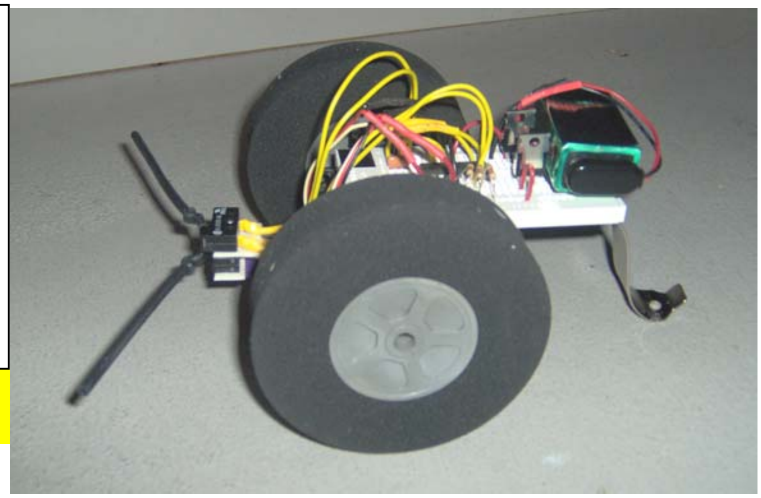
PROTOBot: Amoeba!

A complete interactive robot

By Camp Peavy and Randy Hootman



The basic concept behind the PROTOBot is that of a solderless breadboard on wheels. Any breadboard will do but I like the "Experimentor 350" from Global Specialties; they're sold through Radio Shack as #276-175. Again any solderless breadboard will do in fact a bigger one will allow you to add more sensors later. After the solderless breadboard the next major component is the continuous rotation hobby servo. Hobby servos (as opposed to industrial servos) are generally limited to 180 degrees of motion; for the rest of this article we will use the term "servo" to mean "hobby servo". Originally you had to modify the standard servo for continuous rotation; which is a good exercise if you haven't done it before or if standard servos are all you have. There are plenty of websites that describe this process; just google "modify servo". Otherwise Parallax sells continuous rotation servos as part number 900-00008.

Complete Parts List:

Prices may vary

The Body
Solderless Breadboard: Radio Shack #276-175 - $8.39
Continuous Rotation Servos: Parallax #900-00008 (2 x $6.95) - $13.90
Double-Stick Squares: ACE #91644 - $3.49
2 x ½" Wood Screws: ACE #1889 - (8 x .09) - .18
Drive Wheels: Dave Brown Products Lite Flite Wheels (pair) #WH35-5535 - $6.25
Tail Skid: PC Slot Cover Jameco #11754 - $1.79

Whisker Sensors
3/16" Heat Shrink Tubing: Tech-Tron TT-100 3/16" RED (4') ($1.39)
One Jumbo Craft Stick: www.chenillekraft.com or Haagen-Dazs - $1.95
Two Snap-Action Switches (Cherry #E61-00R): Jameco #456382 (2 x $4.85) - $9.70

Power System
Heavy Duty 9-Volt Battery Snap: Radio Shack #270-324 - $2.59
Two 7805 Voltage Regulators: Radio Shack #276-1770 (2 x $1.59) - $3.38
1" Sticky Back Velcro (1 hook, 1 loop): ACE #5006036 - $1.50

The Brain:
PIC16F628 microcontroller: Jameco #193447 - $3.49
Three 1K ¼ Watt Resistors: Radio Shack #271-1321 - 5 for .99
One 3-pin 4MHz Ceramic Resonator: www.glitchbuster.com #CR-4 - .44

Wires and Heat Shrink Tubing
22-Gauge Solid Wire (5 colors): Philmore Wire Kit #12-2276 - $5.99
Black 1/8" Black Heat Shrink Tubing: Tech-Tron TT-100 1/8" BLK (4') - $1.39
Red 1/8" Red Heat Shrink Tubing: Tech-Tron TT-100 1/8" RED (4') - $1.39
Yellow 1/8" Yellow Heat Shrink Tubing: Tech-Tron TT-100 1/8" YEL (4') - $1.39

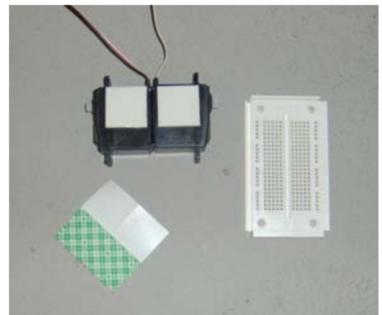
Programmer:
EPIC Plus – microEngineering Labs - $60
www.microengineeringlabs.com

Software:
PICBASIC PRO Compiler – microEngineering Labs - $249
www.microengineeringlabs.com

Last year I wrote an article for SERVO magazine called "Introducing the PROTOBot" (Oct, 2005). In that article I describe how to build an inexpensive Stamp-based educational robot called the "PROTOBot". I still believe the "Stamp" computer or microcontroller from Parallax is one of the best ways to get started in robotics and suitable for more advanced applications as well. However Stamps are costly; fifty bucks is a major expense for an "inexpensive" kit.

Step 1: Lay the continuous rotation servos back-to-back with gears facing outward.

