RoboBrain 2.1

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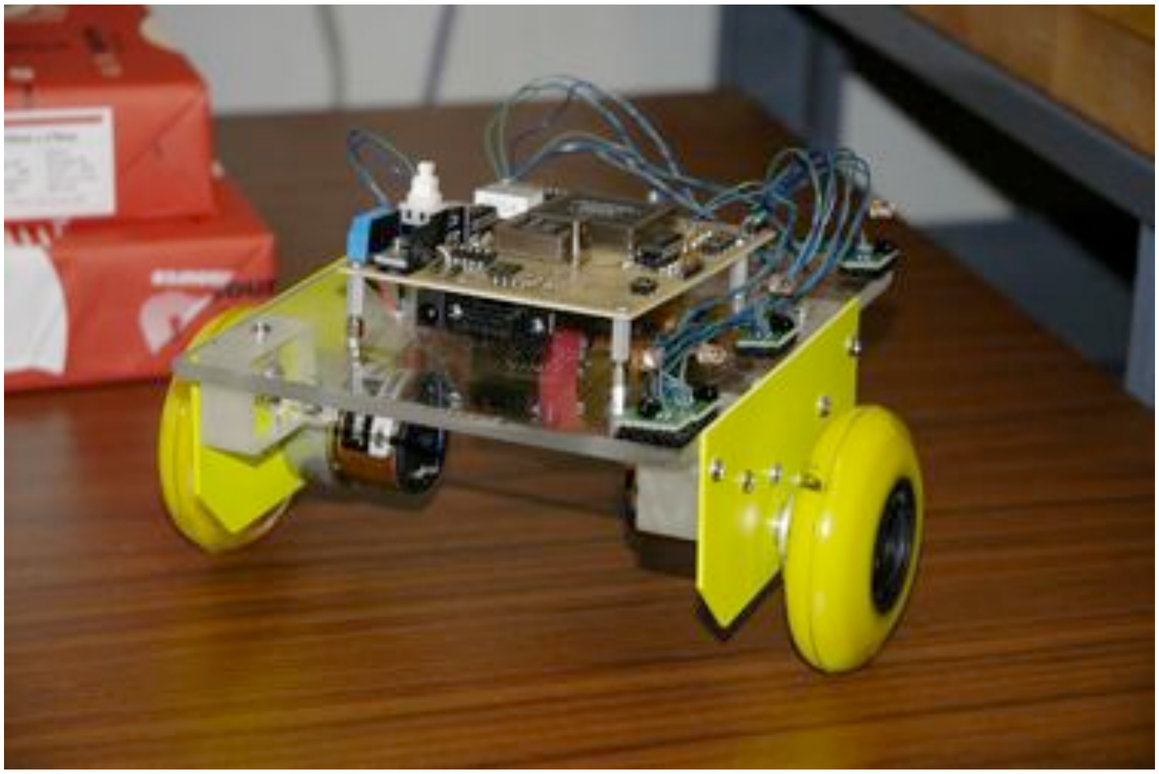

CE123 Senior Design Project

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Mission

Our mission is to introduce High School students to the Computer Engineering profession through an easy to use microcontroller kit. We will do this by designing a more economical solution to what schools, Aptos High School in particular, is currently using. Our microcontroller kit, named *RoboBrain* will be a much more powerful kit when compared to our competitors. Parallax's microcontroller kit, the "Board of Education," is what Aptos HS is currently using for their robotics project. We hope to change that. Although it is geared towards High School Students, it can also be used by Computer Engineers or Robot Hobbyists as a Development Board.

Most High School students do not have the slightest idea of what differentiates a Computer Engineer from a Computer Scientist or an Electrical Engineer. This kit is intended to cover all 3 aspects of these fields, with an emphasis on Computer Engineering. It will cover the design layout and why certain IC parts were used where they are.

This project will also cover some of the history, tools, and methods to help aide the user in understanding the objectives of each lesson.

The goals of the second version of RoboBrain were to simplify the original design into a more discrete IO system while adding potential for additional sensor inputs and control. Version two is a redesign simply omitting unnecessary components and adding more useful and optional functionality.

This entire project is non-proprietary, and does not have any bonds with other companies. The compiler, text editor, and downloader are all freeware. All that we ask is that you do not redistribute this product for profit.

INTRODUCTION 5

ROBOBRAIN ASSEMBLY 6

PARTS 6
ASSEMBLY / SOLDERING 8

TURNING ON ROBOBRAIN AND PROGRAMMING 19

SYSTEM TOOLS 21

COMPILER 21
DOWNLOADER 21
INTEGRATED DEVELOPMENT ENVIRONMENT 21
COMPILING THE ROBOBRAIN LIBRARIES 21
COMPILING A PROGRAM WITH JEDIT 22
COMPILING A PROGRAM WITHOUT JEDIT 22
USING BATCH/SCRIPTS TO COMPILE YOUR CODE 25
DOWNLOADING A PROGRAM TO ROBOBRAIN WITH JEDIT 25
DOWNLOADING A PROGRAM TO ROBOBRAIN WITH FLASHMAGIC 25
TEST PROGRAM 27

SAMPLE PROGRAMS & LESSONS 27

IR INTENSITY 27
LCD 27
PLAY MUSIC 28
PROGRAMMABLE INTERRUPT BUTTONS 29
EXTERNAL PORT READING AND WRITING 30
INFRARED SENSORS 32
ROBOIR EXAMPLE I: DETECTING INFRARED 33
ROBOIR EXAMPLE II: MEASURING IR INTENSITY 33
ROBOIR EXAMPLE II: MEASURING IR INTENSITY 34

MOTORS 41

DC MOTORS 41
STEPPER MOTORS 42
SERVO MOTORS 42

FUNCTION INDEX 43

CONSTANT DEFINITIONS 44
TIME FUNCTIONS (TIME.H) 45
SERIAL I/O LIBRARY (SIO.H) 45

MOTOR FUNCTIONS (MOTOR.H)	47
LCD FUNCTIONS (LCD.H)	49
PIN I/O FUNCTIONS (IO.H)	50
I2C FUNCTIONS (I2C.H)	54
APPENDIX A – ROBOTS FOR COSMOS	**58**
PARTS	58
CHARACTERIZING THE IR SENSORS	60

Introduction

RoboBrain is a microcontroller kit intended for High School Students. The idea was brought to us by William Thompson, and Cyrus Bazeghi. It involves a complex design that involves interfacing a microcontroller with other ICs; incorporating a development board or a kit that can be easily expandable to support other functionality.

The kit includes include a circuit board, the microcontroller, some discrete components, an introductory manual, a sample program, along with any other parts that they might need. Assembly will involve soldering some SOIC surface-mount and “through-hole” parts onto the PCB, and connecting the proper resistive and capacitive loads throughout the board. This will give the user a tremendous understanding of what is required to meet certain noise margins, and why circuit design is important, in addition to being a great experience. Surface mount parts are widely used in PCB designs and give the user an idea of what goes on in industry.

Philips P89C668:

- Speed up to 20 MHz with 6 clock cycles per machine cycle (40 MHz equivalent performance); up to 33 MHz with 12 clocks per machine cycle
- Fully static operation
- 64 KB of internal Flash Program ROM
- On-chip Flash Program Memory with In-System programming
- 8 KB of internal RAM
- Four 8-bit I/O ports
- Three Counter/Timers
- Full-duplex enhanced UART
- I^2 C serial interface
- Programmable Counter Array (PCA)
    - PWM
    - Capture/compare

Functions will be called using high-level wrapper functions written in C and Assembly language. All this functionality placed on a PCB with an easy use programming interface will get the user up and running with the RoboBrain in no time.

RoboBrain Assembly

Parts

The following part list will help you construct your RoboBrain in no time. The parts are categorized and some part reference numbers and/or surface mount sizes have also been provided.

ICs

1		Linear Regulator 7805		DIGIKEY:LM7805CT-ND/TO-220
1		Philips 8051 Microcontroller		PHILIPS:P89C668
1		Altera CPLD		ALTERA:EPM7128S
1		MAX232I/SO Serial Transceiver		DIGIKEY:296-6940-5-ND
2		SN754410 Half H-Bridge Driver		DIGIKEY:296-9911-5-ND
3		PHILIPS PCF8591 8bit A/D converter		DIGIKEY:568-1088-2-ND
3		LMC6484 Quad Op Amp SOIC		DIGIKEY:LMC6484AIMX

Capacitors

2		27pF		Surface Mount 0805
7		10uF		Surface Mount 0805
22		.1uF		Surface Mount 0805
1		1uF		Surface Mount 0805
1		47uF 25V		Axial

Resistors

3		470ohm		Surface Mount 0805
8		4.7Kohm		Surface Mount 0805
10		10Kohm		Surface Mount 0805
10		330ohm		Surface Mount 0805
1		100ohm		Surface Mount 0805
6		270ohm		Surface Mount 0805
6		100Kohm		Surface Mount 0805
3		47Kohm R_NETWORK_BUS_9		DIGIKEY:4310R-1-473-ND
1		470ohm R_NETWORK_BUS_9		DIGIKEY:4310R-1-471-ND
1		470ohm R_NETWORK_ISO_8		DIGIKEY:767-163-R470-ND

Diodes

9		Green LED Surface Mount 0805		DIGIKEY:SML-LXT0805GW-TR
18		1N4001 DIODE Axial		DIGIKEY:1N4001
1		1N5401 DIODE 3Amp Axial		DIGIKEY:1N5401
1		1-Digit 7-Segment-Display		DIGIKEY:160-1575-5-ND

Switches

3		Tact Pushbutton SPST		
1		SW DIP-8		DIGIKEY:CT2098MS-ND
1		SW DIP-4		DIGIKEY:CT2094MS-ND
1		POWER SW DPST		DIGIKEY:P8102S-ND

Sensors and Emitters

4		IR emitter		DIGIKEY:QED523-ND
4		IR sensor		DIGIKEY:QSD733-ND
6		Line detection Sensor/Transducer		DIGIKEY:QRB1114-ND

Jacks and Sockets

1		PJ-102BH DC POWER JACK		
1		3 Input Terminal Blockk		
1		FEMALE D-SUB9 Serial Jack		JAMECO:104951
1		PLCC 84pin Thru Hole TO Socket		DIGIKEY:ED80027-ND
1		PLCC 44pin Thru Hole TO Socket		DIGIKEY:ED80024-ND

Headers and Other Parts

1		40pin Male DIP Header		
2		20pin Male SIP Header		
1		20pin Female SIP Header		
1		PIEZO SPEAKER		JAMECO:207950
1		Regulator Heatsink		
2		Motor Driver Heat sink		Staver V7 Heatsink
1		20Mhz Crystal		DIGIKEY:CTX062-ND
4		FF Spacers		

Optional LCD

1		10Kohm Trimpot		
1		LCD 24 character x 2 lines		OPTREX:DMC24201

The RoboBrain, along with having simplified access to the microprocessor’s pins, will have built-in drivers to operate several outside devices:

- Motors (DC, Servo, Stepper)
- IR Sensors
- UART
- I2C
- Basic sound via a Piezo speaker
- Character LCD
- IR communication

Assembly / Soldering

The following instructions will guide you through RoboBrain v2.1 board assembly. Following these step by step instructions should allow for the easiest possible assembly. Steps 3 and 5 in this assembly are OPTIONAL. Optional steps need not be considered for minimal operation.

1) Bottom side surface mount capacitors.

   Solder the following capacitors onto the bottom side of the board. These components are un-polarized, so orientation does not matter.

• Blue:	100nF Ceramic Capacitor (18)
• Pink:	27pF Ceramic Capacitor (2)
• Green:	10uF Ceramic Capacitor (7)
• Red:	1uF Ceramic Capacitor (1)

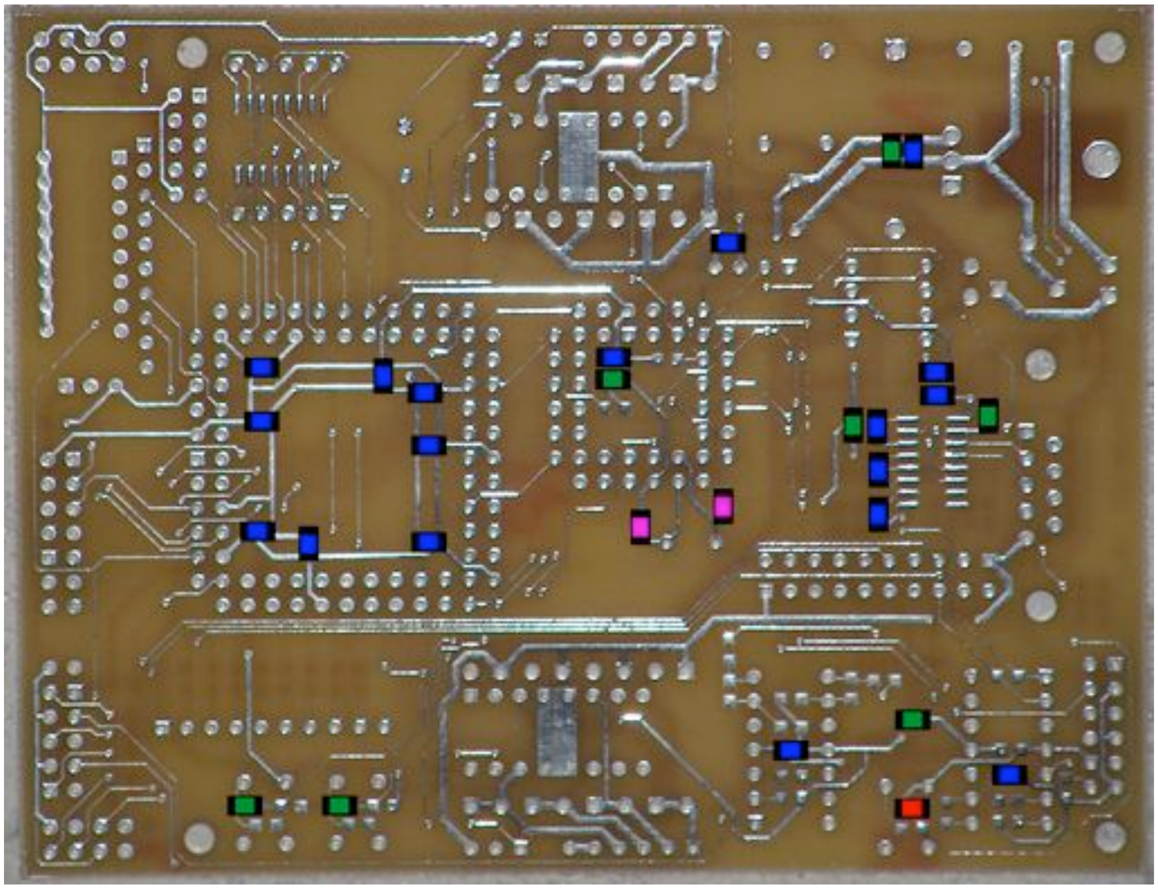


Figure 1: Bottom side

2) Bottom side surface mount Resistors / IC's.

