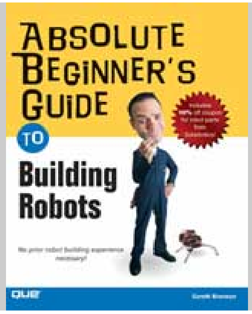


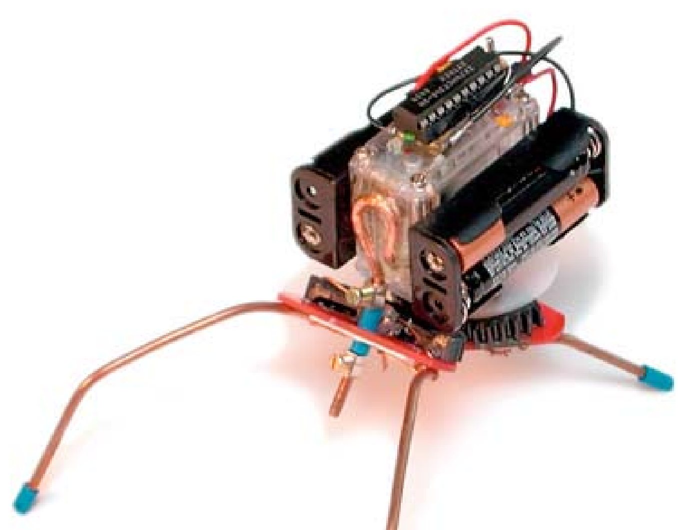
The following is a version of a project that first appeared in my book the Absolute Beginner's Guide to Building Robots. You can find out more about the book, look at details of two other projects, and order it, on the book's companion website. This Walker was also pictured in Make Vol. 6 and on the Make website. Here's how to make it yourself!

Note: Most of the images are larger in size than they appear inline here. View them in a new window if you want to see a bigger view.

The Coat Hanger Walker

By Gareth Branwyn
Photos by Jay Townsend
Illustrations by Mark Frauenfelder

In this project, we'll build a little critter out of surprisingly simple, minimal parts. We'll even make use of one of those coat hangers that seem to breed in the bedroom closet. This project is an ingenious little hardware hack dreamt up by a Canadian BEAM enthusiast named Jérôme Demers. It wonderfully illustrates a number of principles of bottom-up, BEAM-friendly robotics. Here are a few:



- It revels in the K.I.S.S. principle ("Keep It Simple, Stupid"). It uses a simple control circuit, a single servomotor, and a single gear to create a four-legged walker.

- It demonstrates use of the popular BEAM Bicore circuit, a two-node timer circuit that tosses a control signal back and forth between the nodes, creating a reciprocating back and forth motion in the motor and gears, and therefore, in the legs attached to the gears.

- It makes use of techno-junk. Okay, so a coat hanger isn't very “techno,” but if you have a decent techno-junk stash (and who among us doesn't have access to old computers, motorized toys, analog modems, old answering machines, etc. at this point?), you likely have some of the other components detailed in the parts list below.

- This project is a good example of the relatively level playing field found on the Internet for the sharing of robot designs and innovative ideas, regardless of who or where you are. I was truly impressed with this project, and many others on Jérôme’s Web site Insectroïdes, even before I discovered that he was only 15-years-old when he ceated the walker! Dang precocious kids today! When I was 15, I was in the backyard playing chicken with a Bowie knife and few of my mullet-headed friends.

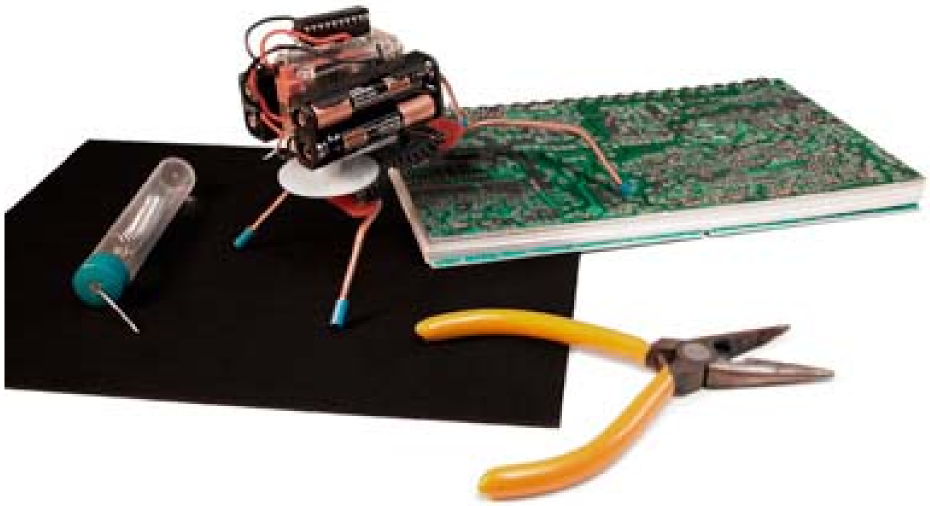


FIGURE 1: What our finished coat hanger walker will look like. Cute, ain't it?

The persnickety among you will be quick to point out that by many definitions of a robot, this ain't no stinkin' robot. It doesn't gather, process, and respond to feedback of any kind. It's really a walking machine rather than a proper robot. We still think it's a cool walker, because of the reasons bulleted above, and because it teaches many of the fundamentals in construction and electronics that can be used in other bot building projects. You also end up with a nifty little "monitor pet" that'll merrily motor across your desk and impress all your geek friends (especially when you tell them: "I made it out of a coat hanger and some junked electronics!"

We're not going to lie to you. Although this critter has relatively few parts, the Bicore control circuit can be a little harrowing to solder (you're up for a challenge, right?). The dual inline package (DIP) IC socket that the control circuit plugs into is very small and the pins are closely populated. Soldering these pins will take some patient effort. That's the bad news. The good news is that DIP IC sockets cost about 10 cents a pop, so you can mess up quite a few in practice and it's no big deal. Hopefully, you'll have logged plenty of soldering practice time by now and be ready for some big boy/big girl soldering. If not, go ahead and read through this entire project, order any parts you need, and then do some soldering practice sessions while you wait for the components to arrive.

Gathering the Parts

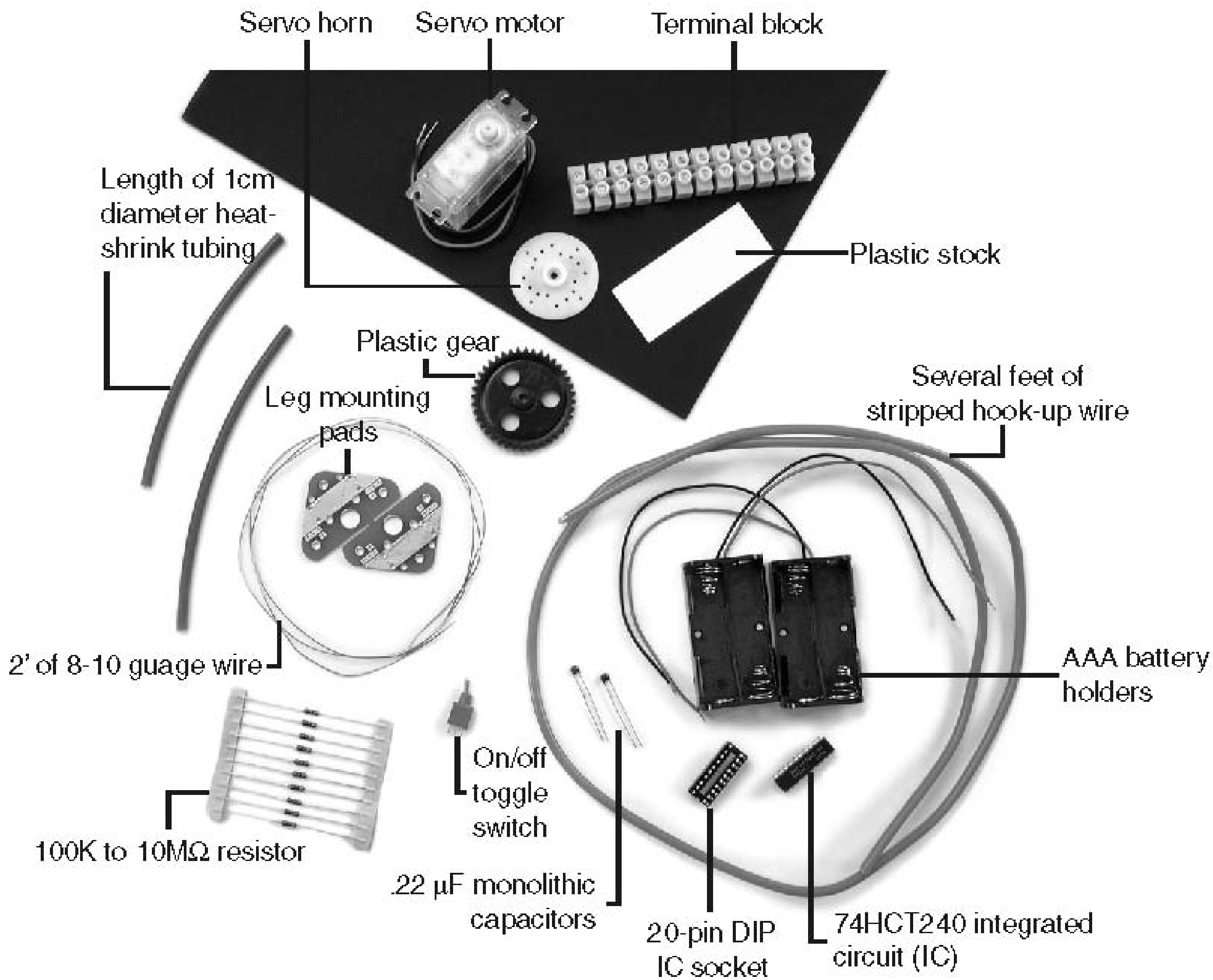
This project requires some materials and parts you might already have lying around the house and some components you'll likely need to purchase at your local electronics store, an online retailer, or some other source. Our pals over at Solarbotics have kindly put together a Parts Bundle of most everything you need for this project. It does not include the 40-tooth gear. We got ours from Jameco.

The Parts List

The Coat Hanger Walker requires the following parts:

- (1) hobby servo motor with "Servo Horn"
  (Solarbotics Part #GM4)
- (1) 1.5 inch (4cm) plastic gear (around 40 teeth are good)
- (1) 2 feet of 8 to 10–gauge wire; can use coat hanger wire or 10-guage copper wire
  (Solarbotics Part #Wleg)
- (1) short piece of 1cm diameter plastic tubing (can use "jacket" from preceding leg wire)
- (1) terminal block (Radio Shack Part #274-678)
- (2) AAA battery holders (each holds two AAA batteries)
- (1) length of 1cm diameter heat-shrink tubing (can use "jacket" from preceding leg wire)
- (2) .22 µF monolithic capacitors
- (1) 100K to 10M• resistor (we recommend 3.2M•)
- (1) 74HCT240 integrated circuit (IC)
- (1) 20-pin DIP IC socket

- (1) on/off toggle switch (smallest you can find)
- (2) leg mounting pads (Solarbotics Part #LMP2); optional, but recommended
- pieces of scrap plastic (from product packaging) or .030" plastic sheeting
- several feet of stripped hook-up wire (or other 22-guage wire)



IC socket

FIGURE 2: All the parts you'll need to build your first robo-critter.

The Tools and Supplies List

You'll also need the tools and supplies listed here:

- Needlenose pliers
- Hobby knife
- Wire cutters
- Screwdriver set
- Soldering iron and related soldering tools and supplies
- Micro-torch or heat gun
- Breadboard and hook-up wire (a.k.a. Breadboard Jumper Kit)
- 2-part epoxy
- Superglue
- Some recycled component leads
- Rotary (Dremel) tool (optional, but highly recommended)
- Metal ruler
- (4) AAA batteries

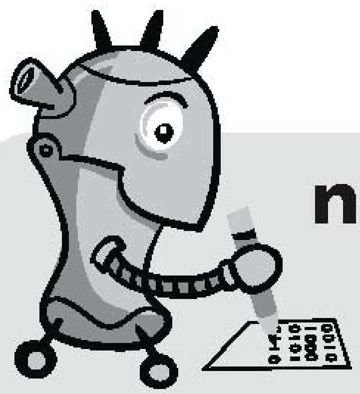
Freeforming the Bicore Control Circuit

The first thing we'll want to do in building our robot is to assemble its brain. The Coat Hanger Walker makes use of the ingenious BEAM Bicore circuit. It's prefixed *bi* because it has two states, or nodes, and *core* because, well, it's the central part of the robot's *nervous net*. Our Bicore uses the 74HCT240 integrated circuit. This chip is an *inverting octal buffer*. That's just a fancy way of saying that it is a chip with eight *logic gates* that invert the signals going into them. Whatever goes in each gate gets inverted, so a low signal becomes a high signal and a high signal becomes a low one. By combining the three gates on one side and three gates on the other (by soldering their pins together), we end up with two "teams" inverting gates that "buffer" the signal and make it more powerful. Bicore! The signal passing back and forth between the two nodes sends high and low (or "on" and "off") pulses to our servo motor. The result is back and forth movement of the motor shaft, which is transferred to our gears to create a reciprocating walking motion. By the way, if you're wondering, the remaining two gates are used as sort of the controller for the two three-gate teams.

Breadboarding the Bicore

Before we actually heat up our soldering iron and start dripping molten metal all over components, we want to breadboard our circuit to make sure that all the components are working properly and that we have a sound design for our Bicore circuit (If you don't know how to breadboard, read the "Thumbnail Guide to Breadboards" later in this project doc before continuing).

You'll want to hook up the wires (from your breadboard jumper kit), the resistor (whichever value you decide to start with), and the two .22µF capacitors to the following tie points on the breadboard. For these numbers, assume that the pin in the upper-left corner of the IC is pin 1 (the pin to the left of the little dimple). Then it's pins 2–10 on the left side, straight across (from 10) to 11, and then up to pin 20.



note

So, if our 74HCT240 chip has 8 logic gates on it, why does the DIP have 20 pins? Well, each input gate has an output pin on the opposite side; that's 16 pins. There's an "enable" pin on each side to "turn on" that side of the side to "turn on" that side of the chip; that's 18 pins. And then there's the positive pin and the ground (negative) pin, used to power up the chip. 20 pins!

Connect jumper wires to the follow tie points:

- Left side of IC: 4-6, 3-4, 5-7, 6-8, 7-9
- Right side of IC: 14-16, 13-15, 12-14, 11-13, 15-18
- From left side to right side: 1-19
- Capacitors: 2-3 and 18-17
- Resistor (across IC): 2-17

The last thing you'll need to do is to connect the positive (+) power wire from pin 20 to a positive tie point on the power bus, and ground (-) wires from pin 1 to a negative tie point *and* pin 10 to a negative tie point. Make sure both of these pins (1 and 10) go to negative.

Figure 3 shows what the breadboard should look like when you've hooked up all of the pins on the IC. (In this photo, the motor is not yet connected.)