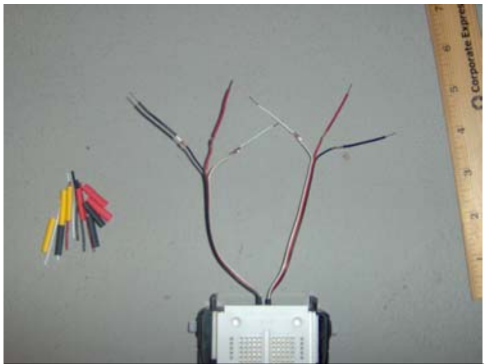
Enter the Ameoba; the idea behind Amoeba is to offer a complete interactive robot kit for $75 that teaches basic electromechanical techniques and can be upgraded to the BASIC Stamp II (BS2) or any other processor at a later time. The original Stamp-based PROTOBot costs ~$125. The cost of the PIC-based Amoeba ~$50; due mainly to the price reduction of the microcontroller from the $50 BS2 to the $4 PIC16F268. The advantages of the BASIC Stamp are the PBASIC development environment is free and the Stamp is easy to program in circuit. Ease of use means fun and entertainment… which makes you more apt to work with it. The PIC on the other hand requires an IC programmer (the "EPIC" programmer from microEngineering for example) and unless you're fluent in assembly language and/or "C"… the software isn't free. $90 for "PICBASIC" and $250 for "PICBASIC PRO" both are from microEngineering Labs www.microengineeringlabs.com . The good news is one can actually get an easy to use BASIC language compiler for the PIC chips and microEngineering Labs does have a free trial download version of PICBASIC PRO; the limitation is 31 lines of code. Fortunately the code that goes into the basic Amoeba actions takes



Step 2: Put a square of double-stick foam tape towards the front and center of the two servos.

Step 3: Carefully stick the solderless breadboard to the two servos aligning the servos with the front edge; press firmly.

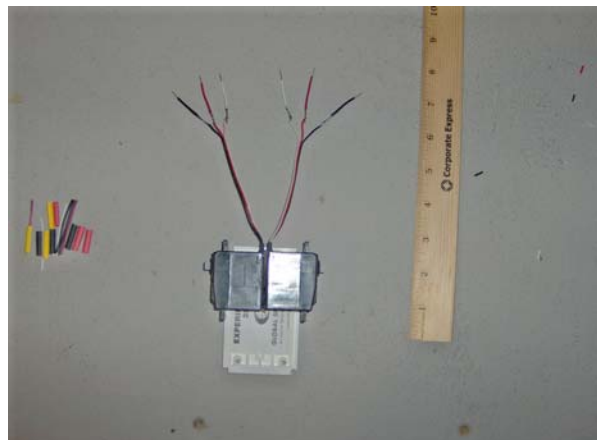
Step 4: Cut the servo leads to 4" and strip ¼" insulation off the ends; spread the wires apart. We'll be soldering 22-gauge solid-core wire to the ends creating breadboard "plugs".



Step 5: Twist the stranded servo wire around one end of the 1.5” 22-gauge solid-core wire with ¼” stripped off each end. Consider doing the wires one at a time.

only 25 lines and could be compressed further. Again if you want to burn your own chips for the Amoeba you’ll need a programmer (EPIC ~$60). Amoeba kits and pre-programmed PIC16F628 chips are available through www.camppeavy.com .

Another amoebic discovery… double-stick foam squares (Ace #91644 - $3.49); designed to hang up to two pounds on the wall (pictures, decorations, etc). In the previous article I wax poetic about the virtues of an adhesive called “E60000”. I still like adhesives but foam double-stick tape has great functionality because there’s literally no wait time and the hold-strength for tabletop robots is good enough.

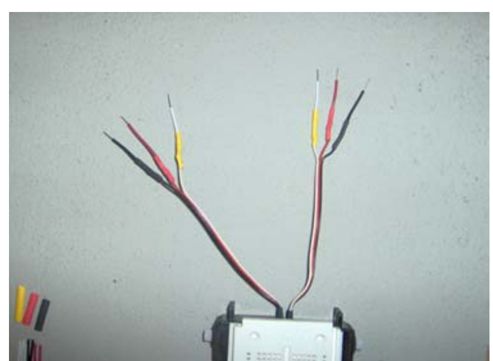


Step 6: solder the six servo leads.

We begin this process by building the body (Steps 1-18). First lay the continuous rotation servos back-to-back with the gears facing outward (Step 1). Much of Amoeba’s construction involves simply soldering 22-gauge solid wire onto stranded wire thereby making breadboard “plugs” which can then be interfaced with the microcontroller.

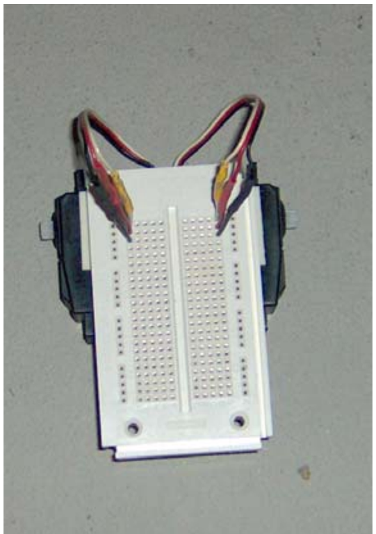
Step 7: Cover the solder joints with heat shrink tubing; otherwise the wires will short. If you don’t have heat shrink tubing use electrical tape or duct tape.

Stick the protoboard to the two servos (Steps 2-3). Cut the two servo leads to 4” and strip ¼” insulation off the end (Step 4). Wrap the 3 stranded wires from each servo around the end of one 1.5” piece of 22-gauge solid wire (Step 5). Solder the six wires (Step 6). Cover the solder joints with heat shrink tubing or electrical tape (Step 7). You should end up with 6 breadboard “pins” that you can plug into the protoboard (Step 8). Use this technique with any sensor or output device. Just solder 22-gauge solid wire and plug it in! Plug the Amoeba’s servo pins into its body; anywhere for now as this is a temporary place to plug it in until we wire up the rest of the system (Step 9).



Step 8: You should end up with six breadboard pins; one positive; one negative and one signal on each servo.

In prototyping “quickness” results in productivity because you are able to try more things. In the original PROTOBot article we glued the servo horns; this time we screw them in because it is quicker (#2 x ½” wood screws) (Step 11); but before you do that you’ll want to drill out the center ¼” or you will not be able to put the servo screw through (Step 10). Put the wheel on the servo and screw it in (Step 12).



Step 9: Plug the servo wires into the solderless breadboard; this is just temporary until we wire up the rest of the system.

Step 10: Prepare the wheels: Drill out center bore to ¼”. If you don’t do this the servo screw will not fit!

Step 11: Drill 4 small holes (1/16”) for servo horn. Use the servo horn as a template; this makes it much easier to thread the screw. If you don’t have a 1/16” drill bit the screws can be driven manually.

