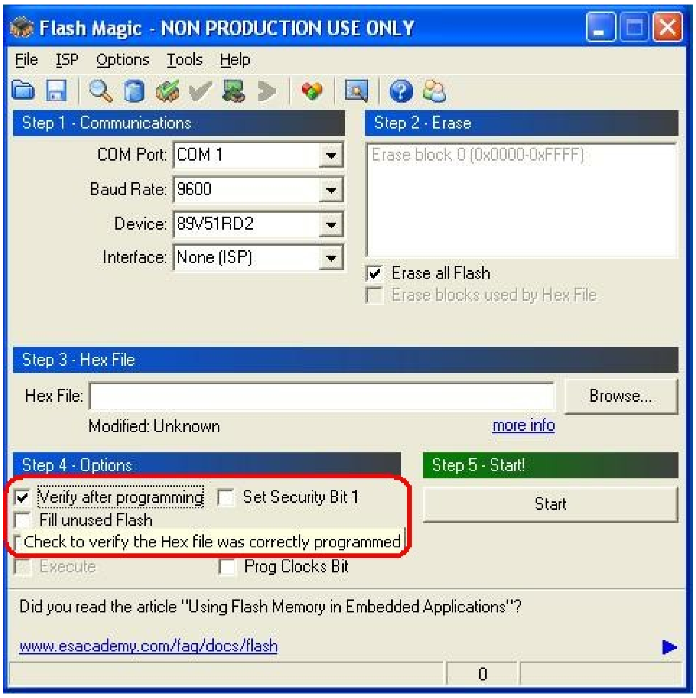

Figure 4.26

Step 7: After doing all the required settings, connect serial cable between robot and PC. Turn on the Fire Bird V P89V51RD2 robot and click on the *'Start'*, it will ask to *'RESET TO DEVICE IN TO ISP MODE'*, now press RESET Switch on the Fire Bird V, Flash magic will load hex file on the robot and verify it for correctness.

If you are using NEX Robotic's USB to serial converter then please refer to Chapter 6. PC Based Control Using Serial Communication for how to use it and identify COM port number.

5. Pin Functionality

P89V51RD2 pin configuration

PIN No	Pin Function	Used For
1	T2/P1.0	Left Motor Direction Control(C)
2	T2EX/P1.1	Left Motor Direction Control(D)
3	ECI/P1.2	Right Motor Direction Control(B)
4	CEX0/P1.3	Pulse width modulation for the left motor (velocity control)
5	CEX1/SS/P1.4	Pulse width modulation for the right motor (velocity control)/SPI SS
6	MOSI/P1.5	SPI MOSI
7	MISO/P1.6	SPI MISO
8	SCK/P1.7	SPI SCK
9	RST	Microcontroller reset
10	RXD/P3.0	RS 232 serial communication
11	TXD/ P3.1	RS 232 serial communication
12	INT0 / P3.2	ADC End of Conversion (ADC EOC)
13	INT1 / P3.3	Position encoder left motor/ INT SW/ TV Remote
14	T0/P3.4	Right Motor Direction Control(A)
15	T1/ P3.5	Position encoder right motor
16	WR / P3.6	ALE for ADC
17	RD/P3.7	Output Enable for ADC
18	XTAL2	11.0592 MHz Crystal
19	XTAL1	
20	Vss	Ground
21	P2.0/A8	LCD Data Line DB4
22	P2.1/A9	LCD Data Line DB5
23	P2.2/A10	LCD Data Line DB6
24	P2.3/A11	LCD Data Line DB7
25	P2.4/A12	LCD Enable
26	P2.5/A13	LCD R/W
27	P2.6/A14	LCD RS
28	P2.7/A15	Buzzer
29	PSEN	NC
30	ALE/-PROG	Clock source for ADC0808 analog to digital converter
31	EA	Vcc (5V)
32	P0.7	ADC output data Lines (D7 to D0)
33	P0.6	
34	P0.5	
35	P0.4	
36	P0.3	
37	P0.2	
38	P0.1	

39	P0.0	
40	Vcc	Vcc (5V)

Table 5.1 P89V51RD2 microcontroller pin functionality

Microcontroller	ADC 0808
Pin 12 - INT0 / P3.2	Pin 7 - EOC (End of Conversion)
Pin 16 - WR / P3.6	Pin 22 - ALE (Address Latch Enable)
	Pin 6 - START (Conversion Start)
Pin 17 - RD/P3.7	Pin 9 - OE (Output Enable)
Pin 32 - P0.7	Pin 21 – D7 (MSB)
Pin 33 - P0.6	Pin 20 – D6
Pin 34 - P0.5	Pin 19 – D5
Pin 35 - P0.4	Pin 18 – D4
Pin 36 - P0.3	Pin 8 - D3
Pin 37 - P0.2	Pin 15 – D2 and Pin 23, ADD C
Pin 38 - P0.1	Pin 14 – D1 and Pin 24, ADD B
Pin 39 - P0.0	Pin 17 – D0 (LSB) and Pin 22, ADD A
Pin 40 - Vcc	Pin 11 - VCC (5V)

Table 5.2 ADC0808 and P89V51RD2 microcontroller pin interconnections

ADC 0808	Sensor
Pin 5 - IN 7	Right IR Proximity sensor no. 4
Pin 4 - IN 6	Right White Line sensor
Pin 3 - IN 5	Centre White Line sensor
Pin 2 - IN 4	Left White Line sensor
Pin 1 - IN 3	Left IR Proximity sensor no. 2
Pin 28 - IN 2	Front Sharp IR Range sensor
Pin 27 - IN 1	Battery Voltage
Pin 26 - IN 0	IR Proximity sensor 3

Table 5.3 ADC 0808 pin connections with analog sensors

6. PC Based Control Using Serial Communication

Fire Bird V P89V51RD2 robot can be controlled through the serial port of a host PC in wired or wireless mode. In order to do this you have to load appropriate hex file (firmware) on the robot. Refer to chapter 4 for how to load hex file.

The communication between the host computer and Fire Bird V robot is made by sending and receiving commands and data byte by byte. The host computer interacts with the Fire Bird V robot by first sending a command byte followed by data byte or it waits for data from the robot. All communication is initiated by host PC. The host computer acts as a master and Fire Bird V robot acts as a slave. PC introduces delay of at least 3ms between two consecutive commands, so that the microcontroller gets sufficient time to process the command send reply to the PC.

You can also use NEX Robotics' USB to Serial converter to control robot over USB or use NEX Robotics' ZigBee wireless communication modules to control robot over wireless data link. GUI based robot control is covered in Chapter 7.

⚠**Warning:**
You need to set jumpers to select between RS232 and Wireless communication mode. Jumper configuration is covered in the later part of the chapter.

6.1 Communication Protocol

Communication protocol used for robot control is given below. You can build your own application by using command set given below to control robot using serial, USB or over wireless communication. It's a simple byte based protocol in which upper nibble is command and lower nibble can be data or command.

Commands to set velocity of the left and right motor:

Motor's velocity can be varied by writing the proper byte into the particular register, which generates the pulse width modulation (PWM) signal with 8 bit resolution. The value of the velocity control register can be set between 00 to FF hex, where a value 0 indicates that the motor is stopped and 0xFF indicates motor is running at full speed.

Command (HEX)	Function
1	Load the lower nibble of the left motor velocity control byte into the robot.
2	Load the upper nibble of the left motor velocity control byte into the robot and execute the command.
3	Load the lower nibble of the right motor velocity control byte into the robot.
4	Load the upper nibble of the right motor velocity control byte into the robot and execute the command.

Table 6.1

Example: Set left motor's speed control byte to 0xAB

To set the speed of the left motor to 0xAB, follow the sequence of commands below. Attach lower nibble "B" with command 1 and upper nibble A with command 2.

Step1: *Send 0x1B* *Load the lower nibble of the left motor speed in the robot.*
Step2: *Delay of at least 3 milliseconds*
Step3: *Send 0x2A* *Load the upper nibble of the left motor speed in the robot and execute the command*
Step4: *Delay of at least 3 milliseconds before loading next command*

Note: It is very important that you send the byte containing command 1 first and then send the byte containing command 2 for proper operation. The same rule is applicable for commands 3 and 4.

Commands to set direction of the robot:

Command (HEX)	**DIRECTION** of **MOTION**	**LEFT BWD (LB) P1.0**	**LEFT FWD (LF) P1.1**	**RIGHT FWD (RF) P1.2**	**RIGHT BWD (RB) P3.4**
51	FORWARD	0	1	1	0
52	REVERSE	1	0	0	1
53	RIGHT *(Left wheel fwd, Right wheel bckwd)*	0	1	0	1
54	LEFT*(Left wheel bckwd, Right wheel fwd)*	1	0	1	0
55	SOFT RIGHT 1 *(Left wheel fwd, Right wheel stop)*	0	1	0	0
56	SOFT LEFT 1 *(Left wheel stop, Right wheel fwd)*	0	0	1	0
57	SOFT RIGHT 2 *(Left wheel stop, Right wheel bckwd)*	0	0	0	1
58	SOFT LEFT 2 *(Left wheel bckwd, Right wheel stop)*	1	0	0	0
59	HARD STOP	0	0	0	0

Table 6.2

Example: To set left motor velocity to 0x84, right motor velocity to 0x65, and move backward.

Step1: *0x14* *Load the lower nibble '4' of the left motor speed into the robot*
Step2: *Delay of at least 3 milliseconds*
Step3: *0x28* *Load the upper nibble '8' of the left motor speed into the robot and execute the command*
Step4: *Delay of at least 3 milliseconds*
Step5: *0x35* *Load the lower nibble '5' of the right motor speed into the robot*
Step6: *Delay of at least 3 milliseconds*
Step7: *0x46* *Load the upper nibble '6' of the right motor speed into the robot and execute the command*
Step8: *Delay of at least 3 milliseconds*
Step9: *0x52* *move backward*
Step10: *Delay of at least 3 milliseconds before loading next command*

Commands to access the Analog sensor data:

Command (HEX)	Data
60	**Battery voltage** Robot sends back 8 bit battery voltage value. To convert this value in to volts use the following conversion formula: Battery Voltage = ADC data x 0.069
62	**Front Sharp IR range sensor data (Front distance)** The Robot will return 8 bit value which indicates distance between the obstacle and front Sharp sensor.
63	**Left IR Proximity sensor** The Robot will return an 8 bit analog value of the left IR Proximity sensor
64	**White line sensor 1 (Left)** The Robot will return an 8 bit analog value of the left white line sensor
65	**White line sensor 2 (Center)** The Robot will return an 8 bit analog value of the center white line sensor
66	**White line sensor 3 (Right)** The Robot will return an 8 bit analog value of the right white line sensor
67	**Right IR Proximity Sensor** The Robot will return an 8 bit analog value of the right IR Proximity sensor

Table 6.3

Commands to turn on / off the buzzer:

69	Turn on the buzzer.
6A	Turn off the buzzer.

Table 6.3

Position encoder data:

Position encoder pulse count for the position tracking:

72	The robot will return lower byte of the pulse count for the left motor**.**
73	The robot will return upper byte of the pulse count for left motor.
79	The robot will return lower byte of the pulse count for the right motor**.**
7 A	The robot will return upper byte of the pulse count for right motor.

Table 6.4

Note: To get an actual pulse count, combine the lower byte and upper byte to get a 16 bit value. For more information on the position encoder resolution refer to the section 3.7.

6.2 Using the Terminal software for Serial Communication to control robot

Terminal is easy to use free software for serial communication. It is located in the "Software and Drivers" folder in the documentation CD. It can also be downloaded from http://hw-server.com/software/termv19b.html. Serial communication protocol covered in the section 6.1 can be used with the terminal software control robot over wire or wireless medium.

Make sure that jumper is configured to enable RS232 serial communication. Jumpers should be in the position as shown in the Figure 6.1.

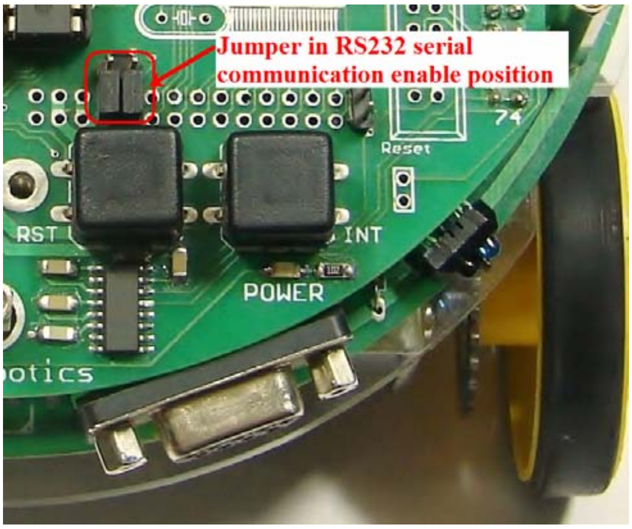

Figure 6.1: Enabling RS232 communication

Load “GUI_ control_serial_P89V51RD2.hex” hex file on the robot, which is located in the documentation CD in the “GUI and Related Firmware” folder. Connect serial cable between robot and PC. If you are using NEX Robotic’s USB to serial converter or ZigBee wireless module then please refer to section 6.3 or 6.4.

Step 1: Copy Terminal software on the PC from the “Software and Drivers” folder of documentation CD and double click the terminal software. The terminal window will open up.

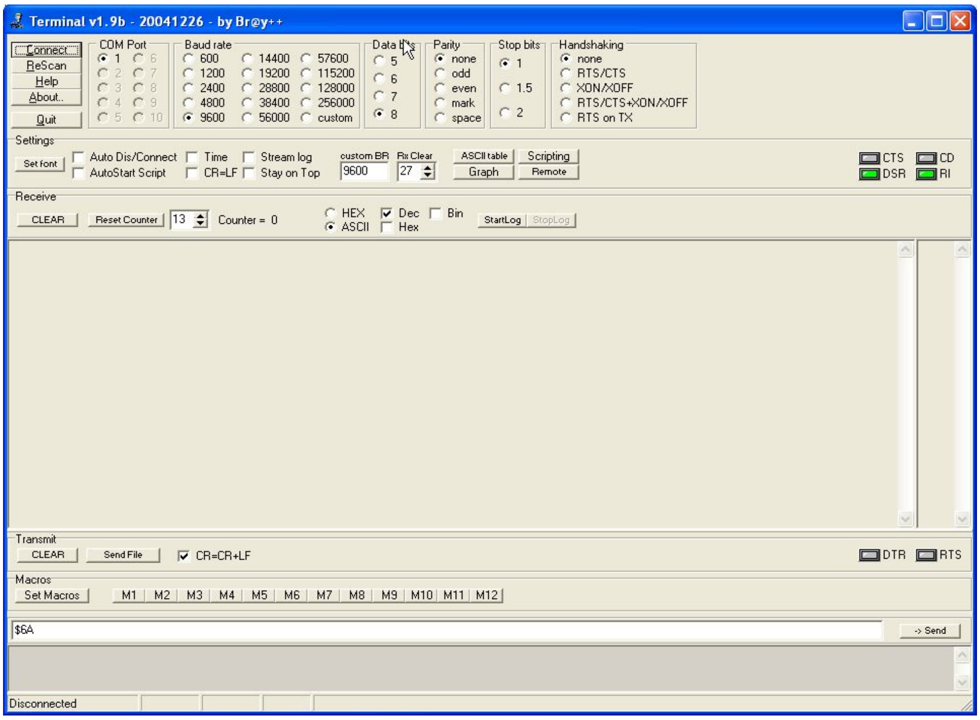

Figure 6.2

Step 2: Select the COM Port and set the baud rate as 9600 and other settings as desired. Once all the settings are done click connect. If you are using serial port then select COM1. If you are using NEX Robotics’ USB to serial converter or Wireless ZigBee module then refer to section 6.3 and 6.4 for how to identify COM port.

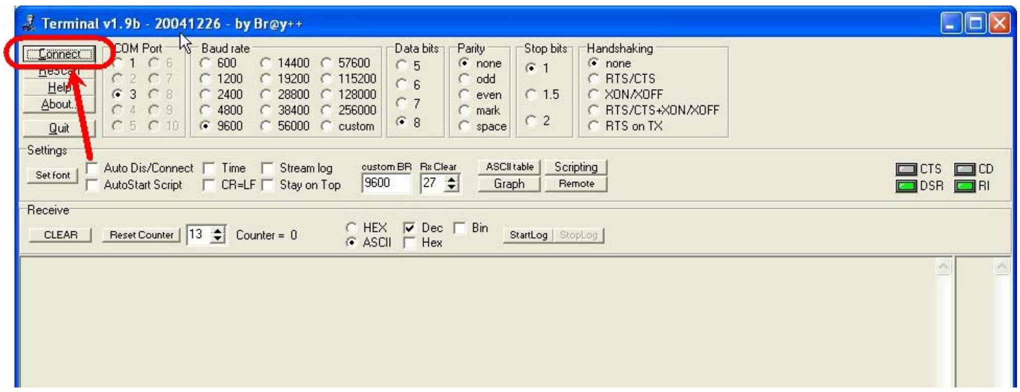

Figure 6.3

Step 3: Now you are ready to transmit the data. Type the data into the text box and click send. For more information about using terminal software click help.

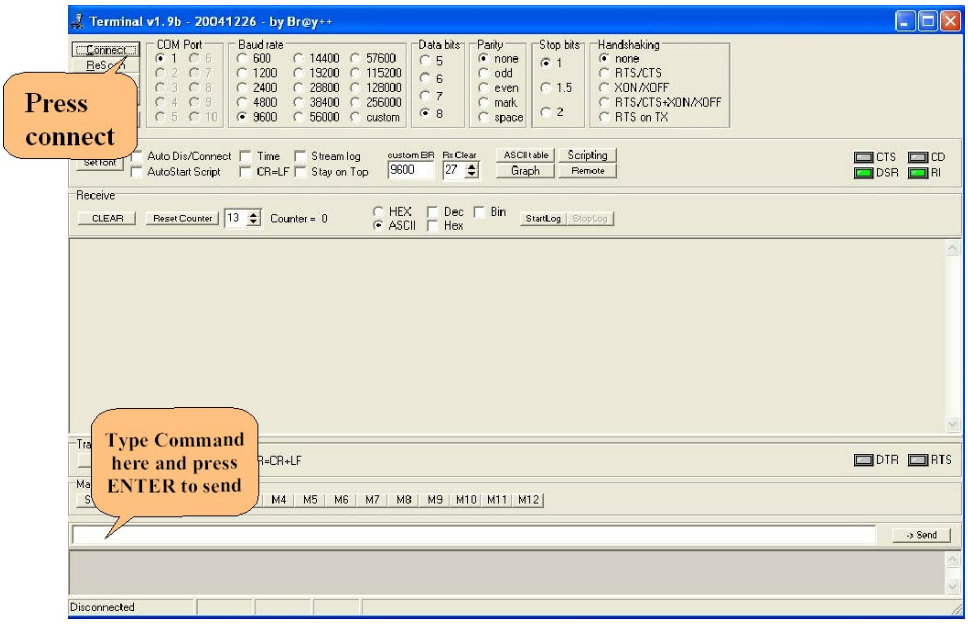

Figure 6.4

Example:

For moving Fire Bird V in the forward direction the command is 0x51. The terminal software understands hex numbers by using $ prefix to the hex code.

For e.g. 0x51 → $51 forward,

Robot can be moved in all directions using following commands.

$51 - forward, $52 - backward, $53 - left, $54 - right and S59 - stop.

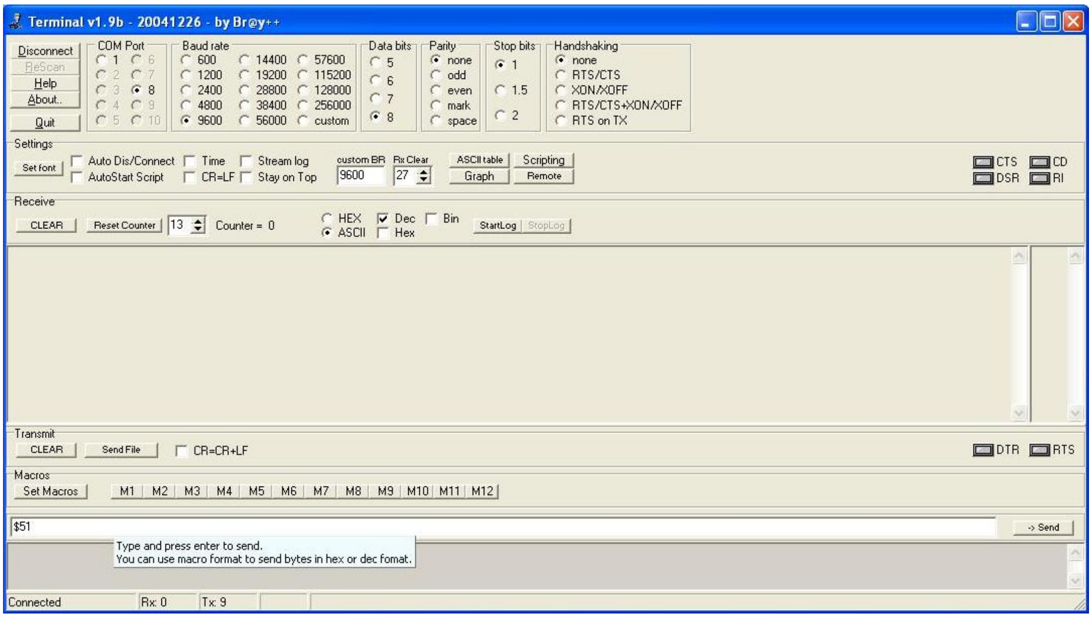

Figure 6.5

6.3 Robot control using USB to Serial Converter

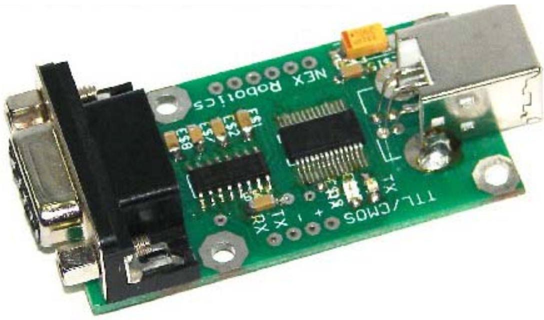

Figure 6.6 USB to Serial converter

Fire Bird V P89V51RD2 can be controlled by USB to serial converter. In order to do this you have to load "GUI_ control_serial_P89V51RD2.hex" hex file on the robot, which is located in the documentation CD in the "GUI and Related Firmware" folder.

Before using USB port we need to install the driver software for FT232 USB to serial converter. The software is located in the "Software and Drivers \ CDM 2.06.00 WHQL Certified" folder. Provided in the Fire Bird V CD or can also be downloaded from the NEX Robotics' website.

Make sure that jumper is configured to enable RS232 serial communication. Jumpers should be in the position as shown in the Figure 6.1.

Steps to install the drivers for USB to serial converter:

Step 1:
Copy the driver installation folder on your PC from "Software and Drivers \ CDM 2.06.00 WHQL Certified" Folder in the CD.

Step 2:
Connect the USB to serial converter cable between robot and the PC

Step 3:
On connecting the device "Found New Hardware" message will appear in the taskbar tray and the following window opens.

Figure 6.7

Step 4:
Click on "No, not this time" and then click on the next button.

Figure 6.8

The following window will appear.

