San José State
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ABSTRACT:

The objective of this project is to design, build and test an autonomous mini-sumo robot, which will participate in Mini-Sumo Robot Competition at San Francisco. This robot project has three subsystems: electrical, software and mechanical. This report deals with the design approach, block diagram, schematic, theory of operations, specifications, cost, and procedure followed to make the mini sumo robot, which is successful.

INTRODUCTION:

Mini-sumo robot is an autonomous fighting robot to participate in the Mini-Sumo Robot Competition. Dallas Personal Robotics Group first started this competition. This group is one of the oldest special interest groups in the world devoted to personal and hobby robotics. This competition is intended to be a safe, enjoyable learning experience for amateur robotics enthusiasts. The competition typically pits two autonomous robots that fight head to head in an attempt to shove each other out of the playing field.

The focus of this project intended to be more towards embedded software and sensors, rather than mechanical. The robot's design specifications are per organizer's requirements. The design specifications of the robot are divided into the following mechanical and electrical subsystems: microcontroller, object and light sensors, and motor. The software is divided into seven different modules. The following section deals with the specifications of the components, testing, timeline, and costs involved to build a robot according to the chosen design.

DESIGN APPROACH:

As in any complex engineering project, this project is divided into several phases: research, basic design, parts acquisition, assembly, testing, debugging, documentation and demonstration.

Research is done to decide on the outcome of the project. This is also done to decide on what kinds of the hardware components and software tools are required, how they can be acquired, what are their costs, and if they are affordable or not. In the basic design phase internal and external appearance of the robot is designed. First the block diagram of the basic operation of the robot is drawn. With that block diagram schematic of electrical components as well as mechanical appearance is modeled. Pseudo-code for the robot is also designed during this phase. The robot is to be designed based upon the following organizers' specification.

The robot is autonomous and fits in a box 10cm by 10cm. However, there are no restrictions on height, type of control method, microprocessor or the amount of memory used. Weight including accessories of the robot, cannot not exceed 500 g (1.1 lb. or 17.63 oz.). The robot cannot move until five seconds after the contestant presses the robot's start button. It does not include any device that obstructs the control of the opponent's operation, such as a jamming device or strobe light; any parts that might damage or deface the ring surface; a device that emits any liquid, powder, or gas; an inflaming device; a throwing device; or any part that fixes the robot to the ring area. In addition to this, the program is written based upon the following offensive and defensive strategy. The offensive strategies are, the body of robot has two wedges, in front and another in the back, the motor will be bidirectional which can run in high speed but only after 5 second the power switch is turned on. The defensive strategies are, the robot with have the full 500 grams or weight nd it will move randomly inside the ring.

After this phase, in order to give the robot the physical form, required parts are acquired. With those acquired components the circuit is then assembled during assembly phase. During this phase, the whole circuit is divided into smaller subsection that can be tested individually. If those individual tests show optimum results, then that section is put together with the main part if the circuit, which is the microcontroller. After both the electrical and mechanical parts are connected with the microcontroller, whole circuit is again tested with the program in the microcontroller. If all of the above phases are successful then the project is ready for documentation and final demonstration.

PROCEDURE:

For the successful product the following procedure is followed. First several videos of previous competition were watched and analyzed. The clips are mainly helpful while writing the code for the robot.

After this first step was taken, the steps below were followed.

