Construction and Implementation of a Mobile Robot Platform in a Microcontroller / Interfacing Class

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Abstract – The use of mobile robotics in a typical microcontroller / interfacing class is not a new idea, but with the budget constraints of recent times, there is a need to implement mobile robotics that is cost effective, uses university owned microcontrollers, and is flexible to enough to be used for experiments in Basic Input / Output, Analog to Digital conversion, Output Compare, and Input Capture but is easily rebuilt or repaired to be used repeatedly.

This paper discusses such a mobile robot platform and includes detailed plans, parts lists and instructions on how it was constructed as well as a discussion on how the robot platform was integrated into the fall 2009, senior level Microprocessor Interfacing Technology class so that it can be replicated at other universities.

Keywords: Microcontrollers, Interfacing, Robotics, Computer Engineering Technology Curriculum

MATERIALS NEEDED

To construct the mobile robot platform the materials that are needed are as follows:

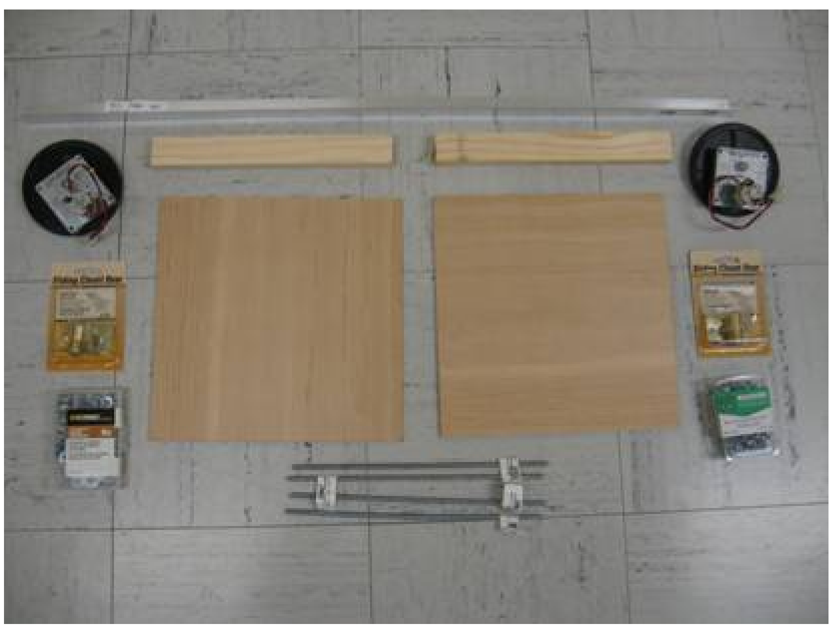

Figure 1 - Parts for mobile robot platform

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Table 1 - Mechanical Parts List

Description	Available from
1/4″ hardwood (plywood) board cut into 12″ squares	Local Hardware store (LOWES / Home Depot / Etc)
1/16″ x 1′ x 3′ Aluminum Angle (cut into 1 ft lengths)	
1/4″ #20 x 12″ Threaded rod (4 pieces)	
1″x2″ x 12″ wood (2 pieces)	
Closet Door Ball Catch (Solid Brass Co N-7287 or Similar) (x2)	
10-24 machine screws (for mounting motor)	
Nuts and Washers for #20 rod (above)	
Mounting Hardware for Electronics	
2 Motors (MPJA part 17971 MD)	MJPA

CONSTRUCTION

First, cut the ¼" board to 1' squares, the 1"x2" board into one foot lengths and the aluminum angle into 1' lengths. Next drill the motor mount holes into the aluminum angle as shown in below keeping in mind that since the motors are offset, the holes must be drilled so that the wheels shafts are center to the robot body (the easiest way to accomplish this is to put the two aluminum angles back to back and measure and drill one time):