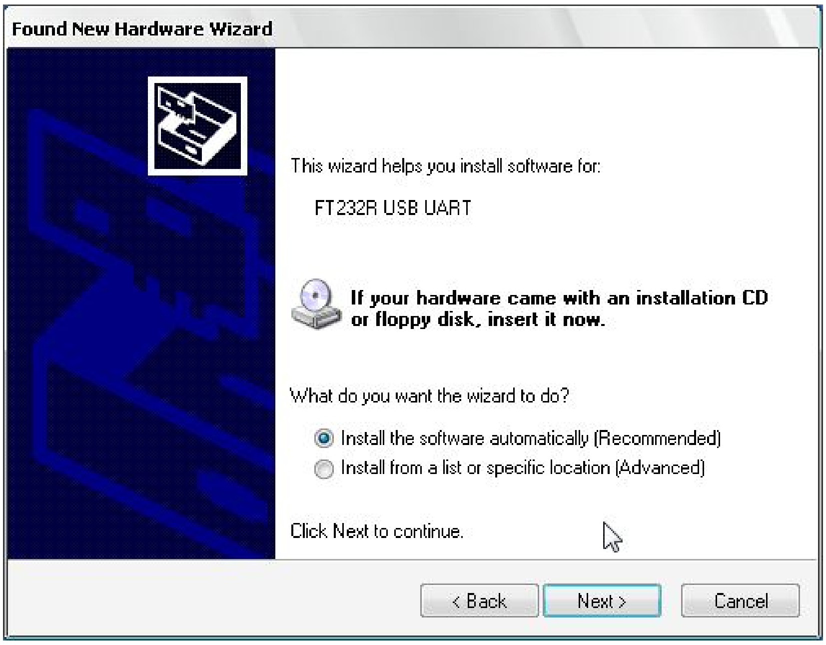

Figure 6.9

Select the second option manually to install the drivers and click on next button.

Step 5:
Now check the second option and set the location of folder containing drivers E.g.(C:\CDM 2.06.00 WHQL Certified).

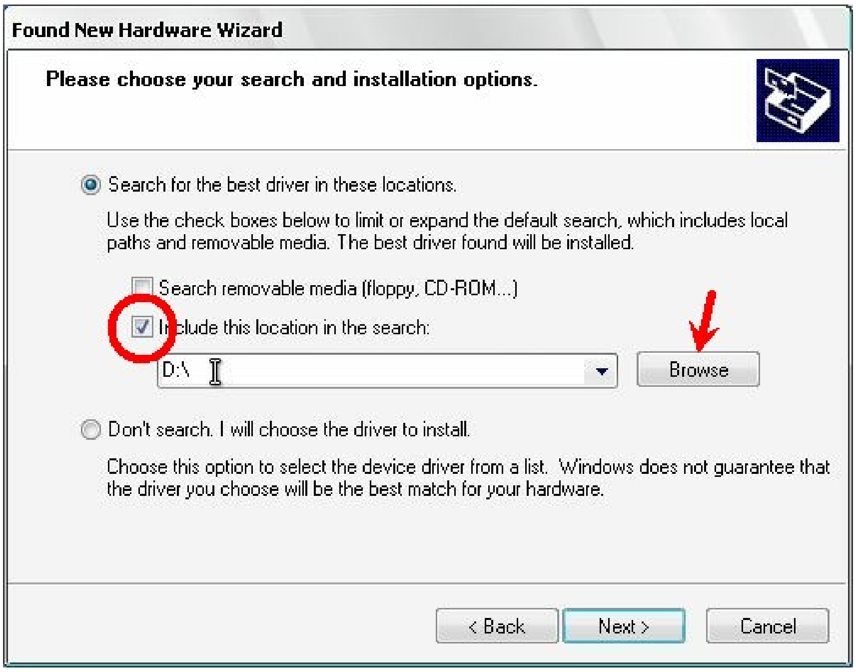

Figure 6.10

Step 6:
On clicking next driver installation will begin.

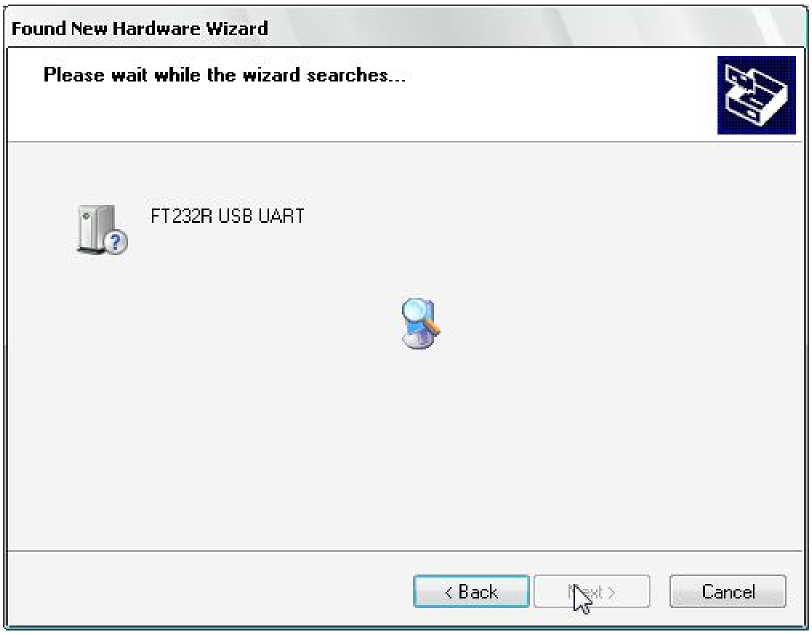

Figure 6.11

Step 7:
On successfully installing the driver following window will appear. Click Finish to complete the installation.

Figure 6.12

After installation of FT232 USB UART software PC will ask for USB serial port software. To install this software follow steps 1 to 7 of USB serial converter software installation.

6.4 Identifying COM Port number of the USB to serial converter or ZigBee wireless module

To use terminal.exe or any other serial control program we need to first identify port (generally referred as COM n, i.e. COM1 or COM2 etc.) on which USB to serial converter or wireless device is connected.
COM port number for your device can be identified by viewing the system properties. Follow these steps to identify your COM Port number.

Step 1:
Right Click My Computer and click on properties. System properties window will appear.

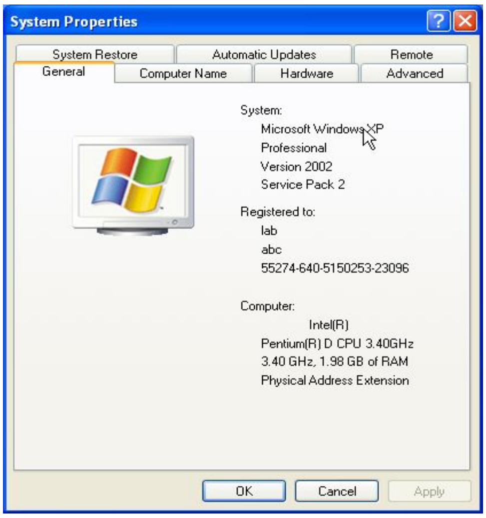

Figure 6.13

Step 2:
Click on the Device manager in the Hardware tab.

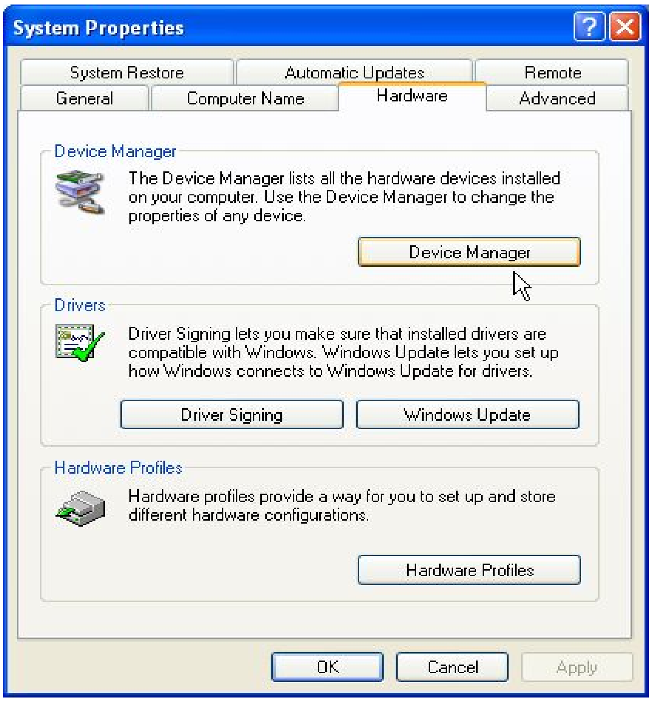

Figure 6.14

Step 3:
Expand Ports (Com & LPT) tree. COM Port number is mentioned in the parenthesis next to USB Serial Port.

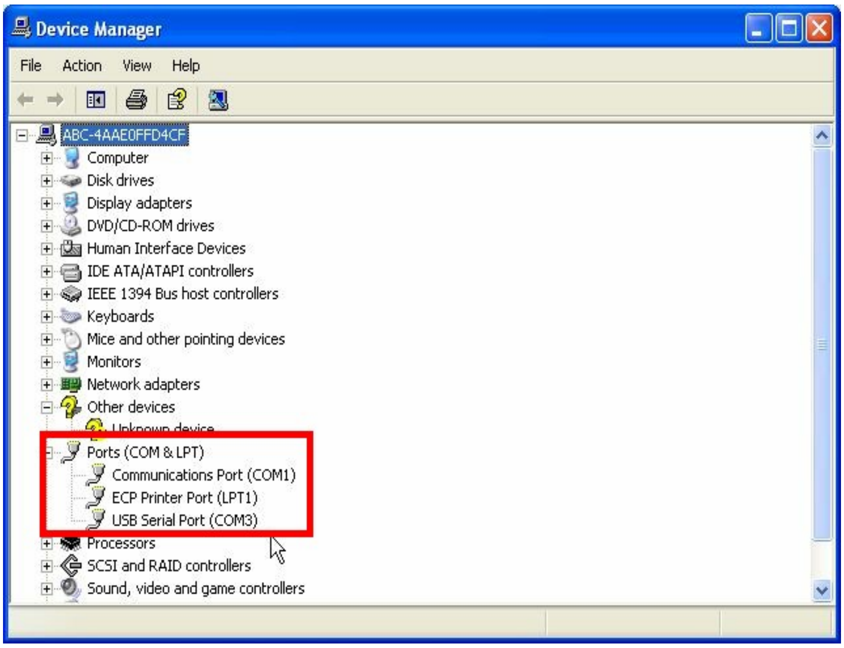

Figure 6.15

Step 4:
If the COM port number is greater than 10 Terminal will not be able to detect it. To resolve this problem, change the port number by right clicking on "USB serial Port" and select properties.

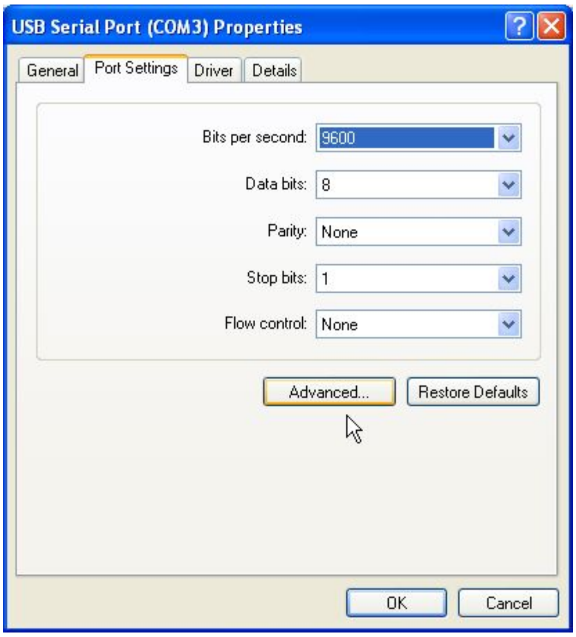

Figure 6.16

In the Port settings tab click on the Advanced button, the following window will appear.

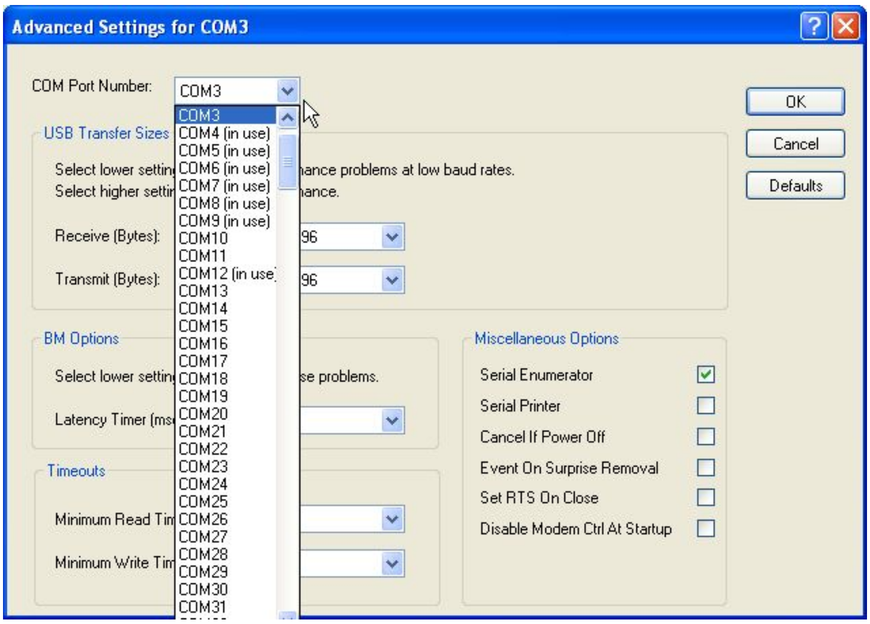

Figure 6.17

You can change the COM port number by clicking on the Com Port number drop down list and select the appropriate number. Make sure the new COM port is not being used by any other device.

6.5 Robot control using ZigBee wireless communication module

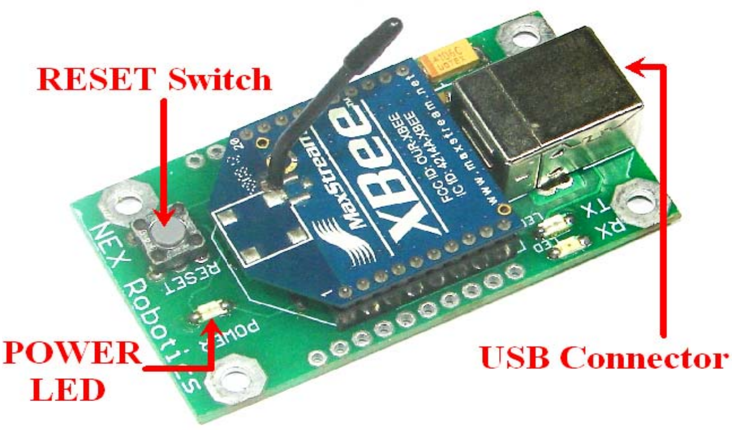

Figure 6.18: ZigBee Wireless USB Module from NEX Robotics

Introduction

USB Wireless Module is the device that enables wireless transmission of serial data through PC's USB port. It uses Xbee module for wireless data transmission. The Xbee module is easily programmable through AT commands sent via PC's USB port. On the PC side this device is treated as the Communication Device Class (CDC) of USB family and it is assigned a virtual Comport number allowing the user to make use of existing GUI. The destination side (robot) requires another ZigBee wireless module for accepting the data transmitted from the PC. The output of the ZigBee wireless module is similar to the RS-232 format allowing the user to interface it directly to the microcontroller by making minor changes in the existing hardware.

Features

- USB 2.0 compatible (No legacy RS232 required)
- USB powered
- Rx and Tx indicator LEDs
- Supports AT and API commands
- Achievable data rates: 2400-115200 bps
- Indoor/Urban Range up to 100 ft. (30 m)
- Outdoor RF line-of-sight range up to 300ft.(100m)
- Compatible with existing GUI (RS-232 based)
- Supports PDA devices

Make sure that jumper is configured to enable ZigBee wireless communication. Jumpers should be in the position as shown in the Figure 6.19. Make sure that ZigBee wireless module s installed on the robot. Refer to chapter 9 for how to install ZigBee wireless module on the robot.

Driver Installation

Step 1:
Locate the wireless communication folder from the CD
Step 2:
Copy "\Drivers\CDM 2.02.04 WHQL Certified" folder from the installation CD.

Step 3:
Follow the same process as in section 6.3 to install the driver.

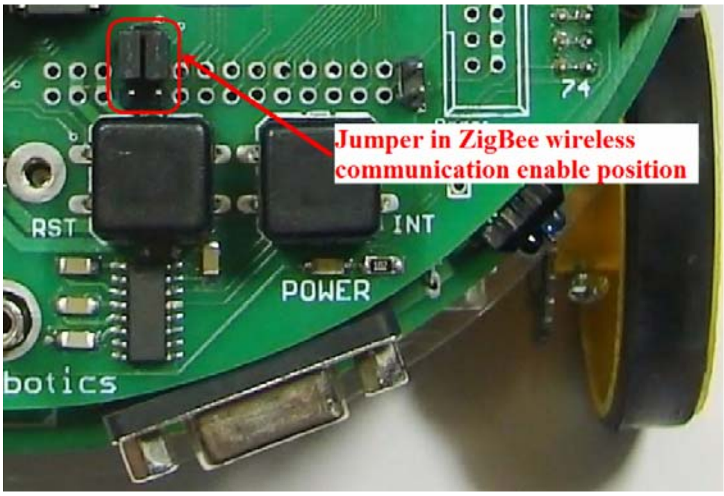

Figure 6.19: Jumper setting to enable wireless communication

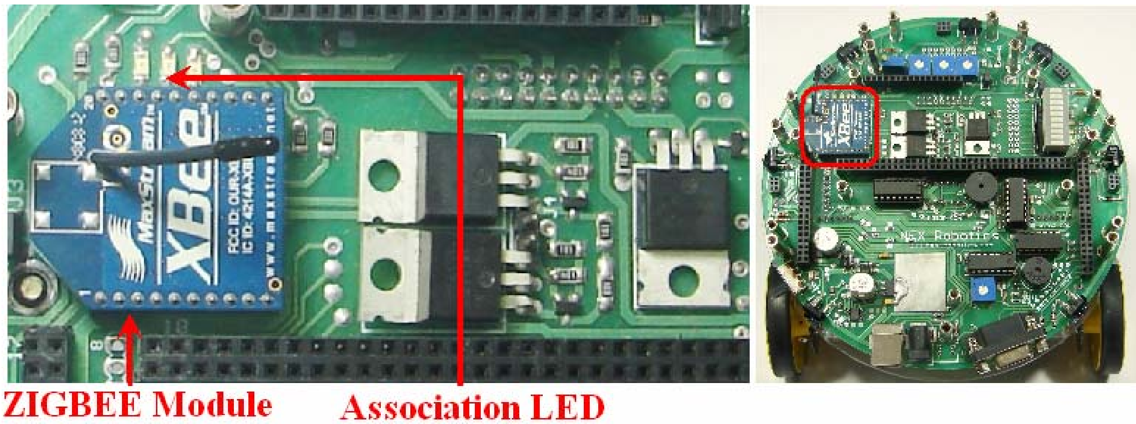

Figure 6.20: ZigBee module installed on the robot

Robot control using ZigBee Wireless module

Now we are going to control Fire Bird V wirelessly using ZigBee wireless module. We need to load 'gui_serial_control.hex' from the experiments folder which is in the documentation CD.

Connect the PC side ZigBee USB module via the USB cable to the PC USB Port.

Make sure that jumper for the serial communication is set as shown in figure 6.1. Identify com port and set it in the terminal software.

Now robot can be controlled wirelessly using Terminal software / your own software / GUI. Robot control using GUI is covered in the chapter 7.

7. Robot Control using ‘GUI’ for Fire Bird V P89V51RD2

Fire Bird V P89V51RD2 robot can be controlled by GUI via serial / USB cable or using ZigBee wireless module. To control the robot using GUI, “GUI 8051.hex” needs to be loaded on the robot which is located in the “GUI and Related Firmware” folder in the documentation CD. Robot’s serial communication jumpers must be set properly as shown in the figure 6.1 for wired serial communication or as shown in figure 6.19 for ZigBee wireless communication depending on the communication options selected. Refer to chapter 6 for more details on the communication protocol and configuring communication options. Install robot GUI control software from the “GUI and Related Firmware” folder in the documentation CD. GUI works on 9600 bps baud rate.

7.1 Loading firmware on the robot

Step 1: Load “GUI 8051.hex” on the robot which is located in the “GUI and Related Firmware \ Fire Bird V P89V51RD2 firmware” folder in the documentation CD. How to load hex file on the robot is covered in the chapter 4 of the hardware manual.

Step 2: Connect serial / USB to serial converter cable between robot and PC or install ZigBee wireless module on the robot and connect wireless ZigBee USB module to the PC.

Step 3: Install GUI software

7.2 Installing GUI

Step1: Copy “FIRE BIRD V P89V51RD2 setup” folder which is located inside the folder “GUI and Related Firmware”

Click on setup.exe which is located in the “FIRE BIRD V P89V51RD2 setup” folder.

Step 2: Click Next Button to continue.

Step 3: Browse the location where set up will install and click Next button to start the installation.

Step 4: When installation is successfully completed, Click Close to exit.

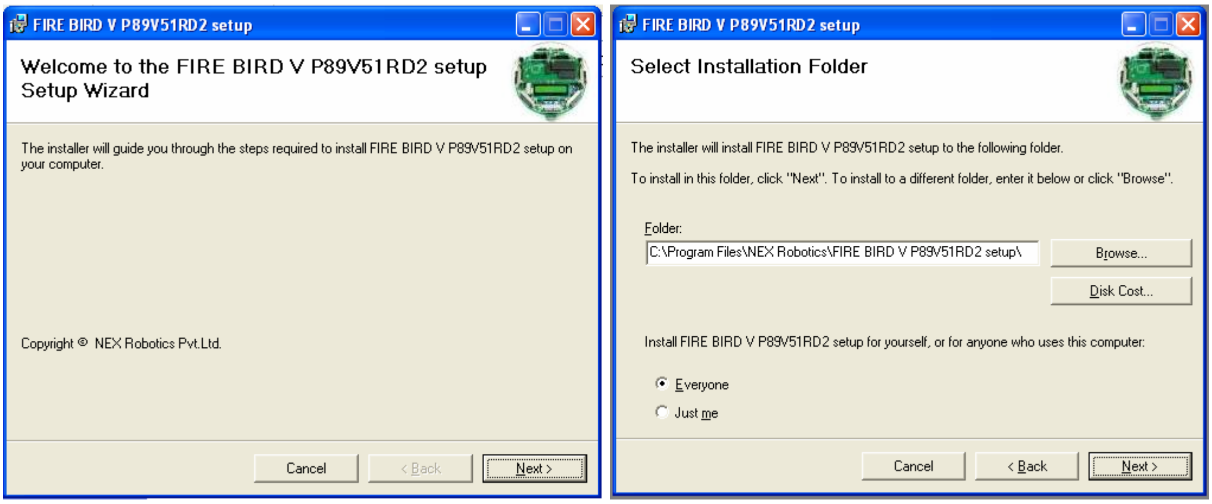

Figure 7.1

7.3 Using GUI

Step 1: After successful installation go to Start -> All Programs -> FIRE BIRD V P89V51RD2 -> FIRE BIRD V P89V51RD2 or click on Fire Bird V P89V51RD2 on your desktop location, GUI will open.