Solder the following resistors on the bottom side of the board. The 0805 resistors are un-polarized, so orientation does not matter. The Isolated resistor network package should be oriented with pin1 to the left side. The Max232 package should be oriented with pin1 on the north side.

• Blue:	4.7kΩ (4)
• Pink:	100Ω (1)
• Dark Green:	470Ω (2)
• Red:	470Ω Isolated Network Resistor Package (1)
• Light Green:	Max232 (1)

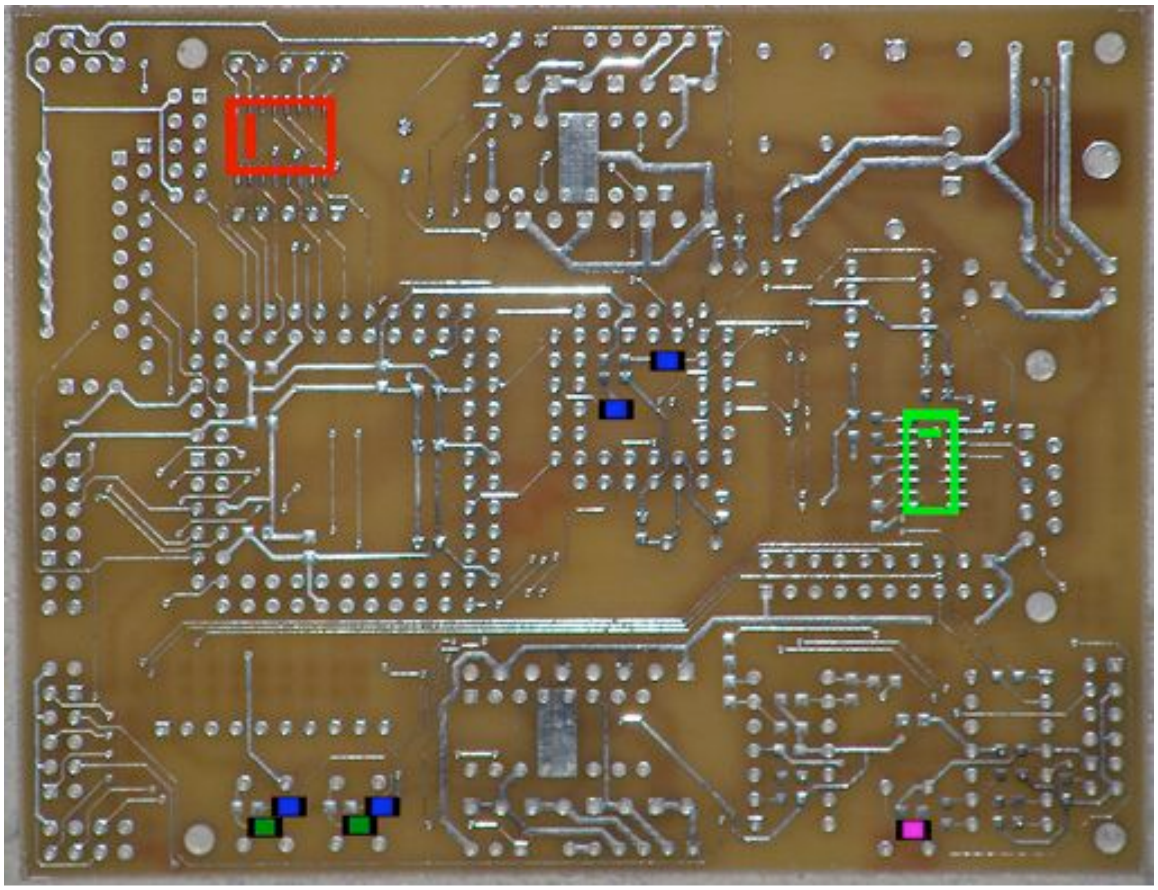


Figure 2: Bottom side

3) Bottom side **OPTIONAL** surface mount Resistors.

   If **line detection** sensors are desired, populate the bottom of the board with the following surface mount resistors. The 0805 resistors are un-polarized, so orientation does not matter. If line detection is not desired, the system will run fine independent of these components, and this step can be skipped.

Blue:	270Ω (6)
Red:	10kΩ (2)
Green:	100kΩ (6)

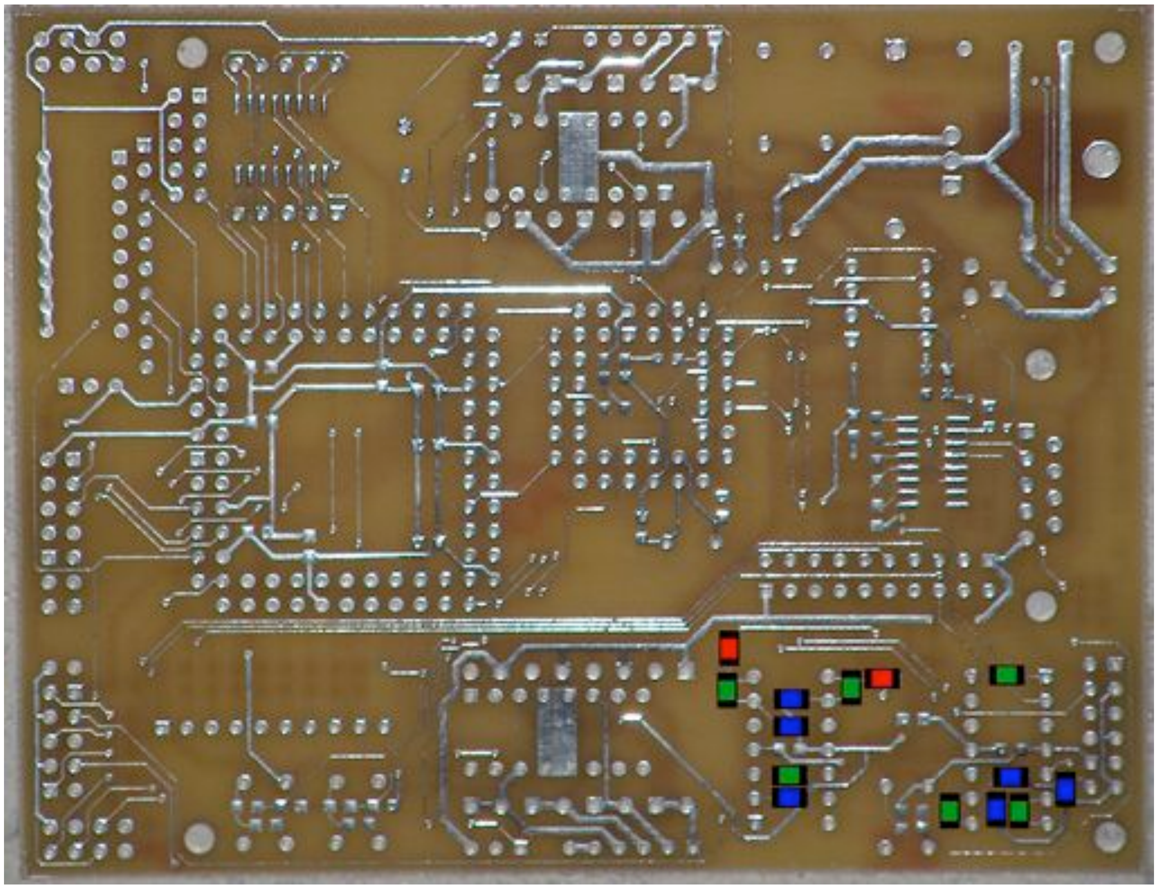


Figure 3: Bottom Side

4) Top side surface mount Capacitors, LEDs, IC's and resistors.

   Solder the following surface mount components onto the top side of the board. The 8 LED's should be placed with Anode south, and Cathode north. The single LED should be oriented with Anode on the right and Cathode on the left. The capacitors and resistors are un-polarized. The A to D Converter should be oriented with pin1 left.

• Dark Green:	330Ω Resistor (4)
• Light Green:	SM LED's (9)
• Red:	10kΩ Resistor (4)
• Blue:	100nF Ceramic Capacitor (3)
• Pink:	4.7kΩ Resistor (4)
• Purple:	470Ω Resistor (1)
• Yellow:	PCF8591 A to D converter (1)

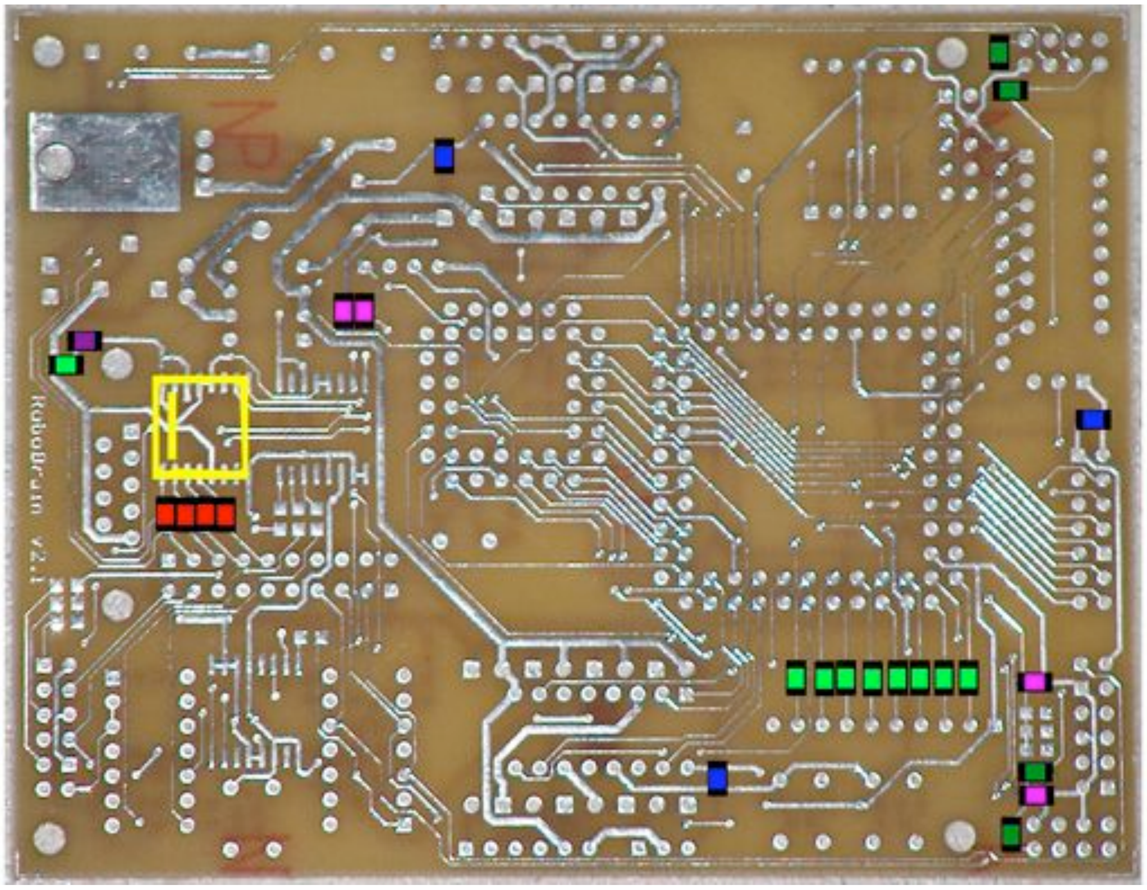


Figure 4: Top Side

5) Top side **OPTIONAL** Surface Mount / Thru-Hole components.

   If **line detection** is desired and step 3 was performed, populate the top side of the board with the following components. If line detection is not desired, the system will run fine independent of these components, and this step can be skipped. The top A to D should be oriented with pin1 left. The bottom one should be oriented with pin1 to the right. For easy chip swapping, populate a 14pin Dip socket where the Op-amps go. Observe the location of the square pin hole for Socket/Op-amp and Resistor network orientation.

