FIRE BIRD V

ATMEGA2560
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.

Important:

1. User must go through the Fire Bird V's Hardware and Software manuals before using the robot.

2. Crystal of the ATMEGA2560 microcontroller is upgraded to 14.7456MHz from 11.0592Mhz in all the Fire Bird V ATMEGA2560 robots delivered on or after 1st December 2010. This documentation is made considering crystal frequency as 14.7456MHz.

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 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 ATMEGA2560

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, 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. Fire Bird V supports ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 (ARM7) microcontroller adaptor boards. This modularity in changing the microcontroller adaptor boards makes Fire Bird V robots very versatile. User can also add his own custom designed microcontroller adaptor board.

Fire Bird V ATMEGA2560 (AVR)

Fire Bird V P89V51RD2 (8051)

Fire Bird V LPC2148 (ARM7 TDMI)

Figure 2.1: Fire Bird V Robots

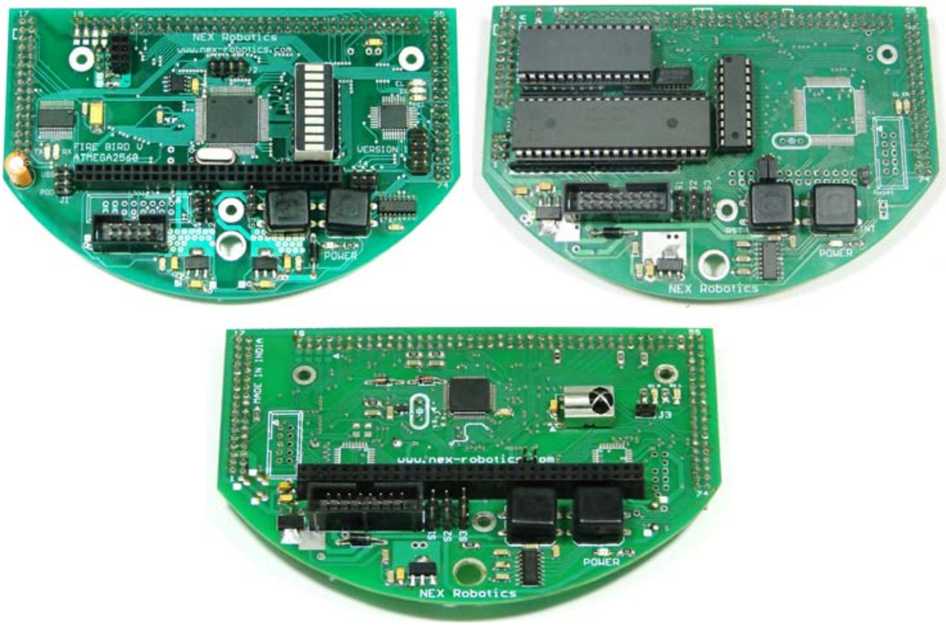


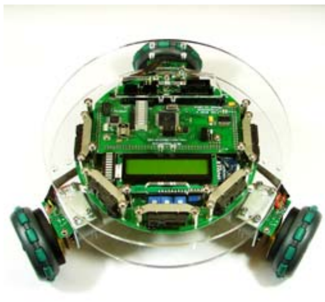
Figure 2.2: ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 ARM7 microcontroller adaptor boards for Fire Bird V

2.1 Avatars of Fire Bird V Robot

All Robots use the same main board and microcontroller adaptor board. All Fire Bird V Robots share the same unified architecture.

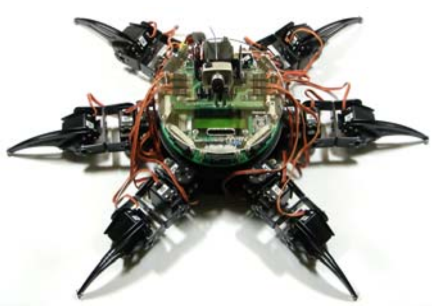
Fire Bird V

Fire Bird V Tank



Fire Bird V Omnidirectional Robot

Fire Bird V Insect



Fire Bird V Hexapod

Fire Bird V 4WD with Gripper

Figure 2.3: Avatars of Fire Bird V Robot

Figure 2.4 Fire Bird V ATMEGA2560 robot

2.2 Fire Bird V Block Diagram:

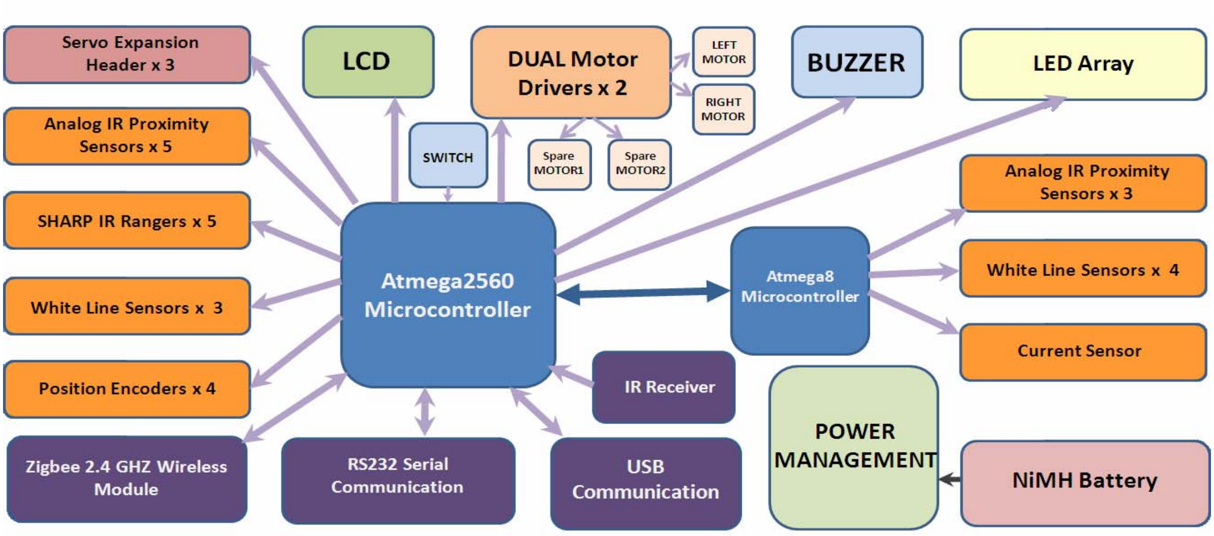


Figure 2.5: Fire Bird V ATMEGA2560 robot block diagram

2.3 Fire Bird V ATMEGA2560 technical specification

Microcontroller:
Atmel ATMEGA2560 as Master microcontroller (AVR architecture based Microcontroller)
Atmel ATMEGA8 as Slave microcontroller (AVR architecture based Microcontroller)

Sensors:
Three white line sensors (extendable to 7)
Five Sharp GP2D12 IR range sensor (One in default configuration)
Eight analog IR proximity sensors
Eight analog directional light intensity sensors
Two position encoders (extendable to four)
Battery voltage sensing
Current Sensing (Optional)

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:
Wireless ZigBee Communication (2.4GHZ) (if XBee wireless module is installed)
USB Communication
Wired RS232 (serial) communication
Simplex infrared communication (From infrared remote to robot)

Dimensions:
Diameter: 16cm
Height: 10cm
Weight: 1300gms

Power:
9.6V, 2100mAh Nickel Metal Hydride (NiMH) battery pack and external Auxiliary power from 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 their principal of operations are explained in detail. It is very important that user go through chapter before starting to use robot.

Fire Bird V robot has 6 important modules:

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

Figure 3.1 Fire Bird V ATMEGA2560 robot

3.1 Connections

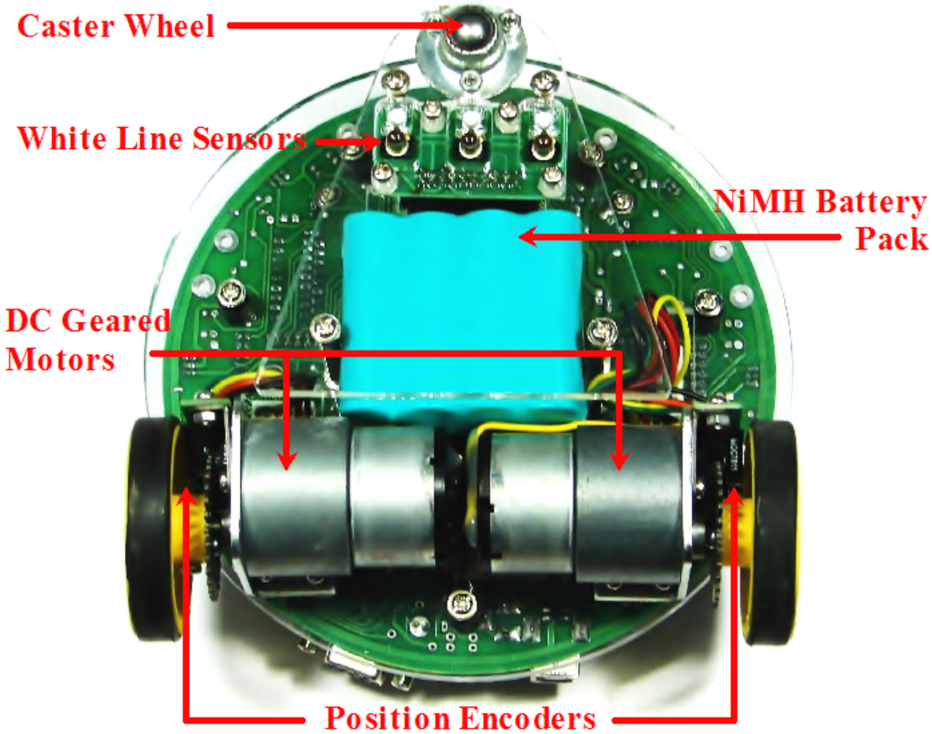


Figure 3.2: Fire Bird V ATMEGA2560 robot bottom view

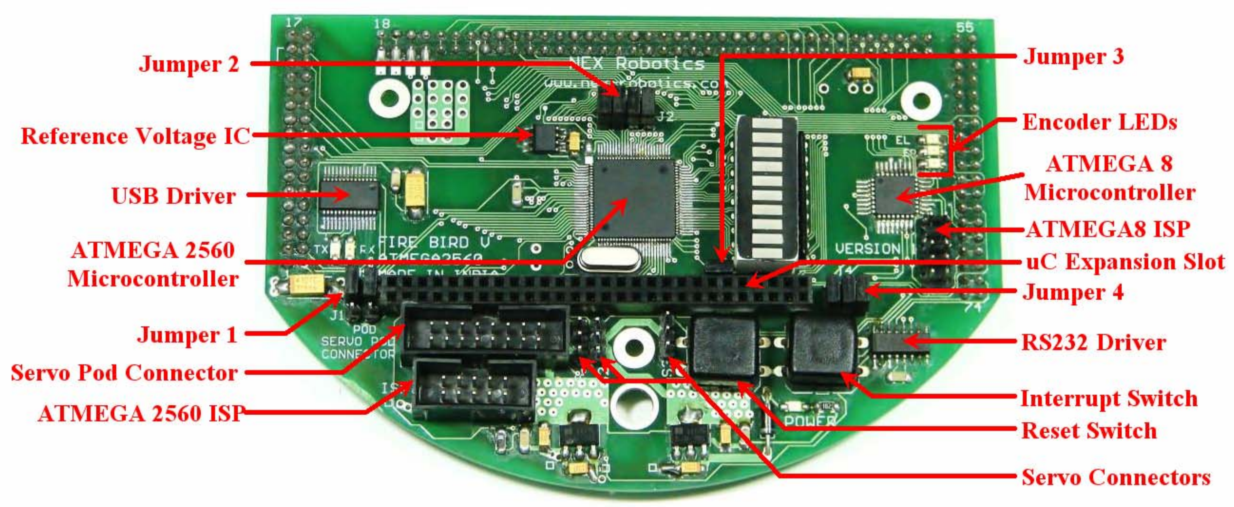


Figure 3.3: ATMEGA2560 microcontroller adaptor board

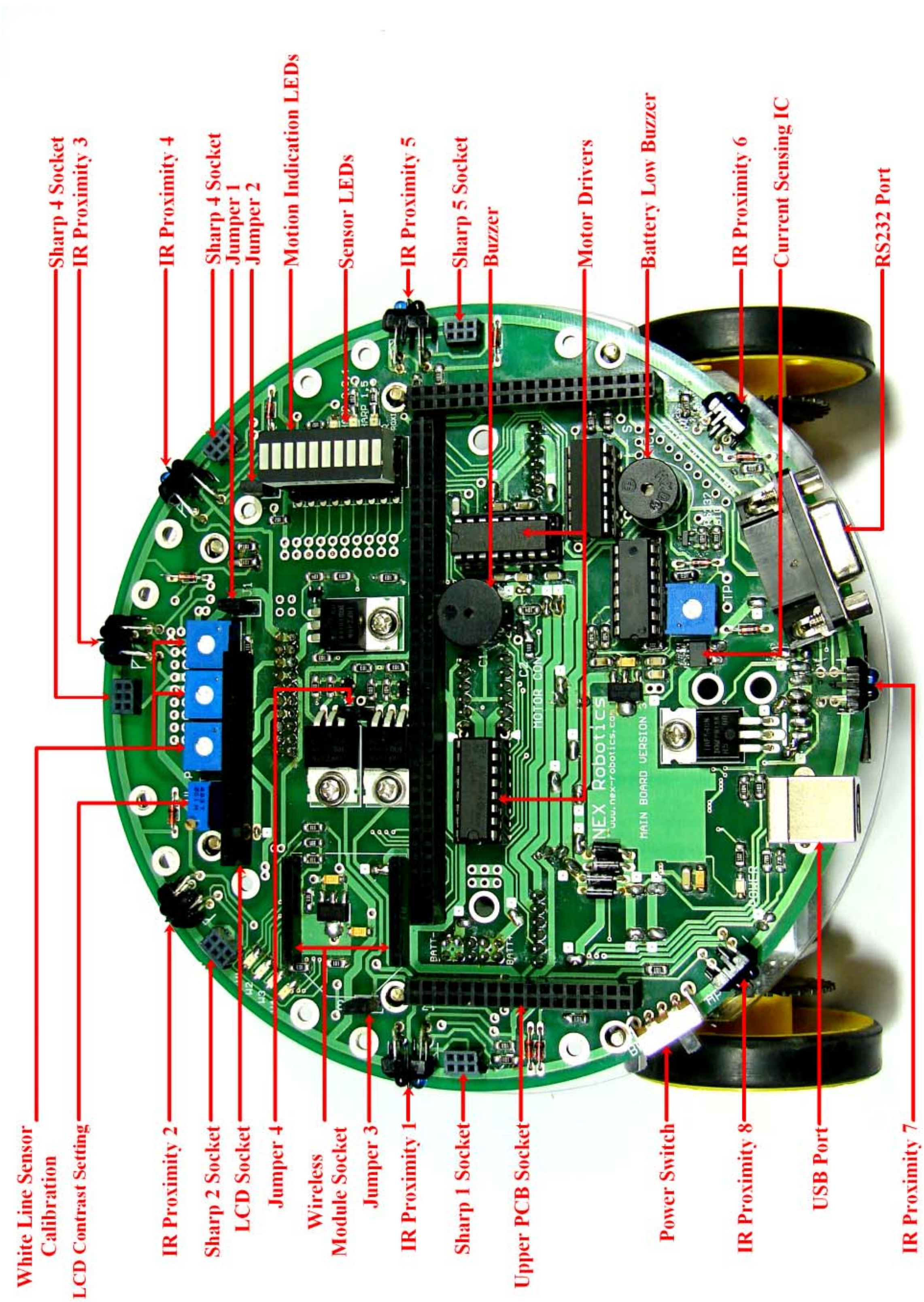


Figure 3.4: Top view of the main board

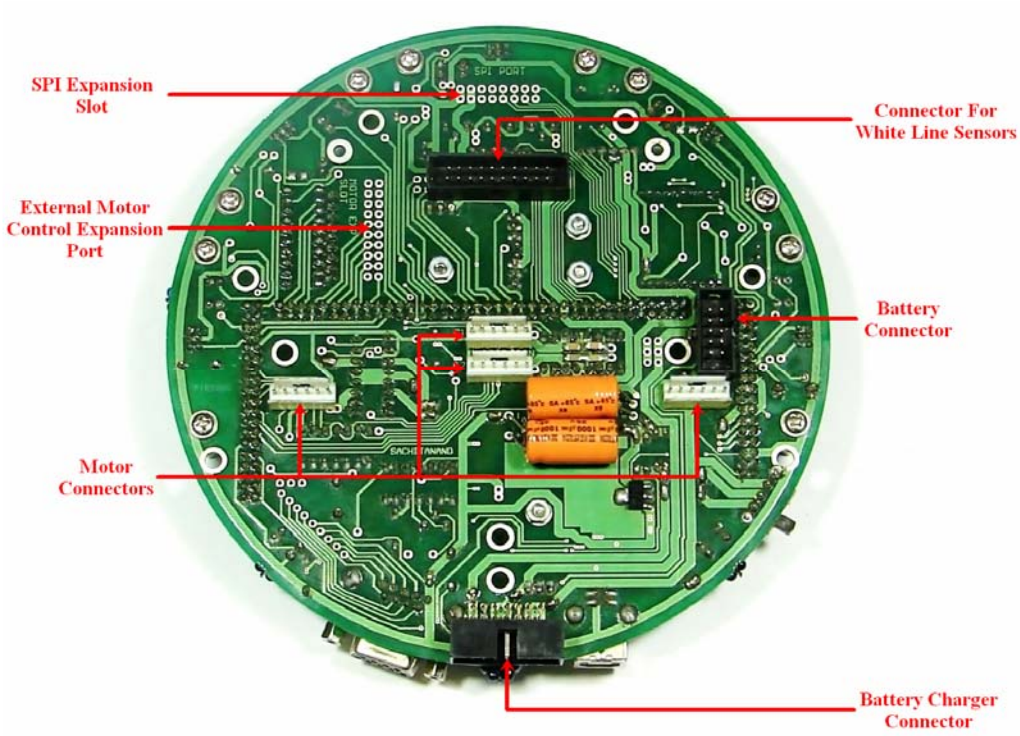


Figure 3.5: Bottom view of the main board

Figure 3.6: Microcontroller adaptor board socket connection numbers on the main board

3.2 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.

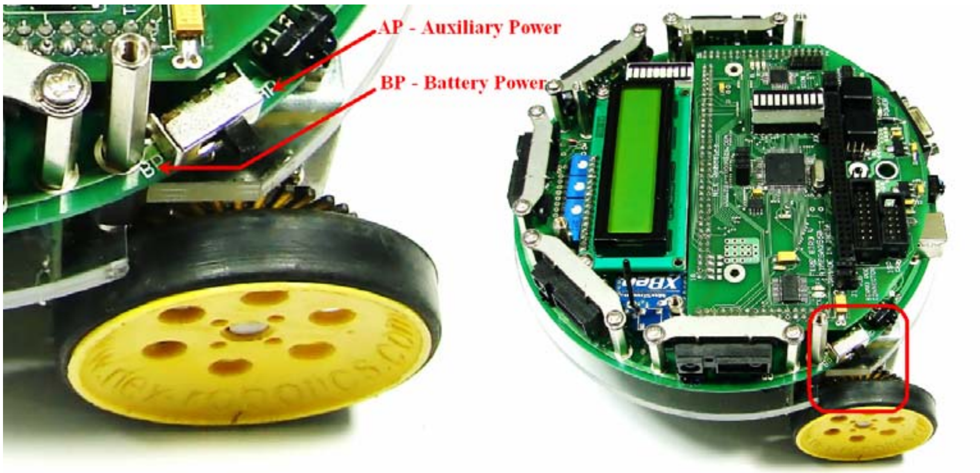


Figure 3.7: Power Switch

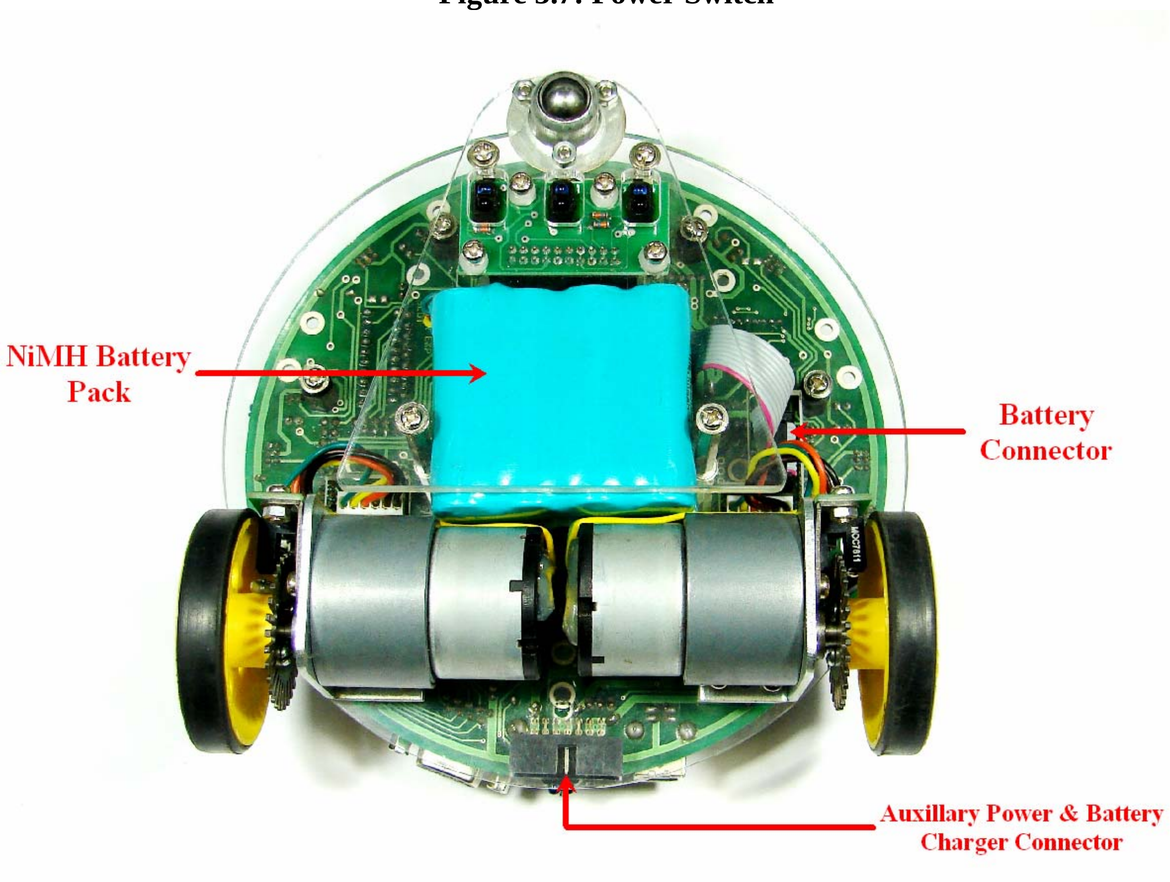


Figure 3.8: Connecting the battery on the Fire Bird V main board

Figure 3.7 shows the power switch. On the two sides of the power switch “BP” and “AP” is marked. “BP” stands for Battery Power while “AP” stands for Auxiliary power. When robot is powered by battery, it will turn on when power switch is moved towards “BP” and will get turned of if switch is moved towards “AP”. Use of Auxiliary power to power the robot without using onboard battery will be covered in subsequent sections.

For the safety during transportation, robot’s battery is disconnected. Before connecting battery to the robot, make sure that robot is turned off. Move the power switch towards the “AP”. Figure 3.8 shows the battery connector. Insert the 10 pin FRC connector of the battery inside the connector. To turn on the robot, move power switch towards the “BP”.

Fully charged NiMH batteries will get completely discharged with in a week. You need to charge the robot batteries before using the robot. Robot is loaded with the program to move robot in forward, backward, left and right.

Refer to section 3.4 for battery charging. For running the robot on battery power or auxiliary power, refer to the section 3.5 and 3.6.

3.3 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 it is 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) for extended 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 low warning in case battery is below critical level
2. Regulated supply for onboard payload
3. Battery current sensing*

* Current sensing is an optional accessory.

3.3.1 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 thermistor for monitoring battery temperature during battery charging.

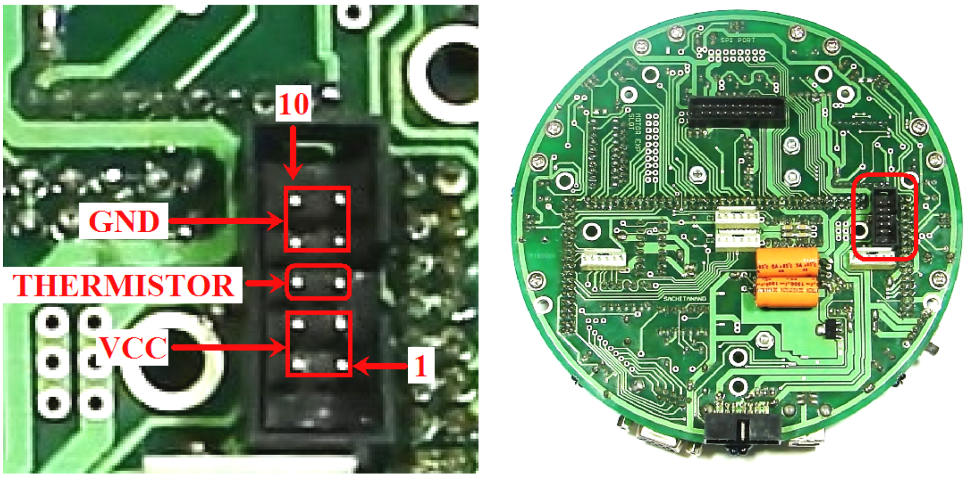


Figure 3.9: Battery Connector on the main board

⚠ The NiMH battery provided with Fire Bird V has 10 pin FRC connector which will fit into the connector on the main board only in one orientation. Do not force the connection in any other way.

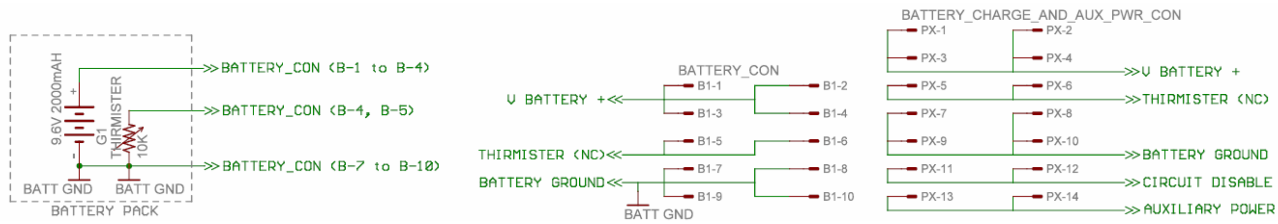


Figure 3.10: Battery for Fire Bird V ATMEGA2560

Pin Number	Function
1,2,9,10	Battery Positive
3,8	Thermistor Connection
4,5,6,7	Battery Negative

Table 3.1: Battery connections

3.3.2 Power sources and voltage regulation on the main board

Fire Bird V is primarily powered by NiMH battery. In order to do experiments for longer duration without worrying about the battery getting low, robot can be powered by external power source which is also known as auxiliary power source. Auxiliary supply provides regulated 12V, 1Amp supply. When robot is powered by battery it can get maximum of 2Amp. current while Auxiliary supply will provide only 1Amp current.

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. This supply line is used to power almost all the payload on the robot.

When battery is almost discharged (about 30% power remaining) and onboard payload draws current in excess of 2 amperes then battery voltage can fall below 6.3V momentary. Voltage regulators will not be able to function properly below 6.3V and its output will fall below 5V. 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 which have 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.

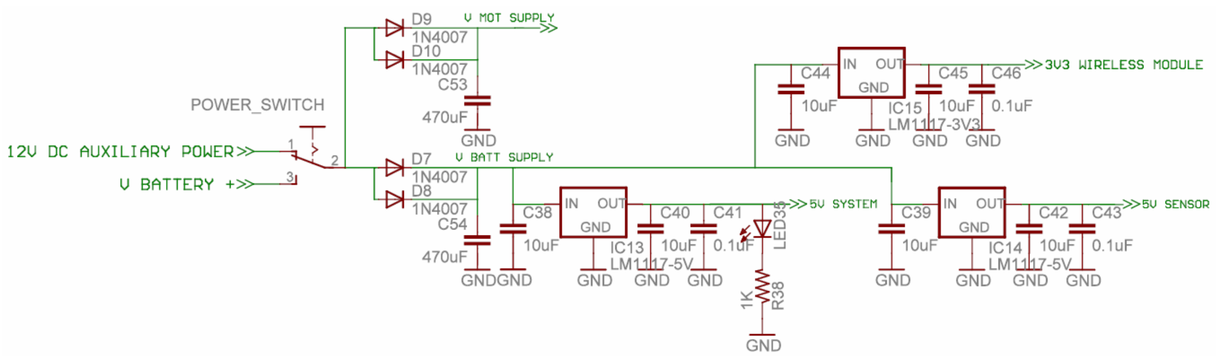


Figure 3.11: Voltage regulators on the main board

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 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.

5. 3.3V Wireless module
3.3V Wireless module supply is used to power XBee wireless module if installed.

Note: Apart from these three regulators Fire Bird V ATMEGA2560 has two voltage regulators for powering microcontrollers and servo motors.

3.3.3 Current sensing

Fire Bird V robot can sense its current consumption using optional Hall Effect current sensor ACS712 / ACS714.

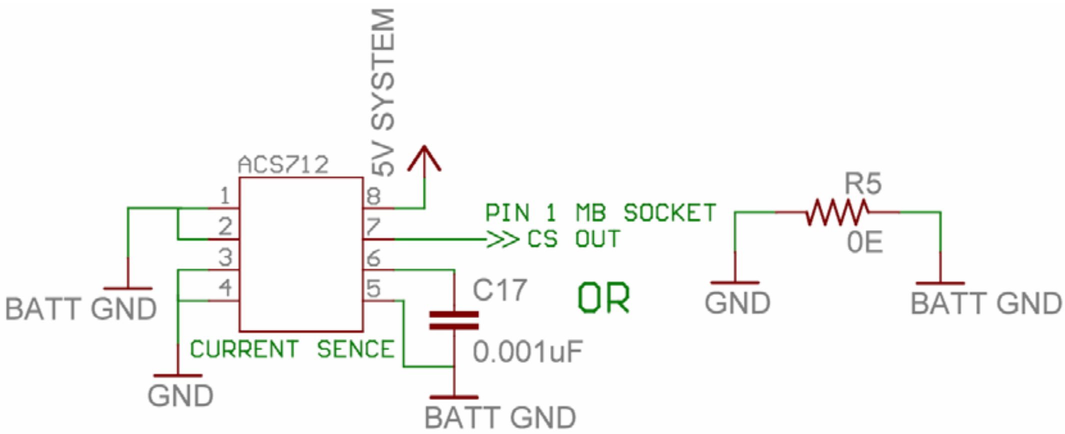


Figure 3.12: Current sensing in Fire Bird V

Sensor'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 if 5 Ampere type sensor is installed. If 20 Ampere type sensor is installed value is reduced by 100mV / ampere. This sensor is an optional accessory. When this sensor is absent its sensing path is shorted with 0 ohm resistor. For more information on the sensor operation, refer to its datasheet which is located in the "Datasheets" folder of the documentation CD.