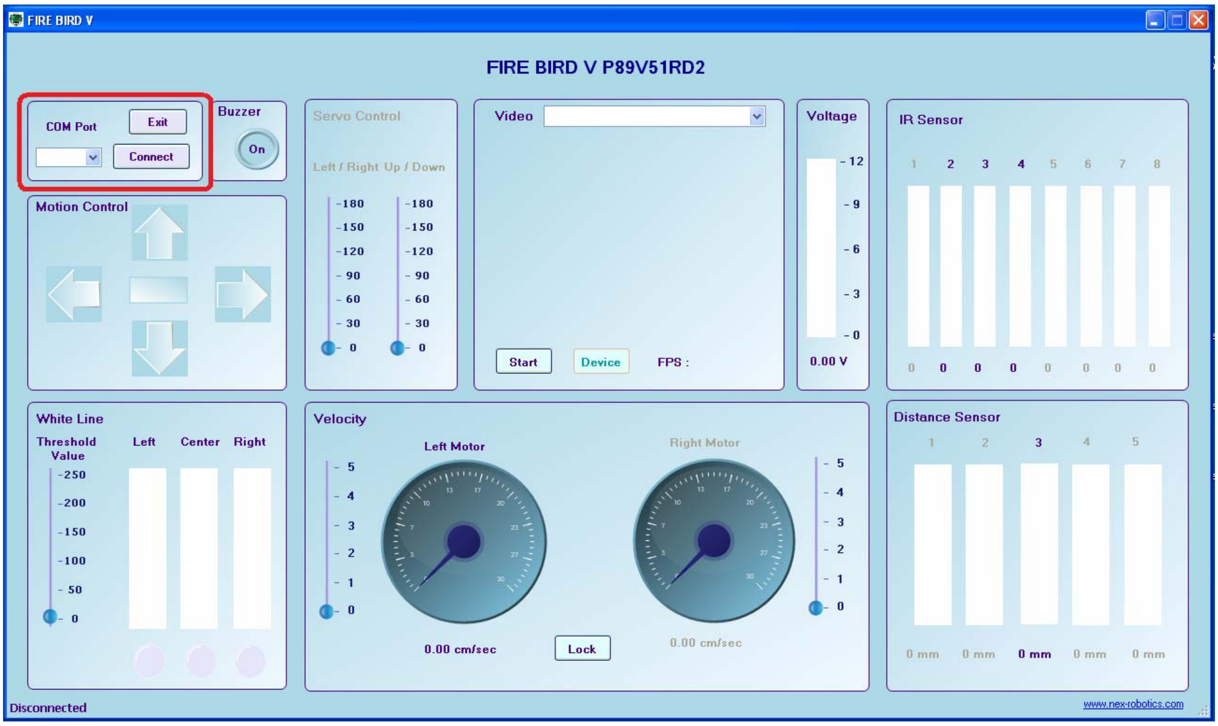

Figure 7.2: Selecting correct com port

Step 2: Connect Robot with the PC using serial cable / NEX Robotics USB to serial converter or with the ZigBee wireless module.

Step 3: If serial port is used then select COM Port as 1. If USB to serial converter module from NEX Robotics or USB ZigBee wireless module is used then identify COM port as mentioned in the section 6.4. Select the correct COM port number and click on connect.

Now robot can be controlled using GUI

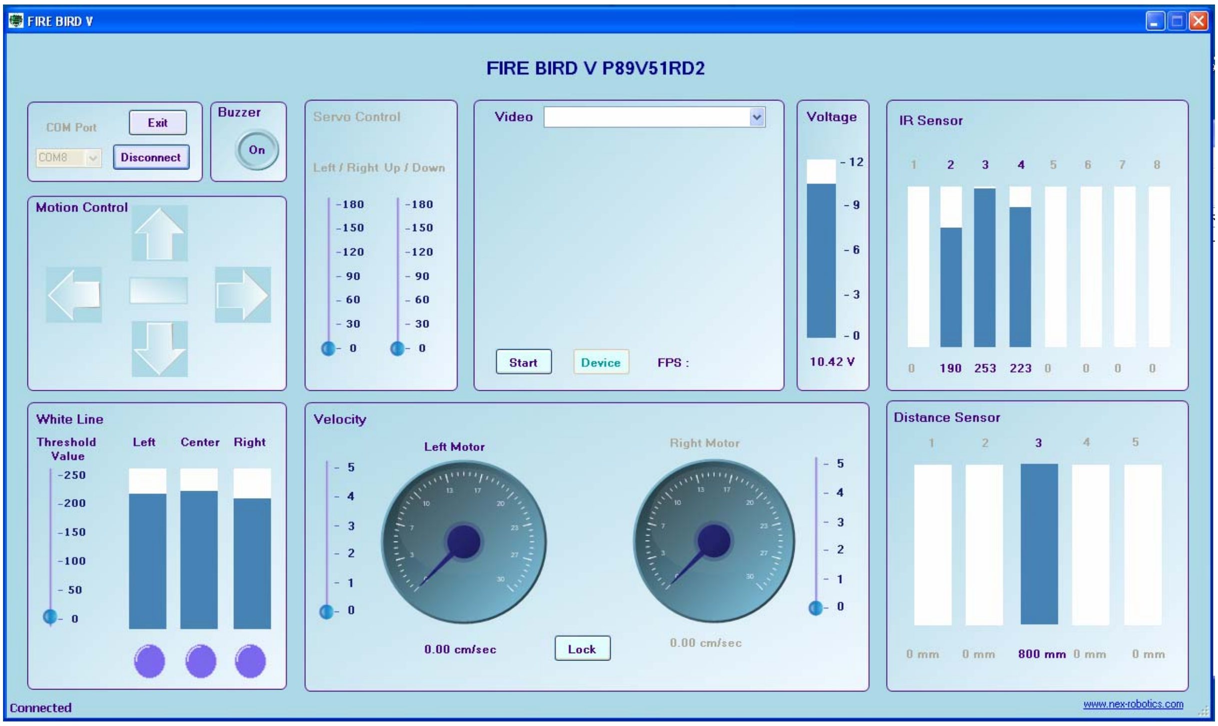

Figure 7.3: GUI showing robot's data

⚠**Warning:**

While changing between wired and wireless communication, ensure that the appropriate jumpers are in place. For more details refer sections 6.2, 6.3 and 6.4 from chapter 6.

7.4 Robot control using ZigBee wireless module

To control robot using ZigBee wireless module refer to section 6.5. All the process remains the same as mentioned in the section 7.1, 7.2 and 7.3. Only difference is that instead of USB to serial converter, NEX Robotics wireless ZigBee USB module needs to be connected to the PC.

8. Hardware Description

This chapter contains the hardware description of the Fire Bird V P89V51RD2 robot. In this chapter full expansion capability of the robot is covered so that user can do custom modifications as per the requirements.

Fire Bird V platform consists of 6 modules:

1. Power management
2. Sensing
3. Actuation (locomotion)
4. Other peripherals
5. Communication
6. Intelligence (microcontroller)

Figure 8.1: Fire Bird V P89V51RD2 top view

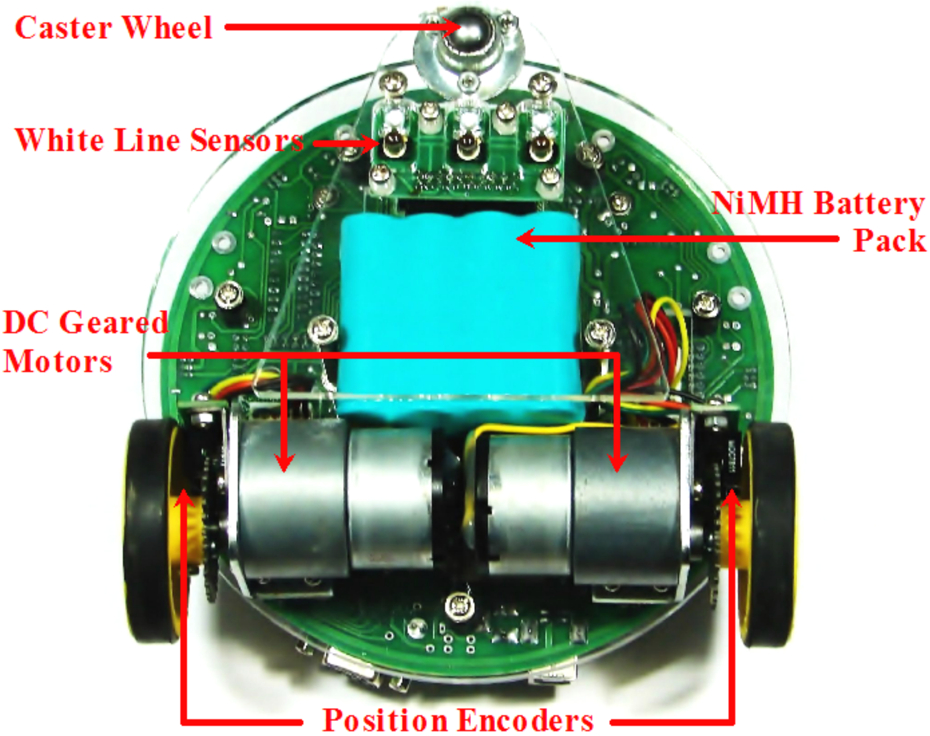

Figure 8.2: Fire Bird V P89V51RD2 bottom view

8.1 Connections

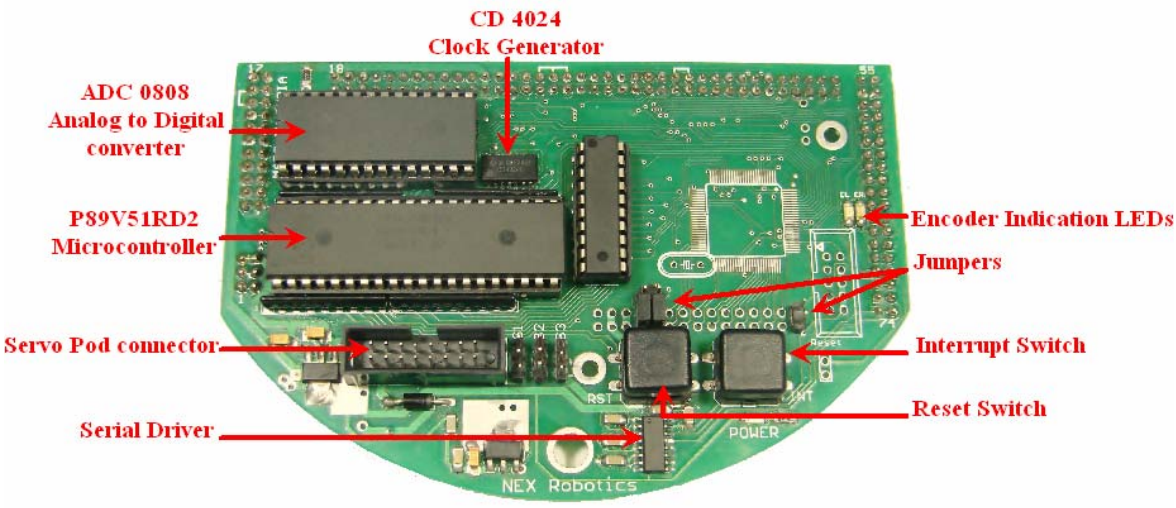

Figure 8.3: P89V51RD2 microcontroller adaptor board for the Fire Bird V robot

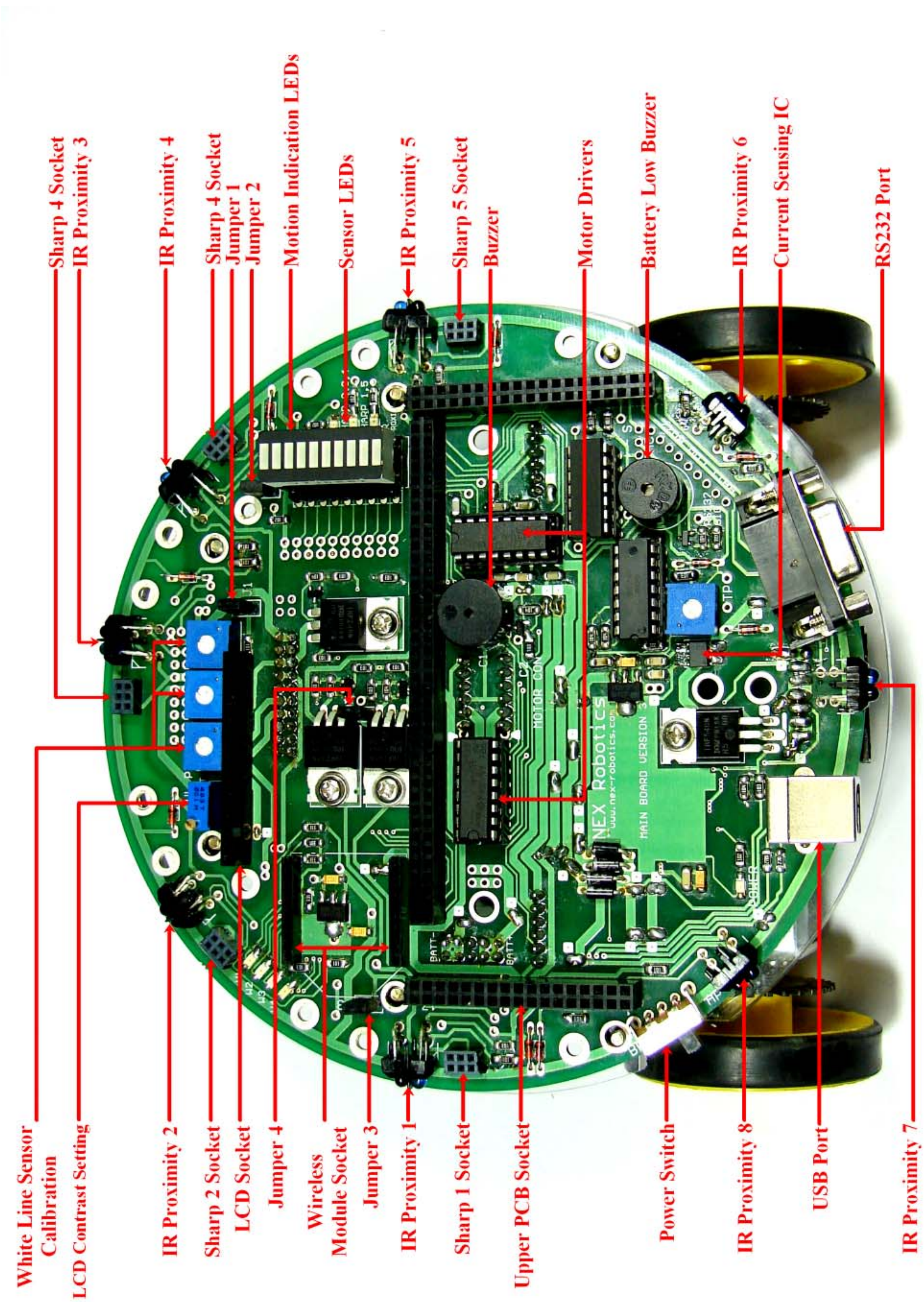

Figure 8.4: Main board, Version 2 (Current production version)

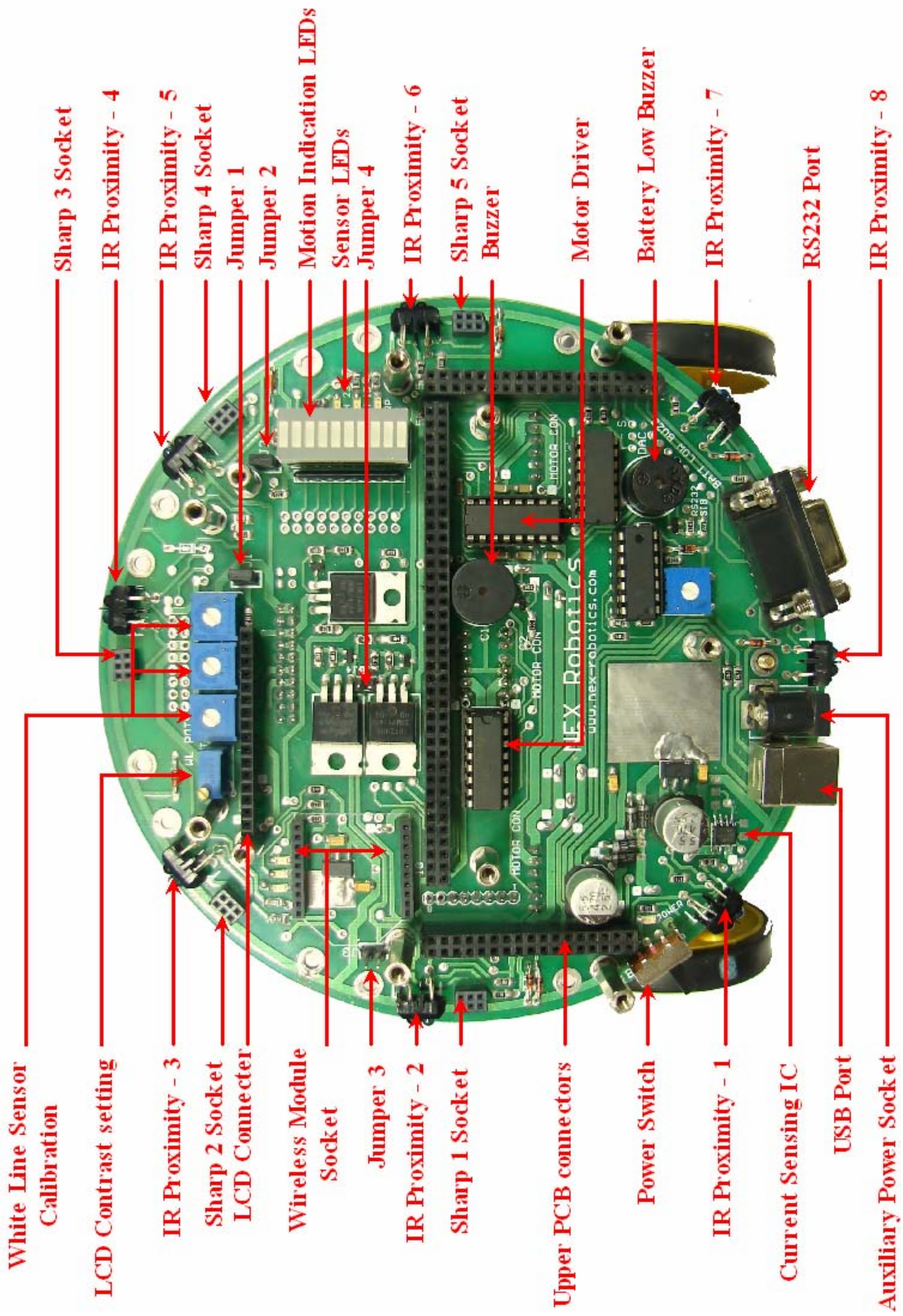

Figure 8.4B: Main board, Version 1 (IIT B old version)

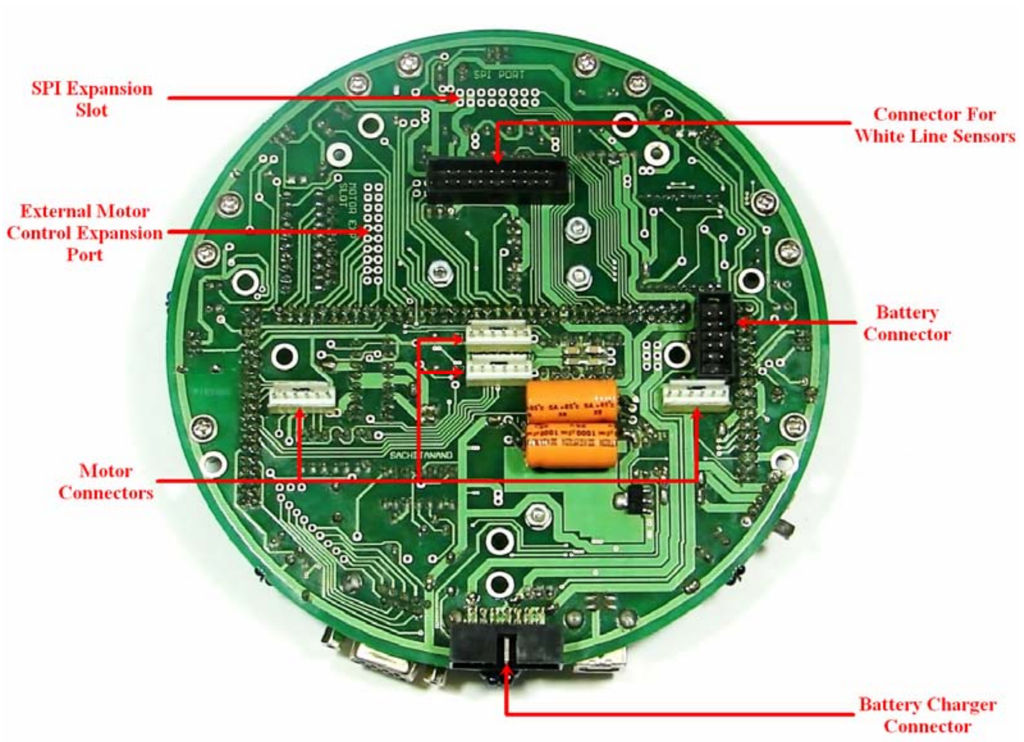

Figure 8.5: Bottom view of the main board, Version 2 (Current production version)

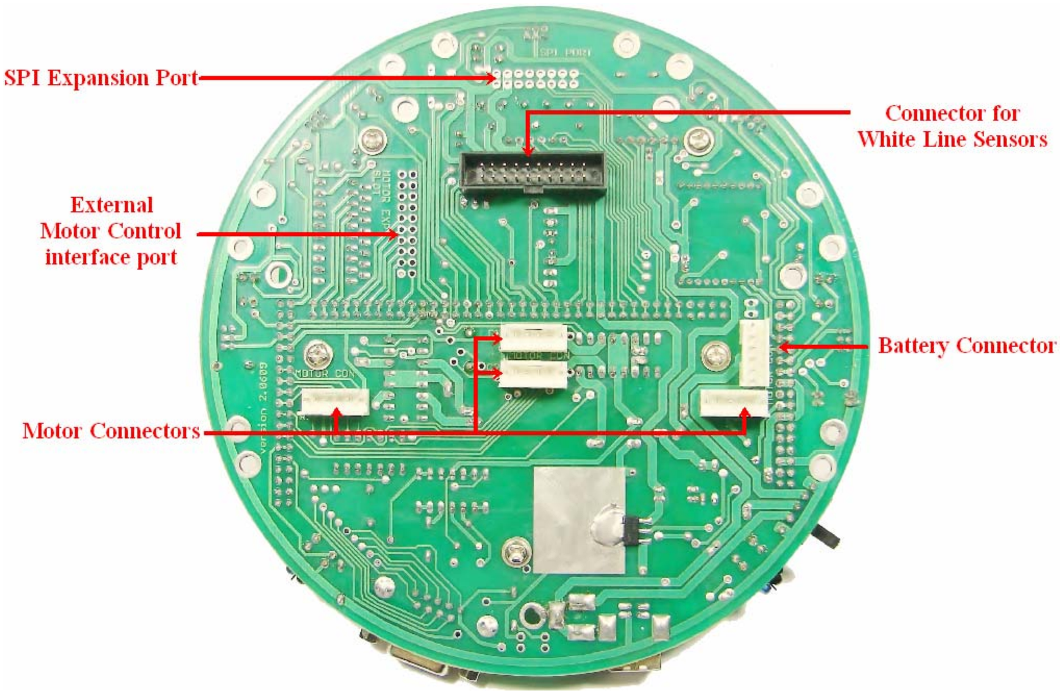

Figure 8.5B: Bottom view of the main board, Version 1 (IIT B old version)

