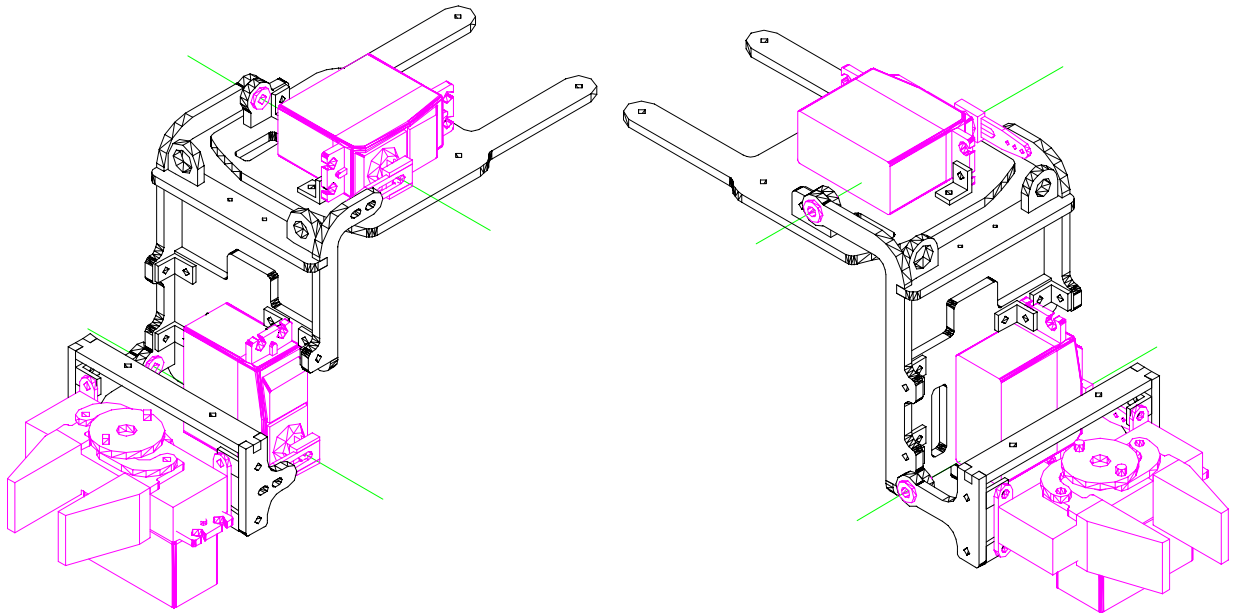




# MEKARM™ PLANAR MANIPULATOR ASSEMBLY MANUAL

by  
Keith L. Doty

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Version 01





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- Low cost,
- Wide availability,
- Open architecture,
- An open, enthusiastic, dynamic community of users sharing information.

Our corporate goal is to help create this new, exciting industry!

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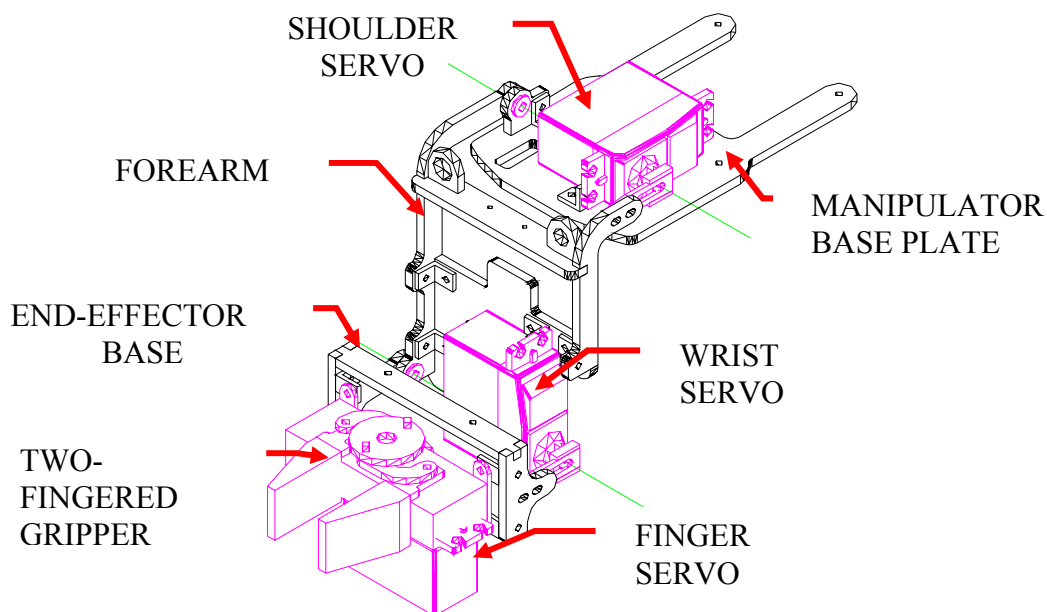
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## 1. DESCRIPTION OF THE MEKARM™ MANIPULATOR

The *MekArm™* manipulator (**Figure 1**) constitutes a two degree-of-freedom (2-DOF) planar robotic arm with an actuated, parallel-finger gripper, all driven by servomotors under control of a robot. The three, independent, servo-driven motions, starting at the base, are called the *shoulder* joint, *wrist* joint and the *fingers*. The green lines projecting out of the shoulder and wrist servos designate the axis of rotation for the joints.

MekArm™ mounts on the TJ Pro™ robot to provide a 4-DOF manipulator with gripper, a total of five degrees of motion. The wheels of the robot provide two degrees of freedom in the plane of motion of the robot. The plane of motion of the forearm and end-effector is perpendicular to the floor and the gripper fingers move parallel with respect to each other.



**Figure 1.** The MekArm™ consists of three principle subassemblies, 1) the manipulator base, 2) the forearm, and 3) the end-effector plate with gripper. The manipulator possesses two rotating, or revolute joints, the shoulder and wrist servos. The gripper servo opens and closes the two fingers in parallel.

The parallel-fingered gripper, or *hand*, detailed in **Figure 2**, illustrates how the servo inserts into the mechanism. Mount the hand with the servo below the fingers. Mekatronix has chosen the servo-below configuration to keep the field of view clear for any sensors mounted on the end-effector cross beam. The servo horn for the shoulder and wrist servos consists of two pieces, a square support plate and a sliding, adjustable tapered link (**Figure 2**). A servo-horn screw holds



the two pieces together and onto the servo output shaft. The tapered end fastens to the shorter of the two forearm/wrist links with two ¼ inch stainless-steel, self-tapping screws.

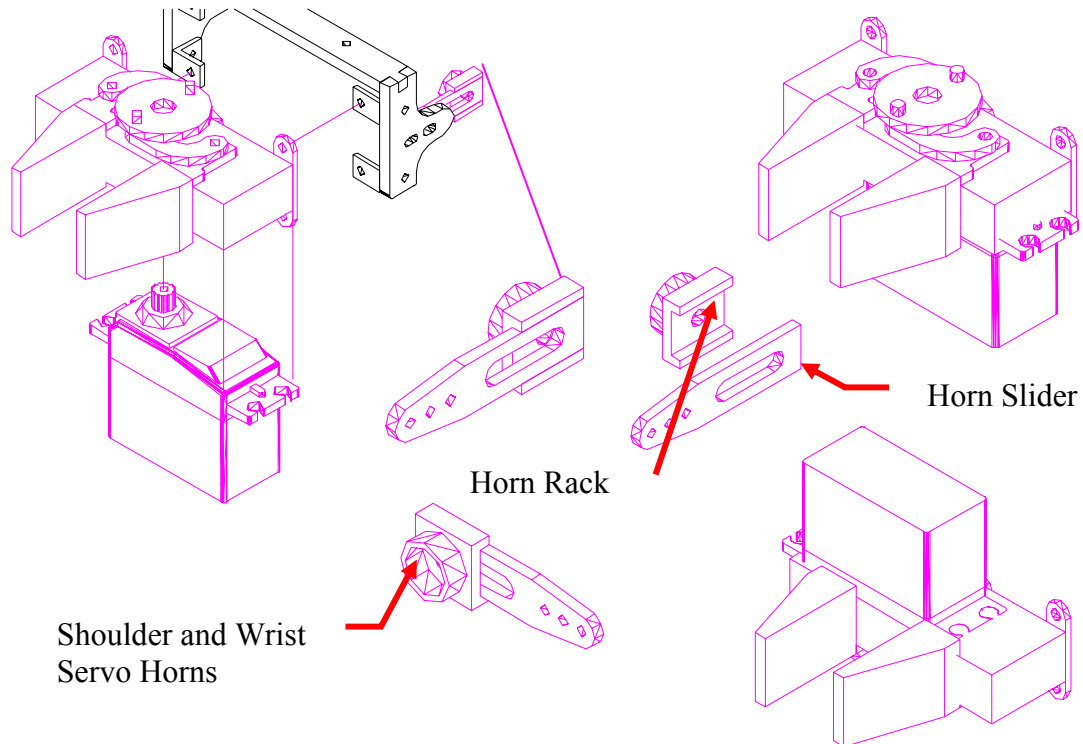


Figure 2. The MekArm™ parallel finger gripper mechanism, illustrated in the upper-right of the diagram, mounts on the end-effector base plate shown in black (upper-left). An MS300 servo, inserted as shown, actuates the fingers. The two drawings on the right show the finger mechanism with the servo inserted. The figure also illustrates the structure of the shoulder and wrist servo horns. In some kits the rack and slider configuration may be replaced with a single-lever-arm horn.

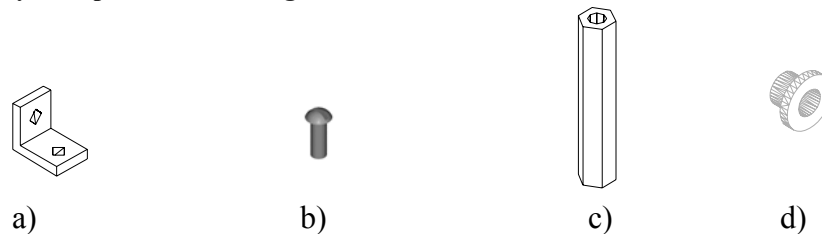


Figure 3. The angle bracket in a) coupled with two 4-40 machine screws (b) fastens the servos, base plates, and different links together on the arm. The 1 inch standoff in c) supports the manipulator base plate (MABP01, Figure 6) on top of the robot base plate. Actually, the 1 inch standoff consists of a ¼ inch and ¾ inch standoff in series. Nylon bushings c) serve as slip bearings for the two joints on the right forearm at the shoulder and wrist.

The metal angle brackets and ¼ inch 4-40 screws (Figure 3) fasten most MekArm™ subassemblies together. Only two parts, the MAFCB02 and the MAEECB03 must be attached



with glue, refer to **Figure 6**. You can also glue the forearm links to the forearm plate for greater strength and stability.

## 2. MEKARM™ DISTRIBUTION SOFTWARE

The MekArm™ distribution software supplies the basic libraries and drivers for the servo mechanism on the arm, a user test program and an application to illustrate how to use the device. Refer to the *MekArm™ Users Manual* for more details.

## 3. APPLICATIONS OF MEKARM™

Mounted on a mobile robot, MekArm™ provides a vital function missing from previous Mekatronix robots, the ability to manipulate objects. This capability propels the TJ Pro™ robot into a higher plane of performance and functionality.

A companion *MekArm™ Education Manual* discusses manipulator characteristics and provides source code for *Coordinated* and *Parallel* motion control. For details and pricing ask a Mekatronix distributor.

While designed specifically for the TJ Pro robot, in the near future, you will be able to attach MekArm™ to other Mekatronix robots, the Talrik II and Robobug. You can also use MekArm™ in stand-alone mode wherein the manipulator mounts on a platform, for example, the MindStamp™, or one of your own design that houses an MTJPRO11 microcontroller.

