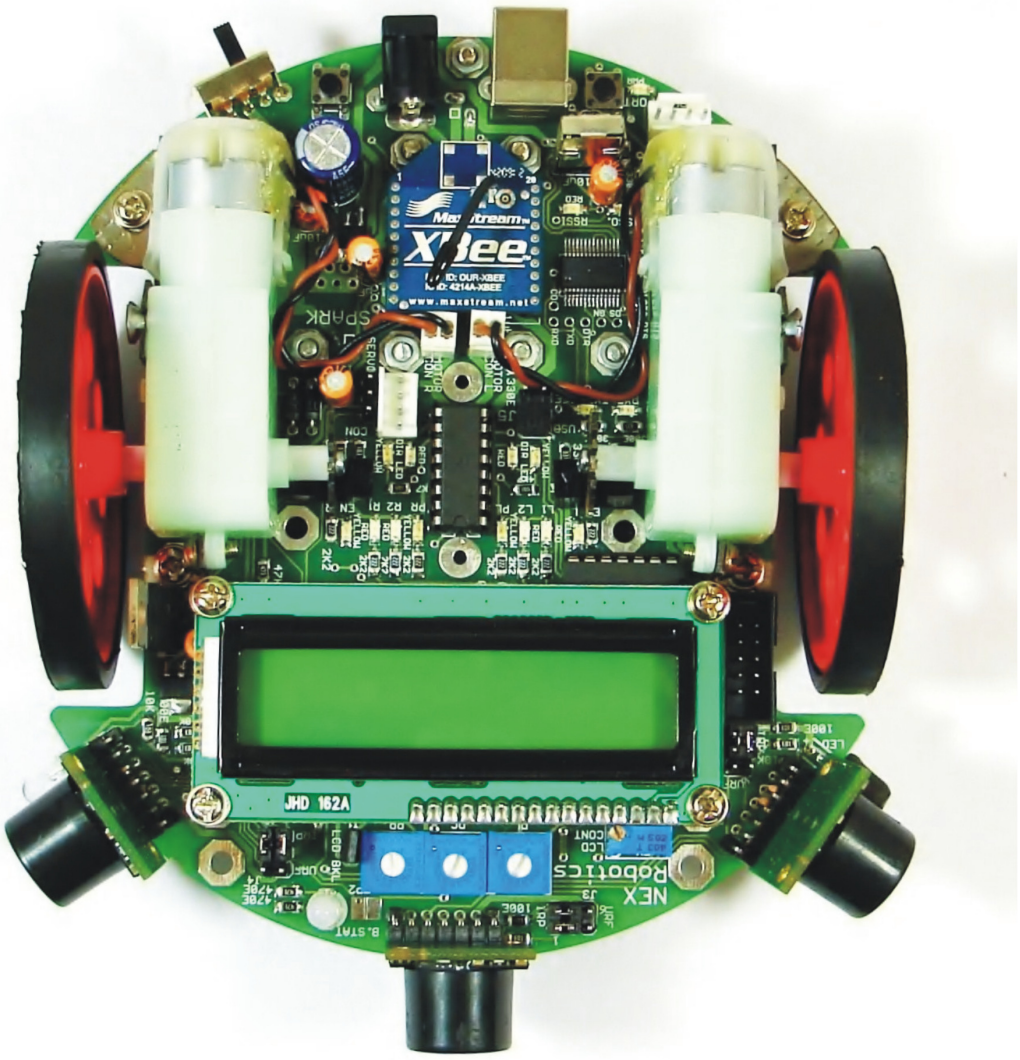
SPARK V

ATMEGA16
ROBOTIC RESEARCH PLATFORM
Hardware Manual



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Manufactured By: NEX Robotics Pvt. Ltd.

SPARK V

HARDWARE MANUAL

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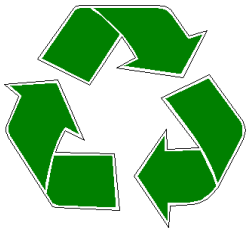
Notice

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

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



Recycling:

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

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1 Introduction

Spark V is a low cost robot designed for robotics hobbyists and enthusiasts. It is jointly designed by NEX Robotics with Department of Computer Science and Engineering, IIT Bombay. Spark V will help you get acquainted with the world of robotics and embedded systems. Thanks to its innovative architecture and adoption of the 'Open Source Philosophy' in its software and hardware design, you will be able to create and contribute to, complex applications that run on this platform, helping you acquire expertise as you spend more time with them.

Safety precautions:

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

Inappropriate Operation:

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

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

Note: For Spark V accessories refer to Chapter 10: Spark V Accessories

2 SPARK V ATMEGA16

Spark V robot is based on ATMEGA16 microcontroller. It has 3 analog white line sensors, 3 analog IR Proximity sensors, 3 directional light intensity sensors and Battery voltage sensing. Robot has support for 3 MaxBotix EZ series ultrasonic range sensors. It also has support for the servo mounted sensor pod which can be used to make 180 degrees scan for the map making. Robot can be powered by 6 AA size rechargeable Ni-MH batteries. Robot has built-in Smart Battery Controller which charges the battery in intelligent way and also monitors the battery charge level when robot is in operation. Robot has on-board FT232 based true USB to serial TTL converter. Robot programming is done using NEX Robotics Bootloader via USB port. There is no need to use external programmer. Robot has 2x16 alphanumeric LCD, Lots of LED indicators and Buzzer etc. for quick debugging. Robot has on-board socket for XBee wireless module for Multi robot and robot to PC communication. Robot has two low power 75 RPM DC geared motors which are powered by L293D motor driver with the top speed of 66cm/second.

Note: You need to buy MaxBotix EZ series ultrasonic range sensors, XBee wireless module and rechargeable NiMh Batteries separately.

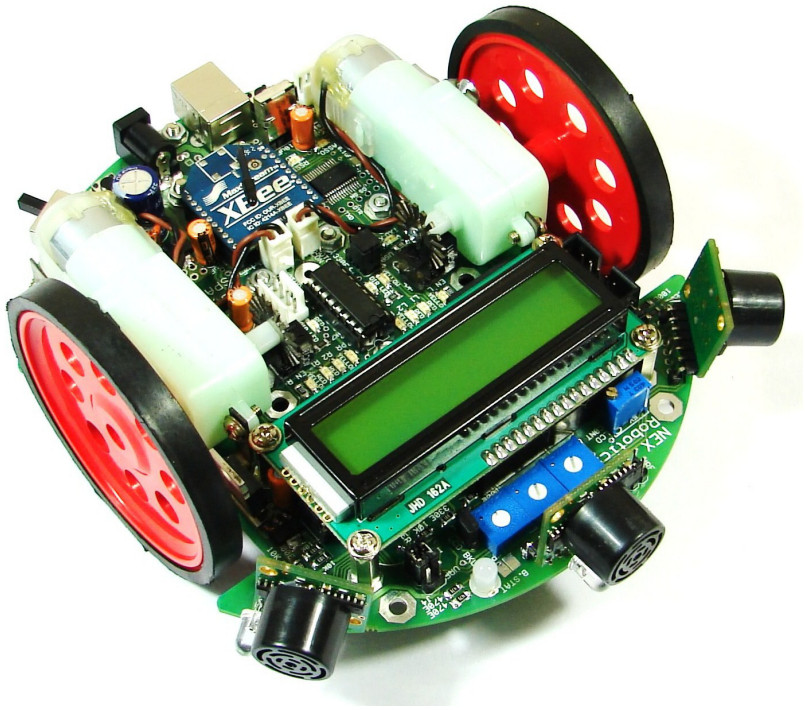


Figure 2.1 SPARK V Robot

3 SPARK V Block Diagram

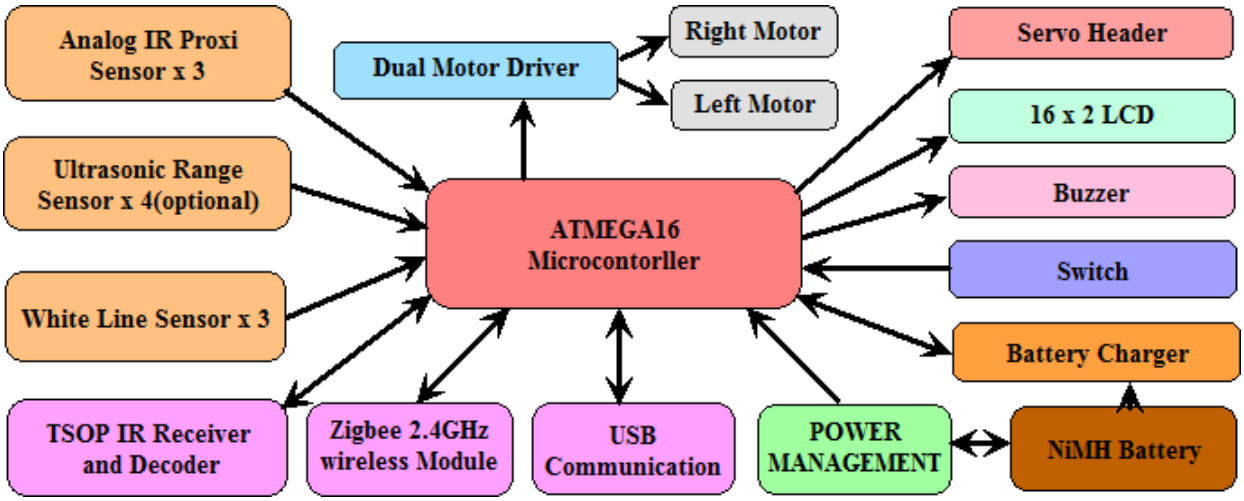


Figure 3.1 Spark V ATMEGA16 robot block diagram

3.1 SPARK V ATMEGA16 technical specification

Microcontroller: ATMEL ATMEGA16

Programming: Using NEX Robotics Boot loader via USB port (no need of separate programmer)

Sensors:
Three white line sensors
Three IR proximity sensors
Three directional light intensity sensors
Two Position Encoders (optional)
MaxBotix EZ series ultrasonic range sensors (optional)
Servo mounted Ultrasonic Range Sensor (optional)
Battery voltage sensing

Indicators:
2 x 16 Characters LCD
Indicator LEDs
Buzzer
Battery low indication

Locomotion:
Two 75 RPM DC geared motors and caster wheel as support
Built-in clutch for protection of the motors from non continuous wheel stalling.
Top Speed: 66cm/second

Operational Modes:
Standalone (Autonomous Control)
PC as master and robot as slave
Distributed (multi robot communication)

Communication:
USB Communication using FT232 USB to Serial Converter
Simplex infrared communication (From infrared remote to robot)
ZigBee (IEEE 802.15.4) (Wireless) (Robots to Robots and Robots to PCs)(Optional)

Dimensions:
Diameter: 15cm
Height: 7cm

Power:
6 AA size NiMH rechargeable batteries (Batteries not included)
On board Smart Battery Controller charges the battery in intelligent way and also monitors the battery charge level when robot is in operation.

Locomotion:
Two 75 RPM DC geared motors and caster wheel as support
Built-in clutch protection for the motors from non continuous stalling of the wheel
Top Speed: 66cm/second

Optional Accessories:
Servo mounted Ultrasonic range sensor for 180 degree scan
Servo mounted directional light intensity sensor for 180 degree scan
Two position encoders
MaxBotix EZ series ultrasonic range sensors
XBee wireless module

Software Support:
GUI Based control, AVR studio, WINAVR
Microsoft robotics studio Visual Programming Language (will be launched shortly)

Requires:
AC adaptor with exact 12VDC with 1Amp. current rating for battery charging.
6 NiMH rechargeable batteries

4 Using SPARK 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.

Spark V robot has 6 important modules:

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

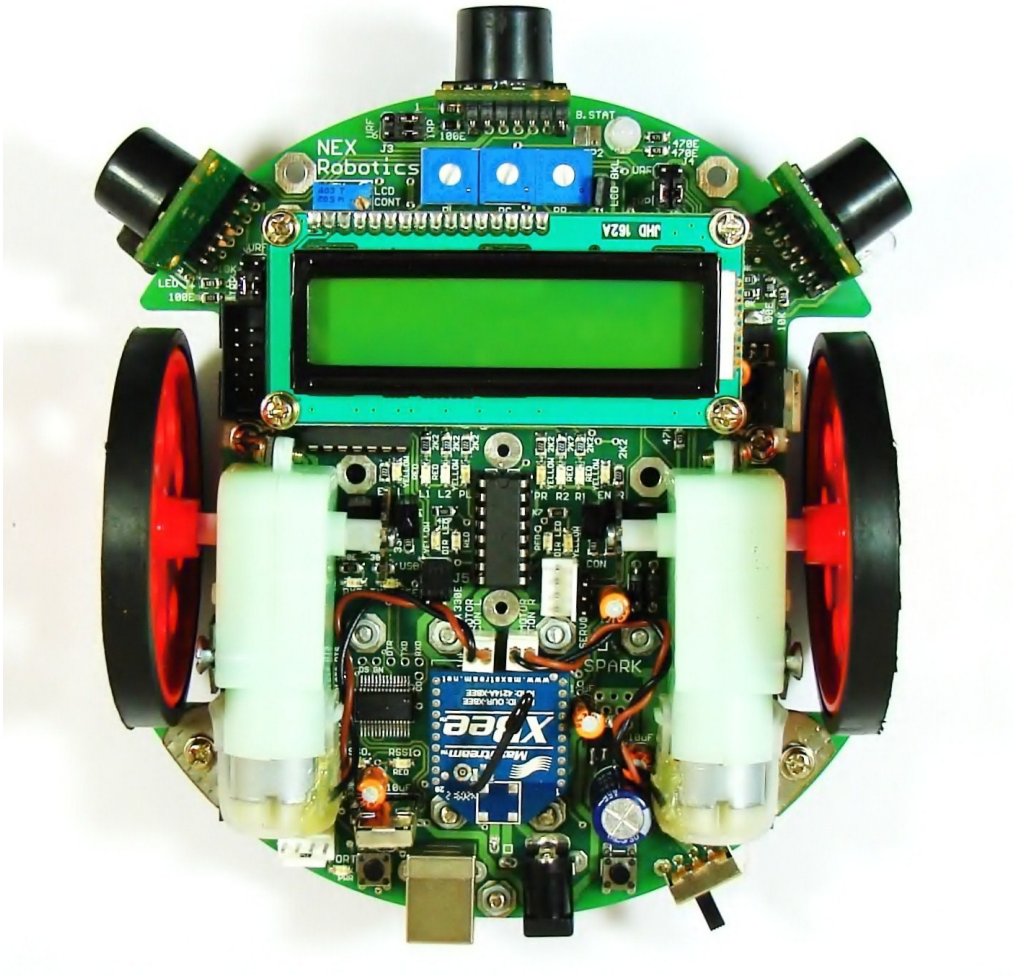


Figure 4.1 SPARK V ATMEGA16 robot top view

4.1 Connections

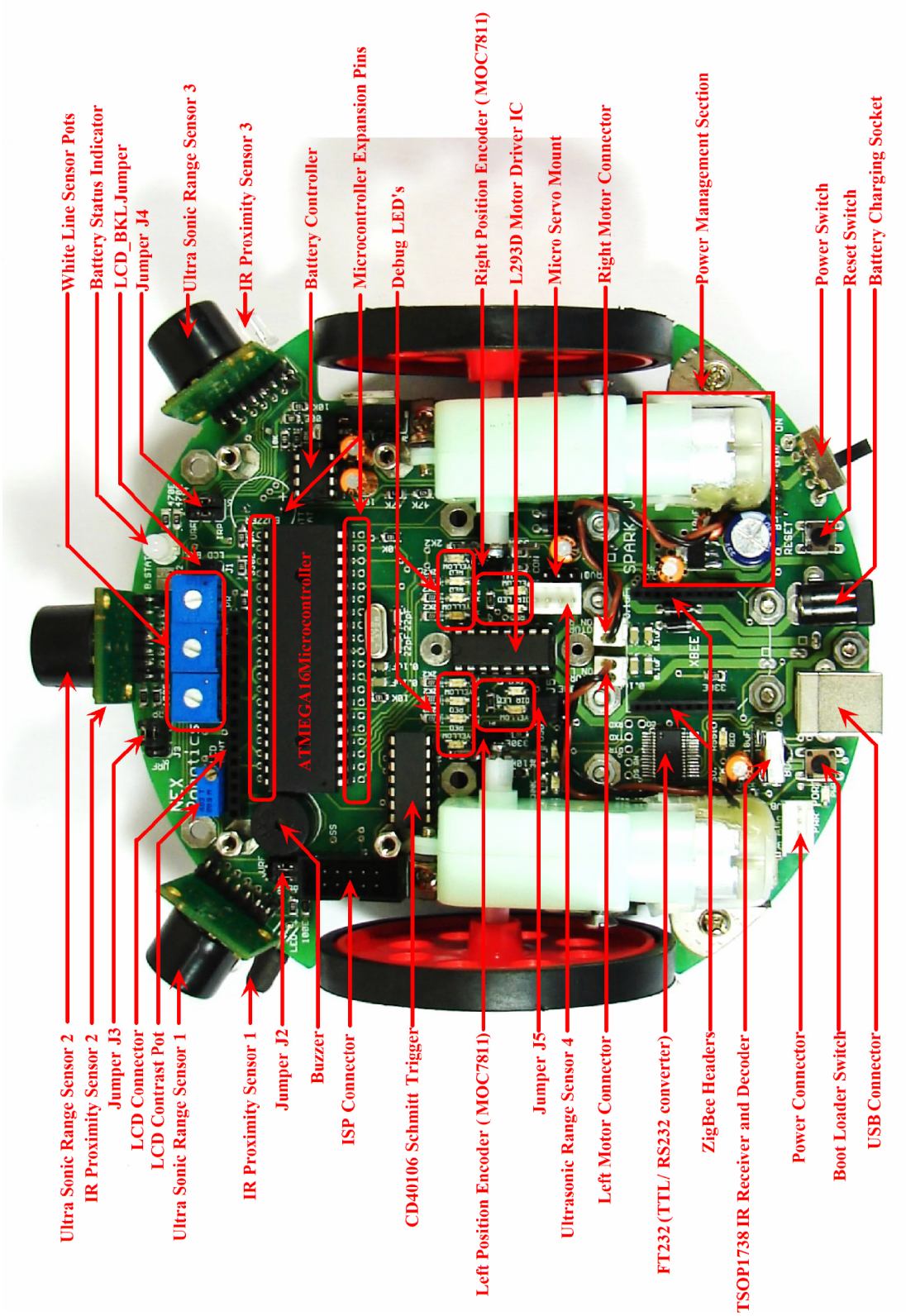


Figure 4.2 Spark V component layout top view

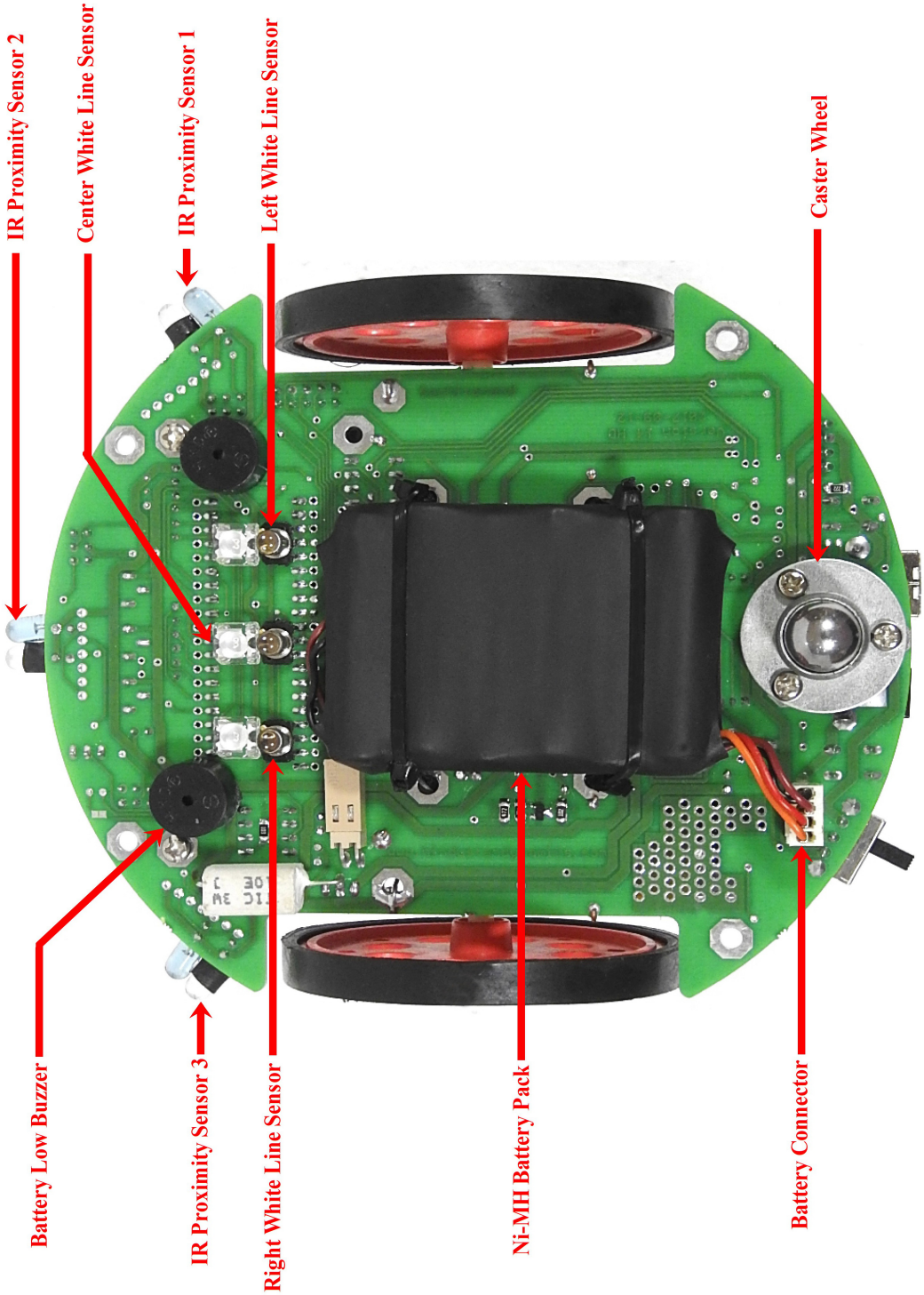


Figure 4.3 Spark V component layout bottom view

4.2 Powering up Spark V

Spark V is powered by six AA sized NiMH rechargeable batteries. 2.1Ah battery gives about two hour battery operation. Battery is available as pre-assembled 6 cell pack or robot has AA sized 6 cell battery holder. Battery is connected with the robot using 4 pin relimate connector which is located in the left sided of the caster wheel.

For safety during the transportation robot's battery connector is disconnected. Connect the battery connector before first use.

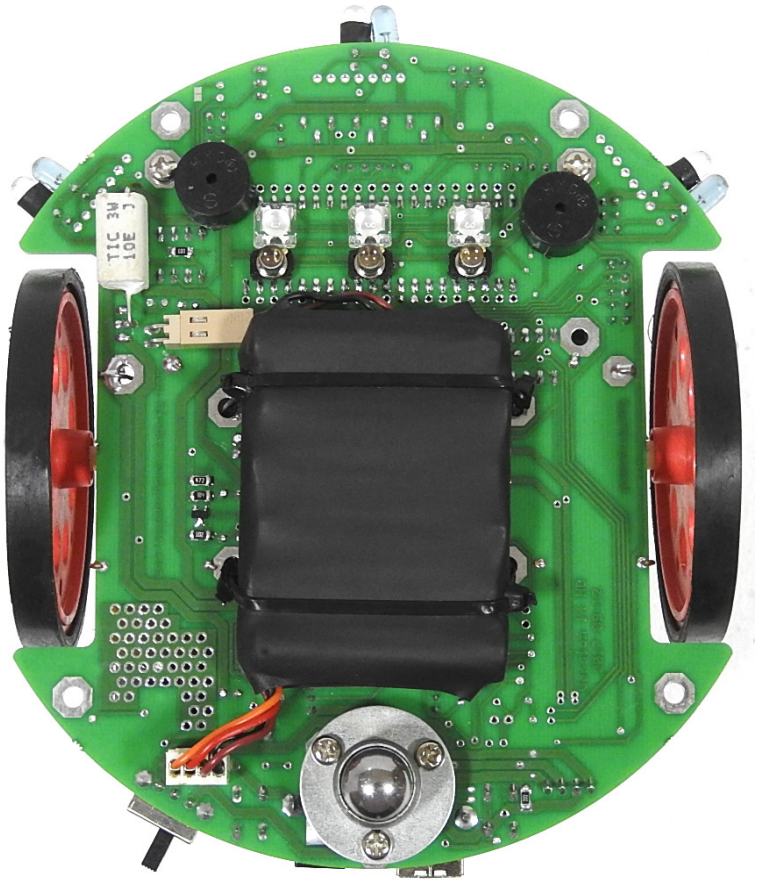


Figure 4.4 Battery packs in Spark V

Before connecting the battery pack or inserting batteries in the socket, make sure that power switch of the robot is off. Robot has on-board smart battery controller which can charge the installed batteries. You need to charge the battery before first use. Use any AC adaptor / SMPS which can give accurate 12V DC and 1Amp current. For battery charging procedure refer to section 4.4. For robot powering options, refer to section 4.5.

4.3 Power management system on the SPARK V

Spark V is powered by 6 NiMH rechargeable batteries of 0.8Ah and above capacity. When it is fully discharged voltage drops to about 7V. Battery pack should not be discharged below 6V (1V per cell) for extended battery life. Spark V has onboard smart battery controller which monitors battery status. Nickel Metal Hydride batteries must be recharged using smart charging circuit which follows the appropriate charging profile for the batteries. To avoid any damage to the batteries, only use onboard battery charger.

Power management block on the SPARK V performs following functions.

1. Battery low warning in case battery is below critical level
2. Regulated supply for onboard payload.
3. Battery charging when robot is powered off and external battery charger is connected.

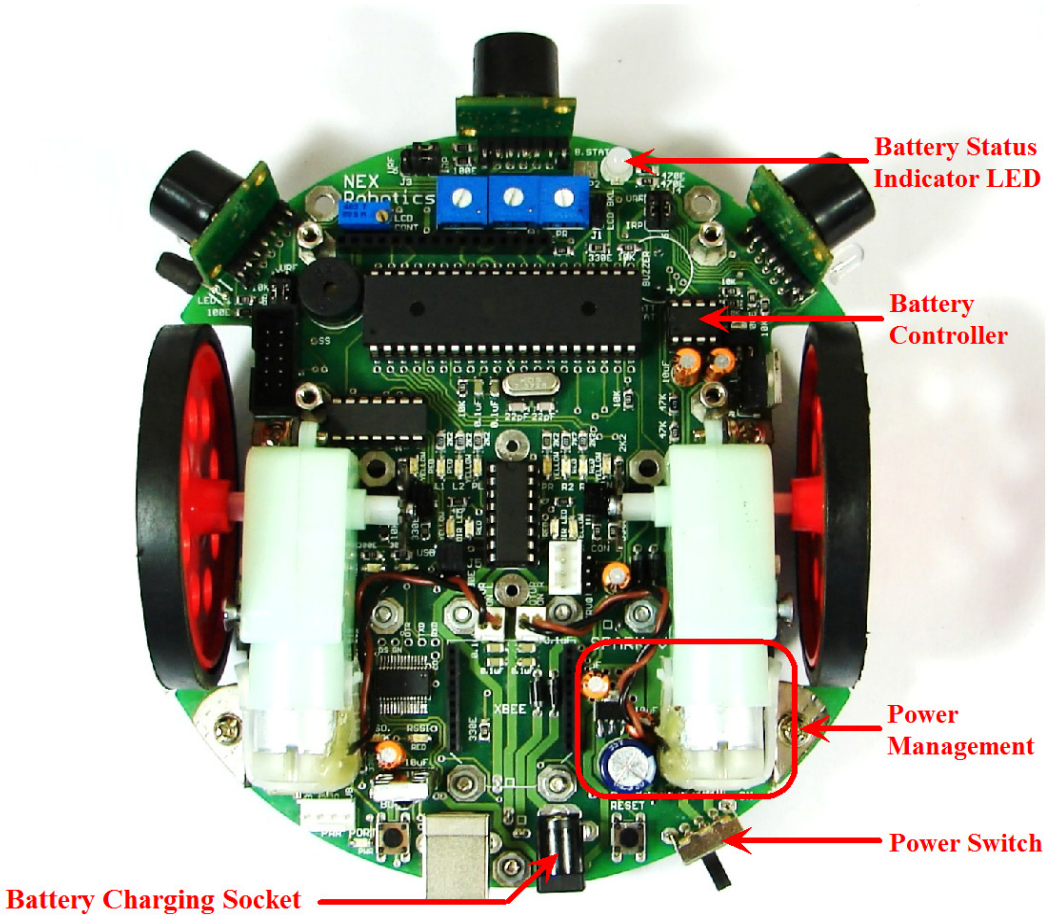


Figure 4.5 Power Management on the Spark V robot

Regulated supply for onboard payload:
Three low drop voltage regulators are used for powering various modules of the robot.
5V System: Powers microcontroller, logic circuit and sensors
3.3V: Powers XBee wireless module
5V Batt. Con: Powers Battery controller

Battery Controller:
When robot is powered up, smart battery monitoring circuit monitors the battery voltage and if it drops below 7V, it starts giving beeping sound and battery status indicator led blinks with green color.

When robot is off and 12V DC is applied to the battery charging socket, Smart battery monitoring circuit charge the battery.

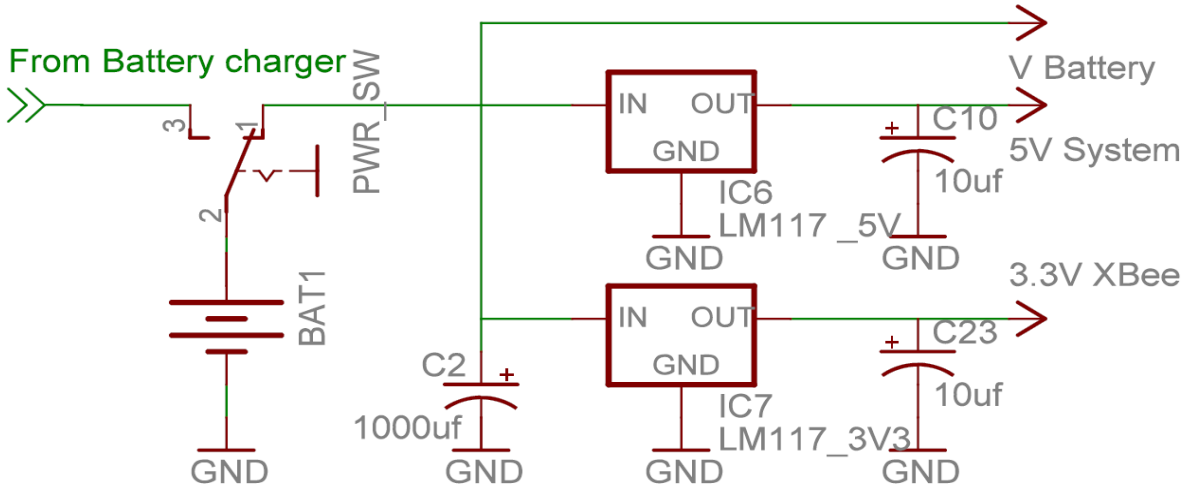


Figure 4.6 Schematic of power management on module

4.4 Battery Charging

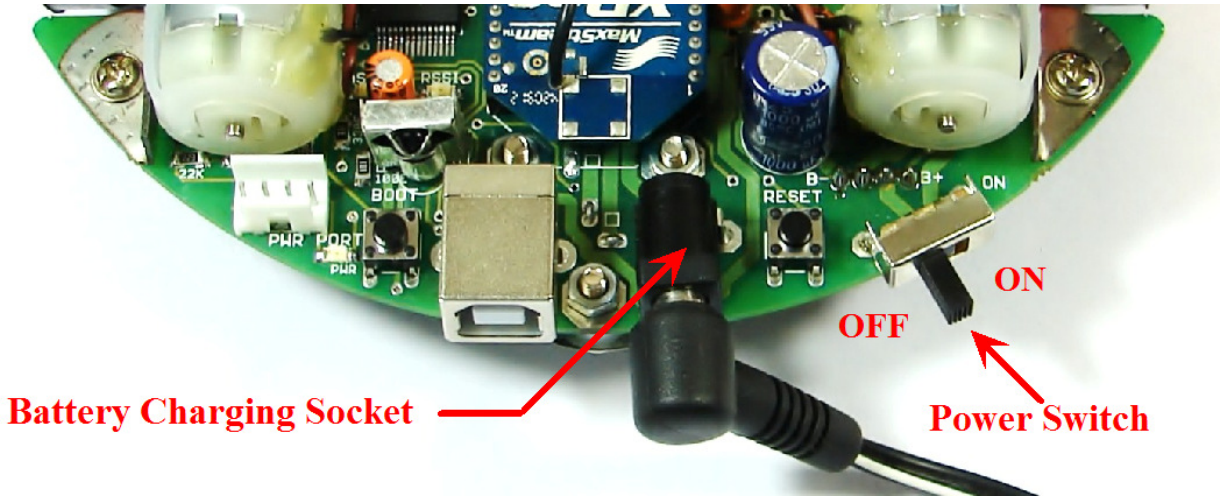


Figure 4.7 Battery Charging

Robot has on-board battery controller which charges robot's battery. Use any AC-DC adapter which can give precise 12V supply with at least 1 amp current. If voltage is more than 12V the battery will not get fully charged.