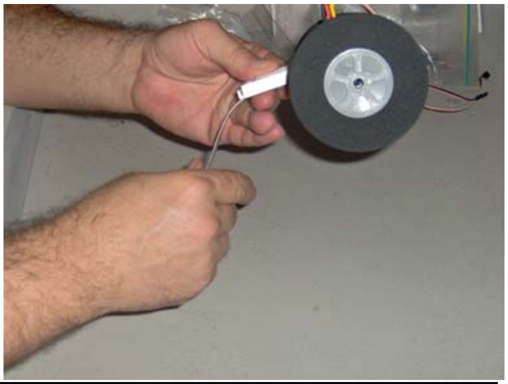
Step 12: Attach wheel to servo with servo screw.

Step 13: Cut the right-angle top from the PC-slot cover. You will have to use a pair of “dikes” (diagonal cutters); you may have to bend it back and forth to break it.

Step 14: Trim it up so it looks nice.

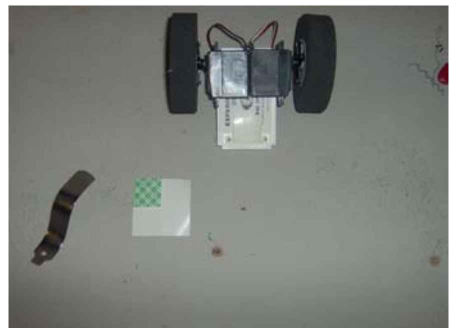
For the original PROTOBot I used a nice tail wheel which I still suggest for improved mobility but it costs $10. For the Amoeba we’ve gotten more practical and will use a PC slot cover (Jameco #11754 - $1.79). You probably have a half-dozen or so in the old computer in the garage. These are the “covers” that you would remove as you added in PC cards to the computer. To start with cut-off the end of the bracket with the 90 degree angle (Step 13). You’ll need a pair of diagonal cutters. This flat piece of metal can be used for the tail skid (Step 15). Stick tail skid to solderless breadboard with a double-stick foam square like you did the servos (Step 17). Shape it so it balances the robot. Now that you’ve completed the Amoeba body… it’s time for the guts (Mwa-ha-haaa!), er electronics.

In the original PROTOBot I used a tri-shaped 2.75" wide bumper made from matt board.



Step 15: Shape the PC-slot cover so it's the proper height and angle for a tail skid.

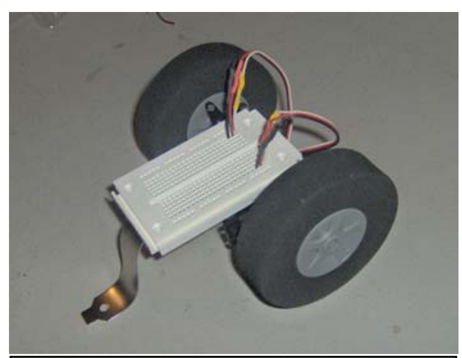
This is actually a better design because it is broader but for the Amoeba we've chosen simplicity over functionality. I've simplified the design into two 3" long whiskers. I've opted for simplicity over functionality. The idea is to get you to an interactive robot as quickly as possible.



Step 16: Put a double-stick foam square on the bottom of the solderless breadboard where you want to mount the tail skid.

Steps 19-29 are concerned with the whisker sensors; Steps 30-38 the power system and Steps 39-45 the brain. After building the body and installing the whiskers it is time to setup the power system. As we delve into the electronics of the system it is important to understand how solderless breadboards actually work. Usually protoboards have rails along the sides (columns) which carry positive (+) and negative (-) connections and perpendicular rows of 5 tie-points or "holes" isolated from each other by a 1/16" gap. This gap is usually straddled by a DIP (Dual Inline Package) chip such as the PIC or the Stamp. One should understand solderless breadboards and electronic diagrams as you take on the rest of the Amoeba project. If you've never used a solderless breadboard you should research the subject before proceeding as understanding the basic layout of the solderless breadboard is critical.

Step 17: Mount the tail skid.

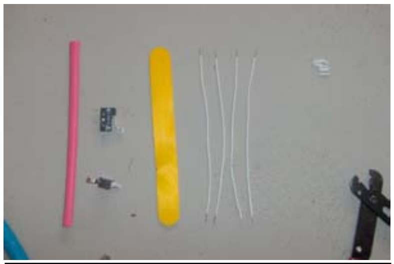


Step 18: Plug the servo pins into any of the tie-points or "holes" in the breadboard. The body: ready for action! At this point you could use whatever processor you like.

The original PROTOBot article www.camppeavy.com/articles/protobot.pdf gives a brief description and googling "solderless breadboard" will yield numerous useful results.

The first thing I like to do as I setup the "power system" is to place red tape on one rail and black tape on the other. If you don't have tape a red and black marker will do the job. At the least mark the negative rail with a black mark (Step 30).

Next we'll build the power cable. Cut the leads on the 9-Volt battery snap to 3" and cut two pieces of 22-gauge solid wire to 1.5"; one red one black. Strip the ends of the solid wire ¼" (Step 31). As with the servos and whiskers much of the construction consists of soldering 22-gauge solid wire to whatever sensor or actuator you want to include in the system. Solderless breadboards are good-enough for many hobbyist's applications.



Step 19: Cut four lengths of 22 gauge solid-core wire to 6" and strip1/4" insulation from each end.

Solder the red solid extension to the end of the red power lead and the black solid extension to the black power lead (Step 32). The color of course doesn't really matter but as long as you're taking time to do it you may as well observe the color codes. Besides it makes it more educational and easier to troubleshoot in the future.

Step 20: Solder one end of the 6" 22 gauge solid-core wire to each terminal on the #E61 snap-action switch and cover with heat-shrink tubing.