## 4. MEKARM™ KIT CONTENTS

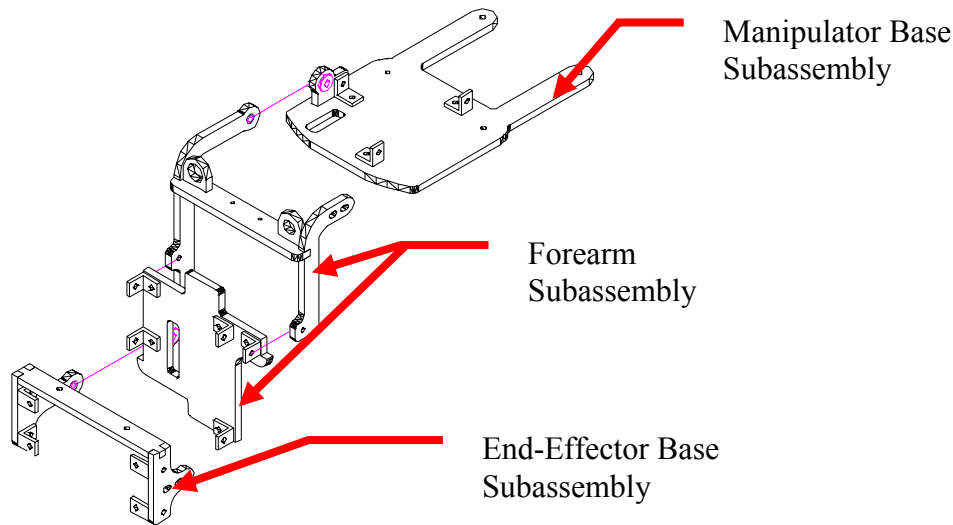
The MekArm™ divides conveniently into three subassemblies (**Figure 4**),

1. Manipulator Base, part numbers with 01 suffix,
2. Forearm, part numbers with 02 suffix,
3. End-effector Base, part numbers with 03 suffix.

Table 1 lists these structural part and **Figure 6** illustrates them.

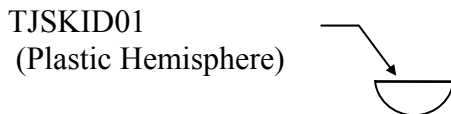
Fasteners for the three subassemblies appear in Table 2 as well as the servo and gripper listings. Two of the servos drive the joints and the third, a two-fingered gripper. The gripper attaches to the end effector base plate. Other end-effectors, future Mekatronix offering or those of your own design, such as scoops and shovels can also be attached to the end-effector base.

You can purchase optional sensors to mount on the MekArm™. Some of these options, listed in Table 3, include IR detection and ranging and light detection. You can also use the eyelets to mount visible LEDs and create headlights.



**Figure 4.** MekArm™'s three principal subassemblies, illustrated above, come in ABS plastic and connect primarily by 4-40 screws and angle brackets, with the exception of the two cross pieces, one on the forearm and the other on the end-effector base, and the forearm mount on the Manipulator Base. The cross pieces provide structural support and a platform for mounting optional sensors.

The weight of the MekArm™, when extended out front, unbalances the robot and tilts it forward. To keep the tilt at a minimum, two plastic skids (Figure 5) can be glued at the intersections of the front cross piece and the two sides of the TJ Pro™ robot.



**Figure 5.** The front skids consist of plastic hemispheres that can be glued to the front of the robot to prevent excessive tilt when the MekArm™ is extended.

Instead of the skids, you may want to attach a small, front caster (not provided) to provide more substantial support.

*Please Note: Because of the robot's light weight, casters often only work like skids anyway and, therefore, do not add any additional capability over skids on smooth surfaces.*



**Table 1 MekArm™ Structural Parts**

Qty	Part #	Description
1	MABP01	Base Plate of the manipulator
1	MAFRM01	Right Forearm Mount
1	MAFLL02	Left Forearm Link
1	MAFRL02	Right Forearm Link
1	MAFCB02	Forearm Cross Beam support and sensor mount
1	MAFP02	Forearm Plate
1	MAEELL03	End-Effector Left Link
1	MAEERL03	End-Effector Right Link
1	MAEECB03	End-Effector Cross Beam support and sensor mount
2	TJCDS20	CDS Photoresistor mount
2	TJIRE20	LED mount, visible or IR
2	TJSKID01	Plastic Skids

**Table 2 MekArm™ Fasteners, Servos and Gripper**

Qty	Part #	Description
12	AB4-40	3/8 inch by 11/32 inch Angle Bracket, 4-40 screw threading
24	MSS25-4-40	1/4 inch 4-40 Slotted/Phillips head, Stainless steel Machine Screw
6	MSS50-4-40	1/2 inch 4-40 Slotted head, Stainless steel Machine Screw
2	HN-4-40	Hex Nut for 4-40 screw
2	LW-4-40	Lock Washer for 4-40 screw
4	WSS25-2	#2 x 1/4" stainless steel, Slotted head Self-tapping screw
2	HAS-300	Adjustable, slider servo horn (solid tapered horn may be substituted)
3	SHS-300	Servo horn screws
3	MS300	Mekatronix Servo 300
1	GF2	2-fingered gripper
4	SAAS75	3/4 inch Anodized Aluminum Standoff
4	SAA25	1/4 inch Anodized Aluminum Standoff
4	NB-6/2	Nylon bushings for shoulder and wrist joints

**Table 3 Optional Parts (Purchased Separately)**

Part #	Description
MIR27E	IR Emitter for MIR58Y40A Detectors
MIR58Y40A	40 kHz <b>Analog</b> IR Sensor
GP2D12	GP2D12 Infrared <b>Analog</b> Rangefinder (Position Sensing Device-PSD)
MCDS01	Photoresistor, Cadmium Sulfide cell
LED-VG/VR	Visible LED, Green (VG) or Red (VR), to place into TJIRE20 eyelet

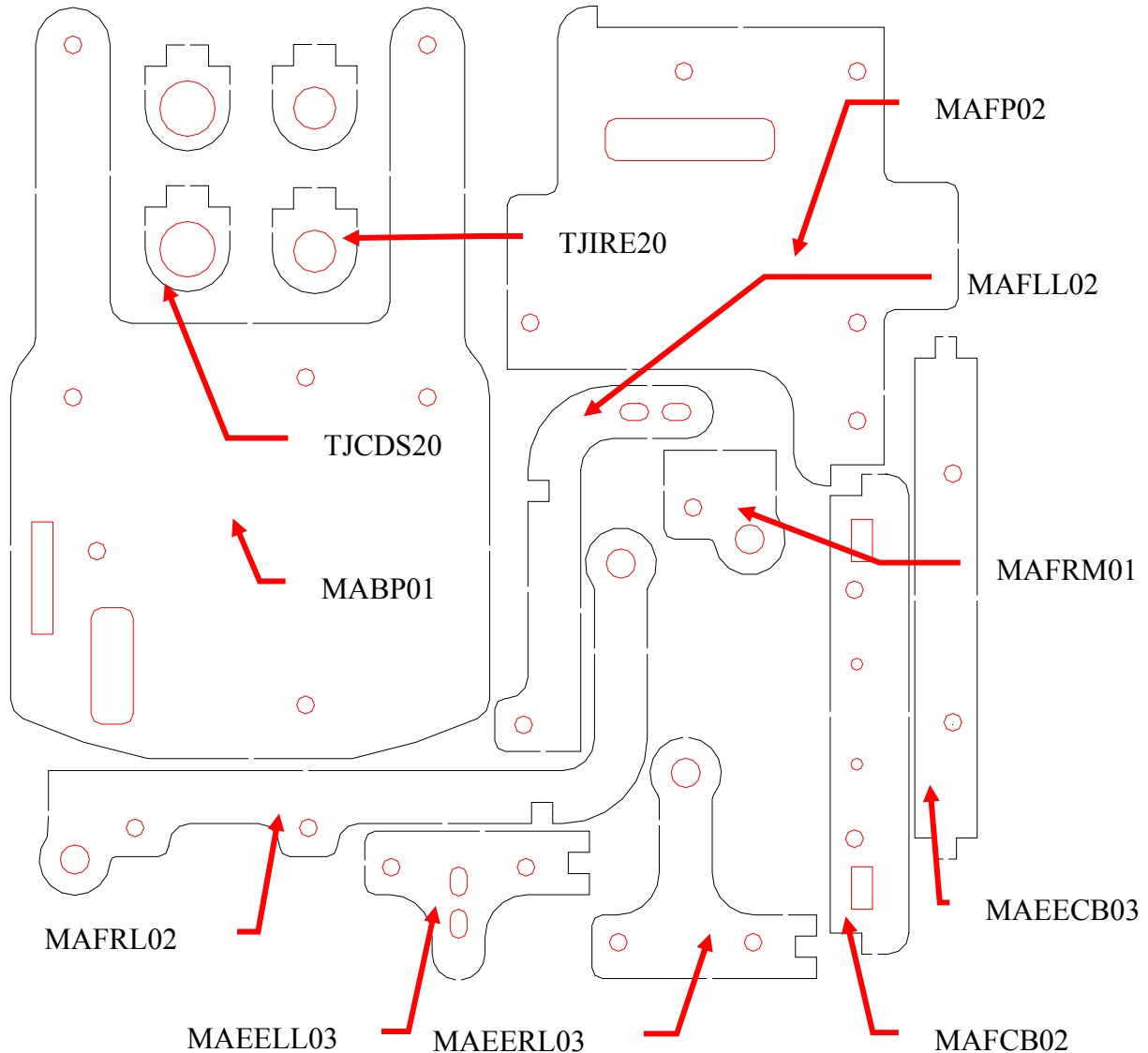


Figure 6. MekArm™ structural parts, illustrated above, come in ABS plastic. The three principal MekArm™ subassemblies, designated by the last two digits of the part name, consist of the Manipulator Base plate assembly (part names ending in 01), the Forearm assembly (parts names ending in 02) and the End-effector Base assembly (part names ending in 03). The TJ IRE20 permits mounting visible and IR LEDs. The TJCDS20 permits mounting a cadmium-sulfide photoresistor cell. The End-effector Base cross beam MAEEB03 allows the mounting of a GP2D12 and the forearm cross beam MAFCB02 supports two eyelets of either or mixed variety and an MIR58Y40A IR sensor. You can also mount a GP2D12 on the MAFCB02, instead of an MIR58Y40A, by using the two 4-40 machine screws holes provided.



## 5. TOOLS

- Small flat-blade screwdriver
- Small Phillips screwdriver
- Knife (sharp, thin blade preferable)
- Small file and/or sandpaper
- Glue –a gel-type superglue.

