Modular Robotic Arm Kit

USER GUIDE v1.1

This guide is only available in English

Ce manuel est seulement disponible en Anglais

RobotShop Inc. www.RobotShop.com

Contents

Introduction

The RobotShop M100RAK “Modular Robotic Arm Kit” is one of the first affordable and versatile intermediate-sized robotic arms on the market. The arm has a maximum reach of just over 24 inches (without the addition of an end effector) and can lift about 500g at maximum extension. The closer the weight is to the body, the more the arm can lift.

Most robotic arms are either too small for regular applications, or too expensive to be used as development platforms by hobbyists. The M100RAK is intended to be the perfect size for most applications since it is roughly the length of a human arm, and still powerful enough to lift a good sized weight.

The kit includes modular joints and several lengths of tuning, allowing you to resize and configure the arm as you wish. The default configuration uses two 8” arms between the shoulder and the elbow, and one 4” tube between the elbow and the wrist. A 90 degree durable metal bracket is included which connects to the wrist joint, to which you are free to design and mount your own end-effector which best suits your needs.

Warning: The arm contains open gears and is very powerful. Please take every precaution to ensure no fingers are snagged, and that no objects (including wires) get caught in the gears. Should you have this fear, we suggest adding a bent cardboard or plastic cover. Keep out of reach of children.

Note that this arm is for hobbyist and research purposes only and is not intended for beginners and anyone under 18 years of age.

Applications

Robotic arm: With the addition of a gripper, a standard robotic arm can be used for many different projects, from doing routing assembly tasks, to playing chess and ever defusing an explosive device.

Camera mount: The basic arm includes a 90 degree metal mounting plate which can, without any modifications, be used to mount a standard sized camera.

CNC machine: Mount a handheld router and create a manual or CNC controlled router arm. Note that we suggest using a flexible shaft extension to minimize the weight at the end of the arm.

Scale Human Arm: The length of the shoulder joint to the elbow joint is almost the same length as an adult's humerus bone, while the length from the elbow to the wrist joint is almost the same as an adult's Ulna. There are two degrees of freedom missing in the arm to make it match that of a human: a rotation joint within the "humerus" and a rotation joint within the "ulna".

Specifications

General

• Four degrees of freedom with 252 degrees of rotation possible at each joint
• Metal power gearbox frame made from 6061-T6 aluminum (anodized)
• Tubing used is 5/8" outer diameter hollow aluminum (6061-T6) with a wall thickness of 0.028"
• Hitec HS-785HB Winch Servo Motor used in each joint
• Servo casing is water and dust tight and features Karbonite gears and ball bearing drive
• 5:1 gears increase torque of each servo motor by a factor of 5
• Dual ABEC-5 Precision ball bearings support each hollow steel shaft.
• Hole pattern uses 5-40 tapped screws
• Operating voltage: 4.8 to 6V (6V suggested for maximum torque).
• Current: 1.5 to 1.8A per motor depending on voltage used.
• Several lengths of tube included for different arm configurations
• Dimensions: variable depending on the configuration.
• Weight: 1.20Kg (not including electronics or gripper/end-effector)

Dimensions

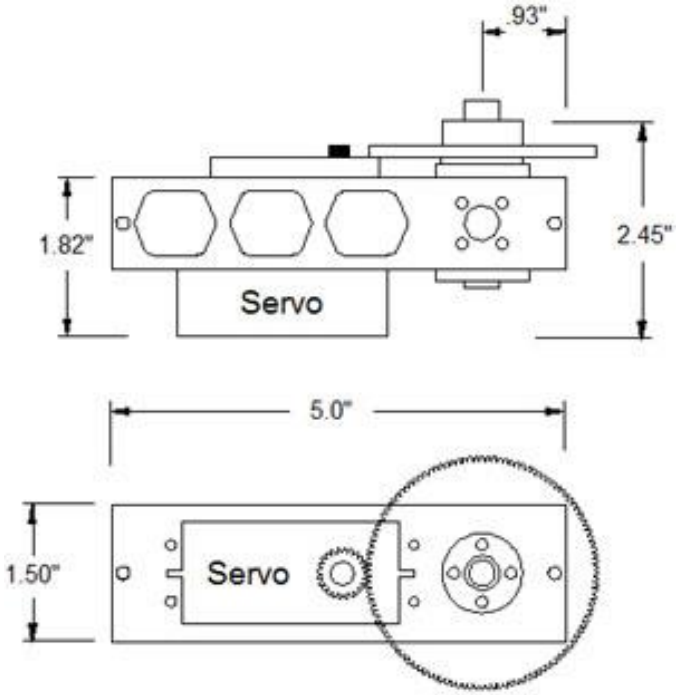
Default configuration:
• Bottom of base to shoulder axis: ~9.5cm (~3.75”)
• Shoulder axis to elbow axis: ~24.4cm (~9.6”)
• Elbow axis to wrist axis: 32.5cm (~12.795”)
• Maximum horizontal reach (base rotate axis to wrist rotate axis): ~60cm (~13.35”)
• Maximum vertical reach: ~69.4cm (~27.32”)
• Weight: 1.2 Kg