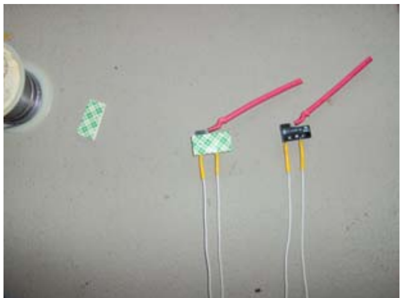
You'll need to put heat shrink tubing around the solder joint otherwise the two conductors will touch and cause a short circuit (not good!). If you don't have a heat-shrink gun or hair blow-dryer you can shrink the heat shrink tubing with your soldering iron. If you don't have heat shrink tubing use electrical tape or duct tape (Step 33).

Step 21: Cut two lengths of 3/16" heat shrink tubing for "whiskers".

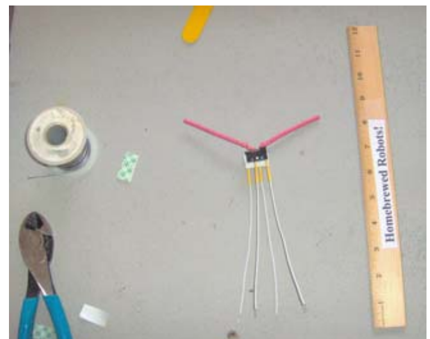
Put one side of the adhesive Velcro perpendicular and to the rear of the solderless breadboard (Step 34). The other side will adhere to the 9-Volt battery. You'll get ~30 minutes from one battery so if you plan on experimenting on the Amoeba for an extended length of time or robotics in general consider investing in rechargeable batteries and a charger. There are two "voltage regulators" in the system… the popular "7805". They look like three-legged black Chicklets. Place the two 7805 voltage regulators in front of the Velcro on opposite sides of the breadboard's center gap. Notice the orientation of the chips with heat-sinks facing left (Step 35).

Step 22: Shrink the 3" whiskers over the snap-action lever. If you don't have a heat shrink gun or blow-dryer you can shrink the tubing with a soldering iron. If you like doing this as a hobby seriously consider getting a heat shrink gun.

Now plug the positive (red) wire from your 9-Volt battery snap into pin 1 on the 7805 on the right (Step 36). Pin 1 is the 7805's input. Pin 2 is Ground and Pin 3 is the output… in this case 5-Volts; just right for driving servos and running microcontrollers like the PIC! Normally one would use only one 7805 voltage regulator but the servos generated so much electronic noise that I had to split the power supply into two separate regulators; one for the servos and one for the microcontroller. Amazing things these 7805's… put in between 7 and 35 Volts (like our 9-Volt battery) and out comes 5-Volts regulated! This means that the voltage will stay consistent (+5 Volts) regardless of the current draw: be aware the heat sink on the voltage regulators will get hot! After connecting the positive lead of your battery connect the negative lead. Here I want you to plug it into an empty row just above the 7805 (Step 36). The last thing we'll do is add a "wire switch" which connects the battery's negative terminal to ground and your robot will be "on" its way. To turn him off remove the wire. Later you will want to get a real SPST (Single Pole Single Throw) switch.



Step 23: Cut a double-stick foam square in half and place it on one of the whisker-switches; be sure and not allow the tape to effect the "snap-action".



Step 24: Carefully place one switch on top of the other facing the opposite direction so the levers go out radially like "whiskers"; when straight press firmly.

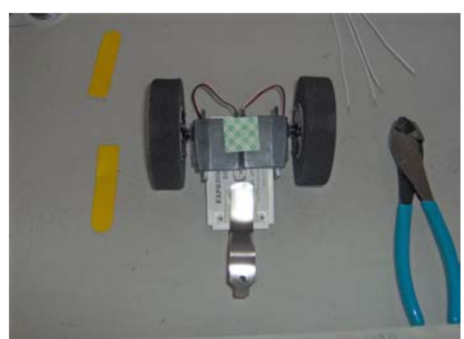
Connect Pin 1 of the 7805 on the right to Pin 1 of the 7805 on the left with a 1.5" piece of 22-gauge solid wire stripped ¼" off each end (Step 37) . Be sure the two 7805s are facing the same direction with their metal heat-sinks to the left. The 9-Volt positive connection (red wire) goes nowhere but the two Pin 1's on the 7805s.

Connect the center pins (Pin 2) on the two 7805s then connect the center pin on the 7805 on the left to your negative rail which we've marked with black tape on the left side (Step 38).

The 7805 on the left will be powering the servos… put a 1.5" piece of 22-gauge solid wire (red) into Pin 3 on the 7805 and the positive rail (the column of holes along left side); it will supply 5 Volts to the servos and switches.

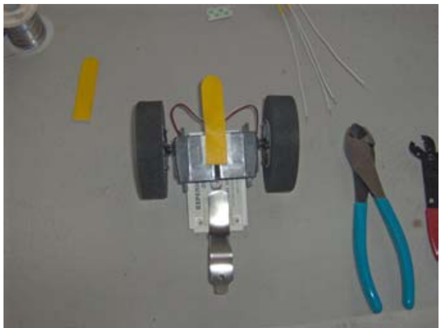
The 7805 on the right side will be dedicated to powering the PIC-chip; put a 2" piece of red 22-gauge solid wire into Pin 3. Do not plug the other end into anything yet as we having plugged in the brain (Mwa-ha-haaa!).

Step 25: Cut a jumbo craft stick to a length of 3".

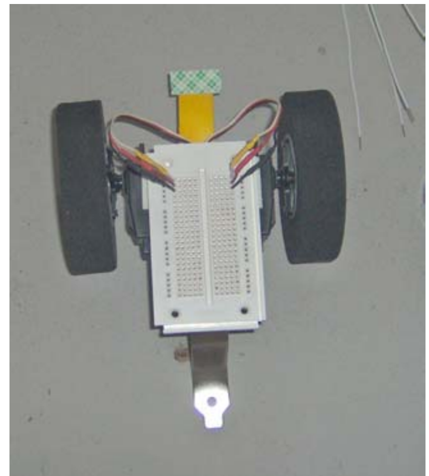


Step 26: Stick a square of double-stick foam tape to the front and center of the two servos.

