Hold the loose end of the nitinol wire and pull it towards the Stiquito body screw. Wrap the other the nitinol wire **clockwise** all the way around the screw once, between the head of the screw and the washer, and pull taut. Be careful not to place the wire between the washer and the plastic body of the Stiquito or proper tension will not be maintained.

Insert Figure 27 here. Photo

Figure 27: Wrap the nitinol wire around the screw

Secure the wire between the head of the screw and the washer. Keep the wire in place by applying pressure with a finger to the head of the screw while finger tightening the nut on the other side of the body. Once the nut can no longer be tightened by hand, hold the head of the screw in place with the small flathead screwdriver. Continue to turn the nut using the needle-nose pliers until a fair amount of resistance is felt. Caution: screws can be stripped if nuts are over tightened

Insert Figure 28 here. Photo

Figure 28: Tightening the brass nut

The goal is to have the wire taut so that there is a slight backwards bend in the horizontal joint. The slight bend ensures there is no slack in the nitinol actuator wire. There is not enough tension if there is no bend in the leg. There is too much tension if the leg is bent more than 2 millimeters backwards at the knee. To make the nitinol more taut, turn the screw clockwise.

Insert Figure 29 here. Drawing

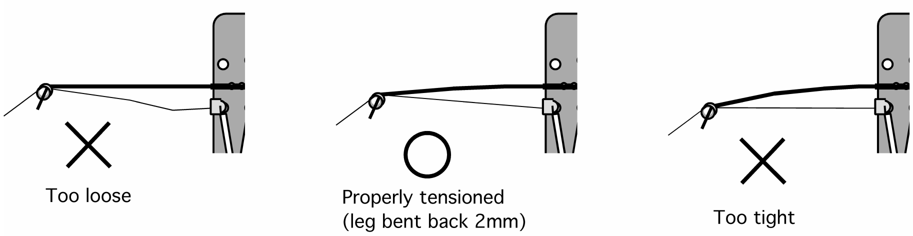


Figure 29: Correct tension (O) and incorrect tension (X)

Once the wire is secured, the excess may be trimmed off. It is still a good idea to leave about 1/4 inch of wire so that the previous steps can be re-done if the tension is not sufficient.

Measure the resistance from the leg near the clip groove to the body crimp where it protrudes above the top of the body. The initial resistance should be between 5 and 7 ohms. The resistance will increase to between 15 and 25 ohms as the connections age. Test the operation of the actuators by applying current from two 1.5 volt AAA cells at the leg near the body and the body crimp for no more than half a second to prevent the actuator wire from overheating. The leg should immediately bend backwards 3 millimeters to 7 millimeters measured at the vertical joint, then return to its original position.

Insert Figure 30 here. Drawing

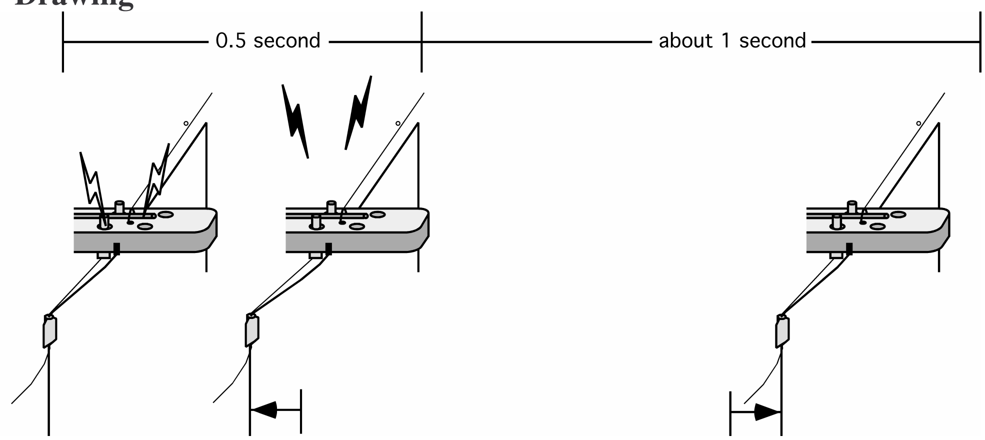


Figure 30: Testing the actuator

Test the leg and actuator assembly after installing each leg nitinol wire.

If the test is successful, continue to attach and test the remaining nitinol wires..