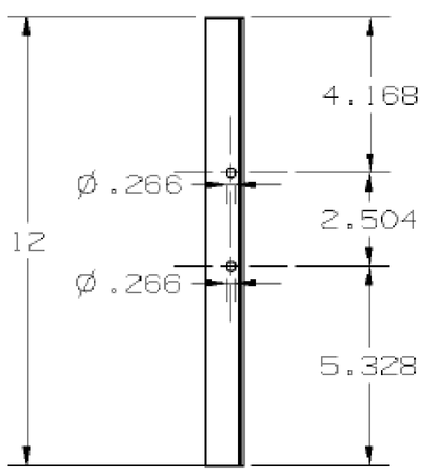


Figure 2 - Left Aluminum Angle

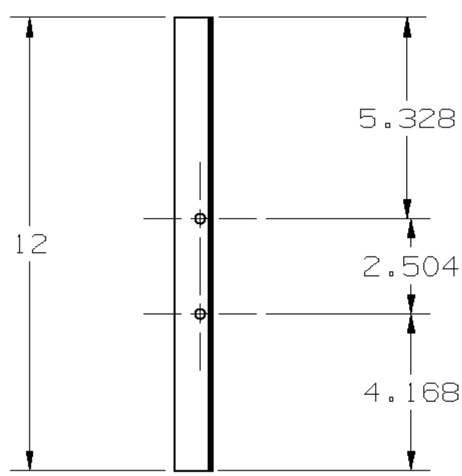
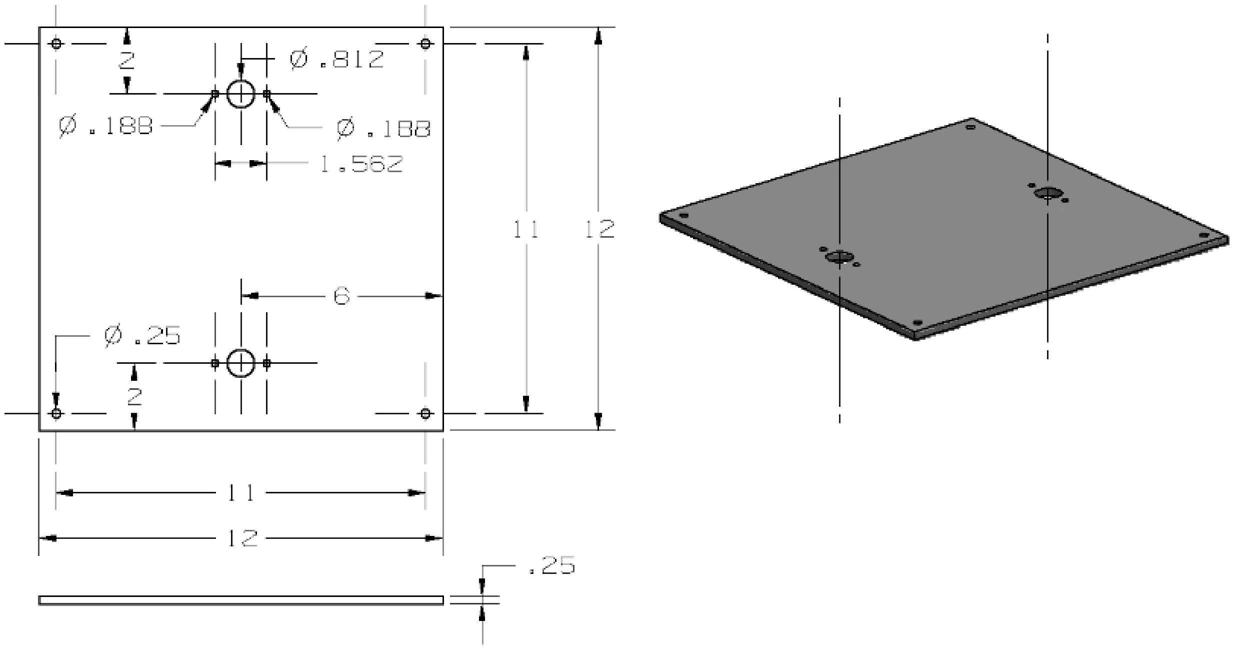


Figure 3 - Right Aluminum Angle

Next drill the mounting holes for the Door Ball Catch as shown in figure 3. This will act as a roller/stabilizer for the robot and can be adjusted both in height and the spring tension for the roller (this can be done after construction is complete).