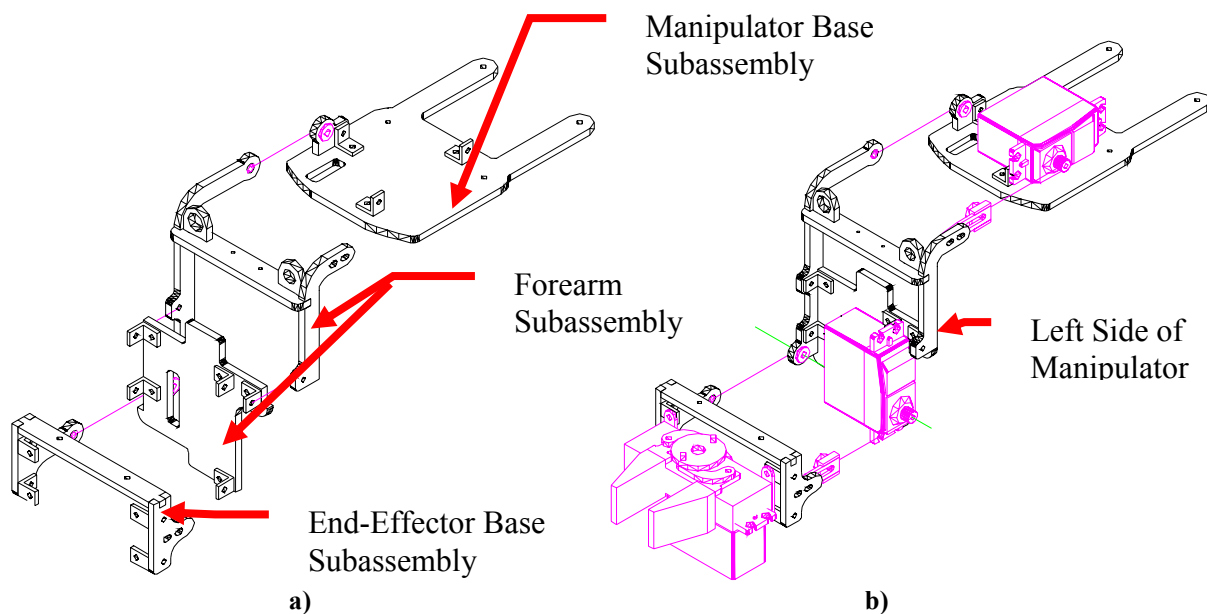
## 6. ASSEMBLY TIPS

- Use the knife to separate the pieces from the plastic sheets. Place backup material (plywood, thick cardboard, etc) to protect underlying table surface from knife blade. Place the knife along the edge of the piece and cut the tabs carefully. This will release the part from the sheet. By placing the knife as close as possible to the edge of the piece, you remove most of the tab from the piece, reducing the amount of time you have to sand or file (a good thing).
- Loosely fit all the angle brackets on a subassembly, square up the pieces joined by the bracket and then tighten.
- Check the fit of the cross beams on the forearm and the end-effector base plate and square up before gluing.
- Adjust the servo horns to square off the following subassembly.

## 7. MECHANICAL ASSEMBLY OF MEKARM™

Constructing the mechanical structure of MekArm™ entails the assembly of three major subassemblies,

1. Manipulator Base, part numbers with 01 suffixes,
2. Forearm, part numbers with 02 suffixes,
3. End-effector Base, part numbers with 03 suffixes.



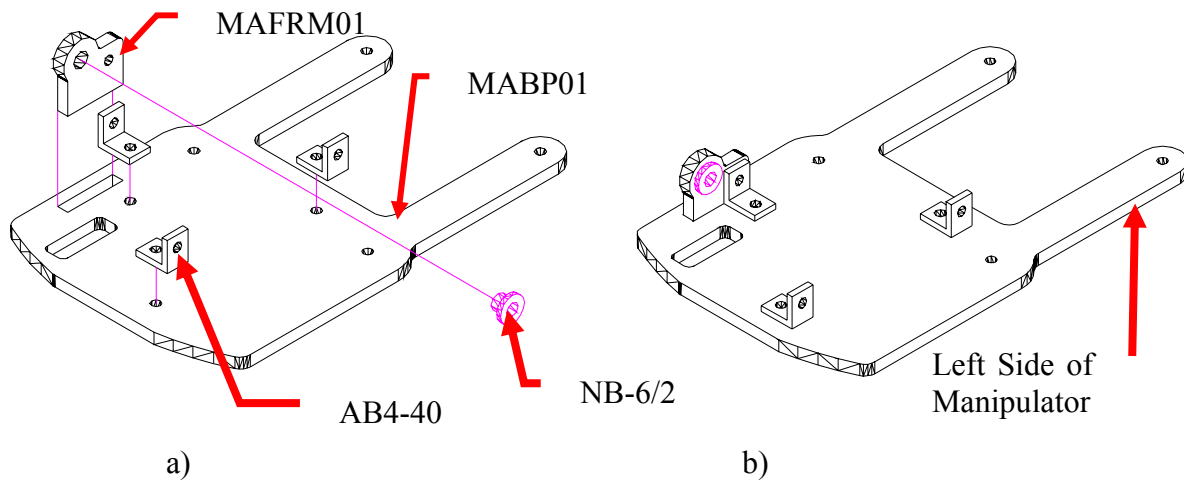
**Figure 7.** Figure a) illustrates the three MekArm subassemblies and b) shows the arm with the servos and gripper mounted. Observe that the shoulder and wrist servos are on the left-side of the arm.

### 7.1 Manipulator Base Assembly

Collect together the parts listed in Table 4.

**Table 4. Hardware for the Manipulator Base Assembly**

Qty	Part #	Description
1	MABP01	Base Plate of the manipulator
1	MAFRM01	Right Forearm Mount
3	AB4-40	3/8 inch by 11/32 inch Angle Bracket, 4-40 screw threading
6	MSS25-4-40	1/4 inch 4-40 Slotted/Phillips head, Stainless steel Machine Screw
1	NB-6/2	Nylon bushings for shoulder joints. Inserts into MAFRM01
1	MS300	Mekatronix Servo 300



**Figure 8.** The manipulator base assembly a) consists of the manipulator base plate, three angle brackets and the mount for the forearm's right link. A nylon bushing NB-6/2 inserts into the MAFRM01 from the inside. The completed assembly is shown in b).

1. Use three  $\frac{1}{4}$  inch 4-40 screws to loosely mount the three angle brackets AB4-40 on the MABP01. Be sure that the LONG side of each angle bracket is on the horizontal surface of the plate and that the brackets face in the direction shown. The screws come up through the bottom of the plate and into the bracket.
2. Insert MAFRM01 into the slot on the RIGHT-side of the MABP01 and fasten to the angle bracket next to it with a  $\frac{1}{4}$  inch 4-40 screw. Be sure the bottom surface of MAFRM01 is flush with the lower surface of the base. Tighten both screws on the angle bracket, keeping the bracket square. For greater strength and stability glue the MAFRM01 as well.

*CAUTION > Be sure the MAFRM01 is on the RIGHT side of the base plate.*

3. Insert the nylon bushing NB-6/2 into the MAFRM01 from the left.
4. Mount the shoulder servo onto the base as shown in Figure 9. Use two  $\frac{1}{4}$  inch 4-40 machine screws to fasten the servo to the two angle brackets. Tighten the base plate screws into the angle brackets as well as the servo mounting screws. Make sure the angle brackets are square as you tighten the screws.

*Note > The servo mounting tabs must be on the outside of the metal angle brackets.*

*Note > Later, you can loosen the servo mounting screws to adjust the servo placement fore and aft, if necessary.*



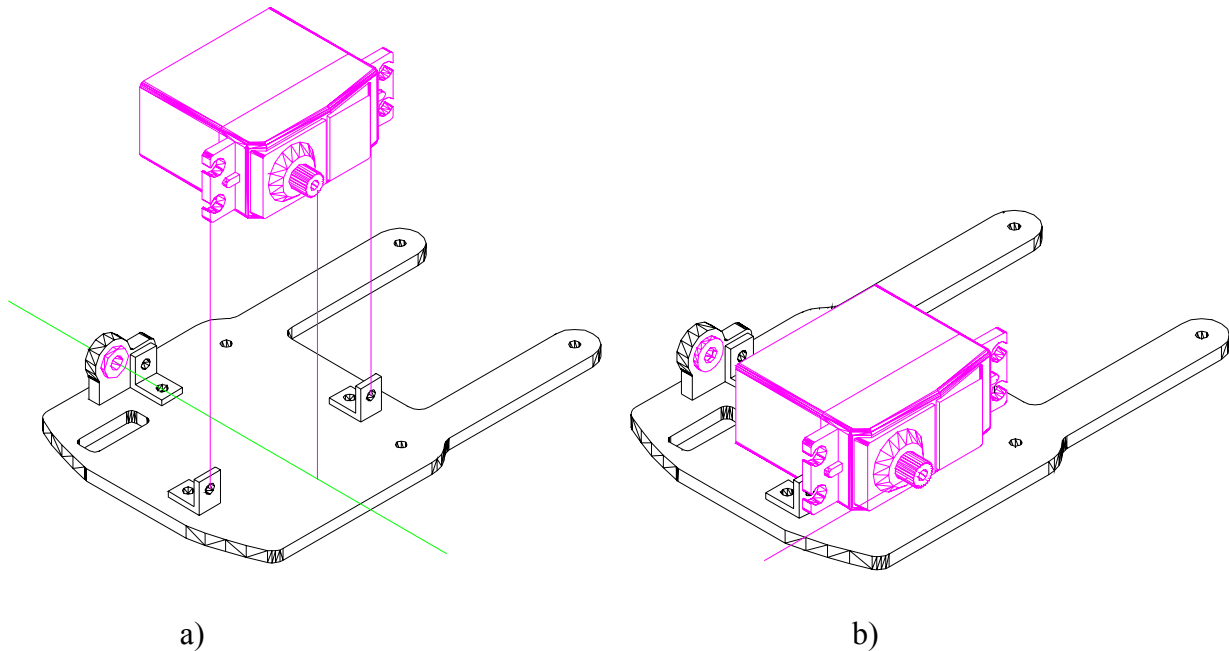


Figure 9 The shoulder servo fastens to the two angle brackets on the manipulator base plate a), resulting in the completed subassembly b).

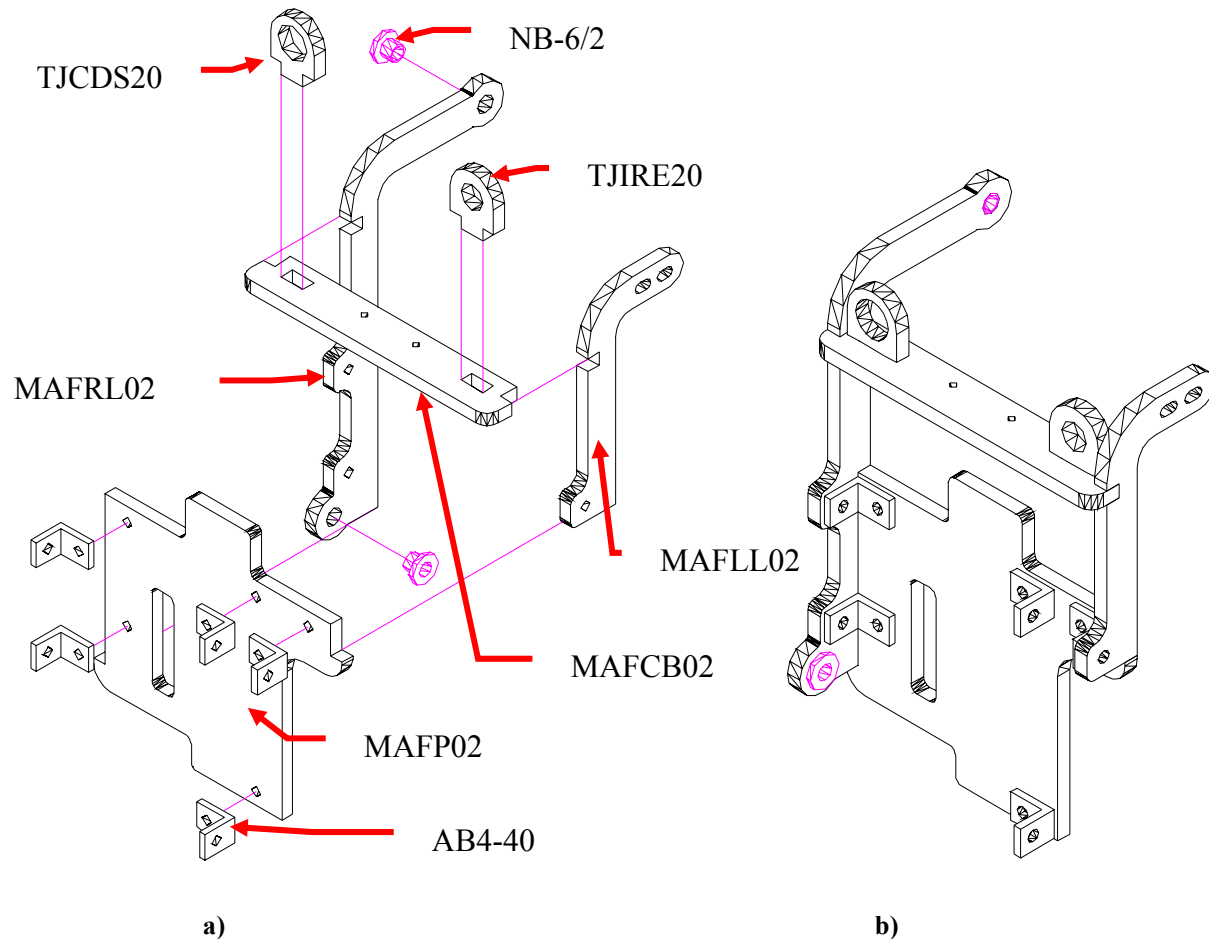
## 7.2 Forearm Subassembly

Collect together the parts listed in Table 5. Refer to **Figure 10** during Forearm assembly.