For exact dimensions, we suggest measuring your assembled unit as the tube length may vary slightly for each kit.

SPG785A-5.0 Power Gearbox

The SPG785A-5.0 Servo Power Tube Gearbox is built to use a stock HS-785HB servo which, unmodified, can provide 1260 degrees of total rotation (version shown includes optional nylon/metal gears). When the HS-785HB servo is installed into the 5:1 power gearbox, the rotation is decreased by a factor of 5, providing 252 degrees at the final output shaft. Similarly, the power and accuracy is increased by a factor of 5. Position feedback remains since the internal potentiometer is not removed. The SPG785A-5.0 can handle tremendous side loads with the dual ABEC-5 precision ball bearing supported hardened 3/8” stainless steel hollow shaft. The shaft is hollow to allow wires from cameras, sensors or other devices to not tangle during multi-turn rotations. The frame of the SPG785A-4.5 is machined from 6061-T6 aluminum (anodized) and offers a standard hub pattern inline with the output shaft.

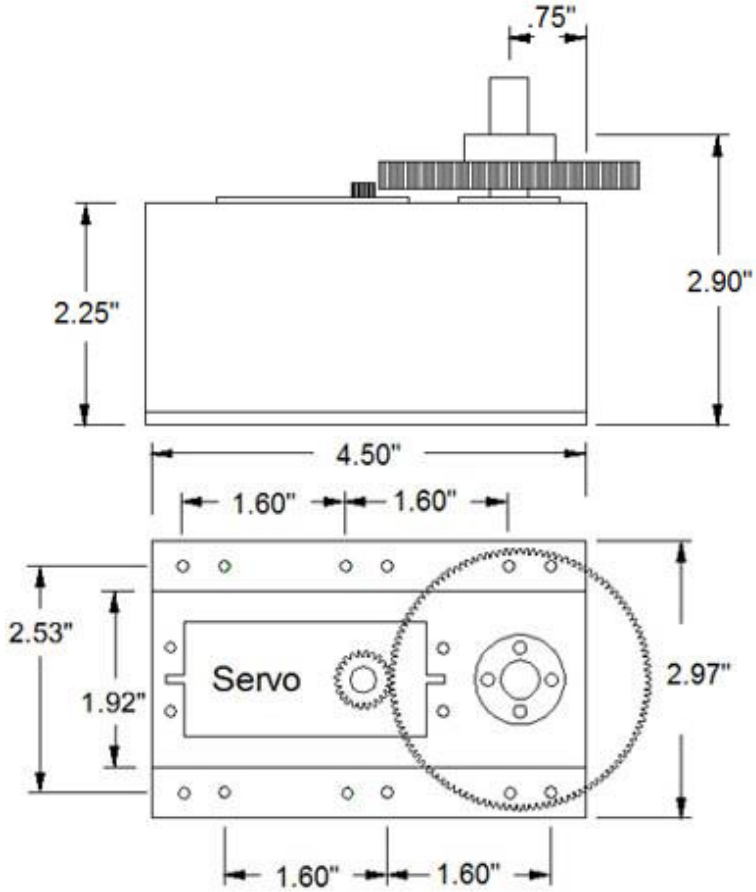
- Weight with servo: 7.1oz
- Rotation: 252 degrees
- 4.8V power: 765 oz-in
- 6.0V power: 915 oz-in
- 4.8V speed: 1.40 sec/60 degrees
- 6.0V speed: 1.15 sec/60 degrees


