

3. Assembly

Tip: before you start, put all plexiglass parts of 3 and 5 mm thick that you can see on the picture below together on a flat surface. This way, you will be able to identify them more easily.

IMPORTANT NOTE: Before you start the assembly, please take into account not to tighten the screws which are in contact with the plexiglass parts too hard.

ALSO: ALL PLEXIGLASS PARTS ARE COVERED BY A TRANSPARENT PROTECTIVE FILM, THAT MUST BE REMOVED BEFORE ASSEMBLY.

A. Base, shoulder & arm

Take the 5 mm plexiglass base, as shown on the picture.

Then fasten the **roller bearing coupling** onto it, using 4 **M4x10 half rounded hexagon head bolts (TBEI)**, 4 **M4 toothed washers**, and 4 **M4 nuts**.

Place the **servo HUB** , which is supplied with the servo, in the center of the base. *Make sure the holes of the hub are perfect in center with the mounting holes of the base. If not, twist it carefully to the perfect position* and fasten it temporarily by using 4 **2.5x12 self-tapping screws** and 4 **3x6 flat washer** (do not fully tighten the screws to allow correct alignment of the HUB with the rotation servo pin that will be mounted later on).

Take the **right shoulder** (made of 5 mm plexiglass) and fasten the **shoulder servo** onto it, with 4 **M4x14 black hexagon socket head bolts (TCEI)** and 4 **M4 self-locking nuts** . Exactly as shown in the following images. Then insert the cable into the indicated slot (check the 2nd picture).

After that, mount the wrist servo on the **opposite shoulder** (shoulder SX) as shown in the picture with 4 **spacers in ABS 4x4 mm in between** and fixing it with 4 **M4x18 hexagon socket head bolts (TCEI)** and 4 **M4 self-locking nuts**. Also, in this case you will need to insert the servo cable into the special "SX" shoulder slot.

Join **two "arm 2" elements (in 3 mm plexiglass)** with 4 **M3x8 cross head bolts(TB)** and complete with 4 **3x6 flat washers** , and 2 **hexagonal F / F M3x15 Spacer bus** as shown below.

Take the **arm 1_S** (in 3 mm plexiglass) and fasten it to the servo HUB (included in the servo package) and the distance HUB exactly as shown in the picture. Using 4 **2.5x10 cross-threaded self-tapping screws (TB)** and 4 **3x6 flat washers**.

Fasten 2 **hexagonal metal spacers M3x22** to the arm 1_S as shown in the following image, by using 2 **M3x8 Cross head bolts (TB)** and 2 **3x6 flat washers**.

Now push the arm onto the servo pin as shown in the picture. Make sure that the arm is slightly inclined towards the front of the shoulder. Make sure that the servo is untouched!

Fix the arm by screwing 1 **M3x5 self-tapping screw (TP)** into the servo pin.

Fix the **arm 1_D** (in 3 mm plexiglass) to the two spacers of the arm 1_S using 2 **M3x8 cross head bolts (TB)** and 2 **3x6 flat washers**.

Take lever 1 (in 3 mm plexiglass) and fix the HUB servo onto it with 4 **2.5x10 self-tapping cross screws (TB)** and 4 **3x6 flat washers** as shown below.

Place lever 1 onto the wrist servo as shown in the picture below. Note the orientation of the lever!

Fix lever 1 to the pin with the **M3x5 self-tapping screw (TP)** supplied with the servo.

Insert the connecting rod into the slots on the right shoulder as shown in the picture below. Secure it with an **M3x14 cross head bolt (TB)** and complete it with a **3,5x9 flat washer** and an **M3 nut**. **Do not over tighten the screw, to prevent cracking of the plexiglass!**

Mount the **base rotation servo** onto the shoulder base (in 5 mm plexiglass) as shown in the picture below. Note the orientation of the servo! Attach it by fastening it with 4 **M4x14 rounded hexagon head bolts (TBEI)** and 4 **M4 self-locking nuts**.

Fit the base shoulder into the right shoulder as shown in the following image.

Fix the two elements together with 2 **M3x14 cross head bolts (TB)** , 2 **3,5x9 flat washers** , and 2 **M3 nuts**.

Insert the support piece (in 5 mm plexiglass) into the slots of the shoulder base and fix it with an **M3x16 cross bolt (TB)**, a **3,5x9 flat washer**, and an **M3 nut**. For the moment, do not fully tighten the screw to allow the support to align with the plug that will be mounted later.

Insert the **Ø6x31.6 mm aluminum plug** into the hole in the arm1_D as shown in the following image and make sure that the lever 2 is placed in between the arms and also held into place by the plug.

Attach the left shoulder to the shoulder base as shown below. Make sure to insert the pin correctly in the hole of the lever 1 and the tie in the appropriate slots of the left shoulder.

Fix the left shoulder to the shoulder base with 2 **M3x14 cross head bolts (TB)**, 2 **flat 3,5x9 washers** and 2 **M3 nuts** .

