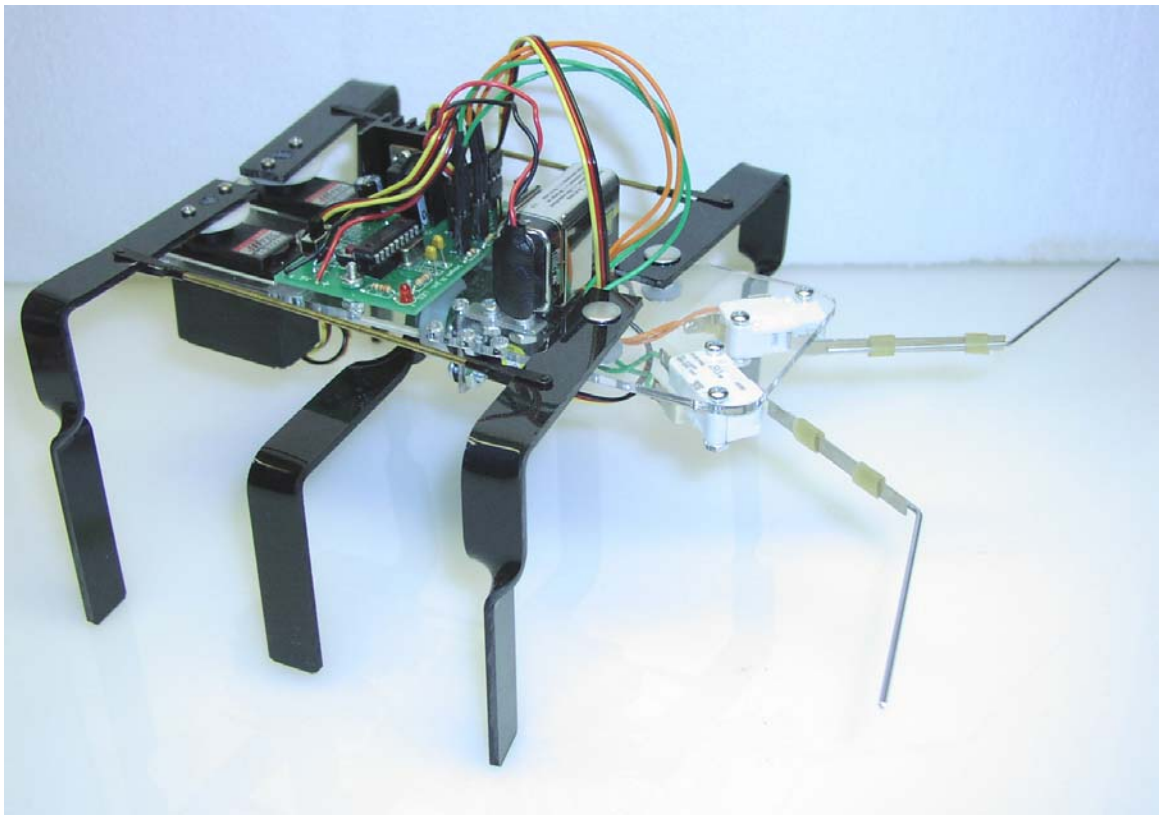
Hexapod Walker Construction Manual



Images Scientific Instruments Inc.
109 Woods of Arden Road
Staten Island NY 10312
(718) 966-3694 Tel
(718) 966-3695 Fax
http://www.imagesco.com

Hexapod Walkers

Legged walkers are a class of robots that imitate the locomotion of animals and insects. Legs provide the potential to transverse rough terrains that are impassable by wheeled vehicles. It is with this in mind that robotists are developing walker robots.

Imitation of Life

Legged walkers may imitate the locomotion style of insects, crabs, and sometimes humans. Biped walkers require balance and a good deal more engineering science than multi-legged robots.

Six Legs Tripod Gait

Using a six legged model, we can demonstrate the common tripod gait used by the majority of legged creatures. In the following drawings a dark rectangle means the foot is firmly planted on the ground and is supporting the weight of the creature (or robot). A light rectangle means the foot is not supporting any weight and is movable.

Figure 1A shows our walker at rest. All six feet are on the ground. From the resting position our walker decides to move forward. To step forward, it lifts three of its legs (see Fig.1B, white rectangles), leaving its entire weight distributed on the remaining three legs (dark rectangles). Notice that the feet supporting the weight (dark rectangles) are in the shape of a tripod. A tripod is a very stable weight supporting position. Our walker is unlikely to fall over. The three feet that are not supporting any weight may be lifted (white rectangles) and moved without disturbing the stability of the walker. These feet move forward. Figure 1C illustrates where the three lifted legs move . At this point, the walker's weight shifts from the stationary feet to the moved feet (see Fig.1D). Notice that the creature' s weight is still supported by a tripod position of feet. Now the other set of legs moves forward and the cycle repeats. This is called a tripod gait, because a tripod positioning of legs always supports the weight of the walker.

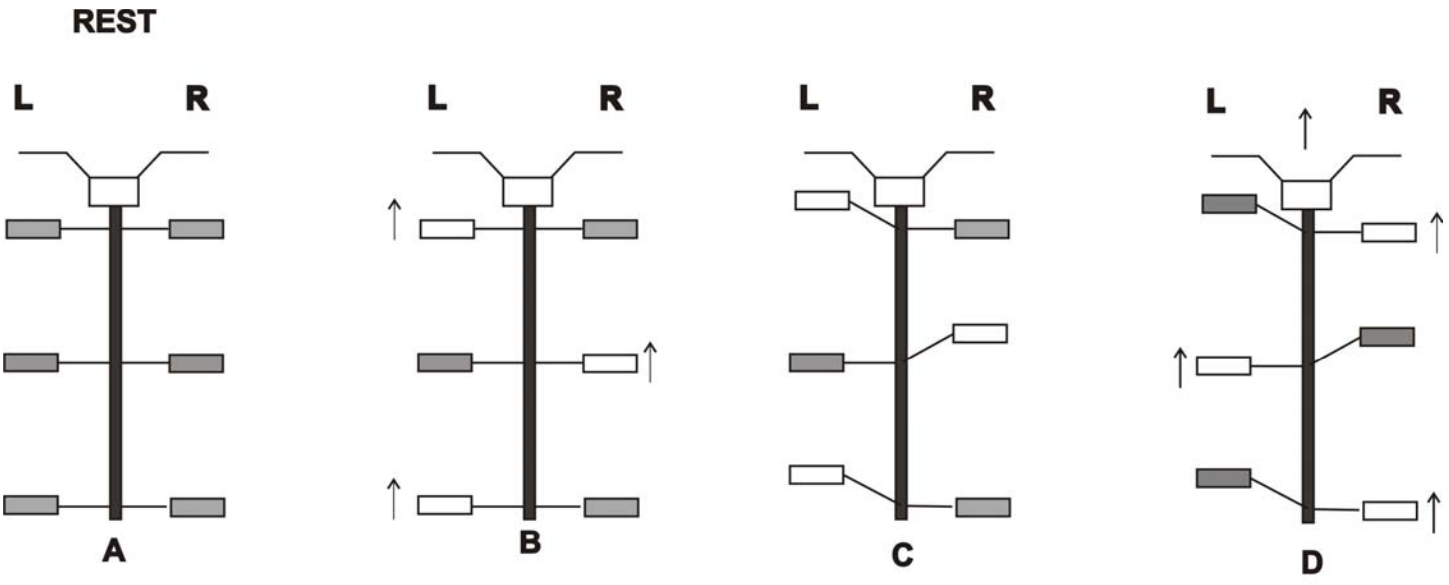


Figure 1 Sample biological tripod gait.

Three Servomotor Walker Robot

The robot we will build is shown in Fig. 2. This hexapod walker robot is a compromise in design, but allows us to build a six legged walker using just three servomotors. The three servomotor hexapod walker demonstrates a true tripod gait. It is not identical to the biological gait we just looked at, but its close enough.

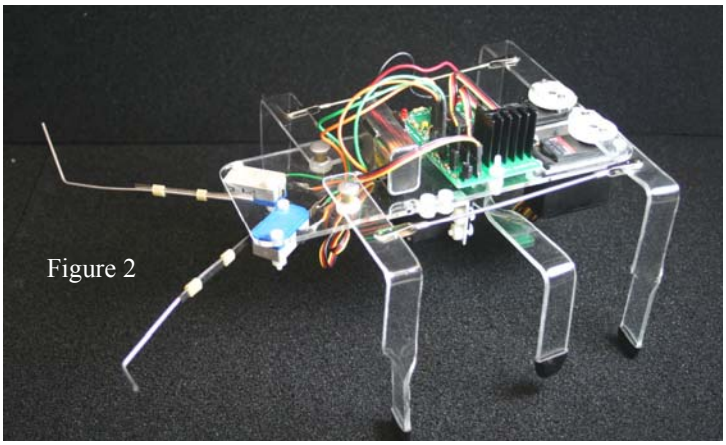


Figure 2

This legged hexapod uses three inexpensive HS322 (42oz torque) servomotors for motion and one PIC 16F84 microcontroller for brains. The microcontroller stores the program for walking, controls the three servomotors, and reads the two sensor switches in front. The walking program contains subroutines for walking forward and backward, turning right, and turning left. The two switch sensors positioned in the front of the walker inform the microcontroller of any obstacles in the walker's path. Based on the feedback from these switch sensors, the walker will turn or reverse to a void obstacles placed in its path.