Battery charging procedure:

1. Make sure that robot's power switch is in off position.
2. Insert the 6 NiMH batteries / battery pack of 800mAh or more capacity.
3. Insert the DC jack of the 12V, 1Amp rating AD-DC adapter n the battery charging socket of the robot and power up the AC adaptor / SMPS.

Now smart battery controller will sense the presence of the battery charging supply and will start charging the battery. It will terminate the battery charging once battery is fully charged. During the charging process battery status can be monitored on the battery status LED. Refer to the table below for battery charging status interpretation using battery status LED.

Indicator LED	Battery Status	Charger Status
Green		
ON	Voltage < 7.2 V	Battery is getting charged
blinking	Fully charged	Battery is fully charged

Table 4.1: Battery status indicator LED interpretation

Important:

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

⚠Warning:

- Many transformer based AC adapter's voltage is 30 to 40% higher when there is no load. Make sure that AC adapter's no load voltage is precisely 12V else it will damage the robot and battery.
- If you are using SMPS, then make sure that it doesn't have mains leakage current flowing through the DC supply. Else when you touch the robot, this high voltage leakage current will damage the robot's electronics.

4.5 Powering the robot using battery or external supply

Ideally robot is powered by on-board batteries but if you want to do experiments or code development for longer duration then you can also power the robot by external supply.

To run the robot on the batteries, make sure that 4 pin relimate battery connector is inserted in the battery connector socket. Refer to figure 4.8 for the battery connector's location.

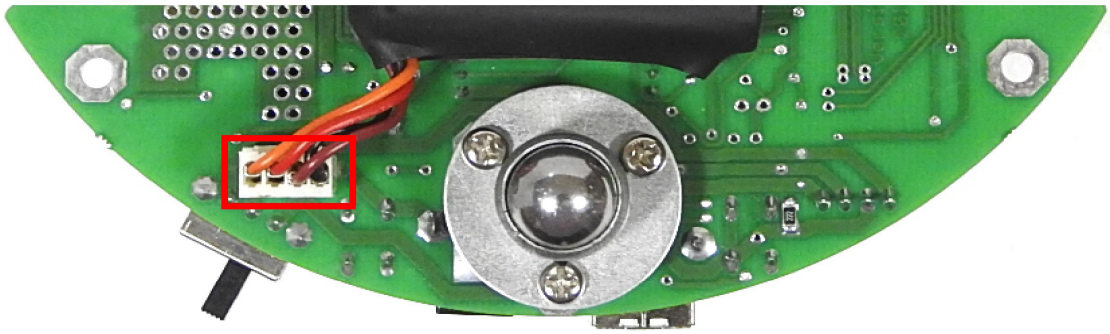


Figure 4.8 Battery Connector and its socket

To run the robot on the external supply, remove the 4 pin relimate battery connector from its socket and use another 4 pin relimate connector to give external supply. External supply should be in between 7.1 to 9V. Red and Orange are the positive terminals. Brown and Black are the negative terminals.

⚠Warning:

- Do not exceed 9V voltage limit else robot will get damaged.
- Battery connector socket is not reverse polarity protected. If supply is applied in reverse polarity, it will immediately damage the robot.
- Use only good quality bench top power supply to power the robot using external supply. Use of AC adaptor or cheap SMPS is not recommended.

4.6 Battery Maintenance

Fully charged NiMH battery will get completely discharged with in a week of storage. Always charge the battery before use. If fully charged battery is kept in storage for about a month and afterwards even if it's fully charged again, it can deliver only 1/3rd power of its rating. In such case to restore battery to its full potential again, perform at least 2-3 charge discharge cycles.

To ensure long life, charge battery at least once a week and discharge it till robot starts giving battery low warning. Before storage, charge the battery again.

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

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

4.7 Motion control

Spark 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 66cm 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. Robot's motors have built-in clutch for protection of the motor's gears from non continuous wheel stalling.

Motion control involves direction control and velocity control. Motors are controlled by L293D dual motor driver which can provide up to 600mA of current to each motor. To change the direction of the motor, appropriate logic levels (High/Low) are applied to L293D's direction control pins. Velocity control is done using Pulse Width Modulation (PWM).

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

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.

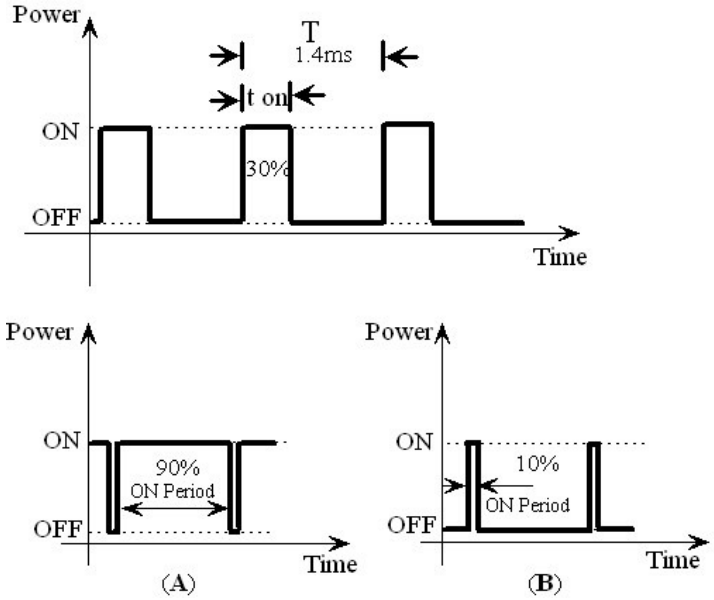


Figure 4.9 Pulse Width Modulation (PWM)

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

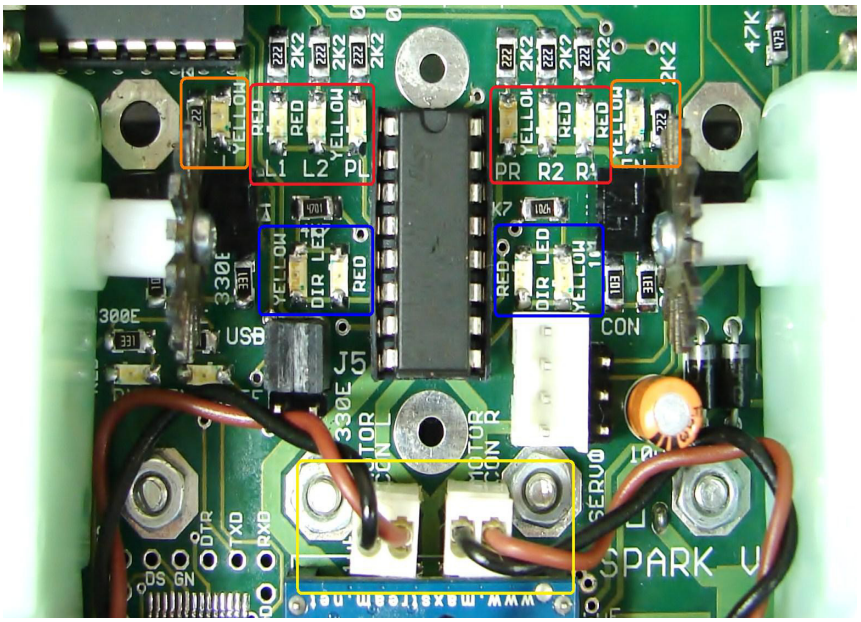


Figure 4.10 Motion Control

In the figure 4.10 area marked with the red border are the LEDs connected to the input stage of the L293D motor driver. Area marked by Blue border shows LEDs connected to the output of the motor driver. Orange border marks position encoder output LEDs. Yellow border marks left and right motor connectors.

Microcontroller pin connections

Microcontroller Pin	Function
PD5 (OCR1AL)	Pulse width modulation for the left motor (velocity control)
PD4 (OCR1BL)	Pulse width modulation for the right motor (velocity control)
PB0	Left motor direction control
PB1	Left motor direction control
PB2	Right motor direction control
PB3	Right motor direction control

Table 4.2 Pin functions for the motion control

LED Direction Indications

Direction	L1 (Red) (I/P) PB0	L2 (Red) (I/P) PB1	PL (Yel.) (I/P) PD3	R1 (Red) (I/P) PB2	R2 (Red) (I/P) PB3	PR (Yel.) (I/P) PD4	Direction Output (Red / Yel.)	
							Left Motor	Right Motor
FORWARD	0	1	1	1	0	1	Yellow	Yellow
REVERSE	1	0	1	0	1	1	Red	Red
RIGHT *(Left wheel forward, Right wheel backward)*	0	1	1	0	1	1	Yellow	Red
LEFT *(Left wheel backward, Right wheel forward,)*	1	0	1	1	0	1	Red	Yellow
SOFT RIGHT *(Left wheel forward,, Right wheel stop)*	0	1	1	0	0	1	Yellow	Off
SOFT LEFT *(Left wheel stop, Right wheel forward,)*	0	0	1	1	0	1	Off	Yellow
SOFT RIGHT 2 *(Left wheel stop, Right wheel backward)*	0	0	1	0	1	1	Off	Red
SOFT LEFT 2 *(Left wheel backward, Right wheel stop)*	1	0	1	0	0	1	Red	Off
HARD STOP	0	0	1	0	0	1	Off	Off
SOFT STOP (Free running stop)	1	1	1	1	1	1	Off	Off

Table 4.3 Direction and PWM LED indications

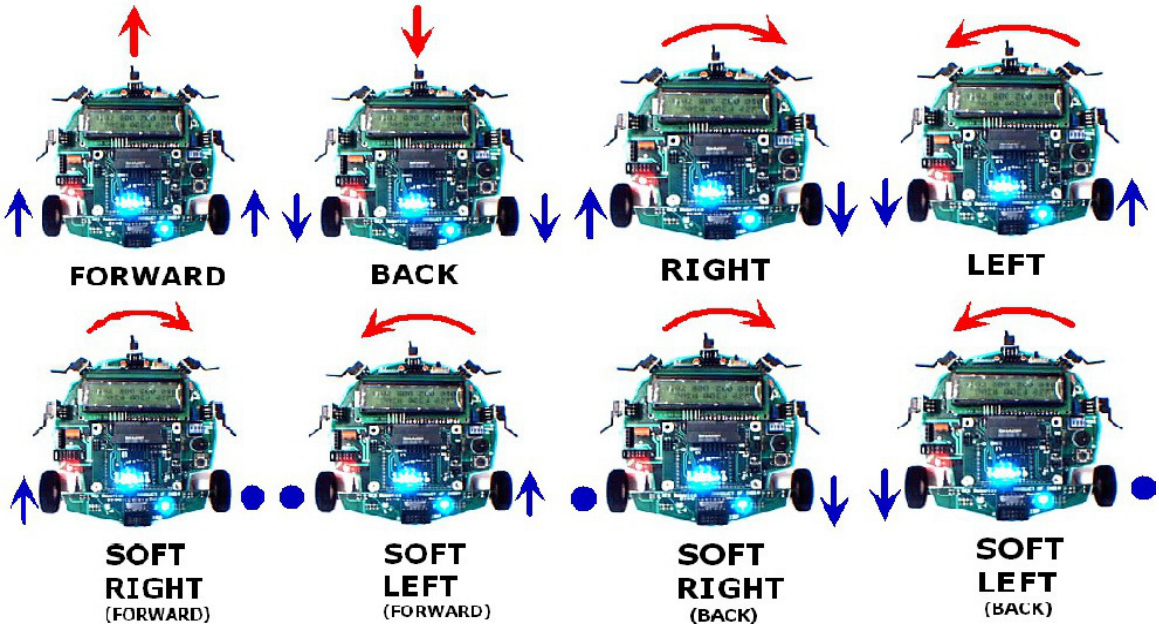


Figure 4.11 Robot direction interpretation

Logic levels for setting direction and velocity

DIRECTION	LEFT BWD (LB) PB0	LEFT FWD(LF) PB1	RIGHT FWD(RF) PB2	RIGHT BWD(RB) PB3	PWM PD5 for left motor PD4 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 4.4 Logic levels for setting direction and velocity

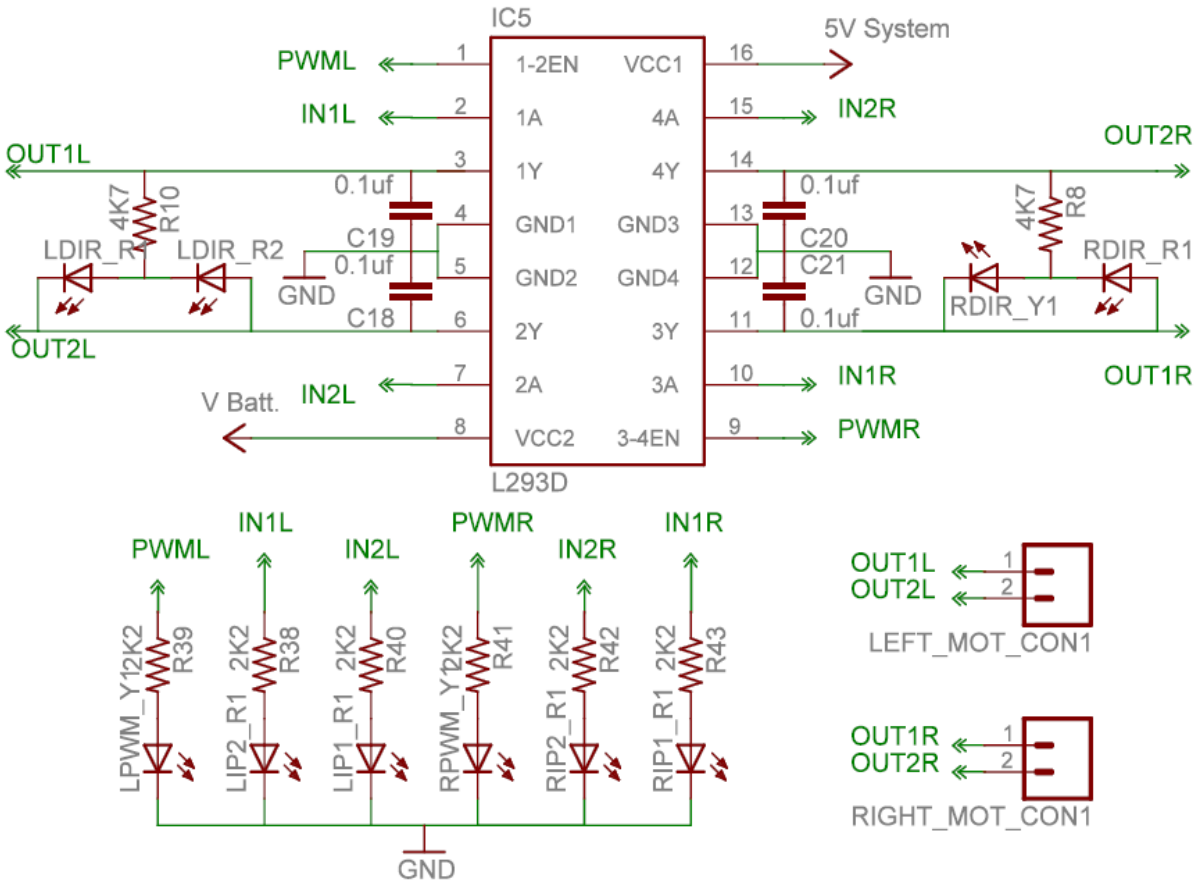


Figure 4.12 Motion Control

4.8 Position Encoders

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

Optical encoder MOC7811 is used for position encoder on the robot. It consists of IR LED and the photo transistor mounted in front of each other separated by a slot in black opaque casing with small slot shaped window facing each other. When IR light falls on the photo transistor it gets in to saturation and gives logic 0 as the output. In absence of the IR light it gives logic 1 as output. A slotted encoder disc is mounted on the wheel is placed in between the slot. When encoder disc rotates it cuts IR illumination alternately because of which photo transistor gives square pulse train as output. Output from the position encoder is cleaned using Schmitt trigger based inverter (not gate) IC CD40106. CD40106 also drives left and right position encoder status LEDs. For more details, refer to figure 4.13.

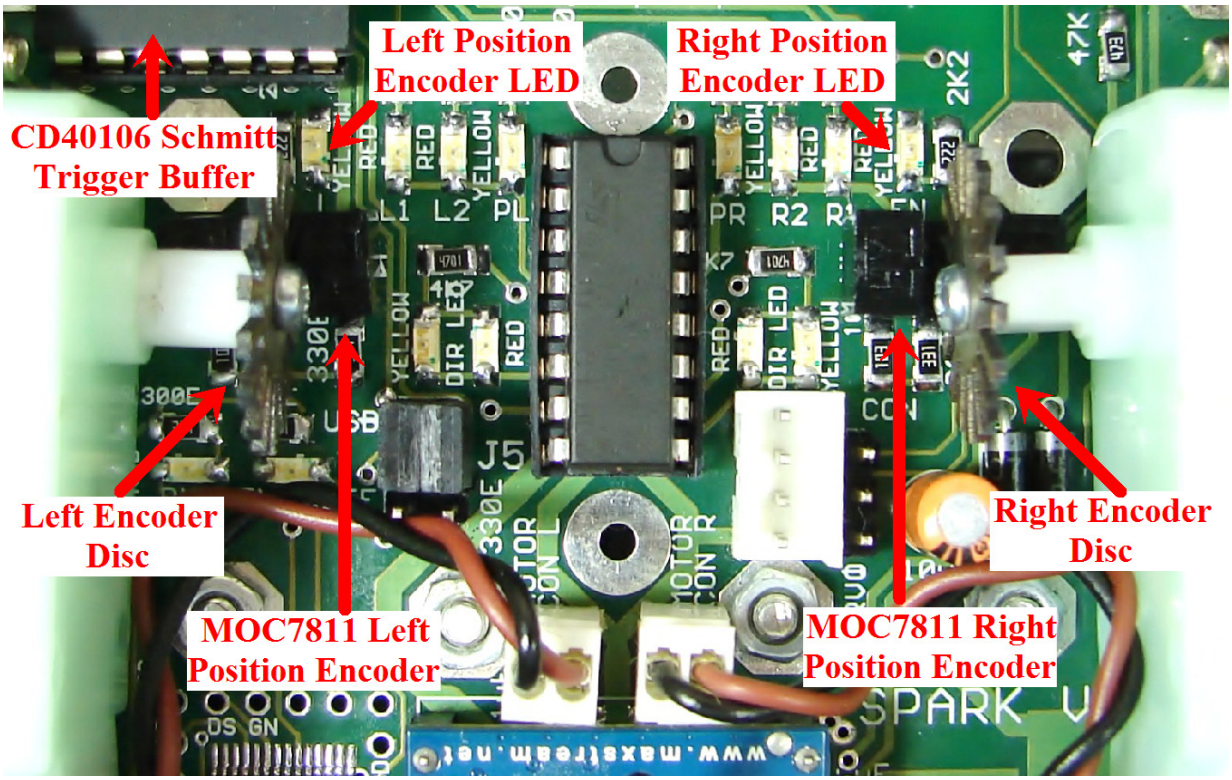


Figure 4.13 Position Encoders

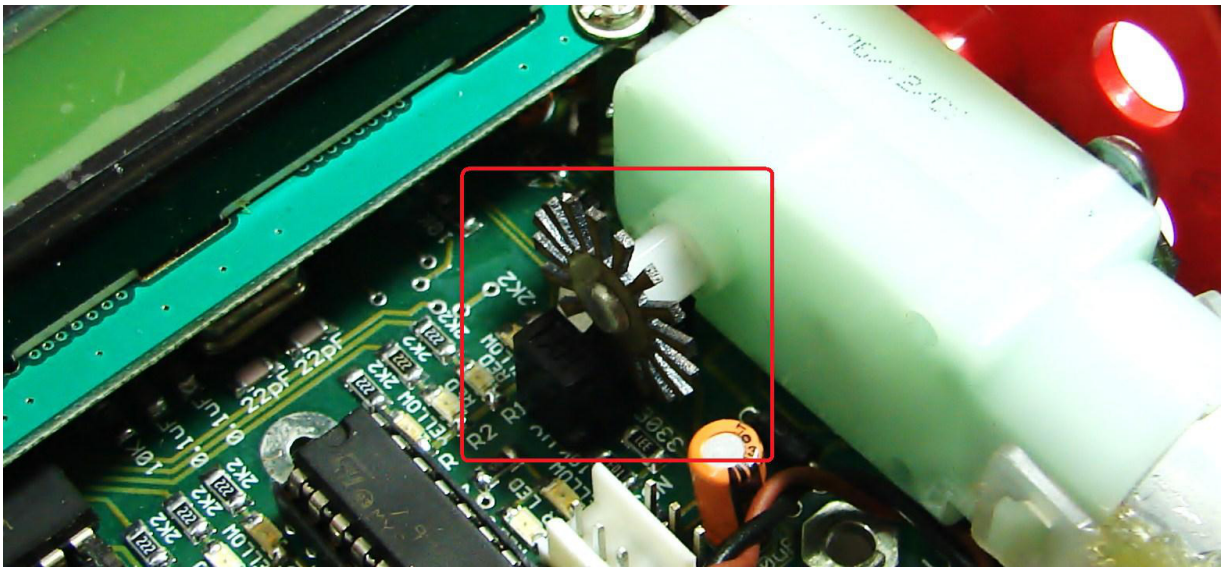


Figure 4.14 Position encoder assembly

Calculation of position encoder resolution:

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

Wheel diameter: 7cm
Wheel circumference: 7cm * 3.14 = 21.980cm = 219.80mm
Number slots on the encoder disc: 17
Position encoder resolution: 219.80 mm / 17 = 12.92mm / 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 = 11.6cm

Radius of Circle formed in 360^0 rotation of Robot = Distance between Wheels / 2
= 5.8 cm

Distance Covered by Robot in 360^0 Rotation = Circumference of Circle traced
= 2 x 5.8 x 3.14
= 36.4 cm or 364mm

Number of wheel rotations in 360^0 rotation of robot
= Circumference of Traced Circle / Circumference of Wheel
= 364 / 219.80
= 1.65

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
= 17 x 1.65
= 28.05 (approximately 28)

Position Encoder Resolution in Degrees = 360 / 28
= 12.85 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
= 11.6 cm

Distance Covered by Robot in 360^0 Rotation = Circumference of Circle traced
= 2 x 11.6 x 3.14
= 72.848 cm or 728 mm

Number of wheel rotations of in 360^0 rotation of robot
= Circumference of Traced Circle / Circumference of Wheel
= 728 / 219.80
= 3.312

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
= 17 x 3.312
= 56.304 (approximately 56)

Position Encoder Resolution in Degrees = 360 /56
= 6.42 degrees per count

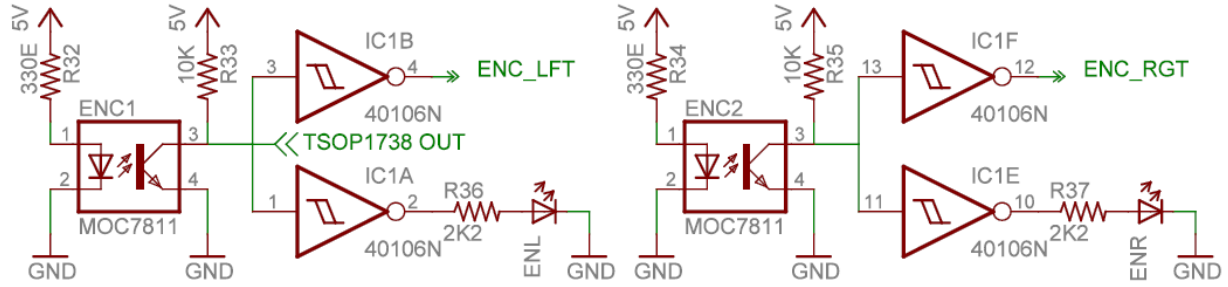


Figure 4.15 Position encoder schematics

4.9 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. Spark V robot has 3 IR proximity sensors.

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

If IR LEDs are disabled using jumpers then same photo diodes works as directional light intensity sensors.

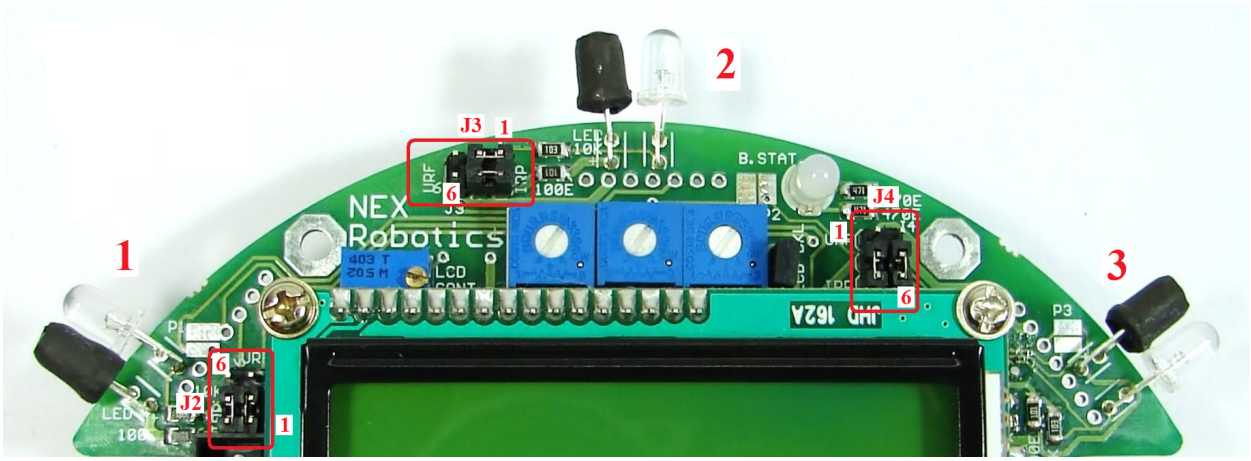


Figure 4.16 Infrared proximity and Directional light intensity sensors and Jumper settings for enabling IR Proximity sensors

Figure 4.6 shows 3 Infrared proximity and Directional light intensity sensors on the Spark V robot. Sensors are numbered as 1, 2 and 3 from left to right in clockwise direction. In all the manuals this numbering convention will be used for addressing the particular IR sensor.

IR photo diode consumes about 0.5mA when bright light drives the sensor in to saturation. IR LED if enabled will consume about 30mA current each. Remove the appropriate jumper to reduce the power consumption of the robot.

Enabling the IR proximity and Directional light intensity sensors

ATMEGA16 microcontroller has only 8 ADCs. 3 ADC pins are shared between IR Proximity sensors and Ultrasonic Range sensors. At any given sensor location either IR Proximity sensor or Ultrasonic range sensor can be used. Both sensors can not remain active at the same time. Figure 4.16 shows J2, J3 and J4 settings for enabling IR proximity sensors. Jumpers are marked with red border. To use IR proximity sensors place the 2 jumper caps of the jumper corresponding to particular sensor towards "IRP" (IR Proximity sensors). Out of these two jumpers one jumper connects power to the sensor and other connects microcontroller's ADC pin to the sensor output.

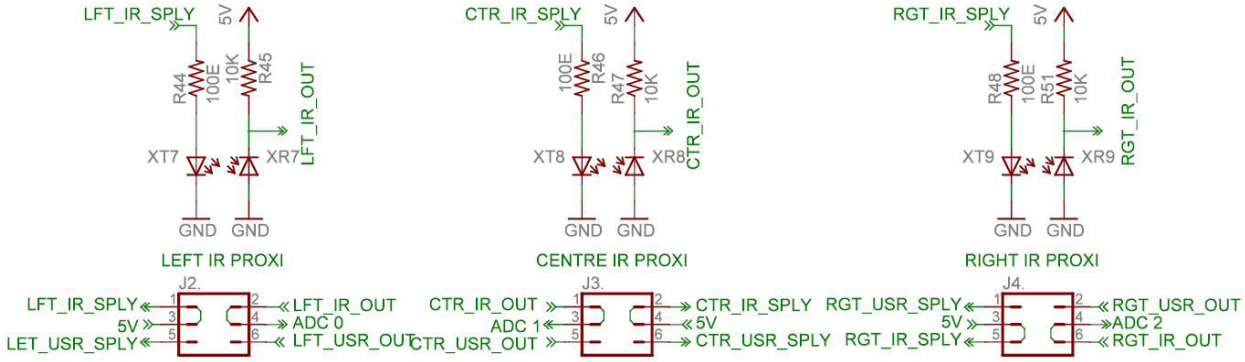


Figure 4.17 IR proximity sensors and correct jumper setting to enable them

Figure 4.17 shows schematic of the IR proximity sensor and the correct jumper setting to enable them. For jumper positions and pin number of the jumpers refer to figure 4.16.

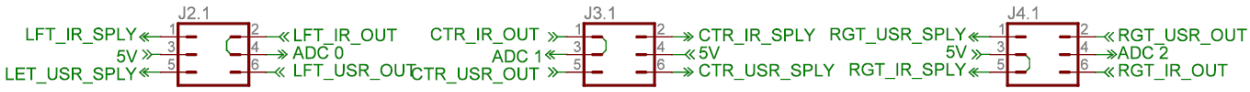


Figure 4.18 Jumper setting to use IR proximity sensor as directional light intensity sensor

Figure 4.18 shows the jumper settings to use IR proximity sensor as directional light intensity sensor. For jumper positions and pin number of the jumpers refer to figure 4.16.