3.3.4 Battery low indication

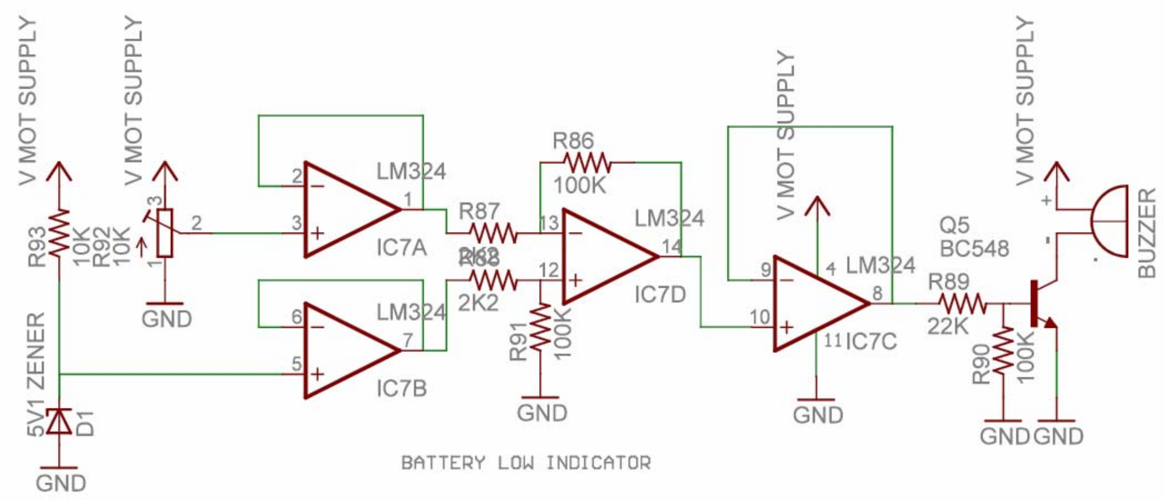


Figure 3.13: Battery low indication

Fire Bird V robot uses 8 cell NiMH battery. When battery is fully discharged its voltage drops below 8V. If robot is operated while battery is low, its performance will be inconsistent. To prevent any abnormality in 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.

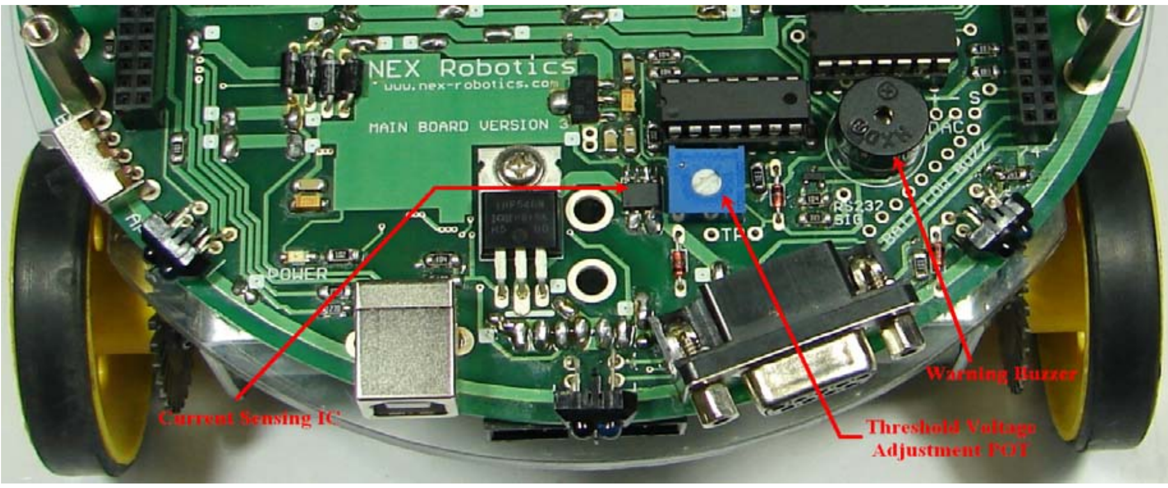


Figure 3.14: Various components of the power management module

3.4 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.

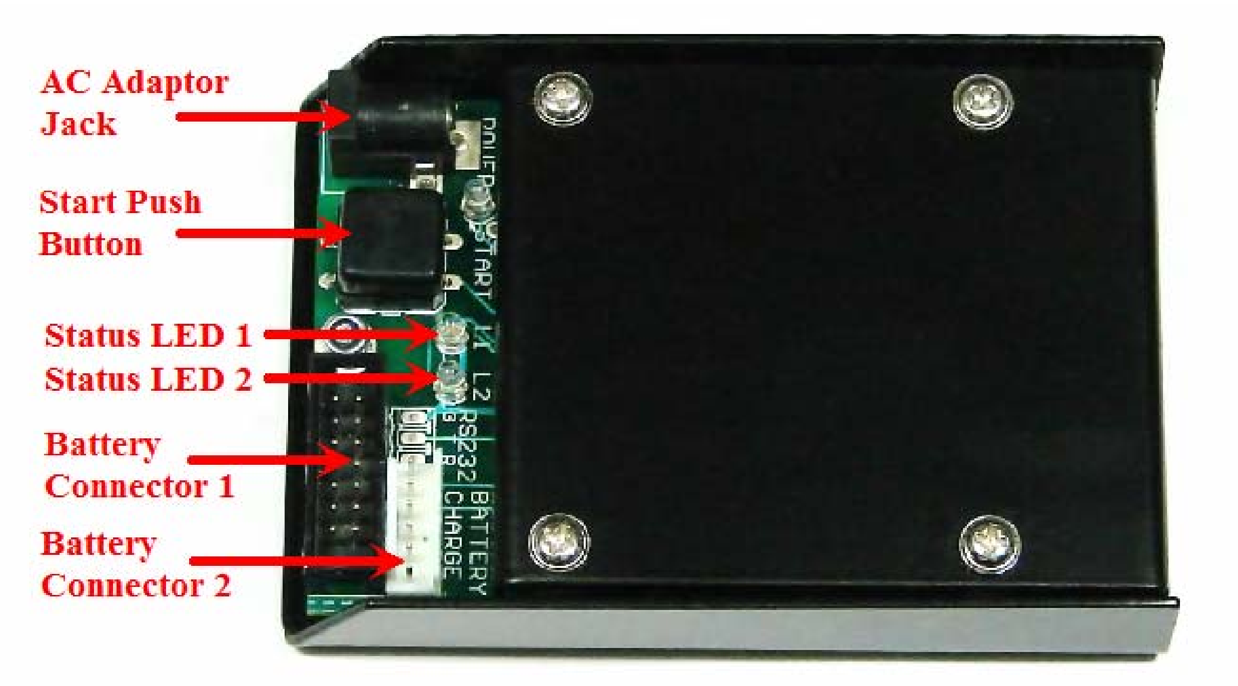


Figure 3.15: Smart NiMH battery charger for Fire Bird V

Figure 3.15 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 3.16: Connection for battery charging

Battery charging procedure:

1. Turn off the robot.
2. Connect AC adaptor in the mains. Connect AC adaptor's DC output connector to the battery charger's "AC Adaptor jack" connector as shown in figure 3.15. Turn on the adaptor. Battery charger's power LED will turn on. Red and green status indicator LEDs will blink twice.
3. Insert one end of the 14 pin FRC Battery Charging cable, which is marked with the label "Battery Charging" in to the "Battery Charging / Auxiliary Power" socket of the robot. It is located at the back side of the robot as shown in the figure 3.16. Insert the other end of the connector in to "Battery Connector 1" of the battery charger which is shown in the figure 3.15. 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 LED indication to indicate nature of fault. Refer to table 3.2 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 3.2 Battery status indicator LED interpretation

Important:

If you are using battery which is not used for long time then you have to charge it and discharge it at least few times to bring the battery to its full storage capacity. To do this you can load any motion program from the "Experiments" folder which is located in the documentation CD and discharge the batteries after charging.

Note:

- If fault condition occurs, then wait for some time till battery is cooled down and start battery charging 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.

3.5 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 3.7

3.6 Powering the robot on auxiliary power

Ideally 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 3.17: Robot Powering via Battery and Auxiliary supply

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

1. Disconnect the battery by removing the 10 pin FRC battery connector on 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 14 pin FRC connector marked with the “Auxiliary Power” in the connector which is located at the back side of the robot as shown in the figure 3.17. Connect the other end of the connector to the “Battery Connector 1” on the battery charger (refer to figure 3.15) 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 power or on auxiliary power depending on the position of the switch. Robot will not get turned off.

3.7 Battery Maintenance

Fully charged NiMH battery will get completely discharged with in a week of storage. Always charge the battery before use. If fully charged battery is kept in storage for about a month and afterwards even if it’s fully charged again, it can deliver only 1/3rd power of its rating. In such case 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. Before storage, charge the battery again.

For discharging the battery quickly, you can load any program from the “Experiments” folder of the documentation CD.

Disconnect the battery connector if robot is to be stored for long duration of time.

3.8 Motion control

Fire Bird V robot has two 60 RPM DC geared motors in differential drive configuration along with the third caster wheel for the support. Robot has top speed of about 24cm per second. 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.

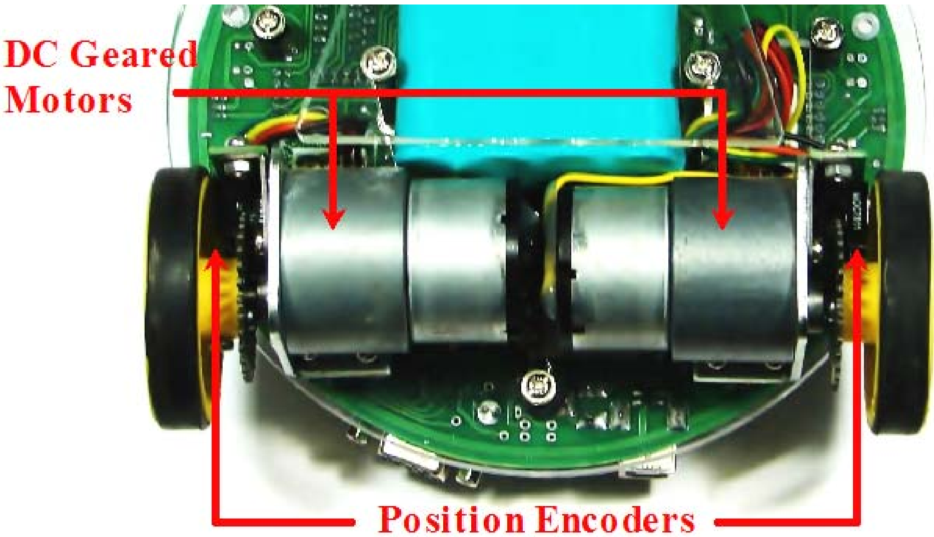


Figure 3.18: DC geared motors and position encoders

Motion control involves direction control and velocity control. Motors are controlled by L293D dual motor driver which can provide up to 600mA of current to each motor. 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).

LEDs are connected at the input and the output stage of the motor driver for quick interpretation of the motion commands.

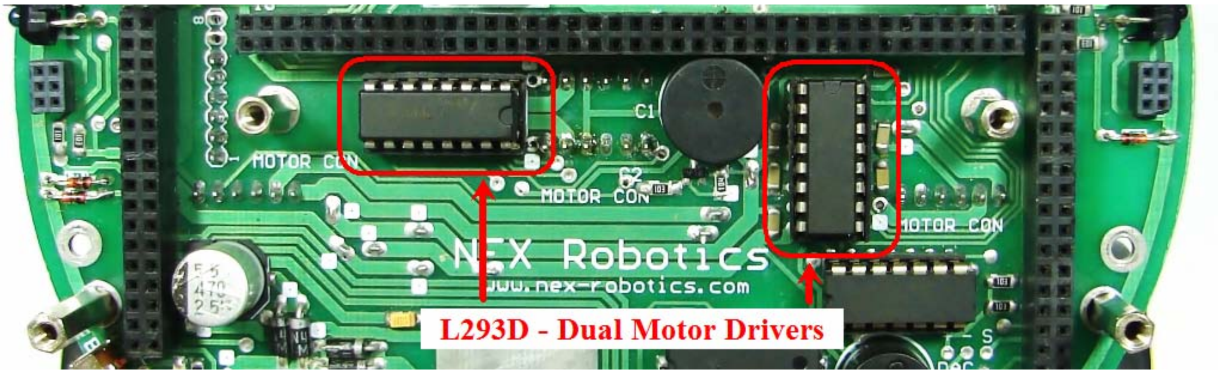


Figure 3.19: Motor Drivers

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.

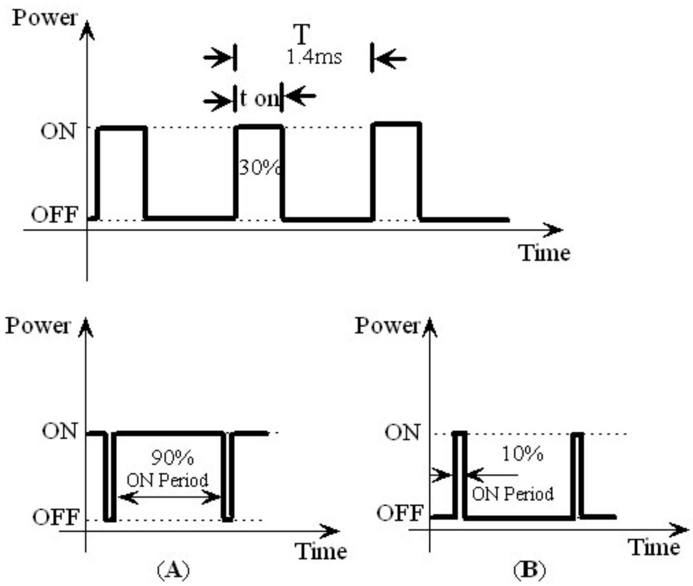


Figure 3.20: Pulse Width Modulation (PWM)

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 ATMEGA2560 version, logic level for the motor direction control is given in the table 3.4.

Microcontroller Pin	Function
PL3 (OC5A)	Pulse width modulation for the left motor (velocity control)
PL4 (OC5B)	Pulse width modulation for the right motor (velocity control)
PA0	Left motor direction control
PA1	Left motor direction control
PA2	Right motor direction control
PA3	Right motor direction control

Table 3.3: Pin functions for the motion control

DIRECTION	**LEFT BWD (LB) PA0 (L1)**	**LEFT FWD(LF) PA1 (L2)**	**RIGHT FWD(RF) PA2 (R1)**	**RIGHT BWD(RB) PA3 (R2)**	**PWM PL3 (PWML) for left motor PL4 (PWMR) for right motor**
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 3.4: 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 3.21 shows the location and function of indicator LEDs related to motion control.

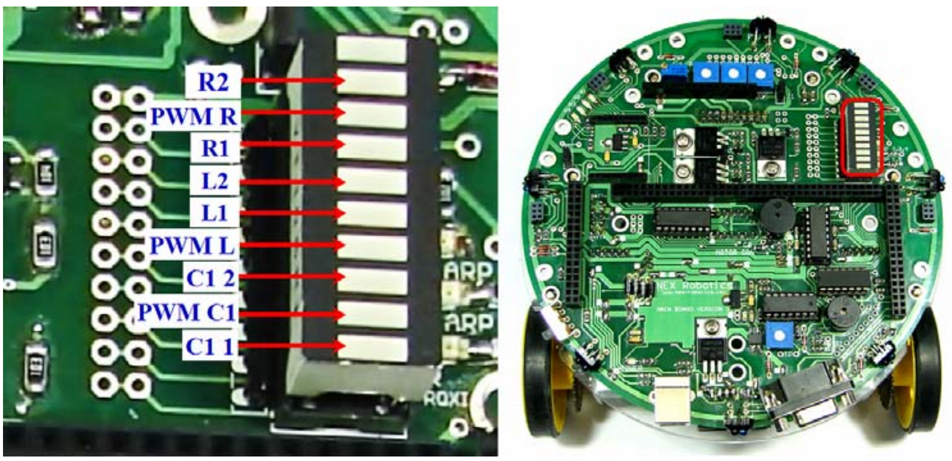


Figure 3.21: Motion status LED indication on the Fire Bird V main board

Warning:
Auxiliary power can supply current up to 1 Ampere while Battery can supply current up to 2 Ampere. When both motors of the robot changes direction suddenly without stopping, it produces large current surge. When robot is powered by Auxiliary power which can supply only 1 Ampere of current, sudden direction change in both the motors will cause current surge which can reset the microcontroller because of sudden fall in voltage. It is a good practice to stop the motors for at least 0.5seconds before changing the direction. This will also increase the useable time of the fully charged battery.

Robot has two L293D motor drivers with four 6 pin relimate connectors for DC motors. Each 6 pin relimate connector provides connections for the DC motor and the associated position encoder. Each connector can drive motor with up to 600mA current rating. Figure 3.19 shows the locations of the two L293D dual motor drivers on the main board. Figure 3.22 shows the location and pin numbers of the Motor connectors.

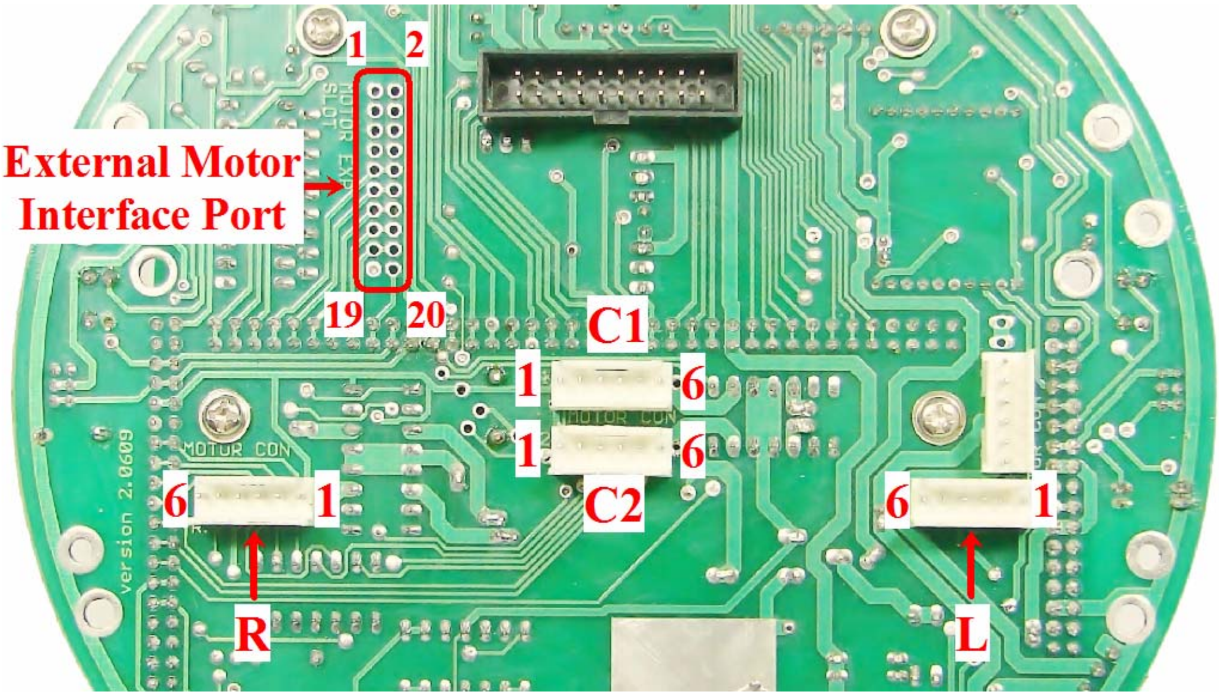


Figure 3.22: Motion control connections on the main board

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 3.5: 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 3.6: Motor connector port pin connections

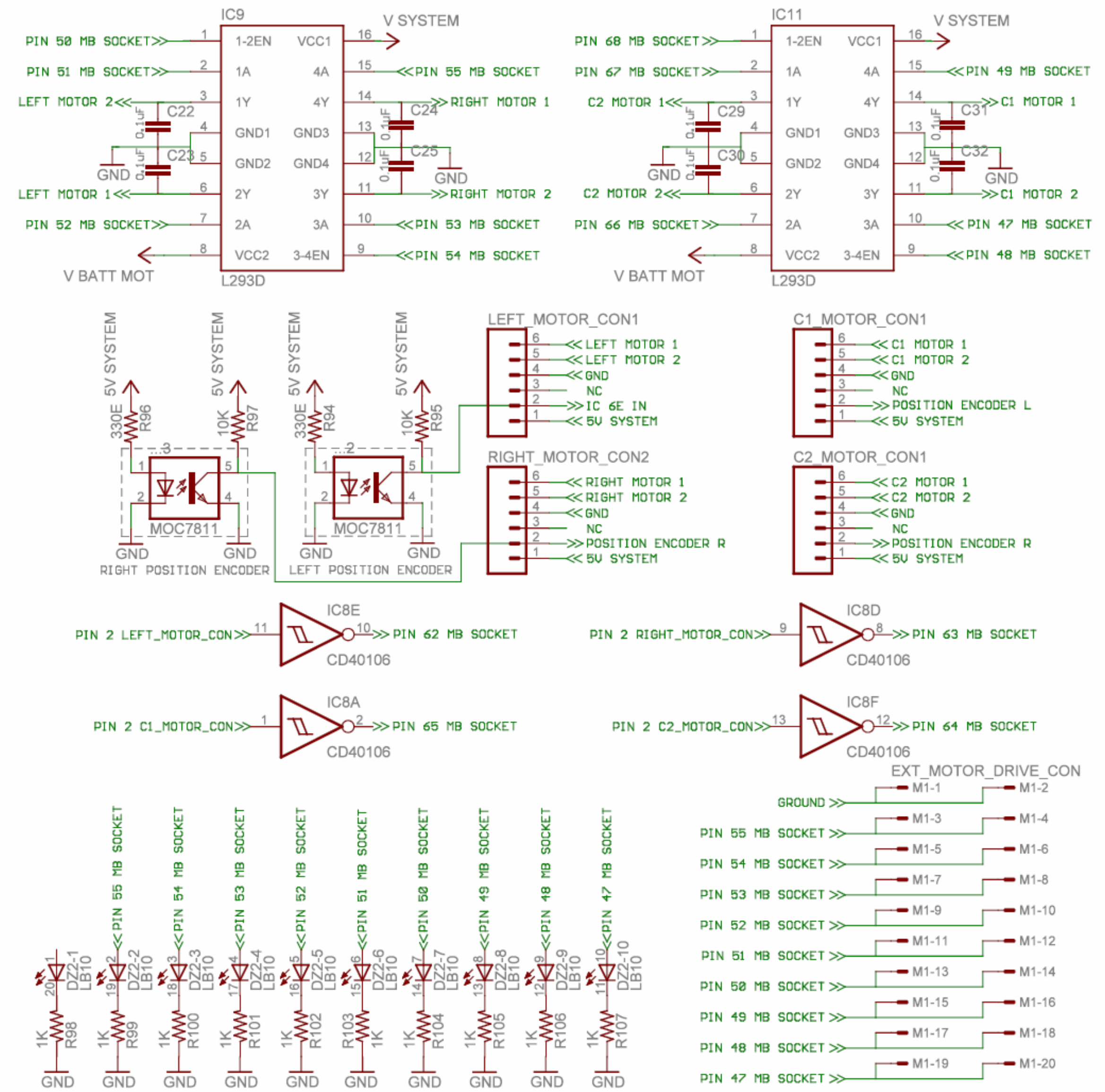


Figure 3.23: Schematic of the motion control module and the position encoder

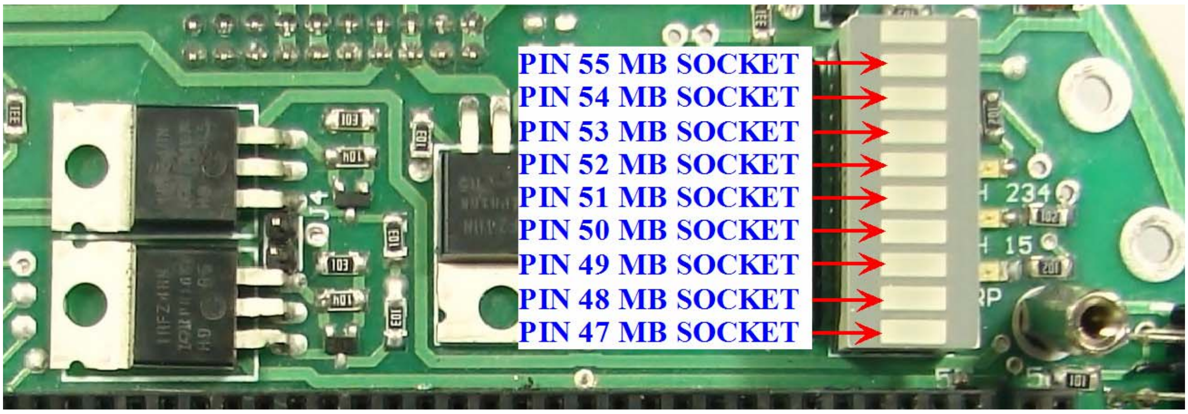


Figure 3.24: Motion status LED indication in terms of microcontroller adaptor socket pin number

“5V system supply” is used for driving L293Ds logic circuits. “V Batt Mot” is used to supply power for the motor. C22 – C25 and C29 – C32 is used for noise suppression. Logic signals to drive the two L293D comes from the pins 47 to 55 and pins 66 to 68 of the microcontroller adaptor board socket. Logic level on the pins 47 to 55 are also connected to the bar graph LED display on the main board.

PIN NO	Pin name	USED FOR	Status
5	OC3A/AIN1/PE3	PWM output for C2 motor drive	Output
38	OC5A/PL3	PWM for left motor.	Output
39	OC5B/PL4	PWM for right motor.	Output
40	OC5C/PL5	PWM for C1 motor.	Output
71	PA7 C2-2	Logic input 2 for C2 motor drive	Output
72	PA6 C2-1	Logic input 1 for C2 motor drive	Output
73	PA5 C1-2	Logic input 2 for C1 motor drive	Output
74	PA4 C1-1	Logic input 1 for C1 motor drive	Output
75	PA3	Logic input 1 for Right motor (Right back)	Output
76	PA2	Logic input 2 for Right motor (Right forward)	Output
77	PA1	Logic input 2 for Left motor (Left forward)	Output
78	PA0	Logic input 1 for Left motor (Left back)	Output

Table 3.7: Connections of the motor driver with the ATMEGA2560 microcontroller

L293D motor drivers on the main board can only provide current up to 600mA per motor. If you want to drive bigger robot using Fire Bird V main board then remove L293D motor drivers from the main board and connect high power external motor drivers to the External motor interface port. Figure 3.22 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 at the bottom of the main board and interface these pins to the external motor drivers. Up to 3 Hercules series 30Amp. Motor Drivers can be interface with this port. Logic state on these pins can be observed on the bar graph LED display.

Figure 3.25: Hercules series 30Amp. Motor Driver

3.9 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 slotted disc which rotates between optical encoder (optical transmitter and receiver). When slotted disc moves in between the optical encoder we get square wave signal whose pulse count indicates position and time period / frequency 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 black opaque casing with small slot shaped window facing each other. 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.

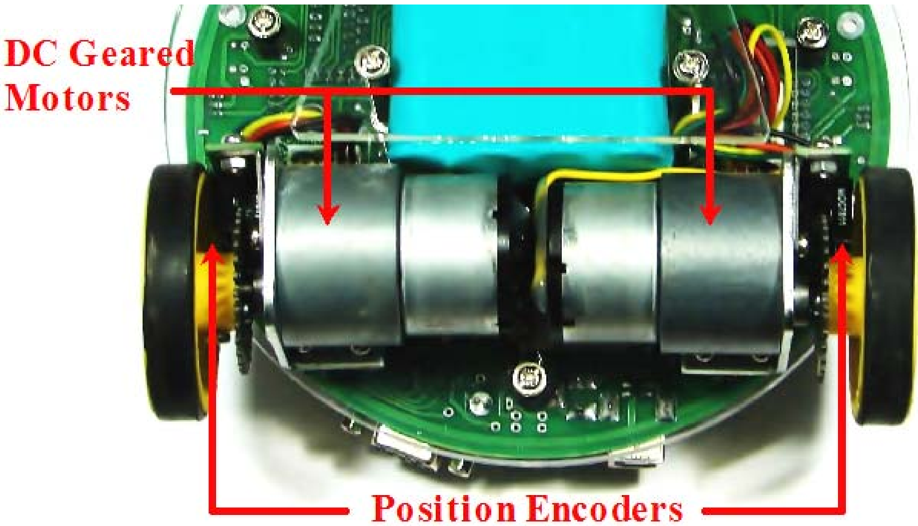


Figure 3.26: DC geared motors and position encoders

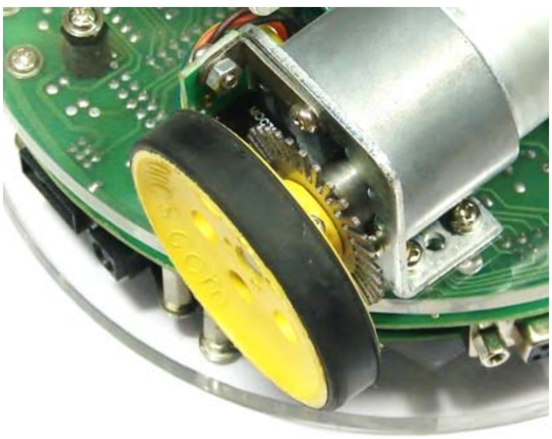


Figure 3.27: Position encoder assembly

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

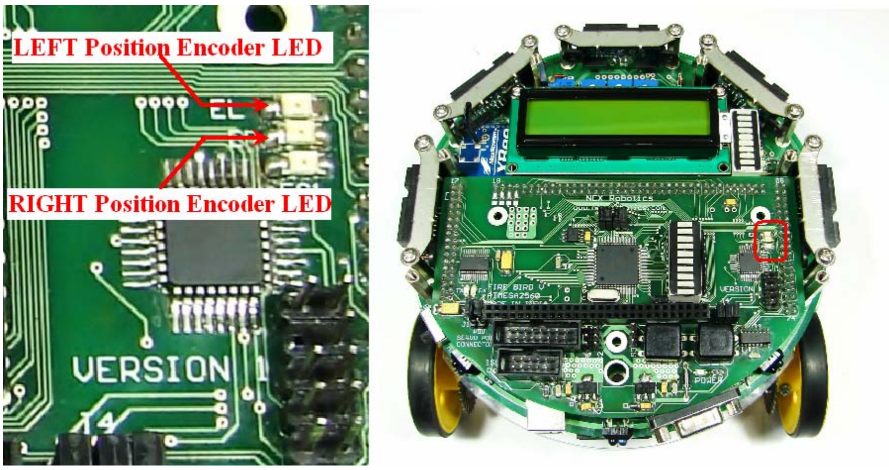


Figure 3.28: Position encoder pulse LEDs on ATMEGA2560 microcontroller adaptor board

Pulses coming from the position encoders are indicated by position encoder LEDs on the ATMEGA2560 board as shown in figure 3.28

PIN NO	Pin name	USED FOR	Status
6	OC3B/INT4/PE4	External Interrupt for the left motor’s position encoder	Input
7	OC3C/INT5/PE5	External Interrupt for the right motor’s position encoder	Input
8	T3/INT6/PE6	External Interrupt for the C2 motor’s position encoder	Input
9	CLK0/ICP3/INT7/ PE7	External Interrupt for Interrupt switch on the microcontroller board, External Interrupt for the C1 motor’s position encoder *	Input

Table 3.8: Connections of the position encoder’s outputs with the ATMEGA2560 microcontroller

***** Connection of the position encoder input corresponding to Motor connector C1 to the INT 7 pin (Interrupt 7) of the microcontroller is disconnected by removing the pin no. 2 of the CD40106 Schmitt trigger IC. Int. 7 pin is also used by Boot switch and TSOP1738 (if connected by shorting the pad below TSOP1738.) This is done in order to simplify the shearing of this pin. If you want to use position encoder of C1 motor then replace CD40106. In this case make sure that pad which connects TSOP1738 with the pin INT7 is open.