**Table 5. Hardware for the Forearm Assembly**

Qty	Part #	Description
1	MAFLL02	Left Forearm Link
1	MAFRL02	Right Forearm Link
1	MAFCB02	Forearm Cross Beam support and sensor mount
1	MAFP02	Forearm Plate
5	AB4-40	3/8 inch by 11/32 inch Angle Bracket, 4-40 screw threading
10	MSS25-4-40	1/4 inch 4-40 Slotted/Phillips head, Stainless steel Machine Screw
2	NB-6/2	Nylon bushings for shoulder joints. Inserts into MAFRM01
1 or 2	TJCDS20	CDS Photoresistor mount (Optional)
1 or 2	TJIRE20	LED mount, visible or IR (Optional)
1	MS300	Mekatronix Servo 300

1. Use five 1/4 inch 4-40 screws to loosely mount the five angle brackets AB4-40 on the MAFP02. Be sure that the LONG side of each angle bracket is on the horizontal surface of the plate and that the brackets face in the direction shown. The screws come up through the bottom of the plate and into the bracket.



**Figure 10.** The forearm assembly a) requires gluing the forearm cross piece to the two side links. Insertion, glued or press fit, of the eyelets is optional and depends upon application. The eyelets can be mismatched, as shown, or matched. You can use thin, black construction papers as shims for a press fit of the eyelets. Five angle brackets, long side down, attach to the forearm plate (MAFP02) with  $\frac{1}{4}$  inch, 4-40 stainless steel machine screws (a). This assembled plate b) forms the lower part of the forearm whose side links attach to the brackets and optionally glue to the side. The two interior brackets firmly fix the wrist servo. The completed upper part of the forearm assembly, without the servo, is shown in b).

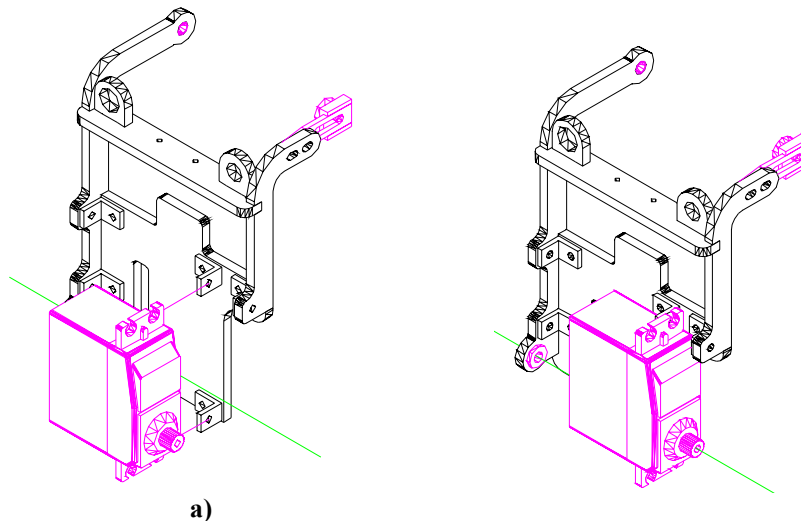
2. Fasten the right forearm link MAFRL02 to the forearm platform MAFP02 using the two angle brackets on the right side of the platform and two  $\frac{1}{4}$  inch 4-40 screws. Square up the angle brackets and tighten all screws on both angle brackets.
3. Mount the wrist servo onto the base as shown in **Figure 11**. Use two  $\frac{1}{4}$  inch 4-40 machine screws to fasten the servo to the two angle brackets near the center line of the MAFP02. Tighten the base plate screws into the angle brackets as well as the servo mounting screws. Make sure the angle brackets are square as you tighten the screws.



*Note > The servo mounting tabs must be on the outside of the metal angle brackets.*

*Note > Later, you can loosen the servo mounting screws to adjust the servo placement fore and aft, if necessary.*

4. With a ¼ inch 4-40 screw, fasten the left forearm link MAFL02 to the forearm platform MAFP02 using the single angle brackets on the left side of the platform. Square up the angle brackets and tighten both screws.
5. *Optional > Glue the left link MAFL02 to the MAFP02 for added stability. If you do this it will be difficult, but not impossible to get access to the aft mounting screw on the wrist servo.*
6. At the shoulder joint of the right forearm link insert a nylon bushing NB-6/2 from the right. On the wrist joint of the right forearm link insert a nylon bushing NB-6/2 from the left.
7. Insert the bracing cross beam MAFCB02 into the slots provided on the right link MAFR02 and the left link MAFL02. **DO NOT GLUE.** Test the configuration of the joined forearm with the manipulator base plate to be sure everything fits and the forearm links square up with each other and the manipulator base plate.



**Figure 11** The completed forearm subassembly of the MekArm™ manipulator includes the wrist servo and the forearm tapered servo horn attached with two ¼ inch #2, stainless steel, self-taping screws to the left forearm link. When you attach the forearm servo horn to the shoulder servo output drive, you can make minor adjustments in its length should that be necessary.

### 7.3 Mounting the Forearm onto the Manipulator Base

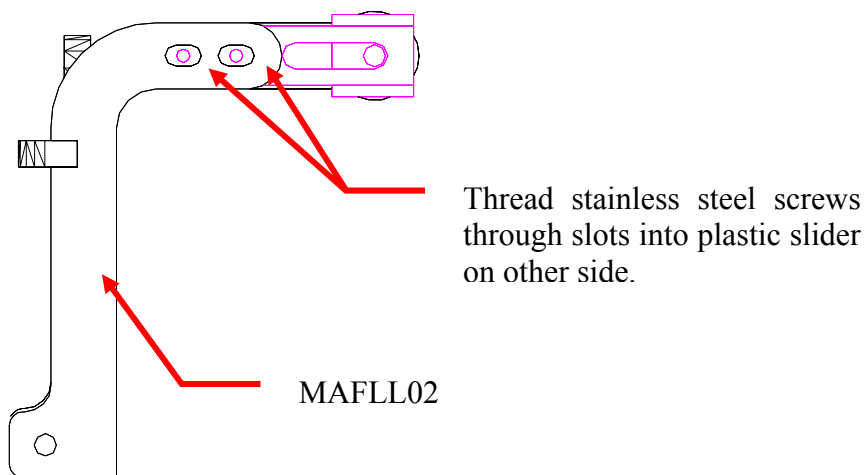
Collect together the parts listed in Table 6. Your objective in this section is to attach the forearm to the manipulator base.

**Table 6. Hardware for the Joining Forearm to Base Assembly**

Qty	Part #	Description
1	HAS-300	Adjustable, slider servo horn (solid tapered horn may be substituted)
2	WSS25-2	#2 x 1/4" stainless steel, Slotted head Self-tapping screw
1	SHS-300	Servo horn screw
1	MSS50-4-40	1/2 inch 4-40 Slotted head, Stainless steel Machine Screw
1	HN-4-40	Hex Nut for 4-40 screw
1	LW-4-40	Lock Washer for 4-40 screw

In this section, you will connect the forearm links to the shoulder servo and link mount. You will complete the construction of the forearm by gluing the cross piece MAFCB02 into place.

1. Mount any unattached servo horn to the shoulder output shaft servo for leverage to turn the shaft by hand, and rotate counter-clockwise (looking down onto the shaft) until the shaft will not turn further. Take the horn off.
2. Attach the shoulder servo horn slider (sliding mechanism of the servo horn HAS-300 in **Figure 2**) to the left forearm link MAFL02 with the two self-taping stainless steel screws WSS25-2 (**Figure 12**). Center the screws in the slotted holes or position them right-most for maximum adjustment on slider.

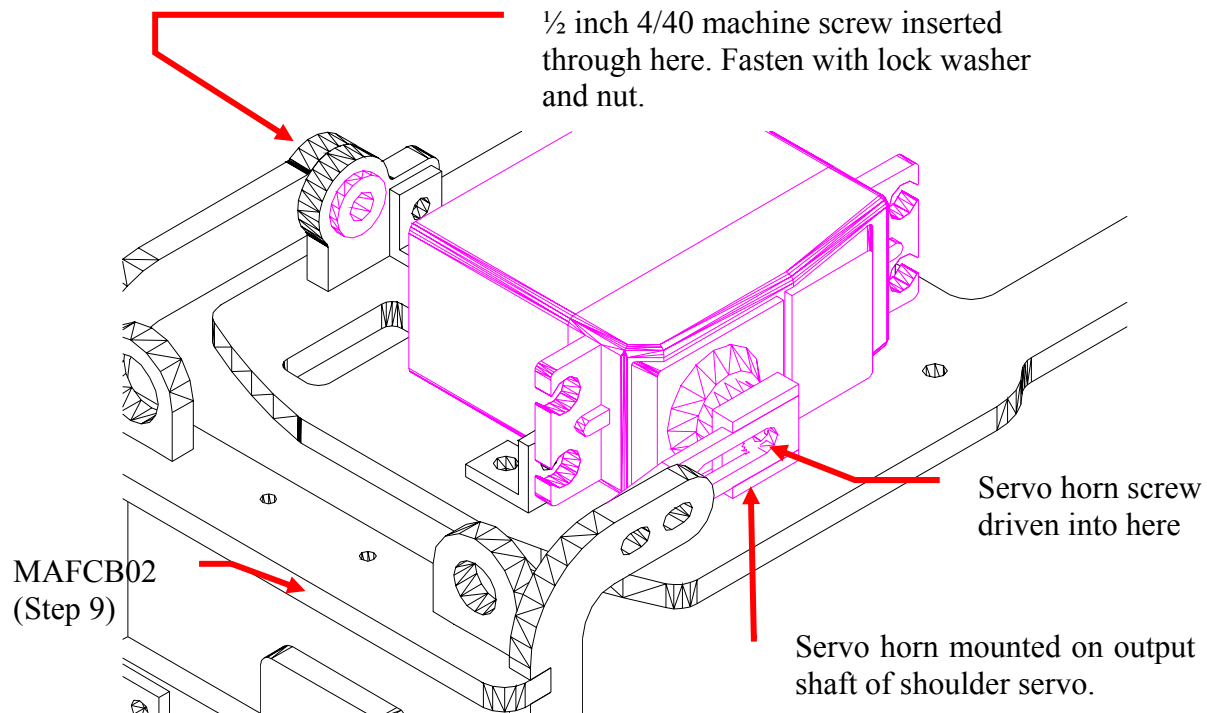


**Figure 12. Attach the slider horn with the screws centered, or as right-most as possible in the slotted holes of the MAFL02 (screws are not shown).**



3. Orient the forearm as shown in **Figure 13**. Mount the servo horn, on the left forearm link, onto the shoulder servo output shaft, all the while aligning the upper right forearm link with the base link mount.
4. Use ½ inch 4-40 screw with lock washer and nut to mate the right forearm shoulder joint with the MAFRM01 on the manipulator base plate (**Figure 13**). The forearm link must be on the outside (to the right) of the link mount MAFRM01. Pass the screw from right-to-left through the link and link-mount so that the lock washer and nut are on the inside of the joint. At the same time place the horn slider into the horn rack of the shoulder servo (you mounted the horn rack in the previous step). Loosely fasten the shoulder joint screw and the servo horn screw SHS-300.

