Insert Figure 10 here. Drawing

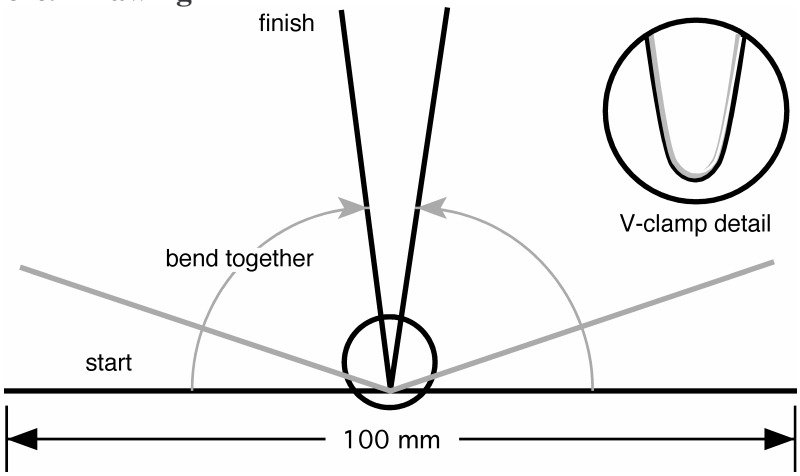


Figure 10: Bending the legs (enlargement 6X)

Remove the 70-millimeter length of 20 AWG copper wire from the kit. This is the power bus.

Insert Figure 11 here. Drawing

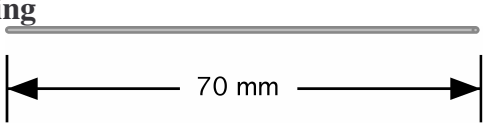


Figure 11: Power bus

Lay the power bus along the top of the body between the leg holes. Temporarily clamp the power bus by bending the legs together, inserting them through the leg holes, and then pulling the legs through from the other side until the power bus is held tightly by the V-clamp.

