Assembly and operation instructions.

Disclaimer: You take this under your own risk, as your solely responsibility, and I make no guarantees that you will not get burned by your lack of soldering skills or get entangled with the fishing line, or some other weird accident while following this manual.

Having said that, and assuming you have successfully printed all parts and have gathered all required materials and tools, *(see pic 1)* and have familiarized to what goes where, and check for proper fitting, and check for length and color of wires needed, let's begin.

1.- Fully charge the battery.

2.- Get the Arduino IDE (software) at: https://www.arduino.cc/en/Main/Software

If you happen to have female to female jumper wires (https://www.adafruit.com/products/266) it will make your life a whole lot easier.

3.- Upload the *Working* sketch to the *Arduino Micro*.

Connect the *Arduino Micro* via USB to your computer and open the *Arduino Sketch (Working sketch),* and click *Upload*.

Once it says it has finished uploading, you are done.

There are a lot of tutorials on how to do this, you can Google it and it should be very easy for you to do it.

You can now disconnect the *Arduino Micro* from your pc.

4.- Trim the 6 pins on the top of the *Arduino Micro*, we won't use those. *(see pic 2, 3)*

5.- Carefully bend the *Arduino Micro* pins labeled as: **2, 4, 3v, A2, Ground** and **VI**, 90 degrees. *(see pic 4)*

6.- Trim, tin and solder the 2 wires for the *Switch*. Leave enough wire to work, you can trim it later. Use the center one and either one of the other 2. *(see pic 5)*

Note that we need all the (-) negative ground terminals interrupted by the switch. The one that comes from the battery enters the switch, and the 4 others (*LED, Arduino Micro, Myoware Sensor* and *Servo*) come out of it. *(see Wiring Diagram, pic 6)*

Also, positive (+) from the battery, must feed the *Arduino Micro* (VI) and the *Servo*.

7.- Place the *Switch* in its place inside the *Arduino Mount* piece, and secure it by pressing the *Switch Clips* fully, on both sides. Use a little drop of Krazy Glue to hold the *Switch Clips* in place. *(see pic 7)*

8.- Trim, tin and solder some *Jumper Wires* to the *LED* terminals. Trim its legs as needed.

9.- Press the *LED* in its place inside the *Arduino Mount* piece. Use a little drop of Krazy Glue to hold the *LED* in place. *(see pic 8)*

10.- Place the *Arduino Micro* inside the *Arduino Mount* piece, and use a little drop of hot silicone glue to hold it in place. Be careful with the bent pins.

11.- Trim, tin and solder the wire with the (+) leg of the *LED*, to the pin #4 on the *Arduino Micro*.

12.- Trim, tin and solder a white male jumper wire to the pin #2 of the *Arduino Micro*. This is the *signal* to actuate the *Servo*.

13.- Trim, tin and solder 2 red jumper wires to the VI *(voltage input)* pin on the *Arduino Micro*.

14.- Using a drop of Krazy Glue, fuse together one of the (+) on the VI, and the (-) plastic connectors from the *Switch*. These will connect directly to the *Battery*. *(see pic 9)*

15.- Do the same on the white and red wires that will feed the *Servo* with signal and (+) respectively.

16.- Create a 3 pin jumper wire, this time for the *Myoware sensor*. First one should be negative (-), center should be positive (+) and last one should be for *signal*.

Push this 3 pin wire in its place in the *Arduino Mount* piece, and secure it in place with some Krazy Glue. Check orientation and wire length needed. Also, be sure to align the rear part of the black connector with the base, so this 3 pin connector is recessed. *(see pic 10, 11, 12)*

17.- Finish the wiring for the common ground (-) *(see Wiring Diagram)*

18.- Trim, tin and solder the *Myoware Sensor* wires to their respective *Arduino Micro* pins. *(see Wiring Diagram* and *pic 23*)

19.- Arrange the wires in a way that there´s the least slack possible, while allowing 1 or 1.5" play for the *Servo* connector.

20.- Insert the *Battery* in its place inside the *Arduino Mount* piece, and secure it with a small drop of hot glue, on the bottom of it.

