

# Technical Report for EE595 Fall 1998

Report by: Eric D. Blom

Advised by: Dr. Janet K. Lumpp

## Introduction

Sensorimotor control is an exciting area of research in which methods are devised to directly control the movement of an object from sensory level outputs. The details of how this is done and the current research in this field are outside the scope of this paper. However, the important concept to remember is that the majority, if not all, of the control structures necessary to activate movement of the object are located on the sensor plane.

Sensory motor control research at the Distributed Microsystems Laboratory uses CMOS prototyping services from MOSIS to fabricate integrated circuit chips with monolithic sensors, sensor processing, and motor control circuits. These chips are designed for mobile tracking applications where the chip is mounted on a motorized mobile platform. Because of the limitations of the CMOS process used and practicality issues, a device capable of sourcing the large currents needed by the motors of the mobile platform is needed. The design and construction of an interface board connected between the sensorimotor control chip and the mobile base are discussed here. This interface board's primary function is to source the currents necessary to drive the mobile platform's motors based on control signals from the sensor board located on the mobile platform. It is the responsibility of the sensor board to control the speed of the motors by using Pulse Width Modulation (PWM) to change the average power delivered to the motors.

## Conventions

To communicate about the mobile platform it is necessary to set a few conventions explicitly.

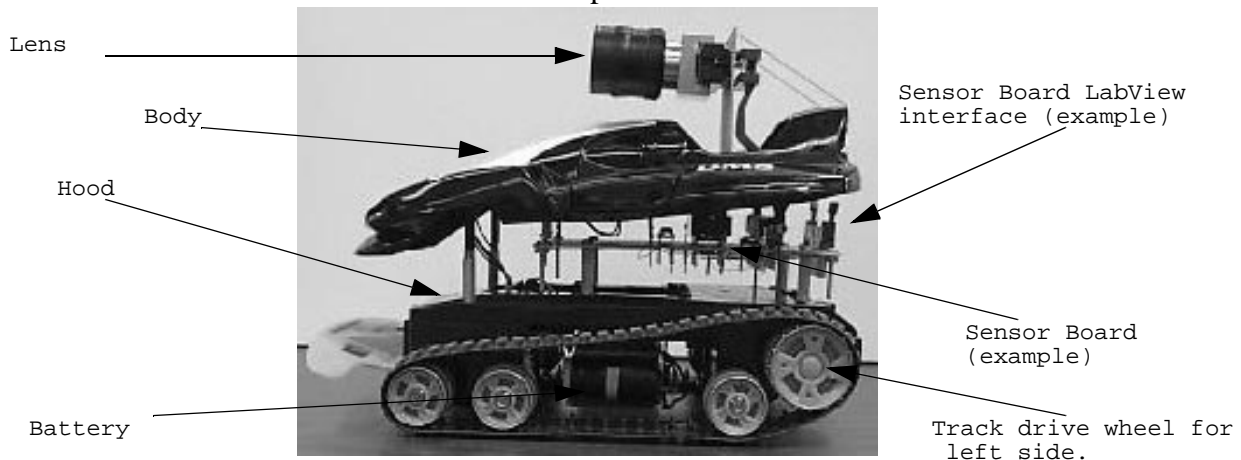
- Left and right are the mobile base's left and right. To make your left align with its left, position yourself behind the mobile base with the front of the vehicle farthest away from you. Now your left is the same as the mobile platform's left.
- Motor rotation is determined by looking towards the motor from the output shaft side. When looking at the output shaft head on rotation towards the right is clockwise and rotation towards the left is counterclockwise. Clockwise rotation produces forward motion. Counterclockwise rotation moves the mobile platform backwards.

## Interface Board: Introduction

The interface board is a printed circuit board (PCB) located on the mobile platform. It is a general purpose interface intended to provide the following services to the sensor board (located on the mobile platform).

- Power supply for sensor board.
- Independent control of the two mobile platform's DC permanent magnet motors.
- Independent selection of rotational direction for two mobile base motors.

These services are accessed through a ten conductor ribbon cable connected between the sensor board and the interface board. In addition to services provided to the sensor board, the interface board must also connect to the battery power supply and motors. The interface board is the junction box for all other electronics on the mobile platform.