1) BLOCK DIAGRAM

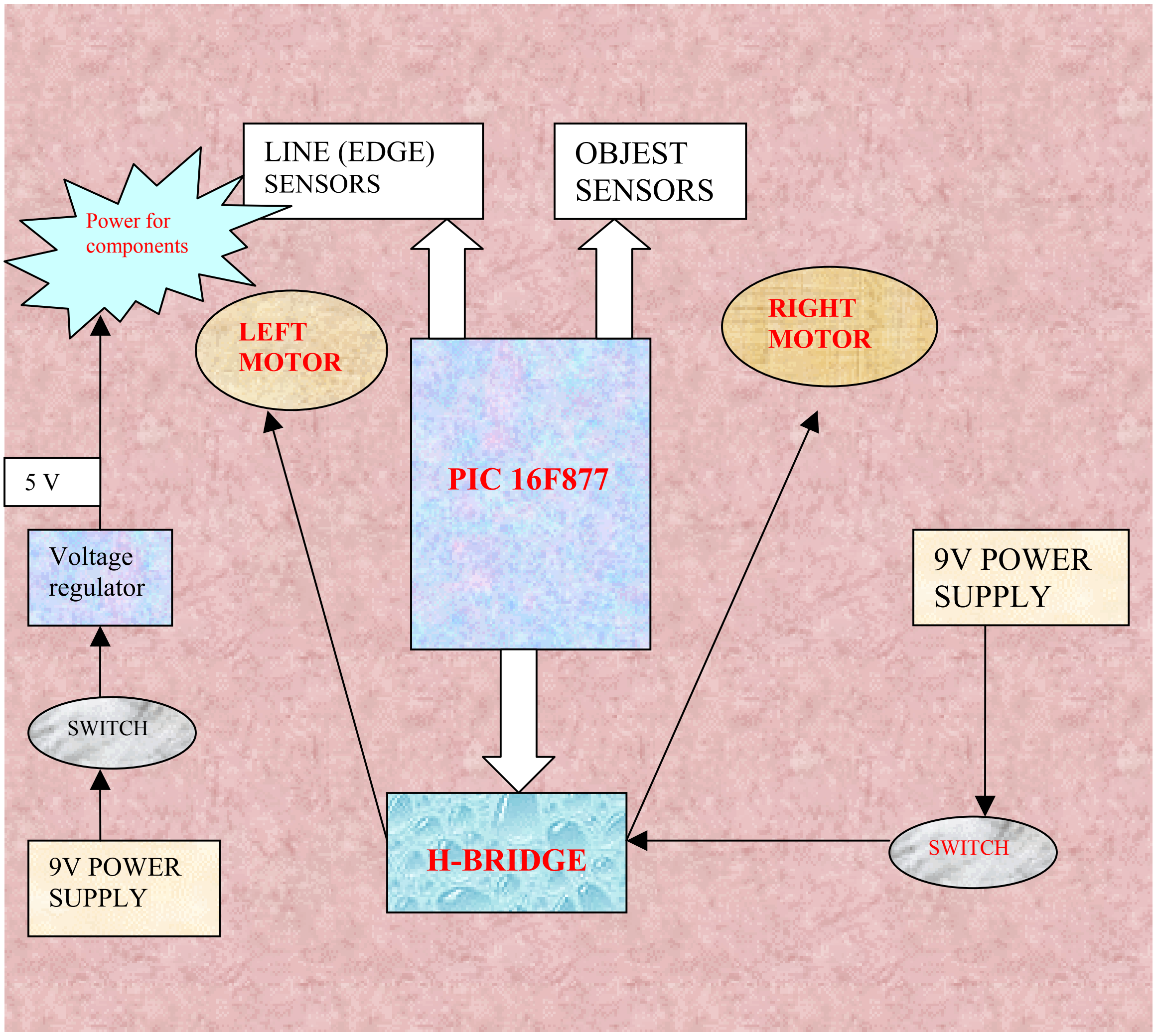

Figure1: Block Diagram of Mini-Sumo Robot

The mini-sumo robot is designed based upon the above block diagram. The main part of the body is the microcontroller. This microcontroller is the brain of the robot which executes the stored program based upon the voltage input coming from the object and line sensors. If the object sensors are active then the microcontroller signals the motor to move towards the object. If the line sensors are active then the microcontroller signals the motor to move away from the line by rotation in a certain angle.

2) SCHEMATIC :