Function

The tripod gait programmed into this robot isn't the only workable gait. There are other perfectly usable gaits you can develop on your own. Consider this walking program a working start point. To modify the program, it's important to understand both the program and robot leg functions. First let's look at the robot.

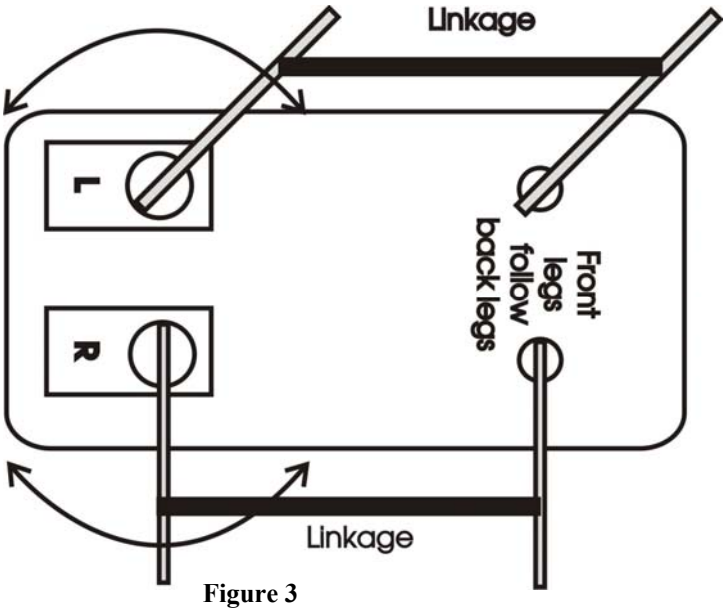


Figure 3

At the rear of the walker are two servomotors. See figure 3 to left. Center legs are not shown for simplicity. One servomotor is identified as L for the left side, the other as R for the right side . Each servomotor controls both the front and back legs on its side. The back leg is attached directly to the horn of the servomotor. It is capable of swinging the leg forward and backward. The back leg connects to the front leg through a linkage . The linkage makes the front leg follow the action of the back leg as it swings forward and back.

The third servomotor, see figure 4 controls the two center legs of the walker. This servomotor rotates the center legs 20 ° to 30° clockwise (CW) or counterclockwise (CCW), tilting the robot to one side or the other (left or right). With this information we can examine how this legged robot will walk.

Figure 4

Moving Forward

We start in the rest position (see Fig. 5). As before, each rectangle represents a foot, and the dark rectangles show the weight bearing feet. Notice in the rest position, the center legs do not support any weight. These center legs are made to be 1/8” shorter than the front and back legs.

In position 5A the center legs are rotated CW by about 25°from center position. This causes the robot to tilt to the right. The weight distribution is now on the front and back right legs and the center left leg. This is the standard tripod position as described earlier. Since there is no weight on the front and back left legs, they are free to move forward as shown in the 5B position of Fig. 5.

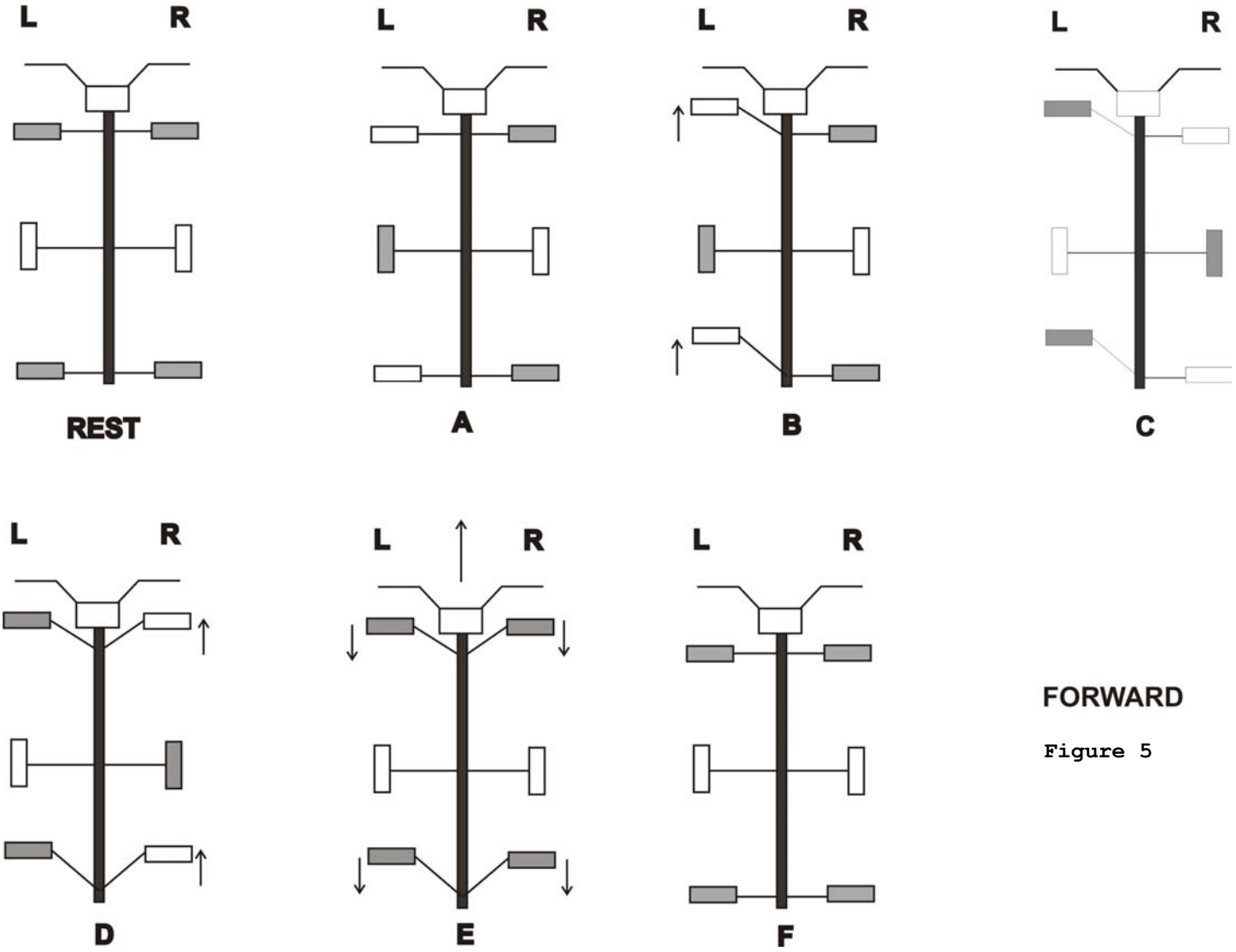


Figure 5

In the figure 5C position the center legs are rotated CCW by about 25° from center position. This causes the robot to tilt to the left. The weight distribution is now on the front and back left legs and the center right leg. Since there is no weight on the front and back right legs, they are free to move forward, as shown in the 5D position. In position 5E the center legs are rotated back to their center position. The robot is not in a tilted position so its weight is distributed on the front and back legs. In the 5E position, the front and back legs are moved backward simultaneously, causing the robot to move forward. The robot’s position in 5F is the same as the rest starting position and the forward walking cycle can be repeated.

Moving Backward

We start in the rest position (see Fig. 6), as before. In position A the center legs are rotated CW by about 25 ° from center position. The robot tilts to the right. The weight distribution is now on the front and back right legs and the center left leg. Since there is no weight on the front and back left legs, they are free to move backward, as shown in the B position of Fig. 6.

In the 6C position the center legs are rotated CCW by about 25° from center position. The robot tilts to the left. Since there is no weight on the front and back right legs, they are free to move backward, as shown in the 6D position. In position 6E the center legs are rotated back to their center position. The robot is not in a tilted position, so its weight is distributed on the front and back legs. In the 6E position, the front and back legs are moved forward simultaneously, causing the robot to move backward. The robot's position in 6F is the same as the rest starting position and the backward walking cycle can be repeated.