8.1.1 Socket connections for the microcontroller adaptor board on the main board

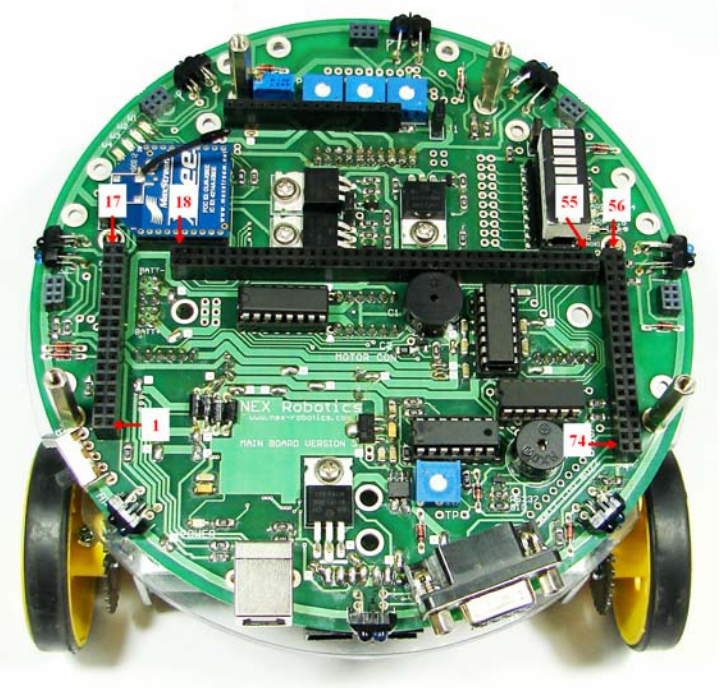

Figure 8.6: Microcontroller adaptor board socket connections on the main board

Pin No.	Pin Name	Function	uC Board Connection
1	CS*	Current sense analog output.	Not connected
2	IR Proximity sensor 8	Analog output.	Not connected
3	Ground	Ground.	Ground
4	USB Data +	Connections from the USB connectors.	Not connected
5	USB Data -		
6	V USB		
7	5V System	5V System voltage. Can be used for powering any digital device. Current limit: 400mA total	Not connected
8	IR Proximity sensor drive	Drain of the IR Proximity sensor switching MOSFET. Any device with current capacity up to 1 Amp. can be connected.	Not connected
9	5V Sensor	5V Sensor supply. Can be used for additional sensor interfacing. Current limit: 300mA total	Not connected
10	5V System	5V System voltage. Can be used for powering any digital device. Current limit: 400mA total	Not connected
11	Sharp IR Range sensor 1	Analog output of the Sharp IR Range sensor 1. (If installed)	Not connected
12	IR Proximity sensor 1	Analog output.	Not connected
13	ZigBee RXD	ZigBee wireless module serial data in.	uC TXD pin via jumper
14	ZigBee TXD	ZigBee wireless module serial data out.	uC RXD pin via jumper
15	Sharp IR Range sensor	Analog output of the Sharp IR	ADC IN 3 **

	2	Range sensor 2. (If installed)	
16	IR Proximity sensor 2	Analog output.	ADC IN 3 **
17	Not used		
18	MOSI	SPI communication lines for expansion header on the main board	Not connected
19	MISO		
20	SCK		
21	SS1		
22	RS	LCD register select pin (command)	uC Port 2.6
23	RW	LCD read / write pin (command)	uC Port 2.5
24	EN	LCD enable pin (command)	uC Port 2.4
25	DB5	LCD data bit 5	uC Port 2.1
26	DB4	LCD data bit 4	uC Port 2.0
27	DB6	LCD data bit 6	uC Port 2.2
28	DB7	LCD data bit 7	uC Port 2.3
29	V Battery system	V battery system (9V to 11.4 V depending on battery status) Unregulated supply for additional module interfacing. Maximum current capacity: 1Amp.	To Microcontroller supply regulator. Battery voltage sensing through resistor divider network to ADC IN 1
32	White line 1	Analog output of the white line sensor 1	ADC IN 4
31	White line 2	Analog output of the white line sensor 2	ADC IN 5
32	White line 3	Analog output of the white line sensor 3	ADC IN 6
33	IR Proximity sensor disable	TTL / CMOS input. Disables IR proximity sensors when V > 2 is applied. When V < 0.65 IR proximity sensors are turned on	Not connected
34	Sharp IR range sensor 1 and 5 disable	TTL / CMOS input. Disables Sharp IR range sensor 1 and 5 when V > 2 is applied. When V < 0.65 IR proximity sensors are turned on	Not connected
35	5V System	5V System voltage. Can be used for powering any digital device. Current limit: 400mA total	Not connected
36	White line 4	Analog output of the white line sensor 4 (If installed)	Not connected
37	White line 5	Analog output of the white line sensor 5 (If installed)	Not connected
38	White line 6	Analog output of the white line sensor 6 (If installed)	Not connected
39	White line 7	Analog output of the white line sensor 7 (If installed)	Not connected
40	Sharp IR range sensor 2, 3 ,4 and white line sensor disable	TTL / CMOS input. Disables Sharp IR range sensor 2, 3, 4 and white line sensors when V > 2 is applied. When V < 0.65 IR proximity sensors are turned on	Not connected
41	Sharp IR Range sensor 3	Analog output of the Sharp IR Range sensor 3. (If installed)	ADC IN 2

42	IR Proximity sensor 3	Analog output.	ADC IN 0
43	IR Proximity sensor 4	Analog output.	ADC IN 7 **
44	Sharp IR Range sensor 4	Analog output of the Sharp IR Range sensor 4. (If installed)	ADC IN 7 **
45	Sharp IR Range sensor 5	Analog output of the Sharp IR Range sensor 5. (If installed)	Not connected
46	IR Proximity sensor 5	Analog output.	Not connected
47	C1 1	Logic input 1 for C1 motor drive	Not connected
48	C1 PWM	PWM input for C1 motor drive	Not connected
49	C1 2	Logic input 2 for C1 motor drive	Not connected
50	PWM L	PWM input for the left motor	Port 1.3
51	L1	Logic input 1 for left motor	Port 1.0
52	L2	Logic input 2 for left motor	Port 1.1
53	R1	Logic input 1 for right motor	Port 1.2
54	PWM R	PWM input for the right motor	Port 1.4
55	R2	Logic input 2 for right motor	Port 3.4
56	5V System	Do not use	Not connected
57	5V System	Do not use	Not connected
58	IR Proximity sensor 5	Analog output.	Not connected
59	Sharp IR Range sensor 5	Analog output of the Sharp IR Range sensor 5. (If installed)	Not connected
60	5V System	Do not use	Not connected
61	IR Proximity sensor drive	Drain of the IR Proximity sensor switching MOSFET. NC. Use pin 8 to drive any device with current capacity up to 1 Amp.	Not connected
62	Position encoder left	Output of the left position encoder (0-5V)	Port 3.3
63	Position encoder right	Output of the right position encoder (0-5V)	Port 3.5
64	Position encoder C2	Output of the C2 position encoder (0-5V)	Not connected
65	Position encoder C1	Output of the C1 position encoder (0-5V)	Not connected
66	C2 2	Logic input 2 for C2 motor drive	Not connected
67	C2 1	Logic input 1 for C2 motor drive	Not connected
68	C2 PWM	PWM input for C2 motor drive	Not connected
69	IR Proximity sensor 6	Analog output.	Not connected
70	IR Proximity sensor 7	Analog output.	Not connected
71	Buzzer	Input, V > 0.65 turns on the buzzer.	Port 2.7
72	DAC out	Reserved for future use	Not connected
73	RS232 TXD	RS232 Transmit, connected to DB9 serial connector on the main board	Port 3.0 (RXD) via MAX202, TTL to RS232 converter
74	RS232 RXD	RS232 Receive, connected to DB9 serial connector on the main board	Port 3.1 (TXD) via MAX202, TTL to RS232 converter

Table 8.1: P89V51RD2 Microcontroller adaptor board socket connections on the main board

Note:
* CS will give output only if ACS712 hall effect current sensor is soldered on the main board

** Outputs of the Sharp IR Range sensor 2 and 4 are shorted with the IR Proximity sensor 2 and 4 respectively with 0 ohm resistor in the bottom layer of the P89V51RD2 microcontroller adaptor board. In this setting only IR Proximity sensor 2 and 4 can be used. If Sharp IR Range sensor 2 and 4 to be used then remove 0 ohm resistors. To do this modification refer to the section 8.3.3.

8.2 Power management module on the main board

Power management block on the Fire Bird V performs following functions.

5. Battery voltage monitoring
6. Battery current sensing*
7. Battery low warning in case battery is below critical level
8. Regulated supply for onboard payload.

* Current sensing is an optional accessory.

8.2.1 Battery

Fire Bird V is powered by 9.6V, 2.1Ah rechargeable Nickel Metal Hydride battery pack. When fully charged, battery pack gives 11.5V and when it is fully discharged, voltage drops to about 8.5V. Battery has built-in thermister for monitoring battery temperature during battery charging.

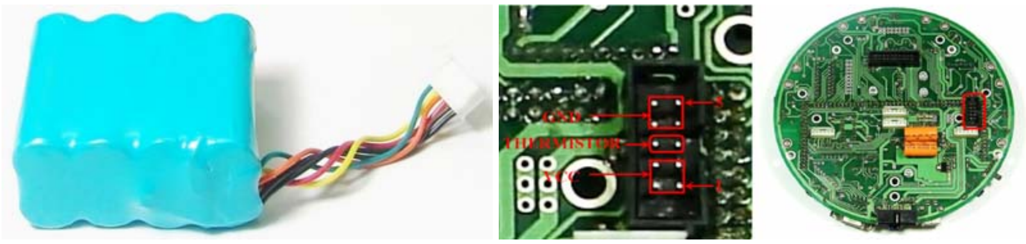

Figure 8.7: 9.6V, 2000mAH rechargeable NiMH battery and pin connection, Version 2 (Current production version)

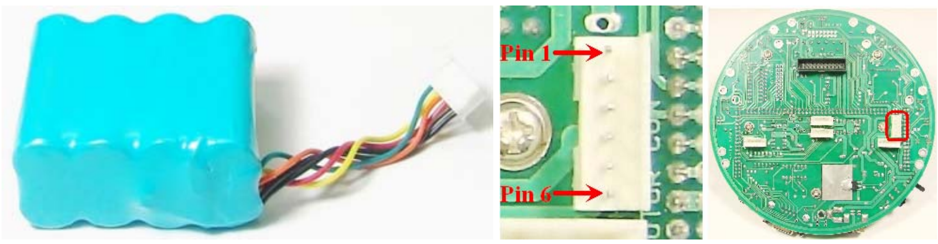

Figure 8.7B: 9.6V, 2000mAH rechargeable NiMH battery and pin connection, Version 1 (IIT B old version)

⚠ The NiMH battery provided with Fire Bird V has a connector which will fit into the above shown connector in only one orientation. Do not force the connection in any other way.

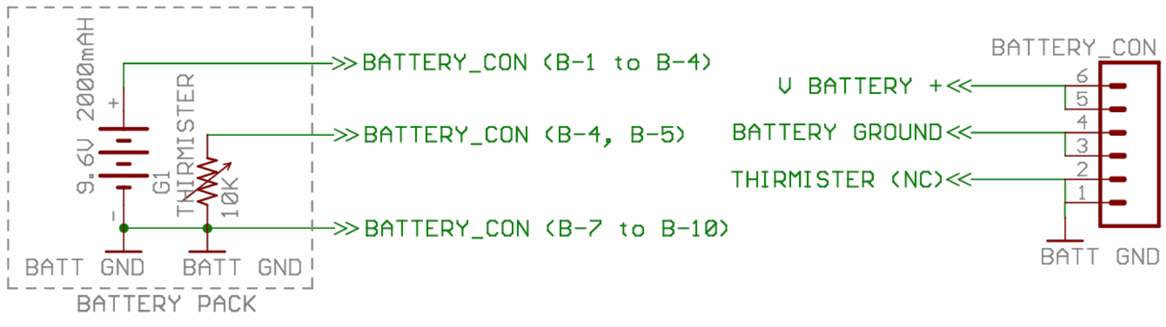

Figure 8.8: Battery for Fire Bird V P89V51RD2

Pin No.	Wire color	Function
1	Green	Battery +
2	Yellow	
3	Orange	Battery -
4	Red	
5	Brown	Thirmister out
6	Black	

Table 8.2: Battery connections

8.2.2 Power sources and voltage regulation on the main board

Although Fire Bird V can be powered by NiMH battery but in order to do experiments for longer duration with out worrying about the battery getting low, robot can be powered by external power source which is also called as auxiliary power source. Auxiliary power source provides regulated 12V, 1Amp. supply to the robot. You can apply up to 18V to the robot with out any problems. Beyond 18V voltage regulators on the robot will start failing and system will get damaged. The entire supply lines combined together robot can supply maximum of 1Ampere current to the external load when operation on the battery.

Most of the systems on board the robot require 5V regulated supply. Only wireless module requires 3.3V supply. Robot’s main board has three voltage regulators and two additional power lines for different types of functionalities.

Depending on the power switch position and the presence of the auxiliary power robot can run either on the battery or on the auxiliary power source. Supply is further divided in two types.

1. V Batt Supply

“V Batt Supply” stands for stabilized supply coming from the battery. When battery is almost discharged (about 30% power remaining) and onboard payload draws large current in excess of 2 amperes then battery voltage can fall below 6.3V momentary. Voltage regulators will not be able to function properly and its output will fall below 5V if input voltage falls below 6.3V. If output voltage falls below 5V then microcontroller can get reset. To extend the usable battery life and to reduce the probability of microcontroller getting reset diodes D7 and D8 along with the capacitor C54 is used. When battery voltage suddenly drops, diode D7 and D8 prevents the reverse flow of the current and capacitor C54 maintains voltage with in safe limits for about 300 milliseconds. For this duration capacitor C54 acts as small battery. Similar arrangement is done in the "V Mot Supply" using diodes D9, D10 and capacitor C53. This scheme extends usable range of the fully charged battery.

2. V Mot Supply

"V Mot Supply" stands for motor supply. It is used to power DC motors and other heavy loads having lots of current fluctuations. It is the nosiest supply line on the robot. It should be used for heavy loads which requires large amount of current. This supply can varied between 8V to 11.7V depending on the battery state and type of power source (battery / auxiliary power) used. This line can supply additional 800mA to the external load.

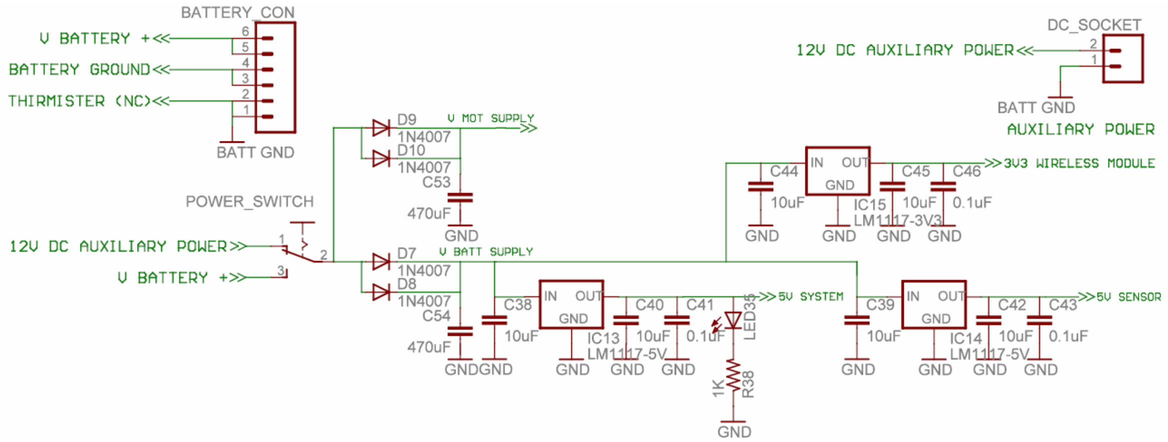

Figure 8.9: Voltage regulators on the main board

3. 5V System

"5V System" is used to power various modules of the robots which does not require high current and where voltage stability is very important. It is used to power logic supply of the ICs, sensing elements of the sensors, LCD etc. It is the most stable source of the supply on the main board. It can source 400mA current for the external load.

4. 5V Sensor

"5V Sensor" is used to power the active elements of the sensors and sensor modules. Its voltage can fluctuate by about 100mV if sensors are turned on or off. In fully loaded Fire Bird V robot this supply should not be used to power external load having current requirement more than 100mA.

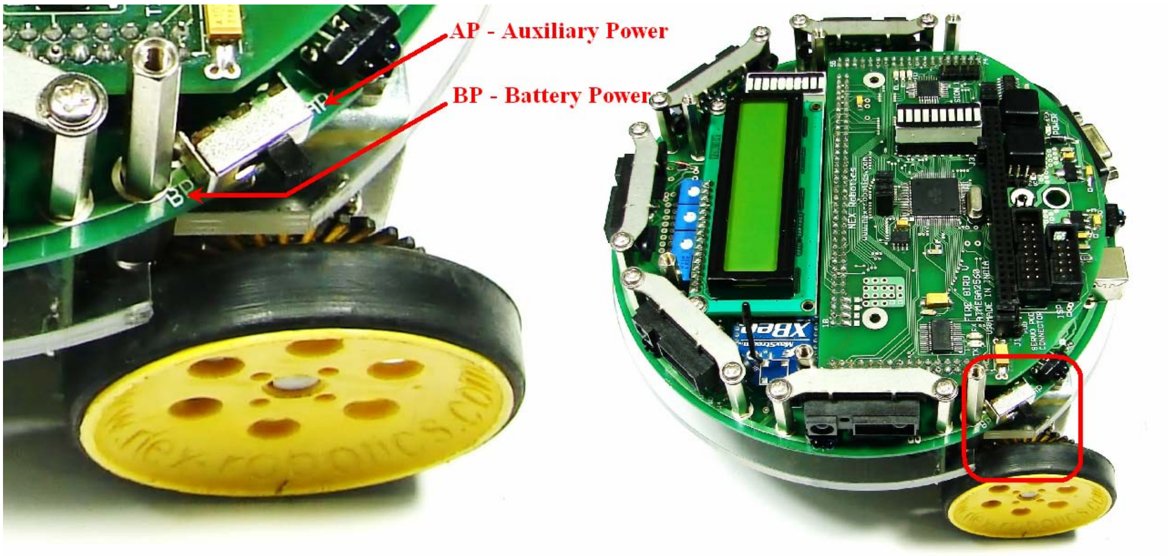

Figure 8.10: On / off switch position

8.2.3 Current sensing

Fire Bird V robot can sense its current consumption using Hall Effect current sensor ACS712.

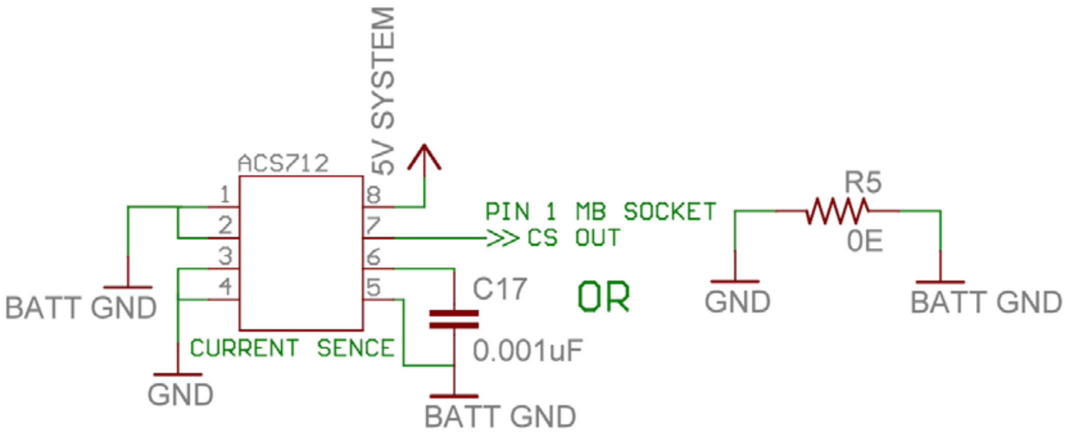

Figure 8.11: Current sensing in Fire Bird V

ACS712's current sensing element is located between robot's ground and the battery ground. When no current is flowing through the sensor, it gives 2.5V output. This output value reduces by 185mV / ampere of current flow. This sensor is an optional accessory. When this sensor is absent its sensing path is shorted with 0 ohm resistor.

Note: P89V51RD2 microcontroller based module does not support current sensing directly. To enable the support user will require doing some modification on the module.

8.2.4 Battery low indication

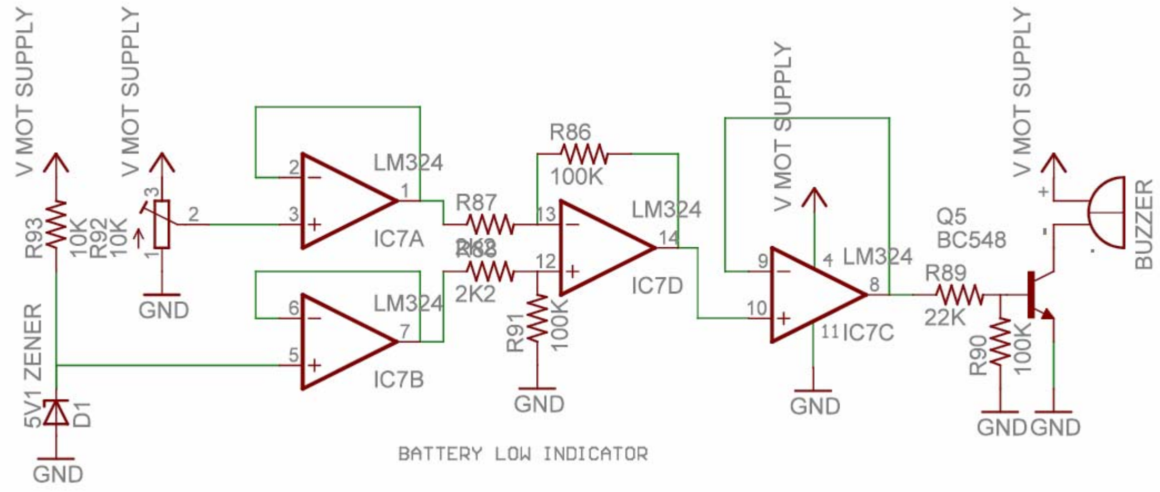

Figure 8.12: Battery low indication

Fire Bird V robot uses 8 cell NiMH battery. Battery is considered as fully discharged if its voltage drops below 8V. If robot is operated while battery is low, its performance will be inconsistent. To prevent any abnormality in the robot's behavior battery low indication is used. When robot's battery voltage goes below 8V robot starts giving beeping sound.