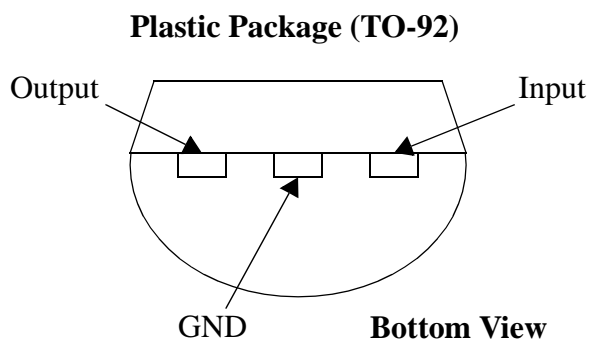
**Figure 1: Example Completed Sensorimotor platform.**

This figure indicates the major points of interest on the mobile platform. This picture shows the platform with a sensor board mounted and supporting optics for this visual tracking application.

### Interface Board: Design

The design of the interface board involved selecting components for two subsystems: voltage regulation, motor drivers. Voltage regulation is necessary because the battery pack used with the mobile platform is inherently variable and the motors of the mobile platform require a higher voltage than the typical sensor boards that will be used with the mobile base.

A fixed voltage regulator (National Semiconductor LM78L05ACZ) was chosen for this application. This regulator is a three terminal device that only requires one additional external component. A capacitor is connected from the output to ground. This capacitor limits high frequency noise that may be caused by load variations (transitions in digital logic lines). The output of the regulator is guaranteed to be between 4.25 and 5.25 volts DC. The one disadvantage of the voltage regulator is that it requires a higher input voltage than its five volt output in order to work properly. For this device the minimum input voltage is 7 volts. A labeled drawing of the voltage regulator may be found in Figure 2.



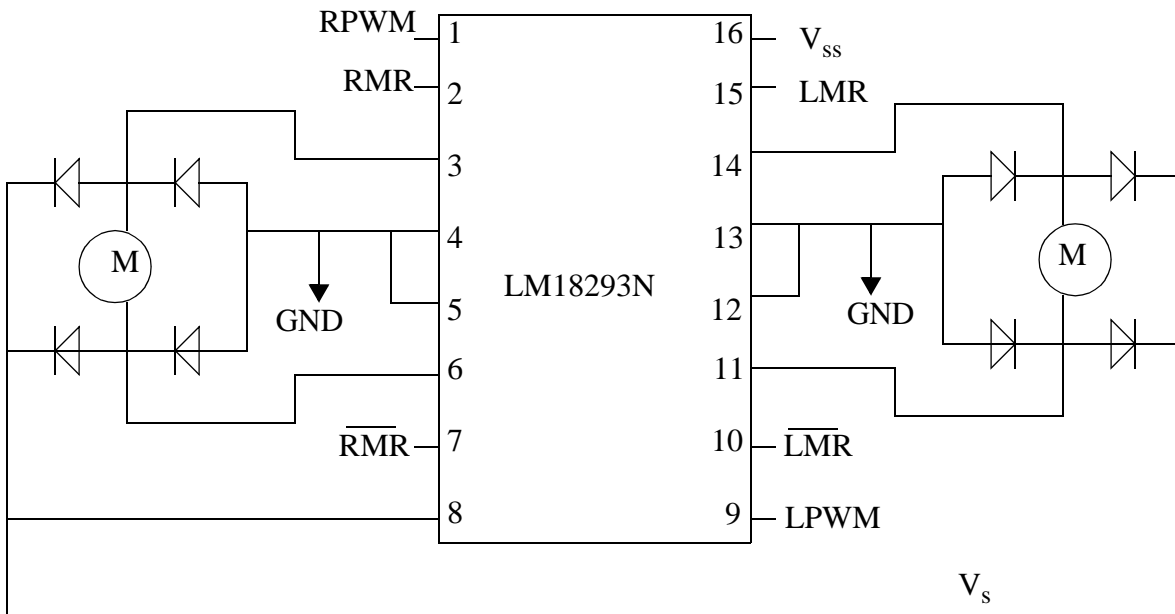
**Figure 2: Voltage Regulator.**

The fixed output, 5 volt regulator used on the interface board is simple to use. The pin out is show to the left. Additional information about the device may be found in the National Semiconductor data sheet included in the appendix.

