Introducing the PROTOBot

By Camp L. Peavy, Jr.

I started building robots in 1982 from a book by David L. Heiserman, "How to Build Your Own Self-Programming Robot" (TAB Books #1241 © 1979). In this book Heiserman describes "Rodney" an 8085 microprocessor controlled device which you program with toggle switches… one byte at a time… in binary. After wrestling with this project for years I eventually applied Heiserman's Alpha level "machine intelligence" theory to a store-bought PC based robot. Since then I have built numerous amateur robots including the 1996 Autonomous Robot Wars Champion, "Gladiator Rodney" and the award winning Burning Man ARTBot "Springy Thingy".

This is an attempt to build and market an open-source, educational robot. It features Parallax's "BS2" (Basic Stamp 2) single board computer. The Stamp belongs to a special class of computer known as "microcontroller" not to be confused with "microprocessor". Microprocessors are generally designed to manipulate logical data usually for computer display. Microcontrollers on the other hand are specifically designed to sense and manipulate physical devices. Perfect for robotics! As far as microcontrollers are concerned… the "Stamp" is as easy as it gets.

Don't let this simple little robot fool you. One is not limited to building a tabletop robot with the Stamp computer nor is one limited to using a single microcontroller per robot. One of my favorite techniques is to use multiple Stamps (a Stamp network) on a single robot each communicating with a "master" Stamp the status of its assigned sensor(s) in parallel! While some might consider this expensive I think it is a good value compared to the learning-curve and actual expense of alternative strategies.

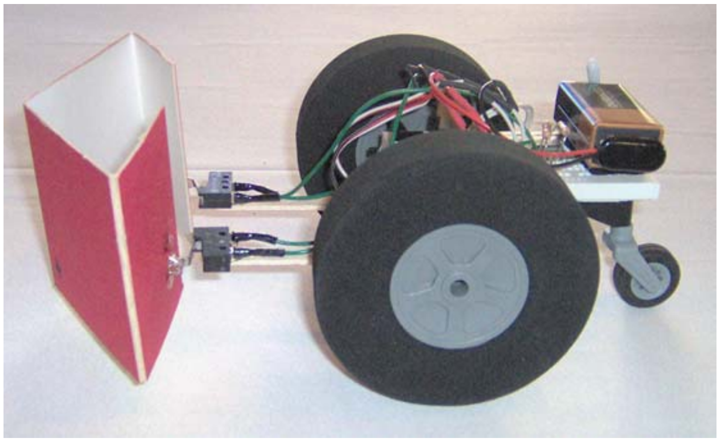

Figure 1: The PROTOBot: A hobbyist's starter robot featuring the BS2 "Stamp" computer.

Be aware the PROTOBot (Figure 1) is not a slick finished kit. It is truly "homebrewed" as it was assembled from off-the-shelf parts and materials. After assembly it is easily unassembled and rearranged into your own homebrew creation as the parts are generally useful and many of the instruction techniques involve "rubberbands and bailing wire". For the beginner the PROTOBot is an excellent introduction to the exciting future of robotics. The only prerequisite is the ability (or at least the desire) to solder and a multimeter; for the experienced builder it's just plain fun!

I hope you enjoy building the PROTOBot and let's keep in mind the reason we build robots… because they aren't going to build themselves, yet.

Fully assembled PROTOBots, kits, parts and support are available through <www.camppeavy.com>. Questions, problems or comments about the PROTOBot should be addressed to camp@camppeavy.com.

Checklist:

1. Build the programming cable
2. Build the chassis
3. Prepare drive wheels
4. Install Stamp
5. Build power cable
6. Install 7805 voltage regulator
7. Wire-up servos
8. Install drive wheels and caster
9. Program I (output)
10. Prepare micro-switch sensors
11. Mount bumper
12. Program II (input)
13. Install on/off switch
14 What's next?

Parts List:

1. Solderless breadboard	Radio Shack (RS) #276-175	$8.39
2. Stamp Computer	Parallax BS2 “Stamp” computer	49.00
3. Two modified servos	Parallax #900-00008	26.00
4. 3.5” Drive wheels	Dave Brown Products #WH35	6.25
5. Caster wheel	Klett Plastics 1” tailwheel and fork	8.95
6. Tailwheel Bracket	Dubro Tailwheel Bracket #376	2.89
7. 1/8” wheel collar	(4) DuBro #139	1.40
8. Heavy-duty battery snap	(5) RS #270-324	2.59
9. 9-Volt battery	Any brand	2.50
10. 7805 voltage regulator	RS #276-1770	1.59
11. 10K 1/4W resistors	(5) RS#271-1335	.99
12. Two micro-switches	Cherry #E61	.98
13. #22-Gauge solid wire	RS #278-1221	5.49
14. Bumper	Be creative find something!	Free!
15. 1” Sticky Velcro	ACE Hardware #90075	2.39
16. Heat-shrink tubing	RS #278-1627B	2.39
17. Two Popsicle sticks	Any flavor or craft store	.02
18. On/off switch	SPST switch (RS#275-324)	2.99

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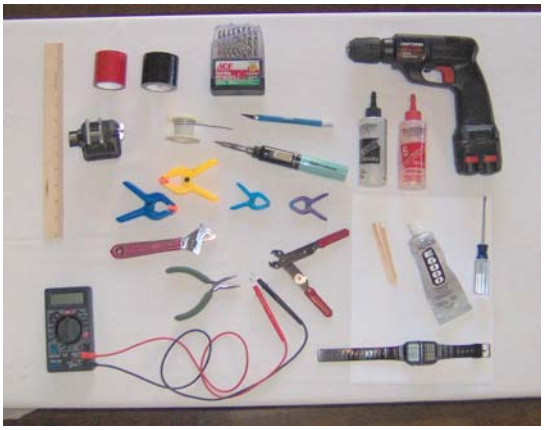

Figure 2: Other tools and materials that you will need. Clamps are useful for keeping things together while glue is drying.

Other tools and materials that you will need are a multimeter, power drill, wire-stripper/cutter, soldering iron w/ solder, small Phillips screw driver, duct tape, E6000 industrial adhesive (Shoe-Goo will do), "Quik-cure" 5 minute Epoxy and clamps (Figure 2). In addition you will need a computer connected to the Internet (to download the PBASIC editor software and Basic Stamp reference manual from www.parallax.com) and a serial cable that you're willing to sacrifice for the cause. If your machine does not have a serial port you can use a USB to serial converter. If you are purchasing a cable I would advise one with all 9 pins wired (mouse or serial extension cable). Once the software is downloaded even an old beater DOS machine will do as there is a DOS version of the PBASIC programming language.

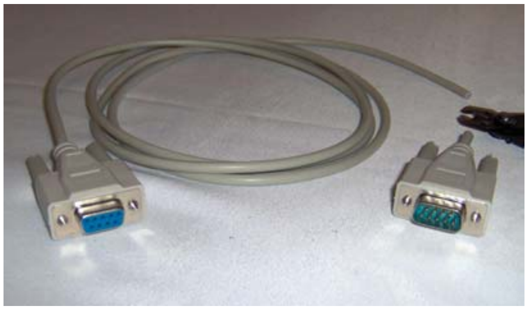

Figure 3: cut off the end opposite the DB9 pin female connector. If you're using a modem cable the cut end will be a DB25.

1. Build the programming cable

To build the programming cable first you'll want to cut off the end opposite the DB9 pin female connector (Figure 3). Double-check before you cut and make sure to get the right end and don't cut too short! If you're cutting a modem cable the hacked end will be a DB25. Regardless, the point is to cut off the end opposite your computer's interface. The necessary pins for programming the Basic Stamp are 2, 3, 4, 5, 6 and 7; which correlate with Rx, Tx, Reset, Ground, DSR and RTS respectively on the serial interface (Figure 4). The best way to do this is strip all the ends of the wires on the cut end (Figure 5) and Ohm them out with a multimeter or continuity tester to the DB9 female connection (Figure 6). Put a paper clip or piece of

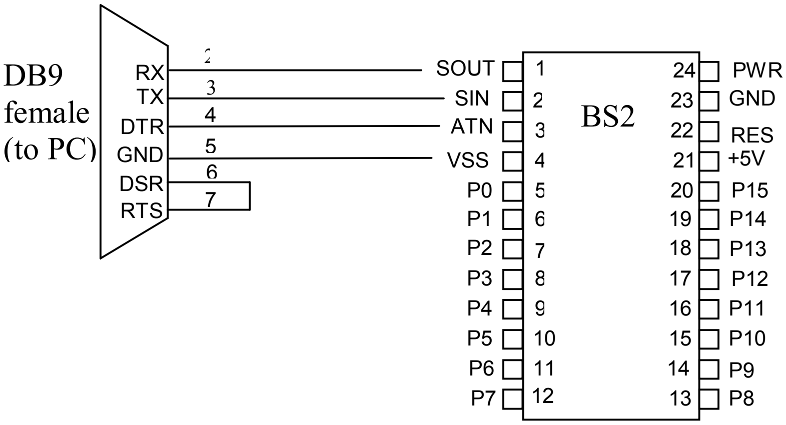

Figure 4: The programming cable connections from a PC to the BS2 Stamp.

