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 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 future generations.

Revision History:

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

2. This hardware manual is applicable from Main board Version 11 dated 12th August 2012 onwards and ATMEGA2560 microcontroller board Version 7 dated 15th August 2012.

3. 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 updated considering crystal frequency as 14.7456MHz.

4. Following are the upgrades made in Main board Version 11 dated 12th August 2012 and ATMEGA2560 microcontroller board Version 7 dated 15th August 2012.

- Main board supports any microcontroller working on 3.3V and 5V.
- On-board NiMH Battery charger along with battery level indicator.
- Auxiliary power connector and battery charging connectors are separated and require a single unified connector from the AC adapter.
- 3mm IR proximity Sensors are replaced with 5mm IR Proximity sensor for better range.
- 3 times reduction in power consumed by IR proximity sensors.
- Added support for 7 channel white line sensors with all 7 sensor calibration potentiometers on main board.
- All Motor, Sensor pod & battery connectors are replaced with relimate 2510 type connectors for better reliability.
- Added Fuse protection.
- Removable battery pack with Velcro battery strap.
- Bottom acrylic plate is replaced with high strength aluminum metal plate.
- Easy to replace motors than previous model.
- Added support for MaxBotix Ultrasonic Range Sensors.
- Added pins to measure signal strength of XBee wireless module.
- Larger heat sink area for the on-board voltage regulators.
- Tin plated power and motor tracks for further increasing power rating of the main board.

Index

1. Introduction

Thanks for choosing the Fire Bird V mobile robotics platform. Fire Bird V will help you gain exposure to the world of robotics and embedded systems. With help of 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 on 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 risk 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:

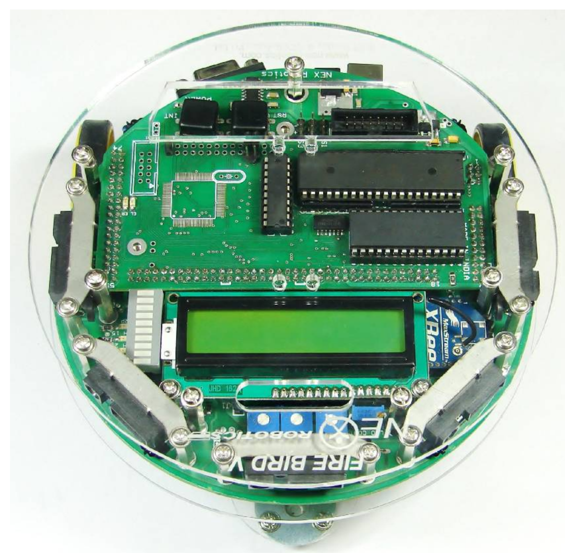
Inappropriate operation can damage your robot. Inappropriate operation includes, but is not limited to:

- Dropping the robot, running it off an edge, or otherwise operating it in 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 is entangled in the robot's axles or wheels.
- All other forms of inappropriate operations.
- 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 from 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 adapter board. Fire Bird V supports ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 (ARM7) microcontroller adapter boards. This modularity in changing the microcontroller adapter boards makes Fire Bird V robots very versatile. You can also add your own custom designed microcontroller adapter board.

Fire Bird V ATMEGA2560 (AVR)



Fire Bird V P89V51RD2 (8051)

Figure Bird V LPC2148 (ARM7 TDMI)
Figure 2.1: Fire Bird V Robots

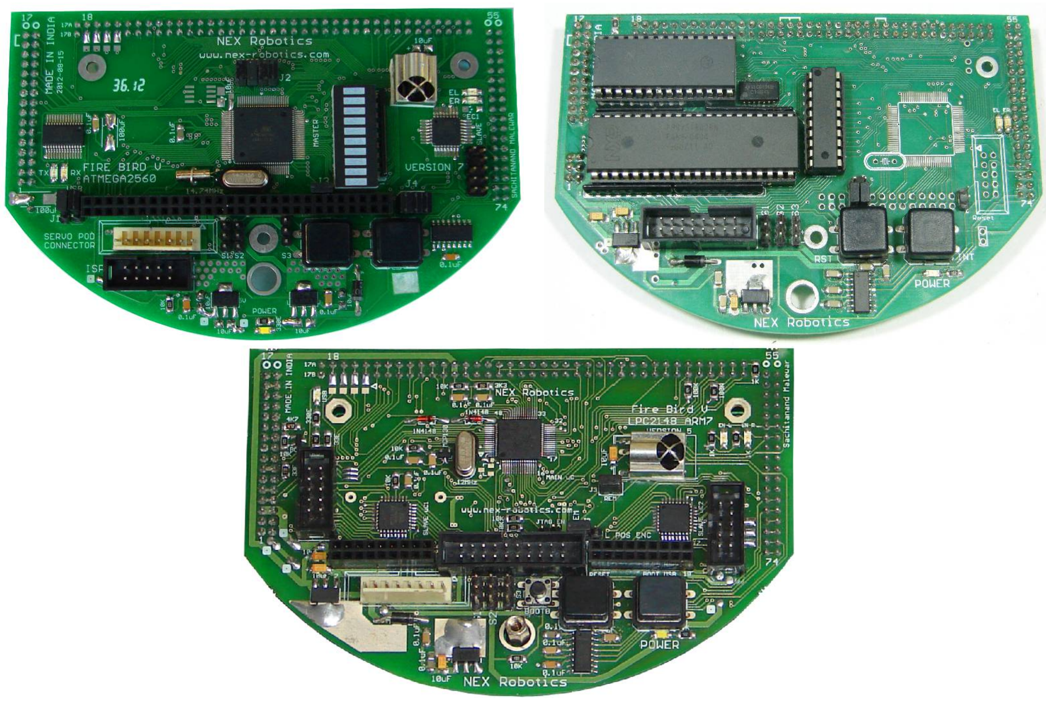


Figure 2.2: ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 ARM7 microcontroller adapter boards for Fire Bird V

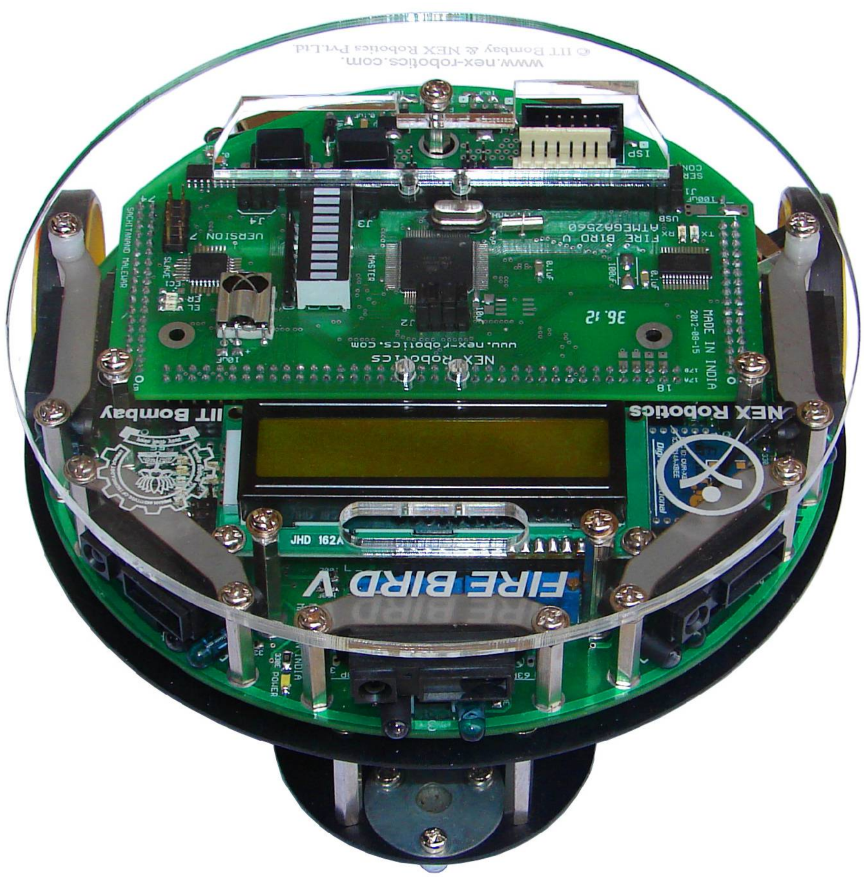
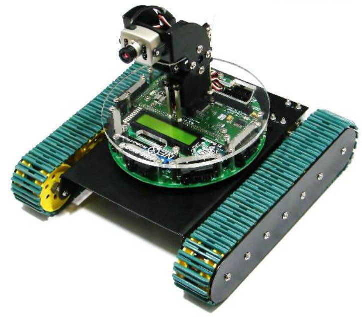


Figure 2.3 Fire Bird V ATMEGA2560 robot

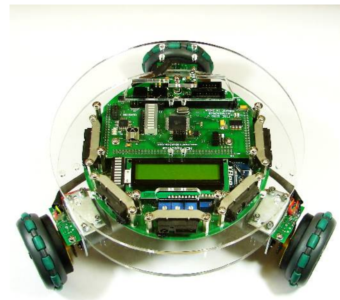
2.1 Avatars of Fire Bird V Robot

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

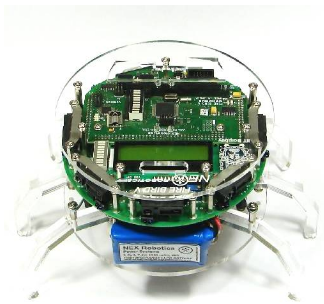
Fire Bird V



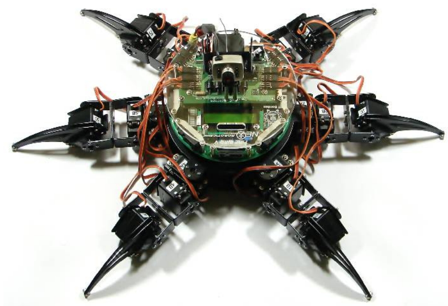
Fire Bird V Tank



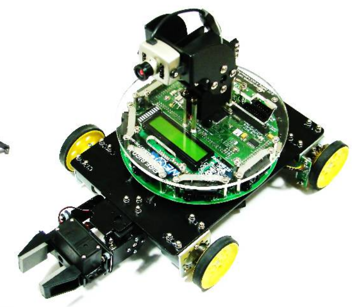
Fire Bird V Omnidirectional Robot



Fire Bird V Insect



Fire Bird V Hexapod



Fire Bird V 4WD with Gripper

Figure 2.4: Avatars of Fire Bird V Robot

2.2 Fire Bird V Block Diagram:

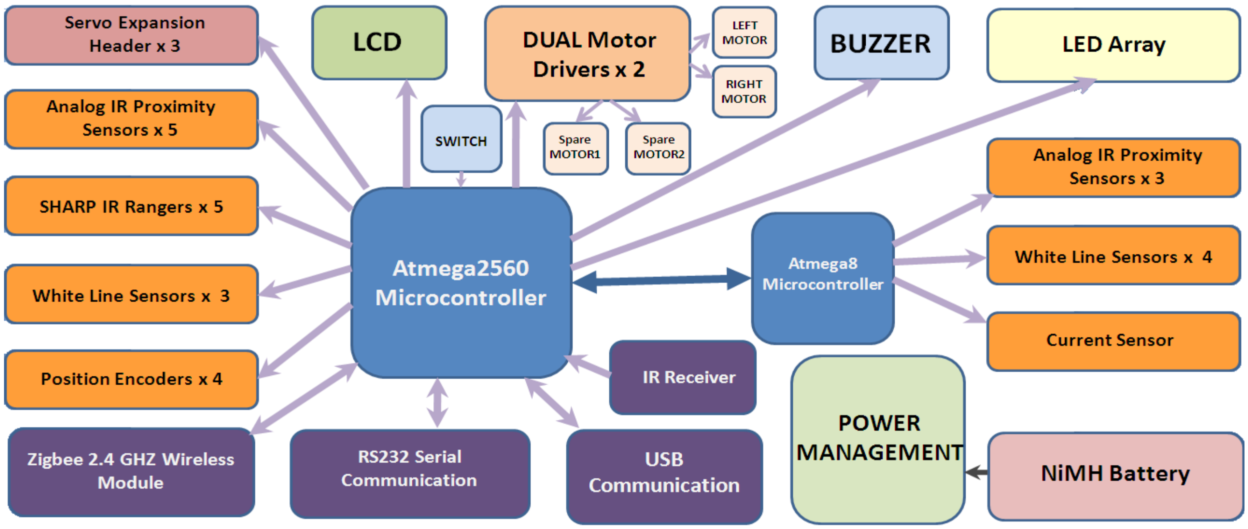


Figure 2.5: Fire Bird V ATMEGA2560 robot block diagram

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 GP2Y0A02YK IR range sensor (One in default configuration)
Eight analog IR proximity sensors
Two position encoders (extendable to four)
Battery voltage sensing
Current Sensing (Optional)
Five MaxBotix Ultrasonic Range Sensors (Optional)

Indicators:
2 x 16 Characters LCD
Buzzer and Indicator LEDs

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

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

Dimensions:
Diameter: 16cm
Height: 8.5cm
Weight: 1100gms

Power:
9.6V Nickel Metal Hydride (NiMH) battery pack and external Auxiliary power from battery charger.
On Board Battery monitoring and intelligent 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)

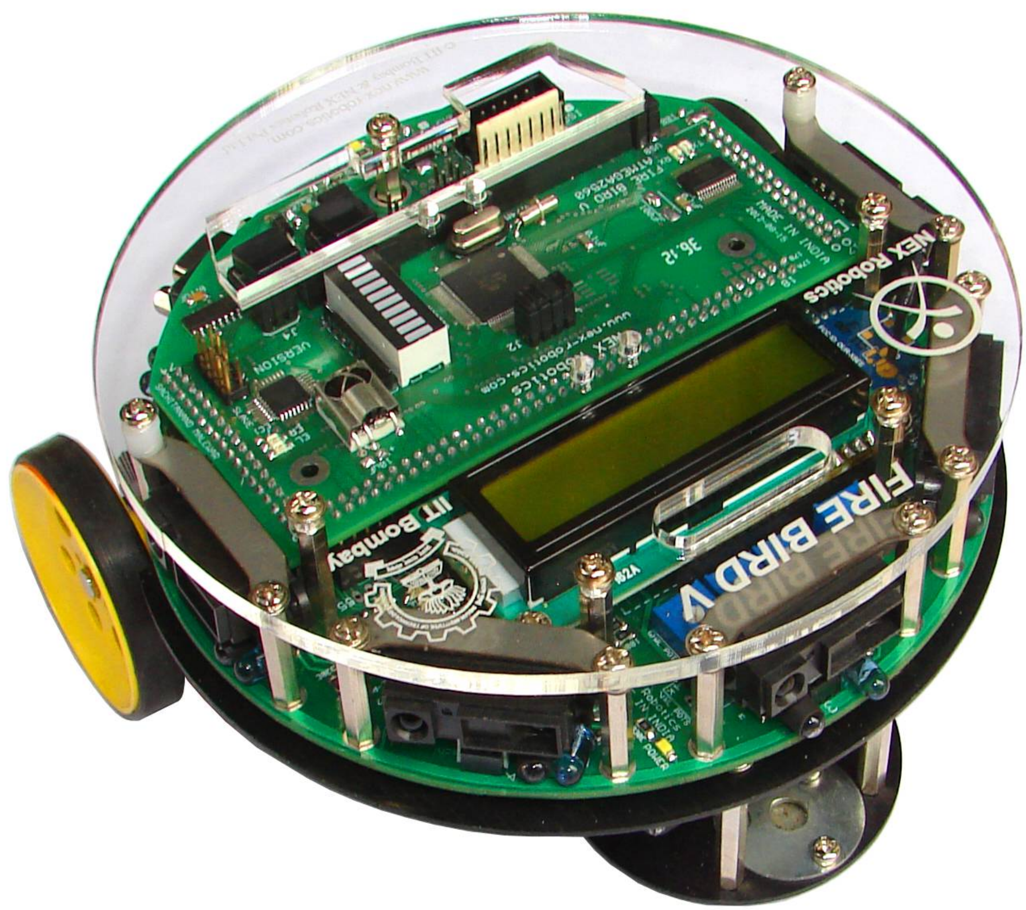


Figure 3.1 Fire Bird V ATMEGA2560 robot

3.1 Connections

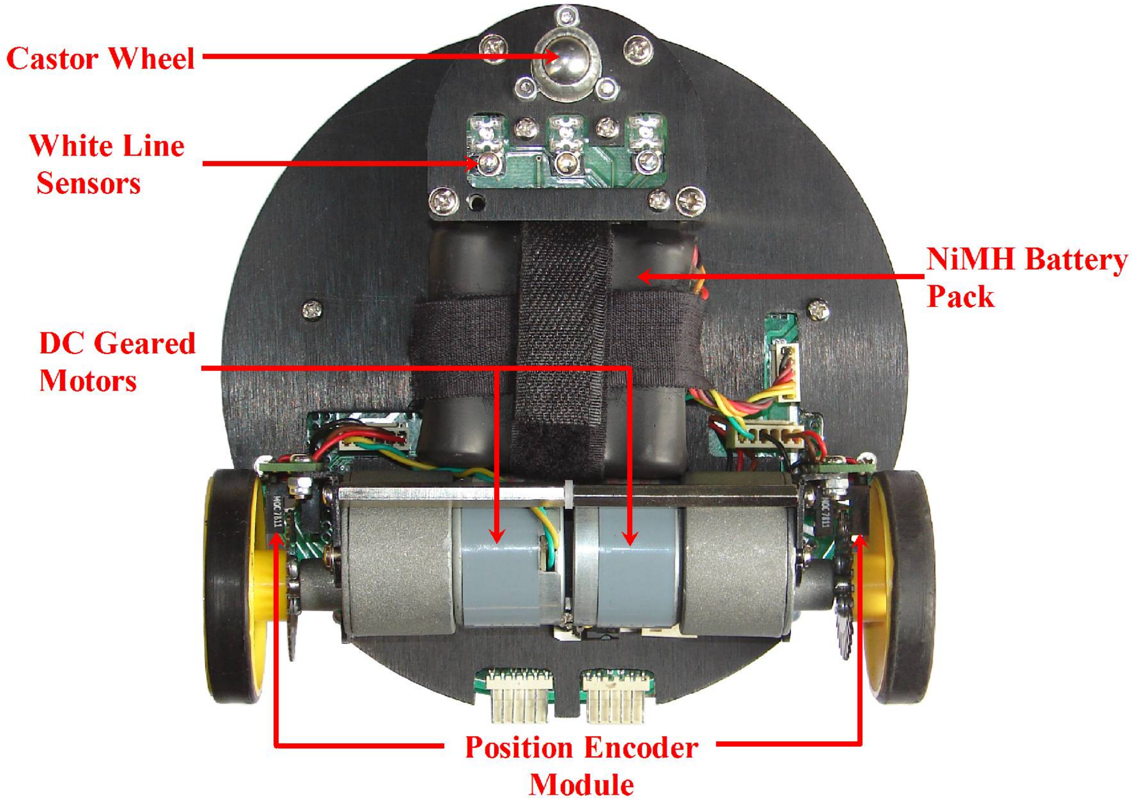


Figure 3.2: Fire Bird V ATMEGA2560 robot bottom view

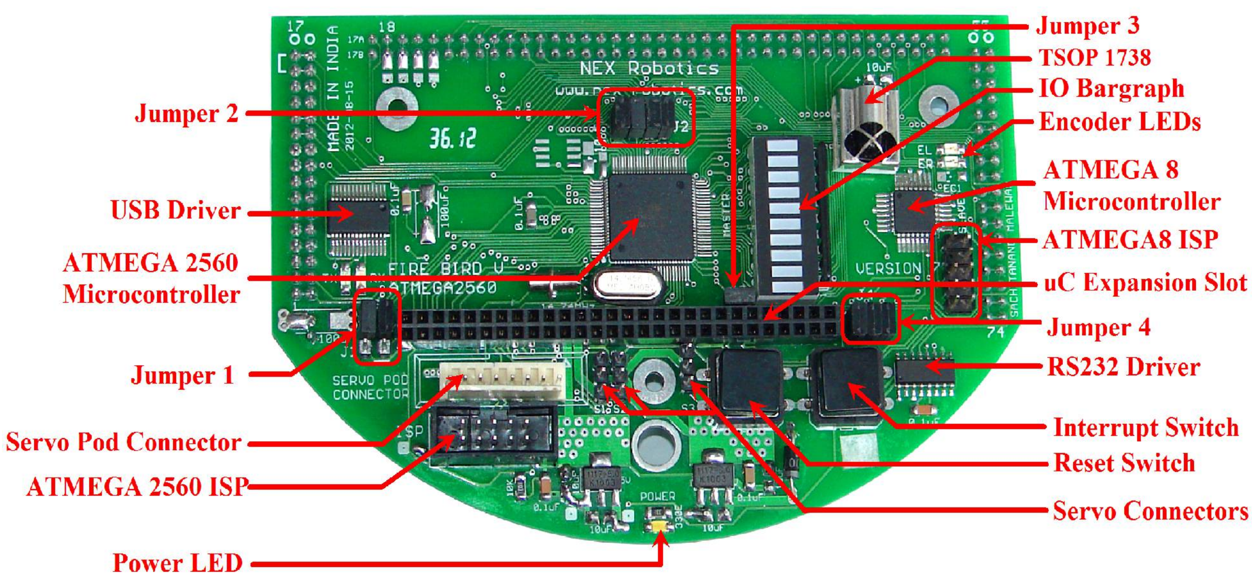


Figure 3.3: ATMEGA2560 microcontroller adapter board

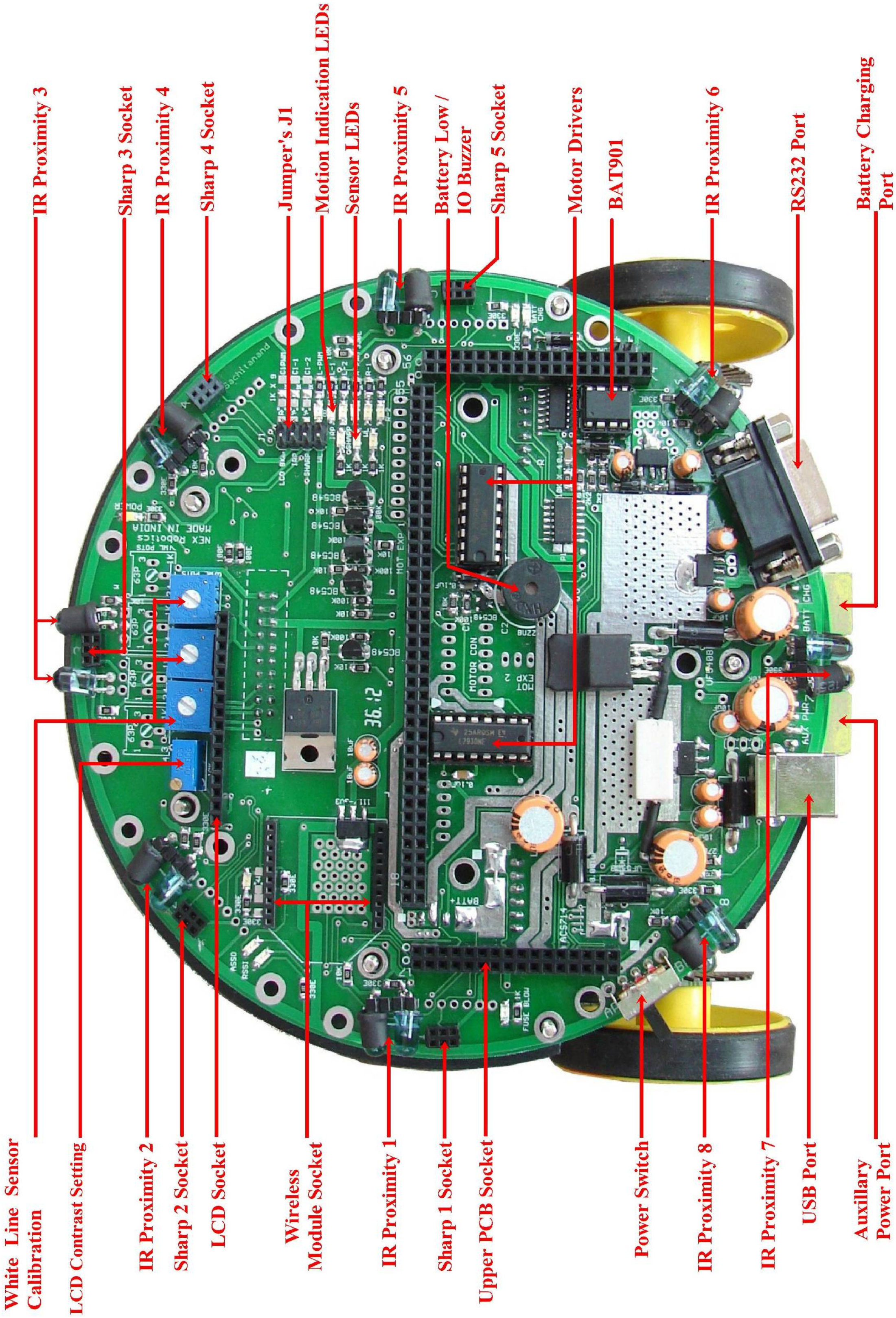


Figure 3.4: Top view of the main board

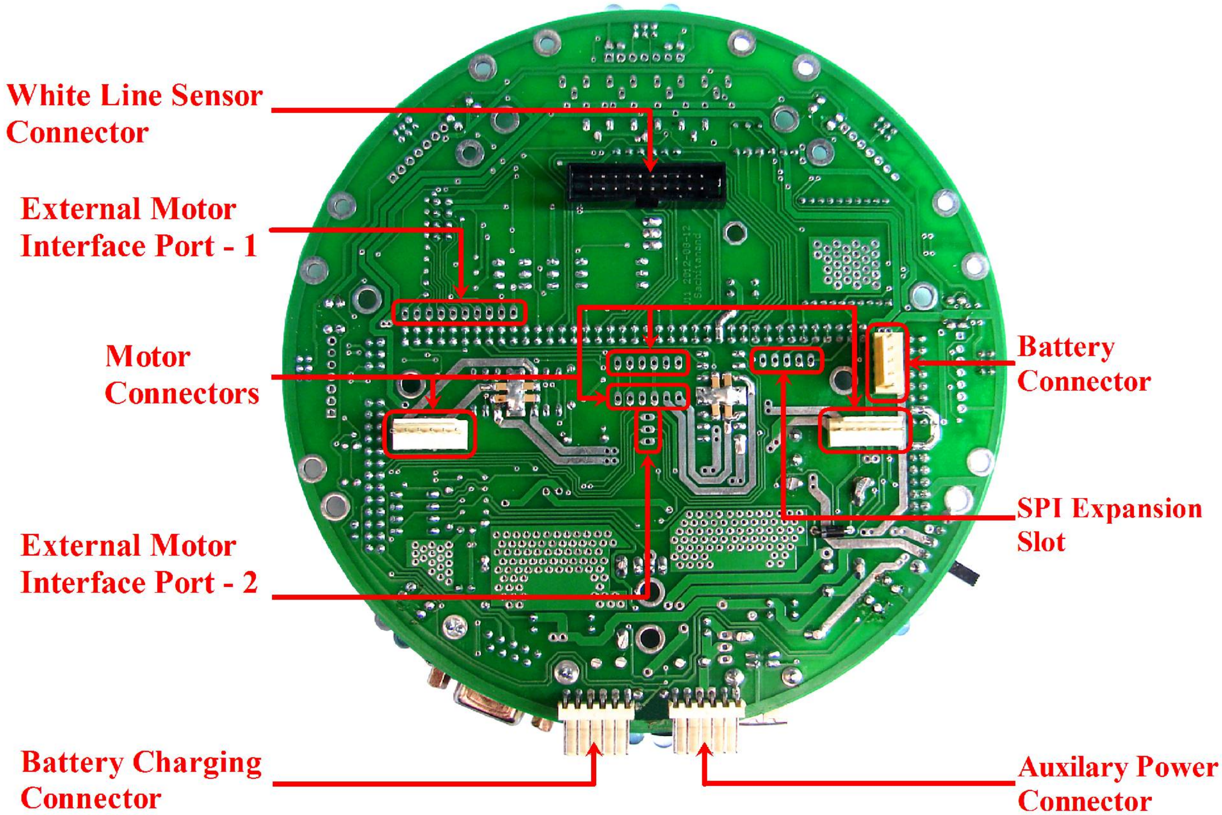


Figure 3.5: Bottom view of the main board

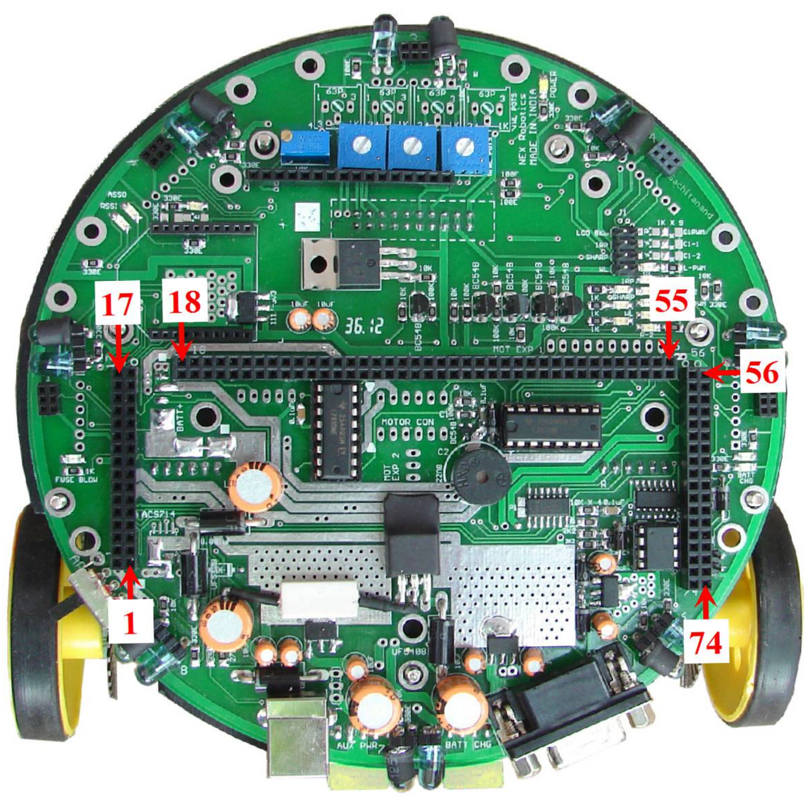


Figure 3.6: Microcontroller adapter board socket connection numbers on the main board

3.2 Powering up Fire Bird V

Fire Bird V has on board rechargeable 9.6V, 2.1Ah Nickel Metal Hydride battery which can power the robot for approximately 2 hours. Battery is fixed using Velcro strap so that it can be replaced easily. In case the experiments are to be performed for an extended period, robot can also be powered by external auxiliary power supply.

