



National University of Singapore

Faculty of Engineering

ME4245/ME4245E - Robot Kinematics, Dynamics and Control

Lab Manual

(Lab location: E4A-03-04, Mechatronics & Automation Lab)

Safety:

- a) Unexpected contact with the robot may cause severe injury. In order to avoid injury keep out of the cell of the robot while it is in operation and do the experiment with extreme care.
- b) Do not touch any of the internal parts of controller module when it is powered.
- c) Students must wear shoes (with toes covered) while coming to lab. Entering the lab is not allowed otherwise.

Pre-Lab work

- Read this manual carefully and answer question 1 given in page 7 (refer section 4.1).

OBJECTIVES:

1. Familiarization of six Degree of Freedom (DOF) industrial robot.
2. Manually controlling the motion of the arm in various DOF.
3. Teaching different positions and doing 'pick & place' task in auto-mode.
4. Solving and verifying forward kinematics problem.

1. Introduction

Robotic manipulators are widely used for automation of mass production in industries. Industrial robots have the ability to perform the same tasks repeatedly without stopping and at high speeds. They are used for applications such as welding, painting, assembly, palletizing, cutting, and material handling.

This experiment introduces an industrial robot ABB's IRB140. It helps to learn the manual and automatic operation of the robot using the various DOF. Transfer of objects from one position to another position is done automatically using the robot. Also the solutions to the forward kinematics problem learned in the class are verified in this experiment.

2. Familiarization of the Robot

Fig.1 is a diagram of the robot depicting the various degrees of freedom. Numbers 1-6 indicate the six axes. Arrows shows positive direction of motion. The dimensions of the robot are shown in Fig.2. Table 1 gives the range of the angular movement of the various links.

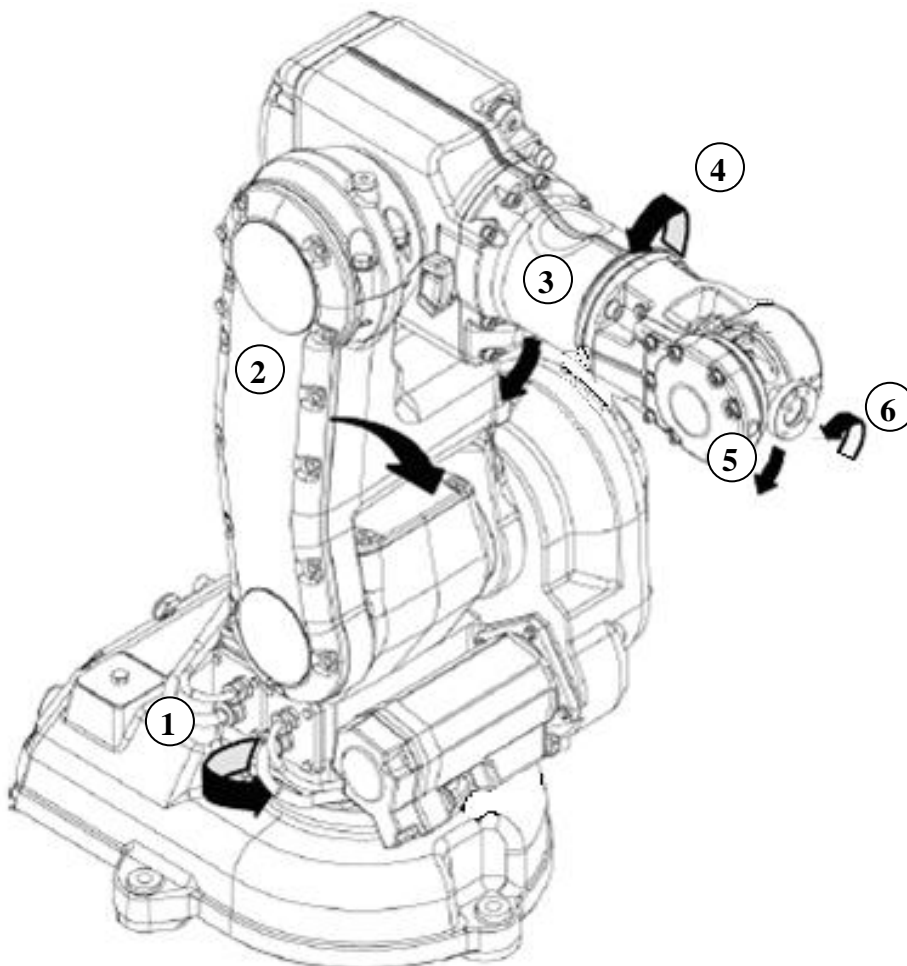


Fig. 1 The Robot (in home position)

