WOW

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VACUUMS

Design and prototype of the Sucker vacuuming robot

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Abstract

This paper introduces the concept and design of Sucker an autonomous mobile robot designed to avoid obstacles while vacuuming a variety of surfaces. Sucker will incorporate a random movement along with wall following to successfully vacuum a room. Sucker will also monitor his batteries and alert the user that they need to be recharged. Sucker will provide safe operation by avoiding all obstacles including humans, and providing feedback through lights, and actions depending upon it's interaction.

Introduction

I don't believe that there is one person on this earth that enjoys to vacuum. Vacuuming is dirty, repetitive, exhausting, and time consuming. There are many elderly and disabled people that are just unable to vacuum on their own and must rely on outside sources to vacuum their own home. I propose to change that by constructing a full size (picks up real dirt and dog hair) automated vacuum (AV). Many others have made AV cleaners but they all have limitations that make it difficult to replace the present day manual vacuum. Roomba shown in figure 1 is currently the most popular AV, it was designed with the help of the Massachusetts Institute of Technology (MIT) robotics lab and sells for approximately $200.00. That's a great price tag for this system, however it has limitations that hinder it's wide spread use. These limitations include it's not recommended for shag or deep pile carpets, charging takes 8 hours for a 90 minute run time, the average room (14' x 16') takes 50 minutes to vacuum and therefore you almost have to charge it after each use. It doesn't charge itself therefore; the owner must take it to charge. To top it off the worst part of vacuuming, empting the bag still has to be done manually.

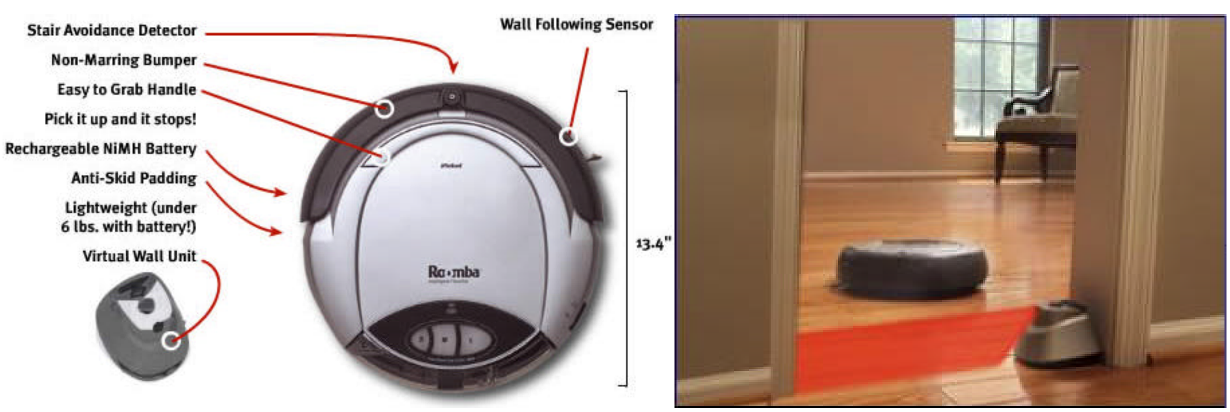


Figure 1: Roomba's anatomy on left and in motion on right utilizing it's virtual wall unit to close off joining rooms.

On the other hand the Karcher Company developed its version shown in figure 2, which is very similar to the Roomba. It even recharges itself and empties its own dirt. But it's not cheep with a price tag of $2000.00. This little baby has been hard to find and it might not be available in the USA any longer.

Figure 2: The Karcher AV good looking and pricey too boot.

There has been many other AV built and sold however these two are in the top of their class. Keep in mind that these machines will work well if you have a conducive environment, but if you're like me and have two dogs and thick plush carpet you need a monster vacuum. My goal is to combine sensors onto a larger platform that can manage a full size vacuum and intelligently vacuum my home. It will roam around a room sucking up any dust or dirt on the floor. It avoids any obstructions in the room (walls, chairs, people), and when it gets low on battery power, it alerts the operator via lights and tones. It can be left alone to do this all day long, or can be switched on at night to clean your floors while you sleep, and stay out of your way.

Integrated System

The Suckers brain is a RCM3000 RabbitCore micro controller mounted on a prototype development board. This chip requires 3.3 Volts in for operation and has 512K Flash and 512 SRAM, 10Base Ethernet port, 52 digital I/O (44 configurable, 4 fixed in, 4 fixed out), 4 PWM channels, real time clock, watchdog, input capture, and a Quadrature decoder. A sixteen A/D multiplexer will be used for the analog inputs. An IR ranger and an Ultrasonic Ranger will be mounted together on servo actuated pan and tilt system in order to acquire surrounding data. Bumper sensors will surround the platform to sense the presence of an obstacle and get close to walls and furniture. Special circuitry will be used to monitor the battery voltage and alert the operator. A block diagram of this system can be seen in Figure 3.

