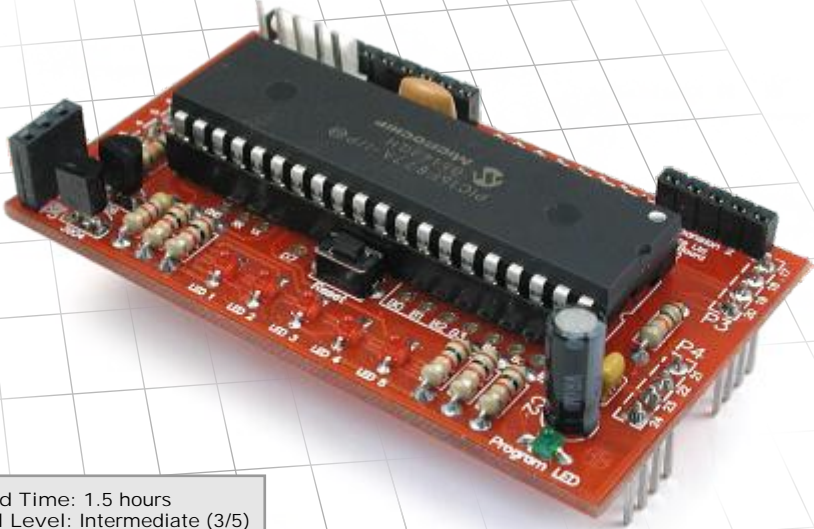


Microchip PIC16F877A Brainboard Add-on V2.0

for the Solarbotics SUMOVORE



Build Time: 1.5 hours
Skill Level: Intermediate (3/5)

Ready to step up from the discrete brain on your stock Sumovore? Try the popular PIC16F877A to add PIC programmability!

The Microchip series of microcontrollers were the first affordable chip that made building programmable robots easy. This brainboard adapter lets you use the powerful PIC16F877A as the controller for the Sumovore! It's a fast, inexpensive, and very powerful upgrade for your Solarbotics Sumovore Robot Kit!

The new version 2 brainboard adds full I2C interface support, better programmability and the ability to add bread-board space!

(Sumovore Sumo robot kit and programmer/DB9 Serial cable required)



We strongly suggest you inventory the parts in your kit to make sure you have all the parts listed. Use a pen, pencil, pricked finger, chocolate bar - anything to mark off the items. If anything is missing, contact us for replacement parts information.

Disclaimer of Liability

Solarbotics Ltd. is not responsible for any special, incidental, or consequential damages resulting from any breach of warranty, or under any legal theory, including lost profits, downtime, good-will, damage to or replacement of equipment or property, and any costs or recovering of any material or goods associated with the assembly or use of this product. Solarbotics Ltd. reserves the right to make substitutions and changes to this product without prior notice. (Sorry, gotta make the lawyer happy!)



The PIC16F877a Brainboard



Parts List

PIC16F877a Brainboard Components

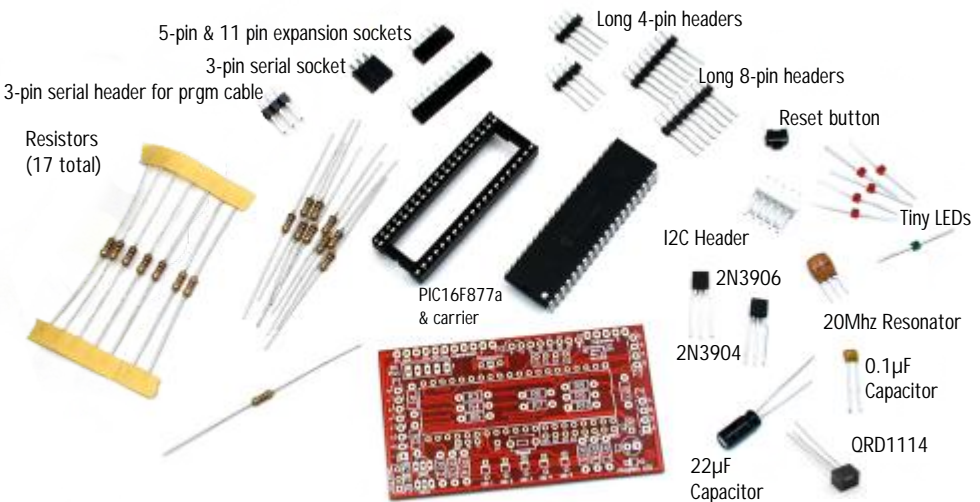
- 1 - Printed Circuit Board (PCB)
- 1 - Microchip PIC16F877a Microcontroller
- 1 - 40 Pin socket
- 1 - 20MHz Resonator
- 1 - Reset Button
- 1 - 2N3904 NPN Transistor
- 1 - 2N3906 PNP Transistor
- 5 - Tiny red LEDs (sensor indicators)
- 1 - Tiny green LED (programming indicator)
- 1 - 0.1 μ F capacitor (labeled '104')
- 1 - 22 μ F capacitor
- 11 - 10k Resistor (Brown/Black/Orange) for Position R1 to R11
- 1 - 4.7k Resistor (Yellow/Violet/Red) for Position R12
- 5 - 1k Resistors (Brown/Black/Red) for Positions R13, R14, R15, R16, R17
- 2 - 4-Pin Sumovore interface headers
- 2 - 8-Pin Sumovore interface headers
- 1 - 5-Pin Low-profile Socket for Breadboard expansion board
- 1 - 11-Pin Low-profile Socket for Breadboard expansion board
- 1 - 3-Socket Programming header
- 1 - 3-Pin Male Header (for building optional programming cable)
- 1 - QRD1114 edge sensor (for Sumovore's middle sensor)
- 1 - Polarized 5-Pin I2C interface header