The other subsystem on the interface board is the motor driver. This subsystem's primary purpose is to act as an amplifier so that the low current sourcing output of the sensor boards may control the high current drawing motors of the mobile platform. This is accomplished by using a low current digital signal applied to the enable line of motor driver IC (National Semiconductor LM18293N). A schematic of the motor driver in this application is shown in Figure 3.

How these digital control lines are used is completely up to the designer of the sensor board. However, as an example, the following information is given. Using the digital motor on/off lines the sensor board can turn the motors on and off. If this is done quickly enough in a periodic fashion, the duty cycle of the signal will determine the speed at which the motor runs. To create such a signal, integrated circuit chips have been made in the DMS lab that have built in oscillators whose duty cycle is variable. Depending on what the circuit senses it will vary the duty cycle of the two on chip oscillators (one for each motor) to determine the speed of each motor and thus where the mobile platform will go.

NOTE: The National Semiconductor 4-channel push pull driver (LM18293) will no longer be available after September 8, 1998. Although it has not been verified, the NTE1749 is believed to be a suitable replacement for the LM18293. NTE Electronics Inc. is not an electronics manufacturer, therefore, it may be that National Semiconductor is supplying their chips and they will also run out of stock soon. NTE would not answer questions as to the future availability of parts or identify their suppliers.



**Figure 3: Motor Driver Schematic**

This schematic shows the configuration of LM18293 (motor driver chip), supporting components, and motors. Additional information regarding the LM18293 is available in the National Semiconductor data sheet included in the appendix of this document.