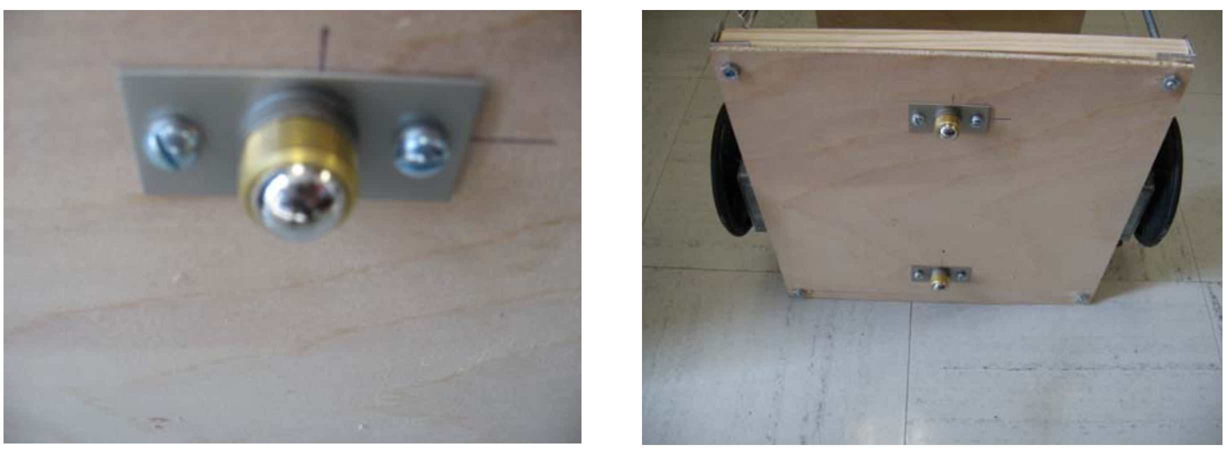


Figure 4 – Base and Roller Assembly

Now drill the ¼" holes for the plywood, aluminum angle and the 1"x2" one half inch from the outside edge on each piece. This can be accomplished by clamping all the pieces together and drilling the hole though all the pieces at the same time (and for the non-machinist this will allow for error as long as all the pieces are assembled in the same orientation as they were drilled) The robot can then be assembled using the ¼" #20 threaded rod, washers, lock washers and nuts as shown below:

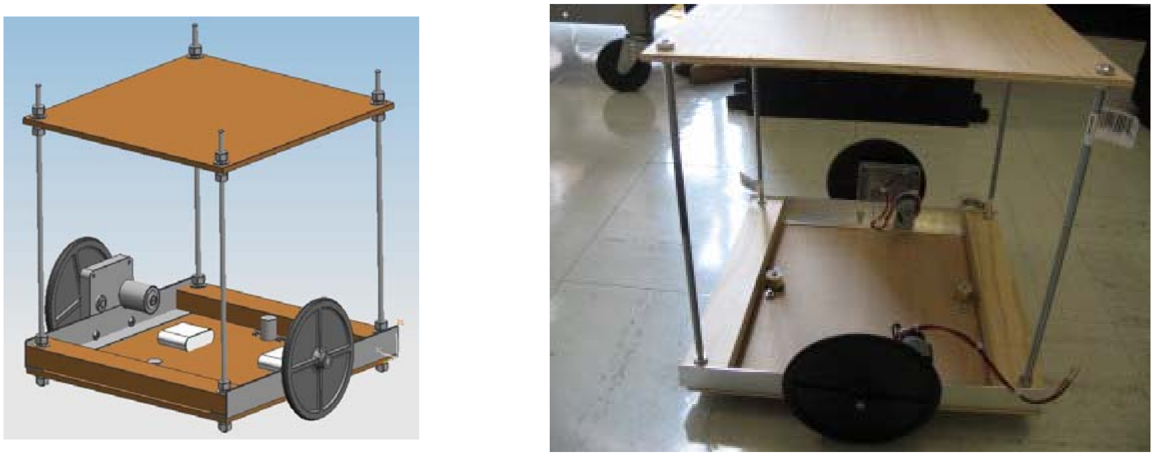


Figure 5 - Completed Robot

The top ¼" board can be easily removed for drilling and mounting of the electronics and will vary based on the processor board and other available components. The batteries can just be placed on the lower base (as shown in figure 5) and the front bar is a convent place to mount line tracking and other sensors.

RECOMMENDATIONS FOR THE ELECTRONICS

It is recommended that a fuse be used to protect the electronics as well as mounting two switches, one for the processor board power and a separate switch for motor power (to allow programming without the motors being engaged). A terminal strip can be used to make the power connections and allow for future expansion of the robot. The batteries were wired up with standard RC battery connectors to allow easy exchange and recharging as well as protecting against improperly installed batteries.

If your processor board comes with protoboard space, you might want to consider mounting the board with the protoboard space at the front of the robot for easy mounting of sensors (see figure 6) but keep in mind that the programming port must also be accessible when mounting the board.