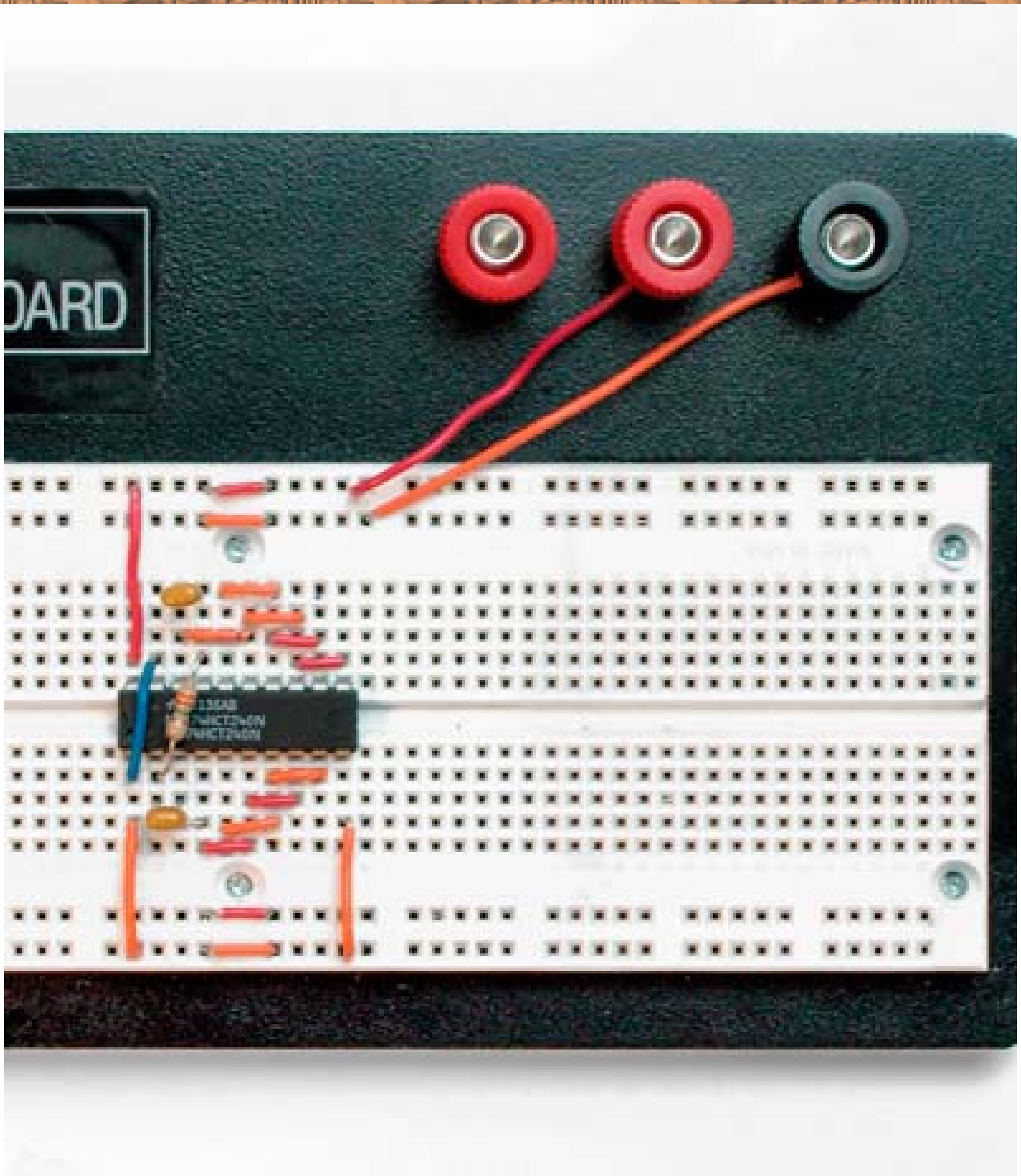


FIGURE 3: The basic breadboard set-up. Note that motors are not shown and the top and bottom breadboard busses are not connected.

Put hook-up wire, the resistor, and the two .22µF capacitors in the tie holes as shown. Note: Make sure the top and bottom power bus strips on your breadboard are connected together (not shown here, but see Figure 13).

At this point, your breadboarded Bicore circuit is all hooked up and ready for juice (battery power) and something to drive (your motor). Before we hook up these final components, you might need to do a little work on your motor to get it ready for reciprocating (back and forth) motion (see Hacking a Hobby Servo Motor below). Make sure the battery pack that you're going to use to power the breadboard is not connected to the breadboard power bus before connecting positive and ground (negative) wires to the bus.

Hacking a Hobby Servo Motor

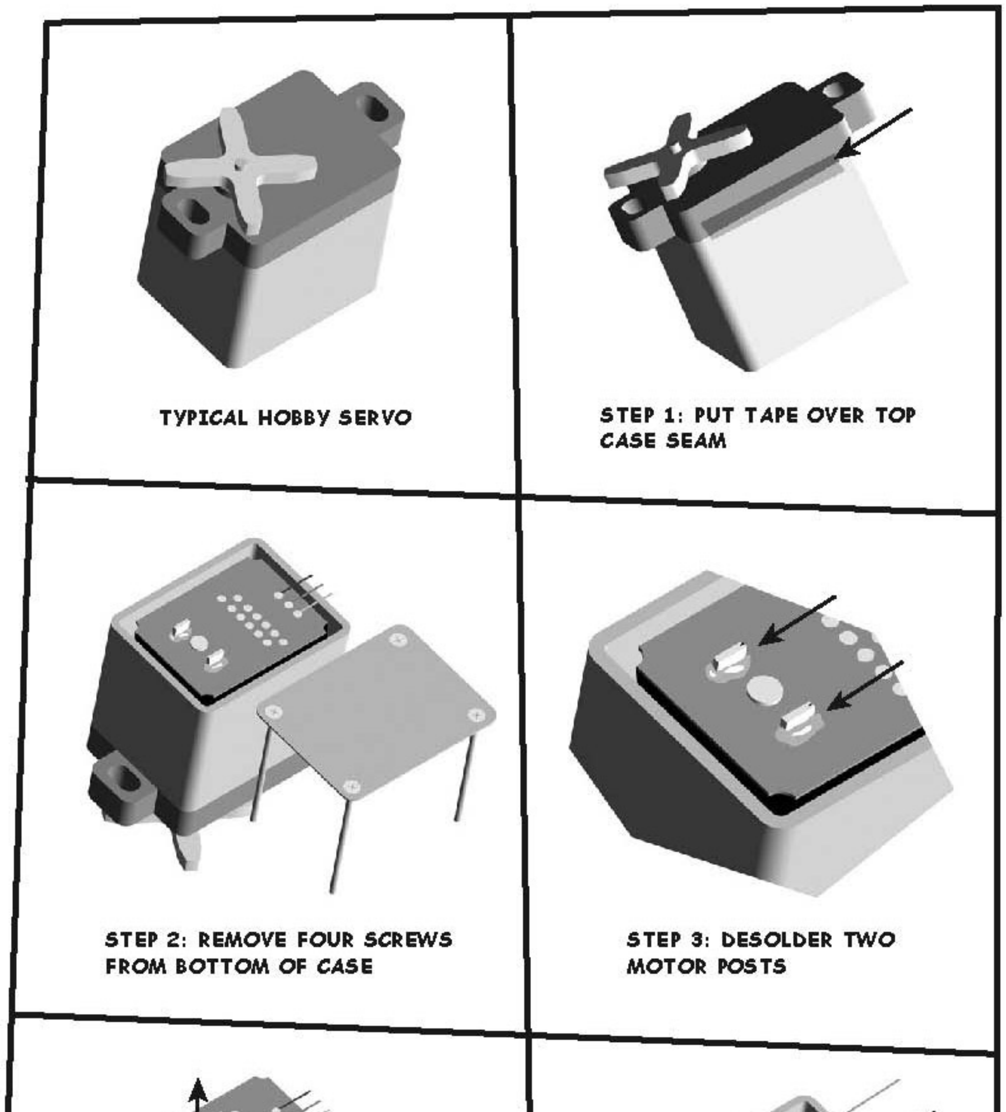
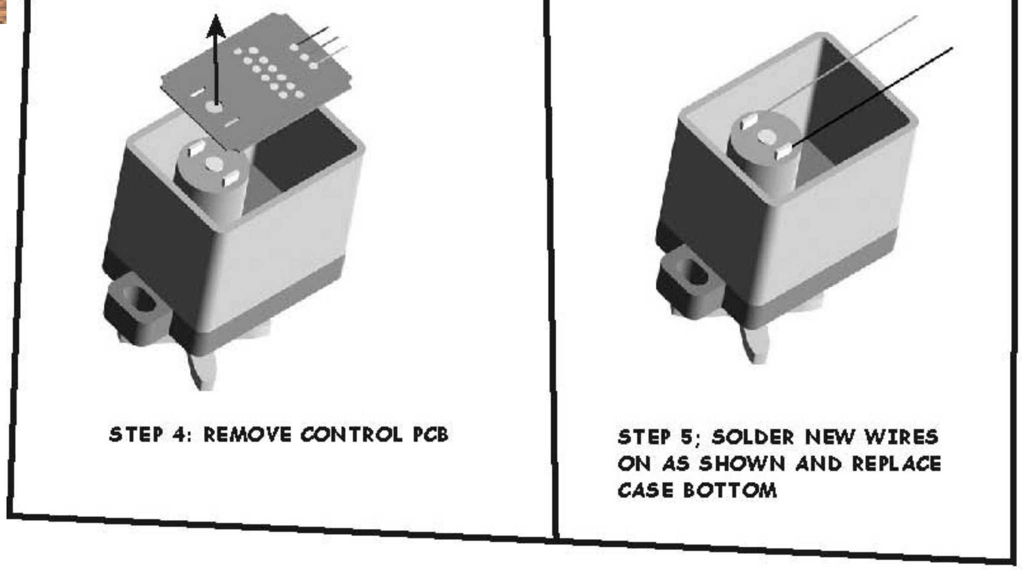


FIGURE 4: (see right) The steps to removing the control circuit from a hobby servo motor.

If you got your servo motor from Solarbotics (Part #GM4), it already has the control electronics removed. If not, you'll need to remove them yourself. Servo motors have built-in control circuitry. We don't want this control on our servo—we want to control its movement with our Bicore chip. Removing the control PCB is simply a matter of opening the case, removing the board, and resoldering the positive and negative wires directly to the motor (see Figure 4).

If you did get your motor from Solarbotics, there are no electronics to remove, but the motor may have been configured for continuous rotation. We want reciprocating back and forth motion. Usually, servo motors have a *final gear* (as the drive gear is called) with a mechanical pin on it that prevents full rotation. The Solarbotics servo has a final gear with no stop pin, but the “servo horn kit” that comes with the motor includes the original final gear with the stop on it. To re-install this gear, all you have to do is



1. Unscrew the four bottom screws on the servo, as in 4.

2. Remove the top part of the case (instead of the bottom).

3. Pull out the middle gear in the center of the gear box (the one on top).

4. Replace the final gear (with the one that has the little plastic stop on it).

5. Replace the middle gear, and screw the case back together.

Before putting the case back together, make sure the gears are well seated and meshed. Also, make sure the plastic stop on the gear is facing toward the wired end of the servo case. When you have a servo motor with a mechanical stop final gear in it and no control electronics, you’re ready to hook it up to your breadboarded circuit to see if it works. Plug the red (+) wire into pin 9 and the black (-) wire into pin 12. Connect 6 volts (V) of power to your breadboard’s positive and negative terminals. If you’re using the two AAA battery holders for the robot, connect them in series as seen in Figure 5.

If, when you power up the motor, you see the motor shaft twisting back and forth, congratulations!

You've just built your first robot control circuit. If nothing happens, go back and check each connection on your breadboard to make sure that they're wired correctly. Look at each hook-up closely, as it's easy to sometimes put a wire or component lead in the wrong tie point on the board. If it still isn't working, try different resistor values. On our robot, we got good action on resistors in the 3.2 to 4.2 M• range. If your circuit *still* isn't working, it's time to get out your digital multi-meter and check all of your components (battery packs, resistors, capacitors, and switch) to make sure that everything's working properly. Consult the manual that came with your DMM to find out how to properly test each component type. To test the motor, touch its wires directly to the battery pack's wires (positive to positive and negative to negative, of course). If you do all this, your circuit should be working properly. There aren't *that* many parts that can fail here.

Creating a Breadboard Power Supply

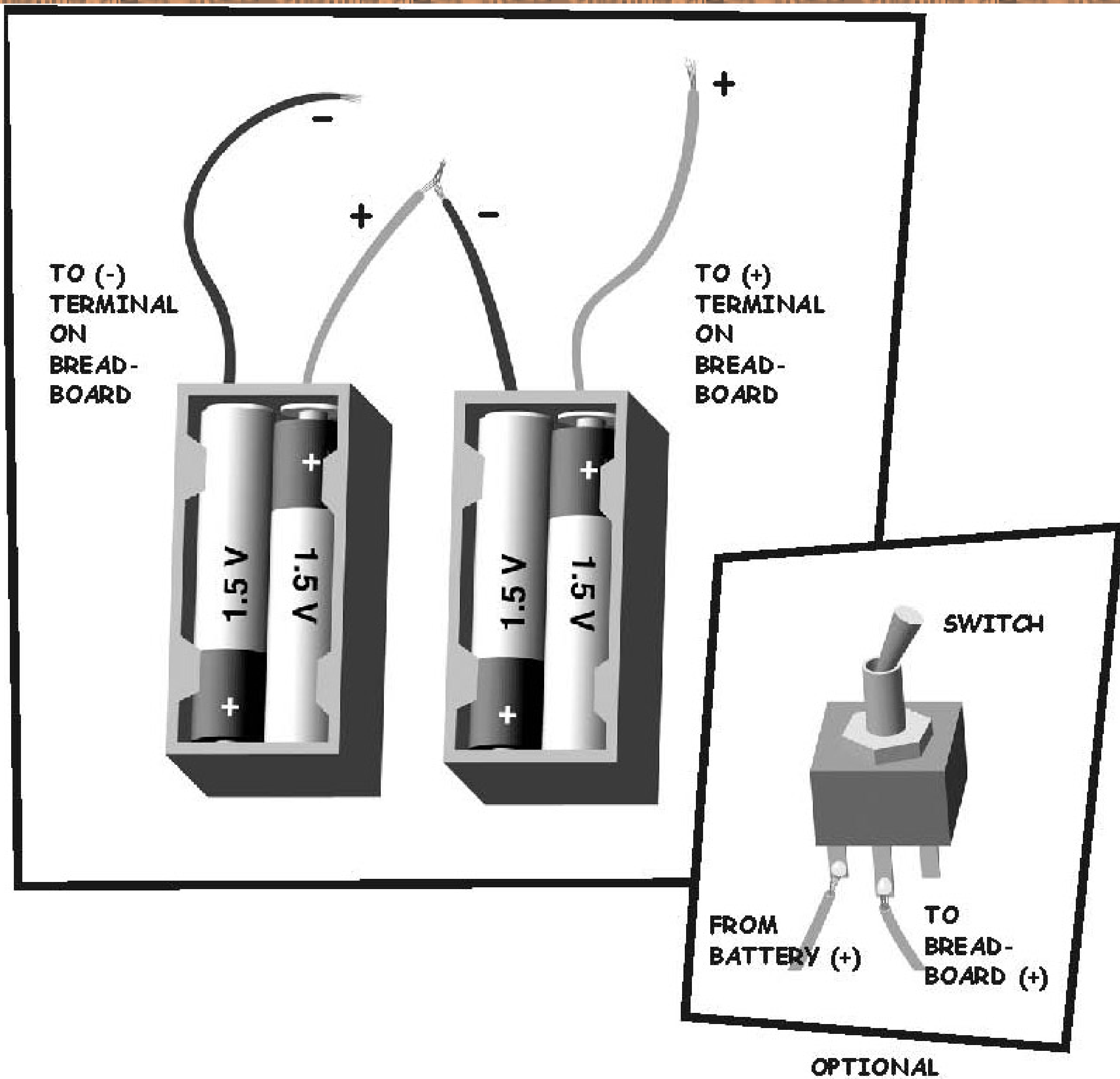


FIGURE 5: The proper way of hooking up your battery packs (in series) to deliver 6V of power to your circuit. Add a switch to the circuit, if you'd like.

