University of Southern Queensland
Faculty of Engineering and Surveying

Educational Robot Design

A dissertation submitted by

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In fulfilment of the requirements of

Course ENG4111 and 4112 Research Project

Towards the Degree of

Bachelor of Mechatronics

Submitted: January 4,2007

Abstract

By introducing children, in the final years of primary school, to simple Engineering principles, children may consider Engineering, when they make the choice of career, in the early years of high school.

Using a Robot, as this vehicle, ties the already existing fascination children have with science fiction to a practical classroom interaction. This interaction should effectively draw attention to Engineering and create interest in the disciplines it encompasses. The exposure of children to Engineering, in this intimate format, should help career choice and the growth of engineering in the future.

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

Date

Acknowledgements

I would like to thank my wife, Hope, and my 3 children, Monika, Sarah and Chloe for their support during my time studying.

Thanks must also go to my supervisor Mark Phythian and Frank Young. Without your help this would never have come together.

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Glossary of Terms

ADC	- Analogue to Digital Converter
AH	- Amp Hour
cm	- centimetres
Comm. Port	- Computer Communication Port
CPU	- Central Processing Unit
D.C.	- Direct Current
DLL	- Dynamic Link Library
EEPROM	- Electronically Erasable Programmable Read-Only Memory
FLASH	- Rewriteable computer memory that holds its content independent of Power supply
Hz	- Hertz
I2C	- Master slave option for connection of multiple microchips or intelligent peripherals
IC	- Integrated Circuit
ICSP	- In Circuit Serial Programming
I/O	- Input/Output
IR	- Infrared
IrDa	- Infrared Data Association
LCD	- Liquid Crystal Display
LDR	- Light Dependant Resistor
LED	- Light Emitting Diode
LVISP	- Low Voltage In-System Programmer
LVP	- Low Voltage Programming
ms	- milliseconds or 0.001s
NPN	-
Opamp	- Operational Amplifier
OCX	- OLE Control Extension
OOP	- Object Orientated Programming
O.S.	- Operating System
PCBoard	- Printed Circuit Board
PNP	-
PWM	- Pulse Width Modulation
RAM	- Random Access Memory
s	- second
SPI	- Serial Peripheral Interface
UART	- Universal Asynchronous Receiver Transmitter
µs	- micro seconds also can be designated us 0.000001s
UHF	- Ultra High Frequency
VREF	- Voltage Reference
ZIF	- Zero Insert Force

Chapter 1. Project Introduction

1.1 Introduction

As a child takes the rite of passage to adulthood there is an expectation, in our society, that the child will make a life choice in the form of a career at the same time. There are a plethora of choices for child, these days, and it is very difficult to expose a child to a variety of career possibilities especially the more technical.

Engineering is a field that is in everyone's daily life but is often overlooked as a career choice. Providing a device that can bring engineering to the attention of children, whilst entertaining and educating, will give children a taste for what engineering has to offer in their future. This introduction could leave a lasting impression that could help a future career choice when it is required.

This project is focused on bringing a robot design that can be readily used in the Queensland teaching curriculum. The current curriculum is a results based plan that allows the teacher a great deal of flexibility to incorporate tools, such as this, in a custom-made teaching programme. By introducing relevant areas of the curriculum, into its design, this project will be able to be adopted as a pertinent teaching tool.

1.2 Research Objectives

The main objectives of the project are:

a) Design, construct and commission a small robot suitable for use by primary school students of grades 6 and 7.

b) Research the current school syllabus and teacher requirements so the project will be relevant.

c) Obtain an overview of the children's expectations of the project and other aspects to make the project suitable for a child's use.

d) Create the robot from low cost components so the final project costs less than $150.

e) Build the robot from off-the-shelf components, where possible, so it could be supplied in kit form and be assembled by a resourceful teacher from plans.

f) Design robot structure, movement components and spatial awareness components taking into consideration interchangeable parts.

g) Add functions including musical and tactile interface.

h) Create a computer interface for interaction with the robot.

i) Create relevant codes for the microchip including distance recognition, motion, light and line following and spatial recognition.

j) Create relevant interfacing components to implement computer/robot normal functioning and remote control.

If time permits:

- Research methods to shape plastic.
- Create a shaped plastic exterior.

The full specification is available in Appendix A.

Learning from observing is an excellent way to learn! Combining the above specifications into a robot will allow the teacher to reinforce theory with application. Using the icon based interface on a computer then activating the robot, via the Wireless interface, will give real world applications for the child to tie together with the theory they have previously learnt. These combinations will allow this unit to become a valuable tool in the teaching environment.

1.3 Research with teacher and children.

It appeared obvious that any project, targeting children and teachers, was doomed to failure unless the target users were consulted early in the planning stage of the project. This was, therefore, an important first step and was implemented early in the process.

The initial approach was to send a letter of outline to the principal of local school. This was a requirement of the Department Of Education. From here the relevant teacher was approached.

This initial research was a two-pronged approach. Firstly, input on what the average teacher would require to integrate the finished product into the everyday classroom situation was required. Secondly, the children needed to be consulted as to what they might find useful and/or interesting if this sort of device was going to be used, by them, in the classroom.

To implement the teacher stage of the project, an outline of questions was put together. The idea was not to be too specific in case the tone and expectations of the questioning skewed the outcome. By sticking to topics and allowing the teacher to run with the ideas a plethora of information was collected. This method, on reflection, took the interview far beyond what was initially perceived as possible parameters for the project.

The following points were highlighted as useful from a teacher's point of view.

The robot should:

- Be able to generate shapes (squares, rectangles etc.) and demonstrated areas and perimeters.

- Be able to operate on a coordinate system to demonstrate graphing.
- Have the ability to draw a picture from the coordinate system.
- Be able to demonstrate basic compass navigation.
- Have an LCD screen for output to take the children away from the computer after the initial programming; and
- Possibly offer some sort of challenge.

It was also discovered, from the interview; that a child could concentrate for up to an hour so the robot tasks could be reasonably involved. It would also be possible to incorporate building the robot as a lesson in itself. A copy of the current teaching curriculum was shared with relevant sections highlighted. It showed many areas where the robot would be useful and easily integrated into the classroom environment.

The child-orientated section of the data collection was in the form of a statistical information collection and a questionnaire for the children. The teacher who was approached had experience in the area of child questionnaires and ethics. After reviewing the proposed questionnaires, he considered them to fit within the requirements of ethics. To maintain the ethical approach the children's questionnaires were conducted as a class activity without the author being present.

The first part of the child's questionnaire (Appendix B (a)) came about on the idea that the robot might be assembled from a group of modular boards that could become a class activity in itself. It involved measuring the hand span of each child so that an average or, as was eventually chosen, the smallest hand size could be found. The results show that by making the boards a maximum of 75mm, on the small side, it would allow all children of this age group to comfortably grip the boards and assemble them.

The questionnaire (Appendix B (b)) was incorporated to see what the children thought would be interesting or useful. The questions were meant to be slightly leading to narrow the field off possible answers. Unfortunately, as W. C. Fields indicated, "never work with children or animals", so, the questions lead to some interesting answers. A full rundown can be found in Appendix B(c). A summary of the answers is included below.

This research greatly helped set the project specification.

Topic	Girls%	Boys%
Motion	Walking 56%	Wheeled 28.5%
Time to Assemble	More then 30 mins 50%	30 mins 38%
Appearance	Sci-fi robot 57%	Sci-fi robot 31.3%

Figure 1: Brief Overview of Child Questionnaire

1.4 Conclusions: Chapter 1

As any parent knows, cost is a real factor in today's "free" education. In the long run parents, through organizations like the P & C (Parents and Citizens Association), supply the money to purchase many of the learning aids that children use in school. Parents want their children to have an education that includes learning with technology-based influences, to prepare them for the future. They know they that this helps create steppingstones for future education choices for the changing world that will be our children's. By providing the above system, while keeping that the system costs down, the real outcome of this project will be a system that can be used in modern schools.

Using the data collected from the questionnaire the project direction was chosen

Chapter 2 Component Selection

An important aspect of the project involved finding cheap and effective ways to implement the mechanical requirements of the Robot. This section will discuss this aspect of the project. Earlier on in the project consideration was given to the size of the final product and ideally for several reasons focus would be put into keeping it small. This consideration was kept foremost in mind, along with price, when considering below.

2.1 Position Sensor Selection

Position sensing offered its own unique challenges. It had to be kept in mind that non-technical people could possibly assemble the Robot, if a kit was developed. Special consideration was therefore required to find the easiest method to enact the position sensing whilst keeping in mind the skill requirement involved. The following systems were considered:

2.1.1 Slotted Encoding wheel

The encoder wheel is commonly used for this style of application. The principles behind its use are very simple. Historically, this style of sensing incorporates a wheel with slots cut at regular intervals around its circumference, a light emitting diode, often infrared, and a matching sensor. As the wheel turns, while the robot is moving, it causes the light beam to be interrupted. The related circuitry converts this to a pulse that can be sent to the microcontroller. This sort of encoding wheel is very often used in computer mouses, the variety with a ball that contacts the mouse pad, where accuracy and small movement detection are required.

The main drawback for this situation comes in the size of the encoder wheel itself. Because of the size constraints underneath the robot this encoder wheel would have to be less than 20 mm diameter.

The simplest way to get a precision wheel, of this size, would have been to purchase a cheap mouse and use the wheels and circuitry from this to enact the system. While this was considered, two objections came against it

(a) Cheap mice seem to be imported in lots and once they are all sold the next lot are of different design. It is possible the changes in design may make them incompatible with the final robot design.

(b) The design of the encoder wheel incorporates a shaft that actually contacts the ball of the mouse. This usually clips at either end to give the unit stability so the movement interaction can take place. The modification of the encoding wheel for incorporation into the robot was less then satisfactory.

Another way to access this style of sensing would be to manufacture the encoding wheel .The manufacture of an accurate encoder of this diameter could be done by:

(a) Cutting from a thin soft material that could be cut with a Stanley knife or a fine cutting implement.
(b) Cutting using a precision cutter e.g. a laser cutter from a thicker piece of material.

(c) Injecting or moulding in plastic by a plastics manufacturer.

The first method is not satisfactory when used in a situation where users, in this case children, could possibly touch or otherwise manipulate the sensor wheel as material fine enough to be cut in this way would be flimsy at best. The method of manufacture is also dangerous and not conducive to producing an accurate final product.

The second method of manufacture is ideal for small run production like this and would create an extremely accurate product. Unfortunately it is quite expensive and has to be done with an expensive precision cutter.

Realistically this unit will be at best a small run production. Having the dies struck to make an encoder wheel by injection or moulding as in (c) is very expensive. The savings on these methods come as large quantities are produced and the cost is shared out among a multitude of items. Though this is the ideal method to produce this sort of precision item, the cost prohibits this.

This style of position sensing was therefore rejected.

2.1.2 Gray Encoder wheel

The Gray encoder wheel is a particularly simple design where a wheel is marked with shaded and white areas of various lengths circumferentially around a circle. The current position, in relation to the sensor, is determined by an optical sensor array detecting the light or dark areas underneath. By having three or four senses in alignment, the current position is output as a binary sequence depending on these areas underneath.

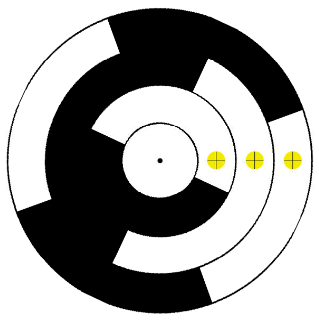


Figure 2. 3-bit Gray Encoder Wheel (Rotary Encoder 2006)

A 3 bit encoder as shown in Figure 2 produces the following binary code as it turns clockwise (you move counter clockwise) starting at the ⊕

000
001
011
010
110
111
101
100

Though this is particularly effective with a position sensing, in this particular application there are several difficulties in its implementation.

(a) The size constraint of the encoder wheel is around 20 mm diameter. This would mean that each particular encoder section would be particularly fine making it a little difficult to produce. This could of course be worked around by supplying the encoder as a sticker.

(b) The electronic componentry of the reader would be very small. Electronics miniaturisation is obtained at a cost. An array of sensors of this size would become quite expensive especially if more accuracy was sought.

(c) To gain accuracy the wheel would need more encoder rings and more sensors to decipher the Gray code produced. Miniaturisation of the electronic sensors again becomes an issue

For the reasons listed above this method was rejected.

2.1.3 Rotary Encoder Potentiometer

Rotary encoder potentiometers are readily available at high-end electronics suppliers. A rotary encoder works, in a similar method to the encoder wheel above, often in the Gray encoder configuration. The main difference is that, in place of light, metal contacts brush on contact and non-contact areas to give a binary representation of the current position. These encoders range in price according to the accuracy or style of encoding starting from as little as $10 and ranging up to several hundred for the more accurate optical variety.

Besides the obvious problem of price for accuracy, this style of device has it's own unique issues in regards to incorporation into this designed. While the devices themselves can be quite small, there is a problem in this instance in regards to mounting because of the closeness of surrounding mechanical and chassis parts. This method was rejected because of these issues.

2.1.4 Stepper Motor

Stepper motors are available in all shapes and sizes and are readily available from old office and computer equipment. The most useful aspect of these particular motors is they can move in small increments of degrees. Power has to be sent to particular coils, within the motor, in a particular order to make the Stepper motor operate. This order means that it is quite easy to track the current position of the motor and how far it has travelled since the pulses started.

The disadvantages of this style of motor:

(a) They are rather bulky in size. This means the size of wheels needed for the vehicle would be fairly large to compensate for the size of the stepper.

(b) This size also means there are difficulties in mounting them to the chassis.

(c) Stepper motors have multiple wires in each unit depending on the amount of steps that are available from the unit. Connecting these units would require either multiple pins on the Microcontroller or a specific controller.

Because of these issues Stepper motors were discounted for this application.

2.1.5 Hall effect sensors

Modern Hall effect sensors are commonly used to detect the presence of metal or magnetic fields. Some models are so sensitive, to magnetic fields, they are capable of detecting the magnet fields of the earth and most electronic compasses are based on these.

In this instance the Hall effect sensors would work by detecting the magnetic fields created by the presence of teeth on a metal cog. The sensor emits a voltage or no voltage in relation to the presence of the metal teeth.

To facilitate detection a magnet is glued to the back of the sensor. This produces the magnetic field with the presence of a metal tooth. By positioning the North or South of the magnet, against the back of the sensor, it can be made to detect the presence of metal or its absence. Hall affect sensors are also quite cheap and reasonable robust electronically.

Surprisingly the Hall effect sensors were sensitive enough to detect very fine teeth on small sprocket. By using a small metallic sprocket, with a large number of teeth, on the main drive shaft, connected to the wheels, minute variations in position can be detected. This happens as the teeth, of the magnetically effected metal sprocket, move past the sensor.

Though this method worked out to be moderately expensive, its ease of implementation, in this situation, and minimal requirement of skill for inclusion or adjustment made it the most obvious choice for this application.

2.2 Motor Selection

Moving the robot about required careful consideration due to size constraints of the robot. Whatever was chosen needed to be small enough to fit under the robot without making the robot look top heavy or unstable. It also required suitable mounting so they remain in situ during the use and abuse the robot would suffer in a classroom environment.

2.2.1 Stepper Motors

Stepper motors are particularly powerful, and by their very makeup incorporate the ability for position sensing. This would make then ideal for this sort of action.

Stepper motors are inherently quite bulky, in particular the cheaper ones available. The bulk of the stepper motor raised the robot significantly with the girth meaning large wheels would be required to give the robot clearance. This would involve more cost and could cause the robot to become or appear top heavy.

The manufacture of a suitable bracket to mount the unit in its final position was also a concern. It would involve metal manufacture to build something substantial enough to counteract the torque of these units. Unfortunately this meant more cost in the form of complicated construction that required specialised input.

These motors can also be quite costly though they can be sourced at second hand shop in the form of second hand computer. Printers have one or two motors inside and can be stripped for salvage. The issue with this source is consistency of product size and specifications with different manufacturers using different motors for their products.

Mounting was the main constraint on the use of stepper motors for this project with the height issue coming next.

2.2.2 Servo motor

Servomotors are commonly used in steering mechanisms or actuation applications. They are very powerful and have good amounts of torque. There is usually a range constraint on their rotation of around 180°. Fortunately, they can be modified so the actuator can do a full 360° revolution. In this application they could easily be used by for the locomotion in this project. The use of servomotors in the design had the following implications:

(a) Cost. The cheapest servo cost $20. This made it one of the more expensive parts of the robot. Considering at least three would be required, in the final design, they quickly became a substantial portion of the final cost.

(b) Technical Skill. An amount of mechanical skill is required to pull down a servo and adjusted it to produce a 360° revolution. It is also easy to damage the servo while doing this. Even in a short run situation considerable time would be required to manipulate a number of units. This labour content would add greatly to the cost of the final unit

The above considerations meant the Servo was removed as a choice for the final unit.

2.2.3 Small DC motor and gear assembly

Small D.C motors that run on voltages up to 6 Volts D.C are readily available quite cheaply. Flat versions are available and avail themselves to easy mounting. Cheap gear trains are also readily available quite cheaply for this size motor.

This flat DC style motor was chosen for the project because of the final price of around $1.50 each. They also are powerful enough to move the lightweight robot around. The flat version of these also allowed easy constraint within the mountings of the drive train.

2.3 Electronic Compass Selection

There are 3 models of electronic Compasses readily available here is Australia. They are all suppled by Wiltronics Electronics in Victoria and all are variations on the same technology. The compasses have special requirements to stop damage from incorrect pin orientation and/or soldering, but generally they are an ideal plug-in component for this project.

2.3.1 Dinsmore Digital Sensor 1490.

This sensor is the cheapest of the range. It supplies a digital signal to the microcontroller that is bought to logic level with pull-up resistors in the circuit. The sensor is made from “a sub-miniature rotor crystal in suspension with Solid State Hal Effect IC’s”(Wiltronics, 2005). This compass can therefore be incorporated into a design without the use of external or internal ADC circuitry.

The component outputs a basic 8-direction compass bearing of N, S, E, and W. The 4 output pins output logic 1 or 0 in regards to these directions. NE, NW, SE and SW are produced by the overlap of two directions. For example North East would have the North Pin high and the East pin High – 1100.

There is also some settling time for a 90° swing but this shouldn't be a major issue as the robot shouldn't be moving at a great rate.

2.3.2 Dinsmore Analogue Sensor 1525

This sensor is more then twice the price of the 1490 model but has substantial features over the later. This component has 2 output pins that output separate analogue sine waves. These can then be processed with either external ADC or the internal microcontroller ADC circuitry. By comparing the sine waves, heading can be defines down to the degree.

This unit has the same considerations as the 1490 in regards to polarity of pins and soldering time in regards to circuit damage.

This compass is also damped so there is an up to 3-second delay for a 90° displacement.

2.3.3 Dinsmore Analogue Sensor 1655

The 1655 has similar characteristics, configuration and consideration to the 1525. It has a little faster recovery time then the later and is similarly priced.

The Dinsmore Digital Sensor 1490 was chosen for use in the project. The main reason being that the demonstration of the 8 basic compass points is all that is required. The others would do this more accurately, but at around $80 for a single component, the last 2 alternatives were way out of the price range of this project.

2.4 Motor circuitry Selection

A 6 Volt motor, while being cheap, brings its own issues in regards to control. Controlling speed and direction, of these motors, is more complicated then plugging a few wires in and hoping for the best. After investigation, the best way to control a motor, in relation to speed and direction, is by incorporating a H-Bridge into the design. A H-bridge works by using electronic switches that let current flow in a particular direction across the motor. Refer Figure 3.

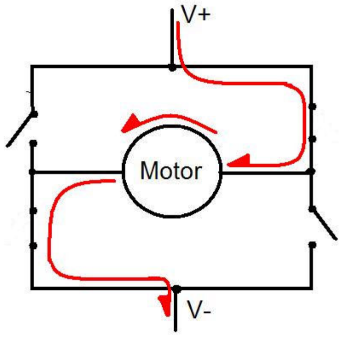


Figure 3. H Bridge simulation -Turning one direction

By changing the switching the motor will turn the other way. Figure 4.

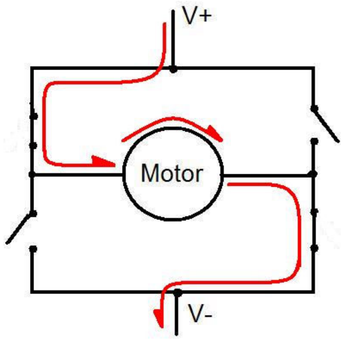


Figure 4. H Bridge simulation -Changed direction

The other beauty of this format is that it can be incorporated with the PWM output from a Microcontroller to control the actual motor speed.

PWM or Pulse Width Modulation is the process where the power is switched on and off at a particularly high-speed rate. The on off rate is usually measured in microseconds so the motor is only receiving power a percentage of each second. This gradually adds up to a percentage of time on in a minute so the speed is adjusted accordingly. Interestingly the on and off rate is at such a speed that measurement with a multimeter would show a constant voltage supplied and measurement requires an oscilloscope.

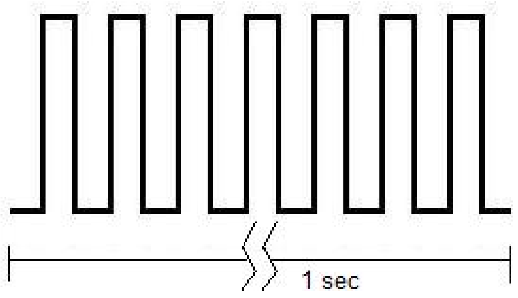


Figure 5. Simulated PWM Output

There are a couple of ways to incorporate a H-Bridge into the design.

2.4.1 H-Bridge

A H-bridge can be constructed using Transistors and a handful of discrete componentry Figure6.

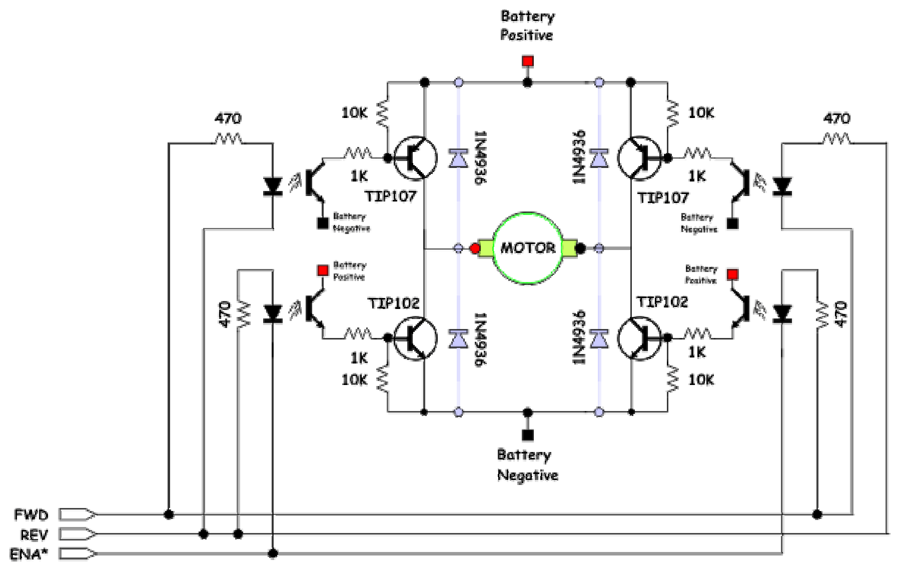


Figure 6. Transistor H-Bridge Circuit (The Complete BJT Circuit, 2006)

There are several configurations of these depending on the style of Transistor used. These have there own consideration so will be addressed separately.

2.4.1.1 Standard transistors H-Bridge

A suitable H-bridge can be easily built from standard Transistors like the PNP BC557 General Purpose Transistor (Phillips, 2006) (Data Sheet available on CD). These are quite capable of handling the power but suffer with large current drains that can be detrimental to a self-contained unit operated from a battery.

2.4.1.2 Mosfet Transistor H-Bridge

A Bridge constructed on Mosfet Transistors overcomes the issues of power because the Mosfet is substantially better on the current drain issue. The main problem with Mosfets is the price.

2.4.1.3 H bridge Dedicated IC

There are quite a few H-Bridge dedicated IC's available in Australia. The main consideration in the selection of a H-Bridge was price verses suitability for the process. The majority of the H-Bridge IC solutions were quite expensive, and quite a bit more powerful then would be required here. These where immediately removed as competitors.

From the rest the L293D (STMicroelectronics, 2006)(Data Sheet available on CD) from STMicroelectronics was a standout in both price and features. It was capable of driving the two motors that were required and the circuitry was incredibly simple to initiate into the design. This unit is also compatible with microcontrollers.

Though some very interesting Transistor H-Bridge designs were found, the IC version of the H-Bridge was the automatic choice because of the ease of implementation and the price.

