

Lab 30 The Robot Competition (version 7 plus stuff from Blackboard)

This laboratory assignment accompanies the book, *Embedded Microcomputer Systems: Real Time Interfacing*, by Jonathan W. Valvano, published by Thomsen Publishing, copyright © 2006. The robot materials were funded by a grant from Tivioli.

- Goals**
- Design a robot that can move forward/backward, turn left/right, and collect/deposit balls,
 - Interface motors, and sensors to the 9S12,
 - Implement pulse-width modulation, input capture and output compare,
 - Write low-level device drivers for the motors and sensors,
 - Develop a high-level control system,
 - Use communication skills to work effectively as team.

- Review**
- Chapter 8 on interfacing DC and stepper motors,
 - Chapter 6 on pulse-width measurement and input capture,
 - Chapter 2 on finite state machines,
 - Chapter 13 on control systems,
 - Construction guide for the erector set,
 - Data sheets for 74HC14, IRF522, IRF540, L293, Ping))) and TIP120.

- Starter files**
- PWM, OC, IC, ADC, FuzzyLogic, LCD, Moore

To win this competition, your team must combine mechanical, electrical and computer skills. Each robot has one switch (in addition to the reset switch) that the students can push to start the competition when instructed by the TA-referee. The **reset** switch (the normal hardware reset) should cause all motors to stop and will be used for safety purposes. You will push your **start** switch once at the start of the competition signifying the start of the 180-second competition. You are not allowed to touch or move your robot any time during the 180-second competition. No buttons are pushed on the robot during the competition.

The Arena

Figure 30.1 shows the arena, which is about 4 feet by 8 feet, flat, and divided in half. The *lines* are made with black tape of different widths. The tape has a different optical reflectance than the white floor. The *side walls* and the *end wall* are about 3 in inches tall. The *walls* are gloss white like the floor. The ball will bounce off the *side walls*. All dimensions are approximate; please refer to the actual arena for more accurate measurements. There are three zones: your side, the neutral zone, and the opponent's side.

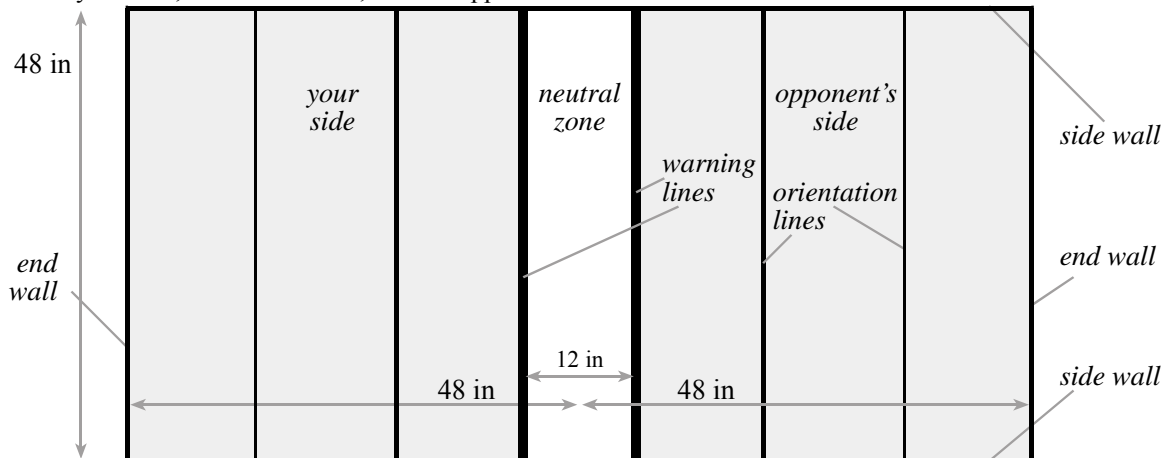


Figure 30.1. Rough sketch of the arena (the grey lines do not exist).

The Beginning and End

Two robots compete against each other, and the starting sides will be chosen by the TA-referee. This information will be announced during the previous game so teams may prepare their robots. The starting position of a robot defines its side of the arena for scoring purposes. The students will have 60 seconds to place their machines

into the arena from the time the TA-referee calls them to set up. Your robot must be touching your *end wall* at the start, but its lateral position and orientation are up to you. When the two teams are ready, the TA-referee says, “Go”, and each team will push its **start** button to activate its software. If a robot fails to start as expected, the TA-referee will award one *false start*, and the round will be repeated immediately. Two *false starts* constitute a loss, and the faulty robot will be removed from the arena and placed in a position of shame. The remaining robot will be allowed to play without opposition. The powered portion of a competition will last 180 seconds. Your robot must stop all moving functions at the end of 180 seconds, and any robot that continues to move after 180 seconds will lose the game. The TA-referee will terminate a game early if neither robot appears to be making any progress. The TA-referee will terminate a game immediately if a robot presents physical danger to spectators, itself or the opposing robot. The TA-referee will terminate a game if any part of a robot extends more than 2 inches past the *center line*, giving victory to the other robot.

The Serve

Service will be alternated during the course of the competition. The TA will determine which robot serves first. A service begins when the TA hands the ball to one team. A team member has 5 seconds place the ball touching the arena floor with no initial velocity or rotational energy. The TA will expect the team member to place the ball in front of their robot, so the robot can see it. Other strategies will not be allowed. The team member can not move the robot during the serve, otherwise the ball may be placed anywhere on their side of the arena.