Zener diode D1 produces stable 5.1V reference irrespective of change in the battery voltage. This voltage is buffered by unity gain opamp module IC7B. Threshold value for the battery low warning is set by the potentiometer R92. Its value is buffered using module IC7A. Reference voltage and voltage form the potentiometer R92 are compared and difference is amplified with the gain of 45.45 (100K / 2.2K) in the module IC7D. Output coming from the module IC7D is buffered with IC7C unity gain opamp and given to the transistor Q5 which drives the battery low warning buzzer.

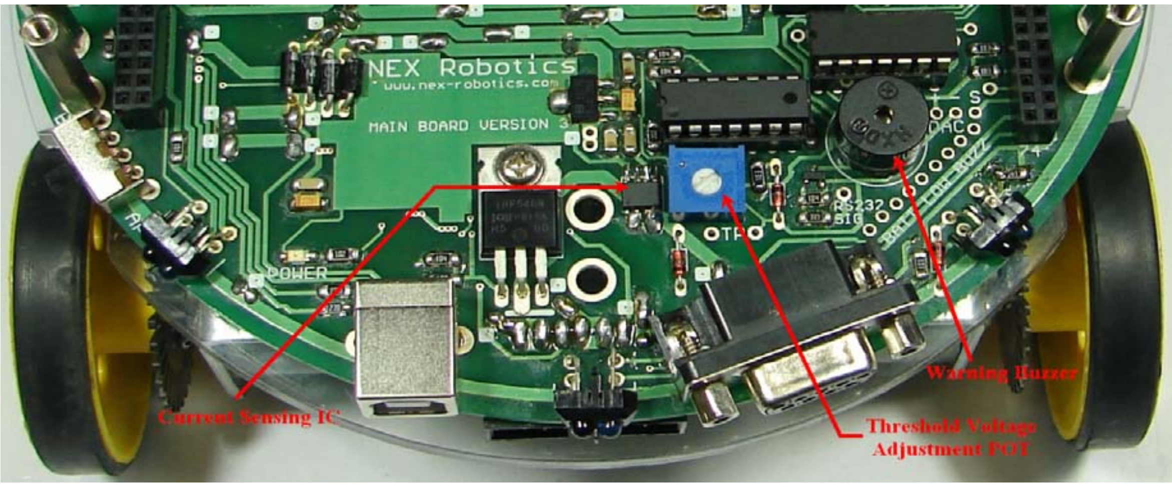

Figure 8.13: Various components of the power management module, Version 2 (Current production version)

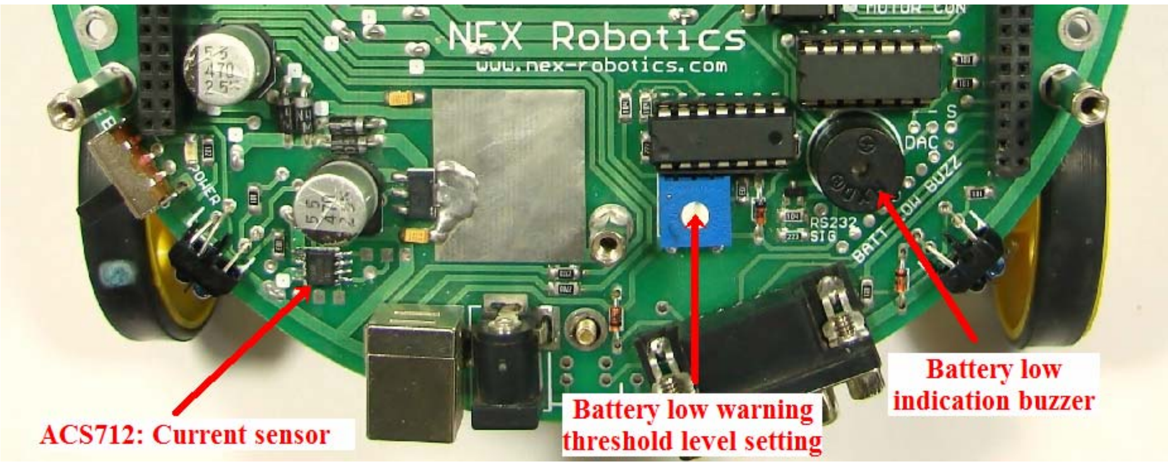

Figure 8.13B: Various components of the power management module, Version 1 (IIT B old version)

8.3 Sensors

Fire Bird V robot contains many types of sensors on the main board, microcontroller adaptor module and on the separate boards. We will cover sensors located on the microcontroller board in the separate section.

If a sensor emits some signal and senses any object based on the reflected signal then it is known as active sensor. If many robots in the same field are using active sensors such as Sharp IR range sensors, IR proximity sensors or ultrasound sensors then they will interfere with the sensors of the other robots.

To prevent this interference from occurring Fire Bird V can switch all of its active sensors on and off. This means that many Fire Bird series robots can work in same field without causing interference with other Fire Bird robot's sensor. Many robot's can synchronize when particular sensor should be turned on or off over wireless communication using ZigBee wireless modules. Another advantage of this facility is that robot can turn off these sensors when not in use to conserve power.

8.3.1 Sharp IR range sensors

For accurate distance measurement, the robot uses Infrared Range sensors. Up to 5 IR range sensors can be installed on the Fire Bird V main board. Fire Bird V supports three types of IR range sensors from Sharp Microelectronics.

GP2D120 GP2D12 GP2Y0A02YK

Figure 8.14: Sharp IR Range sensors for Fire Bird V

Sensor	Range	Blind Spot
GP2D120X	30cm to 20cm	4cm to 0cm

GP2D12	80cm to 10cm	10cm to 0cm
GP2Y0A02	150cm to 20cm	20cm to 0cm

Table 8.3: Sharp IR Range sensors coverage

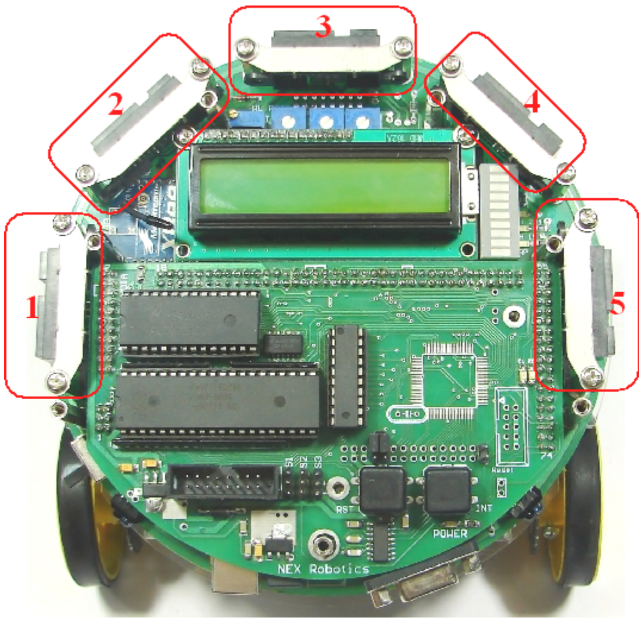

Figure 8.15: Sharp Sensors mounted on Fire Bird V

Working of the Sharp IR range sensors is covered in detail in the section 3.8 of the chapter 3. Sharp IR range sensor is an active sensor i.e. it emits signal (IR beam) and measures angle of reflection for distance from the obstacle.

In order to prevent interference with other robot's sensors all the sharp sensors can be turned on or off by the microcontroller.

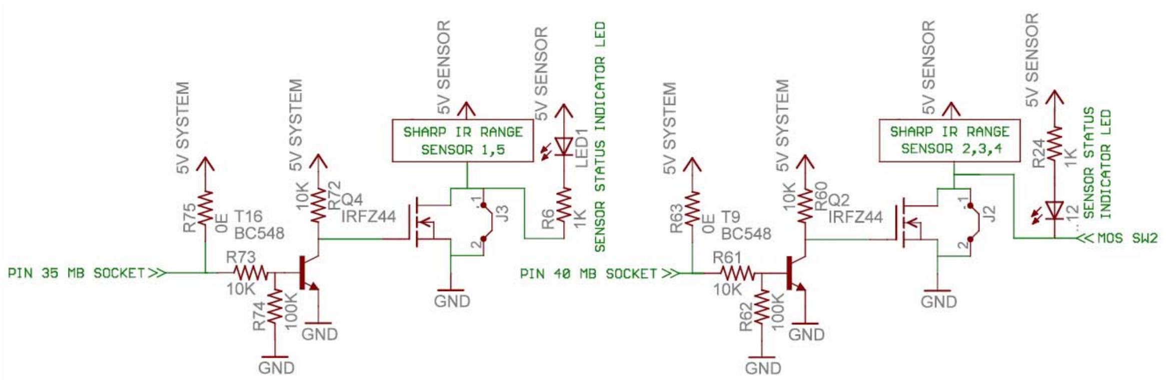

Figure 8.16: Sharp IR range sensors

Sharp IR range sensor 1 and 5 are controlled by the MOSFET Q4. Sharp IR range sensors 2,3 and 4 are controlled by the MOSFET Q2. These sensors can be permanently enabled by putting jumper J3 and J2 on the main board. In the normal case when input is less than 0.65V or there is no input at the Pin 35 and 40 of the main board's socket, corresponding transistors T16 and T9 are off. Gate of the MOSFETs Q4 and Q2 gets 5V which drives them in to saturation and sensors are turned on. When input voltage more then 1V is applied at the Pin 35 and 40 of the main board's socket, corresponding transistors T16 and T9 goes in to saturation, there by grounding gates of the MOSFETs Q4 and Q2 which turns off the MOSFETs and sensors are switched off.

Sensors	**Main board socket pin number**	**Logic state**	**Jumper to turn on sensors permanently**
Sharp IR range sensor 1,5	34	0: Sensors are turned on 1: Sensors are turned off	J3
Sharp IR range sensor 2,3,4 and LEDs of the white line sensors (left, center, right)	40	0: Sensors are turned on 1: Sensors are turned off	J2
IR proximity sensors 1 to 8	33	0: Sensors are turned on 1: Sensors are turned off	J4

Table 8.4: Sensor power control pins and jumpers

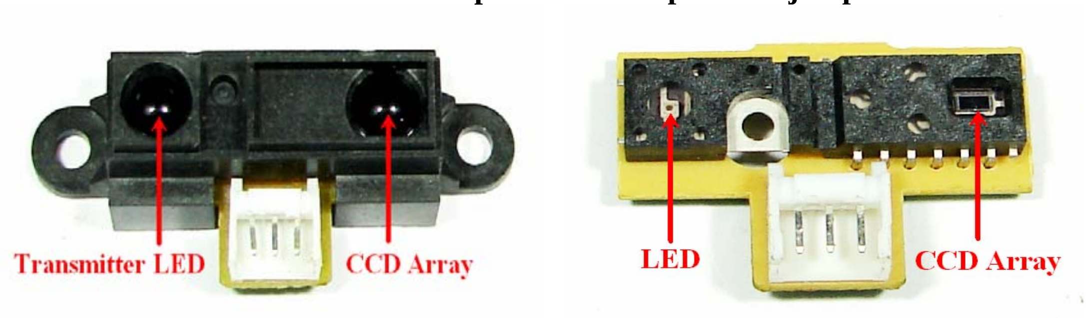

Fig 8.17: Infrared Range finder sensor and its inside view

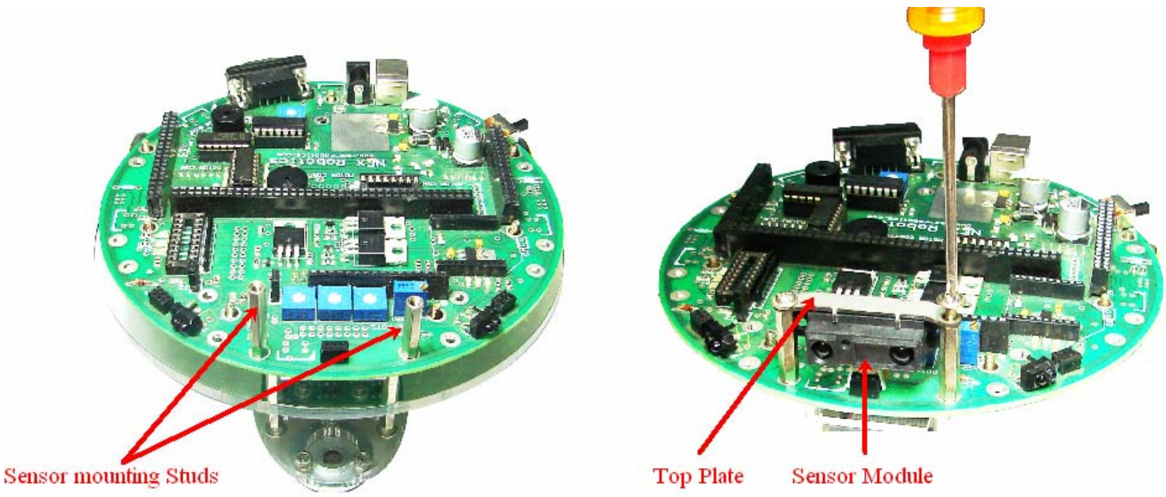

Figure 8.18: Installing Sharp IR range sensor on the main board

Note:

- MOSFET Q2 also controls the turning on / off of the red LEDs of the white line sensors.
- If you are not going to switch sensors on / off using MOSFETs then corresponding jumpers as per the table 8.4 should be shorted on to turn on sensors permanently.

- P89V51RD2 microcontroller based module only supports Sharp IR range sensor number 3(front sensor). To add Sharp IR range sensor number 2 and 4 you have to remove two 0 ohms resistors on the microcontroller adaptor board. (Covered in the section 8.3.2
- P89V51RD2 microcontroller based module can not turn on or off any of the active sensors.
- Sharp GP2Y0A02 sensors body is made up of conductive plastic. Hence foam tape is added as an insulator between the sensor and the metal strip. If This isolation is not provided then sensor will get direct ground path and switching MOSFTT will get bypassed which is not recommended.

8.3.2 IR Proximity and directional light intensity sensors

Infrared proximity sensors are used to detect proximity of any obstacles near the robot. Directional light intensity sensor gives intensity of the light in particular direction. IR proximity sensor consists of IR LED and IR photo diode. When obstacle comes within sensing range IR photo diode detects reflected light of the IR LED. To reduce interference with ambient light photo diode is cased in material which allows only IR light to pass. In order to eliminate interference due to ambient light while sensing obstacle, reading should be taken while IR LED is on and off. By comparing these two values effect of ambient light can be nullified. To detect directional light intensity, IR LED is turned off and light intensity at photo diode is measured. Fire Bird V has eight IR proximity sensors. IR LEDs of all these sensors can be turned on and off by MOSFET Q3. To turn on IR LEDs permanently J4 needs to be shorted. Refer to table 8.4 for more details. MOSFET operates in a same way as explained in section 8.3.1.

In the absence of the obstacle there is no reflected light hence no leakage current will flow through the photo diode and output voltage will be around 5V. As obstacle comes nearer, more light gets reflected and falls on the photo diode and leakage current flowing through the photo diode starts to increase and voltage across the diode starts to fall.

When IR proximity sensors used in conjunction with Sharp IR Range sensors, IR proximity sensors covers sensing range in which Sharp IR Range sensors have blind spot. IR proximity sensors working together with Sharp IR range sensors covers range from 0 to maximum range of the Sharp IR sensor without having any blind spot.

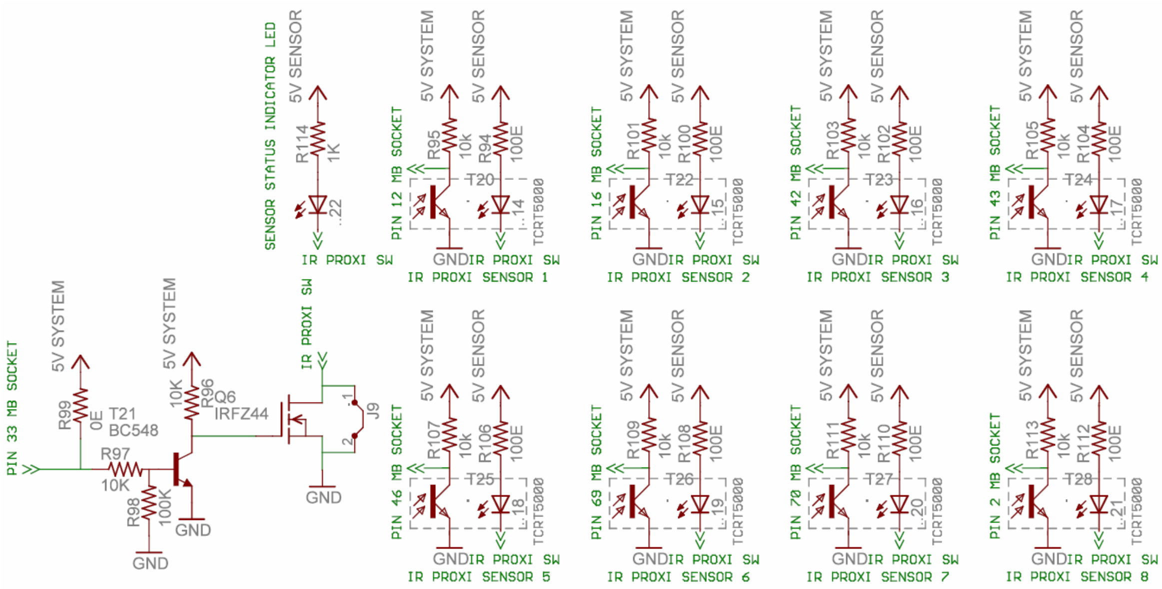

Figure 8.19: IR Proximity sensors

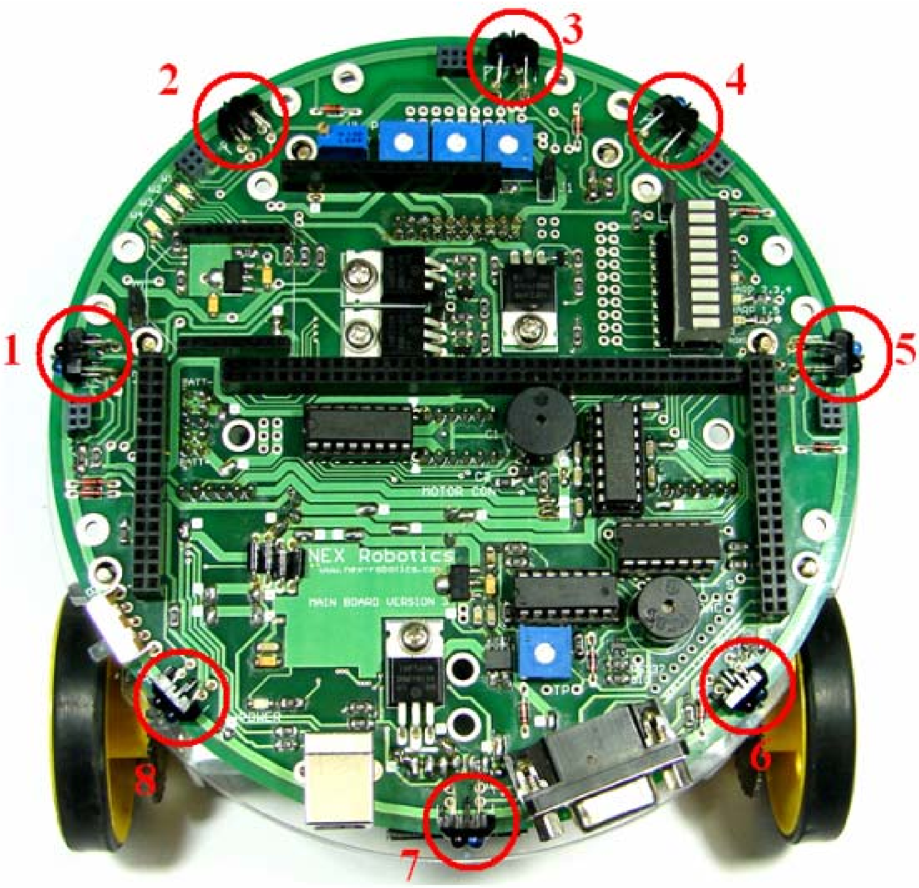

Figure 8.20: IR Proximity sensor positions

8.3.3 Enabling Sharp IR range sensor 2 and 4

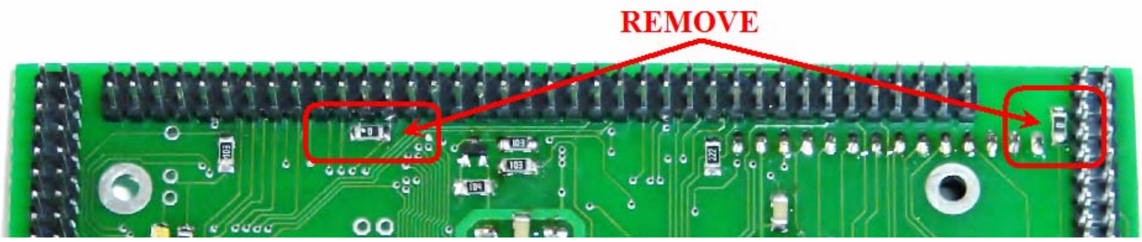

Figure 8.21: Modifications for enabling Sharp IR range sensor 2 and 4 in P89V51RD2 microcontroller adaptor board

In the default state P89V51RD2 microcontroller adaptor board is interfaced to IR proximity sensors 2,3,4 and Sharp IR sensor 3. If you want to add Sharp IR proximity sensor 2 and 4 then you have to remove two 0 ohm smd resistors connected between pin 15-16 and pin 42-43. These resistors are located just below the corresponding pins.

8.3.4 Sharp IR range sensors and IR proximity sensor status indicator and jumpers

Figure 8.22 shows jumpers and corresponding MOSFETs used to turn on / off the sensors. Figure 8.23 shows the LEDs which indicates the status of the sensors.