Soldering Up the Circuit

Now it's time to heat up your soldering iron, take a few deep breaths, and begin soldering the pins of your IC socket together, and then the discreet components onto it. Here are the steps involved:

1. Get your 20-pin DIP socket and turn it over. Using your needlenose pliers, bend over pins 1 and 19 so that they are as close to touching each other as possible. Don't hold metal parts directly. Use needlenose pliers or other tools. Next, bend pins 2, 5, 7, 9, and 10 outward. Bend pins 6 and 8 inward. Try to keep all the pins as straight and on the same level as possible. Now bend outward pins 12, 14, 16, 17, and 20. Then bend inward pins 11, 13, 15, and 18. When you're finished, the chip should look similar to the one shown in Figure 6.

FIGURE 6: All of the pins on the IC socket bent and ready for soldering.

1. Using a small piece of component lead (clipped from one of your resistors, capacitors, techno-junk, and so forth) bridge the gap between pins 1 and 19. Solder the lead to one pin and then the other. If it makes it easier for you, you can solder the lead to the first pin when it's upright, and then bend it over, solder it to the other pin, and then clip off the excess.

2. Now find pins 3 and 4 and solder them together (see Figure 7).

3. Solder together pins 6 and 8 and pin 4 (which was already soldered to pin 3 in step 3) with a piece of component lead. In other words, you should have one long wire connecting pins 6 and 8 to pins 3/4 (see Figure 8).

4. Solder together pins 11, 13, 15, and 18 with a piece of component lead (also shown in Figure 8).

FIGURE 7: (below) Pins 1 and 19 (the enable pins) and pins 3 and 4 connected to each other as shown.

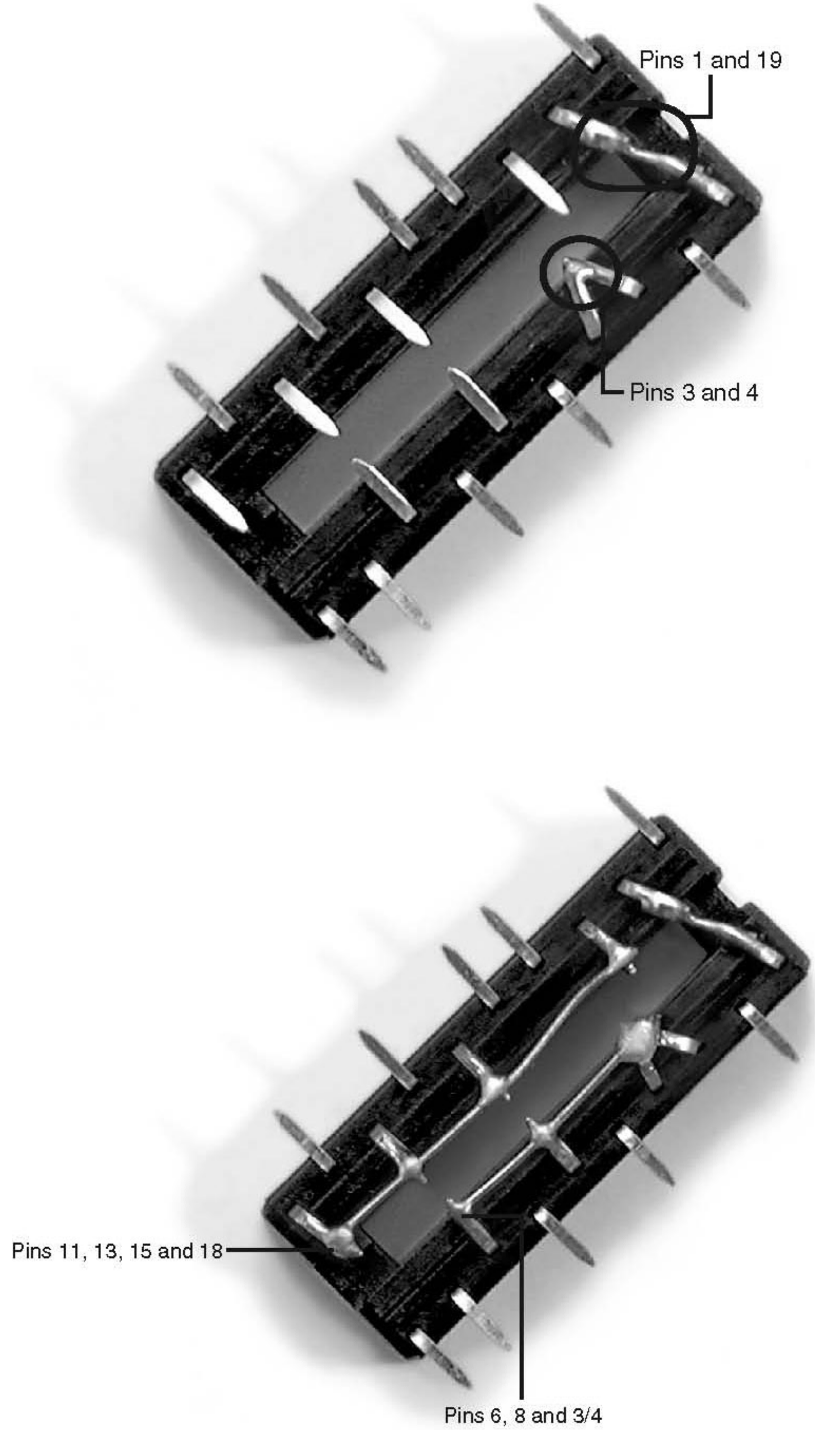


FIGURE 8: (above) Pins 6, 8, and 3/4 soldered together on one side, and pins 11, 13, 15, and 18 on the other.

1. Get a piece of hook-up wire and cut it so that it reaches from pin 10 to the join you made between the enable pins 1 and 19. Strip off just enough of the wire jacket to solder it to these pins and try to get the wire as straight (with as little slack) as possible (see Figure 9).

2. Solder together pins 5, 7, and 9 with a piece of component lead (see Figure 10).

3. Solder together pins 12, 14, and 16 with a piece of component lead (also shown in Figure 10).

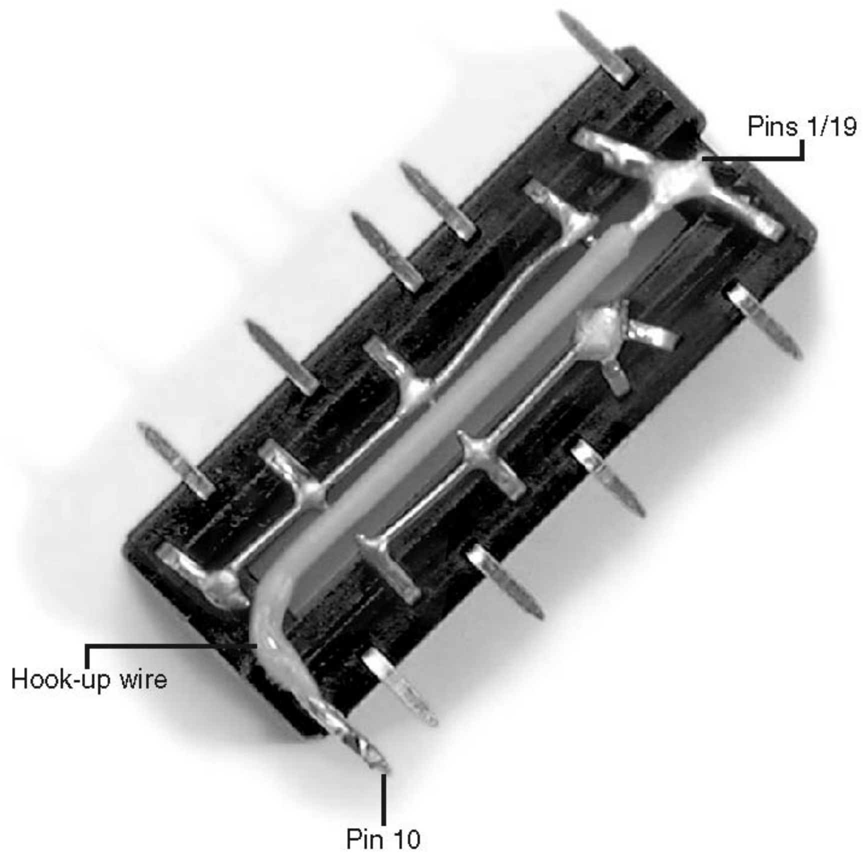
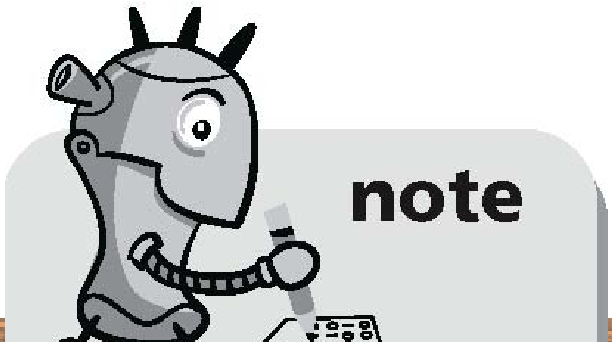


FIGURE 9: Pin 10 (the negative, ground pin) connected via insulated wire to the enable pins 1/19.



These two pins, 1 and 19, are the "enable" pins. They "switch on" each side of our chip. By connecting them together, you're making one big "on" switch (see Figure 7.7).

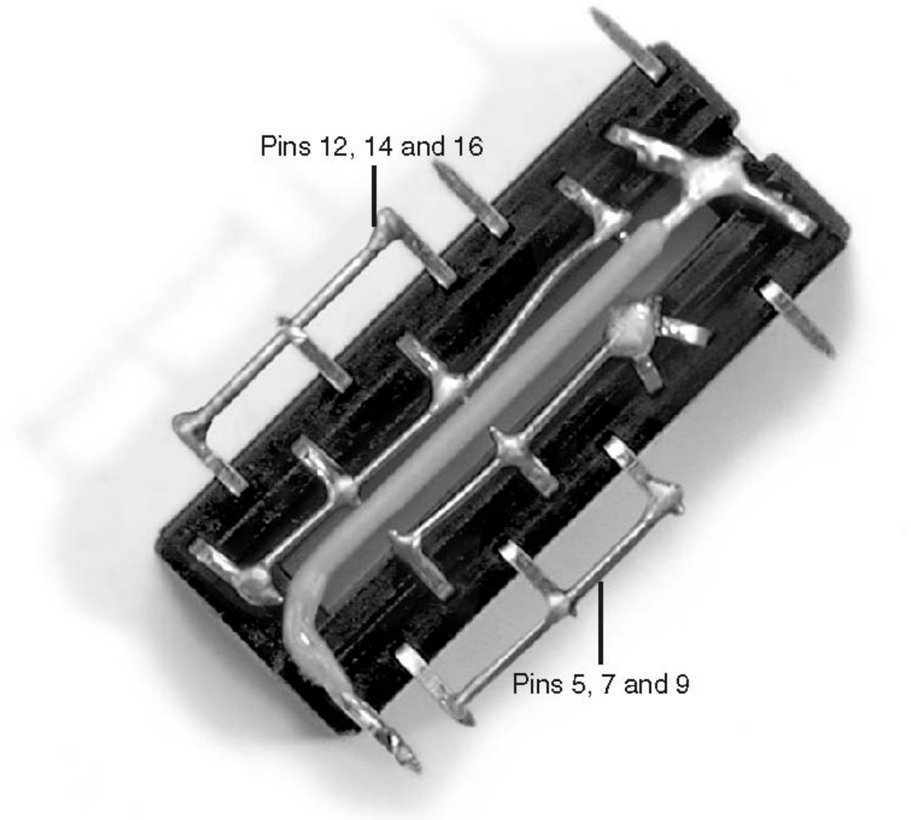


FIGURE 10: Pins 5, 7, and 9 connected together, and then pins 12, 14, and 16.

1. Get the two .22µF monolithic capacitors. Trim the leads down (if you haven't already cannibalized them for lead clippings) so that they're of a manageable length. Solder one of them to pins 2 and 3 and the other one to pins 17 and 18. Solder them with enough"slack" lead so that they can be bent to the sides, and out of the way when you flip the socket over and insert the IC into it (see Figure 11).

2. Now we need to add our final component: the resistor. Hopefully, you experimented around during the breadboarding stage and found a resistor value that gives your walker the right amount of back and forth action. Here, you *don't* want to clip the resistor's leads because you're going to want to solder it around the top edge of the socket, from pin 2 to pin 17. We need to go around the socket because we don't want the resistor to get in the way of plugging the IC into the socket, or when mounting the socket/IC assembly to the top of the walker.

With plenty of lead on the resistor, we can bend and twist it during the final assembly phase to make sure it's out of the way of other components (as shown in Figure 11).

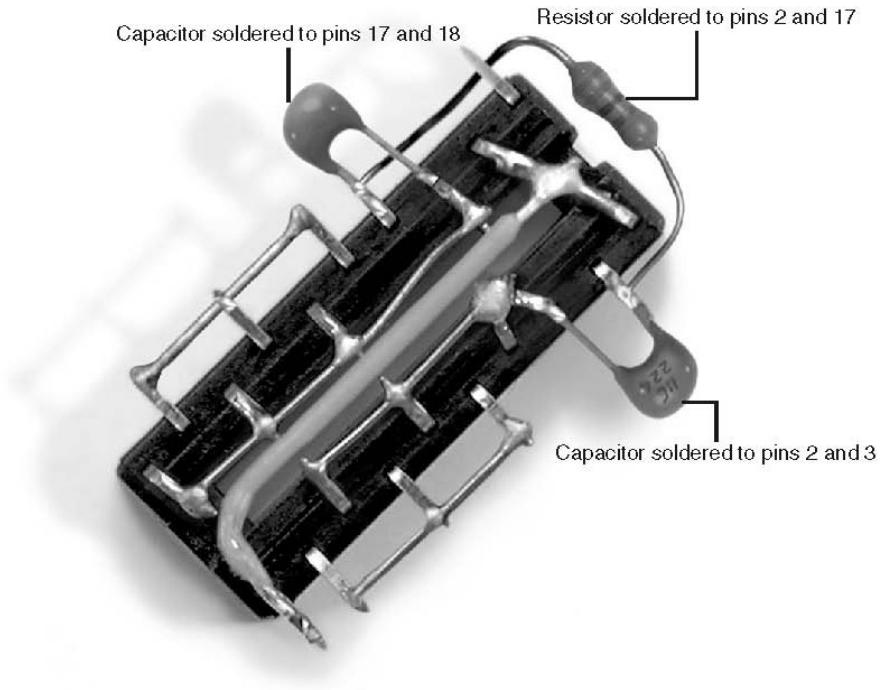


FIGURE 11: Our two capacitors soldered in place (one across pins 2 and 3 and one across pins 17 and 18) and our resistor installed (from pins 2 to 17).