3.10 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 3.29. Sharp IR range sensors consists of IR LED and linear CCD array, both encapsulated in the housing with separation and with precision lens assembly mounted in front of them. IR LED with the help of the leans transmits a narrow IR beam.

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 3.30 shows the internals of the sensor. Figure 3.31 explains how change in the distance from the obstacle can be measured by measuring angle of reflection of the reflected 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. These sensors have blind spot in the range of 0 to some specific distance depending on the type of the sensor. In the blind spot region sensor gives incorrect readings. Table 3.9 gives information about sensing range and the blind spot distance for the particular sensor.

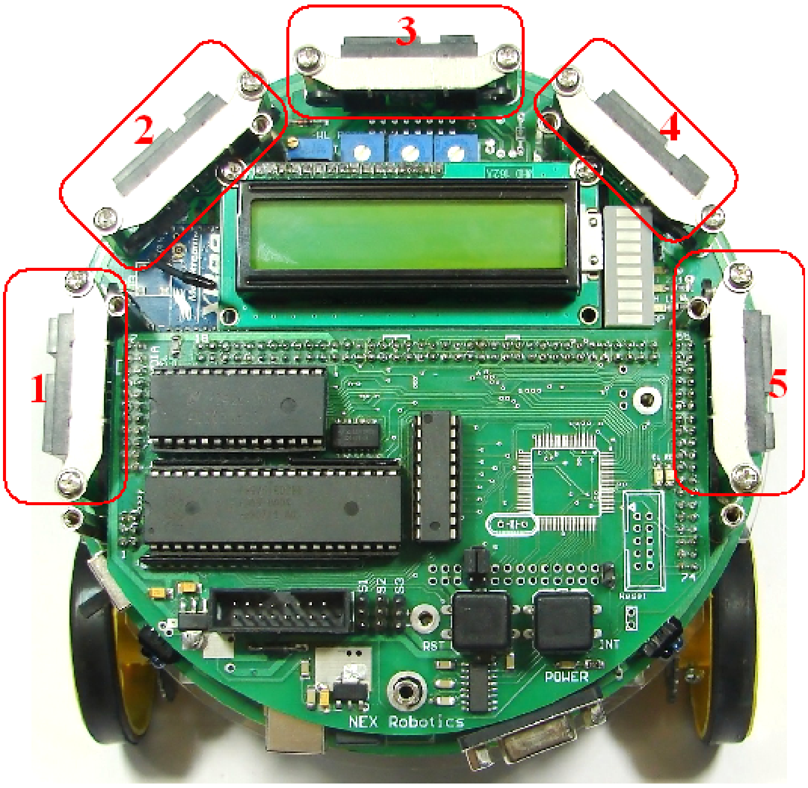


Figure 3.29: Sharp Sensors mounted on Fire Bird V

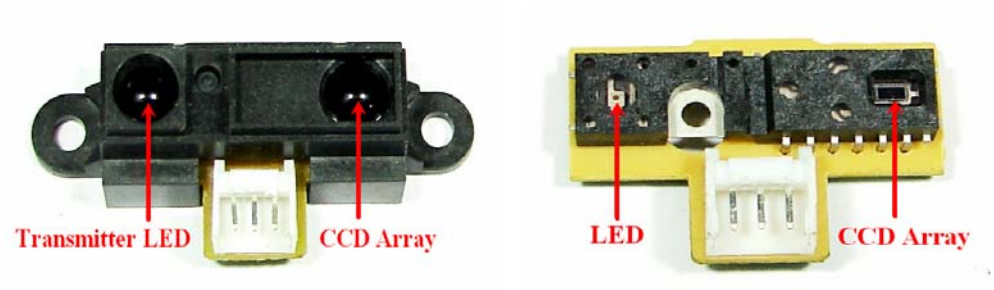


Figure 3.30: Infrared Range finder sensor and its inside view

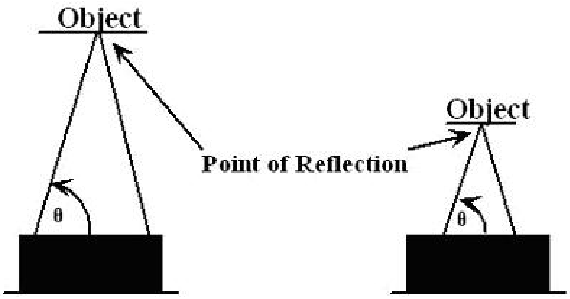


Figure 3.31: Distance measurement based on angel of reflection

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

GP2D120 GP2D12 GP2Y0A02YK

Figure 3.32: 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 3.9: Sharp IR Range sensors coverage

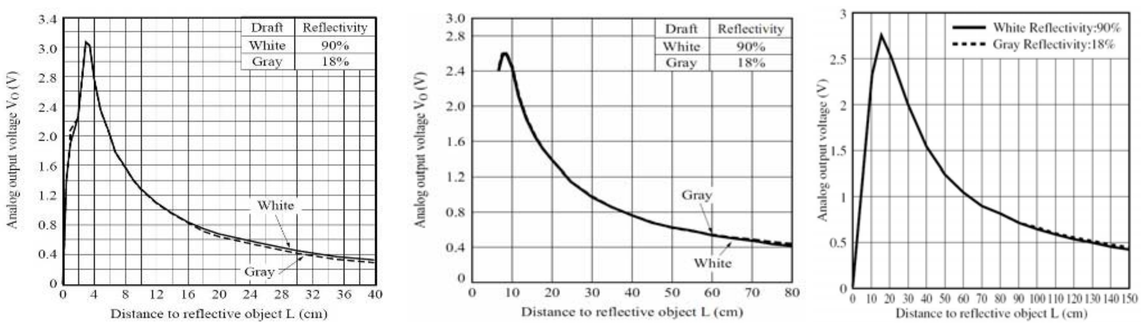


Figure 3.33: Distance Vs. Output voltage of GP2D120, GP2D12 and GP2Y0A02YK

Figure 3.33 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)))));

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.

In order to avoid sensor interference between many robots, each 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 robot's sensor should be turned on or off over wireless communication using XBee wireless modules. Another advantage of this feature is that robot can turn off these sensors when not in use to conserve power.

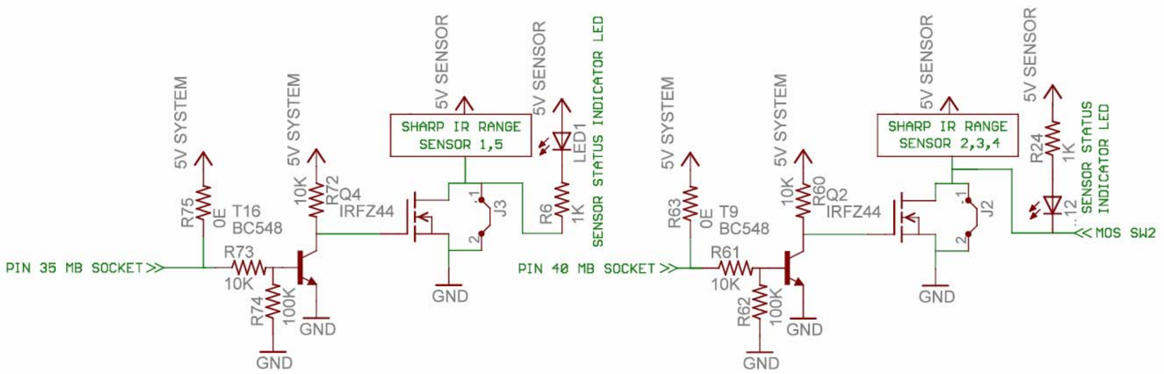


Figure 3.34: Sharp IR range sensor's power control circuit

Figure 3.29 shows the location of the Sharp IR range sensors on the robot. They are numbered from 1 to 5 in the clockwise direction. Figure 3.34 shows the schematics of the MOSFETs and jumpers which controls switching on/off of the 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 turned on by putting jumper J3 and J2 on the main board. These jumpers short the drain and the source of the MOSFETs.

For Jumper locations, refer to figure 3.38.

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

Table 3.10: Sensor power control pins and jumpers

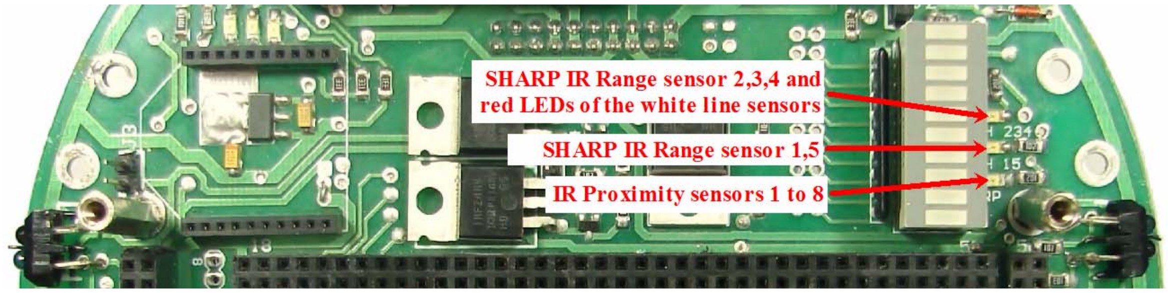


Figure 3.35: Sensor status indicator LEDs

Figure 3.35 shows the LEDs which indicates the power status of the active sensors.

Jumpers J2, J3 and J4 are shorted as the default factory setting. In order to enable sensor's power switching capability required jumpers should be removed.

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 3.10 should be shorted on to turn on sensors permanently.
- 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 which holds the sensor in place. If this isolation is not provided then sensor will get partially off when corresponding MOSFET is turned off. In such case sensor will still consume power and might give incorrect reading when sensor is turned off. To avoid this small insulator foam is inserted between the sensor and the metal stripe which holds the sensor in place.

PIN NO	Pin name	USED FOR	Status
14	XCK2/PH2	Sharp IR ranges sensor 1and 5 disable. Turns off these sensors when output is logic 1 *******	Output
70	PG2/ALE	Sharp IR ranges sensor 2, 3, 4 and the red LEDs of white line sensor 1, 2, 3 disable. ******* Turns off these sensors when output is logic 1	Output
84	PK5/ADC13/PCINT21	ADC input for Sharp IR range sensor 5	Input (Floating)
85	PK4/ADC12/PCINT20	ADC input for Sharp IR range sensor 4	Input (Floating)
86	PK3/ADC11/PCINT19	ADC input for Sharp IR range sensor 3	Input (Floating)
87	PK2/ADC10/PCINT18	ADC input for Sharp IR range sensor 2	Input (Floating)
88	PK1/ADC9/PCINT17	ADC input for Sharp IR range sensor 1	Input (Floating)

Table 3.11: Connections of the Sharp IR range sensors and its power control MOSFETs with the ATMEGA2560 microcontroller

3.11 Infrared proximity and directional light intensity sensors

Infrared proximity sensors are used to detect proximity of any obstacles in the short range. IR proximity sensors have about 10cm sensing range. These sensors sense the presence of the obstacles in the blind spot region of the Sharp range sensors. Fire Bird V robot has 8 IR proximity sensors. Figure 3.36 shows the location of the 8 IR proximity sensors. Sensors are numbered as 1 to 8 from left to right in clockwise direction. In all the manuals this numbering convention will be used for addressing the particular IR sensor.

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

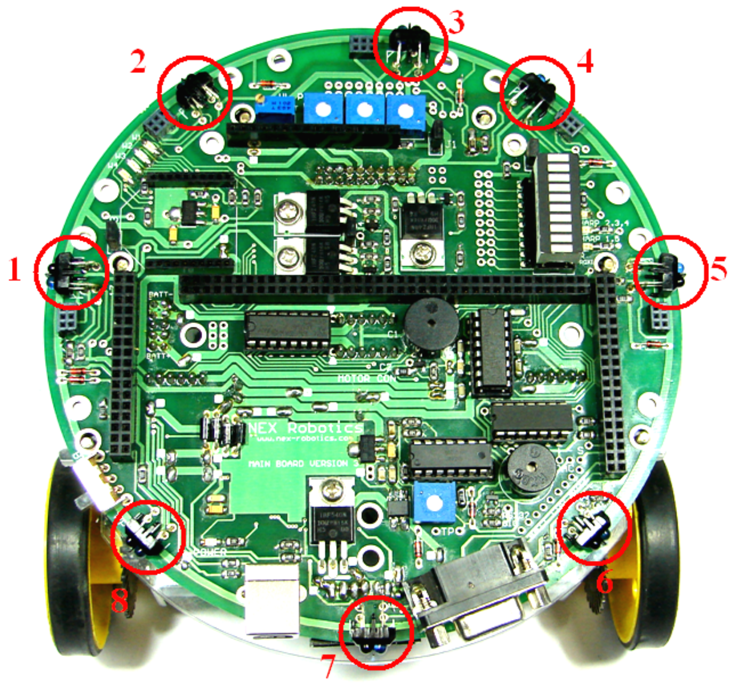


Figure 3.36: Eight IR proximity sensors on Fire Bird V

IR photo diode consumes about 0.5mA when bright light drives the sensor in to saturation. IR LED if enabled will consume about 30mA current each. When enabled 8 IR proximity sensors combined together consumes about 250mA current. It is the biggest power consumer on the robot after the motors. Refer to table 3.8, these sensors can be turned off by applying logic 1 (5V) to the pin no. 33 of the main board. To enable these sensors permanently connect the jumper J4. For jumper location refer to figure 3.38. Operation of the sensor power switching module is described in the previous section 3.10.

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.

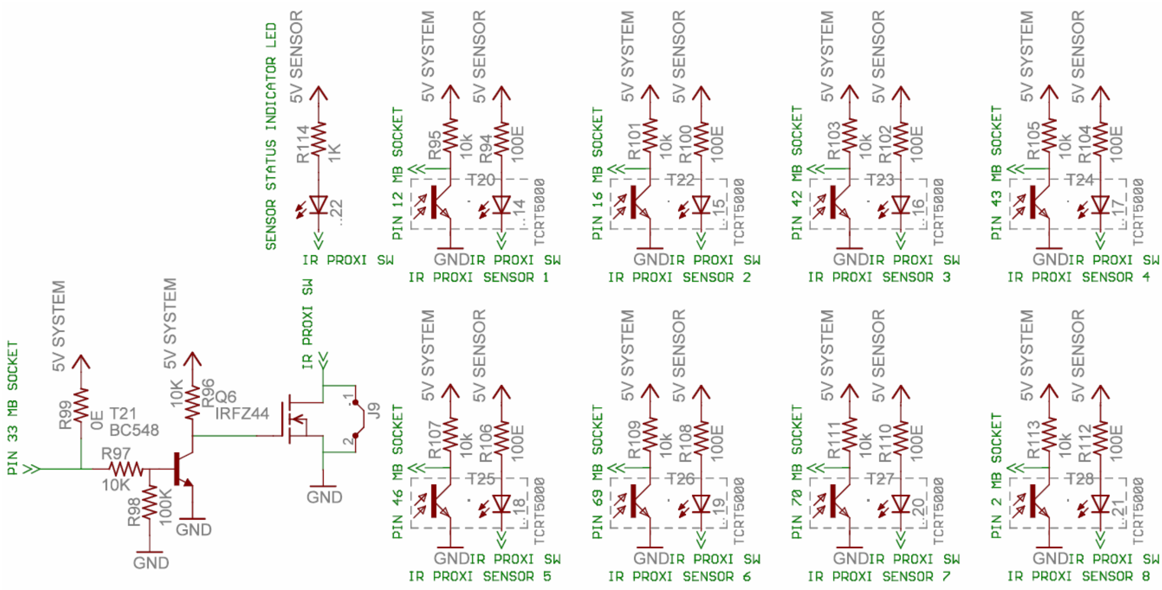


Figure 3.37: IR Proximity sensors

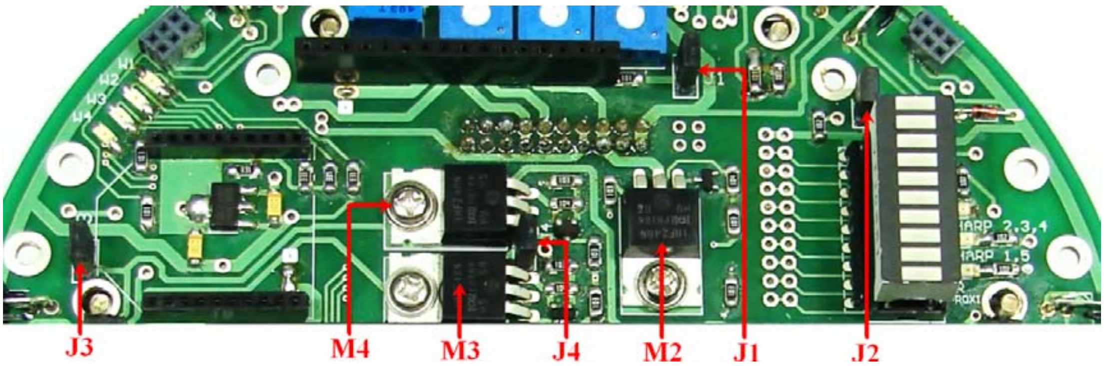


Figure 3.38: Sensor Control Switches and Jumpers

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 3.12: Jumper functions

PIN NO	Pin name	USED FOR	Status
15	OC4A / PH3	IR proximity sensors 1 to 8 disable. Turns off these sensors when output is logic 1 *	Output
89	PK0/ADC8/PCINT16	ADC input for IR proximity analog sensor 5	Input (Floating)
90	PF7(ADC7/TDI)	ADC input for IR proximity analog sensor 4**	Input (Floating)
91	PF6/(ADC6/TD0)	ADC input for IR proximity analog sensor 3**	Input (Floating)
92	PF5(ADC5/TMS)	ADC input for IR proximity analog sensor 2***	Input (Floating)
93	PF4/ADC4/TCK	ADC input for IR proximity analog sensor 1**	Input (Floating)

Table 3.13: Connections of the IR Proximity sensors and its power control MOSFET with the ATMEGA2560 microcontroller

* For more details refer to section 3.10 and 3.12.

**For using Analog IR proximity (1, 2, 3 and 4) sensors short the jumper J2 on the microcontroller adaptor board. For more details refer to section 3.19.6. To use JTAG via expansion slot of the microcontroller socket remove these jumpers.

PIN NO	Pin name	USED FOR
14	(SS/OC1B) PB2	ISP (In System Programming) and SPI Communication with ATMEGA2560. *
15	(MOSI/OC2) PB3	
16	(MISO) PB4	
17	PB5 (SCK)	
19	ADC6	ADC input for IR proximity analog sensor 7
22	ADC7	ADC input for IR proximity analog sensor 8
28	PC5 (ADC5/SCL)	ADC input for IR proximity analog sensor 6

Table 3.14: Connections of the IR Proximity sensors with the ATMEGA8 (slave microcontroller)

***** MOSI, MISO, SCK and SS pins of ATMEGA2560 are associated to the ISP (In System programming) port as well as the SPI interface to ATMEGA8. J4 needs to be disconnected before doing ISP. To communicate with ATMEGA8 jumper J4 needs to be in place.

Note: IR Proximity sensor nos. 5, 6 and 7 are connected to the ADC pins of ATMEGA8 slave microcontroller.

3.12 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 photo transistor for line sensing and bright red LED for the illumination. Due to the directional nature of the photodiode it does not get affected with ambient light unless it is very bright.

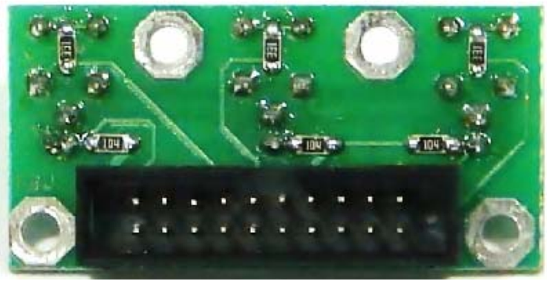
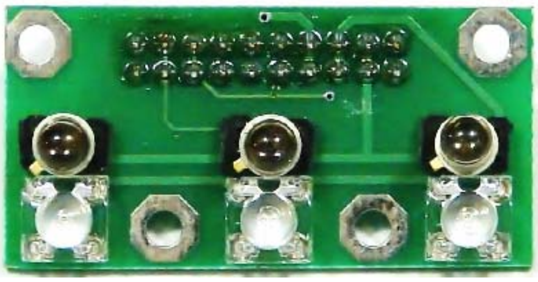
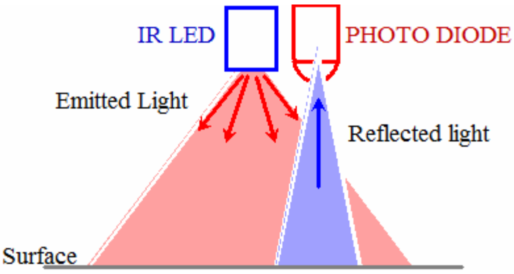



Figure 3.39: White line sensor



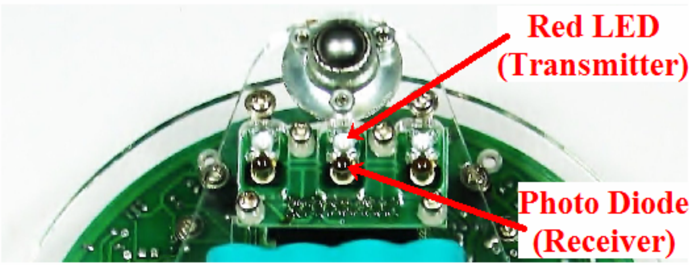


Figure 3.40: White Line sensor

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 2V to 5V. When the sensor is on a white line, more light gets reflected resulting in considerable increase in the leakage current which causes voltage across the sensor to fall between 2 to 0.1V.

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 3.12 and section 3.10 and 3.11 for more information on jumper settings.

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 not adequate. 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 red LEDs and take sensor readings at the same place and nullify the effect of the ambient light.

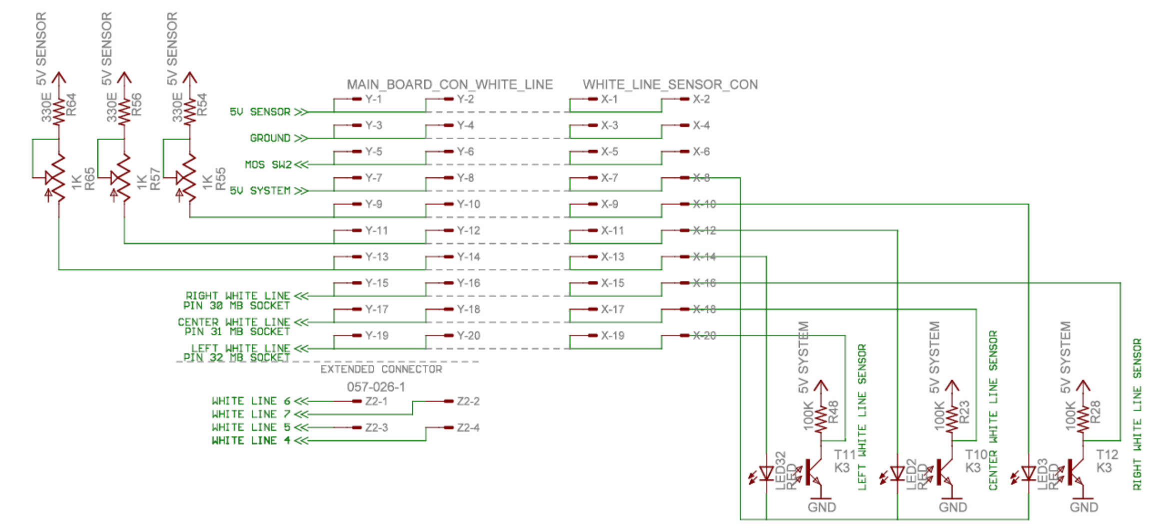


Figure 3.41: Schematic of the white line sensor

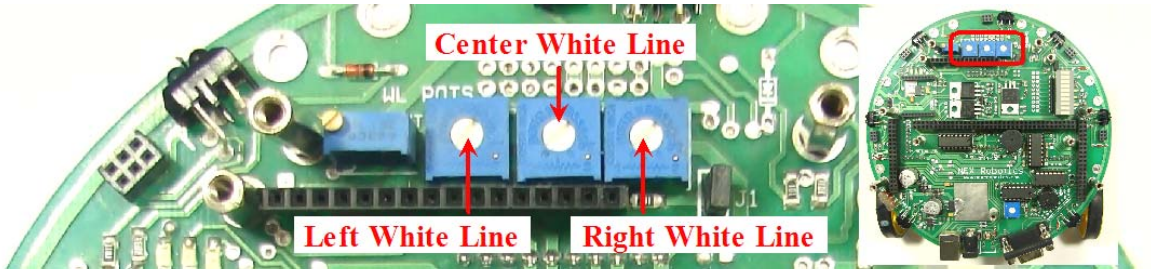


Figure 3.42: Potentiometers for white line sensor calibration

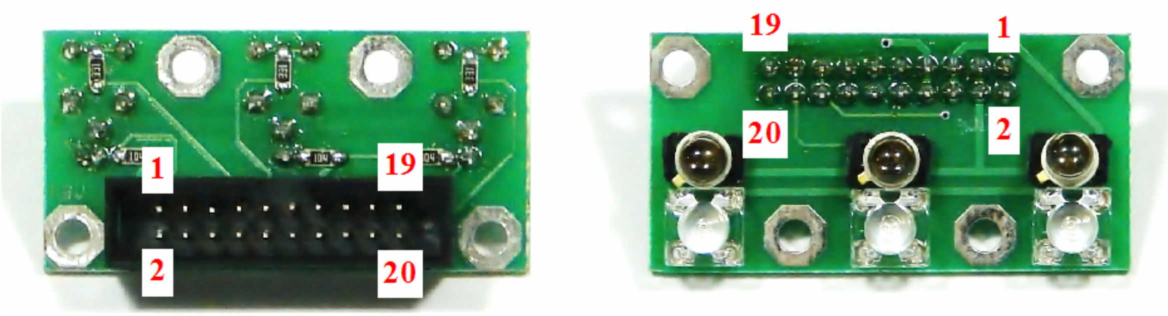


Figure 3.43: White line sensor pin connections

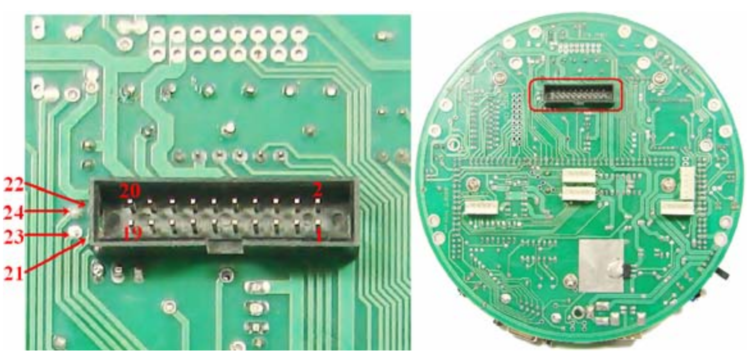


Figure 3.44: White line extension to mount 5 or 7 channel white line sensor

Pin No.	Function
1,2	White line sensor 1 (Left sensor) Data Out
3,4	White line sensor 2 (Centre sensor) Data Out
5,6	White line sensor 3 (Right Sensor) Data Out
7,8	White line sensor 1 LED
9,10	White line sensor 2 LED
11,12	White line 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 3.15: 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 3.41 and figure 3.44, pins Z2-1 to Z2-4 are used for connecting additional 4 white line sensors. Figure 3.44 shows the location of these pins on the main board.

PIN NO	Pin name	USED FOR	Status
70	PG2/ALE	Sharp IR ranges sensor 2, 3, 4 and red LEDs of white line sensor 1, 2, 3 disable. * Turns off these sensors when output is logic 1	Output
94	PF3/ADC3	ADC input for white line sensor 1	Input (Floating)
95	PF2/ADC2	ADC input for white line sensor 2	Input (Floating)
96	PF1/ADC1	ADC input for white line sensor 3	Input (Floating)

Table 3.16White line sensor connections with ADC of ATMEGA2560

* For more details refer to section 3.10 and 3.12.