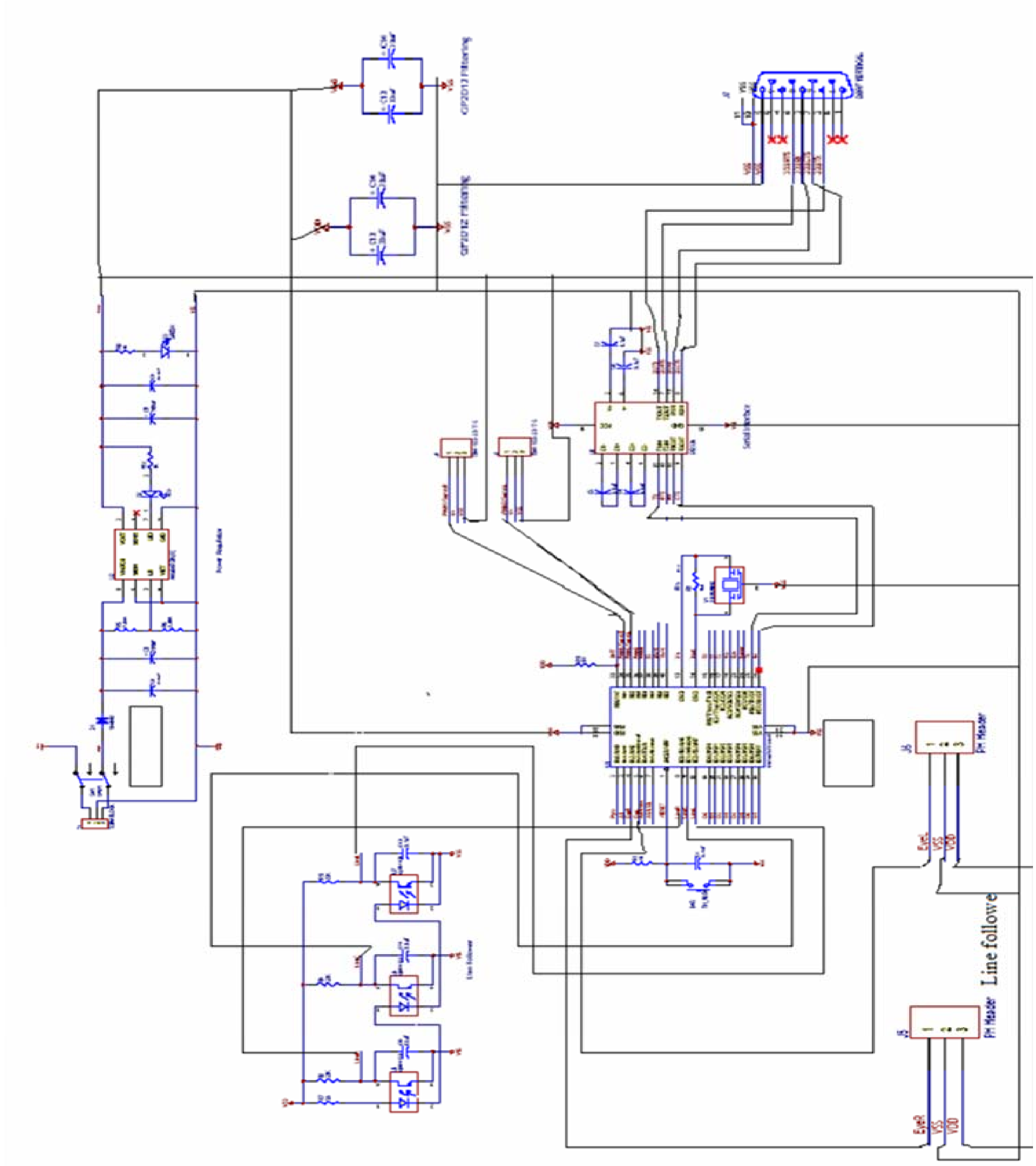

Figure 2: Schematic for Mini-Sumo Robot

3) DESIGN SPECIFICATIONS:

This is the main part which determines the success of the project. All the components in of the system run with 9V dc power supply. After a through research, the following integrated circuits were chosen for the reasons as described in the respective sections.

a. MICROCONTROLLER: PIC 16F877:

This sis 40 -pin 8-bit CMOS Flash microcontroller, which runs at 20MHz frequency. This microcontroller has interrupt capability up to 14 sources. The pin-out of this chip is compatible to the PIC16C73B/74B/76. The most important feature it is it consumes less power. This is very important feature because during the competition the robot has to run for long time which requires a lot of power. Low power consumption feature will help to save power during the competition.

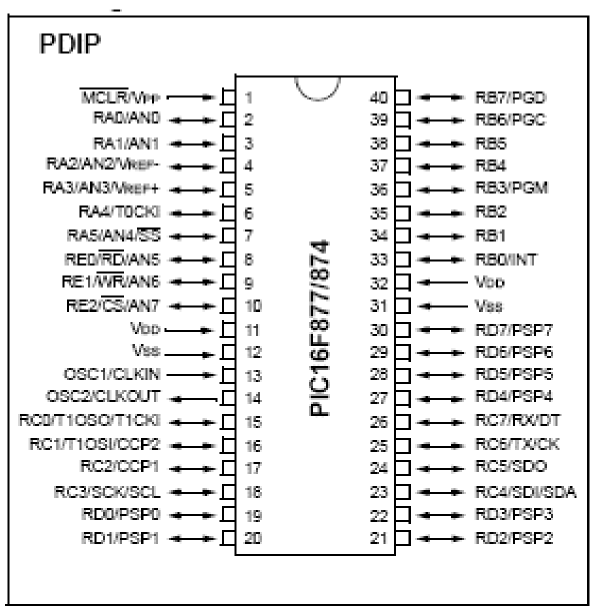

Figure 3: Microcontroller PIC 16F877

b. REFLECTIVE OBJECT SENSOR: QRB1133

This is the integrated circuit that makes the robot stay inside the ring during the competition. It mainly senses the white reflective object. There are three of reflective sensors in the circuit which are mounted in front of the robot behind the wheel shaped protuberance. This component was chosen because of the following appealing features.

- Phototransistor Output
- No contact surface sensing
- Unfocused for sensing diffused surfaces
- Compact Package
- Daylight filter on sensor

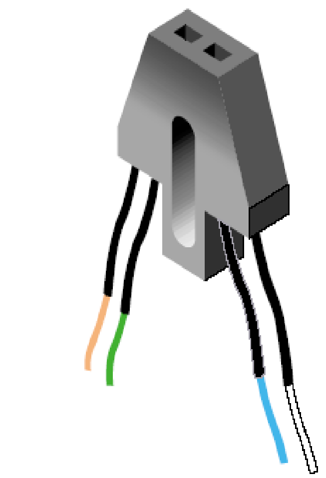

Figure 4: Line Sensor QRB 1133

c. DISTANCE MEASURING SENSORS: GP2D120

This component detects the distance of the opponent and makes the motor turn in that direction. This chip was chosen because of the following features.

- It detects the distance form 4 cm to 30cm. This is the most important feature because in order to win the sensor has to detect the opponent at least form 27 cm distance. The reason is the ring of the competition is 27cm in diameter and both the robots can wander anywhere within that circle.
- This chip has less influence on the color of reflective objects, reflectivity. This feature prevents the robot from mistakenly detect the opponent as the edge of the ring.
- Eternal control circuit is unnecessary, which helps to reduce the weight of the robot.

Figure 5: Object Sensor GP2D12

d. DC MOTORS X 2: MSYS-1717

This motor was chosen mainly because of its bidirectional feature. TThis is the most important feature for the victory. This is because the bidirectional nature helps to attack the opponent form both sides. In other words, even if the opponent attacks from the back the robot will be able to defend. Another appealing feature is its plastic body, which will help to maintain the maximum weight of the robot (according to the organizer's specification).