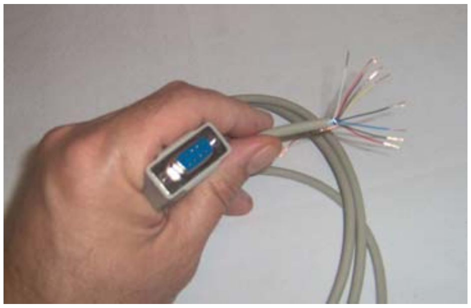

Figure 5: Strip the individual wires on the cut end.

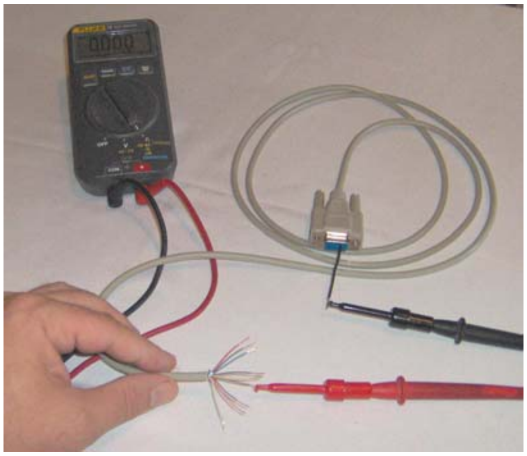

Figure 6: "Ohm" all the wires to find pins 2, 3, 4, 5, 6 and 7.

#22-Gauge wire into each DB9 female socket and check all the wires at the other end until the meter "beeps". Again, you are looking for pins 2, 3, 4, 5, 6 and 7. Double-check your pins and wires. You can see the numbering of the pins in the socket of your DB9 connector. You may need a light and/or magnifying glass (Figure 7). Solder a 1.5" piece of #22-Gauge solid core wire (not stranded!) with ¼" stripped off of each end to the wires associated with pins 2, 3, 4 and 5 (Figure 8). Solder the wires associated with pins 6 and 7 together. You'll also need to insulate the wires after soldering to prevent short circuits (Figure 9). If you don't have heat-shrink tubing use duct tape. Don't let anything stop you from building this robot! What initially seems complicated is nothing more than many simple concepts and processes. Too many good robots die from minor hang-ups. The hardest step is getting started. The next hardest step is the next step and then the next and the next... if you can just keep taking small steps you will eventually have a completed robot. Try not to think about the entire project and focus on just the next step. Remember, "Good enough is good enough". You can always improve it on the next iteration. You weren't going to just build just one robot and quit were you?

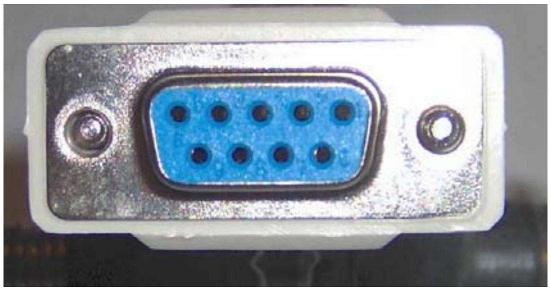

Figure 7: If you look closely at your female DB9 connector you can read the numbers. You may need a light and/or magnifying glass.

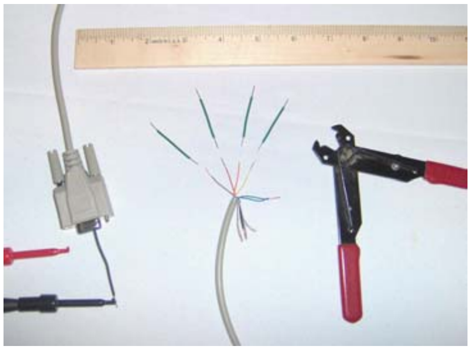

Figure 8: Solder 1.5" inch 22-Gauge solid core wire to pins 2, 3, 4 and 5 and solder the wire from pins 6 and 7 together. Fold the other wires including the uninsulated ground wire back and cut them. They are not used.

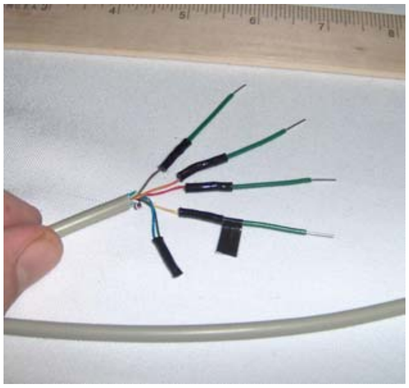

Figure 9: Insulate the solder joints with heat-shrink tubing. If you don't have heat-shrink tubing use duct tape.

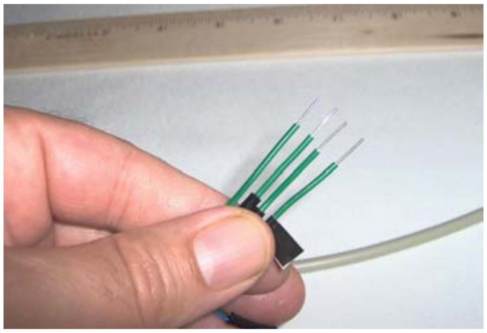

Figure 10: You may need to re-cut and re-strip the wires so that they are even. Tag or label the ground pin (5) with black tape and maintain the order as these 22-Gauge wires will be plugged into pins 1-4 on the Stamp.

Tag or label the ground pin (5) with black tape or a label to indicate that this is the wire to plug into pin 4 on the BS2 (GND). You may need to re-cut and re-strip the wires so that they are even (Figure 10). Be sure and maintain the order of the wires (2, 3, 4 and 5) as they will be plugged into the Stamp's pins 1, 2, 3, and 4 respectively. If you line them up in order and plug them into the breadboard, anywhere, not skipping a hole (Figure 11) and wrap a piece of duct tape around it makes a decent plug and saves buying a special programming board plus I think it's easier to apply to other creations (Figure 12).

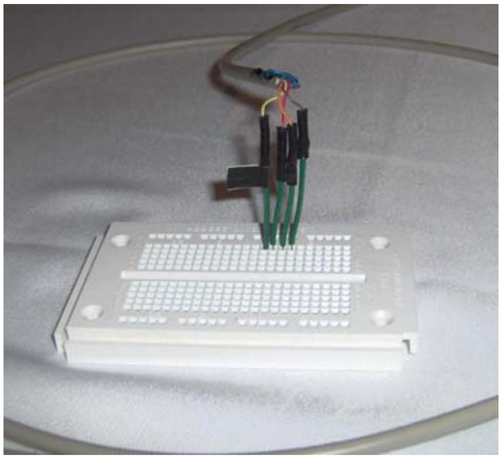

Figure 11: Plug the wires into the breadboard making sure to maintain the order of the pins.

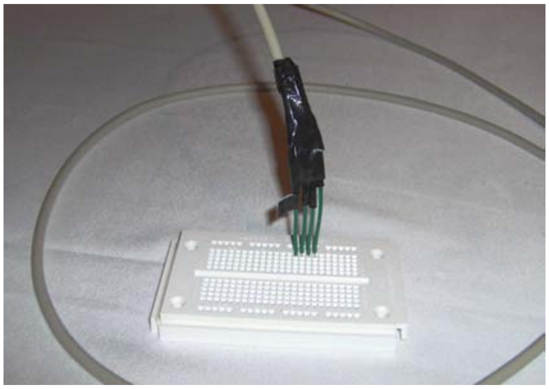

Figure 12: Wrap duct tape around the cable and press flat. You are trying to create a little 4 pin plug to plug into pins 1-4 on the Stamp computer.

2. Build the Chassis

After making the cable the next step is building the chassis. If you think about it all we're trying to do is put a solderless breadboard on wheels. Normal RC servos are limited to 90-degree rotation. For the PROTOBot we need "continuous rotation" servos. There are several websites that describe how to modify a standard servo (Futaba S148, S3003, etc) into a gear motor. Do a search for the key words, "modify servo". Otherwise pre-modified (continuous rotation) servos can be acquired through Parallax (#900-00008). If you decide to roll-your-own I'd suggest you test them before gluing them to the chassis. Other ways to mount the servos are double-stick tape or Velcro but glue makes it permanent. I use and suggest an industrial strength adhesive called E6000 (Figure 13). No kidding this stuff is right up there with Velcro and duct tape. I like it because it is very strong, shock resistant plus if you want a "redo" you can remove the servo (or whatever) and just peel the adhesive off. It's like a really strong rubber sealant. The drawback is it takes 24 hours for a maximum strength bond. On the other hand it's usually good enough after a few hours. Before gluing the modified servos to the breadboard remove the servo horns from the servos

Figure 13: E6000 industrial/craft adhesive

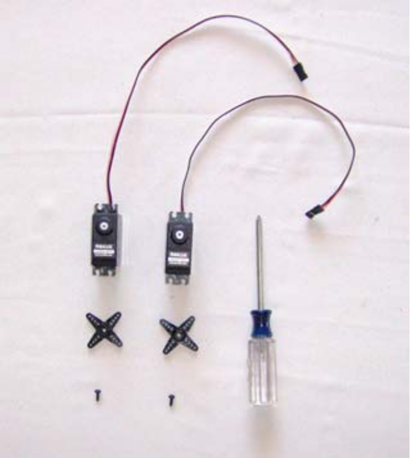

Figure 14: Remove the servo horns from the servo. Eventually we will glue them to the center of the 3.5" foam wheels.