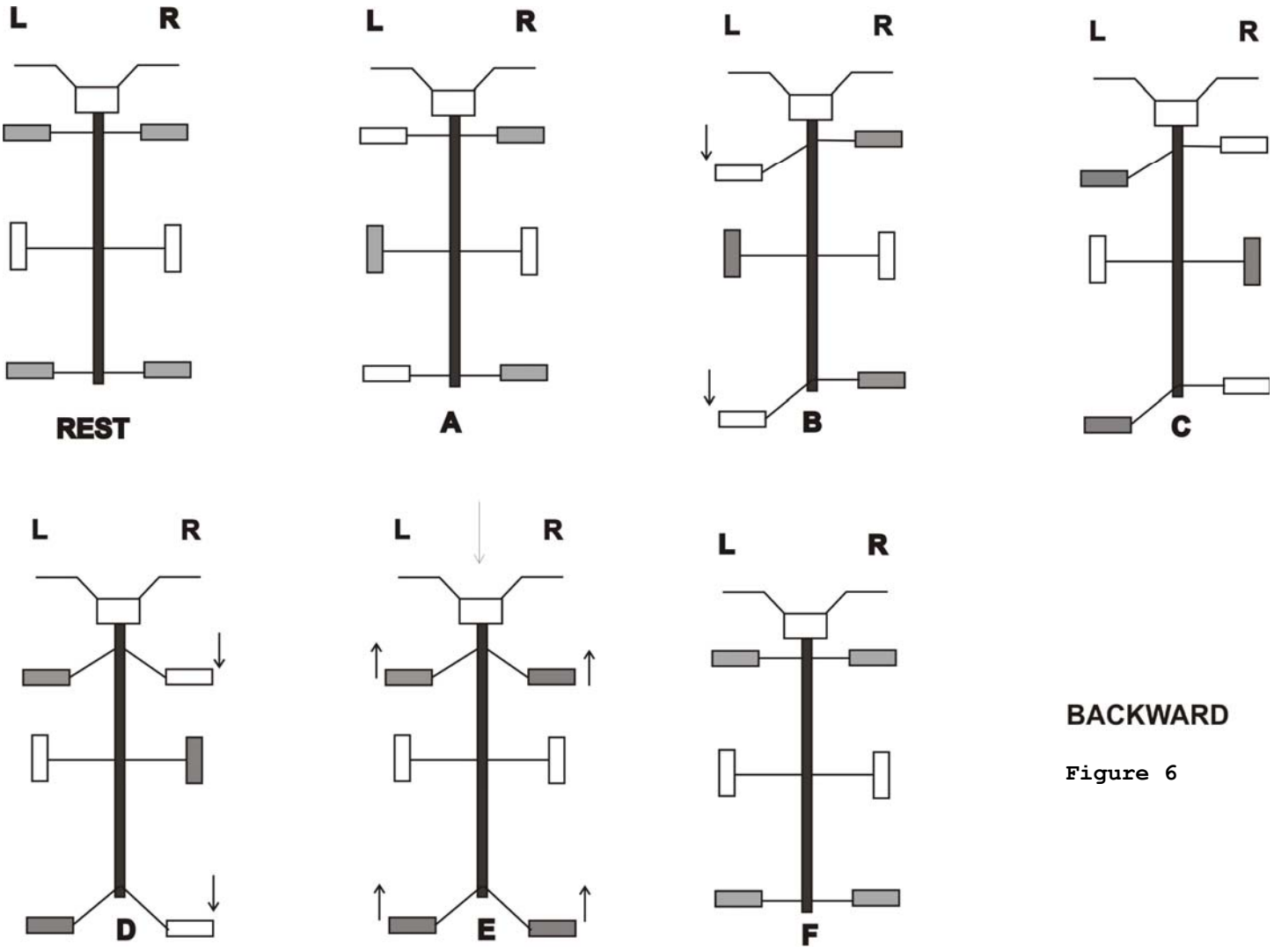


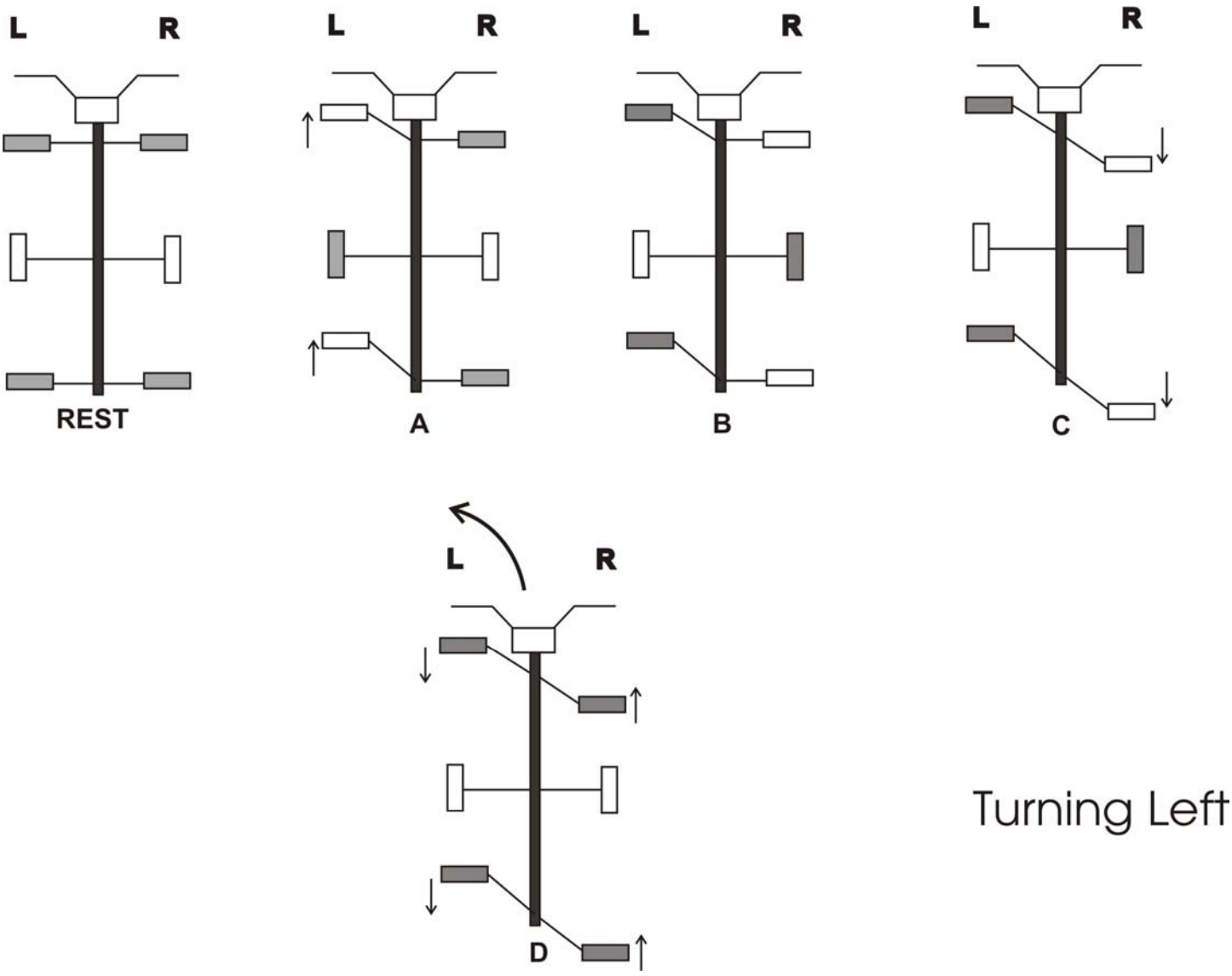
Figure 6

Turning Left

The leg motion sequence to turn left is shown in Fig. 7. In position 7A the center legs are rotated CW by about 25° from center position. The robot tilts to the right. The weight distribution is now on the front and back right legs and the center left leg. Since there is no weight on the front and back left legs, they are free to move forward. In the 7B position, the center legs are rotated CCW by about 25° from center position. The robot tilts to the left. Since there is no weight on the front and back right legs, they are free to move backward, as shown in the 7C position.

In position 7D, the center legs are rotated back to their center position. The robot is not in a tilted position, so its weight is distributed on the front and back legs. In this position, the left legs moved backward while the right legs moved forward, simultaneously causing the robot to turn left. It typically takes three or four turning cycles to turn the robot a full 90°.

Figure 7



Turning Right

Turning right follows the same sequence as turning left, with the leg positions reversed.

Printed Circuit Board Construction

Figure 8 is a top view of the PC board. Begin construction by mounting and soldering the 18 pin socket for the PIC microcontroller. Align the indent in the socket with the indent in the silk screen outline of the socket. Next mount and solder the 1N4007 diode D2. Align the band on the diode with the band on the silk screen outline of the diode. Mount and solder the four 10K 1/8 watt resistors R1 through R4. At this point in the construction the pcb will look like figure 9 below.