4) MECHANICAL DESIGN:

Overview:

The body of the robot is square shaped with two wedged shaped protuberance on front and back of the robot, which is about 10cm wide and 10 cm long and 5cm high. The circuit board is implemented in the middle of the square. Going back to the 5cm high wheel end, we note that there are be two DC motors controlling each wheel, where the motors again will be controlled by the micro propeller. The wedge shaped geometry was selected because we have the option of flipping the opponent, plus it gives the electronics better protection, given its dimensions. Furthermore it makes the attacker have a hard time damaging the interior. The wedged shape geometry allows quick maneuverability, and stability which is desirable for robotics competition.

5) PROGRAMMING:

Programming is the main part of the system because it is the section which gives life to the robot. The software section of the robot is divided into seven modules that define:

i. the main function of the robot,
ii. the common routines and variables,

iii. the finite- machine that runs the robot,

iv. the routines to decode the output of the object sensors,

v. the routine to decode the output of the reflective object sensors,

vi. a menu-driven debug and test facility over the serial port, and

vii. the module interface with the voltage regulator.

Based upon the above modules software the code is written in assembly language. They are then converted into the hex file. This hex file is loaded into the chip through the serial cable with the help of RS232Chip (Dual RS232 transmitter/ receiver for serial interface)

. With all of the above specification the finished product is as shown in the figure below.

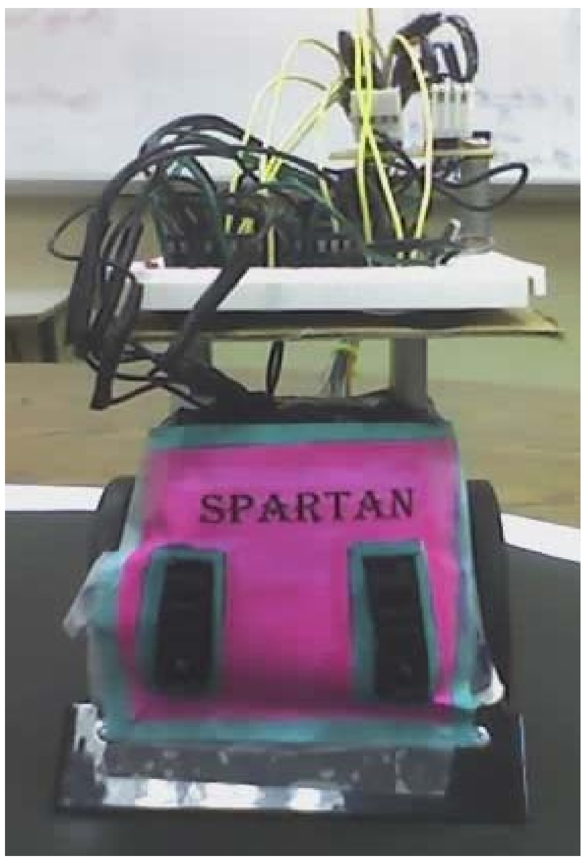

Figure 6: Complete Spartan Mini-Sumo Robot

PROBLEMS AND SOLUTIONS:

In this section predicted problems in the design process is analyzed. The following table shows the problems occurred while building the robot as well as applied and possible solutions.

Predicted Problems	Applied	to be Applied Solutions
Integration of components	Identified specifications: What load each component must drive Amount of voltage each needs Power Limitations What current it can operate with	
Writing the software code	Worked closely with the students in Computer Science Department who has knowledge about the assembly language	
Making the robot size 500gm		The circuit board has to be made on PCB
Making the line sensor detect the line fast enough when the robot is moving with high speed		Use the fast detecting line sensors

Table 1: Problems and Solutions

CHANGES FROM PREVIOUS DESIGN:

In the course of designing, three major changes are made from the original design. First, the microcontroller was changed from PIC 16F876 to PIC 16F877. The main reason is the ability to handle more sources. PIC 16F877 has 40 pins compared to 28 pins in PIC 16F876. This microcontroller is chosen basically for the future improvements such as to adding two object sensors each on all four sides of the robot (currently, there are only two object sensors at front), three more line sensors in the back of the robot in addition to the existing three line sensors at front, and making the robot four wheeler instead of two wheeler for better stability. Second, the line sensors are also changed from QRD1114 to QRB1133. QRB1133 (figure 7) has more flexible shape than the QRD1114 (figure 8). In order to mount the QRD1114 one has to decide well in advance where and how high from the ground it should be placed in the robot; however, QRB1133 has a middle elongated groove with an adjustable screw, which makes the mounting very easy and flexible. In addition QRB1133 sensor senses the line 0.125 mils ahead of the QRD 1113.

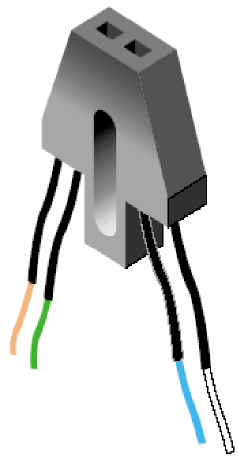

Figure 7: Line Sensor QRB1133

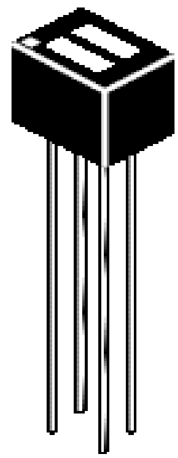

Figure 8: Line Sensor QRD 1114

Third, the voltage regulator from LM2940 (Figure 9) to MAX667 (Figure 10) is changed because of MAX667 has the pins which allows user to test it operation by connecting the LED. This is also easy to mount on the board because of the it's rectangular chip shape.