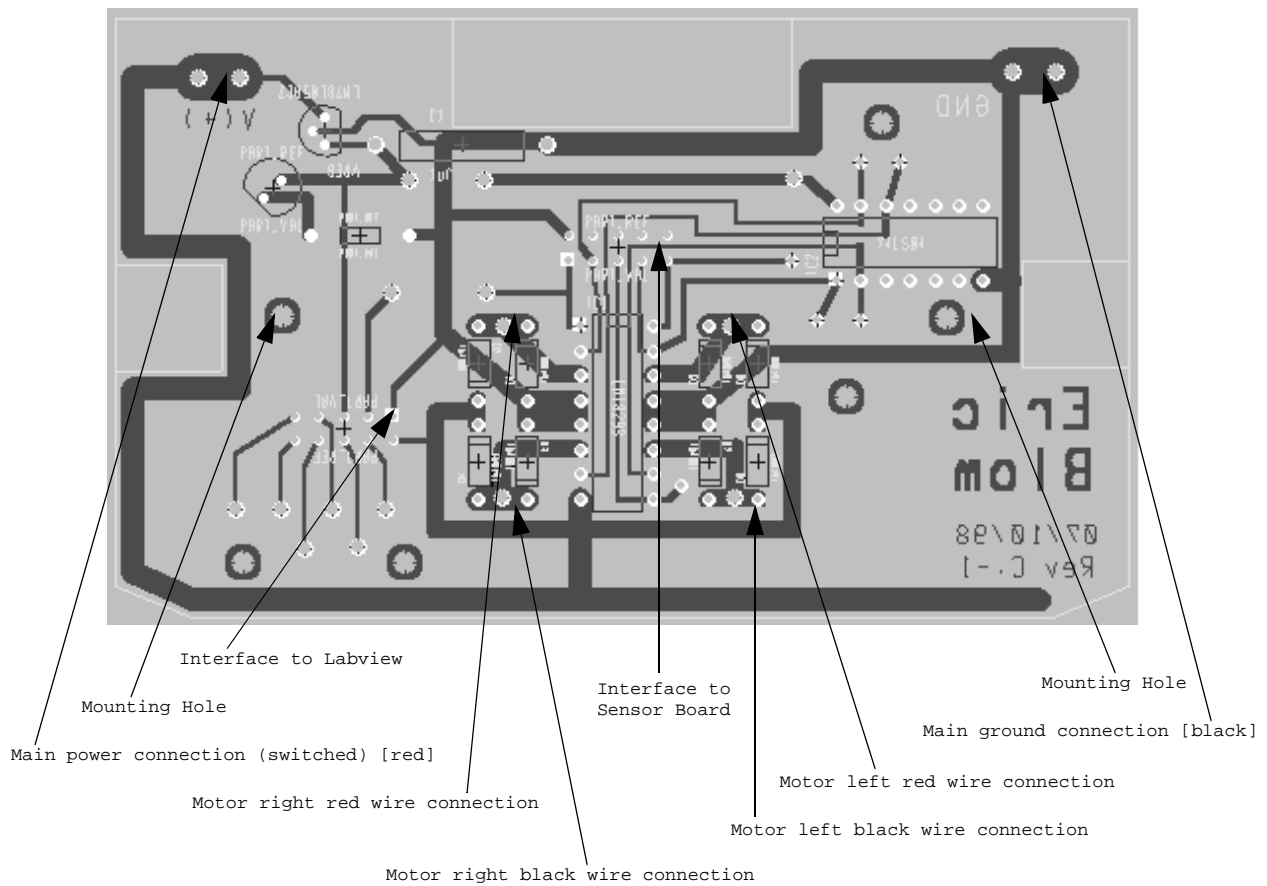
## Printed Circuit Board Description

The functions of the interface board are all implemented on a Printed Circuit Board (PCB) located in the front of the mobile platform under a black plastic plate (the hood) held down with three screws. A labeled drawing of the PCB is shown in Figure 4 with the important connections labeled. This drawing is of the PCB metal traces and the component outlines, it is a top view as if you were looking down on the component side of the PCB, not the metal trace side of the PCB. For information on component placement please refer to the enlarged component diagram in the appendix.

Power and ground for the board are located in the upper corners as labeled in the drawing. The ground wire (black wire) comes directly from the battery connector. Located next to the solder joint where the ground wire connects to the PCB is a pin suitable for a miniature hook (test clip) used during testing of the board. The positive voltage connection (red wire) is located on the other side of the PCB and also has a soldered wire and a test pin. However, this red wire comes from the back of the mobile platform where a switch is located to turn the power to the PCB on and off. Another red wire runs from this switch back to the front of the car to the battery connector. When the hood is off the mobile platform, you can see this red wire near the ground pin.

Connections to the two motors in the mobile platform are also made with red and black wire (the only colors available). The black wire for each motor runs from the PCB back to the motor. While the red wire runs from the PCB to a switch located on the side of the mobile platform and then to the motor. The purpose of the switches is to enable the user to turn off the motors while bench testing without disrupting any other mobile platform operations.

The final two connections on the PCB are for the LabView interface and the sensor board interface. The sensor board interface is located near the top center of the board. It is a blue header with lock/eject hooks. The socket that goes in this header only fits one way. A polarizing key on the socket that goes into the header should make it clear which way is correct. The pin out of this connection is described in Table 1, later in this document. The LabView interface is similar to the sensor board interface without the blue header connection. The LabView interface is intended to be used less frequently and is therefore not accessible when the hood is on the mobile platform (you have to lift the hood to check the performance). Because there is no header on the LabView interface that limits the mechanical fit with the ribbon cable socket, one must be careful to ensure that the interface cable is connected correctly. Pin one of the labview interface has a square pad. The Labview interface's orientation is rotated 180 degrees from that of the sensor board interface. The signals available for each pin of the LabView interface are described in Table 2 later in this document.