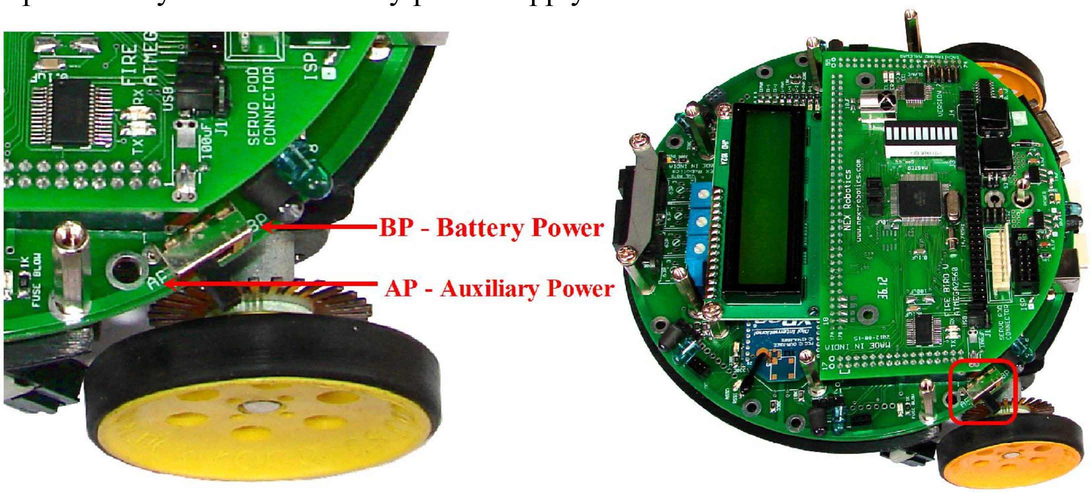


Figure 3.7: Power Switch

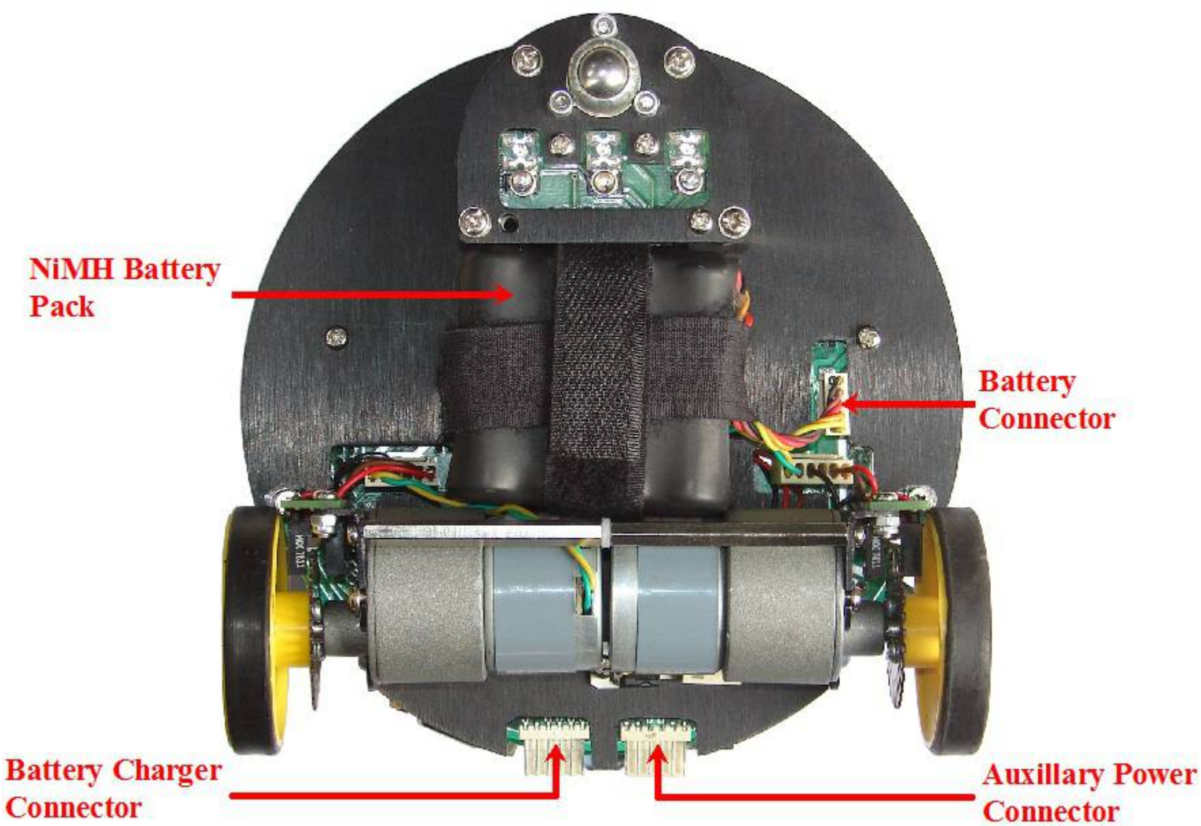


Figure 3.8: Connecting the battery on the Fire Bird V main board

Figure 3.7 shows the power switch. Power switch can either be “BP” (Battery Power) or “AP” (Auxiliary Power) position. When auxiliary power or battery charger connector is not connected, robot can be turned ON when power switch is in BP position. Use of Auxiliary power to power the robot for extended amount of time 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. To do this, move the power switch towards the “AP”. Figure 3.8 shows the battery connector. Insert battery's 5 pin relimate connector in the socket. To turn ON the robot, move power switch towards the “BP”.

The NiMH batteries are fully charged before delivery. However, NiMH batteries will get discharged over the period of time. Therefore its recommended to charge the batteries before using the robot.

Robot is pre-loaded with a program to move robot in repeatedly in forward, backward, left and right directions.

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 rechargeable Nickel Metal Hydride battery pack. The battery voltage can vary between 12V (fully charged) to 8V (discharged). Battery pack should not be discharged below 8V (1V per cell) for extended battery life. Fire Bird V robot has on-board intelligent NiMH battery charger which follows the correct charging profile for the batteries. To avoid any accidental damage to the batteries, do not use external battery charger.

Warning: Charge the battery as per the instructions given in this manual. Do not use any external charger to charge the battery. Using external charger may damage the battery permanently.

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

1. Battery voltage monitoring and Smart battery charging
2. Regulated supply for on-board payload
3. Battery current sensing*

*** Current sensing is an optional accessory.**

3.3.1 Battery

Fire Bird V is powered by 9.6V rechargeable Nickel Metal Hydride battery pack. When fully charged, battery pack gives 12V and when it is fully discharged, voltage drops to about 8V. NiMH battery pack has 5 pin 2510 relimate connector which will fit into the connector on the main board only in one orientation. Do not force the connection in any other way.

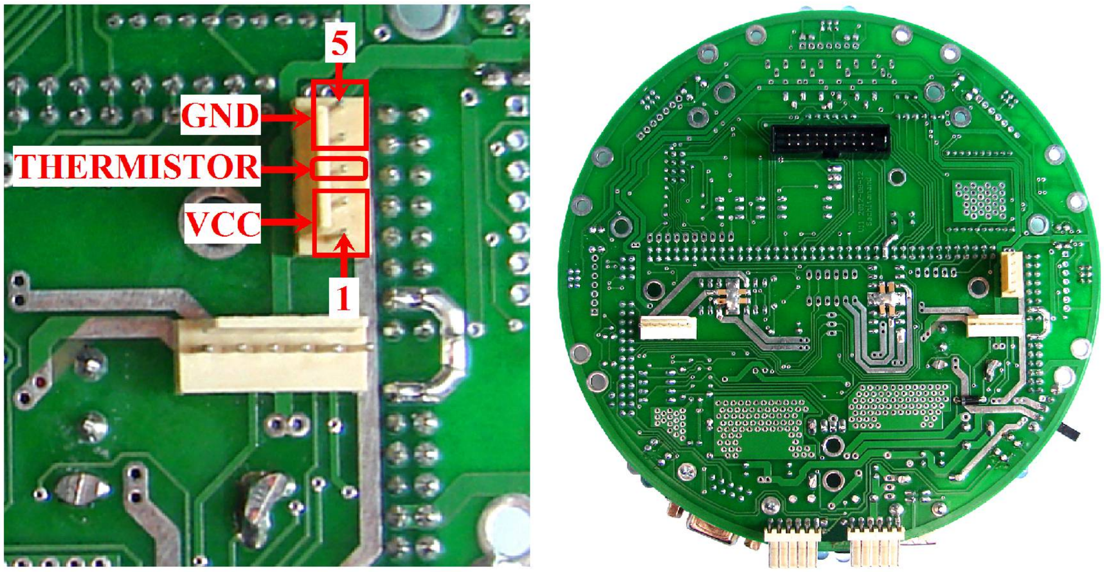


Figure 3.9: Battery Connector on the main board

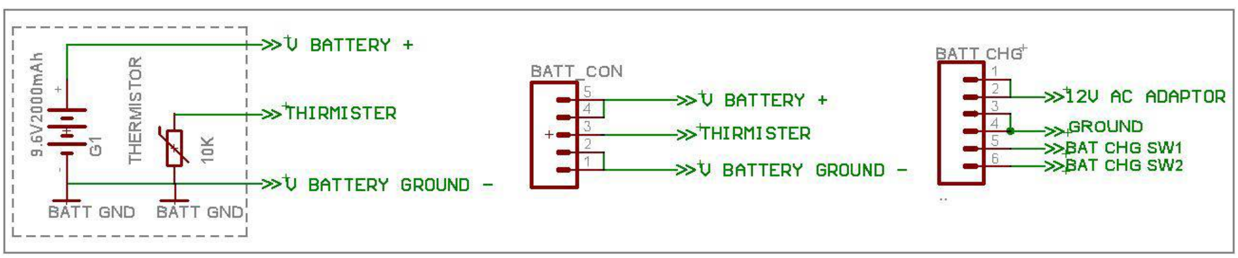


Figure 3.10: Battery for Fire Bird V ATMEGA2560

Pin Number	Function
1,2	Battery Positive (VCC)
3	Thermistor
4,5	Battery Negative (GND)

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 continue use 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 use maximum of 2Amp current while Auxiliary supply will provide only 1Amp current.

Robot's power is divided in two separate power rails. “V Mot Supply” provides power to all the noisy devices on the robot such as motors and other heavy loads. “V Batt Supply” powers most of the electronics on the robot. Most of the systems on the robot are powered by 3.3V and 5V via voltage regulators.

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 the battery voltage can fall below 6.3V momentary. Voltage regulators will not be able to function properly below 6.3V and their output will fall below 5V. In this case the microcontroller can reset. To extend the usable battery life and to reduce the probability of microcontroller getting reset when battery is about to fully discharge, diodes D7 along with the capacitor C54 is used. When battery voltage suddenly drops, diode D7 prevents the reverse flow of the current and capacitor C54 maintains voltage within safe limits for about 100 milliseconds. For this duration capacitor C54 acts as small battery. Similar arrangement is done in the “V Mot Supply” using diodes D9 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 that require large amount of current. This supply can be varied between 8V to 11.3V depending on the battery's charging state and type of power source (battery / auxiliary power) used. This line can supply additional 500mA to the external load.

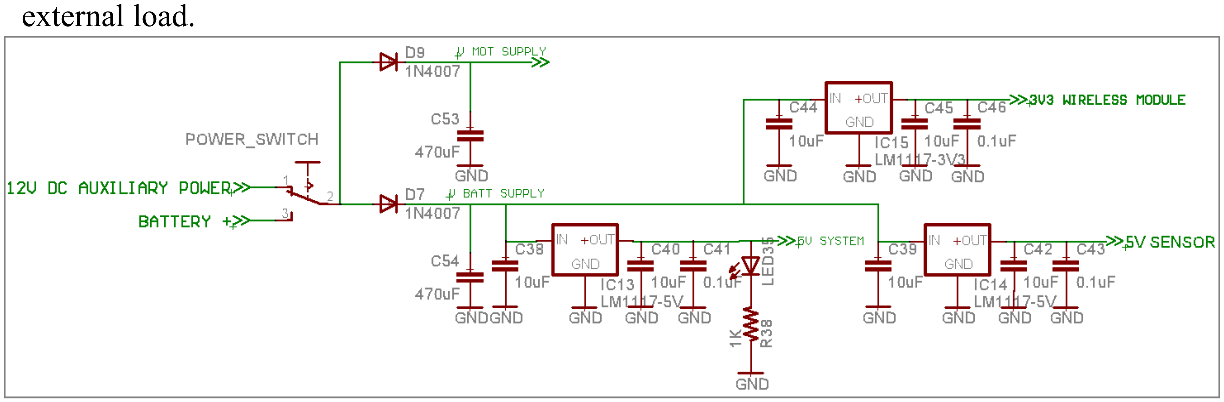


Figure 3.11: Voltage regulators on the main board

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, Sharp 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. 3.3V Sensor
"3.3V Sensor" is used to power 8 IR proximity sensors, up to 7 white line sensors. 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.

6. 3.3V Batt Mon supply
Batt Mon Supply provides 3.3V to the Smart battery monitoring and charger circuit.

Note: Apart from these four voltage regulators Fire Bird V ATMEGA2560 has two voltage regulators for powering microcontrollers and servo motors on the microcontroller adapter socket.

3.3.3 Current sensing.

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

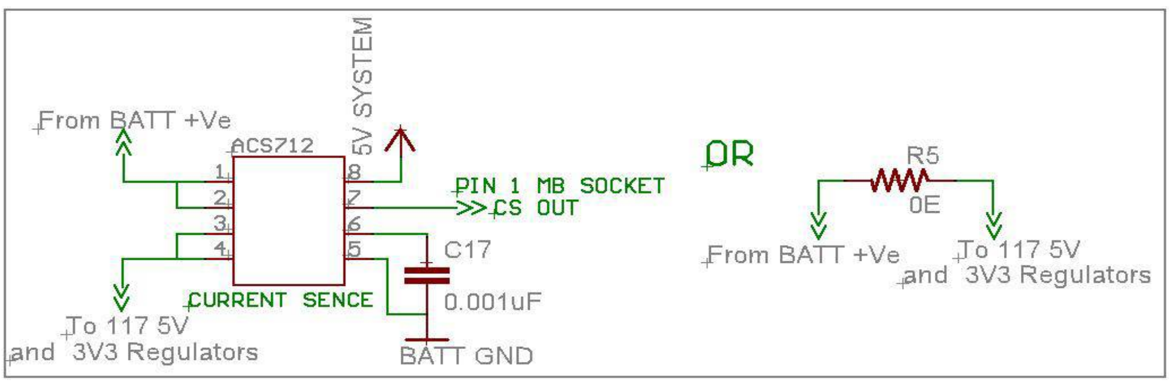


Figure 3.12: Current sensing in Fire Bird V

Sensor's current sensing element is located between battery's positive terminal and robot's electronics. When no current is flowing through the sensor, it gives 2.5V output. This output value reduces by 185mV per ampere of current flow if 5 Ampere current sensor is installed. If 20 Ampere current sensor is installed then value is reduced by 100mV per ampere. This sensor is an optional accessory. When this sensor is absent, the sensing path is shorted with 0 ohm resistor or with a wire. 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

Fire Bird V uses smart battery monitoring system based on IC BAT901. When battery voltage goes below 8V, buzzer starts giving one long beep followed by 2 short beeps with delay of half second. At the same time red led marked in figure 3.14 starts flashing.

3.4 Battery Charging

Fire Bird V is powered by 9.6V NiMH rechargeable battery. The on-board NiMH charger will charge the battery in 3 to 5 hours depending on the battery state.

Battery charger checks state of battery before initiating the charging process. While charging the battery, by looking at battery voltage, current and temperature it selects optimal charging algorithm. Battery charge status is indicated by a buzzer, a red LED and a green LED shown in figure 3.14.

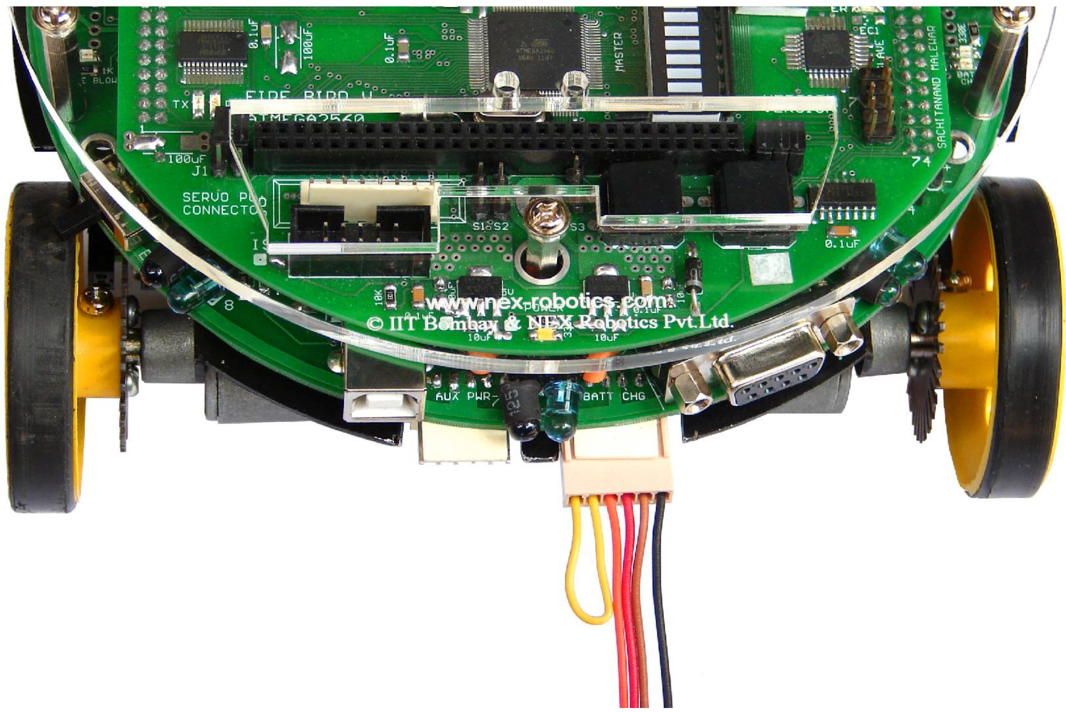


Figure 3.13: Connection for battery charging

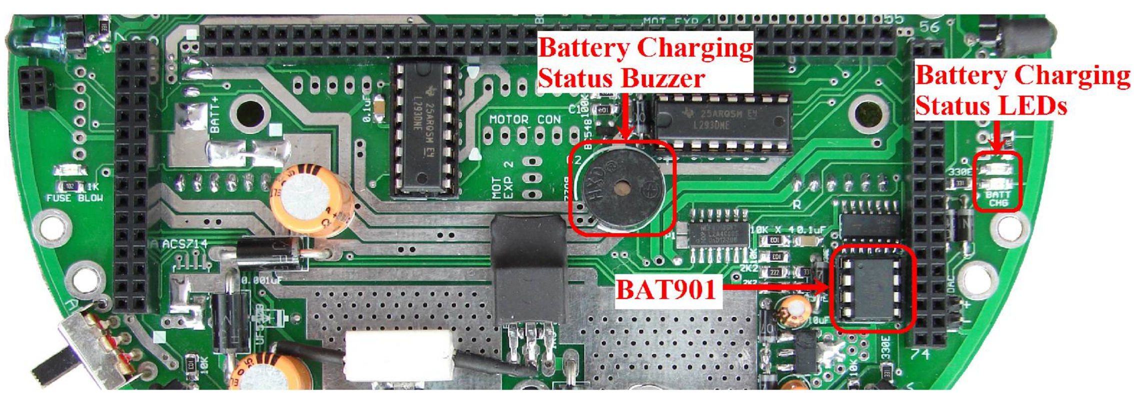


Figure 3.14: Battery charging status indicator LEDs & Buzzer

Battery charging procedure:

1. Make sure that battery is inserted in battery connector, and robot is turned off.
2. Connect AC adapter in the mains. Connect the 6pin 2510 relimate battery charging connector to the main board in the battery charge socket as shown in figure 3.13.
3. Now turn on the AC adapter. After a small delay, green LED will turn on along with the one long beep two short beeps followed by delay of 1 second. This tone will be sounded only once. This audio tone confirms that robot is entered in the battery charging mode. If you do not here this tone, then repeat steps 1, 2 and 3.
4. When battery is fully charged, green LED will turn off and buzzer gives 2 short beeps followed by 1 second delay continuously. Depending on the version sometimes robot will also give 1 long beep followed by delay.
5. If there is any fault then charger will give different buzzer beeps to indicate nature of fault. Following section describes the interpretation of the battery state with beeping buzzer.

Battery status indication based on the buzzer beeps and red and green LEDs:

Important: Battery status indicator Red LED blinks in sync with buzzer. So in the following text only buzzer's status is mentioned.

1. Battery Low: (only applicable when robot is running on battery power)
One long beep followed by 2 short beeps repeated after delay of 1 second continuously.

2. Battery entered in the charging mode:
When AC adapter is connected to the battery charging connector and powered up and if robot enters in battery charging mode, it gives One long beep followed by 2 short beeps only once. During battery charging mode green LED remains ON. It blinks for 3-4 seconds after 3-4 minutes.

3. Battery is fully charged:
When battery is fully charged, green LED will turn off and buzzer gives 2 short beeps followed by 1 second delay. Depending on the version, sometimes robot will also give 1 long beep followed by delay.

4. Charge termination due to over current:
During charging process, if charge current exceeds safe threshold value then robot terminates charging and buzzer gives 1 short beep repeated after delay of 1 second continuously.

5. Charge termination due to time out:
If battery is not fully charged in 6 hours, then robot stops battery charging and buzzer gives 3 short beeps repeated after delay of 1 second. If battery is unused for long time then it is possible that robot terminates battery charging due to timeout. In such case, discharge the battery fully and again start charging. You should repeat this 3 to 4 times till issue gets resolved. If still the issue is not resolved then batteries have reached end of its usable life but you can still use battery with the robot. However the run time of the charged battery will be reduced significantly.

6. Charge termination due to battery failure:
At any time during battery charging if robot detects failure in the battery then it stops battery charging and buzzer gives 1 very long beep with a very short delay in between. In this case battery needs to be replaced.

Note: Buzzer is shared between battery monitoring circuit and main microcontroller socket.

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.

⚠ **Warning:**

Never ever attempt to charge the robot while its powered on. In case, if robot is powered up first and if you insert the battery charging socket, it will not enter in charging mode. In case, when you insert battery charging socket first and start charging, and then power up the robot, the robot will be powered up and at the same time battery will get charged. This is a very dangerous scenario where robot's battery charging circuit may get confused because of noise from motors and both battery and robot may get permanently damaged.

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 back direction (BP) as shown in the figure 3.7

⚠**Warning:**
Do not run the robot if battery is low. It will reduce the battery life cycle.

3.6 Powering the robot on auxiliary power

Under normal condition robot is powered by on-board battery. In order to do experiments for longer duration without worrying about the battery running low, robot can also be powered by external power source. Auxiliary power source provides regulated 12V, 1Amp supply to the robot.

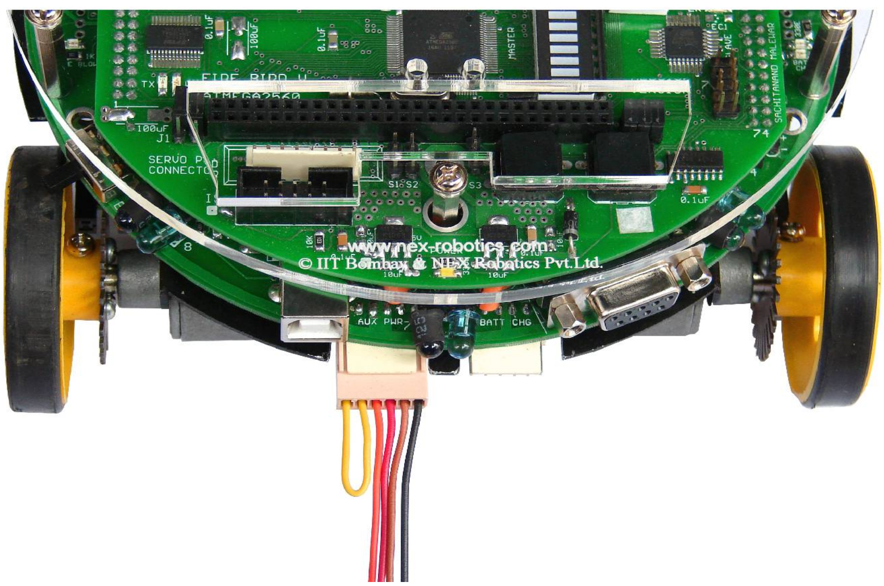


Figure 3.15: Robot Powering via Battery and Auxiliary supply

To run the robot on the auxiliary power, use following steps:

1. Disconnect the battery by removing the 5pin relimate connector on the main board which is located at the bottom of the robot. (refer to figure 3.8)
2. Move the power switch to the BP position (refer to figure 3.3). This is off state for Auxiliary power mode.
3. Connect AC adapter in the mains. Connect other end of AC adapter in the AUX PWR relimate male connector on the main board (connector on the right side) and turn on the AC adapter.
4. Now to turn on the robot, move power switch towards “AP” (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 can not be turned off in this scenario.

3.7 Battery Maintenance

If not used, fully charged NiMH battery can get completely discharged within few weeks. Always charge the battery before use. If fully charged battery is kept in storage for about a month and afterward even if it is fully charged again, it can deliver only 1/3rd power of its rating. In such case, to restore the 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. Program involving motion discharges battery quickly. You can put robot upside down and let motors run for faster discharge.

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

3.7A Current limiting and short circuit protection:

In the Version 11 of main board, solder pads for the fuse are added. These pads are shorted together as shown in left side image of figure 3.18. You can mount fuse of 2A to 10A rating on these pads as shown in the right side image of figure 3.16.

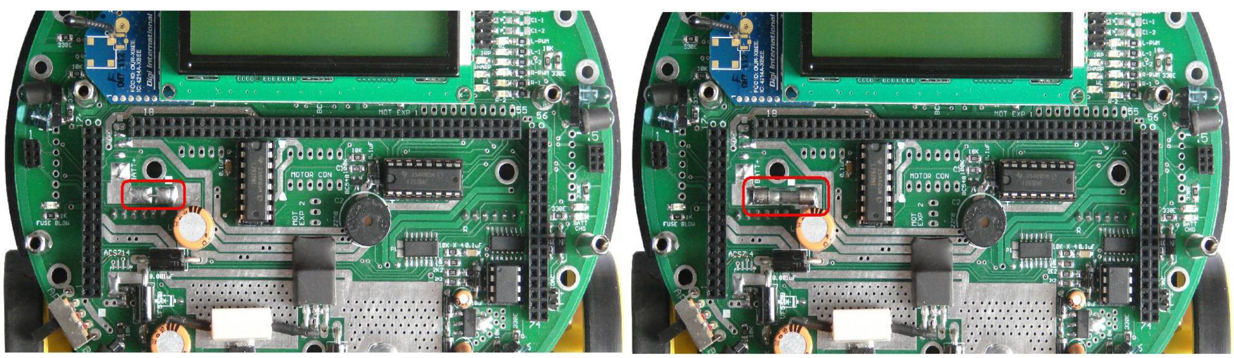


Figure 3.16: Optional Fuse on the main board

3.8 Motion control

Fire Bird V robot has two 75 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 encoders are mounted on both the motor's axles to give a position feedback to the microcontroller.

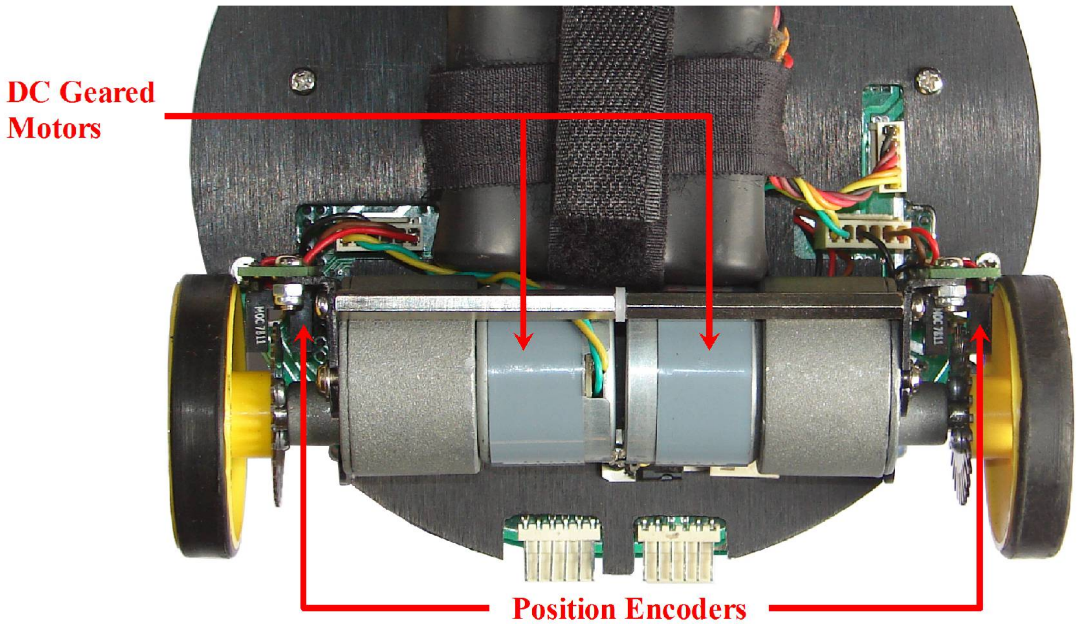


Figure 3.17: DC geared motors and position encoders

Motion control involves velocity and direction 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 stage of the motor driver for quick interpretation of the motion commands.

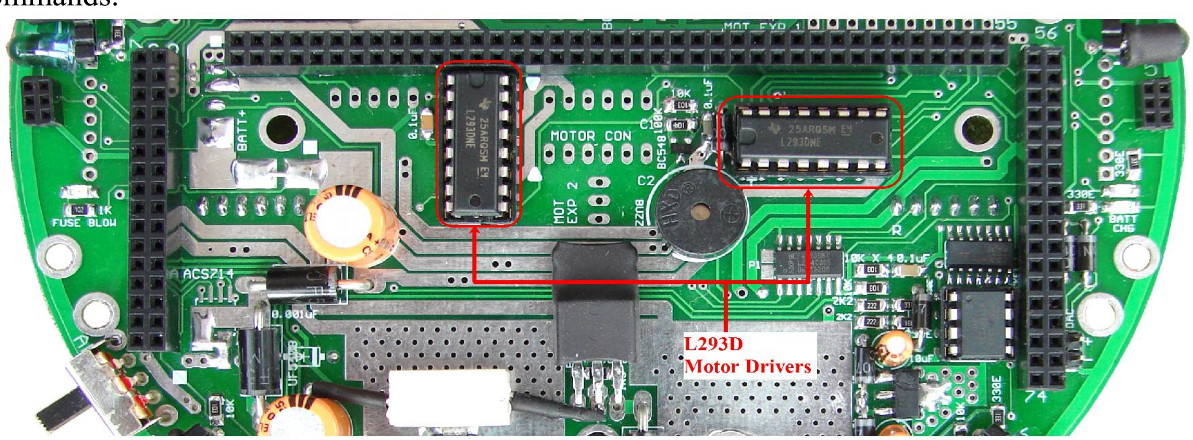


Figure 3.18: Motor Drivers

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.

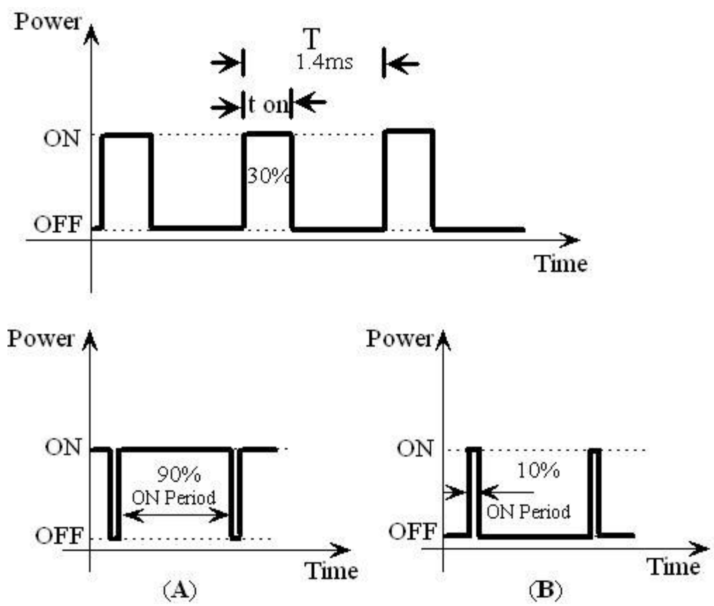


Figure 3.19: Pulse Width Modulation (PWM)

Figure 3.19 shows the PWM waveforms for motor velocity control. In case (A), ON time is 90% of time period. This wave has more average value and 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 1 direction control
PA1	Left motor 2 direction control
PA2	Right motor 1 direction control
PA3	Right motor 2 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 observe all the commands given on the LEDs located at the top right side on the robot. Figure 3.20 shows the location and function of indicator LEDs related to motion control.

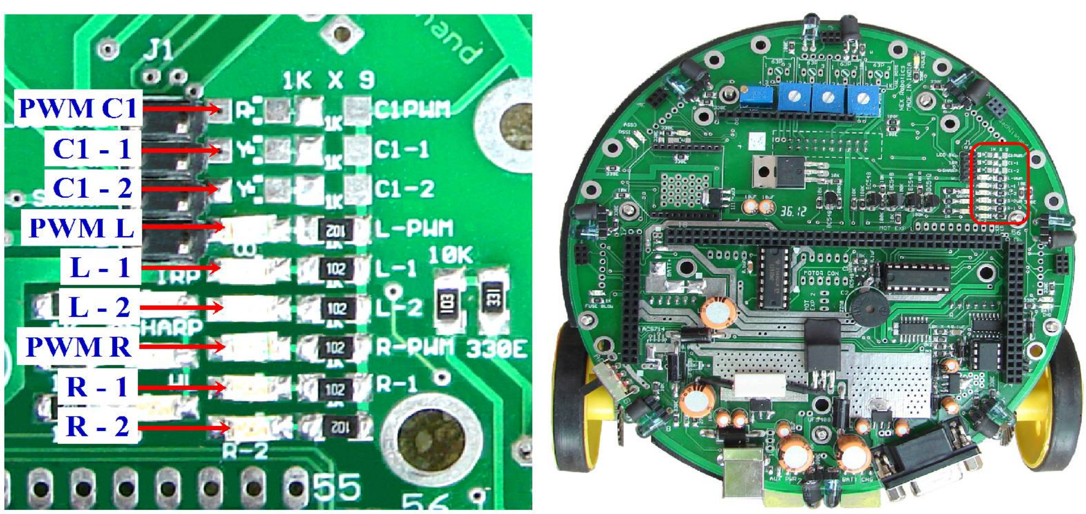


Figure 3.20: Motion status LED indication on the Fire Bird V main board

Note: C1 and C2 motor connectors are used in omnidirectional and 4 wheel drive robots. LEDs for C1 motor channels are present if C1 motor channel is used.