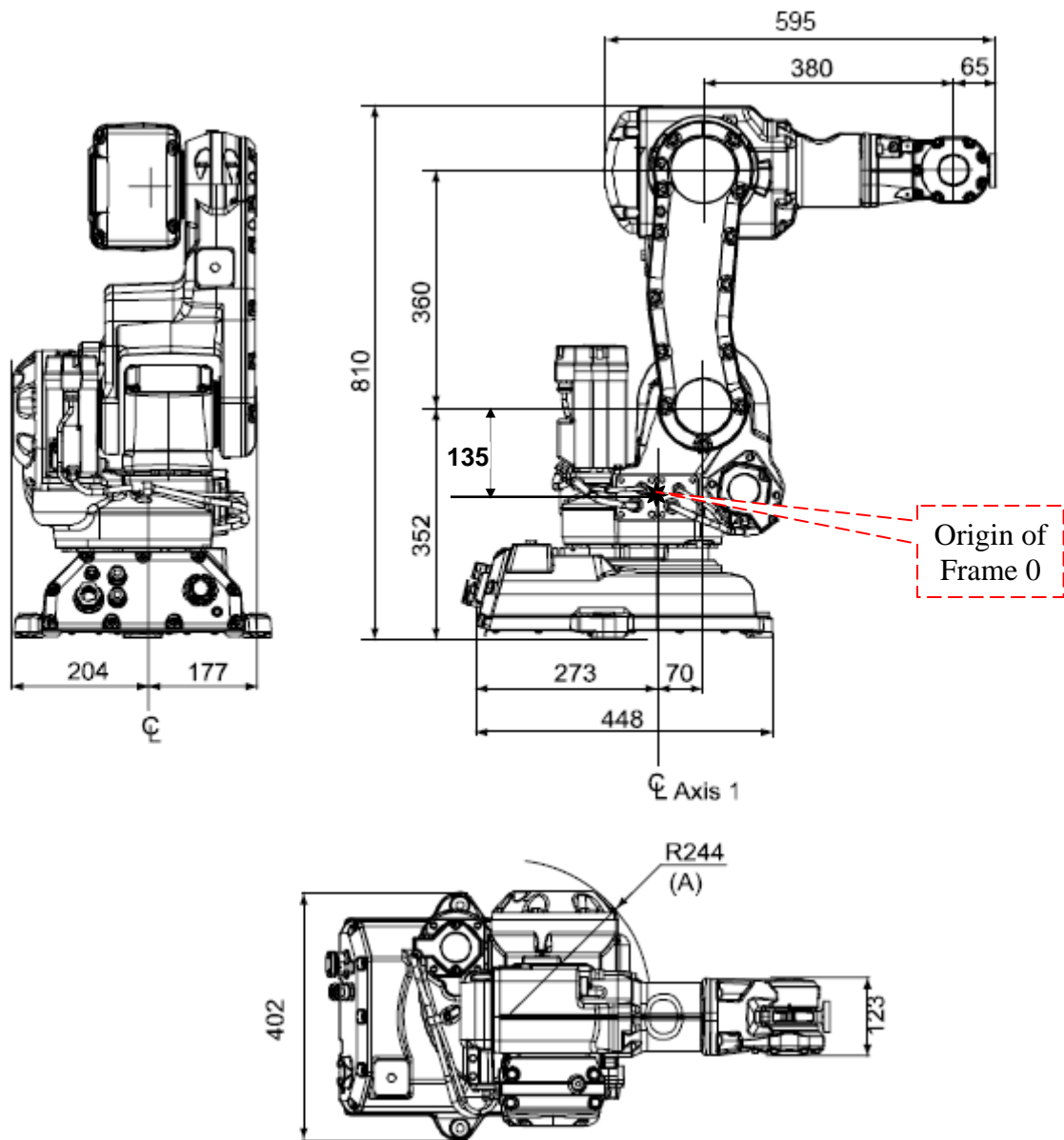


Fig. 2 View of the robot from rear, side and top (dimensions in mm)

Type of motion	Range
Axis 1: Rotation motion	+ 180 ° to - 180 °
Axis 2: Arm motion	+ 110 ° to - 90 °
Axis 3: Arm motion	+ 50 ° to - 230 °
Axis 4: Wrist motion	+ 200 ° to - 200 °
Axis 5: Bend motion	+ 115 ° to - 115 °
Axis 6: Turn motion	+ 400 ° to - 400 °

Table 1 Range of movement of different DOF from home position.