Tools Required

Soldering equipment

Side-cutters or fine snips

Computer (for programming / downloading code!)





Looking for a more flexibility out of your Sumovore? Well, welcome to the next in our series of brainboards - the PC16F877a. The '877 offers an impressive list of features, including (but not limited to):

- 14kB flash memory
- 2 Comparitors
- 2 capture/compare/PWM functions
- Eight 10-bit Analog-to-digital converters (ADCs)
- In-circuit programmable
- 33 programmable Input/Output (I/O) lines
- I²C protocol for sensor networking

Programming the PIC with Microchip's own "MPLAB" Integrated Development Environment is a very capable way to program if you are comfortable using assembler, but it also supports programming environments like Hi-Tech software's free "PICC Lite" C-compiler. There is also the free JAL (Just Another Language) compiler too.

This is not a kit for a microcontroller beginner. Anybody using this brainboard should have the appropriate skills, or be ready to learn the techniques that make a microcontroller... microcontrol!

This kit lets you swap out the default discrete brainboard for a programmable version. If you run into any problems, it's a simple process to swap a different brain. Hmmm, that would be desirable in real life!

This brainboard features:

- Microchip PIC16F877a microcontroller
- 5 indicator LEDs & 1 programming LED indicator
- Built-in shift-leveller for direct RS-232 serial programming
- Microprocessor Reset Switch
- Standard 0.1" expansion interface holes for breadboard add-ons
- Expansion interface featuring:
 - 5 digital I/O (RDO-4, shared with LED indicators)
 - 5 analog/digital I/O (RA0,1,2,3,5 shared with line sensors)
 - I²C Bus (RC3,4)
 - Regulated 5V and Raw 6V
 - Direct access to the microcontroller TTL serial interface
 - Full Port B & E A/D expansion access, A4 (time capture & compare), & D7 (digital I/O) port access



The PIC16F877a Brainboard

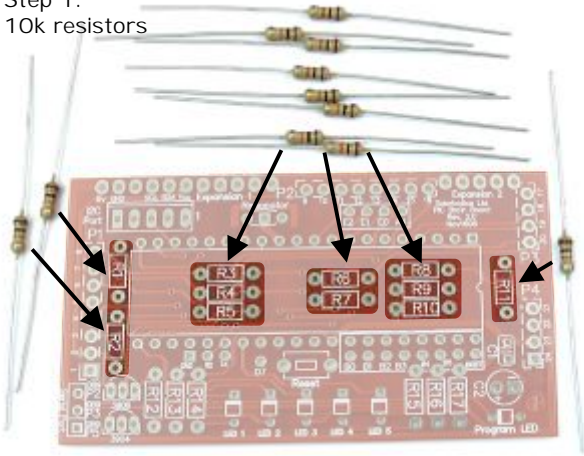


Building It - Steps 1, 2, 3

When building this kit, you *must* bend the resistors down right near the resistor body. This PCB is designed on the tight side, so being compact counts!

Step 1 - 11 x 10k Resistors (Brown / Black / Orange): The 10k resistors are used for many things on this brainboard, and are installed at positions R1 through R11. What are they used for? You really want to know? Ok...:

Step 1:
10k resistors



R1, R2, and R5 are used for RS-232 shift-leveilling.

R3 & R4 are pull-downs for motor control.

R6, R7, R8, R9 & R10 are pullup for the QRD sensors on PortA.