⚠**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 change 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 0.5 seconds before changing the direction. This will also increase the useable time of the fully charged battery.

Robot has two IC holders for two L293D motor drivers with each having two 6 pin 2510 relimate connectors for two 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 3.18 shows the locations of the two L293D dual motor drivers on the main board. Left side L293D drives C1 and C2 motors and right side L293D drives Left and Right side motors. In the two wheel drive robot left side L293D is absent as its not used however to use C1 and C2 motor driver channels you can insert L293D in the left side IC holder.

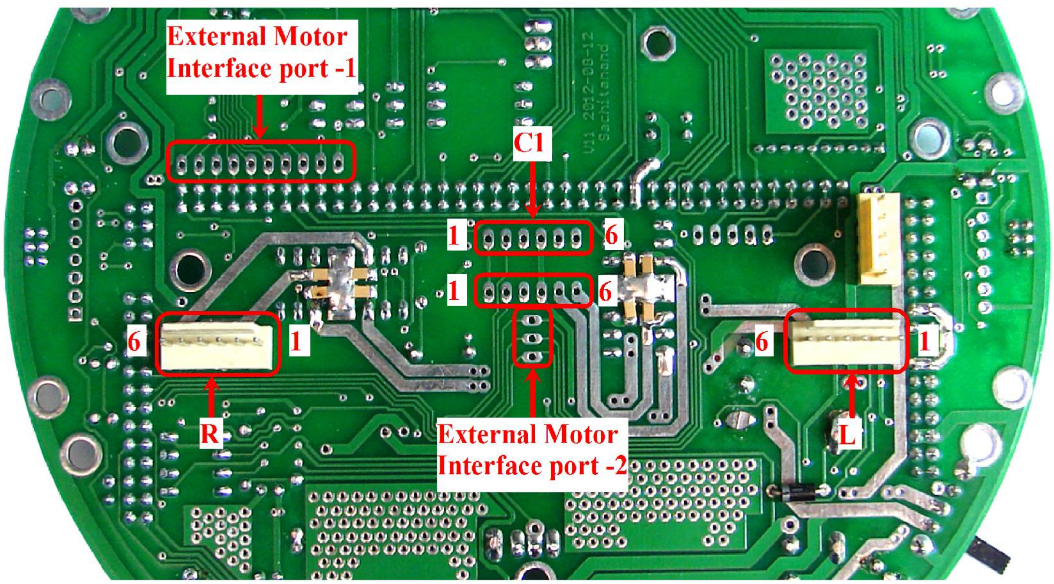


Figure 3.21: Motion control connections on the main board

Connector Name	Description
L	Left motor connector 1
R	Right motor connector 2
C1	C1 motor connector
C2	C2 motor connector
External Motor Interface Port1	Logic signals of pins 47 to 55 of the main board socket for interfacing external high power motor drivers for L,R and C1 motors
External Motor Interface Port2	Logic signals of pins 66 to 68 of the main board socket for interfacing external high power motor drivers for C2 motor

Table 3.5: Use of connectors of the motion control module

Pin No.	Function
1	VCC, 5V System
2	Position Encoder data
3	NC
4	GND
5	Motor 2
6	Motor 1

Table 3.6: Motor connector port pin connections

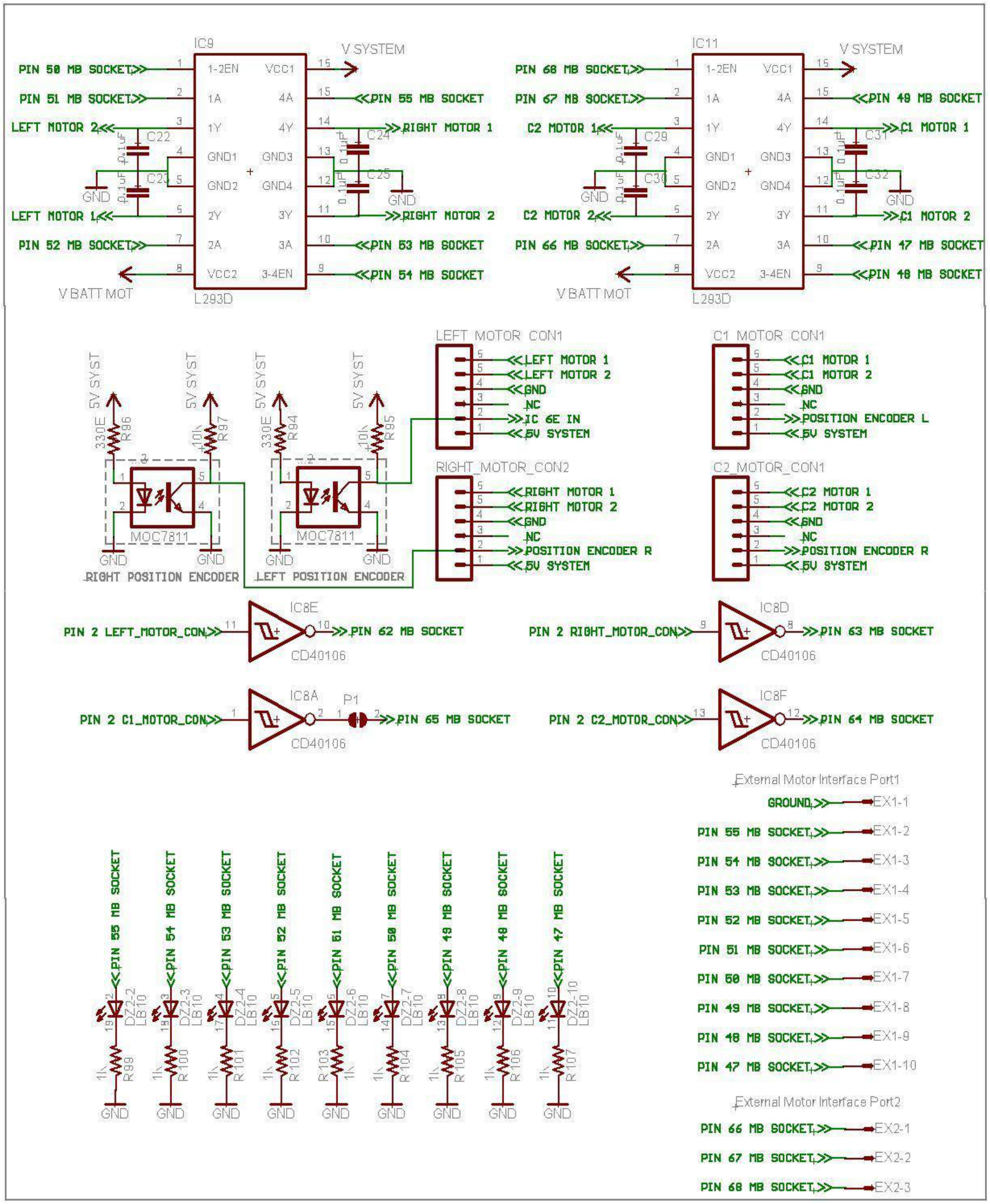


Figure 3.22: Schematic of the motion control module and the position encoder

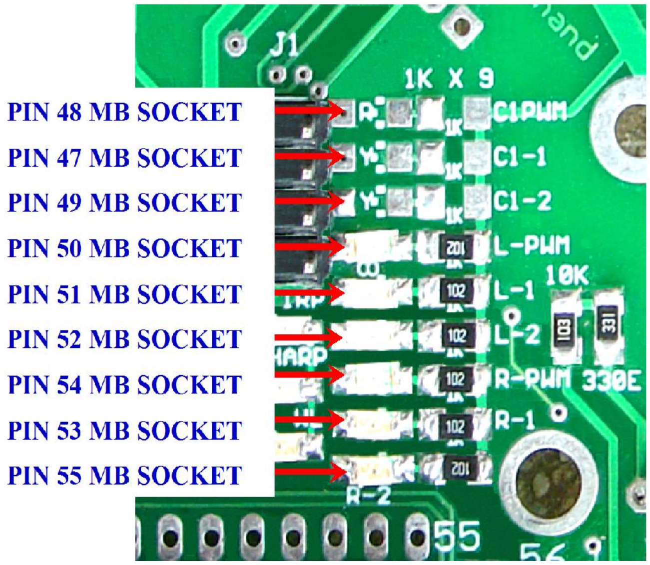


Figure 3.23: Motion status LED indication in terms of microcontroller adapter socket pin number

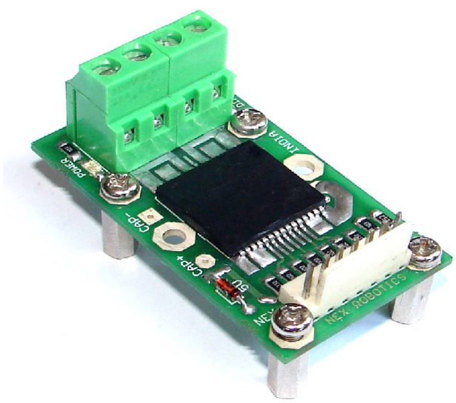
"5V system supply" is used for driving L293Ds logic circuits. "V Batt Mot" is used to supply power to the motors. C22 – C25 and C29 – C32 is used for noise suppression. Logic signals to drive the two L293D comes from the pins 47 to 55 and pins 66 to 68 of the microcontroller adapter board socket. Logic level on the pins 47 to 55 are also connected to the motion LEDs the main board as shown above.

uC PIN NO	Pin name	USED FOR	Status	Main Board Pin No.
5	OC3A/AIN1/PE3	PWM output for C2 motor drive	Output	68
38	OC5A/PL3	PWM for left motor.	Output	50
39	OC5B/PL4	PWM for right motor.	Output	54
40	OC5C/PL5	PWM for C1 motor.	Output	48
71	PA7 C2-2	Logic input 2 for C2 motor drive	Output	66
72	PA6 C2-1	Logic input 1 for C2 motor drive	Output	67
73	PA5 C1-2	Logic input 2 for C1 motor drive	Output	49
74	PA4 C1-1	Logic input 1 for C1 motor drive	Output	47
75	PA3	Logic input 1 for Right motor (Right back)	Output	53
76	PA2	Logic input 2 for Right motor (Right forward)	Output	55
77	PA1	Logic input 2 for Left motor (Left forward)	Output	52
78	PA0	Logic input 1 for Left motor (Left back)	Output	51

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

Connecting Fire Bird V robot board to bigger robot

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 their IC sockets. You can interface high power motor drivers such as Hercules or Hercules lite from NEX Robotics which can drive motors up to 36V and 30Amps to the external motor interface ports. Location of L293D ICs is shown in figure 3.18 and External Motor Interface port 1 and External Motor Interface Port 2 in figure 3.21.



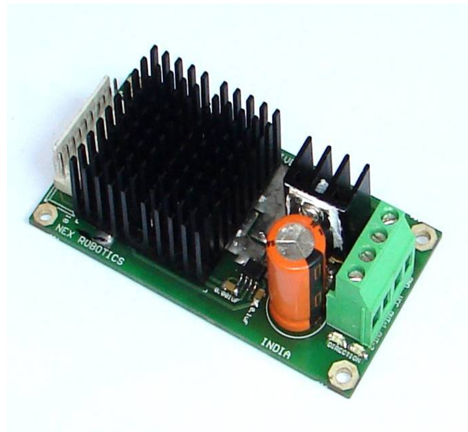


Figure 3.24: Hercules series 30Amp. Motor Drivers

Important:
Give high current power supply to the motor drivers directly without going through Fire Bird V's main board and make sure that Robot's ground and motor driver's ground are common.

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 as position encoder on the robot. It consists of IR LED and the photo transistor mounted in front of each other separated by a slot and encased in black opaque casing and facing each other through narrow window. 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 of MOC7811. 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.

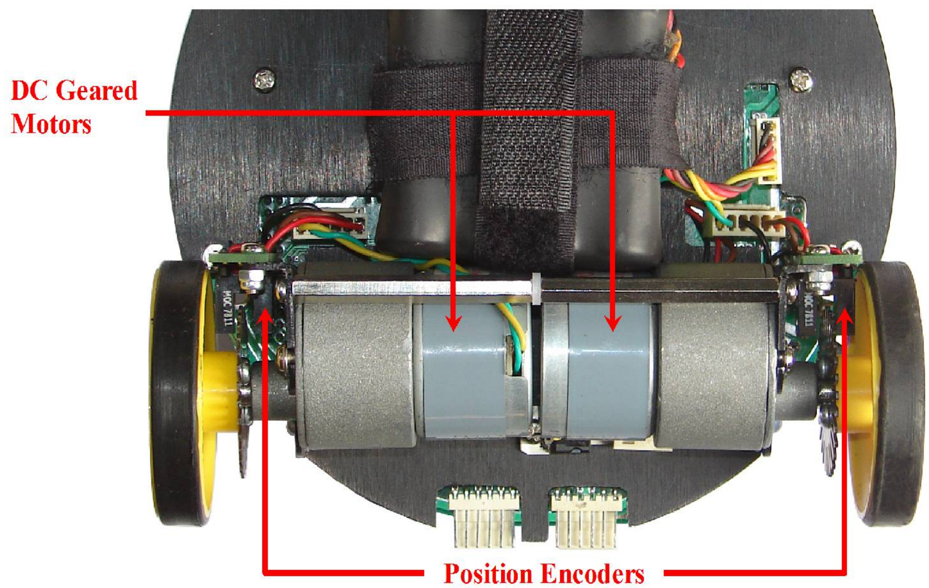


Figure 3.25: DC geared motors and position encoders

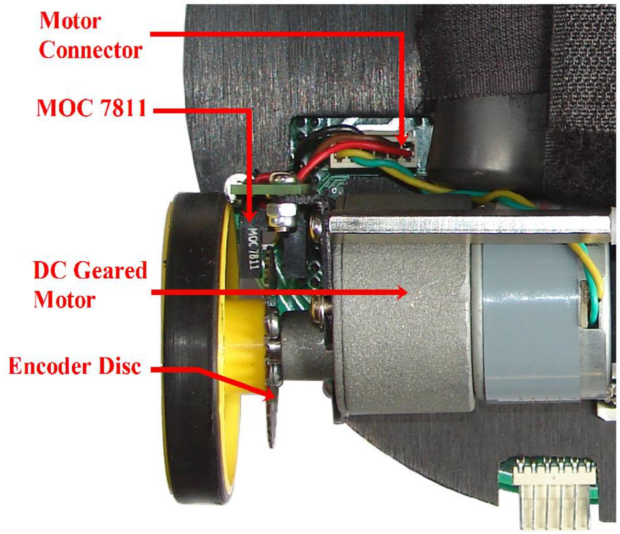
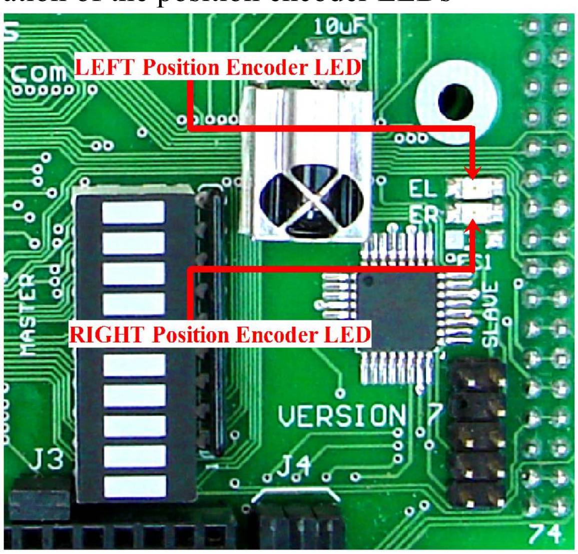


Figure 3.26: Position encoder assembly

Position encoder output is displayed on the microcontroller socket board. Figure 3.27 shows location of the position encoder LEDs



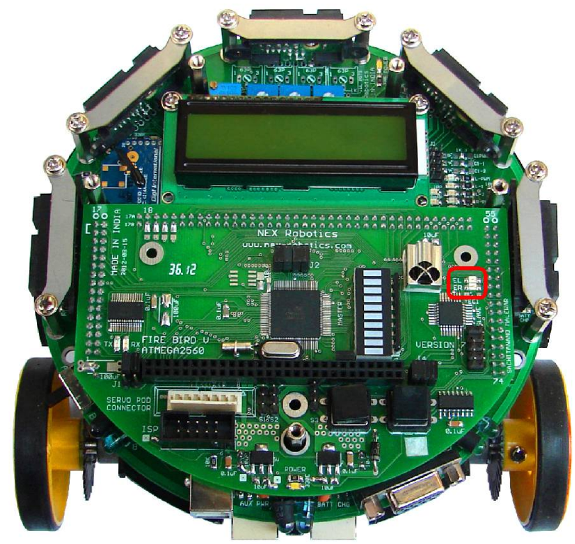


Figure 3.27: Position encoder pulse LEDs on ATMEGA2560 microcontroller adapter board

uC PIN NO	Pin name	USED FOR	Status	Main Board Pin No.
6	OC3B/INT4/PE4	External Interrupt for the left motor's position encoder	Input	62
7	OC3C/INT5/PE5	External Interrupt for the right motor's position encoder	Input	63
8	T3/INT6/PE6	External Interrupt for the C2 motor's position encoder	Input	64
9	CLK0/ICP3/INT7 / PE7	External Interrupt for Interrupt switch on the microcontroller board, External Interrupt for the C1 motor's position encoder *	Input	65

Table 3.8: Pin Connection of the position encoder's outputs

* Position encoder of the motor C1 is connected to the INT7 pin of the ATMEGA2560 microcontroller via soldering pad P1. INT7 interrupt pin is also connected to bootloader switch and TSOP1738 (via pad on microcontroller socket). If you want to use position encoder of C1, then make sure that bootloader code is removed from the the ATMEGA2560 microcontroller and soldering pad for TSOP1738 connection on the microcontroller socket is open. After these two precautions are taken, solder pad P1 on the main board to connect C1 motor's position encoder to the ATMEGA2560 microcontroller socket. This is very important. If not done then because of pulse from C1 motor's position encoder, ATMEGA2560 microcontroller will go in to boot mode. Figure 3.28 shows location of the pad P1 on the main board.

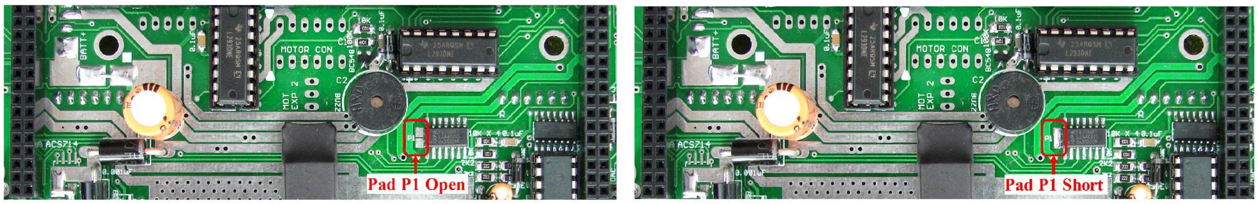


Figure 3.28: Pad P1 open and with short

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

3.10 Sharp IR range sensors

For accurate distance measurement, robot uses Sharp IR range sensors. 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 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 0mm 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.

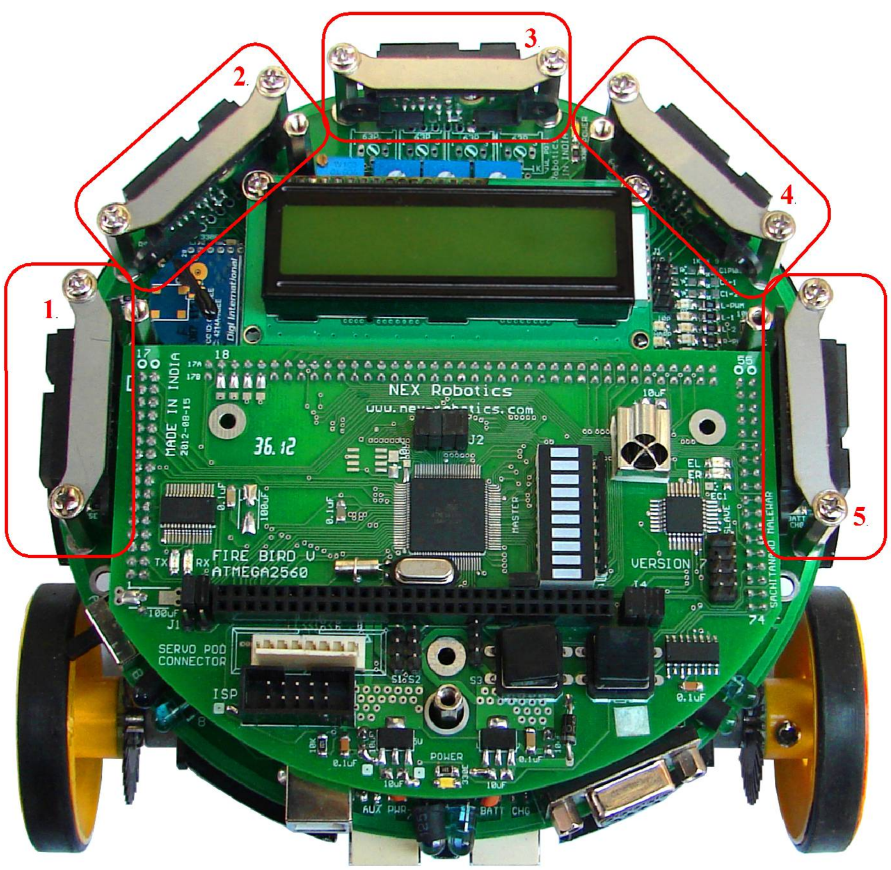


Figure 3.29: Sharp Sensors mounted on Fire Bird V

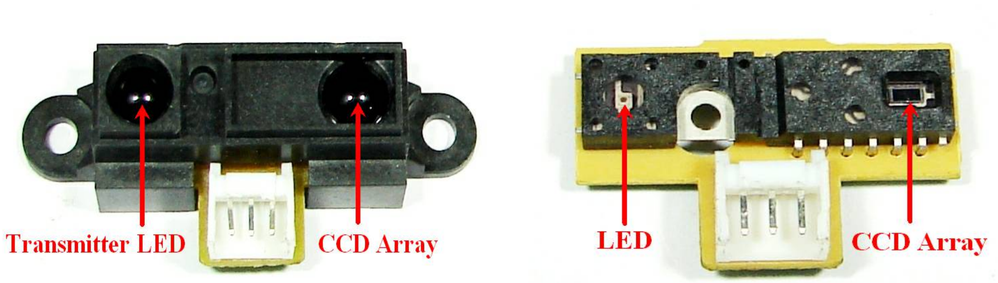


Figure 3.30: Infrared Range finder sensor and its inside view

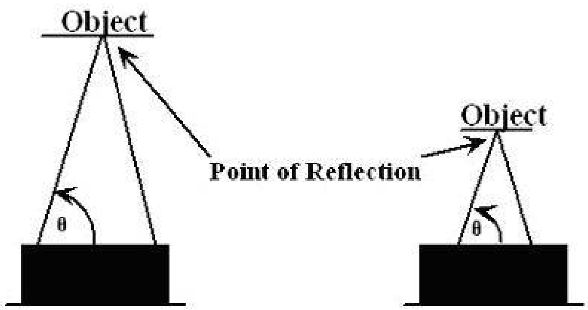


Figure 3.31: Distance measurement based on angel of reflection

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
GP2Y0A02YK	80cm to 10cm	10cm to 0cm
GP2Y0A02	150cm to 20cm	20cm to 0cm

Table 3.9: Sharp IR Range sensors coverage

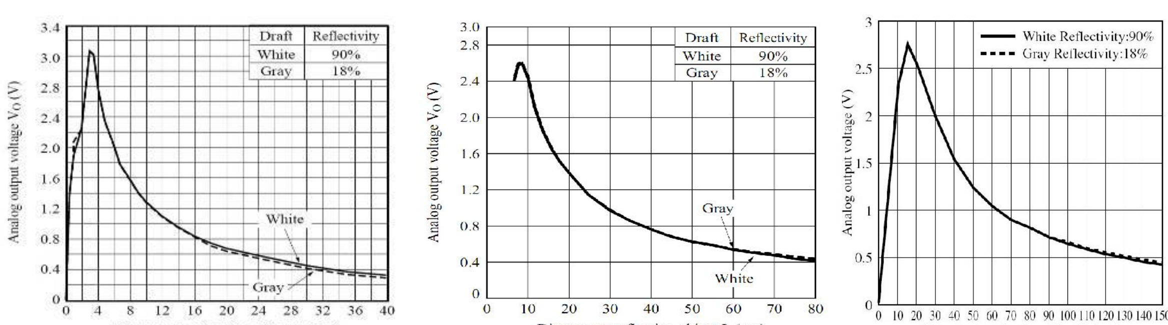


Figure 3.33: Distance Vs. Output voltage of GP2D120, GP2Y0A02YK and GP2Y0A02YK

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 GP2Y0A02YK =
(int)(10.00 * (2799.6 * (1.00 / (float)((double)(ADC_Value)^(double)(1.1546)))));

UC PIN No.	Pin name	USED FOR	UC pin correct I/O setting
15	OC4A/PH3	Sharp IR ranges sensor 1 to 5 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 3.10: Connections of the Sharp IR range sensors and its power control MOSFETs with the ATMEGA2560 microcontroller

* Sharp IR range sensor enabling and disabling is covered in section 3.10A

3.10A Avoiding sensor interference in multirobot environment

Many of the sensors used in the Fire Bird V emits some sort of signals to sense the object such as Sharp IR range sensors, ultrasonic range sensors, IR proximity sensors, white line sensors etc. All these sensors are known as active sensors.

If many robots with such active sensors are placed in same space then their sensors will interfere with each other. Only way to operate many robots in same space without jamming each other sensor is to use, sensors on each robots in time division multiplexing way. This can be done by synchronizing each robot's sensor switching using wireless modules such as XBee, WiFi or Bluetooth of the robots.

All the sensors on the Fire Bird V robots can be turned on or off by software. This enables Fire Bird V to work in multirobot environment without jamming each other.

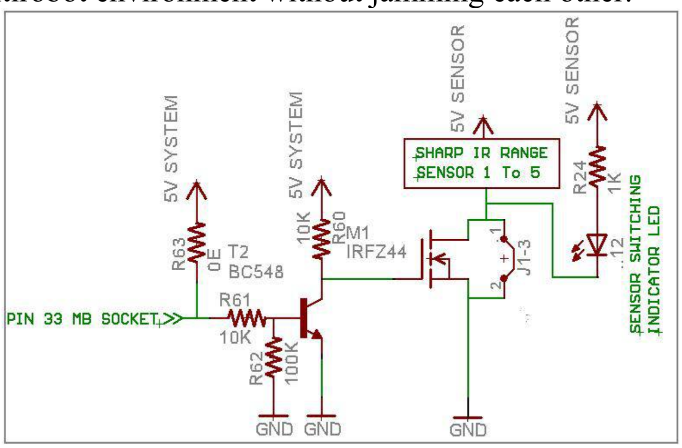


Figure 3.34: Sharp IR range sensor's power control circuit

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 MOSFET and jumper which controls switching on/off of the sensors. Sharp IR range sensor 1 to 5 are controlled by the MOSFET M1. PH3 (pin15) of the ATMEGA2560 microcontroller is connected to the Sharp IR range sensor's power switching circuit via pin 33 of the main board socket. Sharp sensors can be turned on and off by switching circuit via microcontroller when Jumper J1-3 shown in figure 3.34 is open (absent). If jumper is inserted then sensors remain permanently ON. Microcontroller will no be able to turn them OFF the sensor once this jumper is inserted.

When microcontroller's pin is at logic low, Transistor T2 is off hence gate of MOSFET M1 is pulled up at 5V which turns on the MOSFET which turns on the Sharp IR range sensors. When Logic 1 is applied at the base of transistor T2 it gets turn on and it pulls down the gate of the MOSFET M1 to turn it OFF. Location of the jumper is shown in figure 3.38.

Same way White line sensors and IR proximity sensors can be switched ON and OFF, which can bee permanently turned ON by placing respective jumpers. Their switching circuits are discussed in their respective topics.

Sensors	Main board socket pin number	ATMEGA2560 uC Pin	Logic state
Sharp IR range sensor 1 to 5	33	PH3 (pin 15)	0: Sensors are turned on
			1: Sensors are turned off
white line sensors (left, center, right)	40	PG2 (pin 70)	0: Sensors are turned on
			1: Sensors are turned off
IR proximity sensors 1 to 8	34	PH3 (pin 14)	0: Sensors are turned on
			1: Sensors are turned off

Table 3.11: Sensor power control pins and jumpers (Assuming corresponding jumper at J1 is open)

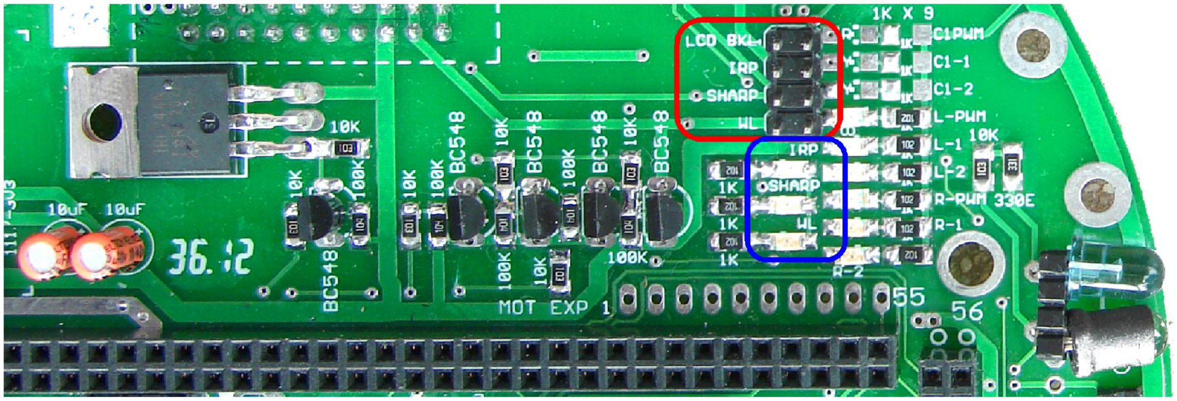


Figure 3.35: Sensor status indicator LEDs

Jumper 1 set is shown by red rectangle in figure 3.35. It consists of set of 4 jumpers. On / Off status of the sensor is shown by 3 yellow LEDs are highlighted by blue rectangle. ON LEDs indicate that sensor is ON. Table 3.11A shows the functions of these jumpers and corresponding sensor power indicating LEDs.

Jumper Name	Function (If jumper is inserted)	Sensor power indicating LED name	Current consumption
J1-1(LCD BKL)	Turn on LCD back light	LCD Back-light	20mA
J1-2(IRP)	Turns on all 8 IR proximity sensors	IRP	51mA (all 8 IR proximity sensors)
J1-3(SHARP)	Turns on installed Sharp IR range sensors	SHARP	25mA per sensor installed
J4-1(WL)	Turns on all white line sensors	WL	16mA typical for 3 channel white line sensor

Table 3.11A: Sensor power on Jumpers and LED indicators

Important

- Robots are factory shipped with all jumpers inserted. So as per factory setting all sensors will remain permanently ON. If you are not going to switch sensors on/off using MOSFETs then leave jumpers as it is.
- 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.

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 IR 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 same 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 photo diode will be around 3.3V. 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.

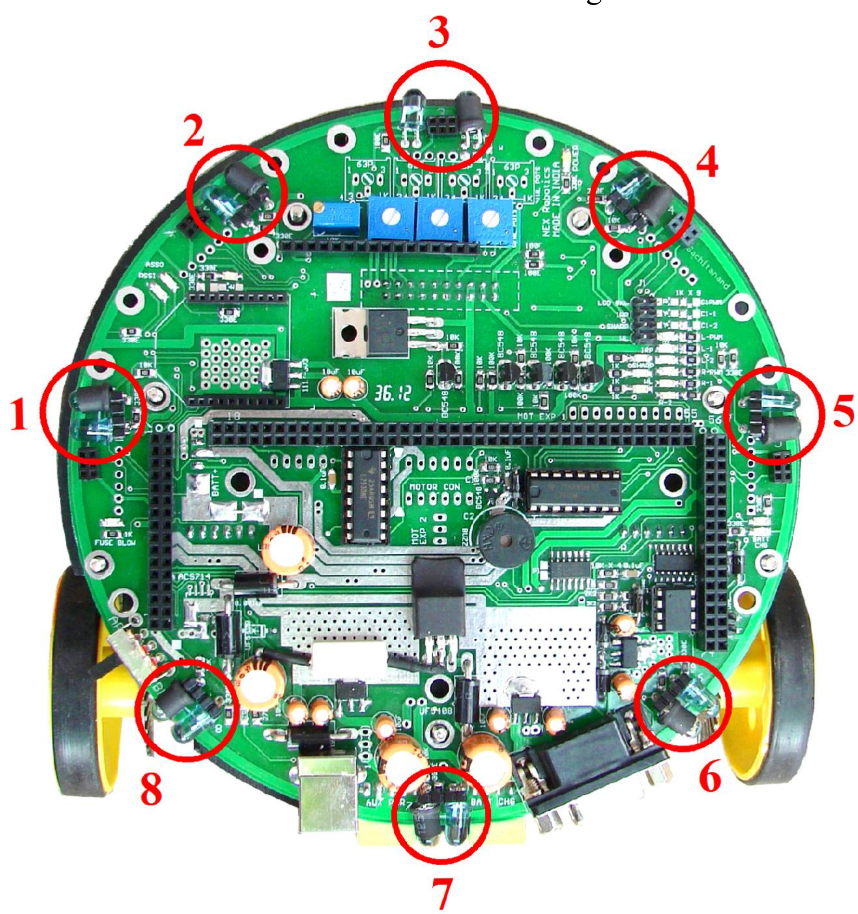


Figure 3.36: Eight IR proximity sensors on Fire Bird V

When enabled 8 IR proximity sensors combined together consumes about 51mA current. You can save power by turning on theses sensors only when required. Refer to table 3.11, these sensors can be turned off by applying logic 1 (5V) to the pin no. 34 of the main board. To enable these sensors permanently connect the IRP jumper on J1 of main board. For jumper location refer to figure 3.38.