The Scoring

Your robot scores two points if the ball touches the *end wall* on your opponent’s side of the arena. During play your robot will score one point if the ball remains on your opponent’s side of the arena for 30 seconds. This 30-second clock restarts after each serve and after each time the ball crosses one of the *warning lines*. After each score, the TA-referee picks up the ball, and the opposing robot will be allowed to serve. If the ball comes to a complete stop in the *neutral zone*, no points will be scored, and the serve will offered to the robot opposite from the one that served last. If your robot causes a ball to leave the arena, even if it bounces over an opponent’s wall or off the opponent itself, the opponent is offered the serve. If you design your robot in such manner that it deflects a rolling ball over the wall, your robot will be considered to have “caused” the ball to leave the arena. Similarly, if your robot strikes the ball causing the ball to bounce (not a smooth roll), and the ball goes over a wall, even if the ball hits off the opponent, then your robot will be considered to have “caused” the ball to leave the arena. At the end of the 180-second competition, your robot must stop all moving parts. After 180 seconds, the game ends, and no more points are awarded. The robot with the most points wins.

+2 points if the ball hits your opponent’s end wall, even if it bounces out (opponent serves)

+1 point if the ball remains on your opponent’s side for 30 seconds (you serve)

no points if you cause the ball to leave the arena over a side wall (opponent serves)

no points if you cause the ball to fly over without touching a wall (opponent serves)

The Strategy and Sportsmanship

The basic goal is to locate the ball and send it rolling to the other side of the arena. The robot is supposed to move in an intelligent manner. Your TA will not allow unintelligent robots to compete. If you are not sure what intelligent means, run your strategy by your TA. Robots designed to cause the ball to bounce or fly will be disqualified. After your robot causes the ball to move (pushes, hits, kicks, blows, punches or strikes) and before the ball hits a wall or the opponent, the ball should not be more than 1 inch off the ground. On the first and second time your robot causes the ball to fly or bounce, play is stopped and the serve is granted to the opponent (no points awarded). On the third time, your robot will be disqualified. Bouncing that occurs after the ball hits a wall or an opponent is not penalized. Robots must move and react to the ball. No pieces may be intentionally dropped by your robot. Pieces unintentionally dropped by your robot will be removed by the TA-referee. Good strategy, skillful ball handling, knowledge of your position/orientation, and reliability will be important. Because sensors can be unreliable, an effective solution will be robust, so that the robot acts in an appropriate manner even when presented with inaccurate sensor data. Your robot is allowed to squat, scoop, shoot, push, and kick the ball during the game. During the qualifying and preliminary rounds, the judges may declare a double loss, a double win, or no result, as appropriate. Good sportsmanship must be followed.

The Ball

The ball is 6 inches in diameter and soft. It can be reliably seen at distances up to 50 cm (± 10 degrees) using the ultrasonic sensor, but not necessarily by the optical sensor. The color of the ball may vary from match to

match. The ball will roll and will bounce off the walls reasonably well. The ball may not be punctured, altered, or modified in any way.

The Robot

Each team will choose a name for its robot (limit 20 characters including spaces.) Robots will be constructed using materials from the robot kit. Input devices include one ultrasonic ranging sensor, one compass, multiple tactile touch sensors, and multiple reflective IR optical sensors. Motors include one servo, four geared DC motors, two stepper motors and two solenoids. The *bounding box* is defined as the smallest 3-D box with 90 degree angles that could contain your robot, including sensors, wheels, flippers and whiskers. The *footprint* of your robot is defined as the floor of its bounding box, as shown in Figure 30.2. The footprint must be less than or equal to 9 inch by 12 inch at all times during the competition. The maximum wheel diameter is 3.25 inches (to limit torque to the motors). The maximum *height* of the bounding box is 12 inches at all times during the competition. In other words, your robot can not unfold so that it becomes larger than the maximums of 9in wide, 12in long, and 12in high. It is acceptable if at most one or two inches of your robot extend into your opponent's half of the arena. Your wheels must be on the ground at all times.

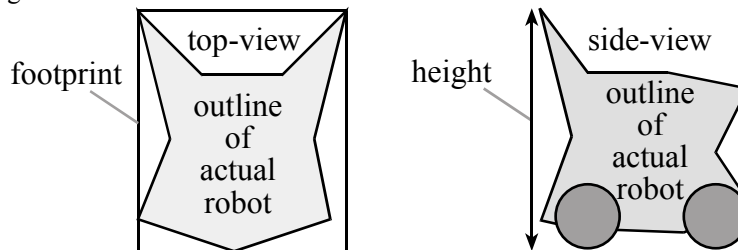


Figure 30.2. Definitions of footprint and height.

Three Laws of EE345M Robotics:

- A robot may not harm a human being, or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given to it by Robin, Seil, Sterling, and Sandy.
- A robot must protect its own existence and the existence of the other robots, as long as such protection does not conflict with the First or Second Law.

The Judges Rule

- The judges are Valvano and Tsang.
- Contestants should ask the judges about possible designs or strategies that may be questionable under any of the rules.
- Contest rules and procedures, or even the game, may have to be altered during the semester. As much notice as possible will be given.
- The judges may alter or eliminate any rule, or add rules, at any time.
- The judges will decide any discrepancies in the contest play.
- All decisions of the judges are final.