Insert Figure 31 here. Photo

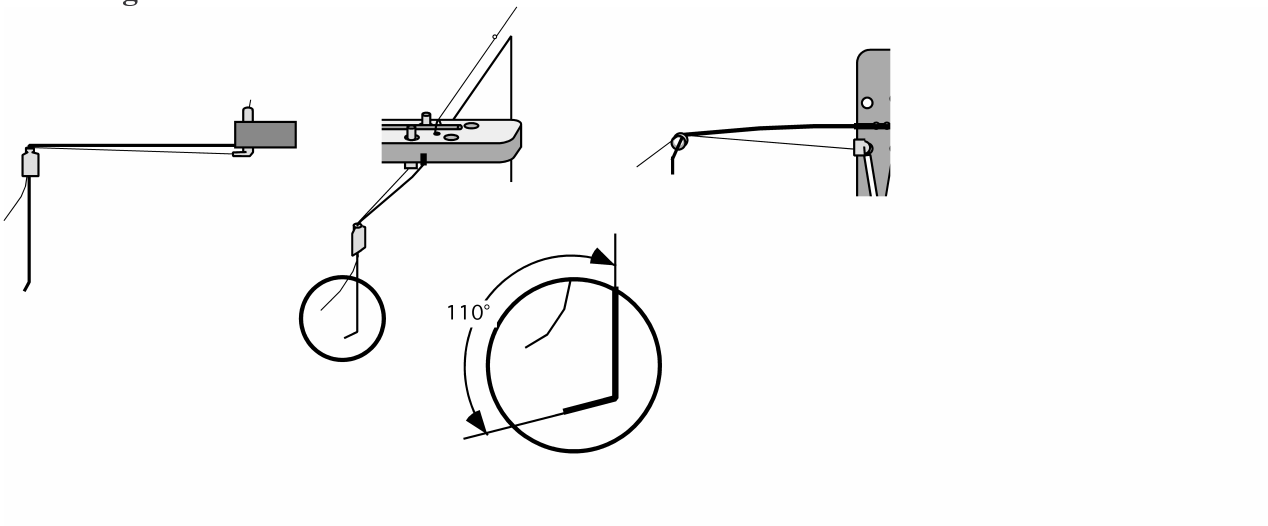
Figure 31: Finished actuators –side view

Insert Figure 32 here. Photo

Figure 32: Finished actuators –bottom view

The Ratchet Feet - Be sure to test the actuators before making the ratchet feet in case the leg crimps must be replaced. Form an ankle and ratchet foot by bending the tip of each vertical joint backwards and slightly outwards. The ratchet foot should be about 2mm long, and make a 110 degrees degree angle downward from the vertical joint. The ankle faces toward the front of the robot.

Insert Figure 33 here. Photo



(a) End view (b) Side view (c) Detail (x4) (d) Bottom view

Figure 33: Ratchet foot

The Printed Circuit Board and Soldering

The Stiquito Controller Board has been pre-programmed to make your Stiquito robot walk with one-degree of freedom. While the board that is included in the book does not include the materials to reprogram the microcontroller, several features were added to the board so that users could solder low-cost connectors, solder them to the board, and be able to expand its capabilities. These features include:

- **Two degree of Freedom Jumper:** If you shunt this jumper (J6), then Stiquito operates in two-degree of freedom mode. If this jumper remains open, it runs in one-degree of freedom mode. Soldering the jumper header connector to the board is described in Appendix D.
- **JTAG connection**: The JTAG header (J2) is connected to a computer using a parallel port interface. The target connector signals for the programming adapter to ensure communication between programming adapter and MSP430 devices and supply low energy to systems without extra supply sources. To use JTAG, you will need to solder a header to the board, and solder several jumper headers to the board to support powering the Stiquito Controller Board. Using the JTAG is described in Chapter 5, and soldering the JTAG connector to the board is described in Appendix D.
- **Using the JTAG cable:** If the Stiquito Robot is attached to the Stiquito Controller Board, then to use the JTAG cable you must shunt jumper J5. Soldering the jumper header connector to the board is described in Appendix D.
- **Powering the Stiquito Controller board from the PC:** Putting a shunt on jumper J1 allows you to use the PC's power for the Stiquito Controller Board through the JTAG cable. Again, DO NOT power the robot legs with PC power. Soldering the jumper header connector to the board is described in Appendix D.
- **Reset Switch/Jumper**: When a software problem occurs, the reset line can be activated to reset the system to reinitialize the microcontroller. There is a jumper available which can support a switch or jumper header. Soldering the jumper header connector to the board is described in Appendix D.