11. Flip the IC socket over and carefully plug the 74HCT240 chip into the soldered-up IC socket (see Figure 12). If it has trouble going in, carefully inspect your socket assembly to make sure that you didn't melt any of the plastic package, and therefore disturb the sockets where the IC pins plug in. If they are misaligned, we hate to break it to you, but you might have to get another socket and do the whole thing over again. We told you to be careful!

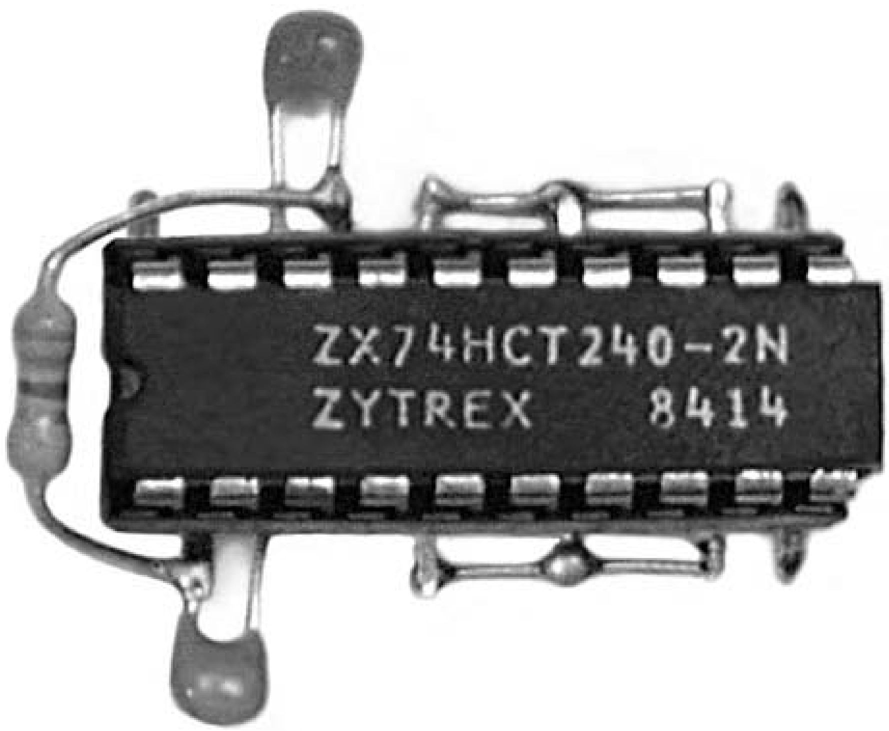


FIGURE 12: The completed soldered up IC socket with the 74HCT240 plugged in.

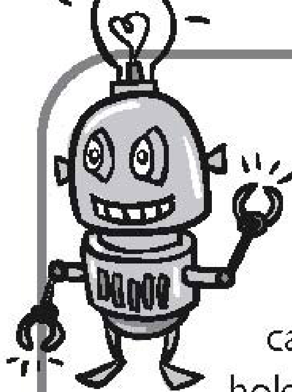
That’s it! If all went well, you should have aworking Bicore control circuit. All you have to do now is connect the power and the motor to the appropriate pins. We’ll hold off on doing that though until we’ve built the rest of our robo-critter.

Go ahead and take a break, indulge in your junk food of choice, play a round of *Enter the Matrix*, run a lap around the house, or otherwise cool out for a bit. I don’t know about you, but these solder fumes are makin' me feel kinda funny.

Thumbnail Guide to Breadboards

Every wirehead worth his or her propeller beanie

knows about breadboards. And no, we're not talking about a cooking utensil from Martha Stewart's kitchen; we're talking about an essential piece of equipment for every electronics hobbyist and professional.



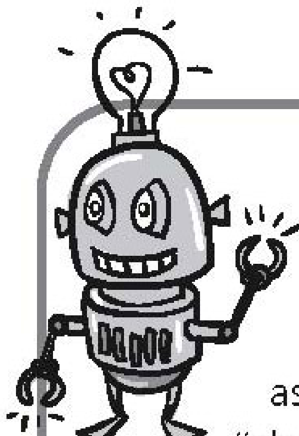
tip

When buying a breadboard, look carefully at the tie-point holes to make sure that the sockets underneath the nylon grid are properly aligned. If they aren't centered in the holes, it can make inserting wires difficult, if not impossible, and that's just…well…crummy.

A breadboard is a simple, inexpensive device (available at any electronics store) for temporarily hooking up and testing an electronics circuit before you solder it together. By using a breadboard, you're checking to make sure that the circuit is designed properly and that all of your components are working as specified.

A breadboard is usually comprised of a metal base plate with a white nylon block mounted on it that's covered with a grid of holes (known as *tie points* or *wire receiving sockets*). There are usually three *binding posts* also on the board, which are screw-down connectors for bringing power to the board.

The nylon grid on a breadboard is divided into two major sections split down the center. This center channel (called the "trench") is just wide enough to accommodate the two rows of connecting pins found on standard DIP ICs. Radiating from the center of the board are vertical rows of tie points (usually five on each side). All of these "5-position groups" of tie points are connected together, so a wire in any one of them electrically connects any wire or component lead in any of the others in that row. Along the top and bottom of the breadboard are a series of power "distribution buses" (or simply "buses"). They (usually) run horizontally and



tip

Try and make your breadboard hook-ups as neat, linear, and "short distance" as possible. There's an almost Zen-like art to breadboarding so that you don't cross wires over each other and you minimize crossing wires over there are often four groups of them (two on the top and two on the bottom). To power the circuit you've set up on your board, you simply connect the leads from a battery to the binding posts (positive to a red post, negative to a black), connect a short wire from each post to the appropriate channel (+ or -) on the power bus, and then a wire from the bus to the appropriate socket in the row of tie points connected to the parts of your circuit that need power. Confused? Check out Figure 13. You'll get the hang of it pretty quickly.

you minimize crossing wires over ICs. Things can get pretty confusing and messy enough when all components and wires are in place—you don't want to compound this with willy-nilly hook-ups. Try to keep your wiring at right angles. (See the breadboarding examples in the project sections of this book to see what we're talking about.)

To make life easier down on the breadboard, electronics stores sell *jumper wire* kits with different lengths of 22-guage *hook-up wire* cut to appropriate lengths that correspond to the tie-points on the board. You'll want to get one of these kits. You'll also need to power your board. For this, all you need to do is hook up the battery pack of the correct voltage needed to power the circuit you're building (for instance, in the Bicore circuit for this project, we need 6V of power). To make things even more convenient, the tops of the binding posts also accept *banana plugs* (also available at electronics shops). You can solder sets of these to various battery packs (6V, AAA, 9V, and so forth) and have these available for your breadboard power source. Then all you need to do is plug the banana plugs into the tops of the binding posts to power your circuit. (Breadboards? Bananas? Is anyone else getting hungry?) If you want to get *really* fancy, you can hook up a power switch to the board so that you can turn the power on and off without having to disconnect the battery.

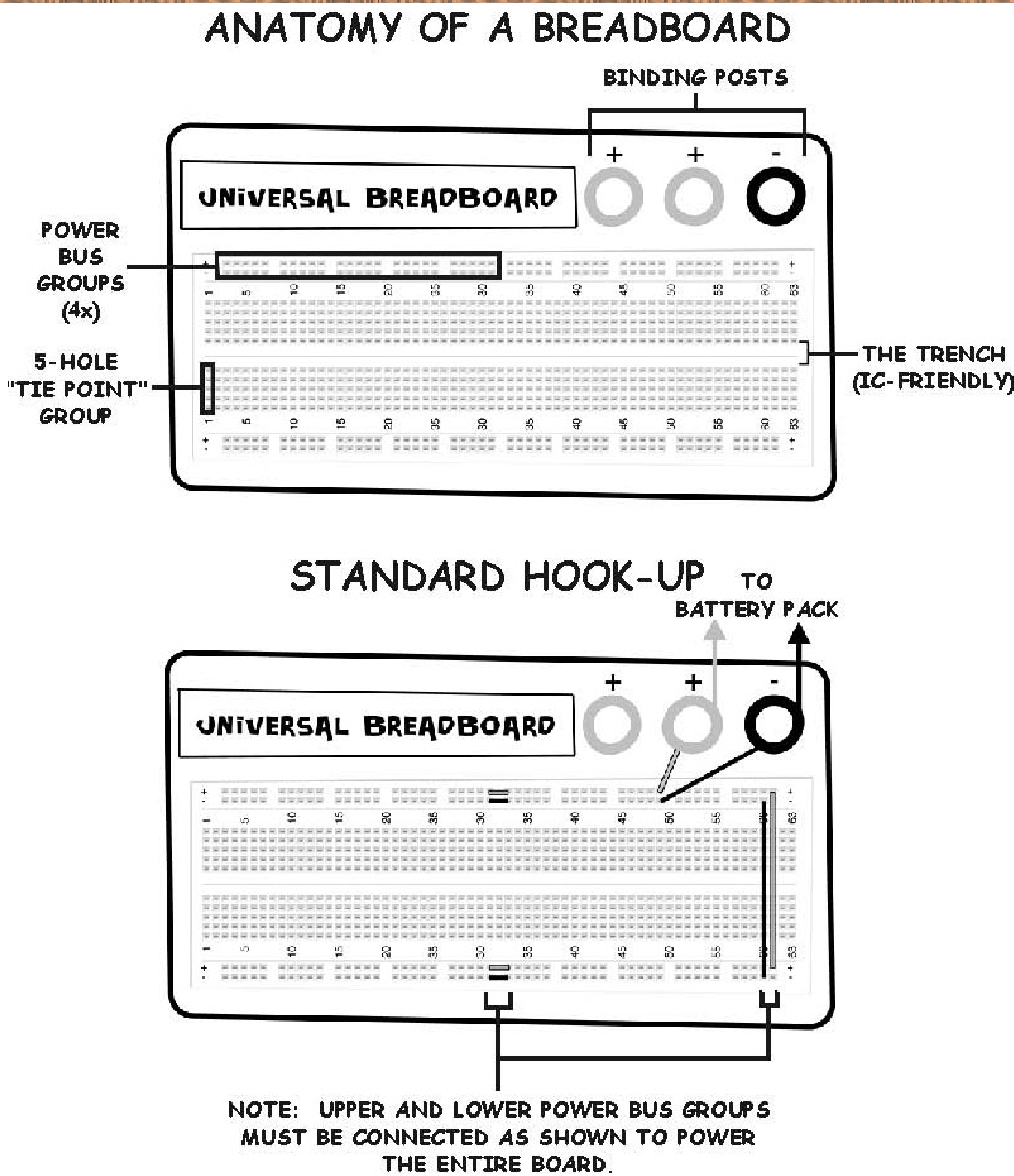
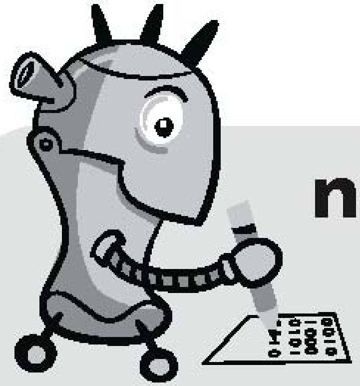


FIGURE 13: Anatomy of a breadboard.

When you first get your breadboard, you'll want to hook it up with a standard power configuration that distributes power throughout the buses on the top and the bottom of the board. As we said earlier, there are usually four power bus groups on the board. To connect them, you need to put a jumper across the two positive and negative groups on the top and the two positive and negative groups at the bottom. You then need to connect the top bus groups to the bottom bus groups (with a positive-to-positive wire and a negative-to-negative wire). Use the standard red for positive and black for negative, if you have them; otherwise, just be consistent (all positive wires one color, all negative wires another). Refer back to Figure 13 if this is getting confusing.



note

Breadboards are sometimes horizontally oriented (in other words, the power buses run along the top and bottom), and other times, they're vertically oriented. In our examples in this book, the breadboard is always horizontal. The functionality is the same with both types of boards.

Besides the breadboard itself, the power supply, and the jumper kit, you'll need two other tools for effective breadboard work. A pair of needlenose pliers are essential for getting those pesky jumper wires onto and off of the board, especially in tight spaces. You'll also want an IC extractor (or a *chip puller*). This is a funny-looking pair of tweezers that is used to safely remove IC chips from a breadboard (or an IC socket) without damaging their delicate pins. (And trust us, without a puller, this is *very* easy to do.)

Go to Part II.
Go to Street Tech.
Go to Robot Book Companion Site.

The Coat Hanger Walker [Part II]

By Gareth Branwyn
Photos by Jay Townsend
Illustrations by Mark Frauenfelder

Building the Walker Body

The body for our Coat Hanger Walker is basically the motor casing for the servo motor itself. The control circuit goes on top (actually, the servo is flipped upside down, so it's technically the bottom of the motor), the two AAA battery packs go on the sides, and the on/off switch gets attached to the back. The motor is oriented so that the drive shaft protrudes from the bottom, delivering power to two sets of gear/legs, one set for the front two legs, and one set for the back. The ingenuity of this design is that four legs are controlled, and that a single motor can achieve a reasonable walking gait. Robotic walking technology is usually hard. The simplest walkers usually have at least two motors and two control circuits (one "master" circuit and one "slaved" to that). Jérôme Demers's design is a study in engineered minimalism. This walking machine doesn't have the most elegant gait in the robot kingdom, but it *does* work, and it shows the kind of insect-like movement and persistence that's the hallmark of biologically inspired robots.

To start building the body, let's first fabricate a few special parts that we'll need.

Making the Gears

The gears that control the front and back leg sets are actually one plastic gear split down the middle and turned back on itself. Because leg walking only requires a back and forth, reciprocating motion (rather than continuous rotation), we don't need all 360 degrees of gear. One-hundred eighty degrees–worth of gnarly gear teeth is more than enough.

To cut the gear in half, choose the notch between two gear teeth on one side of the gear's circumference and count half of the notches between gear teeth to arrive at the point where you want to cut. So, if your gear has 40 teeth (as ours does), choose a space between two teeth and count between teeth to the 20th notch. Most plastic gears have holes in the area between the hub and the toothy rim (to cut down on weight). Try to align your cut so that you don't cut through any of these holes. Structurally, this doesn't really matter; it just looks nicer.

After you've found your centerline to cut, use your hobby knife and a ruler (preferably a metal one) to scribe a line across the gear. Use a cutting mat, scrap cardboard, or something else that you don't care about marring. Because the gear likely has a raised rim around the outer edge and a raised edge around the hub, cut into each of these surfaces in turn (in other words, don't just drag the knife along the ruler, at one depth, and in one long stroke). Take your time and cut repeatedly, applying more pressure each time. Don't try to cut through all in one stroke. If you have a hobby razor saw, or a razor saw blade for your regular hobby knife, that will make cutting easier (see Figure 14).

FIGURE 7.14
Cutting the gear in half to make two 180-degree walking gears.