The Competition Format

The contest is a three phase competition, which are qualifying, preliminary, and finals. During the qualifying round, which will demonstrated to any TA or instructor during any regularly scheduled lab on or before Friday April 25, your robot must "beat the brick" —win a game played against an inert opponent— in order to qualify for the next round. During the qualifying round your robot will serve every play, but you are not allowed to move your robot during the 180-second competition. Qualified machines will then play three or four preliminary competitions, arranged at random. Preliminary competitions occur in the second floor lab on Monday 4/28 7:30-9pm. The results (+1 for a win, 0 for a tie, and -1 for a loss) of these preliminary games will be recorded and used only for seeding into the final competition. The total number of points scored during the preliminary rounds will be used as a tie-breaker in the seedings. The final competition will take place just outside the front door of ENS on Wednesday 4/30 and continue on Friday 5/2 10-11am. The final competition will be double elimination, and the exact pairings will depend on the number of qualifying robots. During the finals, the judge will award exactly one winner and one loser for each round. Depending on the number of qualifying robots, some robots with a high seeding may be awarded a bye for the first set of games, as shown in Figure 30.3.

Schedule (three arenas)

Wednesday April 30, 10am
 10:08, Game #2, Arena A
 10:08, Game #7, Arena B
 10:08, Game #6, Arena C
 10:16, Game #9, Arena A
 10:16, Game #4, Arena B
 10:16, Game #3, Arena C
 10:24, Game #14, Arena A
 10:24, Game #11, Arena B
 10:24, Game #12, Arena C
 10:32, Game #10, Arena A
 10:32, Game #19, Arena B
 10:32, Game #20, Arena C
 10:40, Game #21, Arena A
 10:40, Game #24, Arena B
 10:40, Game #22, Arena C

Friday May 2, 10am
 10:08, Game #17, Arena A
 10:08, Game #18, Arena B
 10:08, Game #25, Arena C
 10:16, Game #26, Arena B
 10:16, Game #27, Arena C
 10:24, Game #23, Arena A
 10:24, Game #28, Arena B
 10:32, Game #29, Arena A
 10:40, Game #30, Arena A
 10:44, Game #31, Arena A (if necessary)

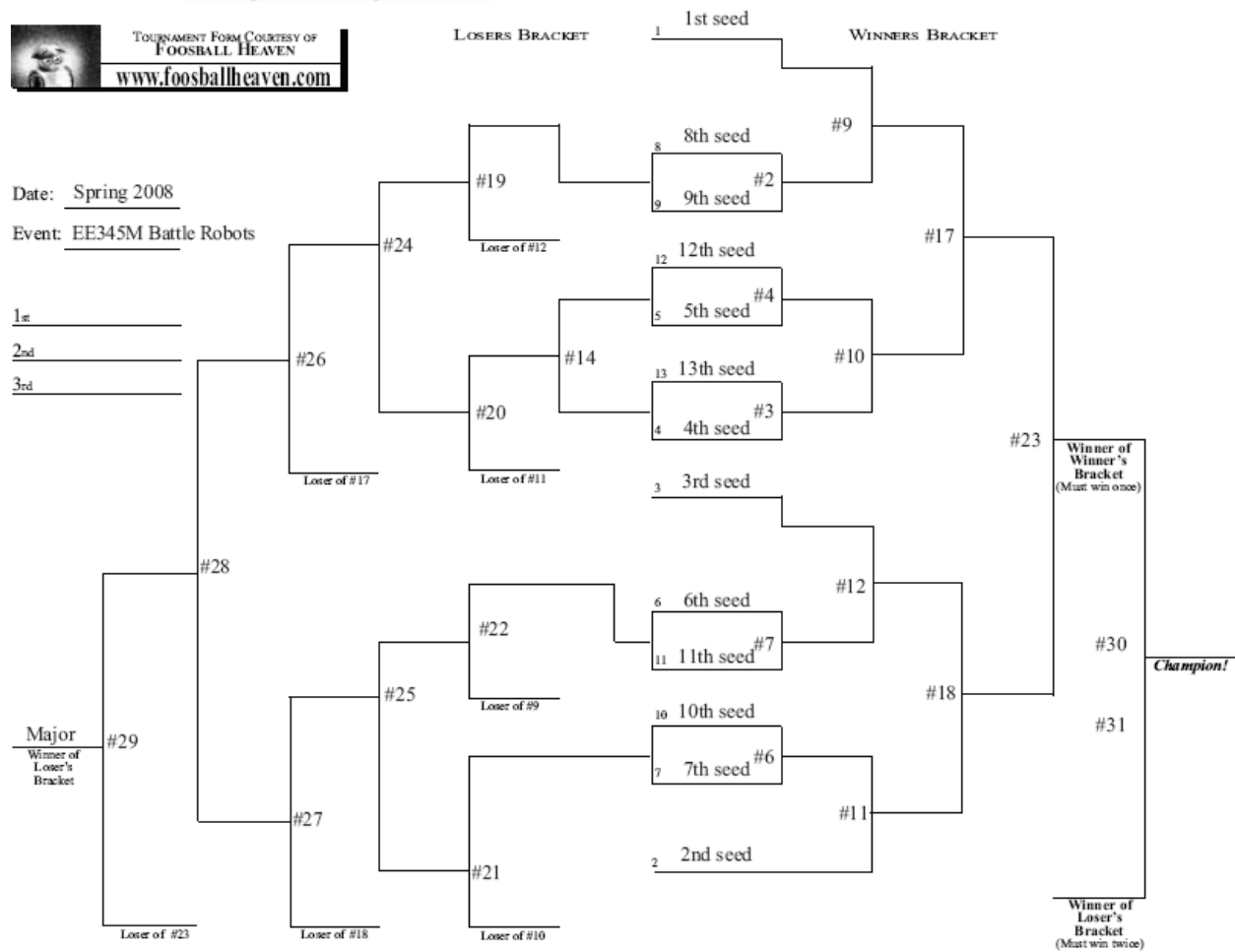


Figure 30.3. A double elimination finals with 13 robots will require 24 or 25 games.