Insert Figure 12 here. Drawing

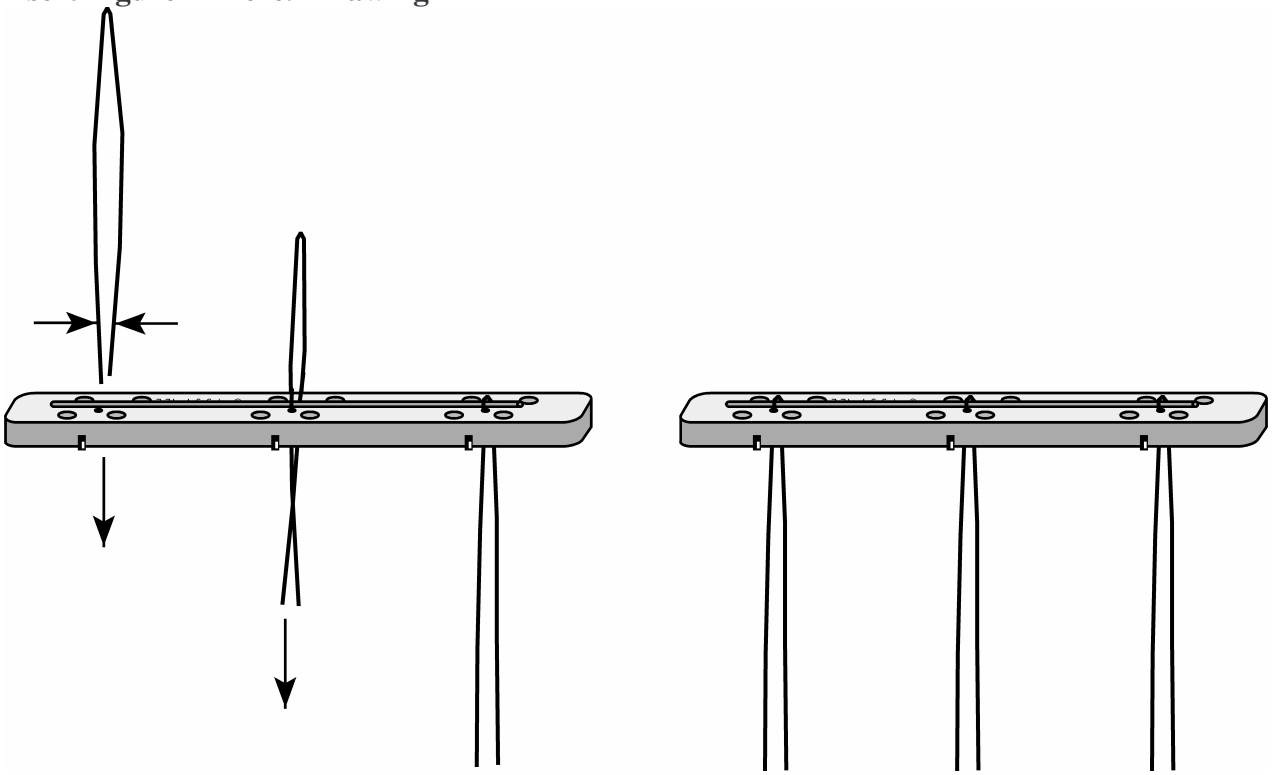


Figure 12: Temporarily clamping power bus with the legs

Turn the body over and permanently clamp the power bus, simultaneously attaching the legs, by spreading each leg in the pair outward by hand, while at the same time pulling upward on the legs. When the legs are almost horizontal, grasp each leg in turn with the needlenose pliers and firmly bend it downward, while continuing to pull outward, until the leg snaps into the clip groove.

At this point the power bus should be securely clamped into place. Check to ensure that it will not touch any of the body screws (insert a screw and check with the volt-ohm meter). Also check that the electrical connection between the power bus and the legs is good. It should be less than 2 ohms.

Insert Figure 13 here. Drawing

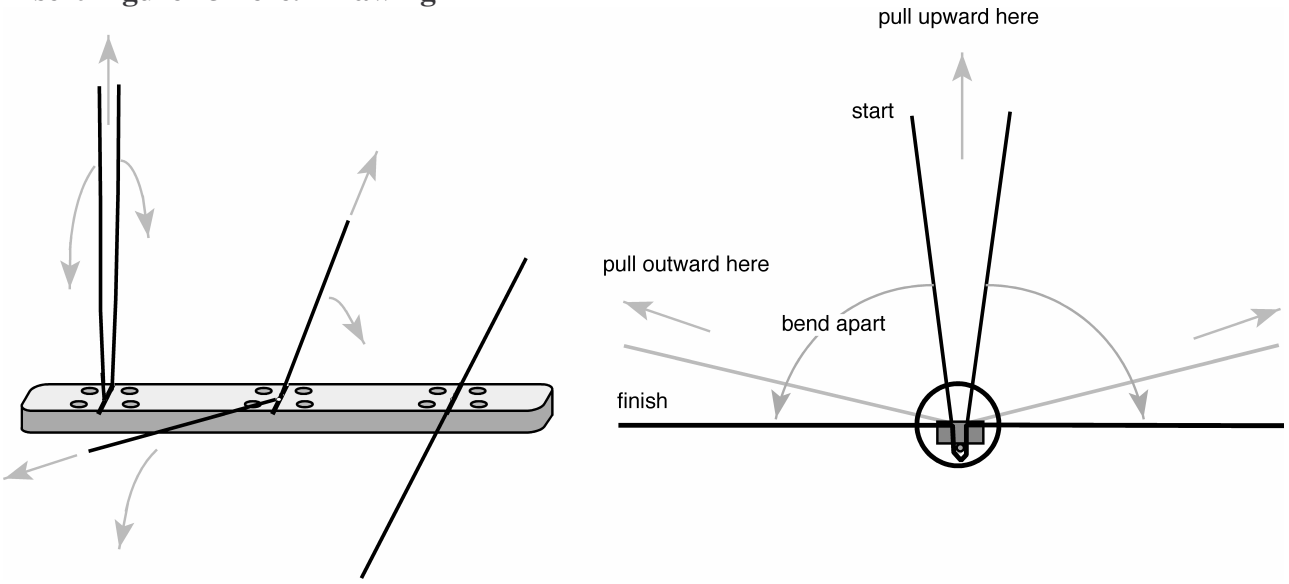
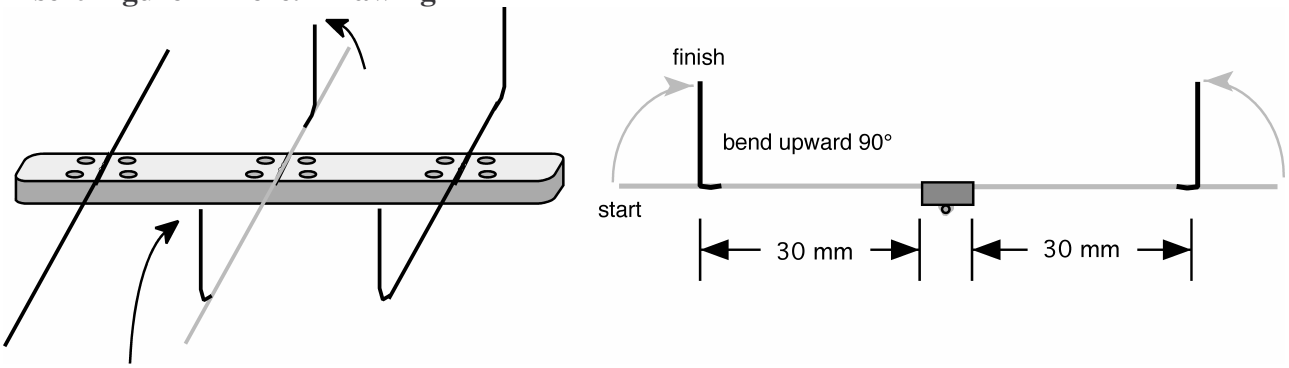