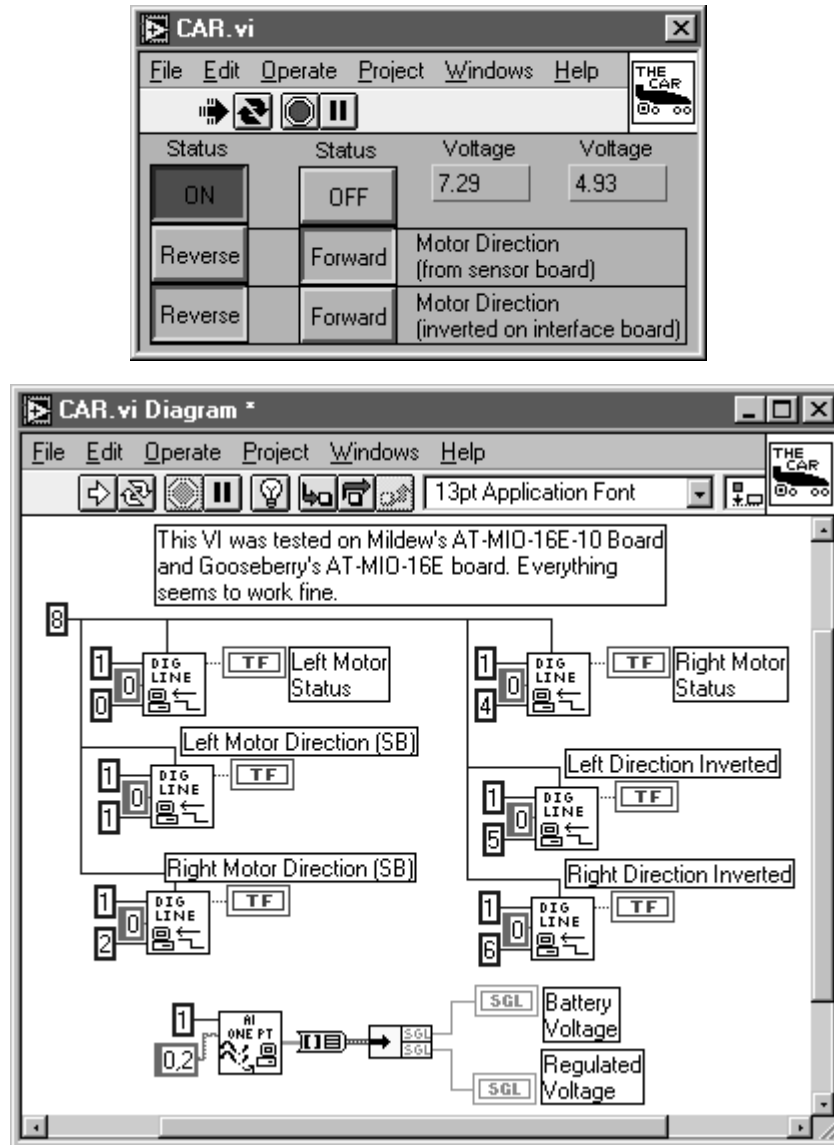


**Figure 4: PCB Layout (interface board)**

This drawing of the PCB pattern shows the important connections between the interface board and other devices. All colors in the drawing are copper except for the gray background, purple package outlines, blue alignment markers, and yellow labels.

## LabView Virtual Instrument

A LabView Virtual Instrument (VI) was created to test the interface boards made and to aid in future use of the mobile platform. The VI (Figure 5) displays the status of the motors including direction. The battery voltage and regulated voltage may also be monitored with this VI.



**Figure 5: LabView VI**

The front panel of the car.vi allows the users to monitor all of the functions of the interface board. This VI may also be used to monitor the output of the sensor board connected to the interface board. Because of the opportunities for loss the design for the VI has been included in the form of a screen capture in addition to a computer files on a diskette.

**Table 1: Definition of Sensor Board Interface by Header Pin Number (HDR1)**

Pin Number	Description of Signal
1	Pulse Width Modulation control of right motor. This control line accepts a digital signal that when high will turn off the right motor and when low will turn it on.
2	GND. The ground line for the sensor board is connected directly to the negative terminal of the battery power supply.
3	Direction control of the right motor. This control line accepts a digital signal that when low, will cause the right motor to run clockwise causing forward motion on the right side. When this signal line is high it will reverse the direction of the motor and cause the right side to move backward.
4	No connection.
5	Pulse Width Modulation control of left motor. This control line accepts a digital signal that when high will turn off the left motor and when low will turn it on.
6	No connection.
7	Direction control of the left motor. This control line is a accepts a digital signal that when low will cause the left motor to run clockwise causing forward motion on the left side. When this signal line is high it will reverse the direction of the motor and cause the left side to move backward.
8	No connection.
9	Vdd. A regulated 5 volt supply is provided to the sensor board via this pin. It has a maximum current sourcing capability of 95 mA. The tolerance for this supply is +/- 0.25 volts.
10	No connection.