2.5 Microcontroller Selection

There are quite a few varieties of microcontroller available. The selection approach was a little slanted, because of previous experience and success with the PICAXE range of microcontrollers, based on the MICROCHIP range. Research on the Internet and at the USQ Library also verified the popularity, ease of use and prolific information sources for this range of microcontroller. On the MICROCHIP website (www.microchip.com) there is also a plethora of addition information on how to use built functions and examples of operation for its entire range of Microcontrollers

The final choice came down to two microcontrollers from this Range

2.5.1 PIC16f628A

The PIC16f628 is an 18-pin microcontroller that offers two banks of 8 pins, called PORTS that are accessible for input and output to peripheral electronics. The chip also offers the following built in functions as standard:

4 Analog input pins
RX USART Asynchronous Receive capability
TX USART Asynchronous Transmit capability
A Synchronous Data Input pin
A Synchronous Clock
A Capture In/Compare Out/PWM Out pin
An Oscillator In/External Clock In Pin
An Oscillator Out/Clock Out Pin
A MCLR - Master Clear pin
A Timer0 clock input
A Timer1 oscillator output
A Timer1 oscillator input
A Serial programming data Pin
A Serial programming clock Pin
A Low voltage programming input
A External interrupt Pin

This CPU uses a RISC format for its instructions and in this case a small set of 35 instructions for programming. The speed of the microcontroller can also be accurately controlled by using an external crystal. This means timing for specific peripheral interfaces can be timed to precision. It has a 2k Flash Program Memory, 224 byte Ram data Memory and 128 byte EEPROM Data memory.

This chip also has the option of LVP (Low Voltage Programming) where the chip can be easily programmed with the relevant code via 5Volts. This is particularly useful when combined with the ICSP (In Circuit Serial Programming). In this mode the chip can be programmed in circuit, via the serial port of a computer with inclusion of a small amount of electronics. This removes the problem of having to programme, remove then insert in its final circuit and the related issues of Static Discharge Damage and/or bent pins.

Finally, this processor has a low Power consumption rate and can be operated on 5 Volts, which lends itself nicely to this sort of application. All of the data above referenced from (Microchip 2006A).

2.5.2 PIC16F877A

The full MICROCHIP range are very compatible, with one another, over the full range. They have similar features and similar Programming commands. This means that the PIC16F877A has all the same features as the PIC16F628A with the following additions.

4 Banks (PORTS) of 8 Pins for input and/or output
1 Bank (PORT) of 3 Pins for input and/or output
7 Analog/Digital input port
Outputs for both SPI and I2C modes
An SPI Data Out pin
An SPI Data In pin
A Data I/O pin
2 Capture In/Compare Out/PWM Out pins
Slave select for the synchronous serial port
Read control for the parallel slave port
Write control for the parallel slave port
Select control for the parallel slave
Parallel slave port

The chip also has much a much larger Flash Program Memory, RAM and EEPROM Data memory. The data above and the functionality included on this Microcontroller (Microchip 2006a). The full datasheet is also available on the CD

The Pic16f877A is available in a 40-pin configuration. This, with the added functionality and memory size made this chip the ultimate choice for the functionality that was intended to be included in the final product.

2.6 LCD Selection

At the time of research there were only 2 LCD displays available at a reasonable pricing. Both were clones of the Hitachi LCD Controller range. Several other models have appeared on the market since then and will not be reviewed in the text.

The first includes the following functions:

Control, Refresh and Display functions executed by a dedicated on-board controller.
Dot Matrix 16 Character x 2 Lines Module
Full 160 characters JIS font set.
Low Power Consumption - 5V Power Supply
5 x 7 Dot Matrix with Cursor

The controller also allows the creation of the new characters. It is also programmable by either 4 or 8 bit mode. The 4-bit mode allows the LCD to be enabled with as few as 6 inputs from the microcontroller. This information and more is available at http://www.dse.com.au/cgi-bin/dse.storefront/458b31df03fe8ca4273fc0a87f9c0754/Product/View/Z4172.

They are relatively easy to use though special steps and timing are required for interaction. An excellent source of information for this LCD is at http://www.myke.com/lcd.htm.

The second LCD display incorporates the above features with the added functionality of being backlit. Unfortunately this addition adds an extra $10 to the price so the luxury was not considered important enough.

The Cheaper version was therefore chosen.

2.7 Wireless Transmitting and Receiving

There are two cheap alternatives for wireless communication between the robot and the computer base. The first is the IR (Infrared) communication which entails a light emitting array and a receiver based in the Infra red spectrum. The second is the UHF based transmitter/Receiver set in the 434Hz range of this band.

2.7.1 Infra Red Communication

Infrared communication is very well documented and has been used for many years in applications from T.V. remote controls to Mobile Phone/Computer interfacing. The system is relatively easy to implement and requires extra circuitry in the form of a decoder/encoder IC to use. It is well proven in many instances but has disadvantages

(a) Because it uses light, the units communicating need to be fairly straight on to one another. There is an angle of Transmission (Figure 7) that allows communication, but the Transmitter and Receiver must be facing each other to communicate. If the Robot turned away from the Transmitter no communication would happen

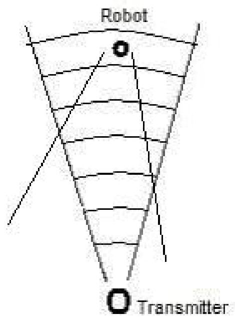


Figure 7. IR Transmission Angle

(b) Infrared used outdoors or in high light conditions can be prone to false signals. As Sunlight contains the Infrared spectrum also this could theoretically cause difficulty when the computer and Robot were legitimately trying to communicate.

(c) Range is also an issue with Infrared with normal ranges in low light situations being on several metres and IrDa Devices usually having ranges up to 1m. More information can be found at http://www.irda.org/ the home page of the Infrared Data Association Web Page.

2.7.2 434 Hz UHF Wireless Communication

This method uses the 434 Hz UHF frequency, which has been set aside for this style of communication device. In difference to the Infrared system, the 434 Hz wireless UHF transmits in all direction at once so the robot does not need to be facing the unit. The system can also have a range of up to 1km with the right power source. The modules for this are incredibly easy to use in an electronic circuit.

The disadvantages of this system are:

(a) Just as the multidirectional properties of 434Hz wireless are a bonus they also become an issue when multiple units are operated in the one area. Where an Infrared unit could be aimed at a particular robot, all robots receive the signal from the 434Hz UHF system. This would require workarounds in the software.

(b) The full effect of radio waves and the human body is still a grey area of science and medicine. Prolonged exposure to these waves could cause a health hazard. The time of exposure in reality should be seconds in an hours use but this is still a small issue.

Both methods use similar electronics to interface and the cost of implementing both are relatively even. In the end it came down to the fact that the sender would most likely be plugged in at the back of a computer and possibly not be able to be used in plain sight of the receiver.

The TX434A and the RX434 sender and receiver from Oatley Electronics www.OatleyElectronics.com were chosen for the application because of price and availability. More information on these two components on the CD).

2.8 RS232 discussion.

The RS232 output from a serial port is based on an old system where logic 1 is at +10 volts and the logic 0 is set at –10 volts. This system has its own standard, which sets the pins of the cable and Computer port. A good source for information on this is http://www.camiresearch.com/Data_Com_Basics/RS232_standard.htm.

Unfortunately the voltage for a Logic 1 is +5 volts and Logic 0 is Zero Volts in a microcontroller. The microcontroller is also unable to produce voltage at the correct voltages to interface directly with a computer. The addition of a wireless connection between the computer and Robot also amplifies this problem, as the wireless connection has similar limitations.

One way around this is to incorporate a RS232 Transmitter/Receiver IC into the Transmission side of the circuit near the Computer. An ideal IC for this is the Maxim RS232 (Texas Instruments, 2006)(Data Sheet available on CD). The Max232 coupled to the output of the Computer turns the voltages into a logic level acceptable by the Microcontroller and wireless system. The Maxim IC also has a built in Voltage Pump so it can convert the Microcontroller output to the correct voltages to interface the microcontroller signal to the computer, if required.

Chapter 3. Chassis Material Selection and Design

As the robot would be used by children, in a classroom situation, and would most likely be mistreated, the chassis of the robot required particular consideration. The following designs and materials were considered and/or tested:

3.1 Chassis Type Selection

One Constraint on the design of the project was the ability to turn in its own axis. There are 2 ways to effectively do this either using tracks like a tank or by creating a three-wheeled design.

Motion by tracks is a common mode of locomotion in the modern world. Many vehicles use this method of motion and it is extremely successful and stable. Tracks would be a simple method of implementing motion in this situation as well as steering. Tamiya offers a kit in their educational Construction series that would work for this situation while supplying the chassis for the robot in one piece.

A three-wheeled robot, in comparison, could be made, quite simply, by inverting a Servo on some sort of chassis and building a mount for the wheel. Because the PIC16F877A has the ability to offer PWM to a servo this method would be easy to incorporate into the design

The Track method would have easily provided the chassis and a simple method of motion and steering. For this project though, the 3-wheel robot method was chosen for 3 reasons.

1) The Tamiya Track model is built from moulded plastic and hence may not stand up to the anticipated abuse during use.

2) The interesting construction, design and programming aspect of the build three-wheeled.

3) The difficulties in designing a substantial Track system as apposed to the three-wheeled system.

3.2 Chassis Material Selection

Once the chassis design was decided upon a suitable material was required to build it from. The following materials were considered.

3.2.1 CD Ply.

CD ply is a common building material readily available at hardware shops and timber stores. It is relatively cheap, lightweight and reasonably easy to work. Its main downfalls are:

a. It is timber and as such can have very raw edges or splinters. This can be a danger for children or people handling the robot. There also could be a danger of injury, from splinters, if the robot brushed past someone, while moving across the floor.
b. If the robot was flexed excessively, as in the case of someone stepping on it, though plywood is relatively flexible it may splinter and injure someone.
c. CD ply is often only available in full sheet size. This would make it rather expensive to make single units.

d. Ply is not very strong in its end grain so screwing or fastening that involved fixing into the end grain would be less then satisfactory.

For these reasons plywood was rejected as a chassis material.

3.2.2 Maranti pine.

This wood is very readily available at any hardware shop or timber sales. It is very strong and is quite reasonably priced.

Its main downfalls are:

a) It is timber and as such can have raw edges or splinters. This can be a danger for children or people handling the robot. There also could be a danger of injury, from splinters, if the robot brushed past someone, while moving across the floor.

b) Pieces of Pine 150 mm wide as required for this project are prone to cupping which would make the robot inoperable overtime unless the timber is treated. Treating could be achieved by painting, another process and another cost for the project.

Pine was therefore removed as an option.

3.2.3 Metal.

One of the strongest chassis materials available would be metal. It is very readily available and could be formed as a flat plate or folded sheet. While this would be the strongest option it offers its own unique disadvantages:

a) Metal is a highly conductive material. This means that all electric and electronics would need to be specifically insulated. This of course would increased the time and cost involved in building.

b) Special tools and skills are required to machine or fold solid and sheet metal. Machining of metal is also labour-intensive and costly. It also requires specialty tools to do successfully so construction would need to outsource this part of construction.

c) The weight of the project would immediately increase in the case of solid metal construction translating into cost as motors and drive assemblies would need to be increased in size to cope.

d) If the chassis is made from steel plate it would require rust protection. More expensive metals like stainless steel could be used but the costs increase accordingly. Galvanized iron could also be used to make a folder chassis though cut edges could be a source of rust.

e) Cut Hazard. Improperly prepared steel plate can also harbour sharp edges or snags that can cause injury.

All of these issues made the use of metal less then desirable for this application. Metal was therefore removed from the option list.

3.2.4 Polypropylene

Polypropylene is a thermoplastic that has some great properties for this style of application. These include:

Lightweightness
Good Tensile strength
Impact resistant
High compressive strength
Excellent dielectric properties
Resists stress cracking
Retains stiffness and flex
Non-toxic
Easily fabricated

It is also readily machined with woodworking tools, which is perfect for the manufacture of this item. (Polypropylene Specifications 2006)

The main disadvantage is that the plastic is very soft so this limits the amount of construction that could be done as an in class project. Repeated assembly would soon strip the plastic from the screw holes.

3.2.5 Final selection

After careful consideration of the above materials, Polypropylene was the stand out choice. Although the in class assembly activity would have to be carefully reconsidered, it offers the best all round properties including safety. The best aspect, for testing, is that it is readily available at the local supermarket in the form of cheap cutting boards. This made the product readily available, for testing or the amateur builder, without having to source it from a specialist plastics supplier. Plastic also gives the product a more professional finish then timber and metal.

3.3 Chassis Design

There was an idea, in the early stages of the project, to include basic assembly, into the design, as an option for the children. This would give a teacher the opportunity to incorporate this as a class activity. Assembly would also give the children a feel for the important hands on aspect that is so relevant to modern engineering.

3.3.1 What is Assembly?

The choice of Polypropylene as the chassis material bought forward the above question. If the robot was to be in several parts, and these parts needed to be to be reassembled, how would this happen?

The most obvious method of assembly would involve screws. Screws are readily available, easy to use and have a proven ability as a fastener. Screws, though, instantly cause several issues:

(a) Polypropylene, while having some very good properties, is a plastic and as such has issues with threading when it is screwed into.

(b) Children of the target age have limited dexterity and as such controlling a screwdriver and negotiating screws into specific holes may be an issue.

(c) Screwdrivers are sharp and pose a stabbing hazard. The best of us have stabbed ourselves with a screwdriver so children unaccustomed to handling this type of tool would be very likely to injure themselves and/or others.

Obviously if assembly is to be involved, some adjustments parameters to the term “assembly” were required.

More thought, with respect to the above issues, showed the robot main chassis, drive train and related parts needed to be supplied in an assembled format. This would mean the parts that required assembly by screwing would need to remain attached permanently.

This revelation then left only one aspect of the robot that could be assembled onto the robot – the electronic component board assemblies. Possibly a way could be found to attached these so the construction aspect of the robot was still available.

Screwing and gluing were automatically removed from the list. The implications of screwing were discussed earlier and carry the same issues in this instance. Gluing is usually final so this was not a consideration.

After a lot of thought, on the issue, it became obvious that circuit boards all have a couple of common features, Thickness and Rigidity.

These meant if slots were cut into the robot the board assemblies could be easily pushed into these. From there the cords would be plugged into the relevant socket on the mainboard and the construction content of the project would be achieved.

3.3.2 Printed Circuit Board Mounting

A slotted upright was then designed to handle the PCBoards. Experimentation showed that a 1mm thick slot 5mm deep adequately help the boards in place while letting a child push the board assemblies into it. The riser design took into consideration that the main board would lie in front of it, though; provision for it to be in another spot was available.

The upright also needed to be robust enough to handle abuse. There was no real need for stress testing, because of the minimal stresses and the properties of Polypropylene, so a 40 mm section was decided on as it looked substantial enough to do the job

The riser board Appendix E Sheet 4 Item 6 was the result. This board allowed assembly without any sort of fasteners. It is worth mentioning that only 2 circuit board assemblies now require fastening on this project. They are the two boards holding the Hall Effect Sensors. These need the stability and adjustment that a screw and slotted board offers. The remaining boards are attached to the unit by locating slots.

Two side braces were also designed Appendix E Item 5 Sheet 3 to give added sideways stability in the event the robot was dropped on its side or it was tripped over. Figure 8 shows these in place.

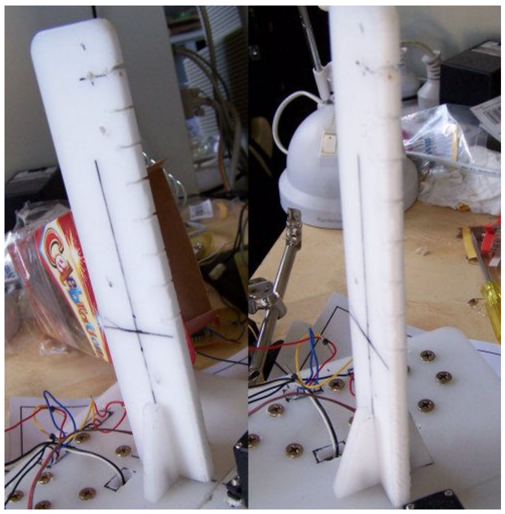


Figure 8. Riser with slots

3.3.3 The Chassis and Drive Assembly.

The chassis layout and structure now required some constraints and rationalisation.

The power supply was finalised and would be salvaged from the cheap spotlights available for $10 to $20. These carry a Sealed Lead Acid Battery (SLAB), charging circuit and power supply to run the charging. Purchased separately these would be a substantial cost to the project. The SLAB batteries are 6V and have a 4.5AH capacity, which, is more then enough for the little bit of current drawn by the electronics and the motors.

The battery would then be the heaviest part of the project. The best place to carry this would be over the rear drive wheels, to let the steering work easily and to stop tipping. These batteries have a footprint of around 70 mm x 50mm.

The upright would need to be allowed for.

A servo for steering would also be required.

Allowing for the above parts and a little extra 220mm long was chosen as the working length for the chassis. .

The drive train was the next consideration. Gearing, motors, shafts and wheels were required. The Tamiya Avante 2001 Snap together racer kit from Dick Smith electronics, at $9.95, was chosen to supply one motor, the drive shafts, cogs and wheels required for the drive. This kit is a 4-wheel drive so it has 2 drive shafts that supply all the necessary parts for the dual motors of the robot.

Laying the two motors and the two drive shafts and wheels out set the width at 150mm. The final design of the chassis board is shown in Appendix E Drawing 5.

3.3.4 Drive mounting

The motor and shaft assemblies required proper mounting so the robot could move and the whole assembly remain stable. This assembly also needed to be robust enough to handle repeated use and interaction with children.

This posed the question what to build the assembly from? Metal would be the ultimately choice but as discussed earlier there are issues with manufacture and weight especially for a homebuilder. With a little thought Polypropylene because the obvious choice for all the reasons discussed earlier for the chassis.

The use of gearing and shafts meant the motor and wheel assemblies would be mounted separately.

Considerations for motor shaft mounting:

(a) The mountings would be as compact as possible

(b) The mountings for the shaft should incorporate mountings for the motor as well.

(c) The parts should be easy to construct

With this in mind the parts were laid out in and the mountings were designed by trial and error.

Technical drawings of the Drive Mountings can be viewed in Appendix E. The mountings were designed from the centre out. The central mountings were designed using the circular end on the motor for mounting and the length of the main shaft. Item 4 on sheet 3 was the final designed to hold these.

The other end of the motor now needed to be mounted. With a small pinion gear directly mounted on the motor an intermediate cog also required mounting. As a result Item 2 on Sheet 1 was designed. The drawing shows how the flat motor shape was used to hold the motor in the mounting.

The Wheel Mount Item 2 of Sheet 2 was designed to hold the other end of the intermediate cog and the wheel end of the main shaft with space for its cog.

The full assembly can be seen in Appendix E – Drawing 7 and in FIGURE 9.

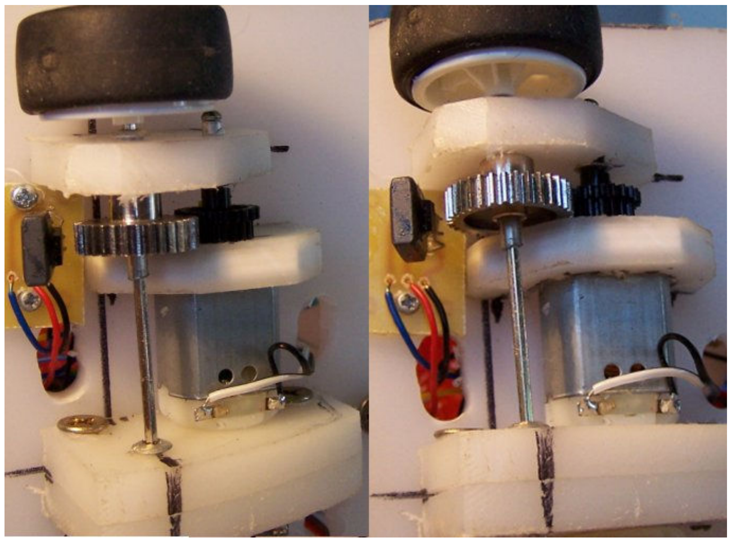


Figure 9. Drive Assembly

Aluminium rivets were used as bushes for the drive, (with the pull removed) and the intermediate cog shafts (with the pull in and trimmed). There use was to stop any wear in the plastic that spinning shafts may cause.

3.3.5 Steering

As was indicated above the Robot was to be three- wheeled. In this configuration the Servo would be mounted, inverted, in a hole cut in the chassis

(Appendix E Sheet 5 Item 7). The wheel is then mounted onto the Servo Horn via a bracket (Appendix E Sheet 6 Item 8). This allowed an easy wheel configuration that was easy to interface with the Electronics.

3.3.6 Peripheral Mountings.

The final mounting consideration was the Line following PCBoards. The nature of this board meant it requires some shielding from incidental light and it needs to hold the board low enough that the line can be detected.

To accommodate this a redesigned version of one the mountings for the drive was produced (Appendix E Sheet 2 Item 3). The new design has a slot along its length that allows the board to slide into and be held while in operation. This is then attached onto the chassis at the front (Appendix E Sheet 7) and can remain in situ.

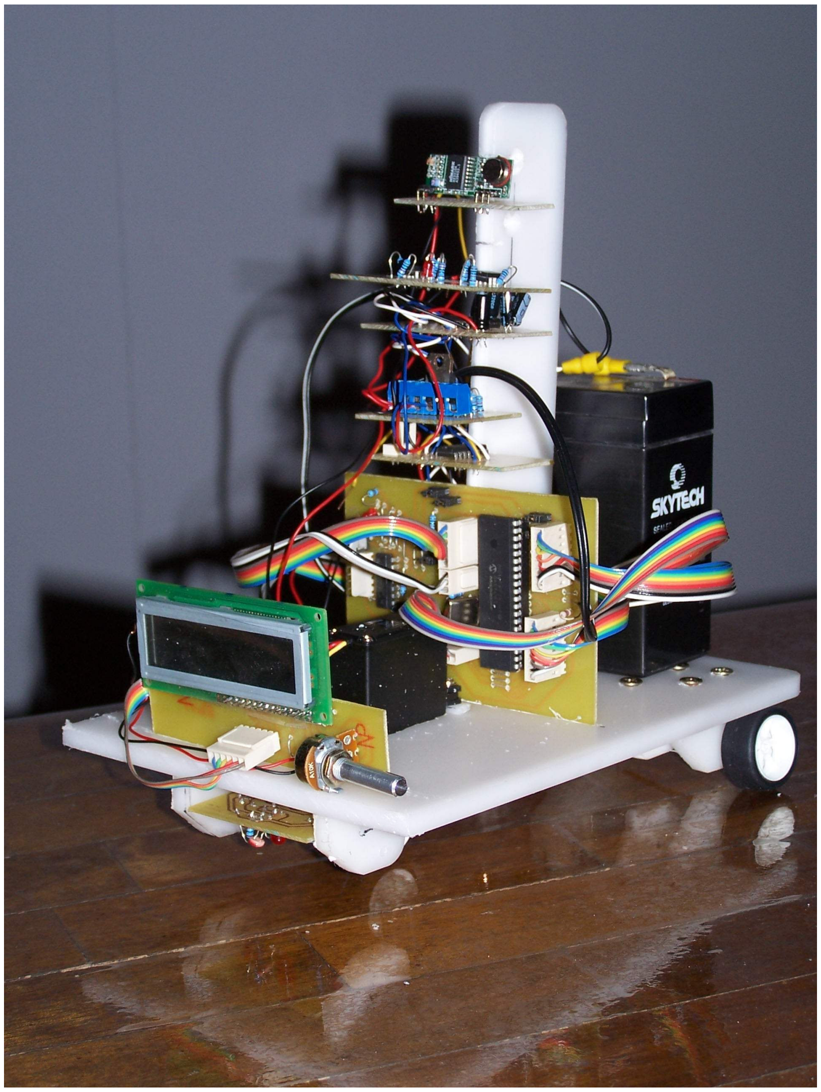


Figure 10. Assembled Robot with boards in situ

Chapter 4. Electronics Design

4.1 Test Bed/Robot Main Board

Once the method of programming and computer interfacing were finalised the next step was to build a testing bed. Originally this was done with a dedicated board using PicPGM (http://www.members.aon.at/electronics/pic/picpgm) and the Low Voltage In-System Programmer circuitry (LVISP)(Appendix C) interfacing with the PIC16f877A on a breadboard. The programming, powering down, removal and reinsertion became time consuming and quite monotonous. As a result the first major board designed to be the test bed was instigated.

The first item, in the design, was to implement the LVISP so the chip could be programmed and then quickly run to test the code. If there was an issue the PIC needed to be able to be quickly reprogrammed again. To get around this Header Terminal Strip and Jumper Shunts were incorporated in the design to facilitate the change.

A careful look at the PIC16F877A Pin out Diagram (FIGURE 10.) will show that, while the microcontroller offers a good variety of functions, its layout is a little jumbled. This meant designing to bring relevant areas together and have all of the same PORT pins accessible from the same point. Doing so allowed for a cheap, user-friendly header plug system to be used to stop the possibility of cables being plugged in backwards. While there was little chance of damage to the electronics, it creates a debugging issue that might not be easily rectified by an inexperienced user.

Another addition was a reset button so the Microcontroller could be reset in case of error or just to restart a sequence of code. The reset button could be easily left out of production assembly without detriment to the circuit.

The power supply circuitry was chosen because it was envisioned that the main board would also supply power to other parts of the robot. Early trials of this showed the microcontroller was prone to reset especially when a high draw item like a motor was changing direction. This was rectified by incorporating a couple of large 470uF capacitors across the feed and supply pins of the LM7805 to smooth the power at the demand time.

Schematics are provides in Appendix E for this main board and a picture of the mainboard can be seen with Figure 11.