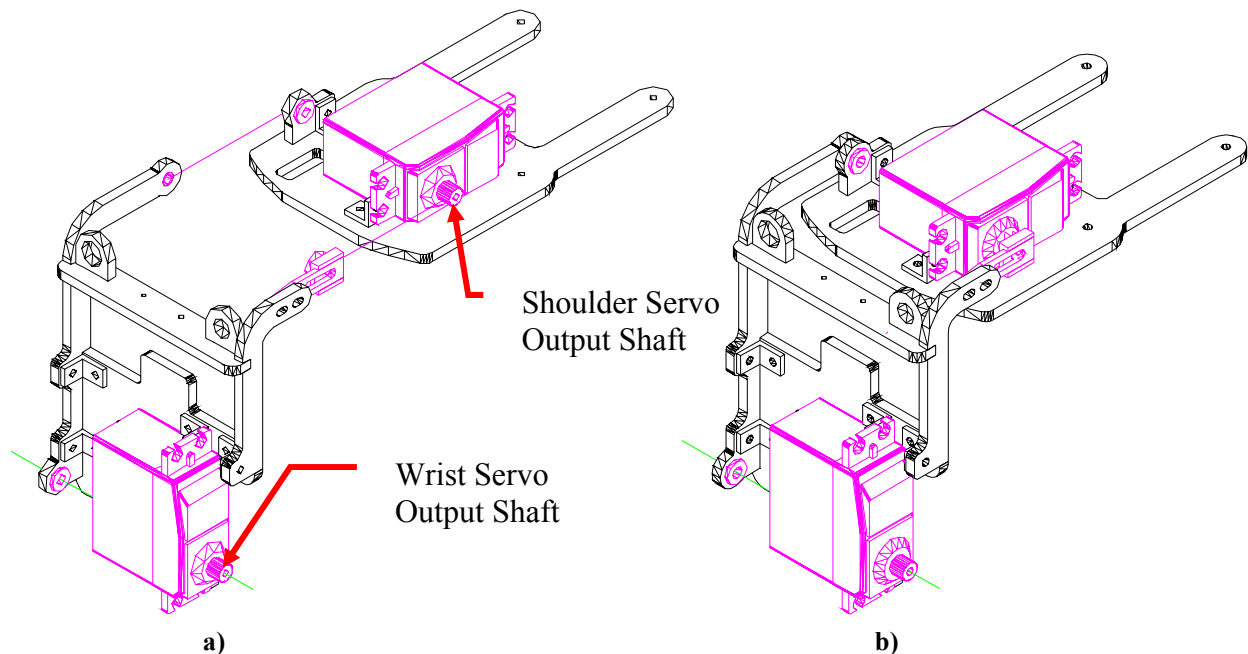
*The forearm should now be loosely connected to the manipulator base.*



**Figure 13. Attach the completed forearm assembly to the manipulator base assembly (screws are not shown)**

5. Make adjustments in the length of the left link, either by moving the slider fore or aft, or the shoulder servo fore or aft, or if this is not enough, loosen the servo slider screws and adjust the left forearm link. Collectively, these adjustments provide enough motion sufficient for squaring out the arm and successfully mating the two subassemblies.

6. While keeping the links and cross piece square and aligned, tighten the servo horn screw and the shoulder mounting screw.
7. Continue to keep the links and cross piece square and aligned. You may need to sand or file the cut-outs at the ends of the cross piece to insure a more precise fit. Glue the MAFCB02 into place. Take extra care here to insure that the side surfaces of the forearm links are perpendicular to the forearm and base plate surfaces (**Figure 14b**).



**Figure 14** The forearm attaches to the manipulator base at two points, the shoulder output shaft and at the link mount on the right side of the shoulder joint.

8. After the glue dries. Move the forearm through 180 degrees, back and forth, to test for smooth operation of the shoulder joint. Make adjustments in the slider horn as necessary to keep the angles square. Adjust tightness of the  $\frac{1}{2}$  inch screw on the link mount MAFRM01 if it binds too much.

#### 7.4 End-Effector Base Assembly

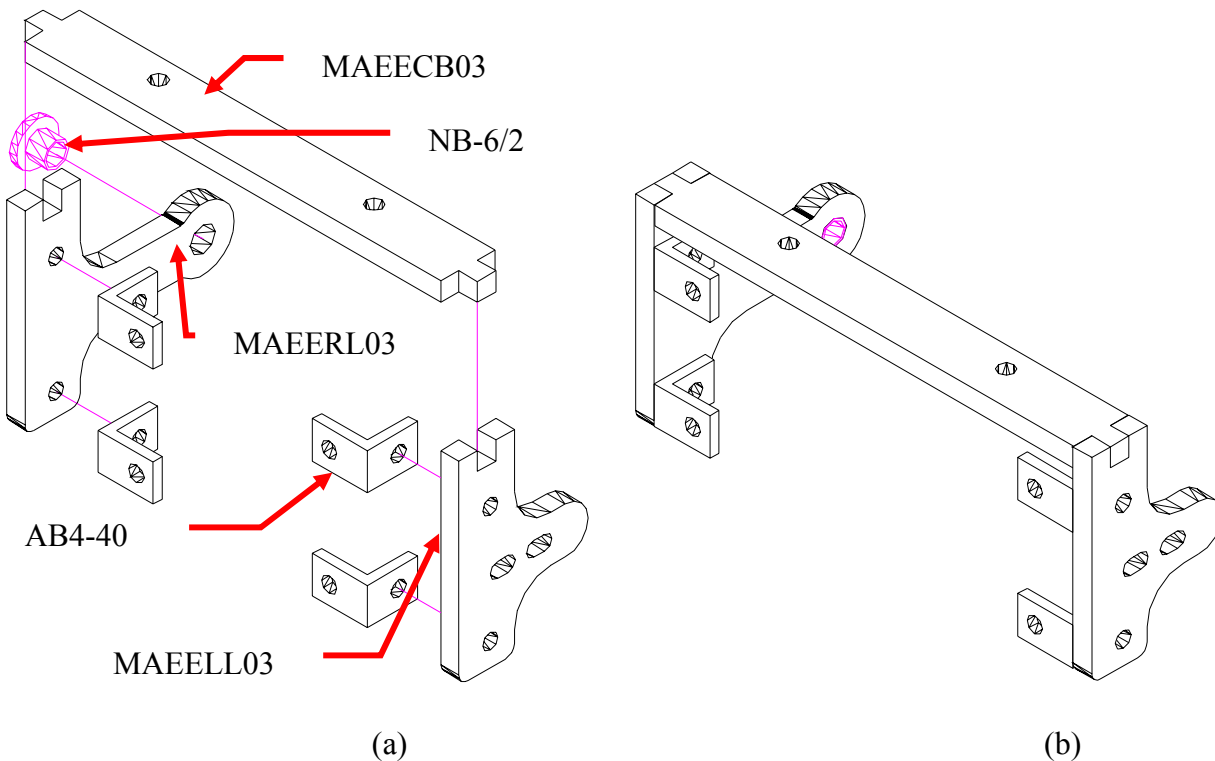
Collect together the parts listed in Table 7 to assemble the end-effector base. Refer to **Figure 15** during assembly. You will also attach the slider to the left-link, the slider that eventually mounts on the output shaft of the wrist servo.



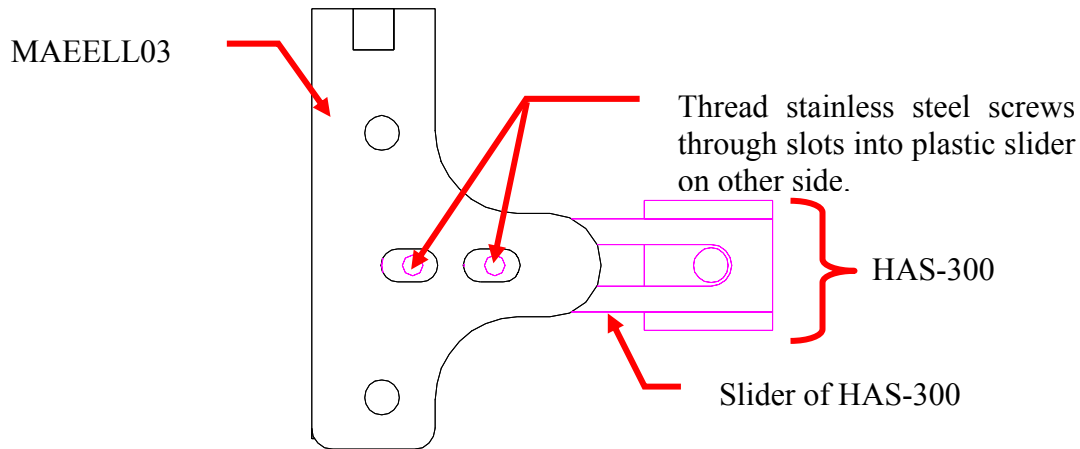
**Table 7. Hardware for the End-Effector Base Assembly**

Qty	Part #	Description
1	MAEELL03	End-Effector Left Link
1	MAEERL03	End-Effector Right Link
1	MAEECB03	End-Effector Cross Beam support and sensor mount
4	AB4-40	3/8 inch by 11/32 inch Angle Bracket, 4-40 screw threading
4	MSS25-4-40	1/4 inch 4-40 Slotted/Phillips head, Stainless steel Machine Screw
1	NB-6/2	Nylon bushings for wrist link. Inserts into MAEERL03.
1	HAS-300	Adjustable, slider servo horn (solid tapered horn may be substituted)
2	WSS25-2	#2 x 1/4" stainless steel, Slotted head Self-tapping screw

1. Screw two angle brackets (AB4-40) each to MAEERL03 and to MAEELL03 with the SHORT(!) side of the brackets on the link surfaces. Orient the angle brackets as shown and do not tighten too tight at this time.



**Figure 15** The end-effector base consists of (a) three structural parts and four angle brackets which are mounted with the long side facing out towards the gripper. An assembled end-effector plate (b) is now ready for mounting an end-effector such as the two-fingered gripper.



**Figure 16. Attach the slider of the servo horn HAS-300 to the left-link MAEELL03.**

2. Attach the wrist servo horn slider (sliding mechanism of the servo horn HAS-300 in **Figure 2**) to the left end-effector link MAEELL03 with the two self-taping stainless steel screws WSS25-2 (**Figure 16**). Center the screws in the slotted holes or position them right-most for maximum adjustment on slider.
3. Insert the nylon bushing NB-6/2 from right-to-left into MAEERL03.
4. Insert the cross piece MAEECB03 for fit, but *DO NOT GLUE* yet.

### 7.5 Assembling and Mounting the Gripper

Collect together the parts listed in Table 8 to assemble the gripper onto the end-effector base. Refer to Figure 17 during assembly.