Figure 13: Permanently attaching the legs and clamping the power bus

Adjust the legs so that they are in a plane horizontal with the bottom of the body, and parallel to each other.

Working with the bottom of the body facing upward, form the knee, which separates the horizontal joint from the vertical joint of each leg, by bending the music wire 90 degrees about 30 millimeters from the edge of the body. Adjust the vertical joints so they are parallel.

Insert Figure 14 here. Drawing



(a) Side view, bottom of body (b) End view

Figure 14: Forming the knee, and the horizontal and vertical joints

Trim the vertical joints using the wire cutters so that all legs touch the ground. This completes assembly of the legs and power bus.

Insert Figure 15 here. Drawing

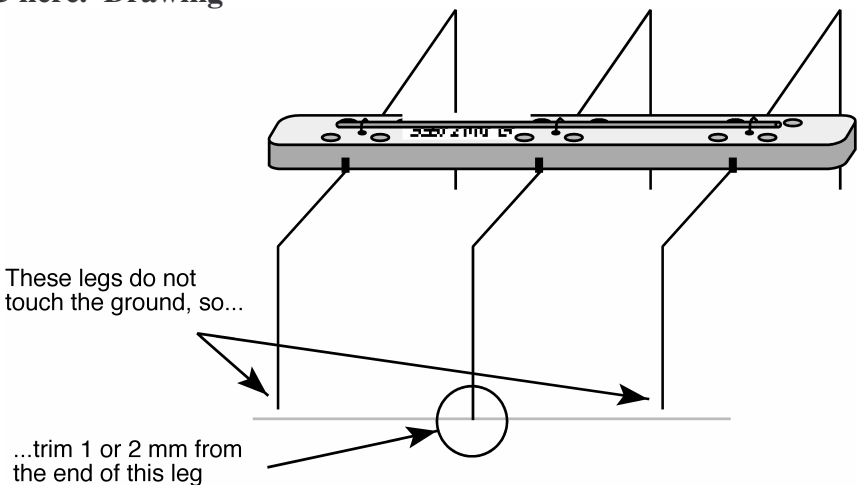


Figure 15: Trimming the vertical joints

Do not bend the music wire to make the ratchet feet now. Wait until the actuators have been completed and tested.