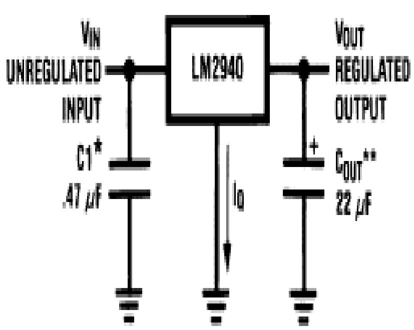

Figure 9: LM 2940

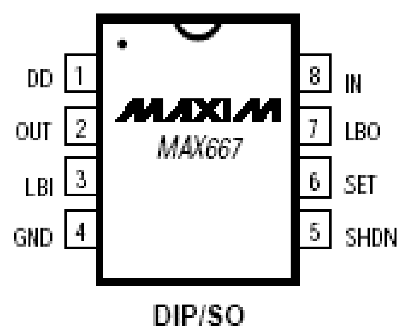

Figure 10: MAX 667

DATA:

Data are mainly collected from the two types of sensors, object sensors and line sensors, which are connected with the microcontroller. The data are mainly the voltage output versus distance. Figure 11 shows the expected curve of analog voltage output of the GD2D12 sensor with respect to object distance in cm. Figure 12 shows the measured voltage output of the same sensor. Similarly, Figure 13 shows the expected voltage output of the light sensor QRB1133 with respect to the distance in mills and figure 14 measured voltage output. The results of this data collection are very close to the expected ones as depicted by the corresponding curves.

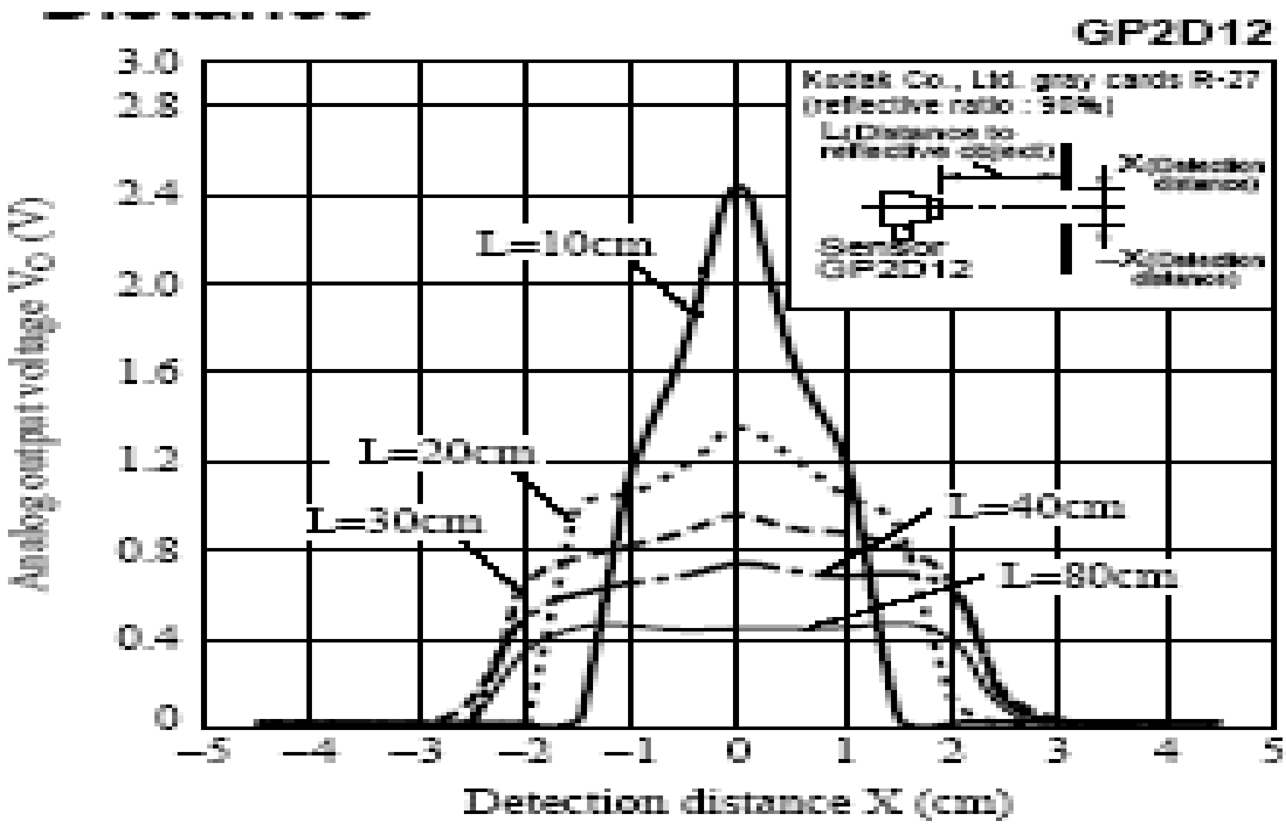

Figure 11: Distance Vs Output voltage for GP2D12 (datasheet)