**Table 8. Hardware for the Gripper Assembly**

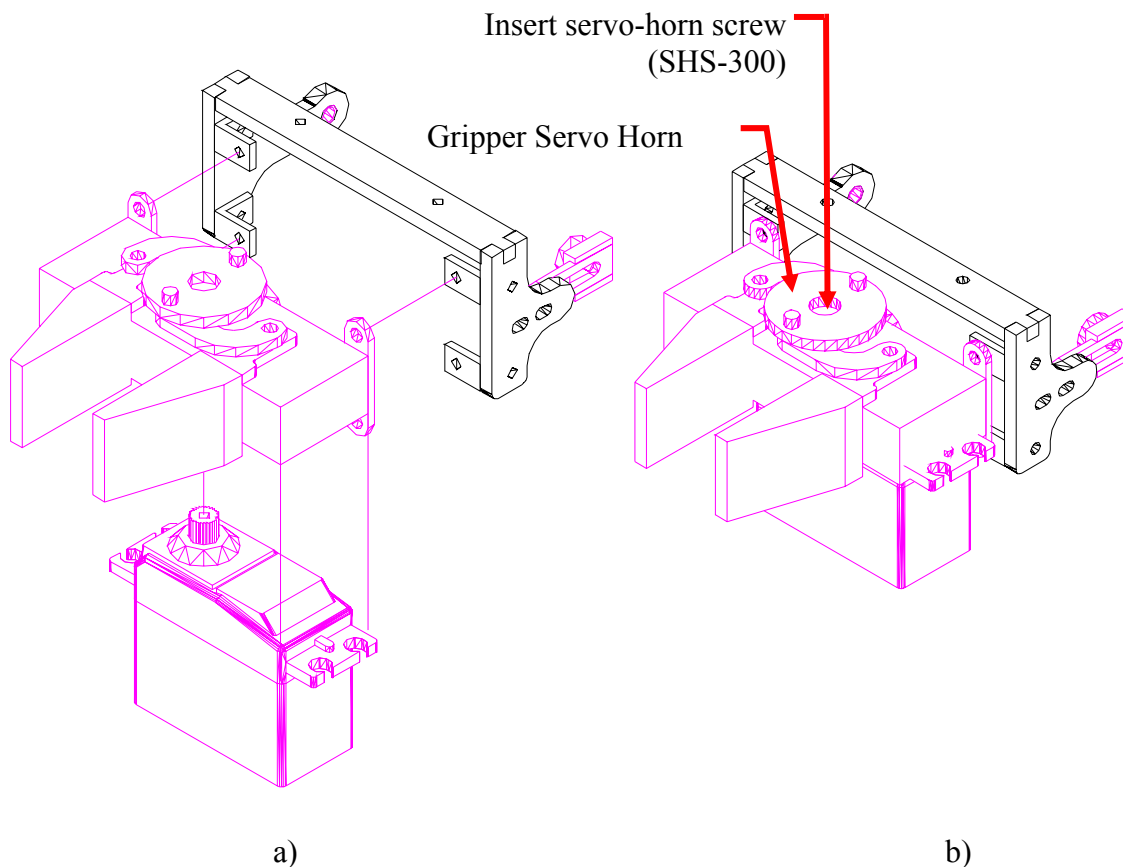
Qty	Part #	Description
1	SHS-300	Servo horn screw
1	MS300	Gripper Servo. Mekatronix Servo 300
1	GF2	2-fingered gripper
4	MSS25-4-40	¼ inch 4-40 Slotted/Phillips head, Stainless steel Machine Screw

1. By hand, rotate the gripper servo horn control mechanism fully clockwise to close the gripper fingers completely.
2. To get leverage, put any unattached servo horn on the gripper servo and, manually, turn the output shaft completely clockwise until it stops. Take the horn off.





3. Attach the Gripper to the four angle brackets with the 4/40 machine screws. Keep the entire configuration square, including the non-glued cross piece MAEECB03, as you tighten all the angle bracket screws.
4. Insert the servo into the gripper as shown in Figure 17. The output shaft of the gripper servo passes through a hole provided and fits securely into the horn mechanism on top of the gripper. Verify the long-side of the servo abuts the left side of the gripper compartment used to hold the servo in place.



**Figure 17** The two-fingered gripper mounts on the four angle brackets of the end-effector base (a). The servo inserts into the gripper and is fastened with a servo horn screw. (b). The resulting configuration in b) constitutes the MekArm's *hand* or *gripper*.

5. Insert the servo horn screw SHS-300 through the gripper servo horn into the servo output shaft and secure.
6. If the MAEECB03 is slightly too long, you may want to sand or file the cut-outs on each end to make it fit more precisely.

7. Glue the MAEECB03 to the MAEERL03 and MAEELL03, keeping the entire gripper configuration square as you do so.
8. Manually work the gripper horn to open and close the fingers to verify the gripper horn and servo have mated properly.

### 7.6 Attaching the Gripper to the Forearm

Collect together the parts listed in Table 9 to attach the gripper to the forearm. Refer to Figure 17 during assembly.

**Table 9. Hardware for Connecting the Gripper and Forearm**

Qty	Part #	Description
1	SHS-300	Servo horn screw
1	MSS50-4-40	½ inch 4-40 Slotted head, Stainless steel Machine Screw
1	HN-4-40	Hex Nut for 4-40 screw
1	LW-4-40	Lock Washer for 4-40 screw

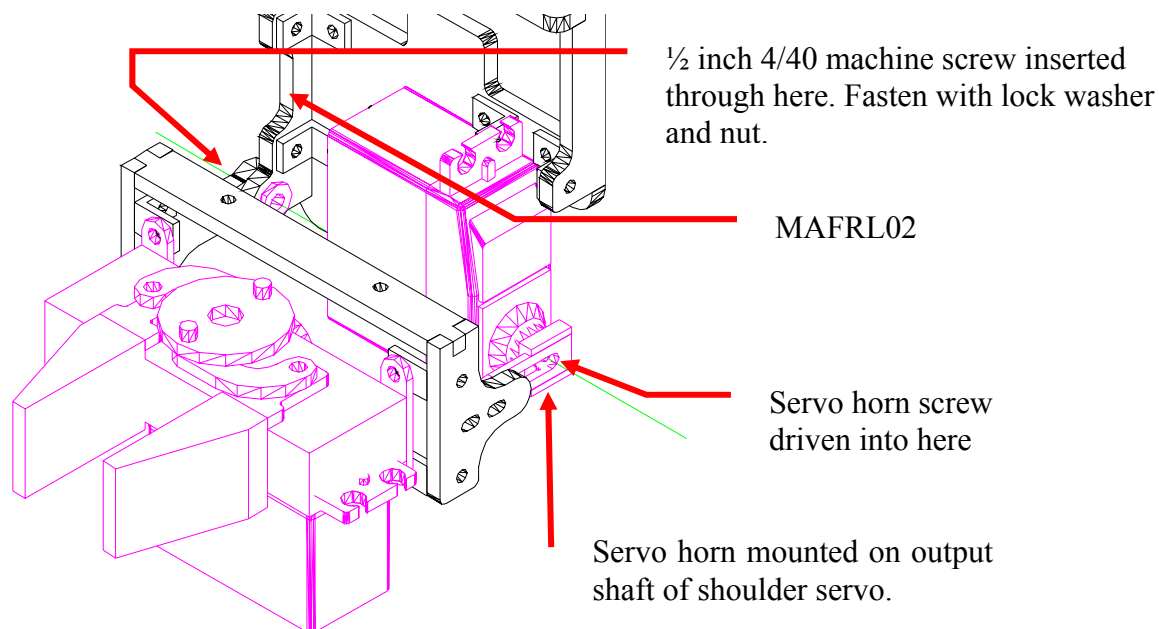


Figure 18. Mount the *hand* or *gripper* onto the forearm as shown.

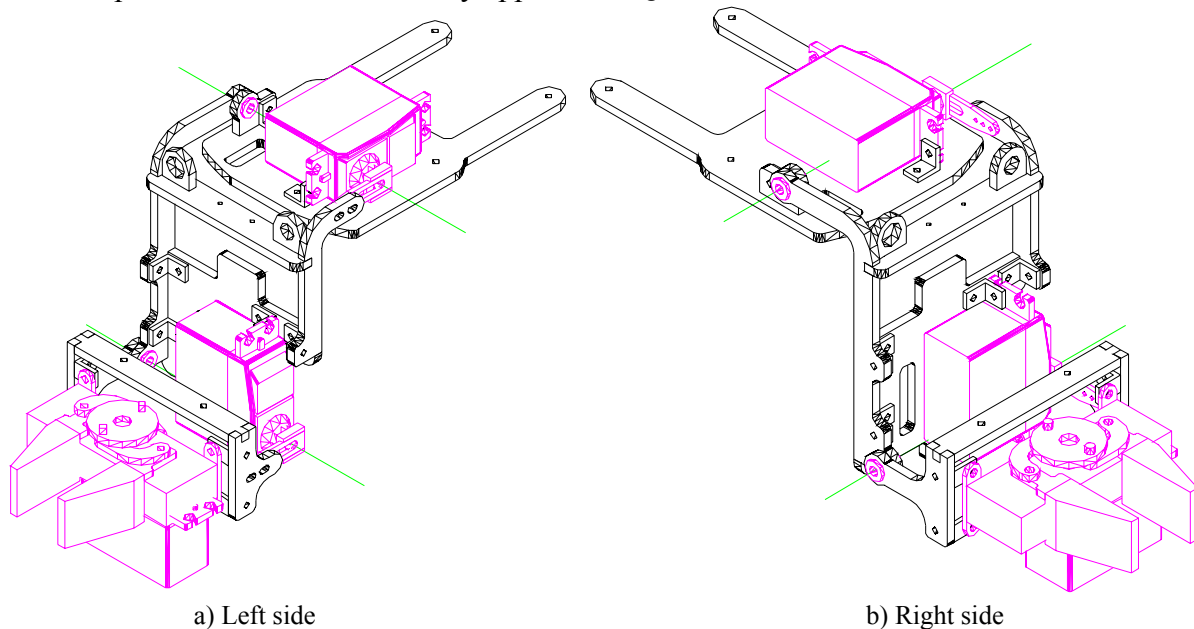
1. Mount any unattached servo horn to the wrist servo output shaft and rotate clockwise (looking down onto the shaft) until the shaft will not turn further. Take the horn off.



2. Orient the *hand* at right angles to the forearm as shown and mount the servo horn onto the wrist servo output shaft, all the while aligning the lower-right forearm link (MAFRL02) with the right end-effector link (MAEERL03).
3. Insert the ½ inch 4-40 machine screw, right-to-left, through the hole in the MAEERL03 and the MAFRL02 and loosely fasten with the lock washer and nut. Call this the right side of the wrist joint.
4. Insert and screw the servo horn screw into the servo horn, attaching the horn to the output shaft. DO NOT TIGHTEN
5. Tighten the ½ inch screw holding the right side of the wrist joint together.
6. Adjust the slider as necessary to make the left link the same length as the fixed right link. When satisfied, tighten the servo horn screw to clamp the slider and fix the link securely.
7. Work the hand 180 degrees, back and forth to check for binding and clearances. Loosen the right wrist joint screw some, if it binds too much.

### 7.7 Completed MekArm™ Assembly

The completed MekArm™ assembly appears in Figure 19.



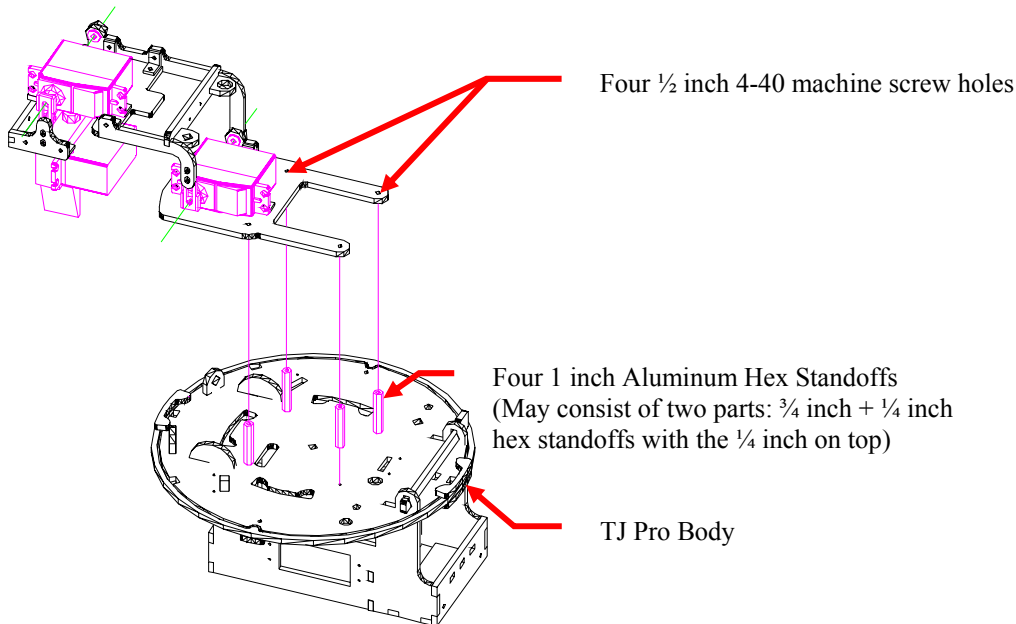
**Figure 19.** This completed MekArm assembly illustrates the Gripper-Forearm and the Forearm-Base couplings.