Dark Green:	330Ω Resistor (6)
Red:	10kΩ Resistor (4)
Yellow:	PCF8591 A to D converter (2)
Blue:	14pin DIP socket or LMC64/84 op amp (2)
Light Green:	47kΩ Network Resistor package (1)

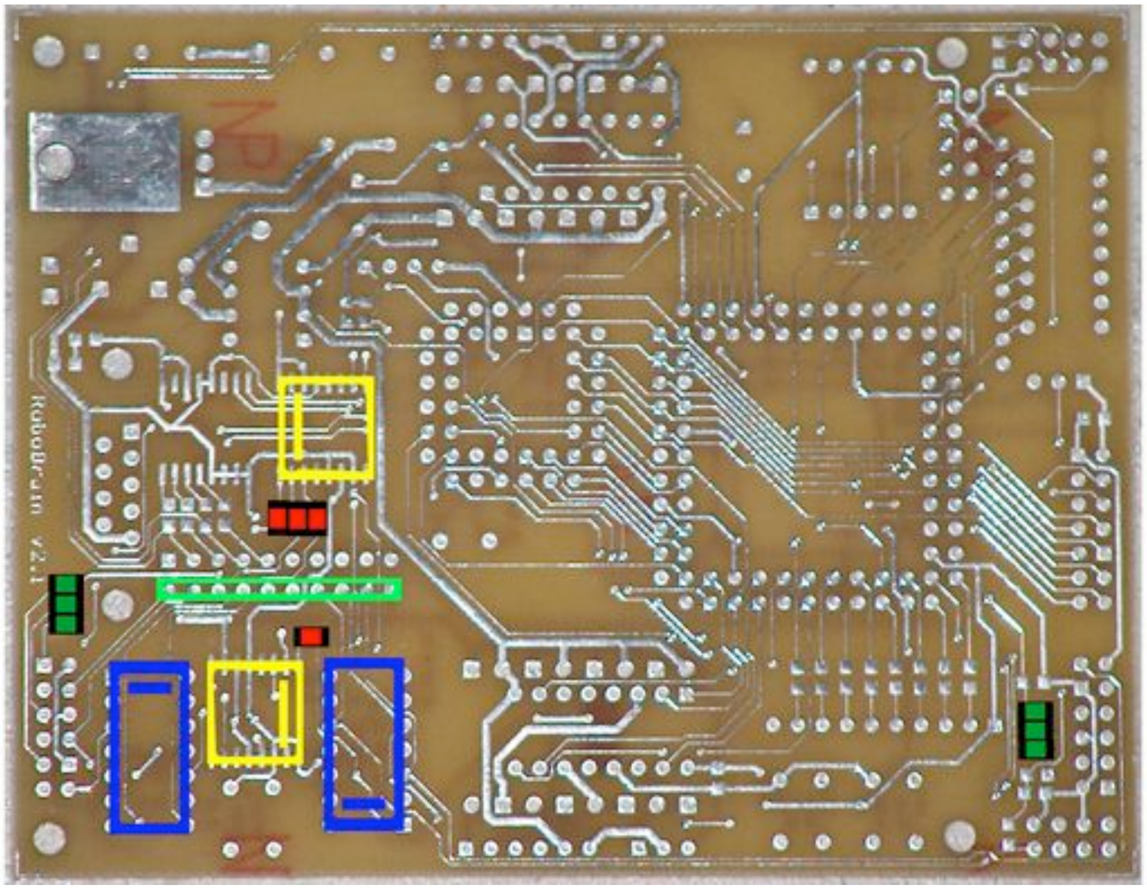


Figure 5: Top Side

6) Top side Thru-hole Motor Sockets / Power Source Diodes.

   The following components must now be soldered to the top side. Parts that will later be added will obstruct your ability to solder these components later. The two 1N1004 diodes should both be oriented with anode left and Cathode right. The 1N5004 diode should be placed with Anode north and Cathode south. For easy chip swapping, populate a 16pin Dip socket where the motor drivers go. Observe the location of the square for Socket/Motor-Driver orientation.

   - Red: 1N1004 diode. (2)
   - Blue: 1N5004 diode. (1)
   - Green: 16pin Dip Sockets or Motor Drivers (2)

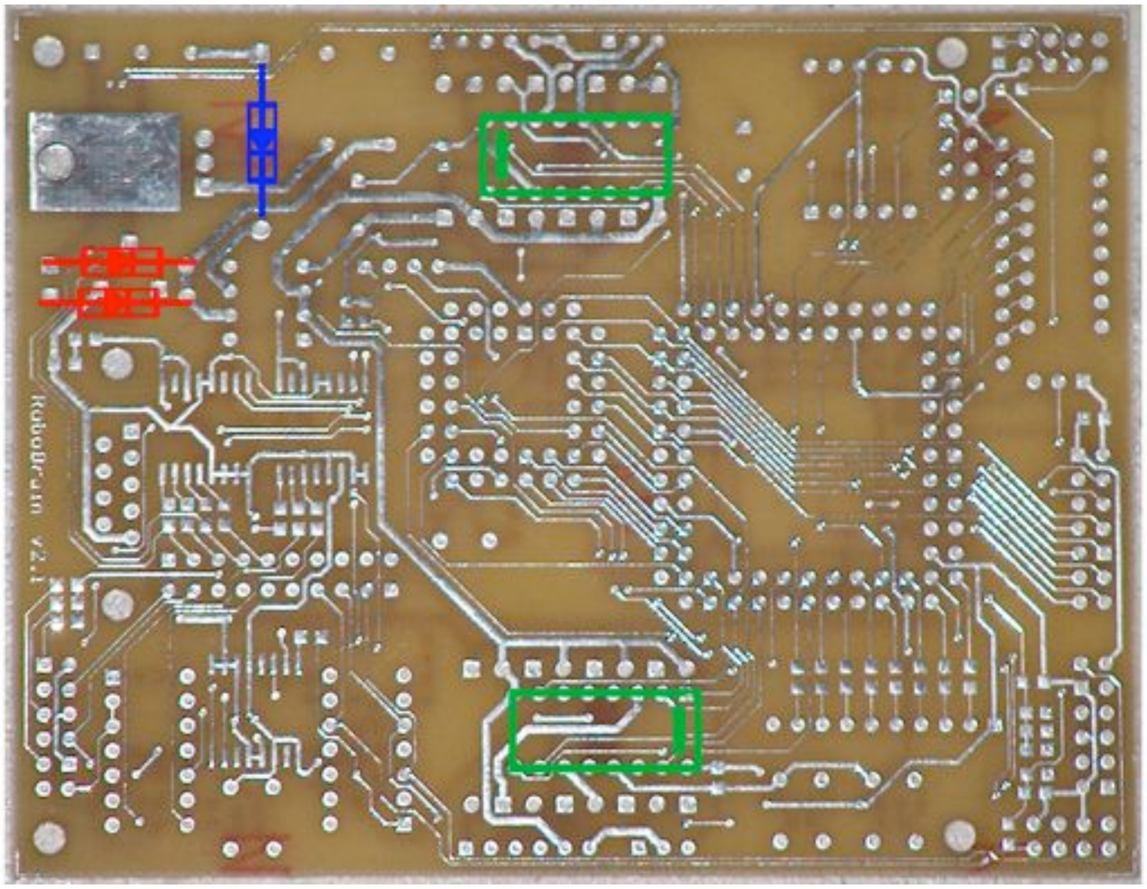


Figure 6: Top Side

7) Bottom Side Thru-Hole Components.

Now populate the remainder of the bottom Thru-Hole components. All diodes shown here are optional, as they provide Induction Kick protection for the motor drivers. The system will work without them. Pay attention to the diode orientation. Square pin hole is Anode, round is Cathode.

Red:	1N1004 Diode (16)
Blue:	AC/DC Jack (1)
Pink:	DSUB-9 Serial Jack (1)
Maroon:	47kΩ Network Resistor (2)
Green:	470Ω Network Resistor (1)

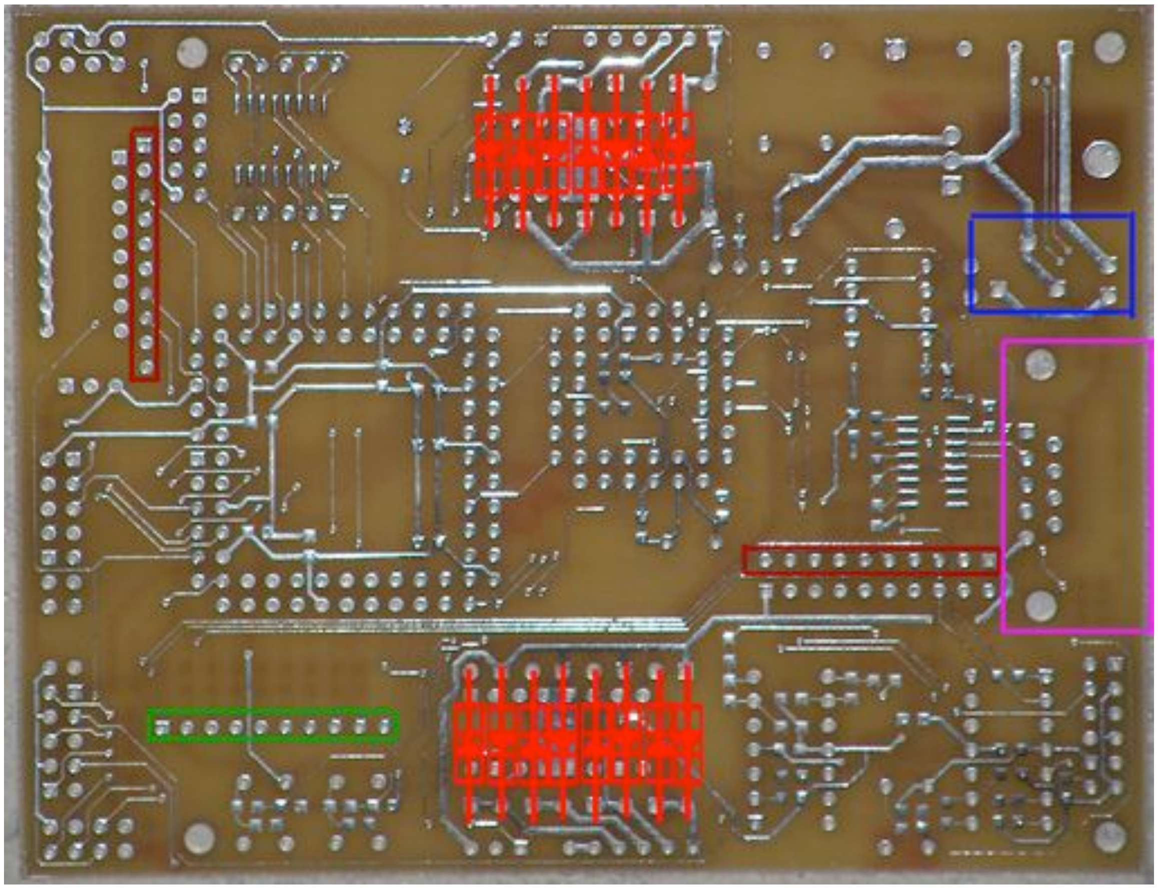


Figure 7: Bottom Side

8) Top Side Thru-Hole Components

The following components make up the remainder of the required top-side Thru-Hole components. When placing the Regulator, be sure to place it with the heat-sink to ensure a good fit. Pin 1 on the 44pin socket should face North. Pin 1 on the 84 pin socket should face Right. Both the Power and Pushbutton switches have no relevant polarity.

• Red:	Power Switch (1)
• Light Blue:	44pin PLCC CPU Socket (1)
• Blue:	84pin PLCC CPLD Socket (1)
• Dark Blue:	8MHz Crystal (1)
• Light Green:	10-DIP Switch Block (1)
• Dark Green:	4-DIP Switch Block (1)
• Pink:	Momentary Pushbuttons (3)
• Purple:	47uF Radial Capacitor (1)
• Yellow:	7805 T0-220 Power Regulator (1)
• Black:	Power Input Terminal Block (1)
• Grey:	7-Seg (1)
• Maroon	Piezo Speaker (1)

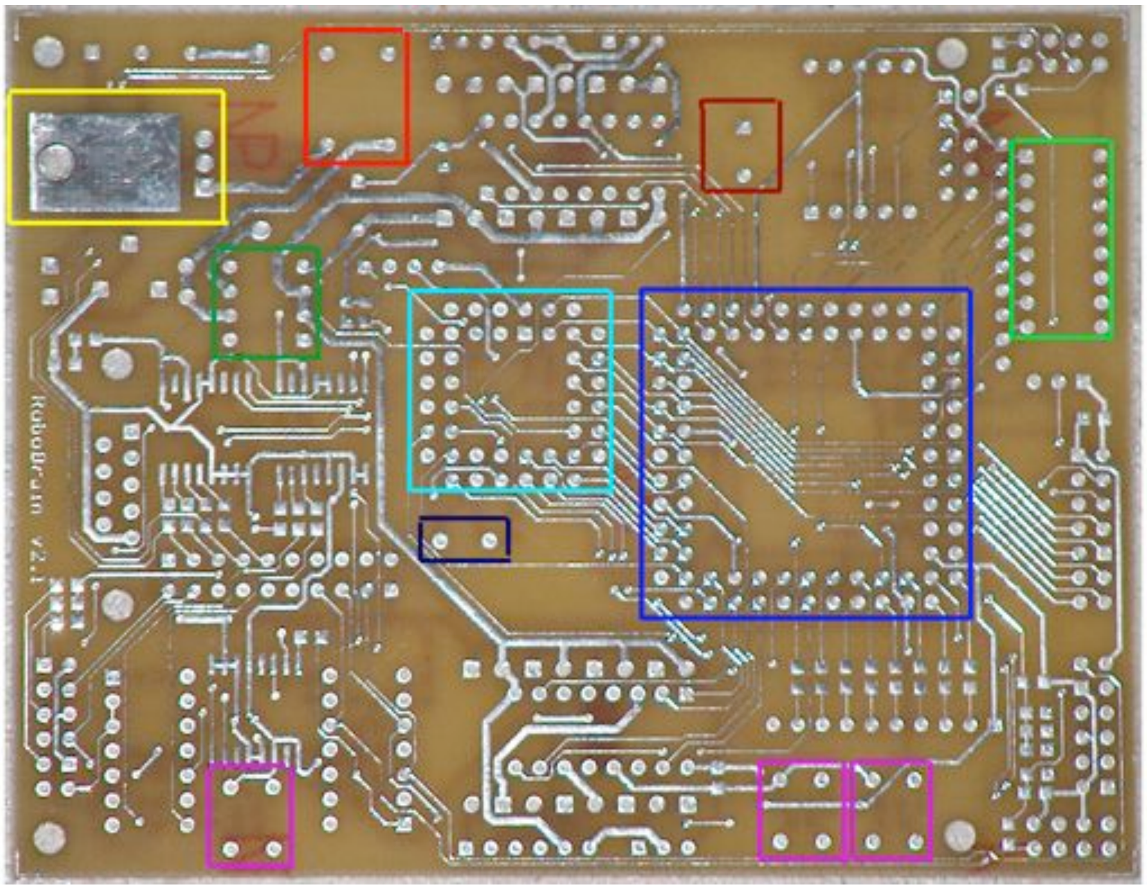


Figure 8: Top Side

9) Top Side Steak Headers & LCD Trimpot

Solder male and female steak headers to the Top side of the board. Some of these headers are optional.