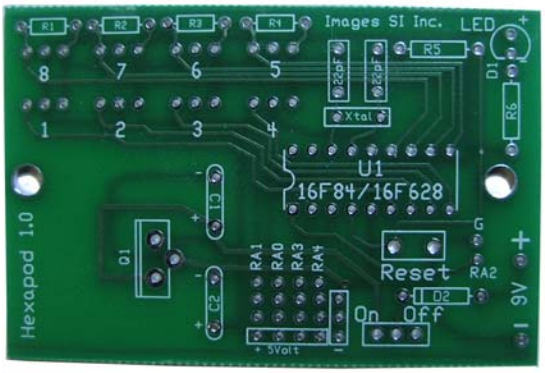


Figure 8

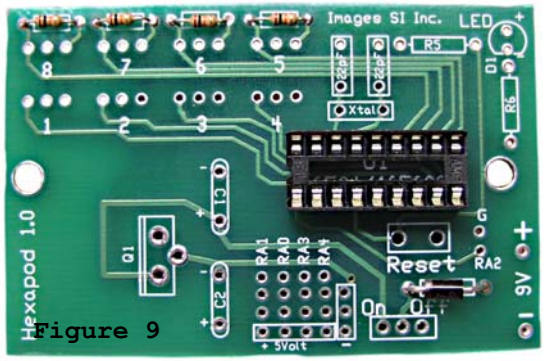


Figure 9

In figure 10 The red boxes show where to mount and solder the following components. Mount and solder the 2-pin sockets, 2-pin headers and 3-pin headers. The headers are provided in a single breakaway strip as shown in figure 11.

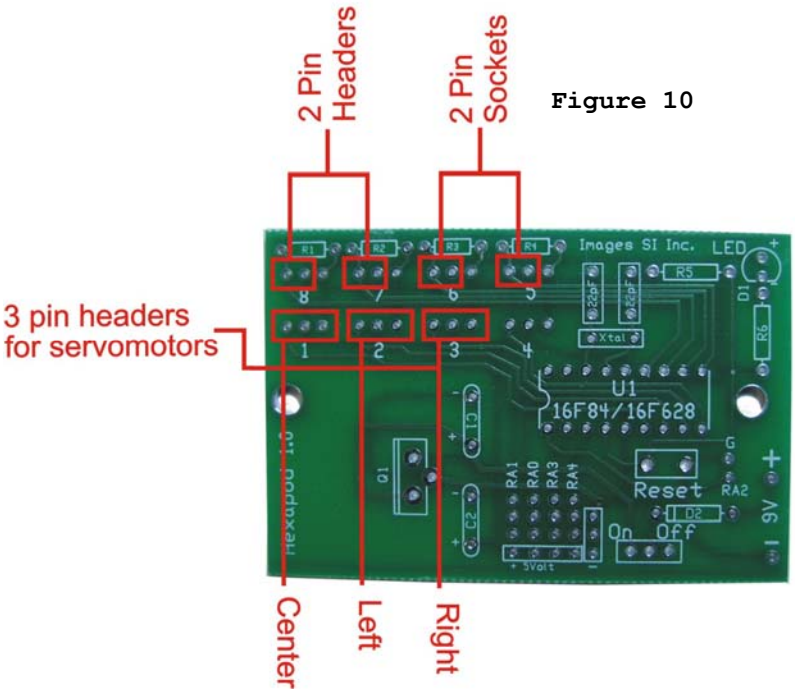


Figure 10

Figure 11

Snap off three 3-pin headers and two 2-pin headers as shown in figure 12. Begin by mounting and soldering the two 2-pin sockets into positions labeled 5 and 6 on the pc board, see figure 10. Then mount and solder the 2-pin headers into positions 7 and 8. When you are finished the board will appear as shown in figure 13

Figure 12

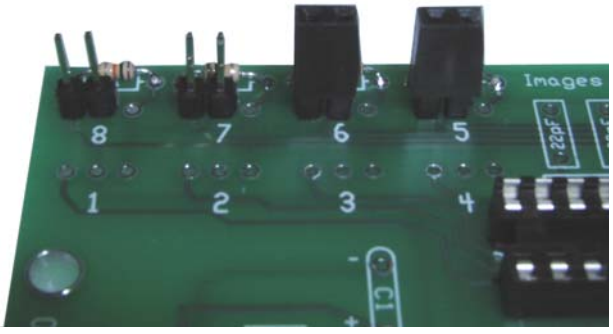
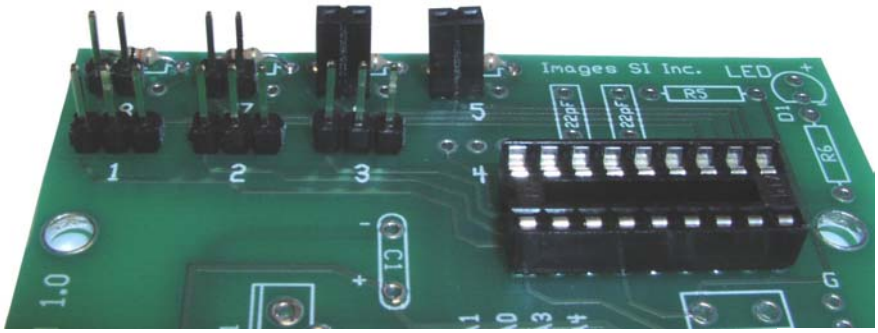


Figure 13

Next mount and solder the three 3-pin headers into positions 1, 2 and 3. See figure 14

Figure 14



Continue to mount and solder components on to the pcb. 4 MHz crystal, 4.7K ohm 1/4 watt resistor (R5), (2) 22 pF capacitors. When mounting the Red diode, the longer lead is (+). Resistor R6 is a 330 ohm 1/4 watt, on-off switch and push button reset switch. Mount the 7805 voltage regulator to the heat sink, see figure 15, before mounting the 7805 to the pcb, see figure 16. Use the 5-40 x 3/8 screw to mount the 7805 to the heat sink. Next add capacitors C1, C2 and 9V battery cap. Finish circuit by mounting the pre-programmed microcontroller IC into the 18-pin socket.

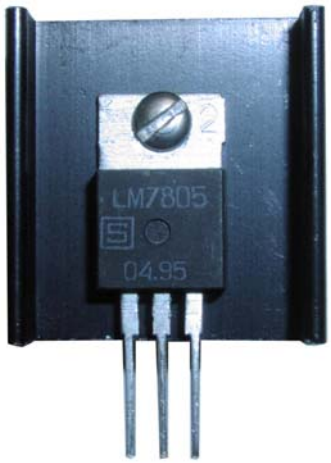


Figure 15

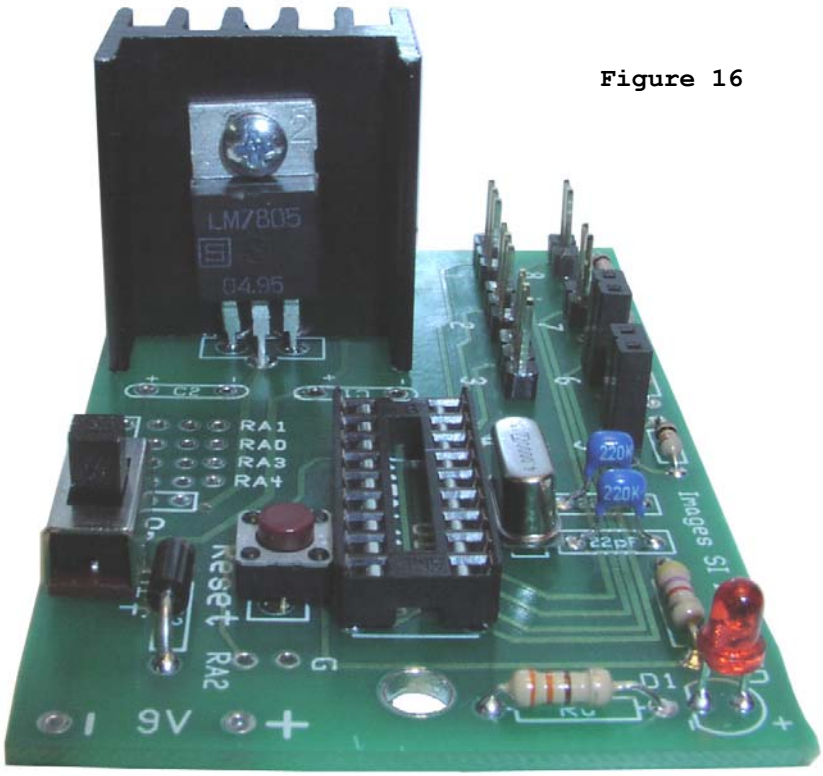


Figure 16

Note:
It's important to build and finish the circuit board before constructing the hexapod walker. You will need the working circuit to align the servomotors during construction.