The hardware for this additional functionality can be purchased from suppliers listed in Appendix B. If you implement any of this functionality, you must solder these connectors/jumpers to the board before you proceed. Go to Appendix D for specific soldering instructions.

The next step to complete your Stiquito robot is to prepare the power buss supply wire. This wire connects the Stiquito power bus to the circuit board. Both ends will be soldered to ensure a effective connection.

First, take the 100mm 30 AWG wire wrap wire and carefully strip 12mm of insulation from one end and 4 mm of insulation from the other end. Use the hobby knife if you do not have a wire stripping tool.

Insert Figure 34 here. Drawing

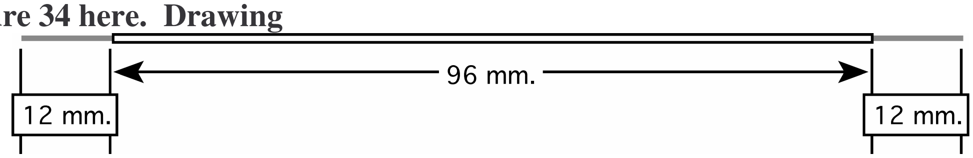


Figure 34: Power bus supply wire

Taking the 12 mm stripped side, gently lift the back end of the power bus wire and wrap the 30 AWG wire-wrap wire around the bus wire a few times. Remember, the back of the robot will have two of the screws close to the end. Solder this wire-wrap wire to the power bus wire. Let the wire cool, then gently press the bus wire down.

Insert Figure 35 here. Photo

Figure 35: Solder power bus supply wire to power bus

Take the Stiquito Controller Board and loosely place it on the Stiquito robot in the correct orientation, as described earlier. The prototype area of the board should be towards the front of the robot. Insert the 30 AWG wire wrap wire, the 4mm stripped end, into the hole labeled “spine” **from the bottom** of the controller board. Take the empty AAA battery holder, and insert the wire leads from them into the controller board in the same way. The red wire should be inserted, through the bottom of the board, into the hole labeled “+”. The black wire should be inserted, through the bottom of the board, into the hole labeled “-”. Bend the wires over toward the back of the robot gently to hold them in place.

Insert Figure 36 here. Photo

Figure 36: Inserting the wires into the controller board

Heat up your soldering iron. Following the guidelines shown at the beginning of the Chapter, solder these three wires to the controller board. Make sure that you do not create any shorts between board traces.

Insert Figure 37 here. Photo

Figure 37: Soldering the wires into the board

Push the Stiquito Controller board all the way onto the Stiquito robot body screws. Put a brass nut on each of the screws and tighten them until there is some resistance against the controller board.

Insert Figure 38 here. Photo

Figure 38: Securing the controller board to the robot

Check that attaching the board to the robot did not cause any of the nitinol actuators to loosen. If an actuator did loosen, use a screwdriver to turn the screw clock-wise and make the nitinol wire taut.

The assembly of your robot is now complete.

Operating the Stiquito Robot

In order to operate the robot, you will need fresh AAA batteries. Since the board does not have an on/off switch, make sure to remove the batteries from the AAA battery hold when not in use.

Insert the AAA batteries into the battery holder. You should see the power LED light (back of the controller board). After a few seconds, you should see the LED on each side of the controller board alternatively light. At the same time, the two tripods of the robot should alternately contract.

In order for the robot to walk effectively, three of the legs in one tripod should fully contract backwards, then relax and return to their original position, and then the other tripod should fully contract backwards, then relax and return to their original position. If the legs are cycling too fast (they do not fully contract), then you will need to adjust the speed potentiometer, located in the center of the robot, to make the cycle longer. If the legs are staying contracted too long, then you will need to adjust the potentiometer to make the cycle shorter.

To adjust the potentiometer, take a small screwdriver (flat head or Phillips), place the tip inside the potentiometer, and:

- Turn clockwise to make the cycle faster.
- Turn counter-clockwise to make the cycle slower.

Insert Figure 39 here. Photo

Figure 39: Adjusting the speed of nitinol wire actuation

Once the legs are contracting at the correct speed, you can attach the battery to the robot using a rubber band. Place Stiquito on a slightly rough surface, and watch it walk!

Insert Figure 40 here. Photo

Figure 40: The complete robot!

Troubleshooting

Troubleshooting is applied logical deduction. To avoid the frustration encountered when a project fails to work as expected, *expect it not to work.* Take this attitude from the start, and think about factors that could affect the operation of the robot, and the behavior (or lack of it) that would result. Then, when the inevitable happens, you will have a set of hypotheses about why the robot failed to work. The hypotheses may be wrong, but that is OK: wrong assumptions lead to right deductions if you are willing to discard assumptions that are not supported by experiment.