Double check your wiring with the schematic at the end of the article.



Step 27: Carefully position the 3" cut craft stick to be centered and protrude 2" beyond the front of the servos; press firmly.



Step 28: Stick ½" double-stick foam square on the end of the jumbo craft stick.

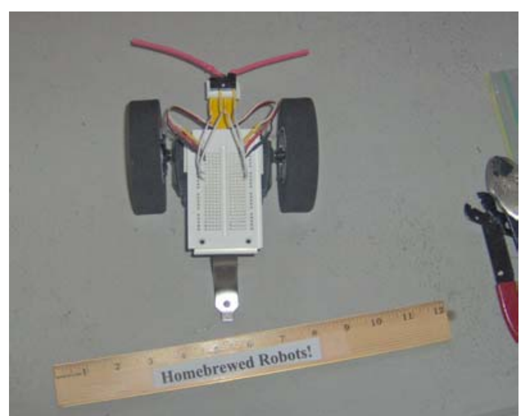
Take the PIC16F628; orient it with the notch up on the package. Pin 1 will up and to the left. Plug the chip into the solderless breadboard (straddle the center gap) (Step 39); leave at least 3 rows in the front for the 4MHz resonator <queue sci-fi music>. No other wires should be connected to the rows at this time. Plug the 4MHz resonator into the first three rows of the solderless breadboard (Step 40).

Pin Connections for PIC16F628

Pin 1 – no connection
Pin 2 – no connection
Pin 3 – no connection
Pin 4 – 10K Ohm resistor to +5 Volts
Pin 5 – Ground (2" 22-gauge solid-core wire; black; stripped ¼" at each end)
Pin 6 – no connection
Pin 7 – 10K Ohm resistor to +5 Volts and one wire from the right snap-action switch
Pin 8 – 10K Ohm resistor to +5 Volts and one wire from the left snap-action switch
Pin 9 – no connection
Pin 10 – White wire from left servo
Pin 11 – White wire from right servo
Pin 12 – no connection
Pin 13 – no connection
Pin 14 – Output (red wire) from right-hand 7805
Pin 15 – connect to pin 1 of resonator
Pin 16 – connect to pin 3 of resonator
Pin 17 – no connection
Pin 18 – no connection

Okay now we're going to work around the CPU (Steps 41-45). Refer to the "Pin Connections for PIC16F628" list and PROTOBot: Amoeba! schematic.

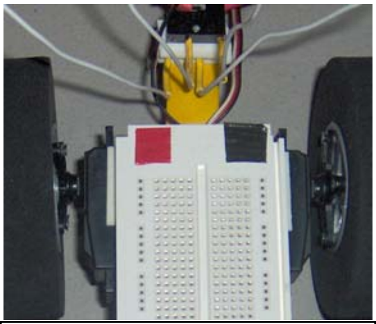
Connect the two negative or black wires from the servo to the negative rail. Connect the two positive or red wires from the servo to the positive rail (Step 44).



Step 29: stick the whisker array on the end of the craft stick and plug the wires into the protoboard… anywhere for now.

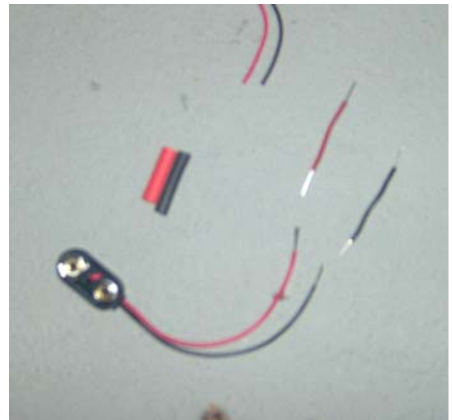
Connect the center terminal of the 4MHz resonator to ground (negative rail) and connect the two remaining wires from the snap-action switches to the negative rail (Step 46).

Attach other side of adhesive Velcro to 9-Volt battery; press onto solderless breadboard and attach battery snap. Nothing should happen yet (Step 47).



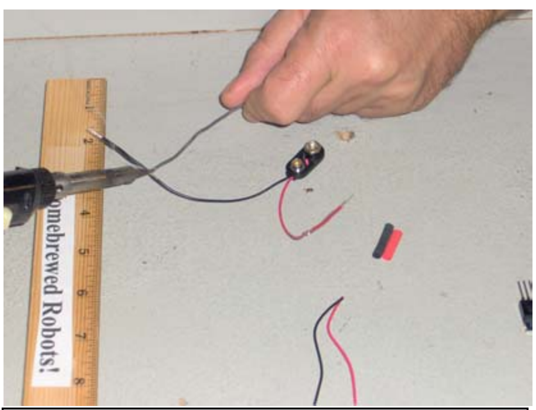
Step 30: Place red tape on one rail and black tape on the other. If you don't have tape a red and black marker will do the job. At the least mark the negative rail with a black mark.

Plug in the "wire switch" between the 9-Volt black wire and the negative rail. Your robot should spring to "life" (Step 48). If nothing happens unplug the wire switch and go back and double check your wiring to the circuit diagram. To turn off your robot remove the wire switch.

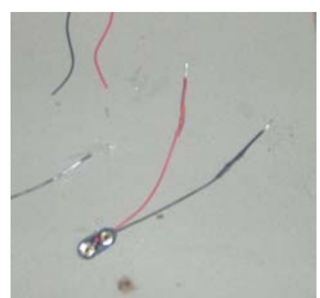


Step 31: Next we'll build the power cable. Cut the leads on the 9-Volt battery snap to 3" and cut two pieces of 1.5" solid-core wire to 1.5"; one red one black. Strip the ends of the solid-core wire ¼".

Is this the end or just the beginning? Consider replacing the pre-programmed PIC chip for an easy-to-program BASIC Stamp II. For information on how to do this look for the original PROTOBot article at www.camppeavy.com/articles/protobot.pdf and the Ultimate TABLEBot at www.camppeavy.com/articles/ultimate.pdf . The PROTOBot design gives a lot of flexibility on a low cost platform. If you want to continue with the PIC get the EPIC programmer and have at it! Robot building is a fascinating hobby and PROTOBots are a great way to get started or a fun and easy project if you're an experienced builder.