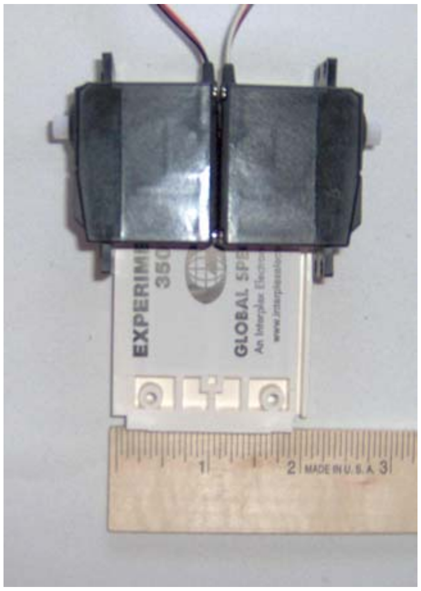

Figure 15: Put the servos end-to-end. They are the perfect width (2”) for the breadboard. You can line them up using the servo mounts as guides along the side. Use the edge along the front. Notice the gears are forward. Before you glue make sure the breadboard is oriented with the “Experimentor 350” label on top towards the front (see Figure 25).

(Figure 14). If you put the servos back-to-back with the drive gear facing outward they are the exact same width as the breadboard (2”) (Figure 15). It doesn’t really matter but to be consistent be sure the breadboard is oriented the way you want it to face. In other words the “Experimentor 350” label on top (the side with the holes) should be near the front (see Figure 25). The servo mounting brackets (ears) lineup perfectly with the sides of the protoboard. Simply move the servos as far forward as possible without hanging over the edge. While you’re at it you should glue the tailwheel bracket but before you do that we need to drill it out. The standard caster wheel from “DuBro” I found to be unsatisfactory especially when compared to the “Klett Plastics” wheel. However Klett tailwheels are hard to find (RC plane hobby stores) and if you do find one it includes unnecessary mounting hardware and costs twice as much. You can call Klett at 817-731-3153 ask for the “one inch tailwheel with fork”. They will send you one for about $9. Be sure and tell them you’re building a robot! Alternatives include hardware store casters, a ping-pong ball, a simple skid or perhaps a leftover tailwheel or caster from an old RC plane or toy. Don’t let anything keep you from finishing this robot! Drill the DuBro tailwheel bracket shaft to 9/64” so to accommodate the 1/8” Klett Plastics fork shaft (Figure 16).

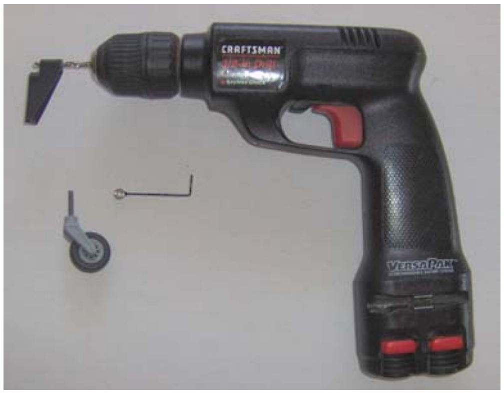

Figure 16: Drill out the bracket shaft to 9/64” so to accommodate the 1/8” Klett Plastics fork shaft. Drill it out before gluing!

Put a dab of E6000 on each servo and the tailwheel bracket (Figure 17) and place them on the breadboard (Figure 18).

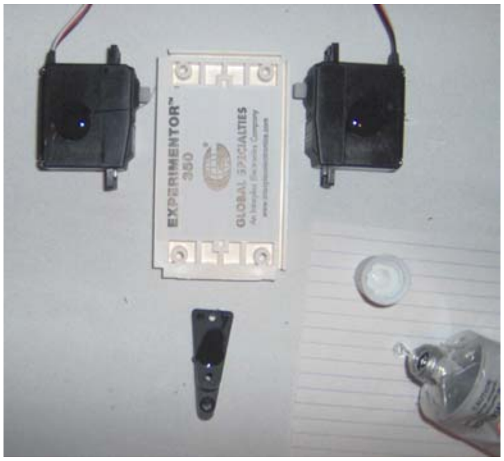

Figure 17: Just a dab'll do ya. Be sure and apply glue to the correct sides of the servos. Remember the gears will be facing outward.

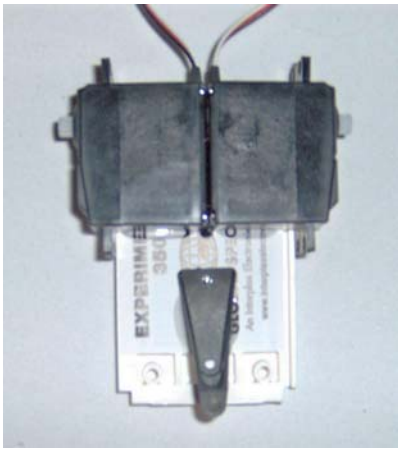

Figure 18: Place the servos and tailwheel bracket on the breadboard. Center the tailwheel bracket and make it flush with the rear edge.

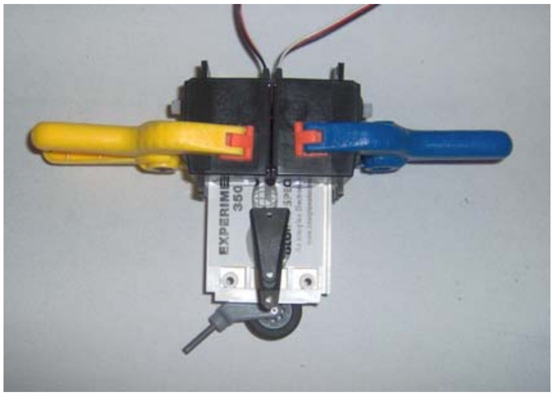

Figure 19: I told you those clamps would be useful. There's enough surface area on the tailwheel bracket so it doesn't need clamping. Just keep it level so it doesn't slide. That's what I'm doing here with the tailwheel.

Clamp the servos to the bottom of the breadboard. There's enough surface area so you shouldn't have to clamp the tailwheel bracket plus it's at an odd angle there really isn't any good place to clamp it. Just keep it level so it doesn't slip and let it dry overnight for best result (Figure 19). If you're in a real hurry (the contest is tomorrow!) use "Quik-cure" Epoxy (Figure 20). It dries fast but becomes brittle over time. You might consider a composite approach. Don't mix the epoxy and E6000 directly but use the E6000 in the center and a little epoxy in the sides or corners. This way you can get to work right way (thanks to the 5 minute epoxy) and it'll be adhered with the more resilient E6000 after 24 to 72 hours.

Figure 20: Quik-Cure 5 minute epoxy. REAL popular for RC planes!

Think of yourself as an artist having a glue "palette". Mix a little epoxy at the top, a little E6000 at the bottom. Use a craft "picks" and "sticks" as brushes. Do not touch this stuff with your fingers and be sure and keep the room well ventilated. We'll be using the epoxy when we mount the bumper.

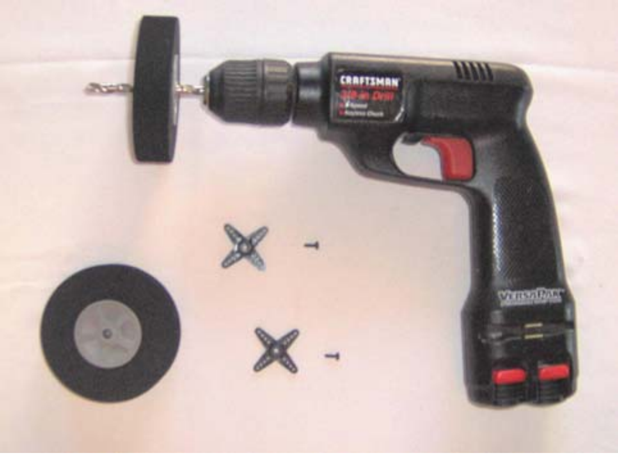

Figure 21: Before gluing the servo horn to the wheel drill out the wheel to 1/4" so the servo screw can pass through. Do this before gluing the servo horn to the wheel!

I usually try and do my gluing late at night so I can set it and go to sleep. By morning it will have bonded. Building homebrew robots is a greatly satisfying pastime. Take your time. Do a good job. On the other hand if it comes down to making it pretty vs. just getting it done… just do it! You can make it pretty later. Be creative. Try different things. Find what you like.

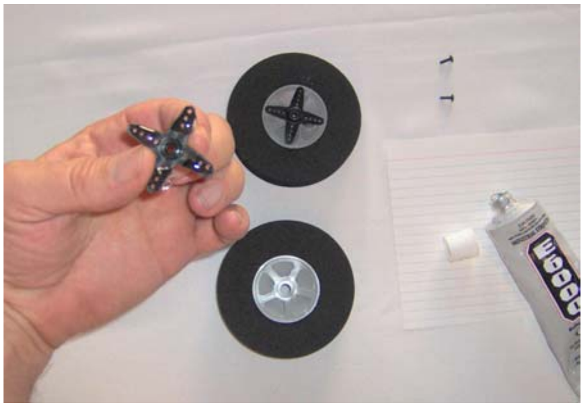

Figure 22: Put a dab of E6000 on each leg of the servo horn. Be sure and apply glue to the side opposite the cap into which the servo plugs.

