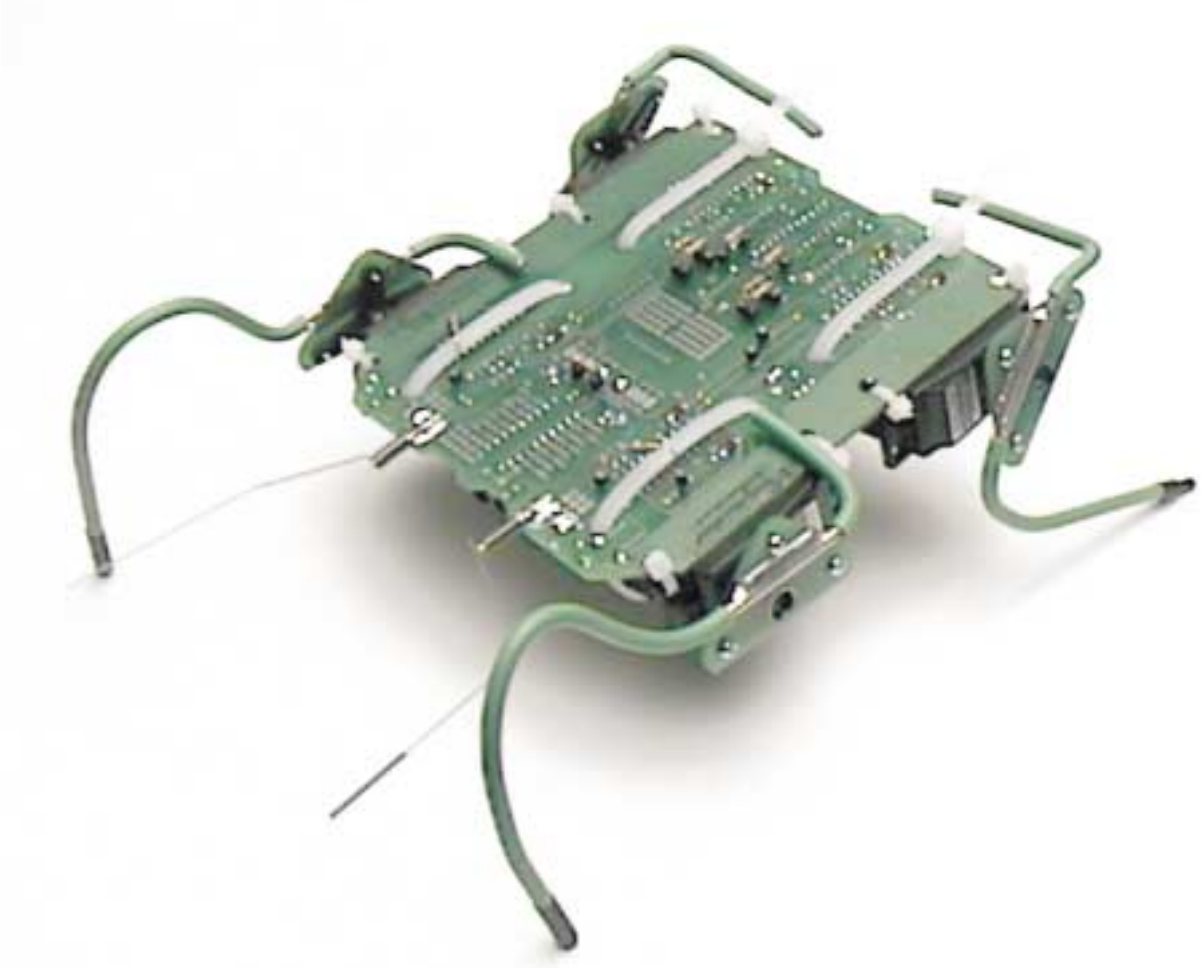
BEAM Robotics® Kit #8

1 2 3 4 5
Skill Level

The LANL Edition BEAM ScoutWalker 2.2 Walking Robot©



This BEAM® Walking Robot uses new Bicore® technology for an adaptive walking gait with Obstacle-Avoiding Behavior. Interfaceable with the SunSeeker Light Seeking Head Robot!

BEAM Walking Robot Technology without a MicroProcessor!

Produced by

SOLARBOTICS Ltd.

Documentation Release - October 30, 2001

SCOUTWALKER 2.2 - PARTS LIST

1 - SW2.2 Printed circuit board
4 - Walker leg mounting pads
2 - 47cm (18.5") Heavy-gauge leg wire (cut each 25.5cm from one end to make 4 legs)
6 - 74AC240 Octal buffer chips
1 - 8cm (3.15") Length of 1/4" Heat-Shrink Foot Sleeve (cut into four 2cm lengths)
4 - Servos and servo accessory pack
1 - 12" Length of servo wire
4 - 'AA' batteries
2 - Dual 'AA' battery holders
1 - Power switch
4 - Large zip ties
8 - Small zip ties
8 - Part 'C1' = Capacitor 0.1μF monolithic - Master Oscillator
6 - Part 'C2' = Capacitor 22μF electrolytic - Power Decoupling
2 - Part 'C3' = Capacitor 6.8μF electrolytic - Reverse Timer
10 - Part 'R1' = Resistor 470 ohm (Yellow / Purple / Brown) - LED Current Limiters
4 - Part 'R2' = Resistor 47k (Yellow / Purple / Orange) - Reverser Bypass & Enable Pull-downs
2 - Part 'R4' = Resistor 1.0M (Brown / Black / Green) - Reverse Time
2 - Part 'R5' = Resistor 3.6M (Orange / Blue / Green) - Master Oscillators
2 - Part 'R6' = Resistor 1.3M (Brown / Orange / Green) - Slaves
2 - Part 'R7' = Same as above (1.3M)
1 - Part 'R8' = Resistor 1.0M (Brown / Black / Green) - 'Corpus Callosum' Link
18 - Socket pins for Resistor Mounting
8 - Yellow Miniature LEDs (Motor activation indicators)
2 - Green Miniature LEDs (Tactile sensor indicators)
12 - #2-1/4 sheet metal screws (Leg pad mounting screws)
2 - Sets of tactile sensors (2-Pins, 1-Length 1/16" Heat Shrink, 2-Sensor Springs)

Not included, but referred to on the Printed Circuit Board:

3* - Part 'D1' . = Diode 1N914 signal - Head Kit interface
2* - Part 'R3' = Resistor 1k (Brown / Black / Red) - Opt. Reverser Inputs
2* - Part 'R9' = Resistor 1M (Brown / Black / Green) - Optional Tactile Sensor Delay
2* - Part 'R10' = Resistor 100 Ohm (Brown / Black / Brown) - Head kit delay
2* - Part 'R11' = Resistor 1k (Brown / Black / Red) - Head kit interface enable override
2* - Part 'R12' = Resistor 240k (Red / Yellow / Orange) - Head limit gate back-off

We strongly suggest you inventory the parts in your kit to make sure you have all the parts listed. If anything is missing, contact Solarbotics Ltd. For replacement parts information.

SCOUTWALKER 2.2 - INTRODUCTION

The ScoutWalker 2 is a new style of walking robot that utilizes a very non-digital approach; Bicore technology. Unlike traditional microprocessor or even BEAM "Nervous Net" technology, Bicore walkers use continuous phase differences between legs to achieve very interesting and unique walking behaviors.