Restrictions

Teams are encouraged to seek advice and help from any source, but the design, robot construction, and software must be exclusively their own work. All entries must be solely controlled by their onboard 9S12 computer(s). You may use any 9S12 board (e.g., 9S12C32, 9S12DP512, 9S12E128) as long as you limit the design to 22 input/output pins for each 9S12. It is ok to employ multiple 9S12 controllers as long as each one uses 22 or less input/output pin. There can be no human intervention once the game begins. A robot that is moved by a team

member during a game will be disqualified for that round. Also, team members touching the arena during play risk disqualification of their robot. Teams may qualify only one robot, and only that robot may play in the preliminary and final rounds. Modifications to your mechanical, electrical or software components following qualification are encouraged. Repair and reprogramming are allowed during the competitions only if time permits. A robot cannot be designed primarily to destroy the physical structure of its opponent. In particular, robots are not allowed to destroy their opponent's microprocessor board, wheels, power, or sensors. However, stopping the ball before it hits your *end line* is an obvious strategy. No parts or substances may be deliberately dumped, deposited, or otherwise left to remain on the arena surface. A machine that appears to have been designed to perform such a function will be disqualified. Pieces that accidentally fall off robots will be removed from the arena during a game by the TA-referee at his discretion. No adhesives or sticky substances (such as glue or tape) may be applied to any part of your robot, the opponent's robot, the arena, or the balls. Any machine that appears to be a safety hazard will be disqualified from the competition.

Robot Structure Restrictions

The electro-mechanical components (motors, steppers, servos, solenoids) are limited to what is in the kit, or is borrowed from the professor's office. Additional electro-mechanical devices can be borrowed from the professor as long as there is sufficient quantity for all teams to have similar quantity. There is a box of random structural components (erector pieces), which may also be borrowed starting 1 week after you receive your kit. Teams may possess only one battery, only one compass, and only one ultrasonic range sensor at any one time. All kits contain approximately the same components, except there is variability in the optical and touch sensors. Electrical components from the second floor may be obtained (such as resistors, capacitors, transistors and IC chips), with the exception that no additional batteries, servos, solenoids, or motors are allowed. You may not employ devices to increase the voltage above the 8.4 volts provided by the battery (e.g., no DC-DC converters). You can have no electrical/mechanical/chemical/nuclear power source other than the provided 8.4 volt battery (no CO₂, butane may be used as a power source). You may use lubricants on the metal parts (not in the motors or sensors), as long as all components are cleaned prior to returning the kits. Rubber bands may be used as structural components (holding things together), but not used as a power source to launch the ball or move the robot. For example, springs and rubber bands may be used to cause a flipper, a leg, or an arm to move to back a resting position, but the energy in a spring or rubber band can not be used to launch the ball or move the robot.

The use of temporary binding components such as nuts, bolts, rubber bands, cable ties, string, and wire is encouraged, but please don't use methods that permanently alter the pieces such as tape, hot glue, epoxy, or welding. You may solder wires to the motors, and sensors, as long as permanent damage is avoided. Drilling additional holes in the erector pieces is allowed, as long as the original usage of the piece is not altered. You may alter your own structural pieces (wood, plastic, metal) as you wish. Purely decorative items may be added, within the size limits and good taste.

The \$50 Rule

Each team is allowed to purchase additional parts up to a \$50 limit. These additional parts may include electrical components (such as sensors, transistors, amplifiers, motor drivers etc.), structural components (such as wood, metal, plastic, wheels, shafts, gears, chains, pulleys, and slip couplings). Repeating from above, you can not purchase or use additional batteries, motors, or actuators. Components from the second floor checkout or the instructor's office do not need to be logged and do not count towards this \$50 limit. You do not need to measure the cost of readily available supplies such as nuts, bolts, rubber bands, cable ties, string, paper, cardboard, wire, your 9S12 boards, or your protoboards. To purchase an additional item, it must be readily available to all teams at that price. *Readily available* means, if it is purchased by 4/21, it can be received by 4/28. Free components may be obtained as long as they are logged and equally available to all teams. The robot name, description, cost, and source must be first approved by a TA or instructor, then logged onto the Blackboard discussion forum, named *The \$50 Rule*. All extra items must be logged by 4/21. After the component is purchased, the receipt must be shown to your TA. Any machines found with added parts that have not been documented in this fashion will be disqualified.

Each robot kit contains the following materials, donated by Tivioli

Amazon.com, Erector Special Edition Anniversary Set, 643 pieces, \$99.99 each

Case, DC motor, wheels, axles, drive belts, pulleys, large and small metal pieces, many nuts and bolts

DC toy motor

BG Micro, bgmicro.com,

- 1, BAT1060, 8.4V/3.8AH, NiMH battery, \$7 each (with charger \$3) (no longer in stock)
- 2, MOT1045, Geared DC motor (\$3.95 each)

Parallax, www.parallax.com

- 1, Ultrasonic Ping))), \$25
- 1, Hitachi HM55B Compass Module, \$24

All Electronics Corporation, <http://www.allelectronics.com>, Phone 1-800-826-5432

- 4, either SMS-189, MINI-SNAP-ACTION SWITCH, \$0.50 each
- or SMS-174, MINI-ACTION ROLLER SWITCH, \$1.25 each
- 4, either 21L900, optical reflective sensor, \$1.00 each (sold out, can't buy any more)
- or QRB1134, optical reflective object sensor, \$2.00 each (Mouser)
- 1, SOL-89, Deltrol Controls #56597-60 INT. Spring-return, push-pull solenoid, \$1.35