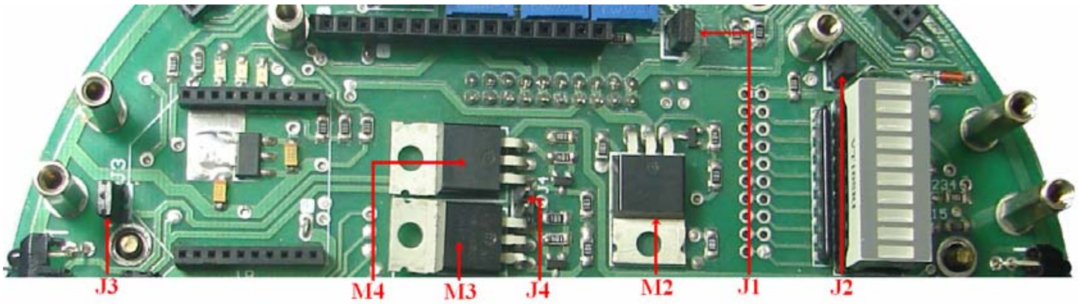

Figure 8.22: Sensor Control Switches and Jumpers

Name	Function
J1	LCD Backlight Enable/Disable
J2	Front Sharp and White line sensors Enable/Disable
J3	Side Sharp Sensors Enable/Disable
J4	IR Proximity(TCRT) Sensors Enable/Disable
M2	Front Sharp and White Line Sensors MOSFET
M3	IR Proximity (TCRT) MOSFET
M4	Side Sharp MOSFET

Table 8.5 Jumper functions

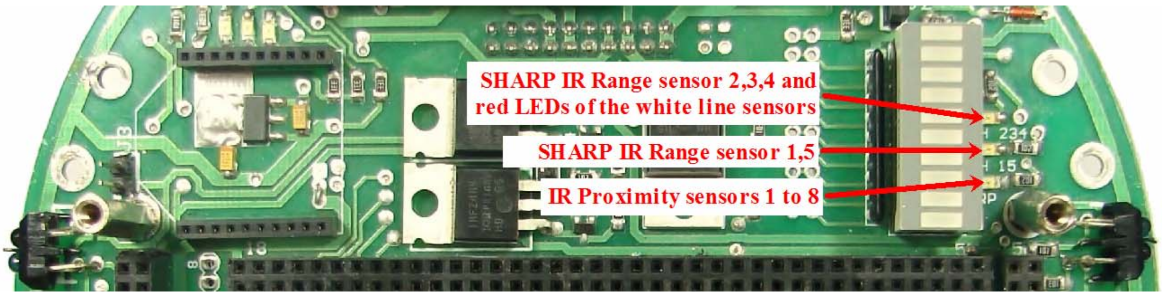

Figure 8.23: Sensor status indicator LEDs

8.3.5 White line sensors

White line sensor consists of a highly directional phototransistor for line sensing and red LED for illumination. Due to the directional nature of the phototransistor it does not get affected with ambient light unless it is very bright.

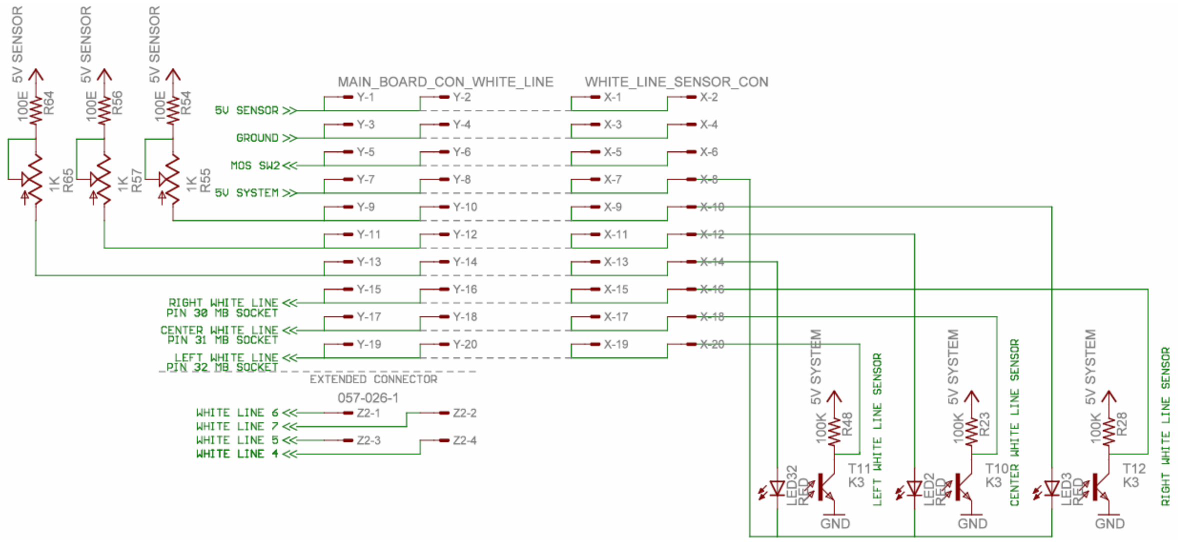

Figure 8.24: Schematic of white line sensor

White line sensor consists of ultra bright red LED and highly directional phototransistor. Ultra bright red LED illuminates the ground surface and the highly directional phototransistor senses the reflected light from very small surface. White line sensor can be calibrated for different types of operating conditions by adjusting the light intensity of the red LEDs. This can be done by tuning potentiometers R65 (left white line sensor), R57 (center white line sensor), R55 (right white line sensor). 100 ohms resistors which are in the series of the potentiometers R65, R57 and R55 protect red LEDs from the excess of current if potentiometers tuned to 0 ohms. Potentiometers are factory set for the best performance. There values should not be changed unless required. LEDs are powered by 5V sensor supply while photo transistors are powered by 5V system supply for better stability. Resistors R48, R23 and R28 determine the sensitivity of the phototransistor. By repeated experimentations we found 100K ohms as the optimal value for best performance in all the conditions.

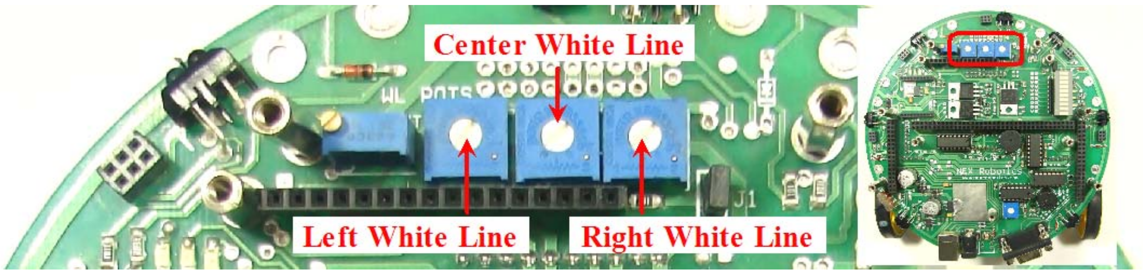

Figure 8.25: Potentiometers for white line sensor calibration

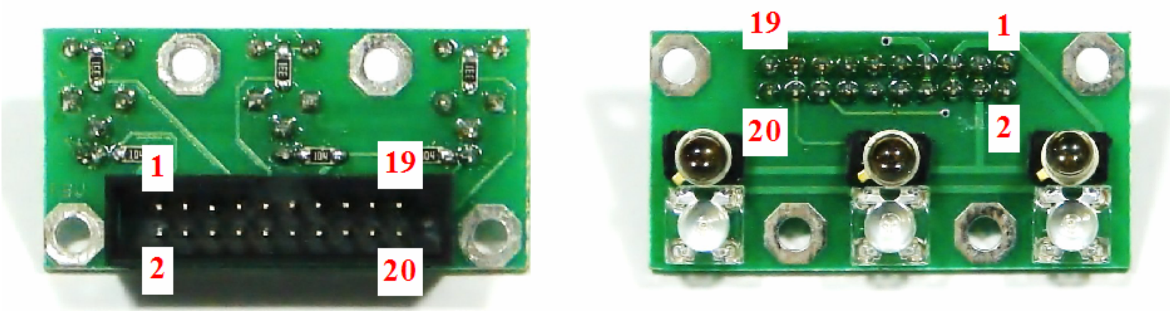

Figure 8.26: White line sensor pin connections

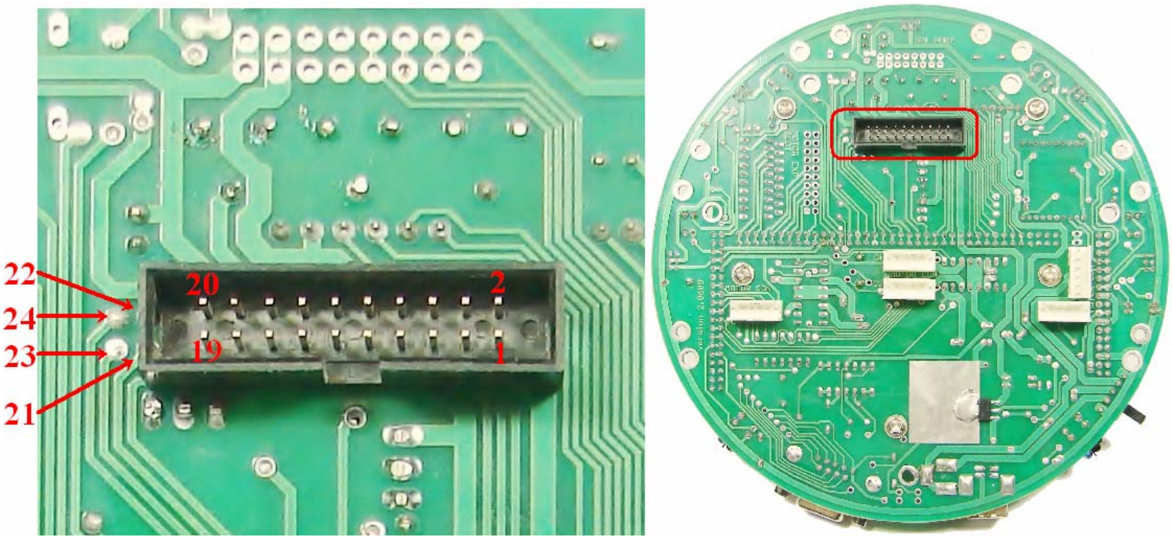

Figure 8.27: White line extension to mount 5 or 7 channel white line sensor

Pin No.	Function
1,2	W.L sensor 1 (Left sensor) Data Out
3,4	W.L sensor 2 (Centre sensor) Data Out
5,6	W.L sensor 3 (Right Sensor) Data Out
7,8	W.L sensor 1 LED
9,10	W.L sensor 2 LED
11,12	W.L sensor 3 LED
13,14	System Supply, 5V
15,16	LED common cathode
17,18	GND
19,20	Sensor Supply, 5V
21	Expansion slot for White Line sensor 5
22	Expansion slot for White Line sensor 4
23	Expansion slot for White Line sensor 6
24	Expansion slot for White Line sensor 7

Table 8.6: White line sensor pin connections

In the default condition Fire Bird V is interface with the 3 channel white sensor. Robot can also be easily interfaced with the 5 or 7 channel white line sensors. In the 3 channel white line sensor 20 pin FRC connector is used. To make support for 5 or 7 channel white line sensors 26 pin FRC connector needs to be added. In the figure 8.24 and figure 8.27, pins Z2-1 to Z2-4 are used for connecting additional 4 white line sensors. Figure 8.27 shows the location of these pins on the main board.

8.3.6 Other sensors

Fire Bird V robot have many more sensors such as current sensor, position encoders, TSOP1738 IR receiver, Voltage sensing and lots of add-on sensors which will be covered in the different topics in the manual.

8.4 Actuation (locomotion)

Fire Bird V robot has four motion control ports. Figure 8.31 shows the location of the required ports. Each Port can drive one DC motor and also provides connections for the position encoder. Motor is driven by L293D motor driver IC. Each IC can drive two DC motors with maximum current rating of 500 mA. Fire Bird V's main board has two L293D ICs.

"5V system supply" is used for driving L293Ds logic circuits. "V Batt Mot" is used to supply power for motor driving. C22 – C25 and C29 – C32 is used for noise suppression.

Optical encoder MOC7811 is used for position encoder on the robot. It consists of IR LED and the photo transistor mounted in front of each other separated by a slot in the casing. When IR light falls on the photo transistor it gets in to saturation and gives logic 0 as the output. In the absence of the IR light it gives logic 1 as output. A slotted encoder disc which is mounted on the wheel is placed in between the slot. When encoder disc rotates it cuts IR illumination alternately because of which photo transistor gives square pulse train as output. Output from the position encoder is cleaned using Schmitt trigger based inverter (not gate) IC CD40106.

Logic signals to drive the two L293D comes from the pins 47 to 55 and pins 66 to 68. Logic level on the pins 47 to 55 can be seen on the bar graph LED display on the main board. Figure 8.33 shows the connections of pins from the main board socket in general. Figure 8.34 shows the same connections but with respect to P89V51RD2 microcontroller adapter board.

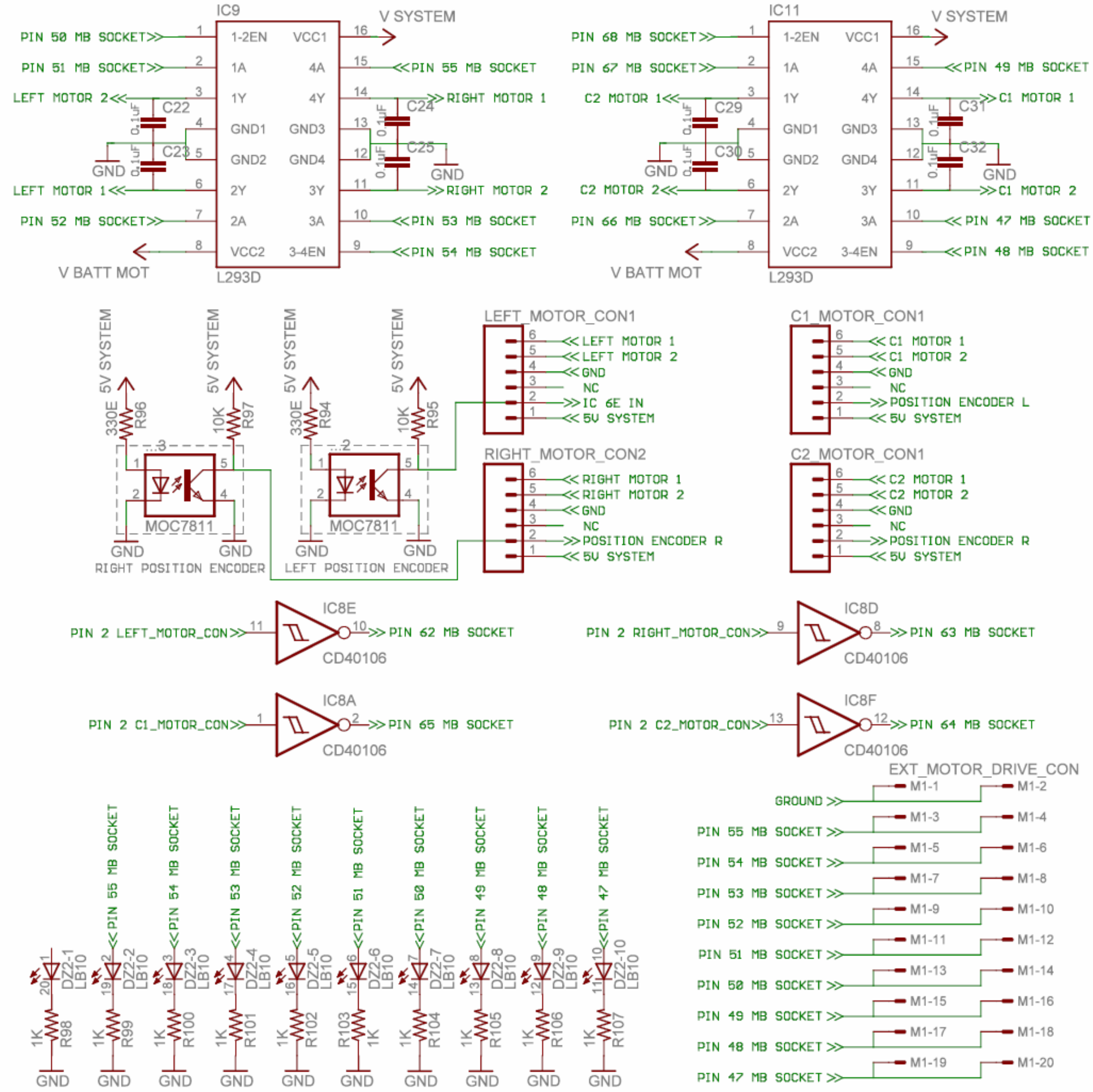

Figure 8.28: Schematic of the motion control module

If you want to drive bigger robot using Fire Bird V main board then L293D motor drivers on the main board can not provide sufficient power. In such case we can use drive high power motor drivers such as [Hercules 30 Amp. Mini Motor Driver] (NR-MDR-02) from NEX Robotics for driving these motors. Figure 8.31 shows the location of the external motor interface port. All the logic signals coming from the pin 47 to 55 and ground pin is connected to this port. User can solder 20 pin FRC connector and interface these pins to the external motor drivers. Up to 3 [Hercules 30 Amp. Mini Motor Driver] (NR-MDR-02) can be interface with this port. Logic state on these pins can be observed on the bar graph LED display.

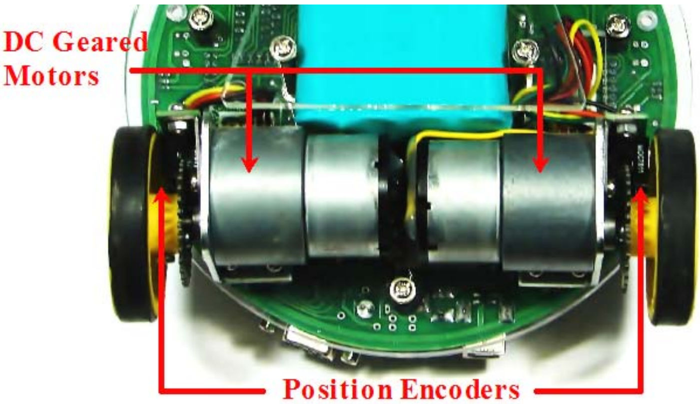

Figure 8.29: DC geared motors and position encoders

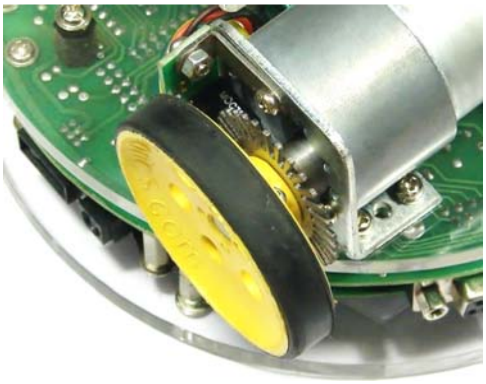

Figure 8.30: Position encoder assembly

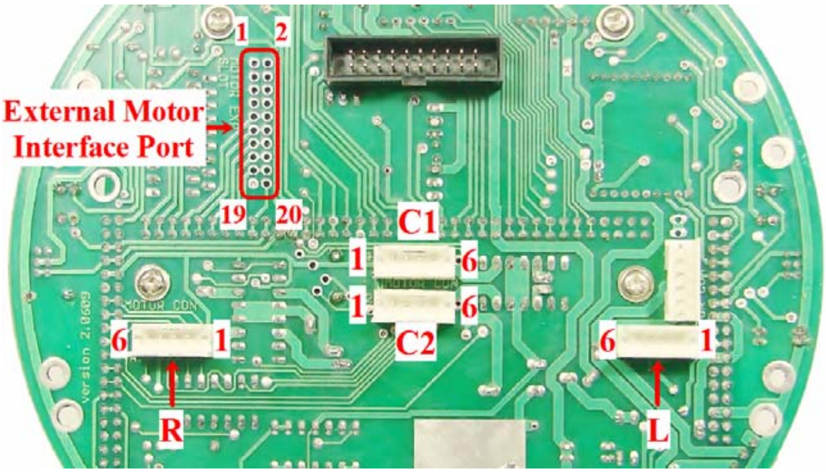

Figure 8.31: Motion control connections on the main board

Connector Name	**Description**
L	Left motor connector 1
R	Right motor connector 2
C1	C1 motor connector
C2	C2 motor connector
External Motor Interface Port	Logic signals of pins 47 to 55 of the main board socket for interfacing external high current motor drivers

Table 8.7: Use of connectors of the motion control module

Pin No.	Motor and encoder module wire colors	Function
1	Black	VCC, 5V System
2	Brown	Position Encoder data
3	Red	NC
4	Orange	GND
5	Yellow	Motor 2
6	Green	Motor 1

Table 8.8: Motor drive port pin connections

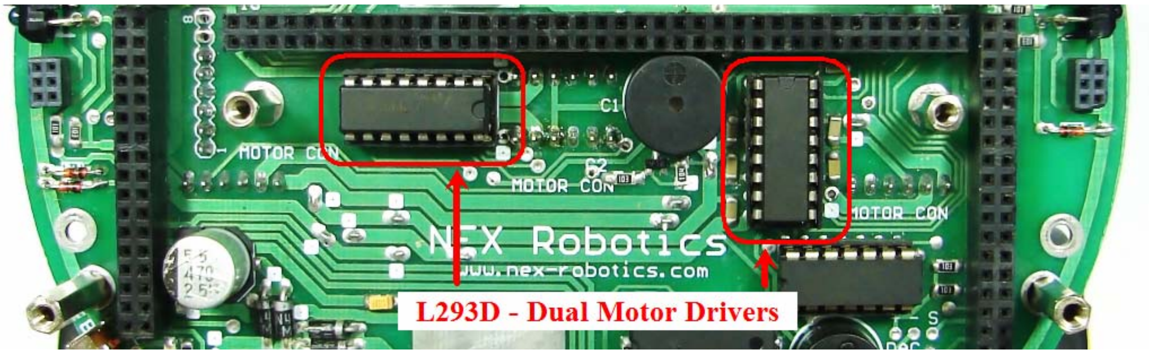

Figure 8.32: L293D motor driver ICs on the main board

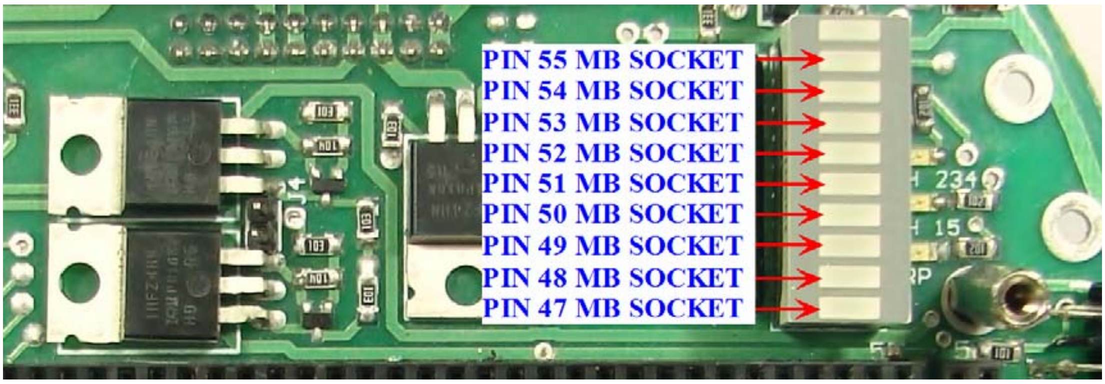

Figure 8.33: Motion status LED indication

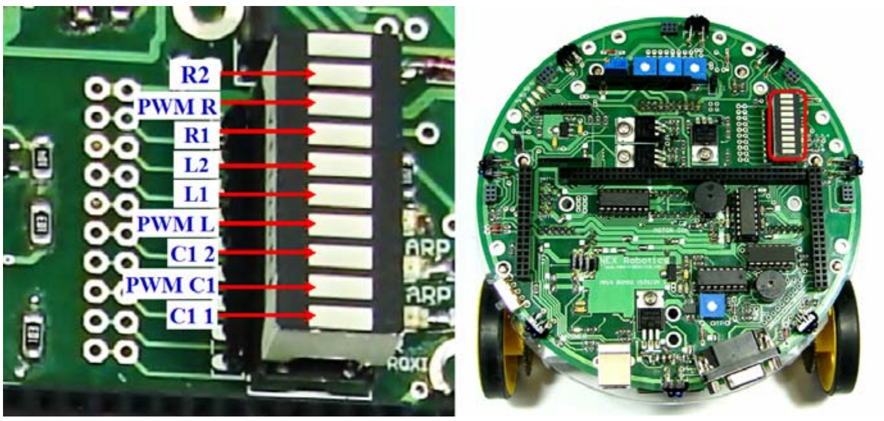

Figure 8.34: Motion status LED indication for P89V51RD2 microcontroller adaptor board for Fire Bird V

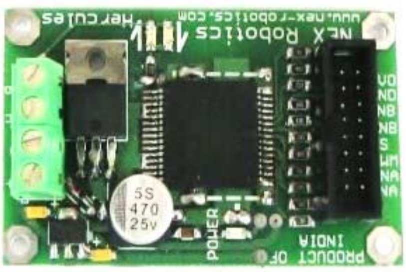

Figure 8.35: Hercules 30 Amp. Mini Motor Driver (NR-MDR-02) for driving high power motors

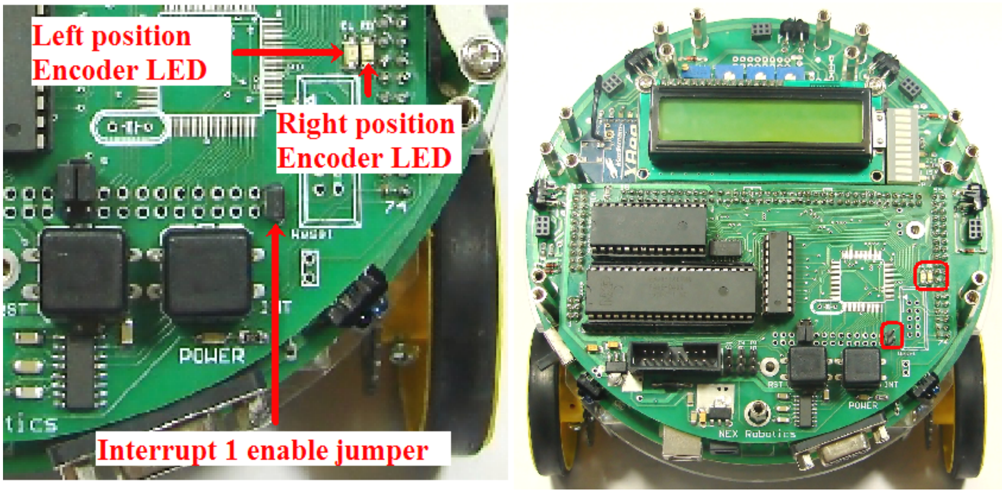

Figure 8.36: Jumper to enable left position encoder and position encoder LEDs on the P89V51RD2 microcontroller adaptor board

Note: To connect the interrupt 1 with the position encoder in case of P89V51RD2 microcontroller adaptor board connect the jumper as shown in the figure 8.36.