• Red:	6pin Male SIP header (2)
• Blue:	3pin Male SIP header (2)
• Green:	2pin Female SIP header (8)
• Yellow:	4pin Female SIP header (1)
• Pink:	6x2pin Male DIP header (2, Line Detection optional)
• Purple:	7x2pin Male DIP header (1, LCD optional)
• Black:	10kΩ Trimpot (1, LCD optional)
• Grey:	5x2 Male DIP header (1, CPLD JTAG optional)

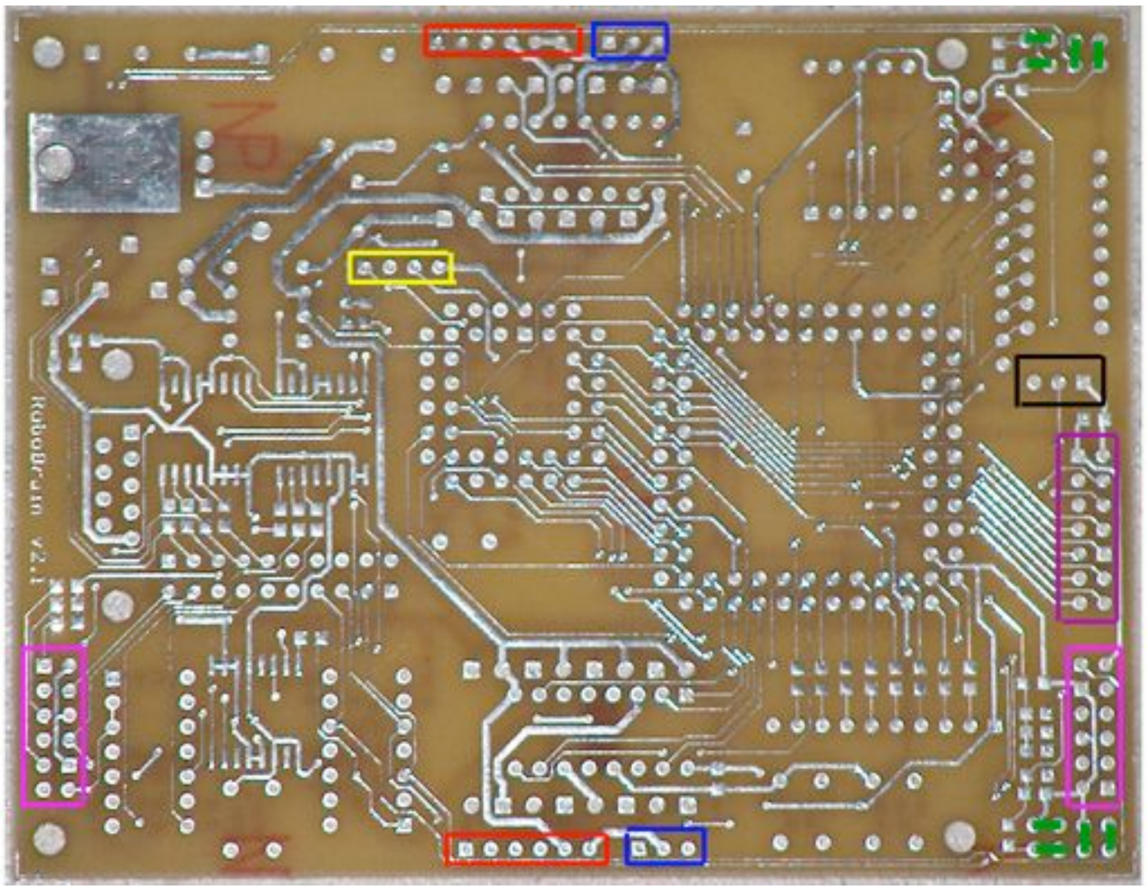


Figure 9: Top Side

Following step 9 you are have now completed your RoboBrain kit assembly. Here are some views on how the board may look. In these images, optional parts were not populatd.

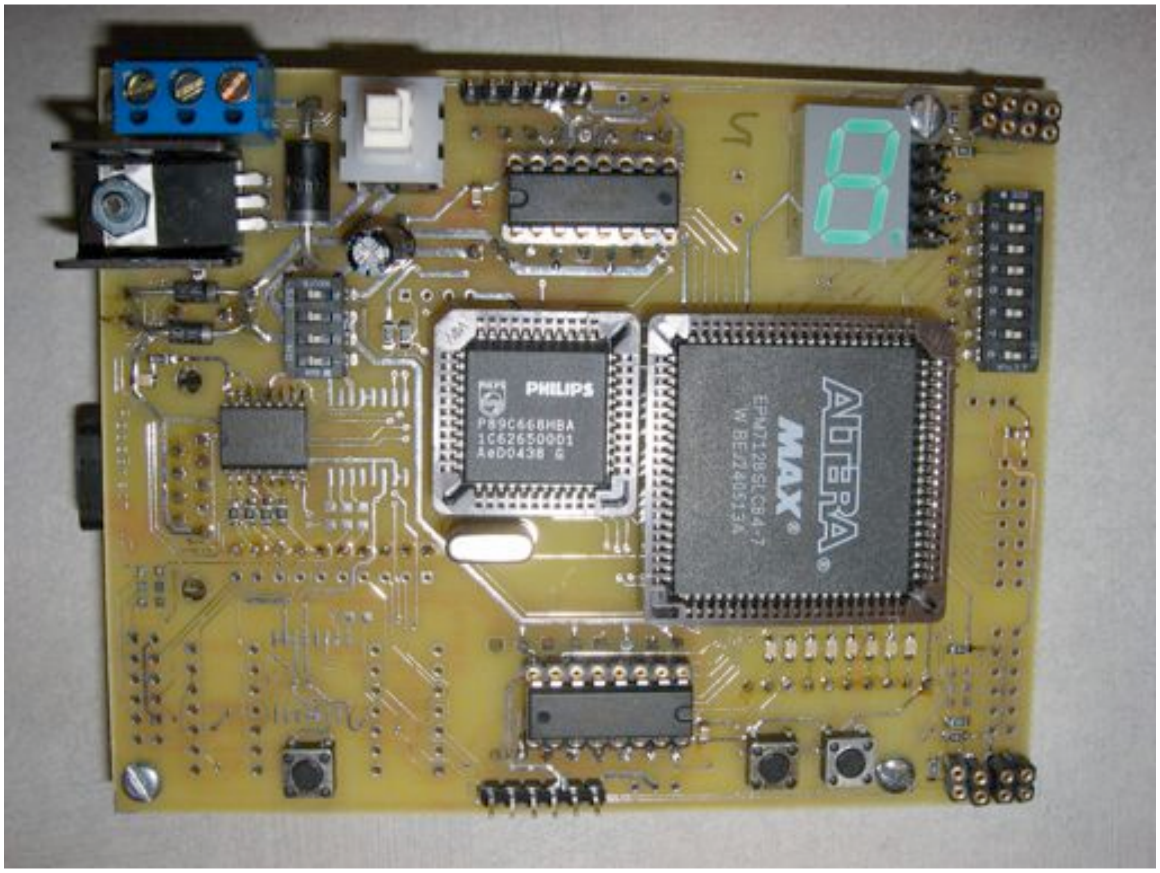


Figure 10: Assembled Top Side

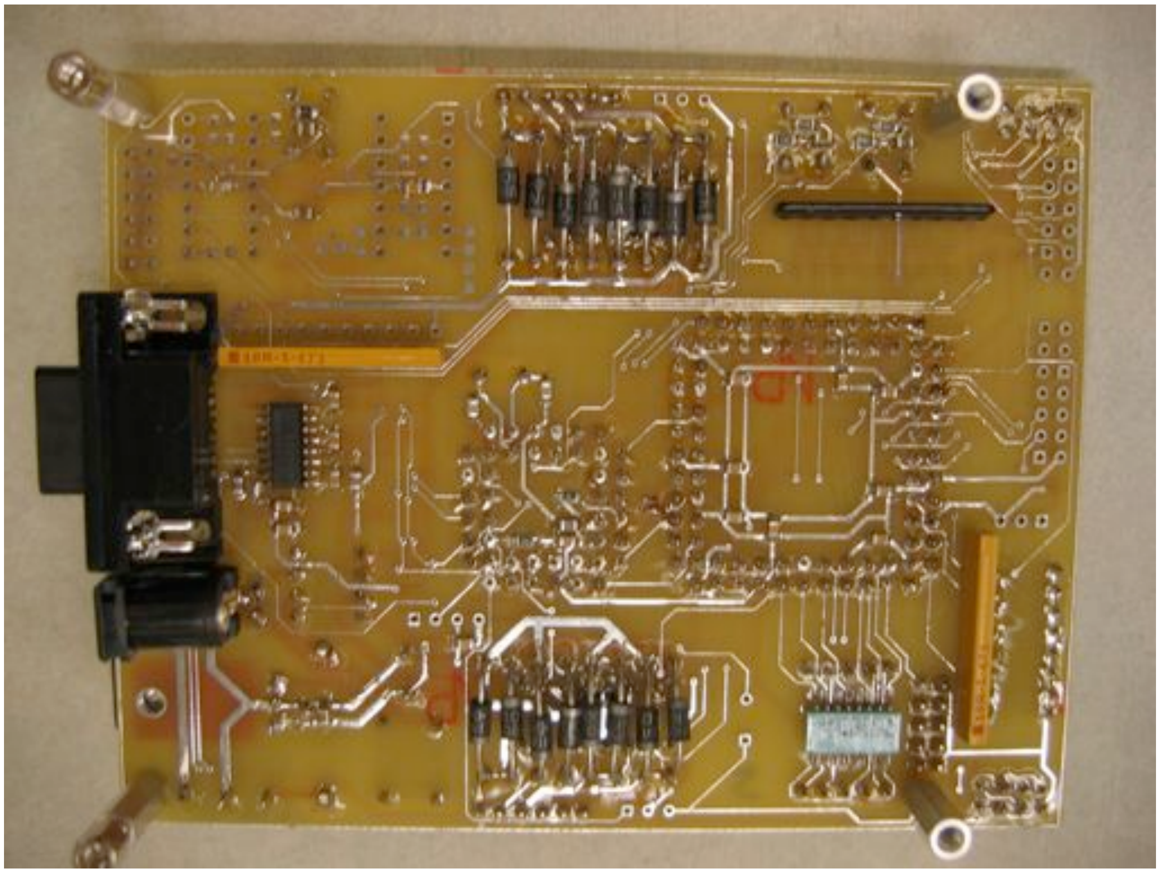


Figure 11: Assembled Bottom Side

Turning on RoboBrain and Programming

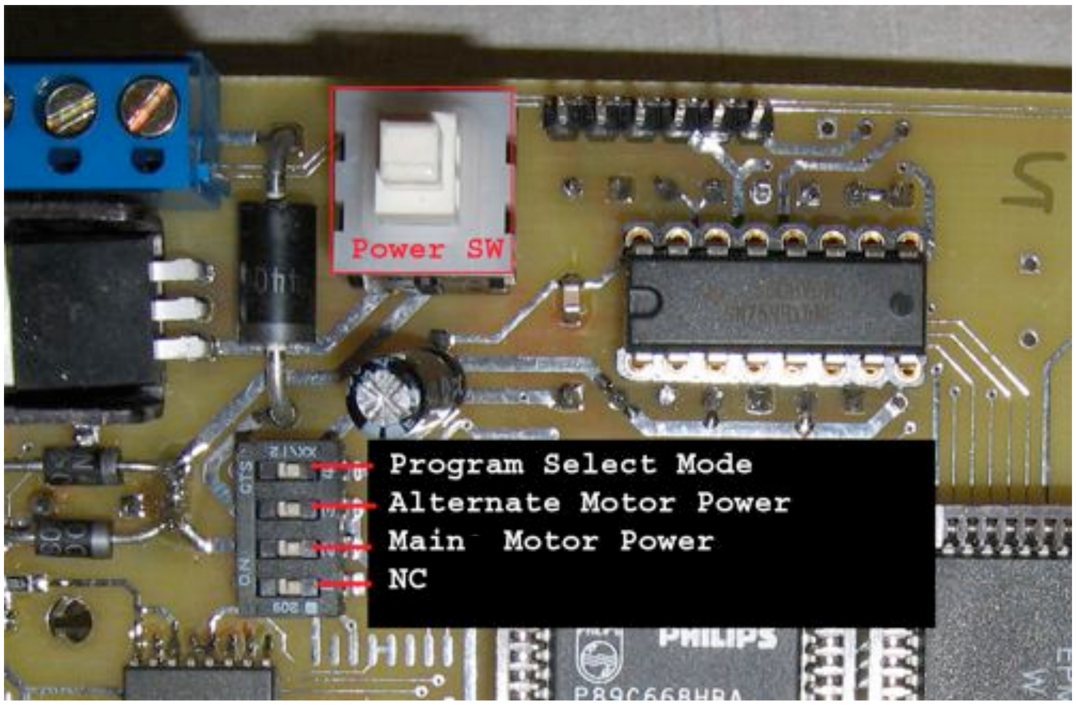


Figure 12: Power and Programming Switches

Main Power:

Main Power can be activated using the large DPST Power Switch on the top left corner of the board. The main power switch controls DC power to the digital devices on RoboBrain.

Power Switch Depressed (down):	Power On
Power Switch Released (up):	Power Off

Board Configuration Dip Switches:

If you look near the Main Power switch on the top side of the RoboBrain board, you will see 4 Dip Switches. Dip Switch 1 is a no connect. Dip Switch 2 and 3 select motor power. Dip switch 4 selects Program or Run mode. See Figure 12 for quick reference.

Program Select Mode:

Dip Switch 4 On:	Program mode
Dip Switch 4 Off:	Run mode

A note about Program mode: A reset is required to place RoboBrain in "Program Mode". When programming, you may choose to switch off dip switches 2 and 3. That way, it is ensured that the motor power is disconnected when programming and you will not have to worry about running out of power.

Motor Power Source Selection:
There are two sources of power for the RoboBrain motors. The first source is tied to main power. To enable/ disable main power driving the motors use Dip Switch 2.

Dip Switch 2 On:	Motor power taken from main power source.
Dip Switch 2 Off:	Motors disconnected from main power.

The second motor power source comes from an alternate power source. To enable/ disable alternate power driving the motors use Dip Switch 3.

Dip Switch 3 On:	Motor power taken from alternate power source.
Dip Switch 3 Off:	Motors disconnected from alternate power.