2.1 Identify the following components of the robot.

1. The controller
2. Drive unit
3. Power and signal cables
4. User interfaces (Flex-pendant & PC)
5. Links and joints
6. Motors and gear boxes
7. End-effector
8. Camera

2.2 Jogging

Jogging is the individual (independent) movement of the robot in each degree of freedom (joint). The six DOF is divided into two sets. First set contains axes 1, 2 & 3 and second set contains axes 4, 5 & 6. The selection of a particular set is done using the *Jogging* menu and the arms are moved using the joystick on the Flex-pendant. The joystick has three degrees of freedom (up-down, left-right, and clock wise- anti clockwise) which helps the movement of arm about the three axes in each of the two sets. The robot speed is proportional to the joystick deflection, the greater the deflection, the higher the speed.

3. Operation in auto mode- Pick and Place task

3.1 Teaching / Programming the robot.

The detailed instruction for teaching the robot will be given during the lab session. Following are some hints.

- a. Programming is done using the *Program Editor* menu on the touch screen of the flex-pendant.
- b. Each action (e.g. moving to particular position, waiting, picking, placing) corresponds to a single line of instruction in the program.
- c. New instructions can be added by tapping corresponding tabs in the *Add Instruction* menu.
- d. Robot is jogged to a particular position and the position is taught using the *Modify Position* tab.
- e. Instruction for moving is *MoveL*.
- f. Instruction for picking / placing is *Set DO / Reset DO*.
- g. Instruction for waiting is *WaitDO*.
- h. Speed of motion can be adjusted by modifying the parameters in the *MoveL* instruction.
- i. *Copy* and *Paste* operations can be done using the *Edit* menu when movement to a particular position is repeated (movement to position 1, 2, 4, 5 are repeated. Refer Fig.4)

3.2 Pick and Place task:

The task is picking an object from Position 3 and placing it at Position 6 (Fig.3). Fig. 4 shows the different steps in the task. After developing the program it is executed in the step by step mode as well as in auto-mode.