Another interesting property of this robot is the multi-purpose use of a logic buffer chip in ways it was never designed to be used. The 74AC240 is designed to buffer data communications in two directions, but Mr. Mark Tilden (the inventor of BEAM Robotics) utilizes it so it acts as a motor driver; multiplexor (for modifying the walking gait); sensor input conditioner; and phasing oscillators. This lets the ScoutWalker 2 achieve all its functions by using the same chip in 6 places.

When finished, the ScoutWalker 2 will be able to walk forward, reverse, and turn on the spot in either direction based on sensory inputs. It also has facility to be adapted to other controlling devices, allowing the interface of the ScoutWalker 2 with microprocessor "brains" that tell it which way to go, or even to the SunSeeker Head Light-Seeker so that it can track sources of light. In its stock configuration, the ScoutWalker 2 comes with a pair of tactile (touch) sensors and a "raw" multiconfigurable bicore section to interface other systems with the ScoutWalker 2. There are also the necessary accommodations made to interface the SunSeeker Head kit to the ScoutWalker so it has an active light-seeking head.

The kit comes with all that is necessary to construct a fully functional walking robot, but we suggest you use the included socket pins to play with the values of the resistors that set the phase variances. This will let you explore what Bicore technology can do, and how robust it can be.

The walking gait is set by the two front Bicores, which oscillate independently, but are loosely linked by a "Corpus Callosum" resistor that makes them gently influence each other. This establishes a left/right coordination. Each of these front "master" Bicores are linked to a "slave" Bicore that controls each of the rear legs. By selecting appropriate resistor values to link the "masters" to the "slaves", the phasing is set that results in a walking gait.

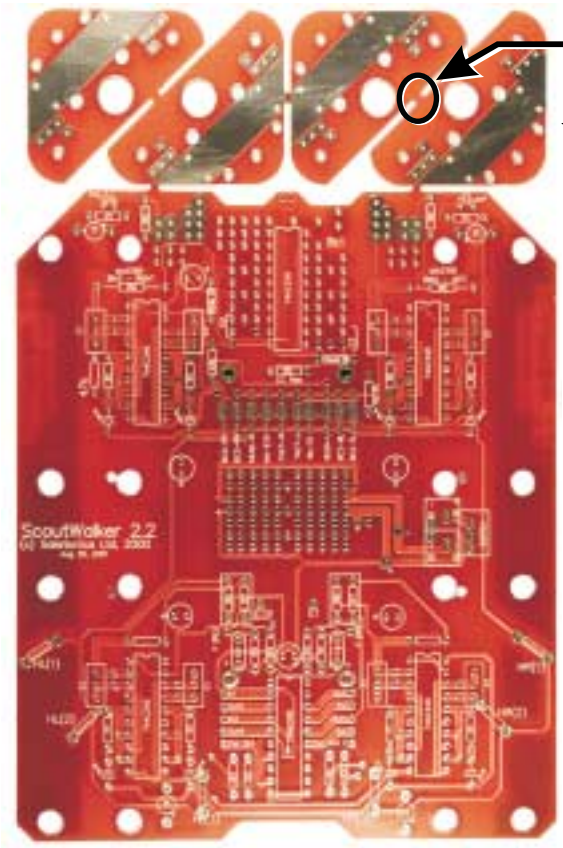
Making the ScoutWalker 2 backup and turn is accompished by the "IMx" Bicore in the lower center of the PCB. This Bicore acts as a multiplexor, and when activated (by the touch sensors or additional circuitry), swaps around the phase resistor connections so the phase difference encourages a reverse walking gait rather than a forward one. A built-in timer governs when the reverse gait times out, and sets the phase angle back to the original configuration.

Required Tools to complete this kit:

- Soldering Iron
- X-Acto Knife or razor blade
- Snips
- Pliers
- Phillips-head screwdriver
- Lighter or Match

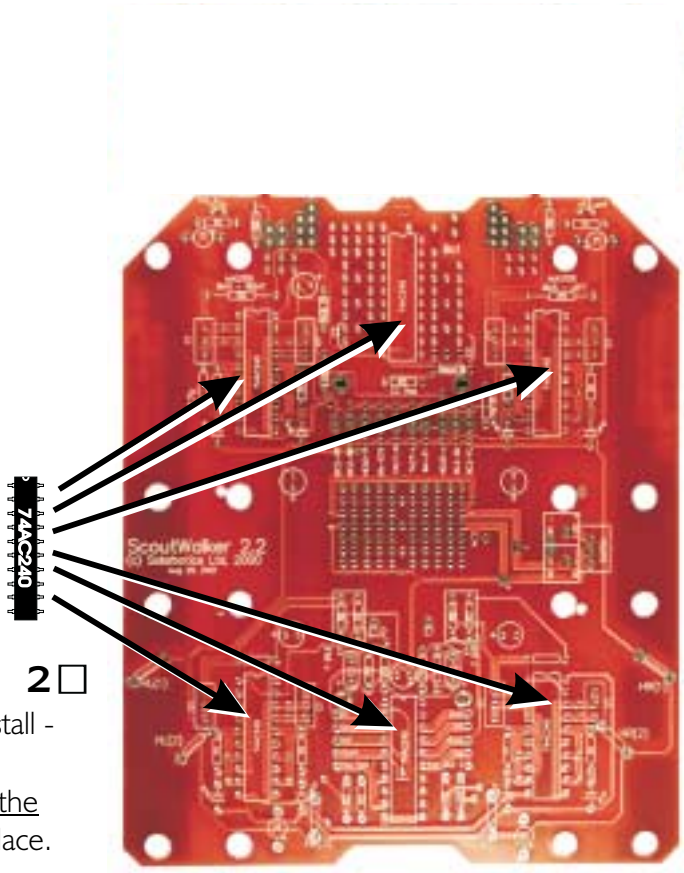
SCOUTWALKER 2.2 - ELECTRONICS ASSEMBLY

The ScoutWalker 2 is pretty straightforward to assemble. Follow the instructions step by step, checking off each box as you progress. This will guarantee that everything gets done in the order needed, and that you don't accidently mount the multi-phasic shield generators in backwards. (And I'm sure we all know how embarrassing that can be!)



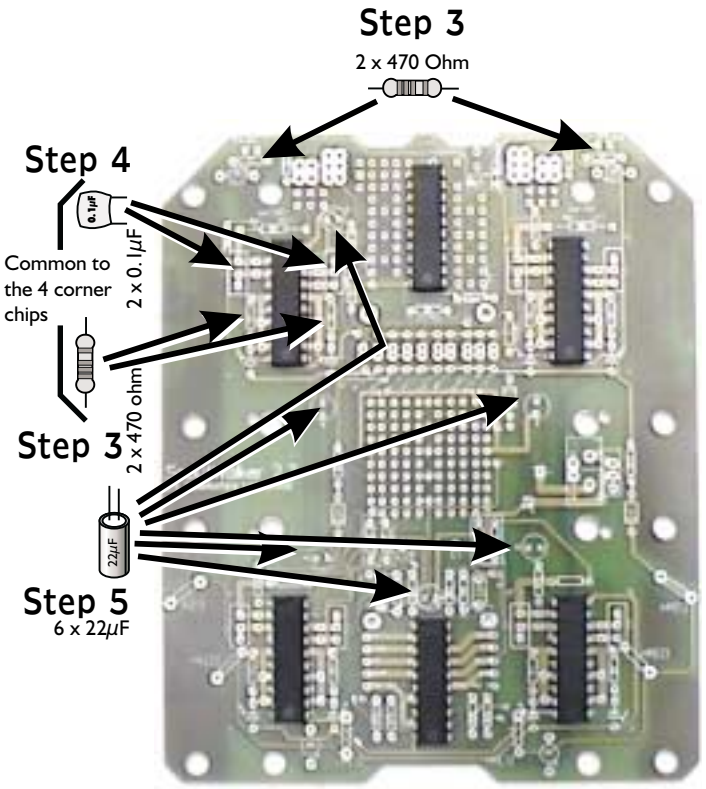
1☐

Start by separating the leg mounting pads from the main printed circuit board (the 'PCB'). Although not necessary, sand or file the little tabs off each part after snapping them off.