IR Proximity Sensor	ADC channel number
Left	ADC channel no. 0
Center	ADC channel no. 1
Right	ADC channel no. 2

Table 4.5 IR Proximity Sensor connections with ADC of the ATMEGA16 (after correct jumper settings)

4.10 Ultrasonic range sensors

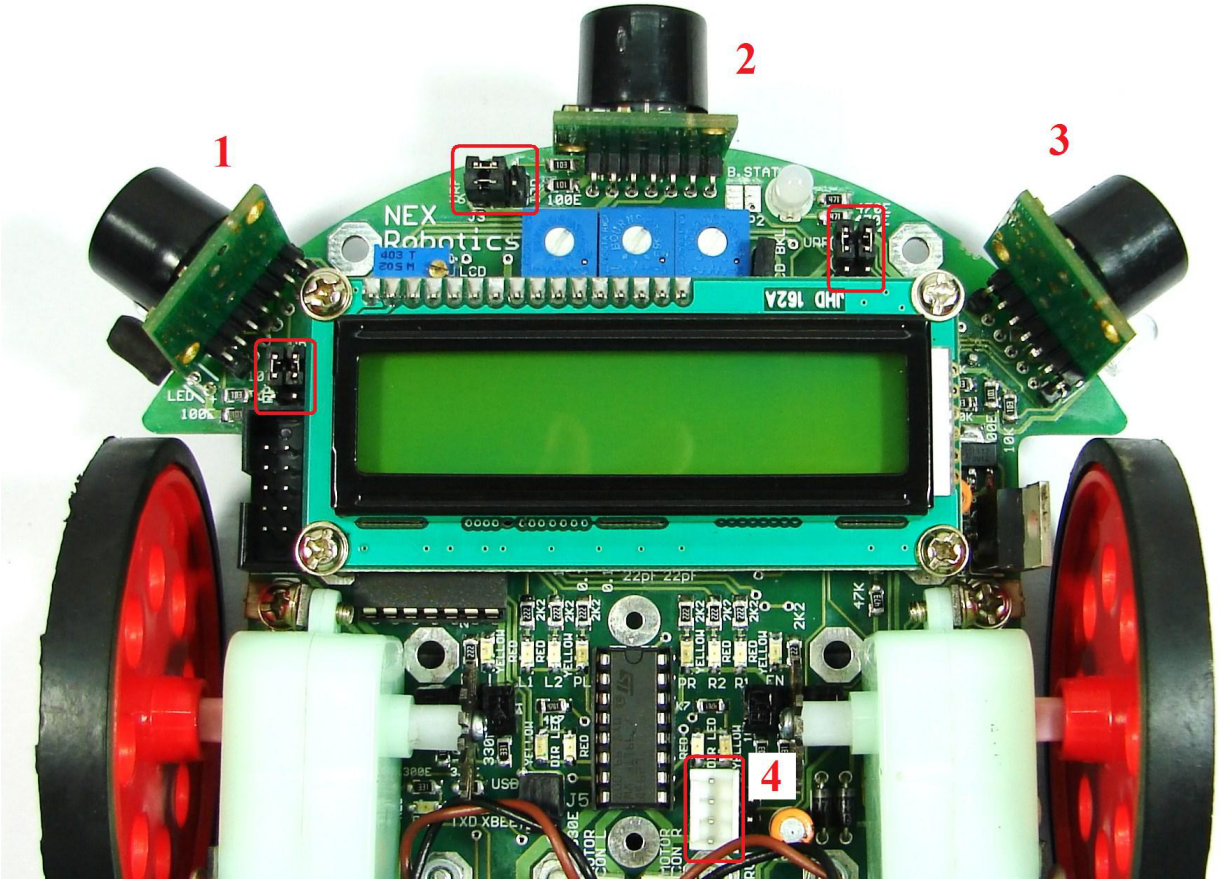


Figure 4.19 Ultrasonic range sensors and jumper settings to enable them

Spark V robot can be equipped with the 4 ultrasonic sensors from MaxBotix. Three sensors are mounted just above the 3 IR proximity sensors. 4th Sensor can be mounted on the servo motor for taking 180 degrees scan for map making (marked as 4). 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.

Spark V robot supports EZ0 to EZ4 series of ultrasonic range 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 4.19 shows locations of the ultrasonic sensors. They are numbered as 1, 2, and 3 from left to right. Number “4” marks connector for the 4th ultrasonic range sensor which can be mounted on the servo motor for taking 180 degrees range scan.

Enabling the Ultrasonic range sensors

ATMEGA16 microcontroller has only 8 ADCs. 3 ADC pins are shared between Ultrasonic Range sensors and IR Proximity sensors. At any given sensor location either IR Proximity sensor or Ultrasonic range sensor can be used. Both sensors can not remain active at the same time. Figure 4.19 shows J2, J3 and J4 settings for enabling Ultrasonic range sensors. Jumpers are marked with red border. To use Ultrasonic range sensor, place the 2 jumper caps of the jumper corresponding to particular sensor towards "URF". Out of these two jumpers one jumper connects power to the sensor and other connects microcontroller's ADC pin to the sensor output.

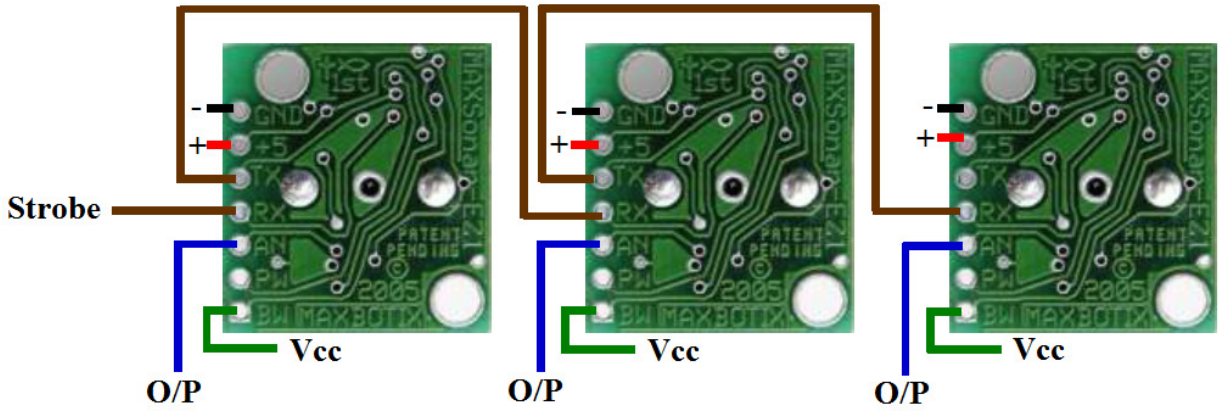


Figure 4.20 Ultrasonic range sensor daisy chaining (courtesy: MaxBotix website)

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.

Figure 4.20 shows sensor daisy chaining. Sensor 1's TX pin is connected to the Sensor 2's RX pin. In this way all 4 sensors are daisy chained. To enable the daisy chaining mode, pin "BW" of the each ultrasonic sensor is tied to Vcc.

A small pulse trigger (more than 100uS) is given to the "RX" pin of the Sensor no. 1 from the microcontroller's PD6 pin. 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.

Ultrasonic Range Sensor	ADC channel number
Left	ADC channel no. 0
Center	ADC channel no. 1
Right	ADC channel no. 2

Table 4.6 Ultrasonic Range Sensor connections with ADC of the ATMEGA16 (after correct jumper settings)

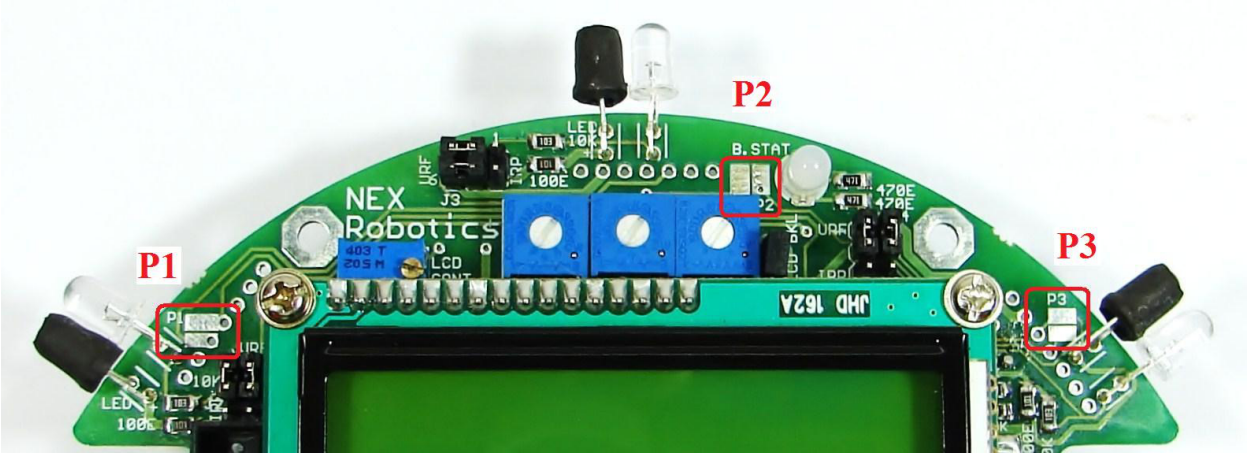


Figure 4.21 Pads for bypassing particular Ultrasonic range sensor

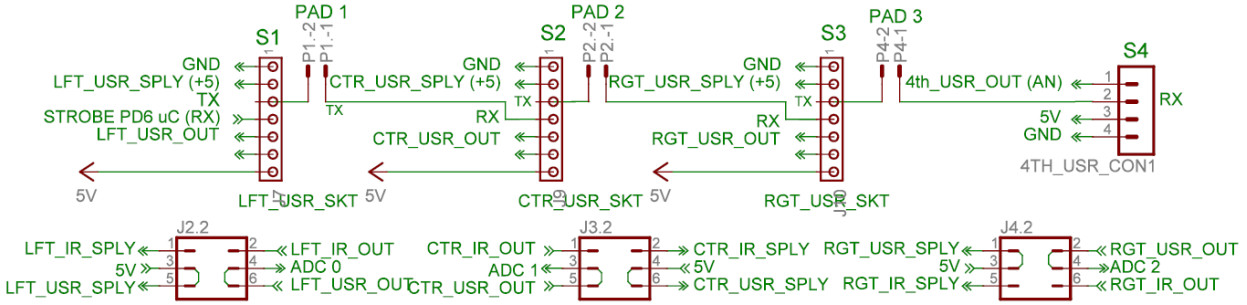


Figure 4.22 Ultrasonic Range Sensor interfacing and jumper settings

If you want to install only one ultrasonic sensor, say sensor number 2 or 4 then you need to short the pins "TX" and "RX" of the sensors which are connected in the daisy chain before the sensor which is installed so that trigger from microcontroller can reach the installed sensor. Figure 4.21 area marked by red border shows pads corresponding to the particular sensors which are labeled as P1, P2 and P3 corresponds to sensor numbers.

For example if you want to use only sensor number 2 then you have to short pad corresponding to sensor 1. If you want to use sensor 4 (connector marked by sensor number 4 in the figure 4.19), then you have to short pad number 1, 2 and 3.

Supported Ultrasonic range sensors

Spark V robot supports 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 figure 4.10 to get rough idea of the sensor characteristics.

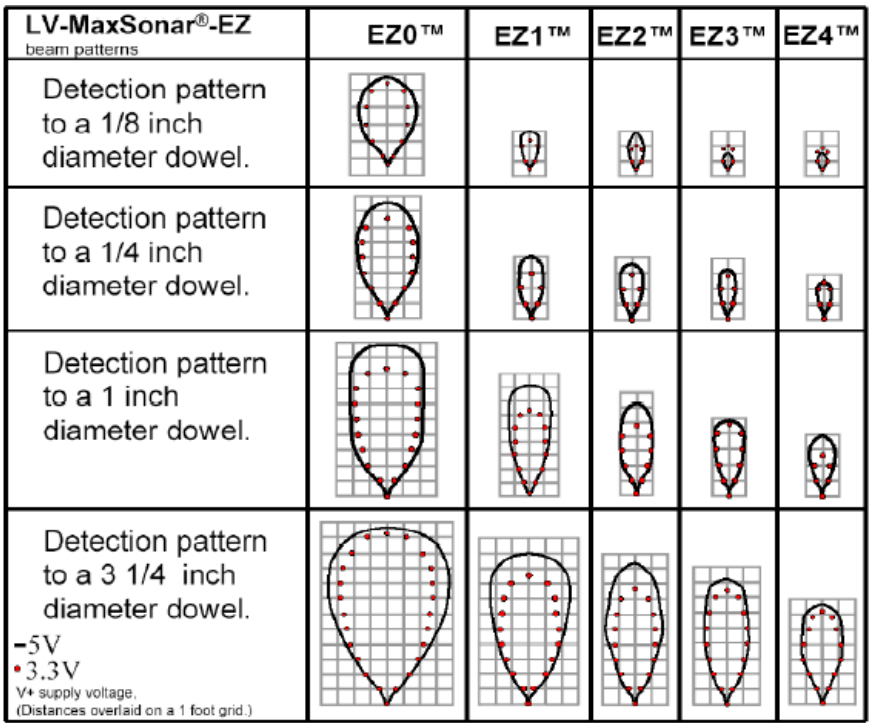


Figure 4.23 Range Shown on 1-foot grid to various diameter dowels

Mounting Ultrasonic range sensors:
Ultrasonic sensors have range of about 5 meters. If sensors are mounted with even slight slanted angle towards ground then sensor will sense ground few meters ahead as obstacle. If sensors are mounted on the female berg connectors then because of loose fitting it is possible that they will get slanted and detect few meters ahead ground as obstacle. Hence these sensors have to be soldered on the main board and bend in such a way that they look slightly upwards.

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

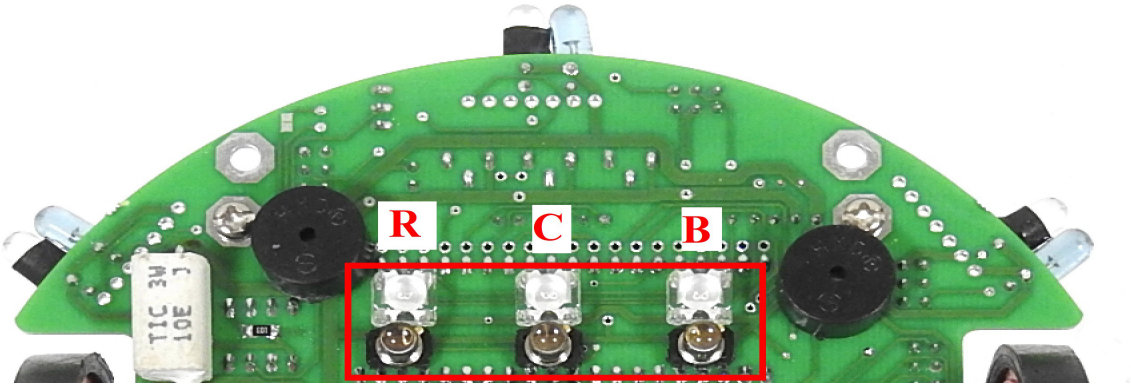


Figure 4.24 White line sensor

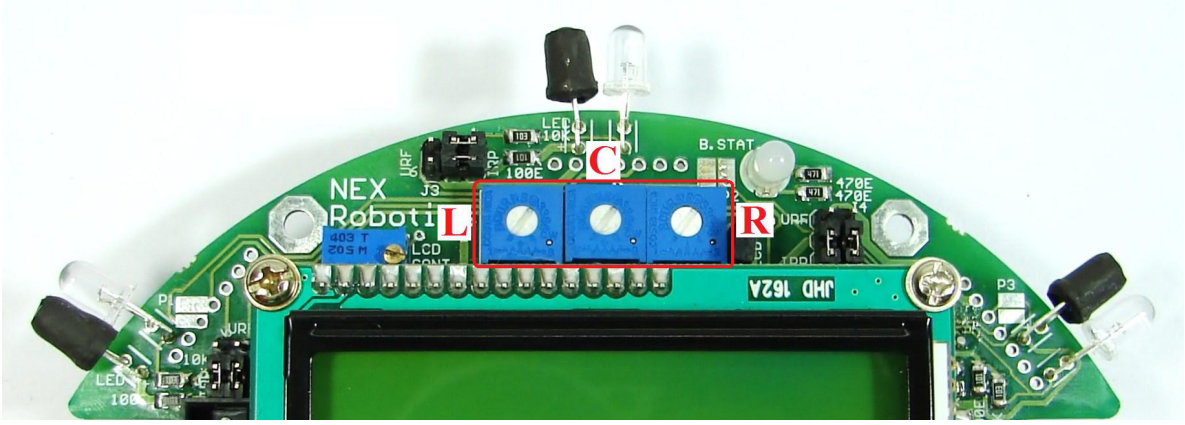


Figure 4.25 White Line sensor calibration potentiometers

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 3volts to 5 volts. 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 3 to 0.1V.

Sensor's sensitivity to the white and dark surface can be adjusted by controlling brightness of the LED. This is done by adjusting potentiometer which is connected in the series of the LED. Figure 4.25 shows the potentiometers used for white line sensor calibration. When potentiometer is moved fully counterclockwise, IR LED's intensity will be maximum. Robot's sensors are calibrated for optimal performance when robot is shipped from the factory.

White line Sensor	ADC channel number
Left	ADC channel no. 3
Center	ADC channel no. 4
Right	ADC channel no. 5

Table 4.7 White line sensor connections with ADC of the ATMEGA16

Note:
Be very careful while selecting black surface for the line following. Black can be from ultraviolet side or from the infrared side. If black is from the infrared side then for IR light it will be like white surface as infrared black will reflect almost all the light. In such case it will be difficult for the robot to differentiate between white and black surface.

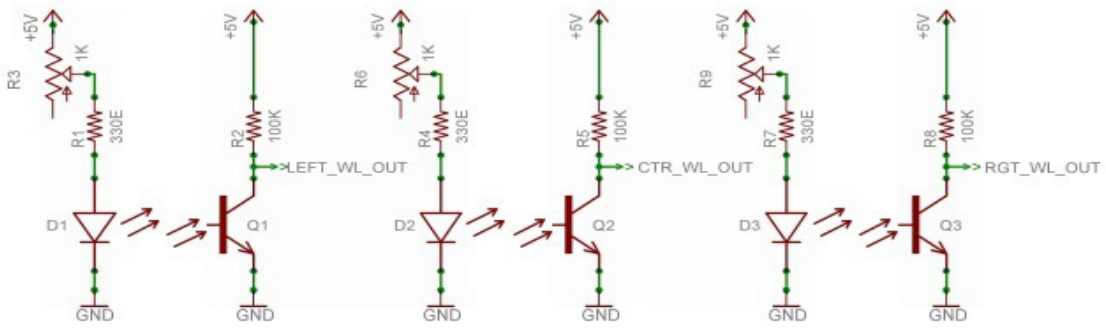


Figure 4.26 White Line Sensor

4.12 LCD Interfacing

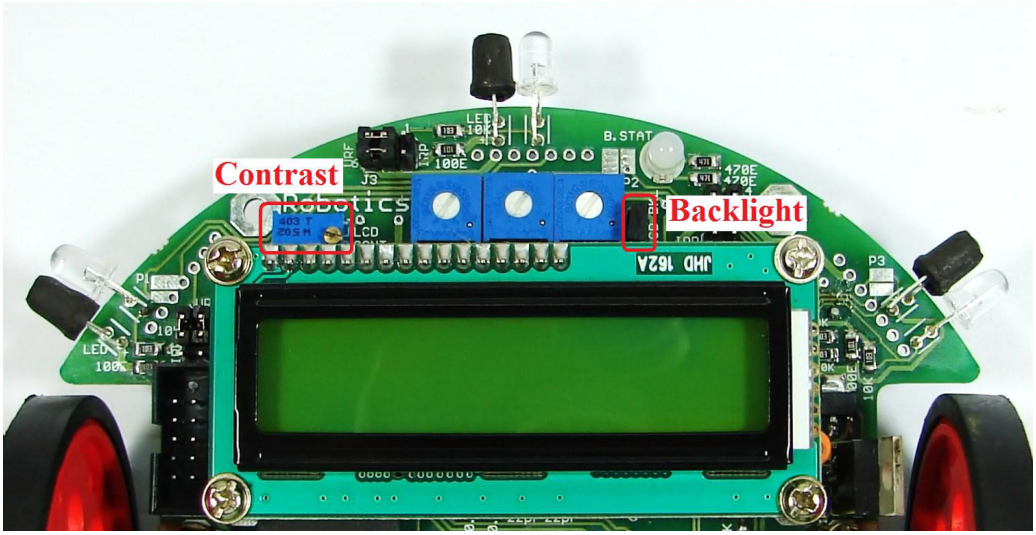


Figure 4.27 LCD contrast and backlight setting

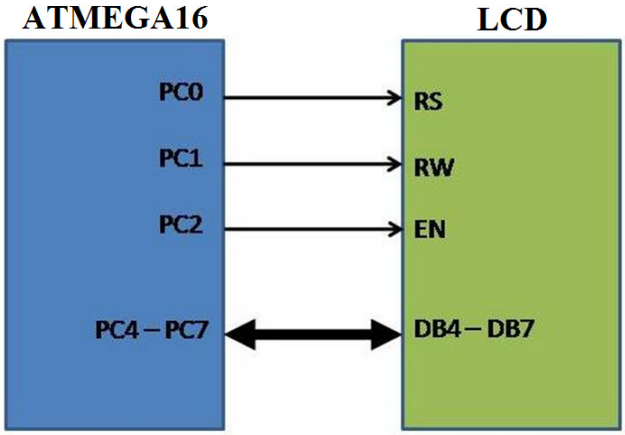


Figure 4.28 LCD interfacing with the microcontroller

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

Table 4.8 LCD pin mapping and functions

To interface LCD with the microcontroller in default configuration requires 3 control signals and 8 data lines. This is known as 8 bit interfacing mode which requires total 11 I/O lines. To reduce the number of I/Os required for LCD interfacing we can use 4 bit interfacing mode which requires 3 control signals with 4 data lines. In this mode upper nibble and lower nibble of commands/data set needs to be sent separately. Figure 4.28 shows LCD interfacing in 4 bit mode. The three control lines are referred to as EN, RS, and RW.

The EN line is called "Enable" and it is connected to PC2. This control line is used to tell the LCD that microcontroller has sent data to it or microcontroller is ready to receive data from LCD. This is indicated by a high-to-low transition on this line. To send data to the LCD, program should make sure that this line is low (0) and then set the other two control lines as required and put data on the data bus. When this is done, make EN high (1) and wait for the minimum amount of time as specified by the LCD datasheet, and end by bringing it to low (0) again.

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

The RW line is the "Read/Write" control line and it is connected to PC1. When RW is low (0), the information on the data bus is being written to the LCD. When RW is high (1), the program is effectively querying (or reading from) the LCD.

The data bus is bidirectional, 4 bit wide and is connected to PC4 to PC7 of the microcontroller. The MSB bit (DB7) of data bus is also used as a Busy flag. When the Busy flag is 1, the LCD is in internal operation mode, and the next instruction will not be accepted. When RS = 0 and R/W = 1, the Busy flag is output on DB7. The next instruction must be written after ensuring that the busy flag is 0.

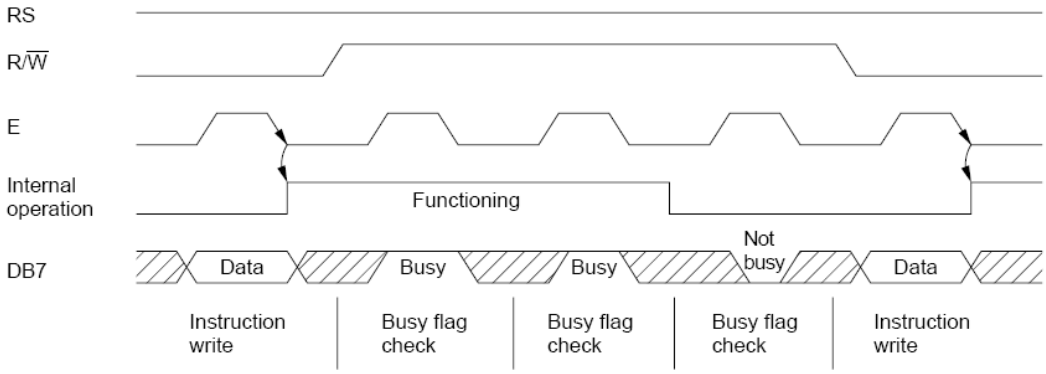


Figure 4.29 LCD Timing Diagram

LCD contrast and backlight setting

Contrast of the LCD can be adjusted by adjusting the potentiometer. To save power its backlight can also be turned off by removing jumper J1. For jumper and potentiometer location, refer to figure 4.27

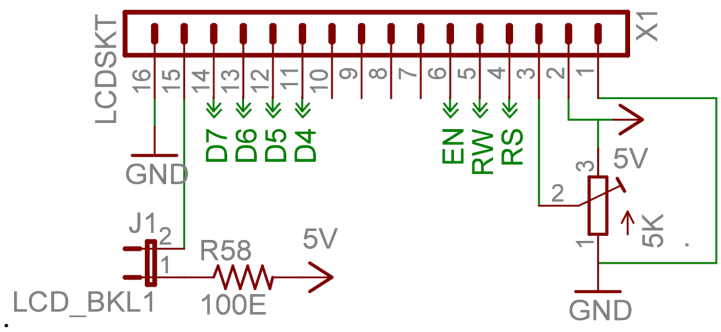


Figure 4.30 LCD schematics

4.13 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.

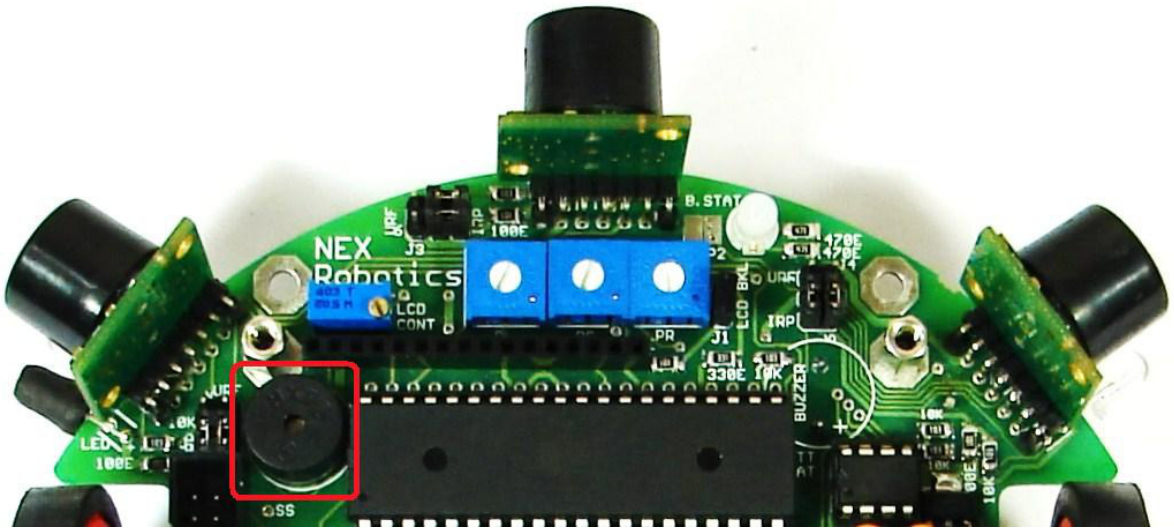


Figure 4.31 Buzzer

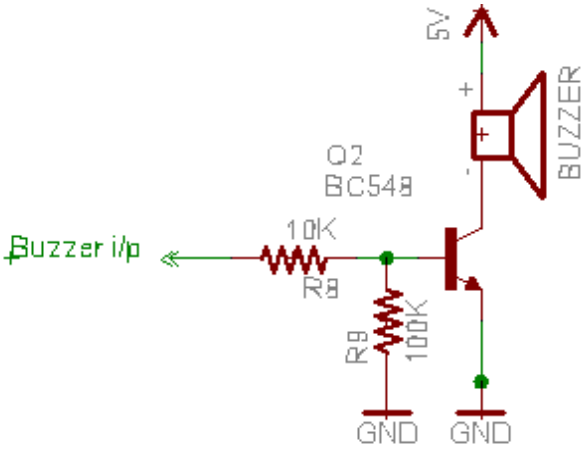


Figure 4.32 Buzzer Schematic

4.14 USB Interface

USB interface is used for interfacing robot with the PC and loading hex file on the robot using boot loading utility from NEX Robotics.
ATMEGA16 microcontroller has one serial port which can be connected to USB port via FT232 USB to Serial converter or to XBee wireless module. To connect FT232 USB to Serial converter with the microcontroller, you need to set Jumper J5 in correct setting. In this setting J5 connects TXD and RXD pins of the microcontroller with the FT232 USB to serial converter.

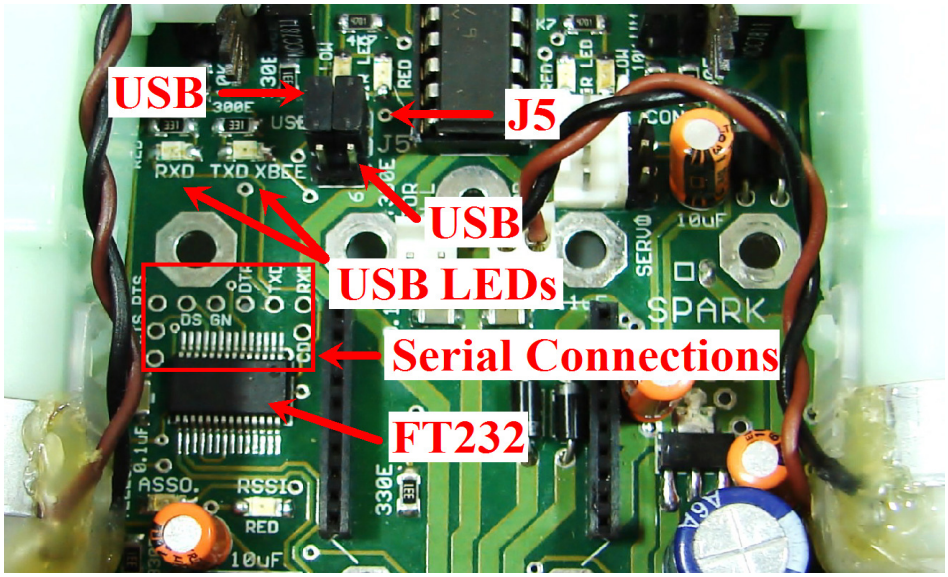


Figure 4.33 USB Connections

Figure 4.33 shows jumper setting for connecting FT232 USB to serial converter to the ATMEGA16 microcontroller. USB LEDs marked by TXD and RXD shows the serial port activity. You can also use other pins of the serial ports which are marked by red border for implementing advance flow control.

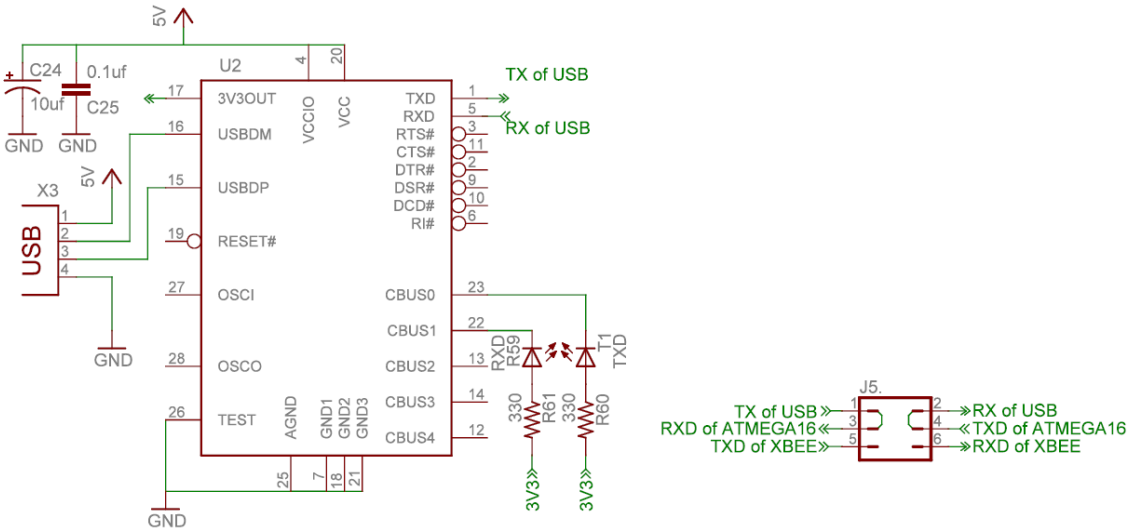


Figure 4.34 USB to Serial converter Schematic

4.15 XBee wireless interface

XBee wireless module is used for communicating with other robots and PCs.
ATMEGA16 microcontroller has one serial port which can be connected to USB port via FT232 USB to Serial converter or to XBee wireless module. To connect XBee wireless module with the microcontroller, you need to set Jumper J5 in correct setting. In this setting J5 connects TXD and RXD pins of the microcontroller with the XBee wireless module.