PIN NO	Pin name	USED FOR
14	(SS/OC1B) PB2	ISP (In System Programming) and SPI Communication with ATMEGA2560. *
15	(MOSI/OC2) PB3	
16	(MISO) PB4	
17	PB5 (SCK)	
23	PC0 (ADC0)	ADC input for white line sensor 4
24	PC1 (ADC1)	ADC input for white line sensor 5/Servo pod
25	PC2 (ADC2)	ADC input for white line sensor 6
26	PC3 (ADC3)	ADC input for white line sensor 7/Servo pod

Table 3.17 Connections of the IR Proximity sensors with the ATMEGA8 (slave microcontroller)

***** MOSI, MISO, SCK and SS pins of ATMEGA2560 are associated to the ISP (In System programming) port as well as the SPI interface to ATMEGA8. J4 needs to be disconnected before doing ISP. To communicate with ATMEGA8 jumper J4 needs to be in place.

3.13 LCD Interfacing

To interface LCD with the microcontroller in default configuration requires 3 control signals and 8 data lines. This is known as 8 bit interfacing mode which requires total 11 I/O lines. To reduce the number of I/Os required for LCD interfacing we can use 4 bit interfacing mode which requires 3 control signals with 4 data lines. In this mode upper nibble and lower nibble of commands/data set needs to be sent separately. Figure 3.47 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 PC2. 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 PC0. 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 PC1. 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 PC4 to PC7 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.

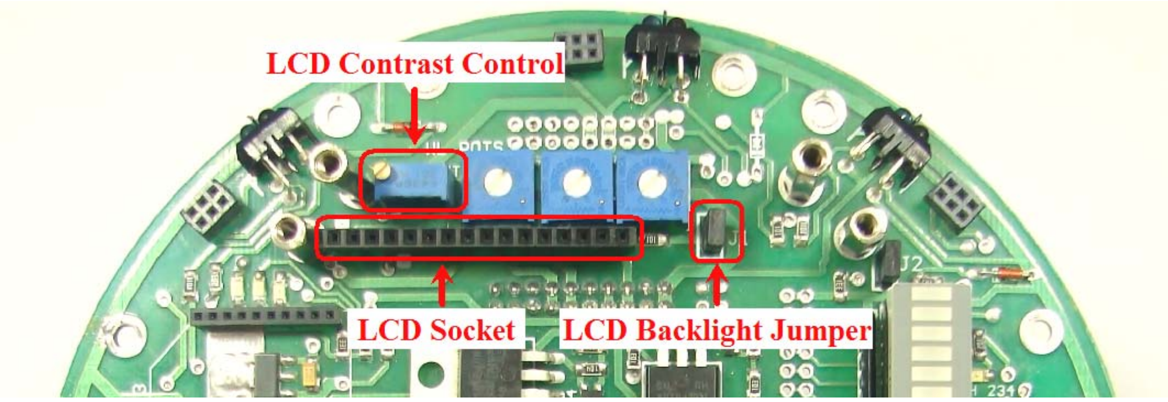


Figure 3.45: LCD socket and other settings

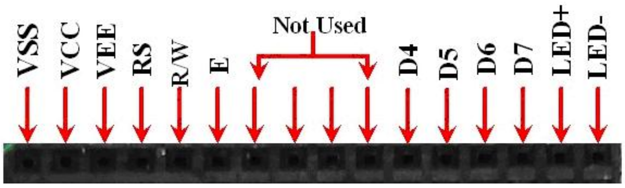


Figure 3.46: LCD socket pin connection

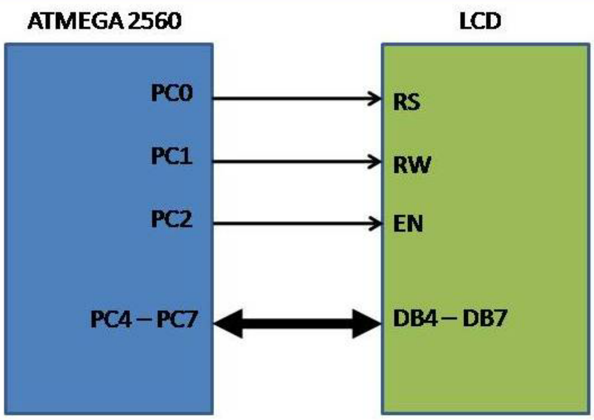


Figure 3.47 LCD interfacing with the microcontroller

Microcontroller	**LCD PINS**	**Description**
VCC	VCC	Supply voltage (5V).
GND	GND	Ground
PC0	RS (Control line)	Register Select
PC1	R/W (Control line)	READ /WRITE
PC2	EN (Control Line)	Enable
PC4 to PC7	D4 to D7 (Data lines)	Bidirectional Data Bus
	LED+, LED-	Backlight control

Table 3.18: LCD Pin mapping and functions

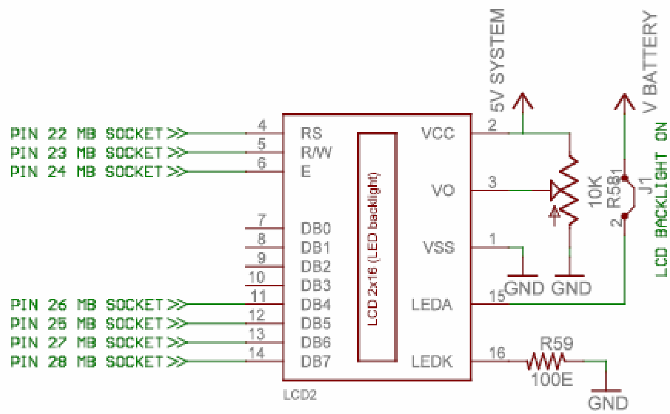


Figure 3.48: LCD display schematics

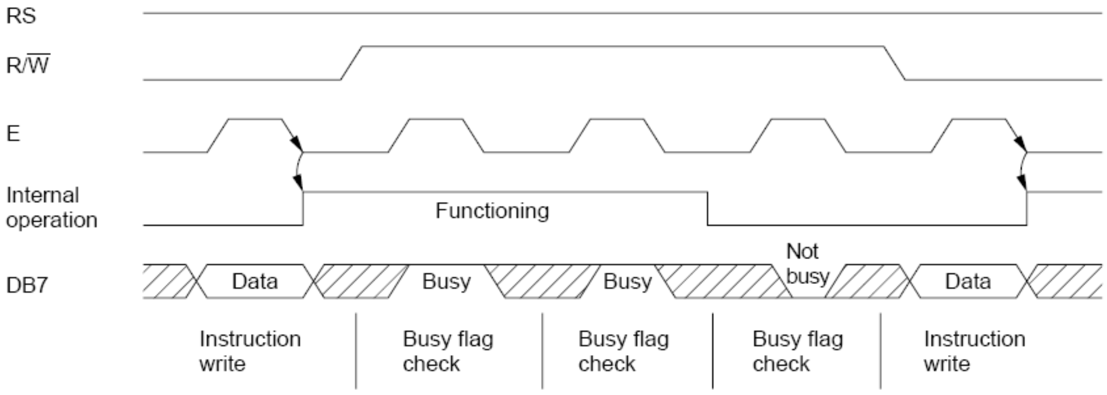


Figure 3.49: LCD Timing Diagram.

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 8.45 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.

3.14 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 PC3 pin of the microcontroller.

Figure 3.50: Buzzer

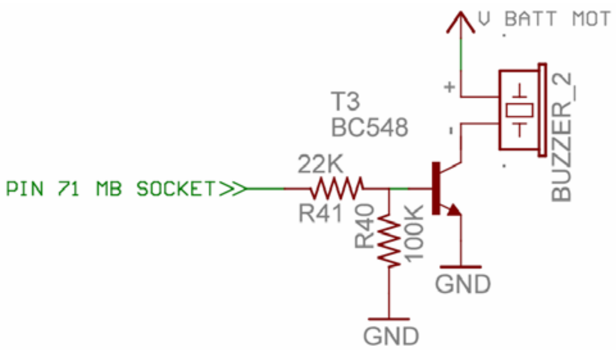


Figure 3.51: Buzzer

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.

3.15 SPI expansion port on the main board

SPI expansion port can be used to add further functionalities like robotic arm, color sensing sensors etc. It has SPI communication pins and important types supply for powering up these devices. Port can be seen in figure 3.5.

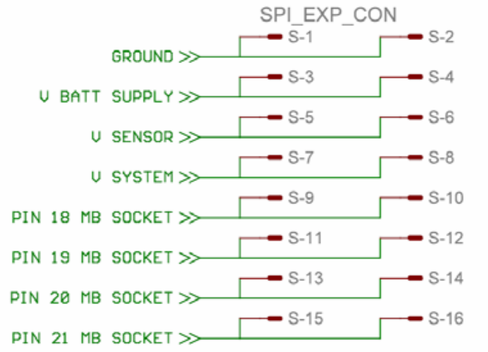


Figure 3.52: SPI expansion port pin functions

3.16 Serial Communication

Serial port's pin 2, 3 and 5 are connected with the microcontroller adaptor board socket. Other pins of the serial port are also available on the main board. Figure 3.53 shows the serial port connector and its connections on the main board and table 3.19 gives the pin functions of the each pin.

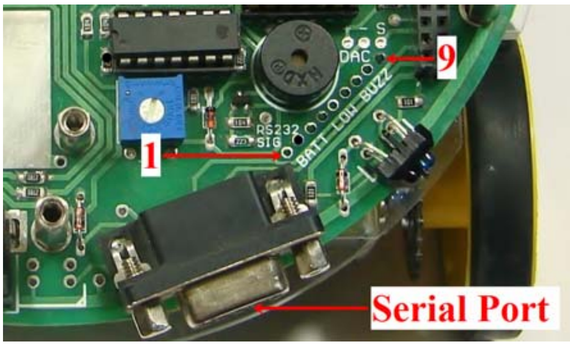


Figure 3.53: Serial port pins

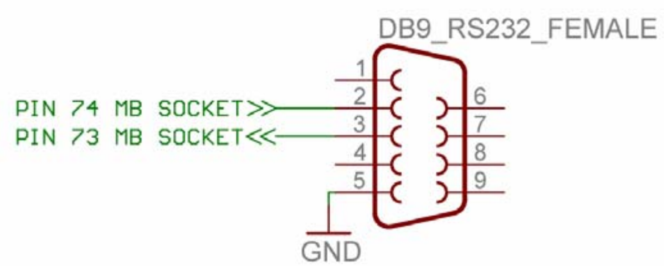


Figure 3.54: Serial port connections with the main board socket

Pin No.	Description
1	Data Carrier Detect (DCD)
2	Receiver Data (RXD) (Pin 74 on the socket for the microcontroller adaptor board)
3	Transmit Data (TXD) (Pin 73 on the socket for the microcontroller adaptor board)
4	Data Terminal Ready (DTR)
5	Signal Ground (GND)
6	Data Set Ready (DSR)
7	Request to Send (RTS)
8	Clear to Send (CTS)
9	Ring Indicator (RI)

Table 3.19: Serial port pin out

3.17 USB communication

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

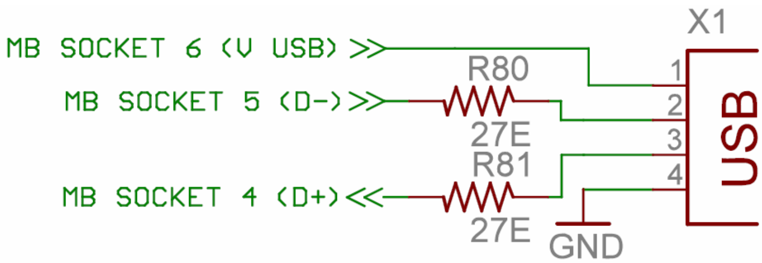


Figure 3.55: USB port connections with the main board socket

3.18 ZigBee wireless communication

Fire Bird V uses XBee wireless modules form Digi international (www.digi.com). It supports XBee and XBee Pro wireless modules which give 100 or 1000+ meters of wireless communication range in line of sight. LEDs W1, W2, W3 and W4 are used for status indication of the wireless module. For more details on the wireless module read the wireless module's datasheet. Table 3.20 shows the functions of the status indicator LEDs.

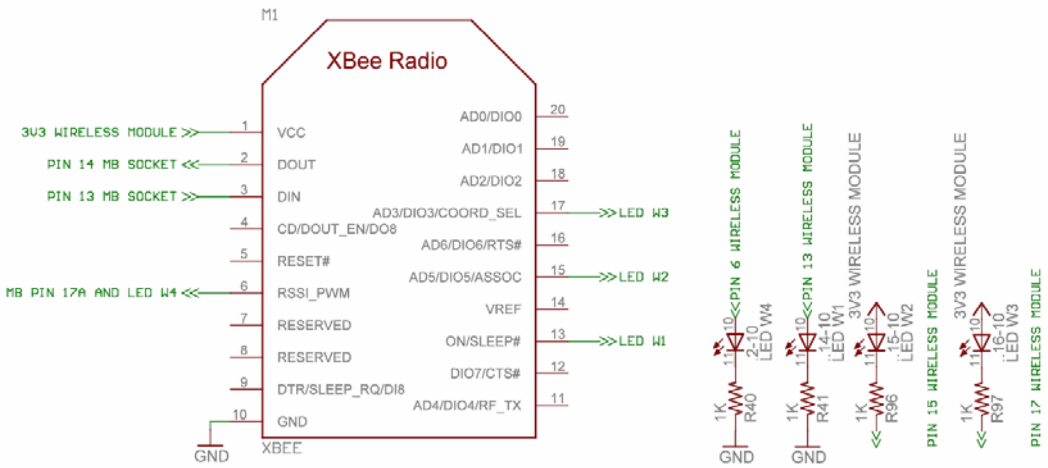


Figure 3.56: ZigBee wireless module schematics

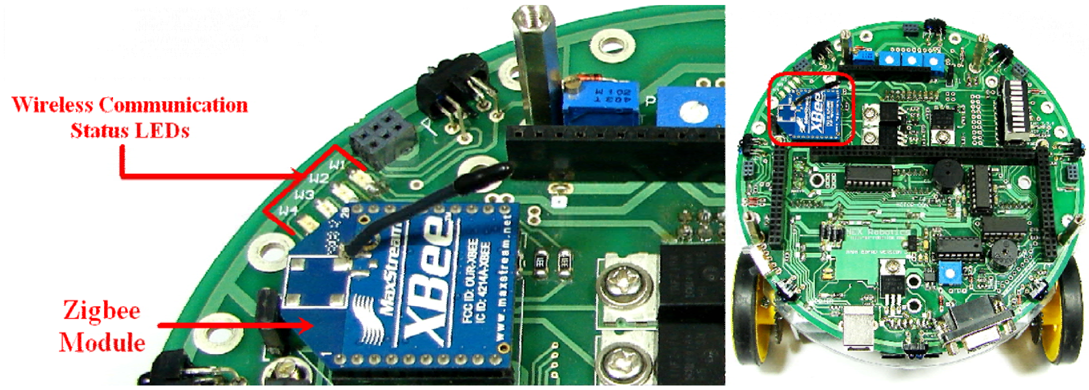


Figure 3.57: ZigBee wireless module and LED indicators

LED	Connection to XBee Wireless module Pin no.	Description
W1	13	On/Sleep Module Status
W2	15	Associate LED
W3	17	Reserved
W4	6	RX Signal Strength Indicator

Table 3.20: XBee wireless module LED functions

Important:
You can change XBee wireless module's frequency, and Pan ID so that multiple XBee wireless modules can coexist at the same time. For more information on this, refer to "Application Notes" folder which is located inside the "Manuals and Application notes" folder in the documentation CD.

3.19 ATMEGA2560 microcontroller adaptor board

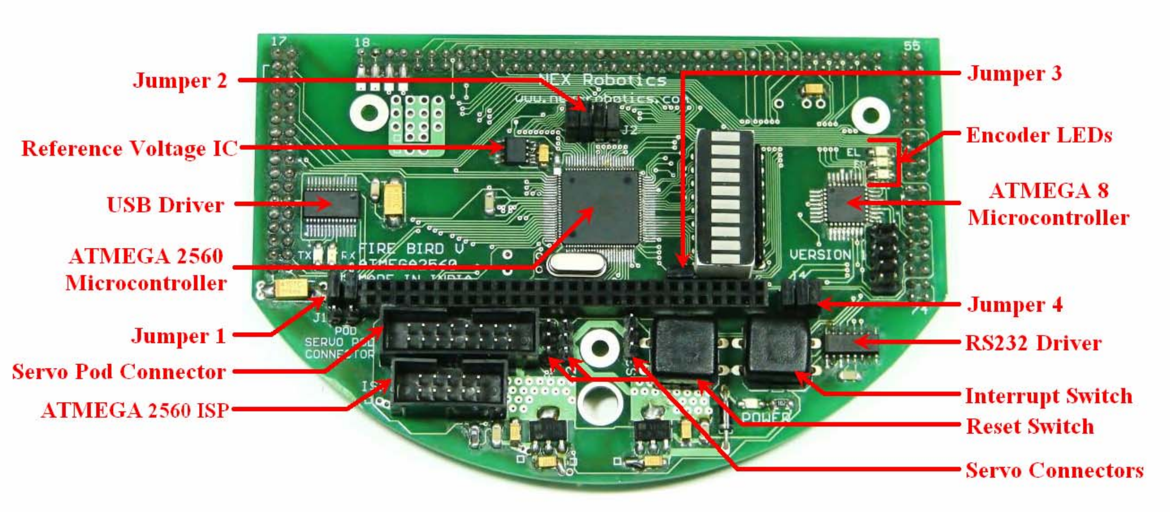


Figure 3.58: ATMEGA2560 microcontroller adaptor board

3.19.1 Power management

Power management block on the ATMEGA2560 microcontroller adapter board provides power to the microcontroller, other devices and the power to the servo motor.

ATMEGA2560 microcontroller adapter board has two low drop voltage regulators:

1. “5V uC” supplies power to the microcontroller and its peripherals.
2. “5V servo” supplies power to the servo motor.

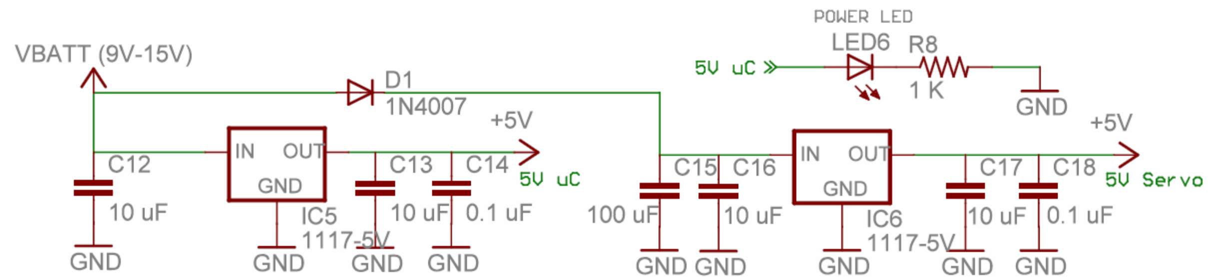


Figure 3.59: Power Supply Circuit

3.19.2 Battery voltage sensing

Filtered battery voltage is used for battery voltage sensing. Analog to Digital Converter (ADC) can measure maximum voltage of 5V. Hence battery voltage is scaled down from 8-15V to less than 5V using resistor divider network formed by R12 and R13. It scales down the voltage by approximately 1/3 of the actual value.

ATMEGA2560 ADC can be used in 8 bit or 10 bit resolution. To calculate voltage from the ADC's acquired digital value in 8 bit resolution we use following formula:

V Battery = 0.7V + (ADC value * (5V/255) * ((10K + 3.3K) / 3.3K))

V Battery = 0.7V + (ADC value * 0.0790)

In the above formula:

- 0.7V represents voltage drop across the diodes D7 and D8. for more details refer to figure 3.11.
- 5V/255 represents the ADC step resolution
- (10K + 3.3K) / 3.3K is a voltage divider formula

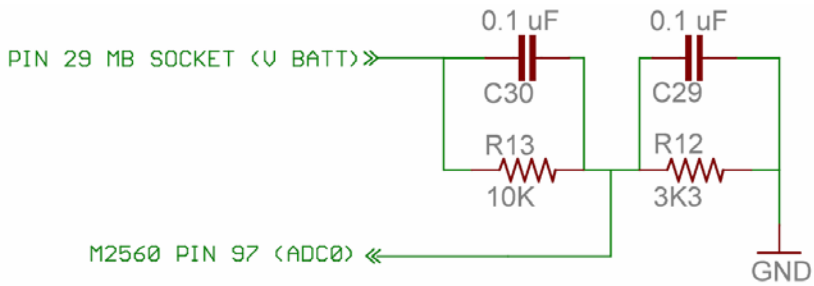


Figure 3.60: Battery Voltage Divider Bias Circuit

Note: For 10 bit resolution replace 255 by 1024.

3.19.3 TSOP1738 RC5 IR receiver and decoder

TSOP1738 is an 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. 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 form of robo-soccer. SJ2 Jumper needs to be connected by soldering for enabling the TSOP sensor. Figure 3.62 shows the location of the SJ2. It connects TSOP1738 with the INT7 (interrupt 7) pin of the microcontroller.

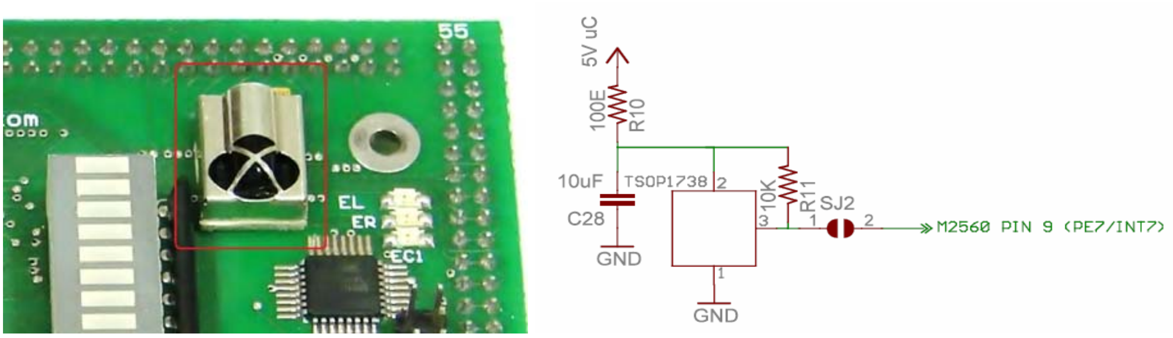


Figure 3.61: TSOP1738 RC5 decoder IR receiver

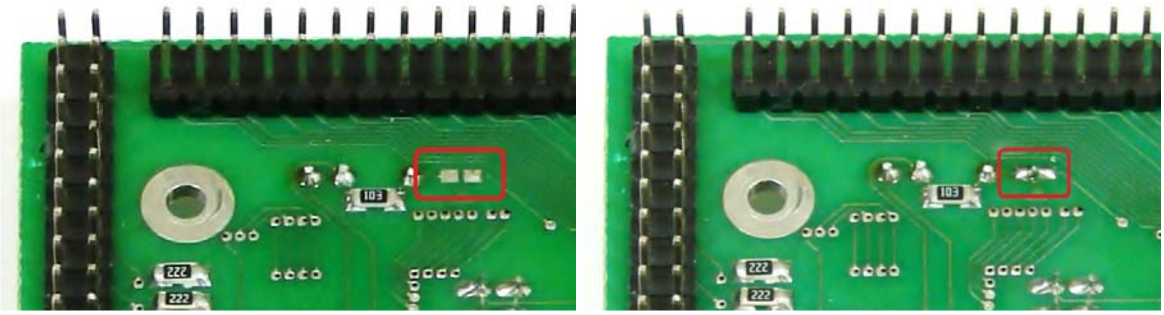


Figure 3.62: Jumper to be shorted to connect TSOP1738 with INT7 (shorted jumper is shown in the right image)

3.19.4 ATMEGA2560 Microcontroller Board Expansion Socket

ATMEGA2560 is a featur rich microcontroller with lots of available I/O ports. Many of the ports are available on the uC Expansion Socket. Table 3.21 lists the connection details of all the pins of the socket.

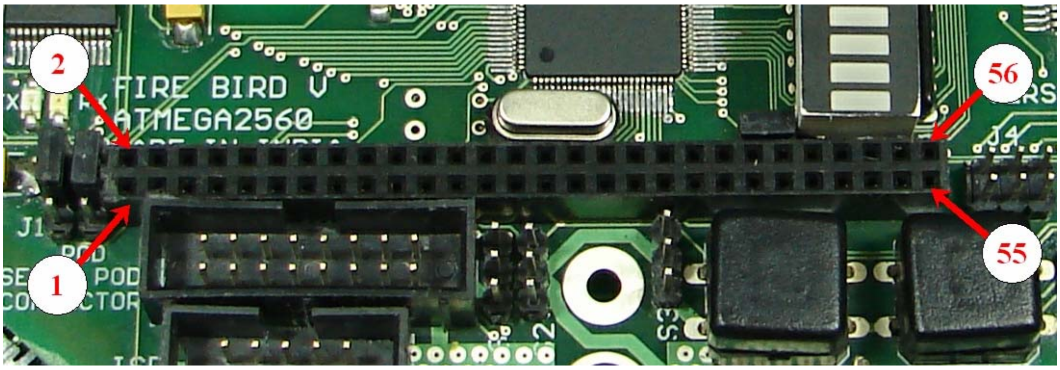


Figure 3.63: Expansion Header on Microcontroller Board

Pin No.	Function
1	UART2 TXD pin of ATMEGA2560 via Jumper 1 (uC pin 13)
2	UART2 RXD pin of ATMEGA2560 via Jumper 1 (uC pin 12)
3	ATMEGA2560 interrupt 7 pin / CLKO / ICP3 (uC pin9)
4	OC4B / PH4 / GPIO (uC pin 16)
5	OC4C / PH5 / GPIO (uC pin 17)
6	OC2B / PH6 / GPIO (uC pin 18)
7	TDO (JTAG)* / ADC6* / IR proximity sensor 3 (uC pin 91)
8	TDI (JTAG)* / ADC7* / IR Proximity sensor 4 (uC pin 90)
9	TMS (JTAG) */ ADC5* / IR Proximity sensor 2 (uC pin 92)
10	TCK (JTAG)* / ADC4* / IR Proximity sensor 1 (uC pin 93)
11	ATMEGA2560 Slave Select (SS) pin PB0 (uC pin 19) **
12	No Connection till the version 2009-12-08. Connected to V Batt supply in version 2010-11-25 onwards.
13	MOSI / PB2 (uC pin 21)**
14	SCK / PB1 (uC pin 20)**
15	RESET (uC pin 30)
16	MISO / PB3 (uC pin 22)**
17	PL7 / GPIO (uC pin 42)
18	PL6 / GPIO (uC pin 41)
19	SDA / PD1 / INT1 / GPIO (uC pin 44)
20	SCL / PD0 / INT0 / GPIO (uC pin 43)
21	5V System Voltage. Can be used for powering up any digital device. Current Limit: 400mA.
22	5V System Voltage. Can be used for powering up any digital device. Current Limit: 400mA.
23	Ground
24	Ground
25	ICP1 / PD4 / GPIO (uC pin 47)
26	T4 / PH7 / GPIO (uC pin 27)
27	ICP5 / PL1 / GPIO (uC pin 36)
28	ICP4 / PL0 / GPIO (uC pin 35)
29	XCK1 / PD5 / GPIO (uC pin 48)
30	T5 / PL2 / GPIO (uC pin 37)
31	PG1 / GPIO (uC pin 52)

32	PG0 (uC pin 51)
33	T1 / PD6 / GPIO (uC pin 49)
34	T0 / PD7 (uC pin 50)
35	No Connections
36	
37	TXD1 / INT3 / PD3: Connected to the MAX 202 for RS232 communication. Do not use for other purpose unless connection with MAX 202 is removed. (uC pin 46)
38	RXD1 / INT2 / PD2: Connected to the MAX 202 for RS232 communication. Do not use for other purpose unless connection with MAX 202 is removed. (uC pin 45)
39	PJ6 / GPIO (uC pin 69)***
40	PJ7 / GPIO (uC pin 79) ***
41	PJ4 / GPIO (uC pin 67) ***
42	PJ5 / GPIO (uC pin 68) ***
43	PJ2 / GPIO (uC pin 65) ***
44	PJ3 / GPIO (uC pin 66) ***
45	RXD3 / PJ0 / GPIO (uC pin 63)****
46	TXD3 / PJ1 / GPIO (uC pin 64)****
47	No Connections
48	
49	
50	
51	
52	
53	
54	
55	
56	

Table 3.21: ATMEGA2560 microcontroller board expansion header table

Note:
* In order to use these pins as JTAG or as ADC for external sensor interfacing, remove all 4 connectors for the jumper 2 of the microcontroller board. When jumpers are removed IR Proximity sensor 1 to 4 will be disconnected from the robot.

** Pins can be used as SPI bus. These pins are already connected to slave ATMEGA8 microcontroller via J4 of the microcontroller board. Before using it as SPI bus for external device interfacing, remove J4 to disconnect ATMEGA8 slave microcontroller or use different pin of the microcontroller as SS (slave select).

*** All the pins of the PORTJ are connected to the bargraph LED display. While using these pins as GPIO to turnoff this bargraph LED display, remove jumper J3 of the microcontroller board.

**** PJ0 and PJ1 can be used as GPIO as well as TXD and RXD for UART 3. These pins are also connected to bargraph LED display. While using these pins as UART 3, jumper J3 must be removed to disable bargraph LED display in order to avoid loading on the TXD and RXD lines of the device which is connected with the ATMEGA2560 microcontroller.

3.19.5 SERVO POD Socket

Servo pod socket is used to connect external sensors / actuators which are mounted on pan / tilt servo pod.