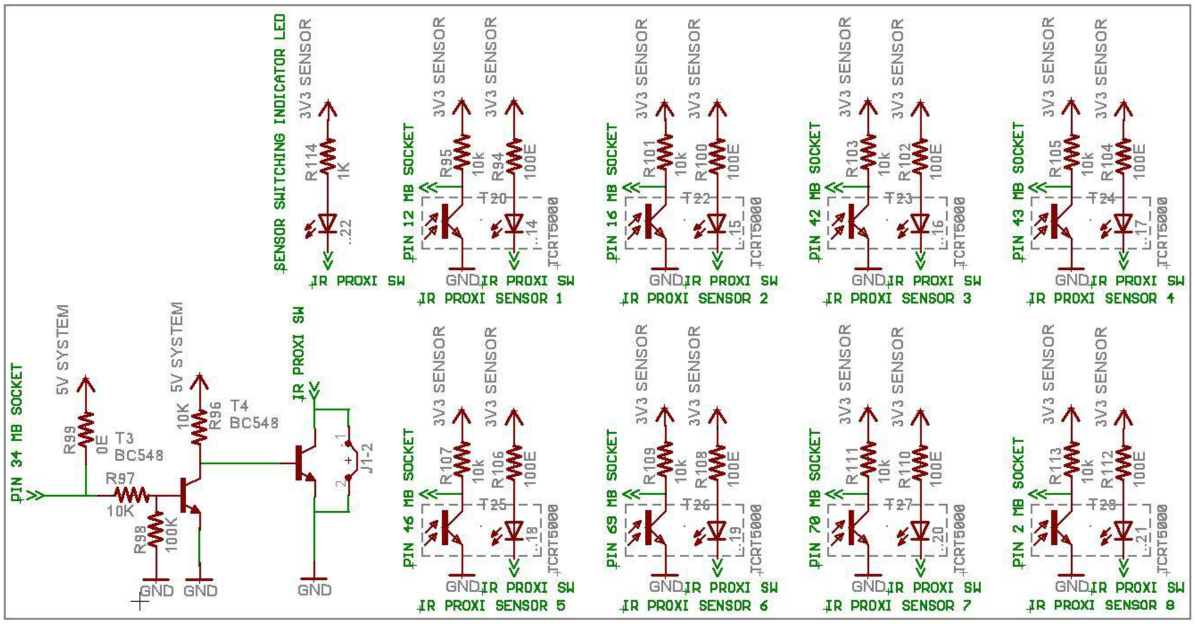


Figure 3.37: IR Proximity sensors

Figure 3.37 shows IR proximity senator's circuit. IR proximity sensors 1 to 5 are connected to m the ATMEGA2560 main microcontroller and IR proximity sensors 6 to 8 are connected to the ATMEGA8 slave microcontroller.

Power switching circuit for IR Proximity sensors is shown in bottom left corner of figure 3.37. Sensors can be permanently turned by inserting jumper. For location of the jumper, refer to figure 3.38. You can turn on / off this sensor if this jumper is open. If logic 1 is applied to the base of the transistor T3 by the microcontroller then it goes in to saturation and pulls base of the transistor T4 and turns off the T4 and IR proximity sensors. When no signal is applied transistor T3 remains off hence resistor R96 drives transistor T4 in to saturation and T4 turns on the IR proximity sensor's IR LEDs.

Important:
You can also use IR proximity sensor's photo diode as directional light intensity sensor by turning off IR LEDs. You can also remove effect of ambient light on the proximity detection by taking reading while IR LED is on and off and checking difference between the readings.

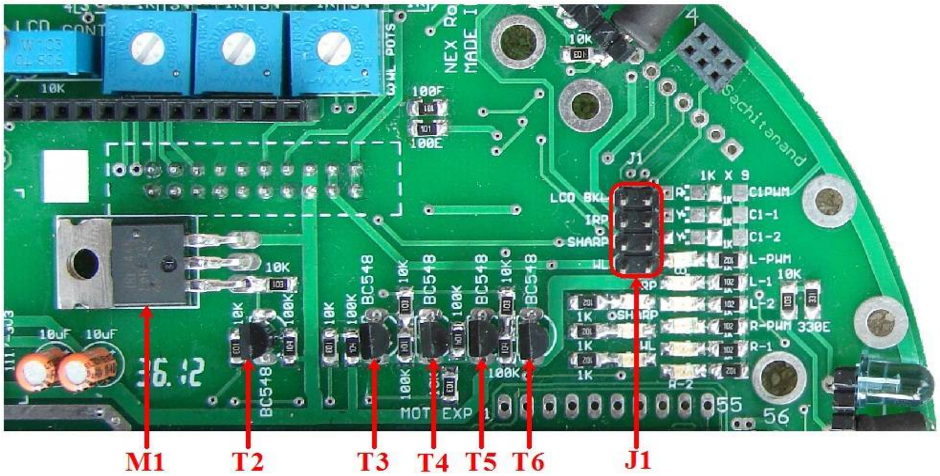


Figure 3.38: Sensor Control Switches and Jumpers

Name	Function
J1	LCD Back-light Enable/Disable jumper IR proximity sensor Enable/Disable jumper Sharp sensor Enable/Disable jumper White line sensor Enable/Disable jumper
M1 & T2	MOSFET M1 and Transistor T2 for Sharp IR range sensors switching
T3 & T4	Transistor T3 and T4 for IR Proximity Sensor switching
T5 & T6	Transistor T5 and T6 for White Line Sensor switching

Table 3.12: Sensor Control Switches and Jumpers functions

PINNO	Pin name (ATMEGA2560 master uC)	USED FOR	Status
15	XCK2/ PH2	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 transistor with the ATMEGA2560 microcontroller (main 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 adapter 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 (ATMEGA8 slave uC)	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)

*** In System programming and Multi-processor communication between master and salve microcontroller**

MOSI, MISO, SCK and SS pins of ATMEGA2560 (master microcontroller) are connected to the ISP (In System programming) port as well as the SPI bus of ATMEGA8 (slave microcontroller). Hence to do ISP you need to disconnect jumper J4 on the microcontroller adaptor board. To access data from the slave microcontroller ATMEGA8 over SPI bus Jumper J4 on the microcontroller socket needs to be connected.

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 photo diode it does not get affected with ambient light unless it is very bright.

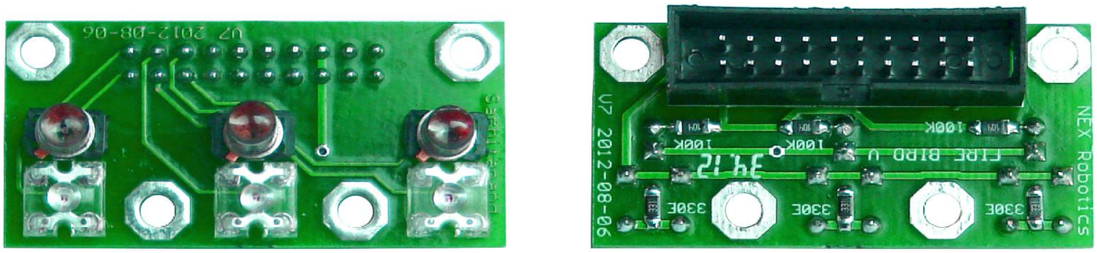


Figure 3.39: White line sensor

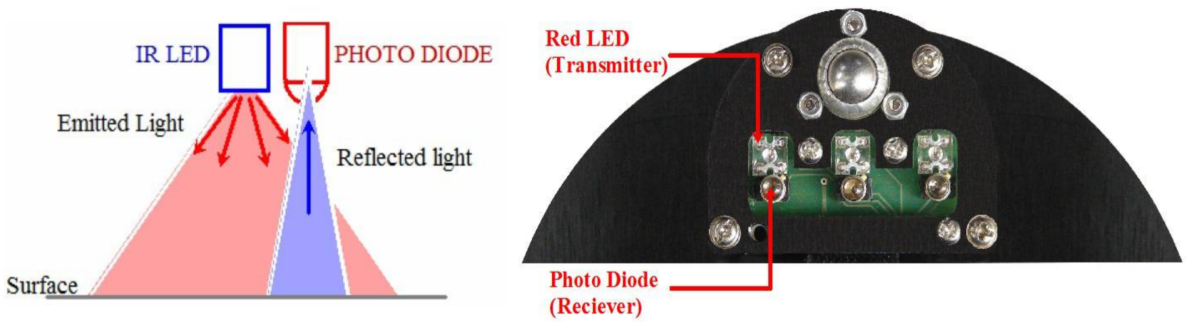


Figure 3.40: White Line sensor

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 3.3V. 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 of white line sensor is controlled PG5 of ATMEGA2560 microcontroller to extend robot's battery life. Switching action of the power control circuit is exactly same as power switching circuit of IR proximity sensors as discussed in section 3.11. Line sensors can be permanently turned on by inserting jumper in the Jumper J1-4. For more information refer to figure 3.35 and table 3.11.

Figure 3.41a shows schematic of the whiteline sensor module on the main board and figure 3.42 shows location of potentiometers for the white line sensor calibration. Standard Fire Bird V robot has 3 channel white line sensor module. It can also be seamlessly upgraded to 7 channel white line sensor module using the same connector. Main board has potentiomenters for 7 ch white line sensors. For more information regarding upgrade, refer to the application note in the application notes section in the documentation CD.

Important:
Standard Fire Bird V robot is shipped with 3 potentiomentrs for 3 channel white line sensor module. Additional 4 potentiomenters can be readly soldered on the main board. Figure 3.42 shows all seven potentiomenters but robot is shipped with only 3 potentiomentrs for left, centre and right side white line sensor.

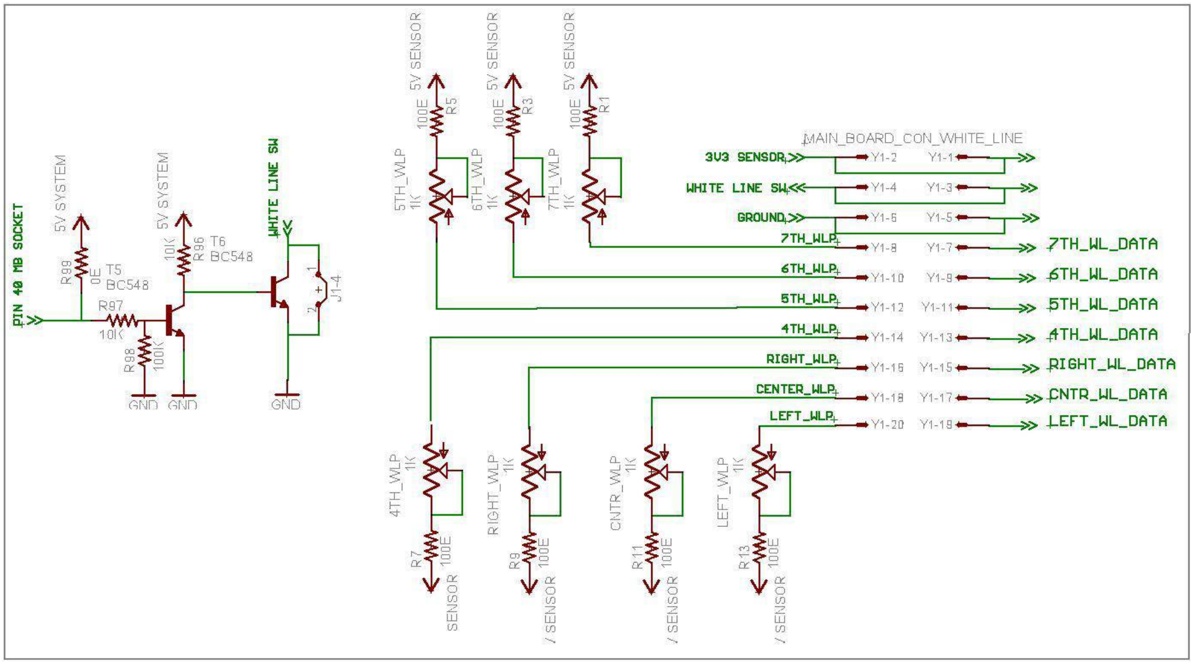


Figure 3.41a. White line sensor module on main board schematic

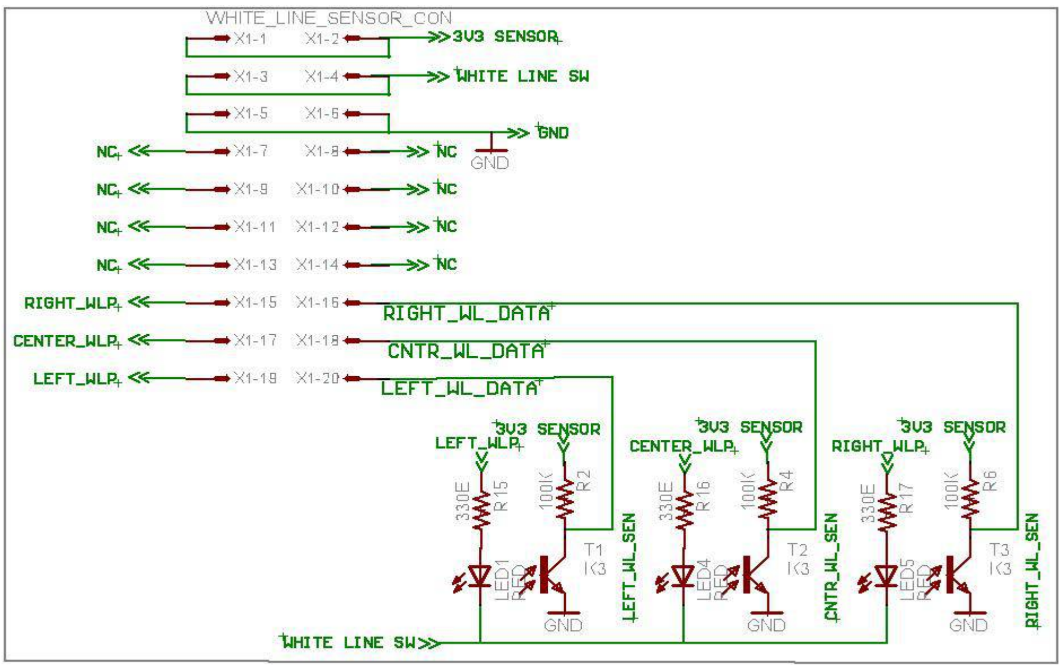


Figure 3.41b. White line sensor PCB schematic

Note:
White line sensor number 4 t o7 uses ADC of the ATMEGA8 slave microcontroller.

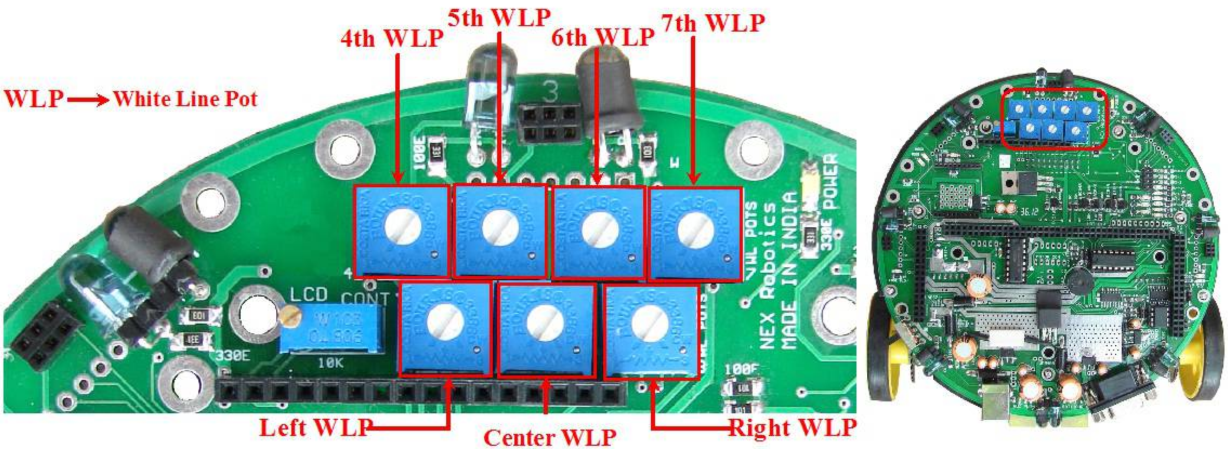


Figure 3.42: Potentiometers for white line sensor calibration

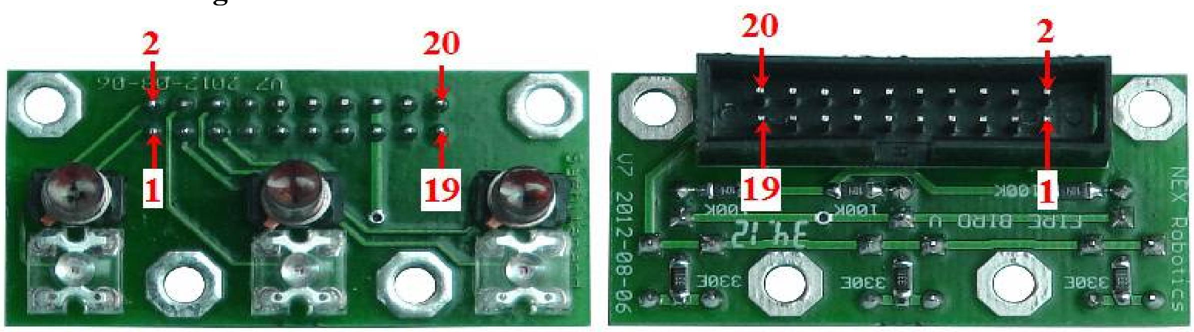


Figure 3.43: White line sensor pin connections (White line Sensor Board)

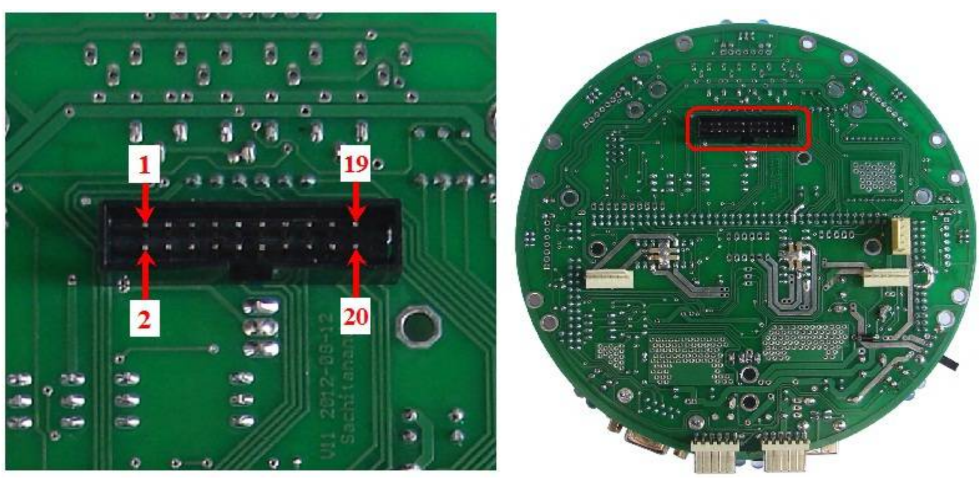


Figure 3.44: White line white line sensor connector pin configuration on main board

Pin No.	Function
1	White line sensor 1 (Left sensor) Data Out
2	White line sensor 1 LED via potentiometer
3	White line sensor 2 (Center Sensor) Data Out
4	White line sensor 2 LED via potentiometer
5	White line sensor 3 (Right sensor) Data Out
6	White line sensor 3 LED via potentiometer
7	White line sensor 4 Data Out
8	White line sensor 4 LED via potentiometer*

9	White line sensor 5 Data Out
10	White line sensor 5 LED via potentiometer*
11	White line sensor 6 Data Out
12	White line sensor 6 LED via potentiometer*
13	White line sensor 7 Data Out
14	White line sensor 7 LED via potentiometer*
15	GND
16	GND
17	White Line switch(Jumper). Refer to figure 3.41a and 3.41b
18	White Line switch(Jumper). Refer to figure 3.41a and 3.41b
19	3V3 Sensor supply
20	3V3 Sensor supply

Table 3.15: White line sensor pin connections

* Potentiometers for white line sensor no. 5 to 7 needs to be soldered and are not included in the package. They are not soldered at the factory.

Pin No	ATMEGA2560 master microcontroller 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	Channel 3 for ADC Left input for white line sensor	Input (Floating)
95	PF2/ADC2	Channel 2 for ADC Center input for white line sensor	Input (Floating)
96	PF1/ADC1	Channel 1 for ADC Right input for white line sensor	Input (Floating)

Table 3.16 White line sensor connections with ADC of ATMEGA2560 (Master microcontroller)

* For more details refer to section 3.10 and 3.12.

Pin No.	ATMEGA8 slave microcontroller 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)

*** In System programming and Multi-processor communication between master and salve microcontroller**
MOSI, MISO, SCK and SS pins of ATMEGA2560 (master microcontroller) are connected to the ISP (In System programming) port as well as the SPI bus of ATMEGA8 (slave microcontroller). Hence to do ISP you need to disconnect jumper J4 on the microcontroller adaptor board. To access data from the slave microcontroller ATMEGA8 over SPI bus Jumper J4 on the microcontroller socket needs to be connected.

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. Robot comes with a flex stripe printed white line. You can use it to calibrrate robots white line sensors by putting them on blace and white sensors.

Effect of ambient light on the white line sensors

White line sensors are highly directional in nature hence they are immune to the illumination from tube light or CFL. Note that tube light which uses simple inductive chock actually blinks 50 times a second and this blink is captured by the white line sensors as ADC can acquire data at very fast rates. Hence it is recommended that use CFL lights or tube lights with electronic chock or ballast. These tube lights are the one which turns on like a bulb without flickering.

White line sensors are essentially sensitive photo transistors with precision lens assembly. All the photo diodes and photo transistors are many times sensitive to infrared than to red light. Hence for consistent result avoid room which have large windows even if they have curtains. Also avoid using robots in area illuminated with filament based bulbs as they have large infrared light radiation

Why red LEDs are used instead of IR LEDs in the white line sensors?
Photo transistors are many times sensitive to IR than to visible light but we still use red light illumination because of following reasons:

- Red light is nearer to the infrared
- Since we can see red light its easier to calibrate it using eyes
- Any color appears black because it does not reflect visible light. Which means black surface can be ultraviolet or infrared in color. If black is infrared color then robot's white line sensors will not be able to distinguish between white and black as black will reflect all infrared waves as effectively as white surface. In case of red illumination which has very less infrared radiation even infrared black is still considered as black which makes red light as color of choice.

3.12A Ultrasonic sensor Interfacing:

Fire Bird V primarily uses Sharp IR range sensors but sometime they are not easily available in market. In year 2010 and 2011 they ware in acute shortage. Hence Fire Bird V's main board version 11 also have support for ultrasonic range sensors. But as a designer I will always prefer Sharp IR range sensors.

FireBird V robot can be equipped with the 5 ultrasonic sensors from MaxBotix. Each sensor can sense distance range from 6 inches to 254 inches. Ultrasonic sensor transmits a narrow beam of ultrasonic pulse and measures time taken for echo of the beam. It gives output proportional to time taken for the ultrasonic beam to return echo from the obstacle.

FireBird V robot supports almost all compact ultrasonic range sensors from MaxBotix. Most of the time robot uses EZ0 to EZ4 series sensors from MaxBotix. Sensor gives out analog output with 1 inch resolution. It gives output voltage of 9.8mV per inch. After powering up, for first 100mS sensor runs calibration cycle. After that it can give readings with 49mS interval.

Figure below shows locations of the ultrasonic sensors. They are numbered as 1 to 5 from left to right in clockwise direction.

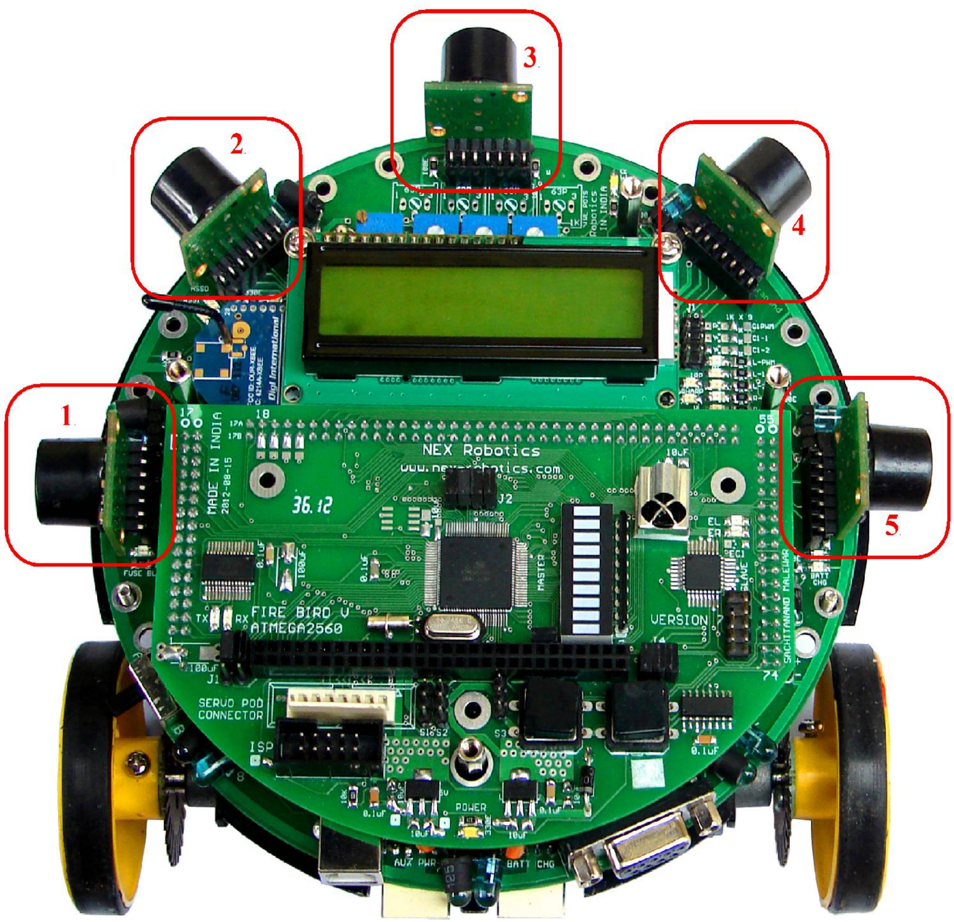


Figure 3.44a: Five Ultrasonic Range Sensors on Fire Bird V

Enabling the Ultrasonic range sensors

The analog output of sharp sensor and analog output of Ultrasonic sensor is connected to the same ADC channels of the microcontroller. Therefore at any given sensor location either Sharp sensor or Ultrasonic range sensor can be used. Both sensors can not remain active at the same time.

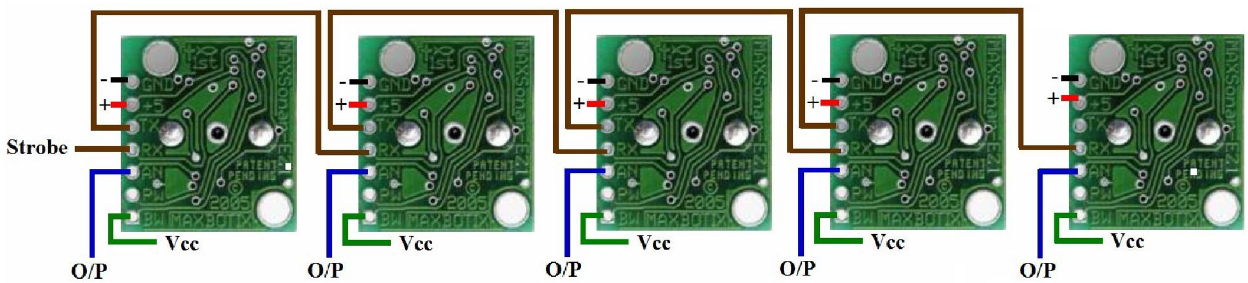


Figure 3.44b: Ultrasonic range sensor daisy chaining (courtesy: MaxBotix website)

If many of the sensors transmit ultrasound simultaneously their reading will get mixed-up. In order to prevent this, all the ultrasonic sensors are connected in the daisy chain. Microcontroller sends a trigger to the first ultrasonic sensor. First sensor takes the distance reading and sends trigger to the second sensor. Second sensor follows the same process. This makes sure that at any given time only one sensor transmits ultrasound.

Above figure shows sensor daisy chaining. Sensor 1's TX pin is connected to the Sensor 2's RX pin and so on. In this way all 5 sensors are daisy chained. To enable the daisy chaining mode, pin "BW" of the each ultrasonic sensor must be tied to Vcc. All sensors are powered at 3.3V sensor supply.

To start taking reading a small trigger pules of more than 100uS needs to be given to the "RX" pin of the first sensor. This pin is connected to the pin PH4 of the ATMEGA2560 microcontroller via pin 17B* of the main board socket. "RX" pin of the 5^{th} ultrasonic range sensor is left open. After triggering a Sensor 1, Sensor 1 transmits ultrasonic pulse and gives out distance reading within 49mS. Sensor 1 triggers the Sensor 2 by transmitting a small pulse on its TX pin to the RX pin of the second sensor. Now Sensor 2 takes reading. In this way sensor in the daisy chain takes distance reading one at a time and triggers the next sensor connected. After all 5 sensors takes reading this process stops. You need to give trigger at the 1^{st} sensor again.

You can trigger 1^{st} sensor at the interval of 49ms x 5 sensors = 245ms if you want to insure that only one sensor remains active at a time. This is the most recommended time interval. It is also possible to keep more than one sensor preferably 90 degrees apart active by giving trigger at the interval of 49ms x 2 sensors = 98mS for faster refresh rate but readings may get affected in small room because of echos from other sensors. Figure 3.44c shows the schematics of the ultrasonic ranges sensors.

*. We need to cut the track of 17B to PH4 pin at bottom side of microcontroller board, please refer the errata section in this manual.

Important

1. You need to connect pin BW of the ultrasonic range sensor to the 3.3V manually.
2. If you want to install only one ultrasonic sensor, say sensor number 3 then you need to short(hard wire) the pins "TX" and "RX" of the sensors which comes before this sensor (in this case 1 and 2), so that trigger from microcontroller can reach the installed sensor.

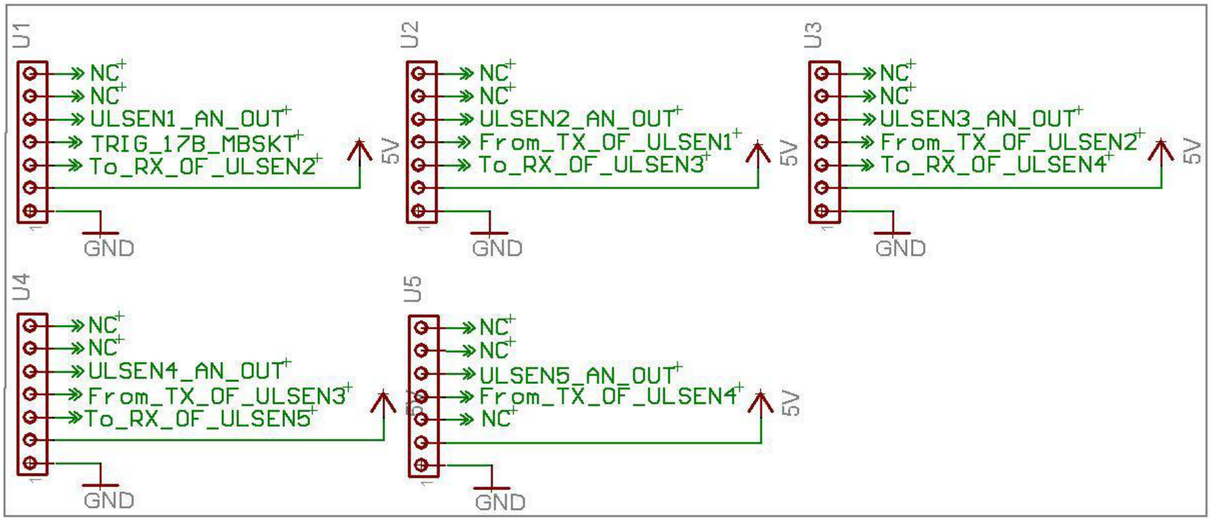


Figure 3.44c: Ultrasonic Range Sensor interfacing and jumper settings

Supported Ultrasonic range sensors

FireBird V robot mainly uses EZ0 to EZ4 sensors from MaxBotix. All these sensors are available on NEX Robotics website. Other sensors from MaxBotix having compatible pin mapping can also be used instead of these sensors. For more details on compatibility, refer to the respective sensor's datasheet.