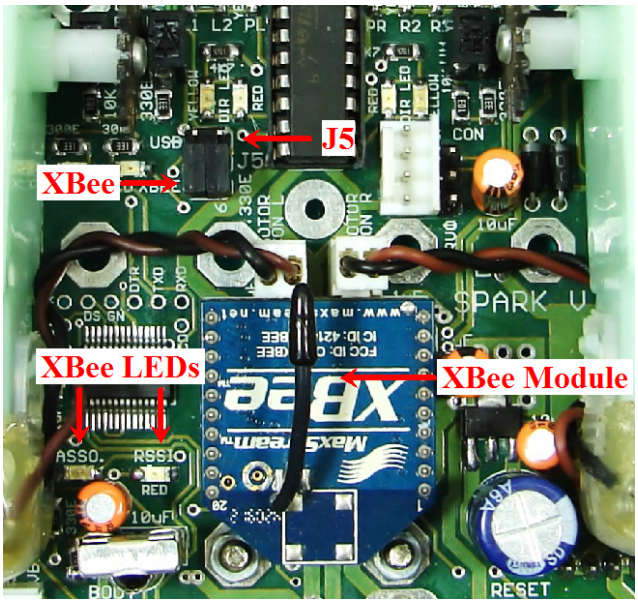


Figure 4.35 XBee wireless module Connections

Figure 4.36 shows jumper setting for connecting XBee wireless module to the ATMEGA16 microcontroller. “ASSO” LED shows the association over the network. “RSSI” LED shows the strength of the wireless signals. For more details, refer to XBee wireless module’s datasheet from the datasheet folder of the documentation CD.

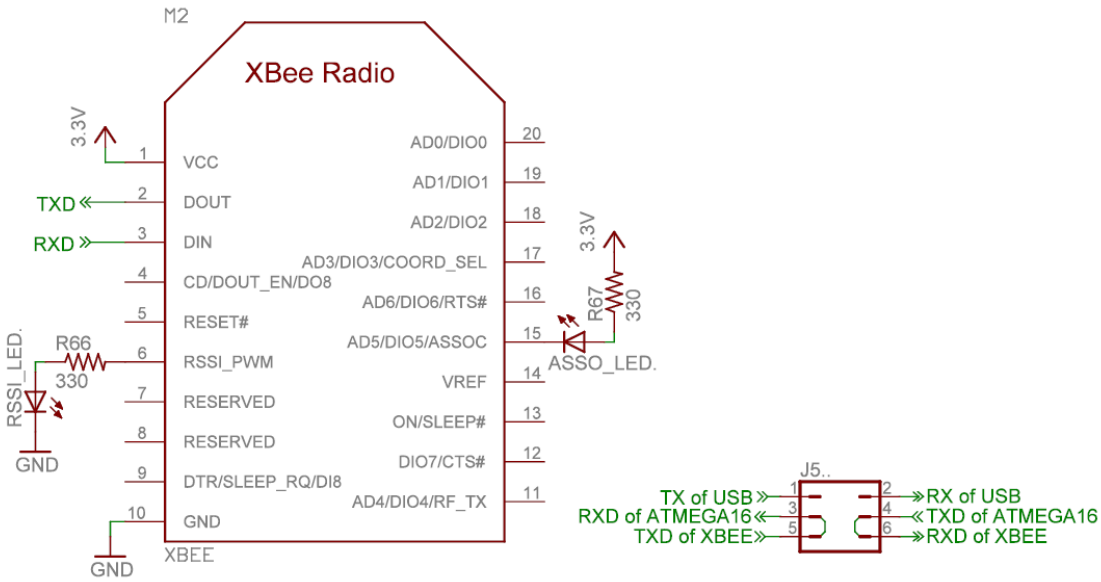


Figure 4.36 USB XBee Wireless Module Schematic

4.16 Servo mounted range sensor

Spark V robot has connectors servo mounted range sensor. Range sensor can be IR range sensor from Sharp or Ultrasonic range sensor from MaxBotix. Servo motor can be connected to standard 3 pin servo connector while range sensor is connected to 4 pin relimate connector.

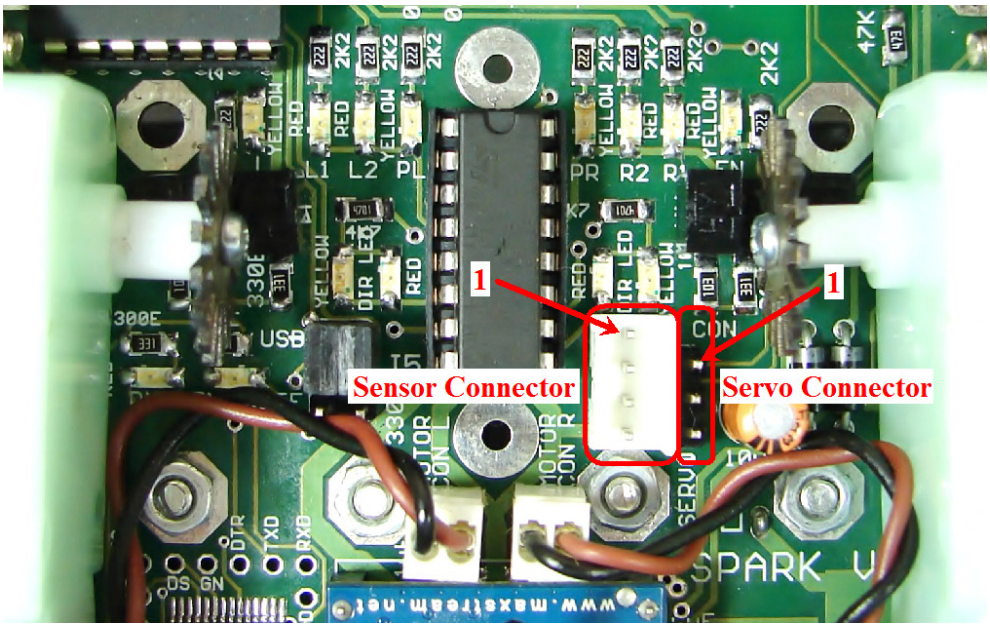


Figure 4.37 Servo motor and Sensor connector

Figure 4.38 Servo motor and sensor connections

4.17 Battery voltage sensing

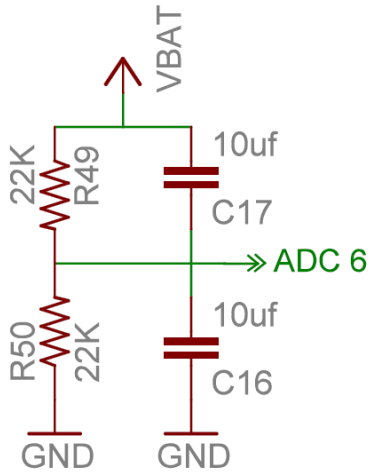


Figure 4.39 Battery voltage sensing

Two registers of 22K ohms are used to scale down the battery voltage below 5V and given to the ADC6 of the microcontroller. Voltage divider network of these register will give half of the battery voltage to the ADC 6 of the microcontroller. If ADC is used with the 8 bit resolution use the following formula for getting the battery voltage level:

Battery voltage = 2 x ADC 6 value of 8 bit resolution x 5V/255

Battery voltage = 2 x ADC 6 value of 10 bit resolution x 5V/1024

Here 5V / 255 and 5V/1024 give ADC resolution in 8 bit and 10 bit mode.

4.18 Power Port

4 pin relimate Power port gives out regulated and unregulated voltages for interfacing with the external device.
Following are the current limitations:

1. 3.3V out: Used for powering XBee wireless module. Can give out current up to 400mA
2. 5V out: Used for powering up sensors and other components. Not more than 200mA current should be taken from this source
3. V Batt: Output from the battery. Maximum output current is dependent on the battery capacity.

Figure 4.40 Power Port

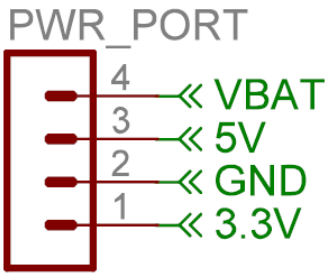


Figure 4.41 Power Port connections

4.19 ATMEGA16 microcontroller

Spark V robot has ATMEGA16 microcontroller running at 7.3728MHz. .hex file is loaded using boot loader software from NEX Robotics. In the bootloading process Reset and Boot switches are used together. To know more about the boot loader, refer to section 5.6. Robot can also be programmed by ISP (In System Programming) using AVR USB programmer from NEX Robotics or ATMEL's AVR ISP mkII. It is recommended that you use boot loader software instead of ISP. If ISP is used then is a chance that boot loader will get erased.

You can also use SPI pins of the microcontrollers as general purpose I/Os or as SPI port for interfacing with external device. SS (Slave select) pin of the SPI port is available as pad. Refer to figure 4.44 and 4.45 for SPI pins location.

You can access all the pins of the microcontroller by soldering on the pads which are located just beside the microcontroller pin.

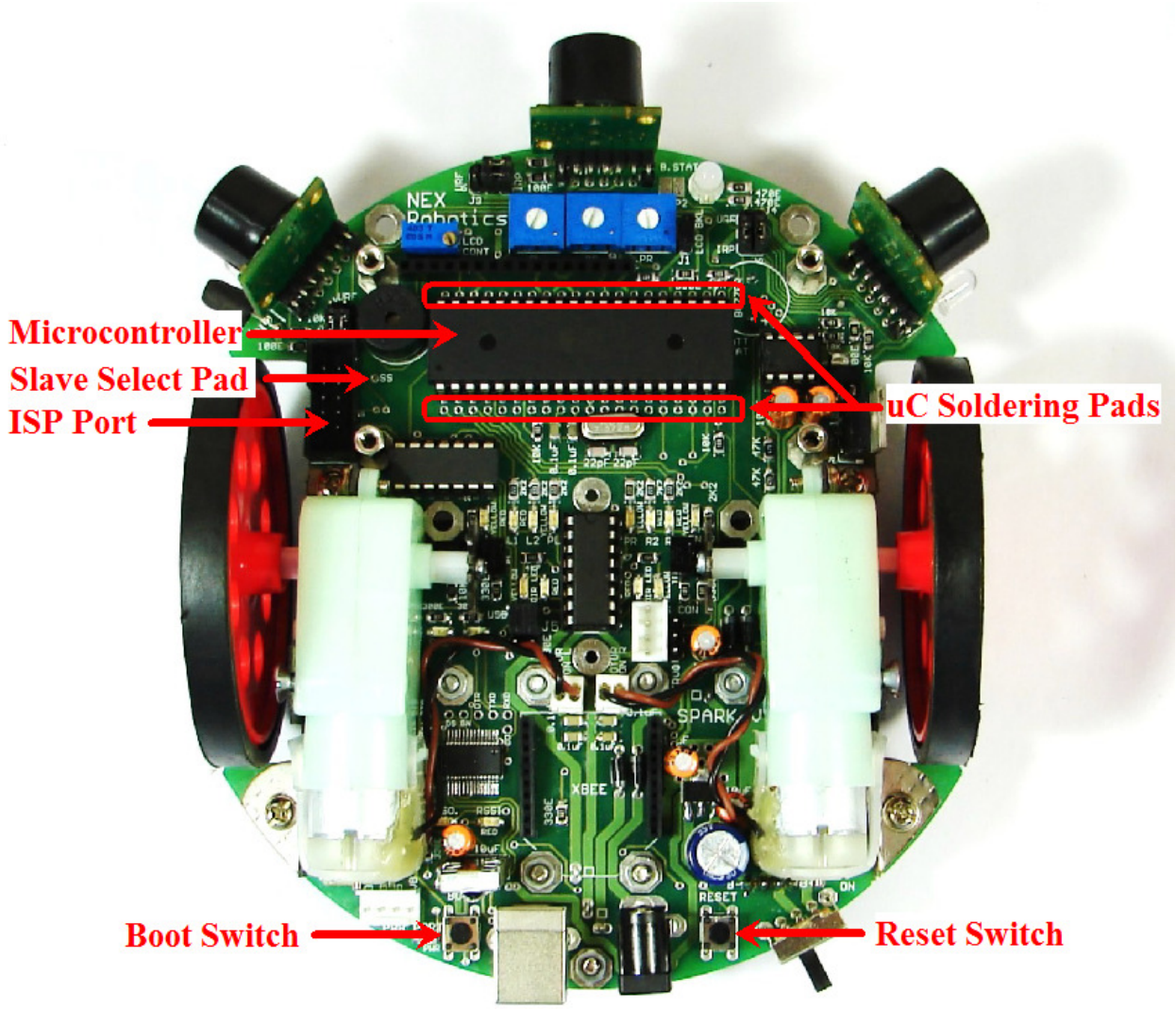


Figure 4.42 Microcontroller on the Spark V robot

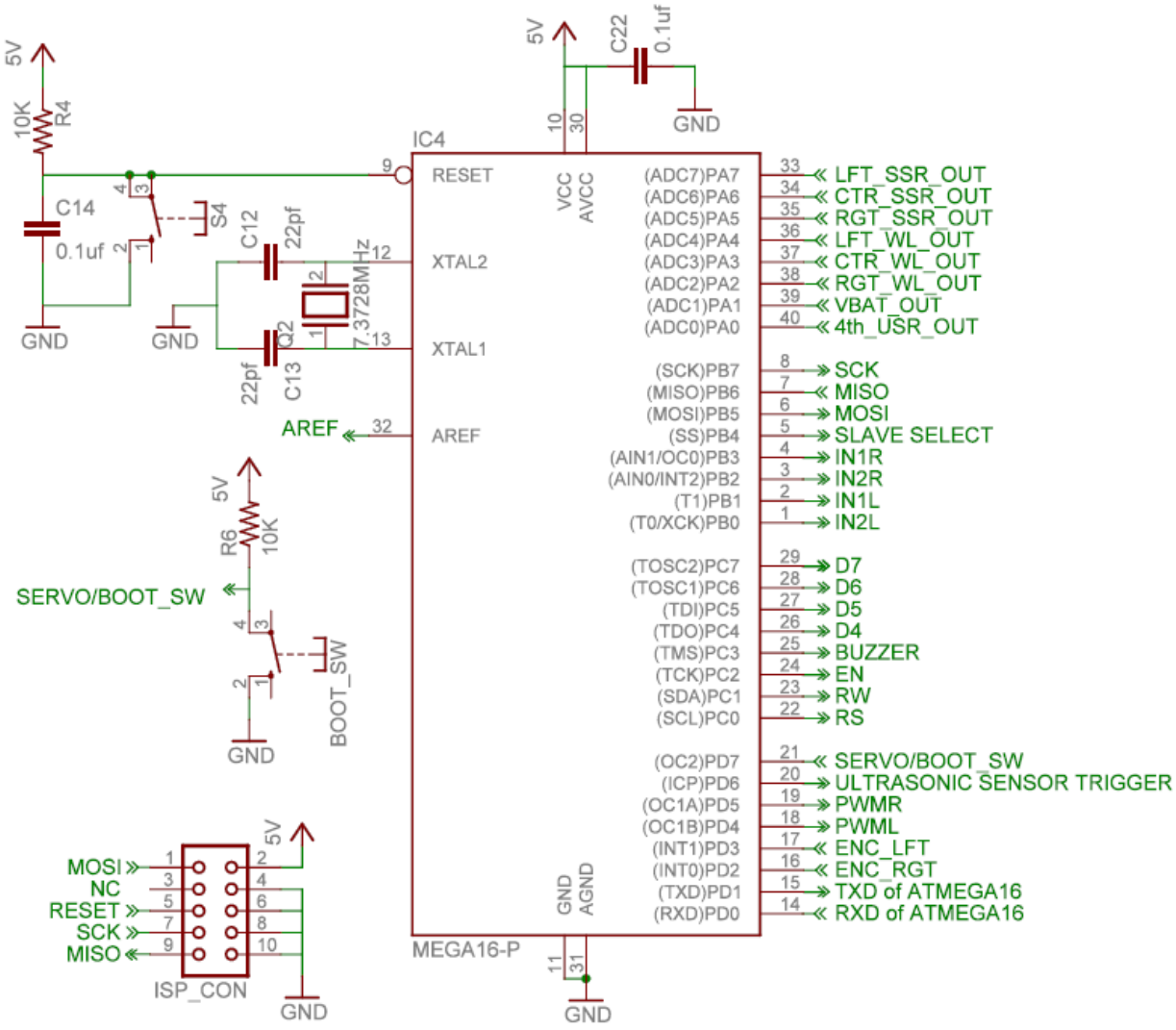
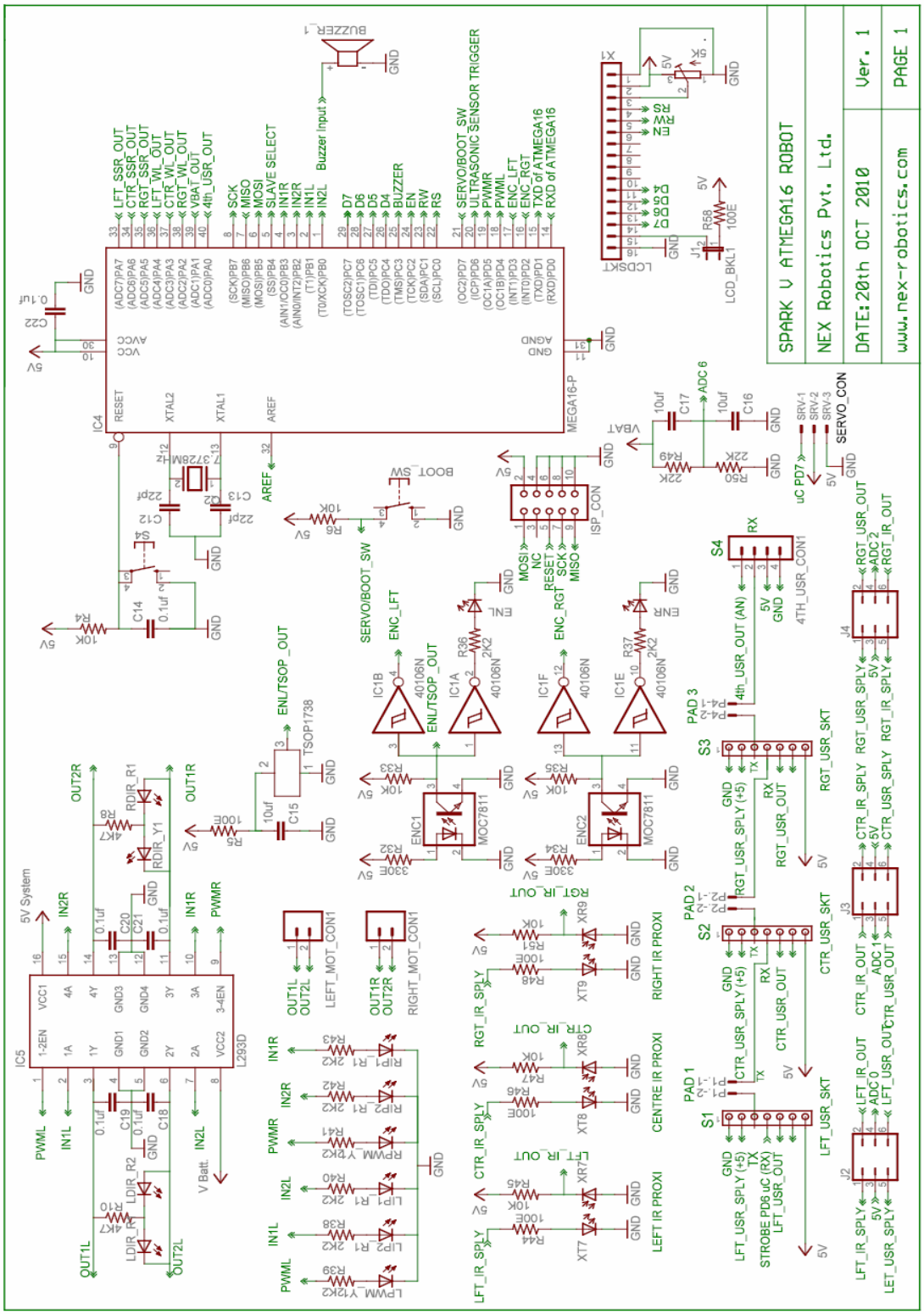
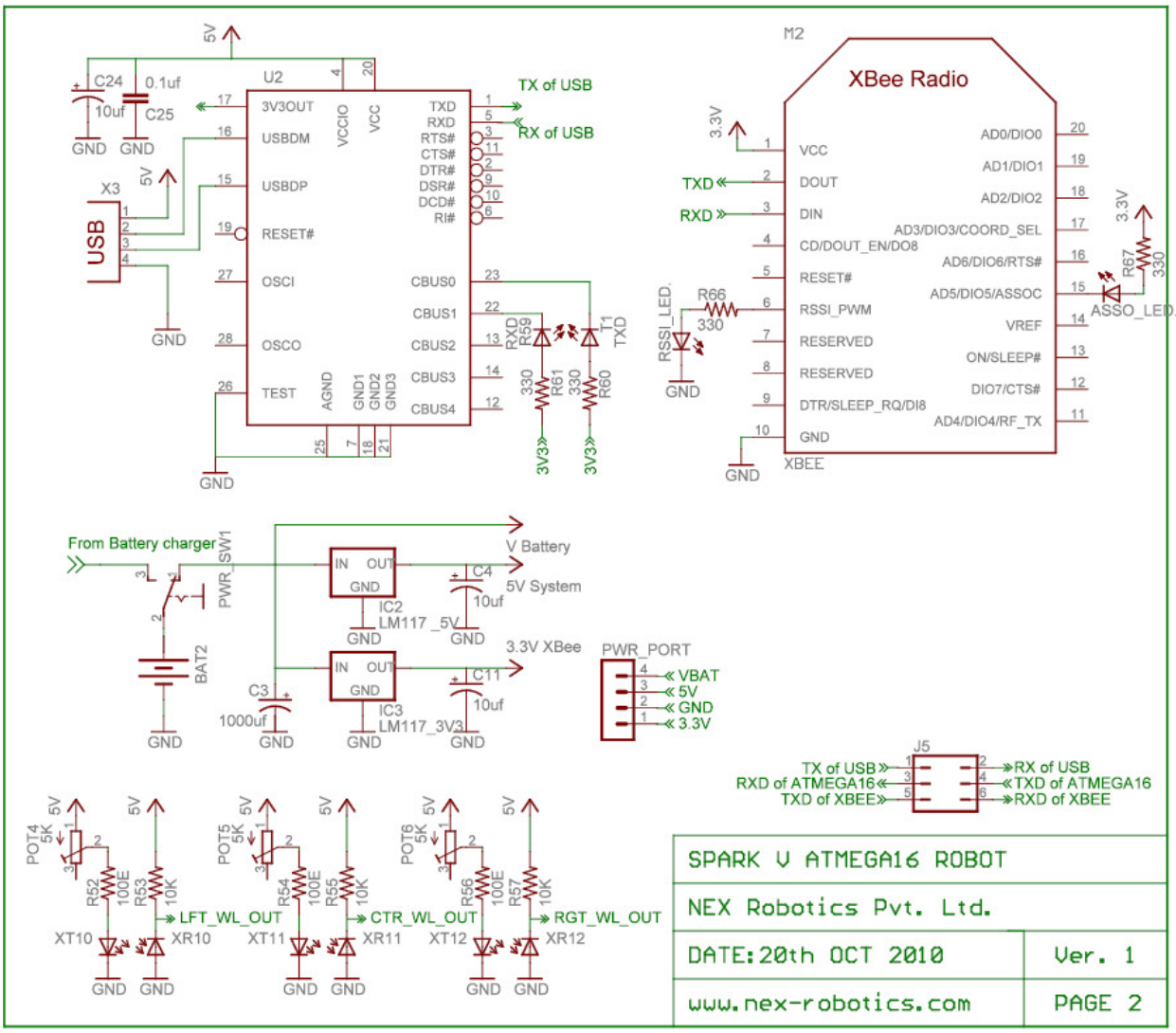


Figure 4.43 Microcontroller Schematics

4.20 Spark V Schematics




XBee Radio
U2
M2
TX of USB
RX of USB
From Battery charger
V Battery
5V System
3.3V XBee
PWR_PORT
VBAT
5V
GND
3.3V
J5
TX of USB
RXD of ATMEGA16
TXD of XBEE
RX of USB
TXD of ATMEGA16
RXD of XBEE
LFT_WL_OUT
CTR_WL_OUT
RGT_WL_OUT
SPARK V ATMEGA16 ROBOT
NEX Robotics Pvt. Ltd.
DATE:20th OCT 2010
Ver. 1
www.nex-robotics.com
PAGE 2

5 Programming Spark V ATMEGA16 Robot

There are lots of IDEs (Integrated Development Environment) available for the AVR microcontrollers. There are free IDEs which are based on AVR GCC like AVR Studio from ATMEL and WIN AVR and proprietary IDEs like ICC AVR, Code vision AVR, IAR and KEIL etc. IDEs like ICC AVR and code vision AVR are very simple to use because of their GUI based code generator which gives you generated code. Almost all the proprietary IDEs works as full version for first 45 days and then there code size is restricted to some size. We have used free IDE like AVR Studio from ATMEL and proprietary IDE like ICC AVR for the robot. In this manual we are going to focus on the AVR studio from the ATMEL. It uses WIN AVR open source C compiler at the back end. It has many attractive features like built-in In-Circuit Emulator and AVR instruction set simulator. After writing and compiling the program it gives ".hex" file. This ".hex" file needs to be loaded on the robot using In System Programmer (ISP).

IDE Installation

Since AVR studio uses WIN AVR compiler at the back end we need to install WIN AVR first (Please note that WIN AVR must be installed before AVR Studio so that AVR Studio can easily detect the AVRGCC plug-in).

5.1 Installing WIN AVR

Insert the Spark V documentation CD and from the "Software and Drivers" folder copy "WIN AVR 2009-03-13" on the PC and click on WinAVRxxxx.exe file.

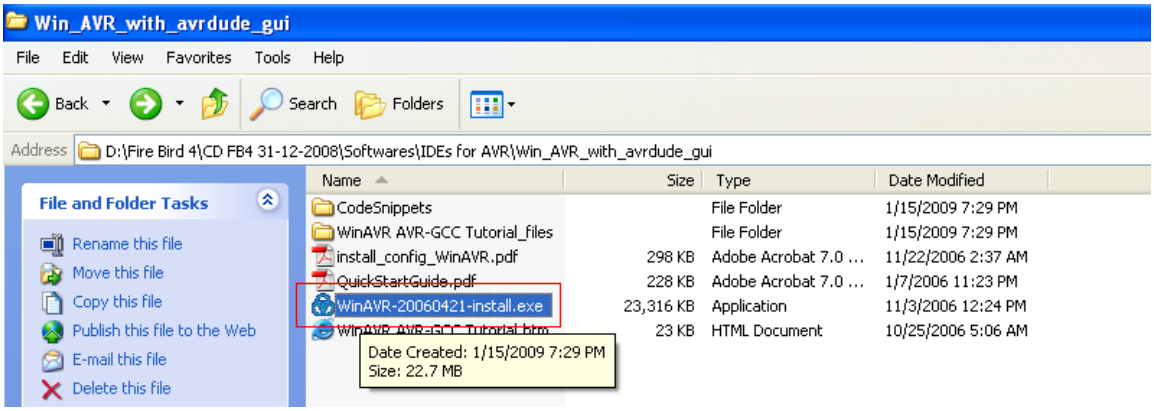


Figure 5.1

WIN AVR installation package will open. Choose language as “English”.

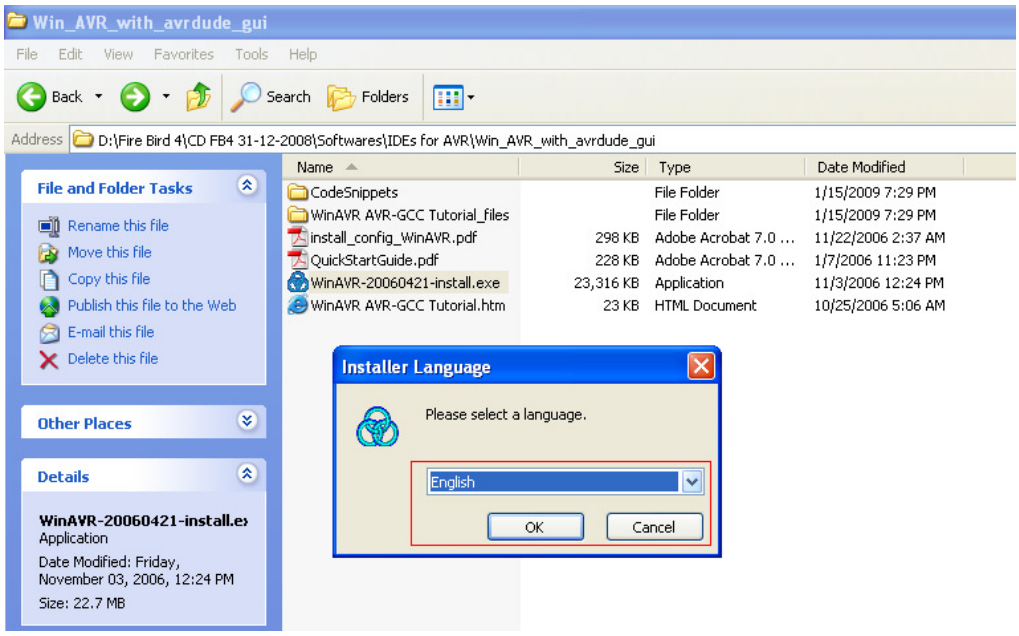


Figure 5.2

Click next in the WIN AVR setup wizard.

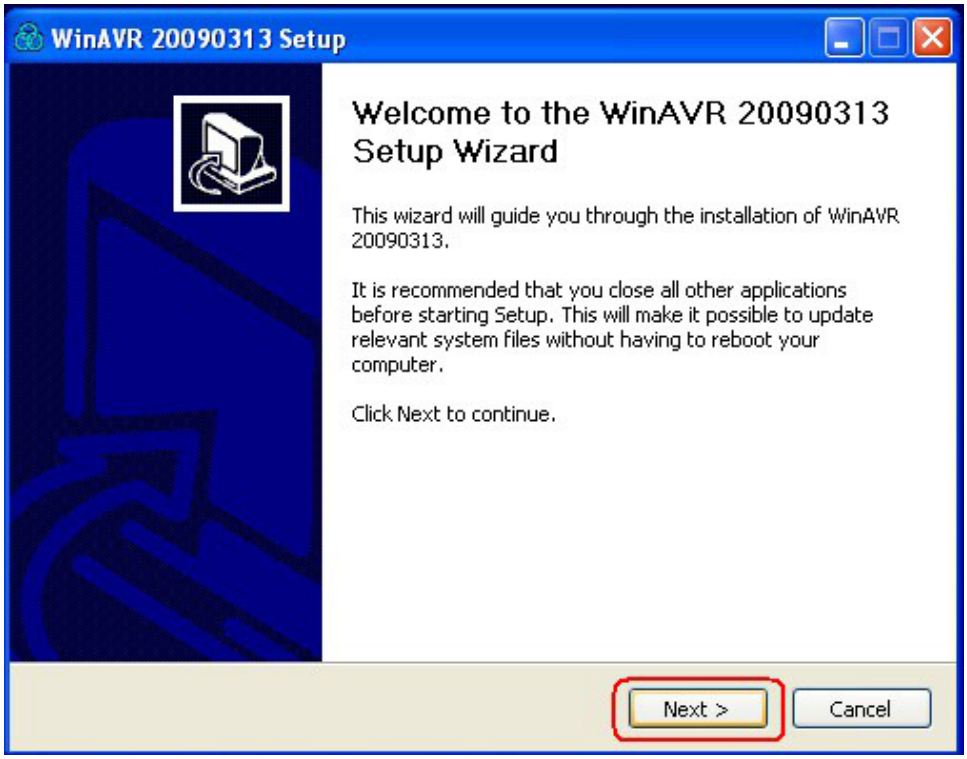


Figure 5.3

Press “I Agree” after going through license agreement.

