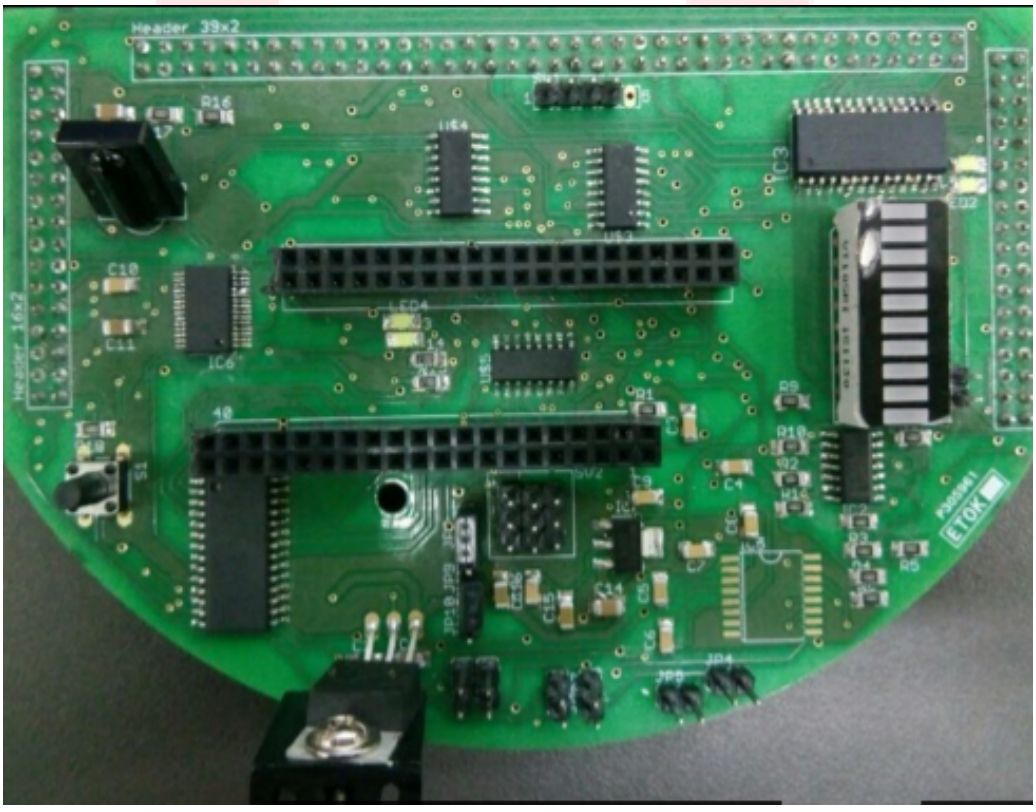
Fi-Pi

Adaptor Board for Firebird V Robot using Raspberry Pi 2

HARDWARE MANUAL



.

Documentation author

Milan Preet Singh
Tejaswini A

Mentors

Rutuja Ekatpure
Deepa Avudiappan

Contents

Chapter 1

1.1 Introduction

Currently Firebird V robot comes with ATMEGA2560, 8051, ARM7 adaptor board. Using a raspberry pi based adaptor board would add to the functionality of the robot. The idea is to integrate the features of Rpi to Firebird V robot.This would facilitate any on-board computations, image processing(Rpi supports PiCamera directly), the robot could even be used for IOT (Internet Of Things) applications. Because of the presence of an operating system, Rpi is a mini computer.Adaptor board for Firebird V would definitely be an advantage.

1.1.1 Components on the adaptor board

- MCP3008 (8 channel 10-bit ADC)
- MCP23017 Port expander IC
- Header pins for interfacing adaptor board with main board, raspberry pi and for the expansion socket.
- FT232 for USB communication
- MAX202 for RS232 communication
- LM324 quad comparator IC
- Bar Graph LED
- L7805 IC for powering Rpi
- LM1117 IC for powering servo motors
- Switches
- Jumpers
- Resistors,capacitors,diodes,LEDs

1.2 Main board pin details

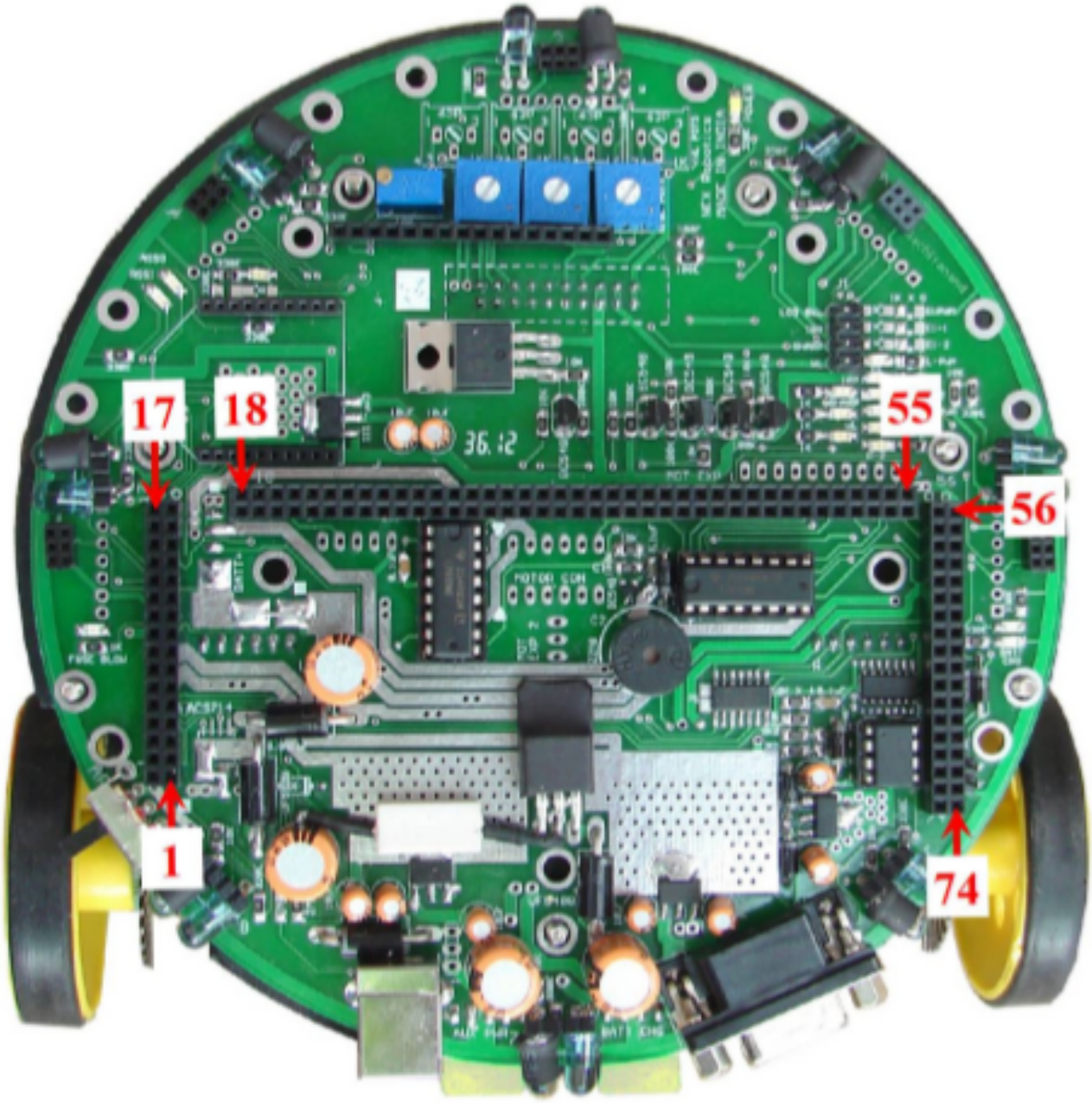


Figure 1.1: Firebird V - Main Board

Table 2.