The Actuators

Stiquito is small and simple because it uses nitinol actuator wires.

Insert Figure 16 here. Drawing

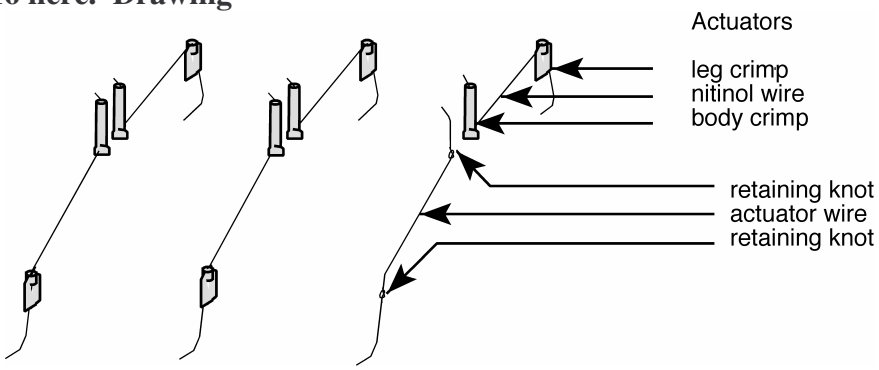


Figure 16: Actuators

The nitinol wire translates the heat induced by an electric current into mechanical motion, replacing stepping motors, screws, and other components otherwise needed to make a leg move. The mechanical motion results from changes in the crystalline structure of nitinol. The crystalline structure is in a deformable state (the martensite) below the martensite transformation temperature, M_t. In this state, the wire may change its length by as much as 10 percent. The nitinol wire provided is an expanded martensite (that is, a *trained* wire).

When the wire is heated above the austenite transformation temperature A_t (1 in Figure 17), the crystalline structure changes to a strong and undeformable state (the austenite). As long as the

temperature of the wire is kept slightly above A_t, the wire will remain contracted. During normal use of the nitinol wire, a recovery force, or tension, is applied while it is an austenite.