Jameco, 1-800-831-4242, www.jameco.com

- 2, 162190, HNGH12-1324Y Geared DC motor, 225RPM 12VDC, 65 mA, \$16.95 each
- 2, 163395, 5017-935, 30 ohm, 280 mA, 400 steps/rotation stepper motor, \$4.95 each
- 1, 157067, 14500 RBT geared servo motor (bag of servo parts), \$17.95 each
- 2, 400961, 3 in Tires, Neoprene Foam Tread, 7.25 per pair
- 2, 386118, Mounting Hub, 4mm shaft, 7.99 per pair
- 2, 386118, Mounting Hub, 5mm shaft (drilled to a 3/16in), 7.99 per pair
- 1, 358336, Ball and caster, \$6.00 each

Electronics available for checkout on the second floor

- IRF522, N CHANNEL MOSFET, drives up to 8A, \$0.40 each
- TIP120, NPN TO-220 DARLINGTON, \$0.65 each
- 1N914, Switching diode
- L293B, H-bridge driver, \$1.15 each
- 7805 voltage regulator use with Servo

DC Motor specifications (HNGH12-1324Y)

- Rated Voltage 12 VDC, 4 mm diameter shaft
- No load 150 RPM at 8.4V, 50 mA (up to 500mA under load)
- Operating Range 4.5 to 12 VDC
- Current @ Max. Efficiency 145 mA
- Speed @ Max. Efficiency 176 RPM
- Torque @ Max. Efficiency 300 g-cm
- Start torque: 700 g-cm
- Gear Ratio: 30/1



DC Motor specifications (MOT1045)

- Rated at 12V
- No load 100 RPM at 8.4V, 50mA (up to 500 mA under load)
- 34.5 mm diameter motor
- 4.8 mm diameter shaft
- See Figure 10.1 at



<http://users.ece.utexas.edu/~valvano/EE345L/Labs/Sp2007/Lab10e.pdf>

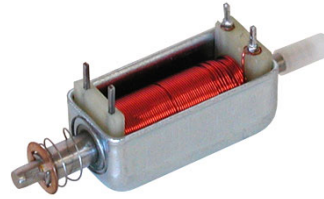
Stepper specifications

- Step angle: 0.9 degrees
- No. of phases: 2
- Drive System: Bipolar
- Voltage: 8.4 VDC
- Phase resistance: 30 Ω
- Current : 280 mA
- Phase Inductance: 25 mH
- Detent torque: 36 g-cm
- Holding Torque: 791 g-cm



Solenoid specifications

- Spring-return, push-pull solenoid.
- 2 Ohm coil (it gets very hot with a continuous input).
- Intermittent duty cycle (send very short pulses).
- Metal-shielded body is 0.91" x 0.42" x 0.45" high.
- 0.1" diameter plunger extends 0.4" on each side of solenoid.
- One end of plunger has a 0.11" diameter nylon cap.
- Four pc pins on 0.75" x 0.2" centers.



HS-303 - Economy Standard Servo

For more information on servos, search the web site:

<http://www.brookshiresoftware.com/>

Servos are a popular mechanism to implement steering in robotics. Ranging from micro servos with 15oz-in torque to powerful heavy-duty sailboat servos, they all share several common characteristics. A servo is essentially a positionable motor. The servo "knows" two things: where it is (the actual position) and where it wants to be (the desired position). When the servo receives a position, it attempts to move the servo horn to the desired position. The task of the servo, then, is to make the actual position the desired position. The first step to understanding how servos work is to understand how to control them. All timing and electrical characteristics described here have been experimentally determined from a "HS-303 HiTec" servo.



The servo is controlled by three wires: ground (black), power (red), and command (yellow). Power is usually between 4V and 6V and should be separate from system power (as servos are electrically noisy). Even small servos can draw over an amp under heavy load so the power supply should be appropriately rated. Though not recommended, servos may be driven to higher voltages to improve torque and speed characteristics. Servos are commanded through "Pulse Width Modulation," or PWM, signals sent through the command wire. Essentially, the width of a pulse defines the position. For example, sending a 1.5ms pulse to the servo, tells the servo that the desired position is 90 degrees. In order for the servo to hold this position, the command must be sent at about 50 Hz, or every 20 ms.