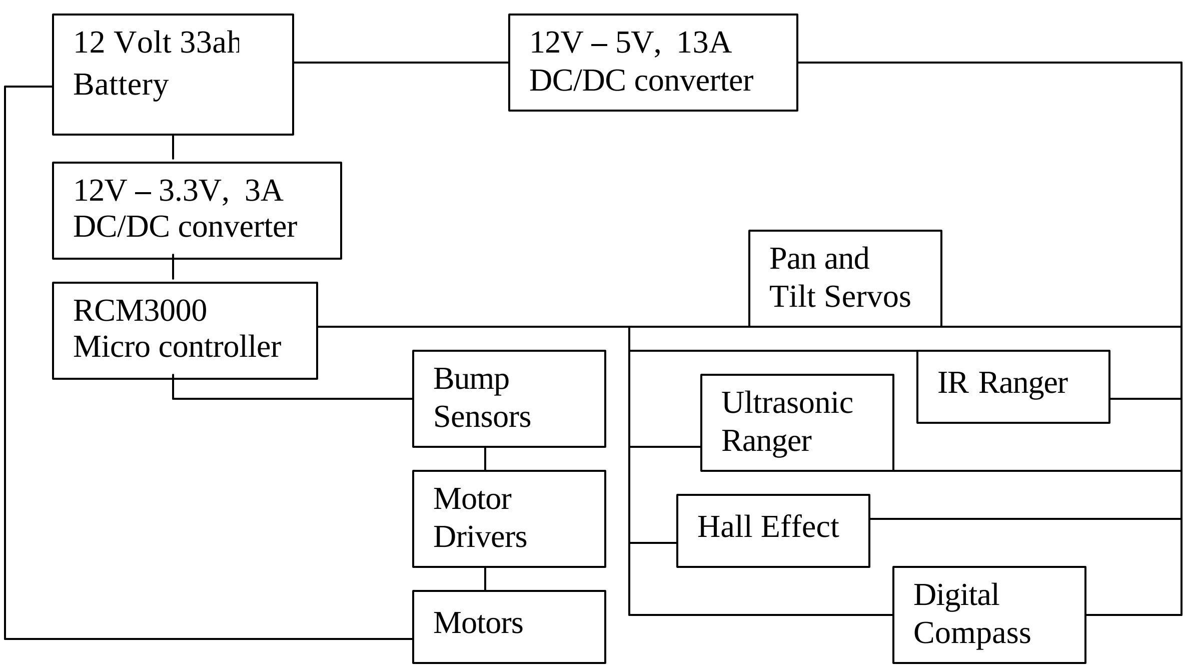


Figure 3: System block diagram of the general control and power structure.

Mobile Platform

The platform will be constructed from 0.5" steel square tubing see figure 4. This tubing will be welded together to form a strong and rugged chasse. This platform will be in a square design for mounting, ease of welding and prototyping. The end product may adapt a cylindrical body to optimize mobility. Please see appendix for more pictures.

Figure 4: Square steel to be used for platform.

Actuation

The chasse will be actuated by two 12 Volt motors taken from a kids motorized car. Two independent motors provide skid steering and therefore no other steering mechanism is needed. Two 10" diameter pneumatic wheels will be used for locomotion. To attach the wheels to the motors new brass bearings, aluminum sleeves and plastic housings needed to be machined as shown in figure 5.

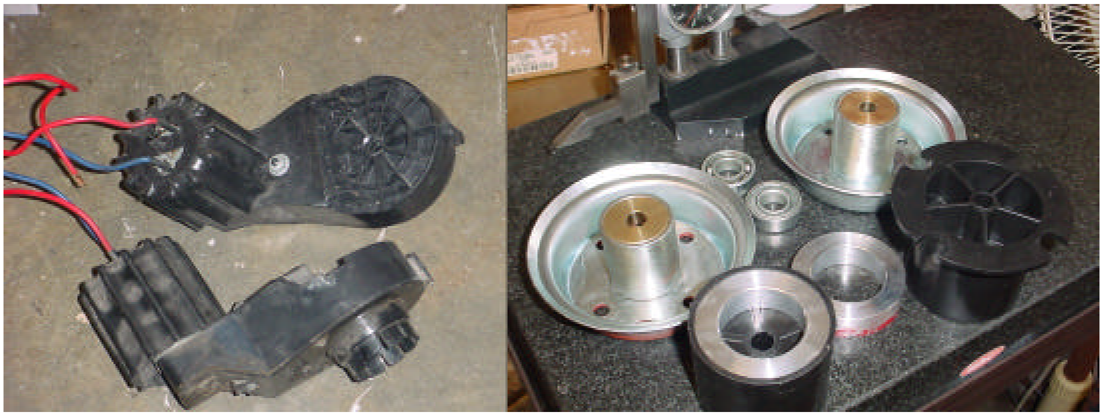


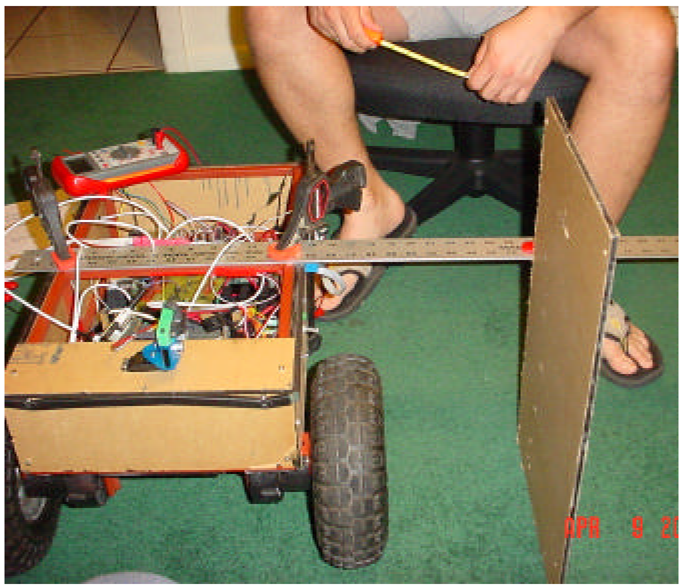
Figure 5: Motors on left and machined bearings, sleeve, and housing on right.