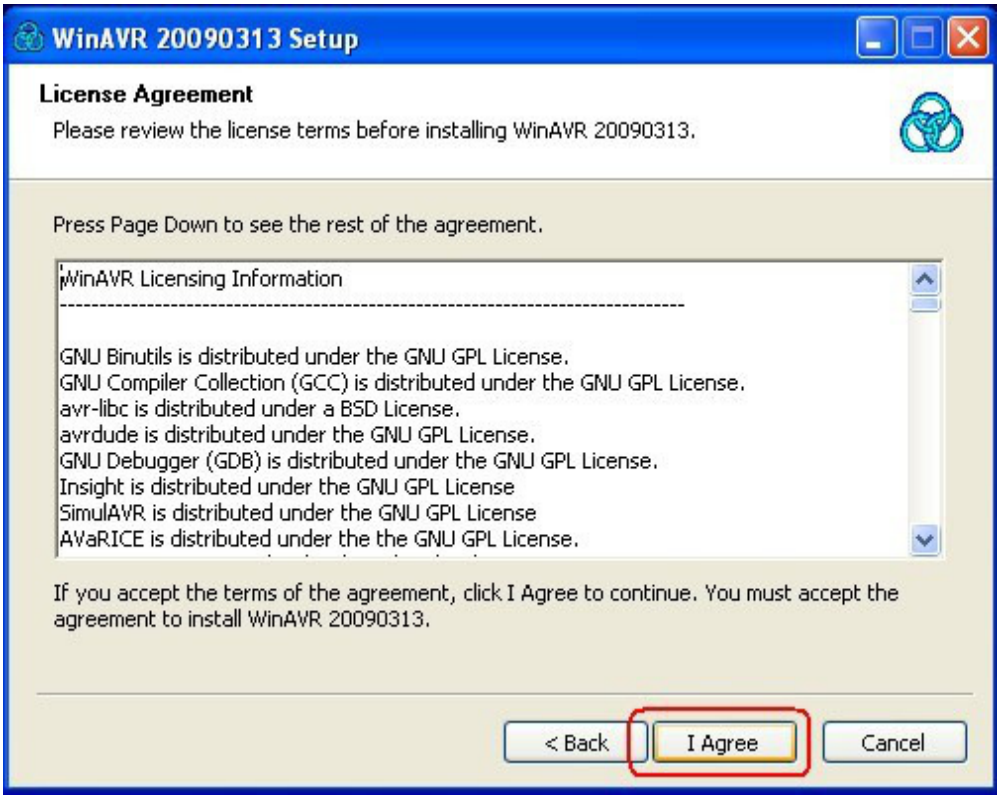


Figure 5.4

Make sure that you select drive on which operating system is installed.

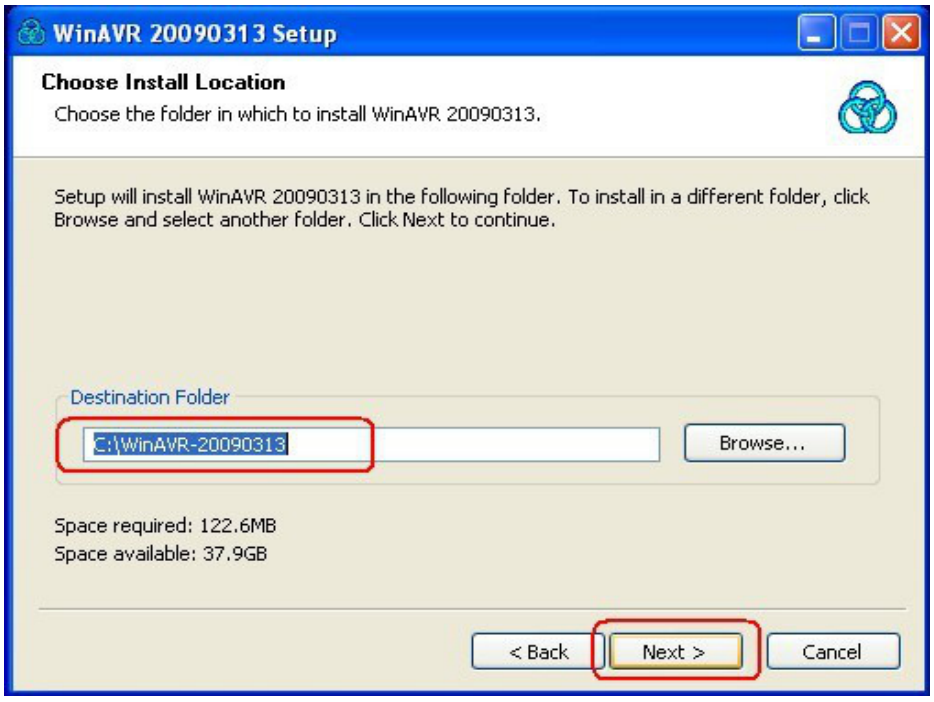


Figure 5.5

Select all the components and press “Install”.

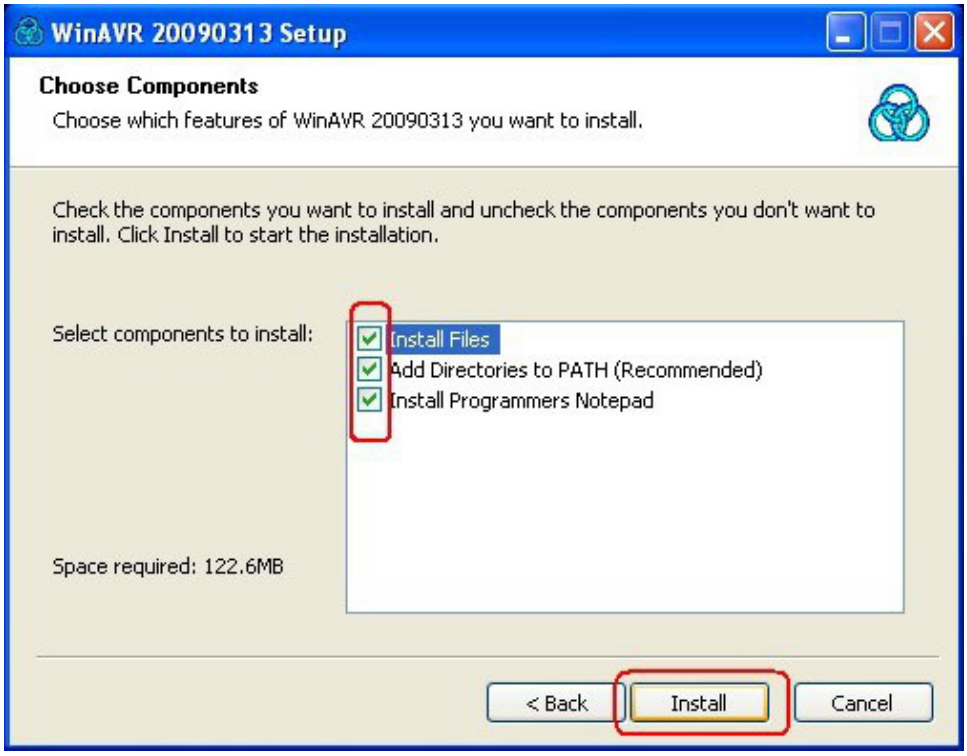


Figure 5.6

Click “Finish” to complete WIN AVR installation

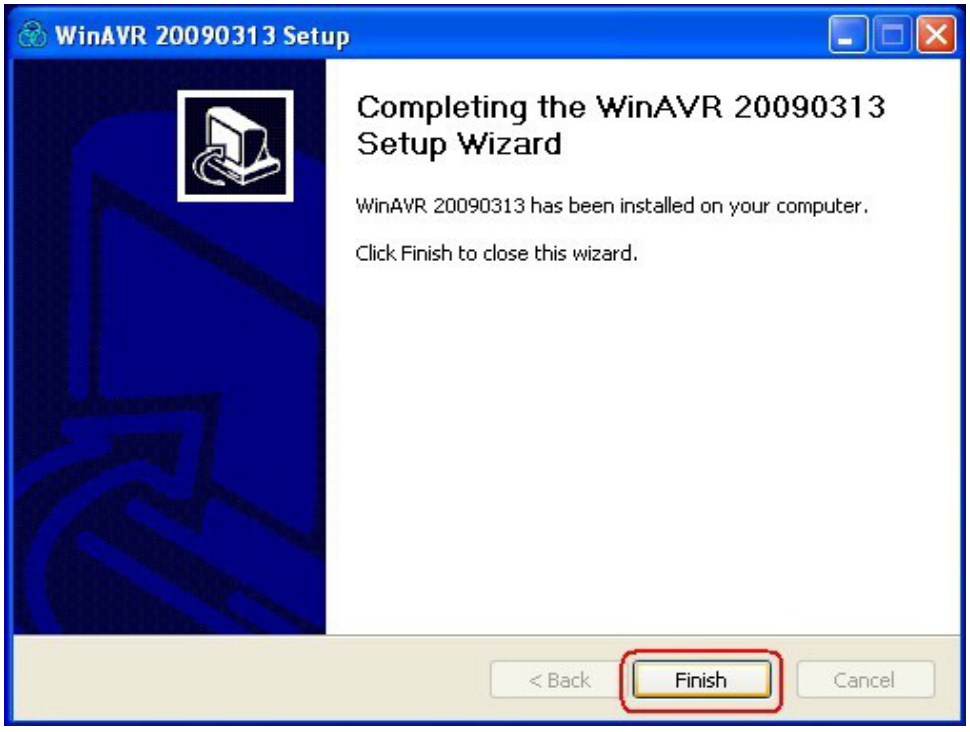


Figure 5.7

5.2 Installing AVR Studio

Go to “Software and Drivers” folder from the documentation CD, copy folder “AVR Studio 4.17” on the PC and click on “AvrStudio417Setup.exe” to start the installation process.

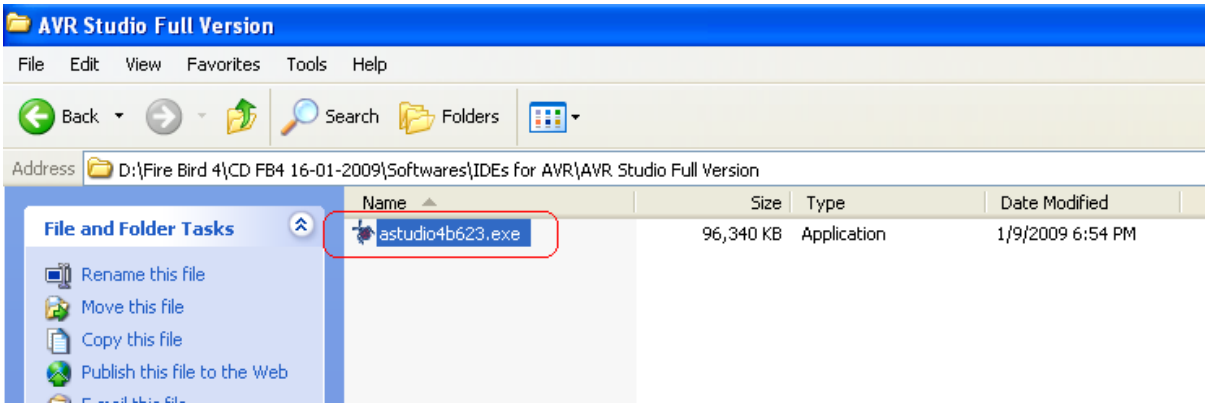


Figure 5.8

Click on “Run”

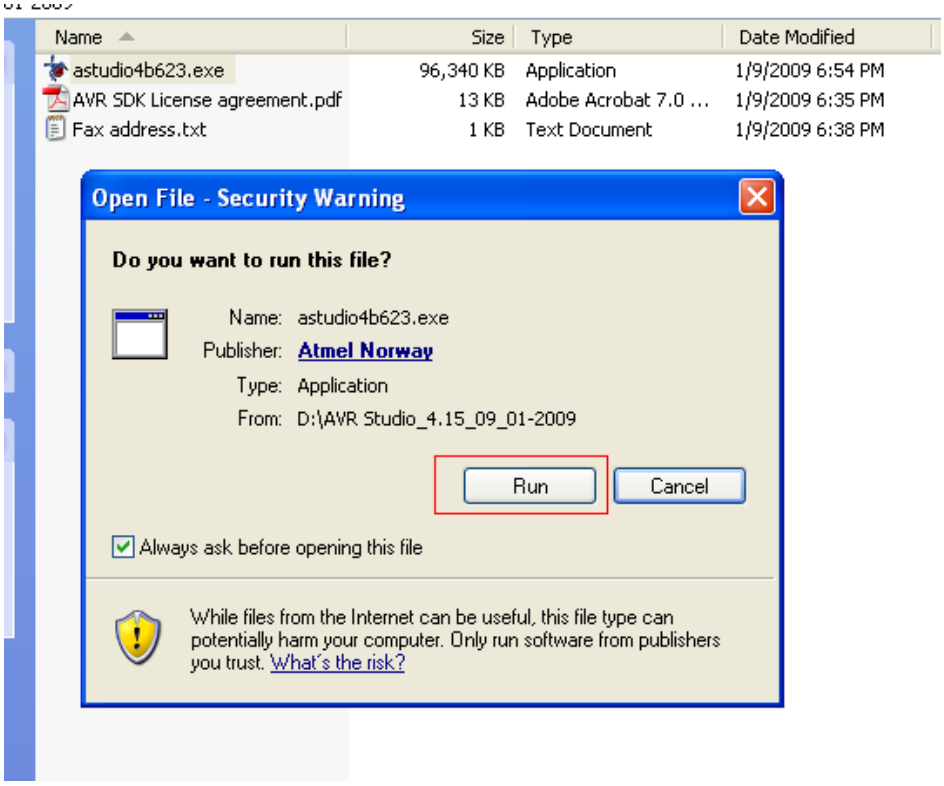


Figure 5.9

Click “Next” to start installation of AVR Studio 4

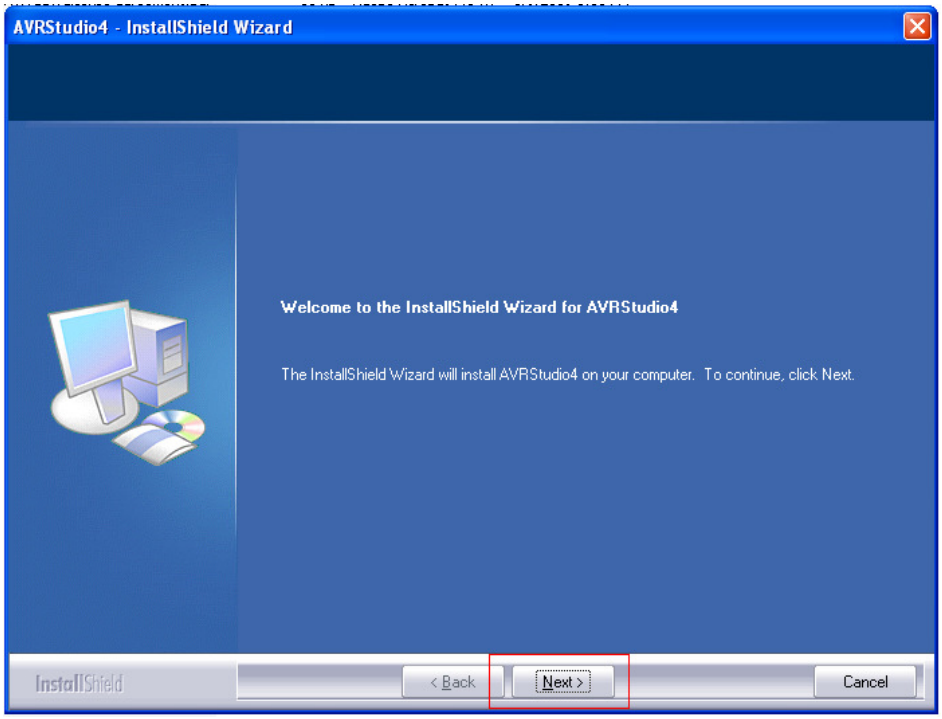


Figure 5.10

After clicking “Next” go through the license agreement. If it is acceptable then click “Next”

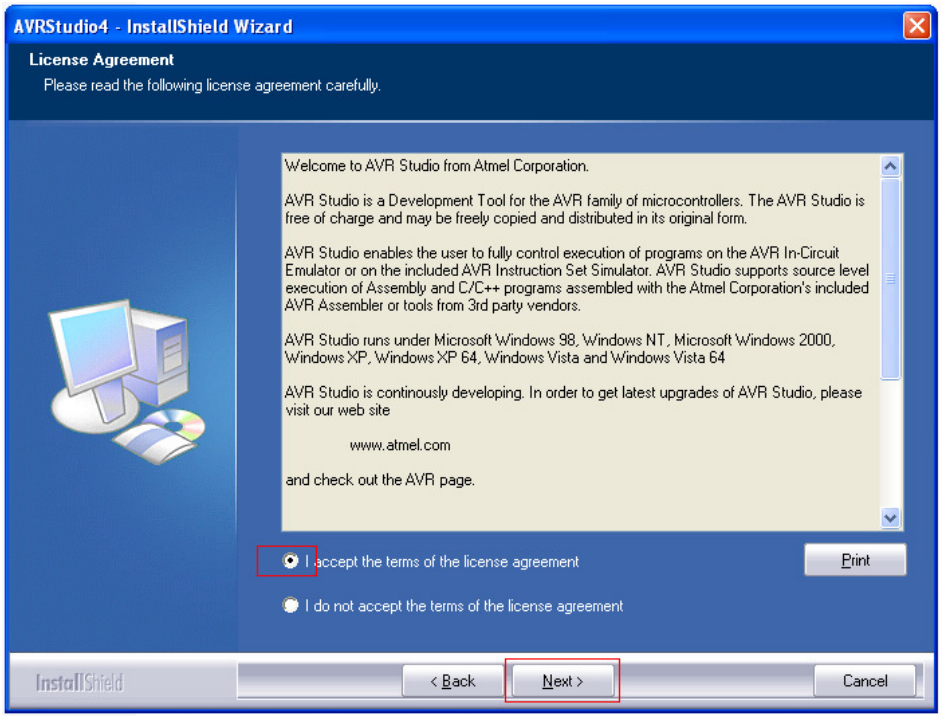


Figure 5.11

Now choose the destination drive. Select the same drive in which your operating system and WINAVR is installed.

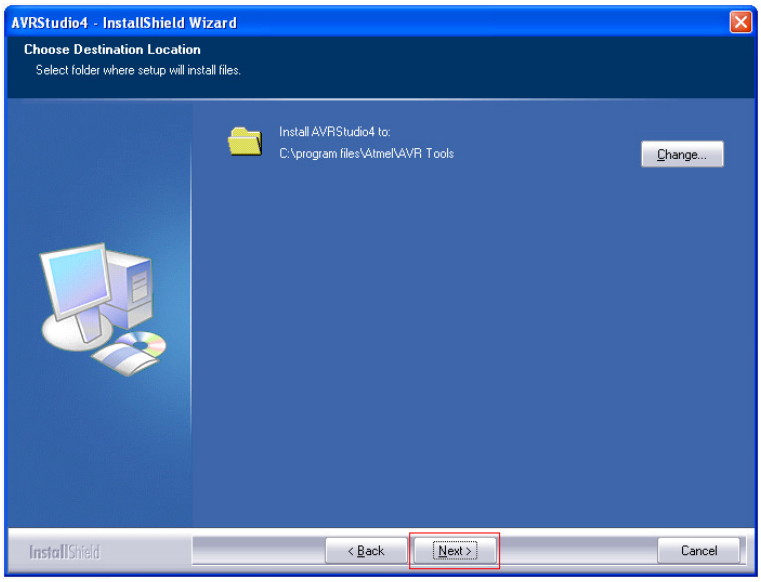


Figure 5.12

Select for the “Install / upgrade Jungo USB Driver” to support In System Programming (ISP) by AVRISP mkII

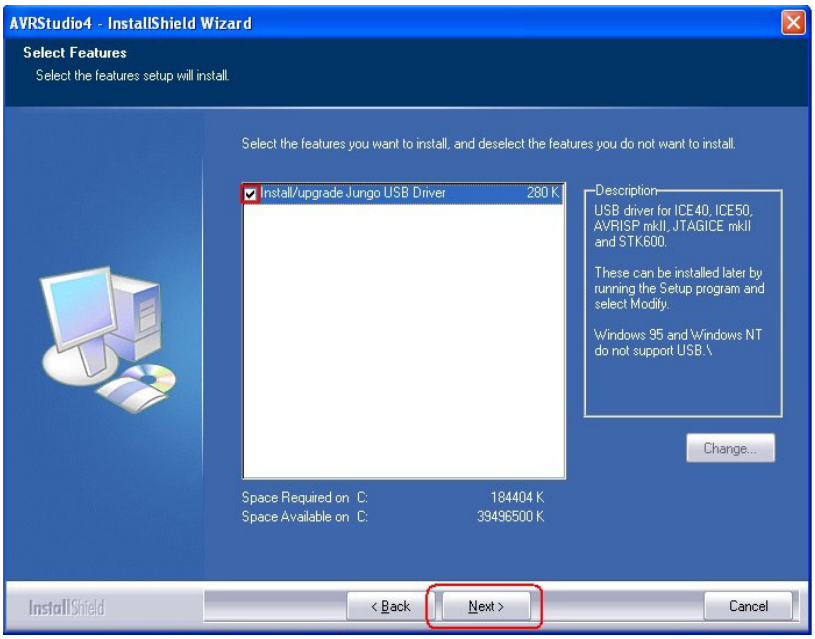


Figure 5.13

Important: If “Install / upgrade Jungo USB Driver” is not selected then AVRISP mkII programmer will not work with the AVR Studio.

Click “Next” to start the installation process.

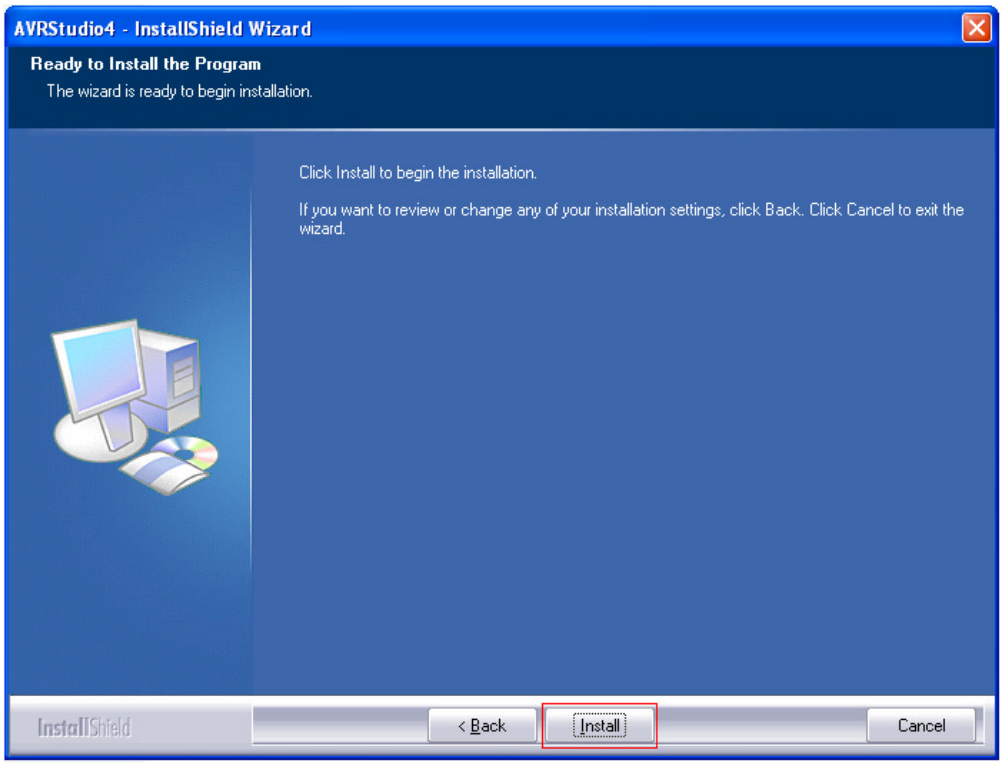


Figure 5.14

Click “Finish” to complete the installation process.

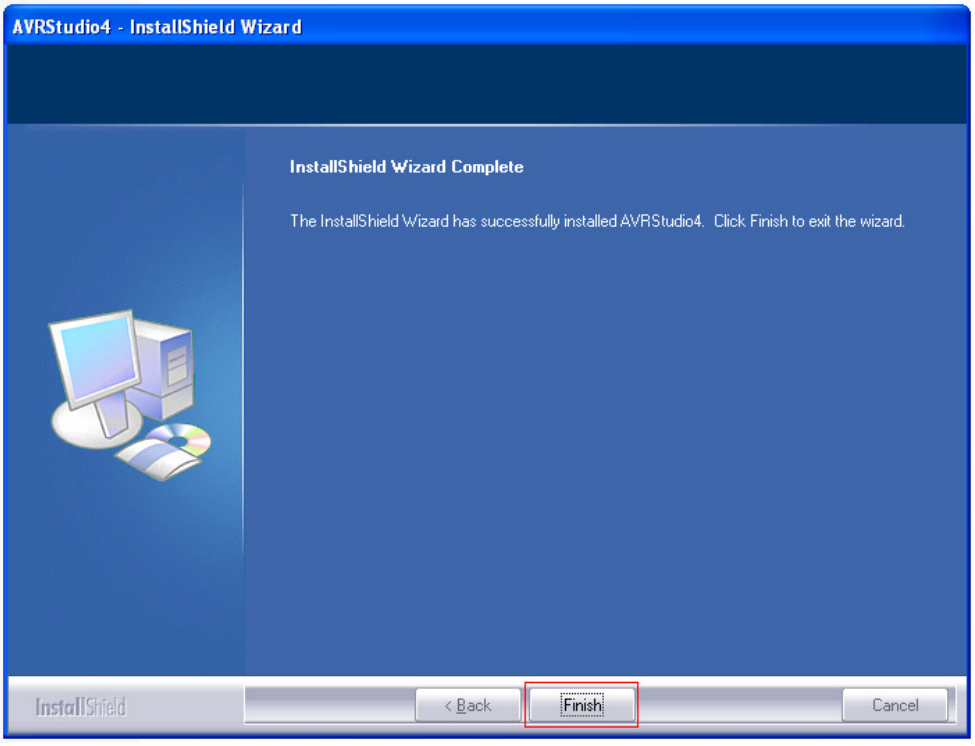


Figure 5.15

5.3 Setting up Project in AVR Studio

AVR studio is an Integrated Development Environment (IDE) for writing and debugging AVR applications. As a code writing environment, it supports included AVR Assembler and any external AVR GCC compiler in a complete IDE environment.

AVR Studio gives two main advantages:

1. Edit and debug in the same application windows. Faster error tracking.
2. Breakpoints are saved and restored between sessions, even if codes are edited.

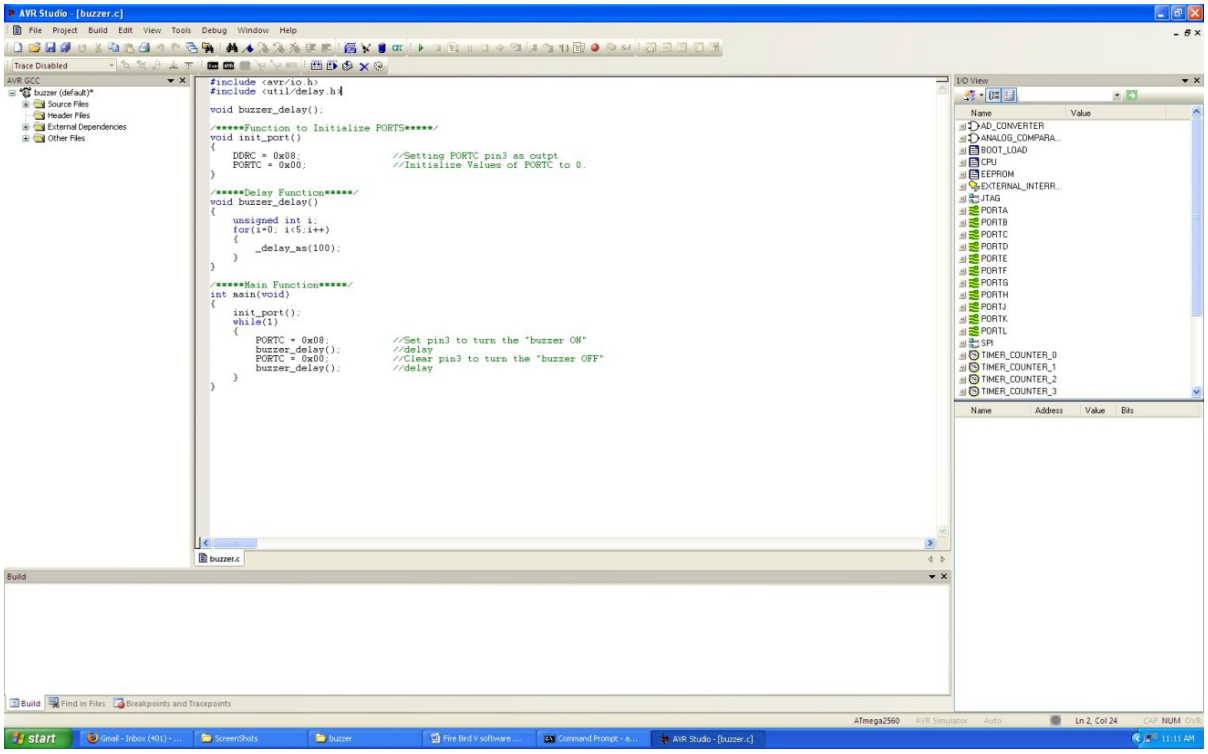


Figure 5.16

Middle window shows current code under development. Window on the left side shows view of source files, header files, External dependencies, and other files. Right side window shows all the ports and other peripheral's status. Bottom window is known as Build window. It shows results of the compilation, errors, HEX file size and other warning messages etc.

1. Open AVR Studio. If any project is running it can be closed by clicking on Project in the menu and select Close Project.

2. To create new project click on Project in the menu and select “New Project”.

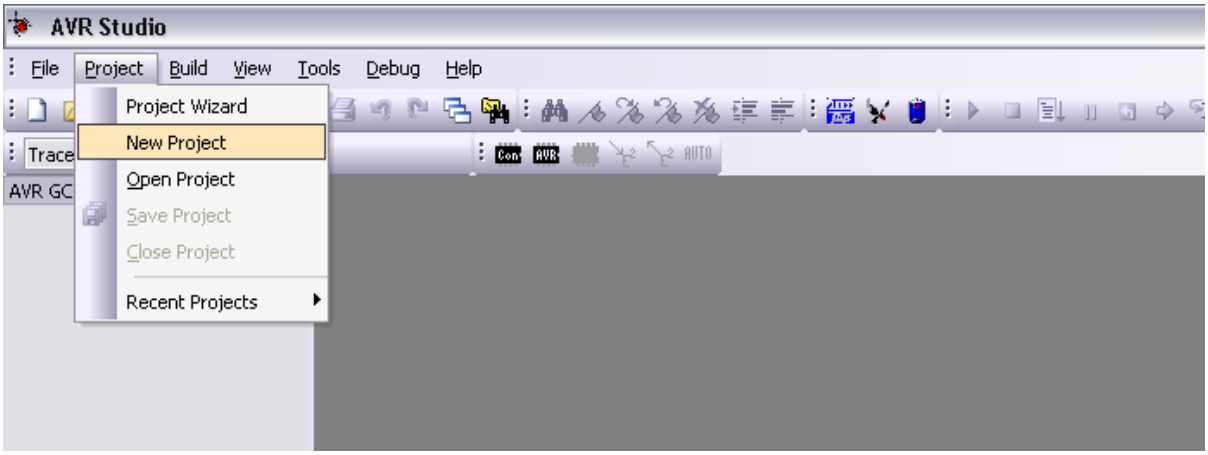


Figure 5.17

3. Select Project Type as “AVR GCC”. Type project name in the “Project name” window. In this case it is “buzzer_test”. Also check on Create folder check box. This will create all the files inside the new folder. In the Location window select the place where would like to store your project folder and then click “Next”.