Fabricating the Idler Shaft

There are two gear shafts on our walker. The driveshaft is the one that comes from the gear box onthe servo motor (which is oriented upside down).It transfers the back and forth motion of themotor to the internal gears of the servo’s gearbox,and then to the gear shaft to which we’ll attachone half of the gear we cut. This gear also servesas the base for mounting our back leg assembly.A second gear shaft is used to hold the other gearhalf and the front leg assembly. This gear shaft isnot powered (its gear uses transferred motionfrom the powered “rear” gear). Because this shaftis unpowered, we’ll call it an *idler shaft.*

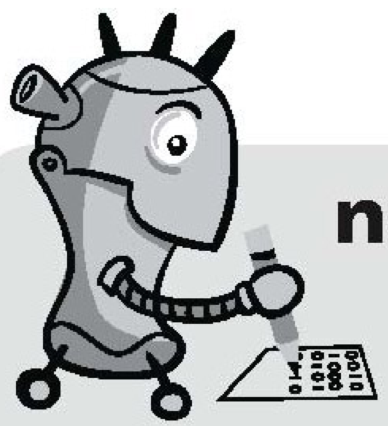
The idler shaft can be made from either a metal coat hanger wire or other wire in the 8 to 10–gauge range. If you want, you can use the “Gumby Legs” wire sold by Solarbotics (which we recommend using for the legs). This wire is simply 10-guage copper wire, so if you have other access to 10-guage solid copper, you can use that.

1. Cut about a 3 1/2-inch length of wire. If you use the copper wire, you’ll likely have to strip off the plastic insulating jacket first. Use your wire-stripping tool. Make sure the wire’s nice and straight. By the way, if you do use the gumby wire (or other jacketed 10-guage), save the jacket pieces. You’ll need them later on.

2. Measure down about an inch on the wire and, using your needlenose pliers, bend the wire above your 1-inch mark into an inverted teardrop shape

caution

You want to be extremely careful cutting the gear in half. Use a new blade on your hobby knife. Make sure the gear is secure as you cut (apply lots of downward pressure on your ruler to hold the gear in place). Use careful, controlled strokes. Don’t rush it, or you could cut yourself.



note

Servo motors often have mounting brackets built into them (on both (think shepherd's crook). It doesn't really matter if the shape is perfect. All we're trying to do here is to create as much surface area as possible for gluing. This bent part of the wire is what gets glued to the servo motor/body (see Figure 15).

3. At the 1 1/2-inch mark, bend the shaft about 35 degrees away from the teardrop as shown in Figure 15. Test fit this on your motor casing. The teardrop part should lay flat against the casing and the shaft should clear the motor mounts on the servo motor (with some wiggle room). If you have a Dremel tool or a razor saw, you might want to go ahead and zip off the motor mount anyway, to give yourself lots of space (we did this). You'll need to be able to bend this shaft (down) a bit during the final assembly so that the idler gear can mesh properly with the drive gear.

brackets built into them (on both ends of the motor casing). Depending on the angle of your idler shaft, the bracket on that end of the motor casing might get in the way of this idler shaft/gear assembly meshing properly with the drive gear. You might want to just go ahead and zip this mount off with a Dremel tool or razor saw. We went ahead and removed the mounts from both ends of the casing, just to make our little beasty look sleeker.

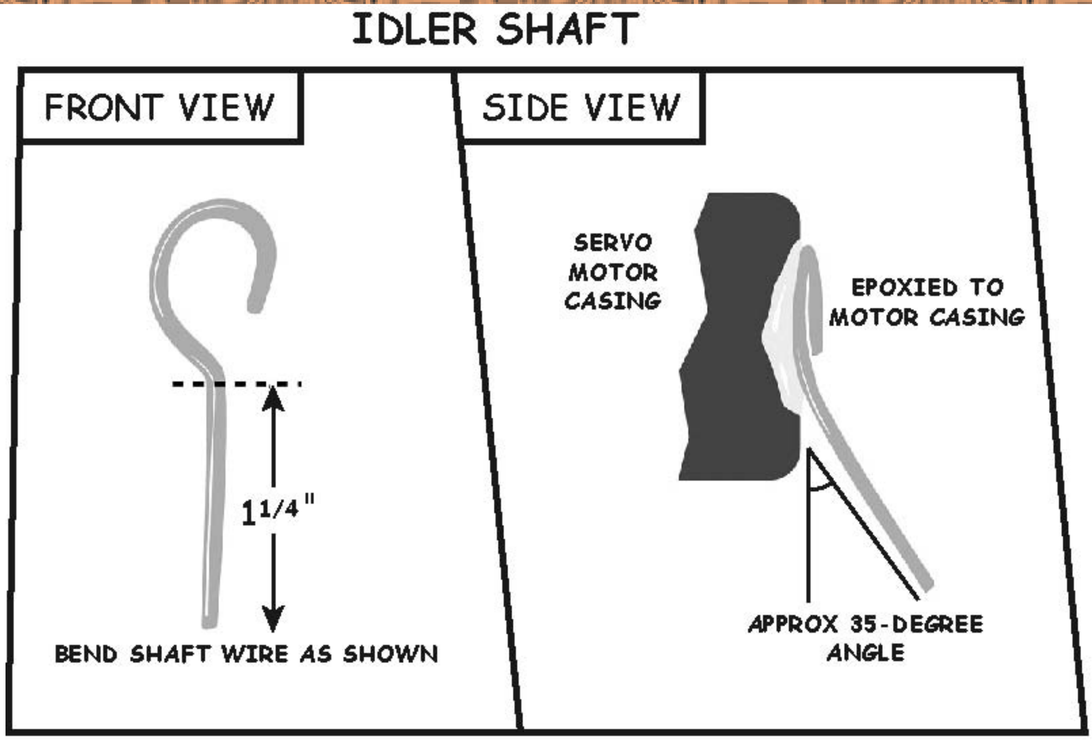


FIGURE 15: Inverted teardrop bend in gear shaft wire for mounting to servo (left), 35-degree bend in wire, seen from side and attached to motor casing (right).

4. Mix up a small batch of 2-part epoxy. Apply it with a wooden coffee stirrer, Popsicle stick, or other similar dis-posable stick, to the end of the servo motor *opposite* the end closest to the drive shaft (see Figure 16). This is very important. Now place the teardrop-shaped crook part of your idler shaft into the glue. You should have a generous amount of epoxy on the motor casing so that the wire gets firmly bonded to it. You'll need to hold the wire in place for a few minutes while the epoxy sets up. Get comfortable, don't rush it, and don't peek! Use a piece of junk plastic (like the clear plastic used in prod-uct packaging) to hold the shaft in place (so you don't glue your fingers to it). You can carefully peel the plastic away after the glue has set up enough to hold the shaft firmly in place. Don't use paper for this, as some of the paper will stick to the shaft and look…ah…tacky. Make sure the shaft, as it comes away from the teardrop mount, is centered right and left on the motor. When the glue has set enough for the shaft to be stable, carefully put the motor down in a safe place for it to dry, preferably overnight.

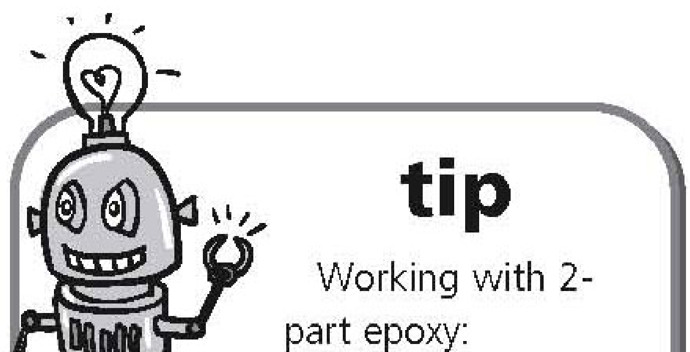
FIGURE 16: Our idler shaft glued to the motor casing (opposite of the drive shaft and motor wires).

Making the Idler Gear

While the epoxy is drying on the idler shaft, we can make the gear and gear mounting hardware that we'll use to attach it to the shaft. Let's start with the gear.

When we cut our original gear in half, we cut the center hub in half as well. This leaves us with no closed hub to hold the gear onto the shaft. We'll need to fabricate our own hub.

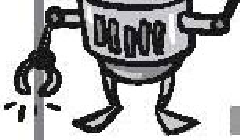
1. First you'll want to use your hobby knife to clean away any of the plastic residue in the hub area that might be left over from cutting the gear in half. You want a nice clean surface on which to bond.



2. If you used the Solarbotics gumby wire (or

other jacketed 10-guage wire), you should have a lot of plastic jacket left over from the stripping. Using your hobby knife, cut a piece about 3/8-inch long. Make sure that your cuts are as straight as possible. If you don't have a 10-guage wire jacket to play with, you'll have to find plastic tub-ing with a 3/32-inch inside diameter. Heat-shrink tubing of this size will work.

3. You could just glue this hub right to your idler gear, but we found that the stress on it eventually broke the gear off. To fix this, we added some plastic reinforcement to help join the hub to the gear. We did this by way of the optional leg mounting pad (attaching the hub/plastic to the LMP). If you're using an LMP, you'll want to trim the LMP first (see details on page 214). To create the reinforcer, we cut a small (1/4 inch × 1 inch) rectangle of plastic and drilled a hole (just using the point of our hobby knife) in the center (for the hub to pass through). We glued the hub to the plastic reinforcement piece and then glued the reinforced hub to the LMP (which will, in turn, be screwed to the idler gear). We used superglue for this bonding job. To create the plastic reinforcement part, we used a piece of .03-inch plastic stock (often called Plasticard), available at most hobby and craft shops, but you can just as easily use more of that junk plas-tic most



part epoxy:

- Keep it clean, buster! Epoxy likes it when you use a clean surface for mixing, and clean (unused) toothpicks, Popsicle sticks, coffee stirrers, and so forth for mixing. Use a new mixing surface and stick each time you mix up a batch.

- Mix *thoroughly*. This is chem-istry, people. Let the two parts come together, do their chemi-cal thang, and generate some heat. That's when the good bonding happens. Mix until the slightly foggy cast and bubbles are evenly distributed throughout—and then mix some more, for good measure.

- If you want to extend the working time (or *pot time*) of the epoxy, spread it out (after it's well-mixed). The more com-pressed the mass of epoxy, the more heat it'll generate (and the faster it will cure).

- Use clamps, tape, rubber

everything we buy is packaged in (see Figure 17).

- Use clamps, tape, rubber bands, and so forth to hold parts in place while they dry, but don't get glue on them! Use a piece of scrap plastic, cardboard, or similar material between the clamps and the object being glued.

4. While the hub assembly is drying, we'll create the mounting hardware. These are the two parts that will be fastened on either side of the idler gear to hold it in place on the shaft. To create these parts, we'll need to "free" two screw terminals from a terminal mounting block. A terminal mounting block is a simple but nifty electronic component that allows quick connecting/disconnecting of rows of wires. To use a terminal block, one sticks wires in holes on either side of the terminal block and tightens them in place with the block's built-in screws. This two-connector pair forms a disconnectable electrical connection. The metal blocks and screws are usually surrounded by a nylon housing. For our gear mounting parts, we'll need to remove a terminal pair from the block, cut away the plastic housing, and then cut the connector pair in half to make two screw-down mounting pieces. Follow the sequence in Figure 18 to create the two parts. It is highly recommended that you use a rotary (Dremel) tool for this operation. If you don't have such a tool, you can use a hacksaw or razor saw. A hobby knife won't work (Barbie says: "Nylon is hard!"). After you've cut out your two mounting parts, use a metal file to remove any burrs where you cut the block pair in half.

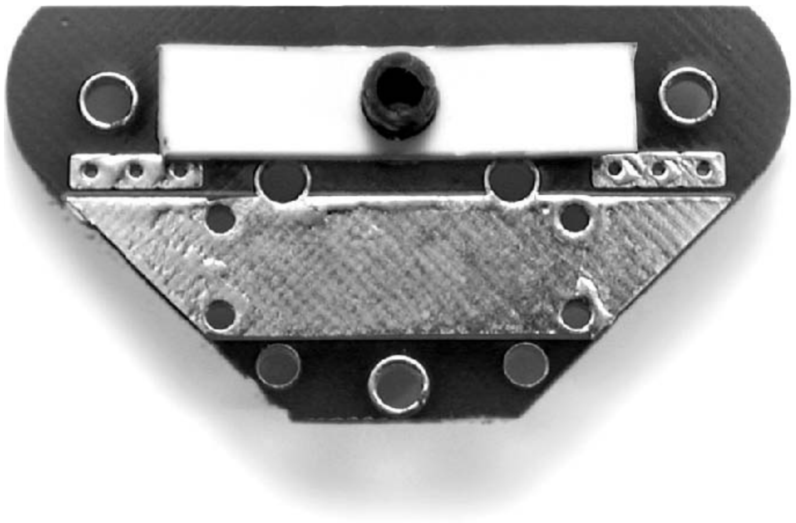


FIGURE 17: The new gear hub and hub reinforcer glued to the LMP. If not using LMP, glue hub/ reinforcer directly to gear-half.

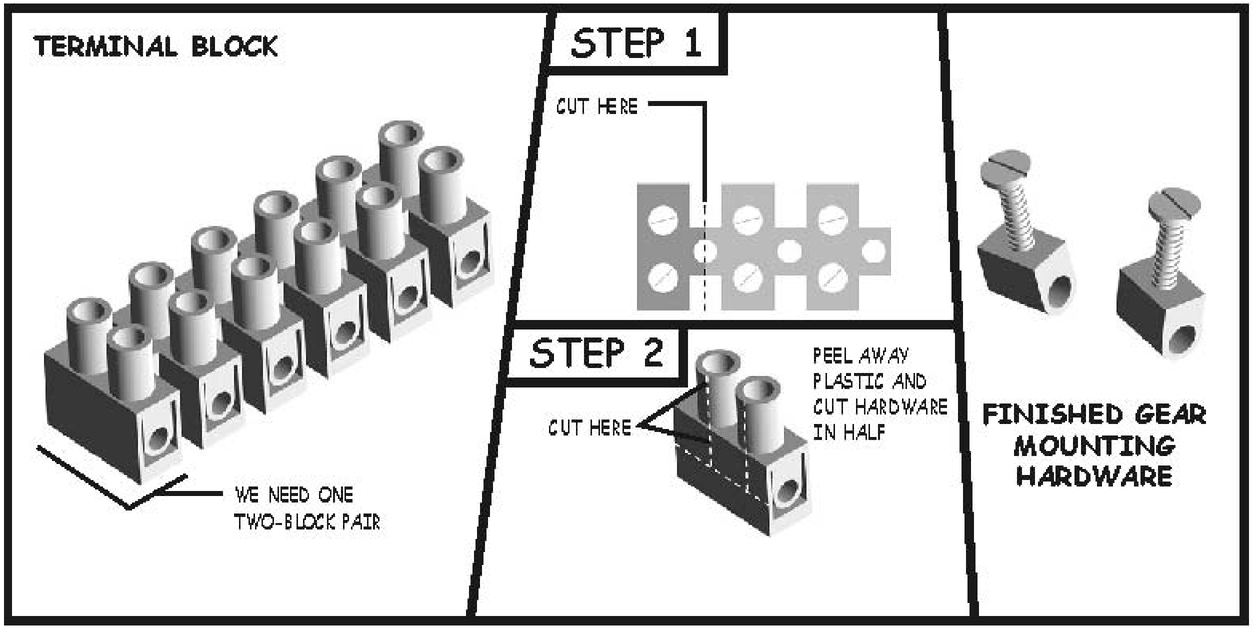


FIGURE 18: The steps required to "free" a terminal pair from a terminal block.