.93"
1.82"
2.45"
Servo
5.0"
1.50"
Servo

SPG785A-BM Power Gearbox

The SPG785A-BM (Bottom Mount) Servo Power Gearbox is intended to be used with a stock HS-785HB servo which can rotate 1260 degrees total (version shown includes optional metal/metal gears). When the HS-785HB servo is installed into the 5:1 power gearbox, the rotation is decreased by a factor of 5, providing 252 degrees at the final output shaft. Similarly, the power and accuracy is increased by a factor of 5. Position feedback remains since the internal potentiometer is not removed. The SPG785A-5.0 can handle tremendous side loads with the dual ABEC-5 precision ball bearing supported hardened 3/8" stainless steel hollow shaft. The shaft is hollow to allow wires from cameras, sensors or other devices to not tangle during multi-turn rotations. The frame of the SPG785A-4.5 is machined from 6061-T6 aluminum (anodized) and offers a standard hub pattern.

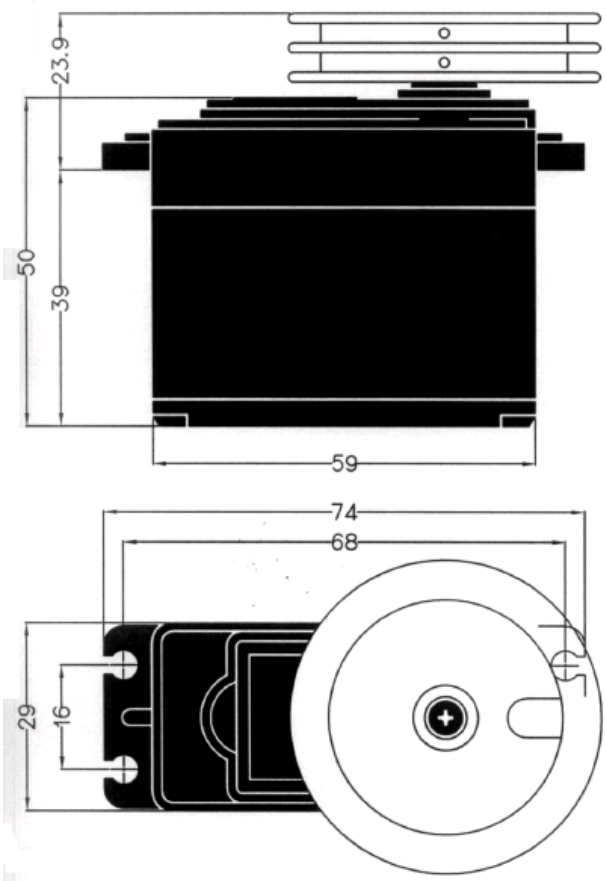
- Weight with servo: 7.1oz
- Rotation: 252 degrees
- 4.8V power: 765 oz-in
- 6.0V power: 915 oz-in
- 4.8V speed: 1.40 sec/60 degrees
- 6.0V speed: 1.15 sec/60 degrees



Hitec HS-785HB Servo

The Hitec HS785HB servo motor is different than most other servos in that it offers 1260 degrees of rotation (3.5 turns) standard versus the normal 180 degrees for a normal servo. The servo does not need to be modified in any way, though it is important to note that only pulses between 600us to 2400us correspond to a position. A pulse of 500us will cause the motor to rotate at full speed in one direction while a pulse of 2500us will cause the motor to rotate in the opposite direction.