2☐

Start with the most important (and fun) part to install - the 74AC240. Install it in the 6 positions labeled 74AC240 as shown, with the notch at the top of the chip pointing upwards! Carefully solder them in place.



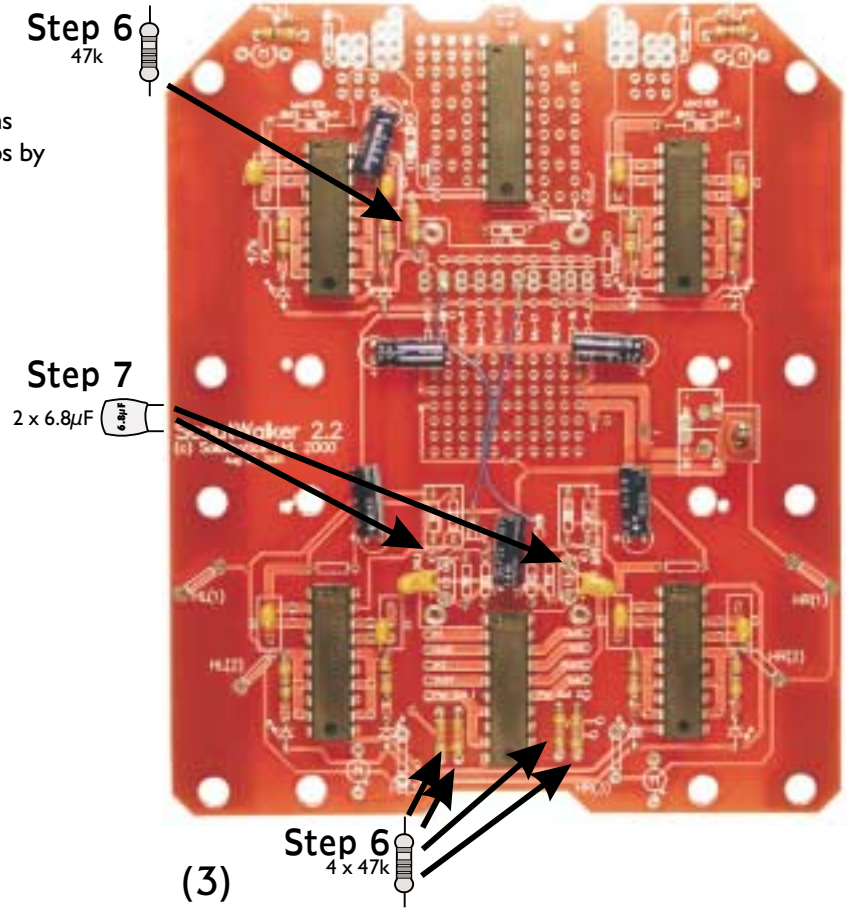
3☐
Install the 10 current limiting 470 ohm resistors for the indicator LEDs in positions labeled 'R1'.

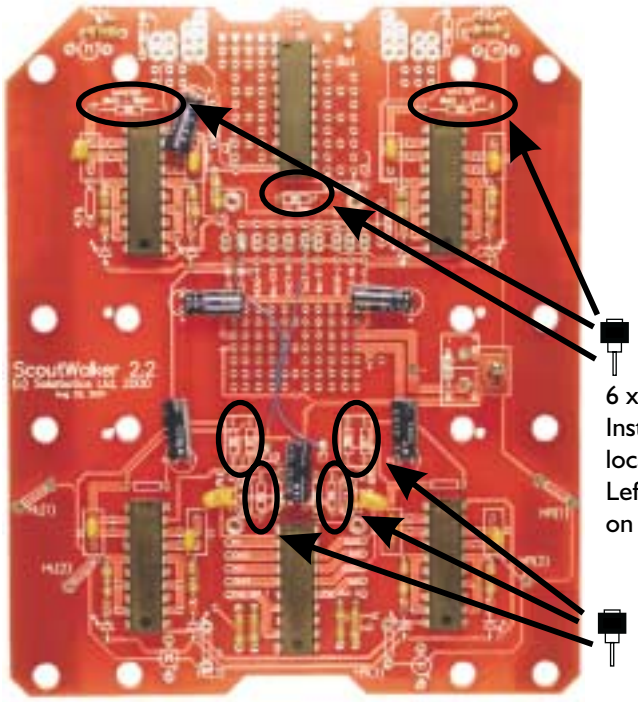
4☐
Install the 8 - 0.1µF (labeled '104') monolithic oscillator capacitors on each of the 4 corner 74AC240 chips in the positions labeled 'C1'. These parts are NOT polarity sensitive.. Note that there are 3 holes in each area indicated for the cap. Two of the holes are joined by a trace to facilitate easier installation of the caps for different pin spacing. Make sure the capacitor is only installed using one of these two joined holes. MAKE SURE THEY LAY FLAT against the PCB!

5☐
Install the 6 - 22µF decoupling (power-smoothing) capacitors for the 74AC240 chips in the positions labeled as little circles with the '+' sign. These caps are polarity sensitive, so make sure they go in with the side with the strip *away* from the '+' sign. Install them with the leads bent over 90 degrees so they lay flat against the PCB.

6☐
Install the 47k resistors (R2) in the positions labeled '47k'. This turns on all the '240 chips by default

7☐
Install the 2 - 6.8µF capacitors in the positions labeled 'C3'. These capacitors ARE polarity sensitive, so make sure the leg labeled with the little '+' goes to the right pad! FOLD THE CAP FLAT AGAINST THE PCB.



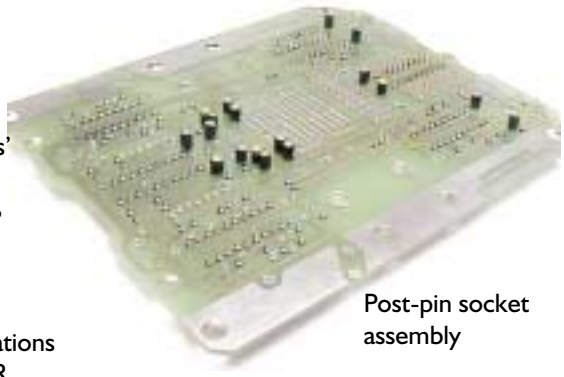


8

Most of the components are now installed on this side of the board, so this is what is should look like.

Now install the 18 jumper pins **on the other side** where shown. This will allow you to easily adjust the resistors that govern how your ScoutWalker 2 walks. Ignore placing them on the pads labeled 'R3'.