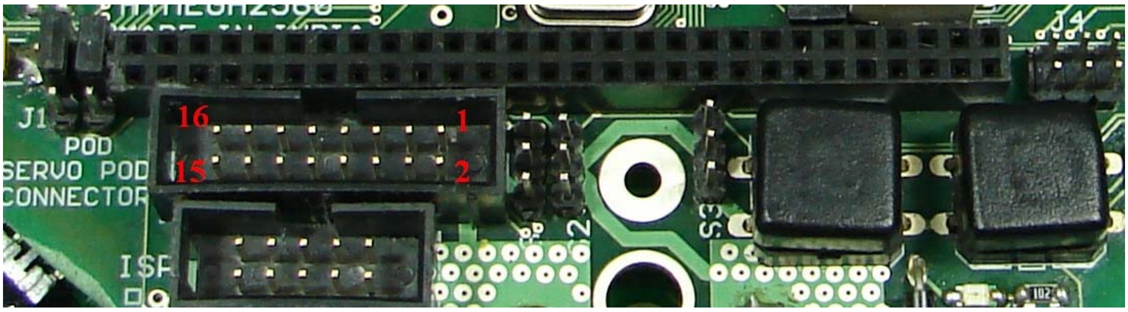


Fig 3.64: Servo Pod Socket

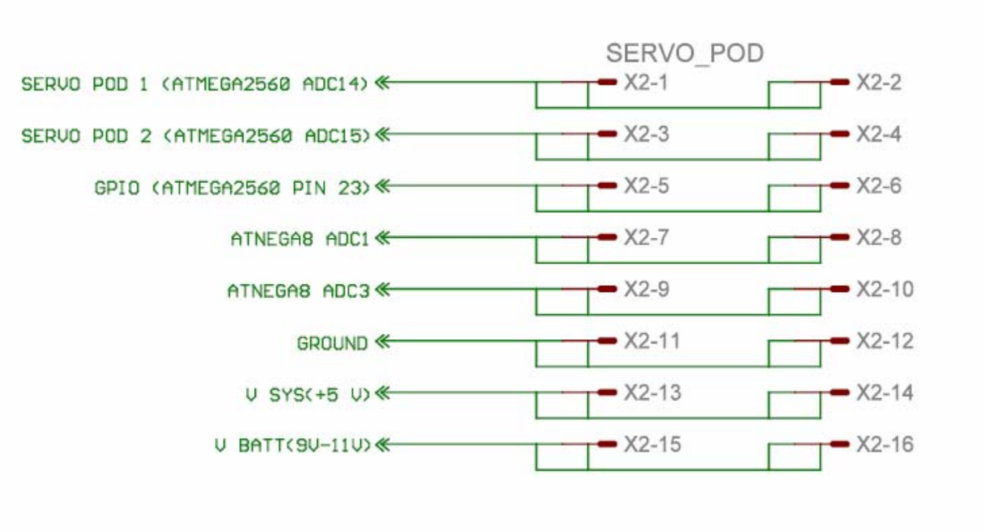


Figure 3.65: Servo pod pin mapping

Pin No.	Pin Name	Description
1	Servo POD1	Connection with ATMEGA2560 ADC channel 14
2		
3	Servo POD2	Connection with ATMEGA2560 ADC channel 15
4		
5	GPIO	Connection with ATMEGA2560 OC2A/PB4 pin (Pin no. 23)
6		
7	Atmega8 ADC	Connection with ATMEGA8 ADC channel 1
8		
9	Atmega8 ADC	Connection with ATMEGA8 ADC channel 3
10		
11	Ground	Ground
12		
13	V SYS	+ 5V (VCC)
14		
15	V BATT	Battery Voltage(9V – 11V)
16		

Table 3.22: Servo Pod socket pin description

3.19.6 Microcontroller Board Jumpers

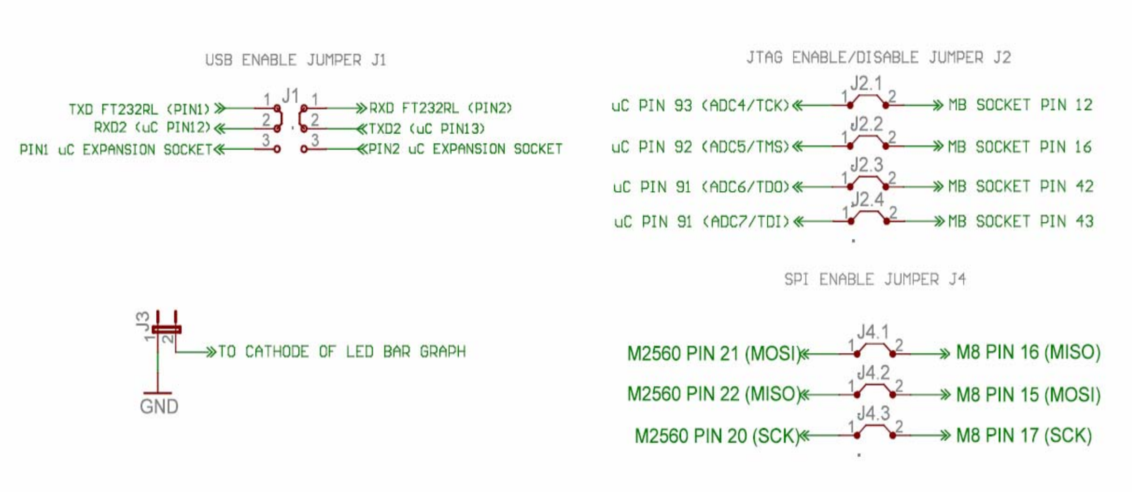


Figure 3.66: Jumpers schematic

Microcontroller board has 4 jumpers labeled from J1 to J4 as shown in Figure 3.58 and figure 3.66.

J1: Jumper J1 is used to select between the UART2 pins connections of ATMEGA2560 on the expansion slot and to the onboard FT232 USB to serial converter circuit. When jumper is in position as shown in the figure 3.66, it enables the onboard USB communication through UART2 (default state).

J2: When J2 is on IR Proximity sensors 1 to 4 are connected to the ADC pins of the ATMEGA2560. When J2 is open, same ADC pins can be used for JTAG on the uC expansion socket or as ADCs for external sensor interfacing. In the default state J2 is on.

J3: If J3 is on, all the pins of the PORT J are connected to the LED bargraph display. It can be used for quick message display for debug purpose. If J3 is off, LED connection is disabled. All the pins of the PORT J are available on the uC expansion socket for use as GPIOs. In the default state J3 is kept on.

J4: When J4 is on, SPI connection between ATMEGA2560 (master) and ATMEGA8 (slave) enabled. Since SPI lines are connected together ISP programming of ATMEGA2560 and ATMEGA8 can not be done. When J4 is off, Communication between ATMEGA2560 and ATMEGA8 is disabled and ISP programming of ATMEGA2560 and ATMEGA8 can be done. In the default condition J4 is kept open. If you use bootloader option then you don't have to remove the J4 while programming the ATMEGA2560 microcontroller.

In System Programming (ISP) sockets

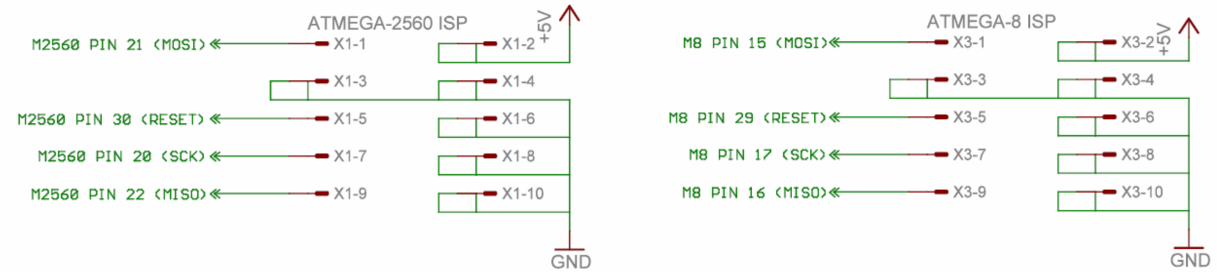


Figure 3.67 ISP Schematic

ATMEGA2560 microcontroller adapter board has ISP sockets for the ATMEGA2560 and ATMEGA8 microcontrollers.

Note: To do In System Programming of ATMEGA2560 and ATMEGA8 microcontrollers jumper J4 must be absent. For more details refer to section 3.19.6.

3.19.7 FT232 USB to serial converter on UART 2 of the ATMEGA2560 microcontroller

FT232 is a USB to TTL level serial converter. It is used for adding USB connectivity to the microcontroller adaptor board. With onboard USB circuit Fire Bird V can communicate serially with the PC through USB port without the use of any external USB to Serial converter. The USBD- and USBD+ pins are connected to USB socket on the main board. TX and RX LEDs are the indicator LEDs situated near the FT232 IC. Refer to figure 3.58 for LED locations. To enable USB to serial communication jumper J1 should be configured in a particular way. Refer to section 3.19.6 for correct jumper settings.

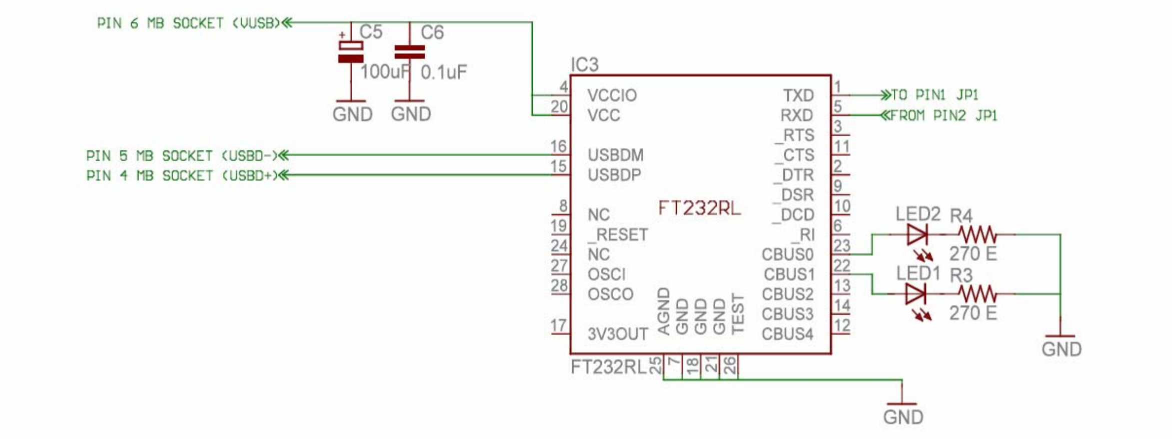


Figure 3.68: FT232 Schematic

Note: Using bootloader from NEX Robotics Robot can be programmed directly via USB port without any need of external ISP programmer.

3.19.8 TTL to RS232 converter on UART 1 of the ATMEGA2560 microcontroller

MAX202 IC is used for conversion of the TTL level signal of the UART 1 to the RS232 level. It is connected to the DB9 female serial connector on the main board. For more details on the hardware connections refer to section 3.16.

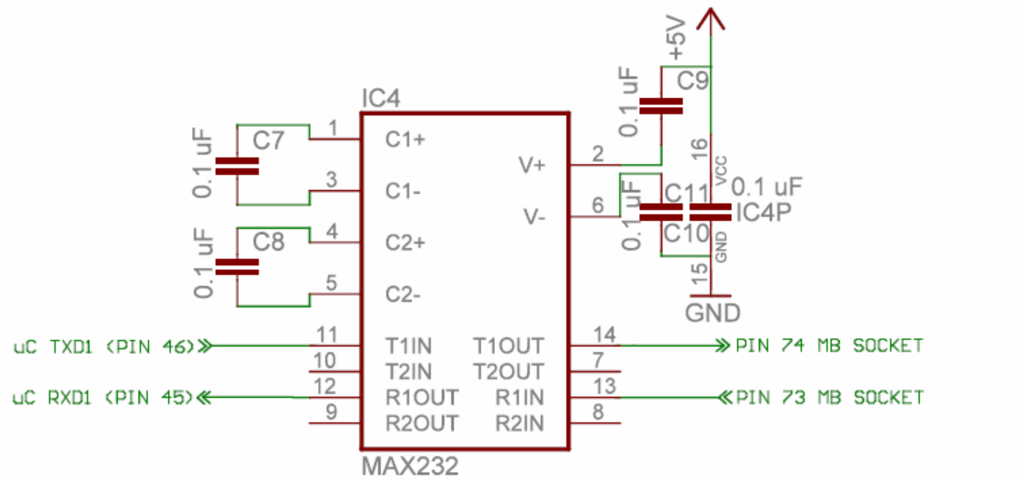


Figure 3.69: MAX202 TTL to RS232 converter

3.19.9 REF5050 precision reference voltage generator

ATMEGA2560 microcontroller's ADC channels require external stable voltage reference. In the default state microcontroller uses "5V uC Supply" as a external reference voltage. In case if you want to interface microcontroller with the sensors where precision is very important then REF5050 external reference voltage generator can be added on the microcontroller board. In the default state voltage reference is directly taken from "5V uC supply" by connecting pins 2 and 1 of the pads of SJ1 which is located just below the J2 on the microcontroller board.

To connect REF5050 with the microcontroller, pins 1 and 2 needs to be unsoldered and pins 2 and 3 needs to be shorted and REF5050 to be added.

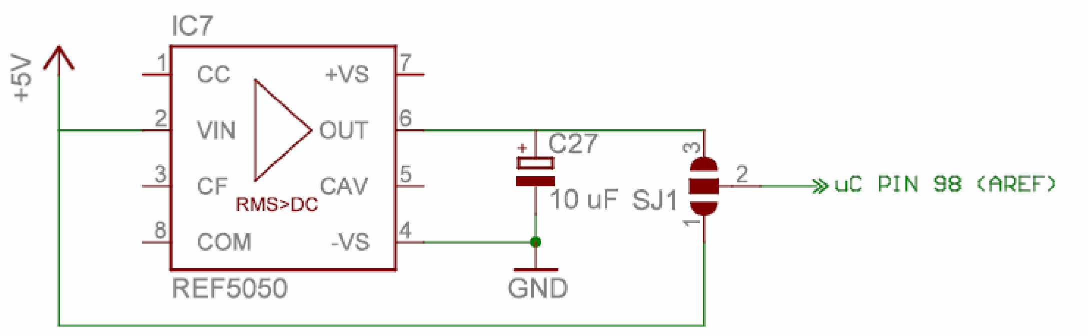


Figure.3.70: REF5050 Schematic

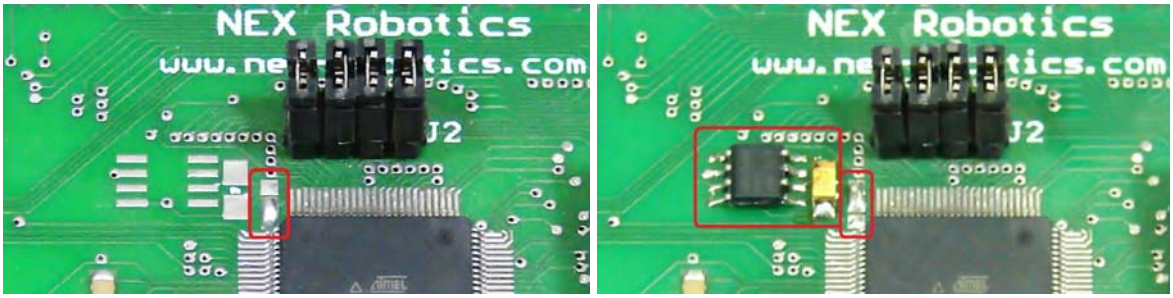


Figure 3.71: Left- Jumper shorted to use 5V uC as A Ref. Right- REF5050 is installed and jumper shorted to use its 5V output as reference.

3.19.10 Interrupt Switch

Interrupt switch on the microcontroller adaptor board is connected to PE7 (INT7) pin of the microcontroller. It has external 10K pull-up resistor. When switch is pressed, PE7 becomes logic low.

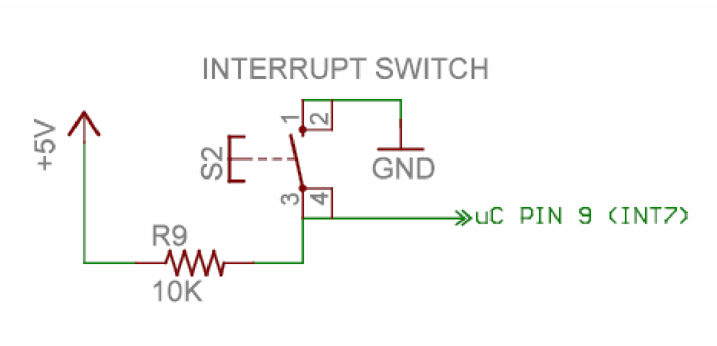


Figure 3.72: Interrupt switch

3.19.11 Servo Connectors

The microcontroller board has three Servo connectors as shown in figure 3.58. It can be used for driving servo motors of camera pod or any other attachment. Power for the servo connector is provided by the "5V servo supply" voltage regulator.

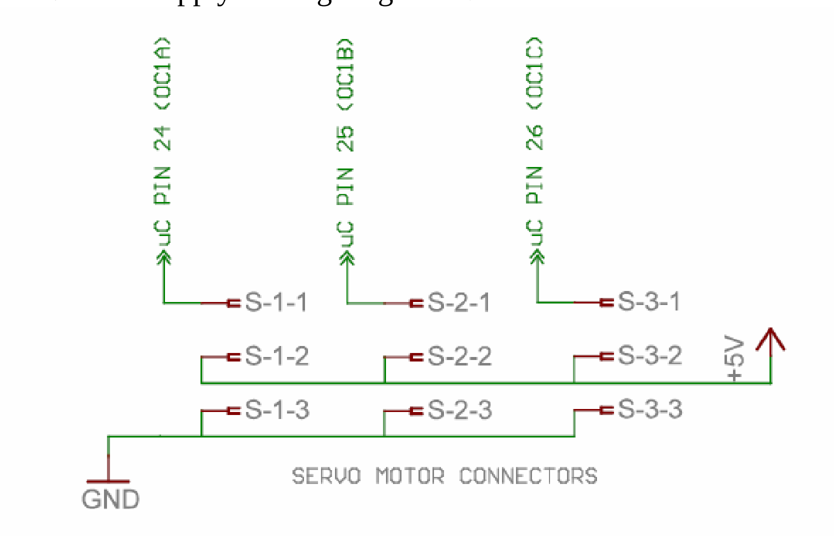


Figure: 3.73: Servo Connectors Schematic

3.19.12 Position Encoder LEDs

These LEDs are used to display the pulses coming from the left, right and C2 motor connectors. In the default configuration Motor C2 is absent, hence input of the CD40106 Schmitt trigger inverting buffer is floating. Because of the floating input its LED might flicker some times.

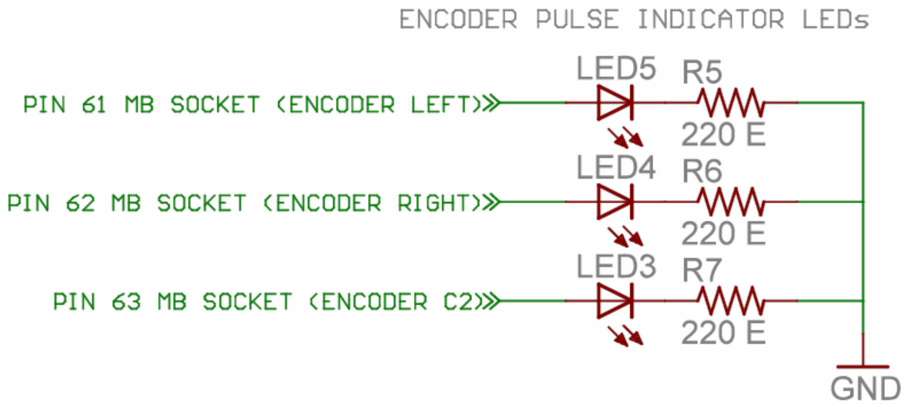


Figure 3.74: Encoder LEDs Schematic

3.19.13 Bargraph LED display

Bargraph LED display is used for quick debugging purpose. It is connected to the PORTJ of the ATMEGA2560 microcontroller. To enable bargraph jumper J3 needs to be connected. For more details refer to the section 3.19.6.

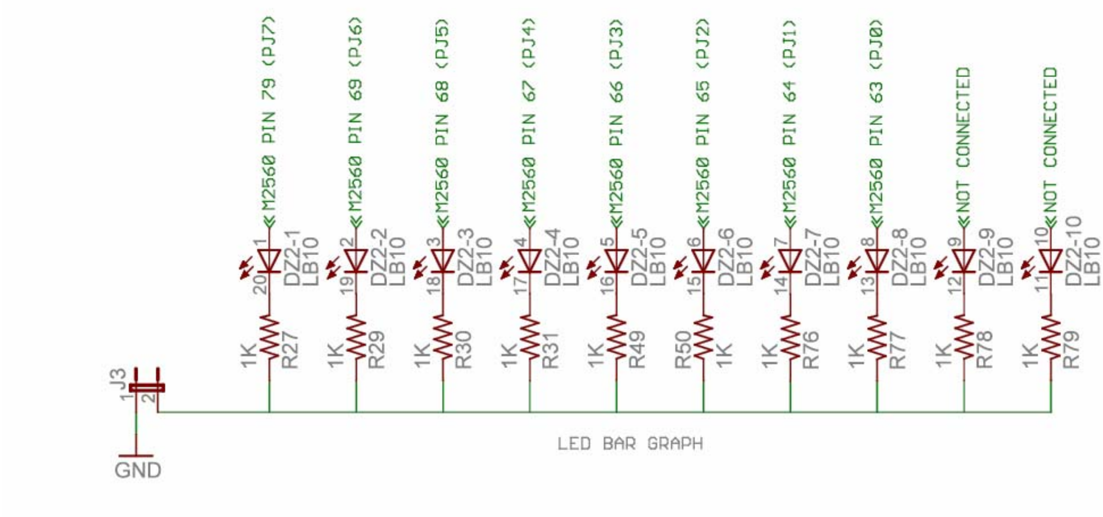


Figure 3.75: LED BAR GRAPH Schematic

3.19.14 ATMEGA8 Slave Microcontroller

Fire Bird V robot can be interfaced with more than 30 sensors at the same time. ATMEGA2560 does not have sufficient number of ADC available of sensor interfacing. Hence ATMEGA8 microcontroller is connected with ATMEGA2560 microcontroller over the SPI port. Jumper J4 needs to be removed before attempting to do ISP with ATMEGA2560 and ATMEGA8 as there SPI lines are connected with the jumper J4. For more details on the jumpers, refer to the section 3.19.6.

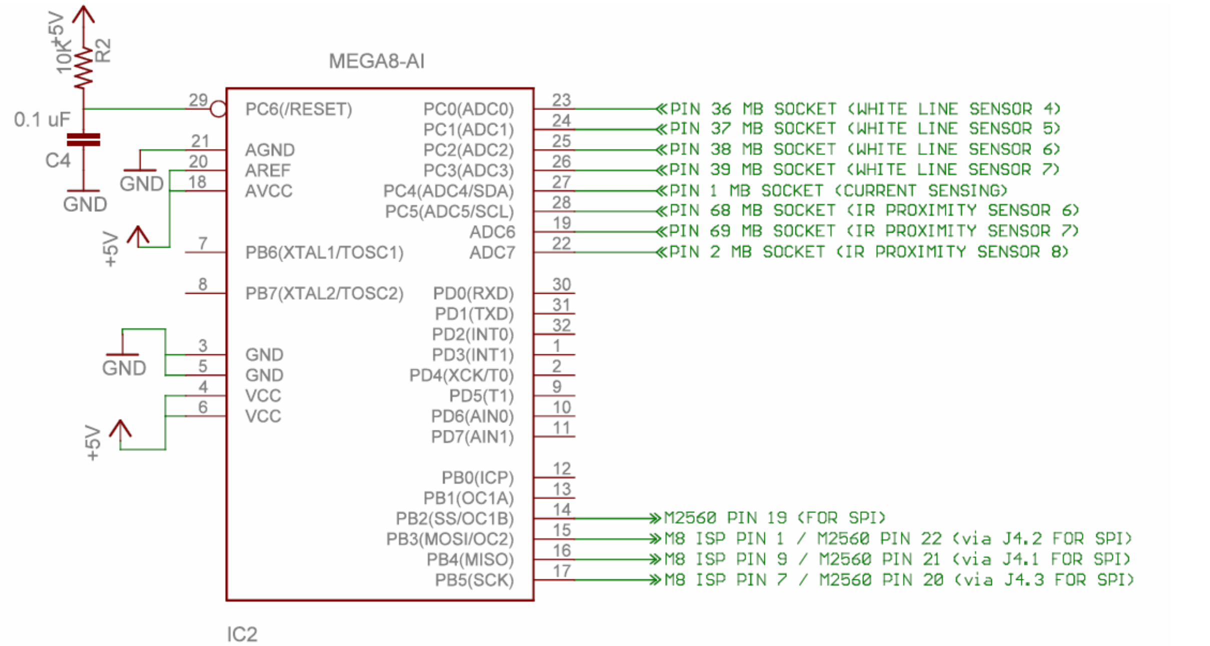


Figure 3.76: ATMEGA8 SCHEMATIC

Note: Firmware (ATMEGA8.hex) for the ATMEGA8 microcontroller is located in the GUI and Related Firmware folder in the documentation CD.

3.19.15 ATMEGA2560 Microcontroller

ATMEGA2560 is interfaced directly to most of the onboard peripherals. Its schematic is shown in the figure 3.78.

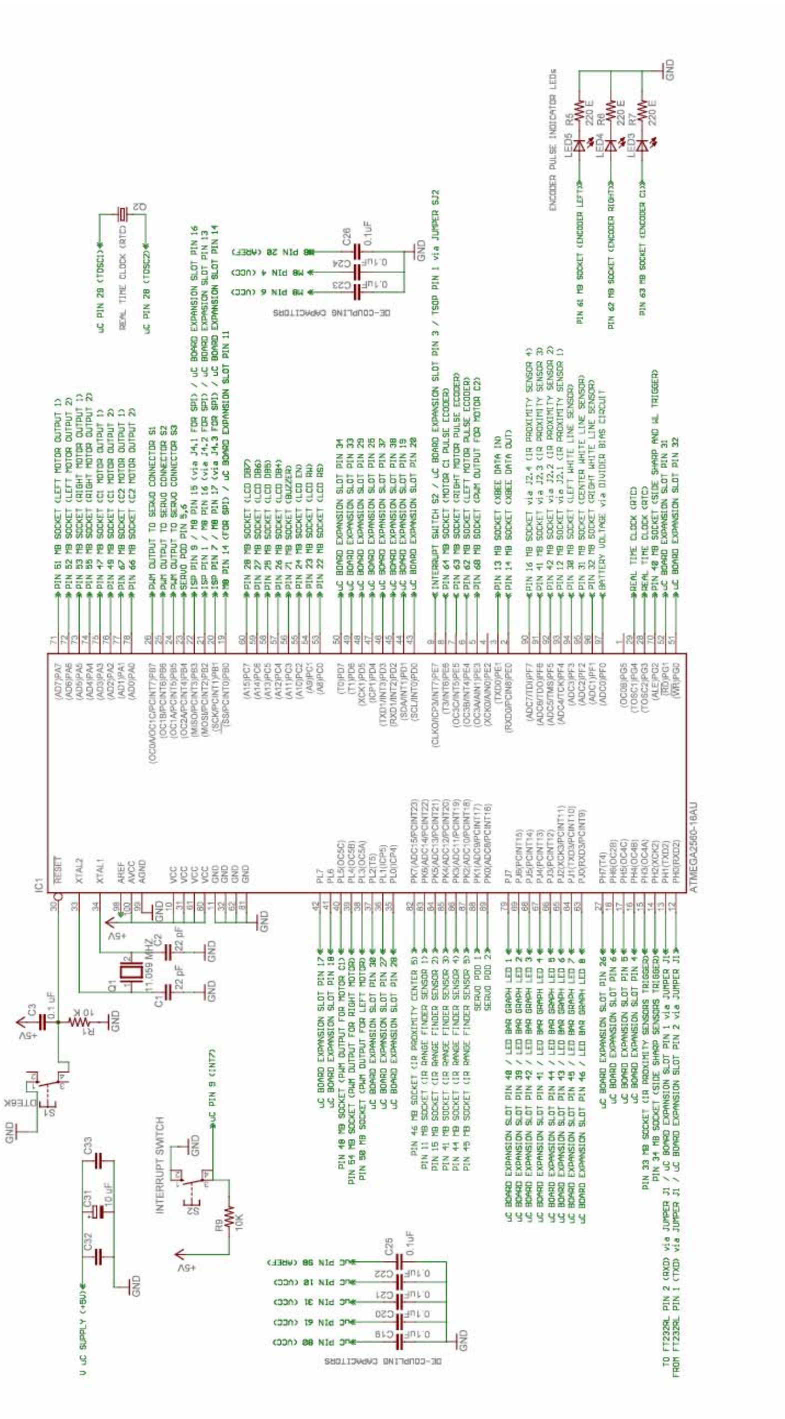


Figure 3.78: ATMEGA2560 microcontroller schematic

4. Pin Functionality

Fire Bird V ATMEGA2560 microcontroller adaptor board has two microcontrollers. ATMEGA2560 (master microcontroller) and ATMEGA8 (slave) microcontroller. ATMEGA2560 communicates with ATMEGA8 using SPI bus.

ATMEGA2560 is interfaced to all the important modules for the robot while ATMEGA8 microcontroller is interfaced with non critical modules such as IR proximity sensors 6, 7, 8, Robot current sensing (if ACS712 current sensor is installed), extended white line sensor channels 4, 5, 6, 7 and pin on the servo expansion port.