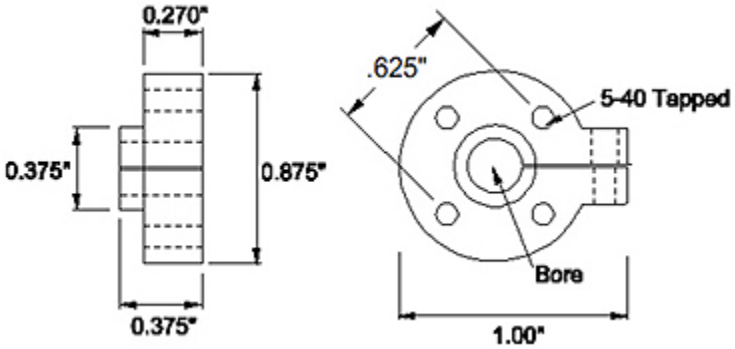
Note that the arm cannot mechanically allow the joints to rotate 360 degrees, so please be cautious about which signals are sent. Additional specifications can be found here: http://www.robotshop.com/PDF/HS-785HB.pdf



Miscellaneous

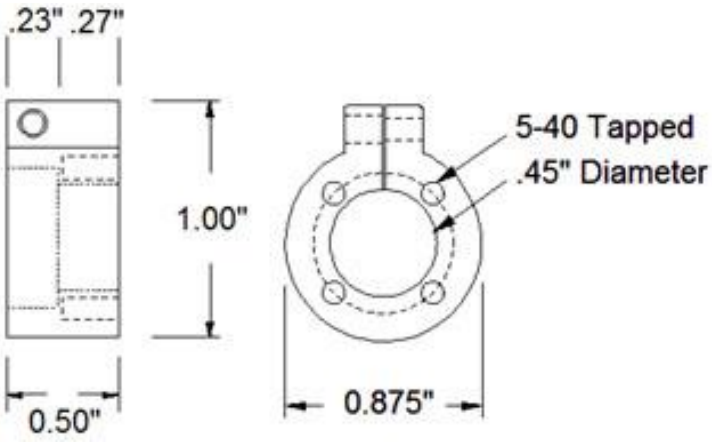
Clamping Hubs

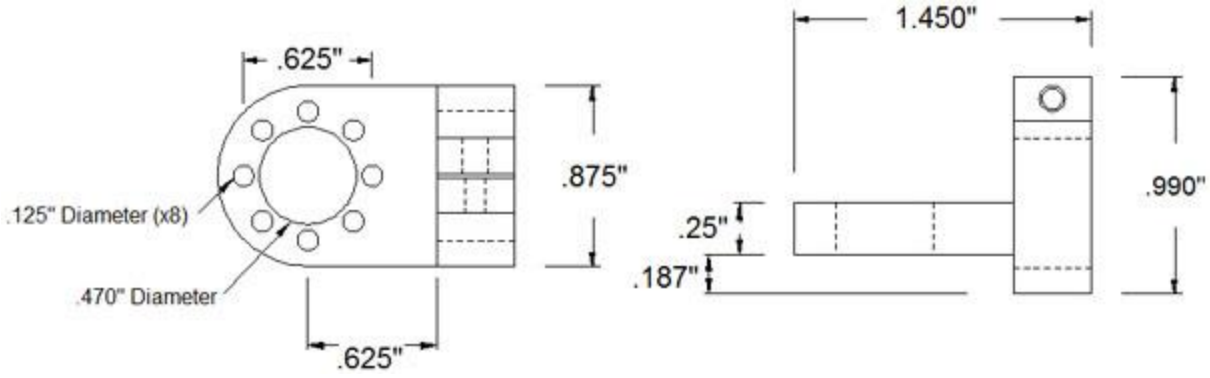
The clamping hubs included with the kit allow the large gears to be easily connected to the 3/8" shaft of the power gearbox. There are 4 equally spaced 5-40 tapped holes and is precision machined from 6061-T6 aluminum. Clamping hubs offer several advantages over set screw hubs. First, they do not damage the shaft which they are attached. Second, they offer more holding power in high torque applications. The side clamping machine screw is 5-40 and accepts a 3/32" hex key:



Clamping Tube Hubs

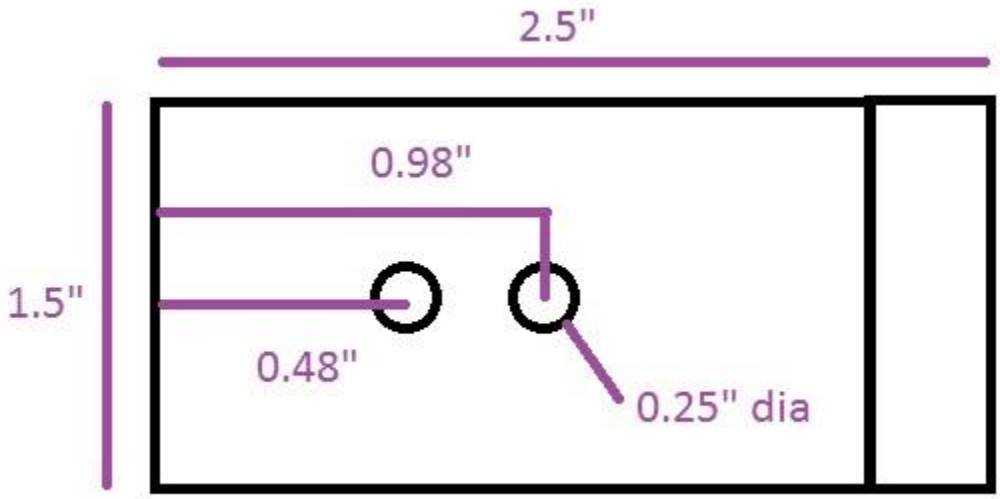
Precision machined from 6061-T6 aluminum, these clamping hubs offer several advantages over set screw hubs. First, they do not damage the shaft which they are attached. Second, they offer more holding power in high torque applications. The side clamping machine screw is 5-40 and accepts a 3/32" hex key.





90 Degree Solid Aluminum Plate

Dimensions:



Package Contents

What's Included

4x Hitec HS785HB servo motors
Function: Motors

1x SPG785A-BM 5:1 gearbox
(*optional metal gears shown)*
Function: Base of the arm

3x SPG785A-5.0 Servo Gearbox
(*optional nylon/metal gears shown*)
Function: Shoulder, elbow and wrist joints

2x End Cap Mount
Function: Connect gearboxes to clamping tubes

4x 3/8” Clamping hub
(*5/16” version shown*)
Function: Holding the 3/8” shaft in place
One on elbow, one on shoulder, one on base, one spare

4x 90 degree clamping Tube Hub
Function: Connect 5/8” tube to clamping hub

2x Clamping Tube Hub
Function: Connect gearboxes to clamping tube

2x Set Screw Collars
Function: Spacer on shoulder and elbow shafts

1x Hub Spacer (pair)
Function: Spacer on shoulder and elbow shafts

2x 3/8” OD 4” hollow aluminum tube
Function: Replacement shafts for power gearboxes

1x 5/8” OD 2” hollow aluminum tubing
Function: Tubing used between elbow and wrist*

1x 5/8” OD by 4” long hollow aluminum tubing
Function: Tubing used between elbow and wrist*

2x 5/8” OD by 6” long hollow aluminum tubing
Function: Tubing used between shoulder and elbow*

2x 5/8” OD by 8” long hollow aluminum tubing
Function: Tubing used between shoulder and elbow*

90 degree solid aluminum plate
Function: Connect end-effectors to the wrist or mount a small camera

1x 6” heavy duty servo extension
Function: Extend shoulder servo cable

1x 12” heavy duty servo extension
Function: Extend elbow servo cable

1x 24” heavy duty servo extension
Function: Extend wrist servo cable

Additional 5-40 Screws
Function: Additional screws used in assembly

- 30x 3/8” long 5-40 Pan Head Phillips Machine Screws
- 4x ½” long 5-40 Pan Head Machine Screws used to mount the shoulder to the base

* Default configuration uses two 8” and one 4” tubes.

What's needed

The M100RAK does not include all parts necessary to get the arm up and running. In addition the arm itself, you would need a controller and power supply.

Servo Controller (and/or Microcontroller)

A servo controller capable of handling up to 6A continuous current (4 channel or more) is necessary in order to continuously send pulses to the servo motors in order to refresh their position. A microcontroller is also capable of sending servo pulses, though it is important to note that most microcontrollers cannot handle the current required by these servos. The servo controller can also be used to position the servos when assembling the arm, though a servo tester such as the GWS Multi-Tester MT-1 is ideal since no programming is required.