3. Prepare Drive wheels

The servo horns will be glued to the 3.5" foam airplane wheels. Again I strongly recommend E6000 as the adhesive. Before you glue the servo horns to the wheels you will need to drill out the wheel to 1/4" so the servo screw can pass

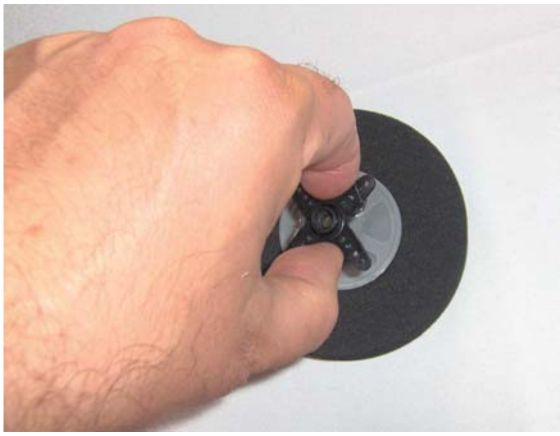

Figure 23: Place the horn on the wheel (cap facing up). You can center it by aligning the four spokes with the outer rim of the hub. Let it sit overnight to cure.

through (Figure 21). Make sure and center the horn and don't get any glue in the hole. The servo screw will go through the wheel to attach it to the servo. Put a dab of E6000 on each leg of the servo horn. Be sure and apply glue to the side opposite the cap into which the servo plugs (Figure 22). Make sure the horn is centered and flat or you'll have a warped wheel. If you just center it by eye-balling the center-hole and outer rim and let it "sit" it will dry flat. (Figure 23) The servo horn spoke's tips end with the rim of the wheel making it relatively easy to center (Figure 24).

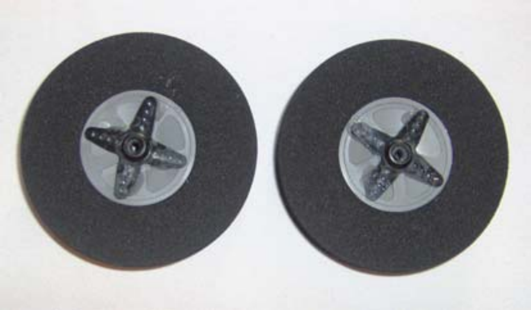

Figure 24: Be sure and glue the servo horn with the cap facing upward. The servo horn spokes end with the rim of the wheel making it easy to center.

4. Install Stamp

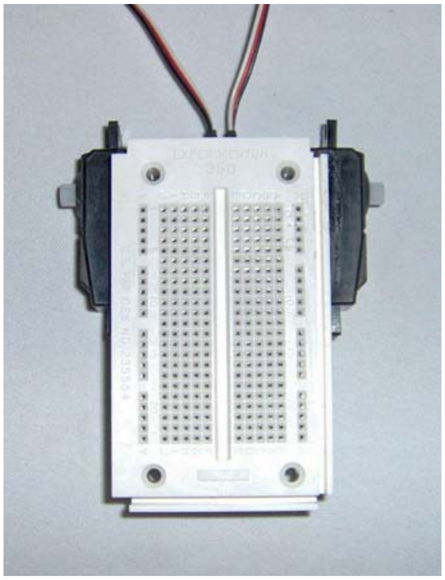

Figure 25: The "Experimentor 350" solderless breadboard is laid out in .1" centered "holes" (A-J) with 5 common tie points on each side of center. The two columns along each side (X, Y) are used to supply power (positive (+) and negative (-)).

Now it is time to install the Stamp computer into the solderless breadboard. Solderless breadboards are designed for quick design and testing. They have .1" centered "tie points" or "holes" which can be jumpered or connected with #22-Gauge solid core wire without soldering hence the name "solderless". Notice the layout of the board (Figure 25). If you hold the board upright with the "Experimentor 350" heading upward you'll notice a grid with the rows labeled "1-23" and the columns "A-J". There is a column along the sides labeled "X" and "Y". These are used for power and ground. I recommend the Global Specialties "Experimentor 350" because of its small size and availability (Radio Shack #276-175) (Figure 26).

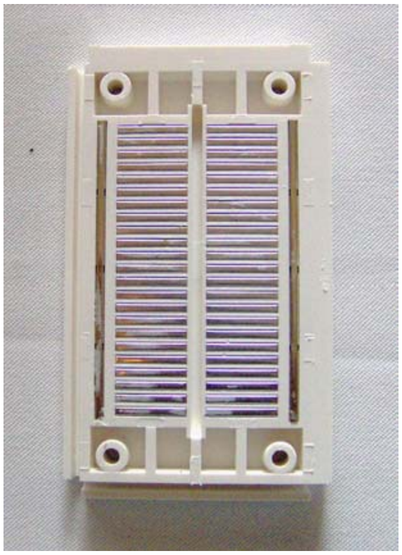

Figure 26: Here I've peeled away the bottom sticker to reveal the underlying connections. Notice the common connection (metal) between the 5 tie points on either side of center and the X and Y power (+) and ground (-) columns along the sides.

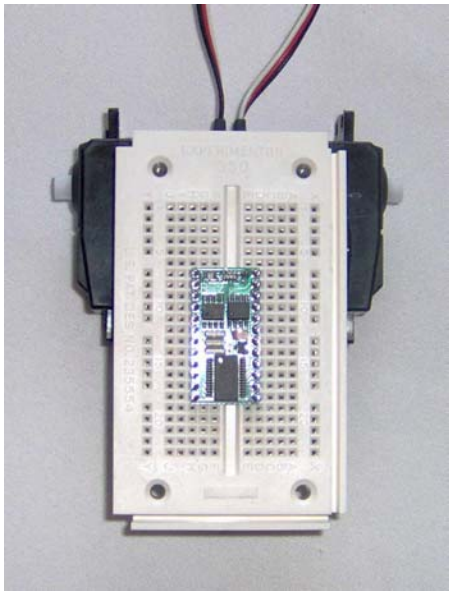

Figure 27: The Stamp computer plugged into the solderless breadboard (hole 7H).

It isn’t necessary that the Stamp computer be centered on the board. In fact it can’t be due to the width of the Stamp’s package. Most chips are .3” wide so they straddle the center of the board perfectly. The Stamp is .6” so one side is going to have 1 more row than the other. When you push the Stamp in you should try and get both pins in at once but one side might “pop” in first and then you have to push in the other side. If you can’t push in the other side try both sides at once again. It’s tight. Be sure and not bend the pins as you push it in. If needed pry it out with a small screwdriver and straighten the pins with needle nose pliers. Be sure and observe the direction of the chip and not plug it in upside down. Plug it in with the letters “BS2” facing up and the label “Experimentor 350” on top. I have plugged Pin 1 on the Stamp (Figure 29) into hole #7H on this particular board (Figure 27).

5. Build power cable

After mounting the Stamp it is time to build the power cable (Figure 28). Take the 9 volt battery snap connector (Radio Shack #270-324) and cut the black and white wires to 3” to and solder two 1.5” pieces of #22-Gauge solid core wire (red and black preferred but don’t let that stop you) to the end of each snap wire. This to make the wires so that they can be plugged into the breadboard the same way we did with the programming cable. After soldering the wires you’ll need to heat-shrink or duct tape over the solder joint so the wires don’t touch and cause a short-circuit. The Stamp can be powered from between 5-15 volts. We’re going to be running it from a 9 volt battery. The positive or red wire goes into Pin 24 on the Stamp and “ground” or the black wire goes into Pin 23 (Figure 29). Be sure and not plug them in backwards or you could damage the Stamp! Until we get the on/off switch wired in you’ll turn the PROTOBot on and off by plugging in and removing the red or positive wire.

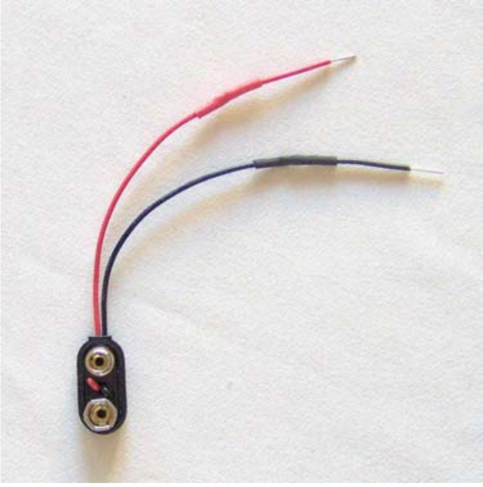

Figure 28: Cut the battery snap wire to 3” and solder a 1.5” piece of 22-GA solid core wire to the ends the same way we did the programming cable. Insulate the solder joints to prevent short circuits.

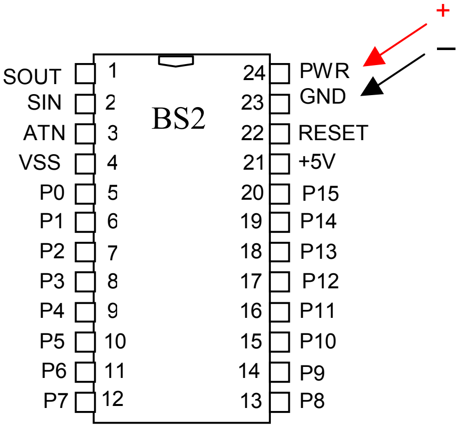

Figure 29: We’re going to be running the Stamp from a 9 volt battery. It could be run from between 6-15 volts. The positive or red wire goes into Pin 24 on the Stamp and “ground” or the black wire goes into Pin 23.