Sensors

Table 1: Sensor and actuator data

Qty	Sensor/Actuator	Range	Precision	Function	Location	Vcc (V)	Icc Max (mA)	Rec	Unit Price	Total Price
1	Sharp GP2D12 Infrared Ranger	4 – 30”	N/A	Close Obstacle Avoidance	Top Front	4.5-5.5	50	X	$13.50	$13.50
2	Sharp GP2D120 Infrared Ranger	1.5 – 12”	N/A	Wall Following	Right Side	4.5-5.5	50	X	$13.50	$27.00
1	Devantech SRF04 Ultrasonic	.125-118"	N/A	Obstacle Avoidance	Top Front	5	50	X	$30.00	$30.00
2	SD100401 Hall Effect	Depends on mag-field	N/A	Velocity Feedback	Next to drive wheels	4.75-24	17	X	$36.18	$72.36
1	Current Sensor	0-10Amps	N/A	Monitor current	Daughter board	5	10,000	X	$0.50	$0.50
1	Voltage Monitor	0-16 Volts	N/A	Monitor Voltage	Power board	12	N/A	X	$0.50	$0.50
1	TCM2-50 Digital 3-axis compass	N/A	(+/-) 1.0 deg	Provide Pitch, Roll, and Yaw	Inside center	5	20	X	$769.00	$769.00
8	Omron EE-SX460-P1	N/A	N/A	For bump sensing	Bump Sensor	5	30	X	$1.00	$8.00
1	Standard Servo	N/A	N/A	Pan	Top Front	5	3	X	$12.00	$12.00
2	DC motors	N/A	N/A	Actuation	Left/Right	12	1500	X	$15.00	$30.00
2	D100-B25 H-Bridge	N/A	N/A	Motor Control	Inside center	5	Variable to 2500	X	$28.00	$56.00

All these sensors had to be calibrated, the IR's were calibrated by measuring out different distances and recording the digital output. The I put it in excel and fit it to a curve so that I could get a function that would input the digital signal and output an accurate distance. As you can see in figure 6 the best fit was a power curve. All outher sensors were similar and data can be found in the appendix.



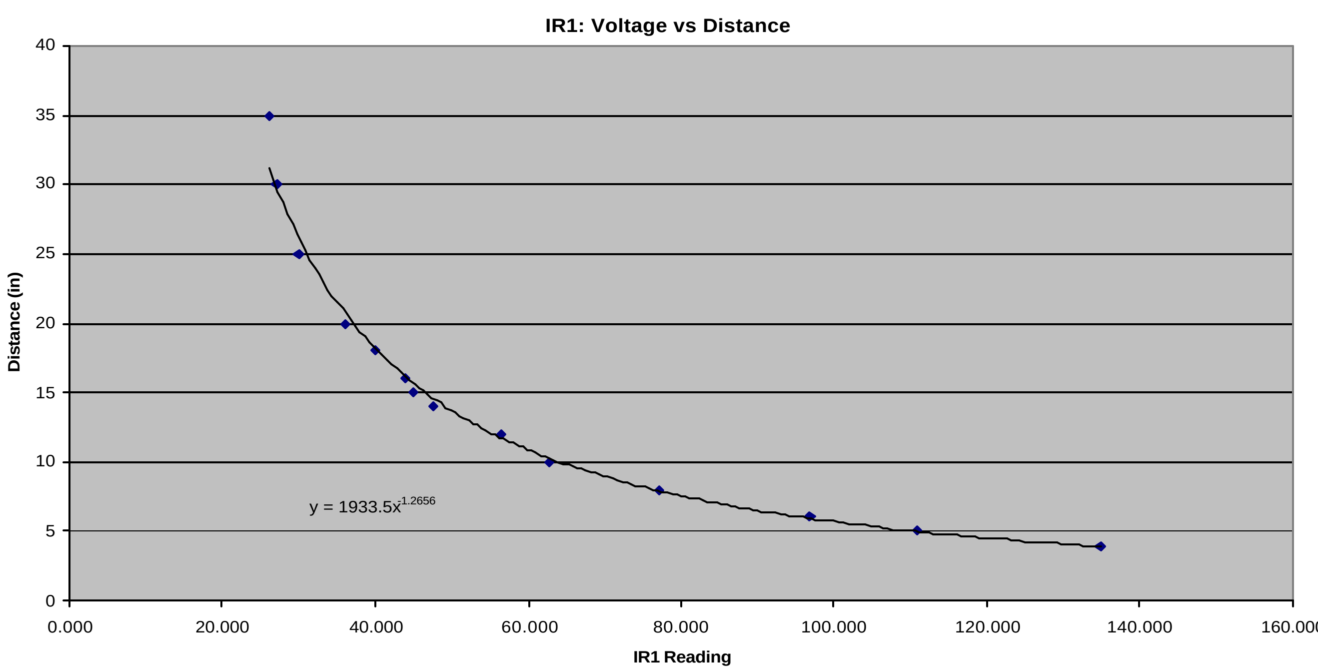


Figure 6: Motors on left and machined bearings, sleeve, and housing on right.