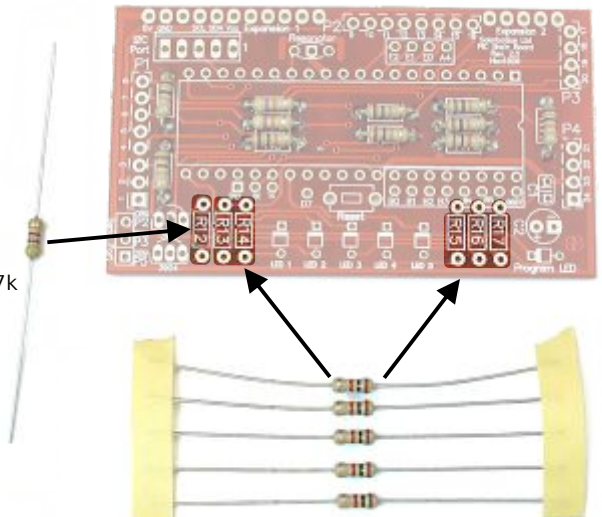
R11 is a pullup for the reset switch.

Step 2 - 1 x 4.7k Resistors (Yellow / Violet / Red): The 4.7k resistor is installed in position R12. It's used as part of the RS-232 shift-leveiler for programming.

Step 3 - 5 x 1.0k Resistors (Brown / Black / Red):

The 1.0k resistors installed at positions R13, R14, R15, R16, & R17, are used for current-limiting the LEDs.

Step 2: 4.7k
at R12



Step 3: 1k resistors at R13 to R17



The PIC16F877a Brainboard



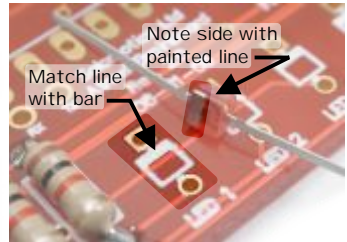
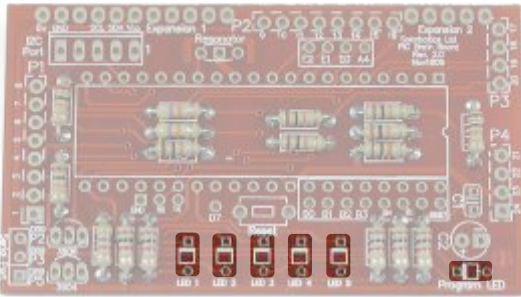
Steps 4, 5, 6

Step 4 - Tiny Red Indicator LEDs: You can't have a robot without blinky lights. Really. Besides, they truly are useful for figuring out what your robot is thinking at any moment.

Unlike resistors, these have to be installed the right-way-around. Look underneath the LED to see which side has the painted bar. That's the side that goes nearest to the bar symbol on the PCB.

Put the red ones in positions LED 1 through LED 5.

Step 5 - Tiny Green Programming LED: This LED is on when connected to the programmer, and flickers during the download process.



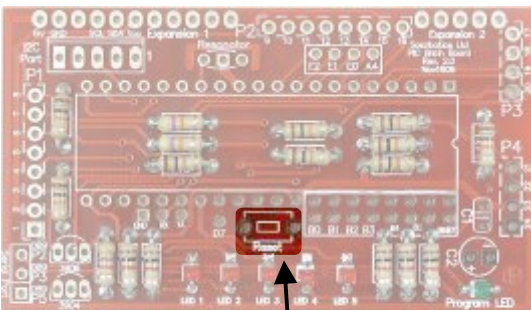
Step 4:
Indicator LEDs



Step 5:
Programming
LED



Step 6 - Reset Switch: Install the reset switch in the location marked "Reset".



Step 6:
Reset Switch
(good for resetting stuff!)



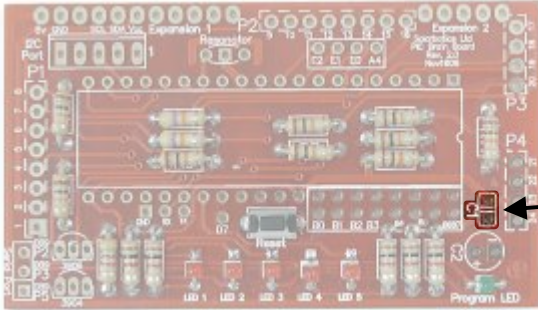


The PIC16F877a Brainboard



Steps 7, 8

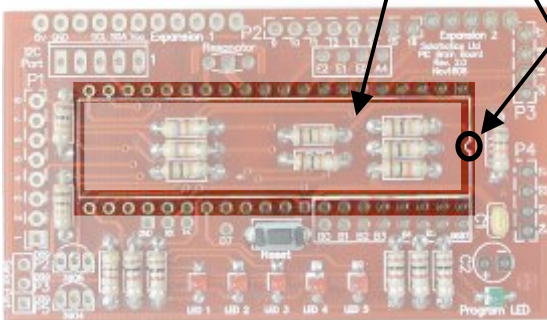
Step 7 - 0.1 μ F Capacitor (Labeled '104'): Install the 0.1 μ F capacitor into the location marked C1. This capacitor is part of the power-smoothing for the microcontroller.