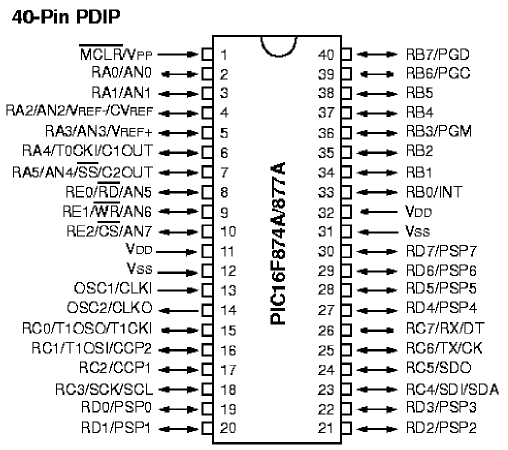


Figure 11. Pic16F87XA Pin out Diagram (Microchip, 2006b)

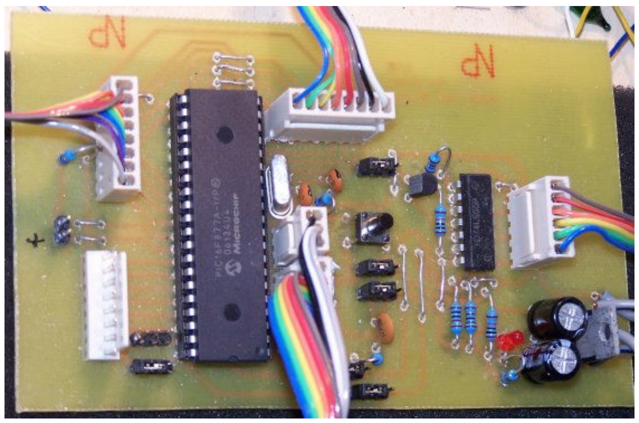


Figure 12. Picture of Mainboard

4.2 Line and light following Circuitry

Light Dependant Resistors (LDR) (Data Sheet available on CD) are used to detect the line or light differences required to follow these sources. Red 5mm LED's were used in conjunction with the LDRs to reduce the effects of incidental light on the sensing. The use of LEDs should also reduce the effect of a darker room where the LDRs will move towards infinite Resistance and move outside the parameters of the Microcontroller ADC.

Even though the LDRs were purchased at the same time from the same outlet there was significant differences in the output resistance at the same light. To counteract this, the 10K resistor suggested for the theoretical circuit were adjusted as necessary to bring resistances within a reasonably close range.

In this configuration the LDR's output is sufficient to interface with the ADC of the PIC16f877A without further electronics.

The addition of a terminal strips and Jumper shunt allows the Leeds to be turned off if the board is used in Light following Mode (Figure 12)

A Schematic is provided in Appendix D.

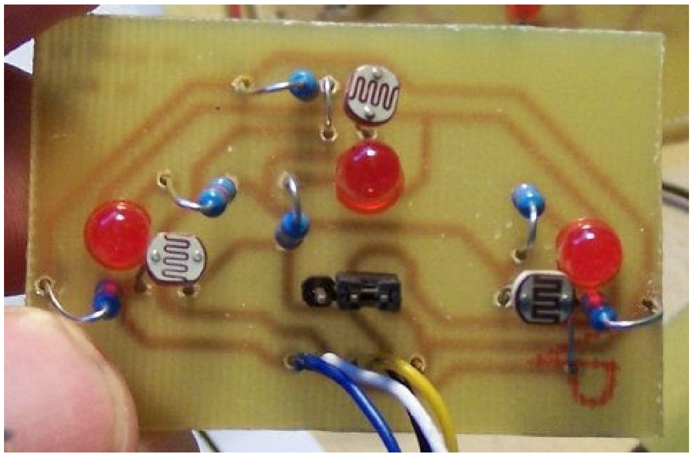


Figure 13. LDR Circuitry

4.3 Compass Circuitry

Two issues need to be acknowledged with the Dinsmore 1490 Compass module discussed in Chapter 2.3. The first being that the pins are very closes together and are a little flimsy in construction. According to the specification sheet crossed or reversed current can destroy the internal circuitry. Likewise, time in the solder pool is also a concern. To combat this a 16 pin IC socket was cut into 4 x 3 pin sockets to insert the component and help remove the above issues. The result can be seen in Figure 13.

Pull-up resistors were then all that was needed to interface with the PIC16F877A. The pull-up resistors create logic 1 or 0 depending on the bearing of the compass. This logic level can be read directly by the PIC16F877A.

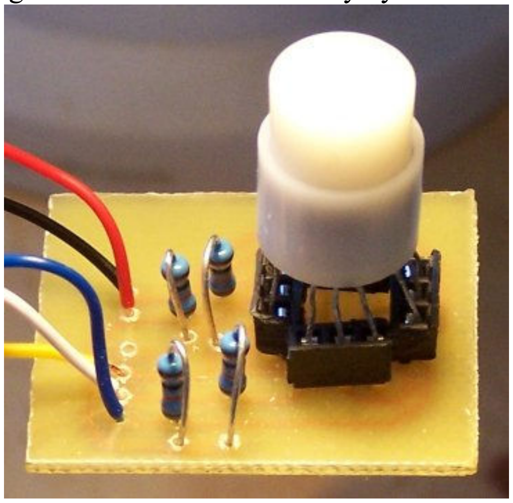


Figure 14. Compass Board

4.4 Hall effects circuitry

The Hall Effects assemblies were constructed in as 3-part design. The first being 2 x 33 pin cogs attached to the drive shafts of the robot. This supplied a method of accurately reading distance in a 13mm diameter piece. Because of the room constraint a single UGN3503 Hall effect sensor board was created for each side of the robot. This board consists of only the sensor and points for power in and sensor output. The board also enabled easy mounting under the robot.

The addition of a magnet to the rear of the Hall effect sensor was then required. The South of the magnet being attached to the sensor meant the sensor would detect when the teeth of the magnetic cog are in the vicinity. These assemblies and the magnets can be seen in Figure 9.

The Hall effect processing board features an LM833 low noise OpAmp (ON Semiconductor, 2006)(Data Sheet available on CD). The LM833 is set up in a Window Comparator configuration using a voltage divider with 200Ω potentiometer and a 100Ω resistor for each side of the robot as the voltage reference. "A 'comparator' is a circuit that compares an input voltage with a reference voltage. The output of the comparator then indicates whether the input signal is either above or below the reference voltage." (VanRoon, T. 2006)

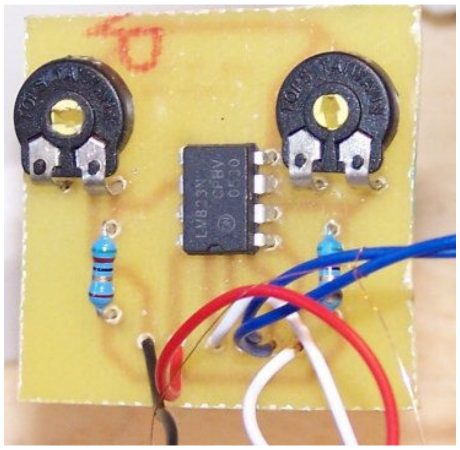


Figure 15. Hall Effect Processing Board

The UGN3503 has an output voltage of around 1 volt when connect in the format when there is no metal in its presence. The 200Ω potentiometers are then adjusted to match this voltage so logic 0 (0 volts) is sent. The output from the LM833 is then a square wave moving between 0 volts and 5 volts that the Pic 16F877 can interpret as movement.

To complete the drive assembly and incorporate position sensing two 33 tooth metallic cogs were chosen from a hobby shop. These allowed the measurement of 1.515mm increments when calculated from the 98mm wheel diameter of the previously selected wheels. This was thought to be quite accurate enough for this application.

4.5 H Bridge Circuitry

The H bridge circuitry is quite unremarkable because the L293D takes all of the complication out of the circuitry. All that is required besides the power and earth is the PWM signal from the Microcontroller for each side and logic high of 5 Volts to enable each side of the H-bridge controller. In this instance they are connected together at the PIC16F8767A because when the Motors are to be shut off both motors will be disabled at once. As mentioned before the PWM is supplied from pins RC1 and RC2, the CCP2 and CCP1 outputs. This is sufficient to supply the power to actuate the L293D. The output is simply 2 power lines that connect straight to the motor.

4.6 434 Hz Transmitter and Receiver

The Receiver module is a straightforward connection only requiring power, an earth and the data out line. A long track on the board was created to act as the antenna to save having an external antenna.

The Transmitter module is a little more involved with the inclusion of a MAX232 IC (Texas Instruments, 2006) (Data Sheet available on CD) incorporated into the design. This IC converts the RS232 output from the Serial Port to Logic levels for the PIC16F877A as discussed in chapter 2.8.

The connection to the MAX232 is a little back the front from the expected. The inputs and outputs are in relation to the IC itself so to transmit a signal from the computer the signal goes into the Received pin 13 (R1 In) and is sent out via Receiver pin 12 (R1 out).

The R1 output then goes to the Data pin on the TX434A (Pin out available on CD). An extended track on this board also acts as an antenna to save having an external antenna. The only other connections required are the power and the earth.

4.7 LCD Module.

The LCD PCBoard is also quite unremarkable and only used to mount the LCD module, a potentiometer and the header to interface to the PIC16F877A. The potentiometer is used to adjust the contrast on the LCD. The potentiometer ties the voltage, the ground and the contrast pins together. Adjusting the potentiometer adjusts the contrast accordingly.

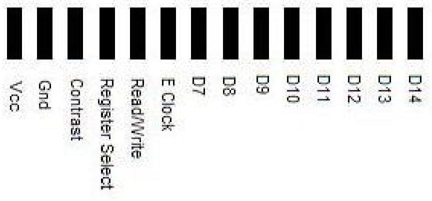


Figure 16. Hitachi 44780 LCD Pin out (Hitachi, 2006)

The LCD has been set up in the 4 Bit configuration so only 6 pins are needed to run the LCD and send the required characters to it. The Read/Write pin is tied to the VCC Line so it is easy to write all of the time. Lines to the Register Select, Eclock, D14, D13,D12 and D11 are all that is necessary then to interface the LCD module and the PIC16F977A together.

4.8 Stop Button Circuit

The Stop button circuit is simply a mount so the button can be pushed if the unit is in eminent danger or needs to be instantly stopped.

4.9 Connecting it together

The schematics in Appendix D show the connections of each electronic module to the Mainboard housing the PIC16F877A. Board groups are connected together with an 8 pin Header so the group plugs into a specific Port and relevant pins are correctly aligned. Inserting the wrong board plug will just result in inappropriate behaviour in the robot.

Power is has been deliberately kept separate so there is no chance of catastrophic failure due to power being introduced into the wrong area. This system will not, of course, stop a concerted attempt to put power into an incorrect spot. It will make it easy for someone who is trying to assemble the system, with limited knowledge, doing accidental damage.

As discussed earlier similar areas are grouped together where possible. The PortA group has the ADC dependant inputs of the Light/ Line following sensors and the compass inputs on it. This is a grouping of directional sensors

The PortB group has the inputs from the LDR and the Emergency button. Both of these peripherals fire interrupts on the Pic16F877A when actuated so are necessarily on PortB, which has this option available.

The PortC group houses the Servo control, H-Bridge, its Enable control, the Motor Directional control and the Received data from the computer interface. The PIC16f877A PortC carries motor functions in the form of PWM generation and the Receive/transmit UART area. Grouping the Motor Direction and the Servo control in the same area utilises this Port to its fullest

The PORTD area houses the controlling of the LCD interface and the Music output board.

Chapter 5. Software Consideration

5.1 Computer Software Programming

With extensive experience in the basic language, a copy of Visual Basic 6.0 Professional and access to a plethora of Visual Basic programming sites for reference the obvious choice for the computer software was Visual Basic. The advantages of this software are:

Pre-Existing DLL's for functions like Port Access
Graphical interface for User Interfacing
Modular programming for ease of debugging

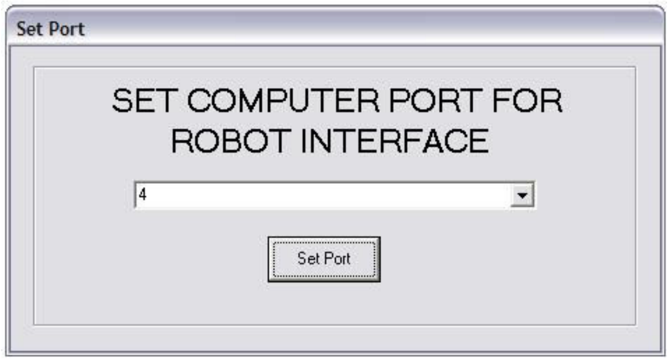
5.2 The Computer Software

This section will be a user manual for the Software. Extensive code remarks are incorporated into the Visual basic code that is incorporated on the CD.

5.2.1 Comm. Port set-up

Each time the software starts it searches for 2 files, the Port number file and the Robot Id file. If these are missing, example at the first start, the program asks for these to be set.

If the Port Id file (PortNumber.txt) is missing the following dialog is opened (Figure 16). By simple error control the program finds the available Comm. Ports and adds them to a dropdown combo box. The user then selects the relevant box and the port number is saved.


Set Port

SET COMPUTER PORT FOR ROBOT INTERFACE

4

Figure 17. Computer interface setting request dialog box

5.2.1 Robot ID Set-up

If the Robot ID file (ID.txt) is missing the following Dialog is opened (Figure 17). The dropdown box is populated with 26 ID Letters. A single unit can use the first letter. This function is not properly implemented here, though the code is ready to apply it, as multiple bots were not available for the testing

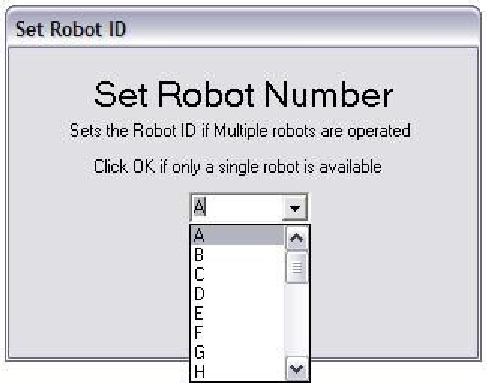

Set Robot ID
Set Robot Number
Sets the Robot ID if Multiple robots are operated
Click OK if only a single robot is available
A
A
B
C
D
E
F
G
H

Figure 18. Robot Number Dialog

5.2.2 Main Menu

The main dialog allows access to the relevant areas of the robot interface. Figure18 shows the interface

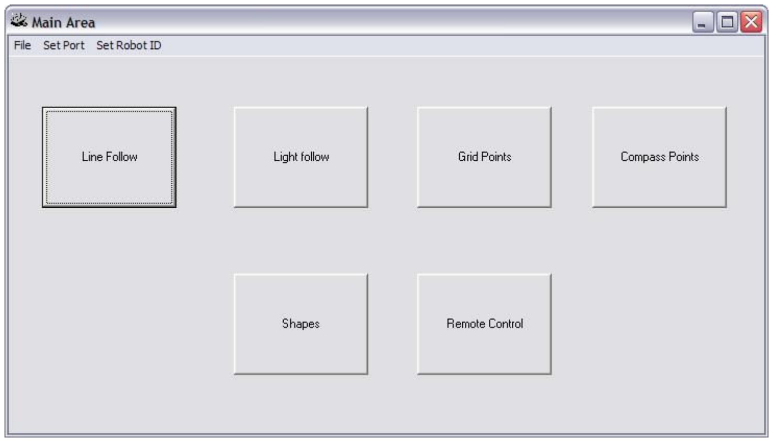


Figure 19. Main Menu Dialog

The menu options do the following

(a) File - Opens Exit that allows the user to Exit the program

(b) SetPort - opens the Set Port Dialog above and allows the port to be changed

(c) Set Robot Id – opens the Robot Id Setup above and allows the Robot number to be changed.

The Menu buttons have the following Functions

(a) Line Following immediately sends the robot the command for Line Following mode.

(b) Light Following immediately sends the robot the command for Light following mode.

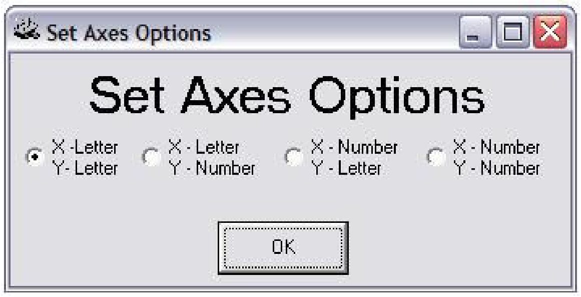
(c) Grid Points – opens the Grid Dialog (Figure 20) so a design can be made on the grid.

(d) Compass Points – opens up the Compass Point Dialog (Figure 21) so compass points can set for the robot to negotiate.

(e) Shapes – opens the shapes dialog (Figure 22) so the user can select a shape for the user to send to the robot.

5.2.3 Grid Points Dialog

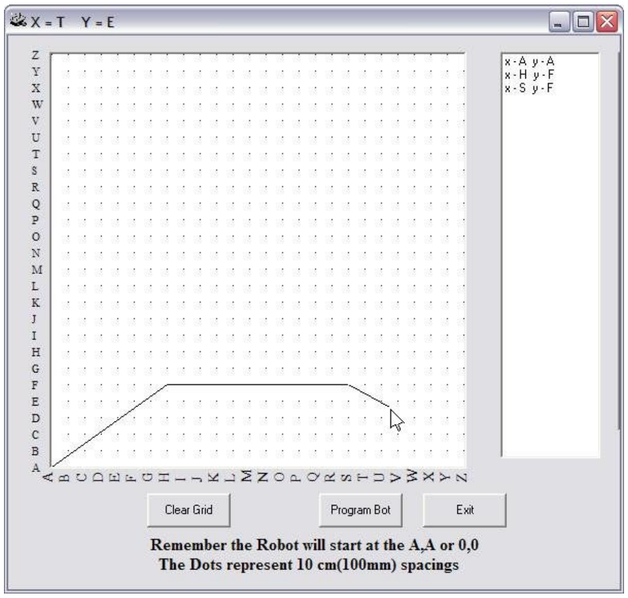
The Grid Points Dialog (Figure 20) allows the user to set the robot a path of movement via a grid system. The Grid can have its axes set to X and Y- Letter, X –Number Y -Letter, X – Letter Y – Number, X and Y Numbers. The Axis Setting Dialog allows these to be set each time (Figure 19).


Set Axes Options

Set Axes Options

[✓ X -Letter Y- Letter] X - Letter Y - Number X - Number Y - Letter X - Number Y - Number

Figure 20. Set Axis Option Dialog


X = T Y = E

x - A y - A
x - H y - F
x - S y - F

Remember the Robot will start at the A,A or 0,0
The Dots represent 10 cm(100mm) spacings

Z Y X W V U T S R Q P O N M L K J I H G F E D C B A
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Clear Grid
Program Bot
Exit

Figure 21. Grid Programming Dialog

Points are plotted on the grid at the same time the points are displayed in the column on the left so the format of X, Y navigation that can be easily understood by children.

To operate the cursor is moved around the grid. A Dragline will show where the line will go. Right clicking will remove the line. Left clicking will place the line as a solid line and activate the next Dragline.

Two things that need to be remembered:

(a) The robot starts from the 0,0 point, whatever combination this becomes by the settings, as any grid navigation would be expected to.

(b) Each increment on the graph represents 10cm (100mm) this needs to be remembered because the robot will hit any objects in or falloff surfaces that are in its path. This format of the robot does not have these external collision sensors.

The buttons have the following functions

(a) Clear Grid – Clears the grid and all the variables related to any previous grid movement.

(b) Program Bot – Sends the coordinates to the Robot so it can start to navigate.

(c) Exit – Returns to the Main Menu.

5.2.4 Compass Interface Dialog

This Dialog (Figure 21) allows Compass Coordinates to be entered via the compass point buttons. A Line appears on the compass screen and the coordinates are displayed in the left list box so the results can be viewed as both a line direction and as the compass bearing. Pressing the C Button cancels the previous points. The lines can be cancelled back to the first point.

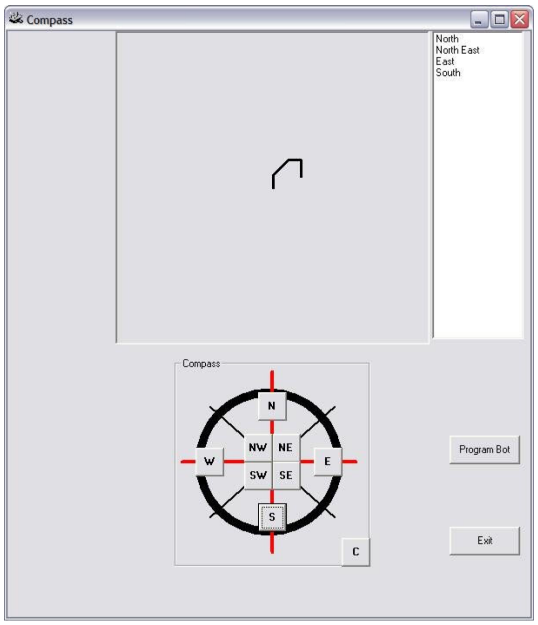


Figure 22. Compass Dialog

The function buttons have the following options:

(a) Program Bot – Sends the set course to the Robot.

(b) Exit – Reloads the Main Menu

5.2.5 Shapes Menu

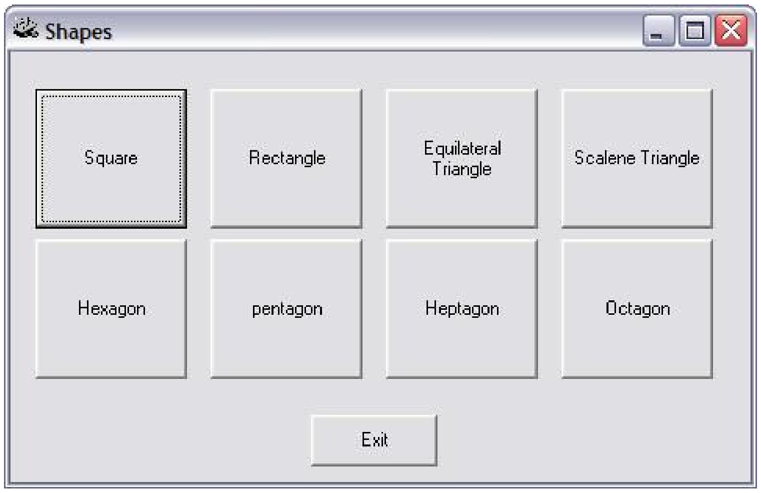
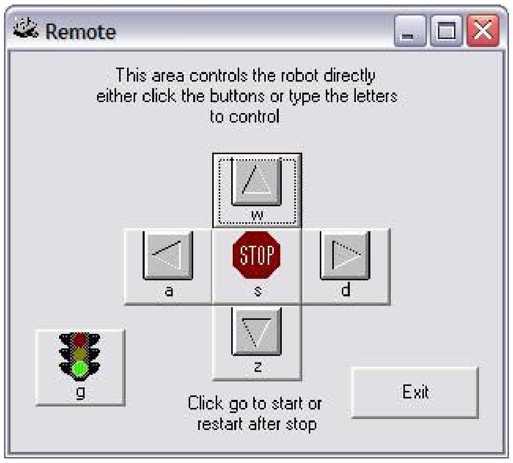


Figure 23. Shapes Menu

The shapes menu simply sends the command to the Robot to tell it which shape to draw. The shapes and sizes are predefined.

5.2.6 Remote control

The remote control interface uses two methods of steering. The appropriate buttons can be clicked, with the mouse, to send a command to the robot. Otherwise, the Key Press option has been set on the Remote control form, so presses from the keyboard are trapped. The w, z, a, d, g and s keys trigger the appropriate button event so the robot can be operated remotely. The go button must be pushed to start the robot or restart after a stop. The exit button automatically stops the Robot at the same time.



This area controls the robot directly either click the buttons or type the letters to control

Click go to start or restart after stop

Figure 24. Remote control menu

5.3 Interesting Aspects of the Computer code.

5.3.1 The Communication Port code.

Visual basic 6 has built in OCXs and DLLs that handle most of this interfacing. These works fine on all Windows O.Ss Pre XP or the NT series. For the later versions a port interface like Inpout32.dll (http://www.logix4u.net/inpout32.htm) is required. Logic4U, the coder of this interface software, was approached and rights were given to include this DLL with this software in any future incarnation.

As for the Visual Basic code (Appendix F.3.) , the relevant comport is called, it is turned on and the data is sent. This interaction is very easy.

5.3.2 The Grid Code.

Many aspects of this code were taken from Multilin.zip by Ethan at www.freevbcode.com/ShowCode.asp/?ID=1240. The original code was horribly fragmented and hard to follow. The code has been reworked and optimised.

The code (Appendix F.1.) initially plots an evenly spaced grid of dots on a Picturebox control. From there a Dragline is fed out behind the cursor. This allows a visual indication of where the line will go. The code also allows for the line to drawn from the nearest Grid Point and the removal of the Drag Line when the left mouse button is pushed.

A coordinate history has been made available so all past coordinate additions can be erased.

Because of the difficulty in working trigonometry and angles in the PIC16F877A, code that works out the angle and movement in relation to the last was created in Visual Basic. This code breaks each direction down into an angle of 360 degrees in relation to the last direction with straight ahead being 0°. The required rotation is broken down into quadrants and the new heading is placed into its quadrant and the angle amount is deducted. The angle and the tangent is then worked out from the remaining angle that is less then 90° The Quadrant amount, in degrees, is then re-added e.g. 250° will be in the 3rd Quadrant. 250 – 180 is 70 degrees. The 70° angle and the tangent are found by the tangent rule. The 180° will be then be re-added to give the true angle.