Hexapod Body Construction

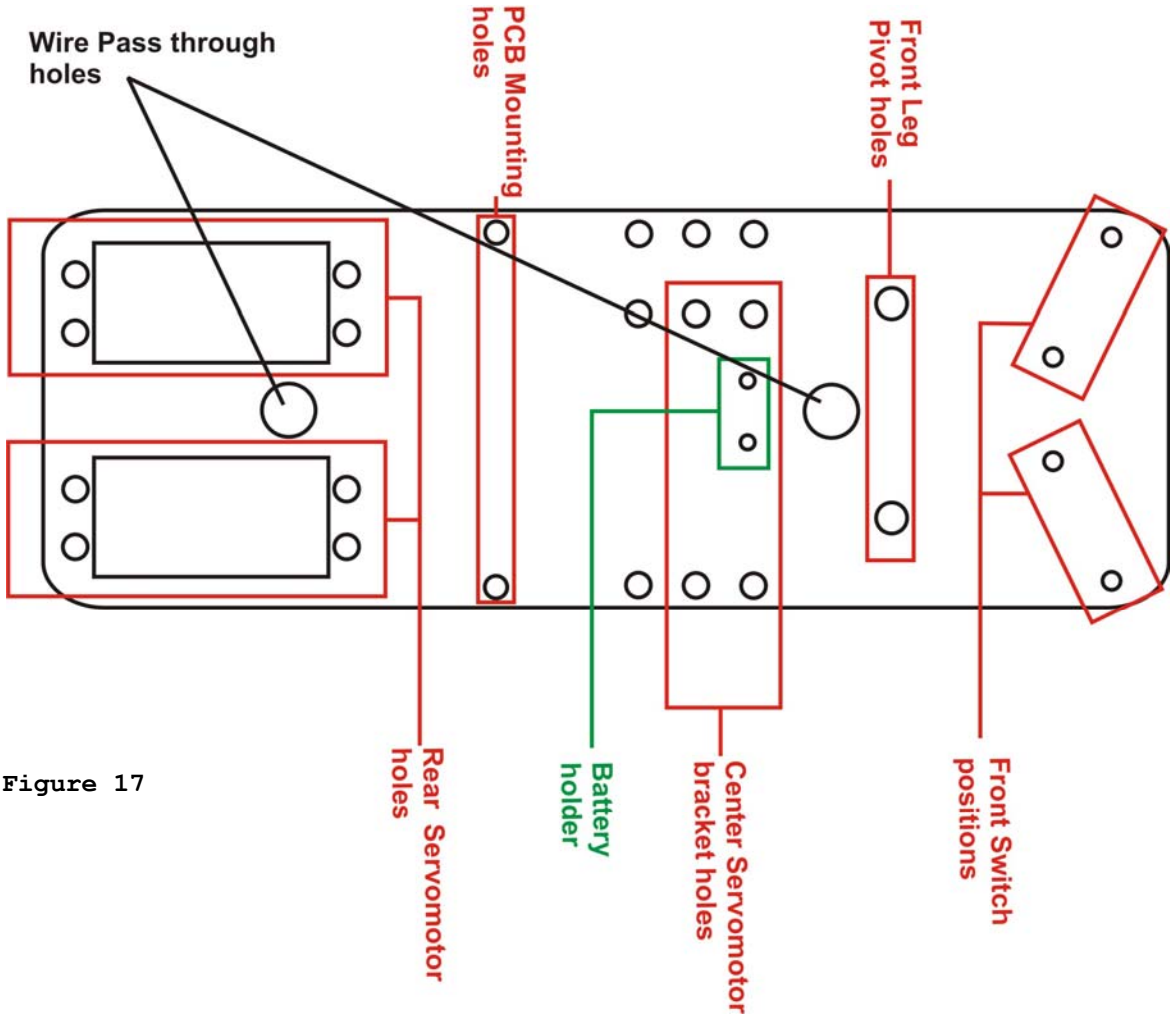
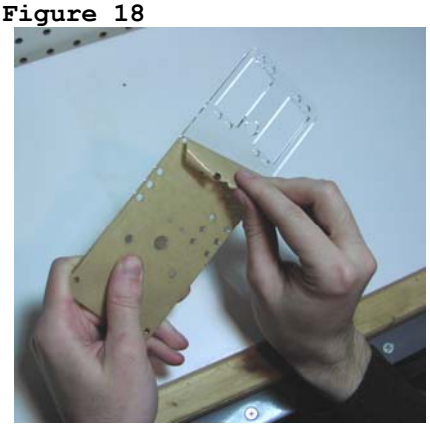


Figure 17

Figure 17 provides the part placement for the hexapod robot body. Refer to this drawing during assembly.

Begin by removing the protective paper off the hexapod body, see figure 18.

Figure 18



Attach the 90’ servomotor mounts to a servomotor using four 6-32 machine screws, nuts and #6 lock washers, see figures 19 and 20

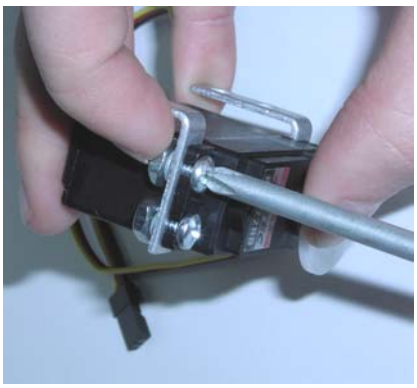


Figure 19

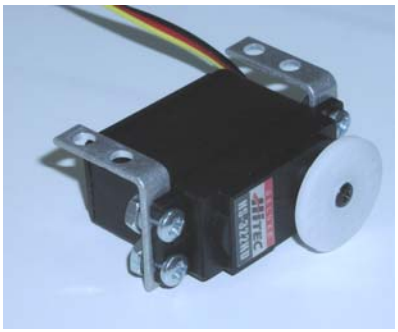


Figure 20


Figure 21

Battery Holder

Attach the battery holder to the hexapod body using the 4-40 machine screw, lock washer and hex nuts, see figure 21.
Next attach the center servomotor using the 90 degree brackets, see figure 22, using 6-32 machine screws, nuts and lock washers.

Attaching Center Servomotor

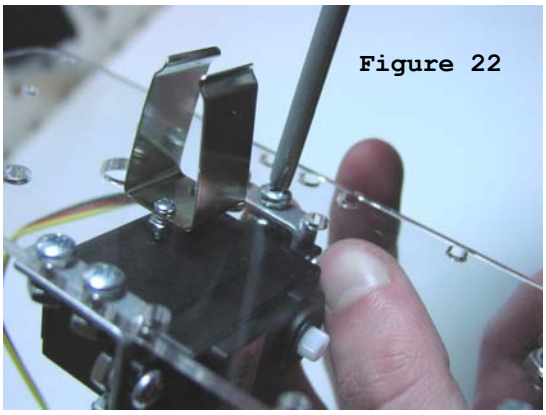


Figure 22

Center Leg Servomotor Horn

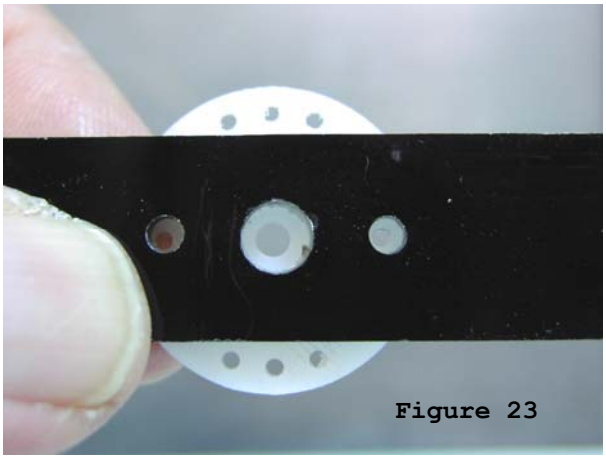


Figure 23

Align the circular servomotor horn to the holes in the center leg. Secure the servomotor horn to the leg using two #4 sheet metal screws. See figure 23.

Mounting Rear Servomotors

Mount the rear servomotors to the hexapod body using four 6-32 machine screws, lock washers and hex nuts per servomotor. See figures 24 and 25.

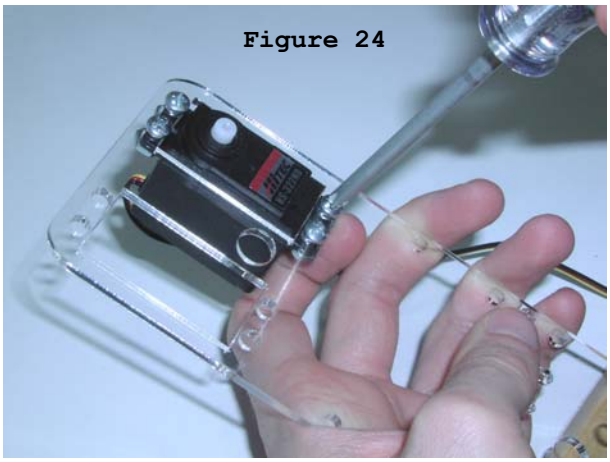


Figure 24

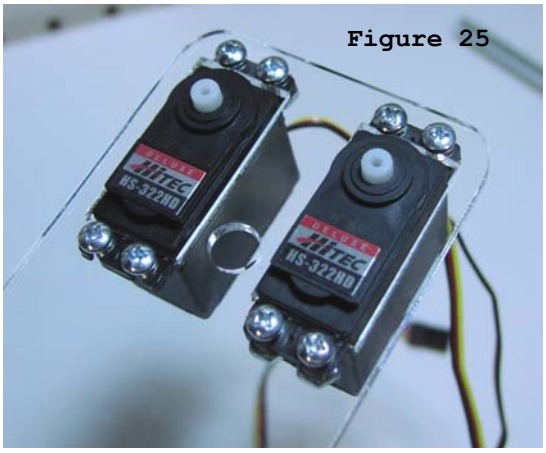


Figure 25

Lever Switch

Solder the 8” length 24 gauge orange wires to one lever switch. See figure 26. Secure the lever switch to the hexapod body using the 4-40 x 3/4 machine screws, nuts and lock washers. See figure 27.