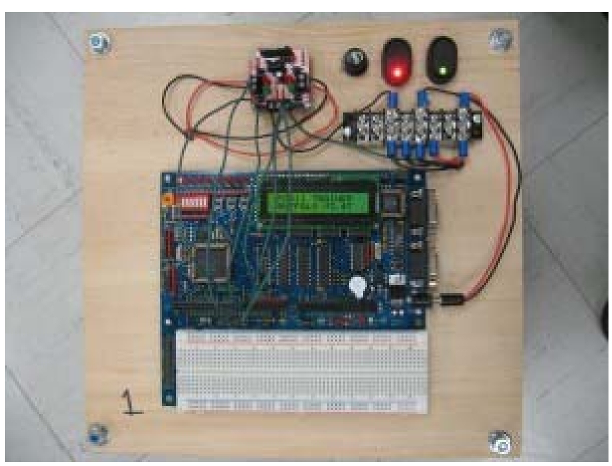


Figure 6 – Suggested Component Mounting

Additional sensors can easily be mounted on the 1"x2" board at the front of the robot's base.

Two 11.1V 2600mAh Li-Ion battery packs in parallel were used to power the robot, but this could vary based on the processor's power requirements. The motor specified is rated at 24VDC / 45 RPM, but runs at approximately 19 RPM (24 feet/min) when powered by 11.1V. Although this is a little slow, there is less chance of a run-a-way robot being damaged at this speed which can be a benefit with students just learning microprocessor interfacing. This battery configuration also allowed the robot to be run continuously for approximately 4 hours so that the batteries would not need to be recharged in the middle of a lab.

The last recommendation for the electronics is to choose an H-Bridge that has separate forward/reverse and on/off control inputs (such as the L298 Compact Motor Driver from Solarbotics Ltd. Listed above). This will allow students to use simple binary outputs to control the robot, but allow the robot's speed to be controlled using Pulse Width Modulation (PWM) later in the semester when the students are more advanced.

Table 2 - Suggested Electronics Parts List

<table>
<tr><th>Description</th><th>Available from</th></tr>
<tr><td>H-Bridge (L298 Compact Motor Driver or similar)</td><td>Solarbotics Ltd</td></tr>
<tr><td>2xLi-Ion 18650 11.1V 2600mAh Rechargeable Battery Pack with PCB Protection and Bare Leads</td><td>all-battery.com</td></tr>
<tr><td>RC Batter Plug</td><td rowspan="7">All Electronics</td></tr>
<tr><td>8 Position Dual Row Terminal Strip</td></tr>
<tr><td>Jumper (for terminal strip above)</td></tr>
<tr><td>Panel Mount Fuse Holder</td></tr>
<tr><td>Fuse (5A)</td></tr>
<tr><td>12v Rocker Switch w/Red Light</td></tr>
<tr><td>12v Rocker Switch w/Green Light</td></tr>
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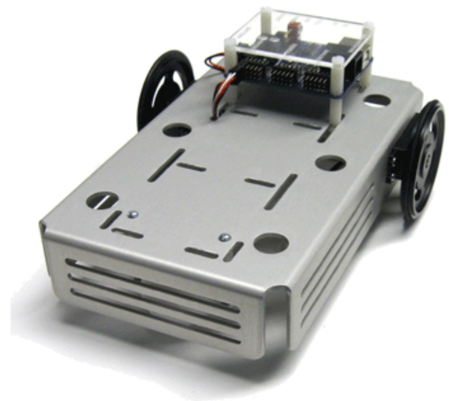
COMPARISON

The robot base described above was constructed at a per-unit cost of just under $50. A survey of similar bases (Table 3) shows that although a number of similar robot bases are available on the market, none are priced below $110.

Each of the bases shown would have met the needs for the class and would be of similar size and speed (except where noted). The commercially available robot bases were well over two times the cost and would need additional mounting hardware, electronics, and additional machining (mounting holes, brackets for sensors, etc).

Table 3 - Robot Bases

 Dale-Robots.com $120 Description: Base (without any electronics) with a 4" caster wheel, two 7" drive wheels & two 12 vdc gear reduction motors. The robot base is made from 1/8" thick aluminum.	 MachineScience.org $110 Description: - Aluminum chassis - Servo motors (2) - Disc wheels (2) - Plastic caster (1) [note: dimensions not available on website]
 Zagrosrobotics.com $169.95 Description: The MAX 97 mobile base platform - Base is 12 in x 12 in - Dual 12 volt 20in-lb torque drive motors - Max speed is 39 feet per minute - Drive wheels are six inches in diameter - Caster wheel is three inches in diameter - Base is balanced with a single rear caster. - A motor driver kit is included with the base - Two free optics are included and can be used for simple pulse encoders - Maximum recommended payload is 35 lbs	 Zagrosrobotics.com $169.95 Description: The MAX 99 mobile base platform - Deck base is 12 inches in diameter - Base has dual 12 volt 20in-lb torque drive motors - Max speed is 39 feet per minute under full load - Drive wheels are six inches in diameter - Caster wheel is three inches in diameter - Base is balanced with two casters - A motor driver kit is included - Two free optics are included and can be used for simple pulse encoders - Maximum recommended payload is 35 lbs.