Insert Figure 17 here. Drawing

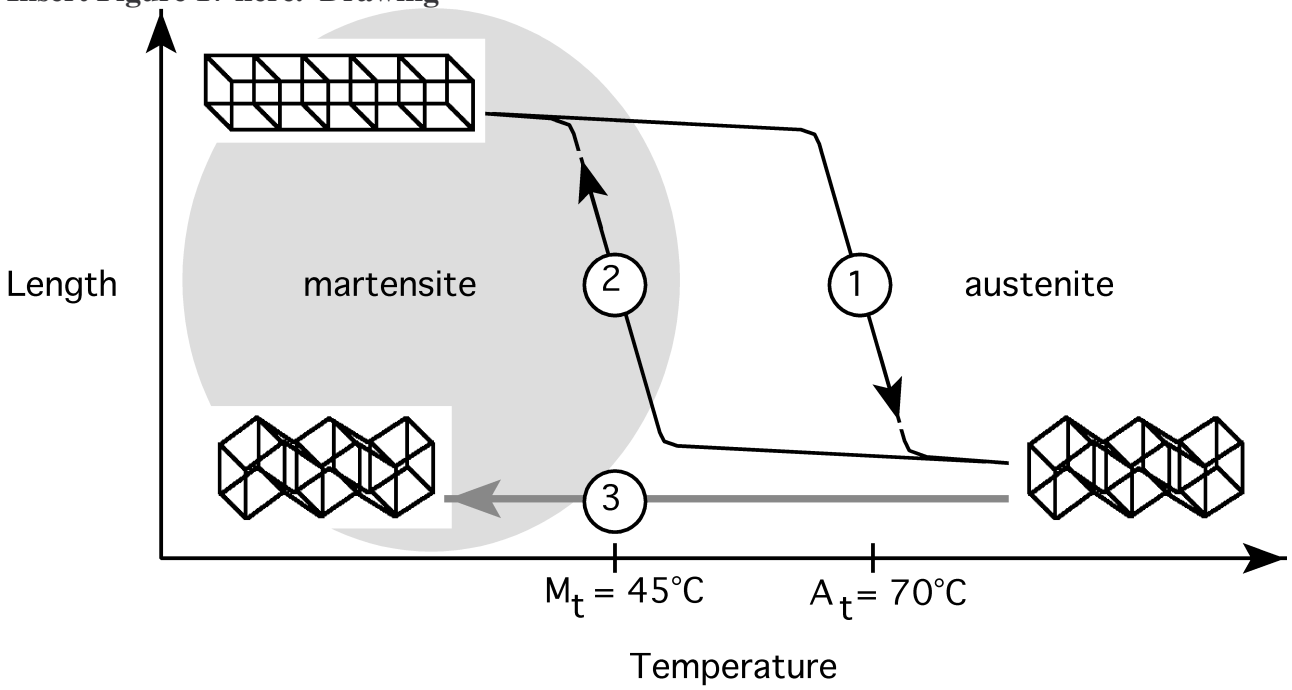


Figure 17: Changes in crystalline structure of nitinol

When the temperature falls below M_t the austenite transforms back into the deformable martensite (2), and the recovery force pulls the wire back into its original, expanded form. If no recovery force is applied as the temperature falls below M_t, then the wire will remain short as it returns to the martensite (3), although it can recover its original length by cycling again while applying a recovery force. If the wire is heated too far above A_t, then a new, shorter length results upon transformation to the martensite; the "memory" of the original, longer length cannot be restored.

Nitinol wire will operate for millions of cycles if it is not overheated and if a suitable recovery force is applied during each transformation. Stiquito's controller prevents overheating if used as directed. Autonomous controllers and software must limit the current supplied to the nitinol actuator wires to avoid overheating them. The music wire legs provide the correct recovery force.

The actuators, legs, and power bus combine to route power, provide the recovery force, and support the robot.

Insert Figure 18 here. Drawing

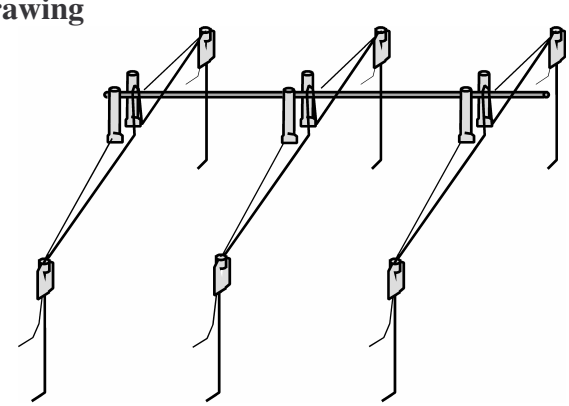


Figure 18: Actuators, legs, and power bus

The following steps are needed to build the actuators, attach them to the legs and body, and form the ratchet feet.

Cut Nitinol Wires To Size - Begin making the actuators by cutting six 60 millimeters lengths of nitinol wire (there will be an extra 60 millimeters length of nitinol wire left over if you purchased the kit). It might be preferable to use some of the extra nitinol in the kit, and cut six 65 millimeters lengths to make it easier to wrap the nitinol around the screws during the tightening of the body screws.

Insert Figure 19 here. Drawing

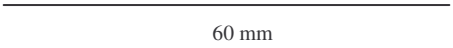


Figure 19: Nitinol wire

Make Leg Crimps - Next select the aluminum tubing from the kit. It will be used to make the leg crimps. Using the knife, cut six 4-millimeter leg crimps from the aluminum tubing. Sand the ends of the crimps, then run the end of the knife through them to deburr the ends.