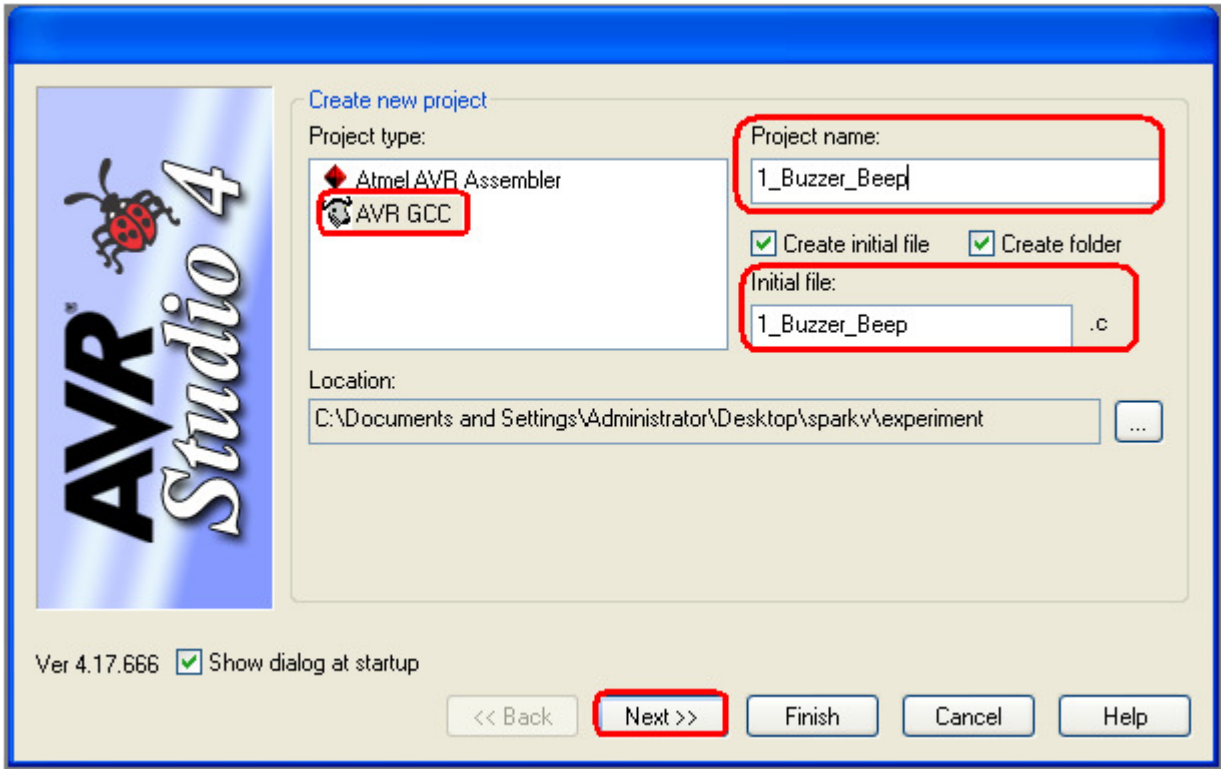


Figure 5.18

4. Select debug platform and Device. In this case we have selected “AVR simulator” and “ATMEGA16” microcontroller and click finish.

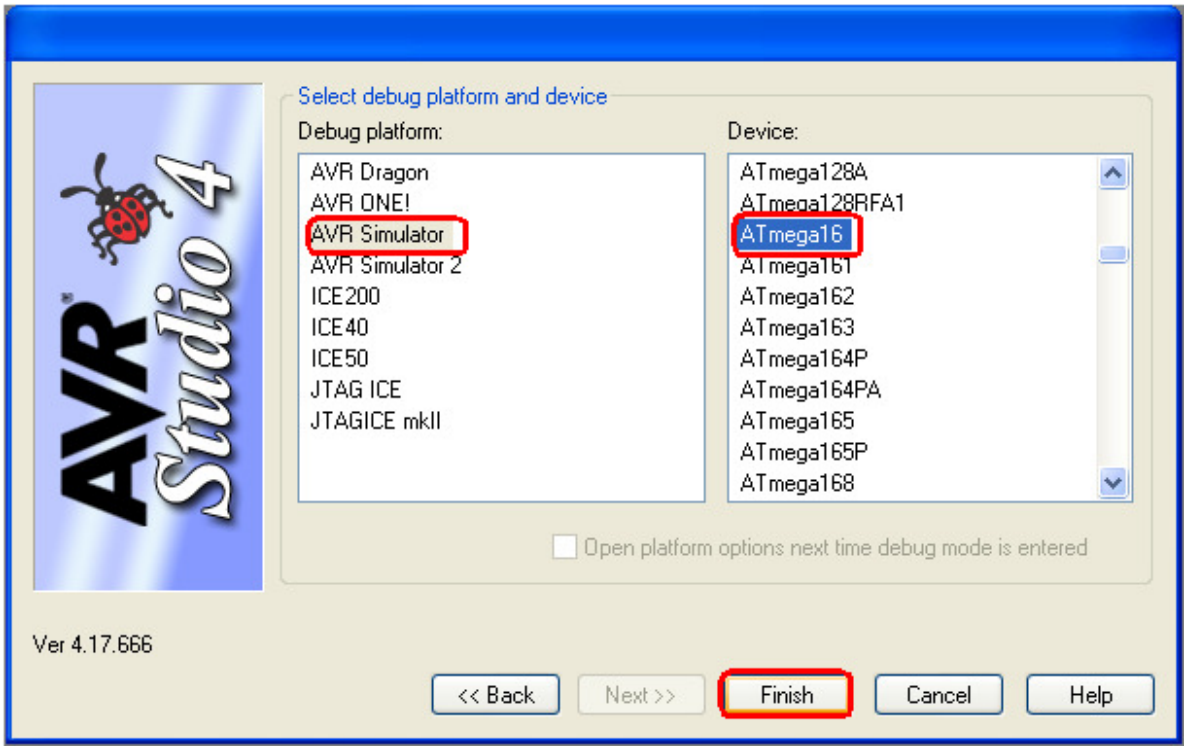


Figure 5.19

5. Now we are almost ready to write our first code. Before we start coding we will check other setting to make sure that they are set properly.

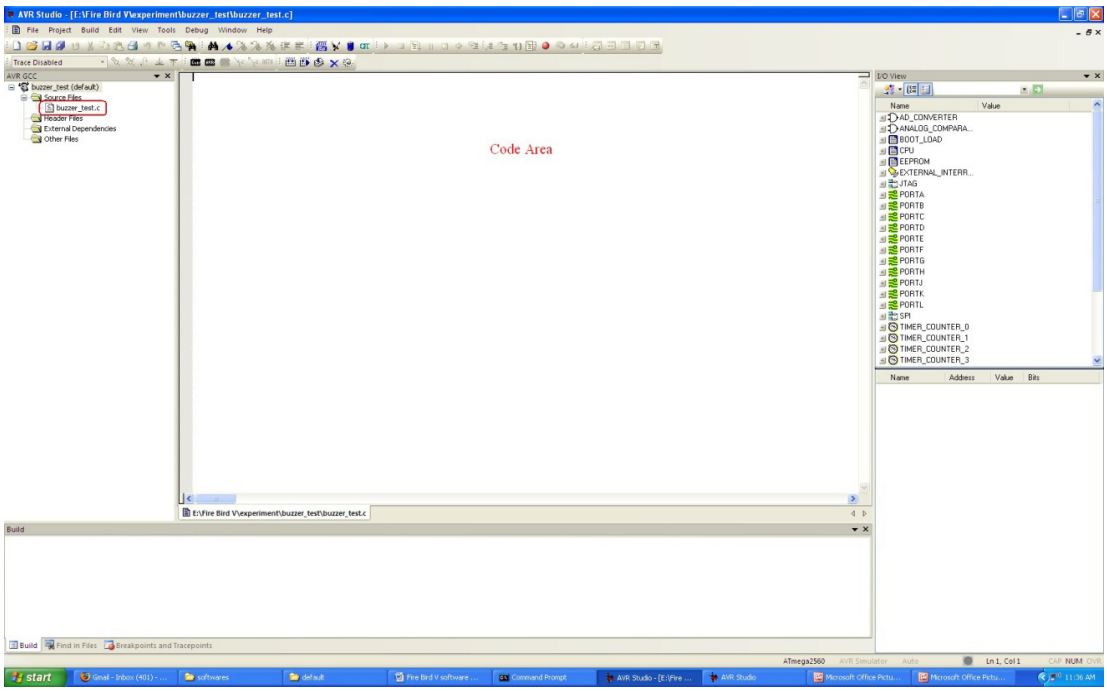


Figure 5.20

6. Open Project menu and click on the Configuration option.

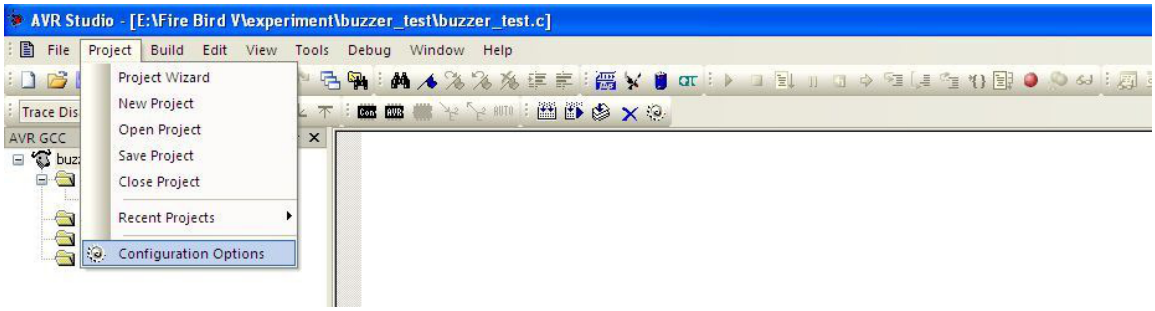


Figure 5.21

7. In the Project Option "General" tab will open. Select device as "ATMEGA16" and frequency (Crystal Frequency) as 7.3728MHz i.e. 7372800Hz. Set the optimization level be at "-O0".

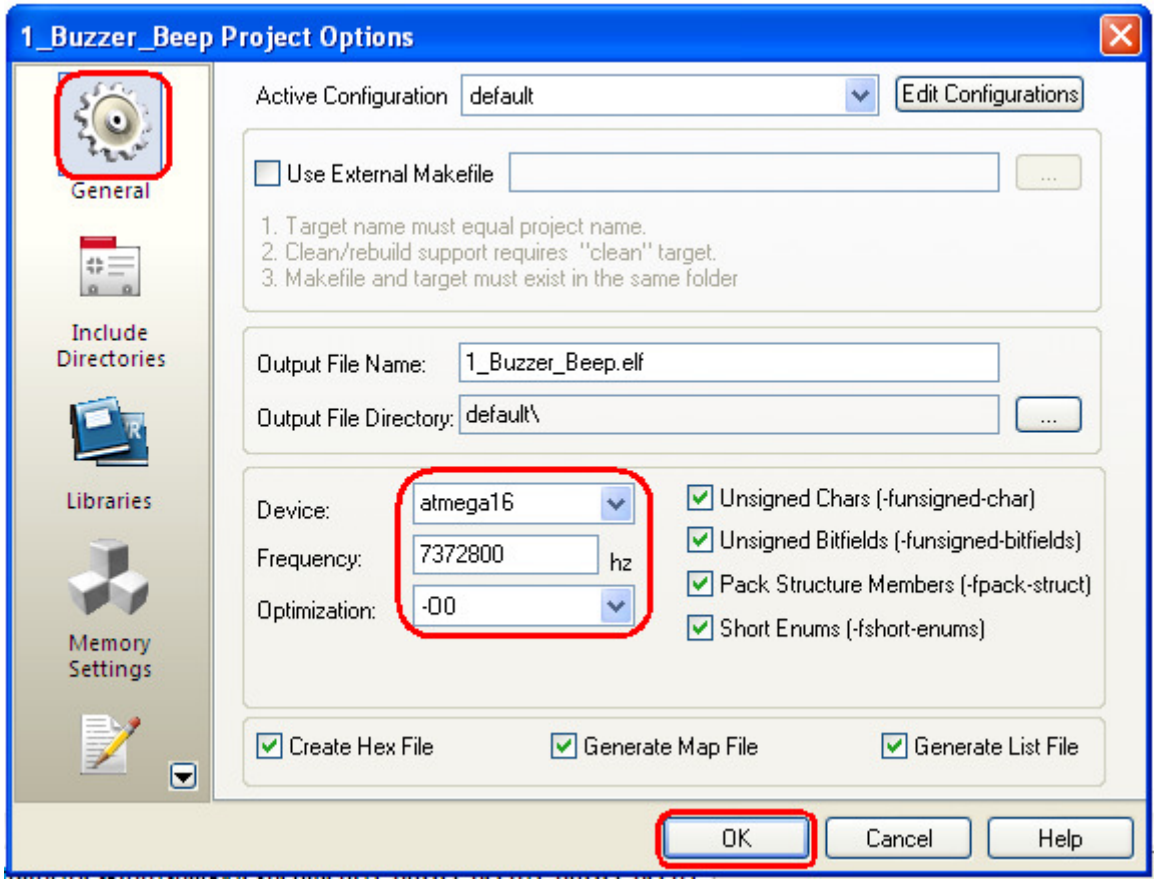


Figure 5.22

Selecting proper optimization options

"Optimization" option defines the optimization level for all files. Higher optimization levels will produce code that is harder to debug. Stack variables may change location, or be optimized away, and source level debugging may "skip" statements because they too have been optimized away.

The levels of optimization are:

- No optimization. This is the same as not specifying any optimization.
- -01 Optimize. Reduces code size and execution time without performing any optimizations that take a great deal of compilation time.
- -O2 Optimize even more. avr-gcc performs almost all optimizations that don't involve a space-time tradeoff.
- -O3 Optimize yet more. This level performs all optimizations at -O2 along with -finline-functions and -frename-registers.
- -Os Optimize for size. Enables all -O2 optimizations that don't increase code size. It also performs further optimizations designed to reduce code size.

For more information on optimization, see the 'man' pages for avr-gcc.

Important: During the coding choose appropriate optimization option. If you feel that code is not working properly as it should be then turn off all optimization by selecting optimization option as "-O0". Once you know that your code is properly working then you can incrementally increase optimization level.

We suggest that always use optimization level as "-O0" at the beginner level.

8. Make sure that in the External Tools, proper path for avr-gcc.exe and make.exe are given and press ok.

Now we are ready to write our first code.

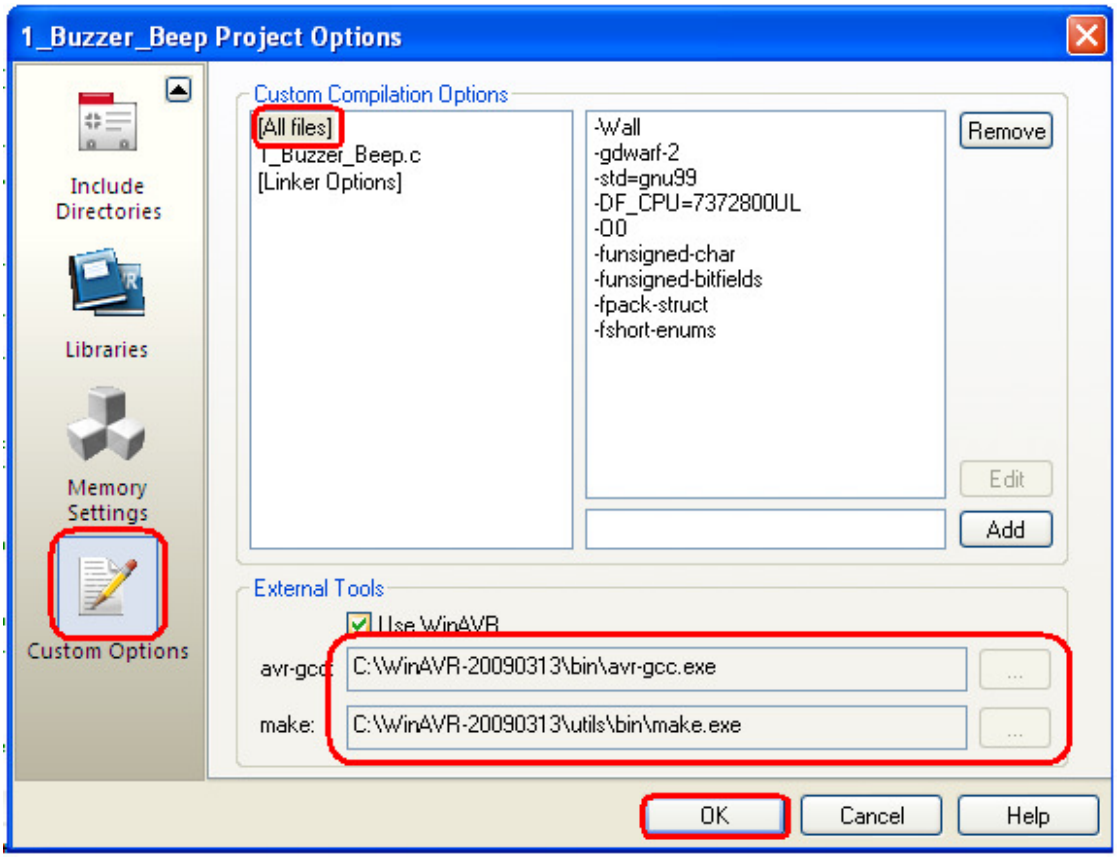


Figure 5.23

5.4 Writing your first code in AVR Studio

We are going to write our first code for our Spark V ATMEGA16 robot.

This program will make robot's buzzer beep.

Copy the following code in window "code area". We will see how this code works in the next chapter.

```
//Buzzer is connected at the third pin of the PORTC
//To turn it on make PORTC 3rd (PC3 )pin logic 1
#include <avr/io.h>
#include <avr/interrupt.h>
#include <util/delay.h>

//Function to initialize Buzzer
void buzzer_pin_config (void)
{
 DDRC = DDRC | 0x08;
//Setting PORTC 3 as output
 PORTC = PORTC & 0xF7;
//Setting PORTC 3 logic low to turnoff buzzer
}

void port_init (void)
{
 buzzer_pin_config();
}

void buzzer_on (void)
{
 unsigned char port_restore = 0;
 port_restore = PINC;
 port_restore = port_restore | 0x08;
 PORTC = port_restore;
}

void buzzer_off (void)
{
 unsigned char port_restore = 0;
 port_restore = PINC;
 port_restore = port_restore & 0xF7;
 PORTC = port_restore;
}

void init_devices (void)
{
 cli();     //Clears the global interrupts
 port_init();
 sei();     //Enables the global interrupts
}

//Main Function
int main(void)
{
            init_devices();
```

```
        while(1)
        {
                buzzer_on();
                //delay
                _delay_ms(1000);
                buzzer_off();
                //delay
                _delay_ms(1000);
        }
}
```

We are now going to compile this code to generate the hex file which we will load on the Robot's microcontroller. Select "Build" menu and click on "Rebuild All". It will compile the "buzzer_test.c" code and will generate "buzzer_test.hex" file for the robot's microcontroller.

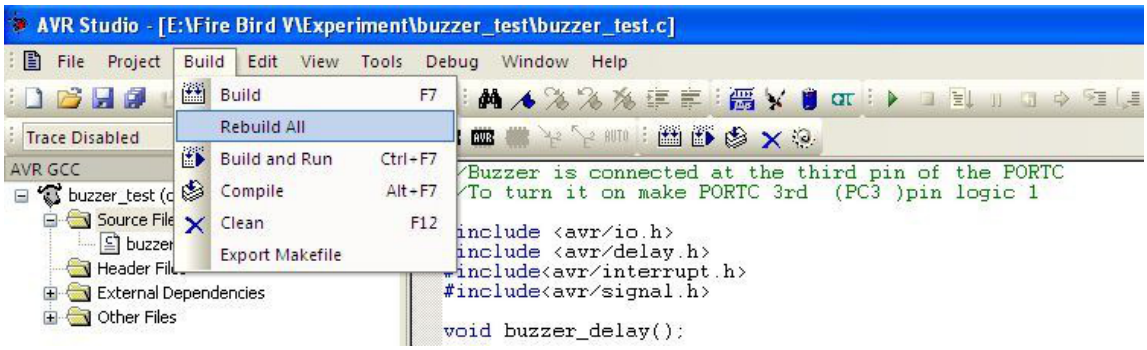


Figure 5.24

You can verify successful compilation in the bottom most "Build" window of the AVR Studio.

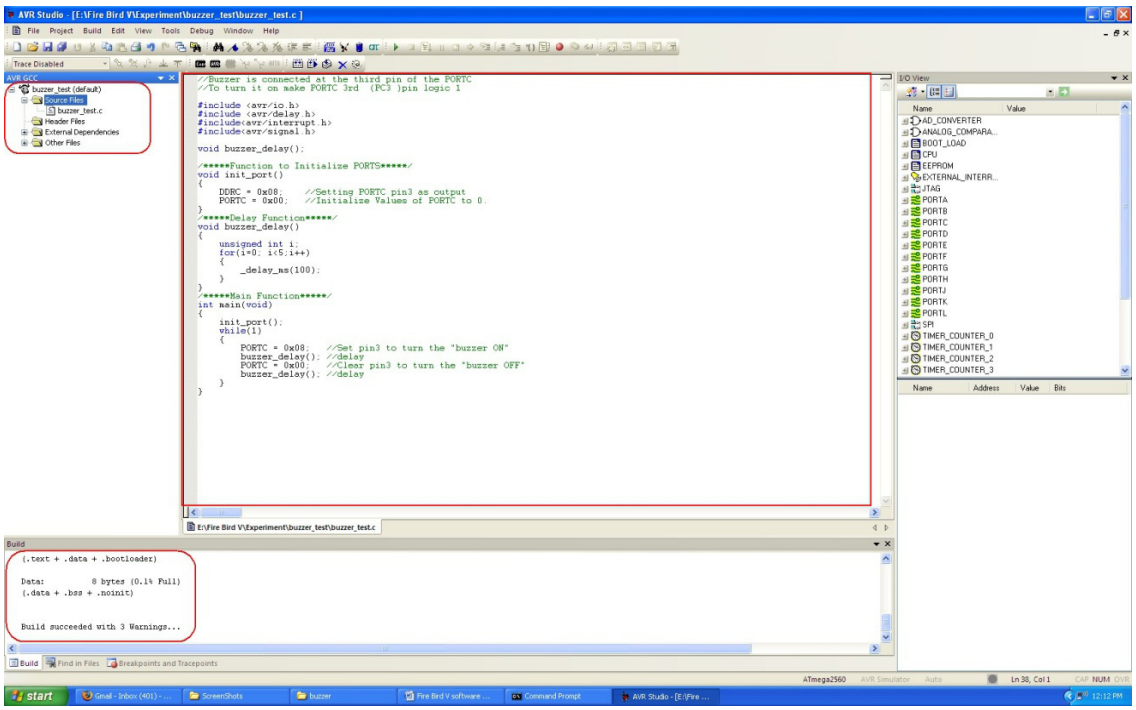


Figure 5.25

You can also verify that “buzzer_test.hex” file is generated in the “default” folder inside the folder you have selected.

5.5 Debugging the code in AVR studio

After successful compilation of the code we can debug the code by AVR Debugger provided by AVRStudio. Here is the illustration of debugging of code given in Exp1 (buzzer ON-OFF folder).

Click on Debug tab in the menu and click on “Start Debugging”.

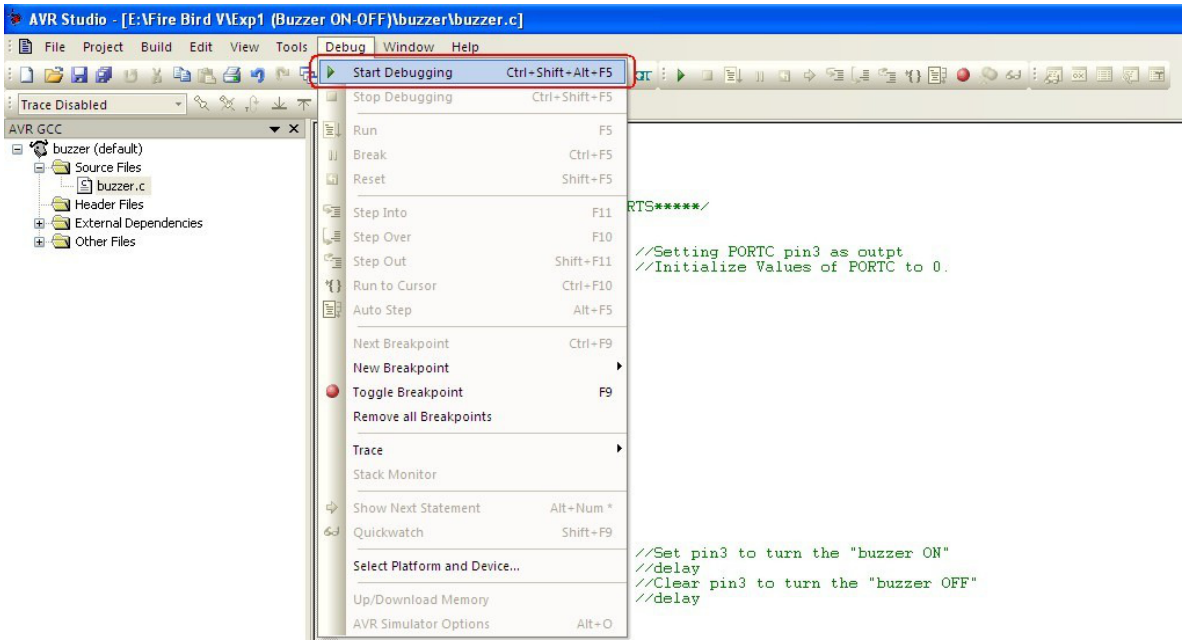


Figure 5.26

Now debugging mode is started and an arrow is visible at the first line of our main function from where the debugging will start.

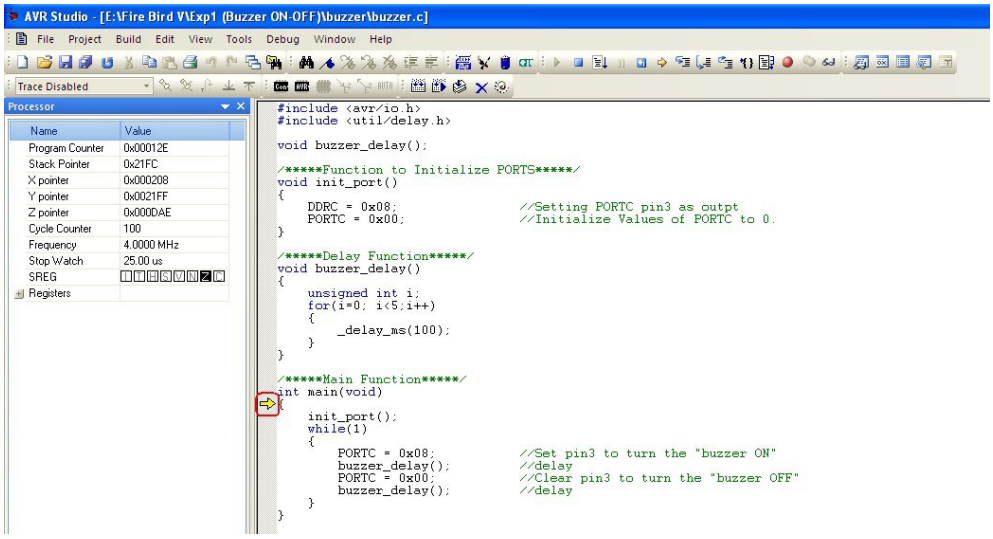


Figure 5.27

Press “F11” key or “Step into” button  from the toolbar to start debugging statement by statement. Processor details are visible at left window and the I/O port status is displayed at the rightmost window.

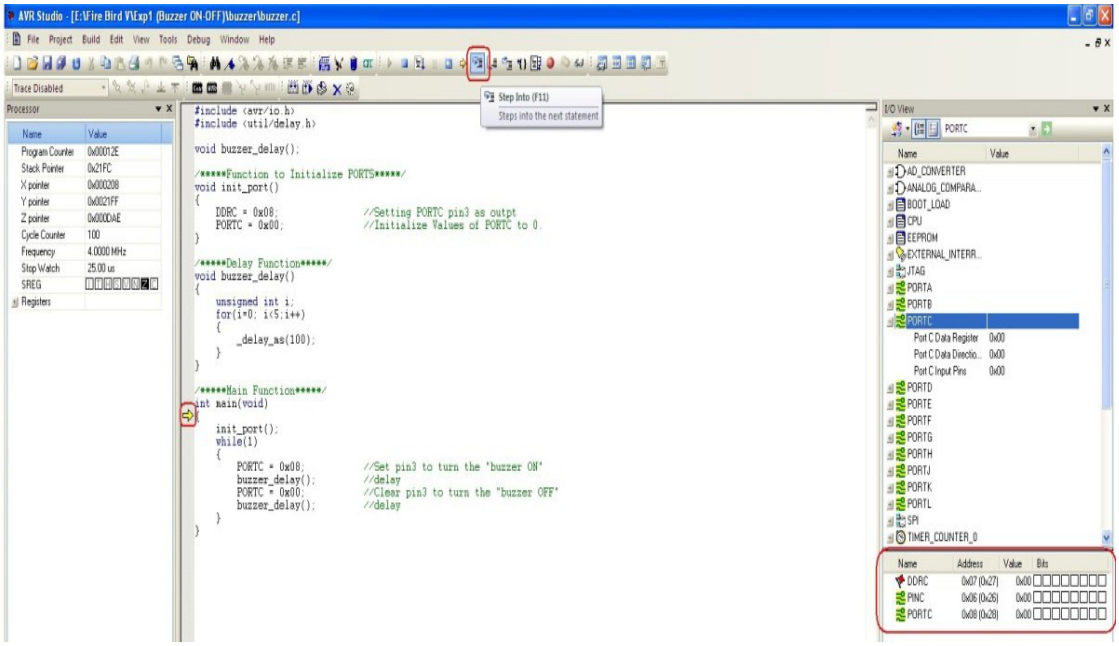


Figure 5.28

By this way we can continuously monitor the bit changes in any of the registers of microcontroller and debug the code before actually burning it to the microcontroller. PORTC bits changes as per our commands and these changes can be seen in right window. After debugging is done select “Stop Debugging” from Debug tab.

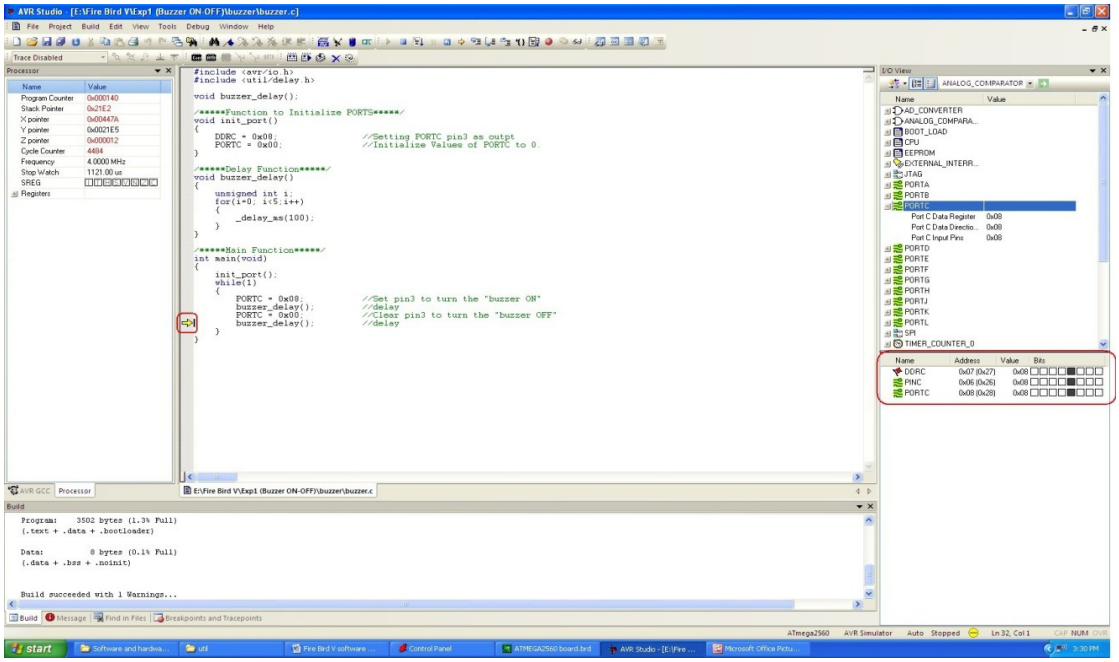


Figure 5.29

5.6 Loading your code on robot using AVR Boot loader from NEX Robotics

All AVR microcontrollers can be programmed using In System Programming (ISP), external programmer or using boot loader. Advantage with the boot loader is that you don't need any external hardware to load the .hex file on the microcontroller.