Main board Pin No.	**Pin Name**	**Function**	connections on adaptor board
1.	CS	Current sense analog value	
2.	IR Proximity sensor 8	IR Proximity sensor 8 analog value	ADC1, Channel7
3.	Ground	Ground	ground

4.	USB Data+	USB connection going to the raspberry pi via FT232 USB to serial converter.To enable USB communication set jumper as shown.	Connected to USBDP of FT232.
5.	USB Data-	USB connection going to the raspberry pi via FT232 USB to serial converter.To enable USB communication set jumper as shown.	connected to USBDM of FT232.
6.	VUSB	Voltage source for FT232	Used for powering FT232.
7.	5V System	5V System Voltage. Can be used for powering up any digital device with current limit of 400mA.	Used in Battery voltage sensing circuit.
8.	5V Sensor	5V Sensor Voltage. Can be used for additional sensor interfacing with current limit 300mA.	
9.	5V Sensor	5V Sensor Voltage. Can be used for additional sensor interfacing with current limit 300mA.	
10.	5V System	5V System Voltage. Can be used for powering up any digital device with current limit of 400mA.	Used in Battery voltage sensing circuit.
11.	Sharp IR Range Sensor 1	Analog output of Sharp IR range Sensor 1	ADC2, Channel 0
12.	IR Proximity Sensor 1	Analog output of IR Proximity Sensor 1.	ADC1, Channel 0.
13.	XBee RXD	XBee wireless module serial data in	connected to raspberry pi TX via jumper 2.
14.	XBee TXD	XBee wireless module serial data out	connected to raspberry pi RX via jumper 3.
15.	Sharp IR Range Sensor 2	Analog output of Sharp IR range Sensor 2	ADC2, Channel 1
16.	IR Proximity Sensor 2	Analog output of IR Proximity Sensor 2	ADC1, Channel 1.
17A.	RSSI	To capture the RSSI signal	
17B.	Ultrasonic Trigger	To give trigger for Ultrasonic sensor	
18.	MOSI	not used	
19.	MISO	not used	
20.	SCK	not used	
21.	SSI	not used	
22.	RS	LCD Register select pin(Command)	connected to GPIO 21 of raspberry pi
23.	RW	LCD Write pin(Command)	Ground
24.	EN	LCD Enable pin(Command)	connected to GPIO 26 of raspberry pi

25.	DB5	LCD Data bit 5	connected to GPIO 19 of raspberry pi
26.	DB4	LCD Data bit 4	connected to GPIO 13 of raspberry pi
27.	DB5	LCD Data bit 6	connected to GPIO 6 of raspberry pi
28.	DB5	LCD Data bit 7	connected to GPIO 5 of raspberry pi
29.	V Battery System	9-12V unregulated power supply for additional module interfacing.	connected to input pin of L7805 for powering Rpi.
30.	White Line sensor 1	Analog output of White Line sensor 1	ADC2, Channel 5
31.	White Line sensor 2	Analog output of White Line sensor 2	ADC2, Channel 6
32.	White Line sensor 3	Analog output of White Line sensor 3	ADC2,Channel 7
33.	Sharp IR Sensor 1 to 5 Disable	TTL or CMOS input.Disable IR range Sensor	GPB5, port expander 1.
34.	IR Proximity Sensor Disable	TTL or CMOS input.Disable IR range Sensor	GPB6, port expander 1
35.	5V System	5V System Voltage. Can be used for powering up any digital device with current limit of 400mA	
36.	White Line sensor 4	Analog output of White Line sensor 4	Can be connected externally to port expansion socket via jumpers.
37.	White Line sensor 5	Analog output of White Line sensor 5	Can be connected externally to port expansion socket via jumpers.
38.	White Line sensor 6	Analog output of White Line sensor 6	Can be connected externally to port expansion socket via jumpers.
39.	White Line sensor 7	Analog output of White Line sensor 7	Can be connected externally to port expansion socket via jumpers.
40.	White Line Sensor Disable	TTL or CMOS input.Disable White Line Sensor	GPB7, port expander 1
41.	Sharp IR Range Sensor 3	Analog output of Sharp IR range Sensor 3	ADC2, Channel2
42.	IR Proximity Sensor 3	Analog output of IR Proximity Sensor 3.	ADC1, Channel 2
43.	IR Proximity Sensor 4	Analog output of IR Proximity Sensor 4.	ADC1, Channel 3
44.	Sharp IR Range Sensor 4	Analog output of Sharp IR range Sensor 4	ADC2, Channel 3
45.	Sharp IR Range Sensor 5	Analog output of Sharp IR range Sensor 5	ADC2, Channel 4

46.	IR Proximity Sensor 5	Analog output of IR Proximity Sensor 5.	ADC1, Channel 4
47.	C1 1	Logic input 1 for C1 Motor Drive	not connected
48.	C1 PWM	PWM input for C1 Motor Drive	not connected
49.	C1 2	Logic input 2 for C1 Motor Drive	not connected
50.	PWML	PWM input for Left Motor Drive	GPA5, port expander 1
51.	L1	Logic input 1 for Left Motor Drive	GPA4, port expander 1
52.	L2	Logic input 2 for Left Motor Drive	GPA3, port expander 1
53.	R1	Logic input 1 for Right Motor Drive	GPA2, port expander 1
54.	PWMR	PWM input for Right Motor Drive	GPA1, port expander 1
55.	R2	Logic input 2 for Right Motor Drive	GPA1, port expander 1
56.		Not Used	
57.		Not Used	
58.		Not Used	
59.		Not Used	
61.		Not Used	
62.	Position Encoder Left	Output of Left Position Encoder (0-5V)	raspberry pi GPIO 17
63.	Position Encoder Right	Output of Right Position Encoder (0-5V)	raspberry pi GPIO 27
64.	Position Encoder C2	Output of C2 Position Encoder (0-5V)	not used
65.	Position Encoder C1	Output of C1 Position Encoder (0-5V)	not used
66.	C2 2	Logic input 2 for C2 Motor Drive	not used
67.	C2 1	Logic input 1 for C2 Motor Drive	not used
68.	C2 PWM	PWM input for C2 Motor Drive	not used
69.	IR Proximity Sensor 6	Analog output of IR Proximity Sensor 6.	ADC1, Channel 5
70.	IR Proximity Sensor 7	Analog output of IR Proximity Sensor 7.	ADC1, Channel 6
71.	Buzzer	Input, V¿0.65V turns on the buzzer	raspberry pi GPIO 4
72.	DAC OUT	Not Connected	
73.	RS232 TXD	RS232 Transmit, connected to DB9 serial connector on main board	Connected to MAX202