Behaviors

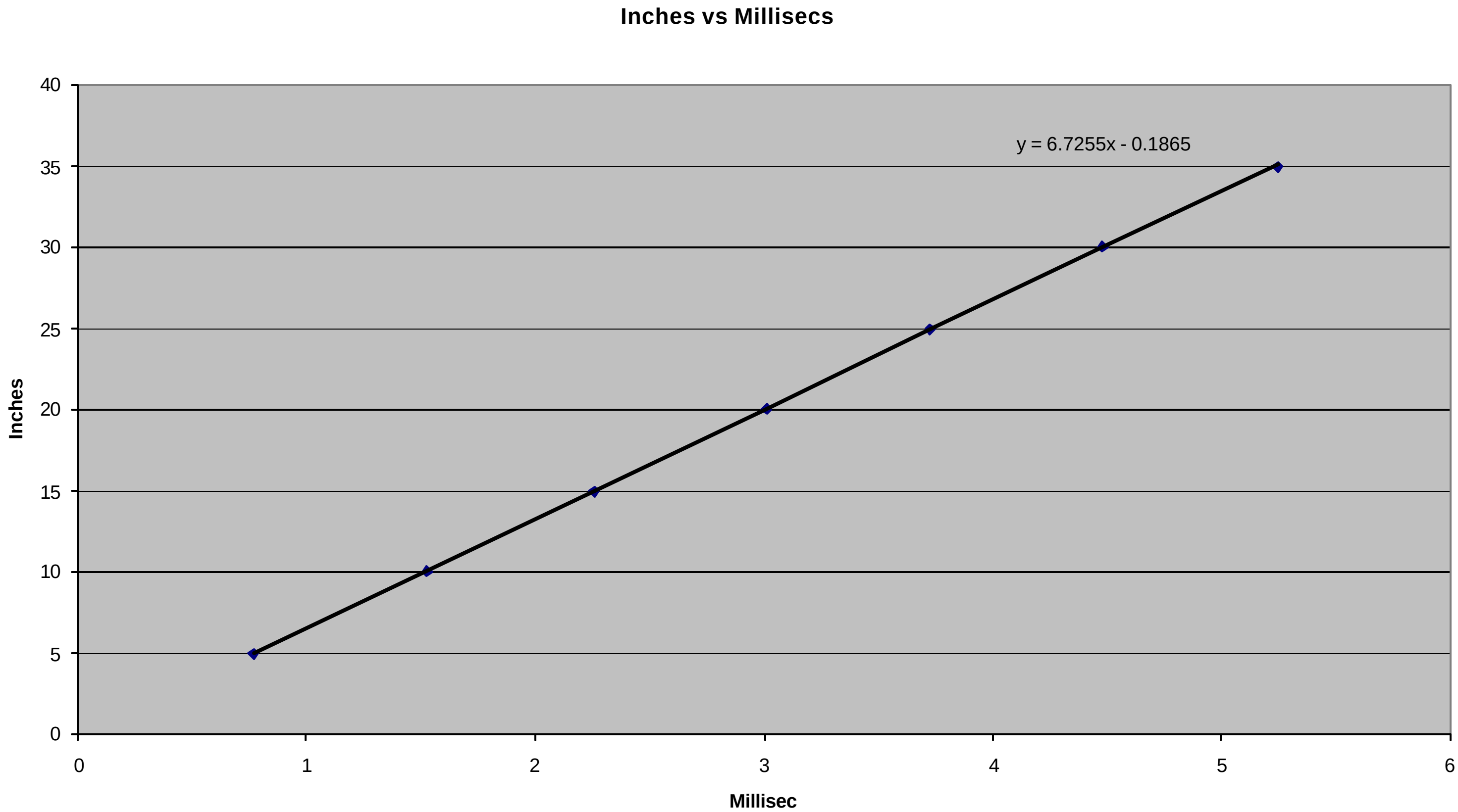
Several behaviors will be incorporated and I am sure that I will add onto this list continually. I currently employ wall following, random pattern, and of course general obstacle avoidance. The trick will be to get close enough to all obstacles so that the vacuum cleaner can do a good job. Other behaviors to add at a later date will be self-charging, where it located the charging station once batteries reach a pre determined level. Special behaviors for hard flooring versus carpet and finally how to handle pets will also be of interest.