21.- Connect the Battery terminal to the negative (-) wire (the one that goes to the switch) and to the positive (+) wire you previously made (VI pin on the *Arduino Micro*)

22.- To protect the wiring and *Arduino Micro* from excessive dust and interference with the *Servo* and *Pulleys*, I used a piece of blue painters tape to cover the whole part. Just make sure you leave some hole for the *Servo* connector. Trim Around as needed. *(see pic 13)*

The *Battery* charging connector may be under the tape. You will need to remove the tape to pull out the connector and charge the *Battery*. I have tested this prototype and my best observation for the *Battery* duration is 2 days, so removing/replacing the tape shouldn't be such a problem.

This is the hardest part, wiring. Phew! Try to make it as nice as possible, following color codes and proper soldering techniques.

You will see that my pics show some ugly parts and several soldering fails, as some wire color mismatch, like using grey wire for the common ground (-) instead of black, but I was in a hurry to finish this and be able to enter it on the Challenge. Also I ran out of proper jumper wires. So, there´s that.

Now the *Servo* and *Pulley* wiring. Even when this is the longest step, it´s very easy if you know how to make knots.

23.- Loosely assemble the *Tensor* piece, using three 3/8" Chicago screws.

24.- Using the fishing line, wire whatever PTD you have *(in this case, a Flexy-Hand, by Gyrobot)* as in the *Tendons diagram (see pic 14),* using a couple screws to fix the *Spacer* in place so you can properly locate the *Tensor* piece.

Try not to bend the fingers too much as you tighten all the knots. The goal is to reach a natural position, slightly bent for the fingers, while keeping the *Tensor* piece at a constant distance from the PTD, hence the *Spacer* piece.

When you start tightening the final knots, the *Tensor*, should rest firmly against the *Spacer*.

Be patient here, as you will need to follow a precise path for each of the strings. *(see PTD Tendon Path diagram on pic 14)*

I´ve found it easier to start a single filament at the tip of the index finger, and make a knot there.

Then you start going towards the wrist of your PTD, then into the spacer, and you can leave a couple inches slack here.

Next go backwards for the middle finger: start at the spacer, then enter your PTD at the wrist, and work your way up to the tip of the middle finger, where you will make the final knot for this pair of fingers. (not yet)

Remember the slack you left back there? Make that loop into the proper *Chicago bolt* by disassembling the *Tensor,* passing the loop around the Chicago bolt, and reassembling the *Tensor*.

Then you can start tightening the string at the tip of the middle finger.

You need to repeat this for the other two fingers.

Start at the tip of the ring finger, down to the spacer, loop, *Spacer* again, and to the tip of the pinky.

You can do these 4 fingers at the same time, since you will only need to disassemble the *Tensor* once.

Again, these steps are dependent on your specific PTD.

This will allow the index finger to move independently from the middle one, and both, independently from the other three, as well as the ring finger independently from the pinky and both, independently from the other three. *(With some restrictions)*

Use a monofilament fishing line to help you with this step, use 40 Lb test if you have it. I used 20 Lb test and it's a struggle since it is too flimsy.

For the thumb, you need to start at the *Tensor*, and finish at the tip of the thumb. Make a knot on the center part of the *Tensor*, and work towards the tip of the thumb, thru the *Spacer*.

When you are done wiring your PTD, you should have some slack on the thumb wire, and around 3/8" between the PTD´s wrist and the *Tensor (remove the Spacer). (see pic 15, 24)* The other 4 finger wires should have some tension. Remember to remove the *Spacer*, it is a sacrificial piece.

In this particular case, using the *Flexy-Hand*, it is better to leave some slack on the thumb line, as it interferes with the other fingers while closing the hand. It all depends on what type of PTD you have and what interference you may encounter while actuating it.