Power Supply

Each servo can potentially draw up to 1.8A under full load, so we suggest a power supply capable of at least 4A at 4.8V and 5A at 6V. The highest current would be when the robot is stretched horizontally and is lifting a weight (it may peak up to 10A momentarily).

Where to buy

The M100RAK as well as replacement parts can be purchased from www.RobotShop.com, search RB-Rbo-85. Not all replacement parts are available online, so if there is part you need which you cannot find online, please contact the RobotShop Support Center and select technical support.
http://robotshop.helpserve.com/index.php?_m=tickets&_a=submit

Warranty

The M100RAK is a robotic kit which requires assembly. It is important to note that robot kits may not be exchanged or refunded once they are assembled in part or in entirety. Only defective components will be replaced if the need arises. Along these lines, please carefully read the construction instructions for the robot and ensure that they are understood before commencing construction. Work carefully on a clean table and take regular breaks in order to maintain your concentration. Should the robot not be assembled and can be resold as new, you can return the item for a refund (minus shipping fees) within 10 days of receipt. Should the robot not be assembled and can be resold as new, you can exchange the product for in-store credit within 30 days of receipt. The Hitec Servos have a 2 year warranty.

Assembly

A basic assembly video is available on YouTube on the RobotShopTV channel:

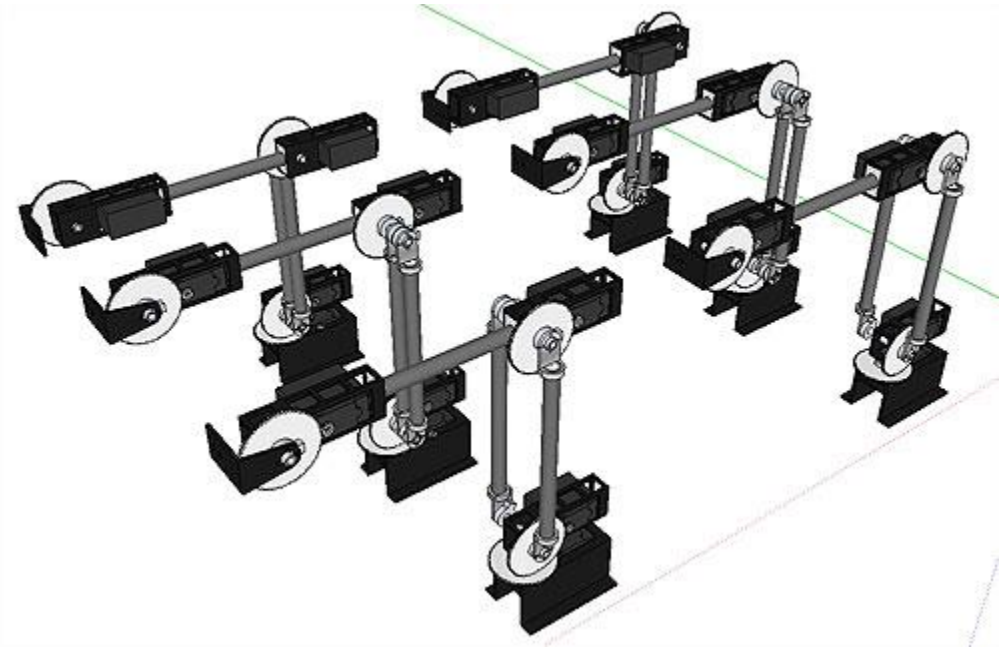
http://www.youtube.com/watch?v=yW68gdpmrRY

Corrections to assembly video:

Step 12: Uses 4x 3/8” long Pan Head screws
Step 17: Uses 3/8” Clamping hub instead of set screw hub
Step 20: Uses ½” long 5-40 Pan Head screws

Please note that many arm configurations are possible. Before starting the assembly, lay out all the parts to ensure nothing is missing. Follow the assembly video to make the default configuration.