It is safe for both Dip Switches 2 and 3 to be "On" simultaneously. In this case motor power will be driven by the highest supplying source. Both power sources are protected with reverse-bias diodes (see figure 6).

A note about motor power sources: The terminal block at the top of the board handle's connections to power. The left terminal is for main power, middle is for ground, and right is for alternate motor power. Use the middle ground terminal for both power supply grounds. See Figure 13 for more details.

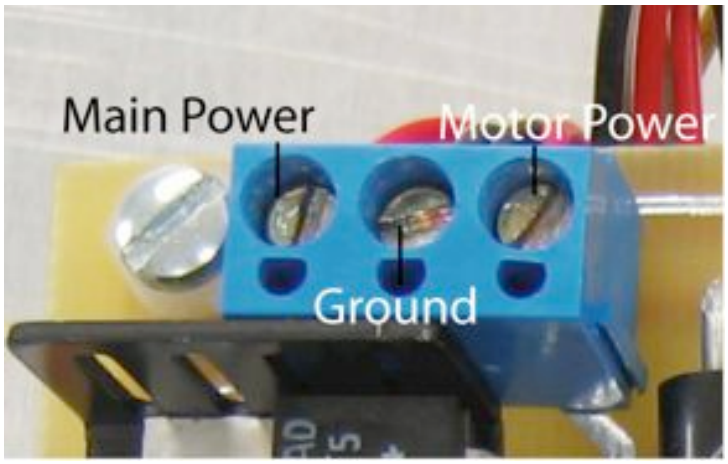


Figure 13: Power source terminal block

System Tools

Compiler

The compiler that RoboBrain uses is SDCC (Small Device Compiler C). It is freeware and is compatible on both Windows and UNIX environments. Documentation can be found online at http://sdcc.sourceforge.net/.

Downloader

We use the Flash Magic downloader in order to download the code to the board through ISP (In System Programming). This technique is a lot easier than having to burn directly to the chip using an EEPROM Burner.

Integrated Development Environment

You can use any text editor that you are comfortable with. We offer you jEdit, which is a Java based text editor that has a lot of cool features. It embeds the compiler into the editor, so with a click of a button, you can compile and download your code.

Compiling the RoboBrain Libraries

Before you begin compiling and downloading programs of your own to the RoboBrain, you first need to compile the RoboBrain libraries, these are located in the Lib\Robobrain Final\ directory on the RoboBrain CD. Copy all these files into the same directory as your program, this will ensure that the compiler will know where to find them.

Once all the library files are copied over, all that is left is to compile them, producing the object code to combine with your program. Each library is made up of a C source code file (.C) and a header file (.H). The header file can be looked at as the table of contents of the C source code file. Open the jEdit program and then open all the C source code files of the libraries you plan to use, if you are not sure what libraries you'll need, we recommend simply compiling all the libraries now, saving you the trouble of having to do it later.

When the C source code file is open, you can compile it by clicking the "Compile" button, represented by the "down arrow" icon in the toolbar, see Figure 5. Clicking this button will bring up a dialog box whose settings that can be ignored for now, just hit the 'OK' button. Some messages will come up on in jEdit's status window saying that the files were compiled successfully. The object file for the library you just compiled has been created and is stored in the appropriate .rel files in your program directory. Once all the necessary libraries have been compiled, you can continue on to compile your program.

Compiling a Program with jEdit

Using the jEdit software that is included, you can compile and download a program to your RoboBrain. Let's set through a simple example.

Start by opening jEdit and creating a new file. For a minimum amount of code, you need the following to be entered;

```
#include "sdcc668.h"

int main(void)
{
   return 0;
}
```

This program does absolutely nothing but gives some base code to start working with. All your program code is to go in between the two curly braces, '}' and '{', after int main(void). Now let's compile this program.

Go to the toolbar and click the run program button, symbolized by the running man icon, shown in Figure 5. From there, a window will open up and show a series of check marks. None of these check marks need to be checked at this point. Once you begin making use of the RoboBrain libraries, you will check the boxes of the libraries you are using. Each check box corresponds to a RoboBrain library. If you are using a function from a library, check the appropriate box (do not forget to add the #include statement for that library as well). After looking over all the libraries to include, hit "OK." The code should compile successfully and the output of the compiler is shown in the bottom pane of the editor.

Should any syntax errors occur, the source of these errors can be found by clicking the "Error List" button in the bottom pane of the jEdit window.

Compiling a Program without jEdit

To begin compiling and downloading for the RoboBrain without jEdit, follow the instructions below. We will implement a rather simple program that will display the hex value being represented on the INPUT SWITCHES located on the RoboBrain.

1. Open a DOS command-line or in any Windows platform, create a new directory on the local hard disk. For the purposes of this exercise, we will name the folder "testRB". To create a folder in DOS, type: mkdir <folder_name>

2. Copy over the libraries (stdio.h, sio.h, sdcc668.h) that were included in the documentation in to the folder just created "testRB". This is necessary to interface the Philips chip, and its surrounding interface components.

3. Open up a text editor, and create a new file, "test.c". This will be the file containing the program code for the RoboBrain.

4. Include the necessary libraries in the test.c file. To do this, type:

```
#include "stdio.h"
#include "sio.h"
#include "io.h"
#include "sdcc668.h"
```

This piece of code will include the stdio.h library which contains printf(), and other useful functions for displaying data from the RoboBrain. sio.h is the library that we created in order to input and output data to and from the RoboBrain. The sdcc668.h library should never be modified. It uniquely maps out all the *special function registers* inside of the Philips chip, and the external ports that the user can interface with. The special function registers include the location of some of the features embedded inside of the chip, for example the Internal Timers/Counters, I2C protocol, and Pulse Width Modulation registers.

5. Create the instance of code that will be executed. For the purpose of the sample program, the following code should display the value represented from the INPUT switches on the 7-segment LED bar.

```
int main() {
   /* Initialize UART to display welcome screen in HyperTerminal */
   initUART();

   cls();      //clear HyperTerminal screen

   printf("Test program without using jEdit\r\n");

   /* Infinite while loop to continuously read the input switch and
   change the values on the 7-segment LEDs simultaneously */

   while(1) {
         seg_driver(SEG_R, IN_SW);
   }
   return 0;
}
```

6. Now it is time to compile and download the code to the RoboBrain. There are two ways to compile code for the RoboBrain. First way will compile the code without the use of a batch file (script). The second way will save time on typing at the command line, and will use the batch file.

At the DOS command line, change directory to the folder where your program code "test.c" is stored. Before we can compile the entire code for downloading to the RoboBrain, we must compile the individual libraries used in the program code. With the exception of libraries that are not paired with *.c files, all other libraries must be precompiled before test.c can be compiled and downloaded. To compile a library file, at the command prompt, type:

```
sdcc -c --model-large sio.c
```

This line of code calls the compiler with the option "-c" to compile the file "sio.c". If the compile is successful, it will create a "sio.rel" file that will be used to compile the entire program code. The option --model-large tells the processor that it is using a large memory map. It is not critical to know what the difference between a small and large memory map is, but you can read more about it in the SDCC and Philips P89C668 Reference Manuals.

7. Compile the io.c library in the same manner as the sio.c library and we can now compile the test.c program code. To do this, type the following:

```
sdcc --model-large --xram-size 0x1eff --xram-loc 0x0100 --code-size 0xffff --stack-loc 0x1000 test.c sio.rel io.rel
```

This piece of code is quite a handful and tedious to type out every time to compile code, so that is why we will make a batch (script) file that will automate all the typing for us. The compiler is called with several options, which specify to the processor how to utilize the embedded memory.

Options:

--xram-size 0x1eff	:	Lets the microcontroller know how much internal memory can be used for internal RAM. The P89C668 has 8k of internal memory, hence 0x1eff in hexadecimal equals 8k in decimal.
--xram-loc 0x0100	:	Indicates where in RAM the dynamic variables can be stored.
--code-size 0xffff	:	Lets the microcontroller know how much internal memory can be used for internal ROM. The P89C668 has 64kb of ROM available for program code.
--stack-loc 0x1000	:	This places the system stack at address 0x1000

After all of the options have been set, include the program file that contains the main() definition, in this case, "test.c". Next, include all the precompiled libraries required to run the test program, "sio.rel" and "io.rel". If there are multiple precompiled header files, you must include the other *.rel files at the end of the compile command (i.e. sdcc (options) test.c sio.rel motor.rel time.rel).

Using batch/scripts to compile your code

Create a new file called “make.bat”. Open this file for editing, and insert all the code that was required for compiling the RoboBrain code into this file. For example:

```
sdcc -c --model-large sio.c
sdcc -c --model-large io.c
sdcc --model-large --xram-size 0x1eff --xram-loc 0x0100 --code-size 0xffff --stack-loc 0x1000 test.c sio.rel io.rel
```

Save and close the file. You can now either double click this file in Windows, or execute it at the command prompt by typing in the filename, make.bat. It will execute each line of code as if you had typed it. If the program code has compiled correctly, a “test.ihx” would have been created. This is the file you will use to download to the RoboBrain board.

Downloading a Program to RoboBrain with jEdit

Once you have successfully compiled a program, it should have produced an Intel Hex File (.ihx), the format that is readable by RoboBrain’s Philips microcontroller. This can then be sent to the board via a serial cable. To download to the board, click the icon with the piece of paper and the running man on it. Select the COM port that is hooked up to RoboBrain and click “OK.” Be sure that no other programs are using the serial port, such as HyperTerminal; that will cause an error programming. Figure 6 shows the download and compile buttons.

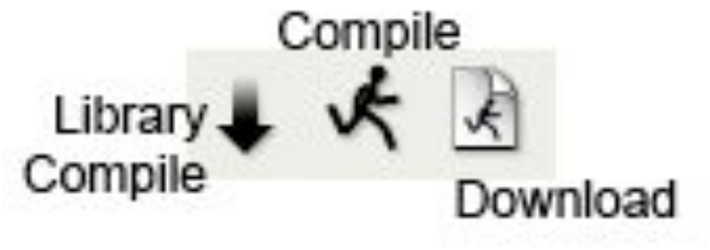


Figure 6. Library Compile, Compile, and Download Buttons in jEdit

After programming is complete, HyperTerminal can be used to view output from the serial port.

Downloading a Program to RoboBrain with FlashMagic

Now we can download to the RoboBrain using FlashMagic, but first we need to setup the application to interface with RoboBrain.

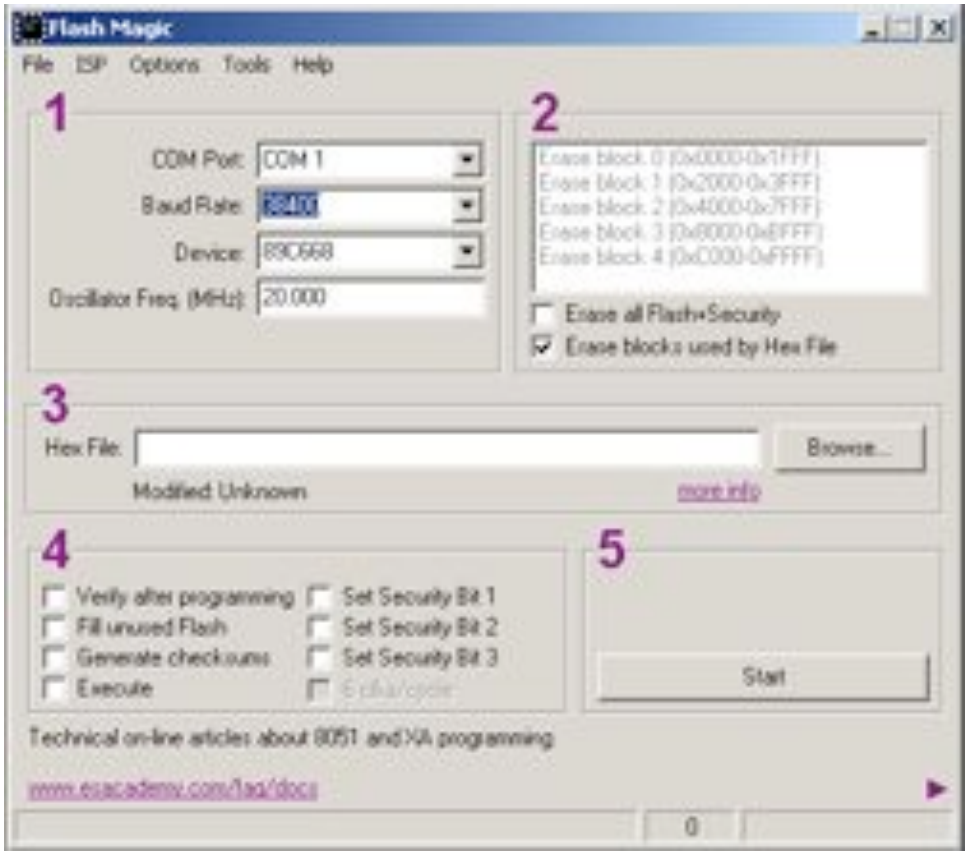
Open the application FlashMagic and set these parameters in the specific boxes in the application window. Reference Figure 7 for help.

In box 1

Set the COM port to the proper setting.
Set the Baud Rate to: 38400
Set the Device to: 89C668
Set the Oscillator Freq. to: 20.000

In box 2

Mark the checkbox that says “Erase blocks used by Hex File”.



COM Port: COM 1
Baud Rate: 38400
Device: 89C668
Oscillator Freq. (MHz): 20.000

Erase block 0 (0x0000-0x1FFF)
Erase block 1 (0x2000-0x3FFF)
Erase block 2 (0x4000-0x7FFF)
Erase block 3 (0x8000-0xBFFF)
Erase block 4 (0xC000-0xFFFF)

☐ Erase all Flash+Security
✓ Erase blocks used by Hex File

Hex File:
Modified: Unknown

☐ Verify after programming
☐ Fill unused Flash
☐ Generate checksums
☐ Execute
☐ Set Security Bit 1
☐ Set Security Bit 2
☐ Set Security Bit 3
☐ 6 clks/cycle

Technical on-line articles about 8051 and XA programming

Figure 7. The FlashMagic program

In box 3

Click the Browse button to search for the test.ihx file. You must change the files of type to “All files (*.*)” in order to search for *.ihx files. After you have found the file in the Browse Dialogue box, click “Select File”. Set the RoboBrain for program mode, hit the RESET button, and then click the “Start” button.