4.1 ATMEGA2560 (master) microcontroller pin configuration

PIN NO	Pin name	USED FOR	Status
1	(OC0B)PG5	Slave Select (SS) of the SPI expansion port on the main board (refer to figure 3.5)	--
2	RXD0/PCINT8/PE0	UART 0 receive for XBee wireless module (if installed)	Default
3	TXD0/PE1	UART 0 transmit for XBee wireless module (if installed)	Default
4	XCK0/AIN0/PE2	GPIO* (Available on expansion slot of the microcontroller socket)	
5	OC3A/AIN1/PE3	PWM output for C2 motor drive	Output
6	OC3B/INT4/PE4	External Interrupt for the left motor's position encoder	Input
7	OC3C/INT5/PE5	External Interrupt for the right motor's position encoder	Input
8	T3/INT6/PE6	External Interrupt for the C2 motor's position encoder	Input
9	CLK0/ICP3/INT7/ PE7	External Interrupt for Interrupt switch on the microcontroller board, External Interrupt for the C1 motor's position encoder, Connection to TSOP1738 if pad is shorted ********	Input
10	VCC	5V	
11	GND	Ground	
12	RXD2/PH0	UART 2 receives for USB Communication. For more details refer to section 3.19.7	Default
13	TXD2/PH1	UART 2 transmit for USB Communication. For more details refer to section 3.19.7	Default
14	XCK2/PH2	Sharp IR ranges sensor 1and 5 enable / disable. Turns off these sensors when output is logic 1 *******	Output
15	OC4A / PH3	IR proximity sensors 1 to 8 enable / disable. Turns off these sensors when output is logic 1 *******	Output
16	OC4B / PH4	GPIO* (Available on expansion slot of the microcontroller socket)	--
17	OC4C / PH5		--
18	OC2B / PH6		--
19	SS/PCINT0/PB0	ISP (In System Programming), SPI Communication with ATMEGA8 **, Connection to the SPI port on the main board	
20	SCK/PCINT1/PB1		Output
21	MOSI/PCINT2/PB2		Output
22	MISO/PCINT3/PB3		Input
23	OC2A/PCINT4/PB4	Servo Pod GPIO	--
24	OC1A/PCINT5/PB5	PWM for Servo motor 1. ***	Output
25	OC1B/PCINT6/PB6	PWM for Servo motor 2. ***	Output
26	OC0A/OC1C/PCINT7/ PB7	PWM for Servo motor 3. ***	Output

27	T4/PH7	GPIO (Available On Expansion Slot)	--
28	TOSC2/PG3	RTC (Real Time Clock)****	
29	TOSC1/PG4		
30	RESET	Microcontroller reset	
31	VCC	5V	
32	GND	Ground	
33	XTAL2	Crystal 14.7456 MHz	
34	XTAL1		
35	ICP4/PL0	GPIO (Available on expansion slot of the microcontroller socket)	--
36	ICP5/PL1		--
37	TS/PL2		--
38	OC5A/PL3	PWM for left motor.	Output
39	OC5B/PL4	PWM for right motor.	Output
40	OC5C/PL5	PWM for C1 motor.	Output
41	PL6	GPIO* (Available on expansion slot of the microcontroller socket)	--
42	PL7		--
43	SCL/INT0/PD0	I2C bus / GPIOs (Available on expansion slot of the microcontroller socket)	--
44	SDA/INT1/PD1		--
45	RXD1/INT2/PD2	UART1 receive for RS232 serial communication	Default
46	TXD1/INT3/PD3	UART1 transmit for RS232 serial communication	Default
47	ICP1/PD4	GPIO* (Available on expansion slot of the microcontroller socket)	--
48	XCK1/PD5		--
49	T1/PD6		--
50	T0/PD7		--
51	PG0/WR	GPIO* (Available on expansion slot of the microcontroller socket)	--
52	PG1/RD		--
53	PC0	LCD control line RS (Register Select)	Output
54	PC1	LCD control line RW(Read/Write Select)	Output
55	PC2	LCD control line EN(Enable Signal)	Output
56	PC3	Buzzer	Output
57	PC4	LCD data lines (4-bit mode)	Output
58	PC5		
59	PC6		
60	PC7		
61	VCC	5V	
62	GND	Ground	
63	PJ0/RXD3/PCINT9	LED bargraph display and GPIO* (Available on expansion slot of the microcontroller socket)	Output
64	PJ1/TXD3/PCINT10		
65	PJ2/XCK3/PCINT11		
66	PJ3/PCINT12		
67	PJ4/PCINT13		
68	PJ5/PCINT14		
69	PJ6/PCINT15		
70	PG2/ALE	Sharp IR ranges sensor 2, 3, 4 and red LEDs of white line sensor 1, 2, 3 disable. *******	Output

		Turns off these sensors when output is logic 1	
71	PA7 C2-2	Logic input 2 for C2 motor drive	Output
72	PA6 C2-1	Logic input 1 for C2 motor drive	Output
73	PA5 C1-2	Logic input 2 for C1 motor drive	Output
74	PA4 C1-1	Logic input 1 for C1 motor drive	Output
75	PA3	Logic input 1 for Right motor (Right back)	Output
76	PA2	Logic input 2 for Right motor (Right forward)	Output
77	PA1	Logic input 2 for Left motor (Left forward)	Output
78	PA0	Logic input 1 for Left motor (Left back)	Output
79	PJ7	LED Bar Graph and GPIO* (Available on expansion slot of the microcontroller socket)	
80	VCC	5V	
81	GND	Ground	
82	PK7/ADC15/PCINT23	ADC Input For Servo Pod 2	Input (Floating)
83	PK6/ADC14/PCINT22	ADC Input For Servo Pod 1	Input (Floating)
84	PK5/ADC13/PCINT21	ADC input for Sharp IR range sensor 5	Input (Floating)
85	PK4/ADC12/PCINT20	ADC input for Sharp IR range sensor 4	Input (Floating)
86	PK3/ADC11/PCINT19	ADC input for Sharp IR range sensor 3	Input (Floating)
87	PK2/ADC10/PCINT18	ADC input for Sharp IR range sensor 2	Input (Floating)
88	PK1/ADC9/PCINT17	ADC input for Sharp IR range sensor 1	Input (Floating)
89	PK0/ADC8/PCINT16	ADC input for IR proximity analog sensor 5	Input (Floating)
90	PF7(ADC7/TDI)	ADC input for IR proximity analog sensor 4*****	Input (Floating)
91	PF6/(ADC6/TD0)	ADC input for IR proximity analog sensor 3*****	Input (Floating)
92	PF5(ADC5/TMS)	ADC input for IR proximity analog sensor 2*****	Input (Floating)
93	PF4/ADC4/TCK	ADC input for IR proximity analog sensor 1*****	Input (Floating)
94	PF3/ADC3	ADC input for white line sensor 1	Input (Floating)
95	PF2/ADC2	ADC input for white line sensor 2	Input (Floating)
96	PF1/ADC1	ADC input for white line sensor 3	Input (Floating)
97	PF0/ADC0	ADC input for battery voltage monitoring	Input (Floating)
98	AREF	ADC reference voltage pin (5V external) ******	
99	GND	Ground	
100	AVCC	5V	

Table 4.1: ATMEGA2560 microcontroller pin connections

* Not used pins are by default initialized to input and kept floating. These pins are available on the expansion slot of the ATMEGA2560 microcontroller adaptor board. Some pins are especially reserved for servo motor interfacing for the Fire Bird V Hexapod robot.

** MOSI, MISO, SCK and SS pins of ATMEGA2560 are associated to the ISP (In System programming) port as well as the SPI interface to ATMEGA8. J4 needs to be disconnected before doing ISP. To communicate with ATMEGA8 jumper J4 needs to be in place. For more details refer to section 3.19.6.

*** PORTB pin5, 6, 7 are OC1A, OC1B, OC1C of the Timer1. These pins are connected to the servo motor sockets S1, S2, S3 on the microcontroller adaptor board.

**** External Crystal of 32 KHz is connected to the pins PG3 and PG4 to generate clock for RTC (Real Time Clock).

***** For using Analog IR proximity (1, 2, 3 and 4) sensors short the jumper J2. To use JTAG or interface external analog sensors via expansion slot of the microcontroller socket remove these jumpers.

****** AREF can be obtained from the 5V microcontroller or 5V analog reference generator IC REF5050 (optional). For more details refer to section 3.19.9.

******* Sensor's switching can be controlled only is if corresponding jumpers are open. For more details refer to section 3.11 and 3.12.
J2: Sharp IR range sensor 2, 3, 4 and red LEDs of white line sensors;
J3: Sharp IR range sensor 1, 5;
J4: IR proximity sensors 1 to 8;

******** External interrupt from the position encoder C1 is disabled by removing pin 2 of the CD40106 Schmitt trigger inverter buffer to avoid its wire anding with the interrupt switch.

4.2 ATMEGA8 (slave) microcontroller pin configuration

PIN NO	Pin name	USED FOR
1	INT1/PD3	Not Used
2	XCK/TOSC1/PB6	Not Used
3	GND	Ground
4	VCC	5V
5	GND	Ground
6	VCC	5V
7	XTAL1/TOSC1/PB6	Not Used
8	XTAL2/TOSC1/PB7	Not Used
9	(T1) PD5	Not Used
10	(AIN0) PD6	Not Used
11	(AIN1) PD7	Not Used
12	(ICP) PB0	Not Used
13	(OC1A) PB1	Not Used
14	(SS/OC1B) PB2	ISP (In System Programming) and SPI Communication with ATMEGA2560. *
15	(MOSI/OC2) PB3	
16	(MISO) PB4	
17	PB5 (SCK)	
18	AVCC	5V
19	ADC6	ADC input for IR proximity analog sensor 7
20	AREF	5V
21	GND	Ground
22	ADC7	ADC input for IR proximity analog sensor 8
23	PC0 (ADC0)	ADC input for white line sensor 4
24	PC1 (ADC1)	ADC input for white line sensor 5/Servo pod
25	PC2 (ADC2)	ADC input for white line sensor 6
26	PC3 (ADC3)	ADC input for white line sensor 7/Servo pod
27	PC4 (ADC4/SDA)	ADC input for Current Sensing IC ACS712
28	PC5 (ADC5/SCL)	ADC input for IR proximity analog sensor 6
29	PC6 (RESET)	Microcontroller reset
30	PD0 (RXD)	Not Used
31	PD1 (TXD)	Not Used
32	PD2 (INT0)	Not Used

Table 4.2: ATMEGA8 microcontroller pin connections

***** MOSI, MISO, SCK and SS pins of ATMEGA2560 are associated to the ISP (In System programming) port as well as the SPI interface to ATMEGA8. J4 needs to be disconnected before doing ISP. To communicate with ATMEGA8 jumper J4 needs to be in place. For more details refer to chapter 3.

4.3 ATMEGA2560 Microcontroller Board Expansion Socket

ATMEGA2560 is a featur rich microcontroller with lots of available I/O ports. Many of the ports are available on the uC Expansion Socket. Table 4.3 lists the connection details of all the pins of the socket.

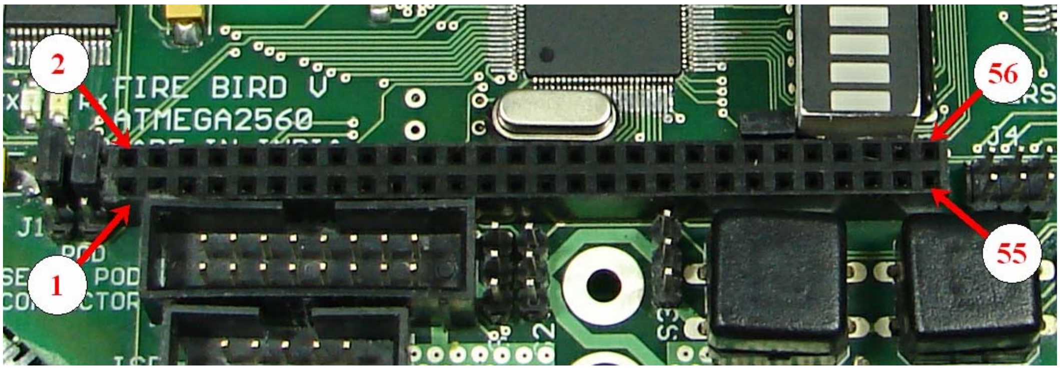


Figure 4.1: Expansion Header on Microcontroller Board

Pin No.	Function
1	UART2 TXD pin of ATMEGA2560 via Jumper 1 (uC pin 13)
2	UART2 RXD pin of ATMEGA2560 via Jumper 1 (uC pin 12)
3	ATMEGA2560 interrupt 7 pin / CLKO / ICP3 (uC pin9)
4	OC4B / PH4 / GPIO (uC pin 16)
5	OC4C / PH5 / GPIO (uC pin 17)
6	OC2B / PH6 / GPIO (uC pin 18)
7	TDO (JTAG)* / ADC6* / IR proximity sensor 3 (uC pin 91)
8	TDI (JTAG)* / ADC7* / IR Proximity sensor 4 (uC pin 90)
9	TMS (JTAG) */ ADC5* / IR Proximity sensor 2 (uC pin 92)
10	TCK (JTAG)* / ADC4* / IR Proximity sensor 1 (uC pin 93)
11	ATMEGA2560 Slave Select (SS) pin PB0 (uC pin 19) **
12	No Connection till the version 2009-12-08. Connected to V Batt supply in version 2010-11-25 onwards.
13	MOSI / PB2 (uC pin 21)**
14	SCK / PB1 (uC pin 20)**
15	RESET (uC pin 30)
16	MISO / PB3 (uC pin 22)**
17	PL7 / GPIO (uC pin 42)
18	PL6 / GPIO (uC pin 41)
19	SDA / PD1 / INT1 / GPIO (uC pin 44)
20	SCL / PD0 / INT0 / GPIO (uC pin 43)
21	5V System Voltage. Can be used for powering up any digital device. Current Limit: 400mA.
22	5V System Voltage. Can be used for powering up any digital device. Current Limit: 400mA.
23	Ground
24	Ground
25	ICP1 / PD4 / GPIO (uC pin 47)
26	T4 / PH7 / GPIO (uC pin 27)
27	ICP5 / PL1 / GPIO (uC pin 36)
28	ICP4 / PL0 / GPIO (uC pin 35)
29	XCK1 / PD5 / GPIO (uC pin 48)
30	T5 / PL2 / GPIO (uC pin 37)
31	PG1 / GPIO (uC pin 52)

32	PG0 (uC pin 51)
33	T1 / PD6 / GPIO (uC pin 49)
34	T0 / PD7 (uC pin 50)
35	No Connections
36	
37	TXD1 / INT3 / PD3: Connected to the MAX 202 for RS232 communication. Do not use for other purpose unless connection with MAX 202 is removed. (uC pin 46)
38	RXD1 / INT2 / PD2: Connected to the MAX 202 for RS232 communication. Do not use for other purpose unless connection with MAX 202 is removed. (uC pin 45)
39	PJ6 / GPIO (uC pin 69)***
40	PJ7 / GPIO (uC pin 79) ***
41	PJ4 / GPIO (uC pin 67) ***
42	PJ5 / GPIO (uC pin 68) ***
43	PJ2 / GPIO (uC pin 65) ***
44	PJ3 / GPIO (uC pin 66) ***
45	RXD3 / PJ0 / GPIO (uC pin 63)****
46	TXD3 / PJ1 / GPIO (uC pin 64)****
47	No Connections
48	
49	
50	
51	
52	
53	
54	
55	
56	

Table 4.3: ATMEGA2560 microcontroller board expansion header table

Note:
* In order to use these pins as JTAG or as ADC for external sensor interfacing, remove all 4 connectors for the jumper 2 of the microcontroller board. When jumpers are removed IR Proximity sensor 1 to 4 will be disconnected from the robot.

** Pins can be used as SPI bus. These pins are already connected to slave ATMEGA8 microcontroller via J4 of the microcontroller board. Before using it as a SPI bus for external device interfacing, remove J4 to disconnect ATMEGA8 slave microcontroller or use different pin of the microcontroller as SS (slave select).

*** All the pins of the PORTJ are connected to the bargraph LED display. While using these pins as GPIO to turnoff this bargraph LED display, remove jumper J3 of the microcontroller board.

**** PJ0 and PJ1 can be used as GPIO as well as TXD and RXD for UART 3. These pins are also connected to bargraph LED display. While using these pins as UART 3, jumper J3 must be removed to disable bargraph LED display in order to avoid loading on the TXD and RXD lines of the device which is connected with the ATMEGA2560 microcontroller.

4.4 Microcontroller adaptor board socket connections on the main board

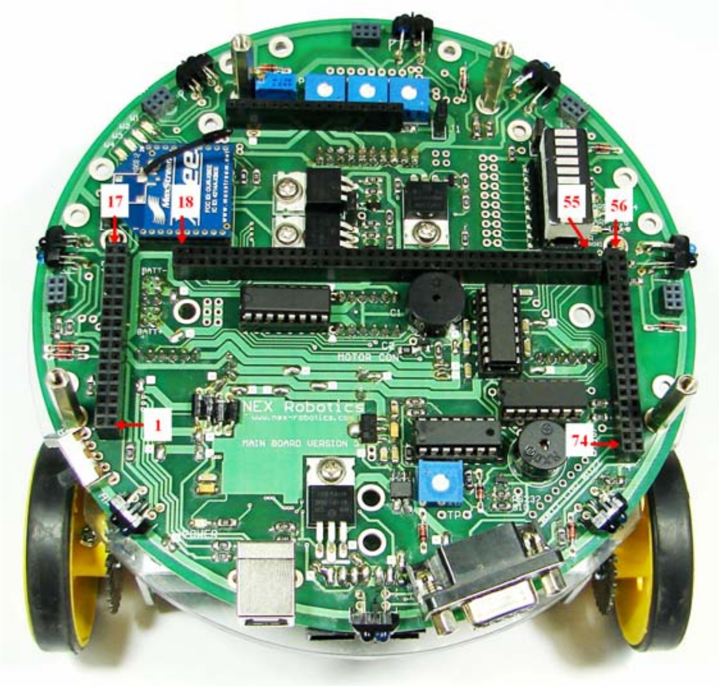


Figure 4.2: Microcontroller adaptor board socket connections on the main board

Pin No.	Pin Name	uC Board Connection	Function
1	CS*	ATMEGA8 ADC4	Current sense analog value
2	IR Proximity sensor 8	ATMEGA8 ADC7	IR Proximity sensor 8 analog value
3	Ground	Ground	Ground
4	USB Data+	Pin 15 of FT232 USB to serial converter going to UART 2 of ATMEGA2560 via jumper J1	USB connection going to the ATMEGA2560 microcontroller via FT232 USB to serial converter. To enable USB communication, set Jumper 1 as shown in the figure 6.2
5	USB Data-	Pin 16 of FT232 USB to serial converter going to UART 2 of ATMEGA2560 via jumper J1	
6	VUSB	FT232 pin20 and pin4 (5V to the FT232 USB to serial converter)	
7	5V System	Not connected	5V System Voltage. Can be used for powering up any digital device with current limit of 400mA.
8	IR Proximity Sensor Drive	Not connected	Drain of the IR proximity sensor switching MOSFET. Any device with current capacity of 1 Amp can be connected
9	5V Sensor	Not connected	5V Sensor voltage. Can be used for additional sensor interfacing with current limit: 300mA
10	5V System	Not connected	5V System voltage. Can be used for powering up any digital device with current Limit: 400mA

11	SHARP IR Range Sensor 1	ATMEGA2560 ADC9	Analog output of Sharp IR range Sensor 1
12	IR Proximity Sensor 1	ATMEGA2560 ADC4	Analog output of IR Proximity sensor 1
13	XBee RXD	UART0 of ATMEGA2560	XBee wireless module Serial data in
14	XBee TXD	UART0 of ATMEGA2560	XBee wireless module Serial data out
15	SHARP IR Range Sensor 2	ATMEGA2560 ADC10	Analog output of Sharp IR range sensor 2
16	IR Proximity Sensor 2	ATMEGA2560 ADC5	Analog output of IR Proximity sensor 2
17	Not used		
18	MOSI	ATMEGA2560 Pin 21	SPI Communication lines for communication with ATMEGA8 via Jumper 4 and for programming ATMEGA2560 in ISP mode
19	MISO	ATMEGA2560 Pin 22	
20	SCK	ATMEGA2560 Pin 20	
21	SSI	ATMEGA2560 Pin 19	
22	RS	ATMEGA2560 PC0	LCD Register Select pin (Command)
23	RW	ATMEGA2560 PC1	LCD Read Write pin (Command)
24	EN	ATMEGA2560 PC2	LCD Enable pin (Command)
25	DB5	ATMEGA2560 PC5	LCD data bit 5
26	DB4	ATMEGA2560 PC4	LCD data bit 4
27	DB6	ATMEGA2560 PC6	LCD data bit 6
28	DB7	ATMEGA2560 PC7	LCD data bit 7
29	V Battery System	ATMEGA2560 ADC0	V Battery System (9V to 11.4V depending on battery status). Unregulated Supply for additional module interfacing. Maximum current capacity: 1Amp
32	White Line Sensor 1	ATMEGA2560 ADC3	Analog output of white line sensor 1
31	White Line Sensor 2	ATMEGA2560 ADC2	Analog output of white line sensor 2
32	White Line Sensor 3	ATMEGA2560 ADC1	Analog output of white line sensor 3
33	IR Proximity Sensor Disable	ATMEGA2560 PH3	TTL/CMOS input. Disable IR proximity sensors when V>2 is applied. When V<0.65 IR proximity sensors are turned on.
34	Sharp IR Sensors 1and 5 Disable	ATMEGA2560 PH2	TTL/CMOS input. Disable Sharp IR range sensors 1 and 5 when V>2 is applied. When V<0.65 sharp sensors 1 and 5 are turned on.
35	5V System	Not connected	5V system Voltage. Can be used for powering up any digital device. Current Limit: 400mA.
36	White Line 4	ATMEGA8 ADC0	Analog output of white line sensor 4
37	White Line 5	ATMEGA8 ADC1	Analog output of white line sensor 5
38	White Line 6	ATMEGA8 ADC2	Analog output of white line sensor 6
39	White Line 7	ATMEGA8 ADC3	Analog output of white line sensor 7
40	Sharp IR Range Sensors 2,3,4 and White Line Sensors Disable	ATMEGA2560 PG2	TTL/CMOS input. Disable Sharp IR range sensors 2, 3, 4 and White line sensors when V>2 is applied. When V<0.65 sharp sensors 2, 3, 4 and white line sensors are turned on.
41	Sharp IR Range Finder 3	ATMEGA2560 ADC11	Analog output of Sharp IR range sensor 3
42	IR Proximity Sensor 3	ATMEGA2560 ADC6	Analog output of IR Proximity sensor 3
43	IR Proximity Sensor 4	ATMEGA2560 ADC7	Analog output of IR Proximity sensor 4
44	Sharp IR Range Finder 4	ATMEGA2560 ADC12	Analog output of Sharp IR Range sensor 4
45	Sharp IR Range Finder 5	ATMEGA2560 ADC13	Analog output of Sharp IR Range sensor 5
46	IR Proximity Sensor 5	ATMEGA2560 ADC8	Analog output of IR Proximity sensor 5
47	C1 1	ATMEGA2560 PA4	Logic input 1 for C1 motor drive
48	C1 PWM	ATMEGA2560 OC5C	PWM input for C1 motor drive
49	C1 2	ATMEGA2560 PA45	Logic input 2 for C1 motor drive

50	PWM L	ATMEGA2560 OC5A	PWM input for Left motor drive
51	L1	ATMEGA2560 PA0	Logic input 1 for Left motor drive
52	L2	ATMEGA2560 PA1	Logic input 2 for Left motor drive
53	R1	ATMEGA2560 PA2	Logic input 1 for Right motor drive
54	PWM R	ATMEGA2560 OC5B	PWM input for Right motor drive
55	R2	ATMEGA2560 PA3	Logic input 2 for Right motor drive
56		Not connected	Not Used
57		Not connected	Not Used
58		Not connected	Not Used
59		Not connected	Not Used
60	5V System	Not connected	Not Used
61	IR Proximity Sensor Drive	Not connected	Drain of the IR proximity sensor switching MOSFET. Any device with current capacity of 1 Amp can be connected
62	Position Encoder Left	ATMEGA2560 PE4(INT4)	Output of Left position encoder (0-5V)
63	Position Encoder Right	ATMEGA2560 PE5(INT5)	Output of Right position encoder (0-5V)
64	Position Encoder C2	ATMEGA2560 PE6(INT6)	Output of C2 position encoder (0-5V)
65	Position Encoder C1	ATMEGA2560 PE7(INT7)	Output of C1 position encoder (0-5V)
66	C2 2	ATMEGA2560 PA7	Logic input 2 for C2 motor drive
67	C2 1	ATMEGA2560 PA6	Logic input 1 for C2 motor drive
68	C2 PWM	ATMEGA2560 OC3A	PWM input for C2 motor drive
69	IR Proximity Sensor 6	ATMEGA8 ADC5	Analog output of IR Proximity sensor 6
70	IR Proximity Sensor 7	ATMEGA8 ADC6	Analog output of IR Proximity sensor 7
71	BUZZER	ATMEGA2560 PC3	Input, V>0.65V turns on the Buzzer
72	DAC OUT		
73	RS232 TXD	UART1(RXD) of ATMEGA2560 via MAX202, TTL to RS232 Converter	RS232 Transmit, connected to DB9 serial connector on main board.
74	RS232 RXD	UART1(TXD) of ATMEGA2560 via MAX202, TTL to RS232 Converter	RS232 Receive, connected to DB9 serial connector on main board.

Table 4.4: ATMEGA2560 Microcontroller adaptor board socket connections with the main board

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

5. Upgrading Robot's Hardware

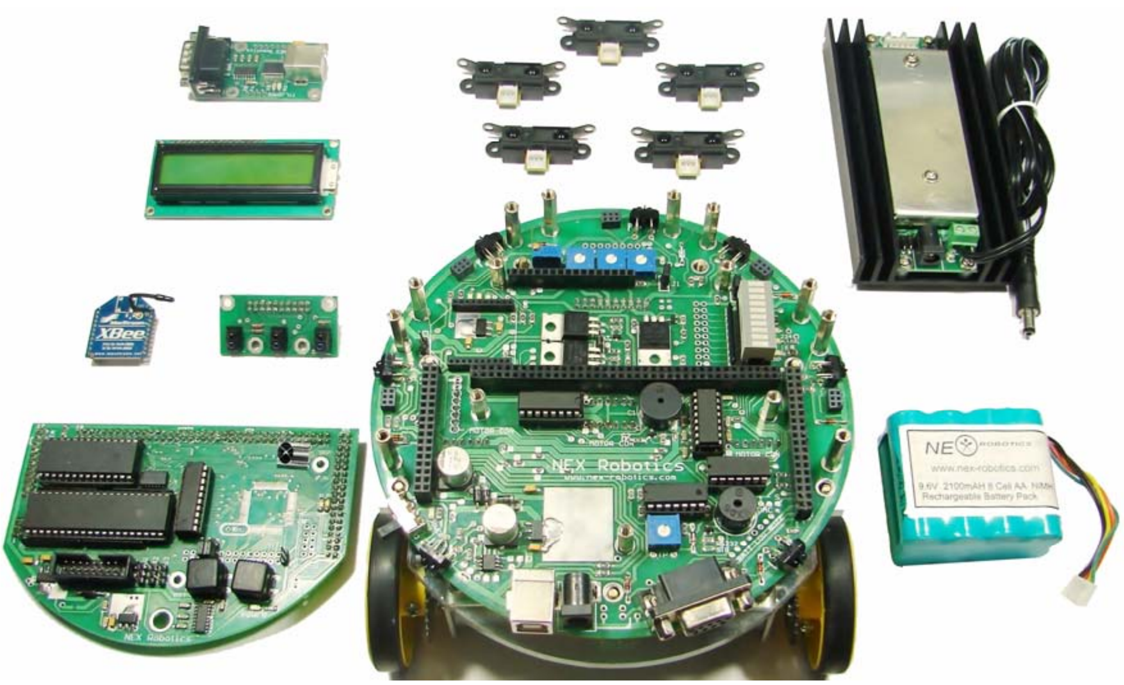


Figure 5.1: Fire Bird V robot and its accessories

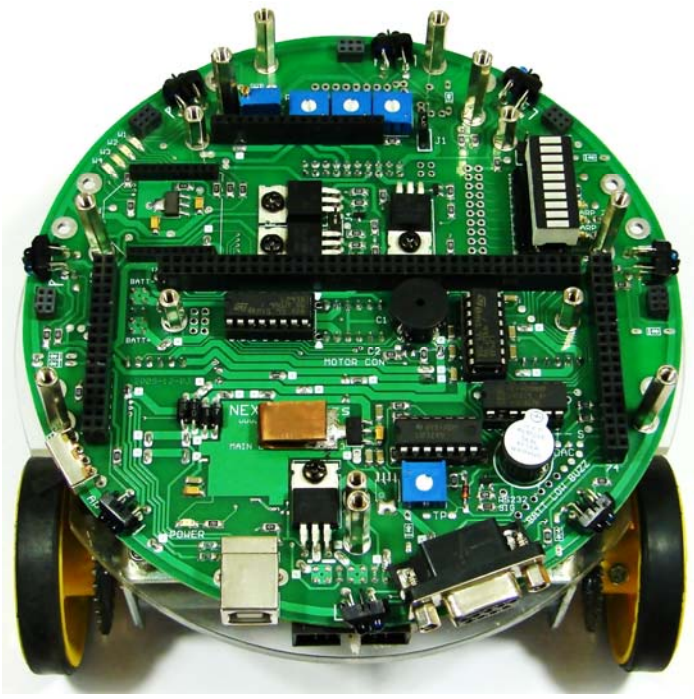


Figure 5.2: Fire Bird V main board

5.1 Installing XBee wireless module

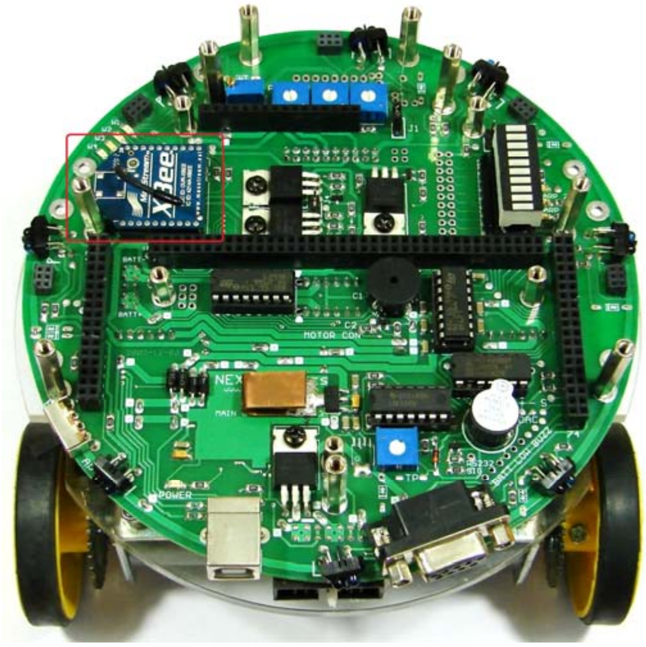


Figure 5.3: Mounting the XBee wireless module

⚠ 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.