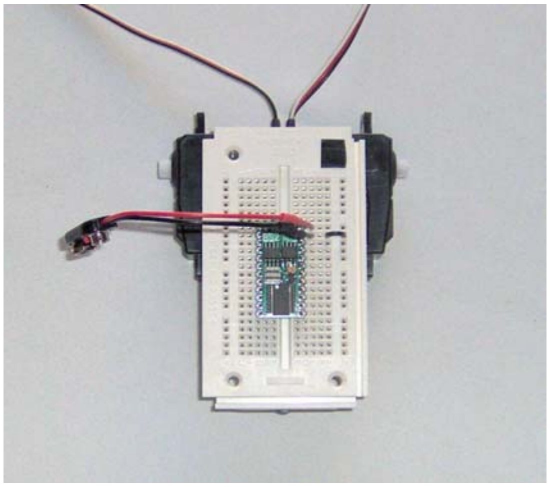

Figure 30: Power cable plugged into Stamp and black wire jumpered to "X" rail for common ground.

Next jumper the ground pin 23 on the Stamp (GND) to one of the rails that runs along the side of the protoboard (Figure 30). This will become the "common ground" between the 9 and 5 volt sources. Mark it with a small piece of black duct tape. Now anytime we need a ground connection we can just use the "X" column. Eventually the "Y" column will be used for +5 volts so if you have it you might as well put a small piece of red duct tape above it. If you don't have colored duct tape you can use red and black permanent marker. This just helps you keep track of which rail is positive and which is negative. At this point stick a 1" piece of adhesive Velcro horizontally along the bottom of the breadboard for the battery but don't connect the battery yet (Figure 31).

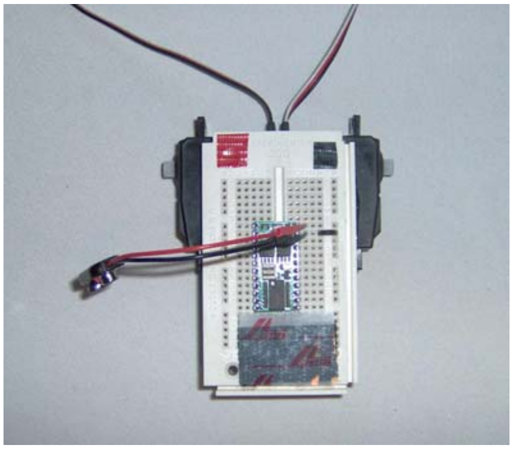

Figure 31: Velcro added for 9 volt battery attachment and red duct tape denotes the positive rail.

6. Install 7805 voltage regulator

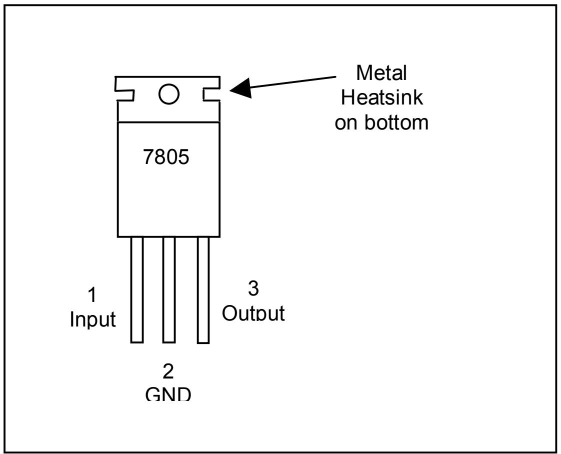

Figure 32: With the 7805 heatsink facing downward the pins are numbered 1, 2, 3. Pin 1 is the voltage input. Plug the 9 volt battery positive connection into it. Pin 2 is ground; jumper it to your negative rail (X). Pin 3 is the 5 volt output; jumper it to your positive rail (Y). It will supply +5 volts to the servos.

Before we can test the servos we need to make a power supply for them. RC servos run on 5 volts so the 9 volt battery would be too much. Some robot kits use a separate 6 volt power supply that consists of 4 AA batteries. For the PROTOBot we're going to minimize weight and part count by using a 7805 voltage regulator (Figure 32). Normally it is not a good idea for your logic (computer) and drive motors to be powered by the same source because power draw from the motors could cause erratic operations on the logic side but in this case the parts and weight tradeoff is worth it. Plug the 7805 vertically above the Stamp (Figure 33) the heat-sink is

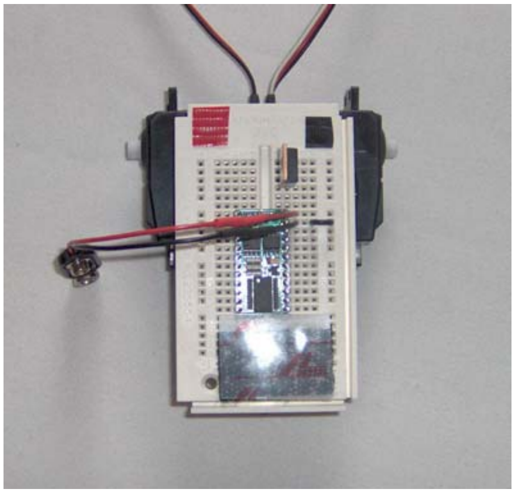

Figure 33: Plug the 7805 voltage regulator in vertically just above the Stamp. Work it in slowly as it is a tight fit.

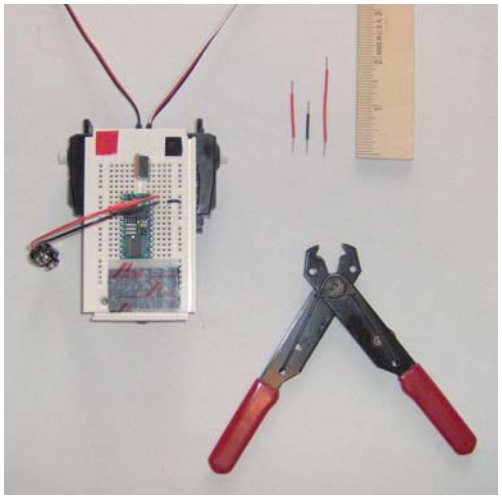

Figure 34: Cut 3 pieces of 22-Gauge solid wire (1 red - 1.5”, 1 black - 1”, 1 red – 2”) to connect the 7805 voltage regulator.

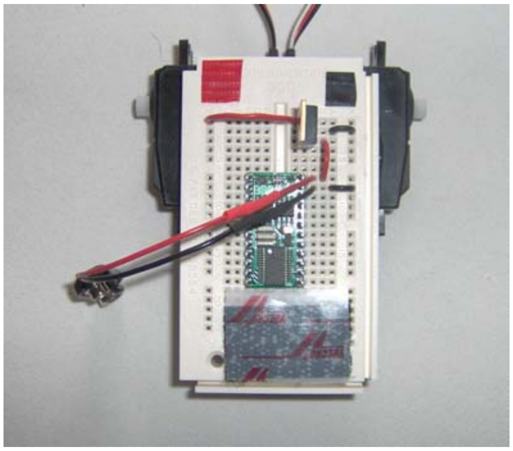

Figure 35: Pin 1 (input) on the 7805 goes to positive +9 volts, pin 2 (GND) goes to ground (X) and pin 3 (output) to the +5 rail (Y).

facing left. Pin 1 (voltage in) is the bottom pin. Work the 7805 in slowly as it is a tight fit. In this case Pin 3 on the 7805 goes into hole #1D. Cut 3 small pieces of #22-Gauge solid core wire (1 black - 1”, 1 red - 1.5”, 1 red – 2”) to make the following connections. It would be preferable to have red and black wire but any color will do (Figure 34). Use the 1.5” piece of red #22-Gauge solid wire for pin 1 (voltage in) and connect it to pin 24 on the Stamp (Figure 29); the same pin as the 9 volt battery snap. Use one of the vacant holes. The center pin on the 7805 goes to “ground”. You can simply connect it to any hole along the “X” rail. The third or top pin is voltage out. In this case that would be 5 volts. Use the 2” red wire to jumper it to the “Y” rail; use hole #1E so you don’t have to bend the wire around the regulator’s leg. This rail will supply power for the servos (Figure 35).

7. Wire-up servos

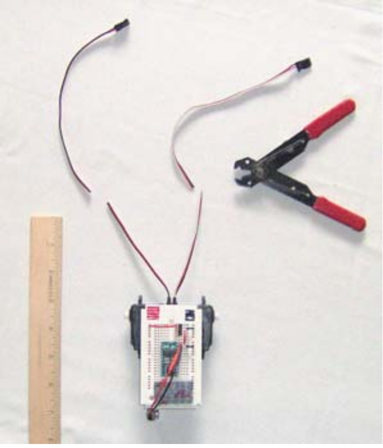

Figure 36: Cut the servo cable so that it’s 4” long.