It was discovered that the graph and grid points could only give 2° accuracy. As a result it was possible to halve the angle before sending it to the robot. This was done to fit within Hexadecimal constraint of Hex FF or 255 decimal. Dividing the angle in half means the angle can be sent in one 8-bit burst, and later doubled at the Robot end, because 360 divided by 2 is 180. Figure 24 demonstrates the constraints of how a single character is sent from the computer to the Robot.

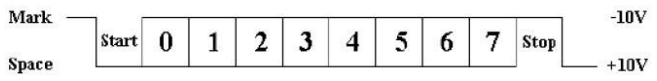


Figure 25. RS232 Protocol Form (Kim, 2006)

"The diagram above shows using the common 8N1 format. 8N1 signifies 8 Data bits, No Parity and 1 Stop bit format. The RS-232 line, when idle, is in the Mark state (Logic 1). A transmission starts with a start bit, which is Logic 0. Then each bit is sent down the line, one at a time. The LSB (Least Significant Bit) is sent first. A Stop bit (Logic 1) is then appended to the signal to make up the end of a transmission. "(Kim. 2006), in layman's terms The PIC16F877A expects to see a zero to start then a combination of 8 ones or zeros to make up the data then a one to say it is finished. The combination of 8 ones and zeros are where the constraint comes in. Figure 25 demonstrates how the largest binary 8-bit number is represented and its equivalent binary representation.

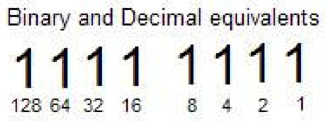


Figure 26. Binary Decimal Equivalents

It can be seen that adding all the digital amounts 128 + 64 + 32 + 16 + 8 + 4 + 2+ 1 = 256. This is how numbers and letters are sent via modems.

In this application using the binary representations of 0 to 180 for the halved degrees. The value can be sent in one 8 bit data bit represented as 1's and 0's and doesn't need to reassembled in the PIC16F877A from two passes as a number like 359 would need. In reality, the 180 degrees would be represented as 0, but to demonstrate the decimal number 180 would be represented in binary as 10110100 in its 8-bit form.

5.3.3 The Compass code

The compass code (Appendix F.2.) uses the picture box again to show the progress of the robot. A representation of a compass is used for the navigation buttons. As the buttons are pushed (Figure 21) a line is drawn on the screen and the compass directions are placed in the list box at the side. The compass directions are converted into a 4-bit code representing the expected input from the compass on the PIC16F877A. This is explained more thoroughly in 5.4.2

Incorporated in this code is a direction history so a sequence of instructions can be deleted back to the initial starting point.

5.4 PIC16F877A Coding

The coding format selected, for programming the PIC16F877A, is ASSEMBLER. Assembler enables a compact code that can even allow code sections to be timed for important functions. Code written in it can be easily optimised. It was chosen for this reason.

Assembler is not the "dream" language it may appear to be. Grasping its concepts is difficult, it is often not very well explained and it has no formatting in the way of modules or the OOP of higher languages possess. To make the code more readable the code for this project have been placed in similar section e.g. Motor codes and codes relating to these go into the same section. This made debugging the code much simpler.

The microcontroller controls nearly every aspect of the robot from producing the PWM for the motors and servo to counting the distances moved. A good amount of commenting is done in the ASM file so an overview of the more important modules will be shown here. The full coding is available in Appendix H.

5.4.1 LDR Sensor Code

The LDR coding (Appendix H.1.) involved using the ADC functionality of PORTA on the PIC16F877A. This function allows the use of the internal ADC unit of the microcontroller. This basically charges and discharges an internal capacitor using the resistance found on the Port Pin. The capacitor discharge is timed then the PIC converts the time into a digital value. Using this method the LDR with the lowest value (the one with the line under it) can be found by continually polling the 3 pins. If the LDR to either side is on the line the robot will turn so the lesser value is in the centre.

5.4.2 Compass Coding

The compass pins are attached to Pins 4,5,6 and 7 of PORTA (Figure 10). These pins are set to digital input because of the output properties of the Dinsmore Compass. The full port is read and the irrelevant bits are removed. The port is read every 0.5 seconds.

The output of the compass is a 4-bit word.

N	1000
NE	1100
E	0100
SE	0110
S	0010
SW	0011
W	0001
NW	1001

This is made up of the logic 1's and 0's that indicate the compass direction.

To find if the robot is heading in the right direction the code checks the current direction against a look up table with the above binary codes in it and takes note of the table number of the relevant binary code. The required direction binary code, sent from the computer, is checked in the same table. Its Table position is also noted. Depending on the differences between these two values the robot will turn either left or right e.g. the robot is heading SW (0011) position 5, keeping in mind the tables first entry is counted as 0, and the new coordinate is E (0100) position 2. The difference is less then 4 table positions before the current bearing so the wheel turns right and the robot reverses until the new position is found. If we were heading SW (0011) and wished to go N (1000). North is greater then 4 positions before in the table so the wheel turns left and the robot reverses until the correct heading is reached.

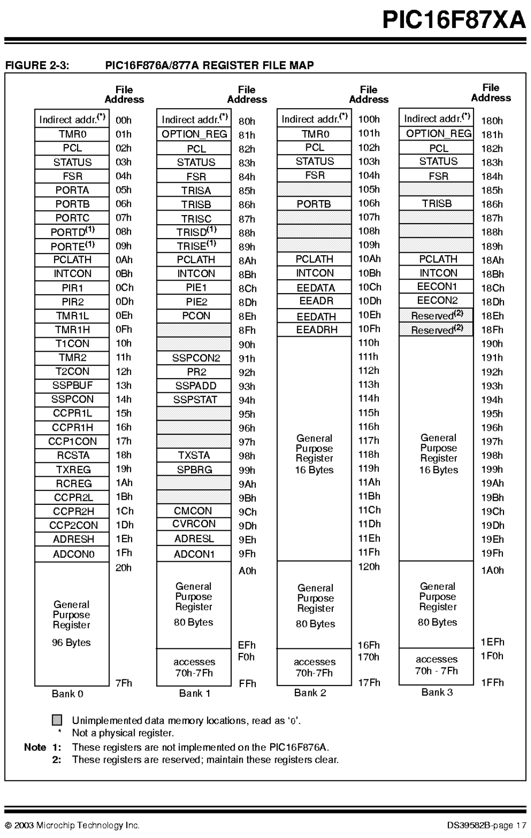
The Hall Effect Sensors are used to detect the distance travelled. This is updated each step and is discussed in the Interrupt section. The code is shown in Appendix H.2.

5.4.3 Grid following code.

The code (Appendix H.3.) firstly receives the list of angles and tangents produced in the Visual Basic code as discussed in 5.3.2. Each piece of data is stored in the memory area range of A0h to FFh (Figure 26). This allows 95 entries or 47 different directions to be added.

The code then loads the first angle. The angle data is halved to see if the angle of movement is greater or smaller then 90 (this represents a full 180 degrees). Depending on the result the robot wheel direction is set. The original angle is then doubled to return it to its true 360° representation. The robot is reverse on one wheel until the angle is correct. The Hall effect Sensors detect the movement. By taking the distance at the centre of the two wheels it was calculated that the sensors would be able to detect approximately 1.5 degrees of change. The code counts the degrees moved in this method and stops when the required distance has passed.

The tangent amount is then loaded from memory and the robot moves forward counting the Pulses from the wheels. The robot is set to move 100mm for each space on the grid. 66 pulses are equivalent to 100mm. So 66 pulses from the sensors are counted for each unit until the tangent amount has been reached.



PIC16F87XA

FIGURE 2-3: PIC16F876A/877A REGISTER FILE MAP

	File Address		File Address		File Address		File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h	▨	105h	▨	185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h	▨	107h	▨	187h
PORTD(1)	08h	TRISD(1)	88h	▨	108h	▨	188h
PORTE(1)	09h	TRISE(1)	89h	▨	109h	▨	189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh	▨	8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h	▨	90h	General Purpose Register 16 Bytes	110h	General Purpose Register 16 Bytes	190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h	▨	95h		115h		195h
CCPR1H	16h	▨	96h		116h		196h
CCP1CON	17h	▨	97h		117h		197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah	▨	9Ah		11Ah		19Ah
CCPR2L	1Bh	▨	9Bh		11Bh		19Bh
CCPR2H	1Ch	CMCON	9Ch		11Ch		19Ch
CCP2CON	1Dh	CVRCON	9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
			EFh		16Fh		1EFh
		accesses 70h-7Fh	F0h	accesses 70h-7Fh	170h	accesses 70h - 7Fh	1F0h
	7Fh		FFh		17Fh		1FFh
Bank 0		Bank 1		Bank 2		Bank 3	

▨ Unimplemented data memory locations, read as '0'.
* Not a physical register.
Note 1: These registers are not implemented on the PIC16F876A.
2: These registers are reserved; maintain these registers clear.

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Figure 27. Pic16F877A Register File Map (Microchip, 2006b)

5.4.4 Motor Codes

The motor codes (Appendix H.4) control the built in PWM function. They use the built in Timer2 function to control CCP1 and CCP2 pins of PORTC (Figure 10). This section also controls PIN 3 of PORTC. This has been set to enable the H Bridge circuitry. Forward and reverse is also controlled from here by raising the logic level on the required pins.

5.4.5 Shapes Codes

The preset shapes are preloaded into the Microchip EEPROM (APPENDIX G). This memory stays viable when the power is removed from the microcontroller and is therefore in memory at all times. The shapes movement code uses most of the Grid following code to operate. Code is shown in Appendix (H.5)

5.4.6. Servo Interfacing

The Servo interfacing section (Appendix H.6.) acts in conjunction with the TMR0 inbuilt timing function. TMR0 is set to run a continual 20ms PWM cycle. Another timed code sequence adds the 13,7 or 18 ms high pulse that selects the direction the servo turns.

5.4.7 Port Interfacing

This area initialises all the timer functions in TMR0 and TMR1 and all of the Ports on the microcontroller for their required function.

5.4.8 Interrupt section

The Pic16F877A has a special interrupt function, which can be set to react to various events. These events can be anything from internal specifically timed interrupts to external inputs from the ADC or other pins on the microcontroller. Once the event fires the interrupt the code leaves what it is doing and moves immediately to the code that services required event. Using this interrupt feature allows the microcontroller to interface with the outside world.

As such the interrupts are the heart of the coding. Important codes like the emergency push button stop are coded here. The interrupt section also houses the Hall effect sensing response so positioning takes priority. The timer functions and the music start here.

Most importantly the wireless interfacing is done here so the message is received on the wireless port, as it is ready.   Code detailed in Appendix H.7.

5.4.9 Sound Section

There are several ways to implement sound on a Pic16F877A. Many involve converting Midi files or similar into electronically identifiable data. Research into implementing music showed that the Pic16f877A is capable of interacting with peripheral electronics to produce quality music. Most of these methods are quite involved and appeared to be outside the scope of this project. An easier way to do this was required. It was noted, during this research, that it is possible to produce a beep in a piezo speaker with minimal peripheral electronics.

Bringing music back to basics, one must realise that providing a vibration at a particular frequency produces a particular musical note. In different musical instruments this is done in various ways. A stringed instrument vibrates its strings at the particular frequency to form a note or a chord, where as a wind instrument might vibrate a reed to produce the required sound waves. Likewise a stereo sends a particular vibration to a speaker to produce each note.

With this in mind research focused on discovering the frequencies for individual musical notes. The theory being if the individual note vibrations could be produced from the Pic16f877A, music could be played by inputting the notes from sheet music.

The internet site http://www.phy.mtu.edu/~suits/notefreqs.html deals with the physics behind musical note frequencies discussing the frequencies in Hz and the wave lengths in cm's. Considering the plethora of information on hand at the site, and trying to put it into perspective for this project, the first idea was not to try producing symphony quality music. With this in mind all notes except the Major scale could be ignored. This would leave the basic notes of A, B, C, D, E, F and G in its three forms lower, middle and high a total of 21 notes.

If this was to be translated for use on the PIC16F877A some more thought was needed as to its implementation. The note frequencies could be hard coded against a fixed number system so an individual note could be accessed. This can easily be done by using a look up table similar to the ones being used for the compass code. With this in place a song could be coded into another table and the individual note frequencies would be called as required.

The Hexadecimal number system is based on 16 numbers. For easy implementation of the hard coded notes, the earlier number of notes would need to be trimmed. Considering that a musical rest should be included this left 15 notes. A quick look at some prospective music showed that realistically the 15 notes could be taken from Low C to High C this is demonstrated in Figure 27 Column 1. The range would allow a reasonable amount of songs to be played if required.

Producing the frequencies took some more consideration. A musical frequency could be looked at another way, as a PWM signal. A PWM signal historically sends a square wave at a particular frequency (figure 5). The on and off period for PWM is a regular on off pulse that if matched to the frequencies of a musical note the problem would be solved.

Unfortunately, the dedicated PWM pins were previously taken by the motor control circuitry of the robot. Using the built in Timers on the Pic16f877A still allow the generation of PWM. By toggling a Pin on and off at the required rate the PWM is generated. After experimentation the use of Timer0 was the easiest to do this with. This is previously used for the servo function, but by using the music functions after the other function has finished both functions are easily satisfied. The output is then channelled to another pin. Full code in Appendix H7.

The built-in Timer0 can measure time increments from 2µs to 65.356ms. Considering that 1000 Hz = 0.001 seconds or 1 ms and the required note frequency range is 262 to 1175 Hz, using this timer to create the musical notes was quite feasible.

Calculating the specifications for these times is quite a tedious calculation. Considering the prescaler goes from 1:2 to 1:256 with dozens of variations of timings being able to be produced with the prescaler and TMR0 setting. To speed up the process a Timer calculator was found on the web http://www.best-microcontroller-projects.com/pic-timer-0.html This calculator allowed the values to be tested and experimented with easily.

One factor that came to light while using this calculator was the fact that the Times ran off at either end on a single Prescaler. This meant that exact values for the Frequencies weren't possible for most of the range, on a single Prescaler setting, but close approximations that would be possible. Exact values could possibly be found by moving the Prescaler for each note but this would be a little involved so the single prescaler approximation was chosen. Two Prescaler ranges were tested and are shown in Figure 27. The 1:32 scale proved to be very inaccurate and cut out the bottom notes where as the 1:16 Prescaler very nicely covered the note range.

With music timing is important. By setting Timer 1 to fire every ¼ second a very basic 4/4 timing was possible. The choice of music was then an issue. Copyright needs to be considered so older classical tunes that had sheet music readily were available on the Internet chosen. The three tunes selected were Also Sprach Zarathustra by Richard Strauss, Blue Danube by Johan Strauss and Ode to Joy by Ludwig van Beethoven. (music-scores.com, 2006). Small sections of these were reproduced in the code table. The format for each note included the note number (Figure 27 column 5) and the time from the sheet music e.g. Low G played for 4 timing beats is represented by 54. The rest of the notes of the tune were laid out in similar fashion

Musical Note	Freq (Hz)	Prescaler 1:32	Prescaler 1:16	Hex Assign
Low C	262	139	20	1
Low D	294	152	45	2
Low E	329	163	69	3
Low F	349	169	79	4
Low G	392	178	99	5
A	440	187	116	6
B	494	195	132	7
C	523	198	139	8
D	587	205	152	9
E	659	211	163	A
F	698	213	168	B
G	784	218	178	C
High A	880	223	187	D
High B	988		195	E
High C	1047		198	F
High D	1175		205	

Figure 28. Musical note, frequency and Timer0 settings compiled from (Physics of Music – Notes, 2006) (Pic Timer 0 Calculator, 2006)

In the children survey the children responded that they would like music in a robot. Unfortunately the children were more thinking playing Mp3's or CD's on the robot. The final solution is a far cry from a surround sound system and it is unlikely that the classics will be converted into this format. It does show that music can be simply produced using this system and very simple electronics.

5.4.10 Remote Control

The Remote control code replies on input from relevant keys on the keyboard, via the computer software and wireless interface, as discussed in section 5.2.6. The code initially checks for a valid key ASCII code so static and radio noise is ignored. The relevant section is then selected to service the key press.

The forward and reverse code checks a Boolean to decide if the robot is moving is the same direction as last time the forward or reverse code was called. If it is the speed is incremented by 5. If not the speed is reset to a low speed that will stop the robot. The subsequent presses will speed up the robot in the new direction. Once the Robot reaches top speed further presses are ignored. This system allows the robot to be sped up incrementally and the robot will then maintain its speed until it is reversed or stopped if the presses stop.

Left and right are controlled by incrementing and decrementing the PWM steering pulse, between 7 and 18, by 1. This represents full left and full right turn with 13 being centre. Once the maximum or minimum is reached further presses are ignored.

A standard computer has a Type Matic Rate (Characters/second) of 6 with a Type Matic Delay (Seconds) of 250ms. This means the PIC16F877A and the computer will interact a maximum of 6 times in a second. At this rate the Servo will turn from full left to full right in around 2 seconds and go from start to full speed in 3 ½ seconds.

Chapter 6. Conclusion

This chapter brings together the project with respect to the previous chapters. Discussed here will be the achievement of objectives and potential for further work. This project has been very difficult at times but has been incredibly rewarding and has pushed personal boundaries aside. It has truly been educational.

The project has allowed the demonstration wide of variety of skills and topics from programming to design both electronic and mechanical. Totally new skills like methods of designing and manufacturing PCBoards had to be learnt and demonstrated. The author designed and produced all of the electronic circuits used and tested. Circuit board designs, designed on PCB123, are included on the CD.

This project was truly a worthwhile educational experience!

6.1 Final Cost

The final cost of the components is listed below. The items from the various suppliers are listed with the prices they were purchased for:

UGN3503U Hall effect x 2	$ 9.90	Jaycar
BC557 transistor	$ 0.26	Jaycar
7805 Voltage Regulator	$ 0.99	Wiltronics
Dinsmore 1490 Compass	$27.95	Wiltronics
LCD Display	$19.96	DSE
4.0 Mhz Crystal	$ 3.95	Jaycar
TX434	$ 6.00	Oatley Electronics
RX434	$ 8.00	Oatley Electronics
L293D H-Bridge Driver	$ 4.95	Wiltronics
Max232	$ 5.34	Wiltronics
LM833 OpAmp	$ 2.40	Jaycar
74LS05 Hex invertor	$ 0.60	Jaycar
PIC16F877A	$12.95	Jaycar
LDR x 3	$ 3.63	Wiltronics
470 uF electrolytic cap x 2	$ 1.10	Jaycar
1 uF electrolytic cap x 5	$ 1.25	Jaycar
10 uf electrolytic	$ 0.20	Jaycar
0.022uf Ceramic x 2	$ 0.28	Jaycar
0.01uf Ceramic	$ 0.28	Jaycar
LED x 4	$ 1.00	Jaycar
Trim Pot 200ohm x 2	$ 0.64	Jaycar
Cutting Board	$ 8.00	Supermarket
DC Motor	$ 1.38	Wiltronics
Tamiya Super Avante Kit	$ 9.66	DSE
Servo	$19.95	Hobby Shop
33 tooth metal cog x 2	$16.00	Hobby Shop

8 pin Header x 4	$ 3.80	Jaycar
8 pin Locking Header x 4	$ 1.60	Jaycar
Jumper shunts	$ 1.45	Jaycar
40 pin terminal strip	$ 0.65	Jaycar
Piezo	$ 4.10	Jaycar
40 pin IC Socket	$ 0.70	Jaycar
16 pin IC Socket	$ 0.34	Jaycar
Resistors x 18	$ 0.90	Jaycar
Switches x 2	$ 1.80	Jaycar
Ribbon Cable 1 m	$ 2.89	Jaycar
Terminal Block	$ 2.98	Jaycar
500000 Candle Power torch	$19.95	Car Store
PCBoard	$16.98	DSE
2 pin Header x 3	$ 1.50	Jaycar
3 pin locking Header x 3	$ 0.30	Jaycar
Total	$222.56	

While this is $70 dearer then the target $150 price, it has to be remembered that all components were purchased at retail prices over the counter. Purchasing at trade or wholesale price, as would be available to a manufacturer, would easily bring the price down to the targe price of $150. Interestingly the cheapest parts and simplest methods of manufacture were searched out at all times.

6.2 Achievement of Objectives

The aims and objectives set out in the Project Specification at the beginning of the project were:

a) Design, construct and commission a small robot suitable for use by primary school students of grades 6 and 7.

b) Research the current school syllabus and teacher requirements so the project will be relevant.

c) Obtain an overview of the children's expectations of the project and other aspects to make the project suitable for a child's use.

d) Create the robot from low cost components so the final project costs less than $150.

e) Build the robot from off-the-shelf components, where possible, so it could be supplied in kit form and be assembled by a resourceful teacher from plans.

f) Design robot structure, movement components and spatial awareness components taking into consideration interchangeable parts.

g) Add functions including musical and tactile interface.

h) Create a computer interface for interaction with the robot.

i) Create relevant codes for the microchip including distance recognition, motion, light and line following and spatial recognition.

j) Create relevant interfacing components to implement computer/robot normal functioning and remote control.

All of the main objectives were touched on and completed during this project. Some of the ways covered may not be optimum e.g. the music coding but all area were attempted and a result was achieved. The final cost was a little disappointing.

Achieving these objectives was much more time consuming than expected. One main area was difficulty debugging the microcontroller live. The expensive boards with microchip debugging would have made for some much less frustrating times.

In hindsight PICBasic would have been used because PIC Assembler is a huge learning curve even for someone who has a background in assembler. Though it is second nature now a considerable amount of time was spent working with poor documentation and even worst examples.

Another difficulty was self-funding the components. This cost more then expected especially trailing different ideas during the process and sometimes resulted in delays in sourcing components. Something like this would be much better done in house at the university.

6.3 Further Work

There is possibility for future work with this project. This could be a valuable tool for use in schools and could easily be implemented and distributed on scale. To integrate in schools the following area would need to be addressed

(a) A plastic moulded cover for the robot. This would finish the robot and allow parts like the LCD to be mounted on the robot. Plastic moulded chassis parts would also be a plus.

(b) Have some sort of touch bumper sensor designed. This would stop the robot bumping into things and possibly causing damage. It could also possibly be used to stop the robot from falling off a table for example. This could also be in the form of an Infrared radar system.

(c) USB interface. At the start of the project the use of USB was tossed around for the interfacing. There was concerned about USB licensing for a marketable product though. Over the last 12 months USB has become more prevalent and many new computers no longer have the serial or parallel ports supplied. It will probably be a couple of years before Schools get the newer computers but this is an issue of obsolescence. Not addressing this would make this final product less then attractive.

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APPENDIXES

Appendix A. Project Specification

University of Southern Queensland
FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project

PROJECT SPECIFICATION

FOR:	MATTHEW BISHOP
TOPIC:	EDUCATIONAL ROBOT DESIGN
SUPERVISOR:	Mr. Mark Phythian
SPONSORSHIP	Faculty of Engineering, USQ
PROJECT AIM:	Design a low cost educational robot, which can be incorporated into current school curriculums targeting student of grade 6 and 7, to stimulate an interest in Engineering. The bias will be to create the robot so it can be reproduced with off the shelf components where possible or supplied in kit form. Another focus will be to make the robot a usable tool that can be used often to demonstrate relevant educational ideas and principles.

PROGRAMME: Issue A, 27 March 2006

1. Research the current school syllabus and teacher requirements so the project will be relevant.
2. Obtain an overview of the children's expectations of the project and the other aspects to make the project suitable for a child's use.
3. Research all suitable "off the shelf" components including chassis, gearbox and controlling components taking into consideration compatibility and price
4. Create a computer interface
5. Design Robot structure, movement components and spatial awareness components taking into consideration interchangeable parts and functions Musical functions and tactile interface.
6. Create relevant codes for the microchip including distance recognition, motion, light and line following, spatial recognition.
7. Create relevant interfacing components to implement computer/robot normal functioning and remote control.

As time permits

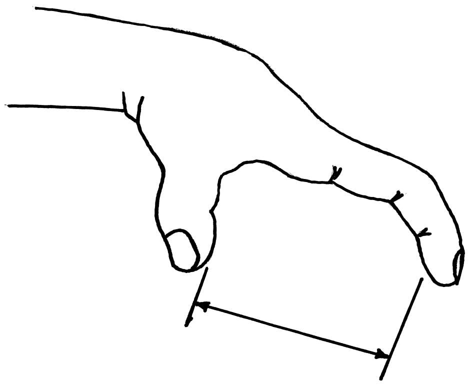
8. Research methods to shape plastic
9. Create a shaped plastic exterior.