EZ0 to EZ4 sensors have progressively more directionality. Refer to below figure to get rough idea of the sensor characteristics.

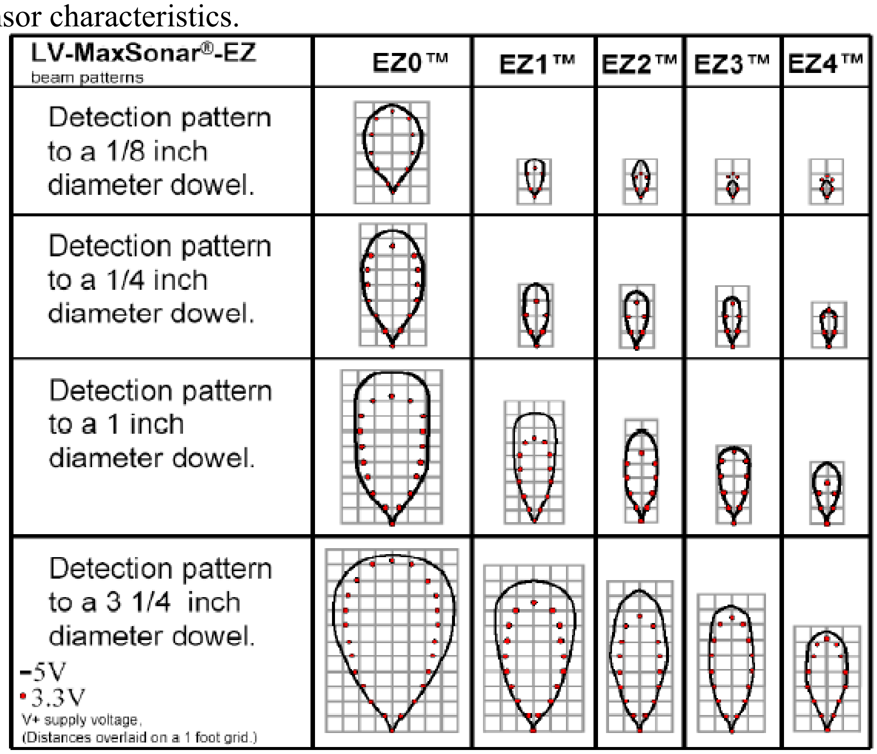


Figure 3.44d: Range Shown on 1-foot grid to various diameter dowels (courtesy: MaxBotix website)

Mounting Ultrasonic range sensors:

Fire Bird V robot's main board has empty slots for the ultrasonic range sensor mounting. You can directly solder them using right angled male berg strip or you can solder flow solder (female berg strip) on the main board and insert sensor which is already soldered to right angled male berg stripe. Once you solder female berg strip on the main board, you can not insert Sharp IR range sensor in to it.

Ultrasonic range sensors have wider beam angle. Even if they mounted in with sensor exactly right angled to the main board it will see ground few meters ahead. It is good idea to solder them directly on main board and slight bend them upward.

3.13 LCD Interfacing

LCD can be interfaced in 8bit or 4 bit interfacing mode. In 8 bit mode it requires 3 control line and 8 data lines. To reduce number of I/Os required, Fire Bird V robot uses 4 bit interfacing mode which requires 3 control lines and 4 data lines. In this mode upper and lower nibble of the data/command byte needs to be sent separately. Figure 3.47 shows LCD interfacing in 4 bit mode with three control lines EN (Enable), RS (Register Select), and RW (Read / Write).

The EN line 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 connected to PC0. When RS is low (0), data is treated as a command or special instruction by the LCD (such as clear screen, position cursor, etc.). When RS is high (1), data being sent is treated as text data which should be displayed on the screen.

The RW line 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. Refer LCD datasheet provided in documentation CD for using Busy flag.

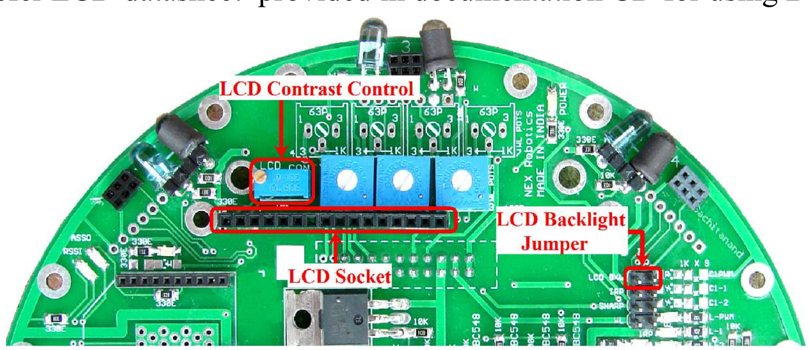


Figure 3.45: LCD socket and other settings

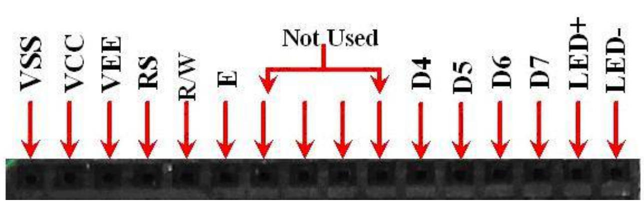


Figure 3.46: LCD socket pin connection

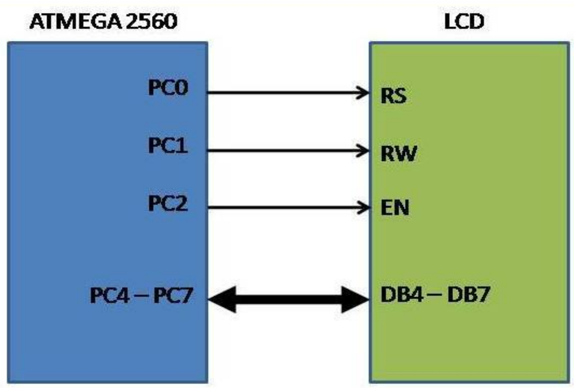


Figure 3.47 LCD interfacing with the microcontroller

ATMEGA2560 Microcontroller Pins	LCD PINS	Description	Main Board Pins Numbers
VCC	VCC	Supply voltage (5V).	----
GND	GND	Ground	----
PC0	RS (Control line)	Register Select	22
PC1	R/W (Control line)	READ /WRITE	23
PC2	EN (Control Line)	Enable	24
PC4 to PC7	D4 to D7 (Data lines)	Bidirectional data Bus	26 to 28
--	LED+, LED-	Back light control	----

Table 3.18: LCD Pin mapping and functions

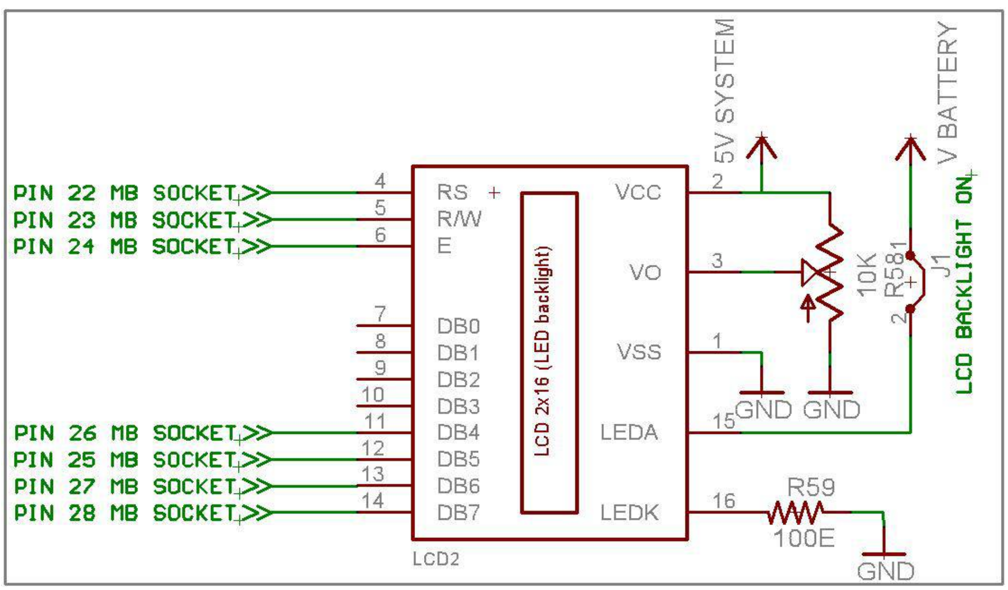


Figure 3.48: LCD display schematics

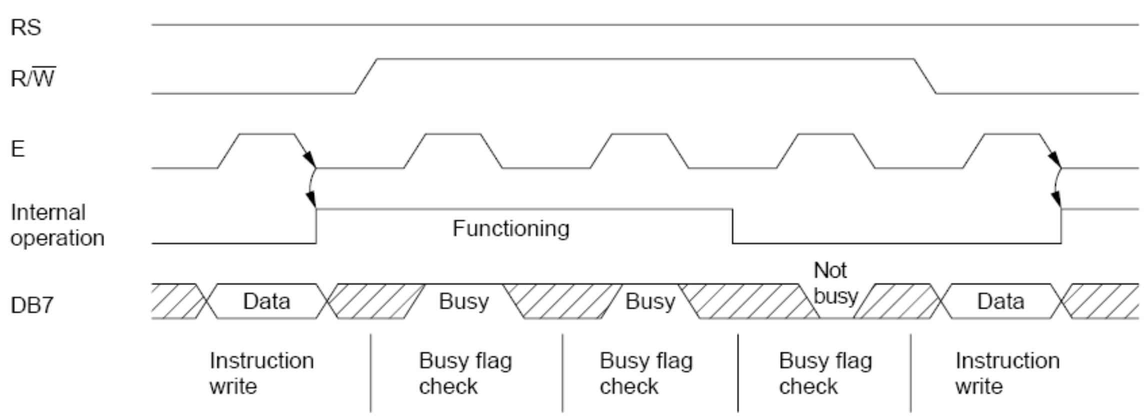


Figure 3.49: LCD Timing Diagram.

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. Also the same buzzer is used in battery monitoring circuit to alert the battery low indication.

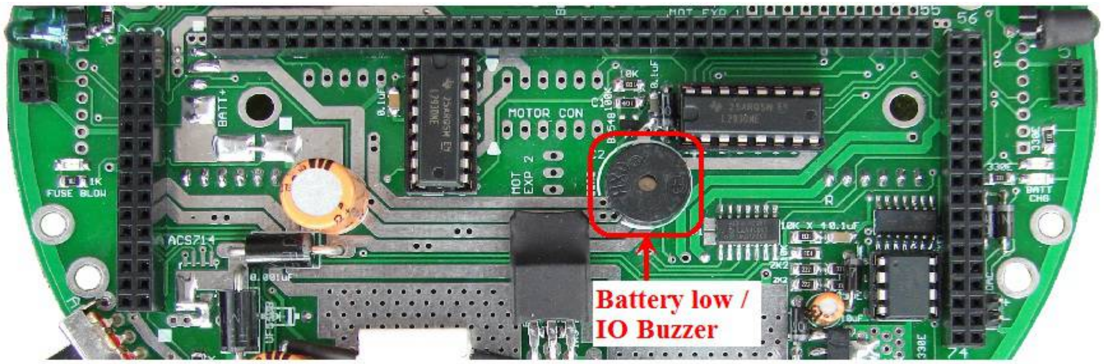


Figure 3.50: Buzzer

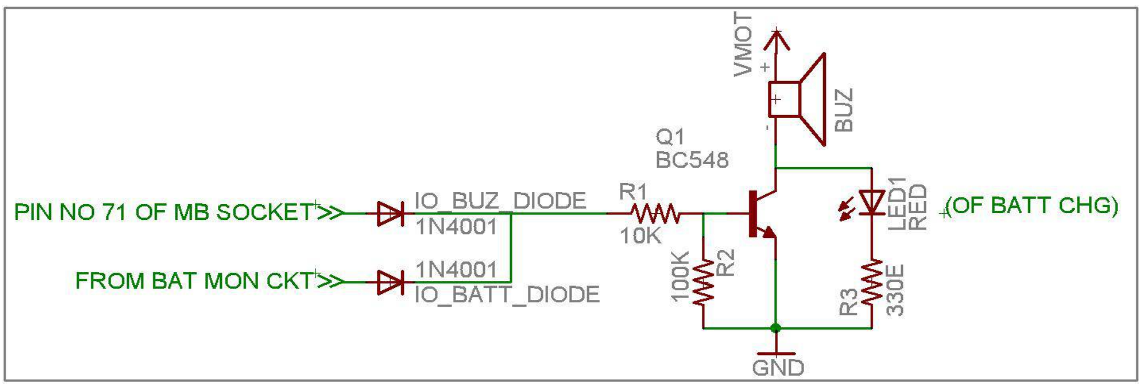


Figure 3.51: Buzzer Schematic

Buzzer is driven by BC548 transistor. Resistor 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

Main board has SPI connector for adding accessories such as robotic arm, color sensor etc. Figure 3.52 shows its location on the main board and figure 3.52a shows its connections.

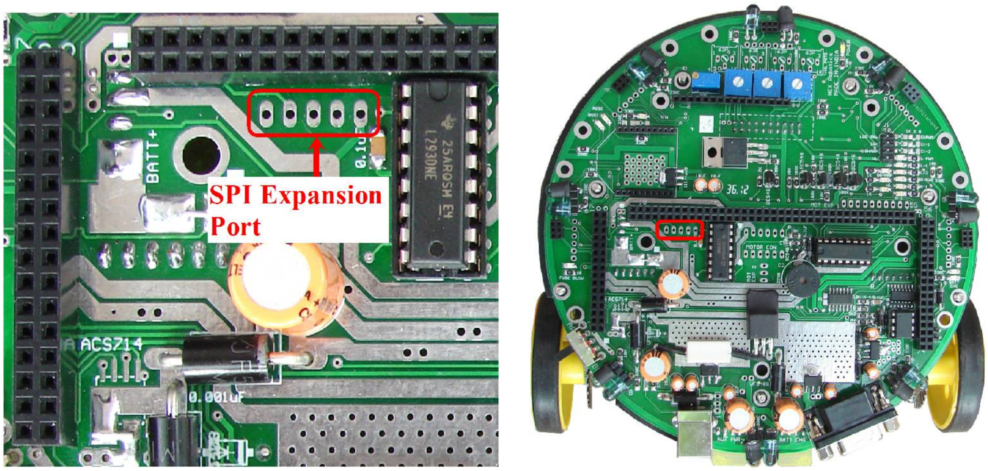


Figure 3.52: SPI expansion port pins

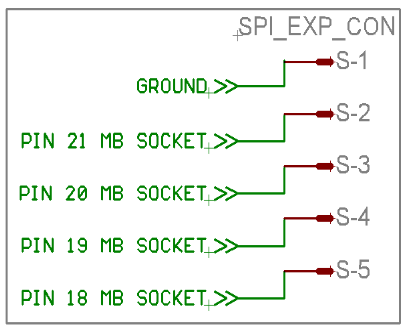


Figure 3.52a: SPI expansion port pins

3.16 Serial Communication

Robot has 9pin female DB9 connector for serial communication. Out of these 9 pins only Tx (pin 3) Rx (pin 2) and ground (pin 5) are connected to the microcontroller via MAX202 RS232 to serial TTL / CMOS logic converter. Figure 3.53 shows location of the serial on main board. Figure 3.54 shows schematic. Table 3.19 shows the connections of the serial port.

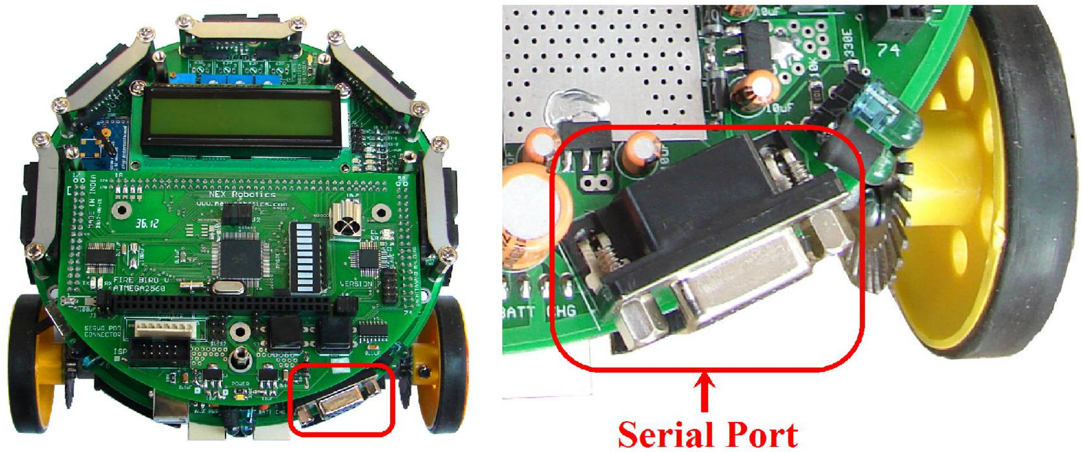


Figure 3.53: Serial port pins

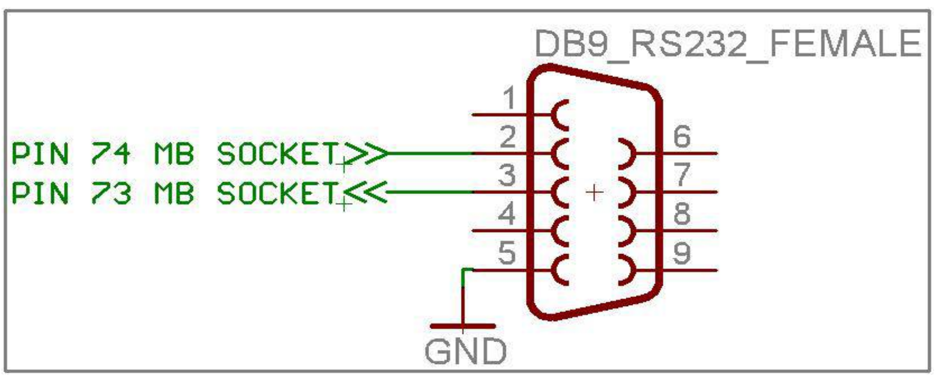


Figure 3.54: Serial port connections with the main board socket

Pin No.	Description	Main Board pin numbers
2	Receiver Data (RXD)	Pin 74
3	Transmit Data (TXD)	Pin 75
5	Signal Ground (GND)	Ground

Table 3.19: Serial port pin out

3.17 USB communication

Fire Bird V's main board has USB port socket. Microcontroller accesses USB port via main board socket. All its pins are connected to the microcontroller adapter board via main board's socket connector.

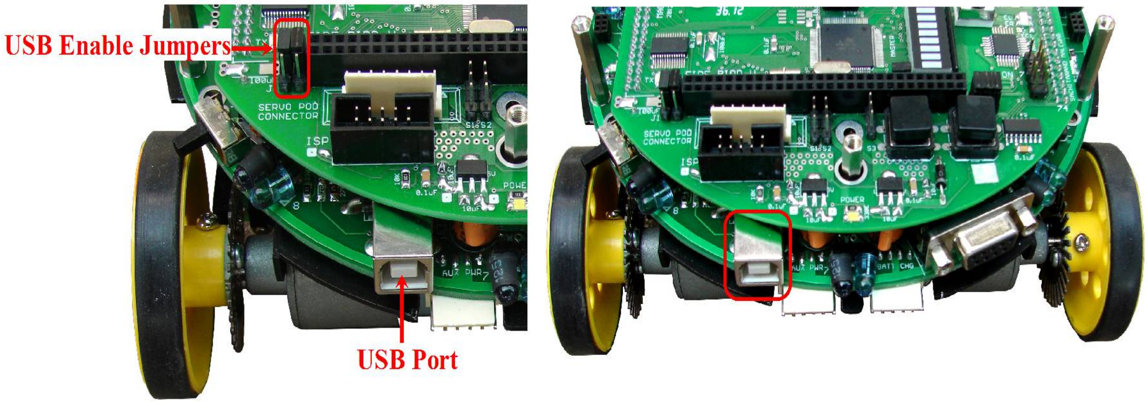


Figure 3.55: USB port on the Fire Bird V main board

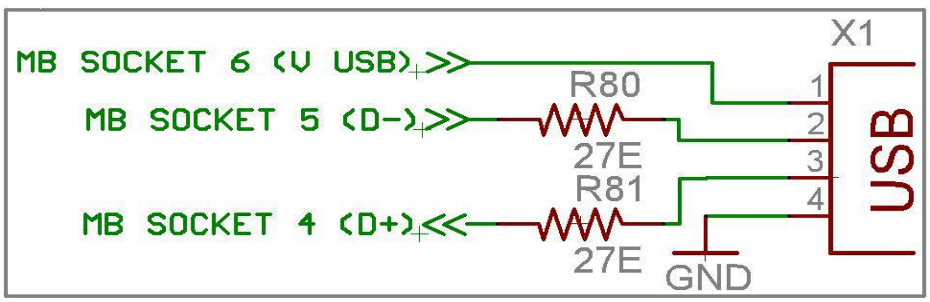


Figure 3.55a: USB port connections with the main board socket

3.18 Wireless communication adaptor

Figure 3.57 shows location of the socket for the wireless module. It supports XBee and XBee Pro series 1 and series 2 ZigBee wireless modules from digi international, RN-XV WiFi to serial module and Bluetooth module. Table 3.20 shows the functions of the status indicator LEDs for the XBee wireless modules.

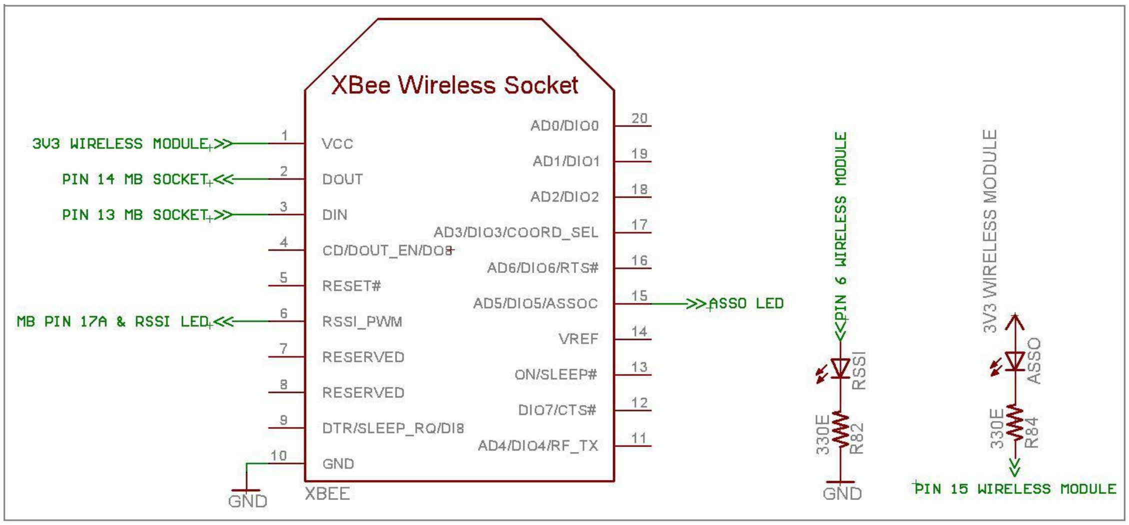


Figure 3.56: ZigBee wireless module schematics

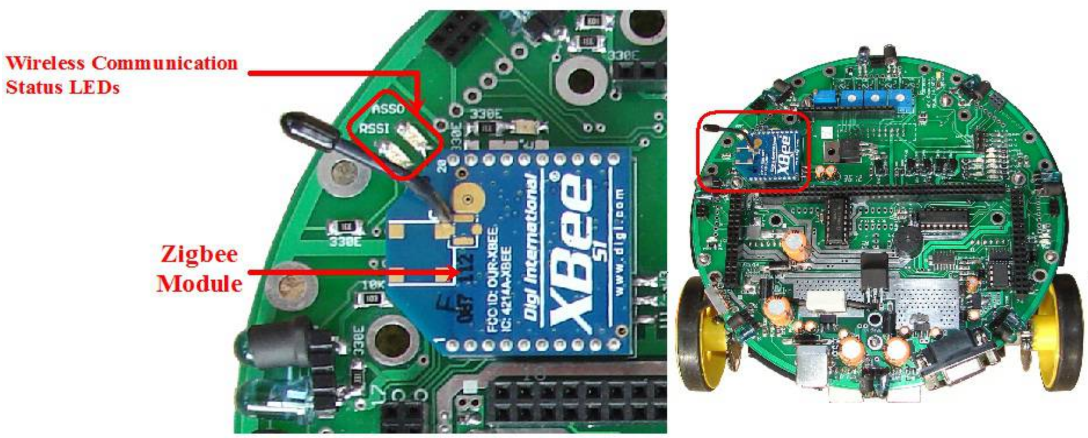


Figure 3.57: ZigBee wireless module and LED indicators

LED	Connection to XBee Wireless module Pin no.	Description
ASSO	15	Associate LED
RSSI	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 adapter board

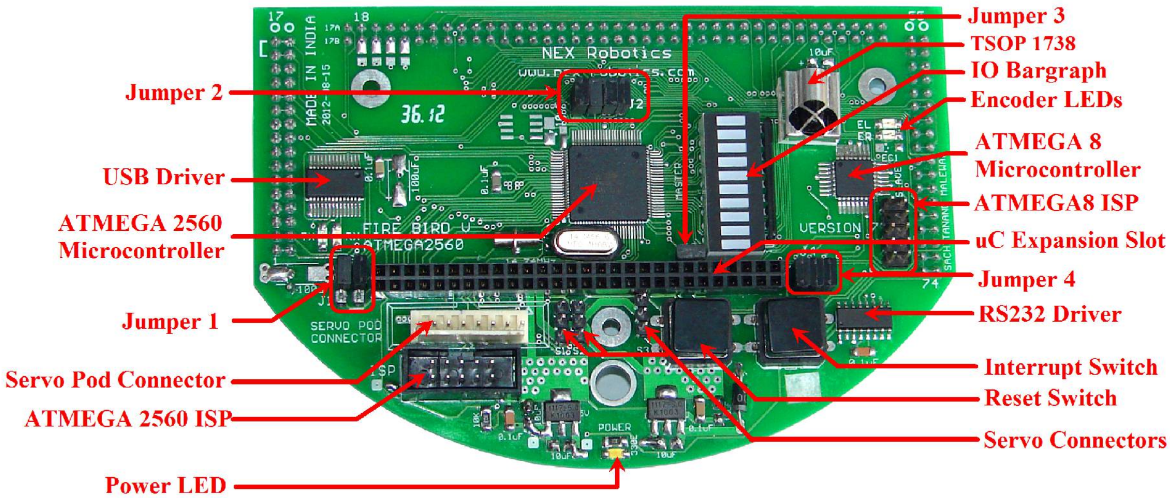


Figure 3.58: ATMEGA2560 microcontroller adapter board

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.

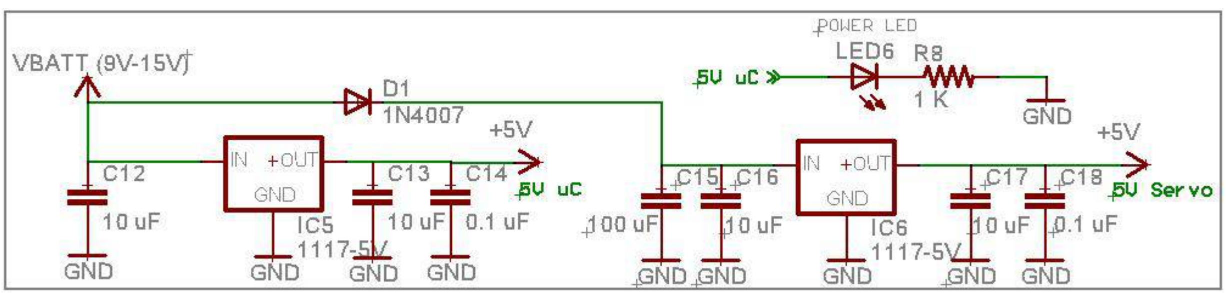


Figure 3.59: Power Supply Circuit

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 D9. 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

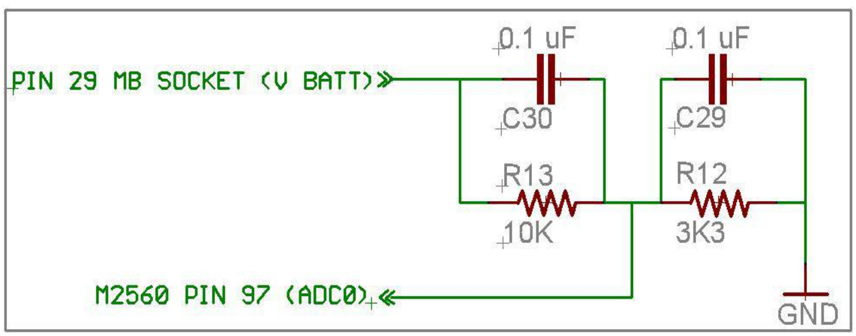


Figure 3.60: Battery Voltage Divider Bias Circuit

Note: For 10 bit resolution replace 255 by 1024.

3.19.3 TSOP1738 RC5 IR receiver and decoder

TSOP1738 is an IR receiver based on 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 also 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 solder pad needs to be connected by soldering for enabling the TSOP sensor. Figure 3.62 shows the location of the SJ2 solder pad. It connects TSOP1738 with the INT7 (interrupt 7) pin of the microcontroller.

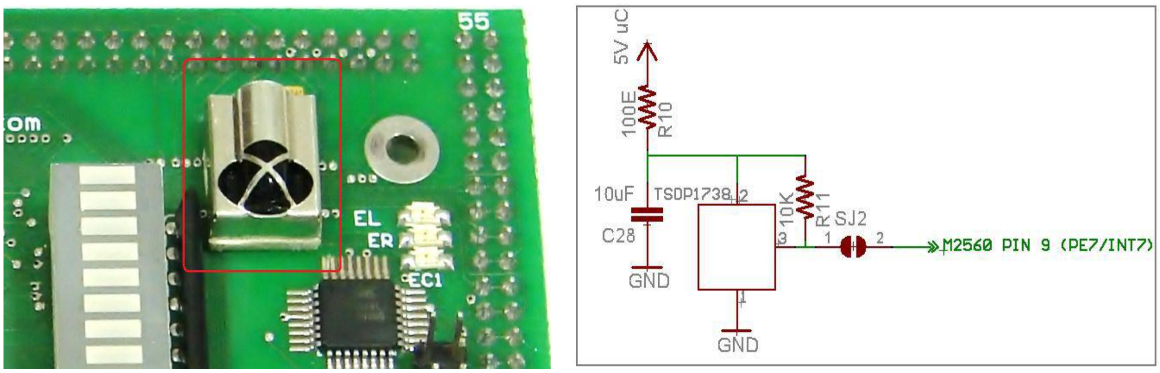


Figure 3.61: TSOP1738 RC5 decoder IR receiver

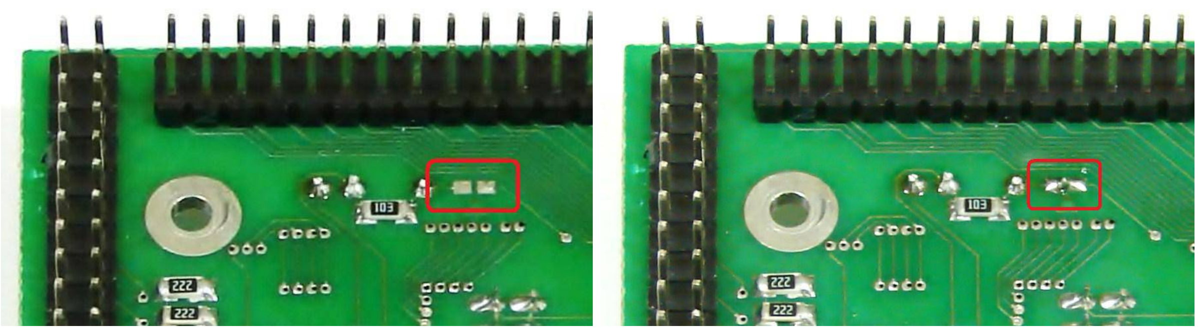


Figure 3.62: Jumper to be shorted to connect TSOP1738 with INT7 (shorted jumper is shown in the right image)

Important:
Before using TSOP1738 insure that solder pad P1 on the main board is not shorted. For more information refer to section 3.9 and figure 3.28.