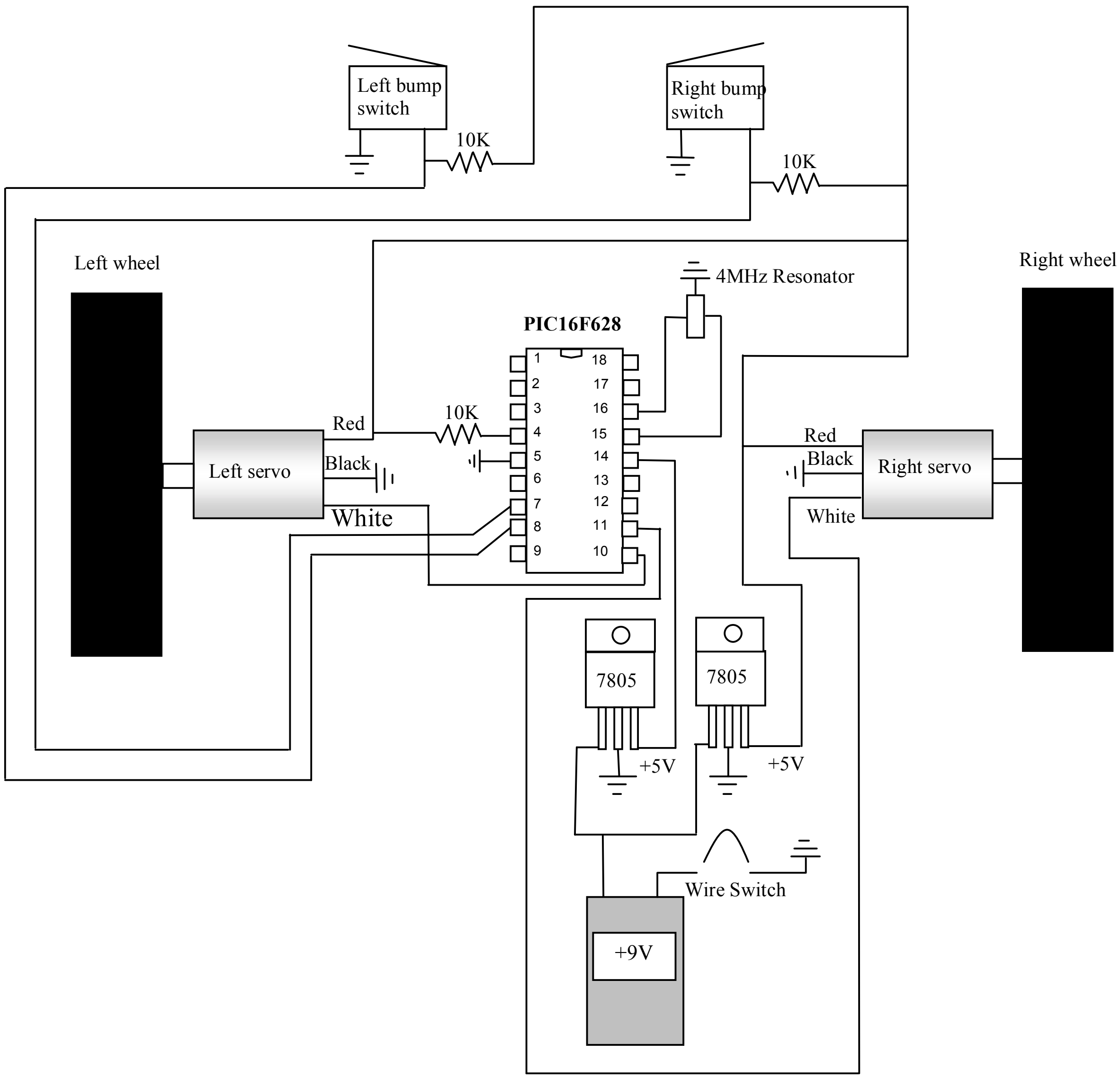


Step 32: Solder the red solid-core extension to the end of the red power lead and the black solid-core extension to the black power lead.



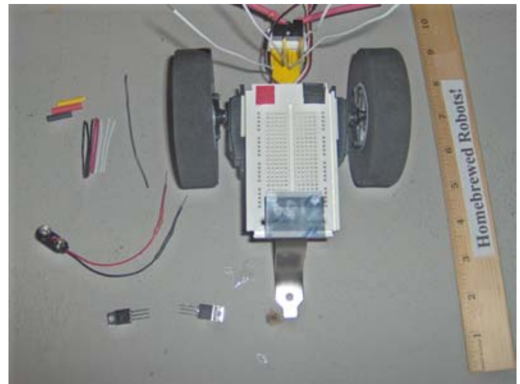
Step 33: You'll need to put heat-shrink tubing around the solder joint otherwise the two conductors will touch and cause a short circuit (not good!)

Schematic for PROTOBot: Amoeba!



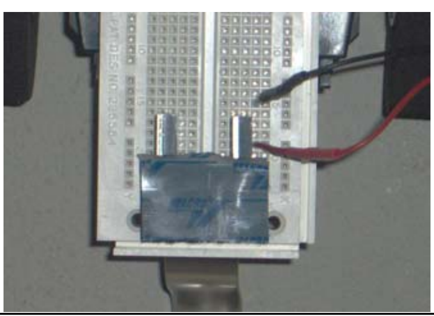
Amoeba Program

```
x var byte
Main:      ' Main program loop
PULSOUT portb.4,200 : pulsout portb.5,100
IF portb.1 = 0 THEN lwskr : if portb.2 = 0 then rwskr
goto main
lwskr:     ' Left Whisker
for x = 1 to 25
pulsout portb.4,100 : pulsout portb.5,200
pause 20
next
for x = 1 to 20
pulsout portb.4,100 : pulsout portb.5,100
pause 20
next
goto main
rwskr:     ' Right Whisker
for x = 1 to 25
pulsout portb.4,100 : pulsout portb.5,200
pause 20
next
for x = 1 to 20
pulsout portb.4,200 : pulsout portb.5,200
pause 20
next
goto main
```