After the RoboBrain has been programmed, you can remove the Program jumper, and reset the RoboBrain. The RoboBrain should now be programmed and running the executed code in main(). You can open up a HyperTerminal session, and see the text that should be printed at the top of the screen, "Test program for compiling and downloading with out jEdit".

Test Program

Once all the components have been placed on the board, testing each of RoboBrain's various capabilities is required. Place the board in program mode and run the "build.bat" shortcut in the RoboBrain "test program" program directory and download the resulting .ihx file to the RoboBrain. This runs a program that runs through all the components on the board and displays output via the serial port. This output can be viewed through HyperTerminal on the proper COM port at 19200 baud.

Sample Programs & Lessons

IR Intensity

This sample program will turn on both Infrared emitters and read in the analogue voltage from that is received from the Photo Darlington receivers. This program makes use of the Analog-to-Digital converter and samples the analog voltage. This sample program can be found in the "Sample Programs" folder of the RoboBrain CD-ROM. Simply load the main.ihx file from the "IR Intensity Ver. 1" folder into FlashMagic, and download it to your board.

LCD

This sample program will initialize and print "Hello World!!!" to the LCD. It will then accept user input and echoes characters that are inputted from HyperTerminal. This sample program can be found in the "Sample Programs" folder of the RoboBrain CD-ROM. Simply load the main.ihx file from the "LCD Ver. 1" folder into FlashMagic, and download it to your board.

If you want to get the same LCD (24 characters by 2 lines) that we used to ensure compatibility with RoboBrain, get LCD part number: EDT# EW24208YLY. This costs about $12 and can be found at allelectronics.com at the URL or by the Catalog # LCD-69:

http://www.allelectronics.com/cgi-bin/category.cgi?category=365&item=LCD-69&type=store

Play Music

Playing a song on your RoboBrain is simple by using the following code. The time library contains definitions of frequencies for five octaves (0 – 5) of musical notes. The letters represent the musical notes values for notes A through G. They are defined as follows for octave 0:

A0
A0s
B0
C0
C0s
D0
D0s
E0
F0
F0s
G0
G0s

For any other the other octaves, replace the ‘0’ with a number 1 – 5. The ‘s’ after the numbers represents a sharp, or half a step above the current note. These can be used to in conjunction with two arrays to play a tune:

First define two constant arrays outside of the main() function. One with the notes you want to play, and the second with how long you want to play them (in ms):

```
const int song[]  = {E4, D4, E4, A4, F4, E4, F4, E4, D4, F4, E4, F4,
                      A4, D4, C4, D4, D4, B4, D4, C4, B4, C4, D4,
                      C4, D4, E4, D4, C4, B4, A4, F4, E4, 0};

const int dur[] = {200, 150, 400, 800, 200, 150, 200, 200, 800, 200,
                      150, 400, 800, 200, 150, 200, 200, 200, 200,
                     600, 200, 150, 600, 200, 150, 200, 200, 200,
                     200, 400, 400, 1000, 1000};
```

Next, inside the main() function, define an integer, i, and using a loop and the freq_out() function, step through the arrays:

```
int main(void)
{
     int i;

     for(i = 0; i < 32; i++)
     {
          freq_out(song[i], dur[i]);

     }

     return 0;
}
```

The 32 in the for loop represents the number of notes to play. You can replace this to match the number of notes in your song. This loop plays one note for a certain period of time and then continues to the next one and then plays that for the specified period of time and so forth. This particular example plays "Final Countdown," by Europe.

Programmable Interrupt Buttons

On the bottom left hand side of the RoboBrain board, you will see two buttons. These can be programmed to execute functions of the user's choice. To enable this functionality, run the function located in the io.h library:

```
initINT(button number);
```

Replace button number with either 0 or 1, depending on what button you want to program. Figure 8 shows the interrupt buttons.

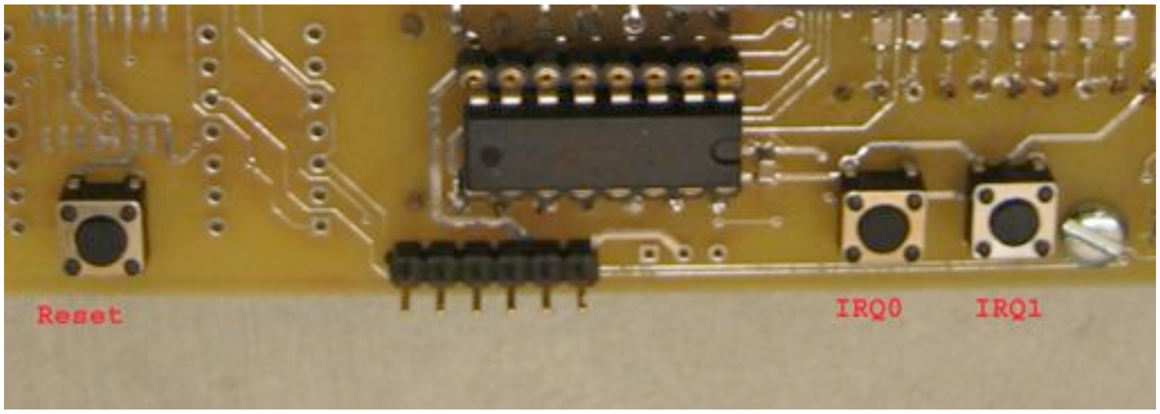


Figure 8. Reset and programmable interrupt buttons

Next, to define functionality for the button, you need to write an interrupt service routine. This is a function that gets called every time the button is pressed. For this the following code is needed:

```
void extINT0(void) interrupt 0
{
    //place code here for button 0
}

void extINT1(void) interrupt 2
{
    //place code here for button 1
}
```

Once you have loaded your RoboBrain with this new code, every time you press the button you programmed, your function will get called.

External Port Reading and Writing

The RoboBrain is equipped with several on-board ports that the user can use to run sample programs on. The user has access to a dual 7-segment LED, an 8-INPUT toggle switch, 8-OUTPUT SMT (Surface Mount) LEDs, LCD, 8-INPUT Proto-Area, 8-OUTPUT Proto-Area, and an “Extra” Port to be used for on-board IR and motor control.

Being able to interface these ports is helpful for easy expansion of a robot module. Particularly when trying to read in the INPUT Proto-Area and assigning the designated OUTPUT ports. The user should only be able to READ OUTPUT ports, but the compiler will not prevent you from reading the OUTPUT ports. Like wise, the user should not be able to write to an INPUT port, but the compiler will not restrict it from happening.

In the RoboBrain library file, the address for the external ports have been statically defined the location in memory where the user should be able to READ and WRITE the corresponding register to the PORT.

PORT	Pseudo-Name	Register	Address
1	LED (SMT)	LED	0xFC00
2	INPUT Switch	IN_SW	0xFC80
3	7-Segment A	SEGA	0xFD00
4	7-Segment B	SEGB	0xFD80
5	OUTPUT Proto-Area	PROTOA	0xFE00
6	INPUT Proto-Area	PROTOB	0xFE80
7	LCD Module	LCD	0xFF00
8	EXTRA	EXTRA	0xFF80

How to READ a PORT

(INPUT Switch, INPUT Proto-Area)

1) Declare an 8-bit register, preferably an unsigned char.
   (i.e. unsigned char SWITCH;)
2) Assign the 8-bit register to one of the INPUT registers defined in the RoboBrain library.
   (i.e. SWITCH = IN_SW;)

Following this technique will successfully allow the user to read input from the PORT, and store it into an 8-bit register, which can be processed elsewhere in the user's code.

How to WRITE to a PORT

(LED, 7-Segments, OUTPUT Proto-Area, EXTRA)

1) Declare an 8-bit register, preferably an unsigned char.
   (i.e. unsigned char smtLED;)
2) Initialize the 8-bit register to some value that will be eventually written to the PORT.
   (i.e. smtLED = 0x55;)

3) Assign the PORT register that is defined in the RoboBrain library to the 8-bit register that was declared in STEP 1.
   (i.e. LED = smtLED;)

Following this technique will successfully allow the user to write to the OUTPUT PORT. Realistically, you can omit the 8-bit data register, and write directly to the PORT.

(i.e. LED = 0x55;)

Infrared Sensors

The RoboBrain supports at least 2 Infrared Emitting Diodes (IRED) located on the Far East side of the board (next to INPUT Switch and LCD Header).

Infrared is a type of light with a wavelength rated between 700nm to over 1200nm. Figure 9 shows where IR is on the light spectrum.

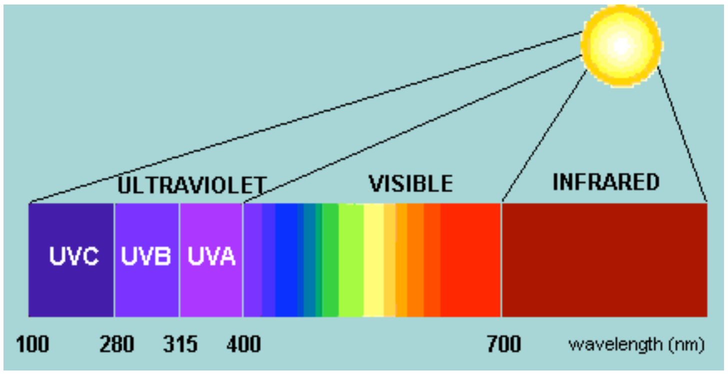


Figure 9. Light Spectrum

The IR Emitting Diodes in your kit emit at 840nm. They are paired up with a matching Photo Darlington receiver which is set to receive IR light at that wavelength. We decided to use Photo Darlington's because it has a current gain of around 1000, enabling us to receive IR at a much stronger signal at a further range.

The emitter acts much like a diode, since it is an LED (Light Emitting Diode). By allowing current to flow from the Anode to the cathode of the LED, infrared light is emitted from the clear dome. Don't worry if you can't see anything, this is because the wave length of IR can not be seen by the human eye.

The receiver acts as a Bipolar-Junction Transistor (BJT). If you are unfamiliar with BJTs, don't worry, for the purposes of this section we do not need to go into detail on how they work. The intensity of IR light at the base of the BJT (lens of the Photo Darlington) determines how much current will flow from Collector to Emitter, thus allowing the voltage at the Collector to be seen at the emitter.

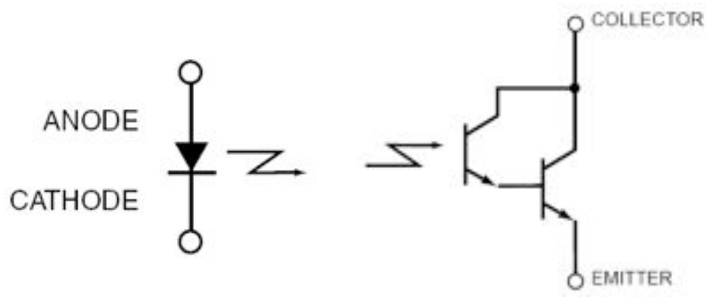


Figure 10. IRED and Photo Darlington Schematic

On the RoboBrain board, we put a limiting current resistor across the emitter to ground so that we cam measure the voltage at the emitter. Much like any other source of light, IR does not reflect well off of dark/black surfaces. In example II of this section, you will sample the voltage using an ADC. By measuring this voltage, we can determine the strength of the IR signal. The example given will allow you to bounce IR off of an object, and in essence, determine how far away your RoboBrain is away from the object.

RoboIR Example I: Detecting Infrared

Materials:

1 IRED	1 Jumper Wire (not included)
1 Photo Darlington	

This experiment demonstrates how to determine when the Photo Darlington has reached a TTL logic level on the INPUT Proto-Area PORT.

1) Connect 1 IRED and matched Photo Darlington pair to the RoboBrain.
2) Jumper the output of the Photo Darlington to the Proto area of the RoboBrain.
3) In software, poll the INPUT PORT to determine when the Photo Darlington has reached a logic level HIGH.

RoboIR Example II: Measuring IR Intensity

Materials:

1 IRED	1 I^2C ADC
1 Photo Darlington	1 Shunt Jumper

By putting a jumper across the Photo Darlington output and to the I^2C ADC, we can sample the intensity of the IRED. Sample code has been produced to already interface with the I^2C ADC, so that you can call a function to immediately sample the IR for you.

1) Connect 1 IRED and matched Photo Darlington pair to the RoboBrain.
2) Jumper the output of the Photo Darlington to the Proto I2C ADC header.

3) In software, call the function “readADC(0x00);”. This will read the IRED intensity from the Photo Darlington near the INPUT Switch.

RoboIR Example II: Measuring IR Intensity

If you want to use the built-in IR connections on the RoboBrain, it is easy to do so; simply hook up the IR receiver and transmitters to your RoboBrain and write some code to use them. The IR sensor in the top right will here after be referred to as the **left** IR sensor (sensor number 2 in code) and the one in the bottom right will here after be referred to as the **right** IR sensor (sensor number 1 in code), see Figure 11 for details. Make sure you connect both the IR sensors and the Voltage Ref. pins on the ADC connector (see section below for how to do this) in order to have the sensors function properly. Note that the anode or positive lead of the IR receiver and transmitter is the longer of the two leads and will go in the bottom holes of the IR port.

Below is some code that can get you started: this program will read in the status of the left and right IR receivers and display the output on the row of LEDs at the bottom right of RoboBrain. The more LEDs that light up, the closer the object is to the IR sensor.