6 x socket pins
Install at resistor locations R5 'Master Bias' Left & Right, & 'CC Res' on OTHER SIDE of PCB

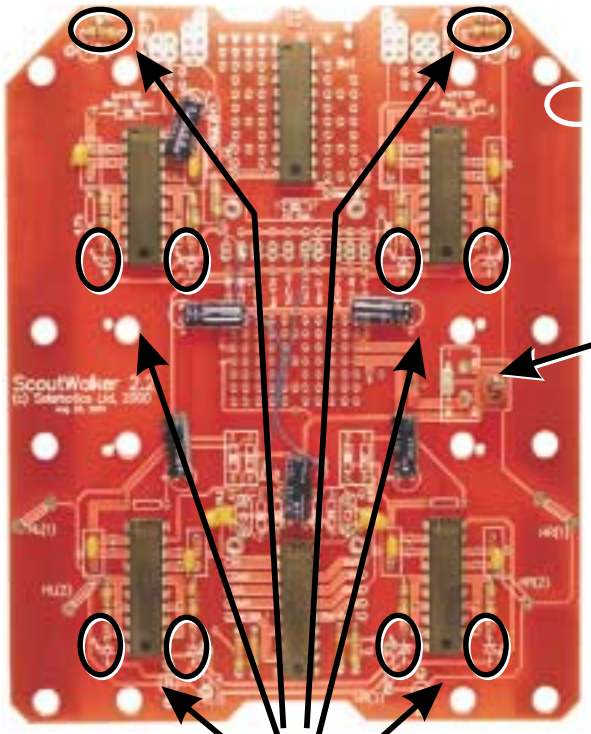


Post-pin socket assembly

12 x socket pins
Install at resistor locations 'R6', 'R7', on OTHER SIDE

9

This one is simple - install the power switch on the pads labeled "Switch". It doesn't matter which way it goes in as it will work either way.

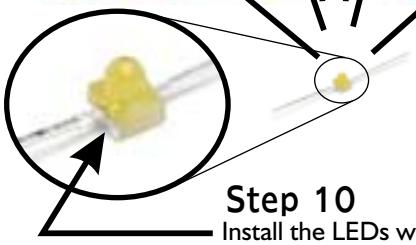


Step 9

10

Let's install the LEDs now - pretty lights always make a robot look cool. Put the 8 LEDs on the lower positions, with the 2 green LED's right up front. **INSTALL ALL THE LEDs ON THE OTHER SIDE OF THE BOARD.**

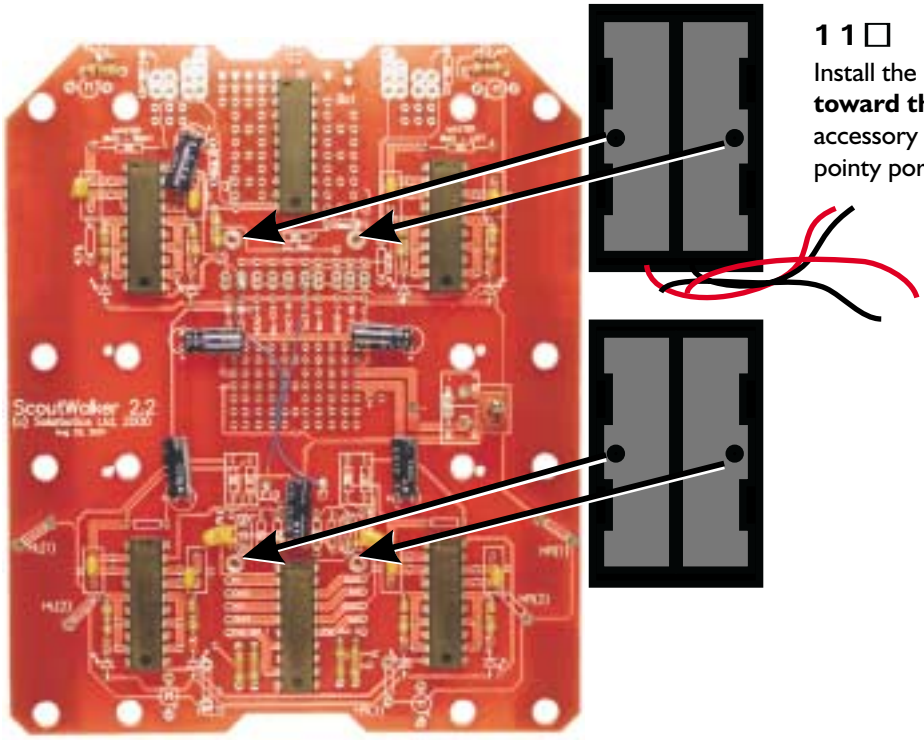
If you're using a water-soluable flux, NOW is the time to go and wash your circuit board under some hot running water. This IS important, as this type of flux will affect the behavior of your robot, sometimes to the point of making it fail completely!



Step 10

Install the LEDs with the side with the bar mark nearest the bar mark on the symbol on the PCB. **INSTALL ON THE OTHER SIDE.**

SCOUTWALKER 2.2 - BATTERY HOLDERS AND WIRING

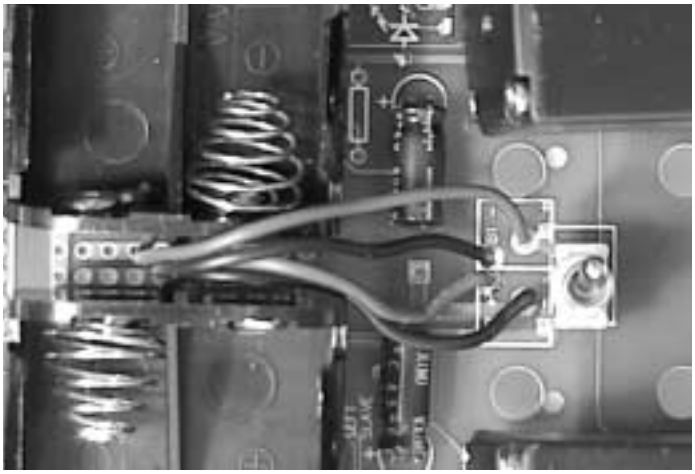


11☐

Install the battery holders as shown, with the wires **facing toward the middle.** Use the mounting screws from the servo accessory pack to screw the holders in. Grind or snip off the pointy portion that sticks through the other side of the PCB.

12☐

Wire up each battery holder so the red and black wires go to one of the two battery connection terminals. Red is '+', black is '-'.



The servos are obviously the business end of the walker. Unfortunately for the servos, you'll be performing a little "open-heart" surgery on them (insert maniacal laughter here). Why? Well, to be honest, we simply cannot find gearmotors near as strong and inexpensive as modified servos, but their internal electronics simply aren't compatible with the Bicore controller. So fish out your Phillips head screwdriver, the length of paired wire, and the servos - we're going to go hacking!

13☐

Start by removing the bottom plate from the servo, and be careful not to lose the screws (sorry to sound like your mom, but these are dang-near impossible to replace).

14☐

Gently pry the servos electronic guts out with a electronic-guts puller tool (if that's not handy, use a screwdriver). The PCB is connected to the servo motor and feedback pot, so expect to see these as you pull the whole assembly out.

15☐

Remove the motor from the PCB by desoldering it from the solder mounting pads indicated. As for the leftover PCB and pot, you can feed it to your cat or dog, but not your hampster - that would be silly...