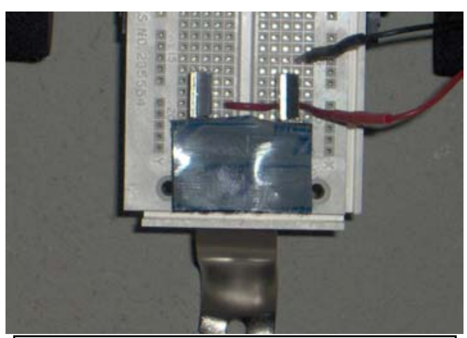


Step 34: Put one side of the adhesive Velcro perpendicular and to the rear of the solderless breadboard. The other side will adhere to the 9-Volt battery.

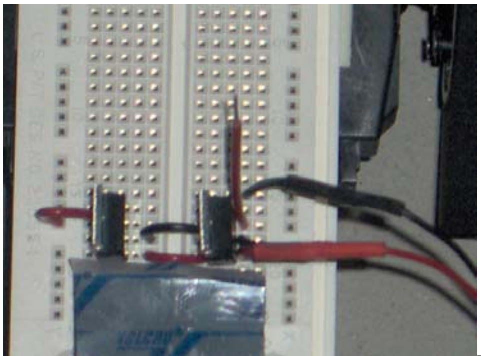
Step 35: Place the two 7805 voltage regulators in front of the Velcro on opposite sides of the breadboard's center gap. Notice the orientation of the chips with heat-sinks facing left. Be aware the heat sinks will get hot!



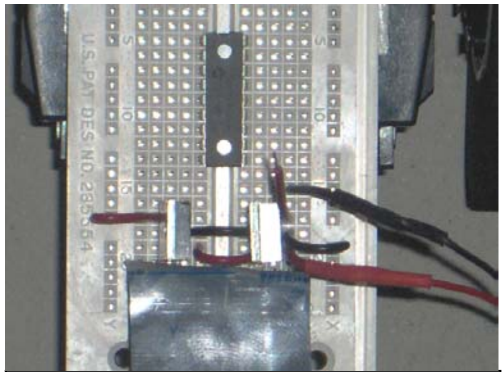
Step 36: Now plug the positive (red) wire from your 9-Volt battery snap into Pin 1 on the right-hand 7805. For now plug the negative lead (black) into a hole two or three above the 7805.



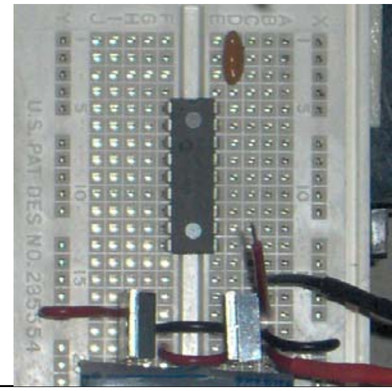
Step 37: Jumper Pin 1 of the 7805 on the right to Pin 1 of the 7805 on the left with a 1.5" (preferably red) piece of 22-gauge solid-core wire stripped ¼" off each end.



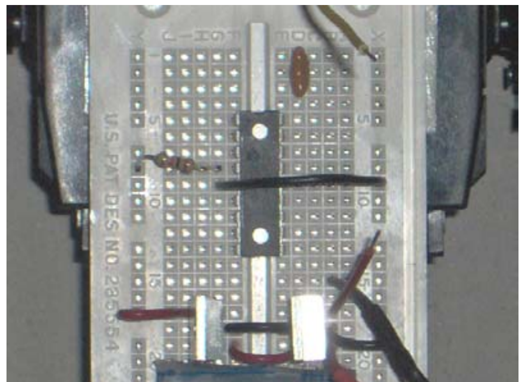
Step 38: Take a 1.5” piece of 22-gauge solid wire (black) and jumper the center pin (Pin 2) on the right-hand 7805 to the negative rail. Now connect Pin 2 (center) on the right-hand 7805 to the center Pin on the left-hand 7805. Of course strip ¼” off the end of each piece of wire. The 7805 on the left will power the servos. Put a 1.5” piece of 22-gauge solid wire (red) into Pin 3 on the 7805 and the positive rail (the column of holes along left side). The 7805 on the right side will be used to power the PIC-chip or “brain” put a 2” piece of red 22-gauge solid wire into Pin 3 and leave the other end unconnected for now.



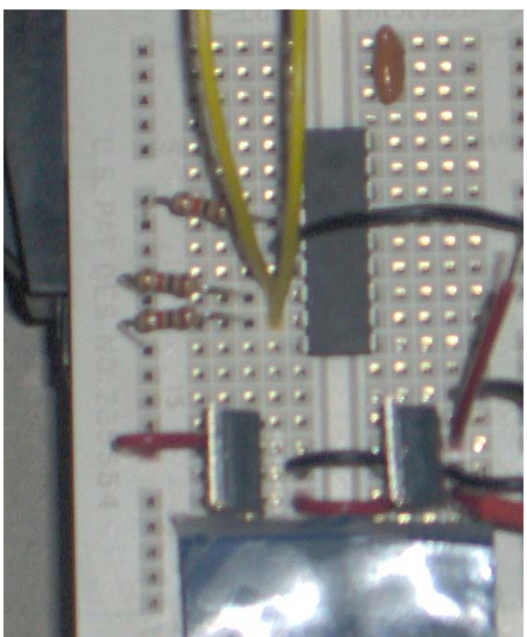
Step 39: Take the PIC16F628; orient it with the notch up on the package. Pin 1 should up and to the left.



Step 40: Plug 4MHz resonator into the first three rows of the solderless breadboard.