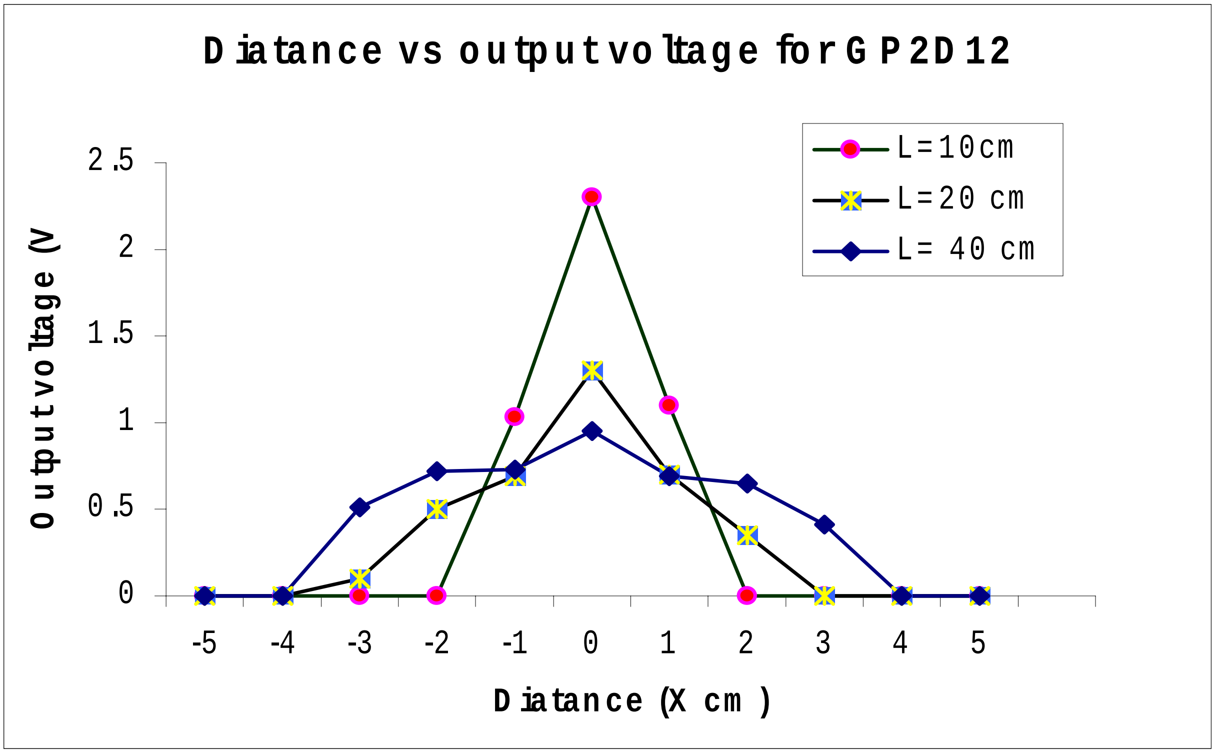

Figure 12: Distance Vs Output voltage for GP2D12 (measured)

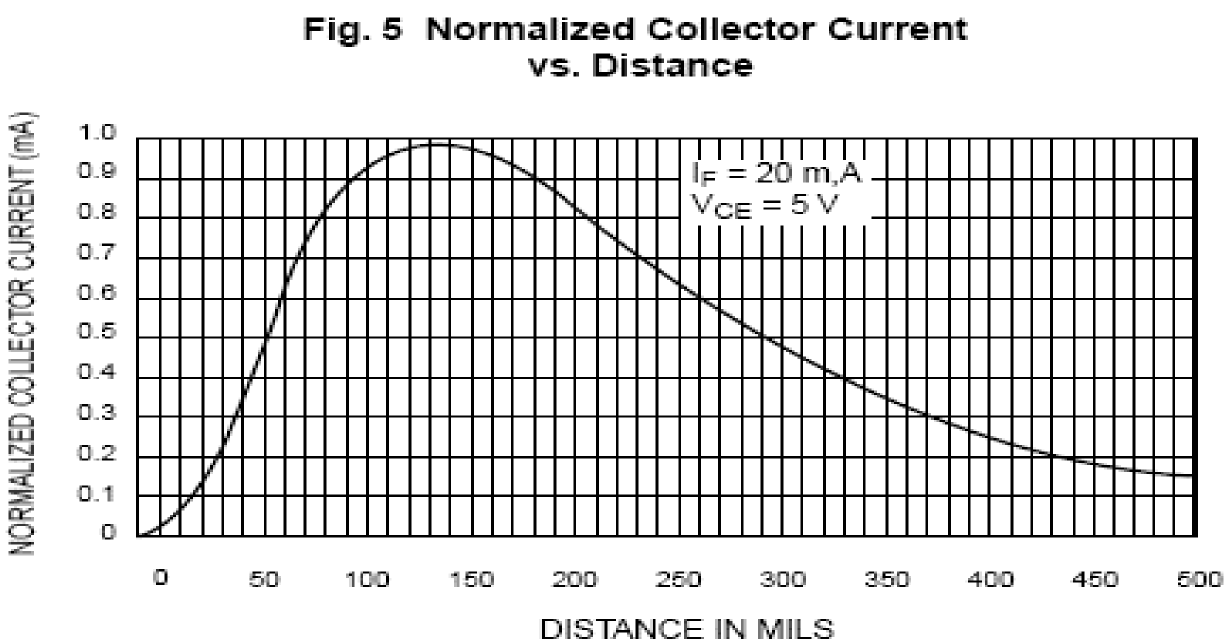

Figure 13: Current Vs Distance (mm) for QRB1133 (Datasheet)