Step 7:
0.1 μ F Capacitor
(marked '104')

Step 8 - DIP Carrier: It's a good idea to put in a carrier for your microcontroller. Nothing more frustrating than soldering in a 40-pin chip backwards (ug!).

Solder the carrier in, and keep the notch aligned up with the notch printed on the circuit board. It will help you install the microcontroller the right-way around (really, really important!).



Note Notch
Position



Finished installation of
DIP carrier & 0.1 μ F capacitor
(note notch location on DIP carrier!)



The PIC16F877a Brainboard

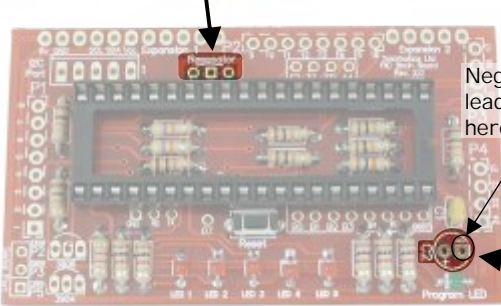


Steps 9, 10, 11

Step 9 - 20MHz Resonator: The resonator is what sets the timing for all the processes in the 16F877a, so it's pretty important. Install it in the position marked Resonator. It doesn't matter which way around you put it in.

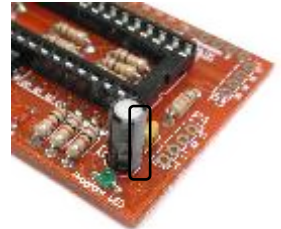
Step 10 - 22µF Capacitor: The 22µF electrolytic capacitor is part of the RS-232 circuitry. You'll see that one side of the capacitor has a stripe - this marks the negative side, and is the shorter leg. Make sure you insert the capacitor into location C2 with the negative side going into the square pad. Installing it backwards isn't good!

Step 9:
20MHz resonator



Negative lead goes here!

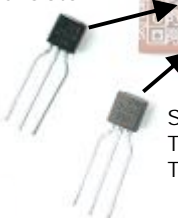
Step 10:
22µF capacitor. Note that the short leg near the stripe is installed in the negative pad!



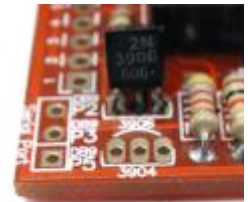
Finished 22µF installation
Note the stripe on the capacitor!

Step 11 - 2N3906 & 2N3904 Transistors: The transistors are part of the RS-232 communication circuitry. Just install them in the locations as marked by 3906 and 3904, making sure that the transistor curve matches the curve on the circuit board.

Step 11a:
The 2N3906
Transistor



Step 11b:
The 2N3904
Transistor



Close-up of the transistor installation

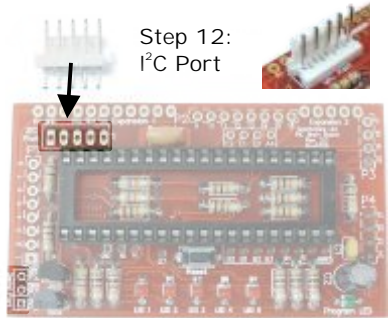


The PIC16F877a Brainboard



Steps 12, 13, 14

Step 12 - I²C Header: Going to interface to other I²C peripherals? You'll need to install this header. Make sure the big flat tab is nearest the top of the PCB, where the long line is shown on the symbol. Install it in the position marked I²C Port.

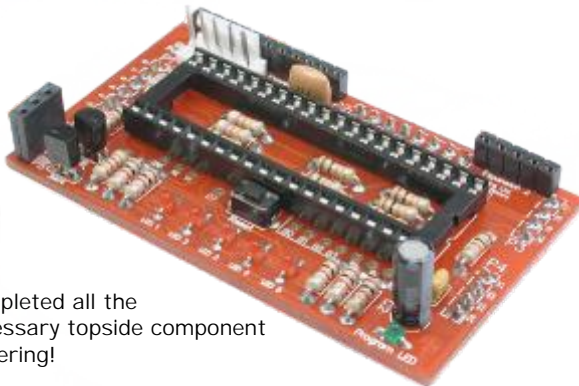
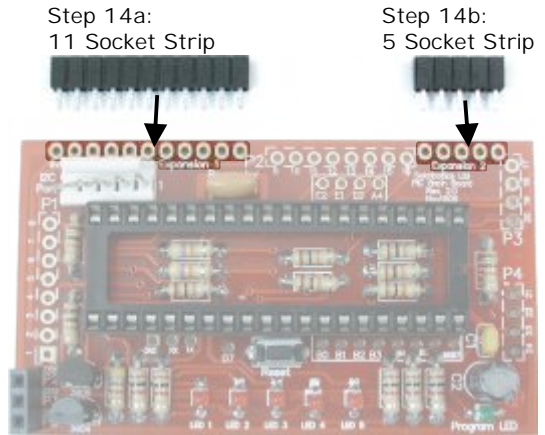


Step 13 - 3 Socket Header: Here's the plug to receive your serial programming cable.