5. When the glue is dry on your hub assembly (and on the idler shaft itself), use two screws that came with your servo motor (or any other sheet metal–type screws long enough) to attach the mounting pad/hub assembly to the idler gear. Now you're ready to test-mount the gear on the shaft. Slide one terminal block onto the shaft all the way up to the teardrop mount, and screw it down tightly. Now slide the idler gear on (with the teeth facing down), followed by the second terminal block, which also gets tightened. The idler gear and shaft are done (see Figure 19)!

caution

Creating this mounting hardware is the most dangerous part of building this walker. You'll need to cut through plastic and metal, and if you use a rotary tool, the chips are gonna fly. It is ideal if you hold the block in a bench vise, and you definitely need to wear safety goggles or glasses. If you don't have a vise, use a C-clamp, spring clamp, or or glasses. If you don't have a vise, use a C-clamp, spring clamp, or some other type of clamping technology. The terminal block *must* be secure for safe cutting.

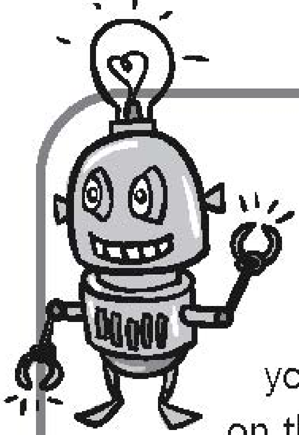
FIGURE 19: Our finished idler shaft and idler gear.

Mounting the Drive Gear

The output shaft (*final gear*) of a servo motor usually ends in a stubby knurled bit that sticks out of the motor casing. These knurls mesh with a complimentary set on a component called a *servo horn* or *control horn*. Servo horns come in many shapes and sizes. They were originally designed for attaching control wires/rods used to control model airplanes, so the horns have many holes in them for such attachments. If you're using the Solarbotics motor GM4, it comes with a bunch of different servo horns, mounts, and mounting hardware. We want to use the 1 3/8-inch disk-shaped horn. If you got your motor else-where, hopefully it came with a horn close to this diameter. It doesn't have to be exactly this size, but when we attach the drive gear half to it, we want the gear/servo horn assembly to be as close to the lead edge of our walker (the edge with the idler gear) as possible. You'll want the idler gear to be at about 35 degrees in relationship to the drive gear.

To create our drive gear, all you have to do is glue (with epoxy) or screw the gear half to the servo horn. We chose to screw ours on. Because the rim of the gear is raised, there isn't much gluing surface. We used the servo mounting screws that came with the Solarbotics GM4. We tapped starter holes in the gear to make screwing the two components together easier. The servo horn has rows of holes already in it, so we made use of those (see Figure 20).

After you've attached the gear to the servo horn, test fit the drive gear (you don't have to bother screwing it in). The two sets of gears should mesh. You might need to bend the idler shaft. The gears will mesh at an angle. This is correct. There just needs to be enough meshing that they don't slip as your critter lumbers along. See Figure 21.



tip

If you need to use pliers to straighten your leg wire, the teeth on the pliers will leave unsightly marks, especially if you're using copper, which is quite soft. Wrap some masking tape around the jaws of the pliers and then you can tweak and twist all you want and leave nary a scar.

FIGURE 20: The drive gear mounted (here via screws) to the servo horn.

FIGURE 21: Test fitting to make sure that the drive gear and the idler gear mesh properly. Bend idler shaft down, if necessary.

Creating the Leg Assemblies

With your robot body all geared up, it's time we go a-walkin'. To do that, you'll need legs—two sets of them. One of the cool things about this robot…er…walking machine, is that it teaches us about different leg designs and how they impact the critter's mobility. If you want, you can just make two sets of legs, epoxy them to the gear halves, and be done with it. That's how Jérôme Demers did his walker. But we came up with a little revision to the design that lets you mount various leg configurations, so you can experiment with different designs. Let's fashion our first two sets of legs because we'll be using them regardless of whether we glue them on or use mounting hardware.

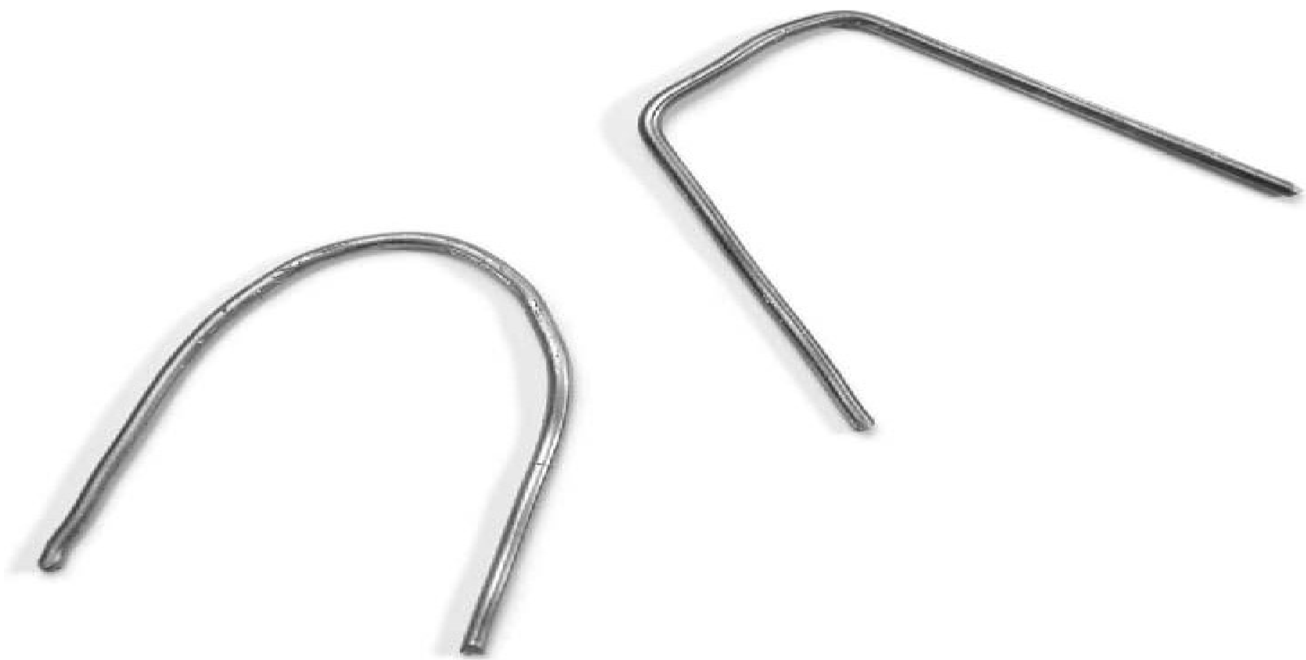
We'll do the back legs first, as they're the easiest.

The Back Legs

To fashion a set of back legs:

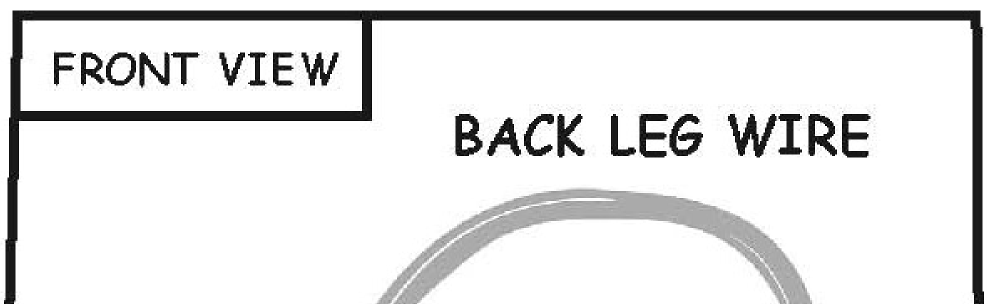
1. Measure out and cut 5 1/2 inches of coat hanger or similar wire. Find the midpoint, and using your needlenose pliers, fashion the wire into an overly wide “U” shape. If you’re planning on gluing the legs directly to the gear, test fit and reshape until the crotch of the “U” fits nicely inside the inside rim of the gear. If you’re using one of the Solarbotics leg mounting pads (LMPs), you’ll want a more square-shaped bottom for your “U” (so that the leg wire doesn’t start bending until it clears the attachment holes on the LMP). Both examples are shown in Figure 22.

FIGURE 22: Legs shaped for gluing (left) or for LMPs (right).



1. Measure about 1 1/4 inches from the tip of each leg and bend wire to angle approximately as shown in Figure 23.

2. If you’re gluing on your legs, mix up a batch of epoxy and glue the legs to the inside rim of the gear. Set the leg/gear assembly aside to dry. You’re done. If you are not gluing, go to step 4.



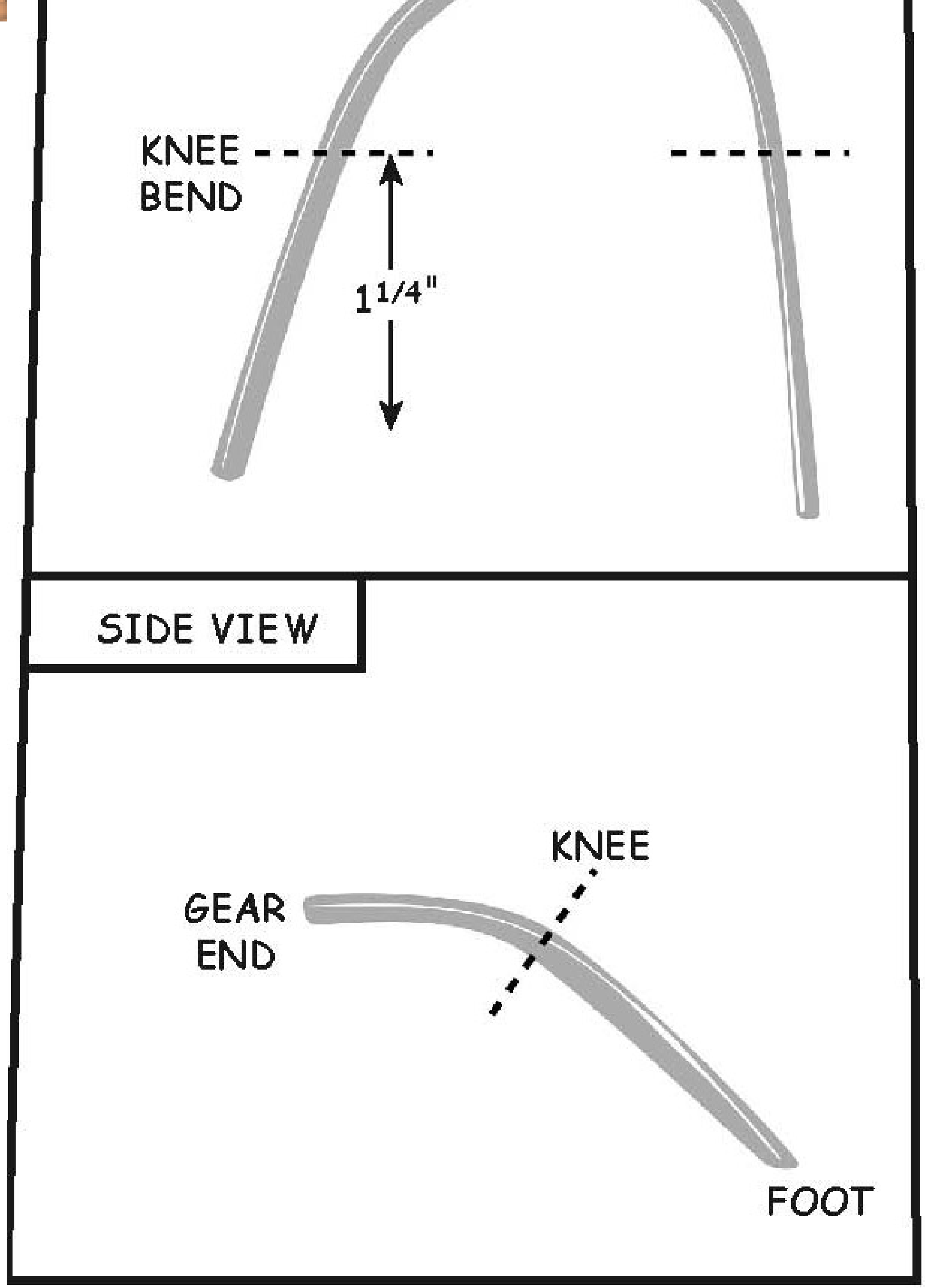


FIGURE 23: Approximate downward angle for walker's back legs.

4. The Solarbotics LMPs have a triangular shape that can't work on our walker as is. So that the LMPs do not touch each other when we attach the gear/leg assemblies, we have to zip off the peaks of the triangles. Using your rotary tool, razor saw, hacksaw, or other cutting tool, remove the pad material from one of the LMPs down to the top-most mounting hole (see Figure 24).

FIGURE 24: Solarbotics LMPs with their tips trimmed to fit our walker.

5. Get a piece of 22-guage hook-up wire (about 4 inches) and strip off the insulating jacket. Place your leg wire on the wide, silver mounting strip on the LMP and thread the hook-up wire through two of the mounting holes on the strip. Using your needlenose pliers, twist the wire tightly to attach the leg. Cut another 4-inch piece and thread it through the other set of holes on the mounting strip. Twist them down. Leaving about 4–5 twists, trim off any excess wire with your wire cutters. Cut a third piece of wire and use it in one of the three-hole tracks on the pad to further secure your legs (see Figure 25).

FIGURE 25: Back legs secured to LMP. Note third wire wrap (far left) to further secure leg.

6. Using the screws that came with the LMPs, screw your leg/LMP assembly to the back servo horn/ gear assembly (see Figure 26). You'll probably want to drill or tap starter holes in the gear.

FIGURE 26: The LMP mounted (here via screws) to the drive gear and servo horn. (Note: The legs are not shown here so that you can see the screw attachment.)

7. To get better traction from the legs, and honestly, to make our robot look a lot cooler, we'll add some robot "feet" to the legs. You can use heat-shrink tubing for this or simply cut four 1/4-inch pieces of the insulating jacket from the 10-guage wire (if you used that in your build) and glue them onto the tips of the leg set (see Figure 27). Your back legs are done!

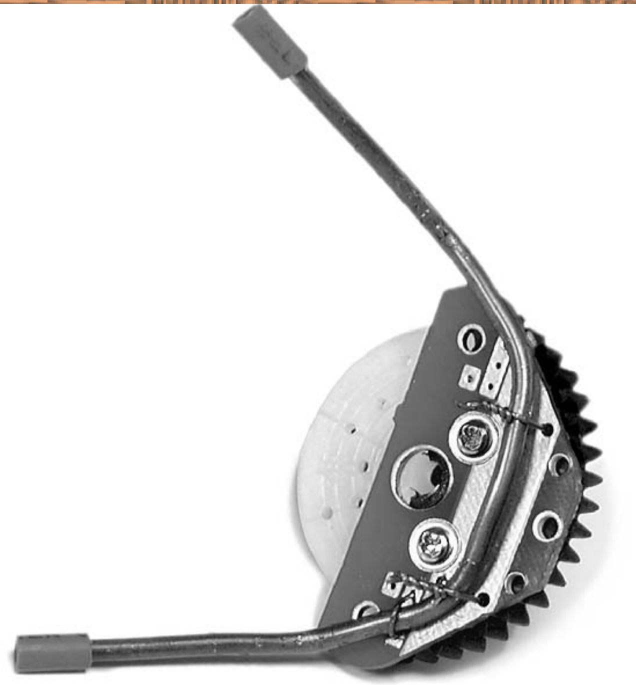
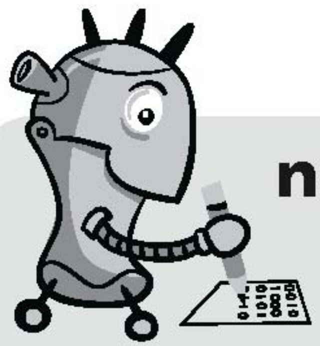


FIGURE 27: The completed back gear/leg assembly.