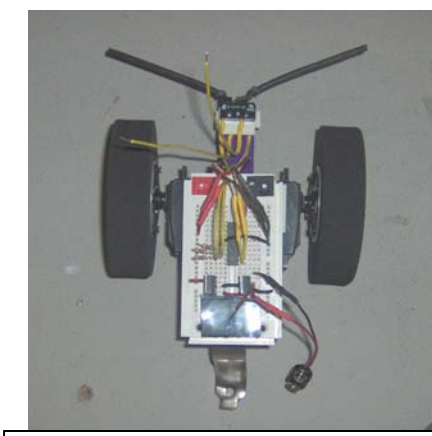


Step 41: Pin 4 – 10K Ohm resistor to +5 Volts Pin 5 – Ground (2” 22-gauge solid wire; black; stripped ¼” at each end)

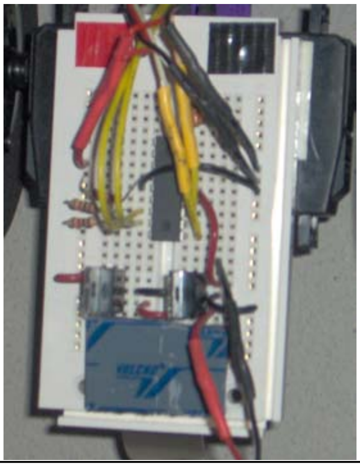


Step 42: Pin 7 – 10K Ohm resistor to +5 Volts and one wire from the right snap-action switch Pin 8 – 10K Ohm resistor to +5 Volts and one wire from the left snap-action switch.

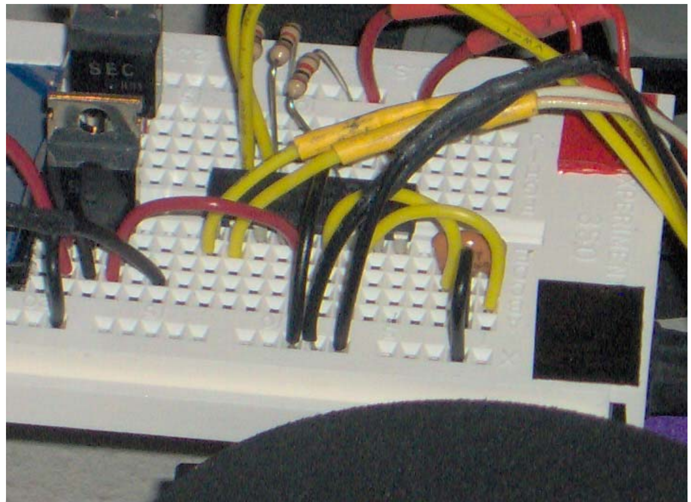
Step 43: Pin 10 – White wire from left servo; Pin 11 – White wire from right servo.



Step 44: Connect the two negative or black wires from the servos to the negative rail (black). Connect the two positive or red wires from the servos to the positive rail (red).

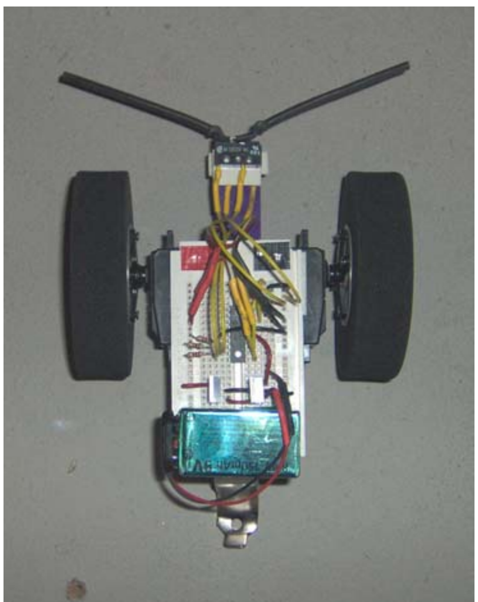


Step 45: Pin 14 – Output (red wire) from right-hand 7805.

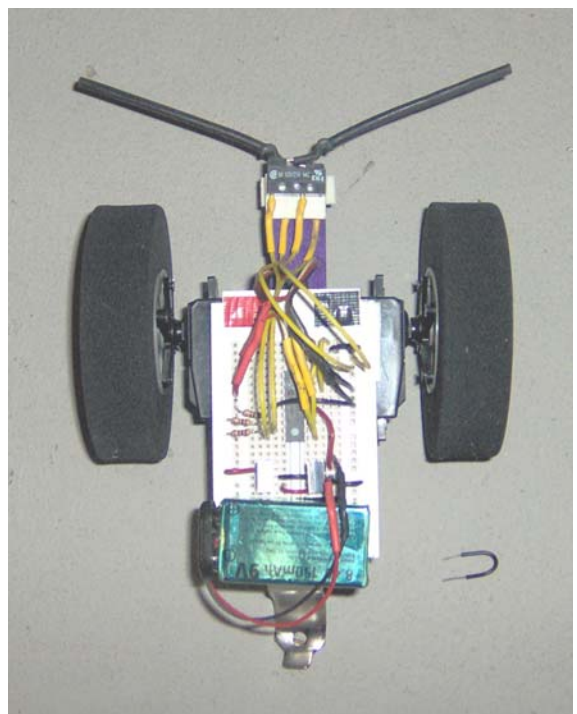


Step 46: Pin 15 – connect to pin 1 of resonator (with 3" jumper wire); Pin 16 – connect to pin 3 of resonator. Connect center pin of resonator to the ground rail (use 3" black jumper wire). Connect the two remaining wires from the snap-action switches (whiskers) to the negative rail.

Note: the microcontroller has been removed for programming.



Step 47: Attach other side of adhesive Velcro to 9-Volt battery; press onto solderless breadboard and attach battery snap. Nothing should happen yet.



Step 48: Plug in the "wire switch" between the 9-Volt black wire and the negative rail (look at the schematic). Your robot should spring to "life"; to turn him off remove the wire. You might find it simpler to just plug and unplug the negative terminal from the battery. Eventually you might want to get a Single-Pole-Single-Throw (SPST) switch (Radio Shack #276-324). Just glue or tape it to the side of the solderless breadboard.