1.3 Adaptor board parts

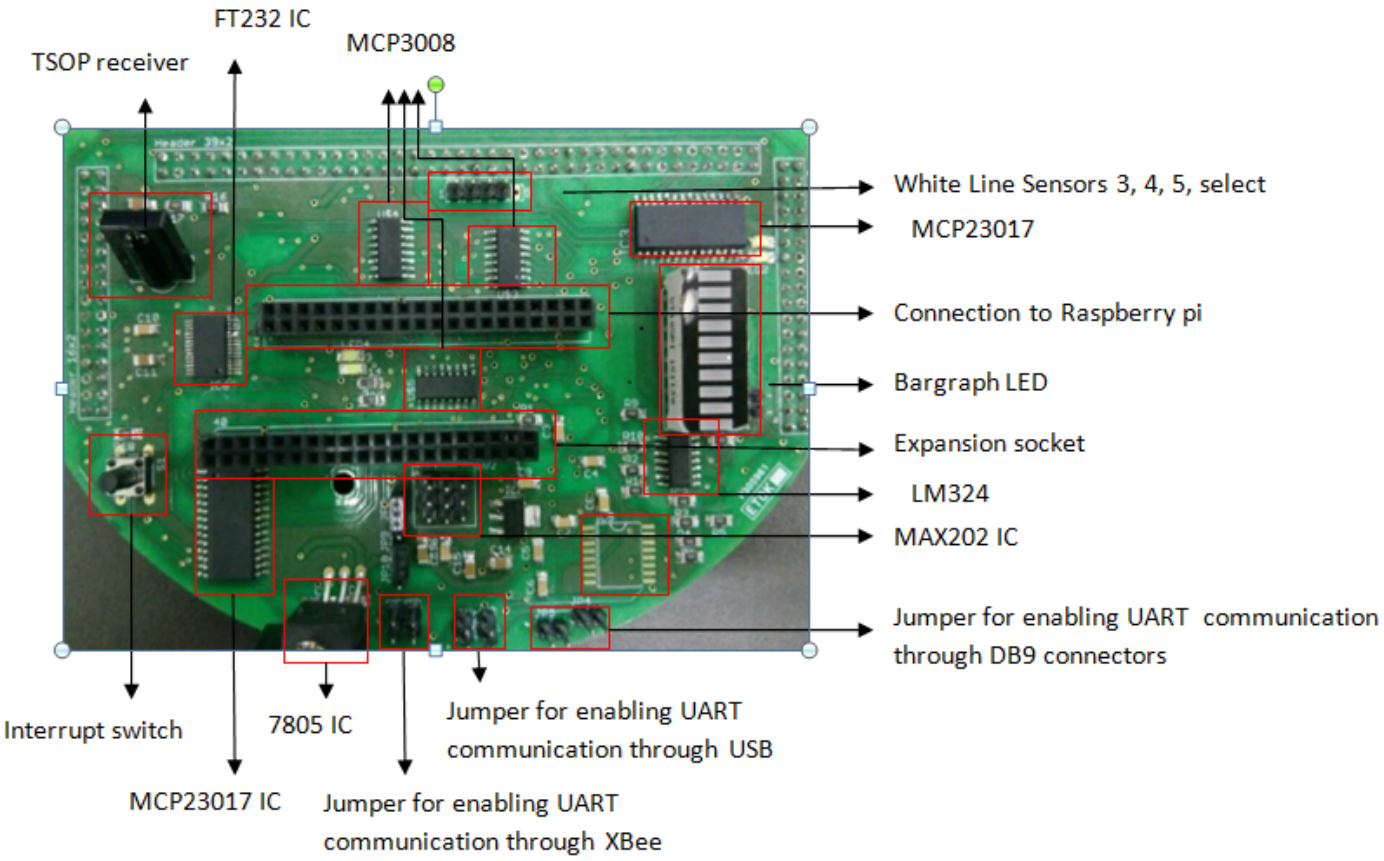


Figure 1.2: Adaptor board

1.4 Powering Raspberry Pi

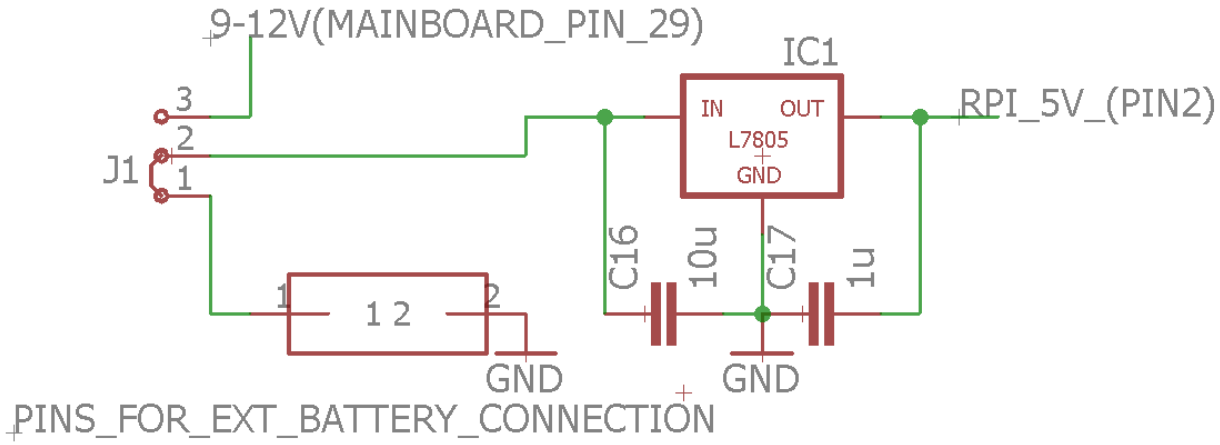


Figure 1.3: Powering raspberry pi

- Raspberry pi needs a constant 5v and more than 1A power supply. L7805 voltage regulator is used to serve this purpose.
- The battery voltage of Firebird V robot is directly obtained by using pin 29 of main board.
- The output of 29th pin on the main board is in the range of 9-12v. Either this or any external battery can be used as an input for the 7805 IC. The selection between the two is facilitated by a jumper.
- The output of 7805 is the regulated 5v output, which is given to 5v pin of raspberry pi.
- Two header pins are provided for the connection with external battery.

1.5 Battery voltage indication

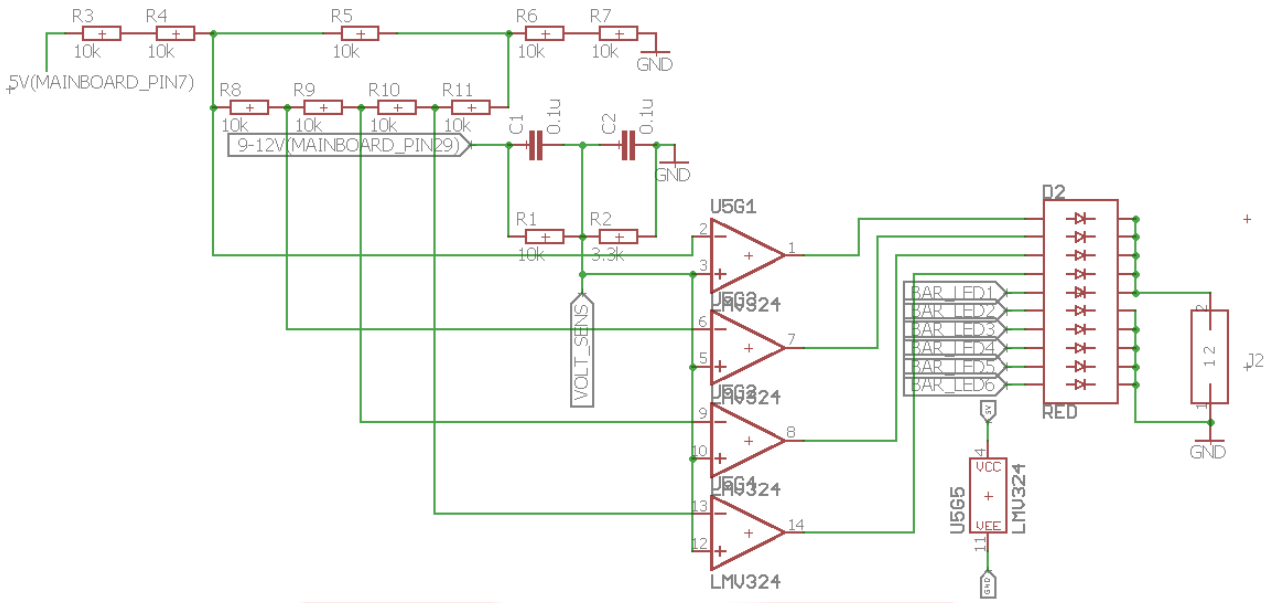


Figure 1.4: voltage sensing circuit

- The battery voltage of the Firebird V robot can be detected by the battery voltage sensing circuit.
- It could be sensed either by connecting the volt_sens pin to ADC and reading its value or by seeing the indications from the bottom 5 LEDs of bargraph LEDs
- First of all, the 9-12v output from mainboard pin 29 is mapped to value less than 5V by using the voltage divider circuit.This circuit apprx divides the voltage by 4 and henceforth mapping 12V to 3V, 11V to 2.75V, 10V to 2.5V and 9V to 2.25V.This output is given to all 4 input+ pins of the quad comparator IC LM324.
- The input for input- pins are given as 3V, 2.75V, 2.5V, 2.25V resp by the simple circuit as given above.
- So, whenever voltage is greater than 12V all the bottom 5 LEDs glow, when greater than 11V and less than 12V bottom 4 LEDs glow, when greater than 10V and less than 11V bottom 3 LEDs glow and when greater than 9V and less than 10V bottom 2 LEDs glow.
- In order to see the battery status, jumper J8 has to be inserted into the two header pins provided at the right of the bargraph LED.