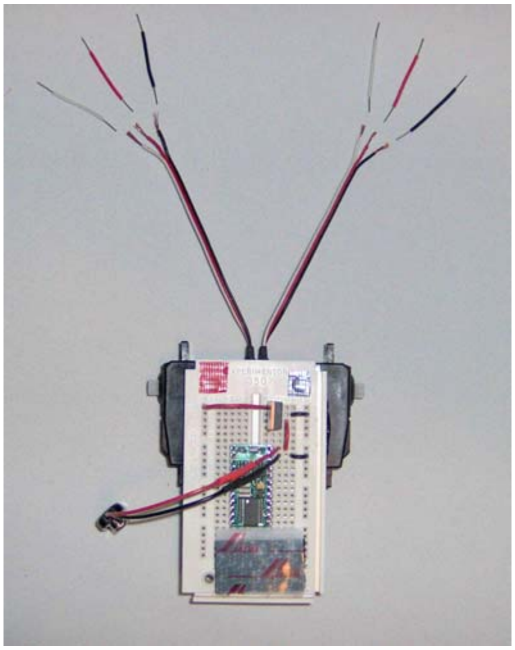

Figure 37: Cut 1.5” lengths of 22-Gauge solid core wire like we did with the programming cable and battery wires

Now we need to modify the servo connectors so they can be plugged into the breadboard. First cut the servo cables to 4” in length (Figure 36). Next cut 1.5” lengths of 22-Gauge solid core wire like we did with the programming cable and battery wires (Figure 37). Solder the 1.5” 22-Gauge solid core wire to each servo wire preferably using red for positive, black for negative and white for signal or at least a different color than red or black. Do the same with the other servo (Figure 38). Insulate the wires to prevent short-circuits (Figure 39). Plug the red wires from each servo into the positive terminal strip (the “Y” rail);

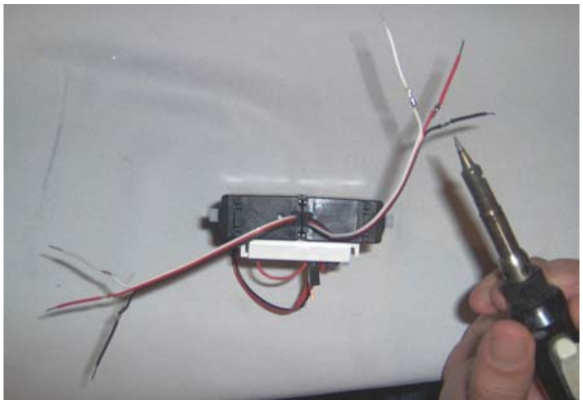

Figure 38: You can set the chassis on end to solder the servo wires. This is a good opportunity to mention one of my favorite tools, the Weller "PYROPEN" butane soldering iron. It's portable and makes a "hissing" sound so you never forget to turn it off.

which you have designated by marking with a red piece of duct tape. Plug the black wire from each servo into the negative column ("X"). Finally plug the signal wires from each servo into pins 5 and 6 on the Stamp computer. That is the left servo in Pin 5 and the right servo into Pin 6 (Figure 40). If you look at diagram of the BS2 microcontroller (Figure 29) you will notice that pins 5 and 6 correlate with data pins 0 (P0) and 1 (P1). What we will effectively be doing is sending pulses to the servos through these pins in order to make the servos go forward, reverse or stop. After plugging in the battery all one needs to do to start programming the Stamp computer is to plug in the programming cable that we built earlier, type in a program and download. The Stamp will run that program whenever power is applied. What makes the Stamp computer so easy to use is the all-in-one PBASIC editor, compiler and programmer. In other words with other microcontrollers you generally program in "C" or assembly language, compile the code with a compiler (which costs) and burn the EPROM in a burner (which costs more). Furthermore the inevitable troubleshooting would require re-writing code, re-compiling and re-burning as opposed to the interactive programming experience of the Stamp. Needless to say I am a big fan of the Stamp although it is not without its limitations; specifically bandwidth and IO ports. In terms of bandwidth for the basic PROTOBot configuration a lot of CPU cycles will be spent driving the servos. In a more advanced iteration one might use a "servo controller" to offload the pulses from the main controller but to begin with let's just get something moving around.

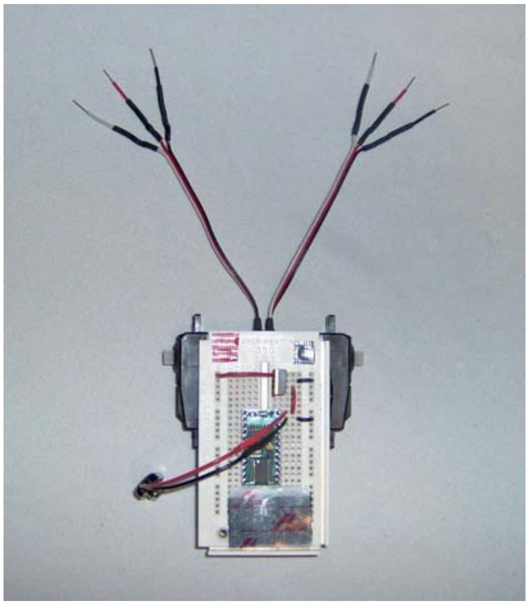

Figure 39: Insulate the solder joints to prevent short-circuits.

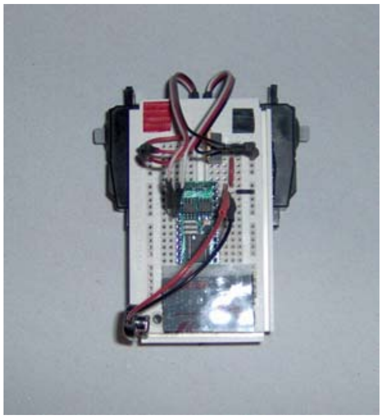

Figure 40: The servo wires plugged into the breadboard.

8. Install drive and caster wheels

Next we need to put on the drive wheels and caster. The drive wheel fits neatly on the servo drive gear. Screw it in with the supplied screw (Figure 41).

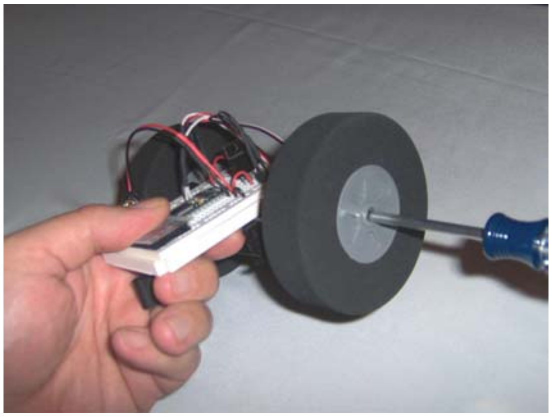

Figure 41: Screw the wheel on with the supplied screw. Hopefully you drilled the wheel out.

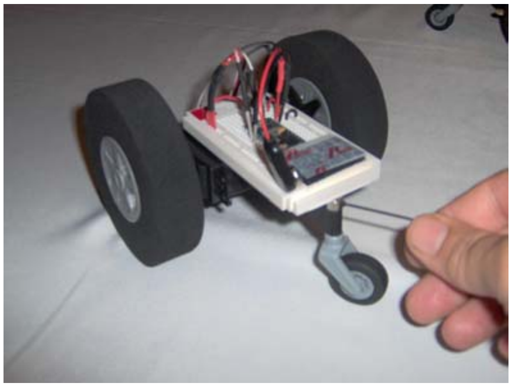

Figure 42: You'll need to use a 1/8" collar (DuBro #139) as the one that came with the bracket will be too small.

Hopefully you drilled the wheel out (Figure 21). Likewise the caster wheel fits nicely through the DuBro tailwheel mount as long as you drilled it out (Figure 16). You'll need to use the 1/8" collar (DuBro #139) to attach the tailwheel as the one that came with the bracket will be too small but the Allen key comes in handy (Figure 42). That's it! The basic chassis! Now snap-in and mount the 9 volt battery on the adhesive Velcro and let's get this thing moving (Figure 43)!

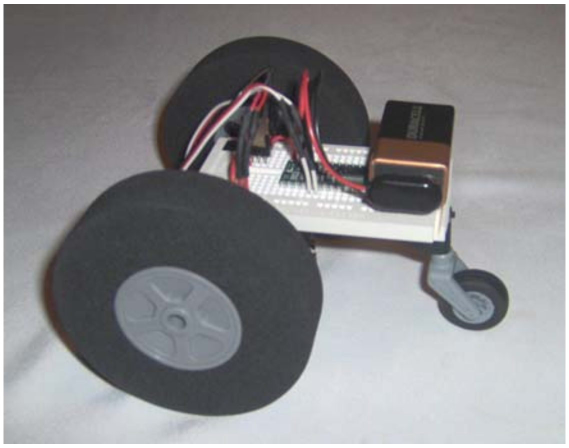

Figure 43: Now it's time for some fun!