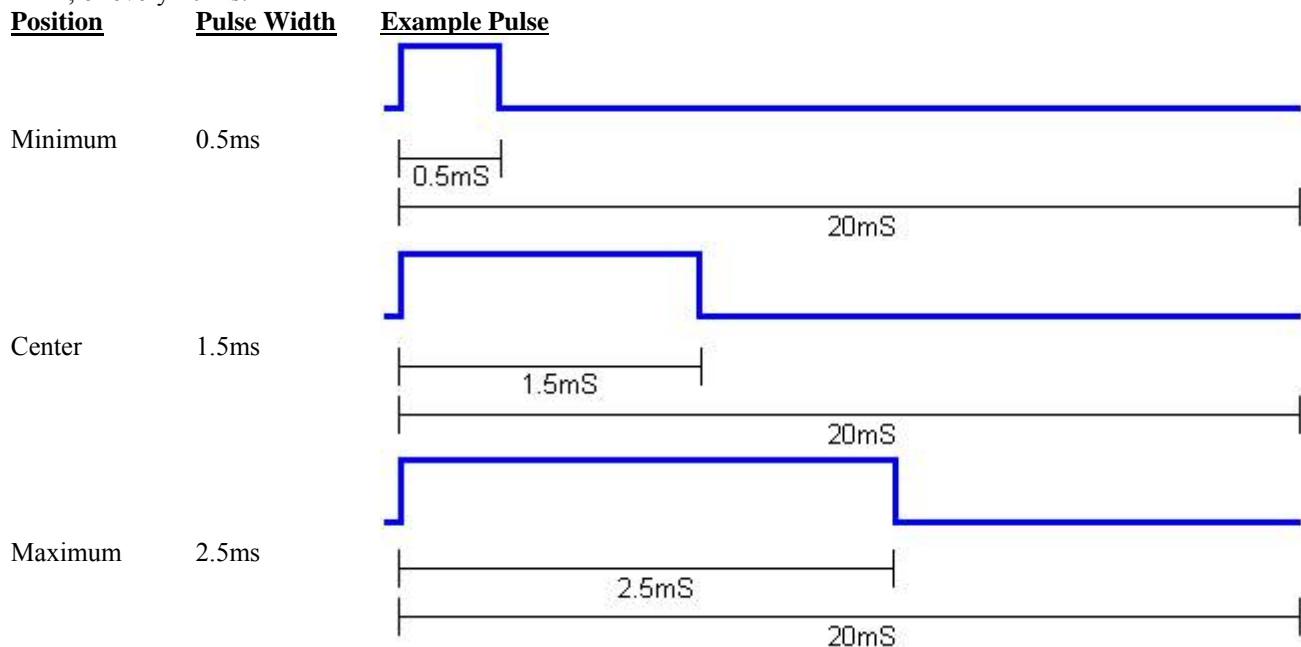


Figure 30.5. The timing constraints of the **HS-303** servo (<http://www.brookshiresoftware.com/>).

If you were to send a pulse longer than 2.5 ms or shorter than 0.5 ms, the servo would attempt to overdrive and damage itself. Once the servo has received the desired position (via the PWM signal) the servo must attempt to match the desired and actual positions. It does this by turning a small, geared motor left or right. If, for example, the desired position is less than the actual position, the servo will turn to the left. On the other hand, if the desired position is greater than the actual position, the servo will turn to the right. In this manner, the servo "zeros-in" on the correct position. Should a load force the servo horn to the right or left, the servo will attempt to compensate. Note that there is no control mechanism for the speed of movement and, for most servos, the speed is specified in degrees/second. Indeed, one of the primary tasks of VSA is to synthesize servo speed control by stepping through a series of positions. *If you plan to use a servo, please consider a 7805 regulator, creating two +5V sources, original one for the 9S12 and the second one for the servo.* If you connect the servo to the +5V used by the 9S12, then the servo will cause transient power losses to the 9S12, causing software resets.



Figure 30.6. HS-303 servos (<http://www.brookshiresoftware.com/>).

Operating Voltage	4.8V	6.0V
Torque	42 oz-in 3.3 kg-cm	49 oz-in 3.7 kg-cm
Speed @ 60 degrees	19 sec	15 sec
	Standard	Metric
Size L x W x H	1.6" x 0.8" x 1.4"	41 x 20 x 37mm
Weight	1.9 oz	48.5g

Table 30.1. HS-303 HiTec" servo specifications (<http://www.brookshiresoftware.com/>).

The 8.4V/3.6AH NiMH battery pack has two connectors. The polarized RC-type connector (like the picture on the right) is used for charging the battery. It takes about 8 hours to fully charge the NiMH battery, using the 12V wall wart (with the matching RC-type connector), but please disconnect the other connector while charging. **Please do not charge for more than 8 hours.** The red (8.4V) and black (ground) wires must be connected to your protoboard for powering the DC and stepper motors (not the servo). The connector should not be plugged into the 9S12C32 board. The 8.4V power should be wired to the Vin (pin 40) and ground (pin 39) of the 9S12C32 board. In this way you will have both +8.4V and +5V power with a common ground. Be very careful that the motor current does not travel through the 9S12 board.