1.6 Buzzer interface

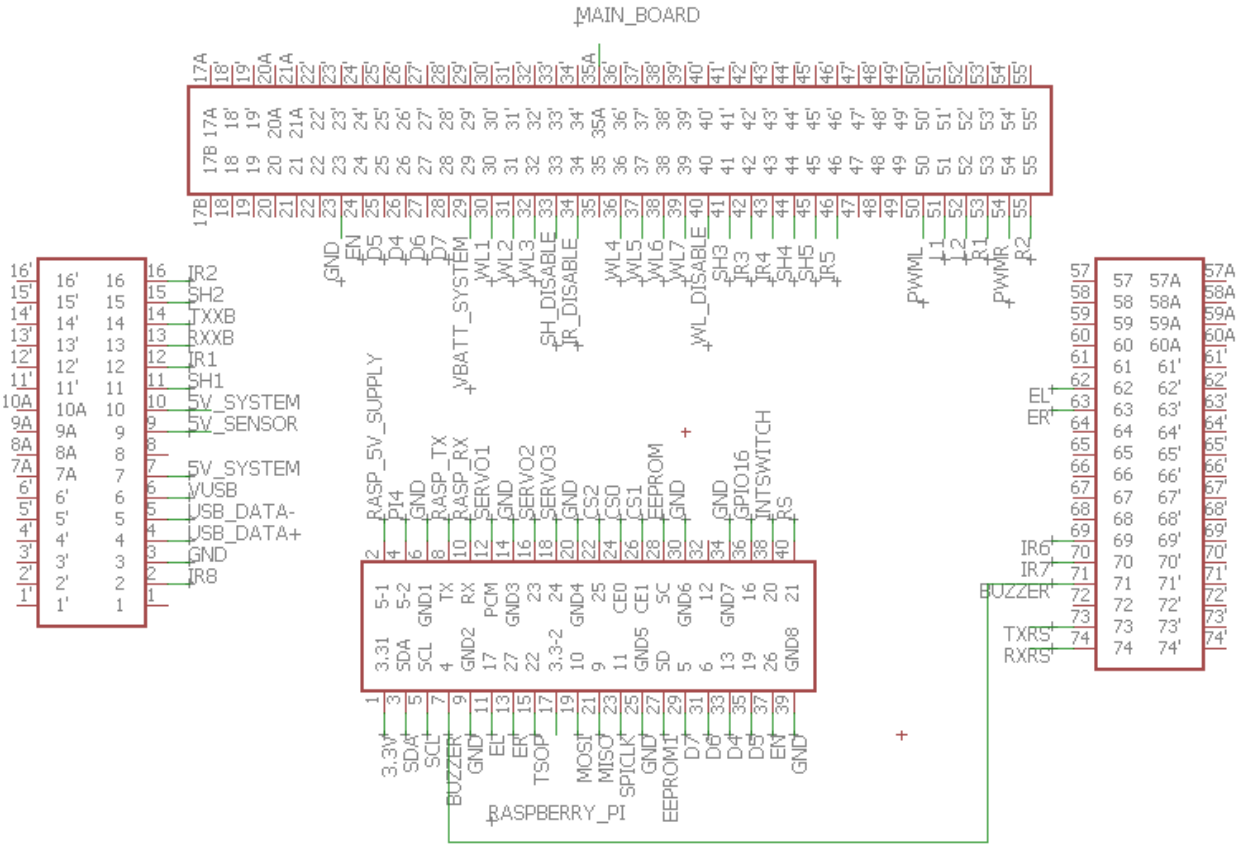


Figure 1.5: Buzzer interface

- Input for buzzer is available at pin 71 of main board.
- This input is given to GPIO pin 4 of raspberry pi.
- In order to program it, this pin should be used.

1.7 LCD interface

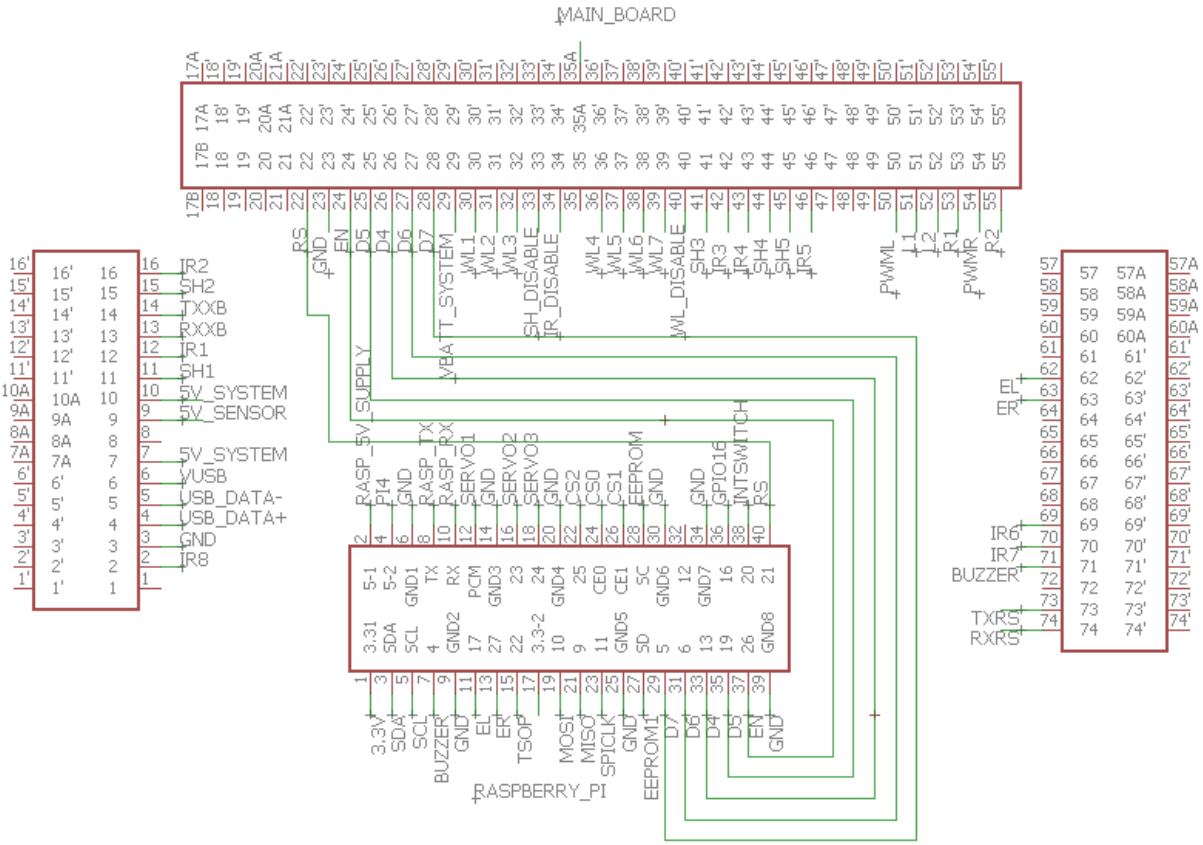


Figure 1.6: LCD interface

- LCD pins RS, EN, DB5, DB4, DB6 and DB7 are available on pins 22, 24, 25, 26, 27 and 28 resp. on the mainboard.
- These are give to pins 21, 26, 19, 13, 6 and 5 GPIO pins of raspberry pi resp.
- The RW pin of LCD is grounded.
- In order to program the LCD, these pins should be used.