Step 13:
3 Socket
Strip

Step 14 - 11 & 5 Socket Expansion Headers: These are not essential to the brainboard, but it's best to install them now just in case if you do ever want to add a custom breadboard.

Simply line them up and solder them into locations Expansion 1 and Expansion 2.



Completed all the necessary topside component soldering!

You're almost done. Let's flip the PCB over, and work entirely on the other side to install the mounting pins.



The PIC16F877a Brainboard



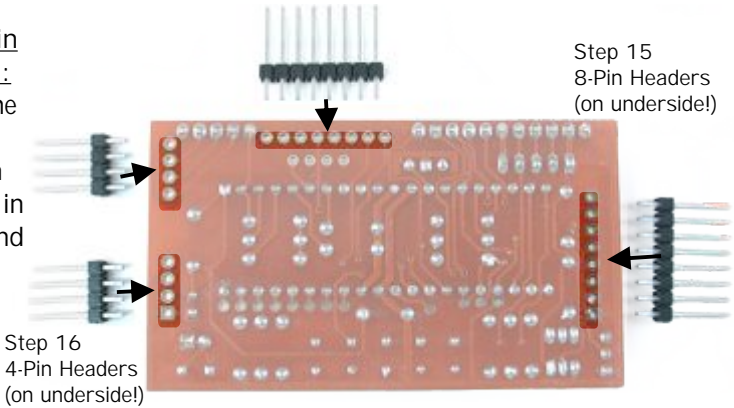
Steps 15, 16

Step 15 - 8 Pin Headers (x 2): To attach your new Brainboard to the robot, you'll need to solder the two 8-pin headers in positions P1 and P2, but on the underside. I don't think you heard me, so...

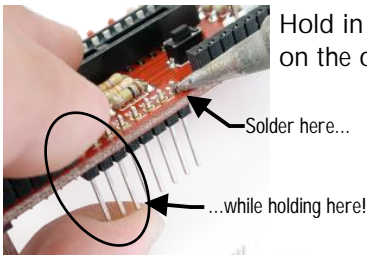
NOTE / IMPORTANT / READ ME, DARN IT: Install all these pins on the bottom of the PCB. See the dashed outline around P1, P2, P3, and P4 on the top of the PCB? That means "This is where they go, but on the bottom." There. Hope we've made that clear! (Once more: "Install them on the bottom!")

Step 16 - 4 Pin Headers (x 2):

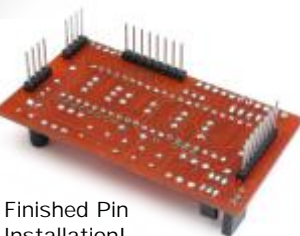
Just like with the 8-pin headers, install these on the underside, in locations P3 and P4.



Another Important Note! Yes, ANOTHER one!: As these pins will mate with the sockets on the main robot body, you should try to get them installed as straight as possible. If you don't get them straight, you'll be fighting to match up all the pins to all the sockets! Here's what we suggest you do:



Bend the strip until it sits perfectly upright (like shown here), then solder the rest of the pins!



Finished Pin Installation!



The PIC16F877a Brainboard

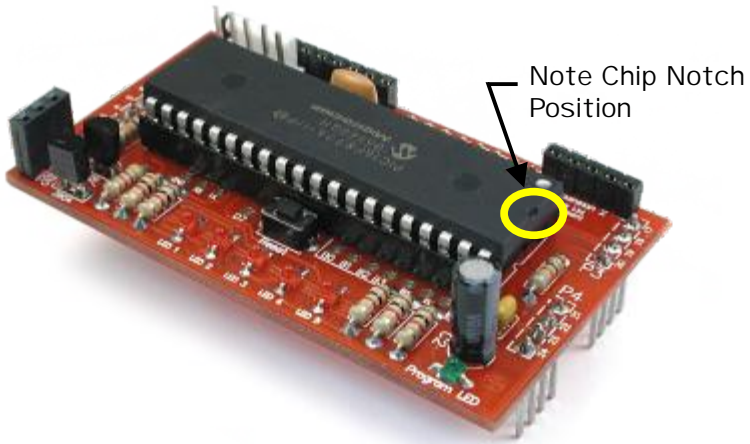


Step 17

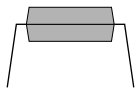
Step 17 - Install the PIC 16F877a: This is a static-sensitive part, so if you frequently “zap” people, you’ll have to be careful. Do this near a sink, and touch the metal faucet just before doing this, as it will remove any static charge.