16☐

Gently push the motor back into place. Then solder the *full length* of the red/black wire onto the motor, with the red wire attached to the motor pole closest to the red dot. After you put the bottom plate back on, **measure 2"** from where the wire leaves the servo, **and clip off the extra wire.**

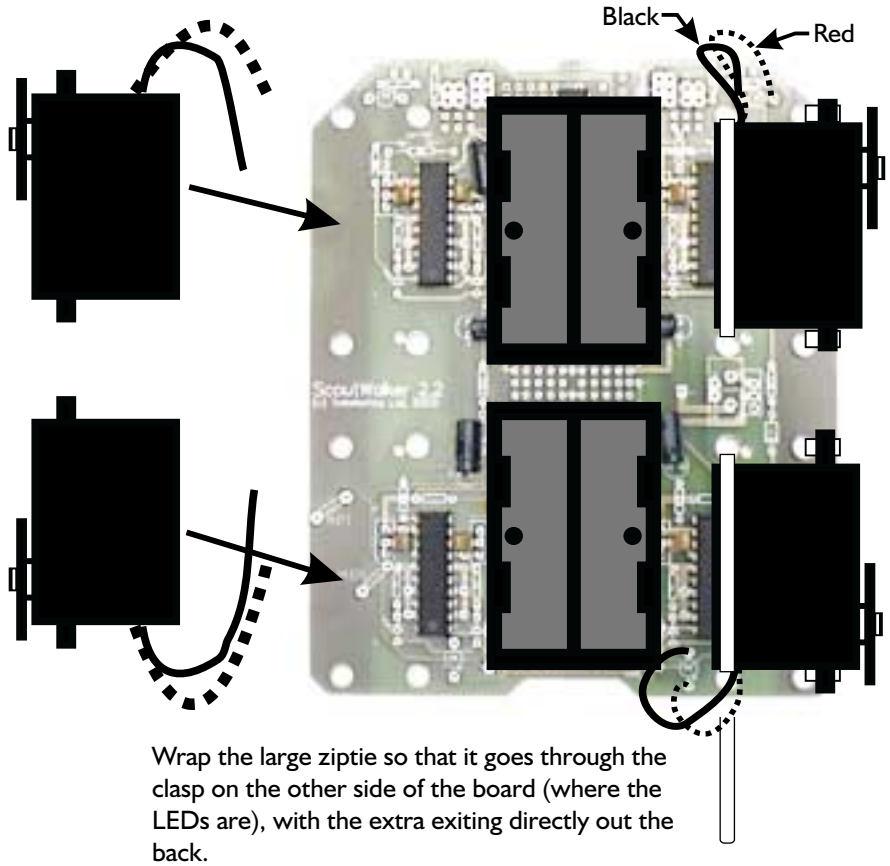
Repeat the whole thing over again on the other three servos.

17☐

The PCB is essentially finished at this point. No more electronics; mechanics instead! Grab the 4 modified servos and install them as shown, going between the large holes, and secure with the zipties. Use the small zipties to secure the servo to the PCB at the holes near the edge, and the large one to secure the servo across the chip underneath. **Pay special attention to how the large zipties are mounted across the rear (bottom) servos - this is *very* important for later use!**

Make sure the servos are oriented so the servo wires face forwards for the front servos; rearwards for rear servos.

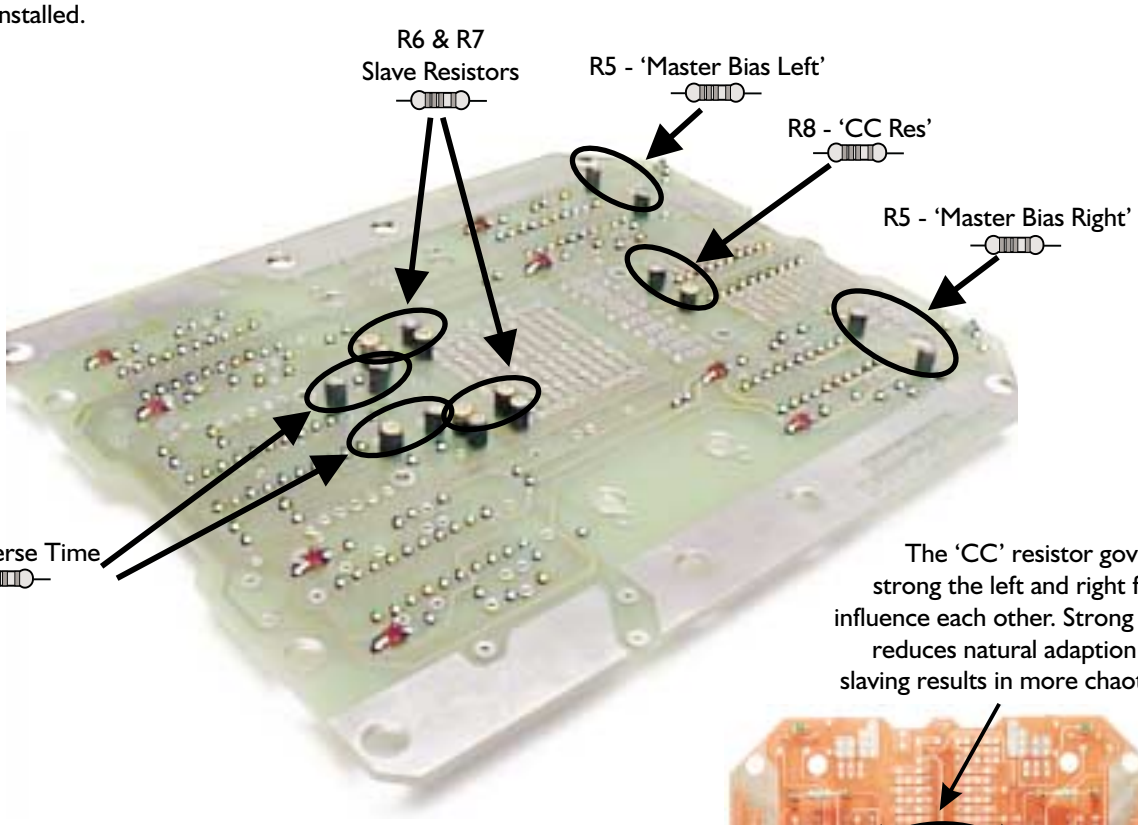
When you're finished with the zipties, solder the red wire to the motor connection pad labeled '+', and the black wire to the other pad.



Wrap the large ziptie so that it goes through the clasp on the other side of the board (where the LEDs are), with the extra exiting directly out the back.

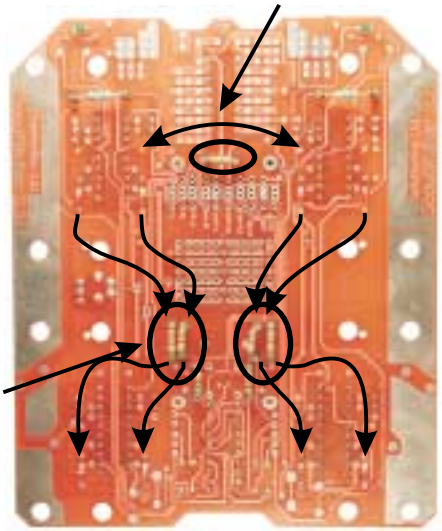
18☐

Now it is time to install the biasing resistors that will make your ScoutWalker develop the rhythms that will make it successfully walk. Install the resistors in the positions shown, and you will have a good baseline for your ScoutWalker. We encourage you to experiment with the phase relationships - that's why you have the jumper pin sockets installed.