AGREED:____________________(Student) ____________________(Supervisor)

Date: _______/_______/_______

Appendix B. School Research

(a) Hand Measurement



Measurement (mm)	B/G	Measurement (mm)	B/G	Measurement (mm)	B/G

(b) Child Questionnaire

Grade 6 and 7 Robot Design Questionnaire

Please circle one (1) of the following in each Question

1. Are you a
   (a) Boy
   (b) Girl

Considering a small robot about the size of a tissue box that you would be able to control using a computer -

2. How do you think the robot should move?
   (a) Walk
   (b) Roll (on wheels)
   (c) Slide
   (d) Other – Please specify_____________________________________

3. If you had to assemble the robot - how long would you like to spend putting it together before you could use it?
   (a) 5 mins
   (b) 10 mins
   (c) 20 mins
   (d) 30 mins
   (e) Other - please specify_____________________________________

4. What should the robot look like?
   (a) A science fiction Robot?
   (b) A car
   (c) An insect
   (d) Other – please specify_____________________________________

5. What should the robot be called? This should be a name like KeFER (Kid Friendly Educational Robot
____
____

6. What else would you like the robot to do?
e.g. Follow a line on the floor, walk forwards and backwards, play music when it finishes its tasks
____
____
____
____
____
____
____

(c) Questionnaire Results

Average Hand Size for children Grade 6 and 7		
	Boys	Girls
	103	90
	90	80
	80	94
	84	81
	77	88
	98	118
	100	108
	90	100
	92	95
	105	83
	105	90
	110	96
	90	86
	100	80
	105	90
	108	95
	107	
	95	
	110	
	100	
	109	
	104	
Total	2162	1474
Average	98.27	92.13
Mode	90	90
Minimum Value	77	80
First Quartile	90.5	85.25
Median Quartile	100	90
Third Quartile	105	95.25
Maximum Value	110	118

Figure 29. Hand Span Results

Boy	Girl	Other	Total
21	15	1	37

Figure 30. Questionnaire Participant Statistics

	Boy	%	Girl	%
Walk	6	28.5	9	56
Roll	9	42.9	4	25
Slide	2	9.5	1	6.3
Other	4	19	1	67
	Others			
	On a sphere		Hover	
	Flies			
	Fly like an insect			

Figure 31. Movement

Time	Boys	%	Girls	%
5 mins	0	0	0	0
10 mins	0	0	1	6.7
20 mins	7	33	3	18.8.
30 mins	8	38	4	25
Other				
15 mins	0	0	1	6.3
1 hr	1	4.8	4	25
1hr 30 mins	1	1.8	0	0
2 hours	2	9.5	1	6.3
3 hours	0	0	1	6.3
1 week	0	0	1	6.3
6 days	1	4.8	0	0
As long as necessary	1	4.8	0	0

Figure 32. Assembly Time

	Boy	%	Girl	%
SciFi Robot	11	57	5	31.3
Car	5	23.8	2	12.5
Insect	4	19	1	6.7
Other				
Person	0	0	3	18.8
Horse	0	0	1	6.25
Guinea Pig	0	0	1	6.3
Dog	1	4.8	1	6.3
Skater	0	0	1	6.3
A Good Looking Guy	0	0	1	6.3

Figure 33. Robot Appearance

BOYS	
Speed Car Race	
Hekker Helpful Educating kind Educational Robot	
RaFaCe Really Fast Car	
ESC	Educational speed Car
FERK	Friendly Educational Robot Kid
FER	Friendly Educational Robot
PERy	Partisipating Engine robot
ER	Educational Robot
FER	Fun Educational Robot
Lenny	
CuCeR	Computer Controlled Robot
Keniffer because it is a good Name	
FRED	Friendly Robot Educational Device
TED	Talking Educational Device
ACER	Australian communication Educational Robot
FRTH	Friendly Robot that Helps
ERFiK	Educational Robot for Kids
KLR	Kids Love Robots
SKIC	Social, Kind, Intellectual Contraption
KILL	Kind Insect Little and Loyal

KNF	Kind Knowledgeable Friend
GIRLS	
ADRIS	
REMI	Really Exciting Machine Invention
CAF	Child and Adult Fun
SALT	Safe Active Loving Talent
SQUIRT	Socializing, quiet, understanding, independent, rough, talkative
FAST	Fast active safe tiny
Crotella	Caring Robot organises talks, excitement, long amazing
BABER	Big and Better Electronic Robots
HEDA	Helps Anyone Do Anything
KeFeR	
PIG	Pretty Intelligent Girl
ART	Australian Robot Toy
Kefer	Kid Friendly Educational Robot
TER	Talking Educational Robot
BETTY	Brilliant Educational Technology, Truthful, Yacker
CISER	Children's, Safe, Educational Robot

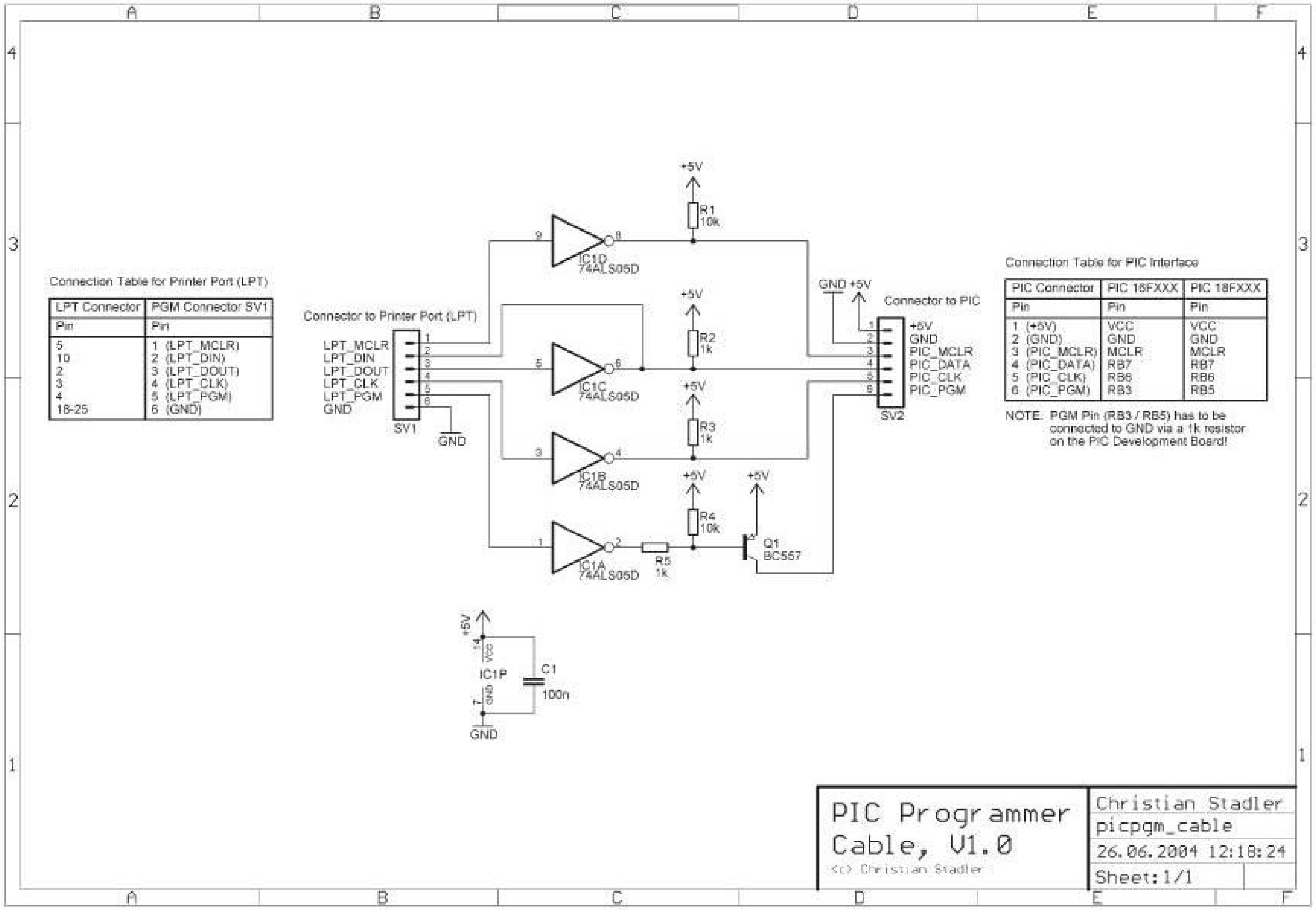
Figure 34. Robot Names

Boys	No.	Girls	No.
Talk	4		8
Play Music	6		7
Be controlled	1		4
Avoidance	2		
Follow Line	2		1
Steer (Remote)	1		
Voice Activated	1		
Walk Sideways	4		
Do School Work	6		
Clean	2		
Cook	3		1
Serve Meals	2		
Autonomous	1		
Answer the Door	1		1
Pick up stuff	3		3
Walk up stairs	1		
Walk on rough	1		1
Dance	2		4
StoreInfo	1		
Fold Up off	1		
Beep when finished	3		
Bark	1		
Read/write	2		2
See	2		
Type	1		
Climb	3		
Help Kids Learn	1		
Play Games	1		3
Fly	1		
Skate	1		
Crush Cans	1		
Run	1		
Xray Vision	1		
House Work			5
Help			3
Reward you			1
Make animal sounds			1

Swish Tail			1
Flash lights			1
Be water Proof			1
Learn			1
Act Real			1
Hug			1
Be Fast			1
Flash Lights			1
Interact			1
Sing			2
Gymnastics			2
Transformer			1
Tell Jokes			1
Jump			2
Sleep			1
Weal Backwards			1
Sense stuff on floor			2

Figure 35. Children's Robot Action Suggestions

Appendix C. Low Voltage In-System Programmer SCHEMATIC.



Connection Table for Printer Port (LPT)

LPT Connector	PGM Connector SV1
Pin	Pin
5	1 (LPT_MCLR)
10	2 (LPT_DIN)
2	3 (LPT_DOUT)
3	4 (LPT_CLK)
4	5 (LPT_PGM)
18-25	6 (GND)

Connection Table for PIC Interface

PIC Connector	PIC 16FXXX	PIC 18FXXX
Pin	Pin	Pin
1 (+5V)	VCC	VCC
2 (GND)	GND	GND
3 (PIC_MCLR)	MCLR	MCLR
4 (PIC_DATA)	RB7	RB7
5 (PIC_CLK)	RB6	RB6
6 (PIC_PGM)	RB3	RB5

NOTE: PGM Pin (RB3 / RB5) has to be connected to GND via a 1k resistor on the PIC Development Board!

PIC Programmer Cable, V1.0
<c> Christian Stadler

Christian Stadler
picpgm_cable
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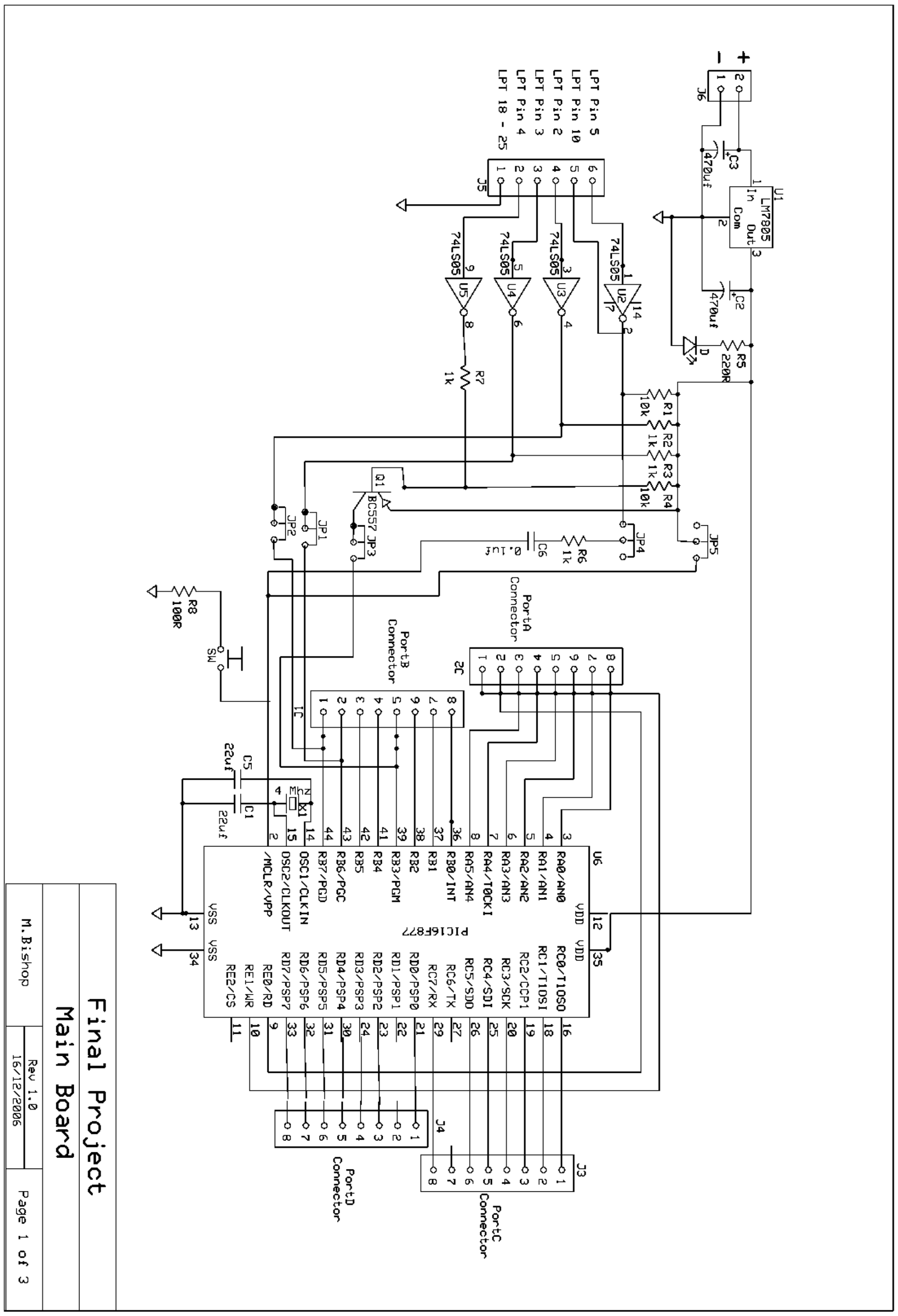
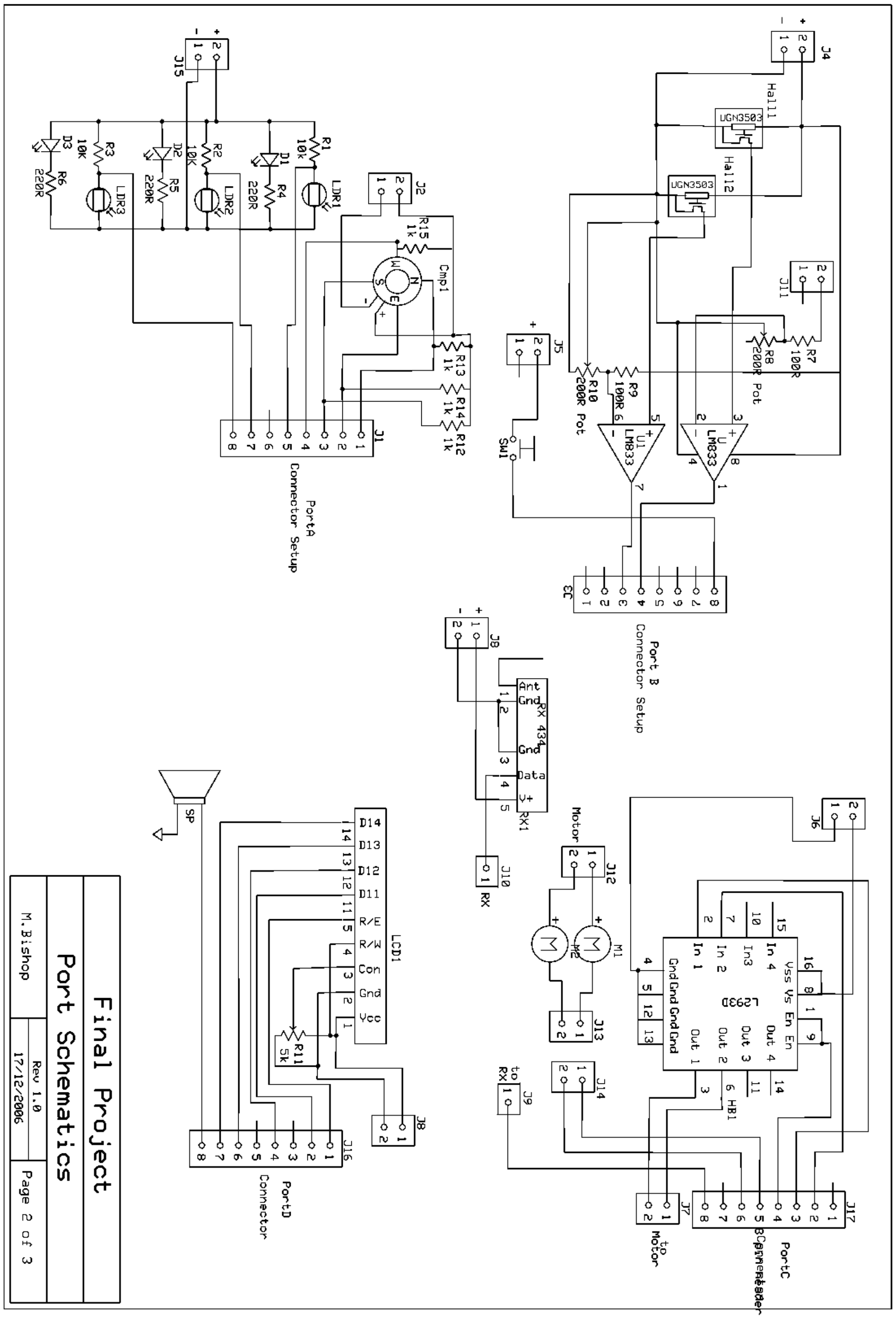
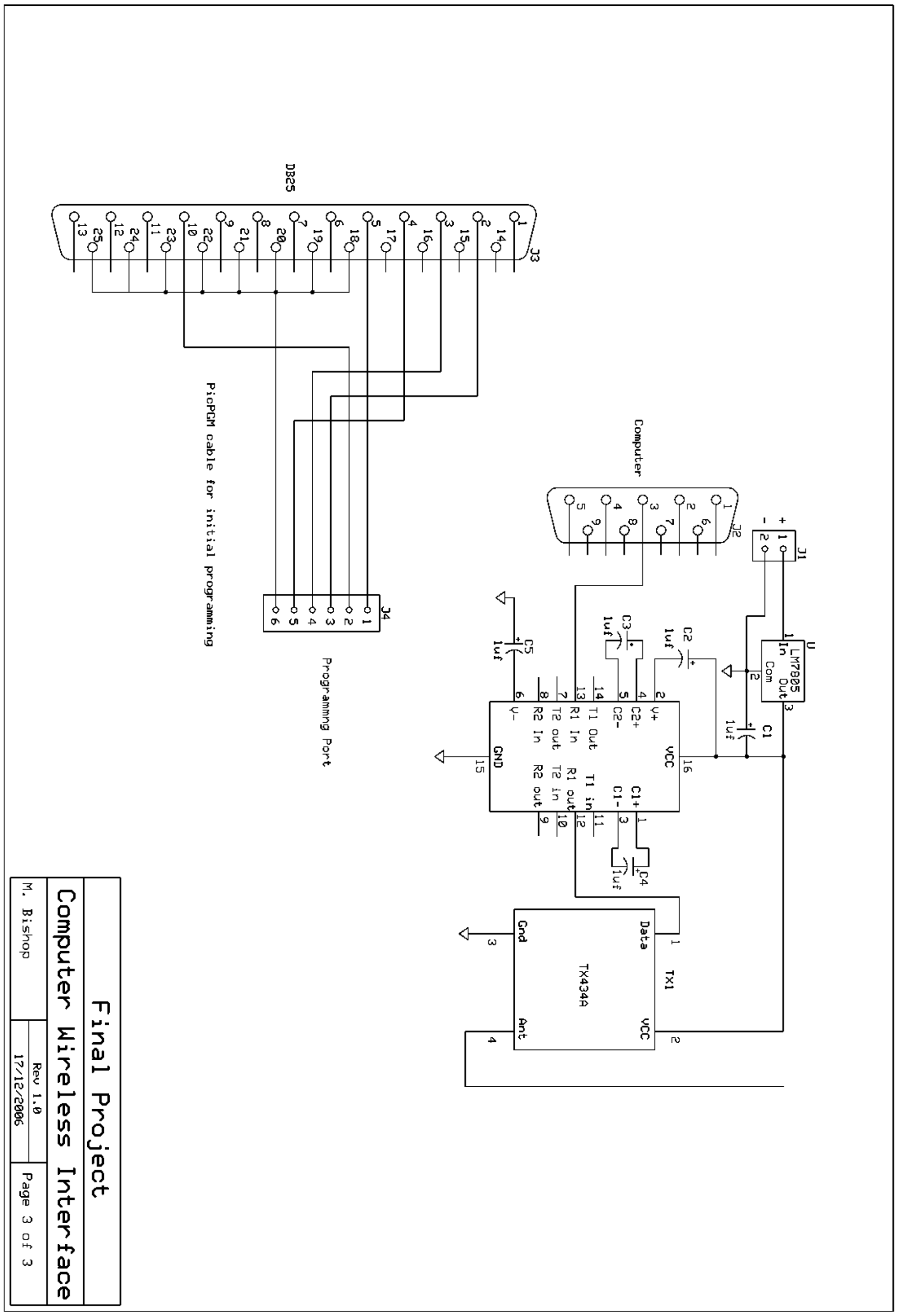
Sheet: 1/1

Appendix D. Electronic Schematics for Robot



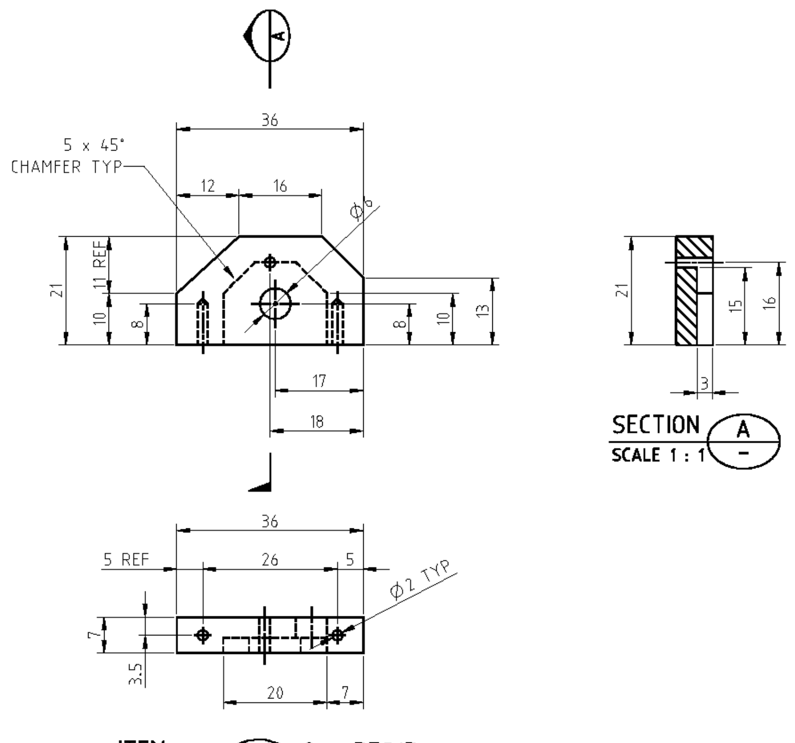


Final Project
Port Schematics
M.Bishop
Rev 1.0
17/12/2006
Page 2 of 3
PortA Connector Setup
Port B Connector Setup
PortC Connector
PortD Connector
J1
J2
J3
J4
J5
J6
J7
J8
J9
J10
J11
J12
J13
J14
J15
J16
J17
LDR1
LDR2
LDR3
R1 10k
R2 10K
R3 10K
R4 220R
R5 220R
R6 220R
D1
D2
D3
R12 1k
R13 1k
R14 1k
R15 1k
Cmp1
N
E
S
W
Hall1
Hall2
UGN3503
R7 100R
R8 200R Pot
R9 100R
R10 200R Pot
U LM833
U1 LM833
SW1
RX 434
RX1
Ant
Gnd
Data
V+
RX
Motor
M1
M2
L293D
HB1
Vss
Vs
En
In 1
In 2
In3
In 4
Out 1
Out 2
Out 3
Out 4
to RX
to Motor
LCD1
D14
D13
D12
D11
R/E
R/W
Con
Gnd
Vcc
R11 5k
SP



Appendix E. Plans for Robot

(NON SCALED REPRODUCTIONS OF SCALE DRAWINGS) FULL SCALE DRAWINGS ON CD



SECTION A
SCALE 1 : 1

ITEM 1
SCALE 1 : 1
2 - REQ'D
1 AS DRAWN
1 OPPOSITE HAND

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REV1	D. THORPE	M. BISHOP		ISSUED FOR CONSTRUCTION		17/12/2006
REVISION						