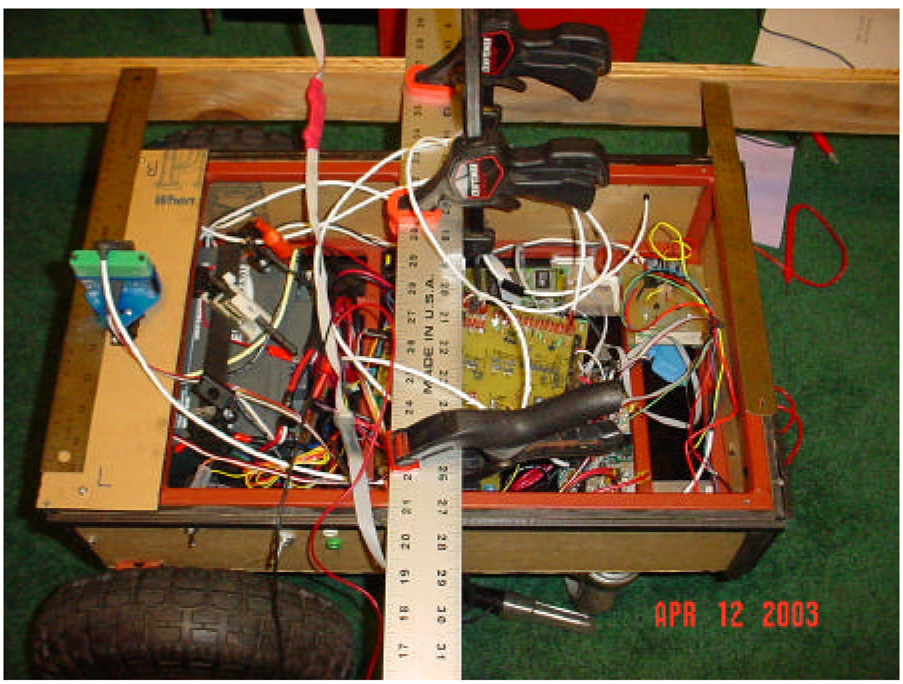
Conclusion

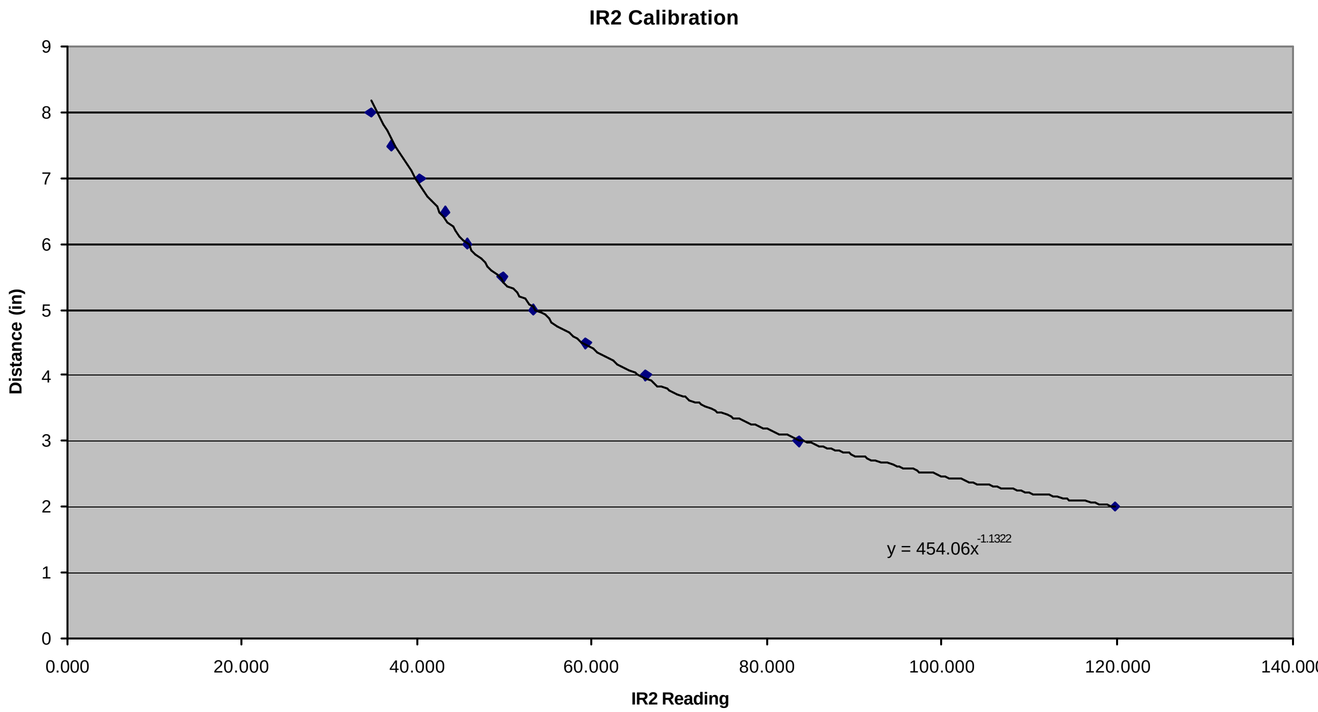
By incorporating today's technology by way of sensory information and high level programs Sucker will be an intelligent mobile platform that can effectively vacuum an entire house with minimal effort form the user and eventually none.