Tighten the fixing bolts securely (without exaggerating).

Fix the connecting rod to the left shoulder with a **M3x14 cross head bolt (TB)**, a **3,5x9 flat washer**, and an **M3 nut** .

Attach the elements of the forearm to those of the arm with a **M3x40 cross head bolt (TB)**, 3 **flat washers 3x7** and a **spacer in ABS 3x15**.

Apply the following in the correct sequence as shown in the picture: a **M3x40 bolt (TB)**, a **3x7 flat washer** , the 3mm plexiglass joint as shown (**note the orientation!**), a **3x7 flat washer** and a **self-locking M3 nut**.

Note! The plexiglass elements that are held together by the bolt must have maximum freedom of movement! Therefore, the nut must be tightened so that only the axial movement of the bolt is prevented.

Fix the tie-rod 1 (oriented as shown) to the right shoulder with an **M3x20 cross-head bolt (TB)** , 3 **flat 3x7 washers** , a **3x4 ABS spacer** and an **M3 locking nut** exactly as shown in the picture . **NOTE! some elements that have already been assembled are hidden to make the sequence easier to understand the image.**

Fix the other side of the tie-rod 1 to the joint with an **M3x12 cross-head bolt (TB)** , 3 **flat 3x7 washers** and a **self-locking M3 nut** as shown in the following image. **Note! In this case it is necessary to tighten the nut just enough to guarantee freedom of movement**

to the plexiglass elements.

Fasten the slender end of the tie-rod 3 to the levers 1 and 2 using a **M3x30 cross-head bolt (TB)**, 2 flat 3,5x9 washers, a **3x12 ABS spacer**, a **3x7 flat washer** and an **M3 self-locking nut**. **Note! Tighten the nut just enough to leave freedom of movement to the plexiglass elements.**

Fix the other end of the tie-rod 3 to the arm elements 2 using an **M3x25 cross bolt (TB)**, 2 **ABS 3x6 spacers** and an **M3 self-locking nut** arranged as shown on the image below. **Note! Tighten the nut just enough to leave freedom of movement to the plexiglass elements.**

Insert the shoulder rotation servo into the prefixed HUB servo at the base, so that the arm is parallel to the sides of the top plate of the roller bearing coupling.

Fix the RH and LH shoulders to the fifth wheel with 4 **M4x12 half rounded hexagon head bolts (TBEI)** and 4 **M4 nuts** as shown in the figure.

Secure the servo pin with the **M3x5 self-tapping screw (TP)** supplied with the servo. At this point, you may fully tighten the 4 2.5x12 self-tapping screws that fixed the **shoulder rotation servo** to the base.

Glue the **4 adhesive feet** near the most external holes of the plexiglass base of the robotic arm.

Place the tie-rod 2 (in 3 mm plexiglass) with the reference hole oriented as shown in the following images.

Now fasten it to the robotic arm by using an **M3x12 cross head bolt (TB)** , 3 **flat 3x7 washers** (positioned as shown in the image below) and a **self-locking M3 nut**.

Note! Tighten the nut just enough to leave some freedom of movement for the plexiglass elements.

Fix 4 **M3x30 hexagonal spacers** to the shoulder base with 4 **M3x8 cross head bolts (TB)**.

Insert the 3 dividing elements as shown below: shoulder valve 1, shoulder valve 2 and the shoulder pump (in 3 mm plexiglass) in the appropriate slots on the shoulder base, oriented exactly as shown in the following figures.

Take the 3 mm plexiglass board support.

If you want to use an **Arduino UNO R3** as control board, insert 4 **hexagonal spacers M / F M3x8 in nylon** in the holes as shown in the following image and fix them with 4 **M3 Nylon nuts**.

If instead you want to use a **Raspberry Pi 3 B + board**, insert 4 **hexagonal nylon spacers** in the holes as shown on the image below. Fix them with 4 **M3 Nylon nuts** .

In both cases, fasten the board support to the **30 mm hexagonal spacers** with 4 **M3x8 cross head bolts (TB)** .

Fix the desired control board to the board support, using 4 **M3x6 cross head bolts (TB)**.

B. Wrist Mount

Place the wrist servo support (in 3 mm plexiglass) in the special slots of the wrist elements (2 pieces in 3 mm plexiglass) as shown in the image below.

Attach the wrist elements with a **M3x35 cross head bolt (TB)** , 2 **3x7 flat washers** , 2 **3x11mm ABS spacers** and a **self-locking M3 nut** . Tighten the nut and screw just enough

to keep the elements locked together.

If you tighten it too hard, it will cause cracks in the plexiglass parts or it might even break!

Attach **the gripper rotation servo** to the servo wrist support (orienting it as shown) using 2 **M2.5x8 cross head bolts (TB)**.