Insert the microcontroller. Note that the notch on the end of the chip must match the notch on the PCB, which is on the right side.

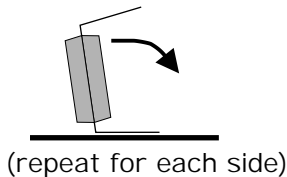
As the chip has legs that splay out a bit, you might want to bend the legs inward so it fits into the chip carrier easier.



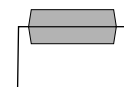
Having trouble getting the Microcontroller installed in the carrier? Try this: Gently bend all the chip pins inwards on a flat surface.



Starts like this...



(repeat for each side)

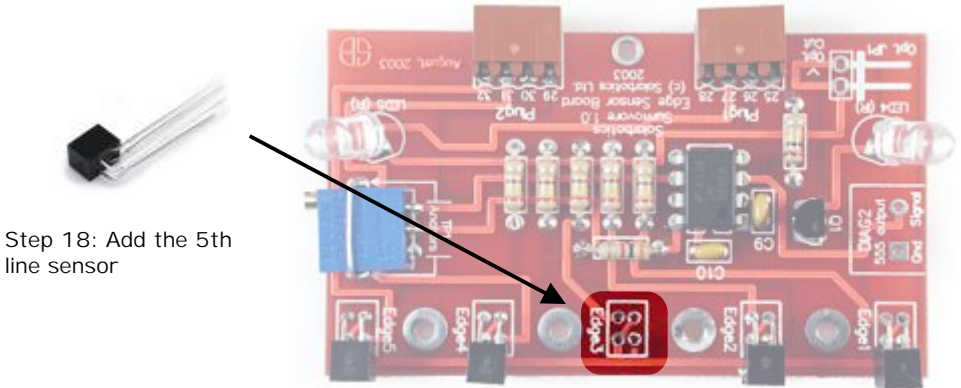


...ends like this!



On the Sumovore, you have to add the center edge-sensor to make full use of the Brainboard:

Step 18 - Installing the 5th line sensor: Yank the edge-sensor board out of your Sumovore, and install the included line sensor in position 'Edge3', just like you did when you originally built your Sumovore.



Step 18: Add the 5th line sensor

The Brainboard has some pretty cool additional features which you may never need to use, but they're here if needed:

- Unregulated 6V power from the main 4-cell battery pack
- I²C for peripheral (sensors/networking) communication
- Tap points for utilizing unused PD2, PBO-PB7, PEO-PE2, and PA4 ports
- Port E offers digital I/O, or analog-to-digital conversion
- Port A4 offers timer compare I/O
- Port D7 offers digital I/O
- Port B offers digital I/O
- Port RC7 (used for serial Rx) can be used as digital I/O
- Port RC6 (used for serial Tx) can be used as digital I/O

P1

- 1 - GND
- 2 - Vcc
- 3 - Left Mot Dir B - P2/13
- 4 - Left Mot Dir A - Pin15
- 5 - Right Mot Dir B - P2/15
- 6 - Right Mot Dir A - Pin24
- 7 - Left Enable - Pin16
- 8 - Right Enable - Pin17

P3

- 17 - R-Edge sensor - Pin7 - Exp2/5
- 18 - RC-Edge sensor - Pin5 - Exp2/4
- 19 - C-Edge sensor - Pin4 - Exp2/3
- 20 - LC-Edge sensor - Pin3 - Exp2/2

P2

- 9 - Left IR sensor - Pin28
- 10 - Right IR sensor - Pin29
- 11 - NC
- 12 - NC
- 13 - Inverted Mot Dir Left - P1/3
- 14 - Non-Inverted Mot Dir Left - P1/4
- 15 - Inverted Mot Dir Right - P1/5
- 16 - Non-Inverted Mot Dir Right - P1/6