PROJECT No: 04-3217

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
DETAILS - SHEET 1 OF 6

DRAWING NUMBER
201-4-1183

DRG. REV. 1
M/F. REV.
A4

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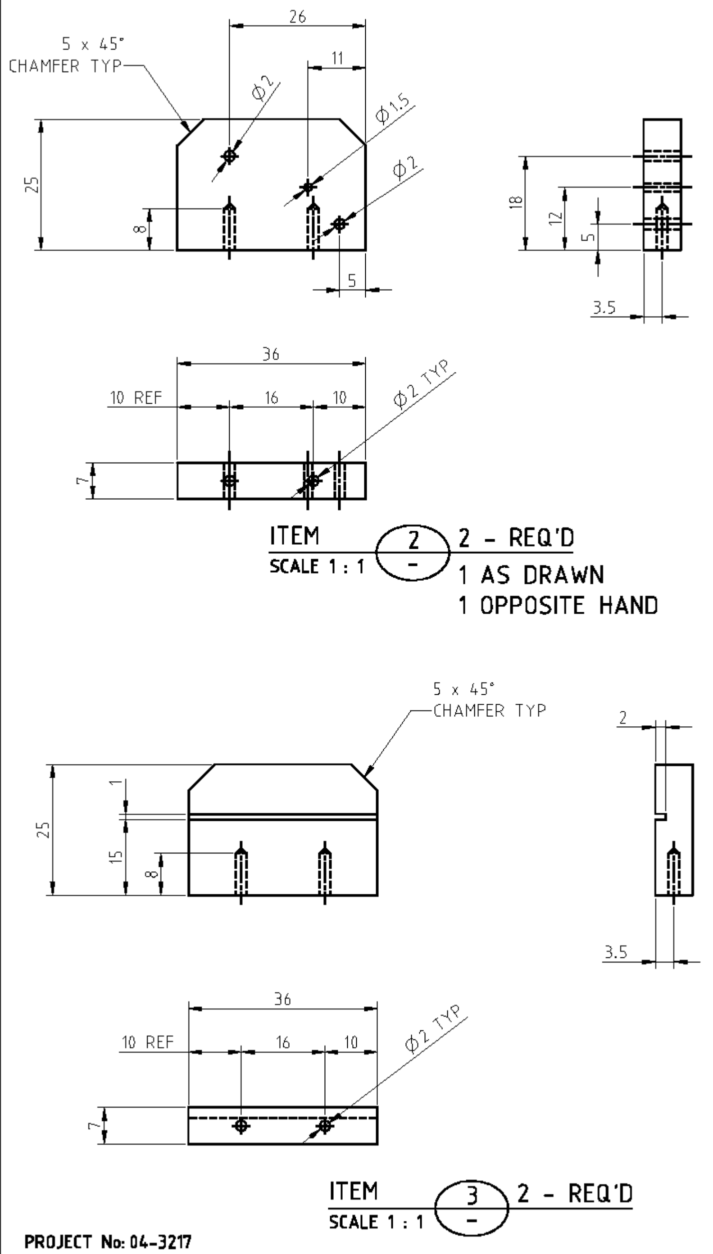

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REVISION

PROJECT No: 04-3217

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
DETAILS - SHEET 2 OF 6

DRAWING NUMBER
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M/F. REV.
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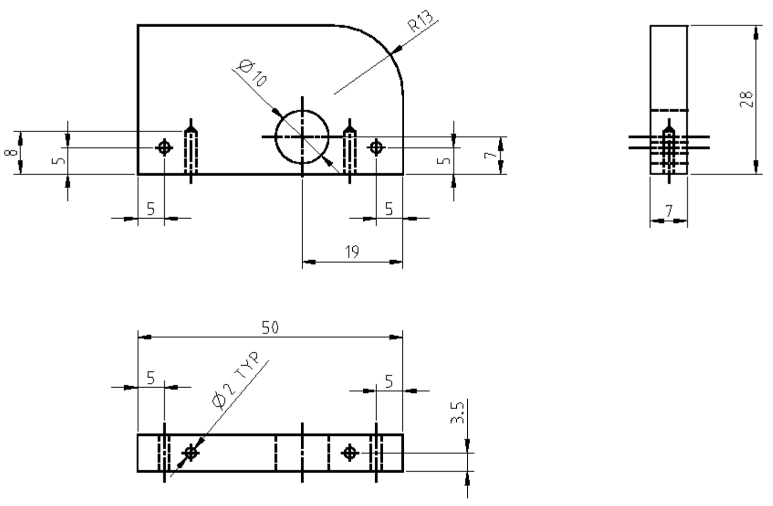

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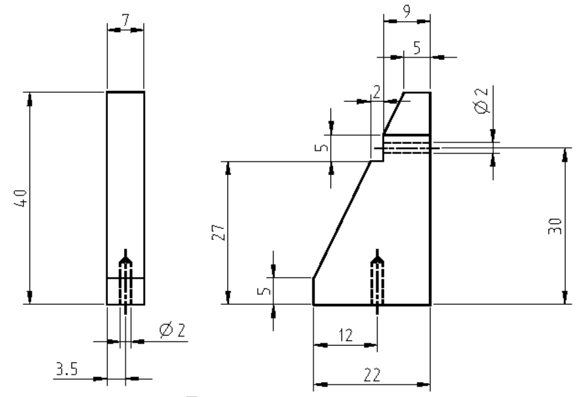
1 OPPOSITE HAND



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1 OPPOSITE HAND

PROJECT No: 04-3217

BISHOP TECHNOLOGIES	SCALE- AS NOTED
FINAL PROJECT BISHOP TECHNOLOGIES PROTOTYPE 41 - 102 DETAILS - SHEET 3 OF 6	DRAWING NUMBER 201-4-1185 DRG. REV. 1 M/F. REV. A4

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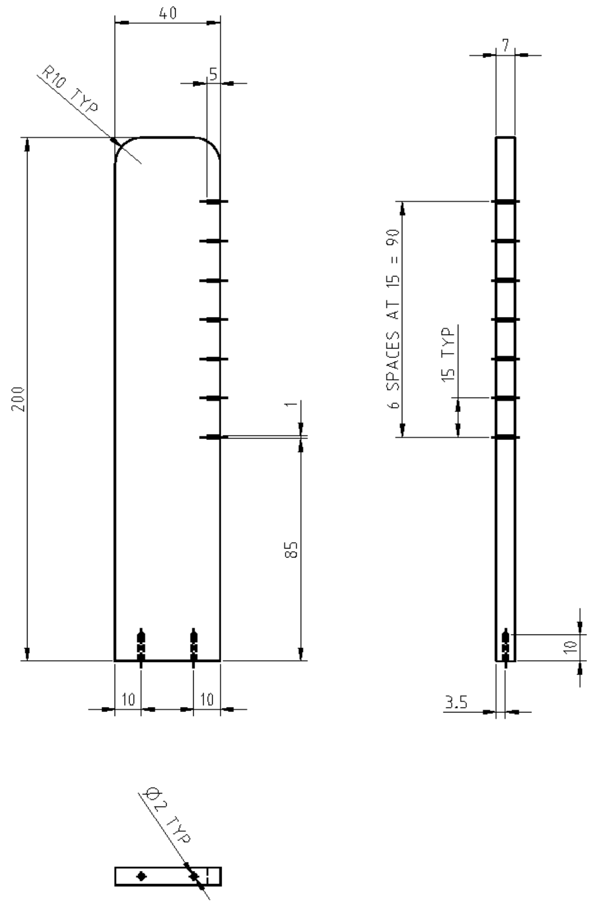
REVISION

ALL DIMENSIONS IN MILLIMETERS U.N.O.



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REVISION						

PROJECT No: 04-3217

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
DETAILS - SHEET 4 OF 6

DRAWING NUMBER
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M/F. REV.
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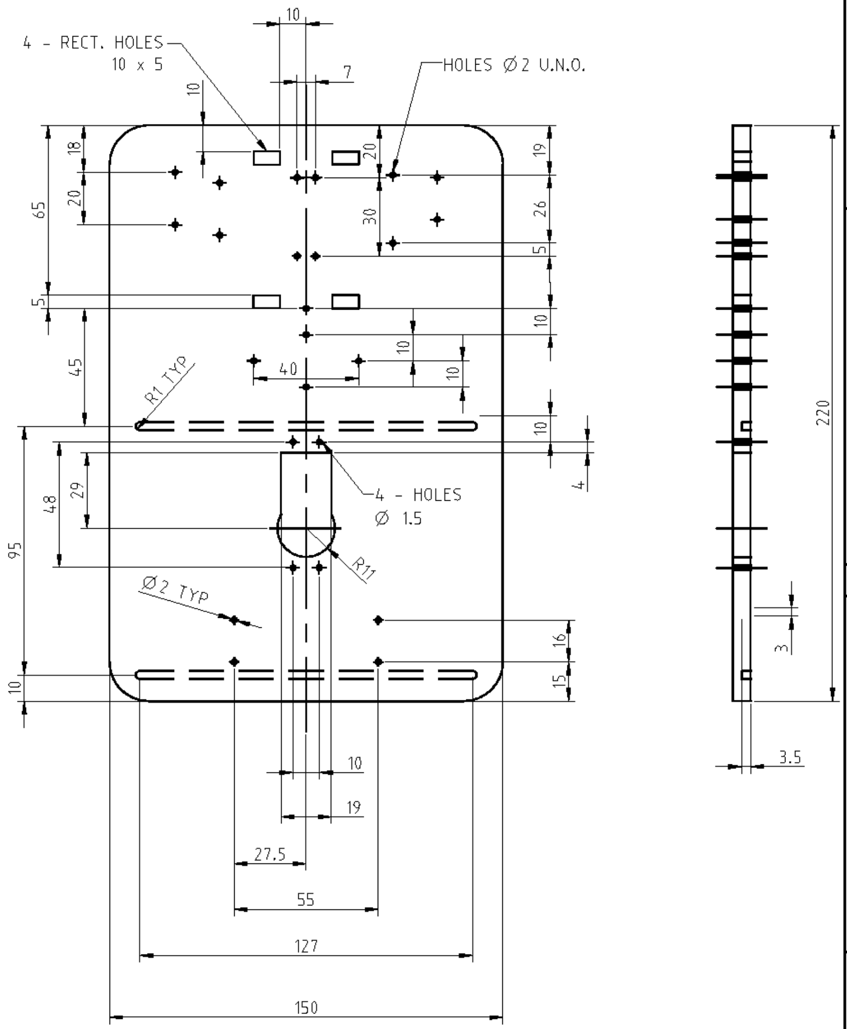

ITEM 7 1 - REQ'D
SCALE 1 : 5 –

PROJECT No: 04-3217

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17/12/2006		ISSUED FOR CONSTRUCTION		M. BISHOP	D. THORPE	REV1

REVISION

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
DETAILS - SHEET 5 OF 6

DRAWING NUMBER
201-4-1187

DRG. REV. 1
M/F. REV.
A4

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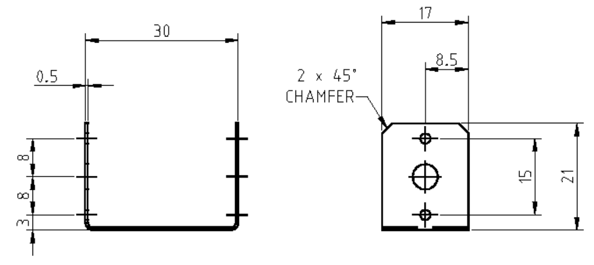

ITEM (8 / –) 1 - REQ'D
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REVISION						

PROJECT No: 04-3217

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
DETAILS - SHEET 6 OF6

DRAWING NUMBER
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M/F. REV.
A4

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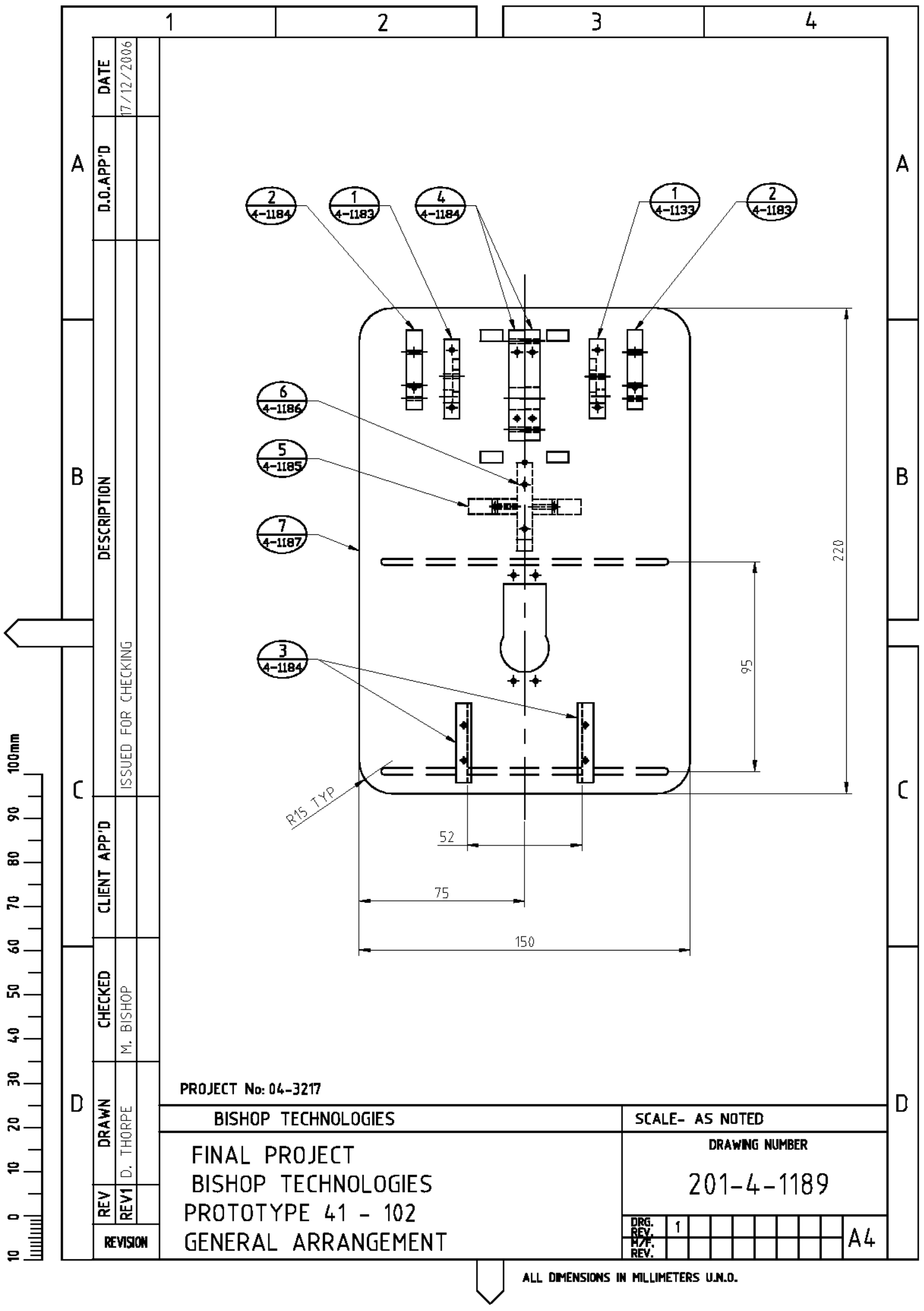

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REVISION

PROJECT No: 04-3217

BISHOP TECHNOLOGIES

SCALE- AS NOTED

FINAL PROJECT
BISHOP TECHNOLOGIES
PROTOTYPE 41 - 102
GENERAL ARRANGEMENT

DRAWING NUMBER

201-4-1189

DRG. REV. 1

M/F. REV.

A4

ALL DIMENSIONS IN MILLIMETERS U.N.O.

Appendix F. Visual Basic Code Excerpts

F.1. Grid Coding (FrmAxis)

```
'********************************** Code Description
******************************
'The Grid code is based on Multilin.zip by Ethan
'www.freevbcode.com/ShowCode.asp/?ID=1240
'

'Instructions:
'One left mouse click turns the line drawing on and anchors the starting point of the
'line. A second click of the left button sets the end of the line.
'Right clicking the mouse terminates the current Line
'******************************************************************
*************
Dim MakeLine As Boolean
Dim XStart As Integer
Dim YStart As Integer
Dim XEnd As Integer
Dim YEnd As Integer
Dim StoreX As Integer
Dim StoreY As Integer
Dim XCoord() As Integer
Dim YCoord() As Integer
Dim ConvertHex As String
Dim WhatUpto As Integer
Dim DoNext As Boolean
Const SpanSize = 240
Dim S As Integer
Const Pi = 3.14159265358979
Dim Quadrant As Integer
Dim Tangent As Integer
Dim xHold As Integer
Dim yHold As Integer
Dim Done As Boolean
Public Sub DrawAxis()
'Draws the grid points on the picturebox

   Dim XPos As Integer
   Dim YPos As Integer
   Dim x As Integer
   Dim y As Integer
  'set picture box settings
   MainAxis.DrawMode = 6
   'put points on axis
   For x = 1 To Int(ScaleHeight / SpanSize)
      For y = 1 To Int(MainAxis.ScaleWidth / SpanSize)
         frmAxis.MainAxis.PSet (XPos, YPos)
         'move to the next spot
         XPos = XPos + SpanSize
```

```
            Next
           XPos = SpanSize
           YPos = YPos + SpanSize
       Next
       'reset drawmode
       MainAxis.DrawMode = 13
   End Sub
   Public Sub LineStart(x As Single, y As Single)
      'snaps the line to the gridponts for the start of the line or Dragline

       'Finds the closest axis point for start of line in x
            If (x Mod SpanSize) >= SpanSize / 2 Then  'if >half span go to next
           XStart = (Int(x / SpanSize) + 1) * SpanSize
       Else
           XStart = Int(x / SpanSize) * SpanSize       ' else drop back one
       End If
       'Find the closest axis point for start of line in y
       If y Mod SpanSize >= SpanSize / 2 Then      'if >half span go to next
           YStart = (Int(y / SpanSize + 1)) * SpanSize
       Else
           YStart = Int(y / SpanSize) * SpanSize       ' else drop back one
       End If
   End Sub
   Public Sub LineEnd(x As Single, y As Single)
      'snaps the line to the gridponts for the end of the line or Dragline

       'Find the closest axis point for end of line in x
       If (x Mod SpanSize) >= SpanSize / 2 Then   'if >half span go to next
           XEnd = (Int(x / SpanSize) + 1) * SpanSize
       Else
           XEnd = Int(x / SpanSize) * SpanSize       ' else drop back one
       End If
       'Find the closest axis point for end of line in y
       If y Mod SpanSize >= SpanSize / 2 Then      'if >half span go to next
           YEnd = (Int(y / SpanSize) + 1) * SpanSize
       Else
           YEnd = Int(y / SpanSize) * SpanSize       ' else drop back one
       End If
   End Sub
   Private Sub CmdOption_Click(Index As Integer)
    'process the relevant button push
        Select Case Index
           Case 0
               'reset drawing
               MainAxis.Cls
               DrawAxis
               S = 0
           Case 1
               'Program the Robot with the drawings
               FrmInterface.Show
               DoMultiple
               Unload Me
               Set frmAxis = Nothing
            Case 2
               'exit
               MainAxis.Cls
               DrawAxis
               S = 0
               FrmMain.Show
               Unload Me
               Set frmAxis = Nothing
         End Select
      End Sub
Public Sub MainAxis_MouseDown(Button As Integer, Shift As Integer, x As Single, y
As Single)
'detects the mouse button pushs
  Static StoreX As Single, StoreY As Single
    Dim Listtext As String
    If S = 0 Then
        x = 0
        y = MainAxis.Height
    End If
    If Button = 2 Then
        'right button is pushed so retract line
        frmAxis.MainAxis.Line (XStart, YStart)-(XEnd, YEnd)
        MakeLine = False
        XEnd = 0
        YEnd = 0

        Exit Sub
    End If
    'If the MakeLine Flag is true
    If MakeLine = True Then
        'Erase the Stretch Line
        frmAxis.MainAxis.Line (XStart, YStart)-(XEnd, YEnd)
        'Turn inverted draw off
        frmAxis.MainAxis.DrawMode = 13

         'Calculate Closest end axis Point to XStart and YStart
            LineEnd x, y
        'Draw the final line
        frmAxis.MainAxis.Line (XStart, YStart)-(XEnd, YEnd), RGB(0, 0, 0)

        'restore coordinates redim if necessary
        S = S + 1
        If S Mod 10 = 0 Then
            ReDim Preserve XCoord(S + 10)
            ReDim Preserve YCoord(S + 10)
        End If
        XCoord(S) = XEnd \ 240
        YCoord(S) = YAxis - (YEnd \ 240)

        'Display Number Or letter
        If XNumber = False Then
```

```
            Listtext = "x - " & Chr(XCoord(S) + 65)
    Else
            Listtext = "x - " & XCoord(S)
    End If
    If YNumber = False Then
            Listtext = Listtext & "  y - " & Chr(YCoord(S) + 64)
    Else
            Listtext = Listtext & "  y - " & YCoord(S)
    End If

    DirectionList.AddItem Listtext

    NextPosition XCoord(S), YCoord(S) - 1, S

    'Set new start line points

        XStart = XEnd
        YStart = YEnd
Else
    'The line has not been drawn yet

        StoreX = x: StoreY = y
        'Find the closest axis point
        LineStart x, y
        'Erase the before axis point line
        frmAxis.MainAxis.Line (XStart, YStart)-(StoreX, StoreY)
        'store coordinates redim array if necessary
        S = S + 1
        If S Mod 10 = 0 Then        'if s > last "10" add another 10 to the variable
            ReDim Preserve XCoord(S + 10)
            ReDim Preserve YCoord(S + 10)
        End If

        XCoord(S) = XStart \ 240
        YCoord(S) = YAxis - (YStart \ 240)
        'put the coordinates in the list box to demonstrate plotting
        If XNumber = False Then
            Listtext = "x - " & Chr(XCoord(S) + 65)
    Else
            Listtext = "x - " & XCoord(S)
    End If
    If YNumber = False Then
            Listtext = Listtext & "  y - " & Chr(YCoord(S) + 64)
    Else
            Listtext = Listtext & "  y - " & YCoord(S)
    End If
    If S = 1 Then
        XCoord(S) = 0
        YCoord(S) = 0
    End If

    DirectionList.AddItem Listtext  'add the direction to the list
```

```
        ' NextPosition Xcoord(S), YCoord(S), S
        XEnd = x
        YEnd = y
        MakeLine = True
    End If
    frmAxis.MainAxis.DrawMode = 6
    frmAxis.MainAxis.DrawStyle = 6


End Sub

Public Sub Mainaxis_MouseMove(Button As Integer, Shift As Integer, x As Single, y
As Single)
   'detects the mouse movements
    'Draw the stretch or rubberband line
    Dim XFinal As Integer
    Dim YFinal As Integer
    If MakeLine Then
        frmAxis.MainAxis.AutoRedraw = True
        frmAxis.MainAxis.Line (XStart, YStart)-(XEnd, YEnd)
        XEnd = x
        YEnd = y
        MainAxis.Line (XStart, YStart)-(x, y)
        XFinal = Xaxis - x
        YFinal = YAxis - (y \ 240)
        If XNumber = True Then
          Caption = "X = " & x \ 240
        Else
          Caption = "X = " & Chr((x \ 240) + 64)
        End If
        If YNumber = True Then
           Caption = Caption & "    Y = " & y \ 240
        Else
           Caption = Caption & "    Y = " & Chr(YFinal + 64)
        End If
    End If
End Sub
Private Sub Form_Load()
    'Sets printbox and line settings
    'postions form and form items
    'Calls the relevant code to draw the axis and dots
     MainAxis.Cls
     MainAxis.Line (0, 0)-(0, 0)
     MainAxis.Refresh
     'set axis size with 120twips between each dot
     If XNumber = False Then
        MainAxis.Width = ((Xaxis) * 240) - 171
     Else
         MainAxis.Width = ((Xaxis + 1) * 240) - 171
     End If
     If YNumber = False Then
        MainAxis.Height = ((YAxis) * 240) - 175
```

```
      Else
        MainAxis.Height = ((YAxis + 1) * 240) - 175
     End If

     'set buttons and screen height
     frmAxis.Height = MainAxis.Height + 2500
     frmAxis.Width = MainAxis.Width + 3000
     CmdOption(0).Top = MainAxis.Height + 600
     CmdOption(0).Left = MainAxis.Width / 3
     CmdOption(1).Top = MainAxis.Height + 600
     CmdOption(1).Left = (frmAxis.Width) / 2
     CmdOption(2).Top = MainAxis.Height + 600
     CmdOption(2).Left = (frmAxis.Width * 2) / 3
     Label3.Top = frmAxis.Height + 500
     Label3.Left = frmAxis.Width / 2
     Label2.Left = (frmAxis.Width - Label2.Width) / 2
    Label2.Top = MainAxis.Height + 1200
    PrintAxes
    'Draw the axis
    DrawAxis
    'set up the axis List
    DirectionList.Top = MainAxis.Top
    DirectionList.Left = MainAxis.Width + MainAxis.Left + 500

    ReDim XCoord(10)
    ReDim YCoord(10)

    DoNext = True
 End Sub
Private Sub Form_Unload(Cancel As Integer)
    'clear everything from memory and exit
    FrmMain.Show
    Unload Me
    Set frmAxis = Nothing
End Sub
Private Sub PrintAxes()
'sets the picturebox dimensions
'sets and positions the axis numbers or letters
Dim i As Integer
Dim c As Integer
Dim A As Integer
Dim D As Integer
  'set the pictureboxes to suit the axes
  PicYAxis.Height = MainAxis.Height + 350
  PicYAxis.Top = MainAxis.Top - 300
  PicYAxis.Left = MainAxis.Left - PicYAxis.Width
  DirectionList.Left = MainAxis.Width + 1000
  DirectionList.Height = MainAxis.Height
  frmAxis.Width = DirectionList.Left + DirectionList.Width + 500

 c = -240
 If XNumber = False Then
```

```
     D = 1
 Else
    D = 0
 End If

 c = 0
 A = PicYAxis.CurrentX


 For i = YAxis To 1 Step -1
        c = c + 240
        'Set Position and Display the Yaxis numbers.
        PicYAxis.CurrentY = c
        PicYAxis.CurrentX = A
        If YNumber = True Then
           PicYAxis.Print i;
        Else
           PicYAxis.Print Chr(i + 64);
        End If
 Next i

 PicYAxis.Print
doxAxis
End Sub
Private Sub DoMultiple()
 'sends the list of controls to the BOT
        Dim A As Integer
        'add the robot number to the code and send
        'set baud rate, bit length etc
        MSComm1.Settings = "2400,N,8,1"
        'set port number
        MSComm1.CommPort = PORTNUMBER

        'SEND THE X DATA TO THE BOT
        S = S + 1
        YCoord(S) = 255
        For A = 2 To S             ' ignore the start position
           TimerSend.Interval = 10    '10 m/s
           TimerSend.Enabled = True
        Do                        'wait for tht timer
             DoEvents             'dont lock up th computer
        Loop Until Done = True
        Done = False               'reset the values
        TimerSend.Enabled = False
        If MSComm1.PortOpen = False Then
              'open the port
              MSComm1.PortOpen = True
           End If
              'send the details
              ConvertHex = Hex(YCoord(A))
              MSComm1.Output = ConvertHex 'send angle
              If A <> S Then
```

```
                'once the end bit FF is sent do no more
             ConvertHex = Hex(XCoord(A))
             MSComm1.Output = ConvertHex 'send distance
          End If
       If MSComm1.PortOpen = True Then
          'close the port
          MSComm1.PortOpen = False
       End If
    Next




 End Sub
Private Sub NextPosition(PosX As Integer, PosY As Integer, W As Integer)
'figure out the movements of the robot
'works out the next movement from the current position
'Works out the degrees in the movement, divides it into the relevant quadrant
'calculates the angle in its quadrant for the robot.
'Calculates the tangent distance for the rovbot to travel
'This same code in the PIC was prohibitively large and comlicated
'so it is done here and sent to the PICc
'divides the angle in half the angle fits the hex 255 requirement
'the grid can only display corinates in about 2 degree increments
'anyway. This with the tolerances of the robot should be sufficiently
'accurate for this purpose.
'tan =  opp/adj
Dim x As Integer
Dim y As Integer
Dim CalcX As Integer
Dim CalcY As Integer
Dim TheAngle As Double
Dim Tang As Single
Dim TangBool As Boolean
Dim HoldMe As String
'find where next point is
x = PosX
y = PosY
If y < 0 Then y = 0
'calculated direction from quadrant from current point
   If x > xHold Then
      'see if in first or fourth quadrant
      CalcX = x - xHold       'calculate x distance
      If y > yHold Then
         Quadrant = 1        'select quadrant
         CalcY = y - yHold   'calculate y distance
      End If
      If y = yHold Then
         Quadrant = 5
         CalcY = yHold - y   'calculate y distance
      End If
      If y < yHold Then
```

```
            Quadrant = 2        'select quadrant
           CalcY = yHold - y   'calculate y distance
        End If
    End If
    If x = xHold Then
        CalcX = x - xHold       'calculate x distance
        If y >= yHold Then
            Quadrant = 1        'select quadrant
            CalcY = y - yHold   'calculate y distance
        Else
            Quadrant = 3        'select quadrant
            CalcY = yHold - y   'calculate y distance
        End If
    End If

    If x < xHold Then
        'x is less so has turned around
        CalcX = xHold - x       'calculate x distance
        If y > yHold Then
            Quadrant = 4        'select quadrant
            CalcY = y - yHold   'calculate y distance
        End If
        If y = yHold Then
            Quadrant = 6        'select quadrant
            CalcY = y - yHold   'calculate y distance
        End If

        If y < yHold Then
            Quadrant = 3        'select quadrant
            CalcY = yHold - y   'calculate y distance
        End If
    End If
'calculate actual tangent of triangle
Tangent = Sqr(CalcX ^ 2 + CalcY ^ 2)
Tangent = Format(Tangent, "##")

'calculate the angle offset in degree
If CalcX <> 0 Then
    If CalcY <> 0 Then
        TangBool = True
        Tang = CalcY / CalcX
    End If
End If
If TangBool <> True Then
    Tang = 0
End If
TangBool = False
TheAngle = Atn(Tang)
TheAngle = TheAngle * 180 / Pi
TheAngle = Round(TheAngle)
'add Quadrant to angle
Select Case Quadrant
```

```
     Case 2
       'greater the 90 degree and less the 180
       TheAngle = 90 + (90 - TheAngle)
   Case 3
       'greater then 180 and less then 270
       TheAngle = 180 + TheAngle
   Case 4
       'greater then 270 and less then 360
       TheAngle = 270 + (90 - TheAngle)
   Case 5  'deal with 90 degrees
       TheAngle = 90
   Case 6
       TheAngle = 270

End Select
'divide the angle in half because there isnt
' a full amount of degrees available in the grid
'this way 360 degrees can be represented in binary 255
TheAngle = CInt(TheAngle / 2)
XCoord(W) = Tangent
YCoord(W) = TheAngle
HoldMe = TheAngle & "," & Tangent
List1.AddItem HoldMe 'Xcoord(W)
'List1.AddItem YCoord(W)
xHold = x   'store the x value for comparison
yHold = y   'store the x value for comparison
End Sub


Private Sub TimerSend_Timer()
'slow the send down a touch. Theoretically this should
'be able to be done at full board but in practice
'it seems the work better with a pause
'timer1.value =1000 = 1 second
'in reality timer is only accurate to 1/18 of a second
   Done = True

End Sub
```