Next solder the two green wires to the other lever switch and mount to the hexapod body, see figure 28.

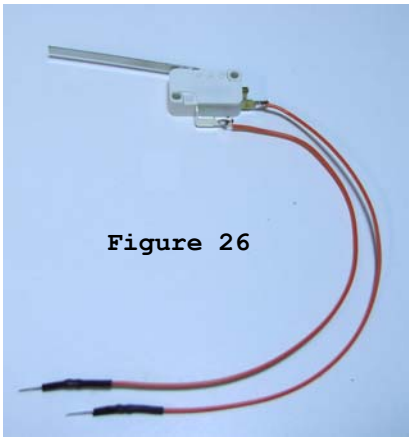


Figure 26

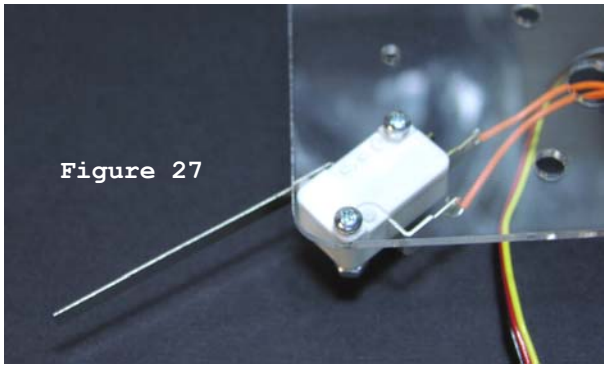


Figure 27

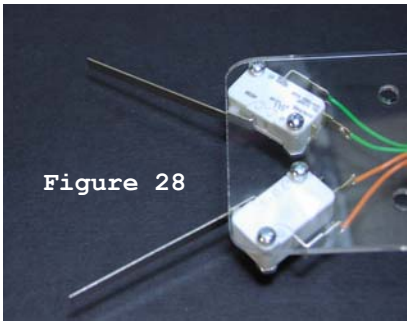


Figure 28

Next we will attach the servomotor horn leg assembly to the rear servomotor. Before attaching the leg you must use the finished hexapod circuit to center the servomotors. Figures 10 and 29 to the right shows our complete pc board.

The center servomotor connects to position 1, left servomotor to position 2 and the right servomotor to position 3.

By placing a jumper on the two pin header labeled Center, will tell the microcontroller to send a center servomotor signal on all of the servomotor connections.

The connector at the end of each servomotor is shown in figure 30. The servomotors plug into the hexapod controller board as shown in figure 31.

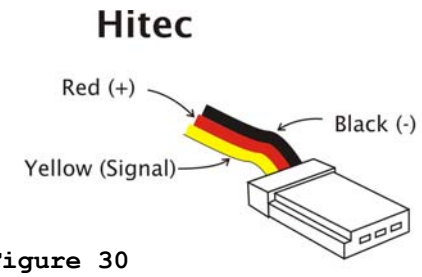


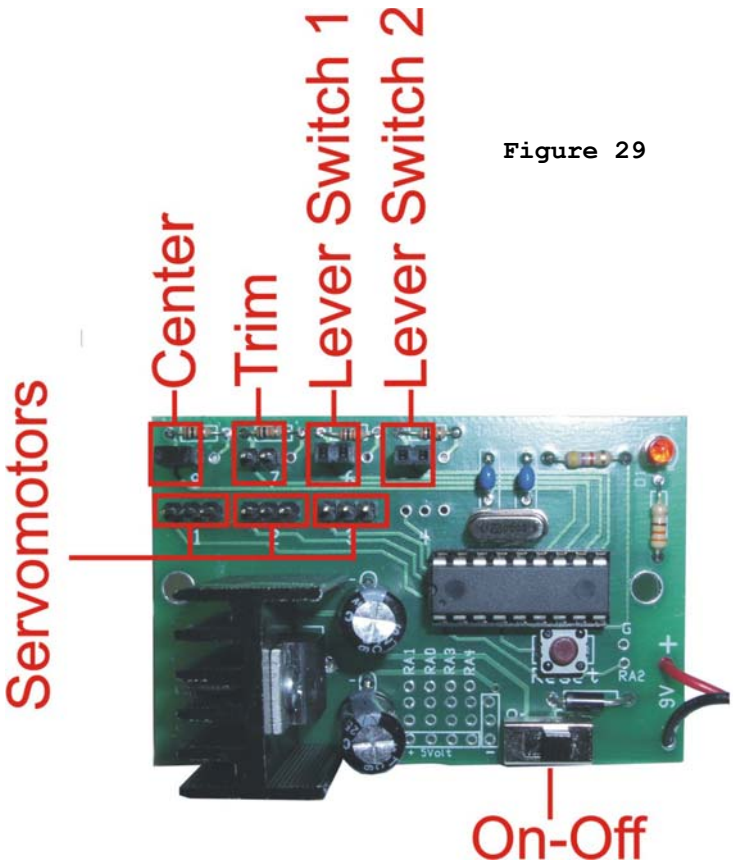
Figure 30

The 3-Pin headers on our hexapod walker controllers are compatible with servomotor connectors.

The servomotor connectors are designed that they can be accidentally plugged into a servo motor controller in reverse. If this happens, the servo motor will not be damaged, the servo motor will simply not work until it’s plugged in correctly.

PCB Connections

Figure 29



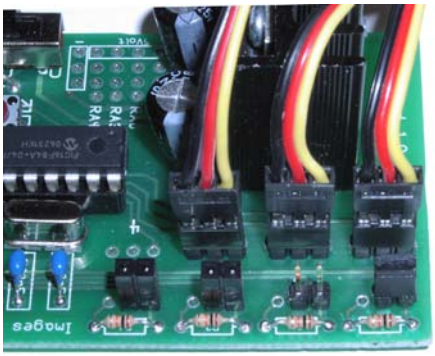


Figure 31

Figure 32 shows the top view of the front and back (rear) legs.

Align and attach the round servomotor horn to the end of the rear hexapod leg, using two #2 x 3/8 sheet metal screws see figure 33. Do the same to the other rear leg.

Turn on the hexapod circuit. The servomotors will quickly move to their center position. Attach the rear leg to the rear servomotor in its center swing position (150) as shown in figure 34. Do the same for the second rear leg. See figure 35.