9. Program I (output)

Download and launch the PBASIC program editor from
http://www.parallax.com/html_pages/downloads/software/software_basic_stamp.asp

Module 1

```
' {$STAMP BS2}
Fwd:
PULSOUT 0,1000
PAUSE 20
PULSOUT 1,500
PAUSE 20
GOTO fwd
```

Type the program "Module 1" into the editor. Go to the "Run" menu and select "run". This should download the program to the Stamp. Careful your new PROTOBot doesn't run off the table! If you have problems at this point check your connections, check the polarity of your programming cable (the 4 pins that you are plugging into the Stamp). You may even need to re-ohm them to verify that they are indeed 2, 3, 4 and 5. Check your power connections… did you ground pin 23 on the Stamp (Figure 30)? Did you connect pins 6 and 7 (DSR, TSR) together? If not you would need to specify the serial port when you launch PBASIC. Is the battery good? Tip: Buy a battery tester! After successfully downloading this program and removing the program cable your PROTOBot should spring to life! If it goes backwards or one of the servos doesn't actuate backtrack the wiring. Do you have the signal wire (white) plugged into the right pins on the Stamp (Figure 29)? Left and right servos signal wires should be plugged into pins 5 and 6 respectively. These pins correlate with data ports "P0" and "P1". Notice how we reference pins 0 and 1 with the "pulsout" command (Module I). To turn your robot off… unplug the power or red battery wire (+9 volts). We will build install a real on\off switch later. Now that you have "forward" you might want to try "backward" to do so simply modify the program as in "Module 2". Notice that it is just a matter of switching the "pulsout" numbers. You can also modify the program so that it turns clockwise and counter-clockwise.

Module 2

```
' {$STAMP BS2}
Fwd:
PULSOUT 0,500
PAUSE 20
PULSOUT 1,1000
PAUSE 20
GOTO fwd
```

```
‘ {$STAMP BS2}
Loop:
Pulsout 0, 750
Pause 20
Pulsout 1, 750
Pause 20
Goto loop
```

Why don’t you give it a try? These are the beginnings of the subroutines that you will use as you begin to program behaviors. Now let’s try and find the numbers that “stop” the servos. It’s a little different on each robot (and each servo) and will require experimentation. Theoretically the value “750” pulses the servos at 1.5ms which should bring the servos to the center position or in our case “stop” but I find you usually have to go up or down 10 or 20 units to really make it “stop”; write a routine using a “FOR… NEXT” loop or just manually increment up or down by manually plugging in different values. Download the Stamp reference manual at http://www.parallax.com/dl/docs/prod/stamps/BasicStampMan.pd to research “pulsout” and all of the PBASIC commands.

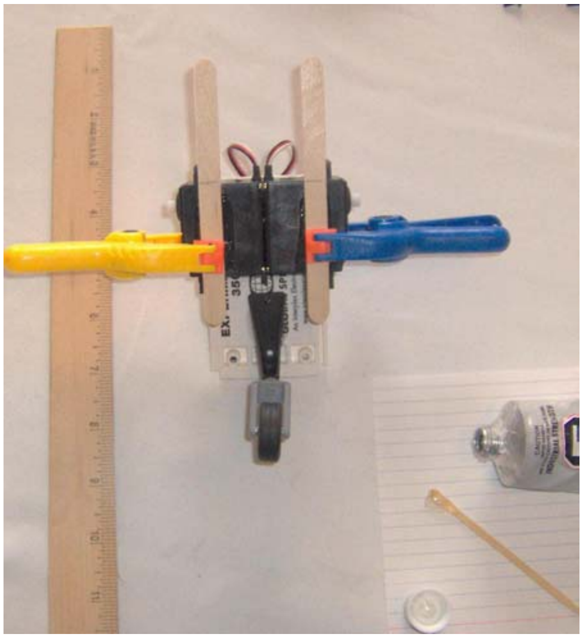

Figure 44: Take the wheels off and glue Popsicle sticks under the servos. The sticks should extend 2” beyond the front of the servos. Notice the glue pick to the lower right.

10. Prepare micro-switch sensors

Now that we’ve got a functioning robot let’s give it some sensors. First take the drive wheels off and glue Popsicle sticks under the servos (Figure 44). The sticks should extend 2” beyond the front of the servos. Solder two 6” pieces of 22 gauge solid core wire to each micro-switch (Figure 45). After the Popsicle sticks dry put the 3.5” foam drive wheels back on and place 10K resisters between the positive rail “Y” and Stamp Pins 7 and 8 (P2 and D3). On the Stamp side plug it into the hole closest to the positive rail as the ones nearest the Stamp will be used by a wire from a micro-switch sensor. Plug one wire from the left micro-switch sensor (left side w/ robot facing forward) into Stamp Pin 7 (use the hole next to the Stamp) and the other one into the negative rail “X”. Plug one wire from the right micro-switch into Stamp Pin 8 and the other into the negative rail (Figure 46). Place the switch on the tip of the stick, center it with the wires and glue into place (E6000). Be careful not to get glue in the micro-switch mechanism or it will be ruined. To that end I generally try and keep the glue towards the

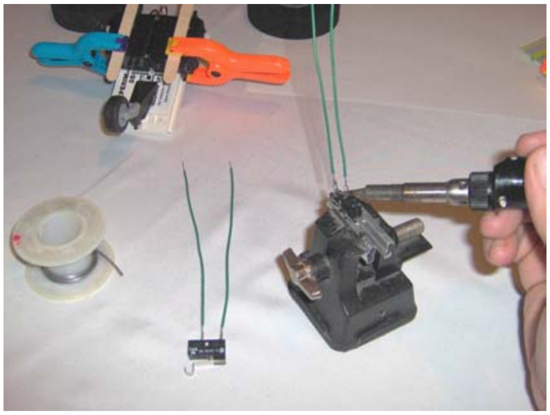

Photo 45: Solder a 6” piece of 22-Gauge solid core to each tab on the micro-switch. Cover it with heatshrink tubing to prevent short circuits.

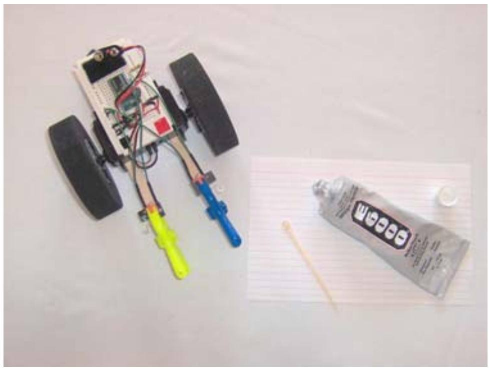

Figure 46: Put 10K resistors between the positive rail (Y) and Stamp Pins 6 and 7. On the Stamp side plug it into the hole closest to the positive rail as the ones nearest the Stamp will be used by a wire from the micro-switch.

Module 4

```
' {$STAMP BS2}
loop:
DEBUG ? IN2
PAUSE 200
DEBUG ? IN3
PAUSE 200
GOTO loop:
```

back of the switch. If you're in a hurry this would be a good time to use the Quik-Cure epoxy but for long-term use stick with the E6000. Again clamps come in handy. The Stamp has a really cool command called "debug". Debug will among other things let you see the input status of a pin. That is whether the circuit connected to it is +5 volts (positive) or 0 volts (ground). After the micro-switches dry type in and "run" the "Module 4" program. Now press switch 1 (left). Let go and press switch 2 (right). The "debug" variable (IN2, IN3) should change from "0" to "1". This is called an "active high" switch. If the signal switched from "1" to "0" when actuated then it would be "active low". Lookup the "debug" command in the reference manual for all the details. You can incorporate this "input" into your code but first we need to make a bumper.

11. Mount bumper

Cut the bumper out of matte board (picture framing stuff) or thin corrugated cardboard (Figure 47). I originally used material from a cardboard auto windshield heat-guard. I've even used holographic Mylar. Be creative! Experiment! The dimensions are 10" in length and 2.75" high. Score the bumper in the middle at 5" so that you can bend it squarely. Score two more lines 2"s in from each end to make panels to which the micro-switches will be attached. To that end cut two ¼" squares ¾" up from the bottom and ½" in from then end. This makes a nice "pad" onto which to glue the micro-switch levers (Figure 48). Bend the bumper at the score lines (Figure 49).

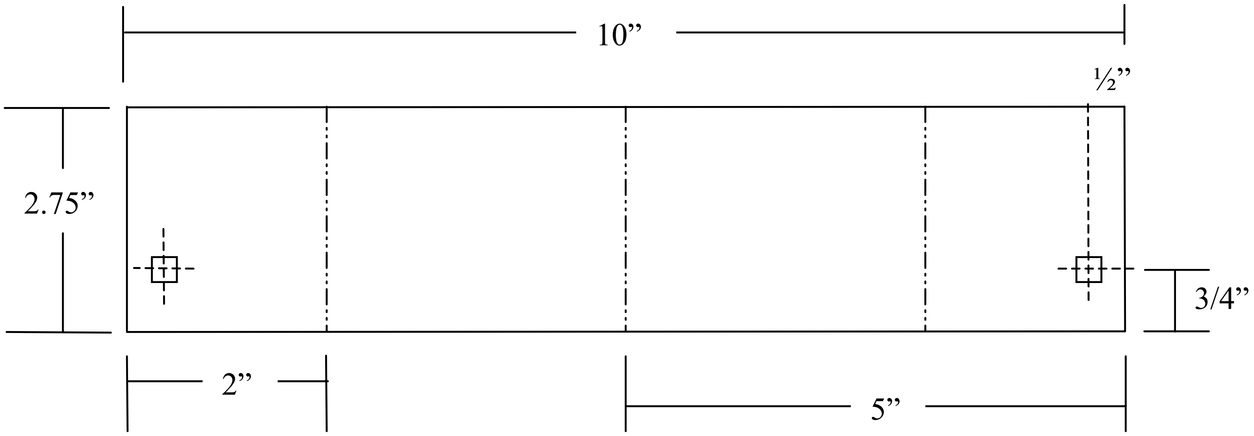

Figure 47: Cut the bumper out of matte board. The dimensions are 10" in length and 2.75" high. Score the bumper in the middle at 5" so that you can bend it squarely. Score two more lines 2"s in from each end to make panels to which the micro-switches will be attached. To that end cut two ¼" squares ¾" up from the bottom and ½" in from then end. This makes a nice pad to fit the micro-switch lever into.