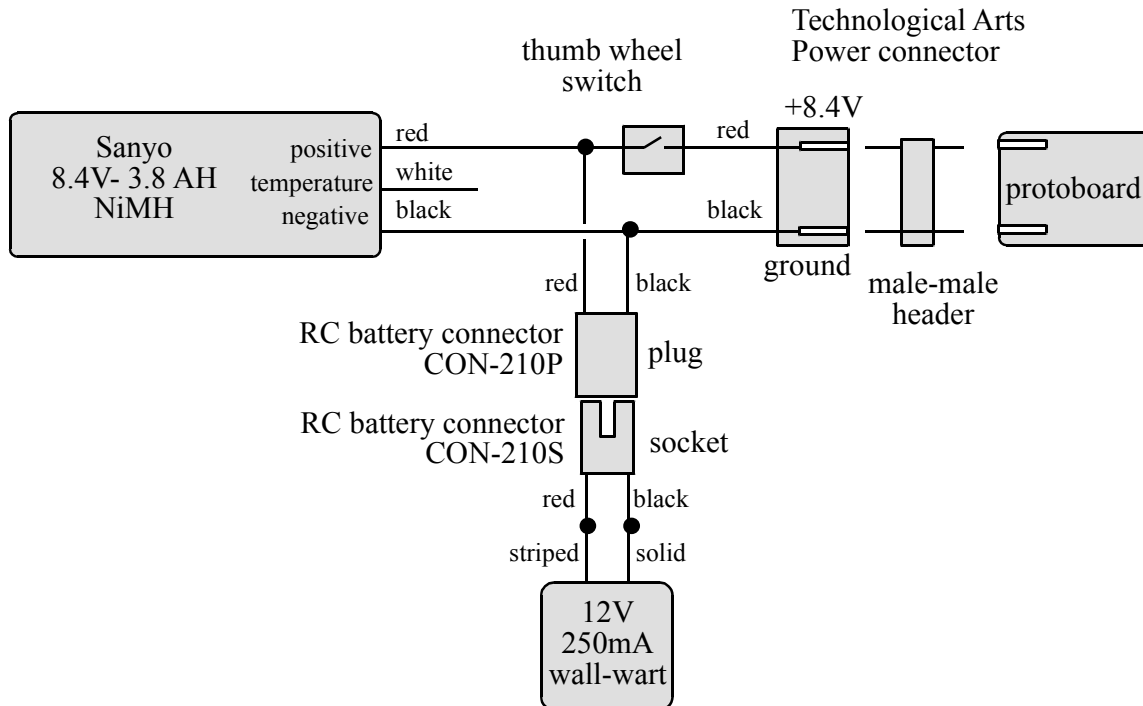


Figure 30.7. Battery connections.

30A. Preparation

1: Form a robot design team with 4 members. The members do not have to be in the same lab section or have the same TA as the previous labs. The ideal team has at least one member with strengths in the areas of mechanical design (e.g., pulleys, belts, motors, and rack-and-pinion steering), electrical interfacing (e.g., transistors, currents, back EMF, servo interfacing, and sensor interfacing), power management (e.g., maintaining constant +5V power to the 9S12 while operating the motors), software design (e.g., device drivers, juggling multiple time-critical tasks, making it fit into 32K of ROM space), high-level control, and project management (e.g., conflict resolution, report generation, and keeping on schedule). Part of your final project grade will be confidential peer evaluations, so choose your team wisely, then make a commitment to get this project finished. Please turn in the following:

robot name

first and last names of all team members

home phone numbers of all team members

email addresses of all team members

select at least two times each week for an official team project meeting (without the TA)

list all the regularly scheduled lab hours that it is possible for all your members to meet weekly with a TA

We will select one of these hours to be when your preparation and demonstrations will be due.

30A. Procedure (do this during your lab period)

1: Design and build the mechanical aspects of the robot. It must move, turn, and carry the electronics. Make a rough mechanical sketch of the robot showing how it moves, turns, carries, and senses. A detailed drawing will be required for the final report, but at this time only a rough sketch is required. I.e., just enough detail for the TA to understand your basic approach, but not enough detail for someone to build a duplicate.

2: Design the electronic interface between the steering and power motor(s) and the 9S12. We expect you to use the 8.4V NiMH battery, but you may use an external regulated supply during testing. Please test the circuitry before connecting to the 9S12. Snubber diodes must be used for all devices having an inductive load. Please consider the required current when designing the interfaces. Use a multimeter to measure the actual voltages and currents across the motors. Watch the +5V signal on the scope during times when motors are turned on and off to verify a constant +5V power supply line to the 9S12. Please thoroughly test all interfaces before connecting to the 9S12. Include low-level sensors like the wheel tachometers, used to measure wheel rotation speed.

3: Show how the system will be powered.

4: Design the low-level software drivers for the movement and steering motors. *It is a requirement that the drive motors use PI, PID, or fuzzy logic control (with sensor feedback).*

5: Write a simple high-level main program to test the movement and steering. Measure the maximum speed of the robot. Experimentally determine the best way to make turns. Calculate the accuracy of the turning algorithm. I.e., if you say turn +90, how many degrees does it actually turn?

6: Debugging a complex system like this is very hard. Please design features into the robot to assist in debugging.

30A. Deliverables (exact components of the lab report, to be included in the final 30C report)

A) Objectives (not required for this 30A)

B) Hardware Design

- 1) Rough mechanical sketch of the robot (Procedure 1)
- 2) Electrical circuit diagram for the motor interfaces (Procedure 2)
- 3) Power supply circuitry (Procedure 3)

C) Software Design (printout of these software components)

- 1) Low-level device drivers for the motor interfaces (header and code files) (Procedure 4)
- 2) High-level test program to evaluate movement and steering (Procedure 5)

D) Measurement Data

- 1) Give the voltage and currents of each of the motors used (Procedure 2)
- 2) Give the robot speed and turning accuracy (Procedure 5)

E) Analysis and Discussion

- 1) Minutes (date, time, duration, attendance, topics) for each team meeting

30A. Checkout

You should be able to demonstrate to the TA your robot moving forward, backward, and turning. You should demonstrate the robot moving and turning. Explain the debugging features of your device.

30B. Preparation (do this before your lab period, but don't turn it in)

1: Develop a high-level plan of how your robot will compete. Your algorithm must involve abstractive methods. I.e., it must be layered, with a high-level algorithm separated from the low-level details of how the machine operates. A finite state machine like `more2.c` is one example of how this abstraction might be implemented. You are of course allowed to develop your own approach, as long as there is a clear mapping from the high-level algorithm to the eventual C code. For example, if you decide to implement a finite state machine, draw the state graph for competition algorithm.

2: Develop an initial data flow graph of the hardware-software system. Include the motors, sensors, interface drivers, interrupt service routines, and strategic global variables.

3: Develop an initial call graph of the software system. Include foreground and background modules and their linkage (which ones call which).

4: Write the header file for the low-level sensor software driver.

30B. Procedure (do this during your lab period)

1: Design the electronic interfaces connecting the high-level sensors to the 9S12 (bumper switches, optical sensors to see lines on the arena floor, ultrasonic and compass). Again, please test the circuitry before connecting to the 9S12.

2: Design the software drivers for the detection of the walls, to avoid damaging the motors (robot safety is a high-priority process).