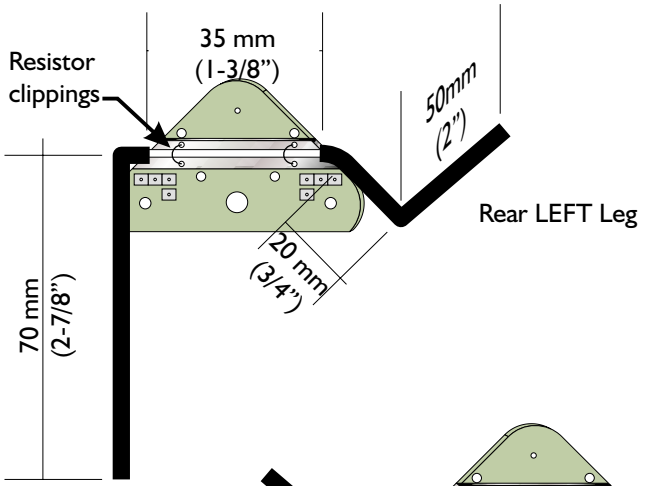
The 'CC' resistor governs how strong the left and right front motors influence each other. Strong slaving (small R) reduces natural adaption, while weak slaving results in more chaotic walking gaits

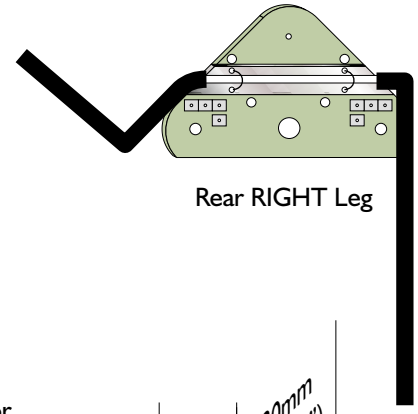
The signals propagate from the front motor bicores to the rear motor bicores through these resistors. You can adjust how long the rear motors delay from the front motors by changing these resistor values.



Now if you're confident that everything is in place, plug in only **3** of the batteries. If you have an accidental short on the robot, you can burn up the batteries and/or damage the circuit board, so the fourth battery has to be installed *quickly* and be ready to pull it out *quickly* if you feel the batteries getting warm, or see/smell smoke! If nothing happens, flip the switch, and watch the motors move in sync to the blinky lights!

SCOUTWALKER 2.2 - LEG SHAPES





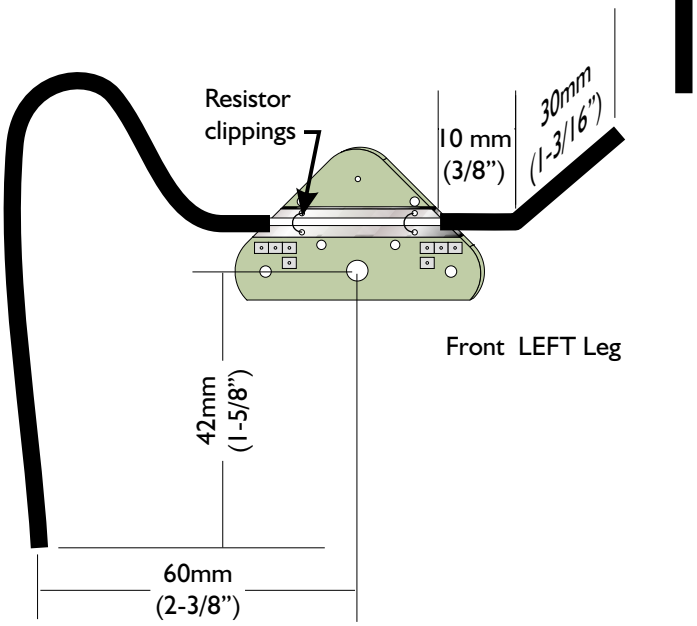
19□

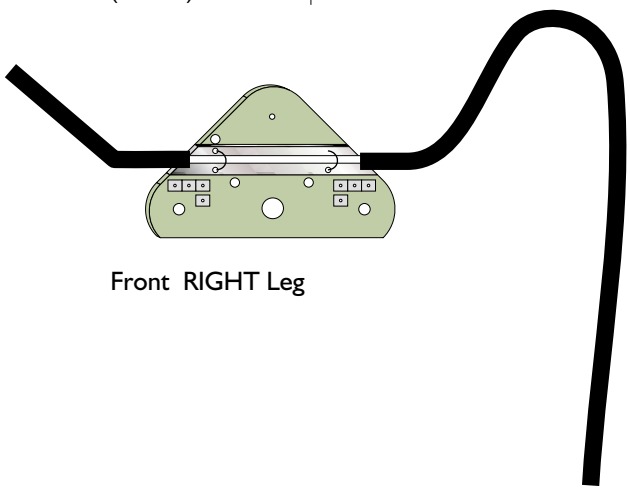
The Rear Legs - Fold one of the thick leg wires into the shape in the diagram, being as accurate as you can reasonably be.

Where you see the triangular plate in relation to the wire, strip off the insulating coating and secure the wire to the mounting pad with resistor clippings. Solder the leg wire to the pad.

Repeat the process for the other leg, but **REVERSE** the fold direction of the 50mm length, and solder it to the other side of the plate, so you have one rear leg, and a mirror image.

Take the servo "X" horn off two servos, and screw the leg assemblies to each horn with the #2-1/4" sheet-metal screws. Don't re-attach the assembly to the servos - they have to be aligned up to the servo on the frame (later).





20□

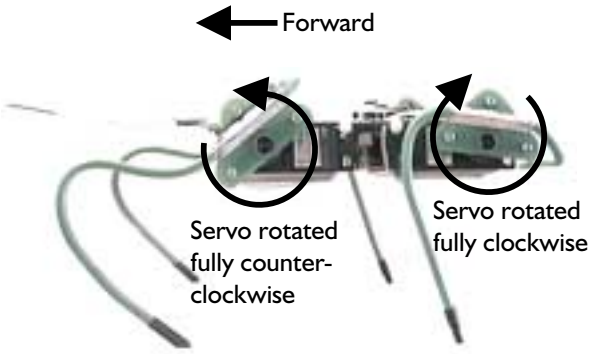
The Front Legs - Fold one of the thick leg wires into the shape in the diagram, being as accurate as you can reasonably be.

Fold one as closely to the diagram as possible. You will note that we haven't given you **exact** dimensions for the front part of the leg. Well, that's because they don't matter. The only thing that does *really* matter is where the front "foot" is in relation to the pivot point on the servo. So use whatever shape you want for the front of the leg, but try to get the tip to touch the ground as close as possible to the dimensions given.

Where you see the triangular plate in relation to the wire, strip off the insulating coating and secure the wire to the mounting pad with resistor clippings. Solder the leg wire to the pad.

Repeat the process for the other leg, but **REVERSE** the fold direction of the 30mm length, and solder it to the other side of the plate, so you have one leg, and a mirror image.

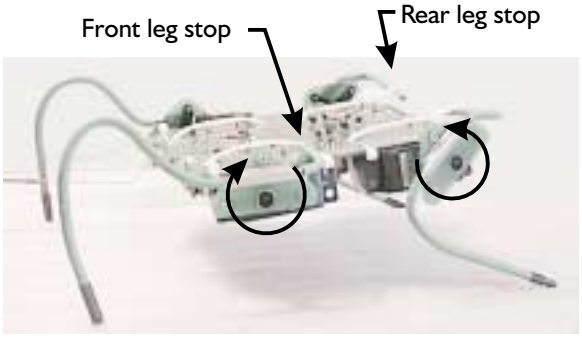
.Take the servo "X" horn off two servos, and screw the leg assemblies to each horn with the #2-1/4" sheet-metal screws. Don't re-attach the assembly to the servos - like the front legs, they have to be aligned to the servos while on the main walker body.