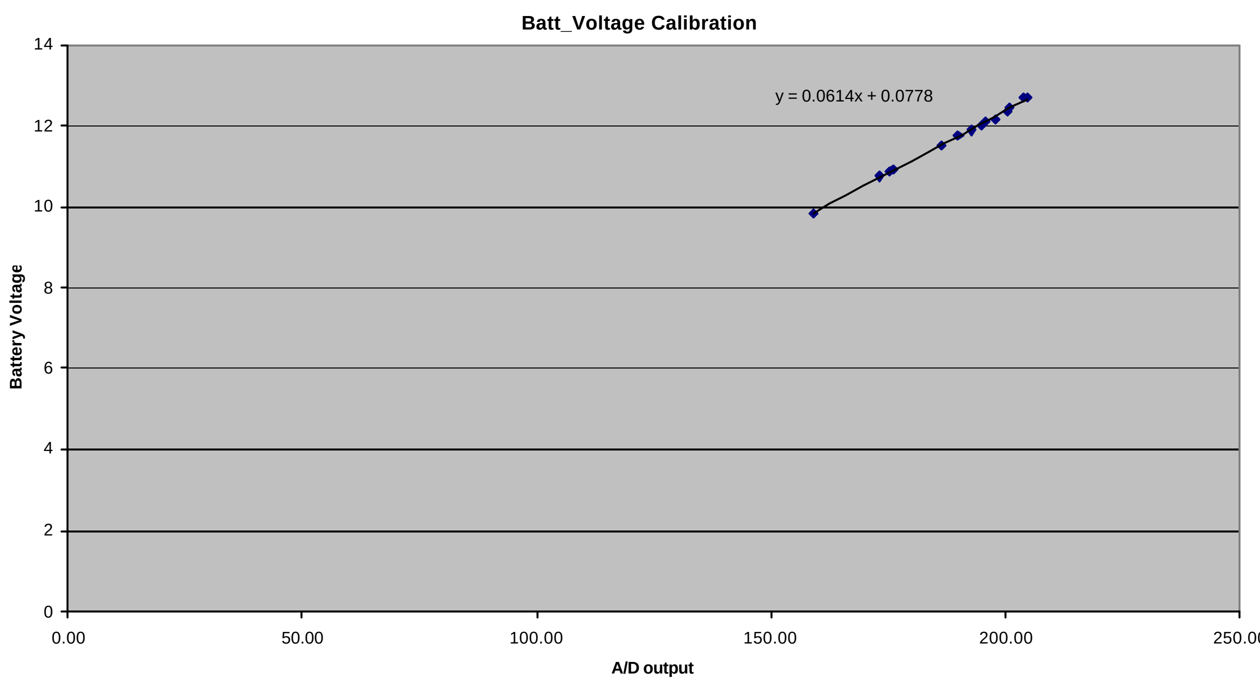
Appendices

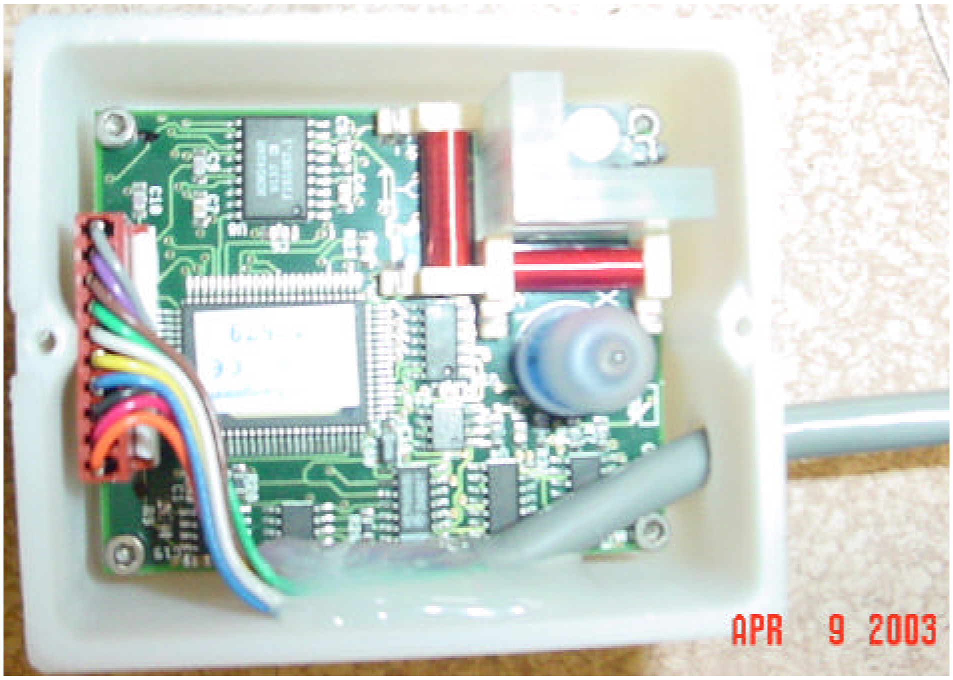
Appendix A: Components and calibration






IR2 Calibration
Distance (in)
9
8
7
6
5
4
3
2
1
0
0.000
20.000
40.000
60.000
80.000
100.000
120.000
140.000
IR2 Reading
y = 454.06x-1.1322