8.5 Other peripherals

8.5.1 LCD

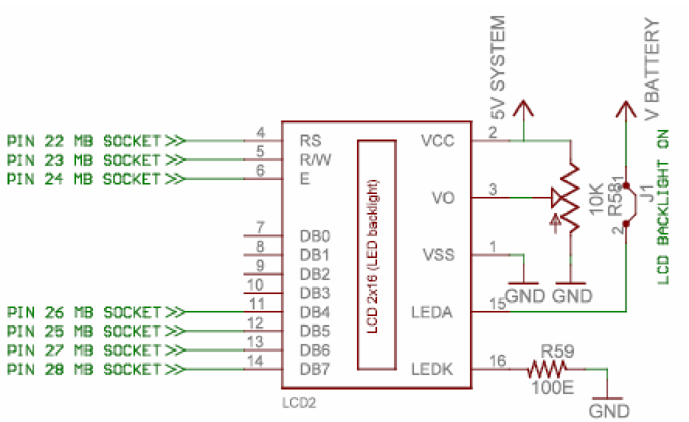

Figure 8.37: LCD display schematics

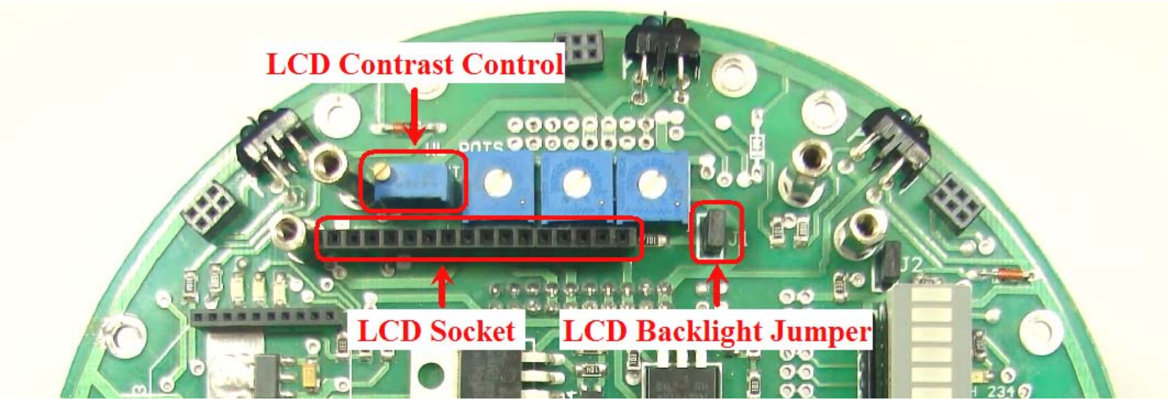

Figure 8.38: LCD socket and other settings

LCD is interfaced to the pins 22 to 28 of the main board socket. LCD uses 5V System supply for its operation. For LCD backlight V Battery supply is used. Figure 8.38 shows LCD backlight jumper and LCD contrast control potentiometer. In order to save power LCD backlight can be turned off by removing LCD backlight jumper. LCD's contrast can be adjusted by LCD contrast control potentiometer.

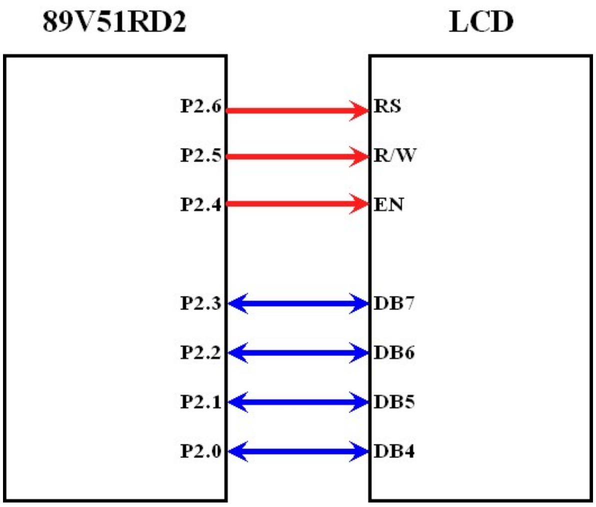

Figure 8.39: LCD interfacing with the P89V51RD2 microcontroller adaptor board

Microcontroller	**LCD PINS**	**Description**
VCC	VCC	Supply voltage (5V).
GND	GND	Ground
P2.4	E (Control line)	Enable
P2.5	-R/W (Control line)	-READ /WRITE
P2.6	RS (Control line)	Resistor select
P2.0 to P2.3	D4 to D7 (Data lines)	Bidirectional Data Bus
	LED+, LED-	Backlight control

Table 8.9: LCD pin mapping with the P89V51RD2 microcontroller adaptor board

8.5.2 Buzzer

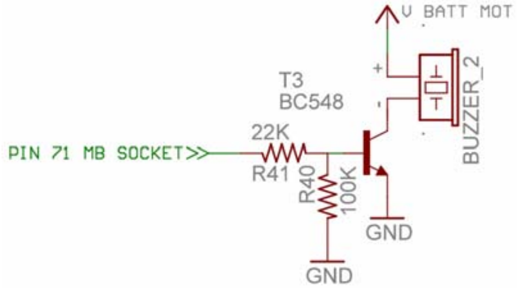

Figure 8.40: Buzzer

Buzzer is driven by BC548 transistor. Resistor R40 of 100K is used to keep transistor off if the input pin is floating. Buzzer will get turned on if input voltage is greater than 0.65V.

8.5.3 SPI expansion port on the main board

SPI expansion port will be used in future to add robotic arm, color sensing sensors etc. It has SPI communication pins and important types supply for powering these devices. Port can be seen in figure 8.5.

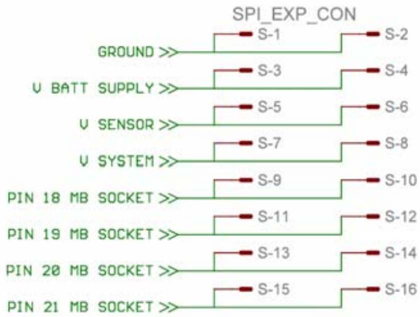

Figure 8.41: SPI expansion port pin functions

8.6 Communication

8.6.1 Serial communication

Serial port's pin 2, 3 and 5 are connected with the main board socket. Other pins of the serial port are also available on the main board. Figure 8.42 shows the serial port connections on the main board and table 8.9 gives the pin functions of the each pin.

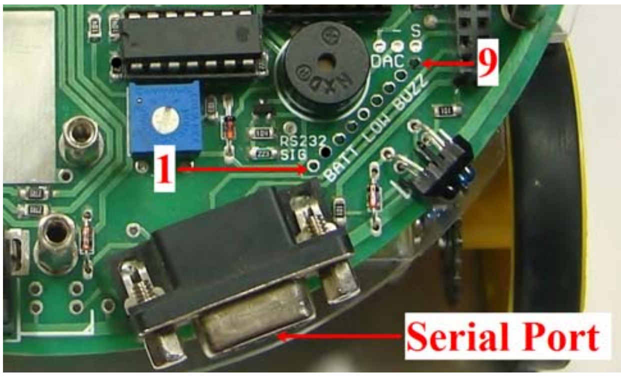

Figure 8.42: Serial port pins

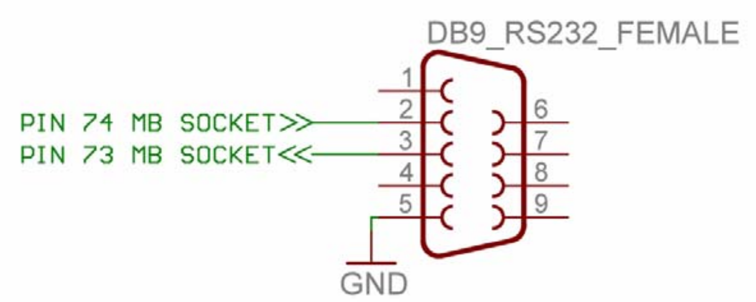

Figure 8.43: Serial port connections with the main board socket

Pin No.	Description	Comments
1	Data Carrier Detect (DCD)	Not Used
2	Receiver Data (RXD)	Used
3	Transmit Data (TXD)	Used
4	Data Terminal Ready (DTR)	Not Used
5	Signal Ground (GND)	Used
6	Data Set Ready (DSR)	Not Used
7	Request to Send (RTS)	Not Used
8	Clear to Send (CTS)	Not Used
9	Ring Indicator (RI)	Not Used

Table 8.10: Serial port pin out

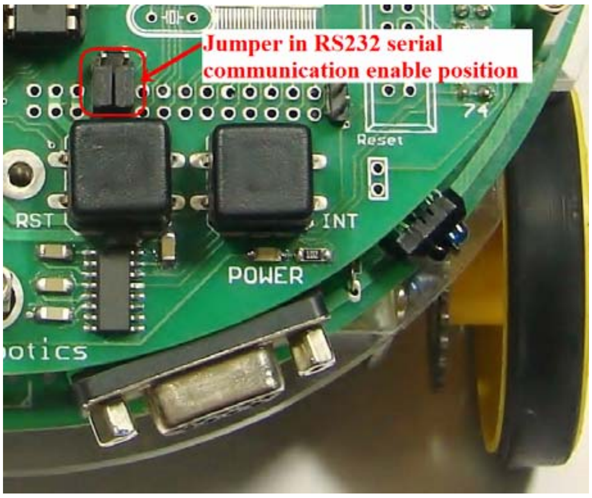

Figure 8.44: Jumper positions to enable RS232 serial communication in case of P89V51RD2 microcontroller adaptor board

Note: In case of P89V51RD2 microcontroller adaptor board, before using RS232 serial communication jumpers should be in the position as shown in the figure 8.44.

8.6.2 USB communication

Fire Bird V's main board have USB port. All its pins are connected to the main board socket.

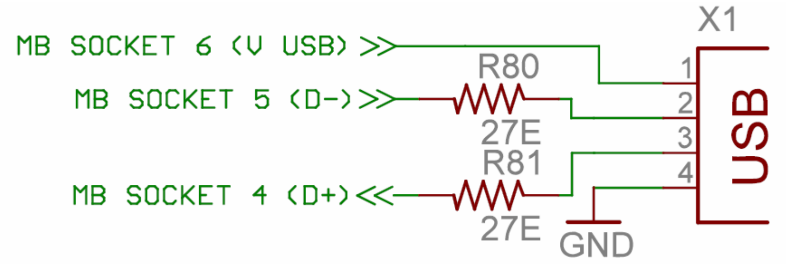

Figure 8.45 USB port connections with the main board socket

8.6.3 ZigBee wireless communication

Fire Bird V uses XBee wireless modules form Digi international (www.digi.com). LEDs A2, A3 and A4 are used for status indication of the wireless module. Read the wireless module's datasheet for more details.

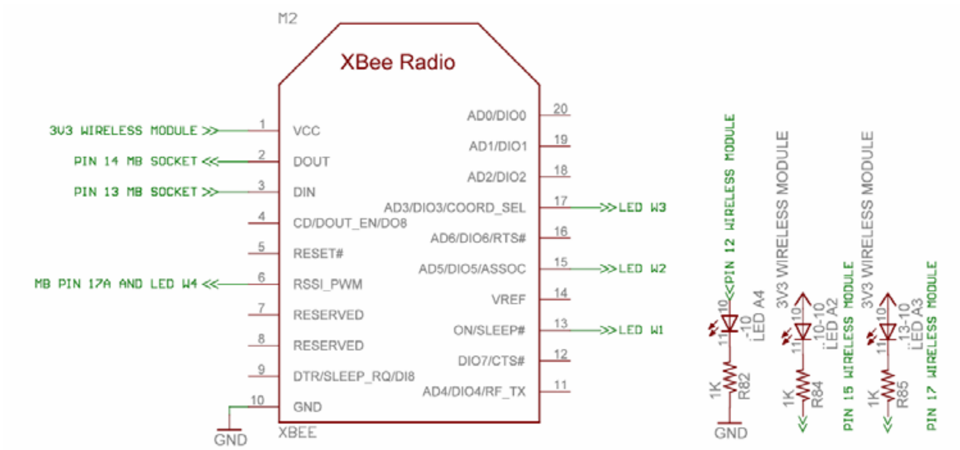

Figure 8.46 ZigBee wireless module schematics

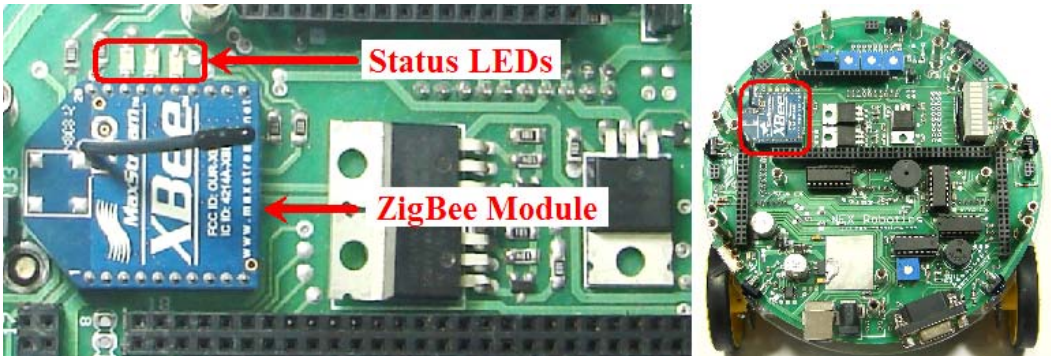

Figure 8.47 ZigBee wireless module and LED indicators

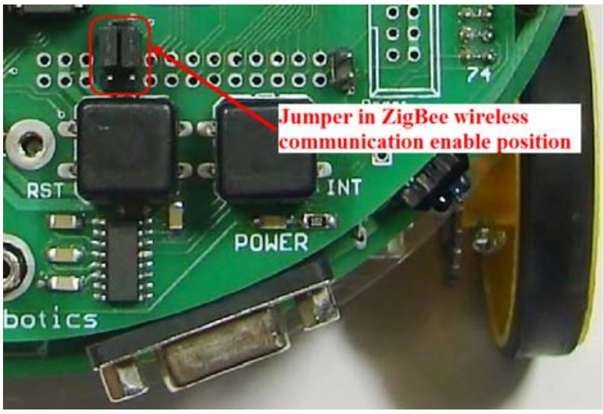

Figure 8.48: Jumper positions to enable ZigBee wireless communication in case of P89V51RD2 microcontroller adaptor board

Note: In case of P89V51RD2 microcontroller adaptor board, before using ZigBee wireless communication jumpers should be in the position as shown in the figure 8.48.

8.7 P89V51RD2 microcontroller adaptor board

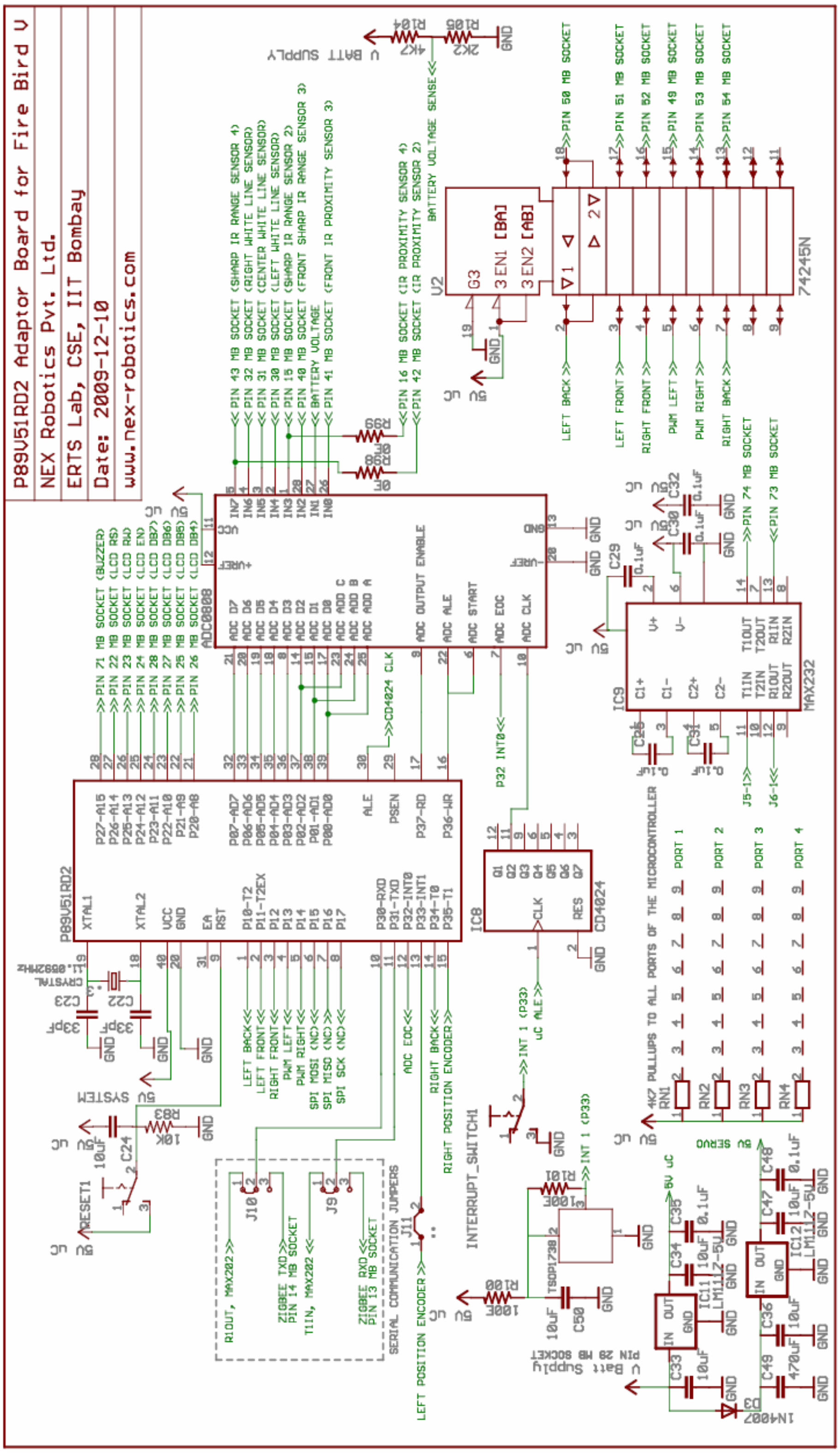

Figure 8.49: P89V51RD2 microcontroller adaptor board schematics

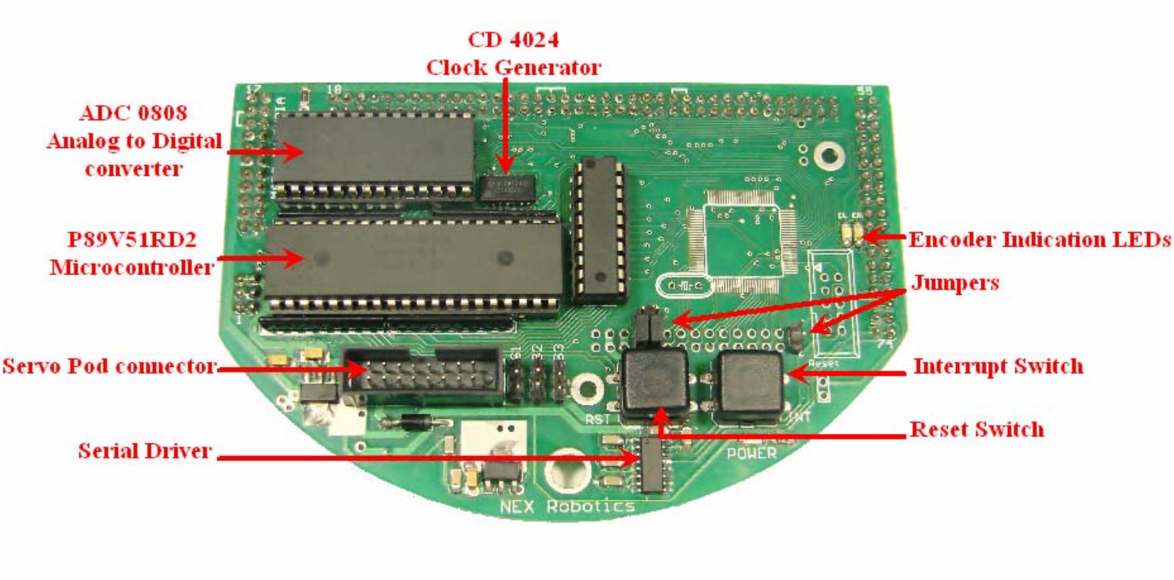

Figure 8.50: P89V51RD2 microcontroller adaptor board for the Fire Bird V robot

8.7.1 Power management

Power management block on the P89V51RD2 microcontroller adapter board provides power to the microcontroller and other devices and the power for the servo motor.