Insert Figure 20 here. Drawing

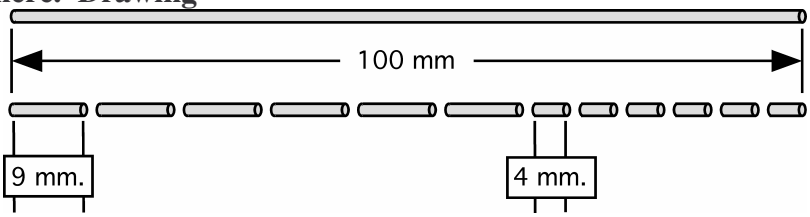


Figure 20: Leg crimps

Preparing the Screws on the Body – Turn Stiquito upside down with the front of the body pointing away from you. Place one washer on each of six screws (there is one extra screw and washer). Insert the screws with the attached washers into the three sets of offset holes near each pair of legs. Secure the screws loosely to the body by threading one brass nut on each brass screw by hand.

Insert Figure 21 here. Photo

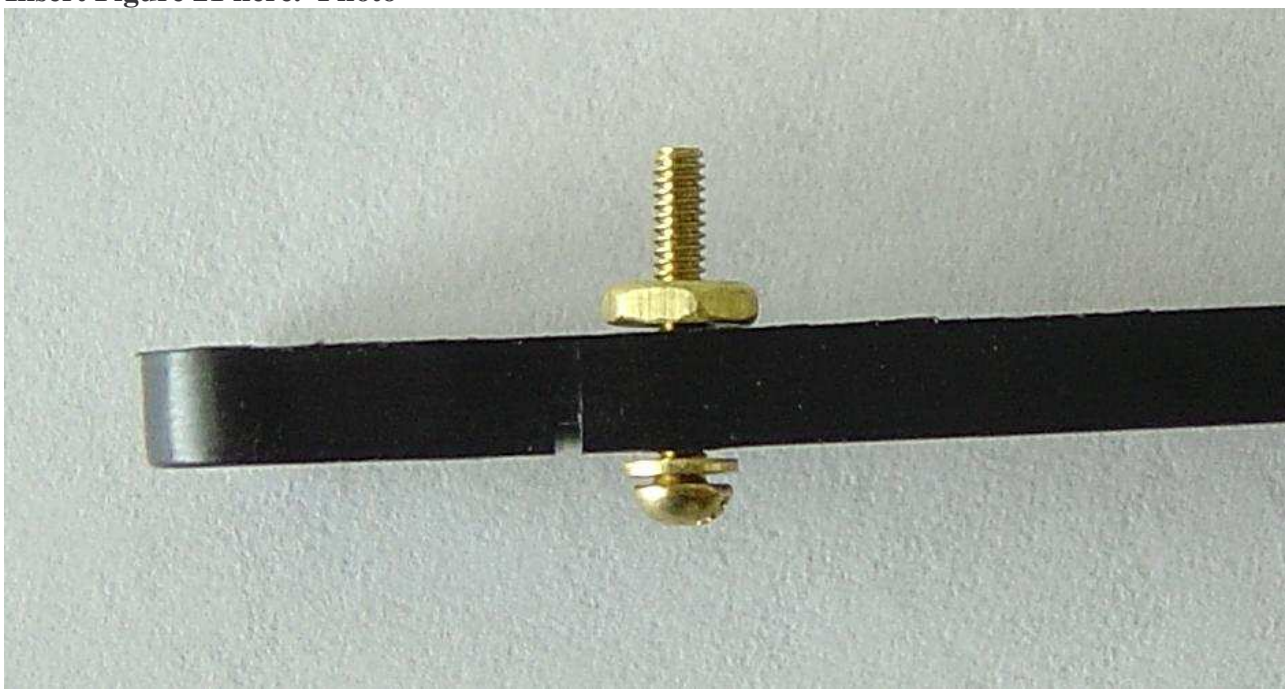


Figure 21: Adding six screws, washers, and nuts to the Stiquito Body

To verify that you have inserted the screws in the correct holes, remove the Stiquito Controller Board from the plastic bag. Place the Stiquito robot on its feet with the front of the robot to your left and the screws to the right of each left. Holding the board by the edges, orient the