3.19.4 ATMEGA2560 Microcontroller Board Expansion Socket

ATMEGA2560 is a feature rich microcontroller with lots of available I/O ports. Many of the ports are available for external use on the uC Expansion Socket. For Pin configuration of expansion header refer section 4.3 from chapter 4.

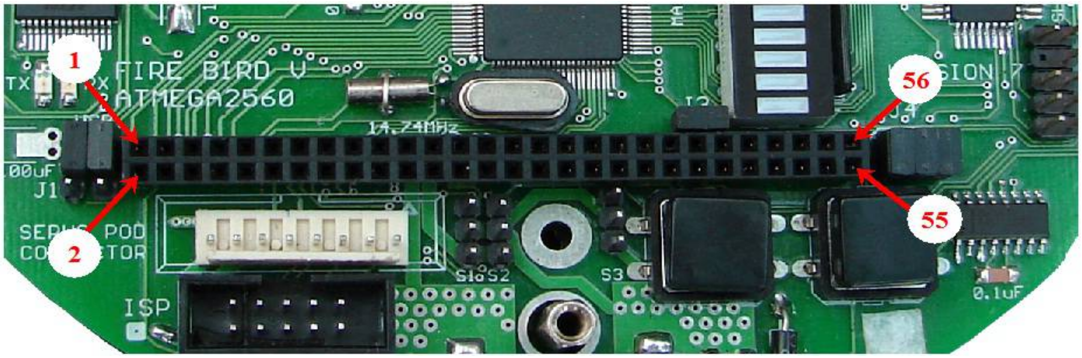


Figure 3.63: uC Expansion Socket on the ATMEGA2560 Microcontroller Board

3.19.5 Servo Pod Sensor Socket

Servo pod sensor socket is used to connect external sensors / actuators which are mounted on pan / tilt servo pod. It is a 8 pin 2560 relimate connector. Table 3.22 gives its pin connections.

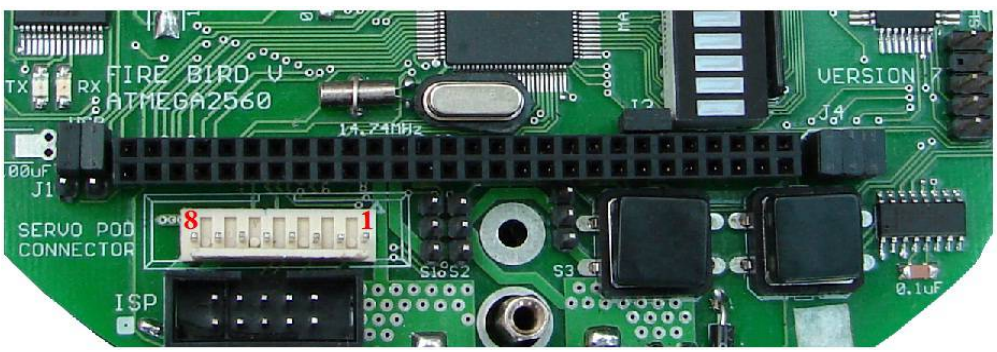


Fig 3.64: Servo Pod Sensor Socket

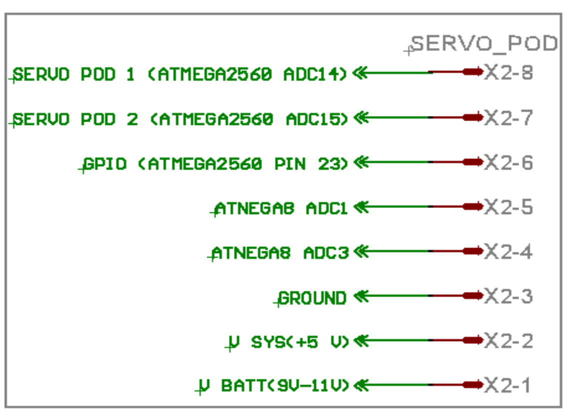


Figure 3.65: Servo pod sensor connector pin mapping

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

Table 3.22: Servo Pod socket pin description

3.19.6 Microcontroller Board Jumpers

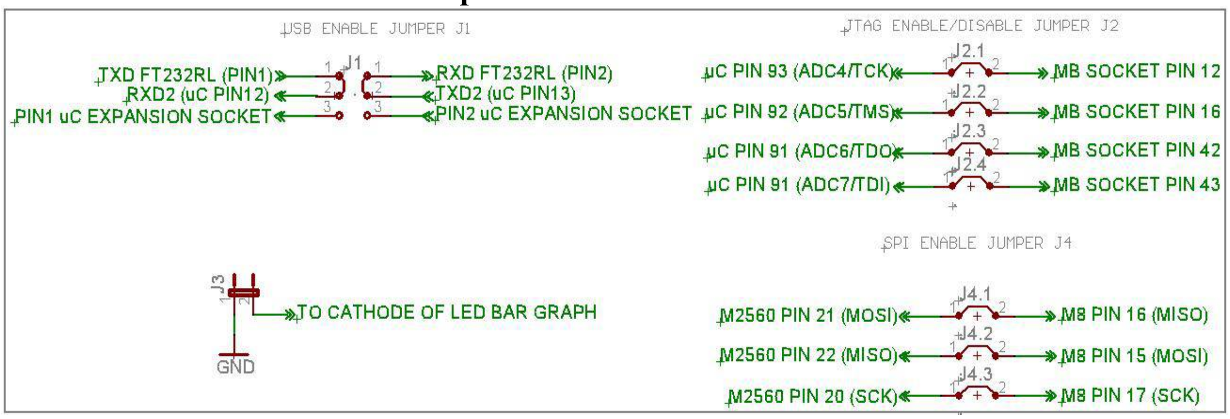


Figure 3.66: Jumpers schematic

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 uC Expansion Socket 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 bus between ATMEGA2560 (master) and ATMEGA8 (slave) is connected and you can access date from the slave microcontroller. Since SPI lines are also used for In System Programming (ISP) to load firmware on the master and slave microcontroller via SPI port you need to remove all jumpers from J4 before attempting ISP. J4 is kept open as default setting.

You can also program robot using boot loader utility via USB port. This will remove the need for frequent removal of jumpers on J4 for loading new firmware.

In System Programming (ISP) sockets

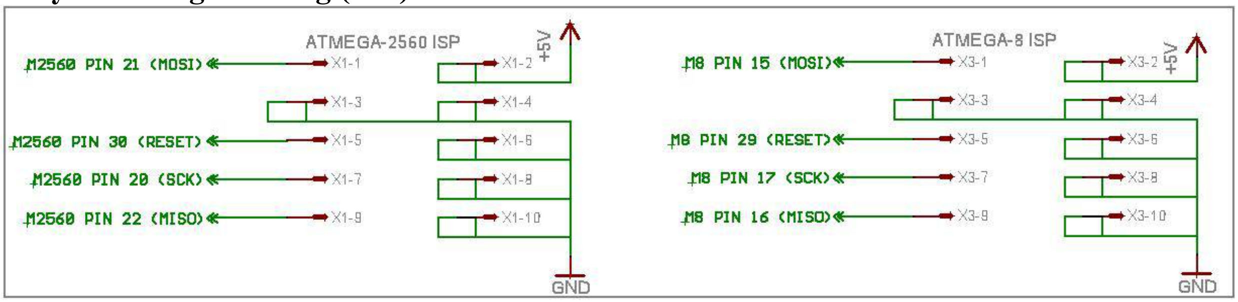


Figure 3.67 ISP Schematic

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 for the J4.

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 adapter 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. Microcontroller socket uses USB port from the main board. Data transmission and reception is indicated suing TX and RX LEDs which are located near the FT232 IC. Refer to figure 3.58 for LED's 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.

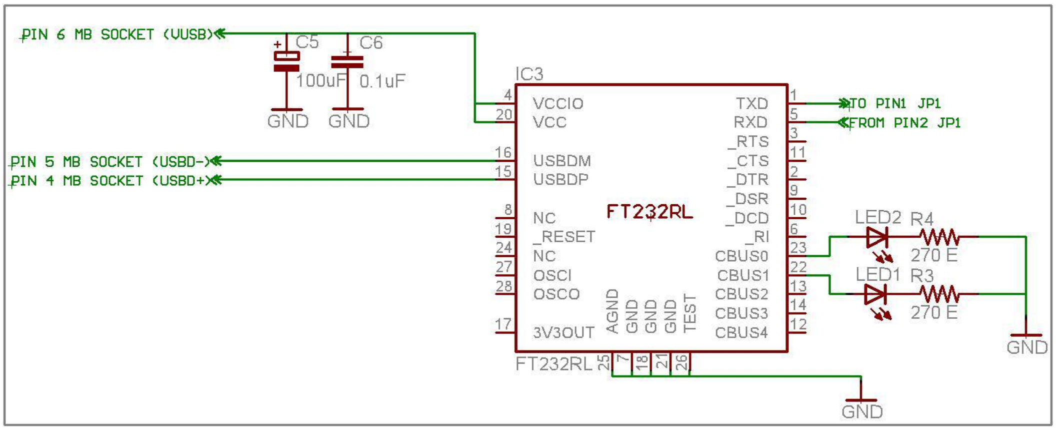


Figure 3.68: FT232 Schematic

Note: Using bootloader from NEX Robotics, Robot can be programmed directly via USB port without any need of external ISP programmer. How to use Bootloader GUI is covered in the software manual.

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.

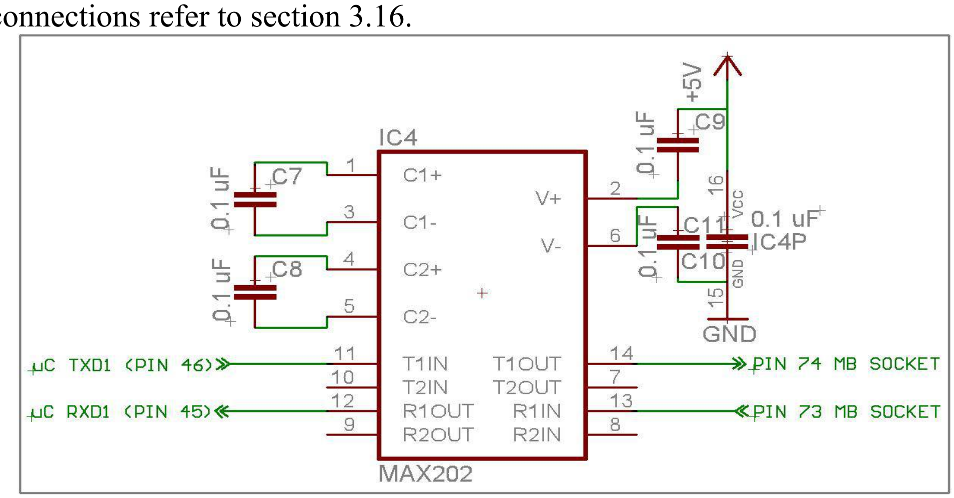


Figure 3.69: MAX202 TTL to RS232 converter

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. Figure 3.71 shows mounting of REF5050 and change in the solder pad shorting.

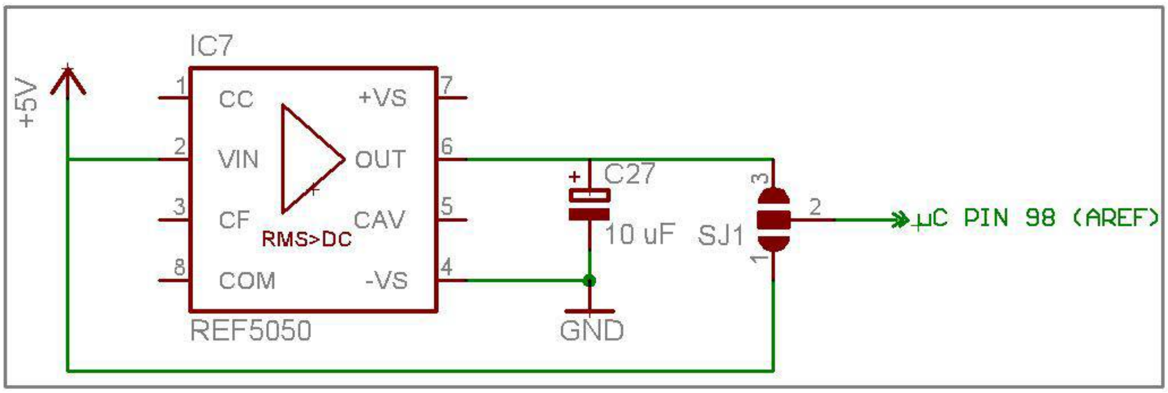


Figure 3.70: REF5050 Schematic

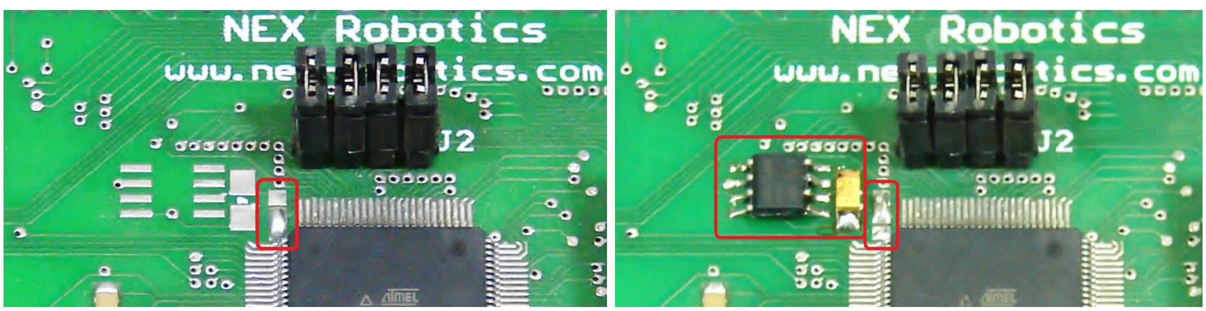


Figure 3.71: Left- Jumper shorted to use 5V uC as A Ref. Right- REF5050 is installed and jumper shorted to use its 5V output as reference.

3.19.10 Interrupt Switch

Interrupt switch on the microcontroller adapter 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. Location of the interrupt switch is shown in figure 3.58.

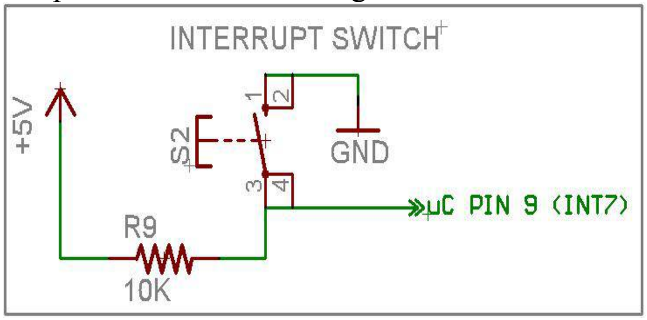


Figure 3.72: Interrupt switch

Important:

Before using interrupt switch, ensure that soldering pad P1 on the main board is open. For more information refer to figure 3.28 and section 3.9.

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 shows correct orientation of the servo motor's connector.

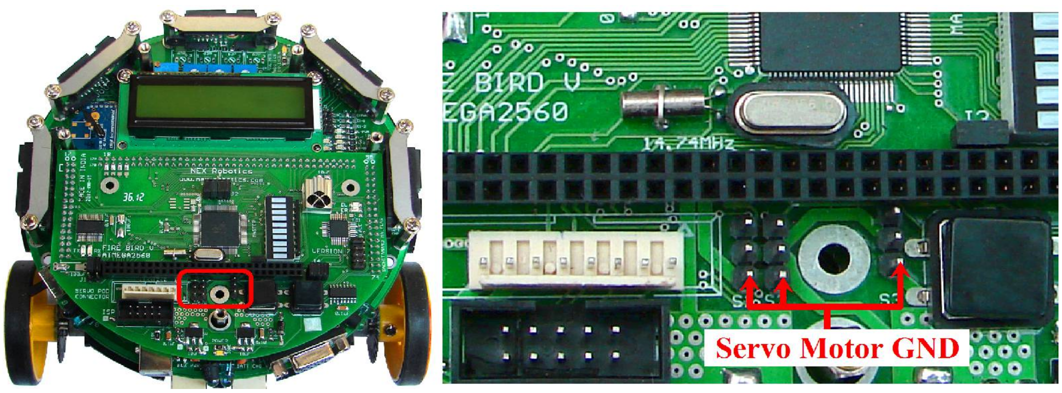


Figure: 3.73: Servo Connectors Schematic.

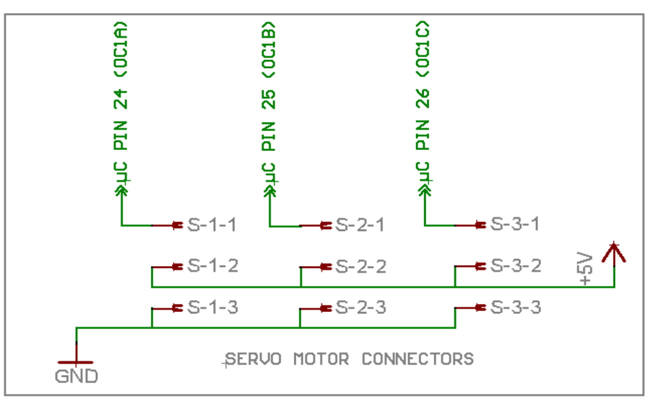


Figure: 3.73a: Servo Connectors Schematic

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 not used hence LED corresponding to C2 is not soldered on the microcontroller adaptor board.

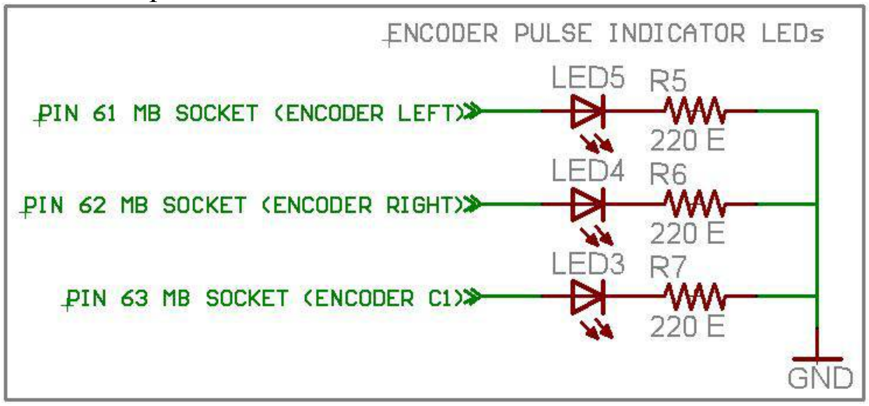


Figure 3.74: Encoder LEDs Schematic

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.

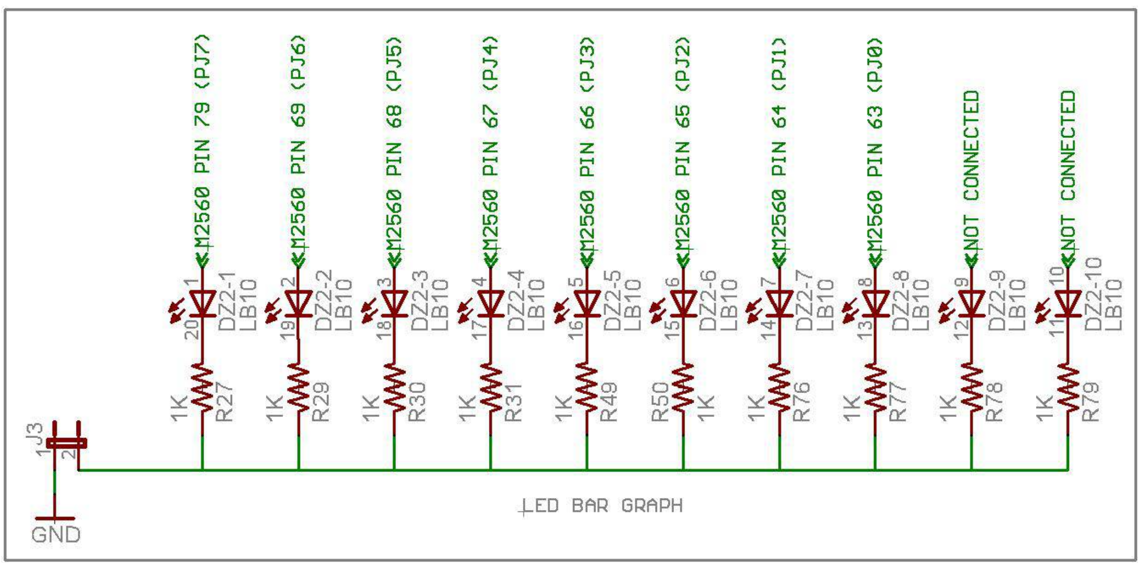


Figure 3.75: LED BAR GRAPH Schematic

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.

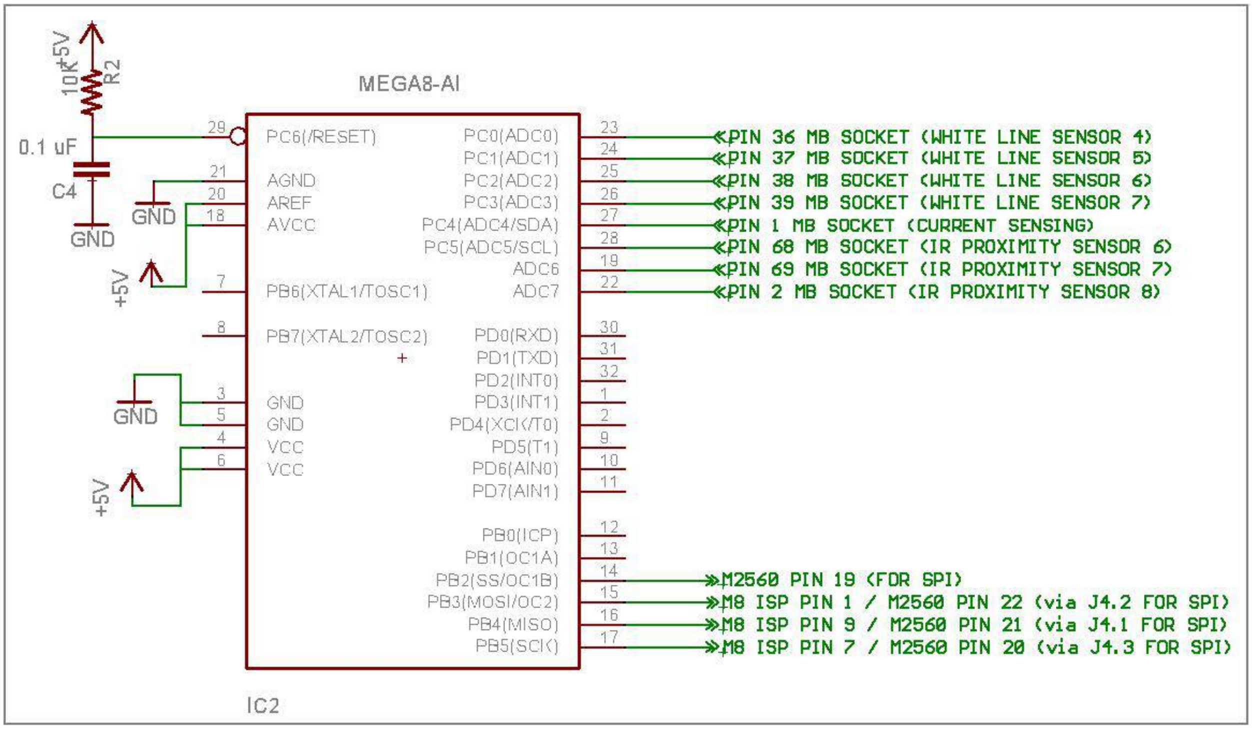


Figure 3.76: ATMEGA8 SCHEMATIC

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.

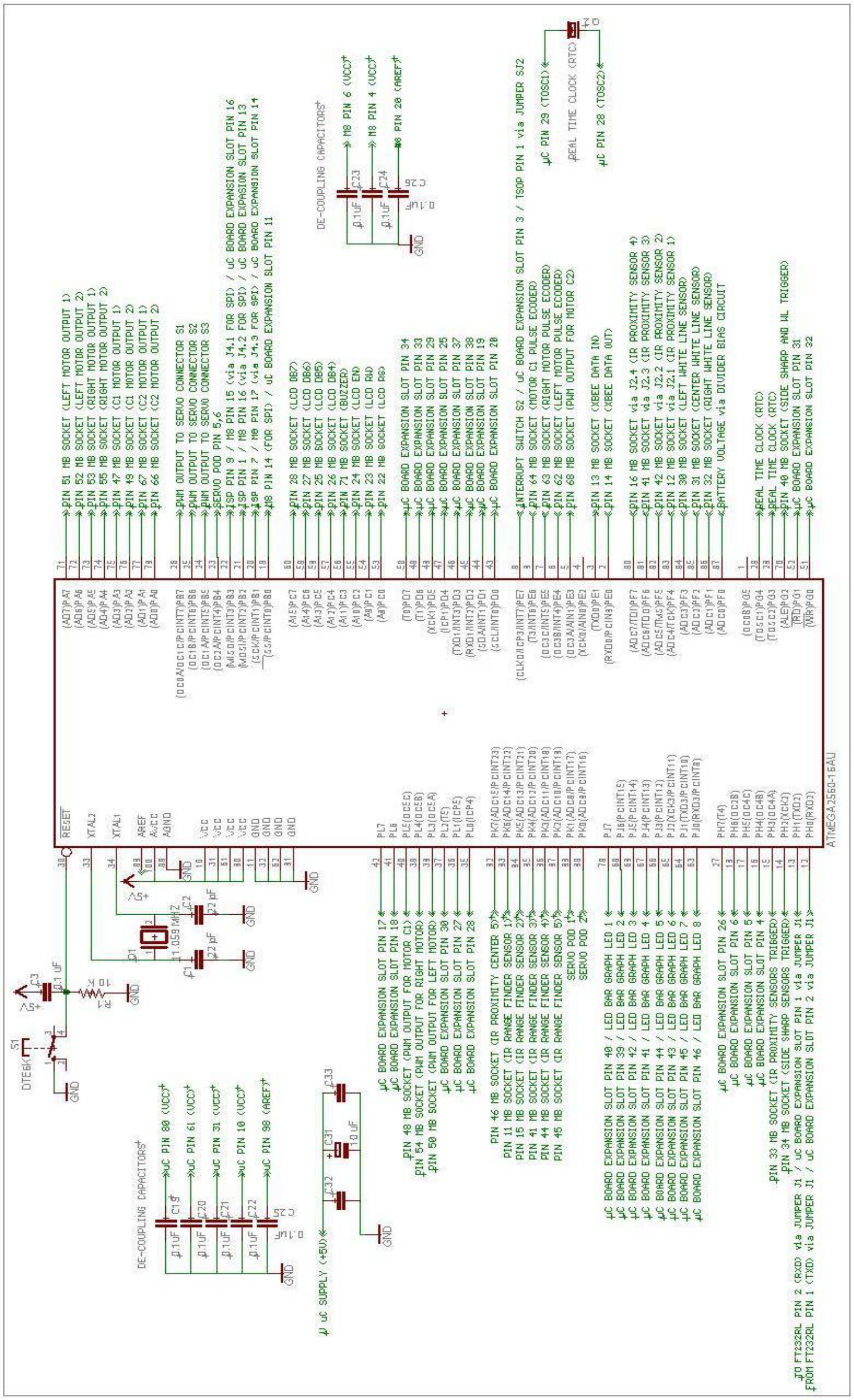


Figure 3.78: ATMEGA2560 microcontroller schematic

4. Pin Functionality

Fire Bird V ATMEGA2560 microcontroller adapter 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 sensor socket etc.

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, can also be used as Boot loading switch ********	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	IR proximity sensors 1 to 8 enable / disable. Turns off these sensors when output is logic 1 *******	Output
15	OC4A / PH3	Sharp IR ranges sensor 1and 5 enable / disable. Turns off these sensors when output is logic 1 *******	Output
16	OC4B / PH4	Connected to Rx pin of 1st Ultrasonic range sensor to trigger the ultrasonic sensor if sensor is mounted. Also Available on expansion slot of the microcontroller socket*********	--
17	OC4C / PH5	Available on expansion slot of the microcontroller socket	--
18	OC2B / PH6	Available on expansion slot of the microcontroller socket	--
19	SS/PCINT0/PB0	ISP (In System Programming), SPI Communication with ATMEGA8 **, Connection to the SPI port on the main board. Also available on expansion slot of the microcontroller socket	
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	Connected to RSSI pin of XBee module. Also Available on expansion slot of the microcontroller socket.	--
36	ICP5/PL1	Available on expansion slot of the microcontroller socket.	--
37	TS/PL2	Available on expansion slot of the microcontroller socket.	--
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	Red LEDs of white line sensor enable/disable. ******* Turns off these sensors when output is logic 1	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
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 adapter 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 adapter 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.

******** External interrupt from the position encoder C1 is disabled by removing short on pad P1 near CD40106 Schmitt trigger inverter buffer to avoid its wire ANDing with the interrupt switch. Refer section 3.9 and 3.19.3 for details.

********* Refer the errata section for more details, where modification required for using PH4 port pin of microcontroller.

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 section 3.19.6 J4.

4.3 ATMEGA2560 Microcontroller Board Expansion Socket

ATMEGA2560 is a feature 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.