C. Gripper Mount

Fix **the gripper servo** (with the cable oriented towards the reference notch indicated on the image) to the gripper support plate (in 3mm plexiglass) using 2 **M2.5x8 cross head bolts (TB)** .

Fix both **grippers** to the gripper support plate. Important: the gripper parts are not identical! The 'first' part has an extra hole, note the orientation of the parts! The 'first' part is closest to the cable of the servo. Use 2 **M3x12 cross head bolts (TB)**, 4 **flat washers 3x7** and 2 **M3 self-locking nuts**. The two grippers must be mounted closed and in a central position! **The relative bolts must be tightened enough to allow them to move freely without having any influence on the calliper supports** .

Apply a **M3x20 cross head bolt (TB)** , 2 **flat washers 3x7** , the **clip** (in plexiglass from 3mm), a **3x9 ABS spacer** and a **self-locking M3 nut** . Position them exactly as shown in the image below. The bolt/nut tightening must be such as to allow free movement of the caliper lever without having excessive play.

First mount the plastic servo lever onto the plexiglass clip by using the **self-tapping screw 2x6 (TB)** as shown in the picture. Then place the servo lever onto the servo pin **while the gripper jaws are closed!** The screw must leave free movement to the two elements!

Test: Run the Arduino sketch from the previous chapter again, but only connect the gripper servo and change the value to 10 (closed) and 95 (open) to check whether the open/close movement runs smoothly.

If everything works properly, fasten the **mini servo lever** on the relative pin using the special **2x4 self-tapping screw (AF)** supplied with the servo kit.

Mount 3 **hexagonal spacers F / F M3x14** on the crosspiece support pliers with 3 **M3x6 cross head bolts (TB)**. Note the orientation on the picture below.

Fix the double lever supplied with the mini servo to the caliper support (in 3 mm plexiglass) using 2 **2x6 self-tapping cross head screws (TB)** and 2 **3x7 flat washers** (screw the screws into the holes of the double lever, closest to the outer ends of the eyelets).

Position the pin of the **mini gripper rotation servo**, which you have previously mounted on the wrist in the middle of the stroke, in the double lever, so that the latter is in a horizontal position as shown in the following images.

Fix the caliper support to the mini-servo pin using the supplied **2x4 self-tapping screw**.

The clamp can be fixed to the arm in two ways; a **HORIZONTAL** position or a **VERTICAL** position.

For the **HORIZONTAL assembly** : insert the lower end of the caliper support into the slot of the caliper support and the upper end into the slot of the caliper support. Then fix the latter to the 3 M3x14 hexagonal spacers by using 3 **M3x6 cross head bolts (TB)**.

The caliper must be able to rotate 90° on the axis of the mini-servo's pin in a clockwise and

anti-clockwise direction.

VERTICAL assembly : the pliers must be rotated for **180 degrees** compared to the wrist. Then insert the lower end of the pincer support into the slot of the servo pincer support, and the upper end into the slot of the pincer jaws support. Then fasten these 3 parts together with 3 hexagonal spacers M3x14 using 3 **M3x6 cross head bolts (TB)**.

You can also choose to mount the gripper and wrist vertical or horizontal.

D. Mounting the gripper and wrist in the horizontal position

If you have chosen to mount the clamp in a horizontal position, proceed as follows: place the caliper oriented as shown in the figure at the end of the forearm, matching the holes of both parts.

Fix the wrist to the forearm using an **M3x35 cross head bolt (TB)** , 4 **3x6 flat washers** , a **3x15 ABS spacer** and an **M3 self-locking nut** arranged exactly as shown in the following images.

Fix the tie-rod 2 to the wrist with an **M3x40 cross head bolt (TB)** , 2 **3x7 flat washers** , a **3x22 ABS spacer** (*alternatively use 2 3x11 mm spacers*) , a **3x4 ABS spacer** and a **self-locking M3 nut** , arrange the elements exactly as shown in the image.

E. Mounting the wrist and gripper in the vertical position

If you chose to mount the caliper in the vertical position, proceed as follows: position the caliper oriented as shown at the end of the forearm matching the holes of both parts.

Fix the wrist to the forearm by using an **M3x35 cross head bolt (TB)** , 4 **3x7 flat washers** ,

a **3x15 ABS spacer** and an **M3 self-locking nut**, arranged exactly as shown in the following images.

Fix the tie-rod 2 to the wrist by using a **M3x40 cross head bolt (TB)**, 2 **3x6 flat washers**, a **3x22 ABS spacer** (or use 2 **3x11 mm spacers**), a **3x4 ABS spacer** and a **self-locking M3 nut**, arranging the elements exactly as shown in the figure.

The assembly of the mechanical parts of the arm is now finished! Congrats!

All that remains is to stretch the electrical cables of each servo so that they can reach the control board, **without interfering with the moving parts!**

For the mini servos, which are positioned a lot farther from the Arduino, it will be necessary to connect extend the cables with **300 mm M / F extensions**.

Let's discuss all connections in the next chapter!

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