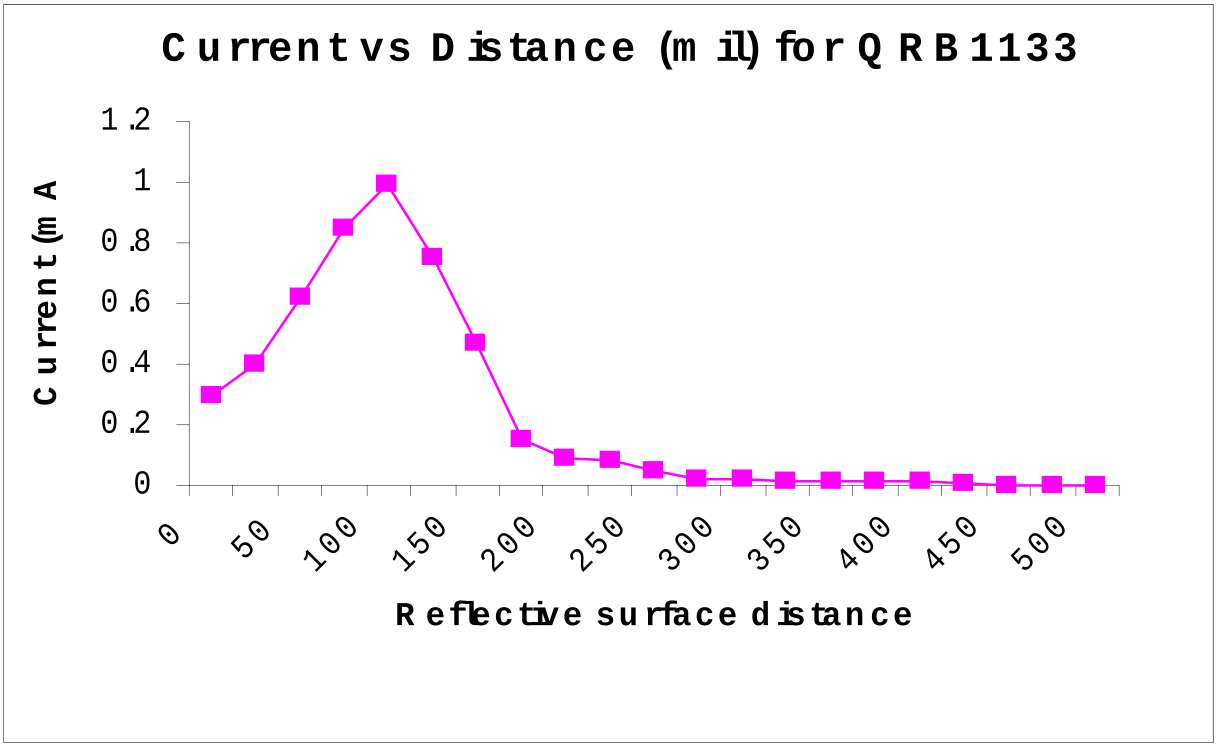

Figure 13: Current Vs Distance (mm) for QRB1133 (measured)

Total weight of the robot = 725 grams

Size of the robot = 9.8cm X 10cm X 17cm

TIMELINE:

The following timeline is follower for the production of a successful robot.