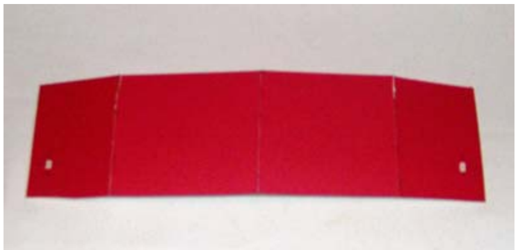

Figure 48: This is the bumper cut out of matte board. Note the ¼" squares cut out of the ends. This is where you attach the micro-switches.

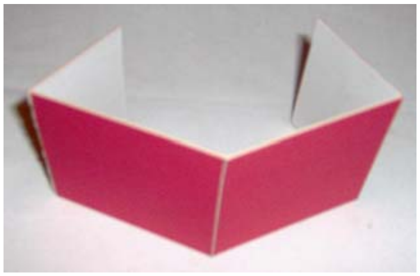

Figure 49: Here is the bumper scored, bent and ready to be attached.

For the next step you really need to use the 5 minute epoxy and a lot of patience (this is one of those “bailing wire” techniques). First have a clock or a watch nearby so that you can easily check the time. If you’re using a watch take it off so that you don’t have to twist your wrist around to check. Mix a little 5 minute epoxy and let it sit for 3 minutes. After the 3 minutes quickly put a dab onto each micro-switch pad (on the bumper) and place them on the micro-switch levers (Figure 50). You’ll actually need to hold this for at least 3 minutes. Think of it as an exercise in patience.

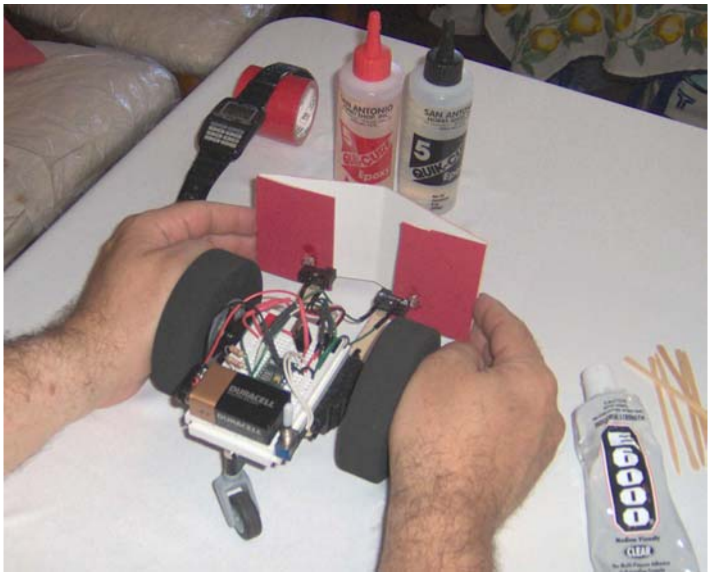

Figure 50: You’ll actually need to hold this for at least 3 minutes after letting it sit for 3 minutes. Think of it as an exercise in patience.

After 3 minutes the glue should hold the bumper on the switches. Add a little E6000 at the top and bottom to reinforce the epoxy (Figure 51). Let dry overnight.

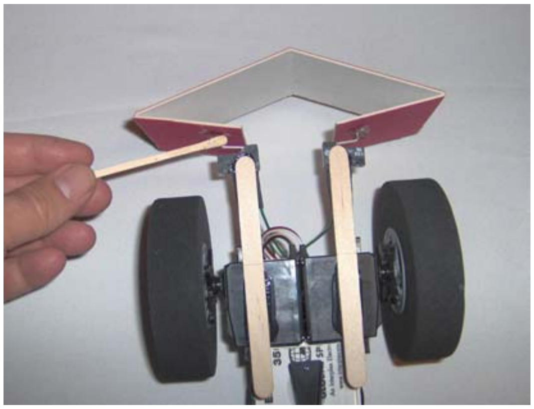

Figure 51: Add a little E6000 at the top and bottom of the micro-switch lever for reinforcement. Careful not to get any into the switch mechanism.

12. Program II (input)

Module 5 is the program that ties the input with the output. Basically it has the robot go forward until it detects an obstacle on the left or right, backup and turn the opposite direction and go forward again. That’s it! That’s the starting place. Now you have a fully functioning robot! You can play around with variations of the code for example try and modify it so when it senses both micro-switches simultaneously it backs up and turns 180 degree.

Module 5

```
' {$STAMP BS2}

x VAR Byte

fwd:
PULSOUT 0,1000
PAUSE 20
PULSOUT 1,500
PAUSE 20
IF IN2 = 0 THEN bwdr
IF IN3 = 0 THEN bwdl
GOTO fwd

bwdl:
FOR x = 1 TO 10
PULSOUT 0,500
PAUSE 20
PULSOUT 1,1000
PAUSE 20
NEXT
FOR x = 1 TO 3
PULSOUT 0,500
PAUSE 20
PULSOUT 1,500
PAUSE 20
NEXT
GOTO fwd

bwdr:
FOR x = 1 TO 10
PULSOUT 0,500
PAUSE 20
PULSOUT 1,1000
PAUSE 20
NEXT
FOR x = 1 TO 3
PULSOUT 0,1000
PAUSE 20
PULSOUT 1,1000
PAUSE 20
NEXT
GOTO fwd
```

13. Install on/off switch

Last we install the on/off switch. Take a single pole single throw switch (SPST) like the Radio Shack 275-324. Solder two 3.5" lengths of 22-Gauge solid core wire. Take the nuts and washers off as we will not be mounting this switch in the normal way. Take the red or positive battery wire; plug it one row up from Pin 24 on the Stamp in an unused row. Make sure that you do not plug it into one of the 7805 tie points! Take a minute, use your multimeter and confirm which direction turns the on/off switch "off". Mount the switch with the "on" position slanted rearward so that as the robot goes forward it doesn't accidentally switch itself "off". Not really an issue with the little PROTOBot but something to keep in mind if you build a bigger robot. Connect one end of the switch to the positive 9-volt battery wire (the one you just moved up one row) and the other into Pin 24 on the Stamp (PWR); where the power cable had previously been. Now when you switch it off and on it should turn the robot off and on (Figure 52). Make sure a program is loaded that will show some sign of life. With the structure of the 22-Gauge solid core wire you shouldn't need to clamp the switch. Just glue it on the edge of the breadboard and let it sit overnight. Use tape to hold it in place until the glue dries.

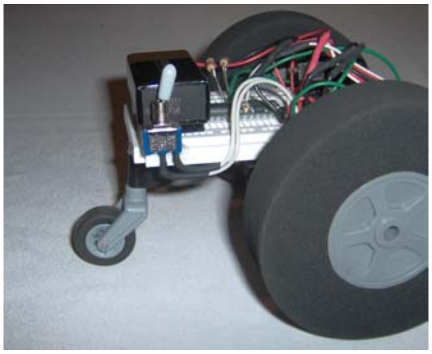

Figure 52: Mount the switch with the "on" position slanted rearward so that as the robot goes forward it doesn't accidentally switch itself "off". Notice how the battery snap is on the opposite side.

14. What's next?

Well that's up to you. You can add a power LED, a speaker, an infrared object detector, etc. You have 12 additional general purpose IO ports to play around with! Browse through the Stamp reference manual and imagine how you might use the circuits and commands available. There are many books, web pages, user groups and other resources for the Stamp computer. In fact any circuit designed to interface with standard +5 volt logic (TTL) can be hooked up to the Stamp computer. How about building more than one PROTOBot to play a game of robot "tag" or follow the leader? Build a soccer team! I'm actually having good success in picking up lint, hair and dust bunnies by attaching one of those sweeper "dry cloths" to the front bumper. In short, this is the beginning not the end. Please take it apart (the E6000 peels right off) and build a completely different robot. The PROTOBot wasn't designed to be an end unto itself but rather a beginning to a world of exploration (Figure 53). One day the robots will build themselves but until that day it is up to us. We are the ultimate robot builders!

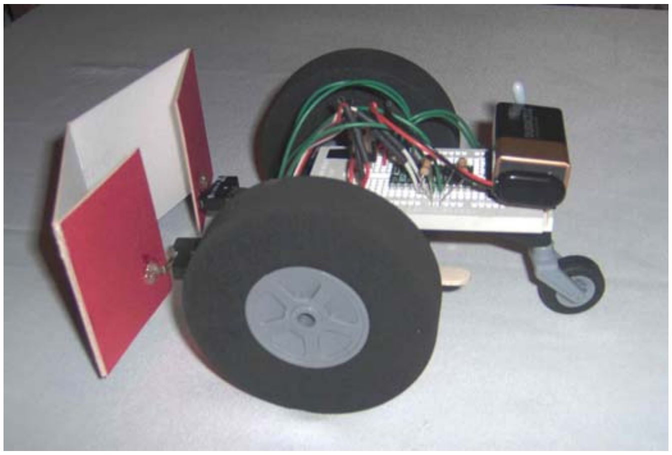

Figure 53: The finished product? Nope, this is the beginning.