F.2. Compass Coding (FrmCompass)

```
Dim x As Integer
Dim y As Integer
Dim XLast As Integer
Dim YLast As Integer
Dim XBack() As Integer
Dim YBack() As Integer
Dim XX As Integer
Dim CoOrd() As String
Dim XMax As Integer
Dim Done As Boolean
Const MoveMe = 240
Private Sub CmdCompass_Click(Index As Integer)
'Sends to the screen the directions to the list box
'displays the line on the screen as a representation
'stores the Hex value as would be expected by the PIC16f877A
'from the compass to save processing
Dim Skipthis As Boolean
Dim F As Integer
Select Case Index
   Case 0 'north
      PicCompass.CurrentY = PicCompass.CurrentY - MoveMe
      LstDirection.AddItem ("North")
      CoOrd(XX) = &H8 'b'1000' north

   Case 1  'south
      PicCompass.CurrentY = PicCompass.CurrentY + MoveMe
      LstDirection.AddItem ("South")
      CoOrd(XX) = &H2 'b'0010' South

   Case 2  'west
      PicCompass.CurrentX = PicCompass.CurrentX - MoveMe
      LstDirection.AddItem ("West")
      CoOrd(XX) = &H1 'b'0001' West

   Case 3  'east
      PicCompass.CurrentX = PicCompass.CurrentX + MoveMe
      LstDirection.AddItem ("East")
      CoOrd(XX) = &H4 'b'0100' East

   Case 4  'north east
      PicCompass.CurrentY = PicCompass.CurrentY - MoveMe
      PicCompass.CurrentX = PicCompass.CurrentX + MoveMe
      LstDirection.AddItem ("North East")
       CoOrd(XX) = &HC    'b1100' North East

   Case 5  'southeast
      PicCompass.CurrentY = PicCompass.CurrentY + MoveMe
      PicCompass.CurrentX = PicCompass.CurrentX + MoveMe
      LstDirection.AddItem ("South East")
      CoOrd(XX) = &H6 'b'0110'    South East
   Case 6  'southwest
      PicCompass.CurrentY = PicCompass.CurrentY + MoveMe
      PicCompass.CurrentX = PicCompass.CurrentX - MoveMe
      LstDirection.AddItem ("South West")
      CoOrd(XX) = &H3 'b0011' SouthWest

   Case 7  'northWest
      PicCompass.CurrentY = PicCompass.CurrentY - MoveMe
      PicCompass.CurrentX = PicCompass.CurrentX - MoveMe
      LstDirection.AddItem ("North East")
      CoOrd(XX) = &H9 'b1001' NorthWest

  Case 8   'the Erase Button
   'Steps back through the history and deletes the lines on each click
   'by putting a background color line over the line
   'removes the deleted point s from memory and the direction display
   'stops the initial point being deleted

     PicCompass.ForeColor = &HE0E0E0     'set the color to grey
     PicCompass.Line (x, y)-(XBack(XX), YBack(XX))    'get the last point
     XX = XX - 1
     If XX < 1 Then
         XX = 1                  'if go back to the start dont erase the
         PicCompass.DrawMode = 6 'point on the screen
         PicCompass.PSet (x, y)
          PicCompass.DrawMode = 13
     End If
     CoOrd(XX) = ""              'delete the coordinate the variable
     x = PicCompass.CurrentX
     y = PicCompass.CurrentY
     Skipthis = True
     F = LstDirection.ListCount
     If F > 0 Then
         LstDirection.RemoveItem F - 1   'delete the direction from the list
     End If
     PicCompass.ForeColor = &H0&          'reset the color to black

End Select
'Adds the points to the history
'draws the new line on the screen
If Skipthis <> True Then
   XX = XX + 1
   If XMax >= XMax Then
      If XX Mod 10 = 0 Then           'make sure the array is always big enough
         ReDim Preserve XBack(XX + 10)
         ReDim Preserve YBack(XX + 10)
         ReDim Preserve CoOrd(XX + 10)
         XMax = XX + 10
      End If
   End If
```

```
     PicCompass.Line (x, y)-(PicCompass.CurrentX, PicCompass.CurrentY) 'draw the
line
    XBack(XX) = x                   'store for history
    YBack(XX) = y
    x = PicCompass.CurrentX         'store the current position for next pass
    y = PicCompass.CurrentY
End If
Skipthis = False

End Sub

Private Sub CmdOption_Click(Index As Integer)
'provceses the buttons pushed
Select Case Index
    Case 0
        'Exit
        FrmMain.Show
        Unload Me
        Set FrmCompass = Nothing
    Case 1
        'Program the pic
            FrmInterface.Show
            DoMultiple
            Unload Me
            Set frmAxis = Nothing
End Select
End Sub

Private Sub Form_Load()
    'add the captions, set the position og the form and its contents
    ' set line and picturebox settings
    'initialise variable
    ReDim XBack(10)
    ReDim YBack(10)
    ReDim CoOrd(10)
    XX = 1
    CmdCompass(0).Caption = "N"
    CmdCompass(0).FontBold = True
    CmdCompass(1).Caption = "S"
    CmdCompass(1).FontBold = True
    CmdCompass(2).Caption = "W"
    CmdCompass(2).FontBold = True
    CmdCompass(3).Caption = "E"
    CmdCompass(3).FontBold = True
    CmdCompass(4).Caption = "NE"
    CmdCompass(4).FontBold = True
    CmdCompass(5).Caption = "SE"
    CmdCompass(5).FontBold = True
    CmdCompass(6).Caption = "SW"
    CmdCompass(6).FontBold = True
    CmdCompass(7).Caption = "NW"
    CmdCompass(7).FontBold = True
     CmdCompass(8).Caption = "C"
    CmdCompass(8).FontBold = True
    PicCompass.Width = PicCompass.Height
    PicCompass.Left = (FrmCompass.Width - PicCompass.Width) / 2
    CompassFrm.Left = (FrmCompass.Width - CompassFrm.Width) / 2
    PicCompass.CurrentX = PicCompass.ScaleWidth / 2
    PicCompass.CurrentY = PicCompass.ScaleHeight / 2
    x = PicCompass.CurrentX
    y = PicCompass.CurrentY
    LstDirection.Height = PicCompass.Height
    PicCompass.DrawMode = 6
    PicCompass.PSet (x, y)
    PicCompass.DrawMode = 13
    CmdOption(0).Left = FrmCompass.Width - CmdOption(0).Width - 300
    CmdOption(0).Top = PicCompass.Height + ((FrmCompass.Height -
PicCompass.Height - CmdOption(1).Height) * 2 / 3)
    CmdOption(1).Left = FrmCompass.Width - CmdOption(1).Width - 300
    CmdOption(1).Top = PicCompass.Height + ((FrmCompass.Height -
PicCompass.Height - CmdOption(1).Height) / 3)

End Sub

Private Sub DoMultiple()
 'sends the list of controls to the PIC16F877A
        Dim A As Integer
        'set baud rate, bit length etc
        MSComm1.Settings = "2400,N,8,1"
        'set port number
        MSComm1.CommPort = PORTNUMBER
        CoOrd(XX) = Hex(254)
        For A = 1 To XX
            TimerCompass.Interval = 10    '10 m/s
            TimerCompass.Enabled = True
        Do                        'wait for tht timer
            DoEvents              'dont lock up the computer
        Loop Until Done = True
        Done = False              'reset the values
        TimerCompass.Enabled = False
            If MSComm1.PortOpen = False Then
                'open the port
                MSComm1.PortOpen = True
            End If
                'send the details
            'CoOrd(A) = ROBOTID & CoOrd(A)'if need to send code each time
            MSComm1.Output = CoOrd(A)
            If MSComm1.PortOpen = True Then
                'close the port
                MSComm1.PortOpen = False
            End If
        Next
End Sub
```

```
 Private Sub Form_Unload(Cancel As Integer)
CmdOption_Click (0)
End Sub

Private Sub MSComm1_OnComm()
Done = True
End Sub

Private Sub TimerCompass_Timer()
Done = True
End Sub
```

F.3. Active Comm. Port Find (FrmPORT)

```
'*******************************************************
'Checks each port to see which are active on the computer
'Loads each active port into the ComboBox
'Sets the port number then opens the next form
'*******************************************************

Dim NoPort(4) As Integer
Dim IsntGood As Boolean
Dim A As Integer
Dim b As Integer
Dim c As Integer

Private Sub CmdPort_Click()
   'set the port nuber then open the next window

   Open App.Path & "\PortNumber.txt" For Output As #2
      Print #2, CmbPORT.Text
   Close #2
   If ResetMe = True Then
      FrmMain.Show
      ResetMe = False
   End If
   Unload Me
   Set FrmPORT = Nothing
End Sub

Private Sub Form_Load()
   'run through each port and see which are available
   On Error GoTo Erra
   For A = 1 To 4
   MSComm1.CommPort = A
   MSComm1.PortOpen = True
   If MSComm1.PortOpen = True Then     'shut the Port if it did Open
      MSComm1.PortOpen = False
   End If
   Next
   For A = 1 To 4                   'see which ones ended up as not available
   For c = 1 To b
      If NoPort(c) = A Then          'check each Port number against the known
unavailables
         IsntGood = True             'not Available
      End If
   Next
   If IsntGood = True Then
      IsntGood = False               'reset for the next pass
   Else
      CmbPORT.AddItem (A)            'Available so add to the ist
   End If
   Next
   CmbPORT.Text = CmbPORT.List(0)      'set to show the first
   Exit Sub
Erra:
  b = b + 1                   'add the unavailable port to the list
  NoPort(b) = A
  Resume Next

End Sub
```

Appendix G. EEPROM Code

The following codes must be inserted from EEPROM Address 00H for the Shape code to work. The commas are of course spacers and not entered.

0, 8, 2D, 8, 5A, 8, 87, 8, Z, 0, 6, 2D, C2, 5A, 6, 87, C, Z, 16, 4, 44 ,4 ,87 ,4 ,Z ,F ,8 ,34 ,4 ,87 ,8 ,Z ,2D ,3 ,98 ,4 ,12 ,5 ,48 ,5 ,76 ,4 ,87 ,4 ,Z ,2D ,3 ,9E ,4 ,16 ,4 ,2D ,4 ,44 ,4 ,70 ,4 ,87 ,4 ,Z ,2D ,4 ,A6 ,4 ,0 ,4 ,E ,7 ,4C ,7 ,5A ,4 ,68 ,4 ,87 ,4 ,Z ,2D , 3 , 98 , 4 , 16 , 4 ,2D ,4 ,44 ,4 ,70 ,4 , 87 ,4 , Z

Appendix H PIC16F877A code Excerpts

H.1. LDR ASM Code Excerpt

```
;-----------------------------------------------
;
; LDR and STEERING
;
;-----------------------------------------------
;-----------------------------------------------
;LDR
;reads the puins in one at a time and checks them
;-----------------------------------------------
LDRStart

                call    SetTMR0                 ;Init TMR0
                call    Init_motor      ;Set the PWM
                call    SetADC
                ;call   SetLED
                call    StartInt;Start Global Interrupt
                call    StartMotors     ;start motors

LDR             movf    i, w            ; Get the Index into the Table
                incf    i, f            ; Increment the Table Index
                call    ADSTORE
                movwf   ADCON0                          ;set the LDR to look at
                call    AD_PORTA                ;check the current LDR

                movf    i,w                             ;is this the front LDR
                sublw   0x01
                btfsc   STATUS, Z
        goto    PutF
                movf    i,w                             ;is this the Left LDR
                sublw   0x02
                btfsc   STATUS, Z
                goto    PutL
                movf    i,w                             ;Is this the right LDR
                sublw   0x03
                btfsc   STATUS, Z
                call    PutR

;-----------------------------------------------
;
;See which LDR is the lowest and hence on the white line
;
;
;-----------------------------------------------
                movf    ADHF,w                  ;subtract the high bits front from right
                movwf   Temp
                subwf   ADHR,w
                btfsc   STATUS,Z        ;higher bit is the same so check against left
```

```
                 goto    CheckL
                BTFSC           STATUS,C      ;one was bigger
                goto    CheckL            ;front was lower - same check as above
                                                        ;right was lower
                movf    ADHR,w                ;subtract the high bits front from right
                movwf Temp
                subwf  ADHL,w
                btfsc   STATUS,Z      ;higher bit is the same so find lower
                goto    CheckAllLower
                BTFSC           STATUS,C      ;one was bigger
                goto    GoL               ;Right was lower
                goto    GoR                       ;Left was lower
;-----------------------------------------------
;find which pin is lower
; depending on the pin
; turn the robot
; to make the centre lighter
;-----------------------------------------------
CheckL
                movf    ADHF,w                ;subtract the high bits front from right
                movwf Temp
                subwf  ADHL,w
                btfsc   STATUS,Z      ;higher bit is the same so check against left
                goto    CheckAllLower
                BTFSC           STATUS,C      ;one was bigger
                goto    GoStr8            ;Straight was lower
                goto    GoR               ;Left was lower

CheckAllLower
                movf    ADLF,w                ;subtract the high bits front from right
                movwf Temp
                subwf  ADLR,w
                btfsc   STATUS,Z      ;higher bit is the same so check against left
                goto    CheckLAll
                BTFSC           STATUS,C      ;one was bigger
                goto    CheckLAll   ;front was lower - same check as above
                                                        ;right was lower
                movf    ADLR,w                ;subtract the high bits front from right
                movwf Temp
                subwf  ADLL,w
                BTFSC           STATUS,C      ;one was bigger
                goto    GoL               ;Right was lower
                goto    GoR                       ;Left was lower
CheckLAll
                movf    ADLF,w                ;subtract the high bits front from right
                movwf Temp
                subwf  ADLL,w
                BTFSC           STATUS,C      ;one was bigger
                goto    GoStr8            ;Straight was lower
                goto    GoR               ;Left was lower

;-----------------------------------------------
```

```
 ;
;Store the LDR values so they can be processed
;
;----------------------------------------------

GetNext     decf    FSR,f           ;  Point to Next LDR
            goto    LDR                     ;continue to check while set in this mode

PutF
            movf    ADValueH,w  ;Store the front value
            movwf ADHF
            movf    ADValueL,w  ;Store the front value
            movwf ADLF
            goto    GetNext
PutL
            movf    ADValueH,w  ;Store the front value
            movwf ADHL
            movf    ADValueL,w  ;Store the front value
            movwf ADLL
            goto    GetNext
PutR
            movf    ADValueH,w  ;Store the front value
            movwf ADHR
            movf    ADValueL,w  ;Store the front value
            movwf ADLR
            clrf    i                       ;reset i for the next round
            return

;----------------------------------------------
;
;
;Turn the Bot
;
;----------------------------------------------
GoL
            movlw d'3'
            movwf ADPos                         ;set direction
            goto GetNext
GoR
            movlw d'2'
            movwf ADPos                         ;set direction
            goto GetNext
GoStr8
            movlw d'1'
            movwf ADPos                         ;set direction
            goto GetNext
```

H.2 Compass Code Excerpts

```
CompassMain
        call    OneSecond               ;wait 2 seconds while the compass
        call    OneSecond               ;settles and get current position
        movlw   0x01                    ;each bearing equals 100mm
        movwf   Tangent
        call    MemoryRead              ;Get required Compass Bearing
        movwf   MemVar                          ;direction
        btfsc   STATUS,Z
        call    OneSecond               ;wait 2 seconds while the compass
        call    OneSecond               ;make sure have a good reading
        movlw   0xFF                    ;check if finished
        subwf   MemVar,w
        skpnz
        goto    CompassEnd
        call    CompassStart
        goto    CompassMain
;---------------------------------------------------------
;CompassMain
;Checks to see it the Actual and Required Bearing
;ar the same
;---------------------------------------------------------
CompassStart
        movwf   MemVar                          ;Check to see if Compass Bearing
        xorwf   Compass,w               ;and required direction are the same
        btfsc   STATUS,Z
        goto    Straight                ;they are the same so continue forward

;---------------------------------------------------------
;FindCompass
;Checks the Actual Bearing against a Table of coordinates
;---------------------------------------------------------
FindCompass
        movf    DirTab,w        ; Increment the Table Index
        call    DirSTORE
        subwf   Compass,w
        btfsc   STATUS,Z
        goto    FindDirection
        incf    DirTab,f        ; Increment Table Index
        goto    FindCompass
;---------------------------------------------------------
;FindDirection
;Checks the Required Bearing against the above table
;---------------------------------------------------------
FindDirection
        movf    DirTab,w
        movwf   DirP
        clrf    DirTab
;---------------------------------------------------------
;Dir
```

```
 ;Compares if the Actual and Required Bearing
;are the same
;---------------------------------------------------------
Dir     movf   DirTab,w          ; Increment the Table Index
        call   DirSTORE
        subwf  MemVar,w                      ;are they the same?
        btfsc  STATUS,Z
        goto   WhereNow
        incf   DirTab,f          ; Get the Index into the Table
        goto   Dir
;---------------------------------------------------------
;Where Now
;Calculates the distance between the Two Bearings
;---------------------------------------------------------

WhereNow
        movf   DirTab,w
        movwf DirD   ;store the value
        ;are the same?
        subwf  DirP,w
        btfsc  STATUS,Z
        goto   Straight          ;its the same direction
        btfsc  STATUS,C
        goto   NoCarry                  ;it after
        goto   WorkCarry         ;its before
;---------------------------------------------------------
;WorkCarry
;Works the distance between the required and the actual
;bearing taking into consideration it the Required is before
;the actual.
;if it is more then 4 the robot turns Left
;if it is less then 4 the rtobot turns right
;---------------------------------------------------------
WorkCarry
        ;which way to go
        movf   DirP,w            ;subtract the 2
        subwf  DirD,w                   ;is the difference more then 4?
        sublw  0x04
        btfsc  STATUS,C
        goto   goright           ;no go right
        goto   goleft            ;yes go left
;---------------------------------------------------------
;NoCarry
;Works the distance between the required and the actual
;bearing this timethe Required is after
;the actual.
;if it is more then 4 the robot turns Left
;if it is less then 4 the rtobot turns right
;---------------------------------------------------------
NoCarry
        ;which way to go
        movf   DirD,w                   ;subtract the 2
```

```
          subwf  DirP,w           ;is the difference more then 4?
         sublw  0x04
         btfsc  STATUS,C
         goto   goright           ;no go right
         goto   goleft            ;yes go left
;--------------------------------------------------------
;GoLeft
; Turns the servo and waits while it turns
;Reverses a wheel to position the robot
;checks that the bearing for correct postion
;--------------------------------------------------------
goleft
         call   AddPerimeter
         bsf           Direction,0
         movlw         d'2'                        ;servo right
         movwf ADPos
         call   OneSecond                 ;Wait until it turns
         call   ReverseMotor        ;Reverse the motor
         call   CompassTurn               ;Wait till we get there
         goto   Straight
;--------------------------------------------------------
;Goright
; Turns the servo and waits while it turns
;Reverses a wheel to position the robot
;checks that the bearing for correct postion
;--------------------------------------------------------
goright
         call   AddPerimeter
         bcf           Direction,0
         movlw         d'3'                        ;servo left
         movwf ADPos
         call   OneSecond                 ;Wait until it turns
         call   ReverseMotor        ;Reverse the motor
         call   CompassTurn               ;Wait till we get there
;--------------------------------------------------------
;Straight
; Turns the servo and waits while it turns
;Starts to move the tangental distance
;--------------------------------------------------------
Straight
         movlw         d'1'                        ;servo straight
         movwf ADPos
         call   OneSecond
         Call   StartMotors
         call   Drive
         call   AddPerimeter
         goto   CompassMain

;--------------------------------------------------------
;DirSTORE
;The lookup table for the Compass Directions
;
```

```
  ;------------------------------------------------------------
DirSTORE
;thanks to Myke Predko and Programming
;and customising PicMicro Microcntrollers
;for this gem of a code to stop the table
;from going scrub
        movwf Temp
        movlw HIGH TheDir
        movwf PCLATH
        movf  Temp,w
        addlw LOW   TheDir
        btfsc STATUS,C
        incf  PCLATH,f
        movwf PCL
TheDir
                dt  b'1001'             ;NorthWest
                dt  b'1000'             ;North
                dt  b'1100'             ;NorthEast
                dt  b'0100'             ;East
                dt  b'0110'             ;SouthEast
                dt  b'0010'             ;South
                dt  b'0011'             ;SouthWest
                dt  b'0001'             ;West


;------------------------------------------------------------
;GetCompass
;  Loads the compass inputs
;  Turn off Readings that arent opf interest
;------------------------------------------------------------

GetCompass
        clrf    CompassTimer
        banksel         PORTA
        movf    PORTA,W
        movwf   Compass
        bcf             Compass,0x00;turn off response from pins
        bcf             Compass,0x01;we not interested in
        bcf             Compass,0x02
        bcf             Compass,0x03
        swapf   Compass,f               ;swap the high and low bits
        return

CompassEnd
        movlw 0x01
        movwf LCD
        call    DoLine1

CompassStop
        goto    CompassStop
```