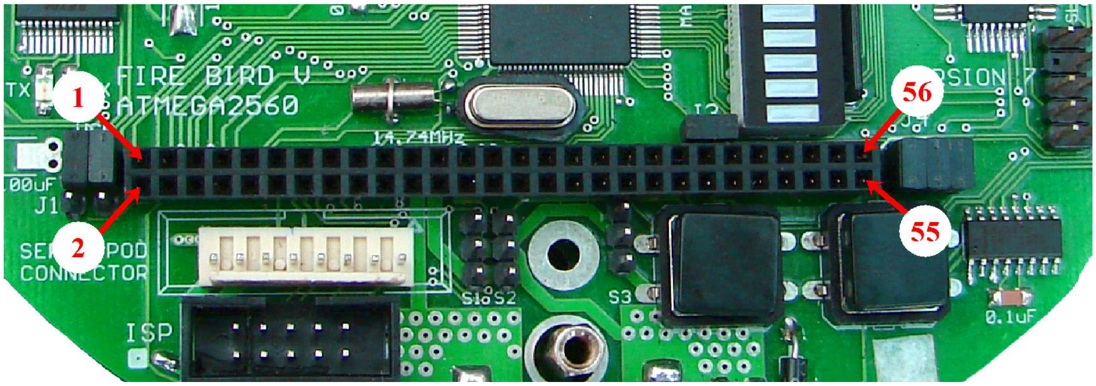


Figure 4.1: Expansion Header on Microcontroller Board

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), Also connected to RX pin of 1st ultrasonic sensor triggering.
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), Also connected to RSSI pin of XBee module

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 adapter board socket connections on the main board

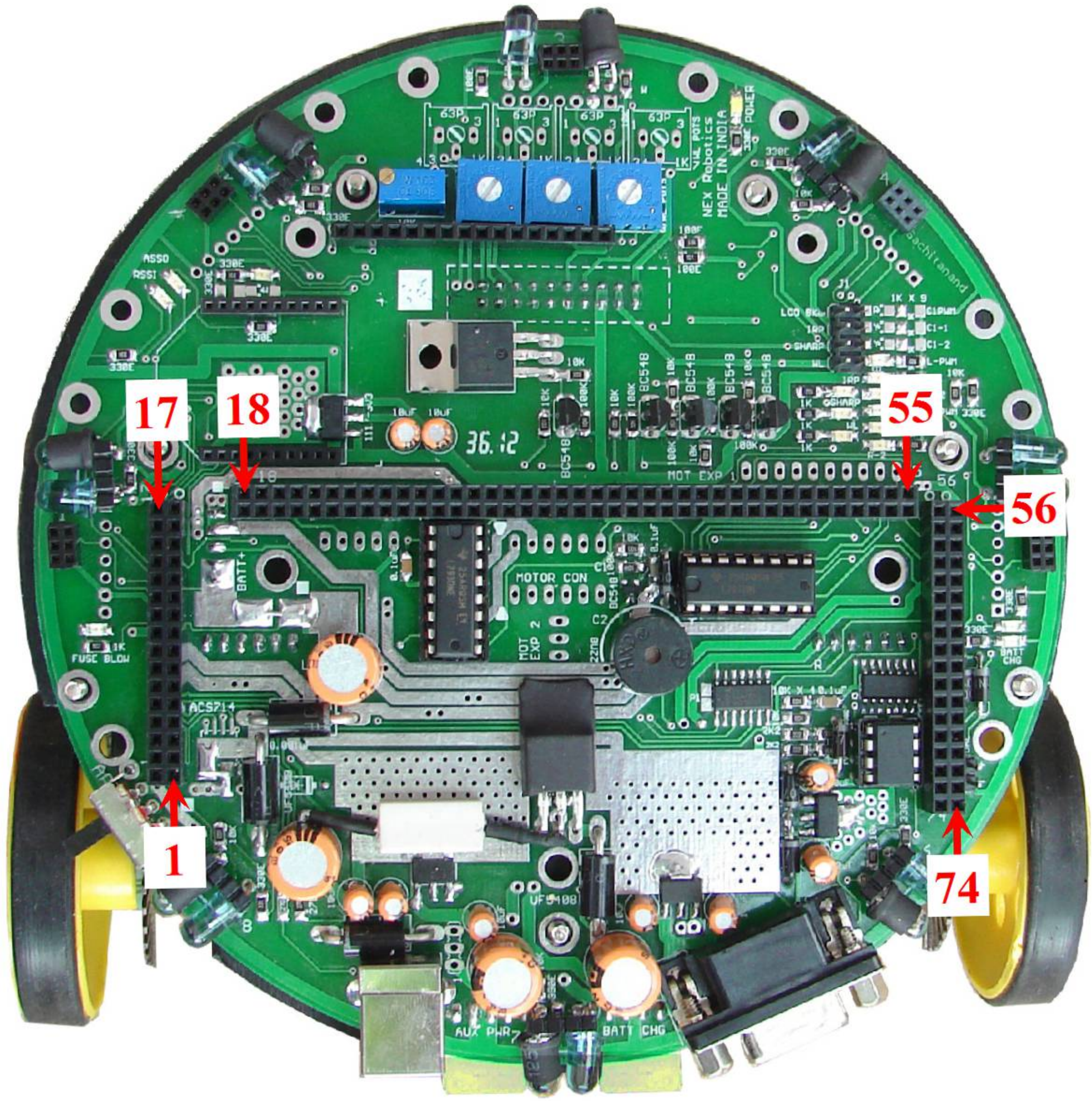


Figure 4.2: Microcontroller adapter board socket connections on the main board

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	5V Sensor	Not connected	5V Sensor voltage. Can be used for additional sensor interfacing with current limit: 300mA
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
17A	RSSI	ATMEGA2560 INT7	To capture the RSSI signal
17B	Ultrasonic Trigger	ATMEGA2560 PH4**	To give the Trigger for 1^{st} Ultrasonic Sensor
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	Sharp IR Sensors 1and 5 Disable	ATMEGA2560 PH3	TTL/CMOS input. Disable Sharp IR range sensors, when V>2 is applied. When V<0.65 Sharp IR range sensors are turned on.
34	IR Proximity Sensor Disable	ATMEGA2560 PH2	TTL/CMOS input. Disable IR proximity sensors 1 and 8 when V>2 is applied. When V<0.65 IR proximity sensors 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	White Line Sensors Disable	ATMEGA2560 PG2	TTL/CMOS input. Disable White line sensors when V>2 is applied. When V<0.65 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		Not connected	Not Used
61		Not connected	Not Used
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	Not connected	Not connected
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 adapter 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

** refer errata section of this manual

5. Upgrading Robot's Hardware

In this chapter mounting of various modules of the robot are covered in pictorial way.

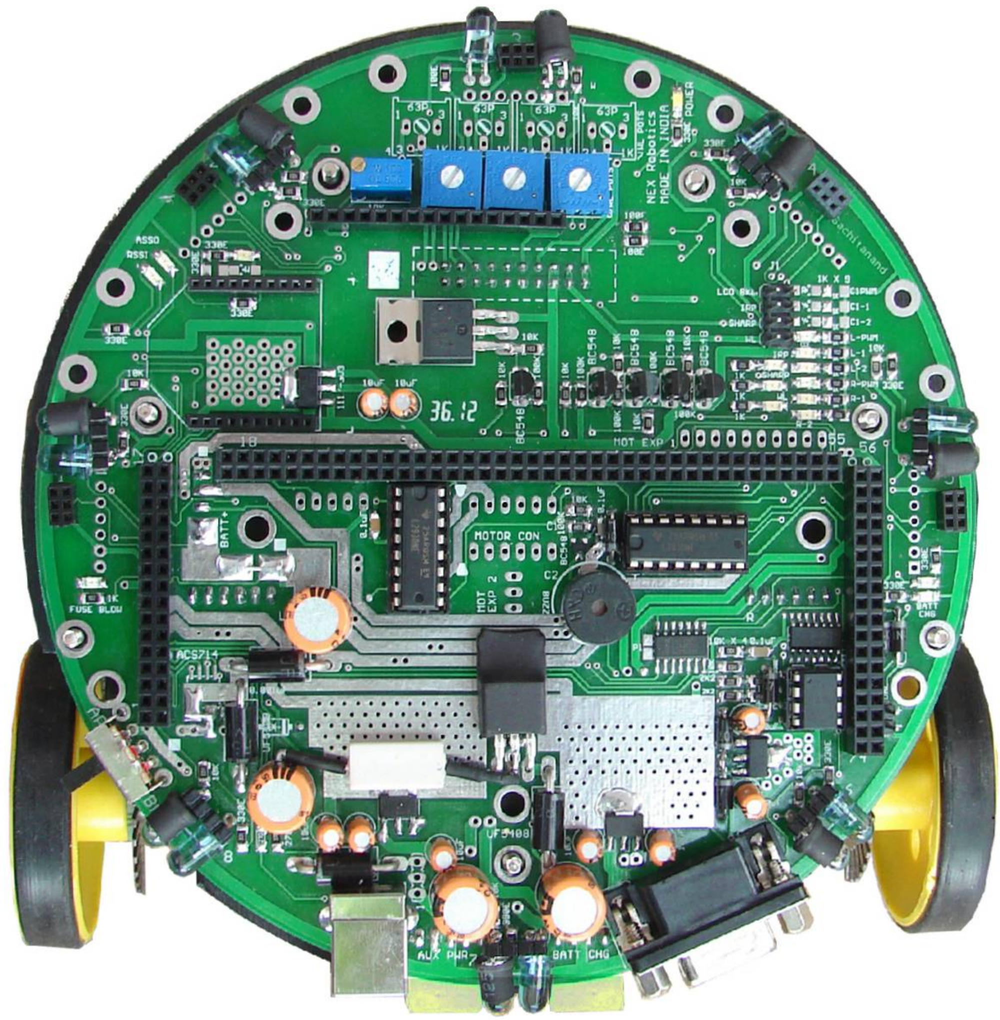


Figure 5.1: Fire Bird V main board

5.1 Installing XBee wireless module

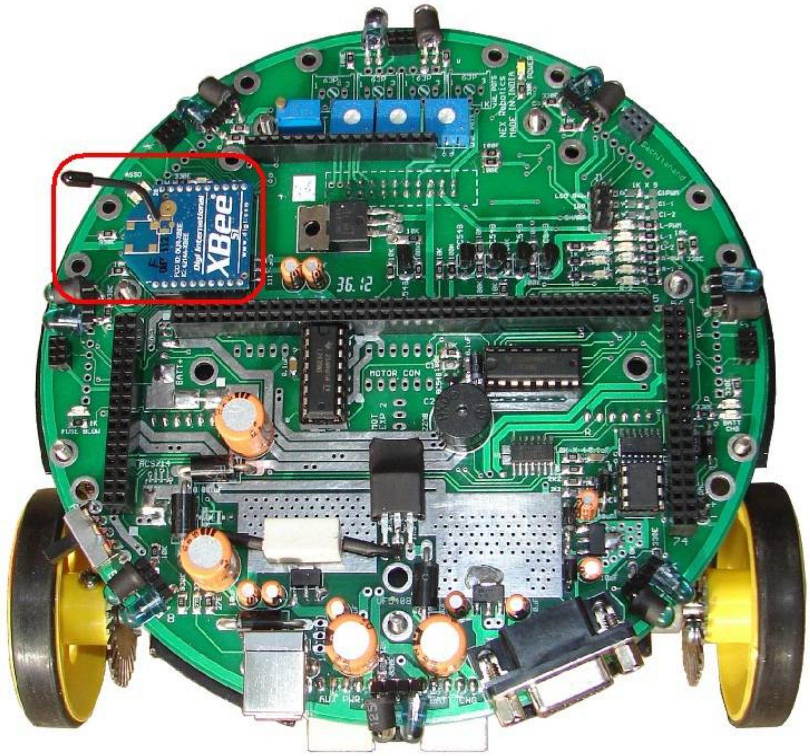
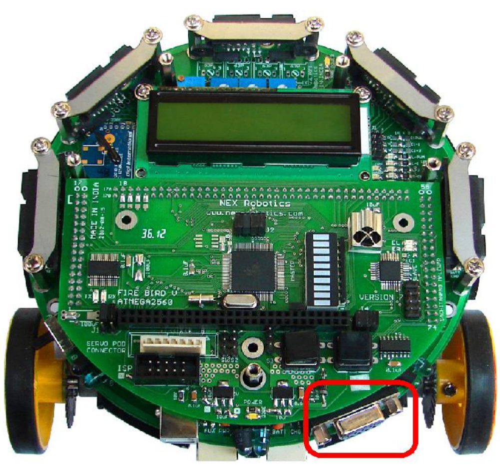


Figure 5.2: Mounting the XBee wireless module

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

5.2 Setting correct jumper settings on the main board



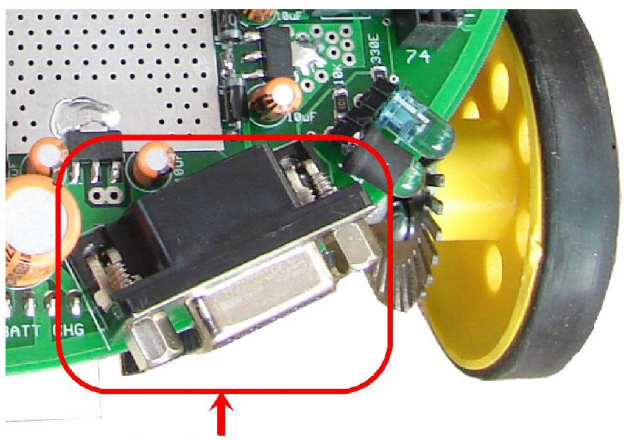


Figure 5.3: Set jumpers as per the requirements (for more details refer to chapter 3)

5.3 LCD mounting

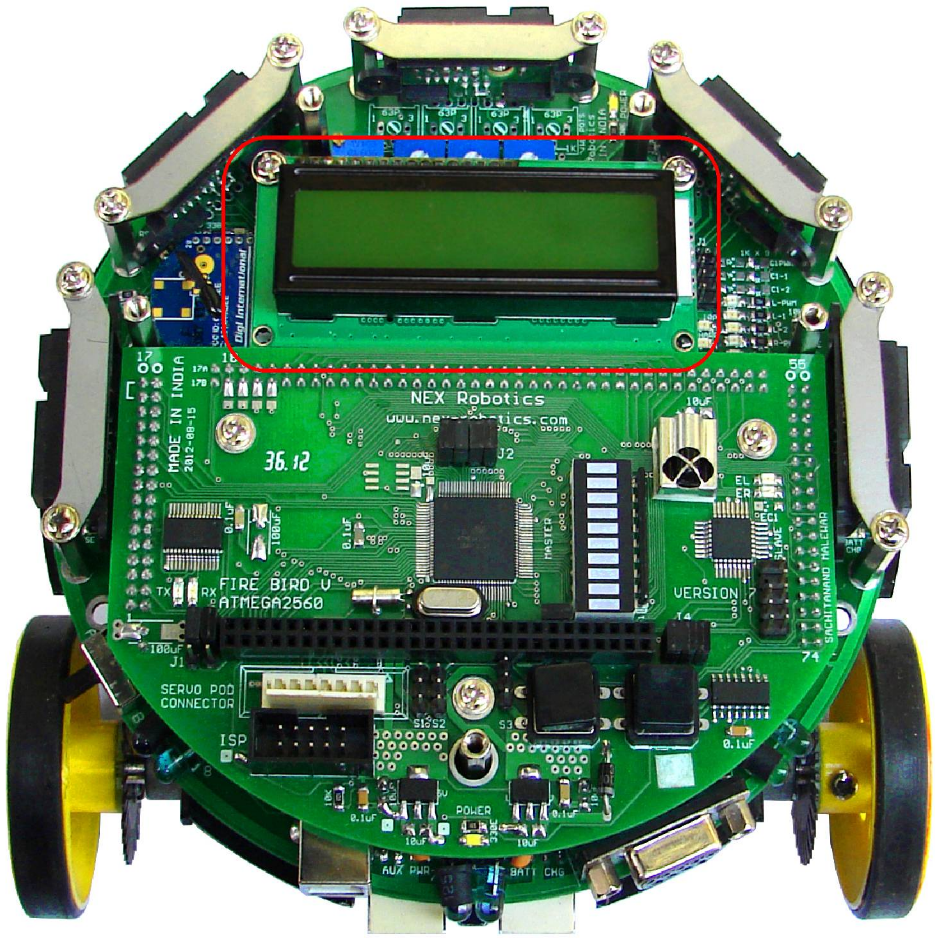


Figure 5.4: LCD mounting

- 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 adapter board mounting

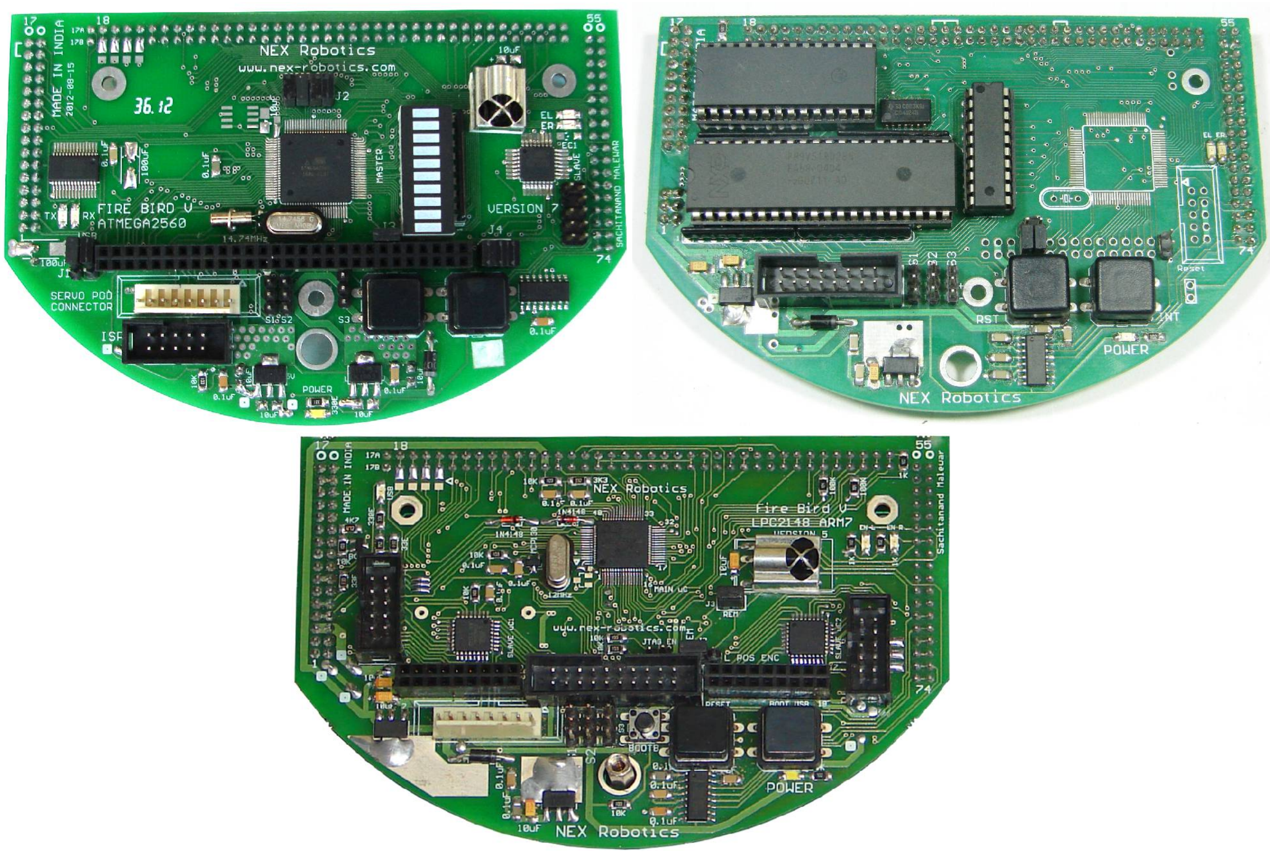


Figure 5.5: ATMEGA2560 (AVR), P89V51RD2 (8051) and LPC2148 ARM7 microcontroller adapter boards for Fire Bird V

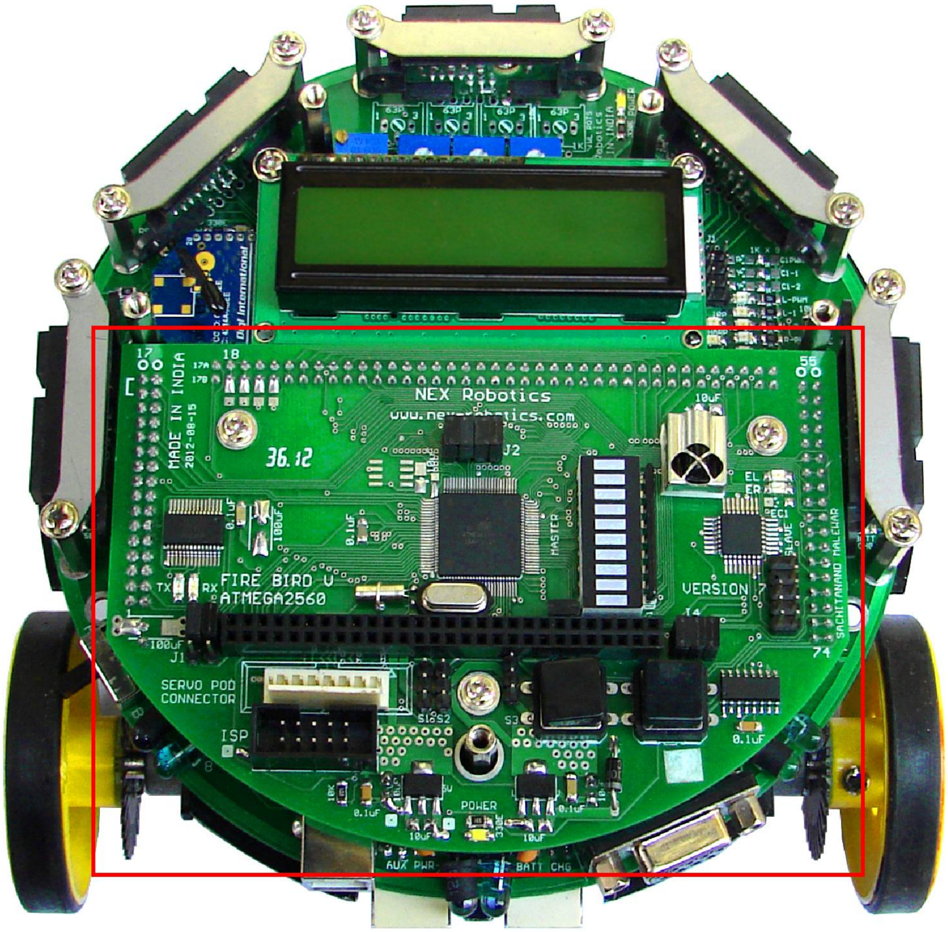


Figure 5.6: Microcontroller adapter board mounting

- 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

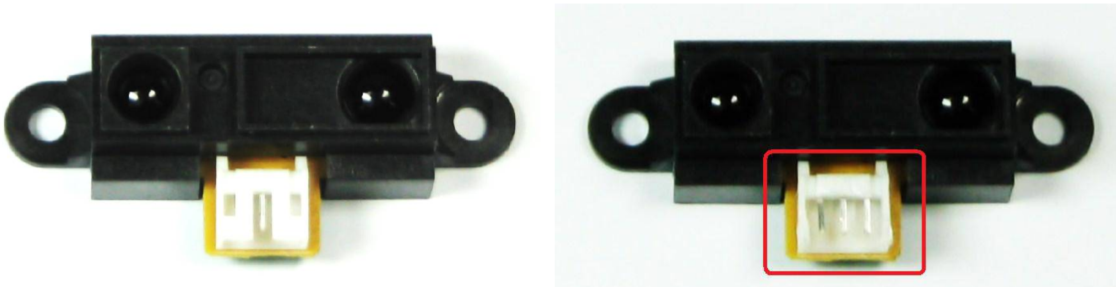


Figure 5.7: Remove front cover of the white connector of the Sharp IR range sensor

Figure 5.8: Sharp IR range sensor mounting kit

Step 2: Mount the 20mm studs on the main board, where sharp sensor is to be fitted. In figure 5.9, area highlighted with the red border shows the mounted studs from the Sharp IR range sensor mounting kit.

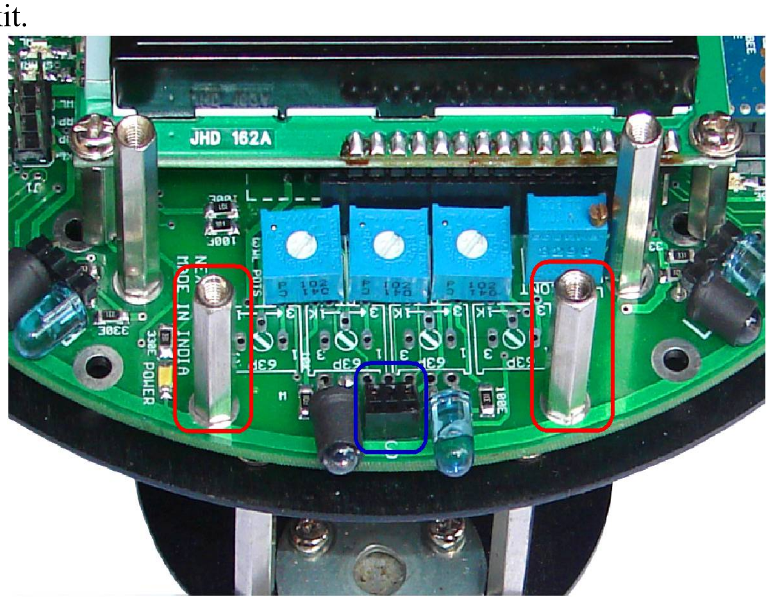


Figure 5.9: Mount 20mm studs from the Sharp sensor mounting kit

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.

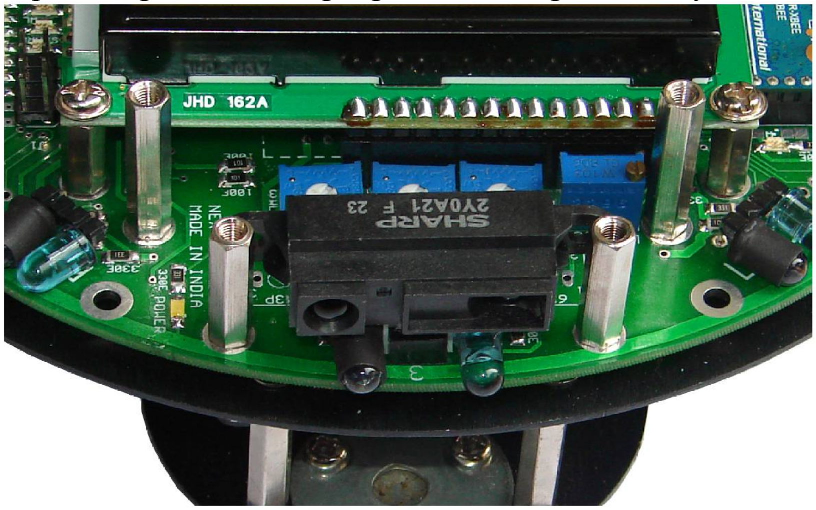


Figure 5.10: Mounting of the Sharp IR range sensor

Step 4: Remove the yellow colored paper stripe from the adhesive tape from the metal plate which is shown in figure 5.8.
Fix the metal plate on top of the Sharp sensor and fit the screws.

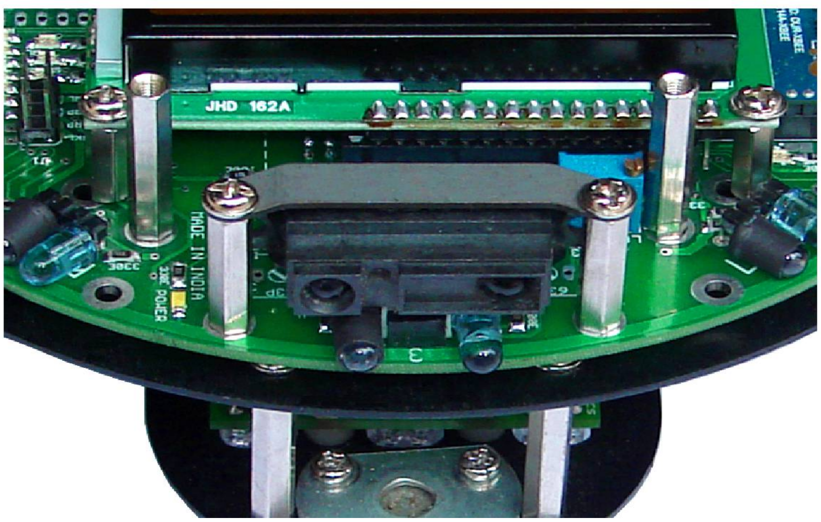


Figure 5.11: Fitting metal plate on top of the Sharp IR range sensor

- 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

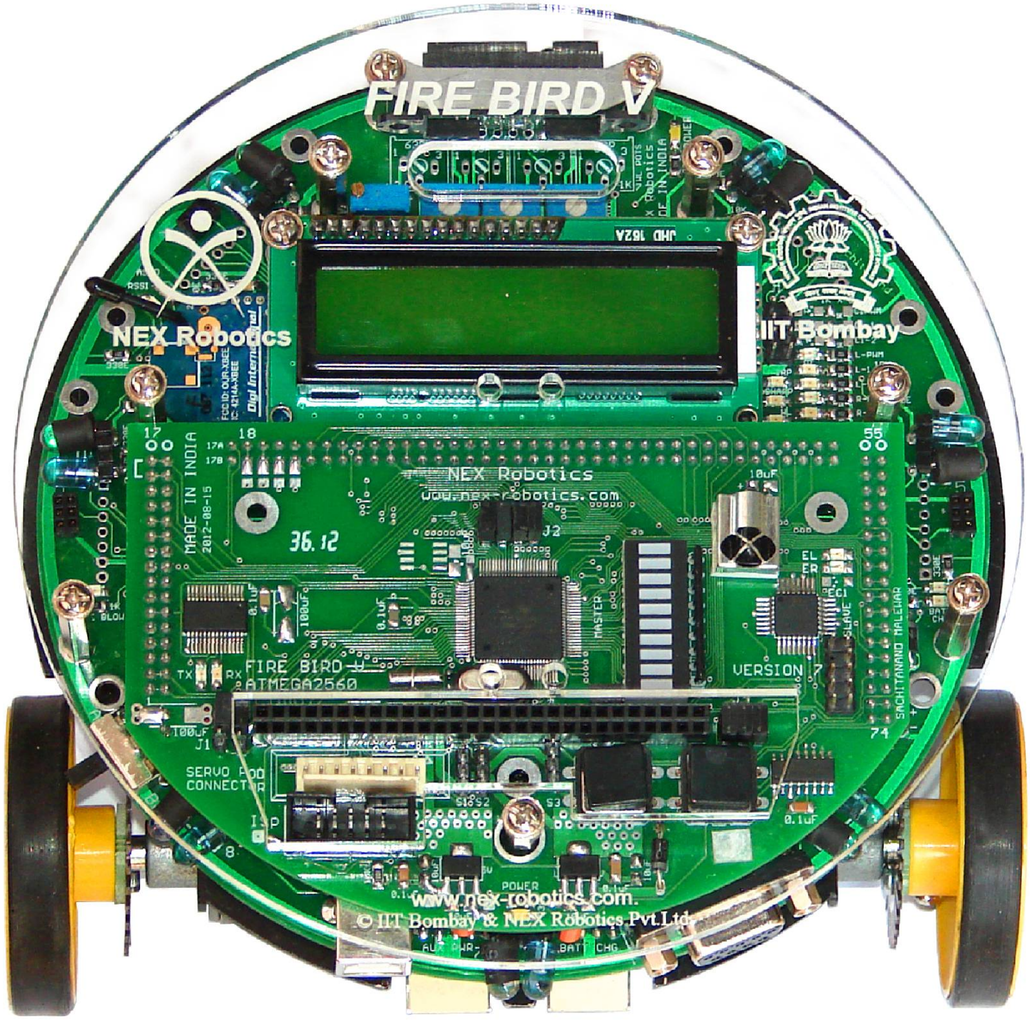


Figure 5.12: Install top acrylic plate

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

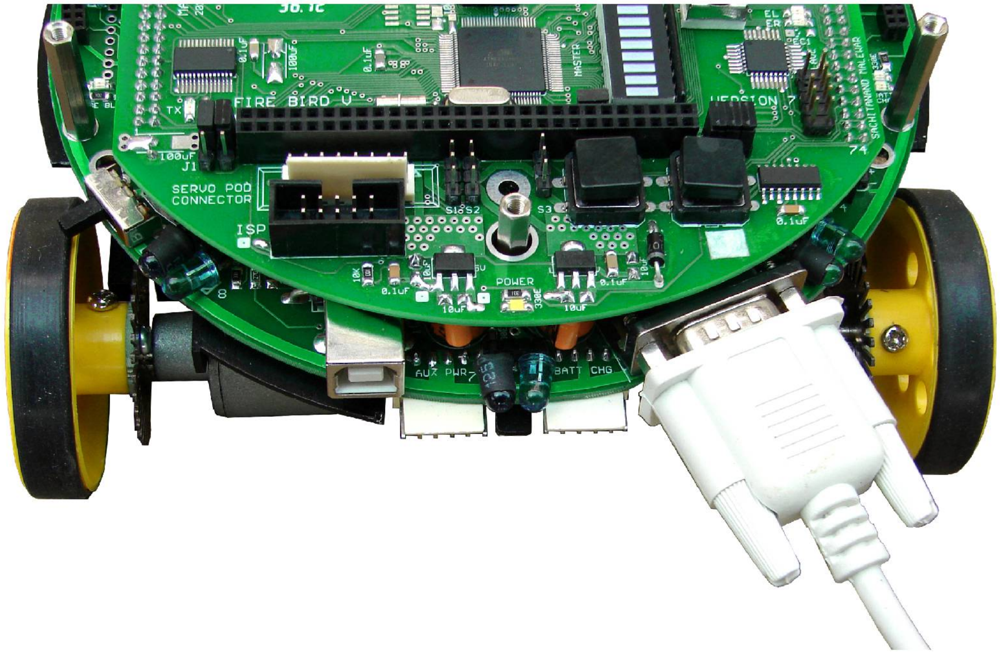


Figure 6.1: Connecting RS232 serial port with the PC

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, 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.

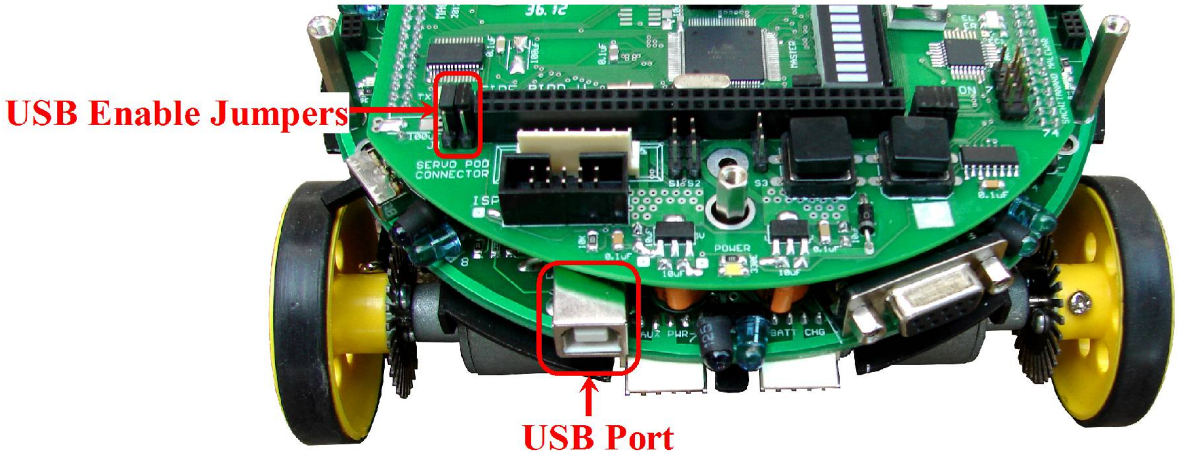


Figure 6.2: Jumper setting to enable USB communication

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 task bar 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).