**Table 2: LabView Interface Pin Out**

Pin Number	Description of the Signal
1	Analog ground
2	Voltage on battery with respect to analog ground ( $V_{bat}$ )
3	Right motor control (high on / low off)

**Table 2: LabView Interface Pin Out**

<b>Pin Number</b>	<b>Description of the Signal</b>
4	Left motor control (high on / low off)
5	5 volt regulated supply with respect to analog ground
6	Direction control for left motor, inverted from sensor board input (pin 7)
7	Direction control for left motor from sensor board
8	Direction control for right motor, inverted from sensor board input (pin 9)
9	Direction control for right motor from sensor board
10	Digital ground (connected to analog ground, pin 1)

Table 3, Table 4, and Table 5 list the connections between the sensor board interface and the two DIP ICs on the interface board. These tables are provided to aid in trouble shooting should it be necessary.

**Table 3: Connections to Sensor Board Interface Header (HDR1)**

<b>Part Reference-Pin</b>	<b>Connected to</b>	<b>Part Reference-Pin</b>
HDR1-01	Enable for Outputs 1 and 2	IC1-01
HDR1-02	GND	NA
HDR1-03	Input 1, Inverter 6	IC1-02, IC2-13
HDR1-04	No Connection	NC
HDR1-05	Enable for Outputs 3 and 4	IC1-09
HDR1-06	No Connection	NC
HDR1-07	Input 4, Inverter 1	IC1-14, IC2-01
HDR1-08	No Connection	NC
HDR1-09	Vss, Vdd	IC1-16, IC2-14
HDR1-10	No Connection	NC

**Table 4: Connections to 4 Channel Push Pull Driver (IC1)**

<b>Part Reference-Pin</b>	<b>Connected to</b>	<b>Part Reference-Pin</b>
IC1-01	Right motor on/off control line	HDR1-1
IC1-02	Right motor rotational direction control line	HDR1-3, IC2-13
IC1-03	Right motor, output 1	Right motor V(-)???
IC1-04	GND	NA
IC1-05	GND	NA
IC1-06	Right motor, output 2	Right motor V(+)???
IC1-07	Right motor rotational direction control line	IC2-12
IC1-08	Vs (main push pull driver supply)	V(+) Battery
IC1-09	Left motor on/off control line	HD1-5
IC1-10	Left motor rotational direction control line	IC2-2
IC1-11	Left motor, output 3	Left motor V(+)???
IC1-12	GND	NA
IC1-13	GND	NA
IC1-14	Left motor, output 4	Left motor V(-)???
IC1-15	Left motor rotational direction control line	HDR1-7
IC1-16	Vss (logic supply for push pull driver)	V(+) Regulator

**Table 5: Connections to Hex Inverter (IC2)**

<b>Part Reference-Pin</b>	<b>Connected to</b>	<b>Part Reference-Pin</b>
IC2-01	Left motor rotation direction control, input 4	IC1-15
IC2-02	Left motor rotation direction control, input 3	IC1-10
IC2-03	No connection	NC
IC2-04	No connection	NC
IC2-05	No connection	NC
IC2-06	No connection	NC

**Table 5: Connections to Hex Inverter (IC2)**

<b>Part Reference-Pin</b>	<b>Connected to</b>	<b>Part Reference-Pin</b>
IC2-07	GND	V(-) Battery
IC2-08	No connection	NC
IC2-09	No connection	NC
IC2-10	No connection	NC
IC2-11	No connection	NC
IC2-12	Right motor rotation direction control, input 2	IC1-07
IC2-13	Right motor rotation direction control, input 1	IC1-02, HRD1-03
IC2-14	Vdd (logic supply)	V(+) Regulator

The table below lists most of the parts necessary to convert the Zig-Zag RC car by Tyco to a mobile platform. However, some parts are not listed and one should look at the completed vehicles to understand what is involved.