* robot photos and specifications provided by retailers (see provided links)

The materials used in the commercially available robots might be considered superior to wood, but metal is hard to work and could cause problems when drilled will the electronics attached. Plastic is easier to work with and does not cause problems when worked around electronics but would have to be replaced from time to time due to wear and tear associated with mounting hardware for various experiments. Wood would also have to be replaced, but unlike plastic that is expensive and sometimes hard to find, wood is inexpensive and readily available.

Lastly it has been the experience of the author that students are less intimidated by wood and are more likely to try various sensor locations and mountings on a wood surface than metal or plastic.

CURRICULUM

Preface

The Engineering Technology program at the University of Memphis has two courses on microprocessor technology. The first is to familiarize the students with microprocessor architecture and ASM programming. Our 2nd class is Microprocessor Interfacing and it was this class that made use of the mobile robot.

Lab 1-3

Most interfacing classes start with basic binary input/output. Two experiments were performed using the LED's and DIP Switches built onto the FOX 11 boards (Wytec) used at the University of Memphis.

Lab one was to take input from the DIP Switches and place the same binary pattern to the LED's to familiarize the students with how to read and write to/from ports.

Experiment two was to produce a binary count on the LED's to show the students that any binary pattern could be sent to an output port. During this lab a simple delay routine was also introduced (using the free running counter and polling) to slow down the count.

The next experiment asked the students to turn the time delay routine into a sub routine, then to send pre-determined output patterns to the port. Unbeknownst to the students, these patters were pre-determined to allow the robot to do a very simple pattern based on time. After the lab was demonstrated using the FOX 11 stand alone boards, the students were then asked to run the same code on the mobile robot.

Lab 4-5

After basic input and output, most interfacing classes move on to Analog to Digital Conversion (A2D).

For our first lab using the A2D, a simple PbS cell was connected to the board to allow the A2D to measure light intensity. This was followed by a similar experiment but using two similar circuits to detect two light levels.

Lab 6-7

This lab was a major lab that included knowledge from all the previous labs being intergraded into one system. For this lab, the students were to create a Light Following Robot. Two light sensors were attached to the A2D and then the values were compared determine the robot's direction.

The students quickly discovered that the light sensors would never be equal (this was by design), so lab 7 was assigned to add a dead band that if both sensor were within a given value, the robot was to go straight.

Lab 8-9

For these experiments, the students were introduced to the Input Capture system. They were to program a robot that measured distance using an SR04 Sonar Module (using a dead time loop to produce the pulse to trigger the device and an Input Capture Interrupt to receive the return time of the pulse). After the sonar was working, they were to program the robot to keep going straight until the robot was within approximately two feet of an object then turn in a pseudorandom direction determined by testing to see if the free running counter was even or odd.

Group Project

The end of semester project was to create a line tracking robot. This was presented as a contest to the students with the fastest / most accurate robot receiving bonus points for their efforts. They also had to integrate the sonar sensor so that the robot would stop if the robot came within two feet of an obstacle.

Future Plans

Those who have taught a microprocessor interfacing / microcontroller course will note that there is no experiment for Output Compare or PWM. It was hoped that this would have been the last lab before the group project and that speed control using PWM could have been incorporated into the final project and in future years this will be incorporated into the curriculum.

EVALUATION / CONCLUSION

The mobile robot platform performed quite well throughout the semester and provided an ideal platform for the semester's experiments.

The robot had few mechanical problems except for the o-ring "tire" that would come off if the robot was pushed or pulled sideways, although it was easily replaced.

The robot is sensitive to minor imperfections in the floor and would stop if the front/back ball catches were not adjusted properly, but with the spring and level adjustments, this was only a problem until they were adjusted properly, except on the most uneven of floors.

The curriculum above will only be modified slightly to insure enough time to include PWM and to possibly include more hardware (ie an assignment to build an H-bridge and to build an input conditioning circuit for the A2D input). The group project will probably be expanded, since it was observed that more significant learning took place when it was a contest and not just a laboratory experiment.

Although the robot does not look high-tech, using wood as the primary building material seemed to encourage more experimentation with sensor placement since the material was easy to work with.

Overall the mobile robot was exactly what was needed for the class, was easy to build and was inexpensive to construct.

ACKNOWLEDGEMENTS

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Daniel Kohn is an Assistant Professor of Engineering Technology at the University of Memphis. He has been teaching for nine years and has over thirteen years of industrial experience in the area of computer control and measurement systems.