Batt_Voltage Calibration
Battery Voltage
14
12
10
8
6
4
2
0
0.00
50.00
100.00
150.00
200.00
250.00
A/D output
y = 0.0614x + 0.0778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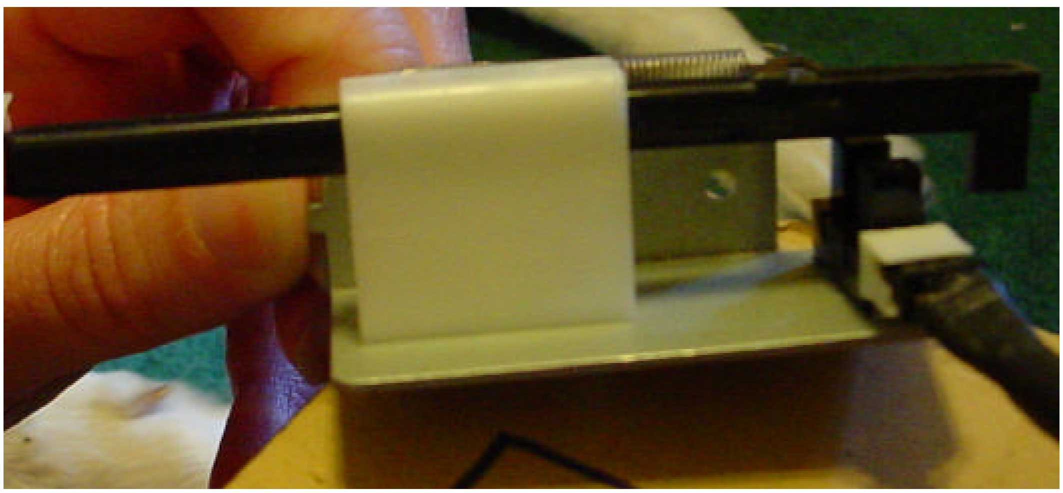
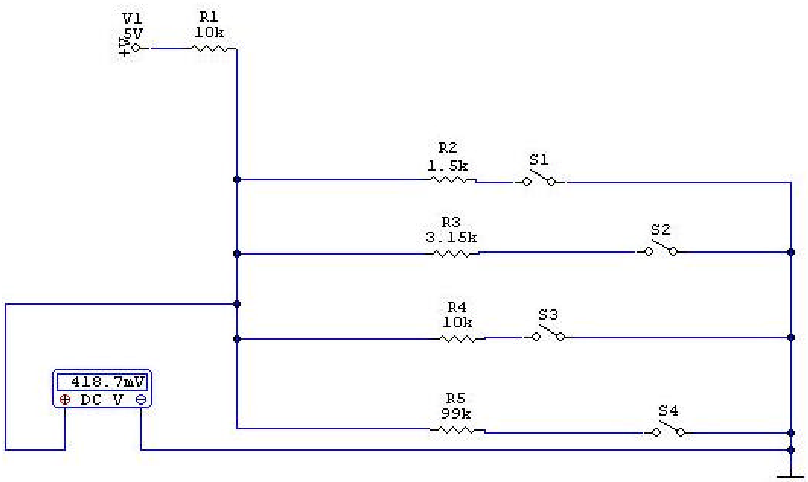
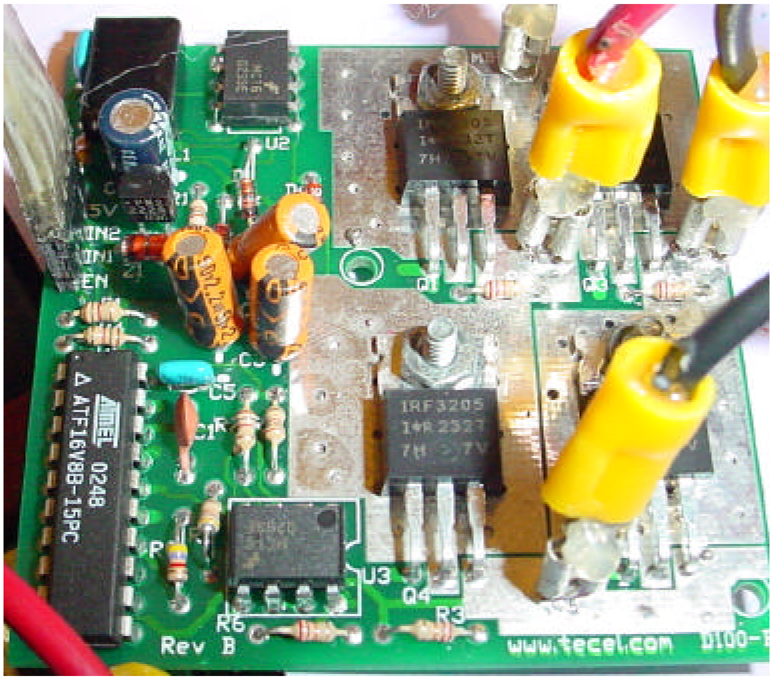



V1
5V
+V
R1
10k
R2
1.5k
S1
R3
3.15k
S2
R4
10k
S3
R5
99k
S4
418.7mV
DC V


ATMEL
ATF16V8B-15PC
0248
IRF3205
Rev B
www.tecel.com
U2
U3
Q1
Q3
Q4
R3
R6
C1
C5
IN2
IN1
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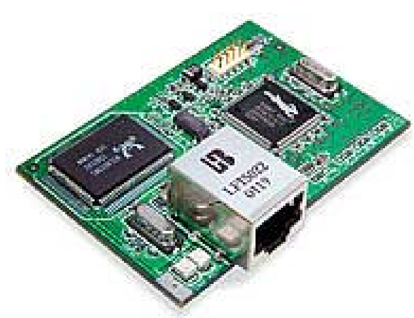
Sample of Code and Library

See end of report.

Appendix B: Partial Component Data Sheets

RCM3000 RabbitCore

Model RCM3000, RCM3010



The RCM3000 RabbitCore is Z-World's most powerful and feature-packed microprocessor core module. Powered by the new Rabbit 3000™—the "EMI-Free microprocessor"—the RCM3000 is the ideal option for designers who want to rapidly develop and implement embedded systems with fully integrated Ethernet connectivity.