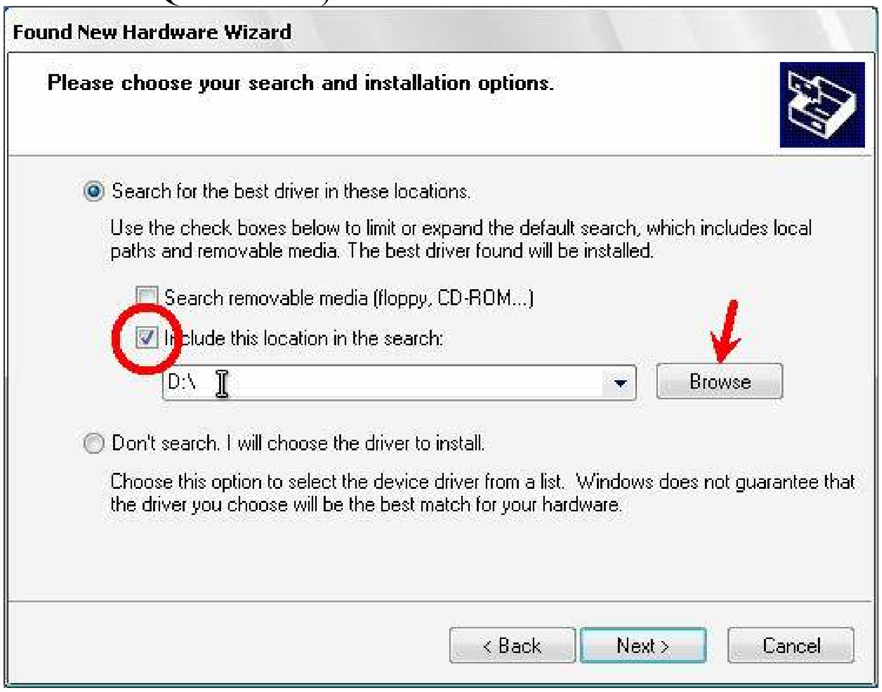


Figure 6.7

Step 6:
On clicking next driver installation will begin.

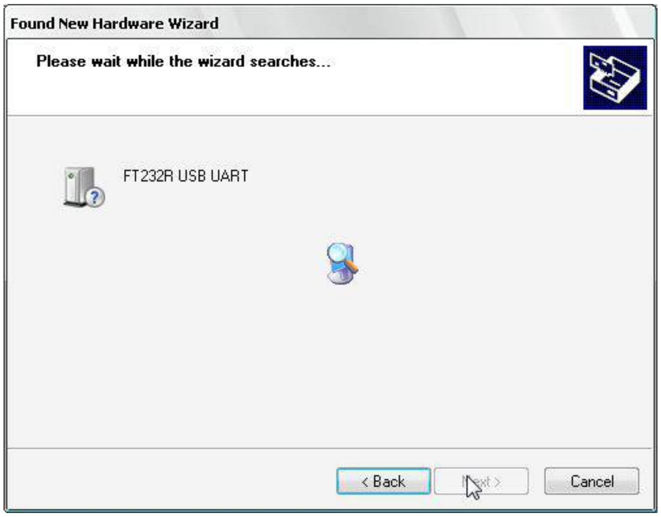


Figure 6.8

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.

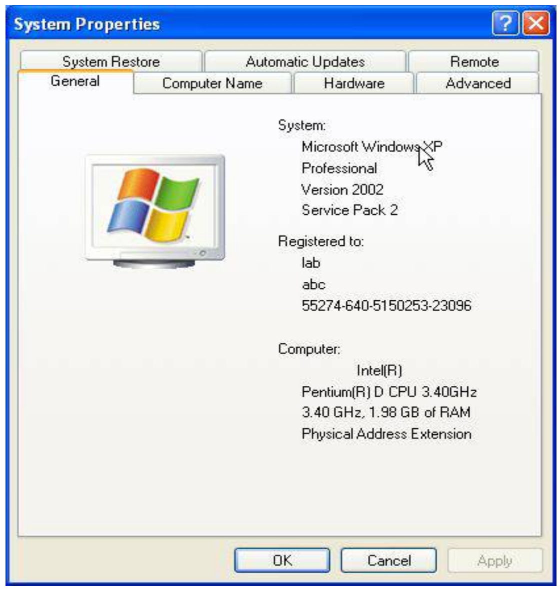


Figure 6.10

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

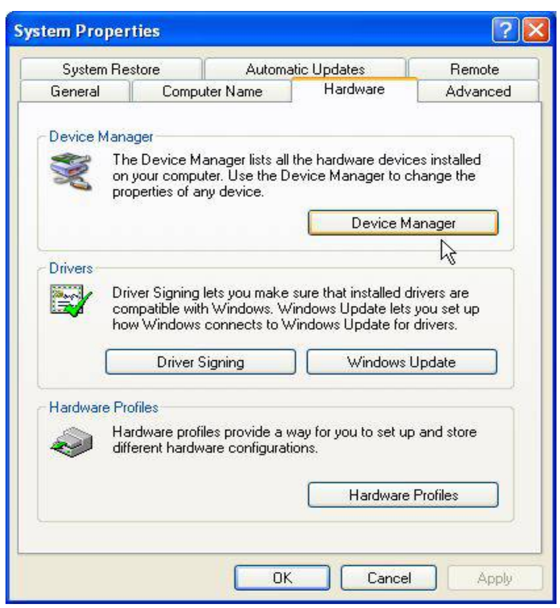


Figure 6.11

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

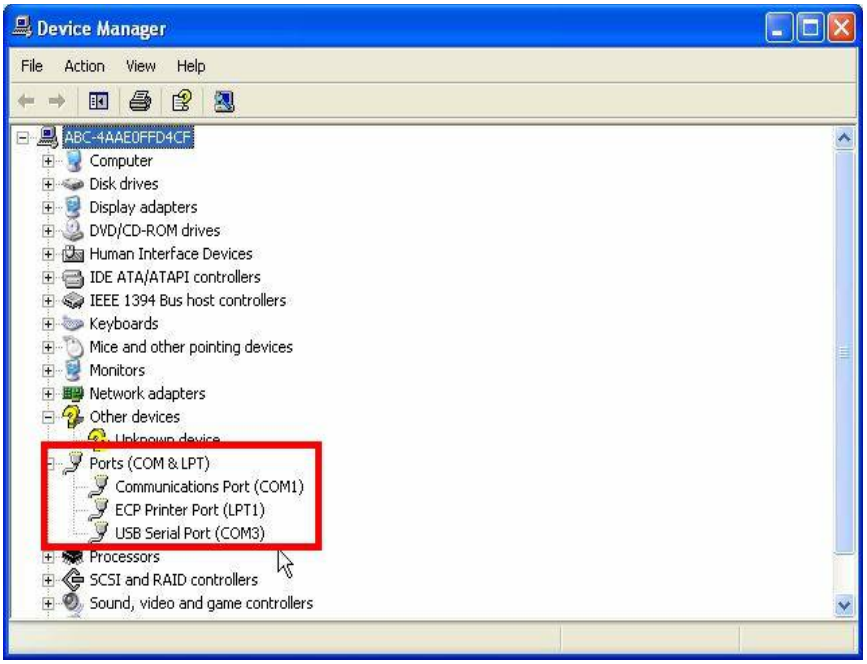


Figure 6.12

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

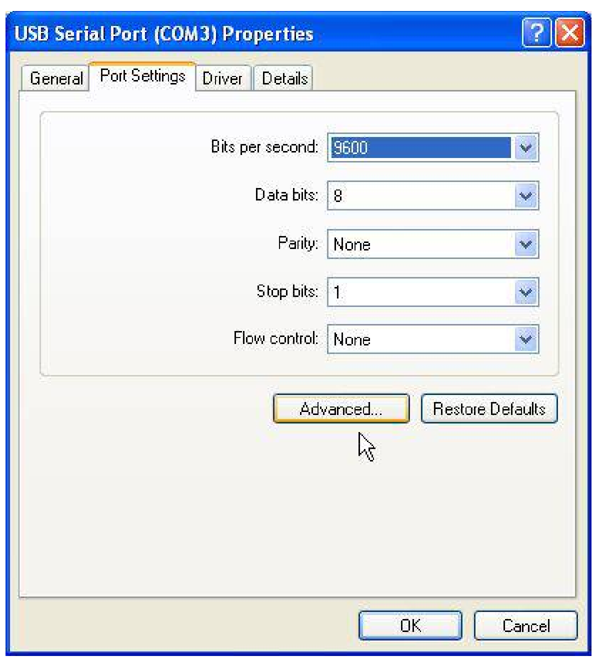


Figure 6.13

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.

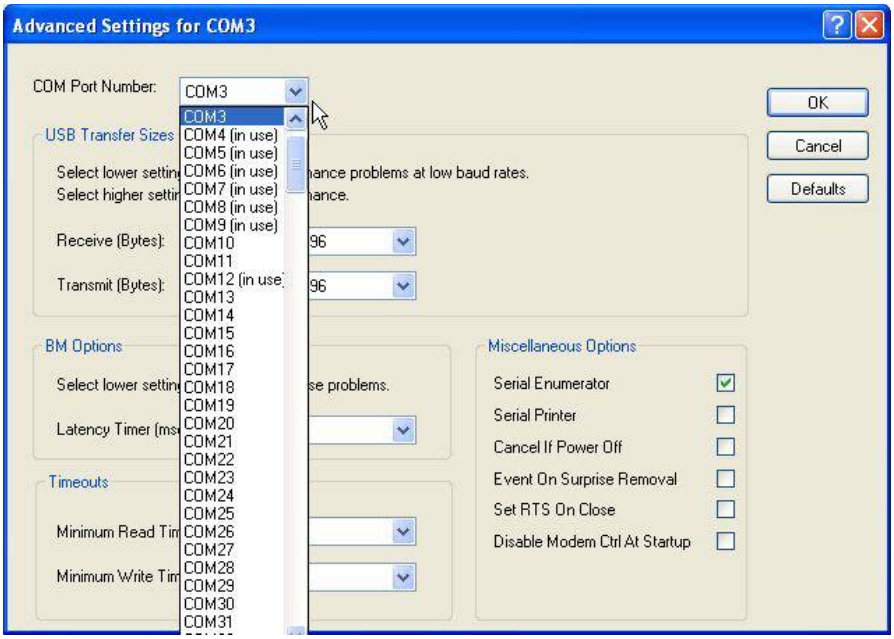


Figure 6.14

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.

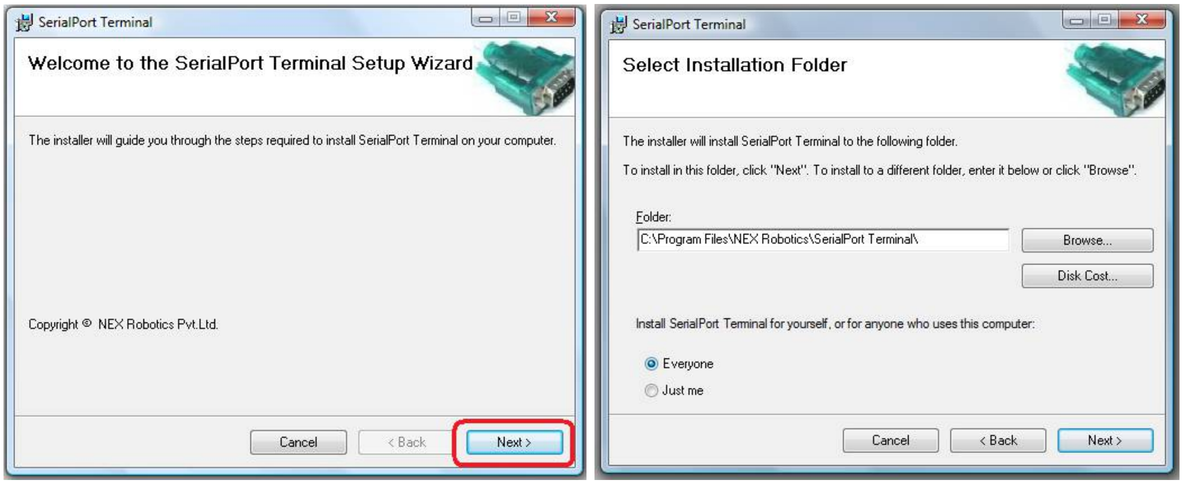


Figure 6.15

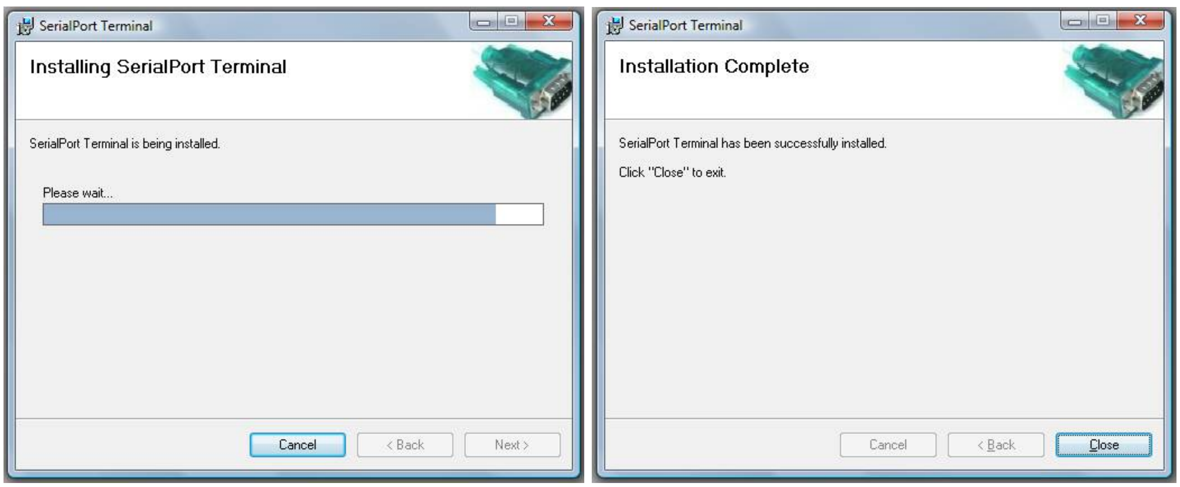


Figure 6.16

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.

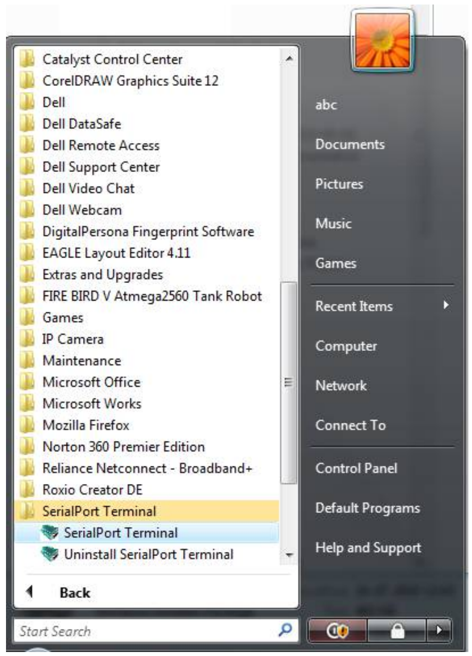


Figure 6.17

Terminal software will open.

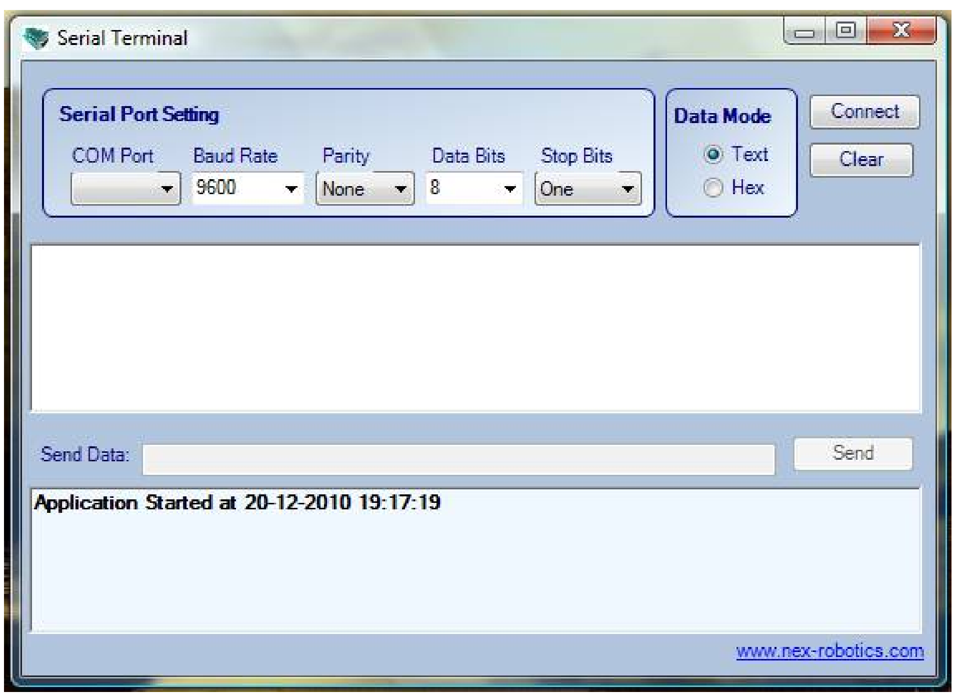


Figure 6.18

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.

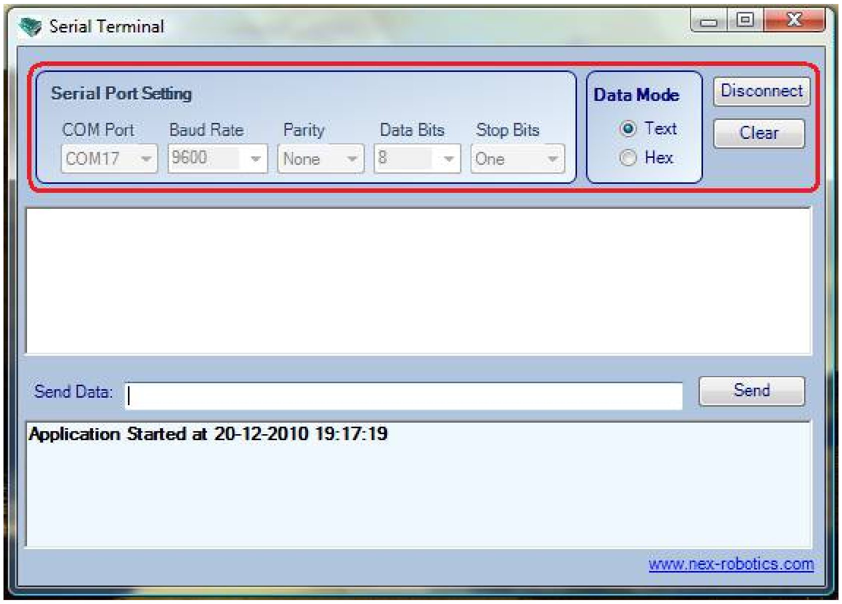


Figure 6.19

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.

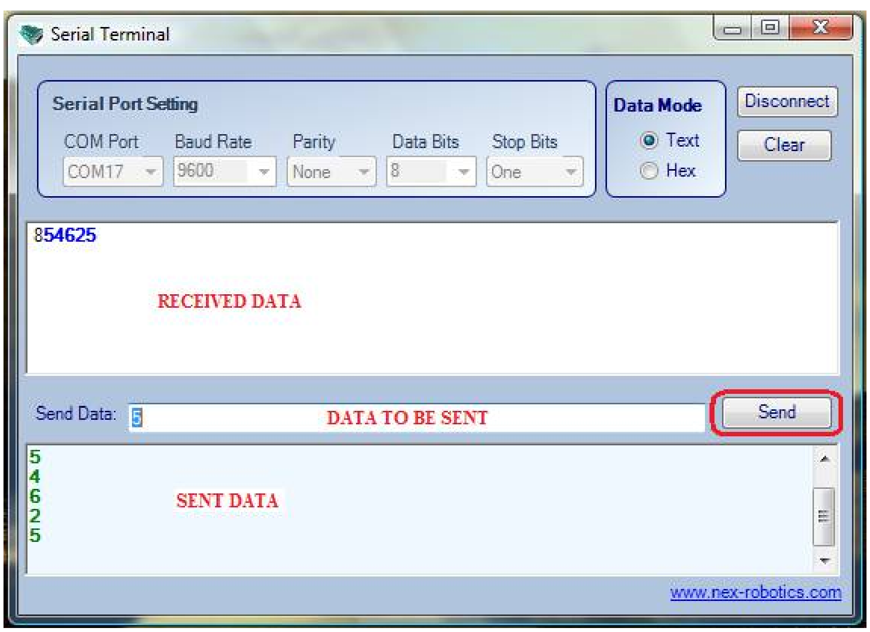


Figure 6.20

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.

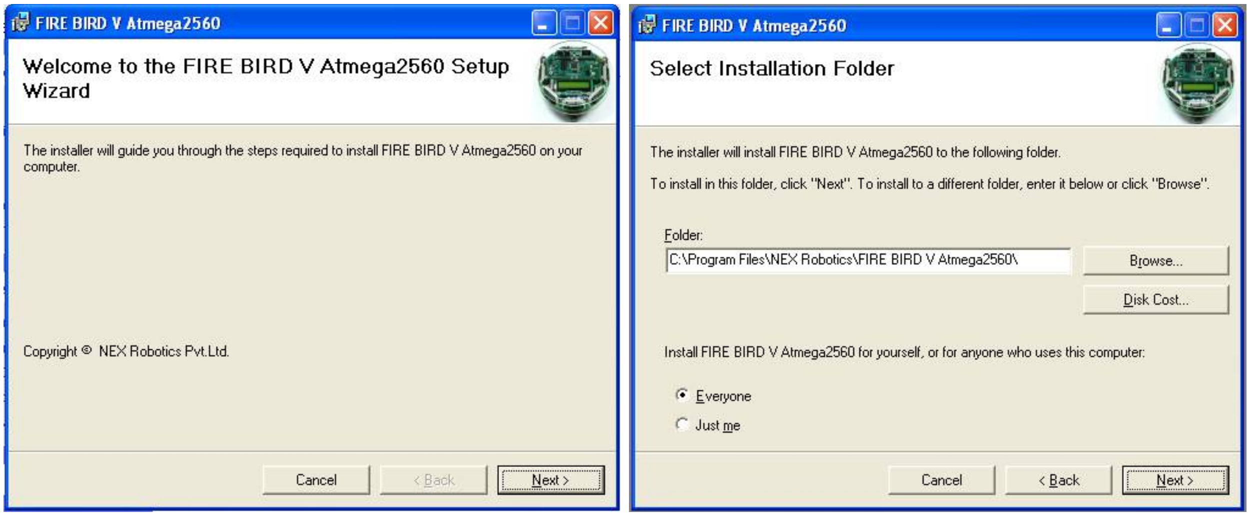


Figure 7.1

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.

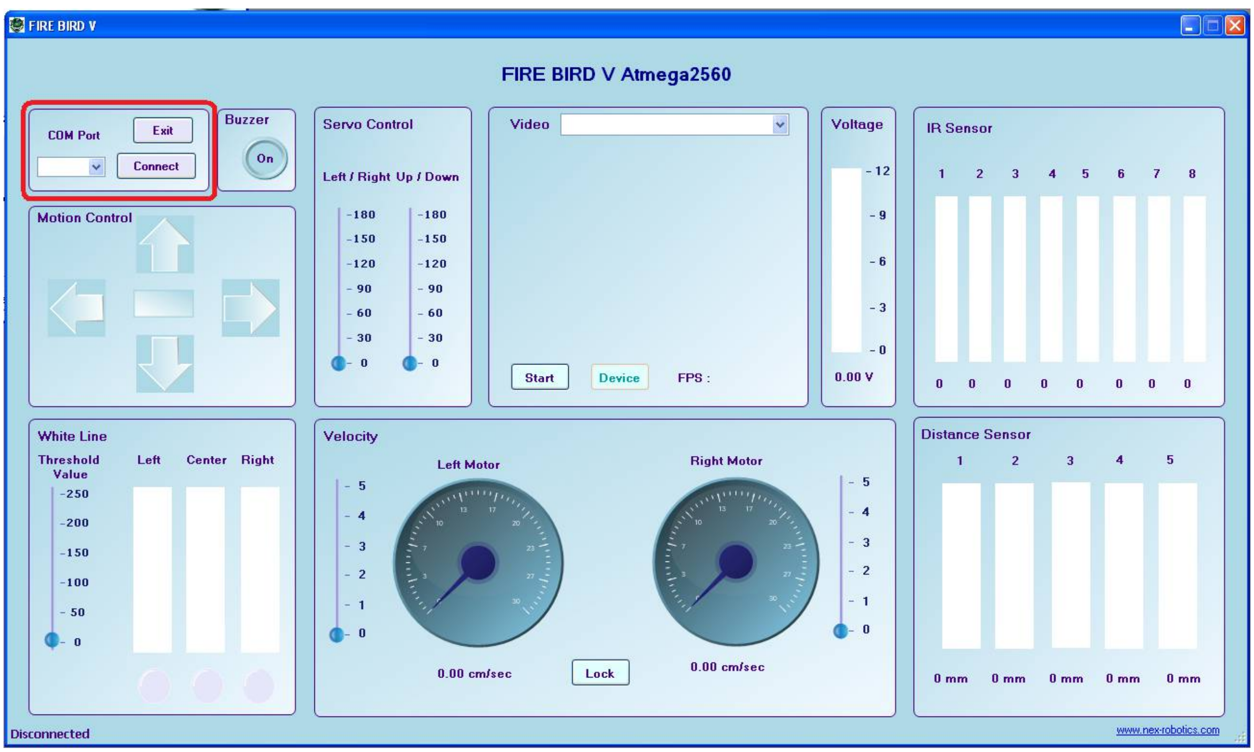


Figure 7.2: Selecting correct com port

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.

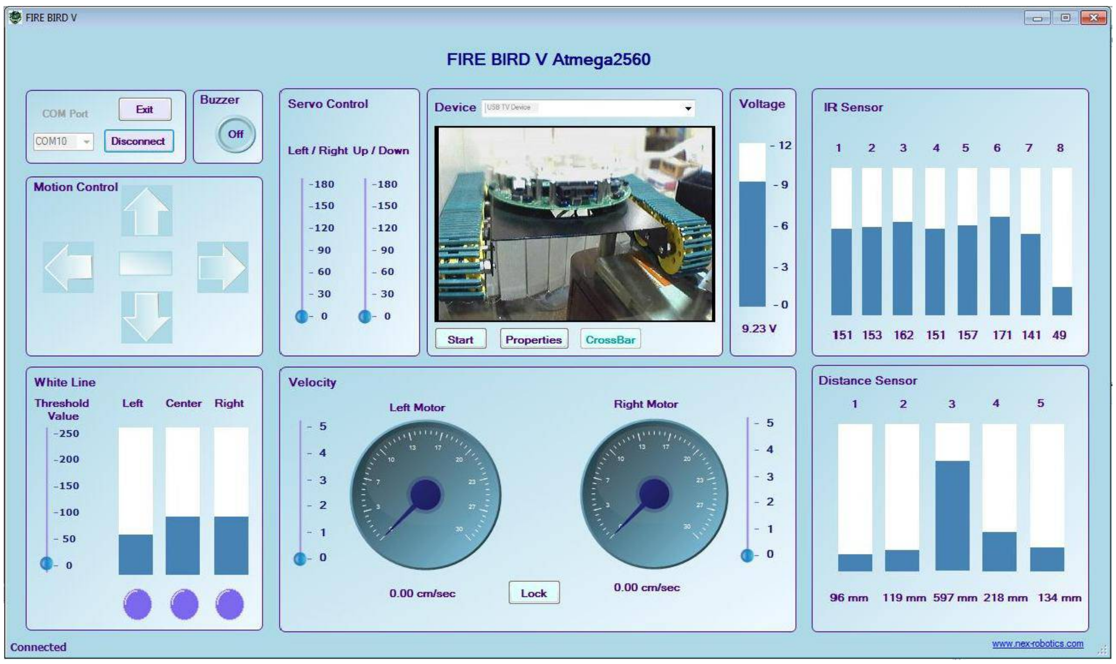


Figure 7.4 : Video display on the Fire Bird V robot's GUI

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. Make sure that XBee module on the robot and XBee module on the XBee USB module are configured at 115200bps.

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 at least 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.

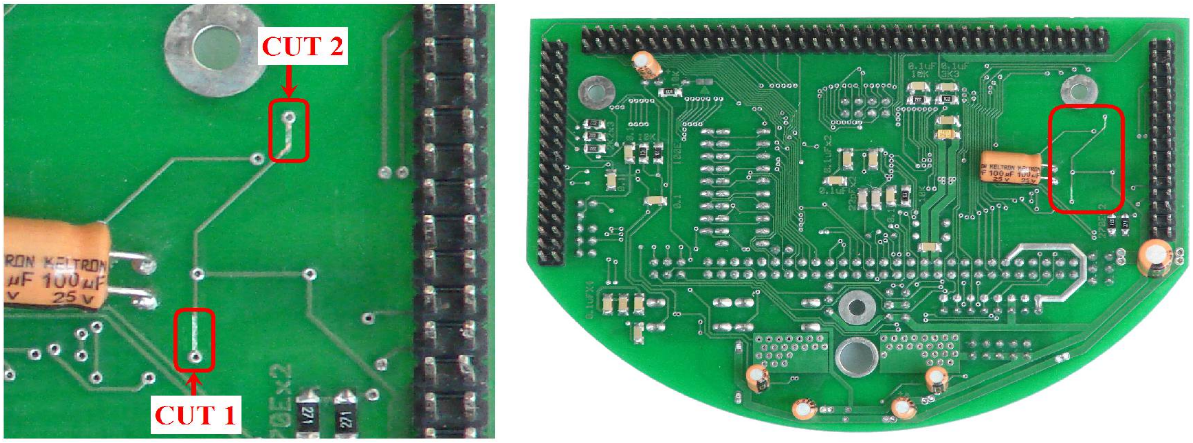
Example: Move servo motor1 by 90 degrees.
Numbers of steps required = 90°/2.25 = 40steps = 0x28 hex
Byte to send = 0x15 + 0x28 = 0x3D
Lower nibble = D hex
Upper nibble = 3 hex

Combining these nibbles with the commands:

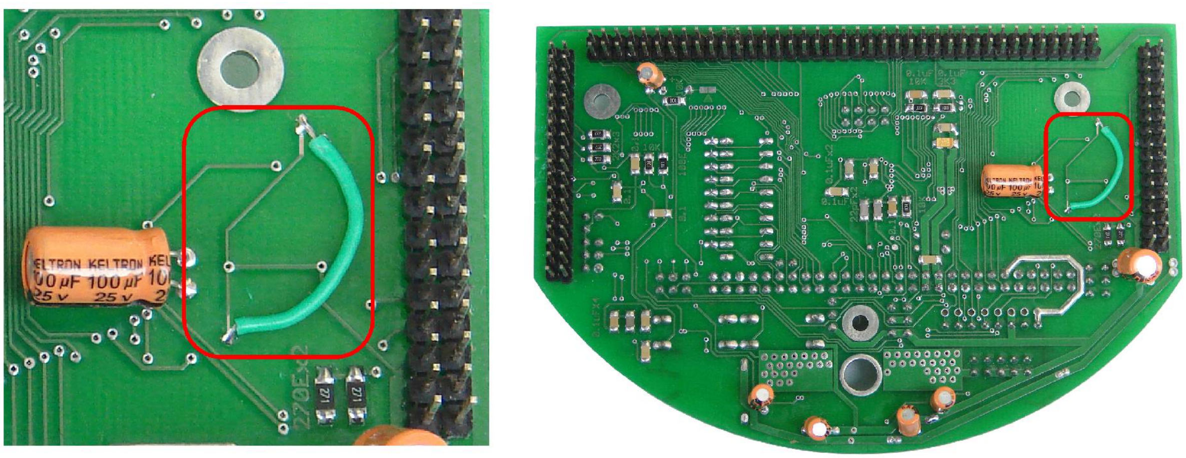
Step1: *send 0x8D through the serial port*
Step2: *delay by 3 milliseconds*
Step3: *send 0x93 through the serial port*

8. Errata

1. 17B pin on the Atmga2560 microcontroller adaptor socket is actually connected to PH4 pin of microcontroller and also connected to ground. To utilize 17B pin and PH4 pin for user application such as onboard ultrasonic triggering, it is recommended to cut the below shown track at 2 places in figure (A) and solder the wire as shown in figure(B).



Figure(A)



Figure(B)

Important: It is also recommended to put some glue on both solder point, where you soldered the wire to give the strengthen the soldering point.