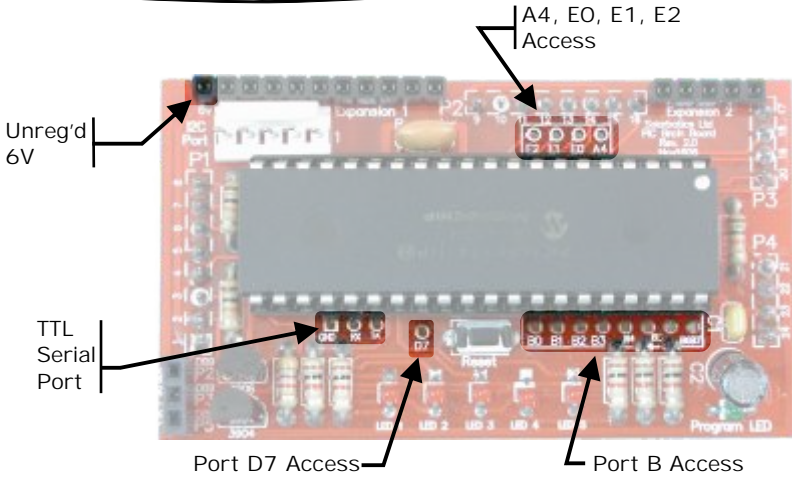
P4

- 21 - L-Edge sensor - Pin2 - Exp2/1
- 22 - Raw 6v
- 23 - Regulated 5v - Vcc
- 24 - GND



The PIC16F877a Brainboard

Brainboard Enhancements, Programming Cable

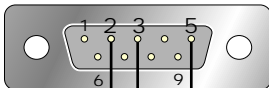


If you don't already have a programming cable, you'll have to make or buy one. Being of the roboticist/hacker sort, we expect you may have an old serial mouse near by. Snip it so you're left with the cable and plug with holes in it.

Use a multimeter, and identify the wires in the following diagram, and solder them to the included 3-pin header. To protect the header, smother it in hot-glue or epoxy, like the one in the picture.

Serial Programming Cable Wiring Diagram

Back of DB9 connector (looking at Solder/Wire side!)



Gnd (connects to DB9 P5)
Rx (connects to DB9 P3)
Tx (connects to DB9 P2)





Programming the PIC16F877a: If you are brand-new to PIC programming, here's a step-by-step process to loading up your own code:

Download: Get these files from the links below, or directly from the support page for the brainboard on <http://www.solarbotics.com>

- 1) MPLAB Integrated Development Environment (the "IDE"), (version 7.40):
http://ww1.microchip.com/downloads/en/DeviceDoc/mp740_full.zip
(free download, but requires site registration)
- 2) HI TECH PICC-Lite C-Programming Language (freeware version 9.50PL2):
<http://www.htsoft.com/products/PICClite.php>
(free download, but requires site registration)
- 3) Shane Tolmie's free PIC Bootloader (version 9-50):
<http://www.microchipc.com/PIC16bootload/>
- 4) (Optional) Sumoline_2.mcp source code template directly from Solarbotics

Install: Start the installation with MPLAB software, then the PICC-Lite software, which will integrate with the MPLAB software. This will form your programming environment.

Unzip the PIC Bootloader software (it doesn't have an installer).

Run: Start MPLAB via the Start Menu/All Programs/Microchip/MPLAB IDE v7.40. Load up the "Sumoline_2.mcp" file to open the source code to make any changes. Once you're satisfied with your code, hit the "Make" button (F10 or under Project/Make). This generates a "Sumoline_2.hex" file which you'll download to your brainboard.

Plug the serial programming cable you made into the brainboard, with the ground line nearest the rear corner socket "DB8-P5". Warning: The "Program" LED will light even if the cable is in backwards!

Load your new .hex file into the PICbootPlus.exe downloader, select your COM port and set the Baud rate to 36400bps. POWER ON your Sumovore (disable the motors is a good idea), and click the "Write" button. Hit the Brainboard's "Reset" button to start the download, which should only take a moment.

Unplug the robot, reset it, and watch the indicator LEDs. Loaded with our code, with the Sumovore placed on a black surface, the lights will show the 5-second count-down, and will start to chase a huge Japanese guy around the ring*, if it's on a white surface when powered up, it will follow a black line.

*Huge Japanese Guy not included with kit. They cost too much to ship.