Stiquito Walks in a Straight Line -- This is perfect. You do not have any trouble. Congratulations on a good job!

Stiquito Walks to the Left or Right, But Not Straight – This is OK, and is very common. The reason is that one or more of the legs is crooked, or does not operate at full extension. Check for loose actuator wires, loose crimps, poor electrical connections (look for open or high-resistance paths from the power supply to the legs and back), a weak power supply (nitinol draws about 180mA per leg, which will drain two 1.5 volt cells after several weeks of occasional use); legs that are not parallel, or ratchet feet bent at different angles.

Stiquito Does Not Walk at All – If there is nothing obviously broken or loose (actuator wires, crimps, brass screws), then check the power source. The two 1.5-volt cells may be dead. Check the power bus and the body screws for shorts. If you did not bend the ratchet feet, or if you operate Stiquito on a smooth surface, the legs may move but will not catch the surface — and Stiquito will thrash around but not walk. Stiquito walks best on slightly textured surfaces such as indoor-outdoor carpet, a cloth-covered book, pressboard, or poured concrete. Stiquito walks poorly on glass, smooth plastic, or tiled floors.

Leg Moves to Full Extension (4-5 millimeters) – This is perfect. You obviously built Stiquito carefully.

Leg Does Not Move at All – The probable causes include a very loose actuator wire or dead 1.5-volt batteries. Check the cells with a volt-ohm meter. If the power is OK, then check the electrical connection between the bus and the body screw. Test single actuator wires using 3 volts supplied by two 1.5-volt AAA cells in series. If the electrical connections are good, then examine the actuator wire. If it is loose, or the body screw or leg crimps are not tight, then the actuator is too slack to operate. Tighten the actuator wire (you may have to loosen, then tighten, one or more screws/nuts), then test the leg. It should work.

Leg Moves Slightly (1-3 millimeters) – The actuator is probably loose, but is taut enough to take up the slack, then move the leg. Re-tension the actuator, turning the body screw. Another cause is increased resistance as the crimps age. Aluminum oxide builds up inside the crimps. Its effects can be alleviated by operating the leg. This causes the retaining knots to expand and improve contact with the aluminum inside the crimp. Squeezing the crimp also helps to improve the electrical connection.

Leg Moves in One or More Jerks – There is probably an intermittent open or shorted connection. If the leg jerks backward continuously in small increments, remove power immediately or the actuator wire may be damaged. Check the assembly for shorts.

Leg Heats Up, Smokes, and/or Melts Plastic Near Body Screws – A little smoke is typical when the actuator wires are first used, probably as oils or oxide on the nitinol wire burn away. But if you see a lot of smoke (equivalent to a cigarette left on the edge of an ashtray), or if you smell something "hot" like burning or melting plastic then remove power immediately or the actuator wire may be damaged. There may be a short in the wiring. You may be powering a slack actuator for longer than one second: a slack actuator will not work. Continuing to apply power to the leg will only cause the nitinol actuator wire to overheat, damaging the wire and heating the body crimp enough to melt the plastic body.

Leg Works OK for Awhile, Then Movement Stops Altogether – The actuator wire has developed slack, a connection has broken, or the batteries are dead. If the actuator wire is slack, it may need to be re-tensioned. Try fresh 1.5-volt cells.

Leg Works OK for Awhile, Then Movement Diminishes by 2 millimeters or More – The actuator is probably somewhat loose, but is taut enough to take up the slack, then move the leg. Another cause is increased resistance as the crimps age. Apply power to the leg, squeeze the leg crimps to improve the electrical connection, and/or turn the body screws.

Actuator Wire Breaks – If the actuator wire breaks during assembly then it was sanded too much, or nicked (probably while removing the knot from a music wire leg). Actuator wires may also break from these causes during operation. Do not power a single actuator wire with a 9-volt cell: the wire will contract so rapidly that it cannot overcome the inertia of the leg, causing the actuator wire to snap.

The Future of Your Stiquito Robot

Now that you have finished building your Stiquito Controlled robot, and it works, you can think about what else you want Stiquito to do. Do you want to make it walk faster? Then you can build a two degrees-of-freedom robot. Do you want it to sense its environment? Then you should add sensors to the front of the robot in the prototype area. Refer to the remaining chapters for ideas on how to expand your new creation. Remember, you can always buy more kits and make more robots!

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