5.6.1 Boot loader operating principle

If Bootloader firmware is loaded on the microcontroller then it can be programmed directly via serial port or USB (using USB to Serial converter) using PC. In the boot loading method a small piece of code is loaded on the microcontroller in the configurable boot memory section. When signaled using external switch while resetting the microcontroller it gets active and waits for communication from the PC. Bootloader software from NEX Robotics which is installed on the PC communicates with the microcontroller. Boot loader software loads the .hex file on the microcontroller. After the boot loading process is complete, newly loaded code can be executed by pressing reset. Once the code is loaded on the microcontroller UART is free and can be used for other applications. Bootloader get invoked only if boot switch is kept pressed while microcontroller is reset using reset switch.

Note:
Bootloader code is loaded on the ATMEGA16 of the Spark V robot using ISP programmer. It is recommended that you only use Bootloader for the robot. If you use ISP programmer with the robot then boot section code might get erased and robot will no longer support boot loading.

5.6.2 Jumper settings for the boot loading

ATMEGA16 has one serial port. In Spark V it can be switched between USB and XBee wireless module by using jumper J5. For serial interfacing FT232 USB to Serial converter is used.

Boot-loading is done via USB Port. Figure 4.30 shows the correct jumper settings of J5 to connect USB port to the ATMEGA16 via FT232 USB to serial converter. Figure54.30 shows the correct jumper settings for the boot loading.

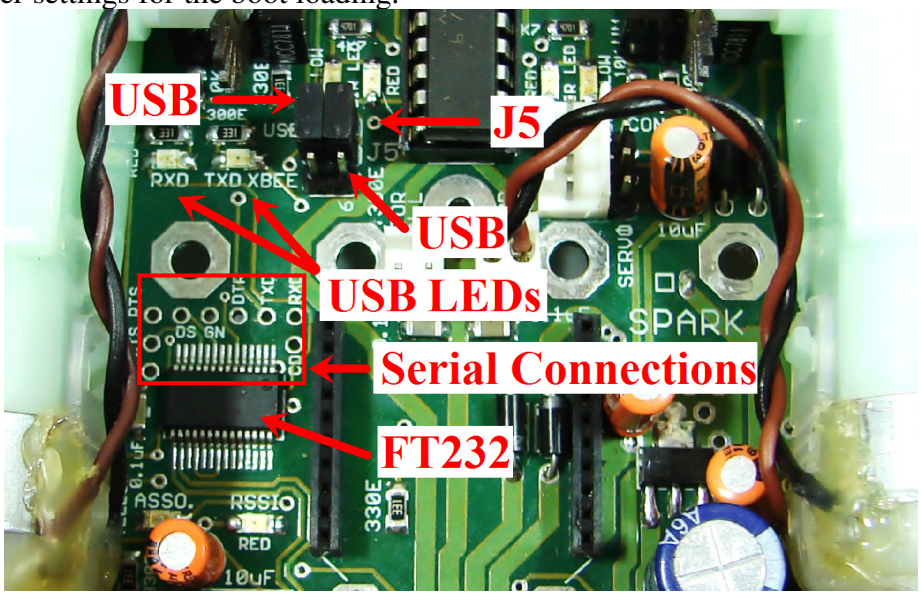


Figure 5.30 Jumper setting for connecting USB port

5.6.3 Installing FT232 USB to Serial converter drivers

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

Important: Make sure that jumper is configured to enable USB communication. Jumpers on J5 should be in the position.

Steps to install the drivers for USB to serial converter:

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

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

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

Figure 5.31

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

Figure 5.32

The following window will appear.

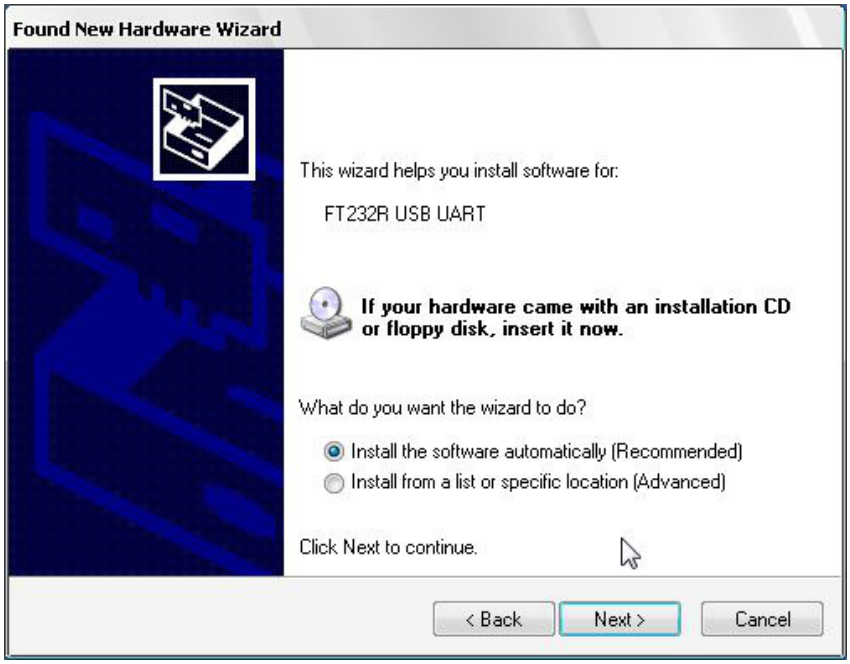


Figure 5.33

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).

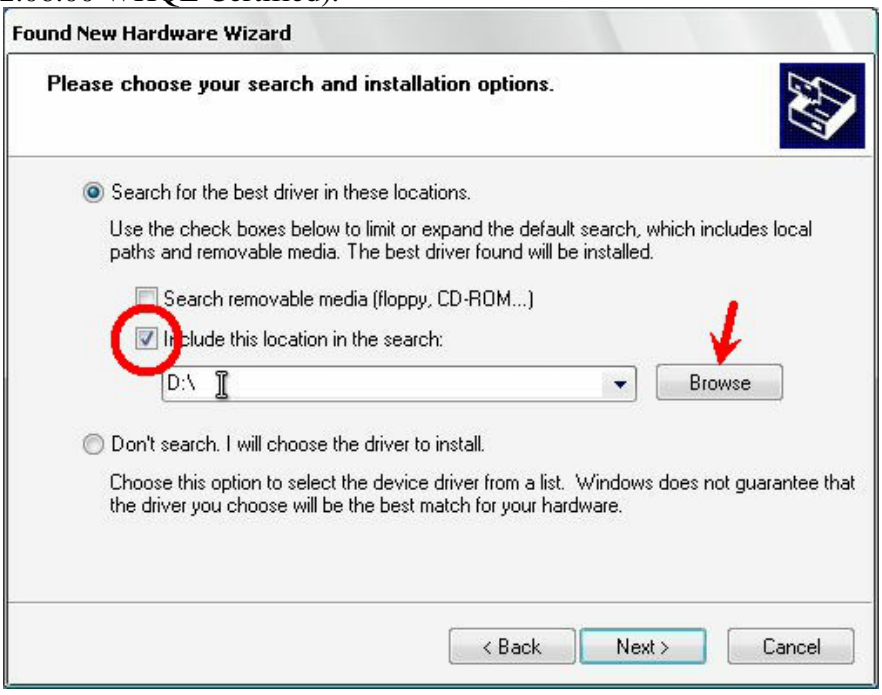


Figure 5.34

Step 6:
On clicking next driver installation will begin.

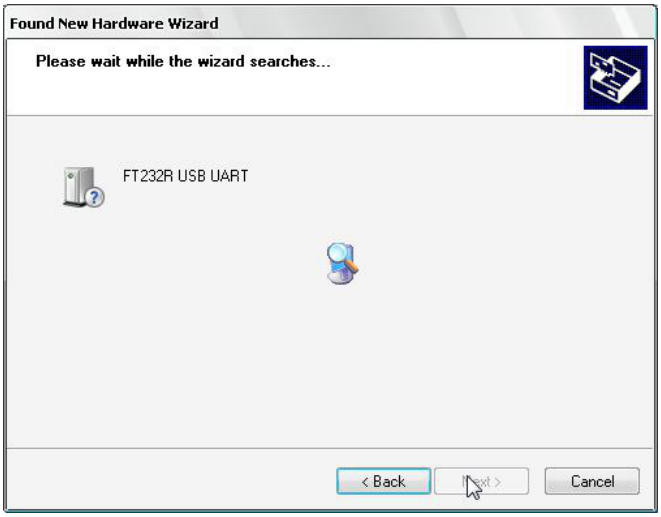


Figure 5.35

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

Figure 5.36

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.

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.

5.6.4 Identifying COM Port number of the USB to serial

To use terminal.exe or any other serial program for robot control we need to first identify communication port which is generally referred as COM n, i.e. COM1 or COM2 etc. on which USB to serial converter or wireless device is connected. Follow these steps to identify your COM Port number.

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

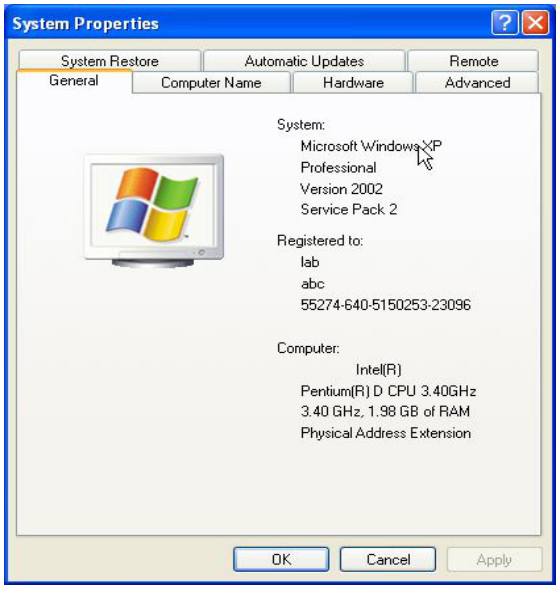


Figure 5.37

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

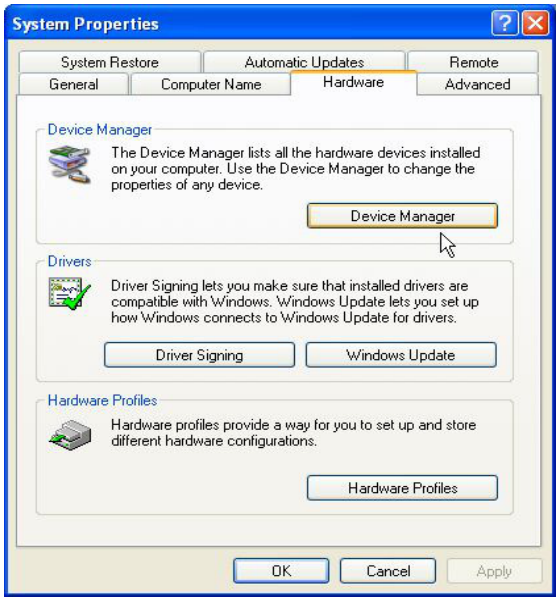


Figure 5.38

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

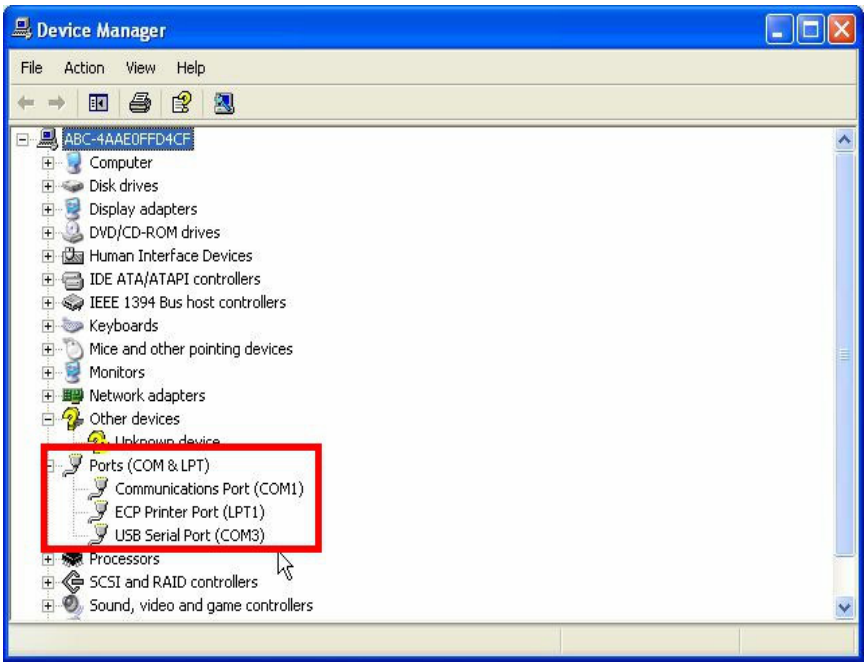


Figure 5.39

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

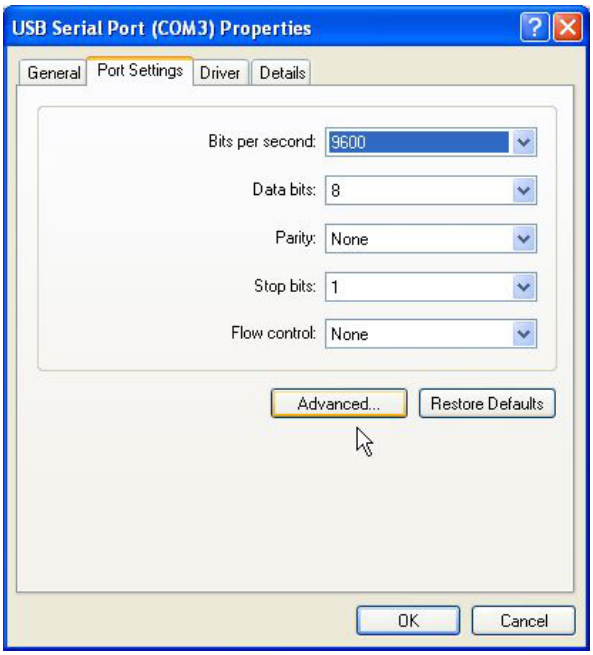


Figure 5.40

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

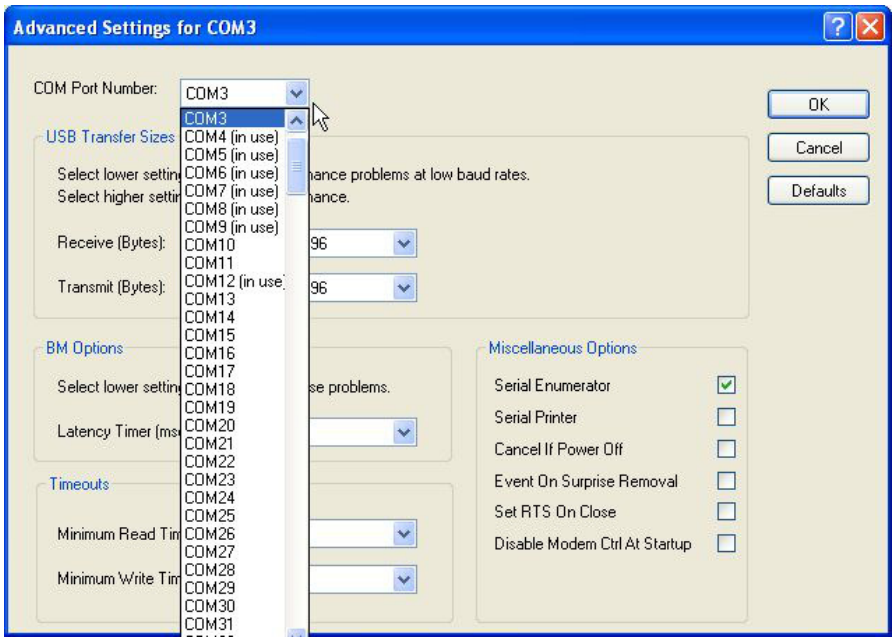


Figure 5.41

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

5.6.5 Installation and Demonstration of AVR Bootloader

For AVR Bootloader application, kindly refer manual of Installation and Demonstration of AVR Bootloader which is provided inside a **"Documentation CD\Manuals\Installation and Demonstration of AVR Bootloader"**.

Otherwise, download "Installation and Demonstration of AVR Bootloader Manual" from the following link:
http://www.nex-robotics.com/resources/avr-bootloader.html

5.7 Loading your code on the robot using STK500V2 AVR USB programmer from NEX Robotics

NEX AVR USB ISP STK500V2 is a high speed USB powered STK500V2 compatible In-System USB programmer for AVR family of microcontrollers. The compatibility with different window platform is given in below table. For more information on how to use this programmer, refer to its manual and drivers which are located in the folder "AVR USB ISP STK500V2" in the robot's documentation CD.

Compatibility Chart

Operating System	AVR Studio (CDC)	Avrdude (HID)
Windows XP	YES	YES
Windows Vista	X	YES
Windows 7	X	YES

Table 5.1

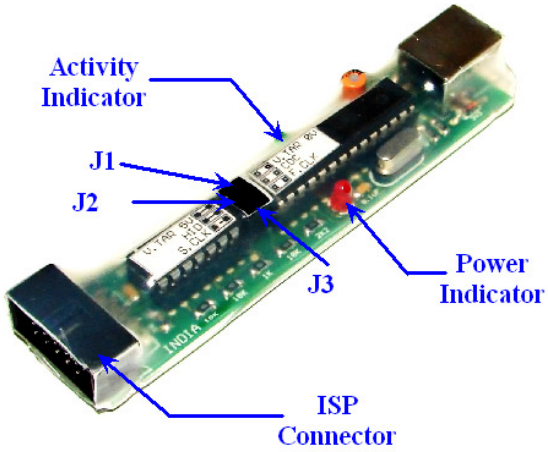


Figure 5.42: NEX AVR USB ISP STK500V2

5.8 Loading your code on the robot using ATMEL's AVRISP mkII Programmer

AVRISP mkII programmer from the ATMEL is the most versatile programmer. It is very easy to use and has more features. Only flip side is that its bit expensive.

Figure 5.43 AVRISP mkII

Step 1: Connect AVRISP mkII to the PC. It will install driver automatically provided that USB driver installation option is selected while installing AVR Studio. For more details refer to figure 4.13.

Start AVR Studio
Go to "Tools tab and click on "Program AVR". Select connect option.
Following window will open.

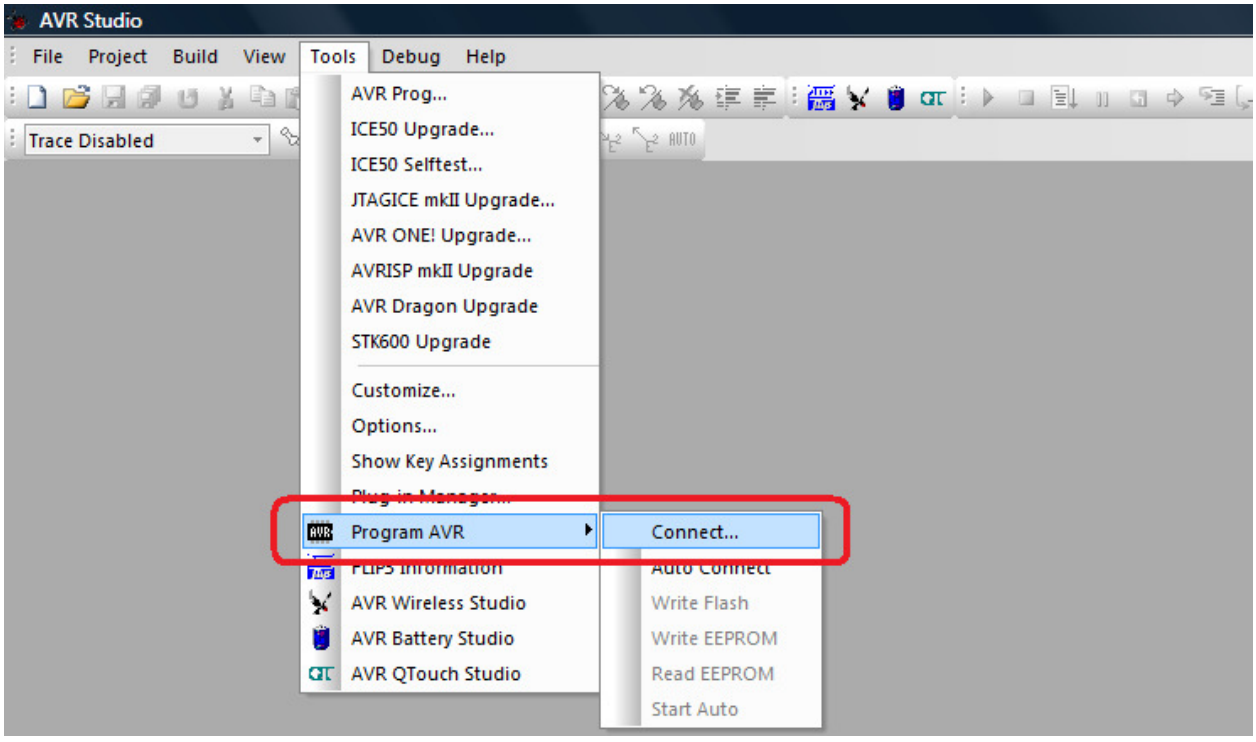


Figure 5.44

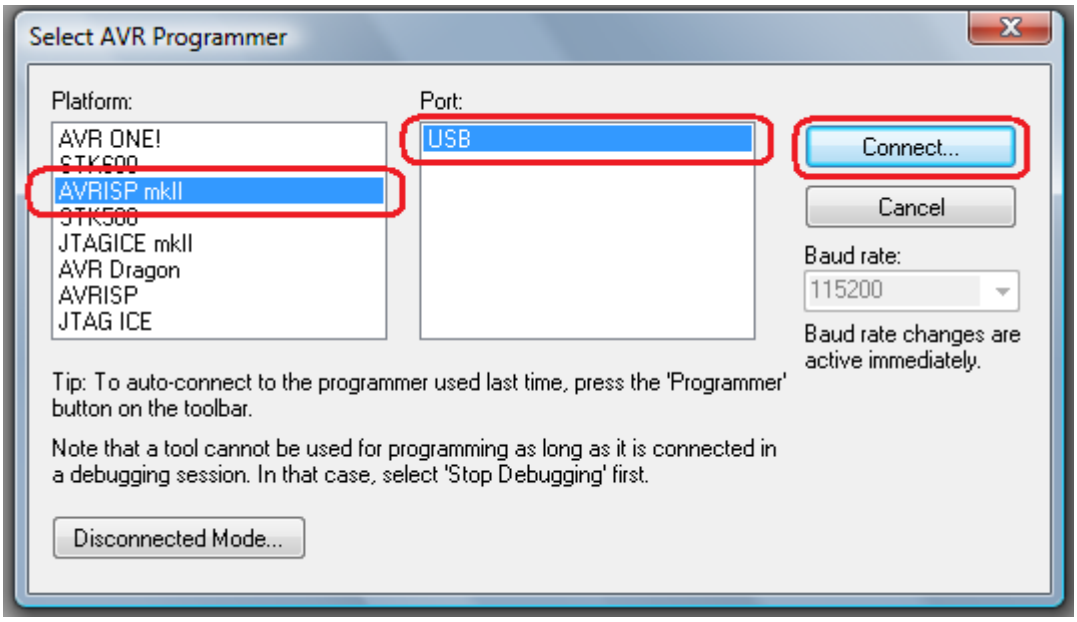


Figure 5.45

Step 2: Select "AVRISP mkII", select "USB port" and press "Connect". Following window will open.

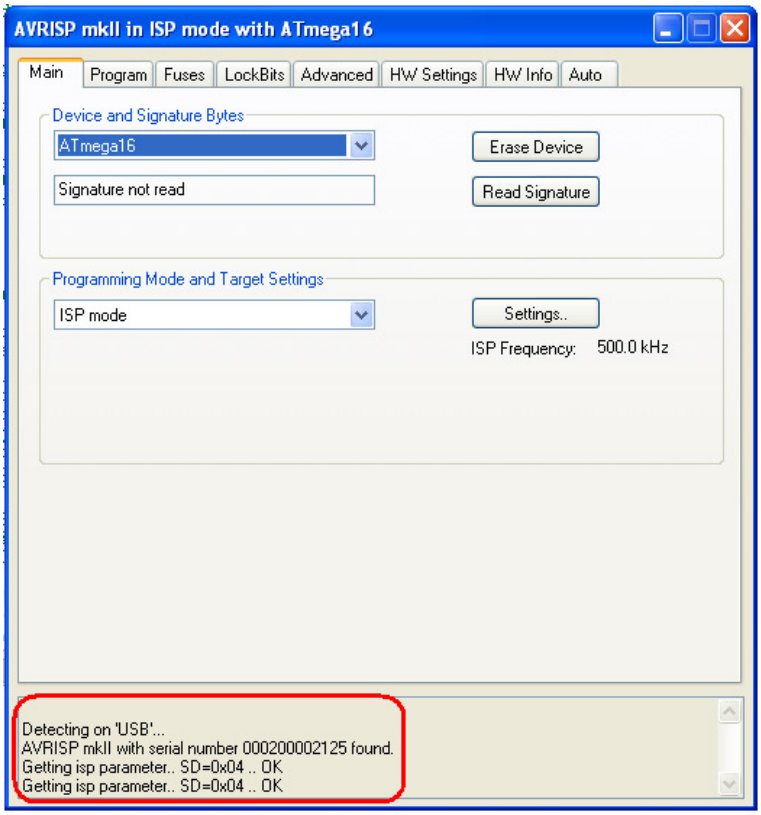


Figure 5.46

AVRISP mkII use 6pin FRC connector for ISP while Spark V robot uses 10 pin FRC connector for programming. We need to use AVR ISP adaptor to convert 6 pin to 10 pin connector which is available on NEX Robotics website. It comes free with the AVRISP mkII programmer if it is purchased from NEX Robotics website.

Step 3: Connect AVR ISP adaptor between robot and AVRISP mkII. Insert 10pin FRC connector in the Spark V ATMEGA16 robot and turn on the power.

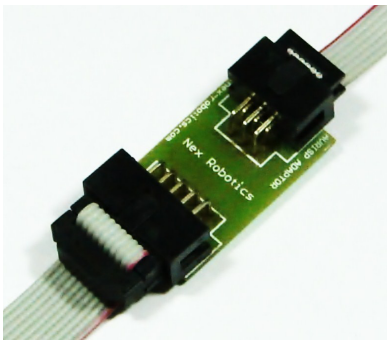


Figure 5.47

Step 4: Go to Main tab
Select "ATMEGA16" microcontroller.
Click on the "Read Signature" button.
It will read the signature and if its matches with the microcontroller signature then we are ready to load hex file on the robot.

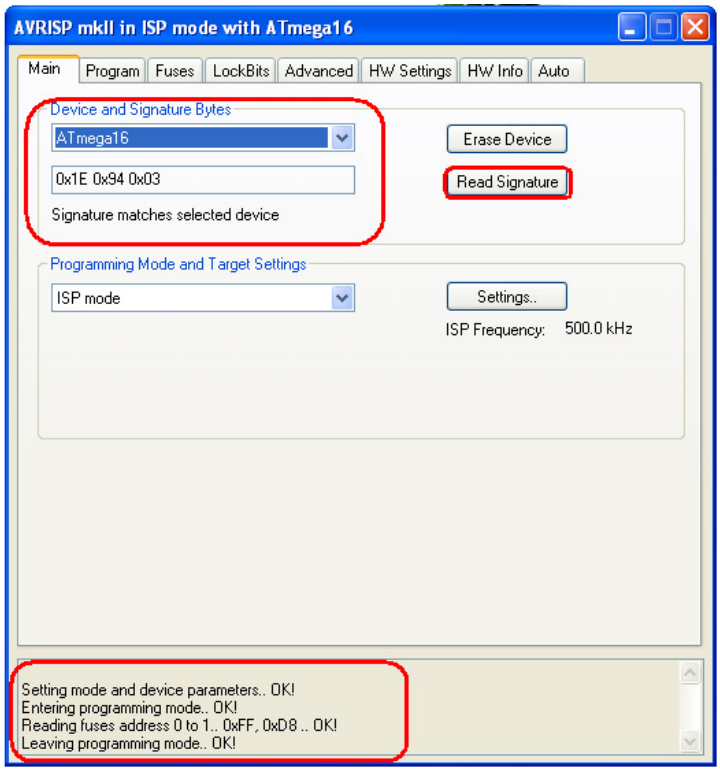


Figure 5.48

If ISP does not work properly then try to reduce the ISP frequency and try it again.

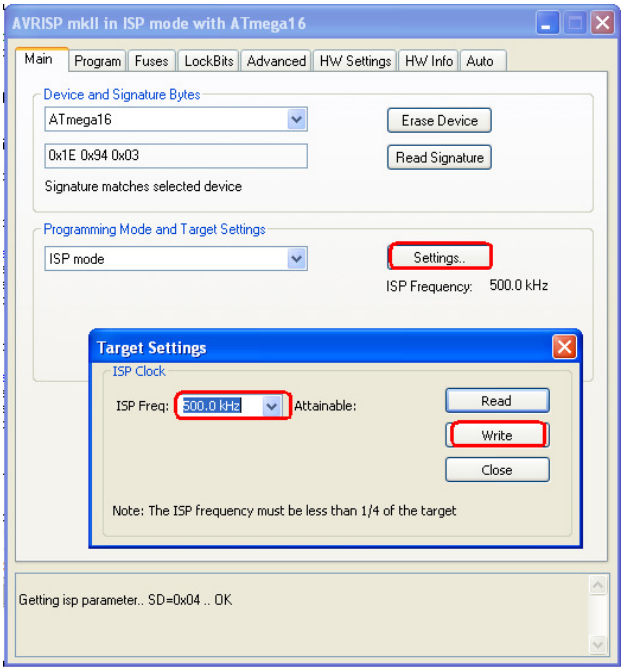


Figure 5.49 Changing ISP frequency if required

Step 5: Go to "Program" tab.
Check on Erase device before programming and Verify device after programming check box.
Browse and select the desired hex file in the flash section
Press "Program" button
Look at the comments at the bottom to verify that hex file is loaded in the flash.

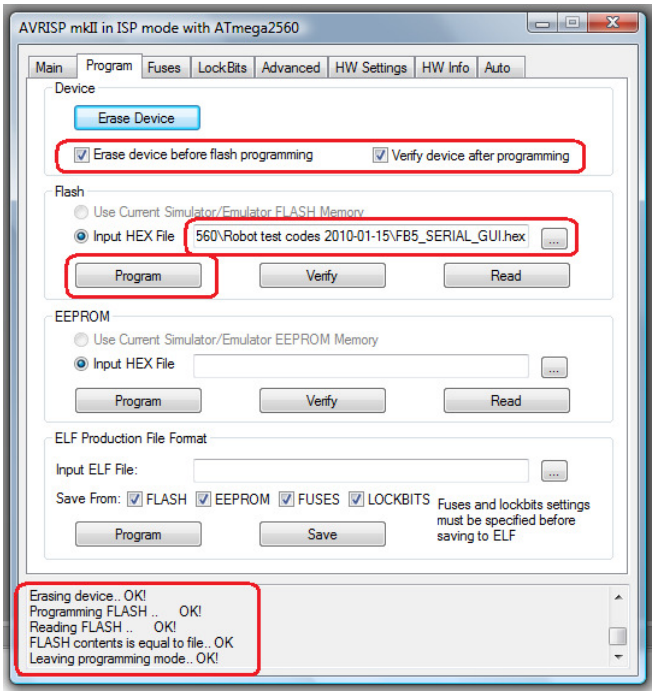


Figure 5.50

5.8.1 Fuse settings for ATMEGA16 microcontroller

Correct Fuse settings are done in the ATMEGA16 microcontroller before shipping out Spark V robot.. Do not change them unless you have very clear understanding of the fuse settings. This information is only given for the reference.