21☐

When putting the servo horn / leg assembly onto the servo, you must rotate the servo until it hits the internal stop inside the servo. Then slide the servo horn onto the splined shaft so it looks like the leg positions in the picture. Screw the servo horn retaining screw back in. **If you want**, clip off the 4th unused servo arm, so it's not poking down where it can catch on other obstacles. It's a good idea, but not absolutely necessary.

22☐

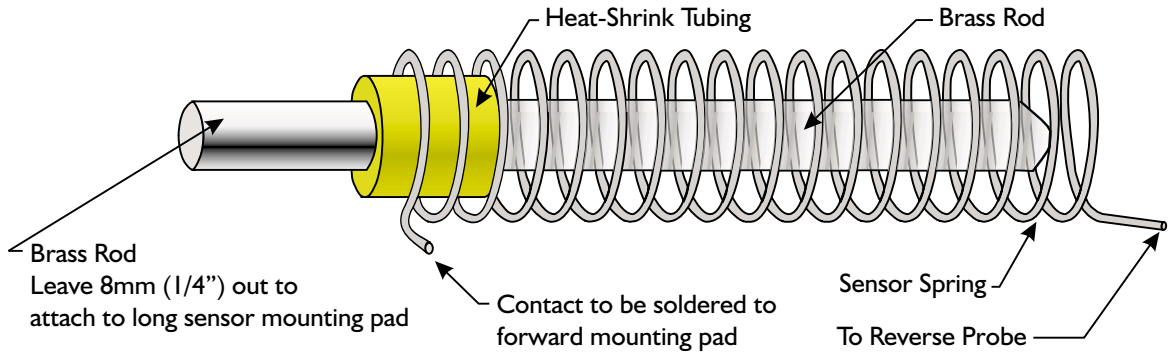


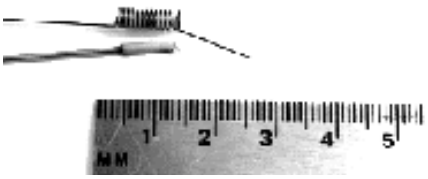
When you rotate the servos the other direction, the leg shapes should make them stop at the points shown. The front legs will have their stop hit the *top* of the PCB, and the rear legs will have their stop hit the *bottom* of the ziptie you used to secure the rear servos.

When you finish mounting the legs, heat-shrink on the little black tube feet onto the end of each leg tip, using a flame. Don't burn them - flames and smoke are bad! *Tip: Try using different materials for "booties" for better traction, like replacement eraser nubs for pencils.*

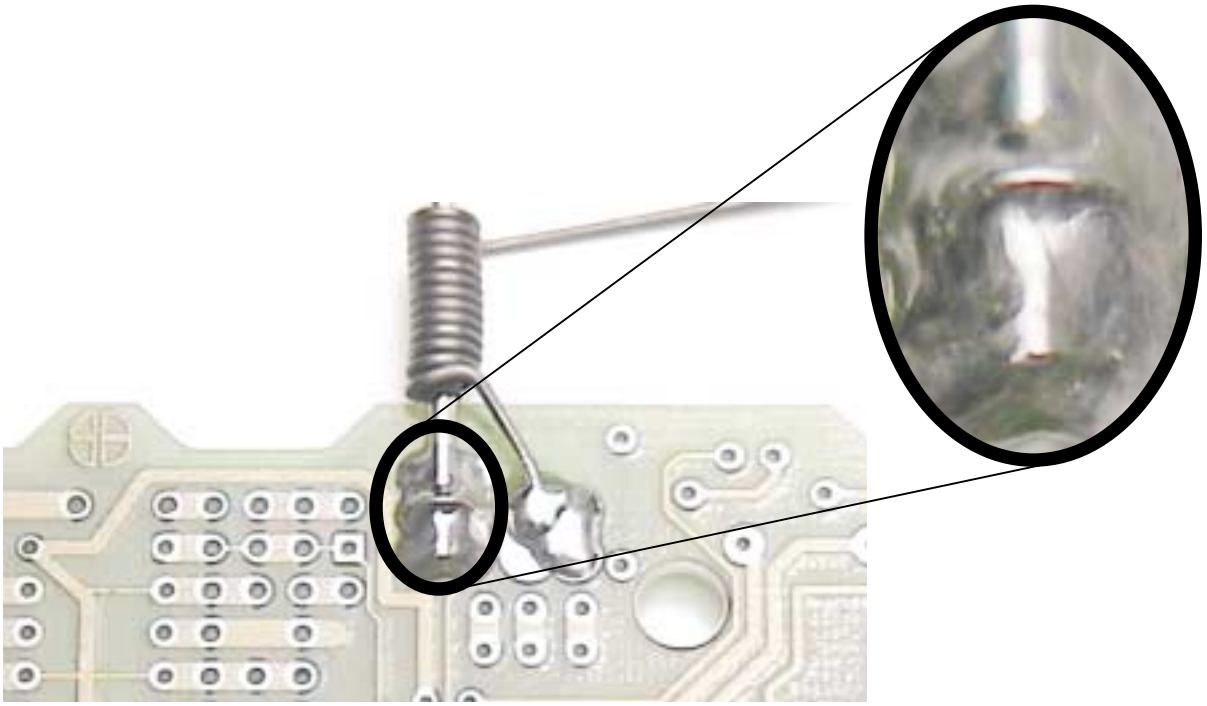
Now that your legs are installed, you can turn on your robot, and place it on a surface to see what it will do. Don't despair if it doesn't walk super-fantastic the first time - the leg shapes most likely will need tweaking before it's fully optimized. Ideally, the ScoutWalker will lift a front leg off the ground, then be pushed forward back onto the ground by the rear leg. You want the legs to each be lifted off the ground in their own turn so it can more easily step over obstacles. Leg design optimization is going to be the hardest task you will face in the construction of this kit, but it is also the most fun!

23☐ There's not too much rocket (or robot....) science here. Simply put, we're building a sensor that activates each ½ reverse circuit when bumped from any direction. When the spring deflects enough to contact the brass rod in the center of the spring, the circuit activates.





Shrink a 1cm (3/8") length of tubing onto the end of the rod, leaving about 8mm (1/4) free on the end Ummm.... That's about it until we get to the next stage where we solder the assembly to the robot board.



26☐

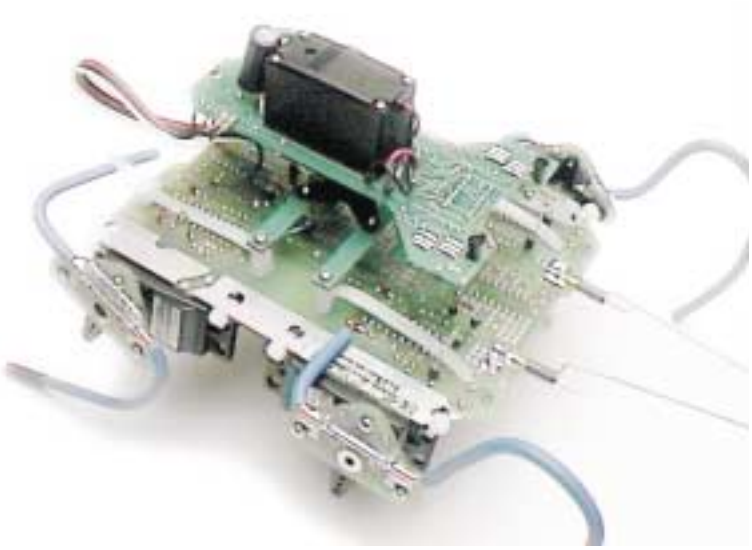
Assuming that your ScoutWalker 2 is functioning properly, now is the time to add the sensors to your robot. Lay out your sensor as shown, soldering the brass pin the innermost pads, and the wire leg to the outermost

You may find it easier to secure the brass pin to the board with a leftover resistor clipping, by tying it to the board before you solder. The close-up image shows what you can expect to see after you solder such an installation into place.