1.8 Sensors and ADC interface

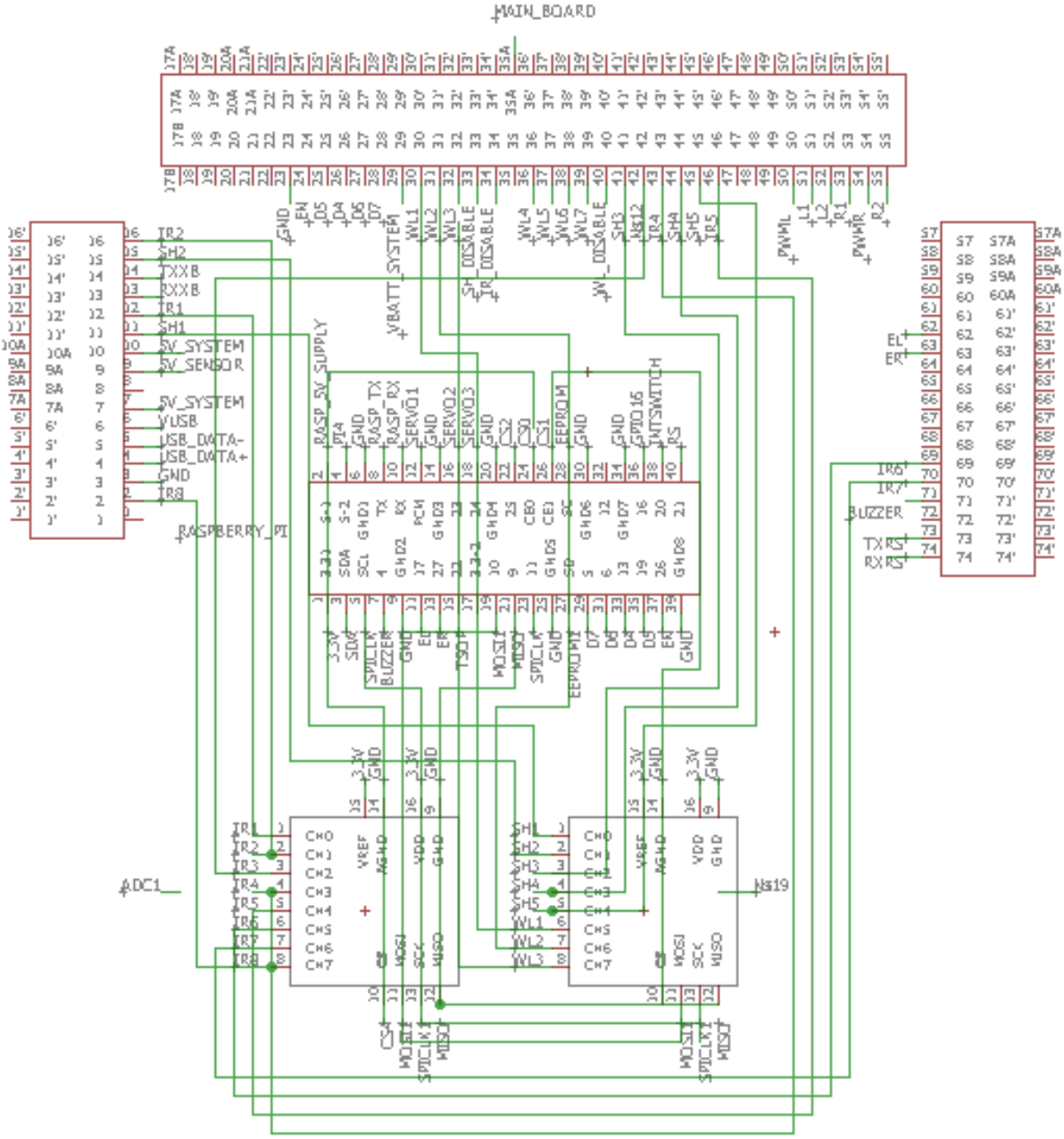


Figure 1.7: Sensors and ADC interface

- Sensors values are read by raspberry pi via external ADC. Raspberry pi communicates to ADC MCP3008 with SPI communication protocol.
- The communication between raspberry pi and MCP3008 happens with 3 lines, which are MISO, MOSI and SCLK.These pins are common to all 3 ADCs. The appropriate device is chosen by its chip select pin which is unique for every device.
- The chip select pin of ADC1 and ADC2 are given to CE0 and CE1 pins of raspberry pi resp.

- There are 3 MCP3008 ADCs on adaptor board. Any external sensor can be connected to ADC3, the pins of which are available on the adaptor board expansion socket.The chip select CS2 for this ADC is given by GPIO 15 of raspberry pi.
- All the 8 IR proximity sensors are connected to ADC1, White line sensors and sharp IR sensors are given to ADC2.

Table 2.

No.	**Sensor**	**ADC Name**	**Channel No.**
1.	IR Proximity sensor 1	ADC1	Channel 0
2.	IR Proximity sensor 2	ADC1	Channel 1
3.	IR Proximity sensor 3	ADC1	Channel 2
4.	IR Proximity sensor 4	ADC1	Channel 3
5.	IR Proximity sensor 5	ADC1	Channel 4
6.	IR Proximity sensor 6	ADC1	Channel 5
7.	IR Proximity sensor 7	ADC1	Channel 6
8.	IR Proximity sensor 8	ADC1	Channel 7
9.	Sharp IR sensor 1	ADC2	Channel 0
10.	Sharp IR sensor 2	ADC2	Channel 1
11.	Sharp IR sensor 3	ADC2	Channel 2
12.	Sharp IR sensor 4	ADC2	Channel 3
13.	Sharp IR sensor 5	ADC2	Channel 4
14.	White Line sensor 1	ADC2	Channel 5
15.	White Line sensor 2	ADC2	Channel 6
16.	White Line sensor 3	ADC2	Channel 7