### 7.8 Mounting MekArm™ onto the TJ Pro Robot™

Collect together the parts listed in Table 10 to attach the MekArm™ to the TJ Pro™ robot. Refer to **Figure 20** during assembly.

**Table 10. Hardware for Mounting the MekArm™ onto the TJ Pro™ Robot**

Qty	Part #	Description
4	SAAS75	¾ inch Anodized Aluminum Standoff
4	SAA25	¼ inch Anodized Aluminum Standoff
4	MSS50-4-40	½ inch 4-40 Slotted head, Stainless steel Machine Screw



**Figure 20.** This figure illustrates how to mount the MekArm on the TJ Pro™ robot.

1. Screw the ¾ inch (1 inch if available) aluminum hex standoffs onto the threads of the printed circuit board mounting screws projecting through the top of the TJ Pro™. There should be enough thread to support the MekArm. If not, tighten the printed-circuit board mounting screws a bit tighter or replace them with 5/8 inch or ¾ inch 4-40 machine screws (not provided).
2. Insert the four 4-40 machine screws through the four holes provided on the top of the MekArm Manipulator Base.
3. If standoffs are not 1 inch, then screw the ¼ inch aluminum hex standoffs onto the ½ inch screws projecting out on the underneath side of the Manipulator Base.

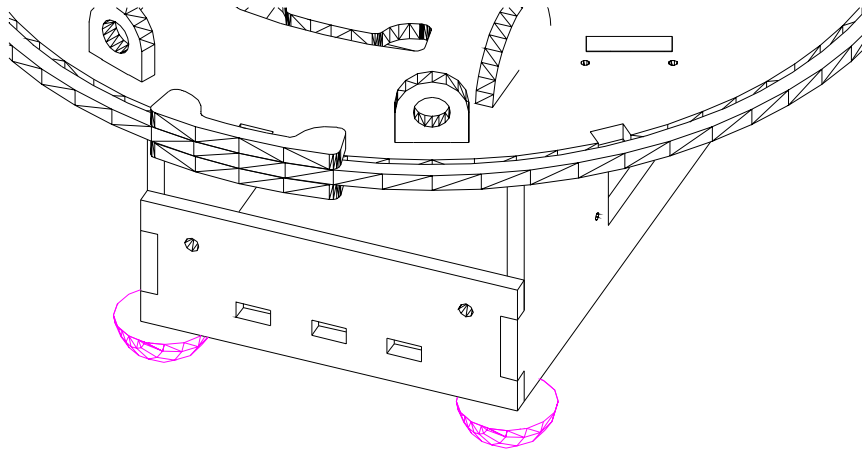


4. Hold the Manipulator Base horizontally and steady and align the four screw protruding through the  $\frac{1}{4}$  inch standoffs (Manipulator Base) with the holes on the four  $\frac{3}{4}$  inch (1 inch) standoffs already mounted on the TJ Pro™ top plate.
5. Gradually tighten the screws going to opposite corners and just a few turns at a time until tightened fully, all the while keeping the manipulator base level.

You have now finished the MekArm mechanical assembly and are ready for connecting it to the MTJPRO11 microcontroller on a TJ Pro™ robot or a MindStamp™ platform or a platform of your own design.

### 7.9 Gluing the Front Skids onto the TJ Pro Robot™

The front plastic skids (TJSKID01, **Figure 4**) should now be glued onto the lower front of the robot. **Figure 21** indicates the placement of the skids.



**Figure 21.** Glue the front skids at the intersections of the sides with the front plate as shown. The skids provide a sliding surface for the front of the robot while it moves on a smooth surface with the MekArm™ extended.



### 8. CONNECTING THE MEKARM™ SERVOS TO THE MTJPRO11 MICROCONTROLLER

Here you will connect the MekArm™ servo cables to the TJ Pro™ robot MTJPRO11 microcontroller.

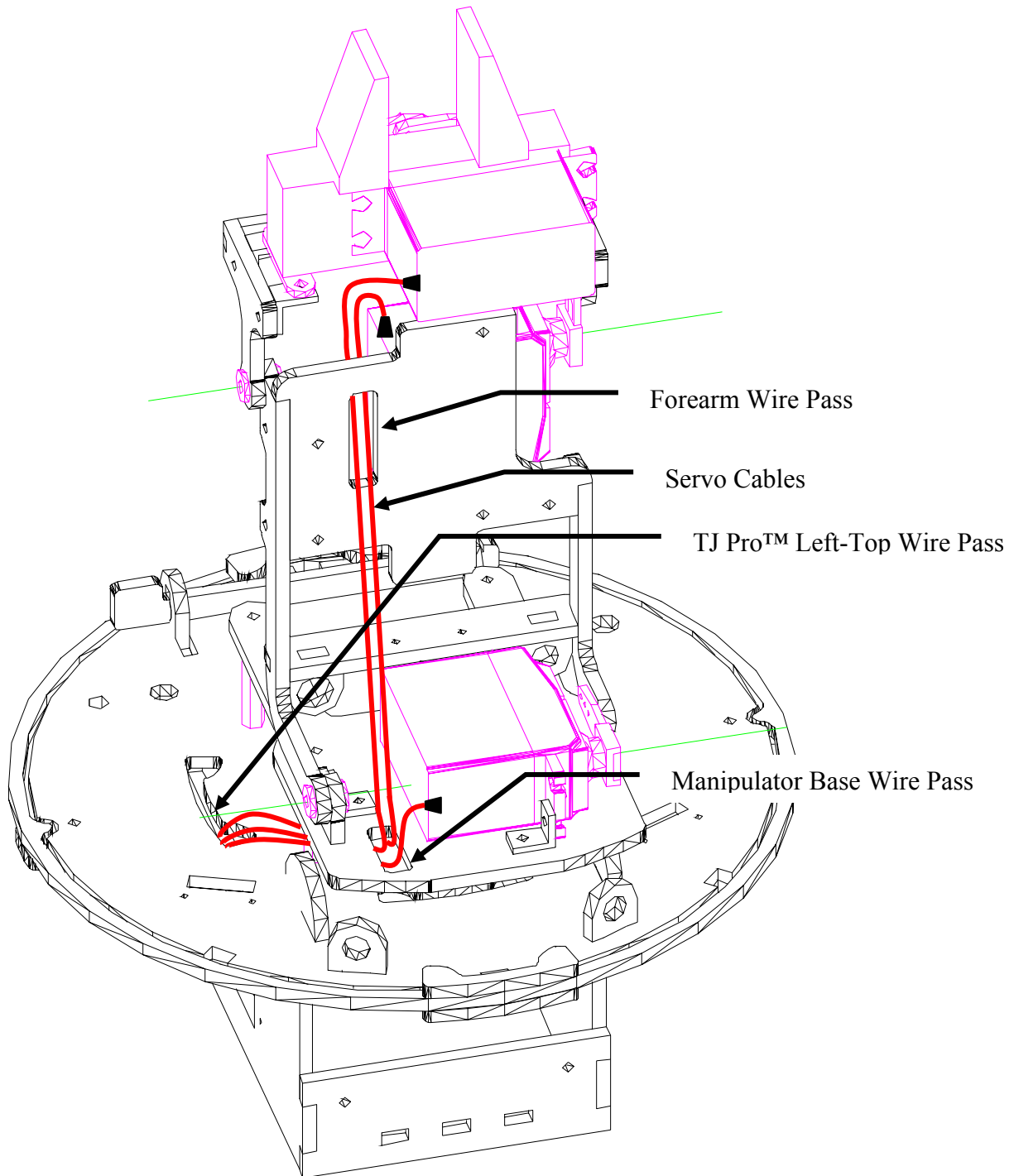
1. Thread the gripper and wrist servo cables through the oblong wire-pass on the right side of the forearm flat plate to the backside of that plate.
2. Continue to thread those two cables and now include a third, the shoulder servo cable, through the top of the oblong wire-pass on the right side of the manipulator base plate.
3. Pass the three cables underneath the manipulator base and pass them through the top of the wire-pass on the right side of the TJ Pro robot's plate and underneath to the MTJPRO11 circuit board.
4. Connect the servos cables to the MTJPRO11 microcontroller male headers as specified in Table 11 and designated in Figure 23. Note that PA6 is just above the LEFT\_WHEEL MOTOR connector on PA7. PA5 is just above PA6 and PA4 is just above PA5.

**Table 11. MTJPRO11 Pin Assignments for MekArm Servo Connectors**

MEKARM™ SERVO	MTJ PRO11 PIN
Shoulder Servo cable connects to	PA4
Wrist Servo cable connects to	PA5
Gripper Servo cable connects to	PA6

5. Manually move the manipulator through its entire range of motion to eliminate any binding of the servo cables. Adjust the slack in the cables so as not to hinder the motion of the manipulator joints.

This completes the servo connections.