Figure 32

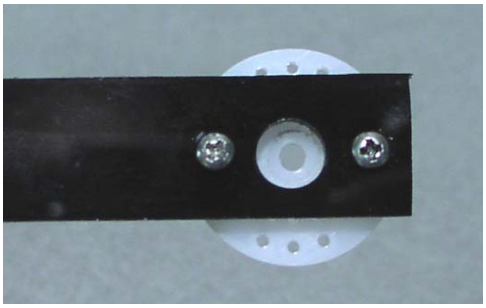


Figure 33

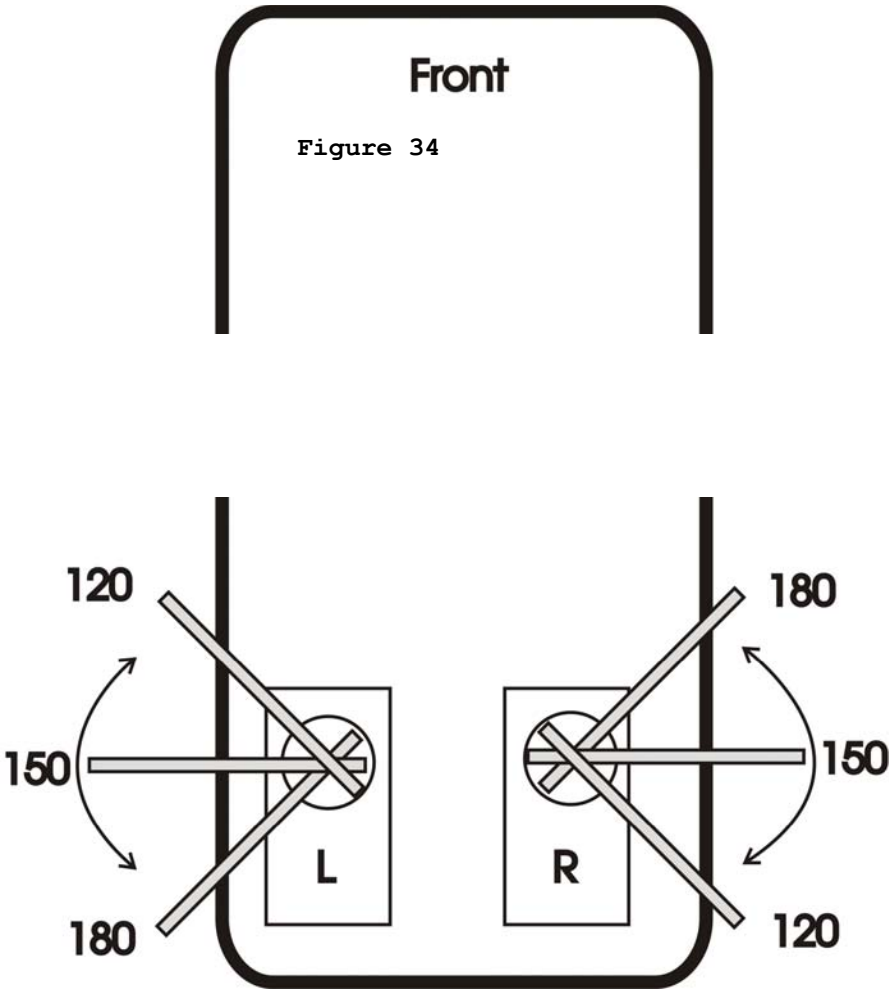


Figure 34

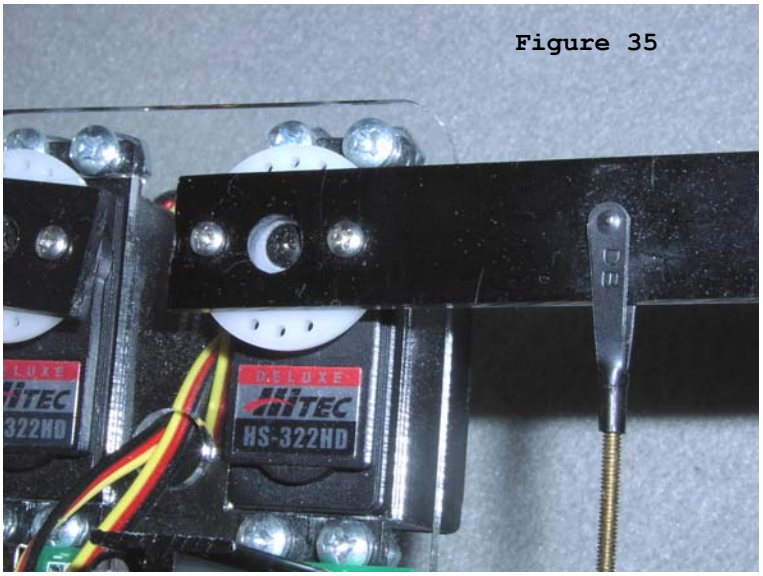
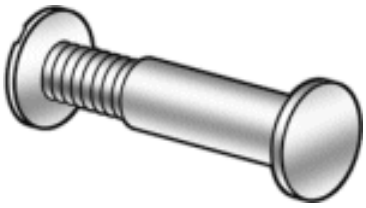


Figure 35

Front Leg Assembly:

The front leg is assembled to the body using a binding post and screw, three plastic washers and a small section of brass tubing, see figure 36. Tightness on the screw assembled needs to be adjusted so that the components are kept together without loosening, but still loose enough to allow the front leg to swing back and forth without too much resistance or binding. An alternative to this adjustment is to coat the threads of the screw with a thread lock compound and make the assemble slightly tight. Then allow the thread locking compound to cure.
Figure 37 is a close up photograph of the front leg assembly.



Binding Post & Screw

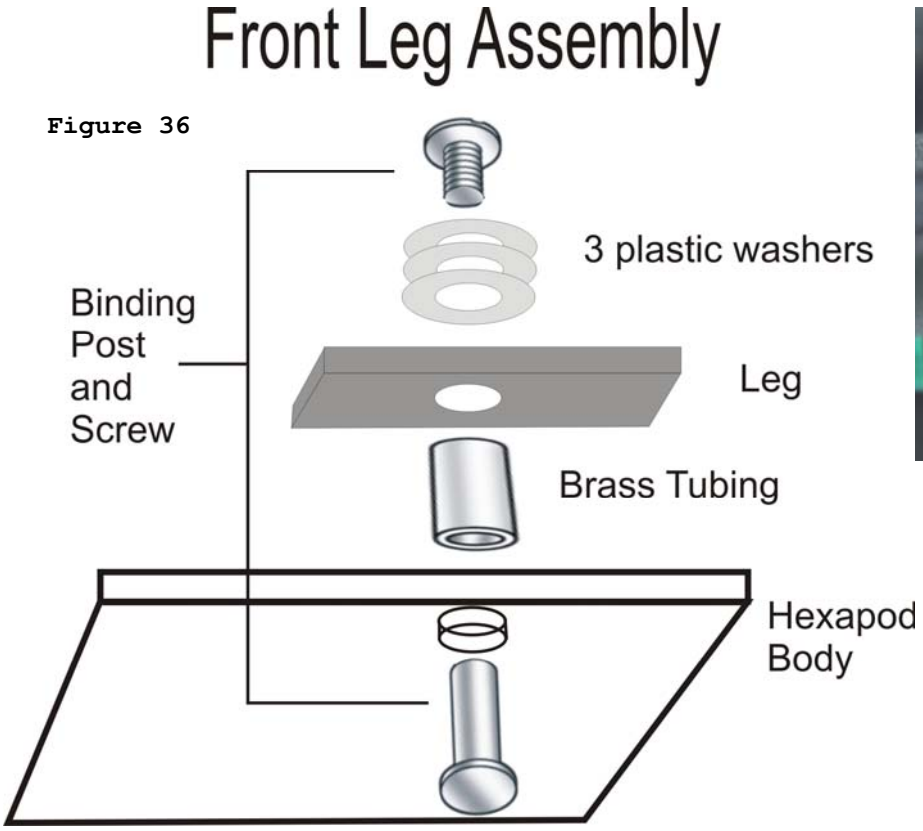


Figure 36

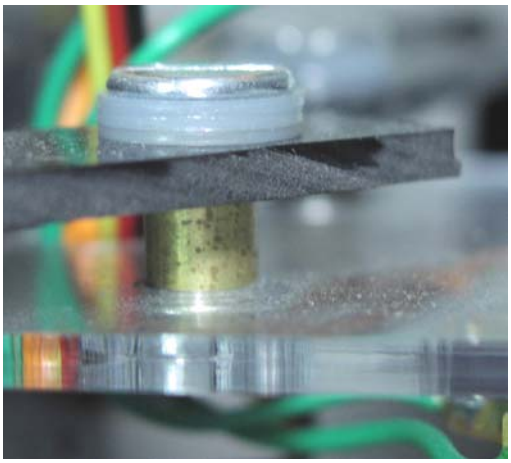


Figure 37

At this point we have the front legs and back legs attached to the hexapod robot. We need to connect the front and back legs. We make a connecting rod for each pair of legs using two clevises, see figure 38 and a small section of threaded rod. We screw the clevises onto the thread rod, see figure 39.

Figure 38

Figure 39

Next screw on a clevis to the other side of the threaded rod, see figure 40.

Figure 40

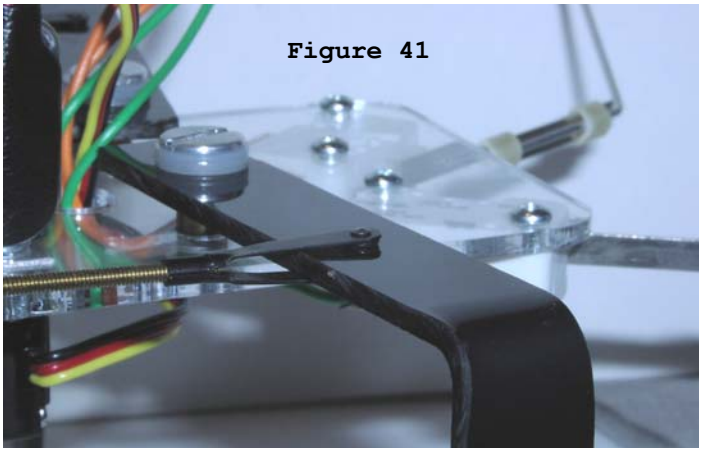


Figure 41

Separate the end of the clevis, push it onto on of the legs, until the protrusion on the clevis snaps into the hole on the leg. Figure 41 shows the clevis attached to the front leg.
Before attaching the other clevis to the back leg, adjust the length of the connecting rod so that the front and back legs are approximately parallel to one another, as shown in figure 42. Then snap the clevis into the back leg as shown in figure 43.