5.2 Setting correct jumper settings on the main board

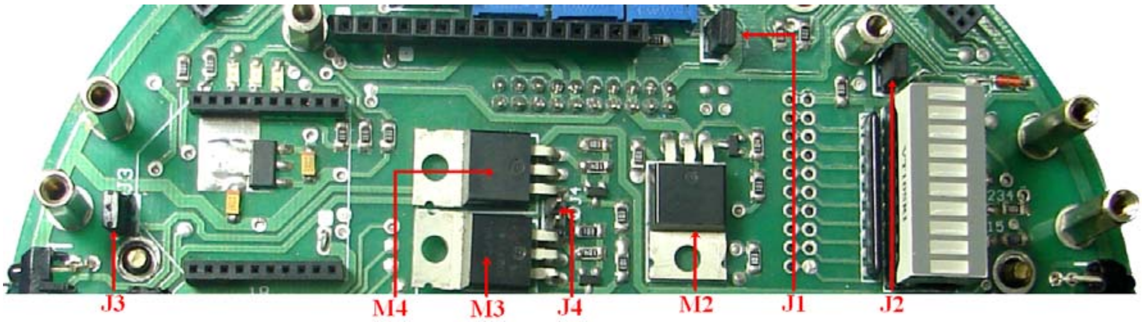


Figure 5.4: Set jumpers as per the requirements (for more details refer to chapter 3)

5.3 LCD mounting

Figure 5.5: 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

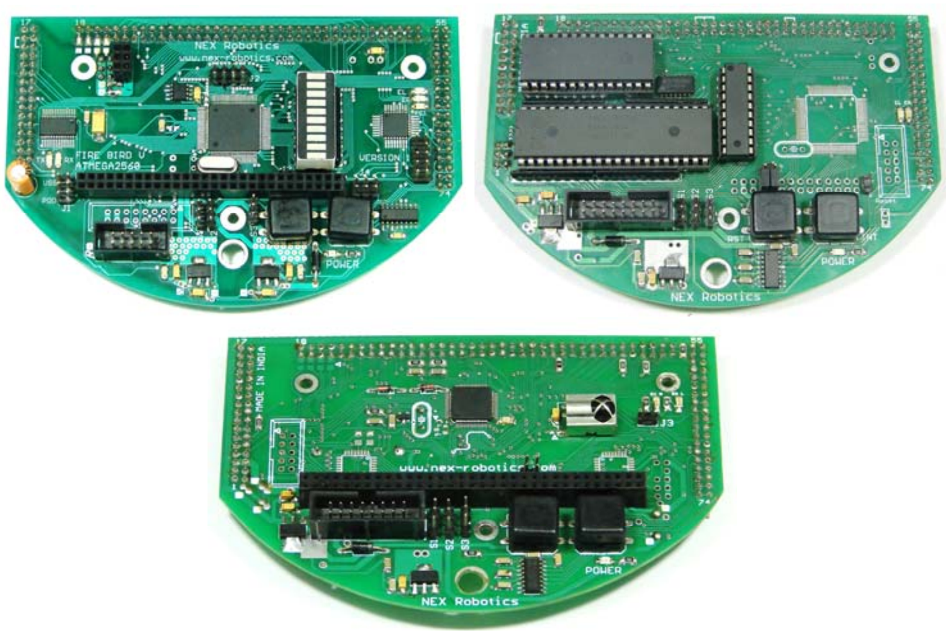


Figure 5.6: ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 ARM7 microcontroller adaptor boards for Fire Bird V

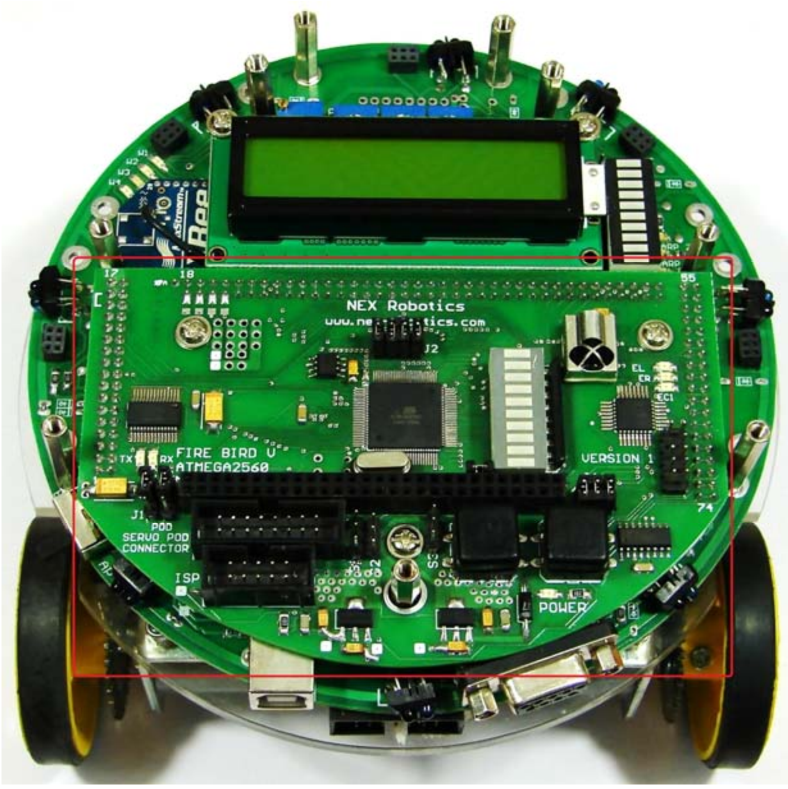


Figure 5.7: Microcontroller adapter board mounting

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.

5.5 Sharp IR Range sensor mounting

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

Figure 5.8: Remove front cover of the white connector of the Sharp IR range sensor

Figure 5.9: 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.

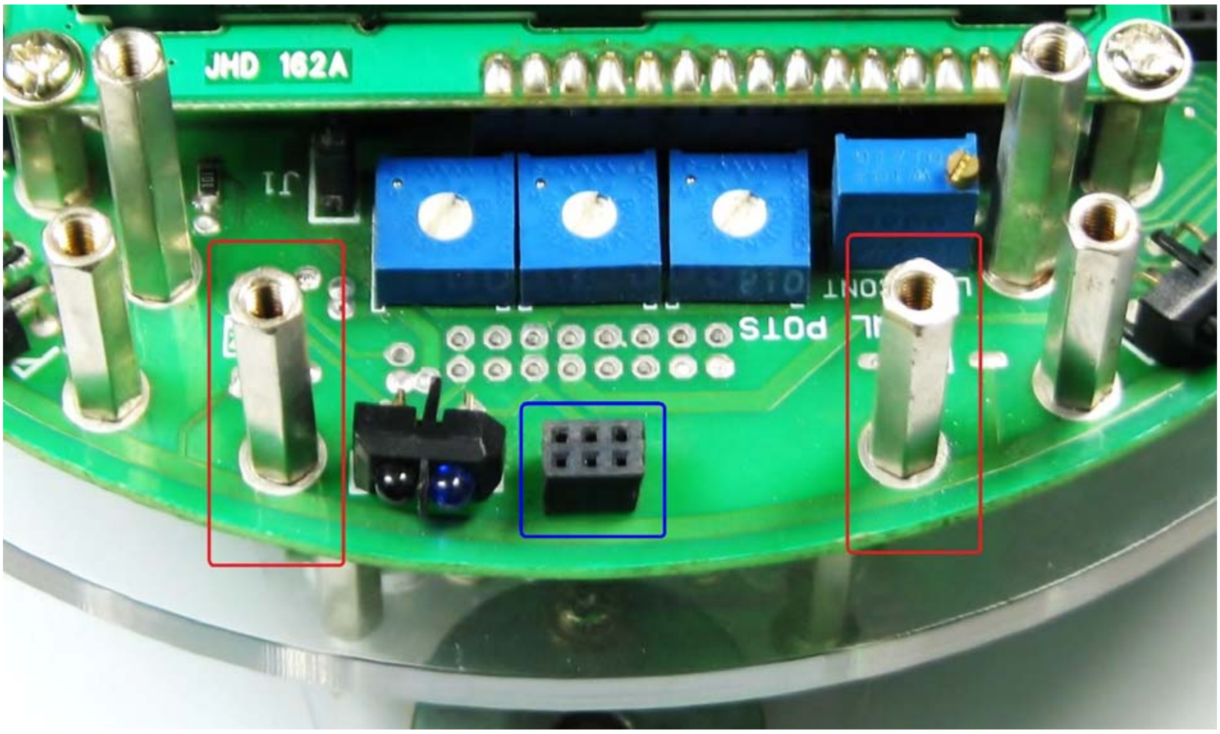


Figure 5.10: Mount 20mm studs from the Sharp sensor mounting kit

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 5.11: 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.

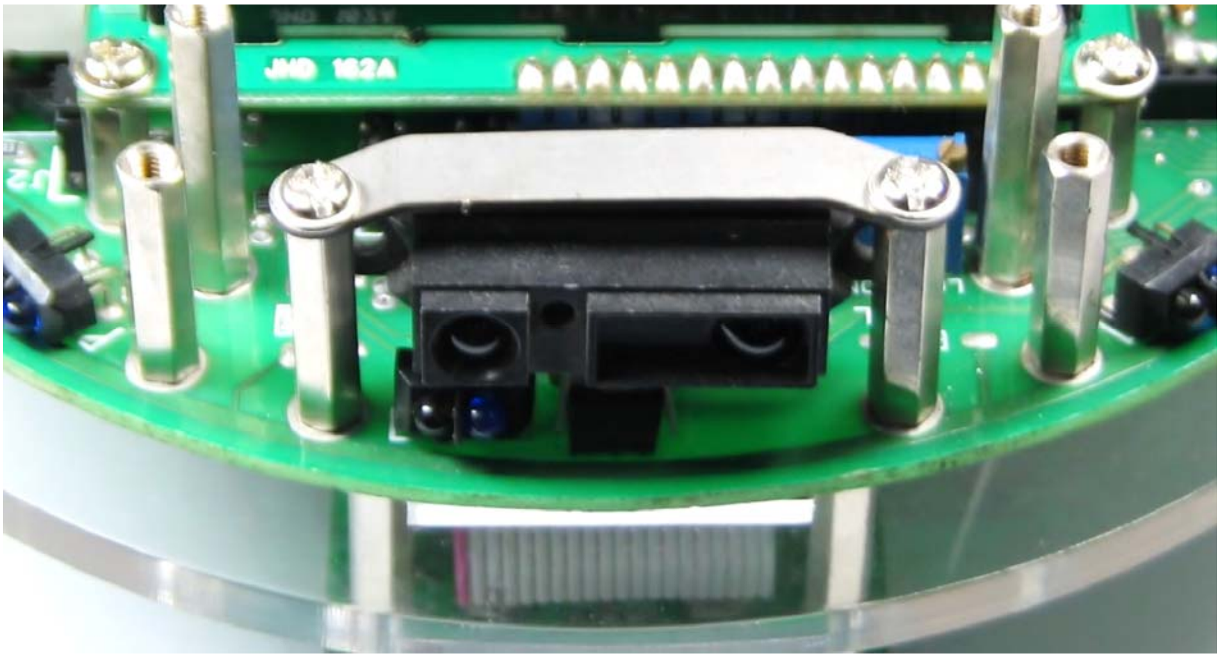


Figure 5.12: Fitting metal plate on top of the Sharp IR range sensor

⚠ 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.

5.6 Mount top Acrylic plate on the robot

Figure 5.13: Install top acrylic plate

6. PC Based Control Using Serial Communication

In this chapter, simple robot control over wired (USB / serial) or wireless medium (XBee wireless module) is covered. User can expand this protocol further to write his own applications. Using good packet based protocol, user can design applications involving complex multi robot communication scheme with robots to robots and robots to PCs simultaneous communication. A more bit advanced communication protocol for the robot control and sensor data acquisition is covered in the chapter 7.

6.1: Communication protocol for simple robot control

Character	ASCII value	Action
8	**0x38**	**Forward**
2	**0x32**	**Backward**
4	**0x34**	**Left**
6	**0x36**	**Right**
5	**0x35**	**Stop**
7	**0x37**	**Buzzer On**
9	**0x39**	**Buzzer Off**

Table 6.1: Control commands for the simple robot control protocol

Table 6.1 shows the simple robot control protocol. Using this, robot can be moved in forward, backward, left or right directions and its buzzer can be turned on or off. You can use any serial port control software such as hyper terminal or terminal.exe etc. For user friendliness keys of the numerical pad of standard 104 keys “querty” keyboards are used. When a particular number key is pressed, its ASCII character value is transmitted over serial / USB port. Robot receives this ASCII values and based on its value it actuates its motors, buzzer etc. Keys are mapped in the intuitive way on the Numerical pad of the keyboard.

This communication protocol is covered in the following experiments which are located in the “Experiments” folder in the documentation CD. All these experiments are exactly same only UART port number is different.

1. 13A_Serial_Communication: Serial communication via RS232 serial port.
2. 13B_Serial_Communication_USB-RS232: Serial communication via onboard FT232 USB to Serial Converter
3. 13C_Serial_Communication_ZigBee_wireless: Serial communication via XBee wireless module (if installed).

Section 6.2 and 6.3 covers robot control using PC’s USB port and XBee wireless module.

Important:
While using “Numerical Pad” of the key board, make sure that “Num. Lock” is on.

6.2 Robot control using RS232 serial port

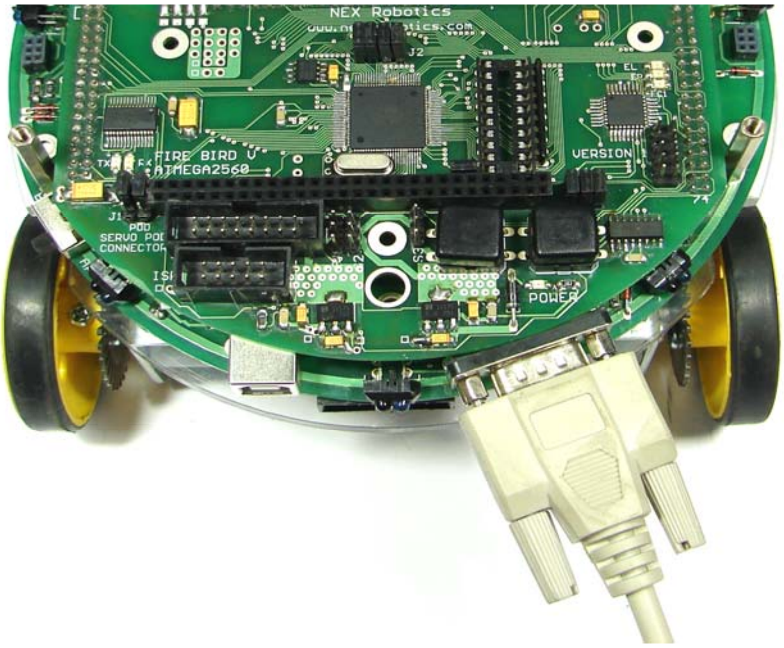


Figure 6.1: Connecting RS232 serial port with the PC

UART1 of the ATMEGA2560 microcontroller is connected to the serial port via MAX202 UART to RS232 converter. For robot control over RS232 serial port application example we need to load "13A_Serial_Communication.hex" on the robot which is located in the "Experiments" folder in the documentation CD.

For robot control over serial port we use Terminal software from NEX Robotics. It is located in the "Software" folder in the documentation CD. Installation and the use of the terminal software from NEX Robotics is covered in the section 6.7.

6.3 Robot control using USB port

Fire Bird V ATMEGA2560 has onboard USB port for direct interface with PC. USB interfacing is based on FT232 USB to serial converter. For robot control over USB port application example we need to load “13B_Serial_Communication_USB-RS232.hex” on the robot which is located in the “Experiments” folder in the documentation CD.

FT232 USB to serial converter can be connected with UART 2 of the ATMEGA2560 microcontroller via Jumper J1. Figure 6.2 shows the correct jumper setting for connecting FT232 with the microcontroller.

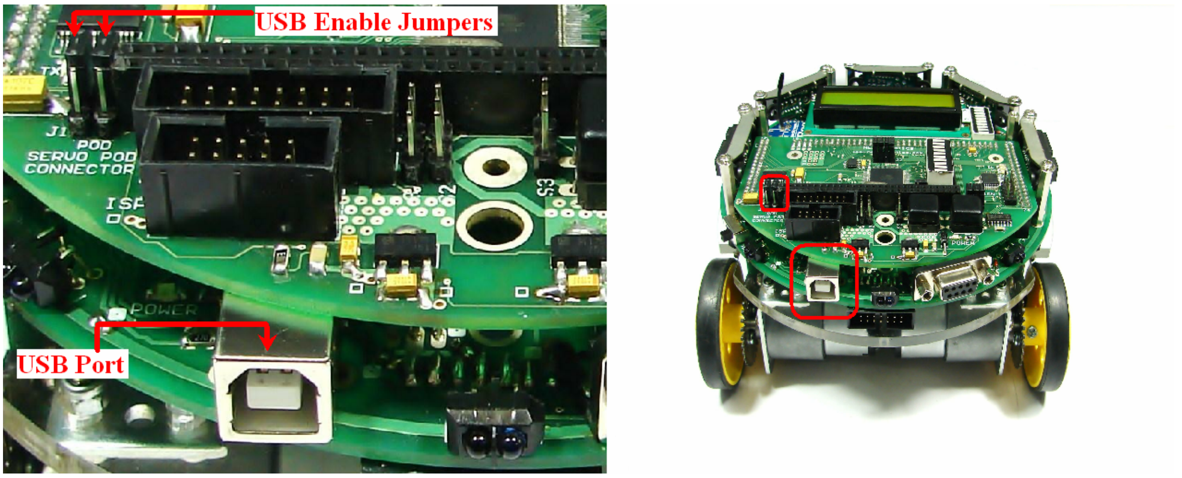


Figure 6.2: Jumper setting to enable USB communication

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. For driver installation process refer to section 6.5.

For robot control over serial port we use Terminal software from NEX Robotics. It is located in the “Software” folder in the documentation CD. Installation and the use of the terminal software from NEX Robotics is covered in the section 6.7.

Important:

- When using USB port for the communication, for proper operation first turn on the robot then insert the USB cable in the robot. We have to follow this sequence because USB to serial converter chip is powered by USB. If any fault occurs then turn off the robot and remove the USB cable and repeat the same procedure.

- Make sure that jumper is configured to enable USB communication. Jumpers should be in the position as shown in the Figure 6.2.

6.4 Robot control using XBee wireless communication module

Figure 6.3: XBee Wireless USB Module from NEX Robotics

Fire Bird V ATMEGA2560 has onboard socket for XBee and XBee Pro modules from Digi International. For robot to PC communication we need to install XBee wireless module on the robot and XBee USB wireless module for connection with the PC. XBee wireless module is connected to the UART 0 of the ATMEGA2560 microcontroller. For Robot control over wireless link we need to load “13C_Serial_Communication_ZigBee_wireless.hex” on the robot which is located in the “Experiments” folder in the documentation CD. For XBee wireless module installation on the robot, refer to chapter 5.

XBee USB wireless module has onboard FT232 USB to serial converter. You need to install drivers for FT232 USB to serial converter before starting communication. software is located in the “Software and Drivers \ CDM 2.06.00 WHQL Certified” folder. For driver installation process refer to section 6.5.

For robot control over serial port we use Terminal software from NEX Robotics. It is located in the “Software” folder in the documentation CD. Installation and the use of the terminal software from NEX Robotics is covered in the section 6.7.

Important:

- XBee wireless modules are factory set at the 9600 bps. While shipping with the robot they are set at 115200 bps by NEX Robotics using XCTU software. Application example “13C_Serial_Communication_ZigBee_wireless.hex” requires 9600 bps. For this application you need to set baud rate at 9600 bps. How to change the baud rate of the XBee wireless module using XCTU software is covered in the application note which is located in the “Manuals and Application notes” folder in the documentation CD.
- Wait for at least 8 seconds to start the wireless communication after turning on the robot and the USB wireless module.

6.5 Installing drivers of FT232 USB to Serial Converter

FT232 USB to serial converter is present on the ATMEGA2560 microcontroller adaptor board and XBee USB wireless module. Before using these devices you need to install drivers for the FT232 USB to serial converter.

Steps to install the drivers for FT232 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 which is located in the documentation 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 6.4

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

Figure 6.5

The following window will appear.

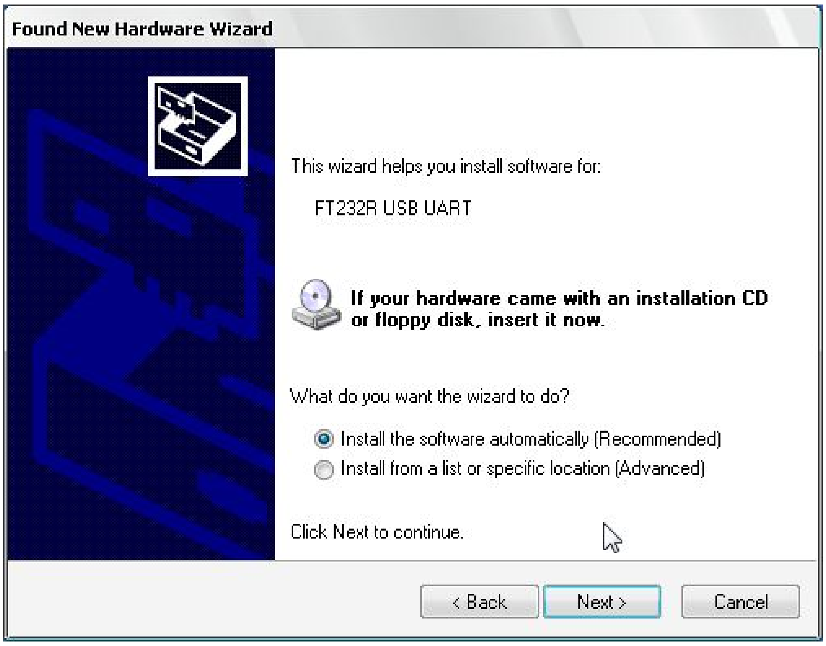


Figure 6.6

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).

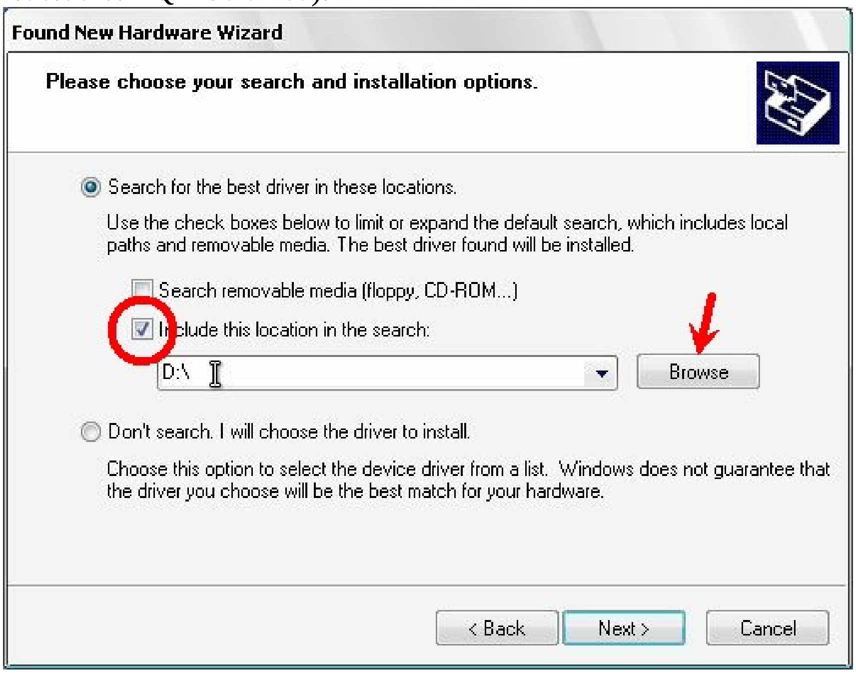


Figure 6.7

Step 6:
On clicking next driver installation will begin.

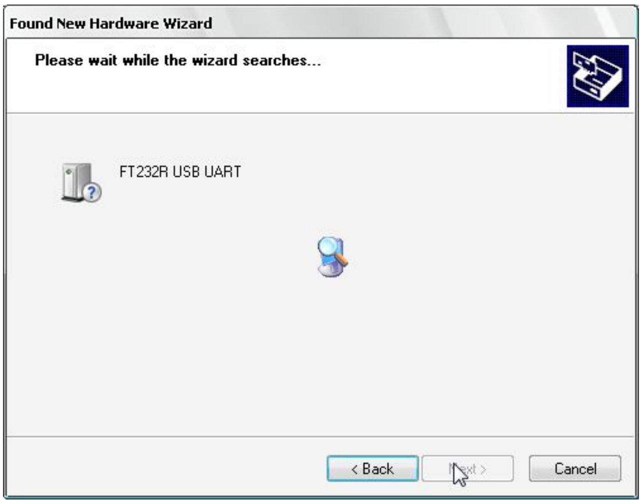


Figure 6.8

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

Figure 6.9

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

6.6 Identifying and changing COM Port number of the USB to serial converter or XBee USB wireless module

In some software you may need to tell the COM port number before establishing communication. Follow these steps to identify or change the COM port number. Don't change the COM port number unless it is absolutely necessary. It may result in making some of your software unstable.

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

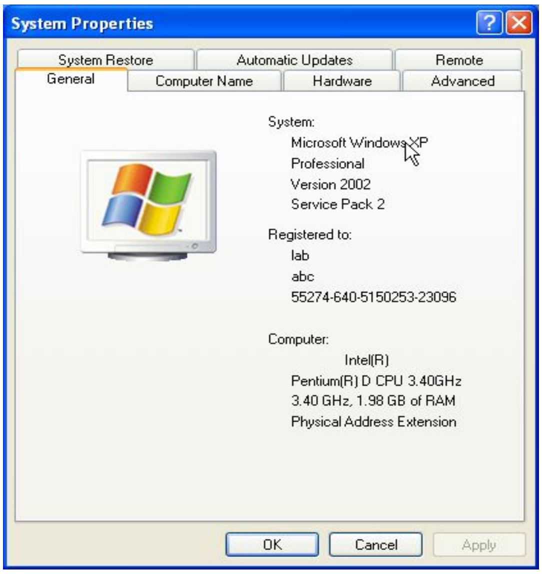


Figure 6.10

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

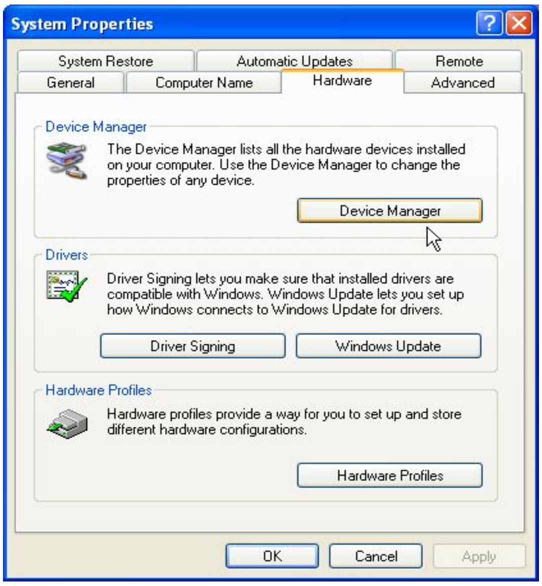


Figure 6.11

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

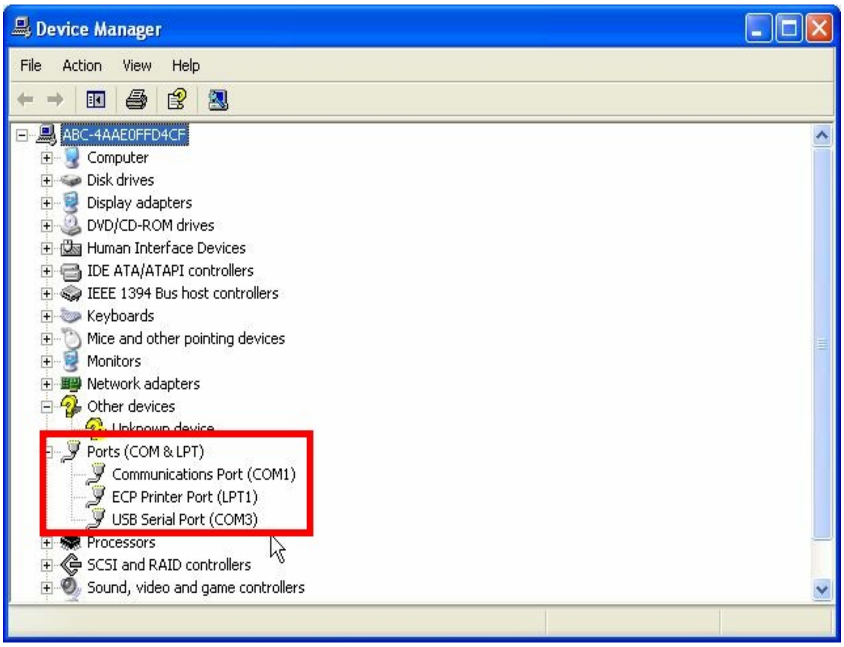


Figure 6.12

Step 4:
You can change the port number by right clicking on “USB serial Port” and select properties.

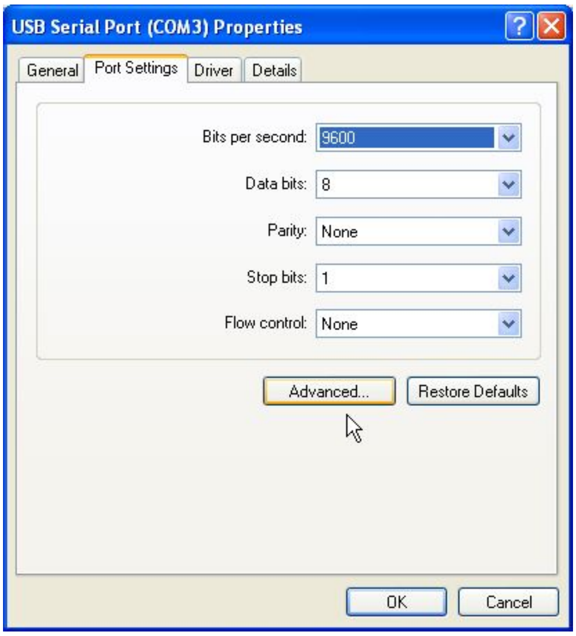


Figure 6.13

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

Step 5:
Select the new COM port number and click ok.