The Front Legs

The front legs are similar to the back legs, but they have a second set of “knees” (read: bends). We wanted our walker to have a nifty insectoid look, and given the angle of the front gear shaft, we thought a double knee leg shape looked the best. You can experiment around with different leg shapes (see “Further Experiments” later in this article), especially if you plan on using the Solarbotics LMPs so that you can change your legs.



If you find that you still don’t get good traction with the plastic “footies,” try gluing some rubber band material over the tips of the feet.

1. The first thing you’ll need to do is measure out and cut a 9 1/2-inch piece of your leg wire (coat hanger or 10-guage copper wire). Find the center point, and as you did with the back legs, bend the wire into a slightly splayed-out “U” shape. Again, if you’re planning on gluing the legs to the idler gear, you’re going to want a rounder crotch on the

"U" (so that it fits within the gear's rim), or a more square shape if you're using the LMPs.

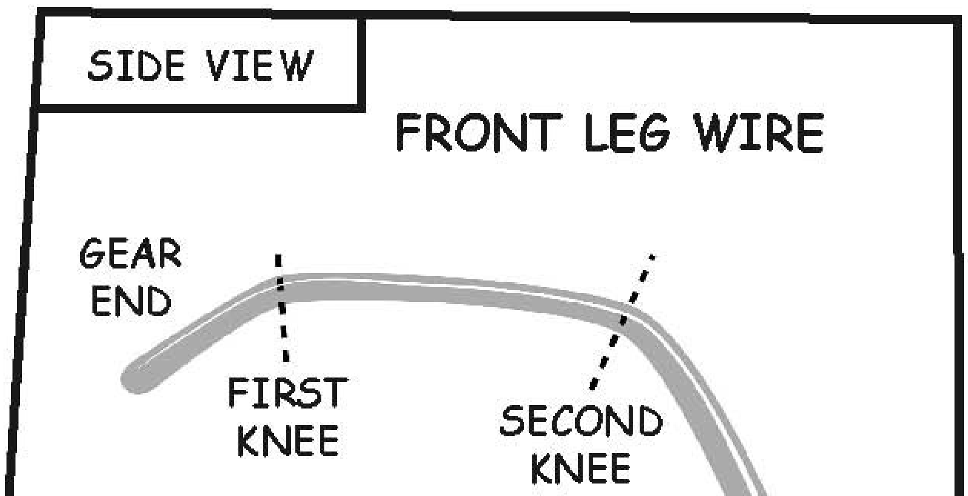
2. Measure 3 inches from each tip of the "U" and mark this point. This is where you'll put the first knee. Bend the wire on both sides as shown in Figure 28.

3. Now measure 1 1/4 inches from each leg tip (the feet!) and bend both leg sides as shown in Figure 28. For shapes of bends (glued vs. mounted), refer back to Figure 22.

4. If you're gluing your legs on, mix up a batch of epoxy and glue the legs to the inside rim of the gear as you did for the back legs. Set the leg/gear assem-bly aside to dry.

5. Using your rotary tool, razor saw, hack saw, or other cutting tool, remove the pad material from the remaining LMP (if you haven't already) down to the top-most mounting hole as we did for the back legs (refer back to Figure 24).

6. Strip a 4-inch piece of hook-up wire. Place your leg wire on the wide silver mounting strip and thread the hook-up wire through two of the mounting holes on the strip. Using your needlenose pliers, twist the wire tightly to attach the leg. Cut another 4-inch piece and thread it through the other set of holes on the mounting strip. Twist them down. Leaving about 4–5 twists, trim off any excess wire with your wire cutters. Cut a third 4-inch piece of wire and thread it through the outside hole of one of the three-hole tracks on the pad. Thread it through the back of the pad and through the outermost hole on the other side of the LMP. Twist the wires together to further secure your legs to the pad (see Figure 29).



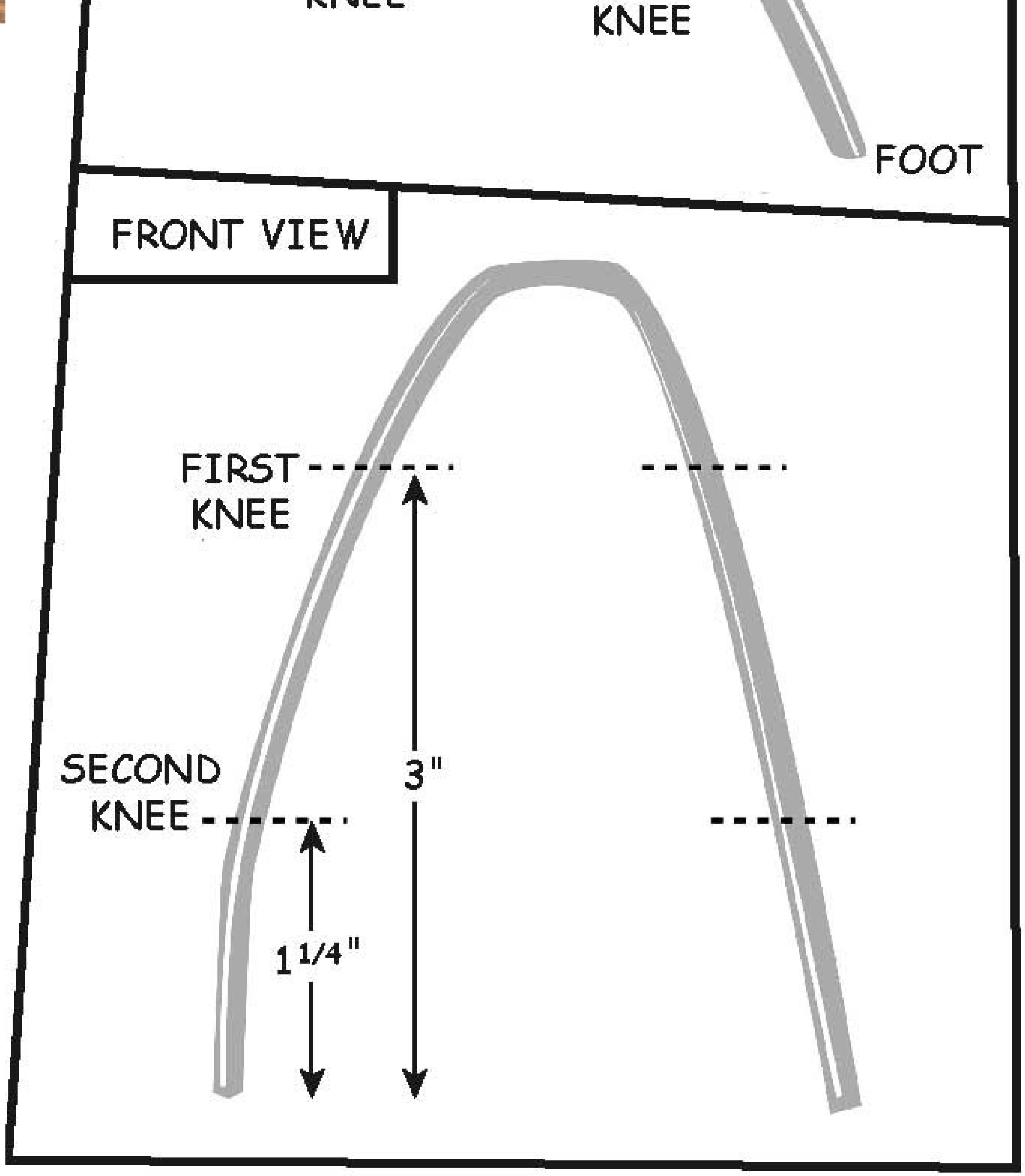


FIGURE 28: The shape of the front legs (here shaped for the LMPs) and the placement of the two knees.

1. Use the screws that came with your servo horn set or other sheet metal screws (in other words, screws with points on ‘em) long enough to fasten the LMP to the idler gear. Use a small nail or drill to tap holes into the gear where you’ll be attaching the leg assembly.

2. Add your bot footies to the legs, as you did with the back legs, either using leftover wire jacket or heat-shrink tubing (also shown in Figure 29).

FIGURE 7.29
Our finished front leg assembly.

Testing the Fit

That's it for the leg assemblies. You're ready to test fit the legs/gears to make sure they mesh properly. Put the drive gear on the servo motor, with the gear basically centered right and left. Now slide the front gear on its shaft and use the screw on the terminal block to fasten the gear in place. The gears should mesh well enough that when you gently twist the drive gear, both sets oflegs/gears move in tandem. If they don't—or if the gears slip—you'll have to push down on theidler shaft, (toward the drive gear) to get a better mesh.

caution

When you bend the idler shaft to adjust the gear fit, hold the teardrop-shaped mounting area of the shaft firmly. If you epoxied it well, you should have a fairly strong bond, but if you put too much stress on it, it might break off.

The Power Plant

We're almost there! All we need to do now is attach the battery packs, add a power switch, and attach the motor and power wires to the control circuit.

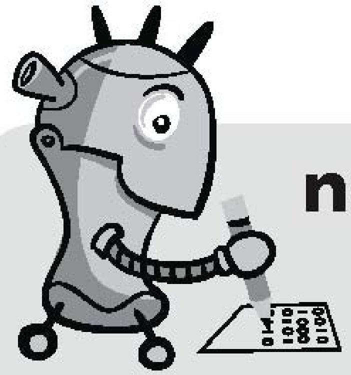
Attaching the Battery Packs

The two AAA battery holders need to be attached to either side of the servo motor. This is easily done.

1\. Orient the first holder so that the power wires face toward the back of the walker and center the holder front to back (on the motor casing). Orient it as close to the bottom of the motor case as you can (so that you keep the center of gravity on the machine as low as possible). When you have it where you want it, place the tip of your hobby knife in the center mounting hole of the battery holder and twist the knife to begin a screw hole. Remove the battery holder and ream out the screw hole a bit more. Don’t make the tap hole too deep or too wide—you’re just looking for something to get the screw started.

1. Apply some superglue or epoxy to the back of the battery holder, and then, using a small sheet metal screw (like the ones that likely came with your servo motor) in the center hole, attach the holder to the walker’s side (see Figure 30).

2. Repeat the preceding steps on the second battery pack (making sure the wires sprout out the back of the bot).



note

If you decided to build the walker’s body first, and then the control circuit, go ahead and attach the battery packs to the sides, but don’t connect the batteries or attach the switch. Do this only after you’ve built and attached the Bicore. It is recommended though that you load the battery packs with batteries (and use another 6V of power on the breadboard). This way, with a “dummy load,” you’ll have a true measure of most of the weight the walker will be carrying on board as you tweak the mechanics and electronics.

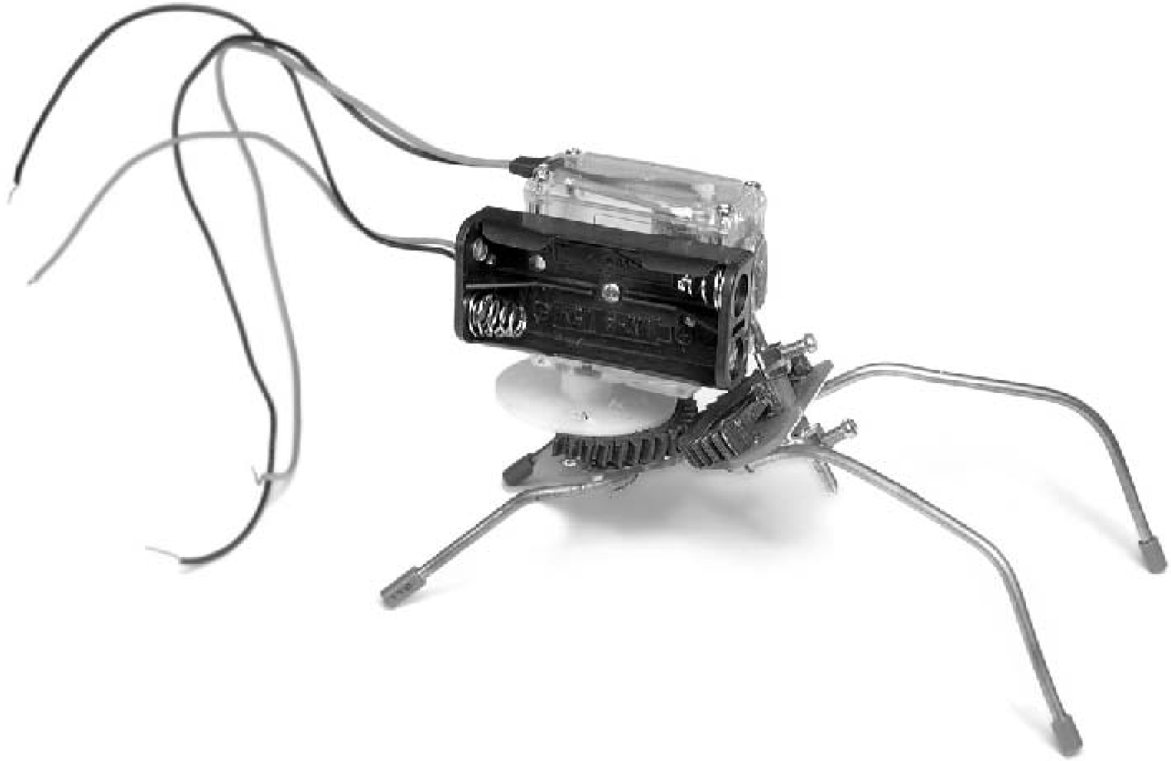


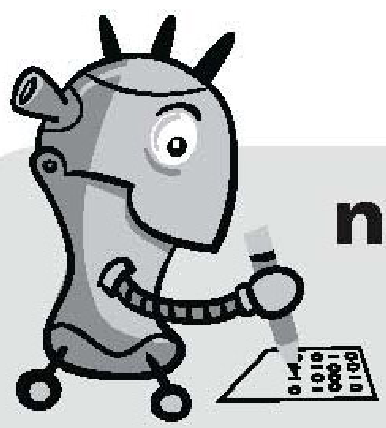
FIGURE 30: AAA battery holders attached to servo motor casing.

Adding a Power Switch

To be able to turn our walker on and off, we need to add a switch. This is easily done.

1. Test fit your microswitch on the back of your servo motor. It should be able to just fit on either side of power wires coming out of the motor casing. When you've decided where you're going to put it, mix up some more 2-part epoxy and glue it into place (see Figure 31). When it's dry, move on to step 2.

2. Find the upper-most red (+) wire on one of the battery packs. Cut and strip the wire as short as



note

If you decided to build the body

possible (so that it's as tight to the bot's body as possible after it's soldered to the closest connecting pole on the bottom of the switch). Thread the wire through the hole in the closest switch pole and then bend and twist the wire for a nice firm connection. Trim the excess wire and then solder the wire wrap to the switch pole (see Figure 31).