1.9 Motors and wheel encoders interface

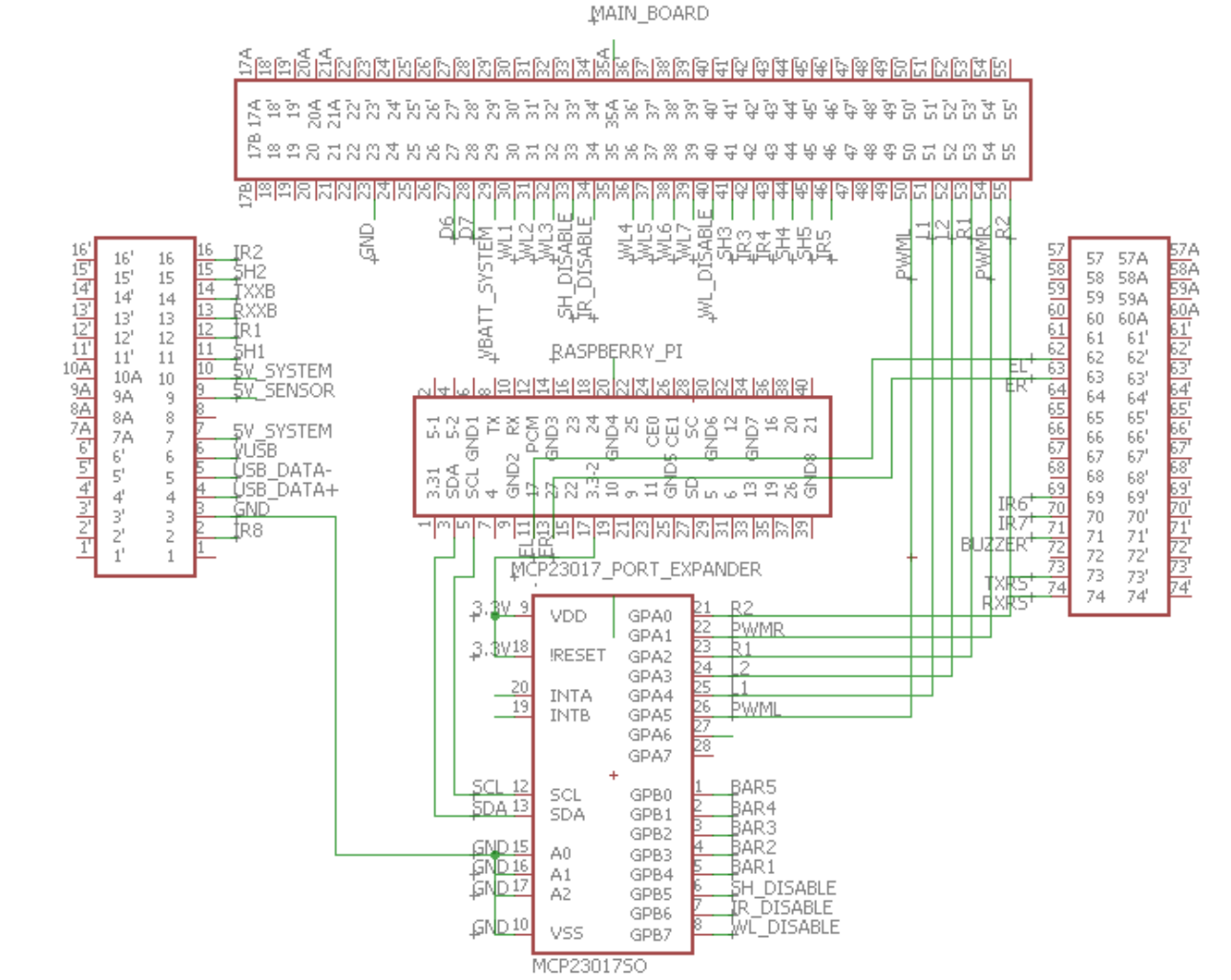


Figure 1.8: Motors and wheel encoders interface

- Left motor control pins(L1,L2), Right motor control pins(R1,R2)and PWM motor control pins(PWMl, PWMR) are available on pins 51, 52, 53, 55, 50 and 54 pins of main board resp.
- The above mentioned pins are connected to MCP23017 Port expander 1 with I2C communication.This would facilitate the usage of more GPIO pins since raspberry pi doesn't have many(27 GPIOs available).
- The GPIO pins of port expander 2 is given to the adaptor board expansion socket.
- Data and clk signals flow through SDA and SCL lines resp between Raspberry pi and MCP23017 port expander.These lines are common for both the port expanders.
- The address of this Port expander as shown in fig.7 is 20 (000) and that of 2nd is 21 (001) which is specified by voltage levels at A0, A1, A2 pins resp.
- R2, PWMR, R1, L2, L1 and PWML pins are available on GPA0, GPA1, GPA2, GPA3, GPA4, GPA5 and GPA6 resp. of the Port expander.

- The Left and Right wheel encoders are connected to the GPIO 17 and 27 pins of raspberry pi.

1.10 Powering servo motors and Servo pod connections

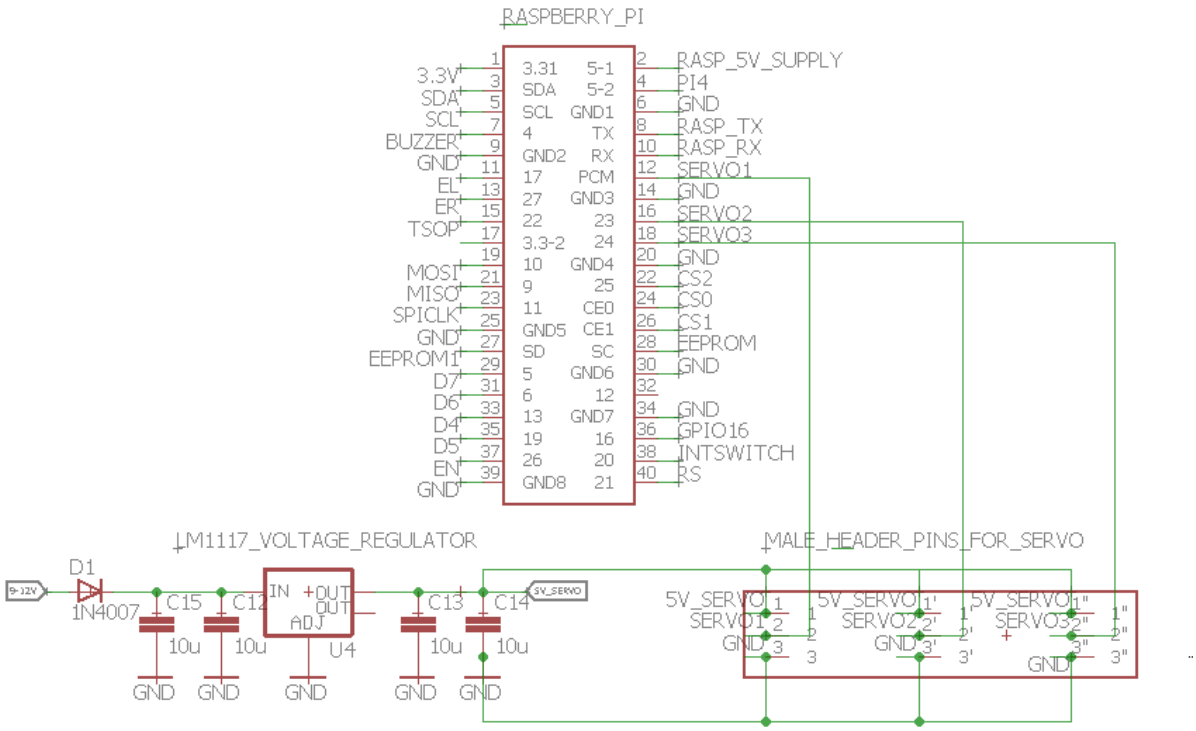


Figure 1.9: Powering servo motors and Servo pod connections

- Servo motors need 5V and more than 500mA current to run efficiently. In order to meet these requirements, the +ve of servo motors is given to the output of LM1117 Voltage regulator IC. The input to which is given by 9-12V (pin 29) from main board.
- A set of 9 male header pins are given on the Adaptor board for interfacing upto 3 servo motors.
- Three of which are for Vcc (5V), three for ground and three for controlling th motion of servo motors 1,2 and 3 resp.
- The servo motor control pins are given to GPIO 5, 23 and 24 pins of raspberry pi resp.