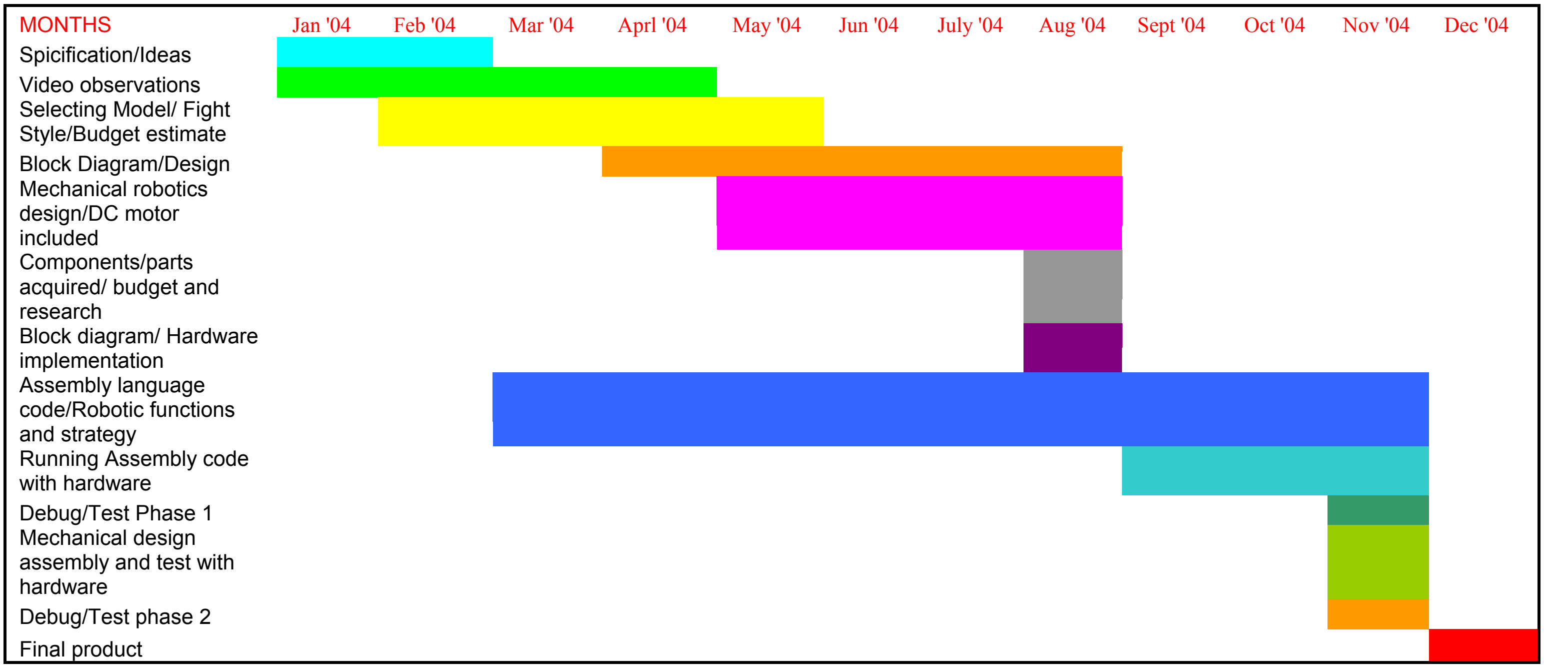

Table 2: Timeline

ELECTRICAL COMPONENT LIST:

PIC 16F877 - 20/P	1	Microcontroller
DS232A	1	Dual RS-232 Transmitter/Receiver
MAX667	1	250mA LDO Regulator
ZTT 20.0 MX	1	20.00MHz Resonator w/caps
GP2D12	2	Object sensor
QRB1133	3	Light sensor
SW1	1	DPDT Slide Switch
SW2	1	6.0mm Tact Switch

Capacitors:

C1, C2, C3, C4, C5,C6, C7, C10, C11,C12	10	0.1uF axial capacitor 50V Z5U
C8, C9	2	00uF radial aluminum electrolytic capacitor 16V
C13, C14	2	33uF radial aluminum electrolytic capacitor 6.3V
1N4148 Fast Switching	1	Diode
Red LED	1	
Green LED	1	

Registers:

R1, R11, R12, R13	4	1K Ohm 1/8W 5% resistor
R2	1	1M Ohm 1/8W 5% resistor
R3,R4	2	4.7K Ohm 1/8W 5% resistor
R5	1	7.5M Ohm 1/8W 5% resistor
R6	1	2.4M Ohm 1/8W 5% resistor
R7	1	56 Ohm 1/8W 5% resistor
R8, R9	2	22 K Ohm 1/8W 5% resistor

R10	1	22 K Ohm 1/8W 5% resistor

COST ANALYSIS:

The following table shows the cost analysis. The total cost will be shared among the group members.

Item	Costs
PIC16F877-20/SP	$5.25
SN754410 H-Bridge	$4.95
QRB1133 IR Sensor - 4 Pack	$12.55
20.000MHz Crystal	$0.20
MX667 1A Power Regulator	$1.20
GP2D12 Detector Package	$11.50
Two DC motors	$15.00
Interior / Exterior design platform /mechanical	$40.00
Actual total Cost	$ 85.65
Predicted cost during research	$95. 59
Compared to retail Mini-Sumo Kit	$160.00

TESTING:

After the whole body of the robot is assembled every component as well as the overall robot is tested. The test was done in three levels. In the first level each and every component were tested individually for its proper functioning. For example the microcontroller is tested by applying simple commands, the motors were tested by directly supplying the voltage source before interfacing it with the microcontroller, and sensors were also tested by supplying the separate power supply. The second level of testing is done when the components are assembled and interfaced along with the microcontroller, which is loaded with the desired software code. During this testing phase, coding errors are also debugged. The last level of testing is done on the final project which is the built robot. This level is done to verify that the robot meets the competition specification and it is reliable to compete in different battles.

Results of Testing;

The robot built is able to meet most of the organizer's specification expect the weight limit. The weight of the robot is supposed to be equal or less than 500 grams but the one built is 725 grams. In order to reduce the weight, the only solution is to design a PCB board for the circuit wiring connections.

CONCLUSION:

In brief, the project objective is to design a mini-sumo robot that will compete in the annual mini sumo robot competition. This robot project has three subsystems: electrical, software and mechanical. The robot is double sided wedge shaped. The inner design will have microcontroller, reflective object sensors, and motor. The major difficulty was in the software integration to the hardware. Overall the project was successful; however, there are still many improvements that can be made such as the efficient use of the many unused outputs of the microcontroller to make the robot respond at faster rate, and have more speed to it. Higher intelligence can also be implemented to the robot via extra unused ports in the future.

ACKNOWLEDGEMENT:

We would like to offer our sincere gratitude to Professor Dr. Ray Kwok, a professor of the electrical engineering department at San Jose State University, CA. Without his advice, guidance, and motivation, it would be impossible for us to finish our project.

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4) http://www.maxim-ic.com/qa/info/milspecs/MAX667.PDF

5) http://www.quisquose.com/download/LM2940.pdf

6) http://www.solarbotics.net/library/datasheets/QRD1114.pdf