3. Measure out and cut about 2 inches of the excess positive wire you just snipped off of the battery holder. Thread this through the hole in the center terminal of the switch (if it has more than two terminals), twist it up, and solder. Leave the other end (which will eventually connect to the Bicore) unconnected (see Figure 31).

4. Now let's hook our two battery packs together in series to deliver all of their 6V of power to the switch (and to the motor and control circuit when we throw it). Take the bottom two wires, one red (+) and one black (-) from each battery holder and overlap them. Eyeball about how much wire you'll need to keep for stripping and wrapping these wires together, and then clip off the excess. Strip and wrap the wires together and add some solder for good measure (see Figure 31). Remember: Neatness counts.

If you decided to build the body first and the Bicore control circuit second, now it's time to hook the body to its (temporary) brain on the breadboard. Add your "dummy load" of four AAA batteries and use two long lengths of hook-up wire to attach the motor to pins 9 and 12 on the breadboard. The positive gets attached to pin 9, the negative to pin 12. Apply 6V of power to the breadboard's power bus, and watch your critter go! Play around with changing leg shapes and resistor values until you have a configuration you like; then go back to the "Freeforming the Bicore Control Circuit" section to create your control circuit.

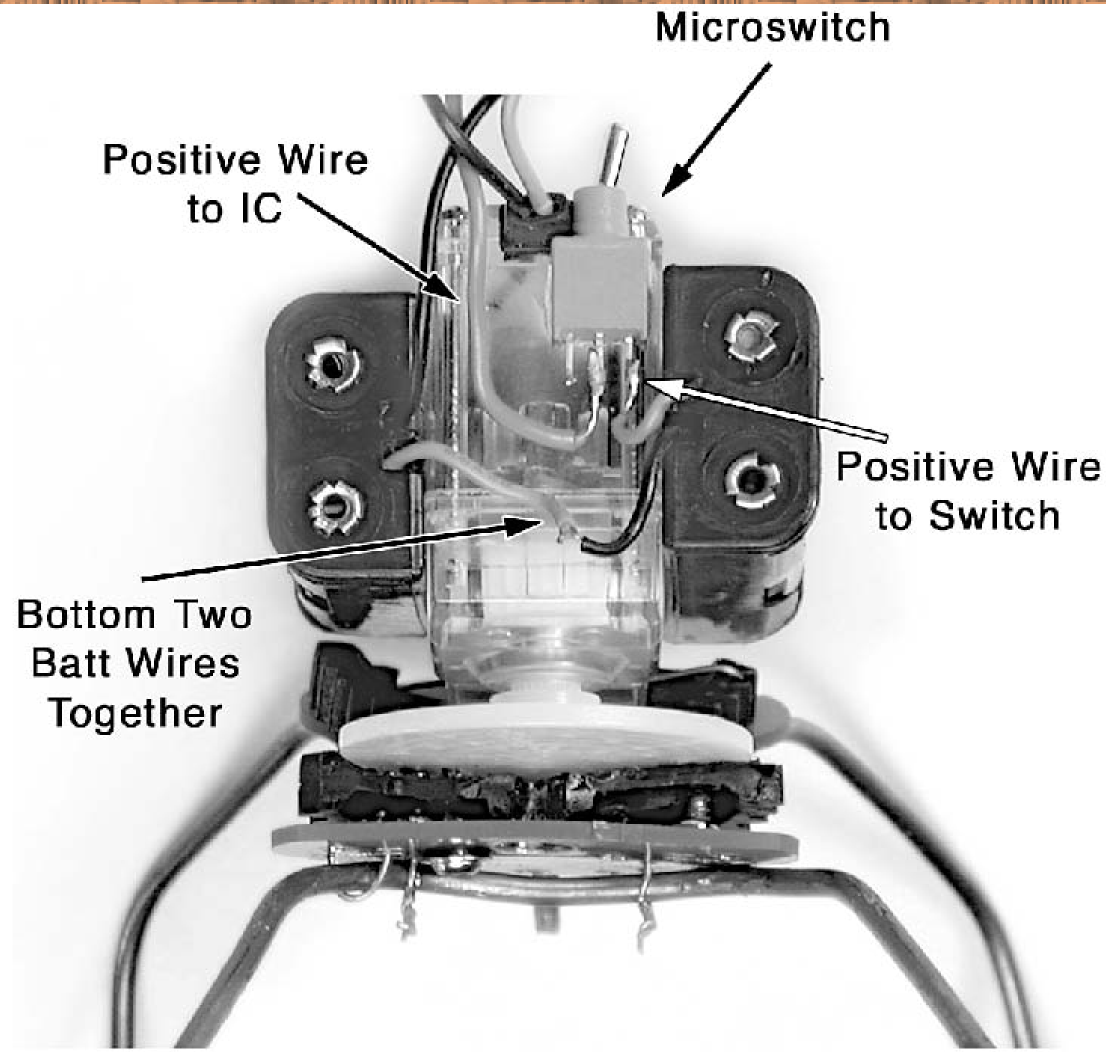


FIGURE 31: Power switch and battery pack all con-nected and ready to deliver the juice!

Final Assembly

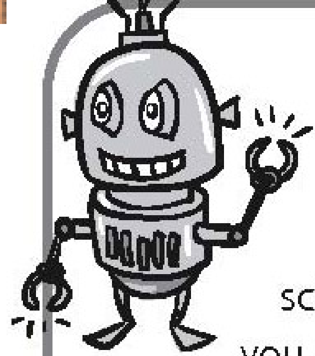
We’re almost there. Now all we have to do is attach the power and the motor wires to the control circuit and then the control circuit assembly to the top of our walker. It goes something like this:

1. Measure out enough of the positive (red) wire coming out of the back of the servo motor so that there won’t be too much

slack in it when the controller gets glued to the top of the motor. In other words, you'll want to solder the wires on before you glue the control circuit in place, but you don't want to end up with a big loop of excess wire when the circuit is connected and glued in place. The positive wire will be connecting to pin 9 on the IC socket.

2. After you've measured and cut the positive motor wire, measure and cut the negative motor wire to the same length. It will connect to pin 12 on the socket.

3. Measure the unconnected red wire from the switch so that it will comfortably reach pin 20 on the IC socket when it's glued to the top of the servo. Cut it.



tip

If you *really* want to be a fancy-schmancy bot builder, you can put heat-shrink tubing over the wire join connecting the battery packs. To do this, slide a piece of heat-shrink tubing onto one of the wires *before* you wrap them together. After they're wrapped and soldered, slide the tubing over the join and heat with your micro-torch or heat gun.

4. Measure the top negative wire from the battery pack so that it will comfortably reach pin 10 on the IC socket when it's glued to the top of the servo. Cut it.

5. Now solder all of these wires that you've cut to the appropriate pins on the IC socket: positive wire from motor to pin 9, negative wire from motor to pin 12, positive wire from switch to pin 20, and negative wire from battery pack to pin 10.

You can see the end result of each of these first five steps in Figure 32.

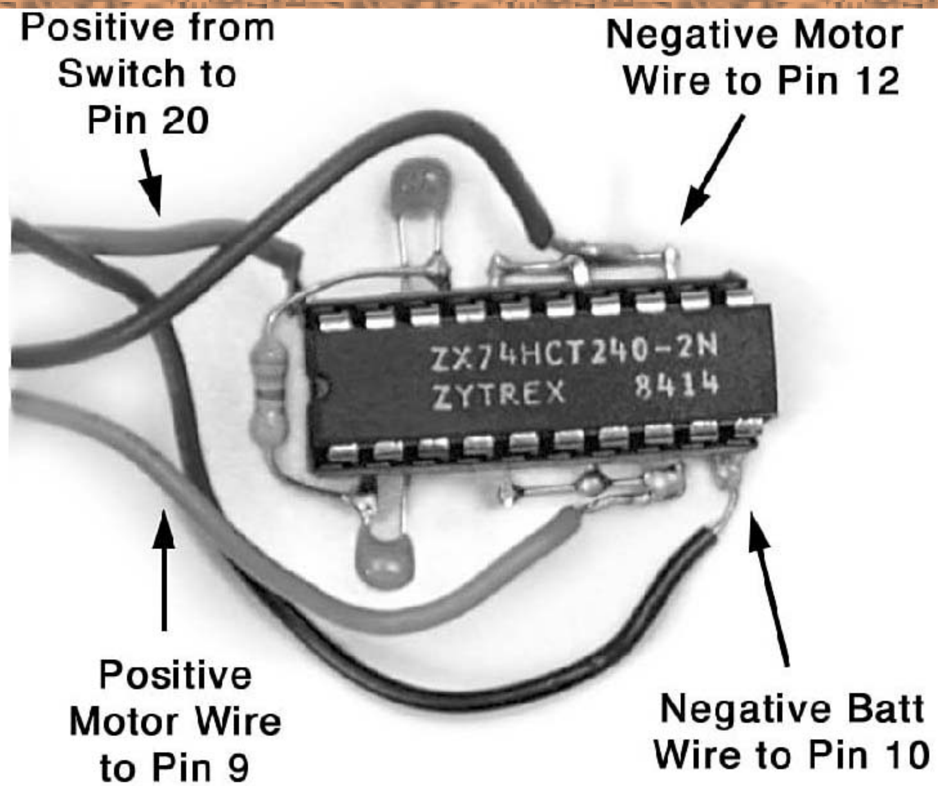


FIGURE 32: The power and motor wires connected to the appropriate pins on the IC socket.

6. Now that all the wires are connected to the IC socket, you're ready to plug in the 74HCT240 chip (if you haven't already). Gently press the chip into the socket holes. Be careful not to damage any of the components and solder joins on the other side. Test fit the control chip assembly to make sure that it can sit on top of the motor. You might have to gently bend the pins so that the socket sits relatively level. It is going to be slightly funky and it will be resting on the leads you soldered on. That's okay.

7. Before you glue on the control circuit, toss in some batteries, flip the switch, and make sure everything works (with the control circuit just hangin' around on the ends of the motor and power wires). If it doesn't work, check to make sure all of your connections were done properly (go back over the preceding steps and check each connection).

8. Now you're ready for the last step: fastening the Bicore circuit to the top of the walker using epoxy. Test fit the control circuit first. You might have to bend some of the parts on the

circuit, especially the caps, resistor, and motor and control connections to make sure the chip lies as flat as possible and pins/wires don't touch each other. If wires touch that aren't supposed to (such as a cap and a resistor lead), the circuit will not work. When the chip is prepped, mix up some epoxy, pile it on top of your motor casing, and squish the IC socket into it. Hold it until it stays. If you think you might want to monkey with the circuit some more, you don't have to glue it down, you could just use some poster putty to temporarily hold it in place.

With these steps complete, your walker is finito (see Figure 33)!

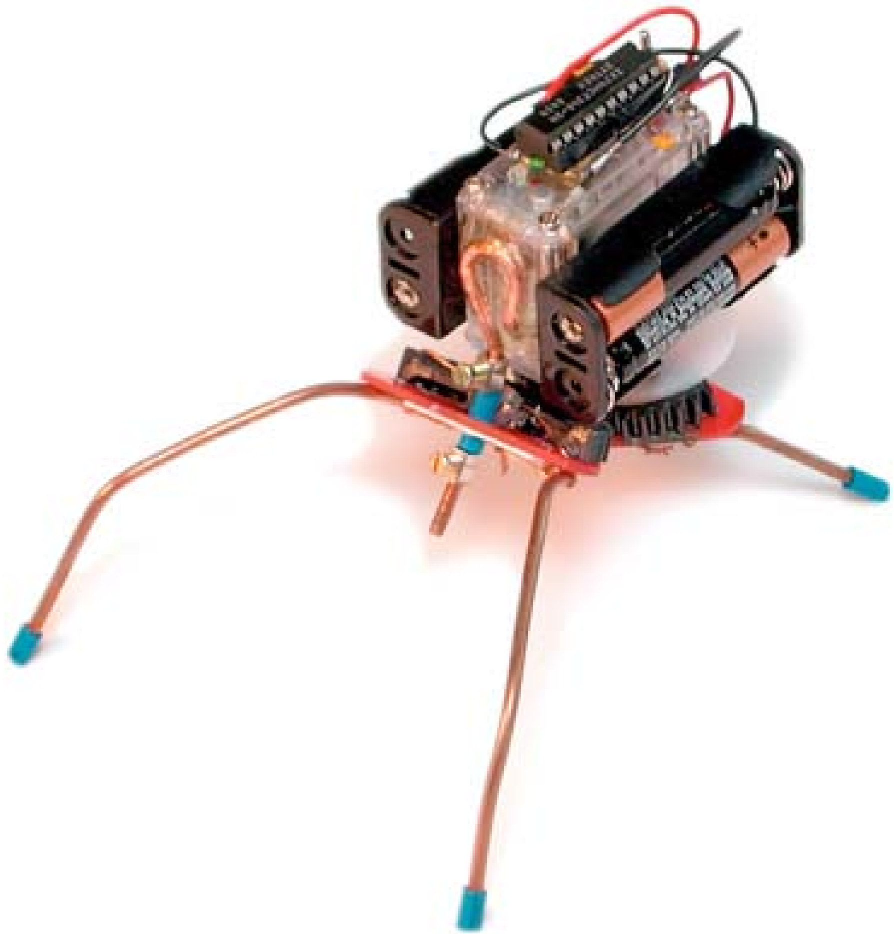


FIGURE 33: Our finished walker in all of its mechanical magnificence.

Further Experiments

One of the things that's really fun to do with building projects like this is to tweak them when they're done. Using the MIT AI Lab's idea of building upon previous successes, you can now think about improvements to your walker—evolutionary upgrades, if you will. Unfortunately, this "robot" is limited in what you can do with it, and it mainly involves reworking the legs. If you used the LMPs in the construction, you can easily remove the existing legs, reshape them, or make new pairs. Try much shorter legs, longer legs, legs that are high in the back and low in the front. Try legs that have "knees" at the feet—in other words, rounded tips on the ends (whereas ours are straight wire) with tubing where the rounded knee meets the ground. Try rubber on the feet, little pieces of sand paper, poster putty, anything that might afford more traction (and of course, look cool). Builders of this project have emailed me and posted on the Projects discussion on Street Tech's Shop Talk (Shop Talk/Building Robots/The Priojects) that they've played around with the COG (Center of Gravity) by moving the battery holders farther to the back and by attaching weights (pennies) to the back end of the walker. You can try all of these tweaks until you find a configuration that gives you the highest degree of walker mobility.

# # #

We don't know about you, but our hands are really dirty and we've got an animated coat hanger scuttling around on our desk. Here are a few things we hope you take away from the experience of building this critter:

- You can design ingenious machines with minimal mechanics and electronics if you're really smart. Barring that, you can find plans for them on the Net, like we did with our cool one-motor walker.

- The breadboard has given "rise" (okay, that's just sad—we apologize) to many an electronics project. Knowing how to use this basic circuit designing/testing tool is essential to good robot building.

- The servo motor is an extremely useful and efficient type of actuating/drive train technology that can be used in many different ways (with or without its control electronics) to create back and forth (i.e. walking) motion or continuous rotation.

- Bug-like walking machines, even ones with no sensors and not even bug brains, can exhibit types of persistence and motion that are extremely lifelike.

  Building stuff is damn-good fun!

Go back to Part I.
Go to Street Tech.
Go to Robot Book Companion Site.