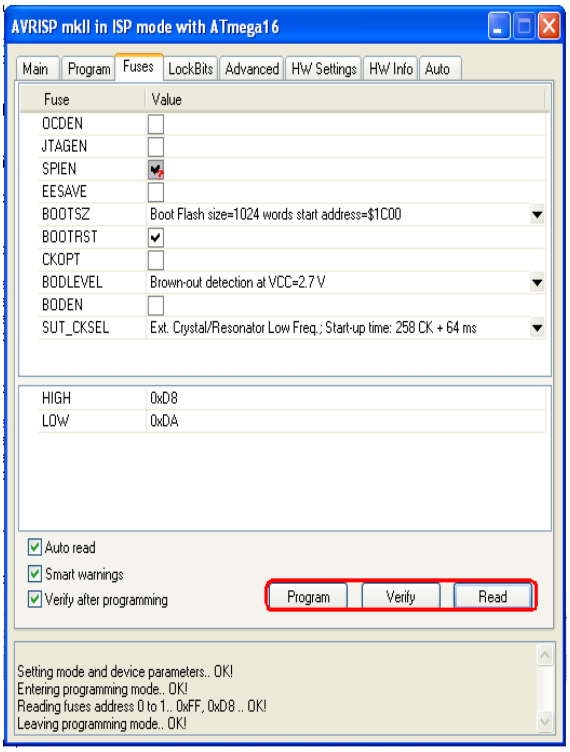


Figure 5.51

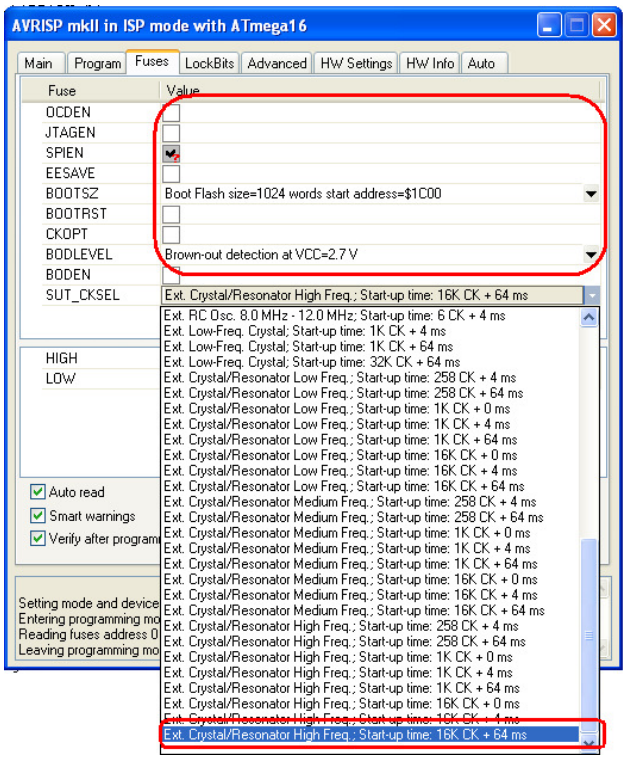


Figure 5.52 Fuse settings of ATMEGA16 microcontroller

Go the “Fuse” tab while robot is powered on and AVRISP mkII is connected. Press “Read” button. All the fuse settings will be visible.
Brown-out detection is disabled.
JTAGEN is set at Brown-out detection at VCC=2.7V
Boot size is at 4096 words with start address = $1C00
SUT_CKSEL is set at External crystal greater than 8MHz with startup time of 64ms
If needed you can set appropriate Fuse setting and write it by pressing “Program” button.

6 Pin Functionality

ATMEGA16 microcontroller pin configuration

PINNO	Pin name	USED FOR	Status
1	(XCO/T0)PB0	Logic output 1 for Left motor (Left back)	Output
2	(T1)PB1	Logic output 2 for Left motor (Left back)	Output
3	(INT2/AIN0)PB2	Logic output 1 for Right motor (Right back)	Output
4	(OC0/AIN1)PB3	Logic output 2 for Right motor (Right back)	Output
5	(SS)PB4	ISP (In System Programming)	Output
6	(MOSI)PB5		Output
7	(MISO)PB6		Input
8	(SCK)PB7		Output
9	RESET	Microcontroller reset	Default
10	VCC	5V	--
11	GND	Ground	--
12	XTAL1	Crystal 7.3728 MHz	Default
13	XTAL2		Default
14	(RXD)PD0	UART Receive*	Input
15	(TXD)PD1	UART Transmit*	Output
16	(INT0)PD2	Position Encoder input for Left Motor,	Input
17	(INT1)PD3	Position Encoder input for Right Motor	Input
18	(OC1B)PD4	PWM output for Left Motor	Output
19	(OC1A)PD5	PWM output for Right Motor	Output
20	(ICP1)PD6	Ultrasonic Trigger Input Left (sensor no. 1) ultrasonic sensor***	Output
21	(OC2)PD7	Boot loader switch / Servo Pod output	Input / Output
22	PC0(SCL)	LCD control line RS (Register Select)	Output
23	PC1(SDA)	LCD control line RW(Read/Write Select)	Output
24	PC2(TCK)	LCD control line EN(Enable Signal)	Output
25	PC3(TMS)	Buzzer	Output
26	PC4(TDO)	LCD data lines (4-bit mode)	Output
27	PC5(TDI)		
28	PC6(TOSC1)		
29	PC7(TOSC2)		
30	AVCC	5V	--
31	AGND	Ground	--
32	AREF	ADC reference voltage pin (5V external) ****	--
33	PA7 (ADC7)	ADC input for External ultrasonic sensor	Input*****
34	PA6(ADC6)	ADC input for battery voltage monitoring	Input*****
35	PA5(ADC5)	ADC input for white line sensor Right	Input*****
36	PA4(ADC4)	ADC input for white line sensor Center	Input*****
37	PA3(ADC3)	ADC input for white line sensor Left	Input*****
38	PA2(ADC2)	ADC input for right side analog IR proximity sensor or ultrasonic range sensor	Input*****

39	PA1(ADC1)	ADC input for center side analog IR proximity sensor or ultrasonic range sensor	Input*****
40	PA0(ADC0)	ADC input for left side analog IR proximity sensor or ultrasonic range sensor	Input*****

Table 5.1: ATMEGA16 microcontroller pin configuration

- UART can be connected between FT232 USB to Serial converter or XBee wireless module using jumper J5.
- Ultrasonic sensors are connected in daisy chain for trigger synchronizing. For more details refer to chapter 4.
- AREF can be obtained from the 5V microcontroller.
- All the ADC pins must be configured as input and floating.

7 PC Based Control Using Serial Communication

In this chapter, simple robot control over wired (USB) 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. Spark V ATMEGA16 robot can communicate with the PC using USB or XBee wireless module.

7.1 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 7.1

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 "10A_Serial_Communication_USB" and "10B_Serial_Communication_ZigBee" projects which are located in the "Experiments" folder in the documentation CD. 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.

7.2 Robot control using USB port

Spark V ATMEGA16 has onboard USB port for direct interface with PC. USB interfacing is based on FT232 USB to serial converter. Serial port of the ATMEGA16 can be connected to either USB port via FT232 USB to serial converter or to XBee wireless module. To connect TXD and the RXD of the microcontroller to FT232 USB to serial converter, Jumper J5 needs to be set in the correct setting. Refer to figure 7.1 for the jumper setting to use USB port.

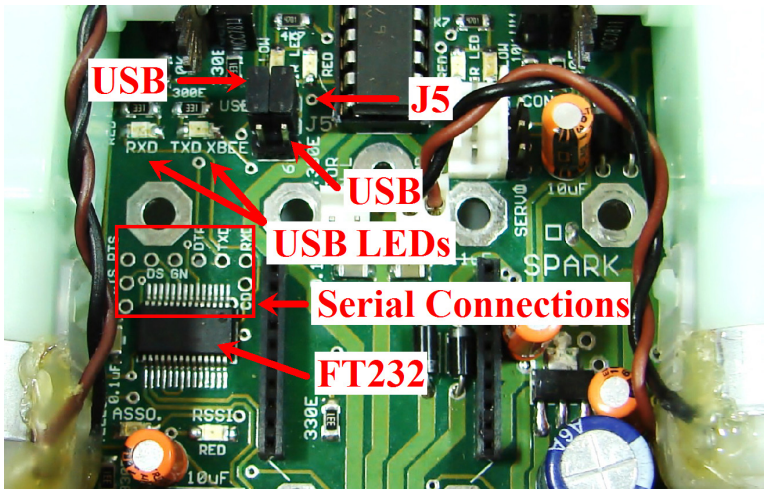


Figure 7.1 J5 Jumper setting to enable USB communication

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 5.6.3.

We need to load "10A_Serial_Communication_USB.hex" on the robot which is located in the "Experiments" folder in the documentation CD. For loading the hex file refer to section 5.6.

For transferring the command and data we are using the "Terminal Software" located in the documentation CD. The Installation of terminal software and its use is explained in section 7.4.

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.

7.3 Robot control using ZigBee wireless communication module

Figure 7.2 ZigBee Wireless USB Module from NEX Robotics

USB Wireless Module from the NEX Robotics enables wireless transmission of serial data through PC's USB port. It uses ZigBee module for wireless communication. The ZigBee module can be configured via PC's USB port easily using X-CTU utility to change frequency, baud rate etc. It is located in the "Software and Drivers" folder in the documentation CD. XBee wireless modules accepts serial data from any device. To interface it with the PC, FT232 USB to serial converter is used. To connect XBee USB Wireless Module to the PC you need to install drivers for FT232 USB to serial converter. To install drivers for FT232 USB to serial converter and to identify or change COM port number, refer to section 5.6.3 and 5.6.4.

On the PC side this device is treated as the Communication Device Class (CDC) of USB family and it is assigned a virtual Comport number allowing the user to make use of existing GUI. The destination side (robot) requires another XBee wireless module.

Make sure that ZigBee wireless module s installed on the robot. Serial port of the ATMEGA16 can be connected to either USB port via FT232 USB to serial converter or to ZigBee wireless module. To connect TXD and the RXD of the microcontroller to ZigBee wireless module, Jumper J5 needs to be set in the correct setting. Refer to figure 7.3 for the jumper setting to use ZigBee wireless module.

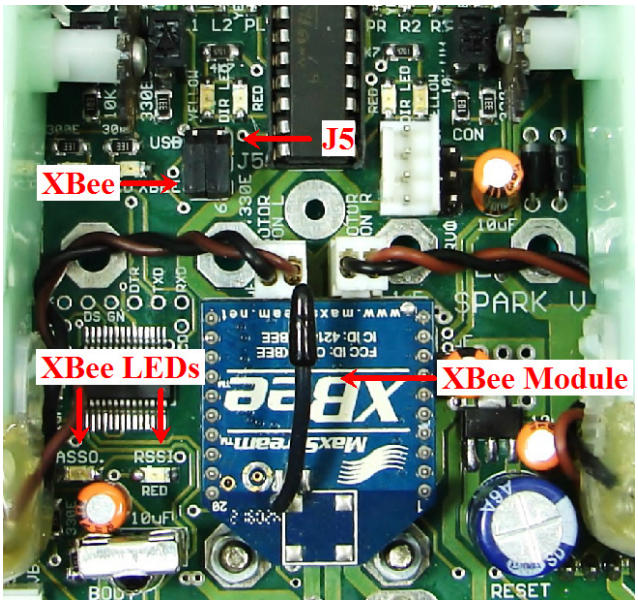


Figure 7.3 Jumper setting to enable XBee wireless module

We need to load "10B_Serial_Communication_ZigBee.hex" on the robot which is located in the "Experiments" folder in the documentation CD.

For transferring the command and data we are using the "Terminal Software" located in the "Software" folder of the documentation CD. The Installation of terminal software and its use is explained in section 7.4.

Note: Wait for at least 5 seconds to start the wireless communication after turning on the robot and the USB wireless module.

7.4 Using the Terminal software to control robot via USB port or XBee wireless module

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

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

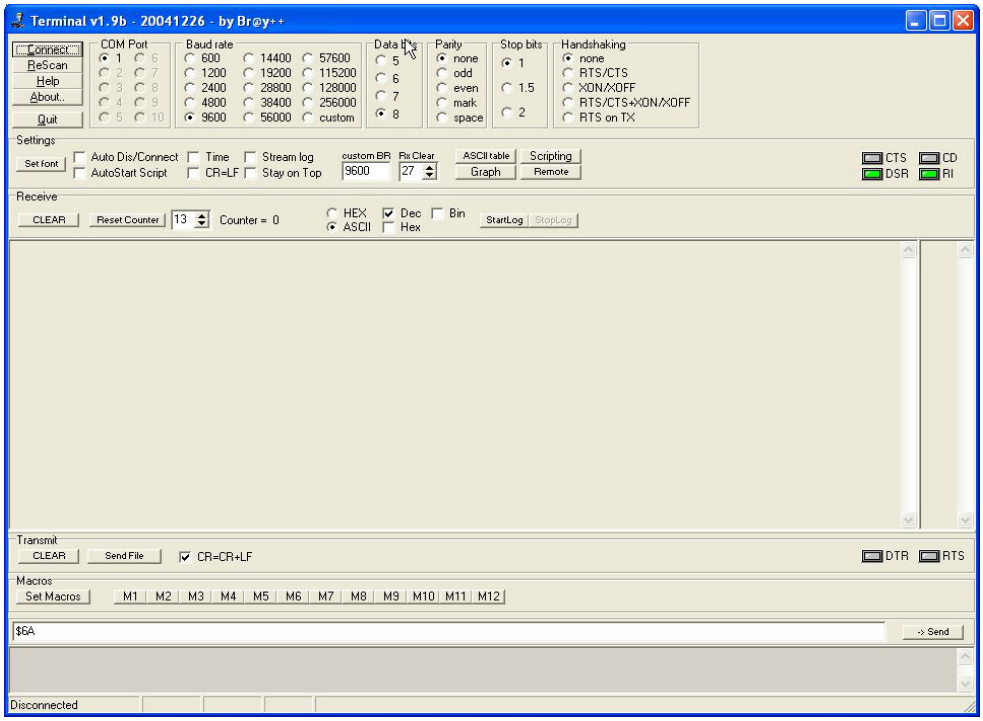


Figure 7.4

Step 2:
Select correct jumper setting of J5 to use USB for XBee wireless module for interfacing with the robot. For more details, refer to sections 7.2 and 7.3
Identify the com port. For more details refer to section 5.6.3
Current version of the terminal software does not support COM port number greater than 10. If identified COM port number is more than 10 then to change it refer to section 5.6.4.
Specify the COM port in the terminal software
Set the baud rate at 9600 bps

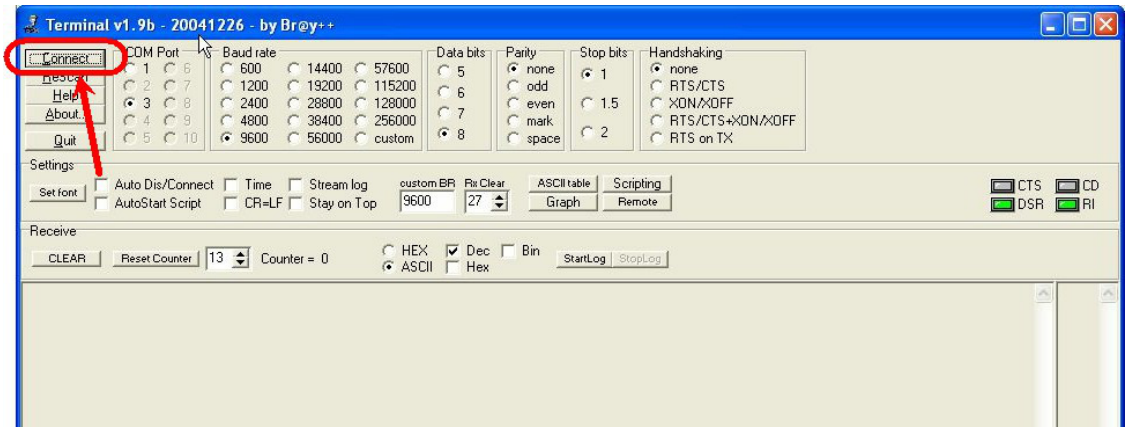


Figure 7.5

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

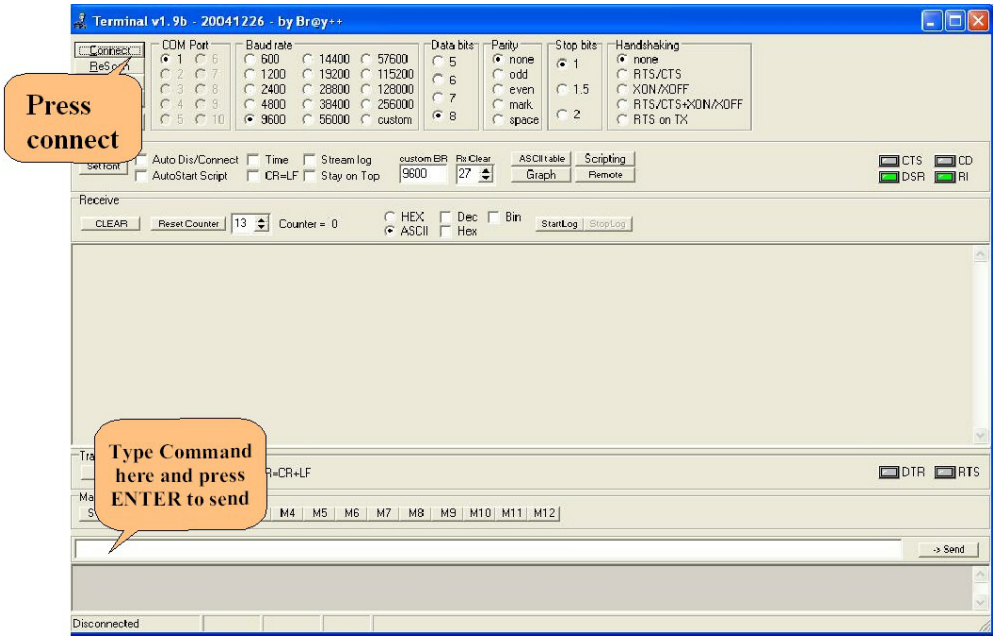


Figure 7.7

Step 4:

Turn on the robot. Connect Robot's USB cable or XBee USB wireless module to the PC.
Make sure that Num lock of the keyboard is on.
Use Numerical keypad to control robot.

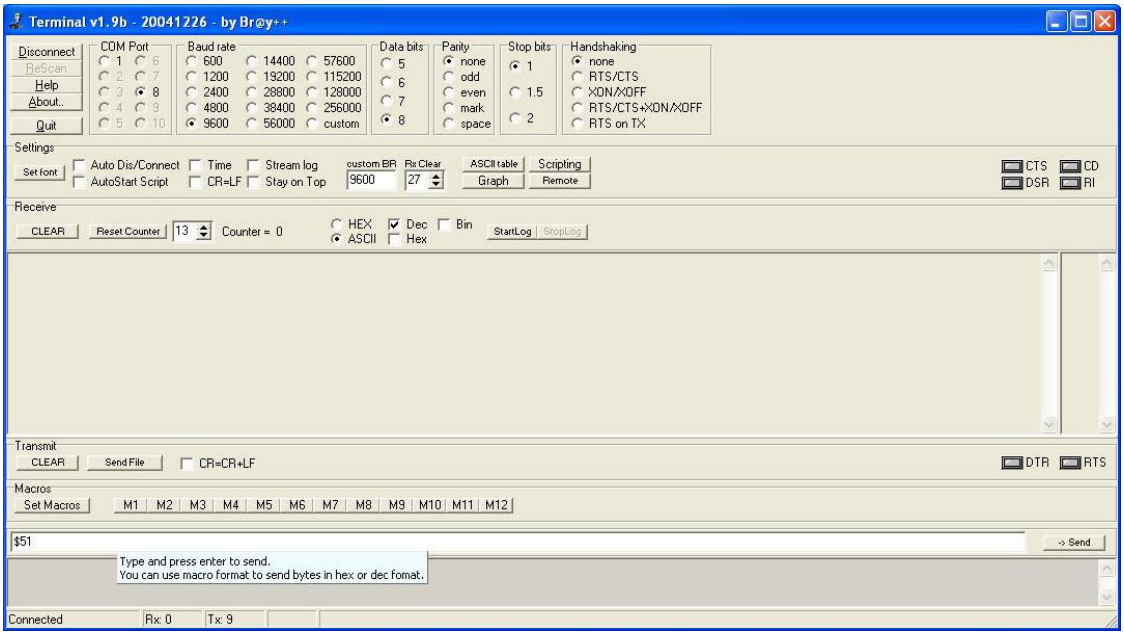


Figure 7.8

8 Robot Control using 'GUI' for SPARK V ATMEGA16

SPARK V ATMEGA16 robot can be controlled by GUI using USB cable or XBee USB wireless module. You need to load "GUI control.hex" on the robot and depending on the mode of communication (USB / Wireless) set the Jumper J5 in correct setting. For correct jumper setting, refer to section 7.2 and 7.3. For how to load hex file on the robot, refer to section 5.6.

In this chapter section 8.1 and 8.2 covers Installation and use of GUI. Section 8.3 covers the communication protocol used in the GUI.

8.1 Installing GUI for SPARK V ATMEGA16

Step1: Copy "SPARK V ATMEGA16 setup" folder which is located inside the folder "GUI and Related Firmware"

Click on setup.exe which is located in the "SPARK V ATMEGA16 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.

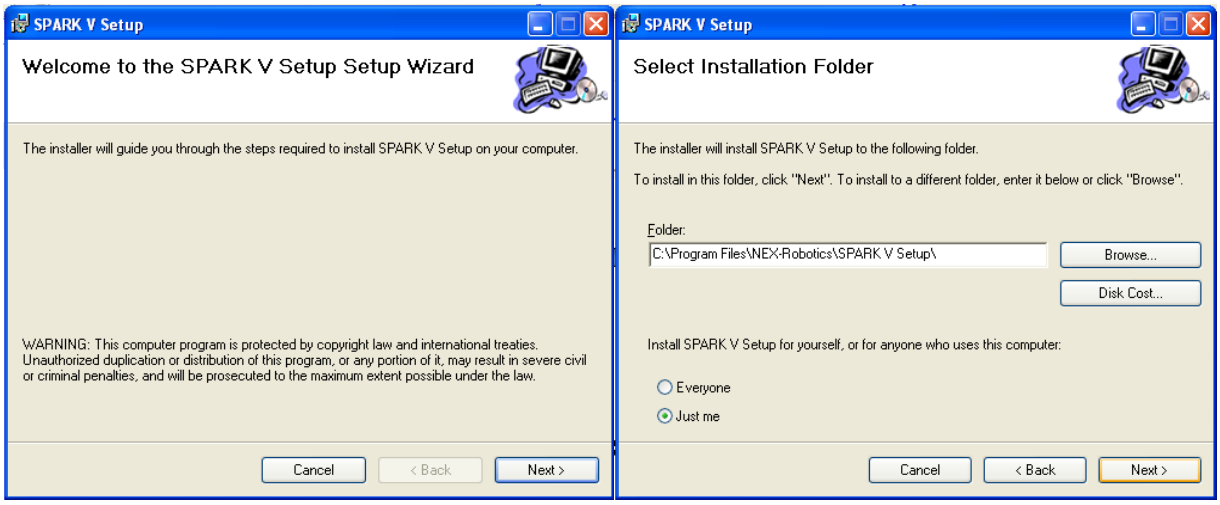


Figure 8.1

8.2 Using SPARK V ATMEGA16 GUI

Step 1:

After successful installation go to Start -> All Programs -> SPARK V Atmega16 -> SPARK V Atmega16 or click on SPARK V Atmega16 on your desktop location, GUI will open.

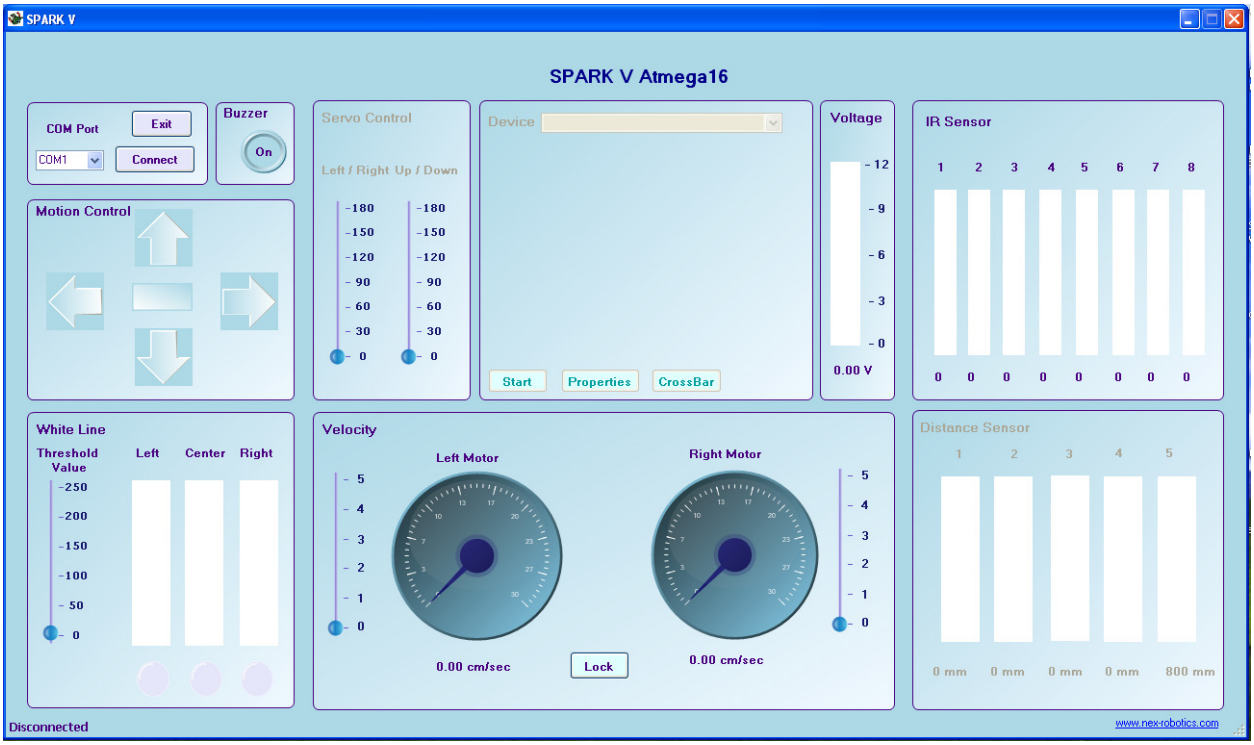


Figure 8.2 Selecting correct COM Port

Step 2:

Connect Robot with the PC via USB cable or XBee wireless communication module.

Make sure that jumper J5 is correctly set for selected communication option. Refer to section 7.2 and 7.3 for correct jumper setting.

Step 3:
Select the COM port. For identifying the COM port, refer to section 5.6.4.
Press connect.
Now robot can be controlled by GUI.

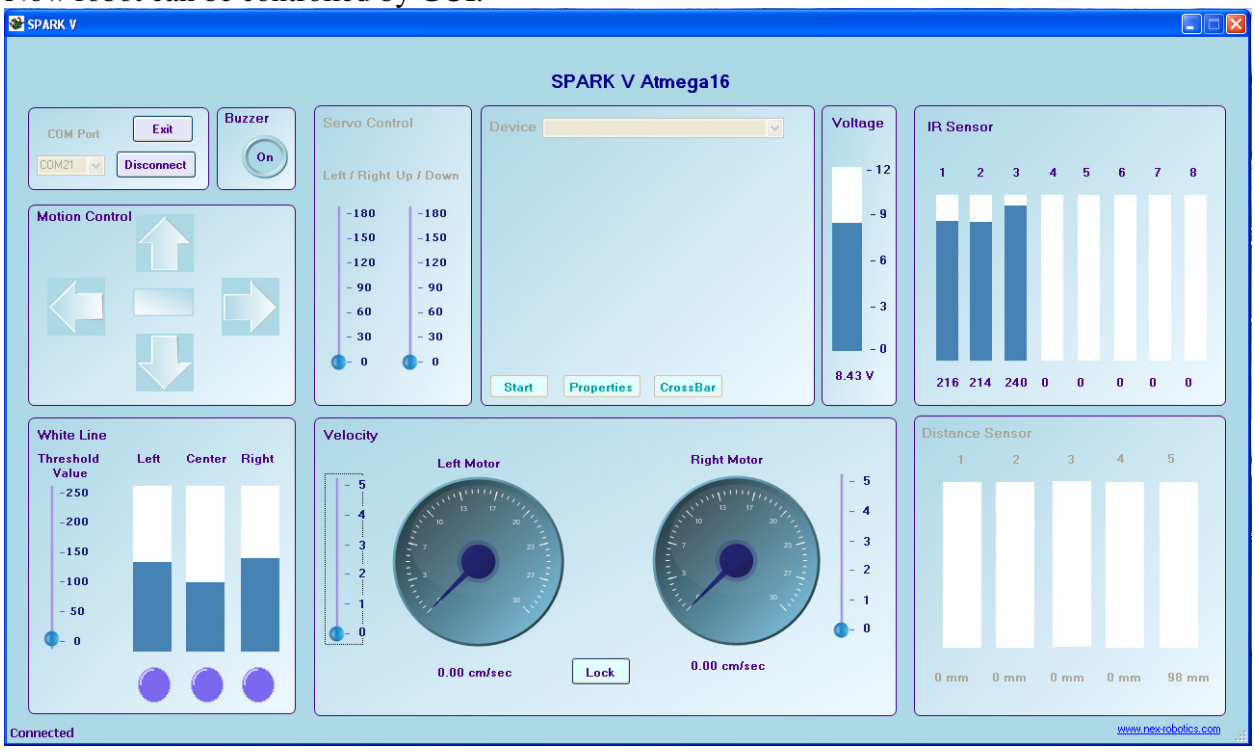


Figure 7.3: GUI showing robot's data

⚠Warning:
While using USB communication, ensure that the appropriate jumpers are in place. For more refer section 6.2 and 6.3

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.

8.3 Communication protocol used in GUI

The communication between the host computer and Spark V robot is done by sending and receiving commands and data byte by byte. The host computer interacts with the Spark V robot by first sending a command byte followed by data byte or it waits for data from the robot. All communication is initiated by host PC. The host computer acts as a master and Spark V robot acts as a slave. PC introduces delay of at least 3ms between two consecutive commands, so that the microcontroller gets sufficient time to process the command sent to it. You can also build your own application by using command set given below to control robot using USB or over wireless communication. It's a simple byte based protocol in which upper nibble is command and lower nibble can be data or command.

8.3.1 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 (OCR), 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 8.1

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.

8.3.2 Commands to set direction of the robot

Command (HEX)	DIRECTION	LEFT BWD (LB) PB0	LEFT FWD(LF) PB1	RIGHT FWD(RF) PB2	RIGHT BWD(RB) PB3
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
59	HARD STOP	0	0	0	0

Table 8.2

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*

8.3.3 Position encoder data

Position encoder pulse count for the position tracking:

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

Table 8.3

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 4.8.*

8.3.4 Commands to access the Analog sensor data

Command (HEX)	Data
60	**Battery voltage** Robot sends back 8 bit battery voltage value. To convert this value in to volts use the following conversion formula: Battery Voltage = ADC data x 0.069
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 (Centre)** 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
C1	**IR Proximity sensor (Left)** The Robot will return an 8 bit analog value of the IR Proximity sensor 1
C2	**IR Proximity sensor 2 (Centre)** The Robot will return an 8 bit analog value of the IR Proximity sensor 2
C3	**IR Proximity sensor 3 (Right)** The Robot will return an 8 bit analog value of the IR Proximity sensor 3

Table 8.4

8.3.5 Commands to turn on / off the buzzer

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

Table 8.5

8.3.6 Robot Version Signature

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

Table 8.6