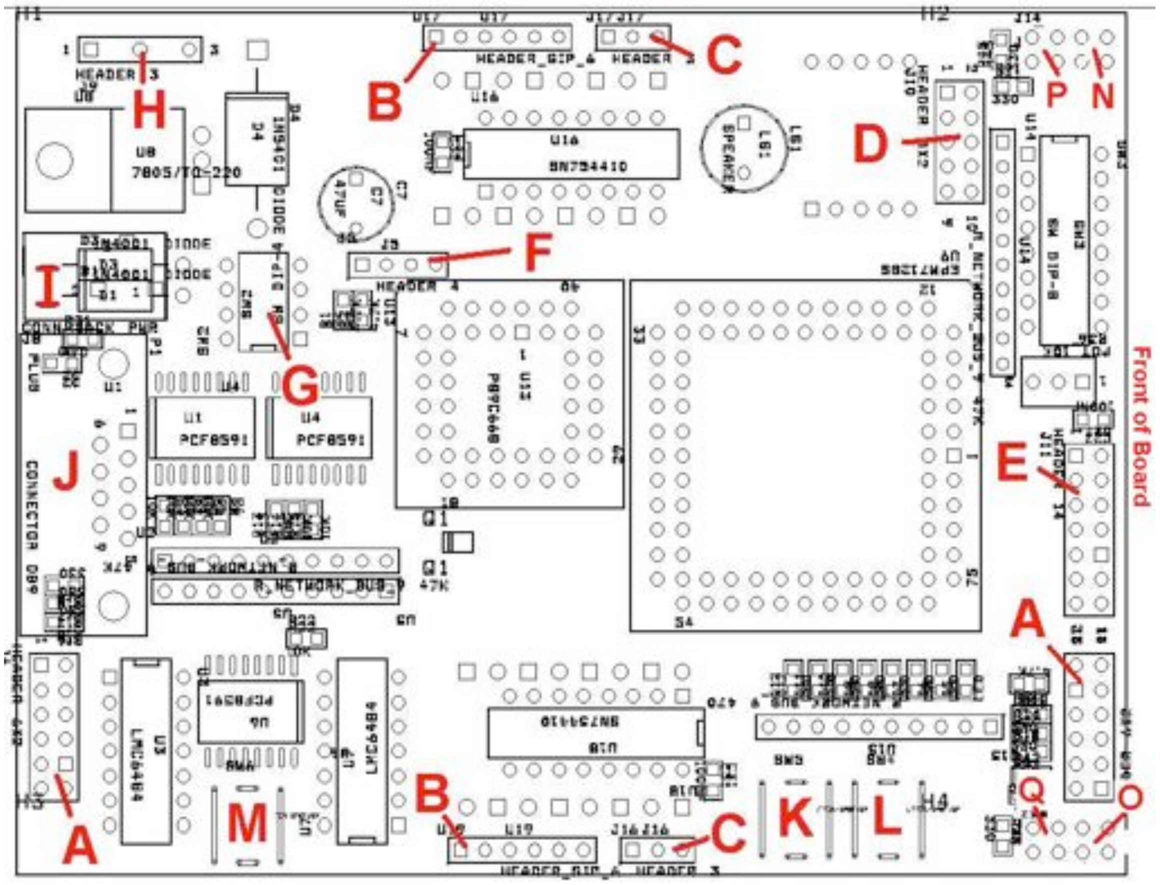
```
#include “motor.h”
#include “ir.h”
#include “i2c.h”

int main()
{
       unsigned char irLeft, irRight;

             initI2C();  //initialize the i2c bus

       //loop infinitely
       while(1)
                 {


            //read the status of the IR receivers
                        irLeft = readIR(2);
                        irRight = readIR(1);

            //provide feedback on the LEDs
                        intensityLED(irLeft | irLeft);
       }

                  return 0;
}
```

These 3 examples should provide you with enough background to interface IR on your own RoboBrain project.

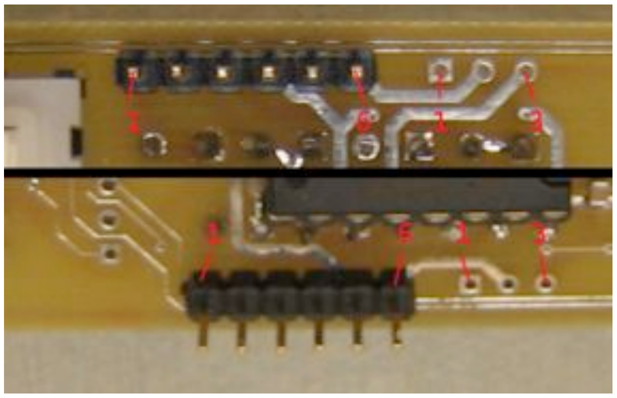
Terminology

ADC	Analog-to-Digital Converter
BJT	Bipolar Junction Transistor
I^2C	2 wire communication interface
IR	Infrared
IRED	Infrared Emitting Diode

RoboBrain v2.1 Board Description



Description 1: Board layout


Description 2: B DC/Stepper, C Servo motor headers

A) Line Detection Emitter / Sensor Headers

QRB1114 #1, 4 (Front and Rear Right Line Detector)

Pin 1:	Emitter Anode (+)
Pin 2:	Sensor Collector (5.0v)
Pin 3:	Emitter Cathode (-)
Pin 4:	Sensor Emitter

QRB1114 #2, 5 (Front and Rear Center Line Detector)

Pin 5:	Emitter Anode (+)
Pin 6:	Sensor Collector (5.0v)
Pin 7:	Emitter Cathode (-)
Pin 8:	Sensor Emitter

QRB1114 #3, 6 (Front and Rear Left Line Detector)

Pin 9:	Emitter Anode (+)
Pin 10:	Sensor Collector (5.0v)
Pin 11:	Emitter Cathode (-)
Pin 12:	Sensor Emitter

B) DC/Stepper Motor Headers

- DC motor:

Pin 1:	Coil 1
Pin 4:	Coil 2
Pin 2, 3, 5, 6:	NC

- Stepper Motor:

Pin 1:	Coil 1A
Pin 2:	Coil 1B
Pin 3:	Coil 2A
Pin 4:	Coil 2B
Pin 5, 6:	Common

C) Servo Motor Headers

Pin 1:	Control
Pin 2:	VCC
Pin 3:	GND

D) Altera MAX 7000 CPLD JTAG Header

Pin 1:	TCK
Pin 2, 10:	GND
Pin 3:	TDO
Pin 4:	Vcc 5.0v
Pin 5:	TMS
Pin 9:	TDI
Pin 6, 7, 8:	NC

E) LCD / ProtoBoard Header

Pin 1:	GND
Pin 2:	Vcc 5.0v
Pin 3:	LCD Intensity
Pin 4:	A0
Pin 5:	!RD/WR
Pin 6:	LCD Chip Select
Pin 7:	Data0
Pin 8:	Data1
Pin 9:	Data2
Pin 10:	Data3
Pin 11:	Data4
Pin 12:	Data5
Pin 13:	Data6
Pin 14:	Data7

F) Power / I2C Access Header

Pin 1:	SDA
Pin 2:	SCL
Pin 3:	GND
Pin 4:	Vcc 5.0v

G) Control Dip Switch Block

SW 1:	Not Used
SW 2:	ON: VCC MOTOR = 5v Regulated
SW 3:	ON: VCC MOTOR = PowerBlock Pin3
SW 4 (PSEN):	ON: Program Mode OFF: Run Mode

H) Power Block Terminal

Pin 1:	Main Power
Pin 2:	Common GND (digital and motor)
Pin 3:	Motor Power

I) AC/DC Power Barrel Jack

J) Serial Connector

K) Interrupt Pushbutton #1

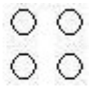
L) Interrupt Pushbutton #0

M) Master Reset Pushbutton

N) Front Left Emitter/Sensor

Front of Board →

Sensor + Emitter -

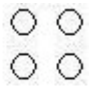


Sensor - Emitter +

O) Front Right Emitter/Sensor

Front of Board →

Emitter + Emitter -

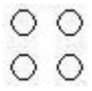


Sensor + Sensor 1

P) Left Emitter/Sensor

Front of Board →

Sensor + Emitter -

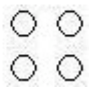


Sensor - Emitter +

Q) Right Emitter/Sensor

Front of Board →

Sensor + Sensor -



Emitter + Emitter -

Motors

The RoboBrain has support for DC motors, stepper motors, and servo motors via various motor ports located at the top of the board (Description Image 2 on page 39).

DC Motors

To connect a DC motor to RoboBrain, simply connect the motor's two terminals to the Coil A and Coil B pins. There are two sets of coil pins so you can connect 2 DC motors to RoboBrain. The code necessary to get the motor doing anything is listed below, further details on these functions can be found in the function index at the end of this guide.

```
enable_motors();         //enable motors

//start moving the motors
//this runs MOTORA port
//until the motor is stopped
//runs the motor full speed in reverse direction
motor_speed(MOTORA, -100);

//this runs MOTORB port
//until the motor is stopped
//runs the motor 50% speed in forward direction
motor_speed(MOTORB, 50);


//move around for a bit
//and then stop

motor_speed(MOTORA, 0);
motor_speed(MOTORB, 0);            //stop both motors
```

The motor_speed() function is the heart of the functionality for the DC motors. It uses I/O pins with a voltage difference across them to control the motor. The signals of the two motor pins are swapped to change direction. They are made the same value to stop the motor due to the lack of a voltage difference across the two pins. Pulse-width modulation (PWM) is used for speed control of the motors.

Stepper Motors

The stepper motors are a little more complicated to connect to the RoboBrain board but are easier to code. RoboBrain supports both unipolar and bipolar stepper motors. To connect the motor, you first need to find out what kind of stepper motor you have. If your motor has 4 wires, then it is a bipolar stepper motor. If it has 5 or 6 wires, then it is a unipolar stepper motor.

For a bipolar motor, there are two coils without any common tap for the coils; this means that the two pins on the far right of the motor connector are not needed for a bipolar stepper motor. Connect the positive ends of the two coils to the Coil A pins and the negative ends of the motor coils to the Coil B pins. Coils pins 1 and 2 are for STEPPERA, and coil pins 3 and 4 are for STEPPERB.

Unipolar motors connect in exactly the same way except that the common taps of the coils are connected to the common pins of the motor connectors, located at the far right of the connector. If your motor has two common taps, connect them to both pins of the common pins. If the motor only has 5 pins, then simply connect the common tap to one of the common pins; it does not matter which common pin you connect it to. Common 1 is for STEPPERA motor and Common 2 is for STEPPERB motor.

Once the motors have been connected, all that needs to be called to get the motors moving is the step() function. This moves the stepper motor forward or backward one step or increment. Speed control is done by placing a call to pause() in between calls to step. The smaller the pause, the faster the motors will turn, but with faster speed comes lower torque, so the motors will not be as powerful. Run them slower for more power. Here is an example of some code to run the stepper motors:

```
enable_motors();         //enable motors

//start moving the motors
//this runs both stepper motors forever
//STEPPERA is moving forward
//STEPPERB is moving backward
While(1)
{
     step(STEPPERA, 1);
     step(STEPPERB, 0);
     pause(100);
}
```

Servo Motors

The servo motors are a three wire motor that connects to the connector just right of the motor connector, see Figure 14. Simply connect the control, Vcc, and GND pins of the motor to the servo motor connector and you are ready to go. The puls_out() function on the SERVOA or SERVOB ports will cause the servo motor to move. With the Parallax servo motors, calling puls_out() with pulse-width values between 37 and 452 will move the motor any where in it's available range (when not modified for continuous motion).

Function Index

All the following libraries can be included in your program by using the #include statement at the beginning of your main program and checking the appropriate box in the compile dialog box. For example, this includes the time.h library:

Constant Definitions

These values are various definitions used throughout RoboBrain. Some are just constants used with functions and some are actual memory mapped registers. Only the LED and IN_SW registers need to be accessed directly. All the other registers have interface functions already defined to easy use. These functions are explained throughout this manual.

Motor/Device Constants

MOTORA	- DC motor A, top row on motor connector
MOTORB	- DC motor B, bottom row on motor connector
STEPPERA	- Stepper motor A, top row on motor connector
STEPPERB	- Stepper motor B, bottom row on motor connector
SERVOA	- Servo motor A, top row on servo motor connector
SERVOB	- Servo motor B, bottom row on servo motor connector
SPEAKER	- Piezo buzzer port. Use with pwm() or freq_out()
SEG_L	-Left seven-segment display. Use with seg_driver() (no longer supported)
SEG_R	-Right seven-segment display. Use with seg_driver()

Device ports (memory-mapped registers)

LCDI	-Address mapped to LCD for sending instructions
LCDD	-Address mapped to LCD for sending data
LED	-Address mapped to LEDs
IN_SW	-Address mapped to switch block
SEGA	-Address mapped to left seven-segment
EXTRA	-Address mapped extra port. Used with IR sensors and motors

2004 Robobrain 1.0 Software by Noah Wilson & Adam Bean
2005 Robobrain 2.1 Software by Noah Wilson

Time Functions (time.h)

```
#include "time.h"
```

void pause(int delay)

Pauses the processor for the amount of time in ms given by the delay parameter. For example, the following code pauses the microcontroller for several different time values:

```
pause(1000);   //pause for 1 second
pause(250);    //pause for ¼ of a second
pause(1);      //pause for 1ms
```

Serial I/O library (sio.h)

```
#include "sio.h"
```

void initUART()

Must call this function in order to receive user input and output from HyperTerminal. This function will initialize the UART to be polled driven, and must be called first, before using any other of the Serial IO functions. To enable the UART, call the function:

```
initUART();
```

void putchar(char c)

Print a character to the UART. This is used in conjunction with HyperTerminal to debug or print out results in your program. For example, to print the character 'A' to the HyperTerminal, call the following function:

```
putchar('A');
```

char getchar(void)

Receive a character from the UART. This is used in conjunction with HyperTerminal to receive user input to interface program application. To use this function, simply assign the function to a variable of type “char” and it will wait for user input. For example:

```
char temp;
temp = getchar();
```

This will assign the variable temp to the first character that the user types in at the HyperTerminal session.

char *getstr(void)

This is similar to getchar(), but it will read an entire string up to 16 characters in length. The string will be terminated when the user enters the return key. To receive a string from the user in HyperTerminal, simple assign the function to a variable of type “char *”. For example:

```
char *temp;
temp = getstr();
```

This will assign the variable temp to a string that is read from user input in a HyperTerminal session.

int getint(void)

Receive an integer from the UART. This is used in conjunction with HyperTerminal to receive user input to interface program application. To use this function, simply assign the function to a variable of type “int” and it will wait for user input. For example:

```
int temp;
temp = getint();
```

This will assign the variable temp to the first character that the user types in at the HyperTerminal session.

void cls(void)

Clear the screen of a HyperTerminal session. Simply call the function “cls(); “ anywhere in your program code, and it will clear the HyperTerminal screen.