board so that the prototype-end of the board (six row of holes) are to your left and the electronic components are facing up. Notice how the very large holes in the board are also offset like the Stiquito body. Align the screws of the Stiquito so that they match the large holes in the board, and GENTLY push the body and board together. If the holes do not align, then you probably did not put the screws in the correct holes – remove the screws and start the step over from the title "Preparing the Screws on the Body." Remove the Stiquito Controller Board to redo this step or to continue.

Insert Figure 22 here. Photo

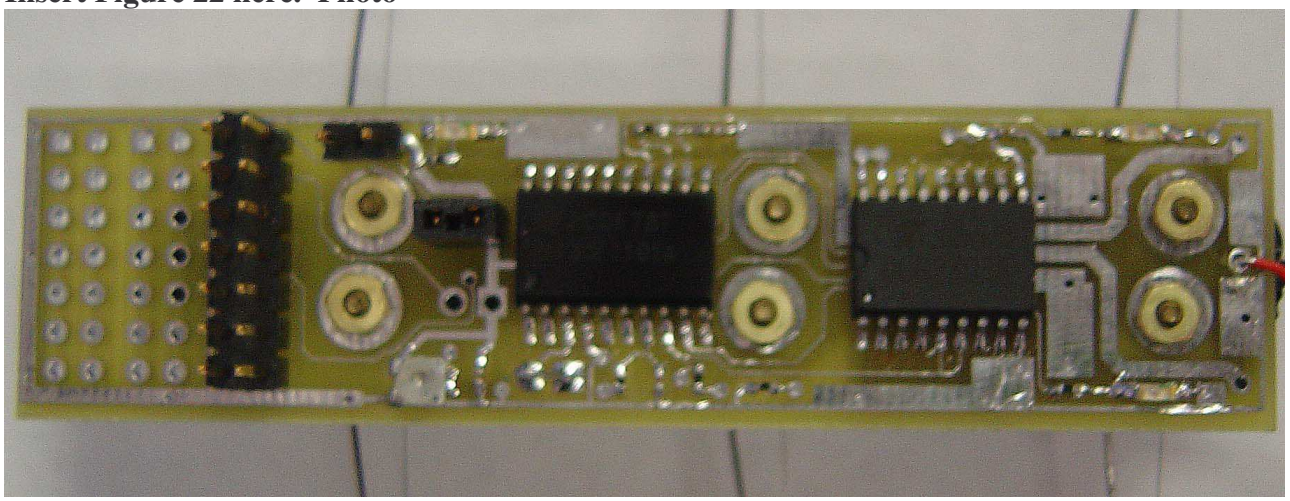
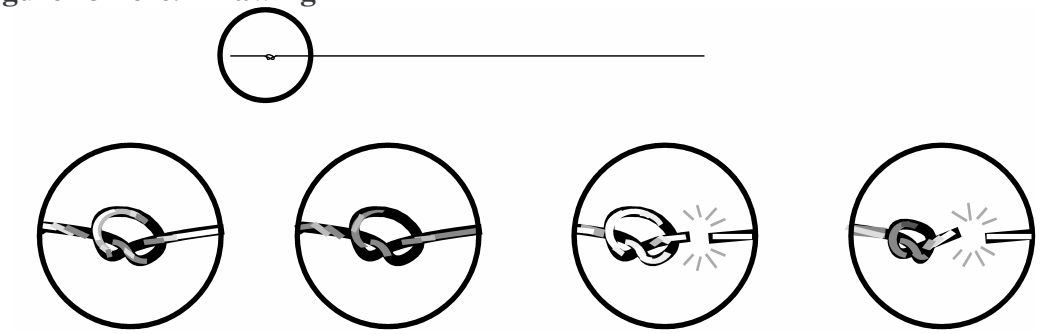


Figure 22: Checking alignment of the Stiquito Controller Board with the Stiquito Body

Attach Leg Crimps – These steps will have you attach each length of nitinol wire to each Stiquito knee using a leg crimp.