P89V51RD2 microcontroller adapter board has two low drop voltage regulators:

1. "5VuC" supplies power to the microcontroller and its peripherals
2. "5V servo" supplies power to the servo motor.

8.7.2 Battery voltage sensing

Filtered battery voltage is used for battery voltage sensing. Analog to Digital Converter (ADC) ADC0808 can measure maximum voltage of 5V. Hence battery voltage is scaled down from 8-12V to less than 5V using resistor divider network formed by R104 and R105. it scales down the voltage by approximately 1/3 of the actual value.

ADC0808 has 8 bit resolution. Hence to calculate voltage from the ADC's digital value we use following formula:

V Battery = 0.7V + (ADC value * (5V/255) * ((4.7K + 2.2K) / 2.2K)

V Battery = 0.7V + (ADC value * 0.06149)

In the above formula:

- 0.7V represents voltage drop across the diodes D7 and D8. Refer to figure 8.9 for more details.
- 5V/255 represents the ADC step resolution
- (4.7K + 2.2K) / 2.2K is a voltage divider formula

8.7.3 TSOP1738 RC5 IR receiver and decoder

TSOP1738 is a IR receiver and RC5 decoder. It is very commonly used in televisions for receiving commands from the remote control. It can be used to control robot using TV remote control or many robots can be controlled simultaneously if you make your own TV remote equivalent and interface it with the PC. Such type of setup can be used in the preliminary from of robosoccor.

8.7.4 Microcontroller and ADC0808

P89V51RD2 is an 8051 core based microcontroller. 11.0592MHz crystal is connected to the microcontroller for clock generation. R83 and C24 forms the power on reset circuit. Microcontroller has only 1 serial channel. Jumpers J9 and J10 are used select wired RS232 or wireless ZigBee communication. MAX202 is used to convert TTL signals to RS232 level. To enable left position encoder Jumper J11 needs to be connected. TSOP1738 IR receiver and external interrupt switches are directly connected to the interrupt 1 pin. Out of left position encoder, TSOP1738 IR receiver and external interrupt switch only one device should be used at a time. Microcontroller's pins which are going to the motor control IC L293D are also connected to the bargraph LEDs on the main board. On most of the pins P89V51RD2 microcontroller can not supply sufficient current to drive these LEDs. Hence IC74245 is used as buffer for the pins involved in motor control.

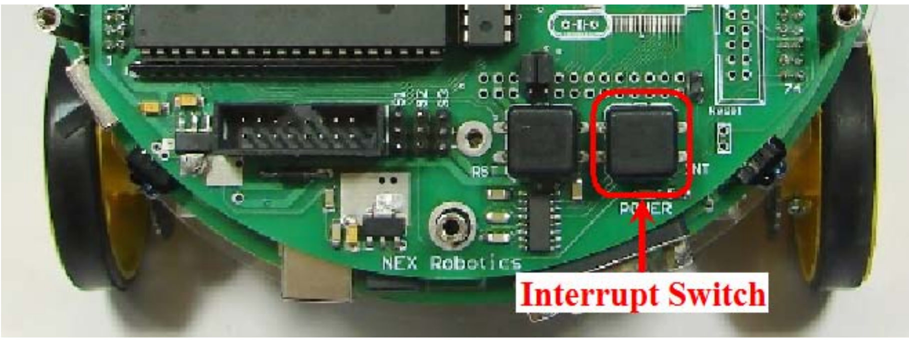

Figure 8.51: External Interrupt switch on P89V51RD2 microcontroller adapter board

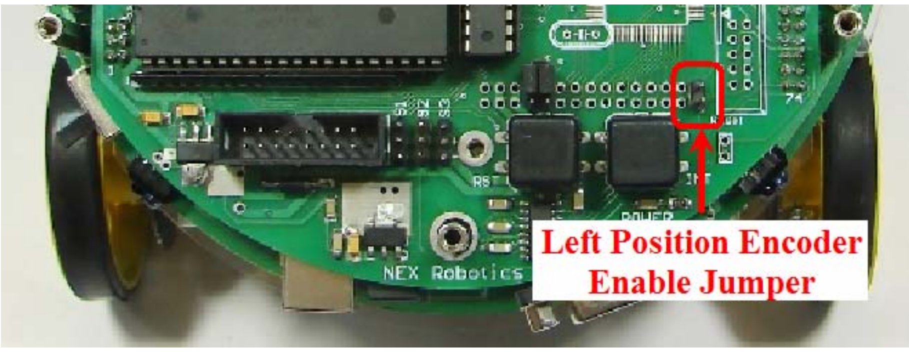

Figure 8.52: Jumper to enable left position encoder on P89V51RD2 microcontroller adapter board

ADC 0808 requires clock for operation. P89V51RD2 microcontroller's pin 30 (ALE) is weakly clocked at the $1/6^{th}$ of the clock cycle. It is divided by 4 using IC CD4024 and given to the ADC0808. To reduce number of I/Os required for ADC interfacing ADC's data and address buses are tied together and multiplexed using ADC output enable pin. ADC's ALE and START pins are tied together and connected to the microcontroller's single pin. ADC's EOC (end of conversion) pin is connected to the microcontroller's Interrupt 0 pin. For detailed operation of ADC, refer to software manual.

9. Upgrading Robot's Hardware

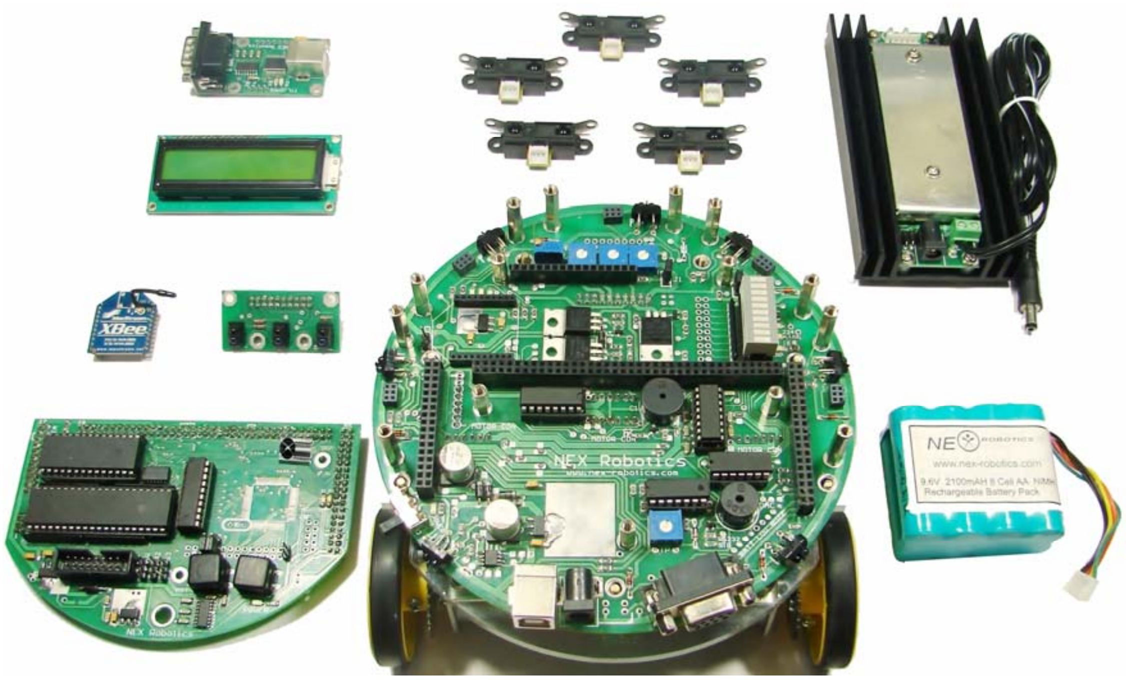

Figure 9.1: Fire Bird V robot and its accessories

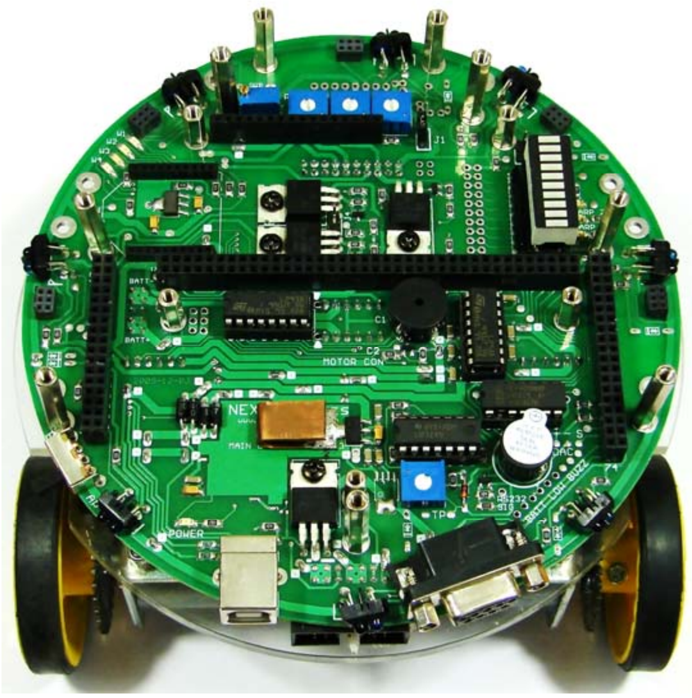

Figure 9.2: Fire Bird V main board

9.1 Installing XBee wireless module

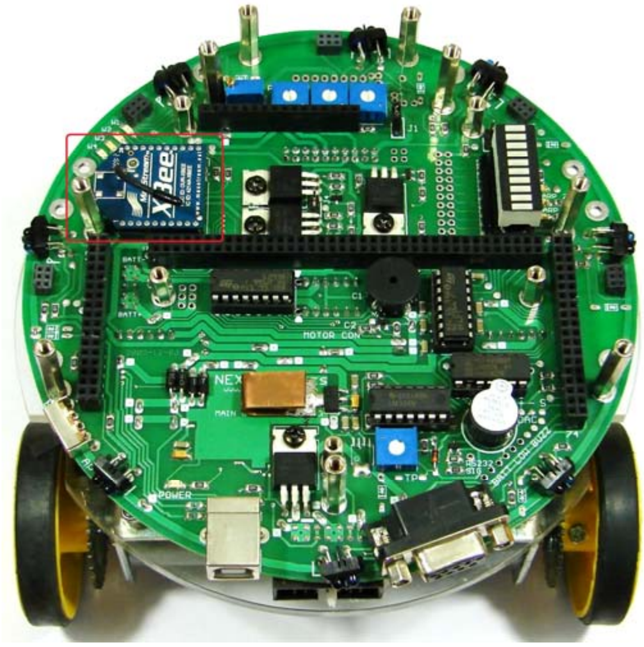

Figure 9.3: Mounting the XBee wireless module

Mount the ZigBee wireless module in the proper orientation.

You might have to configure ZigBee wireless module to the appropriate settings using USB wireless module and X-CTU software. For more details refer to Application notes.

9.2 Setting correct jumper settings on the main board

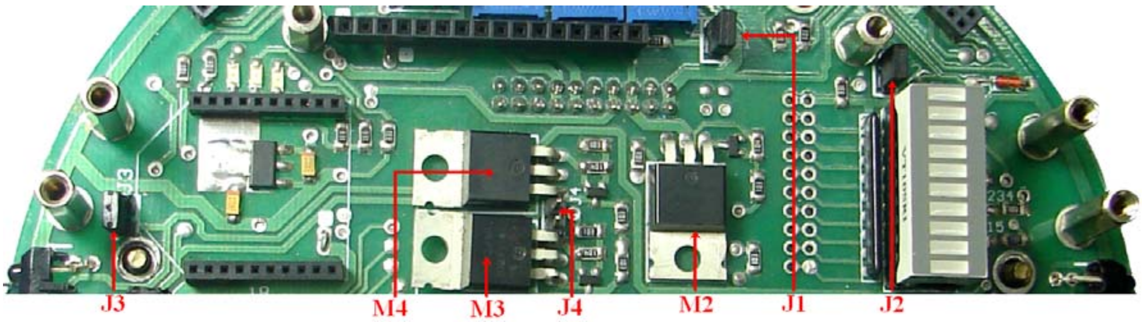

Figure 9.4: Set jumpers as per the requirements (for more details refer to chapter 3)

9.3 LCD mounting

Figure 9.5: LCD mounting

Be careful while inserting LCD connector pins into the socket on the main board. Screw in the LCD firmly on the studs.

5.4 Microcontroller adaptor board mounting

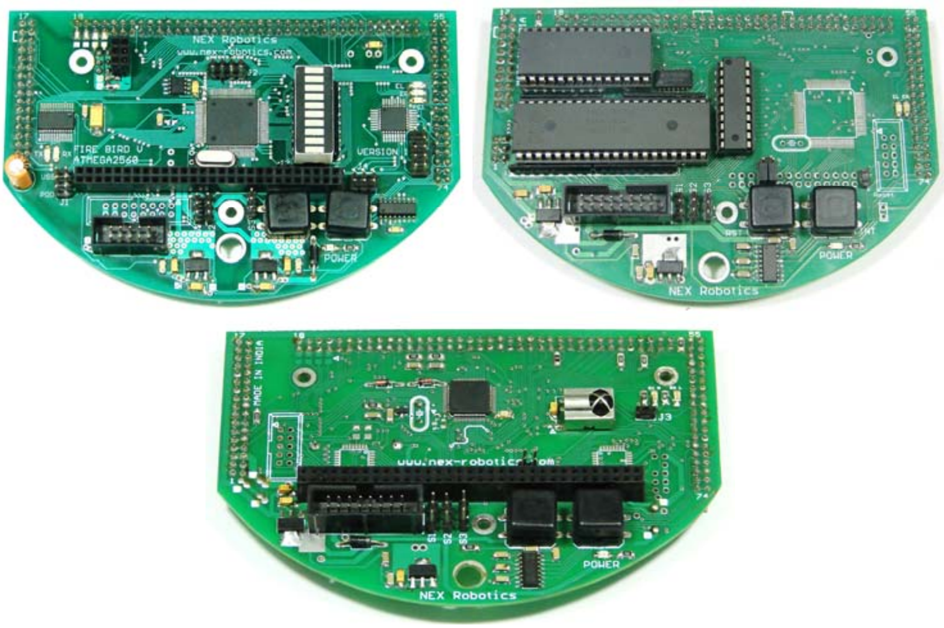

Figure 9.6: ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 ARM7 microcontroller adaptor boards for Fire Bird V

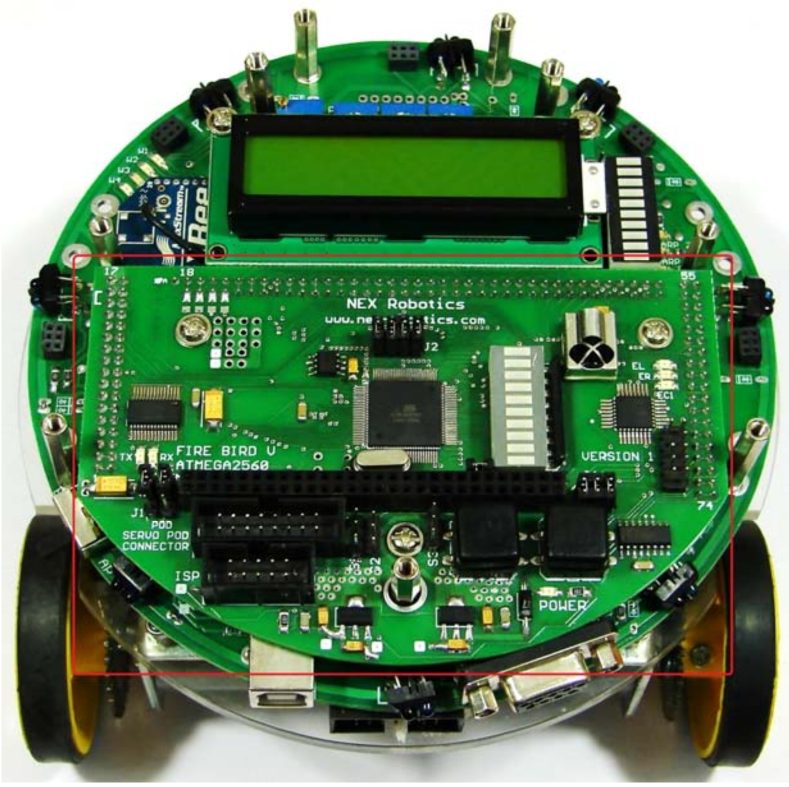

Figure 9.7: Microcontroller adapter board mounting

⚠ Do not apply unnecessary pressure onto the PCB while inserting into the connectors on the main board. Check for any bent pins before inserting the PCB. Mount 3 screws on the microcontroller board.

9.5 Sharp IR Range sensor mounting

Step 1: Cut the front section of white connector of the Sharp IR range sensor

Figure 9.8: Remove front cover of the white connector of the Sharp IR range sensor

Figure 9.9: Sharp IR range sensor mounting kit

Step 2: Mount the 20mm studs on the main board on the position where sharp sensor is to be fitted. In figure 5.10 area highlighted with the red border shows the mounted studs from the Sharp IR range sensor mounting kit.

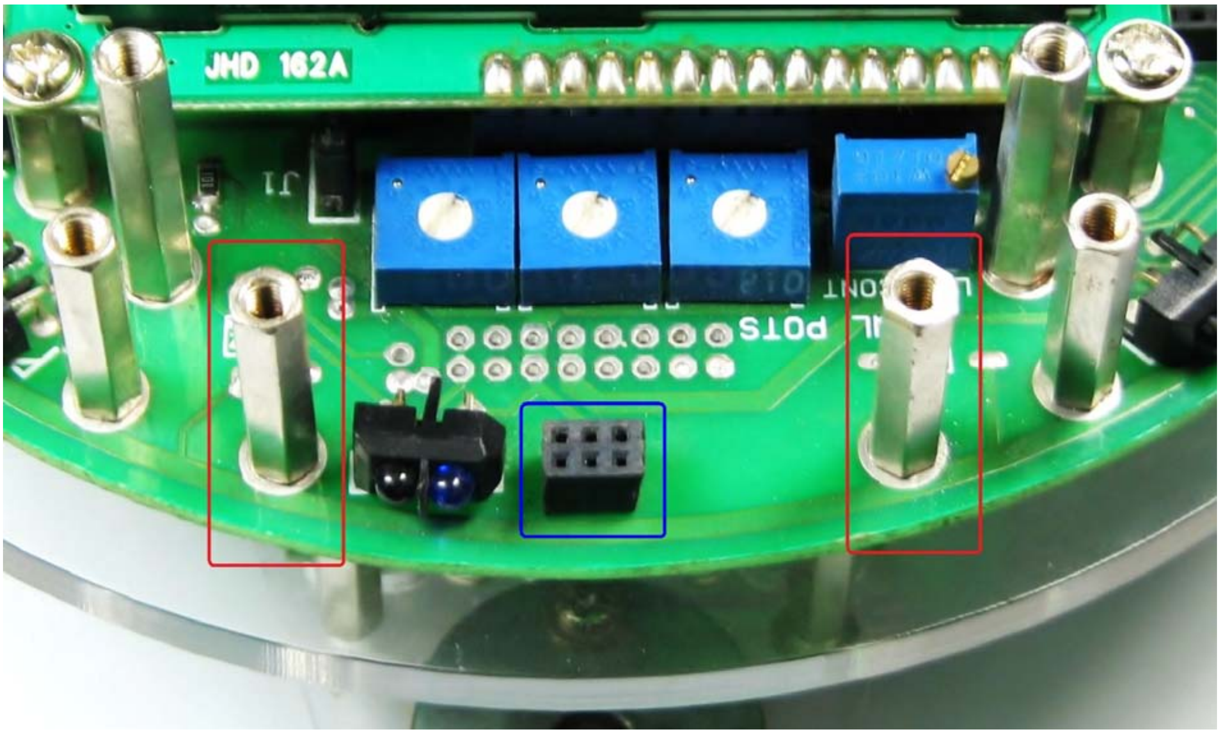

Figure 9.10: Mount 20mm studs from the Sharp sensor mounting kit

Step 3: Fix the Sharp IR range sensor on its holder.
Holder for the Sharp IR range sensor is highlighted in the figure 5.10 by blue border.

Figure 9.11: Mounting of the Sharp IR range sensor

Step 4:
Remove the yellow colored paper stripe from the adhesive tape from the metal plate which is shown in figure 5. 9.
Fix the metal plate on top of the Sharp sensor and fit the screws.

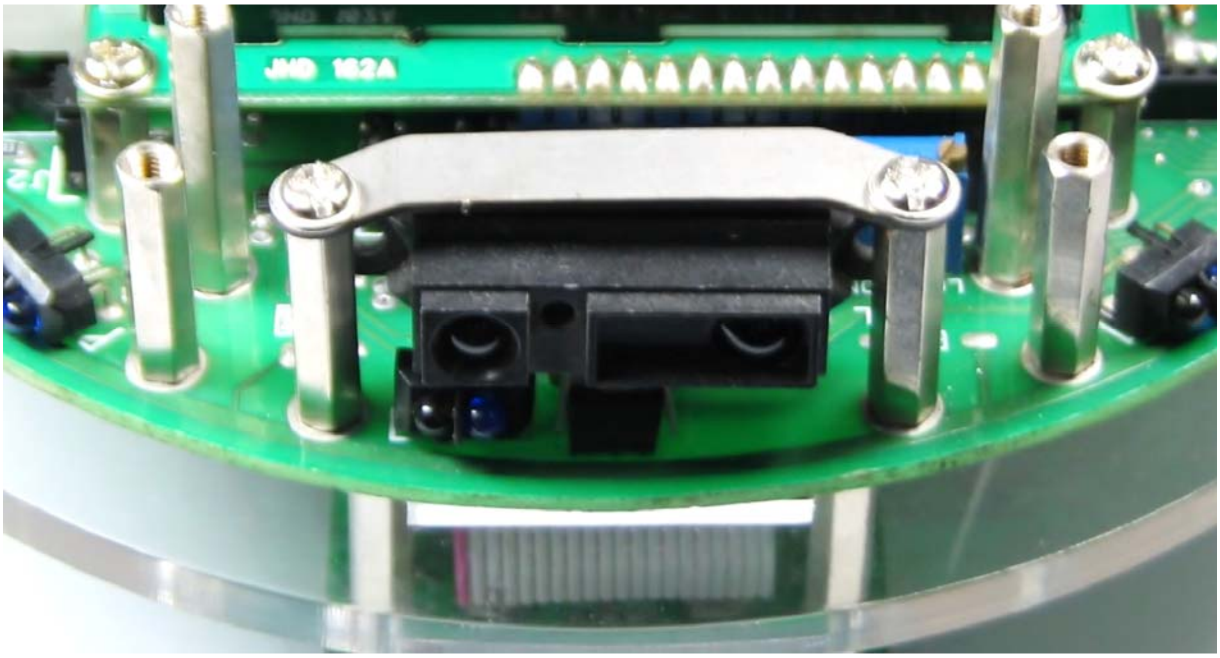

Figure 9.12: Fitting metal plate on top of the Sharp IR range sensor

⚠ Do not apply extreme pressure while pressing down the sharp sensors to fit into the socket.

⚠ Make sure that you remove yellow paper before mounting the metal plate on the Sharp IR range sensor.

9.6 Mount top Acrylic plate on the robot

Figure 9.13: Install top acrylic plate