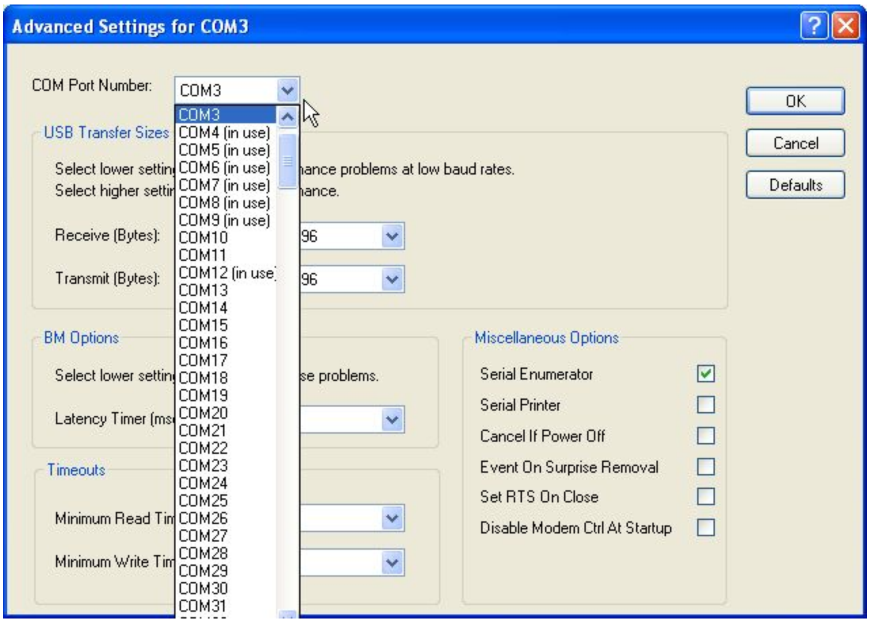


Figure 6.14

6.7 Use of Terminal software from NEX Robotics for Robot control

Terminal is easy to use free software for serial communication written by NEX Robotics. It is located in the "Software and Drivers" folder in the documentation CD. In the following example we will be using Serial communication protocol covered in the section 6.

Connect Serial / USB cable between robot and PC or connect XBee wireless module on the robot and connect XBee USB wireless module on the PC and load correct .hex file on the robot as mentioned in the sections 6.2, 6.3 and 6.4. Pay special attention to the text highlighted as "important".

6.7.1 Terminal Software Installation

Step 1:
Copy Terminal software setup from the "Software" folder of the documentation CD to PC. To start installation process click on the "Setup" thumbnail (not "Terminal Setup" thumbnail).

Step 2:
Go through the installation process and select correct options to complete the installation.

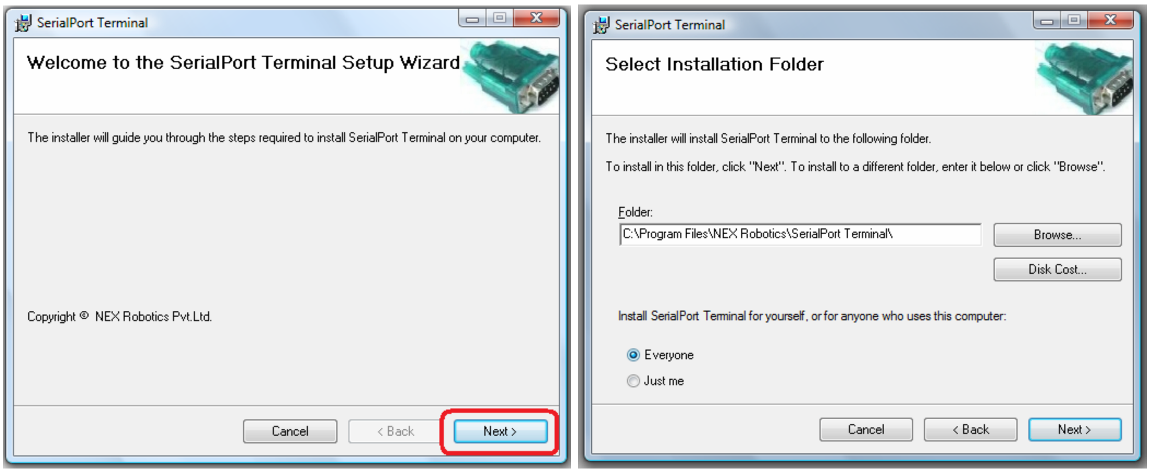


Figure 6.15

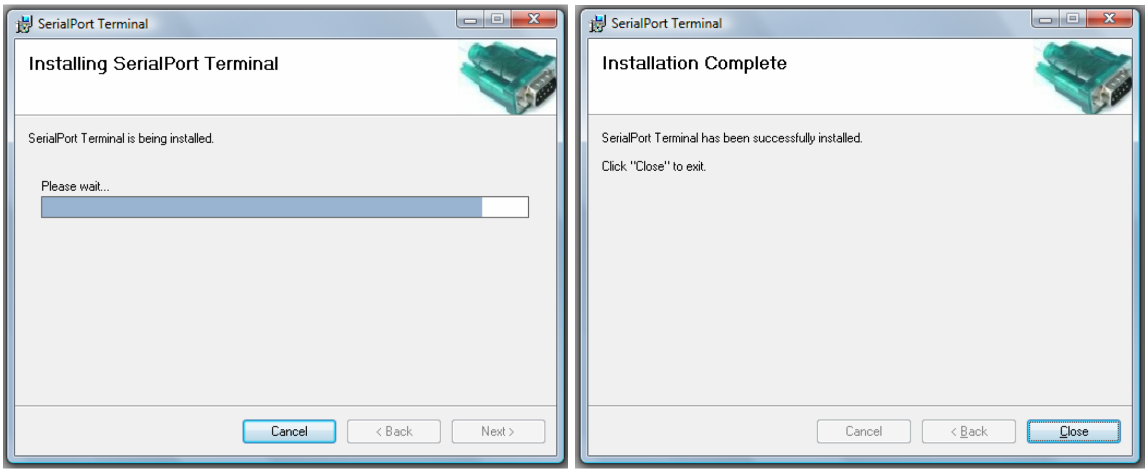


Figure 6.16

6.7.2 Using Terminal Software

Step 1:

Connect any device which is to be used to USB / serial port. Install its driver.
Go to Start menu and click on the Serial Terminal.

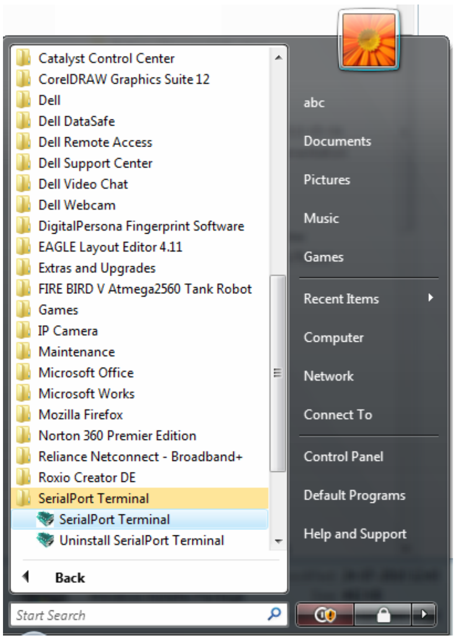


Figure 6.17

Terminal software will open.

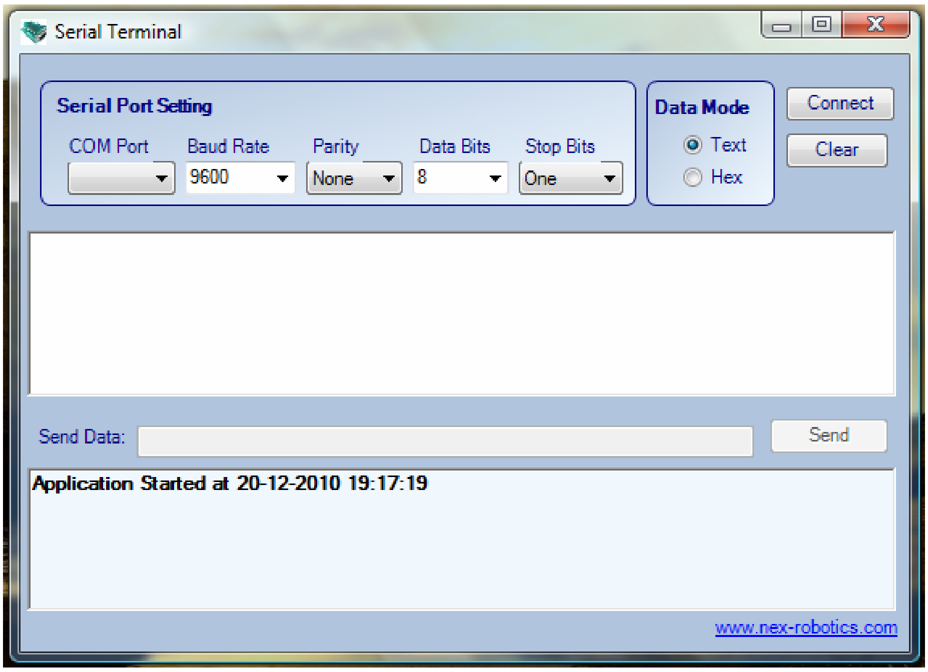


Figure 6.18

Step 2:
Select the COM port. If required, identify the COM port (refer to section 6.6)
Set the baud rate at 9600bps, Data Mode as text and press connect.

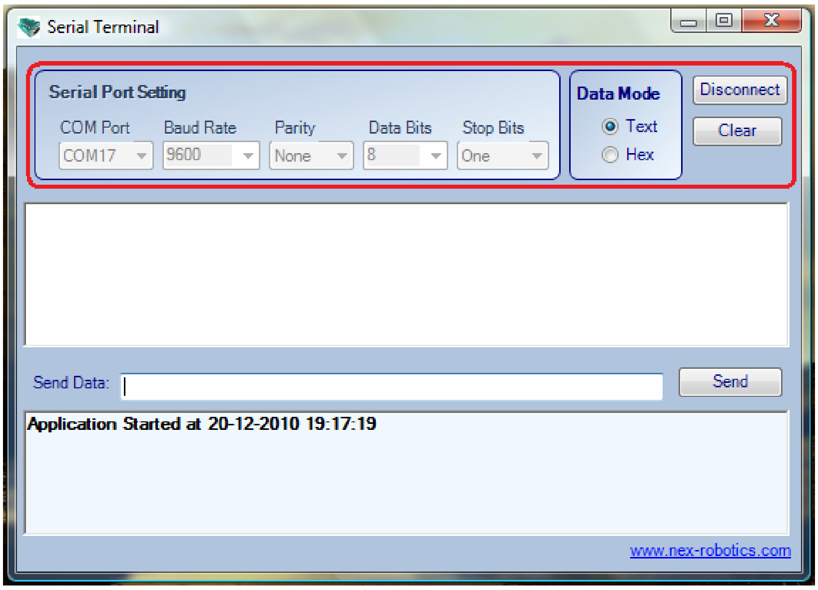


Figure 6.19

Step 3:
Make the Num lock on for the keyboard.
Load proper firmware (.hex file) on the robot as per the mode of communication (refer to section 6.2, 6.3 and 6.4).
Turn on the robot. Connect the Serial / USB wire or XBee wireless link between robot and PC
Use number keys of the key pad to control the robot.
For control commands refer to table 6.1.

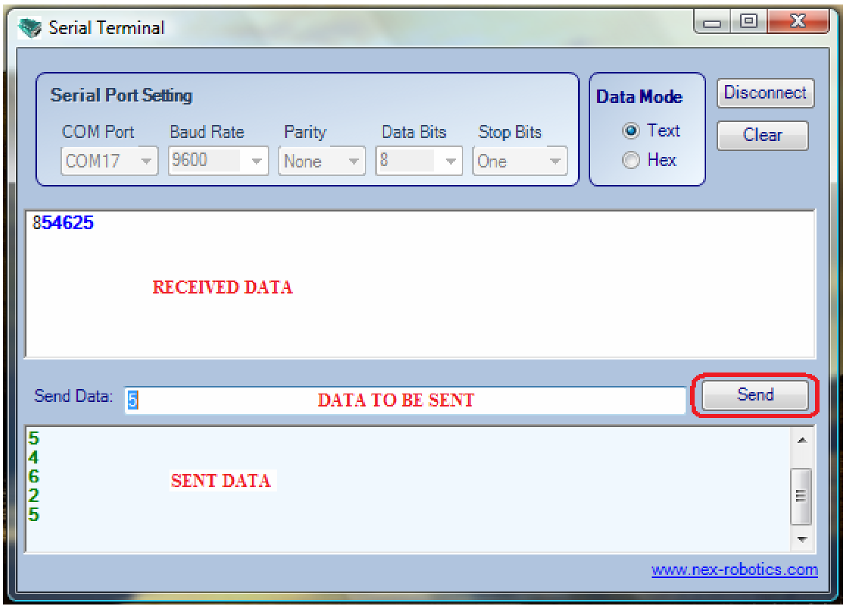


Figure 6.20

Refer to figure 6.20. Serial Terminal software has 3 windows. In the middle window you can type data to be sent. You can also send a single number of the strings of numbers

To send the ASCII value of the character typed select Data Mode as text. It you want to send HEX data then select hex button in the Data Mode frame.

Sent data is displayed in the bottom window.

Received data is displayed in the top window.

In all three application examples mentioned in section 6.2, 6.3 and 6.4 robot sends back echo of the received data apart from executing the motion commands.

7. Robot Control using ‘GUI’ for Fire Bird V ATMEGA2560

Fire Bird V ATMEGA2560 robot can be controlled by GUI via serial / USB cable or in wireless mode using XBee wireless module. To control the robot using GUI via appropriate mode of communication, load appropriate hex file on the robot. GUI works on at the 115200 baud rate.

7.1 Loading firmware on the robot

Step 1:
Following firmware (.hex file) needs to be loaded on the robot depending on the mode of communication used.

RS232 serial communication: “GUI_ control_serial.hex”
USB communication: “GUI control USB.hex”
ZigBee wireless module based communication: “GUI_control_wireless.hex”

All these hex files are located in the “GUI and Related Firmware” folder.

For information on how to load hex file, refer to software 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. For connections refer to section 6.2 to 6.6.

Step 3: Install GUI software

7.2 Installing GUI

Step1: Copy “FIRE BIRD V ATMEGA2560 setup” folder which is located inside the folder “GUI and Related Firmware” from the documentation CD on the PC.

Click on “setup.exe” which is located in the “FIRE BIRD V ATMEGA2560 setup” folder.

Step 2: Click Next Button to continue.

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

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

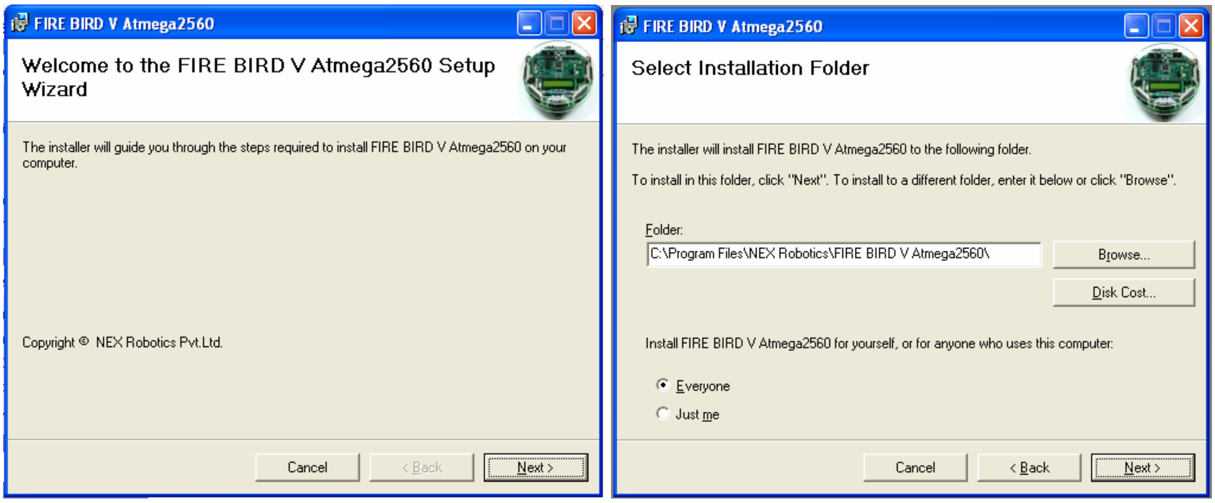


Figure 7.1

7.3 Using GUI

Step 1: After successful installation go to Start -> All Programs -> FIRE BIRD V Amega2560 -> FIRE BIRD V Amega2560 or click on Fire Bird V Amega2560 on your desktop location, GUI will open.

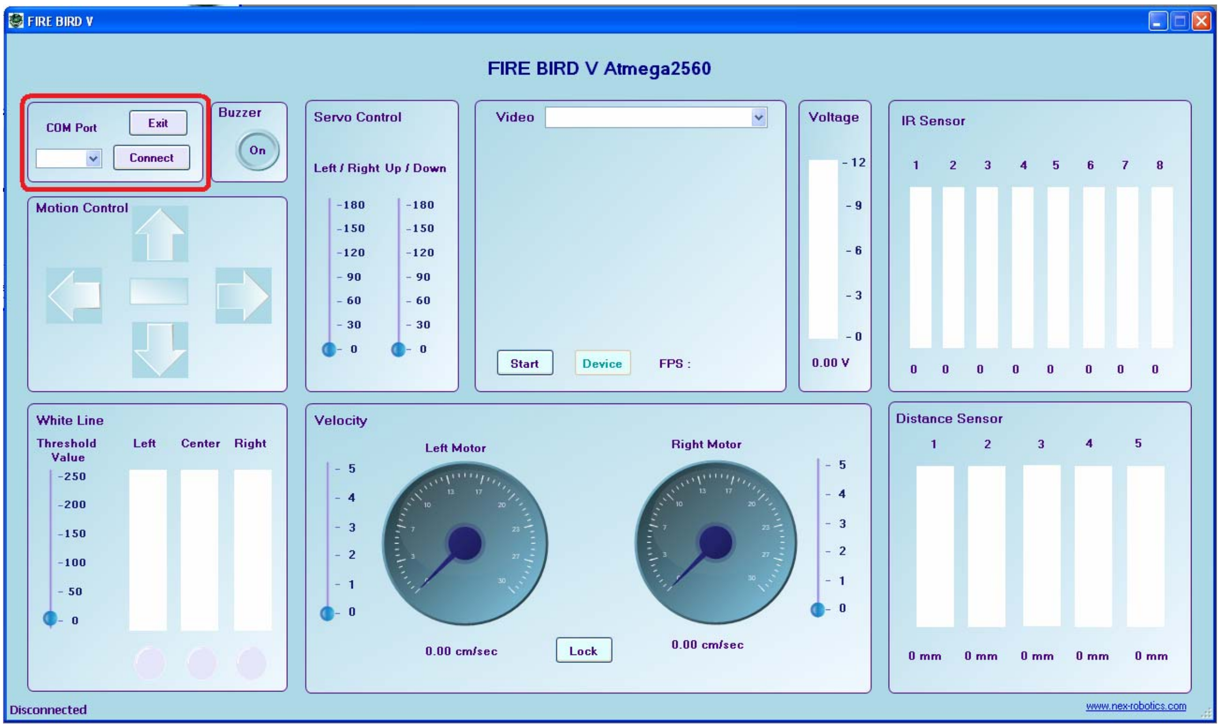


Figure 7.2: Selecting correct com port

Step 2: Connect Robot with the PC using serial cable / NEX Robotics USB to serial converter or with the XBee wireless module. For connections refer to section 6.2 to 6.6.

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 GUI automatically identifies the COM port number. To manually identify the COM port, refer to section 6.6. Select the correct COM port number and click on connect.

Now robot can be controlled using GUI

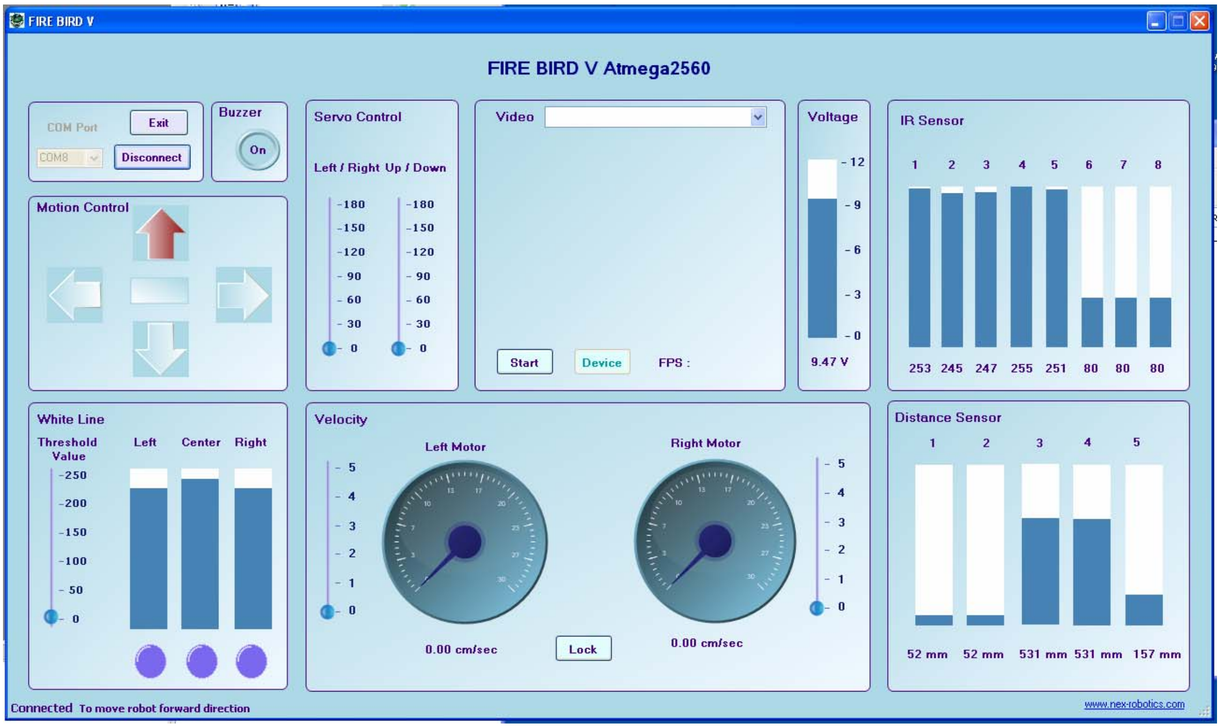


Figure 7.3: GUI showing robot’s data

⚠**Warning:**
While using USB communication, ensure that the appropriate jumpers are in place. For more details refer section 6.3 USB based communication.

Step 4:

If you have Wireless camera pod from NEX Robotics and USB TV Tuner card then you can also see the video on the GUI.

For more information on the installation and usage process, refer to documentation of the wireless camera pod.

Follow these steps for video acquisition:

1. Connect USB TV Tuner card with PC and wait for 5 seconds.
2. Start the Fire Bird V robot's GUI
3. In the video window, select devices as USB TV Device. This option will be visible only if USB TV Tuner card is installed and connected.
4. Press start button to acquire the video.

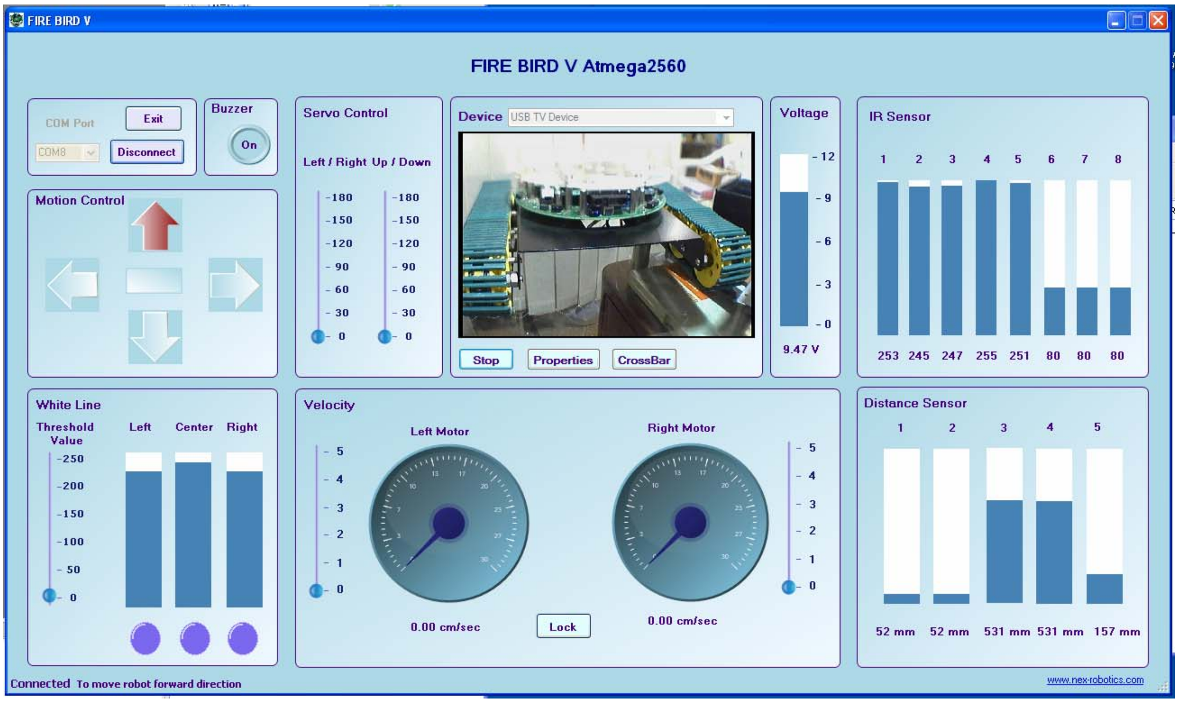


Figure 7.4 : Video display on the Fire Bird V robot's GUI

7.4 Robot control using ZigBee wireless module

To control robot using ZigBee wireless module refer to section 6.4. 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 XBee USB module needs to be connected to the PC and XBee wireless module needs to be installed on the robot.

Important:

- If you want to see data on the IR proximity sensors 6, 7, 8 then connect jumper J4 on the ATMEGA2560 microcontroller adaptor board. For more details refer to section 3.19.6.

- When using USB port for the communication, for proper operation first turn on the robot then insert the USB cable in the robot. We have to follow this sequence because USB to serial converter chip is powered by USB. If any fault occurs then turn off the robot and remove the USB cable and repeat the same procedure.

- In case of XBee wireless module wait for atleast 8 seconds to establish the communication after turning on the robot and connecting XBee USB wireless module with the PC.

7.5 Serial communication protocol used in robot control GUI

All the firmware used for Fire Bird V ATMEGA2560 robot control over wired USB / RS232 link or XBee wireless module are exactly the same. Only difference is that they use different UARTs of the ATMEGA2560 microcontroller. All the firmware uses 115200bps baud rate. It’s a simple byte based protocol in which upper nibble is command and lower nibble can be data or command. You can use these firmware for controlling your robot using any software such as Matlab, Scilab or Lab View etc.

To control robot in wired or wireless mode load the respective firmware on the robot which are located in the “GUI and Related Firmware” folder inside the documentation CD.

GUI control USB.hex: Controls robot over USB port.
GUI_ control_serial.hex: Controls robot over RS232 port
GUI_control_wireless.hex: Controls robot over wireless link using XBee wireless modules.

Read chapter 6 carefully for configuring the ports, setting correct jumpers, installing devices and their device drivers.

This is a simple byte based protocol. Fire Bird V ATMEGA2560 robot uses more complex packet based protocol which can also be used for efficient robot control.

7.5.1 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 a 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 7.1

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.

7.5.2 Commands to set direction of the robot:

Command (HEX)	**DIRECTION**	**LEFT BWD (LB) PA0**	**LEFT FWD(LF) PA1**	**RIGHT FWD(RF) PA2**	**RIGHT BWD(RB) PA3**
51	FORWARD	0	1	1	0
52	REVERSE	1	0	0	1
53	RIGHT *(Left wheel forward, Right wheel backward)*	0	1	0	1

54	LEFT*(Left wheel backward, Right wheel forward,)*	1	0	1	0
55	SOFT RIGHT*(Left wheel forward,, Right wheel stop)*	0	1	0	0
56	SOFT LEFT*(Left wheel stop, Right wheel forward,)*	0	0	1	0
57	SOFT RIGHT 2 *(Left wheel stop, Right wheel backward)*	0	0	0	1
58	SOFT LEFT 2 *(Left wheel backward, Right wheel stop)*	1	0	0	0
59	HARD STOP	0	0	0	0

Table 7.2

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*

7.5.3 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 for 8 bit ADC resolution: 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	**Sharp IR range sensor 2 data** The Robot will return 8 bit value which indicates distance between the obstacle and Sharp 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	**Sharp IR range sensor 4 data** The Robot will return 8 bit value which indicates distance between the obstacle and Sharp sensor.
C1	**IR Proximity sensor 1** The Robot will return an 8 bit analog value of the IR Proximity sensor 1
C2	**IR Proximity sensor 2** The Robot will return an 8 bit analog value of the IR Proximity sensor 2
C3	**IR Proximity sensor 3** The Robot will return an 8 bit analog value of the IR Proximity sensor 3
C4	**IR Proximity sensor 4** The Robot will return an 8 bit analog value of the IR Proximity sensor 4
C5	**IR Proximity sensor 5** The Robot will return an 8 bit analog value of the IR Proximity sensor 5
C6	**IR Proximity sensor 6** The Robot will return an 8 bit analog value of the IR Proximity sensor 6
C7	**IR Proximity sensor 7** The Robot will return an 8 bit analog value of the IR Proximity sensor 7
C8	**IR Proximity sensor 8** The Robot will return an 8 bit analog value of the IR Proximity sensor 8
C9	**Sharp IR range sensor 1 data** The Robot will return 8 bit value which indicates distance between the obstacle and Sharp sensor.
CA	**Sharp IR range sensor 5 data** The Robot will return 8 bit value which indicates distance between the obstacle and Sharp sensor.

Table 7.3

7.5.4 Commands to turn on / off the buzzer:

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

Table 7.4

7.5.5 Robot Version Signature

6B	If 6B is sent to the robot will send back its ID

Table 7.5

7.5.6 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 7.6

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 3.9.

7.5.7 Commands for servo motor control:

ATMEGA2560 microcontroller adaptor board can drive three servo motors. Out of which S1 and S2 servo motors can be controlled with serial control protocol. These motors are used to move the camera or sensor pod in pan and tilt direction.

8	Data	Load servo angle lower nibble
9	Data	Load servo angle upper nibble and move the servo motor.
A	Data	Load servo angle lower nibble
B	Data	Load servo angle upper nibble and move the servo motor.

Table 7.7

The servo motor will move between 0° to180° given an 8 bit value between 0x15 and 0x65 (in hex)
The Servo motion resolution is = 180 / (0x65 – 0x15) = 2.25 degrees / step.

Example: Move servo motor1 by 90 degrees.
Numbers of steps required = 90°/2.25 = 40steps = 0x28 hex
Byte to send = 0x15 + 0x28 = 0x3D
Lower nibble = D hex
Upper nibble = 3 hex

Combining these nibbles with the commands:

Step1: *send 0x8D through the serial port*
Step2: *delay by 3 milliseconds*
Step3: *send 0x93 through the serial port*