Motor Functions (motor.h)

```
#include “motor.h”
```

void step(int motor, int direction)

Move a stepper motor forward or backwards one step. Use either STEPPERA or STEPPERB for motor parameter.

Example Usage:

```
step(STEPPERA, 1);
//move STEPPERA forward one step

step(STEPPERB, -1);
//move STEPPERB back one step
```

void enable_motors()

Enables the motor driver chips.

void disable_motors()

Disables the motor driver chips to save power on RoboBrain.

void motor_speed (int motor, int speed)

Run a DC motor connected to the motor connector until another call to motor_speed() stops it using 0 for the speed argument. MOTORA and MOTORB are possible values for the motor. In the direction argument, possible values are any integer from -100 to 100.

A call to `enable_motors()` is required before the motors will function.

Example Usage:

```
enable_motors();

//run MOTORA forward
motor_speed(MOTORA, 100);

//run MOTORB backward
motor_speed (MOTORB, -100);

//stop the motors
motor_speed (MOTORB, 0);
motor_speed (MOTORB, 0);
```

unsigned char readIR(unsigned char channel)

Turn ON the on-board IR channel that is connected to the EXTRA interface PORT and return the value for that IR sensor on the A/D. The parameter "channel" specifies which of the 2 channels to turn ON. This function will return an 8-bit value corresponding to the intensity of the IR light entering the IR receiver. To read the first channel of the IR LED, call:

```
Value = readIR(0x01);
// Read A/D value of IR emitter
// closest to the 7-segment
// and save to 'value'
```

LCD Functions (lcd.h)

```
#include "lcd.h"
```

void initLCD(void)

Initialize the LCD in order to interface with RoboBrain. This function call only needs to be run once, and requires that the timer is initialized before hand. To initialize the LCD, simply call:

```
initLCD();
```

This function must be called before the charLCD() function can be used properly.

void charLCD(unsigned char character)

Prints a character to the LCD Device. For example, the following code prints the letters ‘R’ and ‘B’ to the LCD screen:

```
charLCD('R');
charLCD('B');
```

Pin I/O Functions (io.h)

```
#include “io.h”
```

void seg_driver(unsigned char seg_number, unsigned char output)

Display a character 1-F in hex on the one of the seven-segment displays.

Example Usage:

```
seg_driver(SEG_L, 0x03);
//display “3” on left 7-segment display

seg_driver(SEG_R, 0x0C);
//display “C” on right 7-segment display
```

void high(unsigned char pin)

Output a logic level high, 5V, on an output pin in the proto area.

Example Usage:

```
high(5);
//output 5V on output pin 5
```

void low(unsigned char pin)

Output a logic level low, 0V, on an output pin in the proto area.

Example Usage:

```
low(3);
//output 0V on output pin 3
```

void toggle(unsigned char pin)

Output the opposite of the current voltage on an output pin in the proto area. For example, if currently outputting a logic high, will output a logic low, and visa versa.

Example Usage:

```
toggle(4);
//output the opposite of the current
//voltage on output pin 4
```

void setPin(unsigned char pin, unsigned char value)

Output the logic level given by the value parameter on an output pin in the proto area.

Possible values for `value` parameter:

```
1 – output logic level high(5V)
0 – output logic level low (0V)
```

Example Usage:

```
setPin(2, 0);
//output 0V on output pin 2
```

unsigned char readPin(unsigned char pin)

Read the state of an input pin in the proto area. Will return either 1, for logic level high (5V), or 0, for logic level low (0V).

Example Usage:

```
unsigned char pin;

Pin = readPin(3);

//Pin variable will now contain the
//value of input pin 3
```

void pwm(int channel, int duty, int num_cycles)

Outputs a pulse-width modulated signal on one of the 5 PWM channels of RoboBrain. The possible channels are the following:

```
MOTORB
SERVOA
MOTORA
SERVOB
SPEAKER
```

The duty parameter determines the duty cycle of the output wave. This is given as a number from 0 to 255; 0 being a solid low signal, 255 being a solid high signal. The formula for a given duty cycle in terms of a percent high vs. percent low is given as follows:

Dutycycle% * 255 = duty

The num_cycles parameter determines the number of full periods that the signal is output. A num_cycles value of 0 will output the signal infinitely until the stop_pwm() function is called.

Example usage:

```
pwm(MOTORA, 128, 5);
```

This will output a 50% duty cycle on the MOTORA port for 5 periods.

void stop_pwm(int channel)

Stops output of pwm signal on the specified channel. Values of channel taken from pwm() function definition above.

Usage:

```
stop_pwm(MOTORA);
```

This would stop output on a MOTORA port.

void freq_out(int pin, int frequency, int duration)

Output a square-wave of a specified frequency for a specified duration in ms. Can be used to output sound through the piezo speaker on the RoboBrain board.

Example Usage:

```
freq_out(5, 5000, 50);
//output 5kHz signal for 50ms on
//output pin 5

freq_out(SPEAKER, 7000, 500);
//output 7kHz signal for ½ second on
//piezo speaker
```

void puls_out(int pin, int pulse_width)

Inverts an output pin for a specified length of time, given in microseconds.

Pins available for function:

SERVOA
SERVOB
1 – 8 (output pins)

Example Usage:

```
puls_out(1, 30);
//output a pulse on output pin 1 for 30us

puls_out(SERVOA, 25);
//output a pulse on SERVOA port
```

void intensityLED(unsigned char value)

Measure the range of the past in parameter. For example, the function:

```
intensityLED(0x7f);
```

This function will light up only half of the on-board LEDs. See the function definition (in io.c) to modify the scale in which these lights are mapped to.

void initINT(unsigned char interrupt_number)

Initialize the external interrupt buttons for interrupts 1 and 0.

```
initINT(0);    //initialize interrupt 0
initINT(1);    //initialize interrupt 1
```

Once the interrupt has been initialized, all that is left is to define a function that is called when the interrupt occurs (button is pressed). See the interrupt section of the manual for information on how to do this.

I2C Functions (i2c.h)

```
#include "i2c.h"
```

void initI2C(void)

This function enables the I2C protocol to be interrupt driven. It is currently function to interface with the I2C Analog-to-Digital Converter, but can be modified to support other ICs as well. To enable the I2C bus, call the function:

```
initI2C();
```

This function must be called before any of the following functions can be used properly.

void writeDAC(unsigned char voltage)

Emit a voltage output corresponding to the 8-bit register value past into the functions parameter field. Will take in any value from 0 to 255. To find out what voltage will output with what value passed to the function, use this formula:

(desired voltage / 5V) * 255 = value to pass to writeDAC()

For example:

```
writeDAC(128);   // Voltage Out on I2C header is 2.5V
writeDAC(255);   // Voltage Out on I2C header is 5V
writeDAC(0);     // Voltage Out on I2C header is 0V
```

unsigned char readADC(unsigned char channel)

Read the digitized analog output from the I2C Analog-to-Digital Converter. The parameter “channel” specifies which of the 4 pins should be sampled. The channels are numbered from 0 to 3 for the four channels. See the ADC section for more details on the location of these pins. For example:

```
unsigned char temp;
temp = readADC(0x01);
// This function call will read the voltage value that
//is on PIN1 of the Analog-to-Digital header.
```

unsigned char readIR(unsigned char channel, unsigned char mode)

Return the digital outputted signal from the I2C Analog-to-Digital Converter. The parameter “channel” (0, 1, 2, or 3) determines which channel from the Analog-to-Digital header should be sampled from. The mode parameter allows you to specify whether to take the sample as single ended, or a differential output, meaning the difference between the first two analog inputs. For example:

```
unsigned char;
char = readIR(1, 0);     // Samples analog input 1,
                         // in single ended mode.
```

Assuming that the Infrared LED has been jumpered on channel 1 of the ADC header, it will return the 8-bit sampled voltage value.

If the mode is set to one, and channel is set to one, it will take the differential values of Analog Input 1 and Analog Input 2. If the channel is set to two, then the differential values of Analog Input 3 and Analog Input 4 will be sampled.

Hardware changes in second version:

- Reduced original I/O system down to single-chip solution described in Verilog on Altera CPLD.
  Resulting Features:
  - In-system programmability for desired I/O changes.
  - Fewer IC's for easier assembly.
  - Almost fully software compatible across versions.

- Reduced two digit 7-segment display down to one digit. SEG_L and SEG_R addresses now point to the same single 7 segment display.
- Removed all system jumpers and replaced with dip switches.
- Added Main Power Switch.
- Removed RF capabilities/connections.
- Removed Latched Proto I/O Ports.
  - Data-Bus and control still accessible for Proto-Board use through LCD interface
  - Use LCD port to address any addons to that interface
- Motor Drivers now socketed and placed closer to their respective motors. Also room for external Staver V7 heat sink for thermal relief above the chips
- Changed Board Dimensions to 3.5in x 4.5in.
- Digital System 9v AC compatible. 7-12V DC recommended.
- Added 16 diodes to motor output to prevent damaging inductive kick from motors.
- Added 2 I2C Analog to Digital converters for up to 6 additional line detection sensors with amplification
- Added two additional Intensity emitters and sensors for left and right IR vision. Accessible on channels 2 and 3 on Analog to Digital Converter 0.
- Removed sensor-enable jumpers.
- Two control signals now enable emitter output
  - One controls line detector emitters
  - One controls radial emitters (left, front left, front right, right)
- Removed Analog output ports access headers.
- Piezo speaker now driven by CPU and not CMOS inverter.

Conclusion

We hope that this kit has been helpful and a learning experience to the user. We tried to cover some of the most basic and important aspects of engineering and simplified it. If we receive enough feedback, there is a possibility for a better revision, depending on what the majority of the users would like to see out of it. The CPLD added gives future uses more development and customization options.

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Appendix A – Robots for COSMOS

The Robobrain robotics platform was originally designed for use with the COSMOS summer programs at UCSC. This program works with high school students and prepares them for their college academic career. The following information will outline what is needed to create Robobrain for your own class as well as cover some of the subtle issues we encountered while teaching the class.

Parts

The following part list will help you construct your RoboBrain for COSMOS. The parts are categorized and some part reference numbers and/or surface mount sizes have also been provided. The approximate cost for one Robobrain using this part list is $180.

ICs

1		Linear Regulator 7805		DIGIKEY:LM7805CT-ND/TO-220
1		Philips 8051 Microcontroller		PHILIPS:P89C668
1		Altera CPLD		ALTERA:EPM7128S
1		MAX232I/SO Serial Transceiver		DIGIKEY:296-6940-5-ND
2		SN754410 Half H-Bridge Driver		DIGIKEY:296-9911-5-ND
3		PHILIPS PCF8591 8bit A/D converter		DIGIKEY:568-1088-2-ND
3		LMC6484 Quad Op Amp SOIC		DIGIKEY:LMC6484AIMX

Capacitors

2		27pF		Surface Mount 0805
7		10uF		Surface Mount 0805
22		.1uF		Surface Mount 0805
1		1uF		Surface Mount 0805
1		47uF 25V		Axial

Resistors

3		470ohm		Surface Mount 0805
8		4.7Kohm		Surface Mount 0805
10		10Kohm		Surface Mount 0805
10		330ohm		Surface Mount 0805
1		100ohm		Surface Mount 0805
6		270ohm		Surface Mount 0805
6		100Kohm		Surface Mount 0805
3		47Kohm R_NETWORK_BUS_9		DIGIKEY:4310R-1-473-ND
1		470ohm R_NETWORK_BUS_9		DIGIKEY:4310R-1-471-ND
1		470ohm R_NETWORK_ISO_8		DIGIKEY:767-163-R470-ND

Diodes

9		Green LED Surface Mount 0805		DIGIKEY:SML-LXT0805GW-TR
18		1N4001 DIODE Axial		DIGIKEY:1N4001
1		1N5401 DIODE 3Amp Axial		DIGIKEY:1N5401
1		1-Digit 7-Segment-Display		DIGIKEY:160-1575-5-ND

Switches

3		Tact Pushbutton SPST		
1		SW DIP-8		DIGIKEY:CT2098MS-ND
1		SW DIP-4		DIGIKEY:CT2094MS-ND
1		POWER SW DPST		DIGIKEY:P8102S-ND

Sensors and Emitters

4		IR emitter		DIGIKEY:QED523-ND
4		IR sensor		DIGIKEY:QSD733-ND
6		Line detection Sensor/Transducer		DIGIKEY:QRB1114-ND

Jacks and Sockets

1		PJ-102BH DC POWER JACK		
1		3 Input Terminal Block		
1		FEMALE D-SUB9 Serial Jack		JAMECO:104951
1		PLCC 84pin Thru Hole TO Socket		DIGIKEY:ED80027-ND
1		PLCC 44pin Thru Hole TO Socket		DIGIKEY:ED80024-ND

Headers and Other Parts

1		40pin Male DIP Header		
2		20pin Male SIP Header		
1		20pin Female SIP Header		
1		PIEZO SPEAKER		JAMECO:207950
1		Regulator Heatsink		
2		Motor Driver Heat sink		Staver V7 Heatsink
1		20Mhz Crystal		DIGIKEY:CTX062-ND
4		FF Spacers		

Motors and Misc. Parts

2		DC Motor		Jameco: 155862
2		Roller Blade Wheels		
1		¼” Plexiglass for Chassis		
1		3/4” Plexiglass for Chassis		
1		Sheet Metal for Chassis		
2		Custom Aluminum Hubs		

Characterizing the IR Sensors

Every one of the IR sensors used here behaves slight different from one another. For a given distance, two sensors may give different values. As a result, characterization of the sensors is necessary to get consistent distance measurements. We devised a simple calibration procedure for the students to perform to calibrate their sensors and then fit the sensor data to a 3rd order polynomial for sensor data to distance conversion during run time. The procedure involved placing each sensor of the robot at some distance and then placing a white surface, in this case we used some white card stock, at 1cm intervals from the sensor and recording the 8-bit sensor value from the analog to digital converter at each interval. This data can be put into an array in MATLAB and the polyfit() function can be used to generate a polynomial function the closely matches the sensor data. This resulting polynomial can then be used the source code on the Robobrain to get consistent measurements from different sensors.