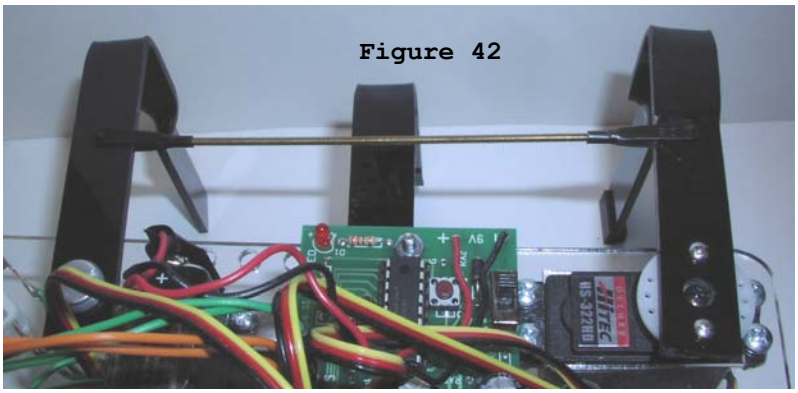


Figure 42

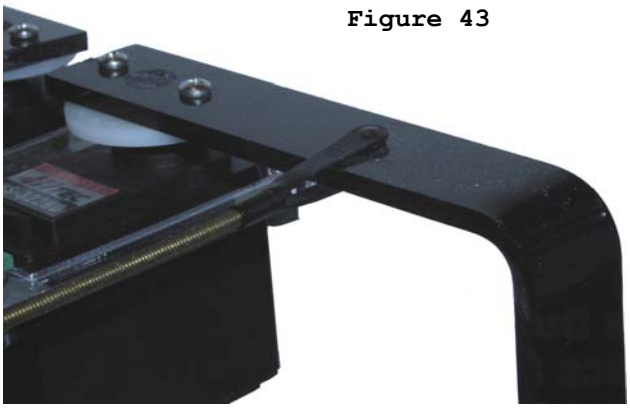


Figure 43

Now we must attach the center leg to the center servomotor. As you may have noticed when attaching the rear leg to the back servomotors, the horn is pressed onto a knurled spindle of the servomotor. Then secured to the servomotor using a screw. The knurled spindle restricts the positioning of the horn on the servomotor, allowing you to adjust the horn position in steps that equal the spacing of the knurl.

When attaching the center leg, it is important that the center leg, in its center "neutral" position, be approximately well centered as shown in figure 44. In this centered position neither side of the leg touches the ground. If you can place the center leg on the center servomotor and its centered you're finish, proceed onto the next step. If however the center leg is tilted too much to the left or right, you will have to trim the center servomotor, to center the leg into a good neutral position.

Trimming the center servomotor.

If because of the knurl you can not position the leg in a center neutral position, there is a trim control that will adjust the center servomotor by half a spindle space, see figure 29. To implement the trim, turn off the hexapod circuit. Place a jumper on the trim header. Then turn the circuit back on. With the servomotor trimmed, you should be able to center the center leg on the servomotor properly.
If you need to trim the center servomotor keep the jumper on the two pin trim header.

Figure 44

Next we attach the hexapod circuit pcb to the hexapod body using two 4-40 x 1/2 machine screws, six 4-40 nuts and two #4 lock washers. Place the machine screw though the hexapod body, and secure using two 4-40 nuts. Place the pcb on top of the 4-40 screws and secure with the lock washer and another 4-40 nut. See figure 45.

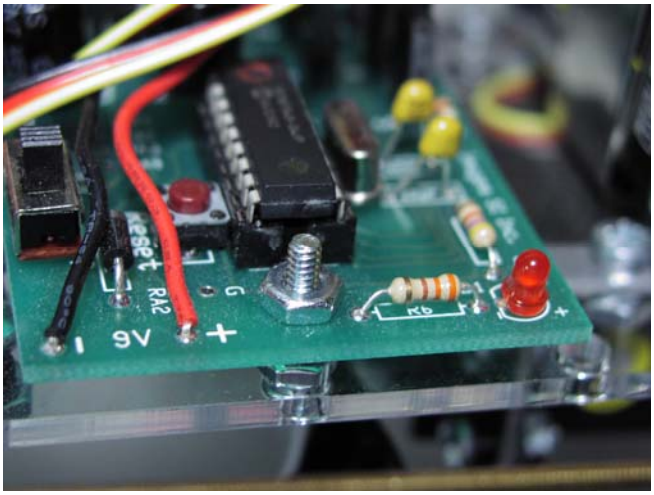


Figure 45

Feed the four wires from the two lever switches through the front hole wire pass through. Plug the two orange wires into the two pin socket labeled "5". Orientation of the wires does not matter. Plug the two green wires into the two pin socket labeled "6". Again orientation of the wires does not matter.

Pass the center servomotor wire through the front hole pass through and plug it into position 1. Pass the rear left and right servomotor wires through the rear wire pass through. Plug the left servomotor plug into position 2. Plug the right rear servomotor into position 3.

There are two four inch small aluminum tubes that we fabricate into antennas, see figure 46. Mark one inch off an end and bend the tube at an approximate 45 degree angle. Do the same for the other aluminum tube. Place two small rubber bands on the end of the lever of the lever switch. Secure the one inch length to the lever of the lever switch using the two small rubber bands see figure 47. Do the same for the other side.

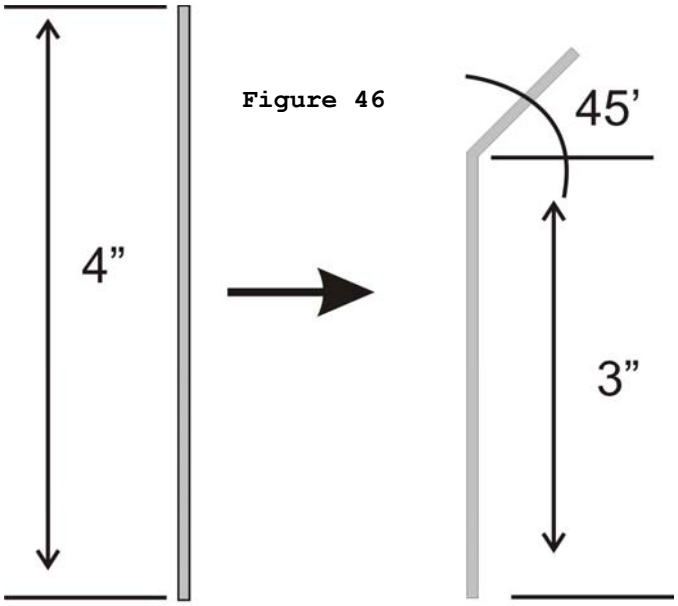


Figure 46

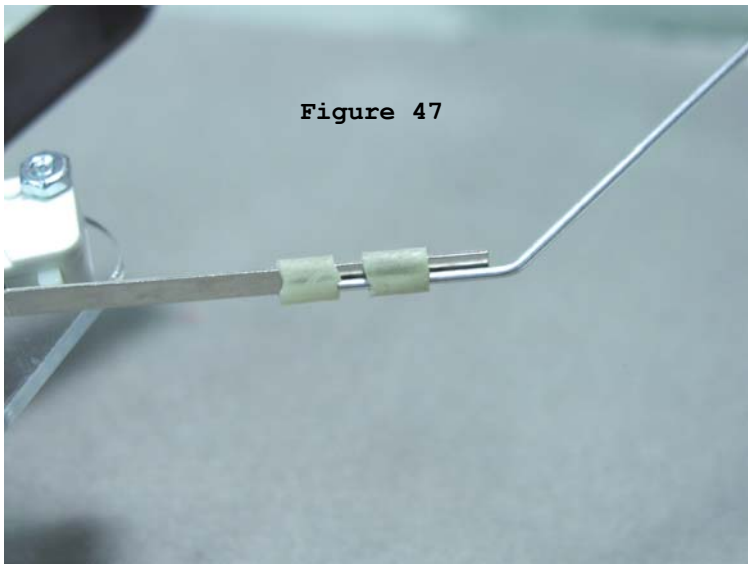


Figure 47

Antenna Fabrication

Place the nine volt battery into the battery holder and plug the nine volt battery cap onto the battery.

Check Out and Use:

Remove the center jumper from the two pin header. If you needed to trim the center servo-motor leg, leave the trim jumper in place. Turning on the robot will start it walking forward, using the standard tripod gait discussed earlier.

If either lever switch is activated by an obstacle the robot will turn toward the right. If both lever switches are activated the robot will first move backward a couple of steps then turn right.

The program for the hexapod was written using the PICBasic Pro compiler. The source code for the program may be found of the Images Company website.

Parts List

Item	Quantity
Plastic Body	1
HS-322	3
PCB	1
330 ohm resistor	1
4.7K resistor	1
10K resistor	4
1N4007 diode	1
2 Pin socket	2
18 pin socket	1
PCB switch	1
Push switch	1
4 MHz Xtal	1
22 pF cap	2
330 uF Cap	2
2-Pin Header	2*
3-Pin Header	3*
LED	1
7805 V Regulator	1
Microcontroller	1
Heat Sink	1
Lever Switches	2
Center Leg	1
Front Leg	2
Rear Leg	2
Rd Servo horn	3
#2 Screw	6

* See text

Parts List Con't

Item	Quantity
9V Battery holder	1
9V Battery Cap	1
Binding Post	2
Plastic Washers	8
2-56 Clevis	4
2-56 Threaded Rod	2
Antenna	2*
6-32-3/8 MS	16
6-32 nuts	16
#12 lock washer	16
2-56 x5/16 MS	2
#2 lock washer	8
2-56 nut	2
4-40 x 3/4 MS	6
4-40 not	10
5-40 x 3/8	1
8" Orange wire	2
8" Green wire	2
90' degree bracket	2
Jumpers	2
Brass tube	2
Rubber bands	4

* See Text