The PIC16F877a Brainboard

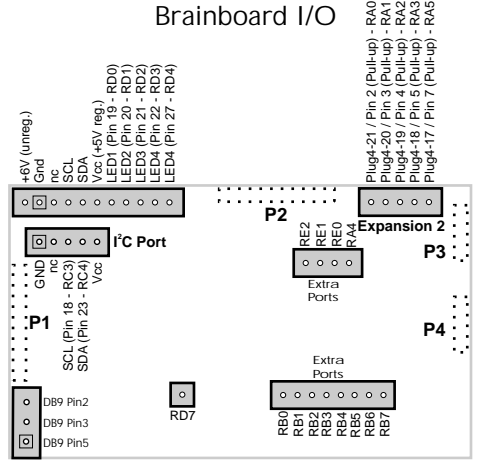
Brainboard Schematics



Microcontroller Pin Usage

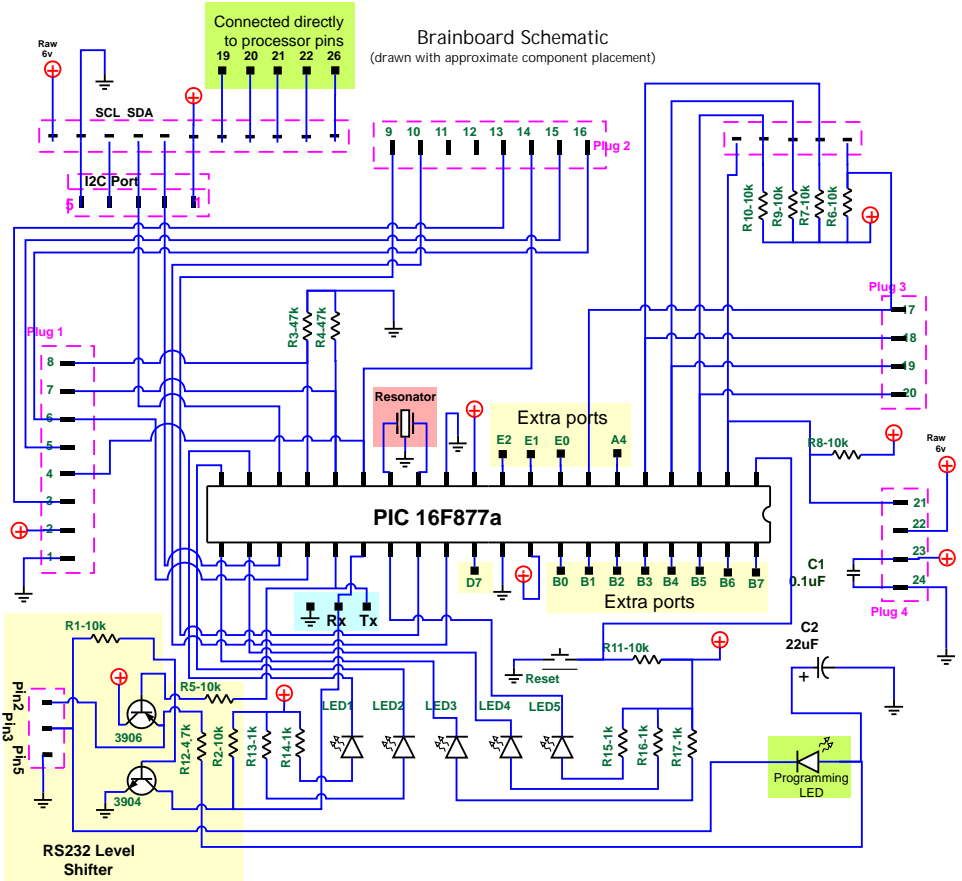
MCLR	1	40	N.C. (RB7)
Edge Left (RA0)	2	39	N.C. (RB6)
Edge Center Left (RA1)	3	38	N.C. (RB5)
Edge Center (RA2)	4	37	N.C. (RB4)
Edge Center Right (RA3)	5	36	N.C. (RB3)
N.C. (RA4)	6	35	N.C. (RB2)
Edge Right (RA5)	7	34	N.C. (RB1)
N.C. (RE0)	8	33	N.C. (RB0)
N.C. (RE1)	9	32	VDD
N.C. (RE2)	10	31	VSS
VDD	11	30	N.C. (RD7)
VSS	12	29	IR Right (RD6)
OSC1	13	28	IR Left (RD5)
OSC2	14	27	LED5 (RD4)
Direction Left M (RC0)	15	26	Tx
Enable Left M (RC1)	16	25	Rx
Enable Right M (RC2)	17	24	Direction Right M (RC5)
I2C SCL (RC3)	18	23	I2C SDA (RC4)
LED1 (RD0)	19	22	LED4 (RD3)
LED2 (RD1)	20	21	LED3 (RD2)

Brainboard I/O



Brainboard Schematic

(drawn with approximate component placement)



The new Version 2 PC Brainboard features:

- ▶ Smaller board outline
- ▶ Onboard RS232 Serial programming (on-chip bootloader preprogrammed in)
- ▶ I2C sensor / communication port compatible with Acroname interface
- ▶ TTL serial pinouts
- ▶ Microcontroller preprogrammed in C for MiniSumo & Line Follower functions
- ▶ Programmability with the FREE MPLAB/PICC-Lite programming environment
- ▶ Expandable custom circuit-building area on separate (not included) protoboard

If you have any questions regarding this kit, please contact us!

Visit us online for more info and cool stuff:

www.solarbotics.com

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