3: Design the software drivers for the sensors, creating software modules with prototypes for public functions in the header file and implementations of both public and private functions in the code file.

4: Write a second high-level main program to test the movement, steering and sensors. This program should demonstrate most of the middle-level building blocks that will be required for the competition. Monitor the power supply current during various operations (stopped, moving and turning).

5. Experimentally verify the robot can tell where it is on the arena.

30B. Deliverables (exact components of the lab report, to be included in the final 30C report)

A) Objectives (not required for this 30B)

B) Hardware Design

- 1) Most recent electrical circuit diagram for the motor interfaces (30A Procedure 2)

- 2) Most recent power supply circuitry (30A Procedure 3)
- 3) Electrical circuit diagram for the sensor interfaces (30B Procedure 1)
- C) Software Design (printout of these software components)
 - 1) Low-level device drivers for the motor interfaces (header and code files) (30A Procedure 4)
 - 2) Low-level device drivers for collision detection (header and code files) (Procedure 5)
 - 3) Low-level device drivers for the sensor interfaces (header and code files) (30B Procedure 2,3)
 - 4) High-level test program to evaluate movement, steering and sensing (30B Procedure 4)
- D) Measurement Data
 - 1) Power supply current for various operations (30B Procedure 4).
 - 2) Accuracy of the positioning system, knowing where it is (30B Procedure 5)
- E) Analysis and Discussion
 - 1) Minutes (date, time, duration, attendance, topics) for each team meeting
 - 2) List of the remaining major problems to solve

30B. Checkout (show this to the TA)

Show Lab 30B Procedure 5 to your TA. Explain how you tested the system.

30C. Preparation (do this before your lab period, do this but don't turn it in)

- 1: Write the C code for the competition algorithm using abstractive methods. It should have a clear mapping from the high-level algorithm to the C code.
- 2: Make detailed mechanical drawings and/or photos of the robot showing how it moves, turns, carries, and senses. There should be enough detail so the robot could be duplicated.

30C. Procedure (do this during your lab period)

- 1: Debug the high-level competition algorithm.
- 2: Draw the final data flow graph of the hardware-software system. Include the motors, sensors, interface drivers, interrupt service routines, and strategic global variables.
- 3: Draw the final call graph of the software system.
4. Run the robot against the brick at least five times and measure your scores.

30C. Deliverables (exact components of the lab report)

- A) Objectives (1/2 page maximum)
- B) Hardware Design
 - 1) Final mechanical drawing of the robot (30C preparation)
 - 2) Final electrical circuit diagram for the motor interfaces (30A Section 2)
 - 3) Final power supply circuitry (30A Section 3)
 - 4) Final electrical circuit diagram for the sensor interfaces (30B Section 1)
- C) Software Design (printout of these software components)
 - 1) Low-level device drivers for the motor interfaces (header and code files) (30A Section 4)
 - 2) Low-level device drivers for the sensor interfaces (header and code files) (30B Section 2)
 - 3) High-level competition algorithm (30C Section 2)
 - 4) Final data flow graph
 - 5) Final call graph
- D) Measurement Data
 - 1) Scores during "beat the brick" competitions
- E) Analysis and Discussion (1 page maximum)
- F) Post-mortem concerning team member interactions (attached to the report)
 - 1) Each team member evaluates each other team member including oneself
 - Simply list one or two weaknesses.
 - Simply list two or three strength characteristics.
 - 2) Major failures in the way the team interacted (if any)
 - 3) Major successes in the way the team interacted
- G) Peer Review (each student submits independently and confidentially directly to the TA)

Classify each team member including oneself as:

 - worked harder than average (explain), worked an average amount, worked less than average (explain)

30C. Checkout is the qualifying, preliminary and final rounds (show this to the class on demo day)

You should qualify, compete in the preliminary, then run the finals.

Lab 30 has a total of 300 points (counts for 3 labs.) Your Lab 30 grade will have four components. The first component is the demonstration of your 9S12-controlled robot that moves. The drive motors must be controlled using PI PID or fuzzy logic running in real time with sensor feedback. There will be no Lab30A report or Lab30B preparation. You will be awarded 50 points if your robot moves under 9S12 feedback control and no points if you fail to demonstrate motion by April 10. There will be no late checkouts of this part. You may demonstrate the motion to any of the TAs, or even to Valvano himself. The second component is qualifying round, where your robot must score more points than a brick. Qualifying is due by Friday, April 25. There will be no Lab30B report or Lab30C preparation. You will be awarded 50 points if your robot scores more points than a brick and no points if you fail to demonstrate these abilities by 4/25. There will be no late checkouts of this part. There will be 20-point bonus if you can qualify on or before 4/23. You can qualify with any TA. The third component is the scoring during the preliminary phase of the competition. The full 100 points will be awarded to teams that score high enough to be in the upper 50% seeding. Fewer points will be awarded for those teams in the bottom 50% seeding, depending on the specific scores and performances of the robot. The final competition will be 10-11am Wednesday 4/30 and Friday 5/2 10-11am. The last component is the Lab 30C report (worth 100 points), which is due by 5pm, Friday 5/2. This report will be graded in the usual manner.

I have additional parts that can be assigned to your kits, such as servos, optical sensors, switches, DC motors, springs, belts, cable ties, rubber bands, heat-shrink, wire, erector pieces, PN2222, IRF540, and 7805 regulators. I will dispense components as long as I have enough stock to allow all teams to have equal access. Unfortunately, I do not have enough batteries or Ping))) sensors for groups to have a second one.

My inventory procedures are limited, so please take good care of your kit, and return the kit in a manner that will make next year's competition enjoyable for the next team using your kit.