1.11 Interrupt switch and controlling bargraph leds

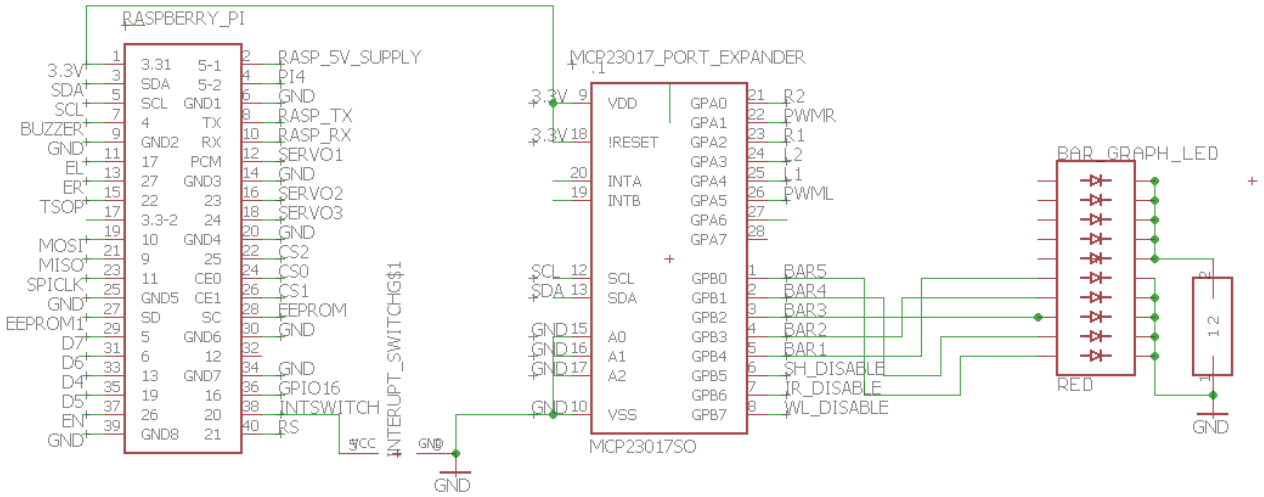


Figure 1.10: Interrupt switch and controlling bargraph leds

- Sudden power cut to raspberry pi may lead to spoiling of the Raspbian OS. Hence, whenever the interrupt switch is pressed on the adaptor board, a python script could be written such that the raspberry pi shuts down systematically.
- The bottom 5 LEDs of bargraph LED can be controlled by the GPB0, GPB1, GPB2, GPB3 and GPB4 pins of MCP23017 port Expander.

1.12 TSOP1738 RC5 IR receiver and decoder

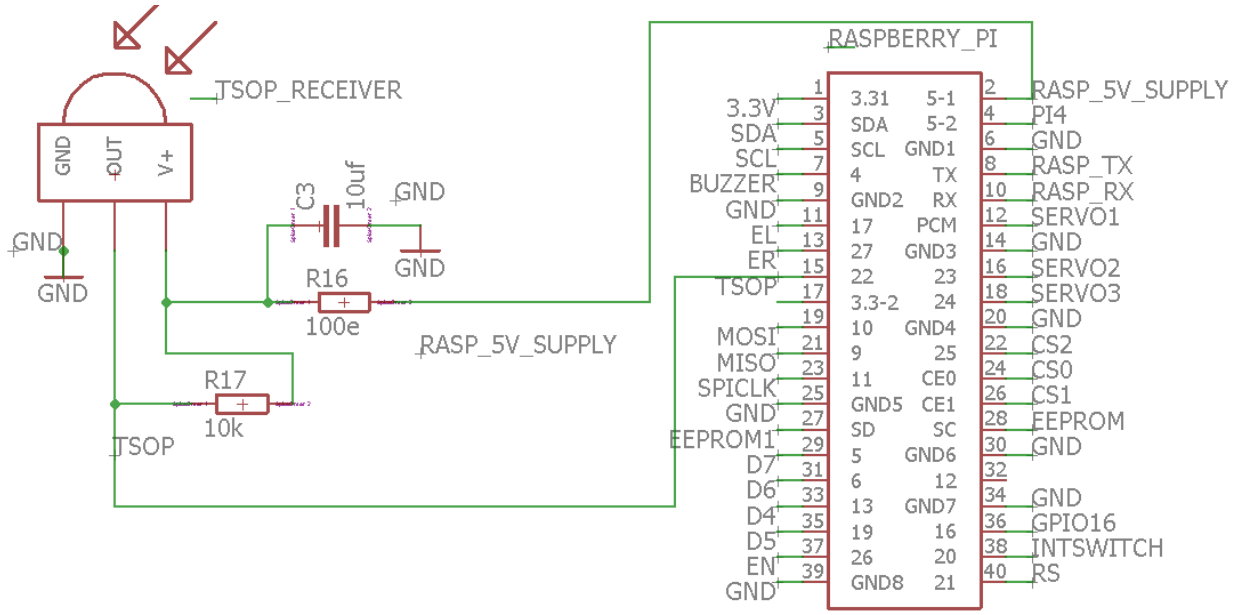


Figure 1.11: TSOP1738 RC5 IR receiver and decoder

- The Firebird V robot can run according to the commands of TV remote, by decoding the IR signals which it receives from the TSOP receiver.
- It has Vcc(3.3V), ground and the output pin, which is connected to GPIO 22 pin rsapberry pi.
- By decoding the data obtained from the IR signals of TV remote, the robot could run accordingly.