To finish, you need to

25.- Insert the servo in its place and secure it by sliding the Servo Clip over it. *(see pic 16, 17)*

26.- Loosely install the remaining two Chicago screws. Let´s call them A and B. A is closest to the

Servo, and B is closest to the wall of the case. *(see pic 25)*

27.- Using the 80 Lb test fishing filament, tie the top of the servo, in its fully compressed state, thru the A Chicago screw, and to the Tensor, and back to B. And attach the PTD to the case via some screws. *(see pic 18, 24)*

28.- Slide the *Arduino Mount* on the *Servo Mount*, and connect the 3 pin wire from the Arduino, to the 3 pin wire from the Servo. This is tricky, but there´s enough room to do it, just remember to tape any excessive slack. *(see pic 19, 20)*

29.- Slide the locking tab in the form of the *Bolt Socket* part. *(see pic 21)* Include M10 bolt if needed.

30.- You should now have something similar to this. *(see pic 22)*

31.- Put the *Myoware Sensor* inside its holder and secure it with a small drop of hot glue.

32.- Close the *Myoware Sensor* cover on and secure with another drop of hot glue. *(see final product on pic 26)*

Make sure you have a color coded, 3 pin, male-female wire, around 12" in length so it can reach from the middle of the biceps to the appropriate side connector on the *Arduino Mount*.

33.- Snap two electrodes on the *Myoware Sensor* and one on its dangling black reference wire.

34.- Properly locate the *Myoware Sensor* and stick it to a clean, shaven arm, along with its reference electrode.

It is far, far easier to snap the electrodes to the *Myoware Sensor* first, and then sticking it to the skin than doing it backwards, as you can bruise the skin very easily using the force needed to snap them in place.

Also, you don't need to mess with the *Gain* setting on the *Myoware Sensor*. Default setting works great.

35.- Insert the 3 pin wire in the *Myoware Sensor*, and then into the *Arduino Mount*.

36.- Turn on the *Myoware Sensor* using its switch on the side. If it doesn't turn on, check the orientation of the 3 pin connector, and reverse it as needed. Check again, it should now turn on.

The process the *Arduino Sketch* follows is described next:

Every time you turn it on, it starts a *Calibration* procedure.

This is a lapse of time during which the *Arduino Micro* reads the values from the *Myoware Sensor*, getting Maximum and Minimum, several times a second for 10 full seconds.

The start of this *Calibration* procedure is indicated by the rapid blinking of the *LED* on the side of the *Arduino Mount*. The duration of the 10 second period is indicated by the *LED* being on. The finishing of the *Calibration* procedure is indicated by another set of quick blinks of the *LED*.

When the *LED* turns off, the *Calibration* procedure is finished.

During this 10 second period, it is very important that the user should flex and extend the target muscle group several times, and with enough force, to get the proper Maximum and Minimum readings from the *Myoware Sensor*.

You can check this, by opening the *Serial Monitor* on the *Arduino Software*, with the *Arduino Micro* connected via *USB* to the computer. You will see on the *Serial Monitor*, the live readings from the sensor during the *Calibration* procedure.

This *Calibration* procedure assures that every time the electrodes placed on the skin get replaced, (thus, varying its readings) this variation is accounted for and the *Arduino Micro* will act according to the Maximum and Minimum values for that particular location of the electrodes.

From now on, and until the *Switch* is turned off, or the *Battery* runs out, the *Servo* will be actuated whenever the target muscle is flexed beyond a certain percentage of the Maximum reading from the *Myoware Sensor*. You can modify this percentage directly on the *Arduino Software*, inside the *Working Sketch*.

Feel free to do so, but from experience, I can tell you that I have tried a lot of combinations, and the current setting seems to work the best.

I still have a lot of work to do to translate the *Arduino Sketch*, and making it more readable with more comments, but I think it should do for now.

The last pictures (27, 28 and 29) show how you can vertically offset the case with the added 3dprinted pieces *(Length Adapter* and *Adapter Plate)* and the M10 bolt.

Also shown in those pictures is the fact that I mounted the *Flexy-Hand* upside down. (oops!) The rails for the *Length Adapter* piece should be on the top side of the case.

For future revisions, I plan on adding inductive charging and Bluetooth communication between the Arduino Micro and the pc, so you can upload new code to it and never need to disassembly the enclosure.