Measuring only 2.73" × 1.85" (69 × 47 mm), the RCM3000 operates at 3.3 V (with 5 V-tolerant I/O) and features 6 serial ports. Built-in low-EMI features, including a clock spectrum spreader, help designers eliminate the kind of emissions-related problems that frequently derail tight development schedules.

Available in two models, the RCM3000 is equipped with 10Base-T Ethernet, up to 512K each of Flash and SRAM, quadrature encoder inputs, PWM outputs, and pulse capture and measurement capabilities. Two 34-pin connection headers provide 52 digital I/O shared with the 6 serial ports and alternate I/O features. The integrated Ethernet port allows instant local or worldwide connectivity. (The RCM3000 is pin compatible with the non-Ethernet RCM3100, facilitating cost-effective implementation of both Ethernet and non-Ethernet systems).

The RCM3000 features a battery-backable real-time clock, glueless memory and I/O interfacing, and ultra-low power "sleepy" modes. A fully enabled slave port permits easy master-slave interfacing with another processor-based system, and an alternate I/O bus can be configured for 8 data lines and 6 address lines (shared with parallel I/O). The Rabbit 3000 processor's compact, C-friendly instruction set and high clock speeds produce exceptionally fast results for math, logic, and I/O.

Features

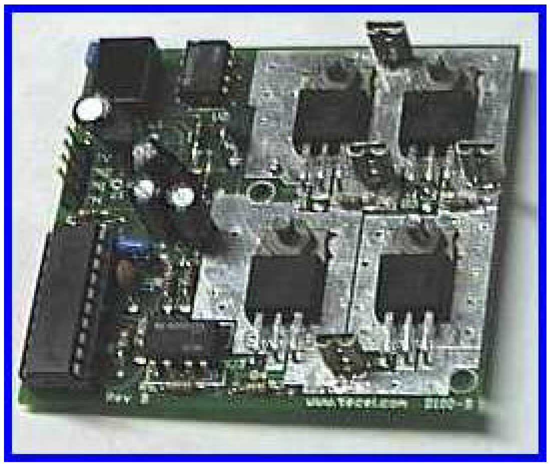
- 3.3 V operation
- Powerful Rabbit 3000™ microprocessor
- Low-EMI (typically <10 dB µV/m @ 3 m)
- Built-in Ethernet for simplified connectivity
- Up to 512K Flash/512K SRAM
- 52 digital I/O
- 6 serial ports (IrDA, SDLC/HDLC, Async, SPI)
- Ultra-low power "sleepy" modes

D100-B25 Features:

- **Power Semiconductors: Four 110A MOSFETS**
- **Rated Current: 25A with on-board heatsinks**
- **Max Current: 110A with Optional Heatsinks**
- **Surge Current: 40A for 5 Seconds**
- **Board's Size: 2.5" x 2.5" (6.35cm x 6.35cm).**
- **Components Type: 100% Solid State, NO Relays**

Voltage Requirements:

- **5 Volts for the Digital and MOSFET Bias Circuits**
- **Any voltage up to 55 Volts for the Motor B+**



The D100-B25's control truth table is 100% compatible with the popular L293D motor driver IC.

Input Lines Truth Table:

Enable	IN1	IN2	Action
H	L	L	Fast Motor Stop
H	L	H	Forward
H	H	L	Reverse
H	H	H	Fast Motor Stop
L	X	X	Free Running Motor Stop

If needed, the enable line can be tied to the 5 volts B+, the motor can still be controlled with the 2 direction input lines.

For motor speed control, Pulse Width Modulation (PWM) is fully possible with the D100-B25. The PWM signal is usualy applied at the EN line.

PLEASE NOTE:* *The only drawback for the D100-B25 is its PWM frequency response of only 1Khz.
But at $28.00 each, we belive that you're still getting your money's worth.

About the Voltage Requirements:

Most DC motor driver boards are advertised as 12, 24 or even 48 volts. That means that if you buy a board rated for 24 volts, it won't work on 12 volts and if you try to run it on 48 volts, it might be destroyed.

Not the D100-B25, the D100-B25 can be used on applications where the motor B+ can be of ANY voltage between 0 and 55 volts. The user will then use a motor rated just right for the applied voltage. If a motor of a lower rating than the motor B+ is to be used, the voltage to the motor can be brought down by pulse width modulation.

Besides the Motor B+, the D100-B25 requires a regulated 5 Volt supply for 2 reasons:

1) For the on board digital circuitry. We figured this should pose no problem, since all digital and microcontroller circuits, which we believe, will be used in conjunction with the D100-B25, are powered by a regulated 5 Volt supply.

2) The on board DC-DC converter. This circuitry generates 3 independent 10 volt supplies for the purpose of supplying the MOSFET's gates with 10 volts no matter what the motor B+ is at in the range of 0 to 55 volts.

So you can, just by example: Safely power a 6 volt DC motor at 10 amps, without worring about biasing the MOSFETs at 10 volts, since that is taken care of by the on board circuitry, powered by the 5 volt supply that you have to have anyways to power your other digital or microcontroller boards.

Upon purchassing the D100-B25 or any of our 8051 based boards, request from us an example to control speed and direction using the P500, F100, T1 or the S100.

D100-B25 MOSFET Characteristics:

RDs = 0.008ohm
ID = 110A
Operating Temperature: 347° F (175 °C)