1.13 UART communication with Raspberry Pi

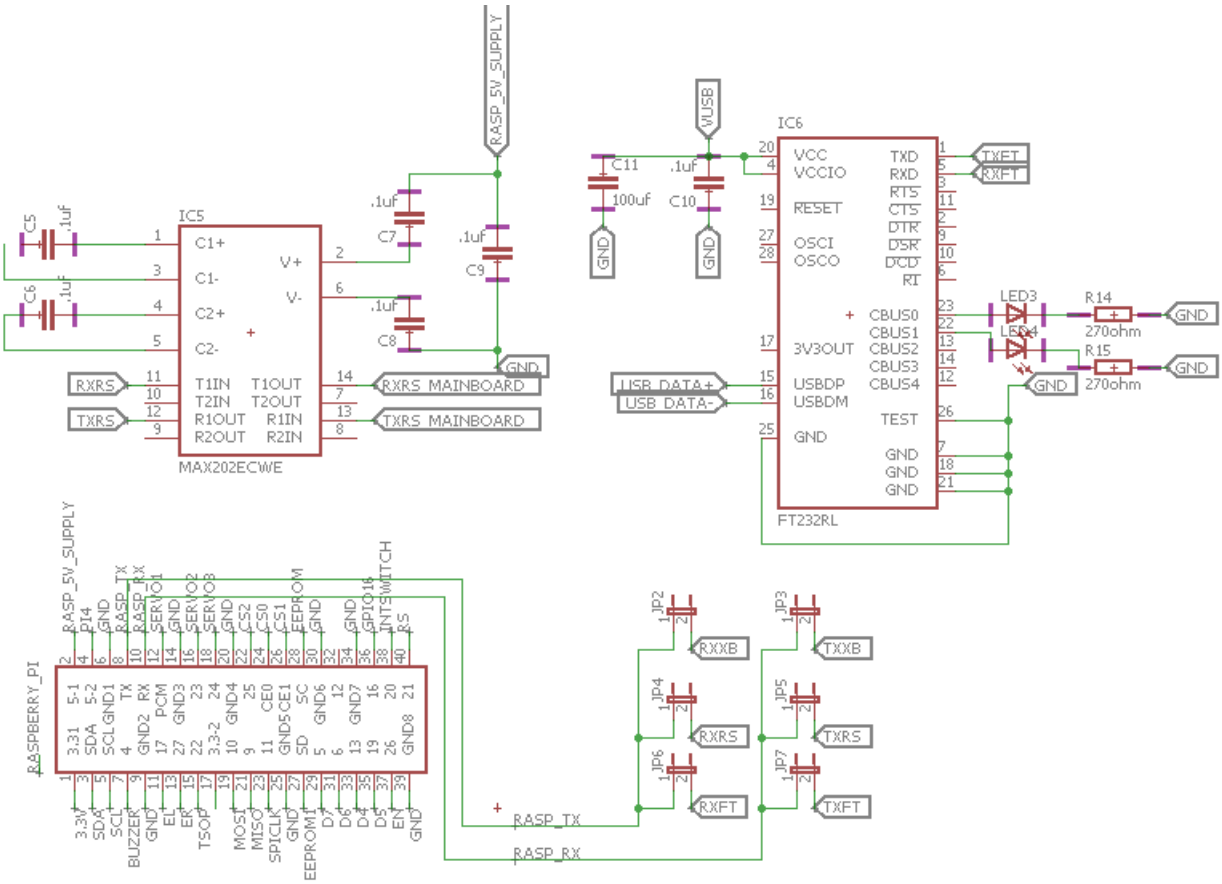


Figure 1.12: UART communication with Raspberry Pi

- Raspberry Pi has only 1 set RX-TX pins for UART communication.
- But, Firebird V robot has 3 modes of serial communication which are through DB9 connectors, USB cable and through XBee.
- In order to use these 3 modes, 3 pairs of jumpers J2-J3, J4-J5 and J6-J7 are provided for completing the TX-RX circuit of XBee, DB connector and USB cable with the TX and RX pins of raspberry pi resp.
- FT232 USB to serial converter is used for UART communication via USB cable.
- TTL to RS232 converter is used for the UART serial communication with DB9 connectors.
- USB+ and USB- pins are available on pins 4 and 5 of main board resp.
- RS232 TXD and RXD are available on pins 73 and 74 of main board resp.
- XBee TXD and RXD are available on pins 14 and 13 of main board resp.

1.14 Adaptor board expansion socket

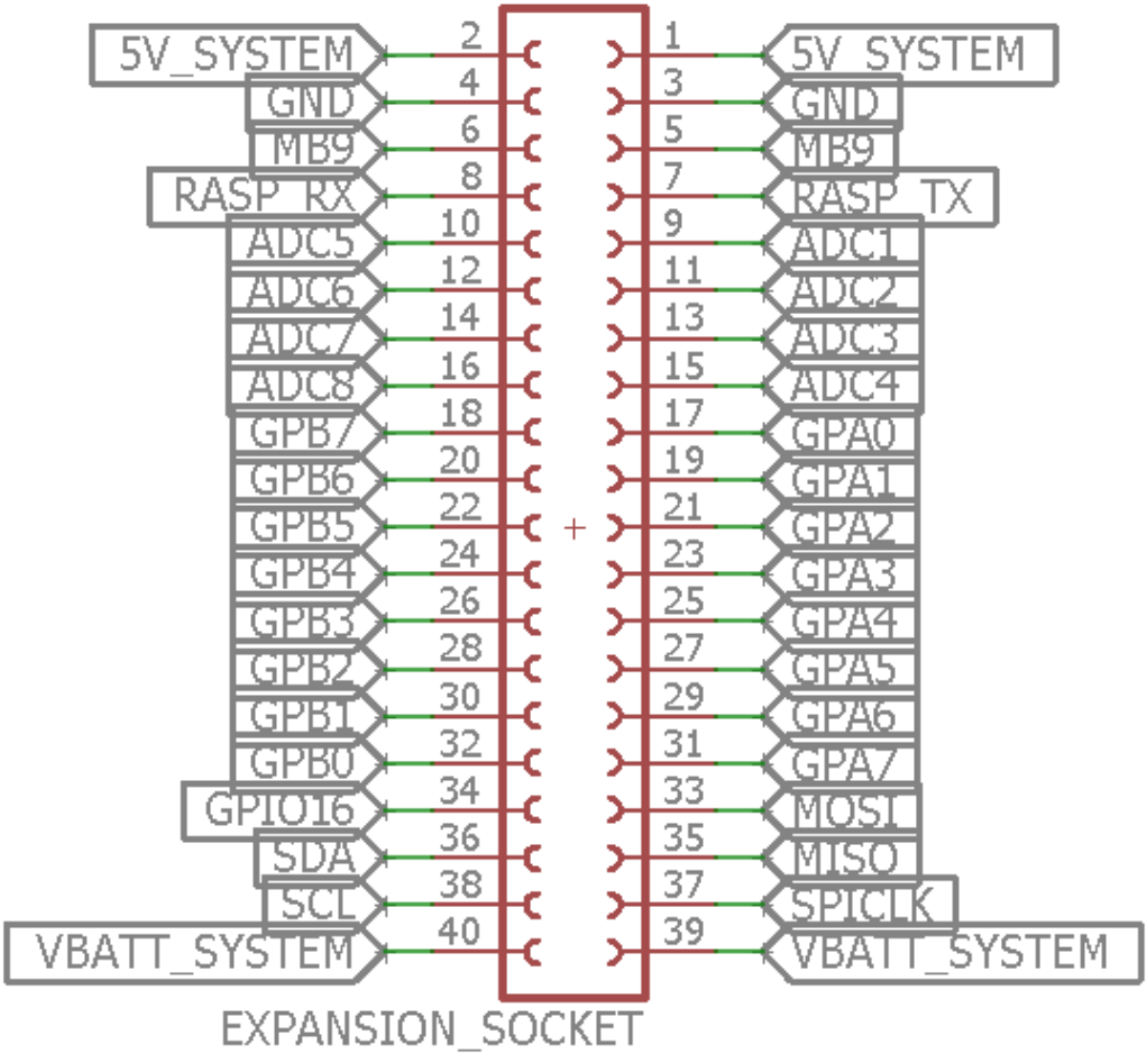


Figure 1.13: Adaptor board expansion socket

- If the attachment of other external sensors or any other device to the Firebird V robot is required, they could be connected to the Adaptor board expansion slot.
- The expansion slot has ADC channel pins, GPIOs connected to port expander, ground, 5V, 9V pins, TX-RX, SPI lines(MISO, MOSI, SPICLK) and I2C lines(SDA,SCL).
- With the help of these pins present on expansion socket, any device could be connected to the robot.

Table 3.

Pin No.	**Connected to**
1.	5V System
2.	5V System
3.	Ground
4.	Ground
5.	Main board pin 9
6.	Main board pin 9
7.	Raspberry pi TX
8.	Raspberry pi RX
9.	ADC3 Channel 0 (chipselect on Rpi GPIO 15)
10.	ADC3 Channel 1 (chipselect on Rpi GPIO 15)
11.	ADC3 Channel 2 (chipselect on Rpi GPIO 15)
12.	ADC3 Channel 3 (chipselect on Rpi GPIO 15)
13.	ADC3 Channel 4 (chipselect on Rpi GPIO 15)
14.	ADC3 Channel 5 (chipselect on Rpi GPIO 15)
15.	ADC3 Channel 6 (chipselect on Rpi GPIO 15)
16.	ADC3 Channel 7 (chipselect on Rpi GPIO 15)
17.	Port Expander 2, GPA0 (Device address 22)
18.	Port Expander 2, GPB7 (Device address 22)
19.	Port Expander 2, GPA1 (Device address 22)
20.	Port Expander 2, GPB6 (Device address 22)
21.	Port Expander 2, GPA2 (Device address 22)
22.	Port Expander 2, GPB5 (Device address 22)
23.	Port Expander 2, GPA3 (Device address 22)
24.	Port Expander 2, GPB4 (Device address 22)
25.	Port Expander 2, GPA4 (Device address 22)
26.	Port Expander 2, GPB3 (Device address 22)
27.	Port Expander 2, GPA5 (Device address 22)
28.	Port Expander 2, GPB2 (Device address 22)
29.	Port Expander 2, GPA6 (Device address 22)
30.	Port Expander 2, GPB1 (Device address 22)
31.	Port Expander 2, GPA7 (Device address 22)
32.	Port Expander 2, GPB0 (Device address 22)
33.	Rpi MOSI
34.	Rpi GPIO 16
35.	Rpi MISO
36.	Rpi SDA
37.	Rpi SPICLK
38.	Rpi SCL
39.	VBatt system
40.	VBatt system