**Figure 22. The red lines indicate how to thread the three servo cables through the MekArm™ wire passes.**

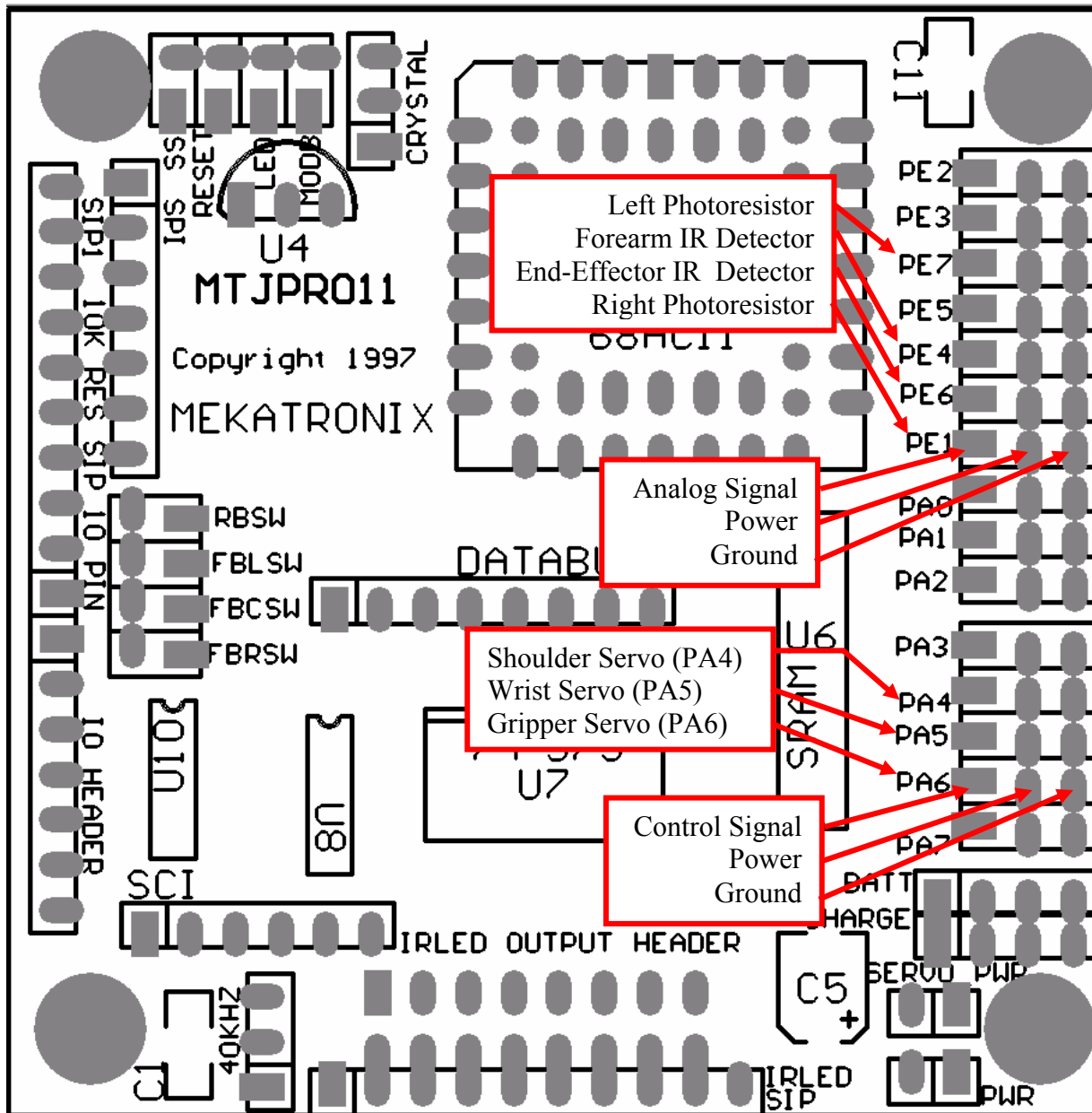


Figure 23. To connect the MekArm servos onto the MTJPRO11 microcontroller requires plugging the three servo female connectors onto the male headers as shown above. The servo cable ground is usually black or brown while the power signal is almost always red. The control signal is typically yellow or orange.





### 9. SENSOR CONNECTIONS (OPTIONAL)

Mekatronix provides several sensor options for the MekArm (Table 12). For IR detection, there are two types of sensors and cables (Figure 24 and Figure 25). The MekArm™ photoresistor cable (Figure 26) is similar to the Argos™ pan-tilt head photoresistor cables. The MekArm™ sensors connect directly to 3-pin male headers (0.1inch pin spacing) on the MTJPRO11 microcontroller. Refer to Figure 23 for the locations of the appropriate 3-pin male headers.

*Refer to a Mekatronix distributor for parts and prices.*

**Table 12. MTJPRO11 Pin Assignments for MekArm Sensor Connectors**

MEKARM™ SENSOR	MTJPRO11 PIN
Left Photoresistor	PE7
Forearm IR Range Detector	PE4
End-Effector IR Range Detector	PE6
Right Photoresistor	PE1

*Note: The sensor assignments for the MekArm™ conflict with those of the Argos™ pan-tilt head.*

Table 13 lists the part numbers for the MekArm™ sensors. You can either make your own cables ( Table 14) for these sensors or order them.

**Table 13. MekArm Sensor Part Numbers and Associated Cables**

MEKARM™ SENSOR	PART #	CABLE DESIGNATION
Left Photoresistor	MCDS01	CPH
Forearm IR Range Detector	GP2D12 or MIR58Y40A	CIRR or CIRD
End-Effector IR Range Detector	GP2D12 or MIR58Y40A	CIRR or CIRD
Right Photoresistor	MCDS01	CPH

**Table 14. MekArm Cable Descriptions**

Cable Name	Cable Type	Color Code and Description
CIRD	F3W3F3	(gray, white, black ) = (signal, 5 volts, ground) = Pin(1,2,3)
CIRR	kF <sub>2</sub> 3W3kF <sub>2</sub> 3 Keyed	(signal, 5 volts, ground) = Pin(1,2,3) 2 mm mechanically keyed female connectors
CPH		
CLED	F2W2F2	(yellow, green) = (anode, cathode)=Pin(3,4) <sup>1</sup> LED cable, visible and IR. (See Section 10 )



When attaching MekArm™ sensor cables, refer to Table 15 and Figure 23.

**Table 15. Cabling the MekArm™ Sensors**

Cable Name	From:	To:	Length:
CIRD	MIR58Y40A	PE4 or PE6 of MTJPRO11™	12 inches (300mm)
CIRR	GP2D12	PE4 or PE6 of MTJPRO11™	12 inches (300mm)
CPH	MCDS01	PE1 or PE7 of MTJPRO11™	12 inches (300mm)

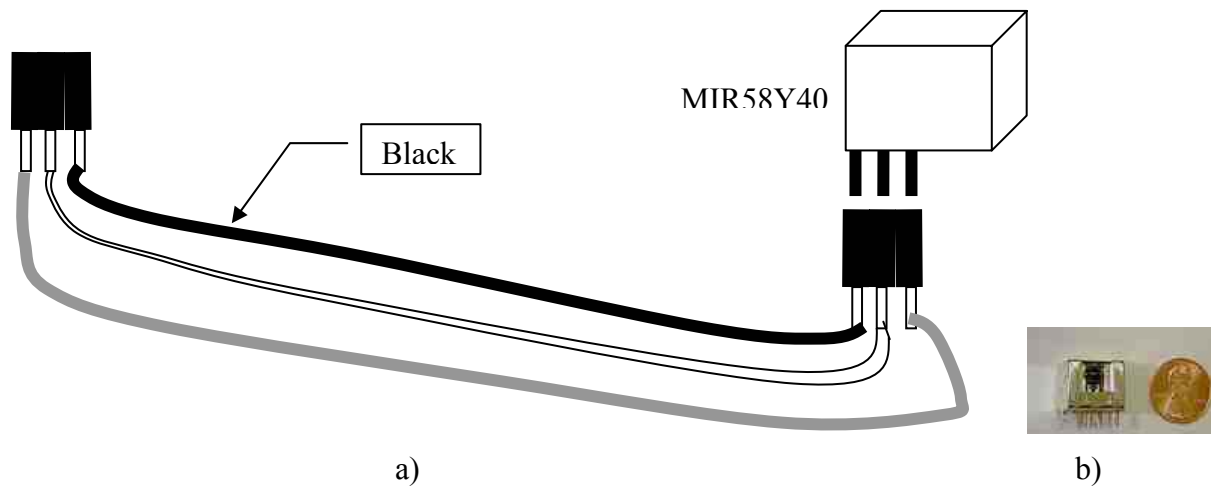


Figure 24. a) Cable CIRD for the IR Detector is terminated at both ends by 0.1 inch pin spacing female connectors. The black wire is ground, the white one power and the gray one is the analog signal coming from the detector. The black wire connects to the outside pin, closest to the side of the cube. b) An MIR58Y40 is compared to the size of a penny.

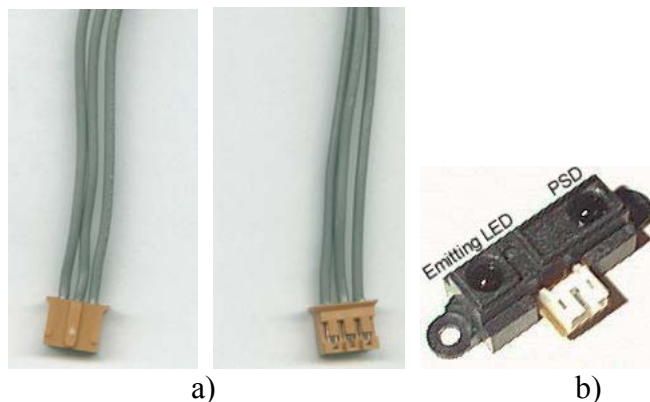
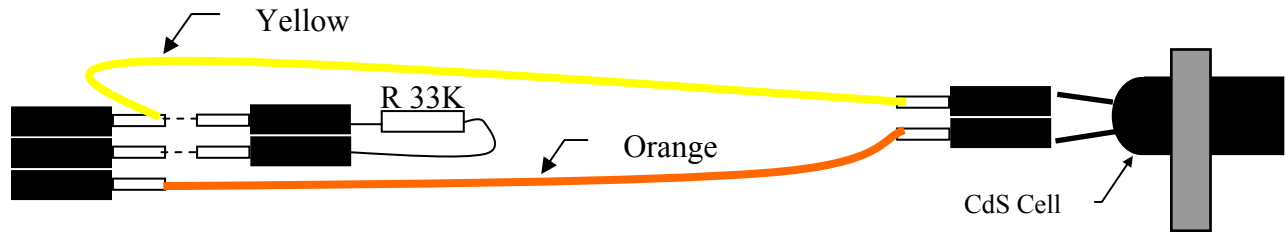


Figure 25. a) The CIRR cable is terminated at one end with a 2 mm, mechanically keyed, female connector. This picture shows both sides of the connector. For the MTJPRO11 microcontroller, the connector at the other end is a 3-pin female with 0.1 inch pin spacing as drawn in the Figure 24. b) The 2 mm connector fits into the white receptacle of the GP2D12.



**Figure 26.** The photoresistor cable CPH requires a voltage divider circuit. This picture illustrates one way to wire it. The 3-pin female connector connects directly to an analog port on the MTJPRO11 (TJ PRO™) robot microcontroller.

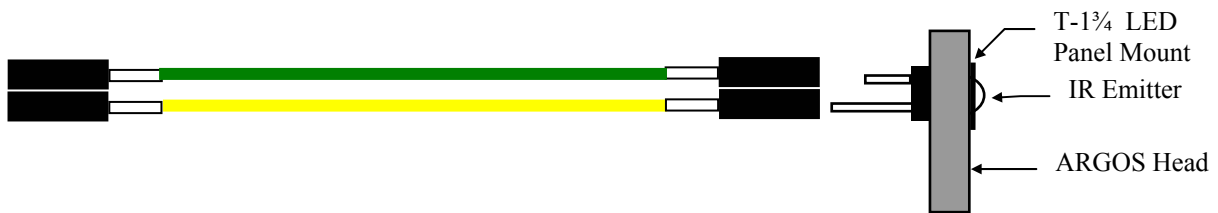
## 10. CONNECTING LEDS (OPTIONAL)

You can mix or match visible and IR (MIR27E) LEDs on your MekArm, which provides two eyelets for mounting them on the forearm crosspiece MAFCB02. Again, refer to a Mekatronix distributor for parts and prices.

Visible and IR LED cables (CLED, Figure 27) attach to the IRLED OUTPUT HEADER at the bottom of the MTJRPO11 circuit board (Figure 23). MekArm uses the same style of LED cable as the TJ Pro™ robot, (yellow, green) = (LED+, LED-). Current through the LED is limited by 330 Ohm series resistor.

**Table 16. Cabeling the MekArm™ LEDs**

Cable Name	From:	To:	Length:
CLED	MIR27E or Visible LED	IRLED OUTPUT HEADER of MTJPRO11™	12 inches (300mm)



**Figure 27.** An IR emitter cable for the TJ PRO™ and TALRIK II™ robots do not require an external resistor. Yellow is the anode and green the cathode of the LED.



## 11. OPERATION OF THE MEKARM™

Once you have assembled, mounted, and connected the MekArm™ to your robot, you are ready to program it.

*Note: The MekArm™ cannot be operated under Interactive C with the MTJPRO11 microcontroller because of a conflict with the usage of pin PA4.*

Mekatronix recommends programming MekArm™ in the C-language, either the freeware version available on the Net, or ICC11, the commercially supported version offered by Mekatronix. You can also program MekArm™ using Assembly Language, but that is much harder to do.

Refer to the *MekArm Users Manual* for more operational details.

Enjoy your MekArm™ (☺)!