Tie a retaining knot in one end of the wire. Using the 600 grit sandpaper, lightly sand the nitinol wire at the knot to remove oxide and improve the electrical connection to the body crimp.

Insert Figure 23 here. Drawing



(a) Correct (b) Sanded too lightly (c) Sanded too much (d) Tied too tightly

Figure 23: Tying and sanding retaining knot (all enlargements ´ 10)

Take a 4 millimeters body crimp, insert the non-knotted end of the wire into a leg crimp and pull it through the crimp; the knot must barely extend out one end.

Insert Figure 24 here. Drawing

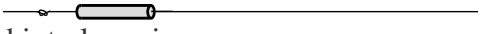


Figure 24: Nitinol wire inserted into leg crimp

Holding the Stiquito body, slide the leg crimp with the nitinol onto the vertical joint of one leg and slide it up to the knee. The knot should still extend out of the crimp. Once the tubing is as close to

the joint of the leg as possible, slowly pull the wire through the tubing until the knot is inside the tubing about one-half the way.

Insert Figure 25 here. Drawing

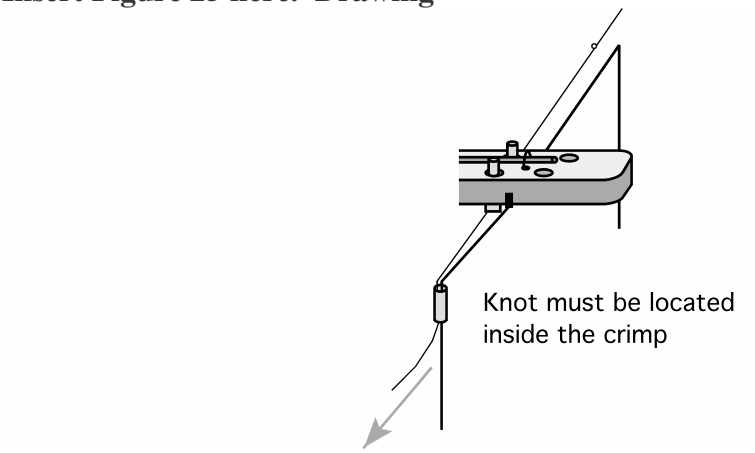


Figure 25: Nitinol wire pulled into leg crimp on the leg

Once the knot at the end of the wire is inside the tubing, using pliers, crimp the entire length of tubing to secure it to the leg. Gently tug up on the nitinol wire to ensure the crimp is holding the knot, and nitinol, inside.

Insert Figure 26 here. Drawing

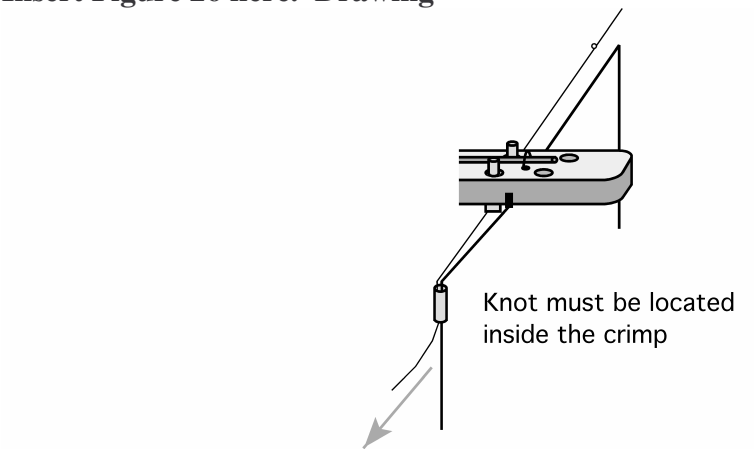


Figure 26: Crimp the tubing to hold the knot in place