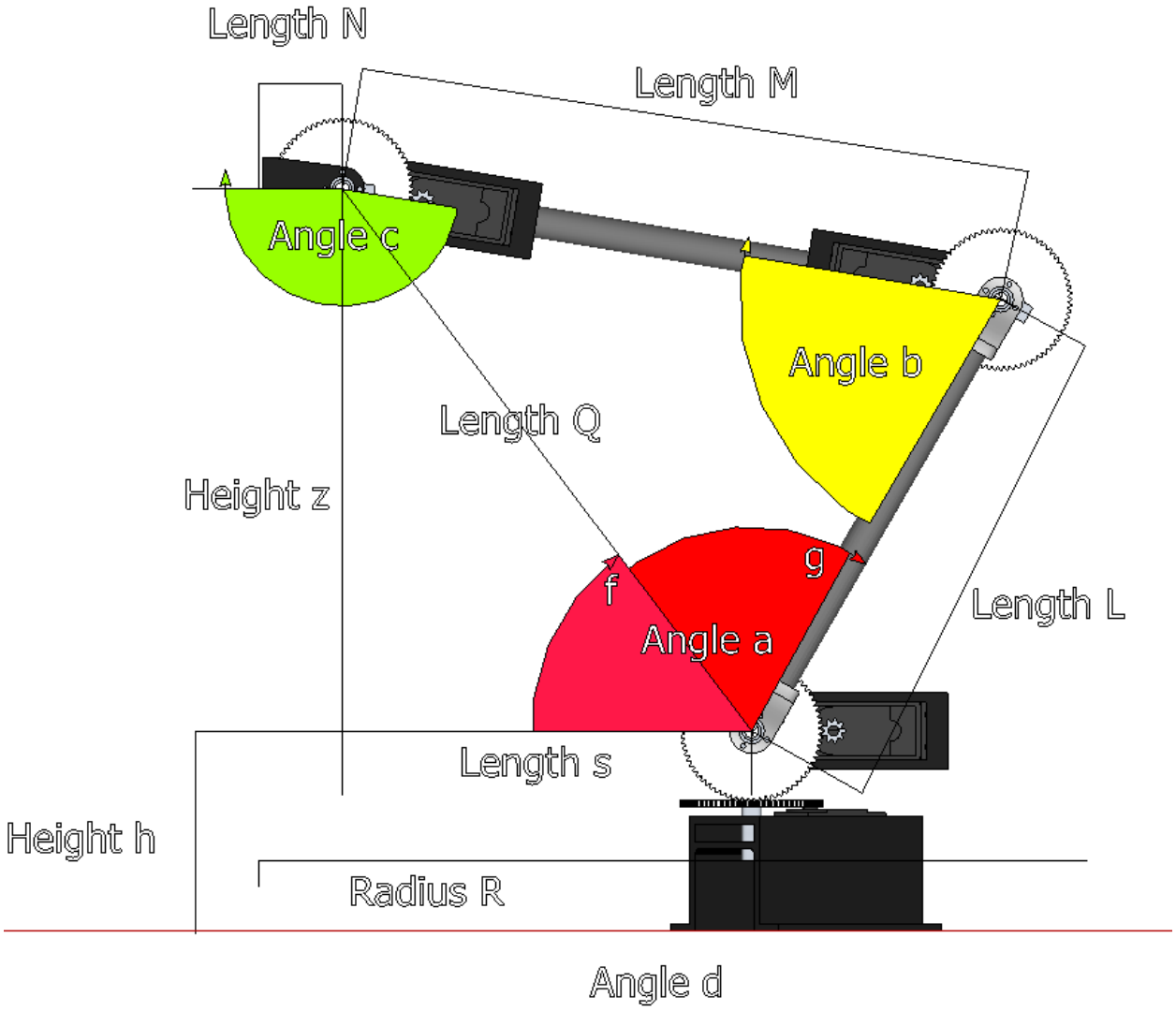
Alternative designs can be obtained by changing the configuration of the joints. The image below shows two elbow joint configurations by three elbow to shoulder connection configurations. The kit also comes with an alternative tube length which can be used to configure the shoulder to elbow to the shoulder (leaving three other tube lengths available for the elbow to wrist joint). There are over 100 different configurations are possible with this kit.



Because of the multiple configurations, we suggest using the set screw collars and hub spacers as spacers in order to prevent the frame from interfering with the servos. You are welcome to devise your own assembly based on the configuration you desire and several spare parts have been included in the kit.