H3. Grid code Excerpt

```
;-----------------------------------------------------------
;
; Grid code
;
;Reads the Compass points and tangents from Memory A0h
;one at a time
;
;The robot moves around the required angle
;
;then moves the required distance n the direction
;
;prints the perimeter and sings at the end
;plays music
;
;
;
;OutPut none
;

; Begin Grid
;Sets all required Ports and registers so the robot can interact
;
;-----------------------------------------------------------
BeginGrid
          call      InitMemory
          call      SetHall
          call      SetTMR0                   ;Init TMR0
          call      SetTimer1
          call      Init_motor           ;Set the PWM
          call      StartInt        ;Start Global Interrupt
          clrf      Perimeter
          clrf      Perimeter + 1
;-----------------------------------------------------------
;Loads in the Tangent and The new Angle
;Moves the robot the required angle
;then sets the distance to travle on the tangent
;-----------------------------------------------------------
GridGo
          movlw          d'1'                           ;servo straight
          movwf ADPos
          call      MemoryRead
          movwf Tangent                       ;read in tangent distance
          movlw 0xFF                 ;see if grid is finished
          subwf  Tangent,w
          skpnz
          goto    GridEnd
          call      MemoryRead
          movwf MemVar                        ;read in Angle
          call      FindAngle
          movf   MemVar,w                  ;calculated angle
         movwf Angle
         btfsc   STATUS,Z
         call      StartMotors              ;set motors for ahead
         btfss   STATUS,Z
         call      ReverseMotor ;Set the motor to turn the bot

         movf    Angle,w                          ;check to see if we are to go striahgt
         sublw  0x00
         btfsc   STATUS,Z               ;if so we dont need anthing else below
         goto    Str8Grid                 ;so set the robot to straight

         btfsc   Direction,0             ;choose which direction to turn
         call      TurnLeft
         btfss   Direction,0             ;make sure doesnt go straight
         call      TurnRight               ; back the other way
;-----------------------------------------------------------
;Str8Grid
;Turns the servo and waits while it turns
;Starts to move the tangental distance
;-----------------------------------------------------------
Str8Grid

         movlw           d'1'                                   ;servo straight
         movwf ADPos
         clrf      DistLeft                       ;remove evidence of the turn
         call      OneSecond                   ;stop while wheel straightens
         clrf      DistRight
         call      StartMotors                 ;go forward
         call      Drive
         call      AddPerimeter
         goto     GridGo                                 ;get next coordinate
;-----------------------------------------------------------
;FindAngle
;Decides if the Bot should turn Left or right
;Depending on whether the angle is larger or smaller then
;90 degrees. 90 Degree is actually 180degrees.
;-----------------------------------------------------------
FindAngle
         movlw 0x5A                    ;90 degrees
         subwf  MemVar,w              ;see if is bigger or smaller then 90
         btfsc   STATUS,C
         goto    SetLeft
         goto    SetRight
;-----------------------------------------------------------
;SetLeft
;Sets the Direction boolean
;so the bot nknows which way to turn
;-----------------------------------------------------------
SetLeft
         movwf MemVar                ;subtract from 90 then retore value
         sublw  0x5A
```

```
          movwf MemVar
         bsf            Direction,0     ;tell the bot which way to rotate
         goto    Dirfinish
;-----------------------------------------------------------
;SetRight
;Sets the Direction Boolean so the bot turns right
;-----------------------------------------------------------
SetRight
         bcf            Direction,0     ;tell the bot which way to rotate
;-----------------------------------------------------------
;DirFinish
;Converts the angle back to the full 360 Degrere
;so it can be stepped out with the HallEffect sensors
;-----------------------------------------------------------
Dirfinish
         rlf            MemVar                  ;convert back to 360 degree relation
         return
GridEnd
         movlw 0x03
         movwf LCD
         call    DoLine1
GridStop
         goto    GridStop
```

H.4. Motor Code Excerpt

```
;---------------------------------------------------------
;
; Motor codes
;
;Contains the codes for the motiors
;
;Including forward
;Reverse Left, Reverse right
;and full stop
;
;---------------------------------------------------------

;---------------------------------------------------------
;StartMotors
;Sets both motors to forward
;moving a value to CCPR1L and CCPR2L sets the speed
;---------------------------------------------------------
StartMotors
        MOVLW       d'125'
        movwf   CCPR1L
        MOVLW       d'125'
        movwf   CCPR2L
MotorPort
        BSF             PORTC,3                 ;this enables the HBridge
        BCF             PORTC,4                 ;this set to forward
        BCF             PORTC,5                 ;this sets to forward
        return
;---------------------------------------------------------
;ReverseMotor
;Chooses which Motor to reverse according to the
;Direction boolean
;---------------------------------------------------------
ReverseMotor
                ;see which motor to reverse
        call    AddPerimeter
        btfsc   Direction,0
        Goto    RevLeft
;---------------------------------------------------------
;RevRight
;Moves the speed value into
; the Right Motor
;Sets the Reverse port to high so the motor
;spins backwards
;---------------------------------------------------------
RevRight
        movlw d'125'
        movwf   CCPR1L
        BSF             PORTC,4                 ;set high to reverse
        BSF             PORTC,3                 ;this enables the HBridge
```

```
            return
;-----------------------------------------------------------
;RevLeft
;Moves the speed value into
; the leftt Motor
;Sets the Reverse port to high so the motor
;spins backwards
;-----------------------------------------------------------

RevLeft
        MOVLW       d'125'
        movwf   CCPR2L
        BSF     PORTC,5             ;set to reverse
        BSF             PORTC,3             ;this enables the HBridge
        return
;-----------------------------------------------------------
;TurnLeft
;This code is used by all of the movement code
;The servo is turned and the bot pasues while this happens
;the distance is rloaded and the bot counts the pulses
;-----------------------------------------------------------
TurnLeft
        movlw d'3'                  ;load a left turn
        movwf ADPos
        call    OneSecond           ;stop while wheel move
        movf    DistRight,w
        movwf Perimeter             ;save the perimeter
        clrf    DistLeft
        clrf    DistRight           ;reset wheel distances
;-----------------------------------------------------------
;Lcont
;Counts the pulses to see if the distance has passed
;-----------------------------------------------------------
Lcont
        movf    Angle,w
        subwf   DistLeft,w      ;count how many pulses the unit has travelled
        btfsc   STATUS,C        ;is over the required?
        goto    StopMotor
        goto    Lcont           ;continue until equal
;-----------------------------------------------------------
;TurnRight
;This code is used by all of the movement code
;The servo is turned and the bot pasues while this happens
;the distance is rloaded and the bot counts the pulses
;-----------------------------------------------------------
TurnRight
        movlw d'2'                  ;load a right turn
        movwf ADPos
        call    OneSecond           ;stop while wheel move
        movf    DistRight,w
        movwf Perimeter             ;save the perimeter
        clrf    DistLeft
        clrf    DistRight               ;reset wheel distances
;---------------------------------------------------------
;Rcont
;Counts the pulses to see if the distance has passed
;---------------------------------------------------------
Rcont
        movf    Angle,w
        subwf   DistRight,w             ;count how many pulses
        btfsc   STATUS,Z                ;1 pulse = 1 - 1.5 degree
        goto    StopMotor
        goto    Rcont                   ;continue until equal

;---------------------------------------------------------
;Drive
;count clicks let them add up every so amny and increment
;then match. robot will move 100mm for each spot on the grid
;of compass - 100mm = 33 clicks normally or 66 becasue of
;the boolean variable GridBool
;---------------------------------------------------------
Drive
        movlw 0x42          ;check to see if 66 clicks have passed
        subwf   DistRight,w ;Take readings from the right wheel
        btfsc   STATUS,Z
        goto    Next100
        goto    Drive
;---------------------------------------------------------
;Next100
;Increments for the next 100
;---------------------------------------------------------
Next100
        incf    DistForward             ;increment the distnce forward
        movf    Tangent,w
        subwf   DistForward,w           ;see if we have gone far enough yet.
        btfsc   STATUS,Z
        goto    StopMotor
        goto    Drive
```

H.5. Shape Code Excerpt

```
;-----------------------------------------------------------
;
; Shape code
;
;Calls the relevant shape memory area in EEPROM
;and loads the Shape rotations and distances one at a time
;prints the perimeter and sings at the end
;
;Input the shape number
;
;OutPut none
;
;-----------------------------------------------------------
ShapeStart
        call    SetHall
        call    SetTMR0                 ;Init TMR0
        call    SetTimer1
        call    Init_motor          ;Set the PWM
        call    StartInt        ;Start Global Interrupt
        return

;--------------------------------------------
;find which shape is to be stepped out
;Get the poistion in the table
;
;---------------------------------------------
BeginShape
        movlw 0x01
        subwf   Received,w
        btfsc   STATUS,Z
        goto    SetSQ           ;Get the Square
   movlw        0x02
        sublw   Received
        btfsc   STATUS,Z
        goto    SetR            ;Get the Rectangle
        movlw 0x03
        sublw   Received
        btfsc   STATUS,Z
        goto    SetPen          ;Get the Pentagon
        movlw 0x04
        sublw   Received
        btfsc   STATUS,Z
        goto    SetHex          ;Get the Hexagon
        movlw 0x05
        sublw   Received
        btfsc   STATUS,Z
        goto    SetHep          ;get the Heptagon
        movlw 0x06
```

```
          sublw  Received
         btfsc   STATUS,Z
         goto    SetOct          ;Get the Octagon
         movlw 0x07
         sublw   Received
         btfsc   STATUS,Z
         goto    SetEQ           ;get the Eq Triangle
         movlw 0x08
         sublw   Received
         btfsc   STATUS,Z
         goto    SetSC           ;get scalene triangle



;--------------------------------------------
; SetShape
; Load the angle to turn and the distance of a side
; Move the robot into positon then step out the
; distance
;--------------------------------------------
SetShape
         call    EEPROMRead
         movwf MemVar
         movlw 0xFF
         sublw   MemVar
         btfsc   STATUS,Z
         goto    ShapeEnd

         call    EEPROMRead                          ;get the distance
         movwf Tangent

         call    FindAngle
         movf    MemVar,w                  ;calculated angle
         movwf Angle
         btfsc   STATUS,Z
         call    StartMotors               ;set motors for ahead
         btfss   STATUS,Z
         call    ReverseMotor        ;Set the motor to turn the bot

         movf    Angle,w                             ;check to make sure we are going
straight
         sublw   0x00
         btfsc   STATUS,Z                  ;if so we dont need anthing else below
         goto    Str8

         btfsc   Direction,0               ;choose which direction to turn
         call    TurnLeft
         btfss   Direction,0               ;make sure doesnt go straight back the
other way
         call    TurnRight
;--------------------------------------------
;Str8
```

```
 ;Straightens the Servo
;Deletes turn in for
;Starts to step out the side
;---------------------------------------------
Str8
        movlw       d'1'                        ;servo straight
        movwf ADPos
        clrf    DistLeft                ;remove evidence of the turn
        call    OneSecond               ;stop while wheel straightens
        clrf    DistRight
        call    StartMotors             ;go forward
        call    Drive
        goto    SetShape

;---------------------------------------------
;ShapeEnd
;Stops motors
;LCD
;Music
;---------------------------------------------
ShapeEnd
        call    StopMotor
        ;do some LCD magic
        movlw 0x02
        movwf LCD
        call    DoLine1
Stopme
        goto    Stopme
;---------------------------------------------
;Loads the EEPROM memory Positions for
;each shape
;---------------------------------------------
SetSQ
        movlw d'0'
        banksel     EEADR
        movwf EEADR
        goto    SetShape
SetR
        movlw d'9'
        banksel     EEADR
        movwf EEADR
        goto    SetShape
SetEQ
        movlw d'18'
        banksel     EEADR
        movwf EEADR
        goto    SetShape
SetSC
        movlw d'25'
        banksel     EEADR
        movwf EEADR
        goto    SetShape
 SetPen
	movlw d'32'
	banksel	EEADR
	movwf EEADR
	goto	SetShape
SetHex
	movlw d'45'
	banksel	EEADR
	movwf EEADR
	goto	SetShape
SetHep
	movlw d'60'
	banksel	EEADR
	movwf EEADR
	goto	SetShape
SetOct
	movlw d'77'
	banksel	EEADR
	movwf EEADR
	goto	SetShape
```

H.6. Servo Code Excerpt

```
;---------------------------------------------------------
;
;                               SERVO INTERFACING
;

;sends the required PWM on time so Timer0 knows how long to
;set the high time and position the servo
;
;---------------------------------------------------------
set_PulseM                      ;go Straight
        movlw d'13'
        movwf DelayCount
        call    SERVOON
        ;MainDelay   .0018
        return
set_PulseL                      ;go left
        movlw d'7'
        movwf DelayCount
        call    SERVOON
        ;MainDelay   .0011
        return
set_PulseR                      ;go Right
        movlw d'18'
        movwf DelayCount
        call    SERVOON
        ;MainDelay   .0022
        return
;---------------------------------------------------------
;SERVOON
;       Controls the on time for the servo positioning
;       allows multiples of 100us
;
;---------------------------------------------------------

SERVOON
                movf    DelayCount, w           ;see if Delay amount = 0
                btfsc   STATUS, Z
                RETURN
                call    TheDelay
                decf    DelayCount, f ;Decrement delay
                goto    SERVOON
TheDelay:                         ;this is the 100us Pause
                movlw d'11';
                movwf  usDelay
TENusDelay                                      ;wait 10us
                decf    usDelay,f
                movf    usDelay,w
                nop
                nop
```

```
  nop
nop
nop
btfss    STATUS,Z
goto     TENusDelay
return
```

H.7. Interrupt Code Excerpt

```
        InterruptHandler
        movwf           _w                          ;save W
        movf    STATUS, w
        bcf     STATUS, RP0
        bcf     STATUS, RP1
        movwf           _status             ;save STATUS
        movf    PCLATH, w           ;Save PCLATH because the code
        movwf           _pclath             ;is larger then 1 page
        clrf    PCLATH
        btfsc   PIR1,RCIF           ;was it the wireless connection?
        goto    RX_HANDLE
        btfsc   INTCON, TMR0IF      ;Was TMR0 interrupt?
        goto    TMR0_int            ;service it
        BTFSC           PIR1, TMR1IF        ; Timer1?
        GOTO            Tmr1_INT ; YES, Service the Timer1 Overflow Interrupt
        goto    PORTBInt            ;will be the PORTB interrupt then
        goto    IntEnd
;----------------------------------------------------------
;RX_HANDLE
;handles the input from the wireless connection
;either sets a mode or loads the next values to
;memory
;----------------------------------------------------------
RX_HANDLE
        movf    RCREG,w
        movwf Received

        movlw 0xFE                          ;reset
        subwf   Received,w
        btfsc   STATUS,Z
        goto    ResetAll

        btfsc   GridBool,0          ;has one of these modes been set?
        goto    GridHandle          ;if so service it
        btfsc   CompassBool,0
        goto    CompassHandle
        btfsc   RemoteBool,0
        goto    RemoteHandle
        btfsc   ShapeBool,0         ;has one of these modes been set?
        goto    BeginShape          ;if so service it


        movlw 0x01                  ;Line Follow n light follow
        subwf   Received,w
        btfsc   STATUS,Z
        bsf             LDRBool,0

        movlw 0x02                  ;Grid
        subwf   Received,w
        btfsc   STATUS,Z
```

```
             goto    GridSet

            movlw 0x03                   ;Compass
            subwf  Received,w
            btfsc   STATUS,Z
            goto    CompassSet
            bsf      CompassBool,0

            movlw 0x04                   ;Remote
            subwf  Received,w
            btfsc   STATUS,Z
            goto    RemoteHandle

            movlw 0x05                   ;Shape
            subwf  Received,w
            btfsc   STATUS,Z
            goto    ShapeSet

            ;something else just reset the port
;-----------------------------------------------------------
;Reset the wireless input for the next message
;-----------------------------------------------------------
RX_END
            bcf              RCSTA,CREN          ;reset everything for the next message
            bsf              RCSTA,CREN
            bcf              PIR1,RCIF
            goto    IntEnd
;-----------------------------------------------------------
;processes the Timer 0 interrupt;
;decides what mode the timer is in and processes
;
;-----------------------------------------------------------
TMR0_int
            bcf      INTCON, TMR0IF    ; Clear TMR0 interrupt
            movlw 0x01
            subwf  MusicBool,w
            skpnz
            goto    DoMusic
            movlw          d'106'
            movwf          TMR0                  ;Re-initialise TMR0
            bsf              PORTC,0                         ;MAKE PIN0 pwm high for servo
            movf   ADPos,w                       ;is this the front LDR
            sublw  0x01
            btfsc   STATUS, Z
            call     set_PulseM
            movf   ADPos,w                       ;is this the Left LDR
            sublw  0x02
            btfsc   STATUS, Z
            call     set_PulseL
            movf   ADPos,w                       ;Is this the right LDR
            sublw  0x03
            btfsc   STATUS, Z
```

```
         call     set_PulseR
        bcf             PORTC,0                         ; set low again to finish PWM pul
        goto    IntEnd
;--------------------------------------------------------
;Processes the Timer1 second counting
;--------------------------------------------------------
Tmr1_INT
        bcf     PIR1, TMR1IF            ;Clear Timer1 Interrupt Flag
        call    resetButton             ;in case the button debounce is called
        decf    TMR1Count
        BCF     PIR1, TMR1IF ; Clear Timer1 Interrupt Flag
        MOVLW         d'133'            ; TIM1H:TMR1L gives 1/4 second
        MOVWF         TMR1H                     ; overflow, at 32 KHz.
        MOVLW         d'238'
        MOVWF         TMR1L ;
        movlw 0x01    ;see if this is just a second count
        subwf  SecBool,w
        skpnz
        goto    IntEnd
        decf    NoteTime
        skpnz
        goto    Load_Next_Note
        goto    IntEnd


;--------------------------------------------------------
;PortBInt
;Processes the PortB interrupt
;
;reads in the pins and recordes their values
;these values are checked against the next pass
;to make sure a pin isnt read twice in error
;
;if there is a change the pin is priocessed
;--------------------------------------------------------
PORTBInt
        movf    PORTB,W
        movwf HoldPortB
        movlw b'10000000'               ;check if Pin7 changes
        subwf  LastPortB7,w             ;this is emergency stop
        btfss   STATUS,Z
        call    Service7

        movlw b'00010000'               ;check if Pin4 changes
        andwf  HoldPortB,w              ;from last time INTB was fired
        subwf  LastPortB4,w
        btfss   STATUS,Z
        call    Service4
        movlw b'00100000'               ;check if Pin5 changes
        andwf  HoldPortB,w              ;from last time INTB was fired
        subwf  LastPortB5,w
        btfss   STATUS,Z
```

```
          call      Service5
        movlw b'00010000'               ;store Pin 4,5 and 7 so can check for changes
        andwf  HoldPortB,w              ;
        movwf LastPortB4
        movlw b'00100000'
        andwf  HoldPortB,w
        movwf LastPortB5
        movlw b'10000000'
        andwf  HoldPortB,w
        movwf LastPortB7
        BCF             INTCON,RBIF
;-------------------------------------------------------
;
;REset the values saved initially so the program continues
;where it left without error
;
;-------------------------------------------------------
IntEnd
        movf    _pclath, w       ; Restore PClath
        movwf           PCLATH
        movf    _status, w ; Restore status register
        movwf           STATUS
        swapf   _w, f            ; Restore W without changing flags
        swapf   _w, w
        retfie
```

H.8 Sound Code Excerpt

```
;----------------------------------------------
;                    Music Section
;
;
;----------------------------------------------
;----------------------------------------------
;Load_Next_Note
;          loads the next note in the seqence and looks
;for the the final note
;----------------------------------------------
Load_Next_Note
          movf   NotePosition,w
          call   Songs                    ;get the next note for the song
          movwf          Note
          movlw a'L'                      ;make sure its not the last note
          subwf  Note,w
          skpnz
          goto   StopMusic
          movlw 0x40                      ;see if it letter or Number
          subwf  Note,w
          btfsc  STATUS,C
          goto   WorkLetter
          goto   WorkNumber
          movlw 0x30                      ;get the hex equivalent of the number
          subwf  Note,w

;----------------------------------------------
;GetNote
;          Finds the Hz equivalent of the note

;----------------------------------------------
GetNote
          call   MusicalNotes
          movwf Note
          banksel        TMR0
          movwf          TMR0                     ;load the note Hz into the Timer0
          banksel        NotePosition
          incf   NotePosition
          movf   NotePosition,w
          call   Songs                    ;get the time for the note
          movwf NoteTime
          movlw 0x30                      ;get the hex equivalent of the number
          subwf  NoteTime,w
          movwf NoteTime
          incf   NotePosition
          goto   IntEnd
;----------------------------------------------
;WorkLetter
;find the Hex equivalent of a letter
```

```
 ;-----------------------------------------------
WorkLetter
        movlw 0x37                    ;Subtract 55 so equals relevant number
        subwf  Note,w
        goto   GetNote
;-----------------------------------------------
;WorkNumber
;Finds the Hex equivalent of a number
;-----------------------------------------------
WorkNumber
        movlw 0x30                    ;Subtract 48 so equals relevant number
        subwf  Note,w
        goto   GetNote
;-----------------------------------------------
;Songs
;       What is says
;-----------------------------------------------
Songs
;thanks to Myke Predko and Programming
;and customising PicMicro Microcntrollers
;for this gem of a code to stop the table
;from going scrub
        movwf Temp
        movlw HIGH TheSongs
        movwf PCLATH
        movf   Temp,w
        addlw  LOW   TheSongs
        btfsc  STATUS,C
        incf   PCLATH,f
        movwf PCL
TheSongs
        ;Also SPrach Zarathustra Intro  - Richard Strauss          Starts @0
        ;Blue Danube                         - Johann Strauss              Starts
@15
        ;Ode to Joy                                  - Ludwig van Beethoven
Starts @58

        DT
"145484F2D2D4D4L5171919101919101717101517191910191910181 81L7171819191
81716151516171718182L"
;-----------------------------------------------
;MusicalNotes
;the lookup table for the notes tmr0 amounts
;-----------------------------------------------
MusicalNotes
;thanks to Myke Predko and Programming
;and customising PicMicro Microcntrollers
;for this gem of a code to stop the table
;from going scrub
        movwf Temp
        movlw HIGH TheNotes
        movwf PCLATH
```

```
	 movf	Temp,w
	addlw	LOW	TheNotes
	btfsc	STATUS,C
	incf	PCLATH,f
	movwf	PCL
TheNotes
		dt	0x00;Rest	0
		dt  .5	;Low C  1
		dt  .20	;Low D		2
		dt  .45	;Low E3
		dt	.69	;Low F4
		dt  .79	;Low G  5
		dt  .99	;A		6
		dt  .116;B		7
		dt	.132;C		8
		dt	.139;D		9
		dt	.152;E		A
		dt	.163;F		B
		dt	.168;G				C
		dt	.178;High A	D
		dt	.187;High B E
		dt	.195;High C	F
		dt	.198;High D G
;-----------------------------------------------
;StopMusic
;	As it says
;-----------------------------------------------
StopMusic
	;I can stop the music
	call	NoteOff
	bcf	INTCON, T0IE ;tmr0 interrupt enabled
	goto	IntEnd
;-----------------------------------------------
;DoMusic
;	Toggles the Sound on and off so they become
; a musical note
;-----------------------------------------------
DoMusic
	movf	NoteToggle,w
	subwf	0x01,w
	skpnz
	goto	NoteOn
	goto	NoteOff

;-----------------------------------------------
;NoteOn
;	Turns DortD pin 0 on for on portion of note
;
;-----------------------------------------------
NoteOn
	bsf		PORTD,0			;turn the note on
	bsf		NoteToggle,0
```

```
        goto    NoteStart
;-----------------------------------------------
;NoteOff
;       Turns DortD pin 0 off for off portion of note
;
;-----------------------------------------------
NoteOff
        bcf             PORTD,0                 ;turn the note off
        bcf             NoteToggle,0
;-----------------------------------------------
;NoteStart
;       loads the note value to TMR0 so the interrupt
;       will fire again
;-----------------------------------------------
NoteStart
        movf    Note,w
        movwf   TMR0
        goto    IntEnd
```