If you find that your sensor is a bit too sensitive, you can implement the solution below - shrink some heat-shrink tubing to the *outside* of the sensor spring. This will dampen (or lessen) the vibrations that may accidently trigger them.

Now you're free to throw the switch and let your ScoutWalker 2.2 go bouncing around the room. We've had great fun with this. Assuming your tactile sensors are arranged so they protect the full front of the robot, it shouldn't get held up by any desk/chair leg, box, bag, or dog that it happens across.

After you're worn out a set of batteries or two doing this, you may be ready for more excitement. The first obvious modification is to add a Solarbotics SunSeeker head to your robot. This conjoining of a light-seeking robot 'rider' on a walking robot 'horse' makes for interesting watching!

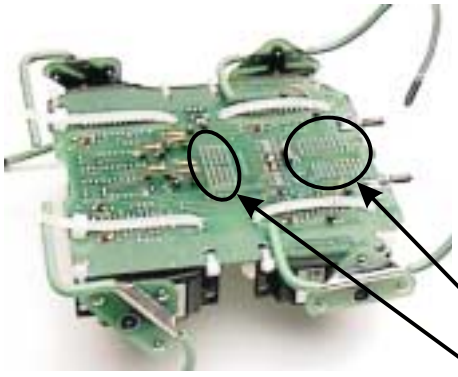


ScoutWalker II interfaced with the SunSeeker Head

The ScoutWalker II quite easily handles the extra load of the SunSeeker (shown without it's Solarcell). In fact, we've witnessed an *increase* in performance, as the legs were better loaded by the increased weight of the SunSeeker.

The SunSeeker isn't the only modification available to you with the ScoutWalker II. As part of the control circuitry for the head/body interface, there are 6 left-over *unused* gates on the front middle 74AC240 which you may use in any way you wish. You will notice that the inputs to the unused gate are connected by a very thin trace to Vcc (*always* tie unused inputs high or low for lower power consumption). Simply scratch these traces off if you wish to use these inputs.

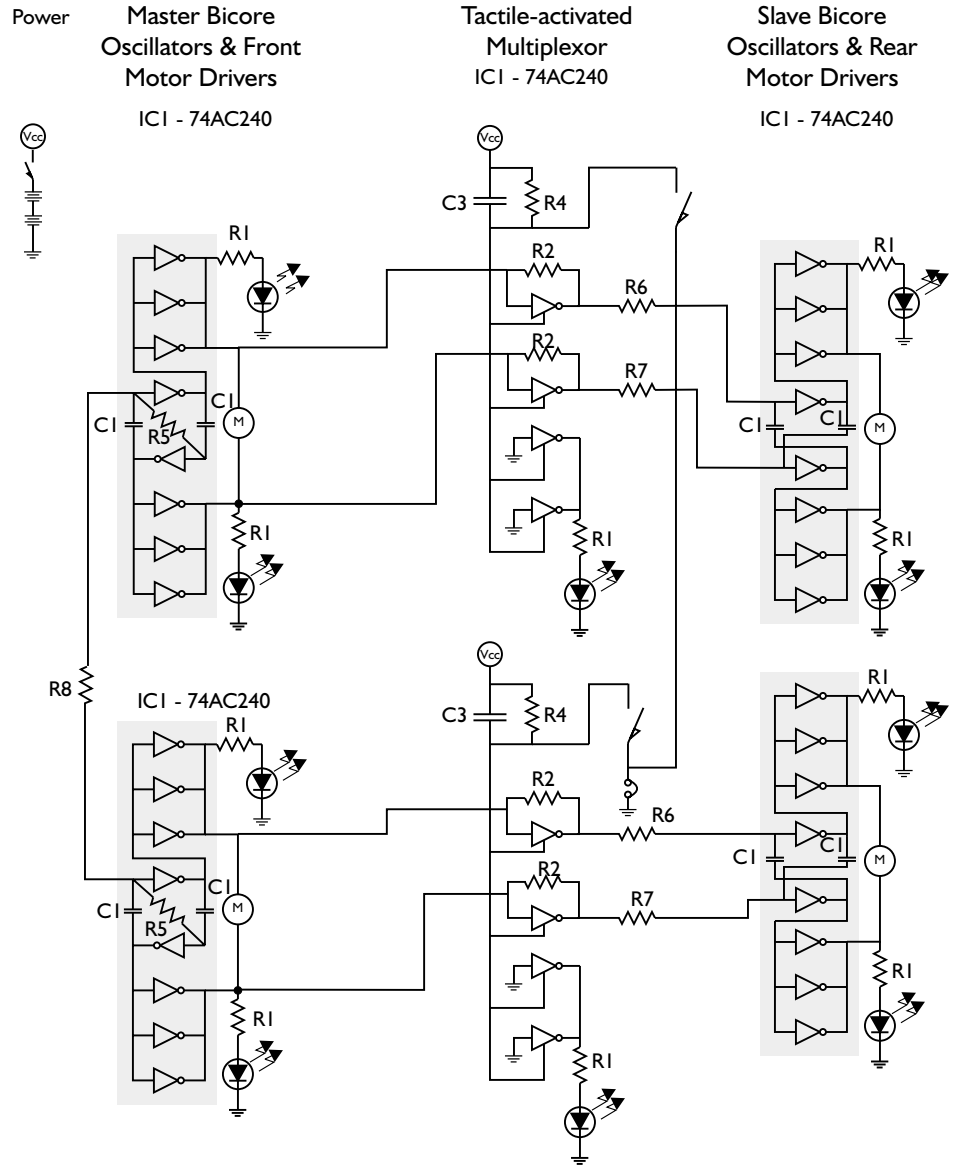
Additional to these unused gates, there is a whole breadboarding area in the middle of the walker. Designed to accommodate a 20 pin DIP IC (ie: a 74AC240/245), you'll find power and ground lines near the appropriate points, and lots of extra pads available for custom electronics. Add your own active IR ranging; night-time "head-lights"; microcontroller (ie: PIC/Basic Stamp) interfaces; Solar charge-pumping nicad rechargers; electronic compass / GPS interface; RF data Interface; or even just a blinky light for the heck of it!



Have fun with your ScoutWalker II, and let us know what you've been able to do with it!

SCOUTWALKER 2.2 - FUNCTIONAL SCHEMATIC & CLOSING WORDS

Omitted from this schematic is the 74AC240 in the front middle of the circuit board. This chip is used for user-designed experiments and for interfacing the SunSeeker Head Robot to the ScoutWalker II.



We hope you have as much fun assembling and ~~playing,~~ ummm, experimenting with your ScoutWalker II as we did. We spent considerable time getting this design right, and we hope it shows in the performance of your robot. If you have any questions regarding this kit, please contact us!

Solarbotics Ltd.
179 Harvest Glen Way N.E.
Calgary, Alberta, Canada T3K 4J4
Ph: (403) 818-3374 / (403) 226-3793 Fax: (403) 226-3741
Website: http://www.solarbotics.com
Email: info@solarbotics.com