Important note: During assembly, try to avoid rotating the servo motors manually as it creates back EMF and added wear on the motors.

Once the assembly is complete, the servos need to be positioned properly. Since there is an additional 5:1 gearing after the servo, each joint rotation angle is not automatically centered. Ensuring the joint is centered is currently a manual / visual process. We suggest configuring it as follows:



Note that the “zero” degree angles for the elbow and wrist would cause the arm to try to reach a position it is mechanically incapable of reaching. Therefore when configuring the arm, we suggest using two different angles (such as 90 degrees and 180 degrees) and the associated servo pulses to develop a linear equation relating the servo pulse to the angle.

Calculating Angles Based on x, y, z

This is just one way of calculating the joint angles based on coordinate (x,y,z) of the end of the gripper. Note that the equations need to be calculated in RADIANS (not degrees) and then converted back to degrees. We also suggest including constraints to ensure the given point can be reached by the arm.

L is the length of the shoulder axis to the elbow axis
M is the length of the elbow axis to the wrist axis
N is the length of the wrist axis to the end of the gripper (or the desired point)

R = [(x^2) + (y^2)]^(1/2)
Represents the radius from the axis of rotation of the base to x,y

s = R – N
Since the arm has four degrees of freedom, there are infinite solutions possible for the arm to reach point (x,y,z). We will therefore introduce an artificial constraint and keep the gripper at a specific angle to the horizontal, and calculate for a new coordinate (x_1, y_1, z_1) of the wrist axis.

Q = [(s^2) + (z^2)]^(1/2)
This is the distance between the shoulder axis and the wrist axis

f = atan2(z, s)
This is the angle between the horizontal and the line Q. The atan function would return two angles whereas the atan2 function determines the correct angle based on the x and y coordinate. The actual height is h + z which can be taken into account when inputting

g = acos[((L^2)+(Q^2)-(M^2)) / (2*L*Q)]
This is the angle between line Q and link L using the law of cosines.

Use the equations above to find angles a, b, c and d:

a = f + g
This is angle ‘a’ above.

b = acos[((M^2)+(L^2)-(Q^2)) / (2*L*M)]
This is angle ‘b’ above using the law of cosines.

c = -b - a + 2*pi
This is angle ‘c’. Angle c is kept horizontal to the (x,y) plane.

d = math.atan2(x, y)
This is the angle ‘d’ of the base.

Useful Links

Hitec HS-785HB Servo Motor:
http://www.robotshop.ca/PDF/HS-785HB.pdf

Robot Arm Torque Calculator
http://www.robotshop.com/robot-arm.html

Robot Arm Torque Tutorial
http://www.robotshop.com/robot-arm-torque-tutorial.html

Troubleshooting and contact (select technical support):
http://robotshop.helpserve.com/index.php?_m=tickets&_a=submit

FAQs

Q1) Can I use other servo motors with this arm?

Only the Hitec HS-785HB and Hitec HS-755MG can fit the space. The 755MG would only be able to rotate 36 degrees without modification.

Q2) What other parts are required to make a “robotic” arm?

You would need a standard servo motor controller capable of providing sufficient current, as well as a 4.8V to 6V power supply. We also suggest a clearly labelled “kill switch” to stop all power to the arm.

Q3) Can the joints rotate 360 degrees?

Sending a signal between 501us and 600us causes the servo to rotate (501 is very fast to 599 is very slow). A pulse between 2401us and 2500us causes it to rotate in the opposite direction. Note that only the base is really able to rotate 360 degrees without being physically impeded.

Q4) Are other gear ratios offered? Can I choose the specific gear ratio for each joint?

Yes, but it is special order. A full metal geardown is also available.

Q5) Why didn’t you include a gripper with the basic kit?
Given the range of tasks the arm can be used for, including a gripper would have increased the price. A gripper may be released at a later date.

Q6) How do I configure the arm to make it as accurate as possible?

Q7) Are there any resources where I can figure out the angles for each joint for a given X,Y,Z coordinate?

Figuring out joint angles based on linear coordinates is called “inverse kinematics”.