**Table 6: Parts List for Mobile Platform**

<b>Qty</b>	<b>Part Reference</b>	<b>Part Number (Digikey)</b>	<b>Description</b>
1	VREG	LM78L05ACZ-ND	5 VOLT 0.1 AMP VOLT REG TO-92
1	IC1	LM18293N-ND	4 CHANNEL PUSH PULL DRIVER
1	IC2	MM74HC04N-ND	IC Hex. Inverter 14 pin DIP
1	---	ED3114-ND	IC socket 14 pin MS tin/tin 0.300"
1	---	ED3116-ND	IC socket 16 pin MS tin/tin 0.300"
1	HDR1	CHS10G-ND	10 pin straight lead connector
1	----	CLKS02-ND	Lock ejector hook--long (2 in package)
1	----	CKC10G-ND	10 pin socket connector w/key
1	----	WM1203-ND	2 circuit plug 0.062"
1	----	WM1202-ND	2 circuit receptacle 0.062"
2	----	WM1000-ND	Pins (male) for WM1203-ND
2	----	WM1001-ND	Pins (female) for WM1202-ND
1	----	CKN1021	Toggle Switch SPDT Solder

**Table 6: Parts List for Mobile Platform**

<b>Qty</b>	<b>Part Reference</b>	<b>Part Number (Digikey)</b>	<b>Description</b>
1	----	P108-F061	7.2V/2.4A battery pack
1	LED1	P300-ND	T-1.75 Red Diffused LED
1	----	CHW10G-ND	10 pin wire wrap connector
8	D1-8	1N4001DICT-ND	1 amp 50 PIV silicon rectifier
1		P1055-ND	0.15 uF polyester cap

### **Fabrication Method**

The interface board described in this document was designed with a CAD tool called WinBoard 2.15b (<http://www.ivex.com>). This software allows the designer to select packages and pin formats that match the components that will be mounted on the finished PCB. Copper traces (electrical connections) may then be made between the pins of the packages to finish the layout of the PCB in the CAD software.

Once the design and layout of the interface board was completed in the CAD software the design was printed on a special paper (Toner Transfer System, Press And Peel Wet, by Techniks). This paper has the special property that when heated will transfer the toner from the paper onto a copper clad board. This toner becomes the mask for the etching step. The mask protects the copper that will become the metal interconnect. More information on this process is included in the attached report on making PCBs.

After the toner was transferred to the copper board, the board was then etched using a heated Sodium Persulfate solution. This solution removed the copper not covered with toner in approximately thirty minutes. After the etch was completed, holes were drilled for each pin of every component to be mounted on the board. The components were then inserted in these holes and soldered in place.

The first completed board was tested with a LabView Virtual Instrument (VI) designed to work with the LabView interface of the interface board. The board was also installed in a mobile platform and tested. After the performance of the first board was verified five additional boards were made and tested with LabView.

### **Conclusion**

The interface board designed and built met all performance expectations. All input output relationships perform as expected and meet published specifications. Long term use will identify any possible performance problems related to the affects of aging. However, no complications are expected.

This was the first implementation of an interface board on a PCB. A previous prototype interface board was implemented with wire wrap. That board lacked the ability to drive the mobile platforms motors in reverse. These new PCB interface boards also improve durability and reliability compared to the wire wrap boards. However, features they lack that may be added to future designs include a low battery indicator and a battery charging circuit. These features could be added with only a few additional components and would increase the usability of the mobile platform.

## Specifications

The following specifications are provided for general information. It is the responsibility of the user to ensure that modifications to the, motors, batteries, or sensor board interface will not interfere with the intended operation of the sensory motor control interface board. Specifications may change without notice.

Input Voltage (main)	7.00	VDC min
	35.00	VDC max
Vdd Sensor Board Supply	4.25	VDC min
	5.25	VDC max
	95.00	mA max
Motor Speed Control	1.50	VDC max $V_{IL}$
	2.30	VDC min $V_{IH}$
Motor Direction Control	1.35	VDC max $V_{IL}$
	3.15	VDC min $V_{IH}$

## Appendix

Please refer to PDF files on the disk for Data Sheets