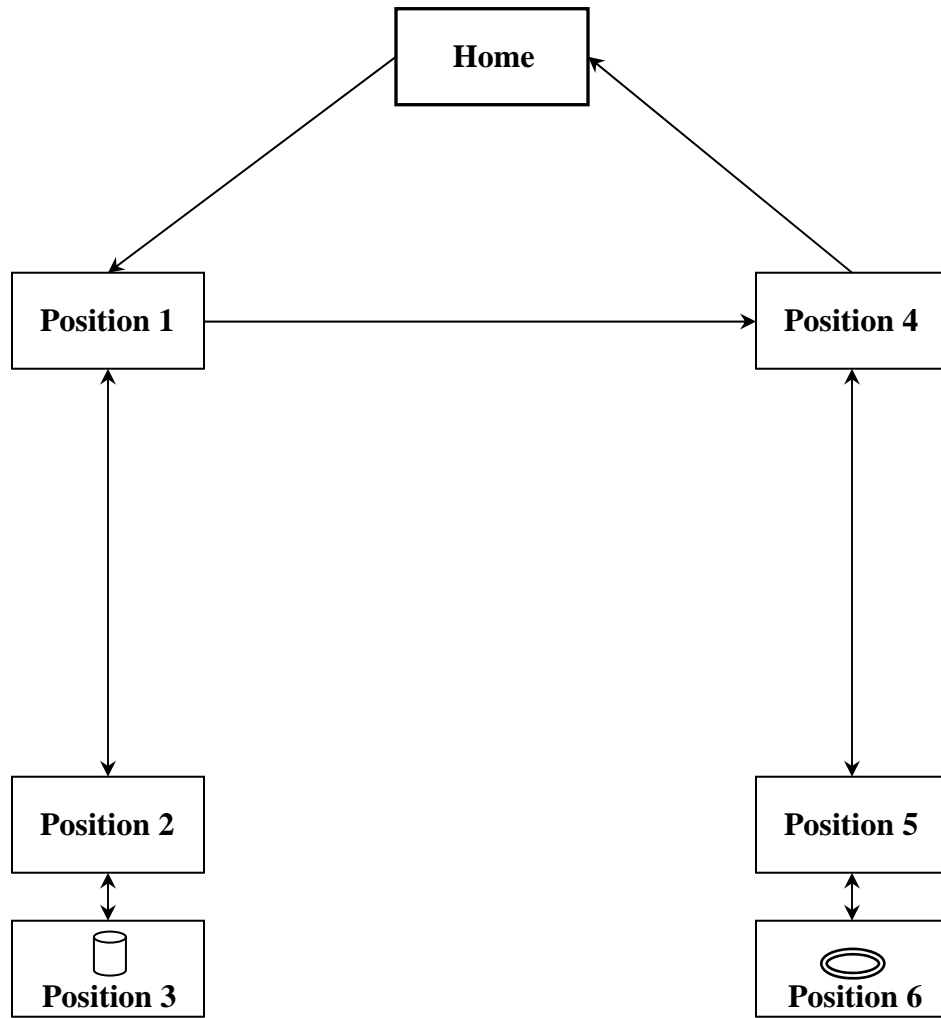


Fig. 3 Pick and place task

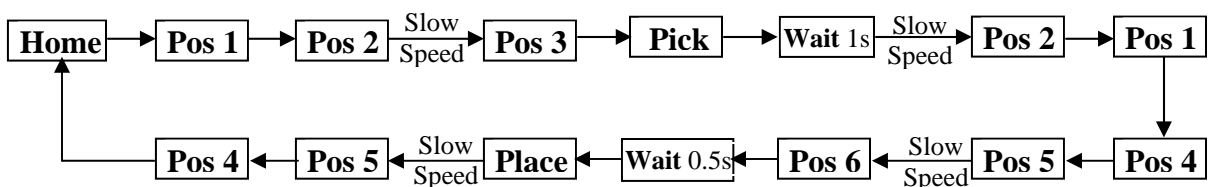


Fig. 4 Movement steps

4. Forward kinematics

The position of the end-effector can be determined by calculating the forward kinematics of the robot. Denavit-Hartenberg (D-H) parameter definition and axis convention learned in the class is to be used for this calculation.

4.1 Assignment of coordinate frames and identification of link parameters (Pre-lab work).

The different co-ordinate frames of the robot are shown in Fig.5 (also refer Fig.1). You may either use these frames or may assign your own co-ordinates. The assignment should be done according to the following guidelines.

- Each (x_i, y_i, z_i) coordinate frame of the robot arm corresponds to joint $i+1$ and is fixed in link i .
- The base coordinates are defined as the 0th coordinate frame (x_0, y_0, z_0) . So there are seven coordinate frames viz. $(x_0, y_0, z_0), (x_1, y_1, z_1), \dots, (x_6, y_6, z_6)$.
- The base frame (frame 0) should be as indicated in the Fig. 5.
- The last frame (frame 6) can be placed anywhere in the end-effector, as long as the x_6 axis is normal to the z_5 axis.

Now you have to identify the link parameters θ_i, r_i, d_i & α_i and fill Table.2 (Question1- calculate θ_i corresponding to home position)

4.2 Calculation of transformation matrix and tool position.

The MATLAB program for computing the transformation matrix and the resultant tool position will be given in the lab (C:\ME4245\kinematics.m). Open the program and input the values of θ_i, r_i, d_i & α_i (Table. 2).

4.3 Verification of forward kinematics

Verify the forward kinematics of the robot you have calculated by moving the robot to various positions as in Table 3. Cross check the calculated tool position coordinate values with the actual tool position shown in the flex-pendant and fill up Table 3 (Question 2).

Note:

- After finishing the experiment submit your answer sheet (Page 7 & 8) for evaluation.
- Copies of page 7 & 8 will be given to you in the lab.

Q.1 Identify the kinematic parameters of the robot and fill table 2.

Q.2 Calculate the tool position corresponding to three sets of the joint angles given in Table 3.

Verify it using the reading on the flex-pendant after moving the robot to these sets of angles.

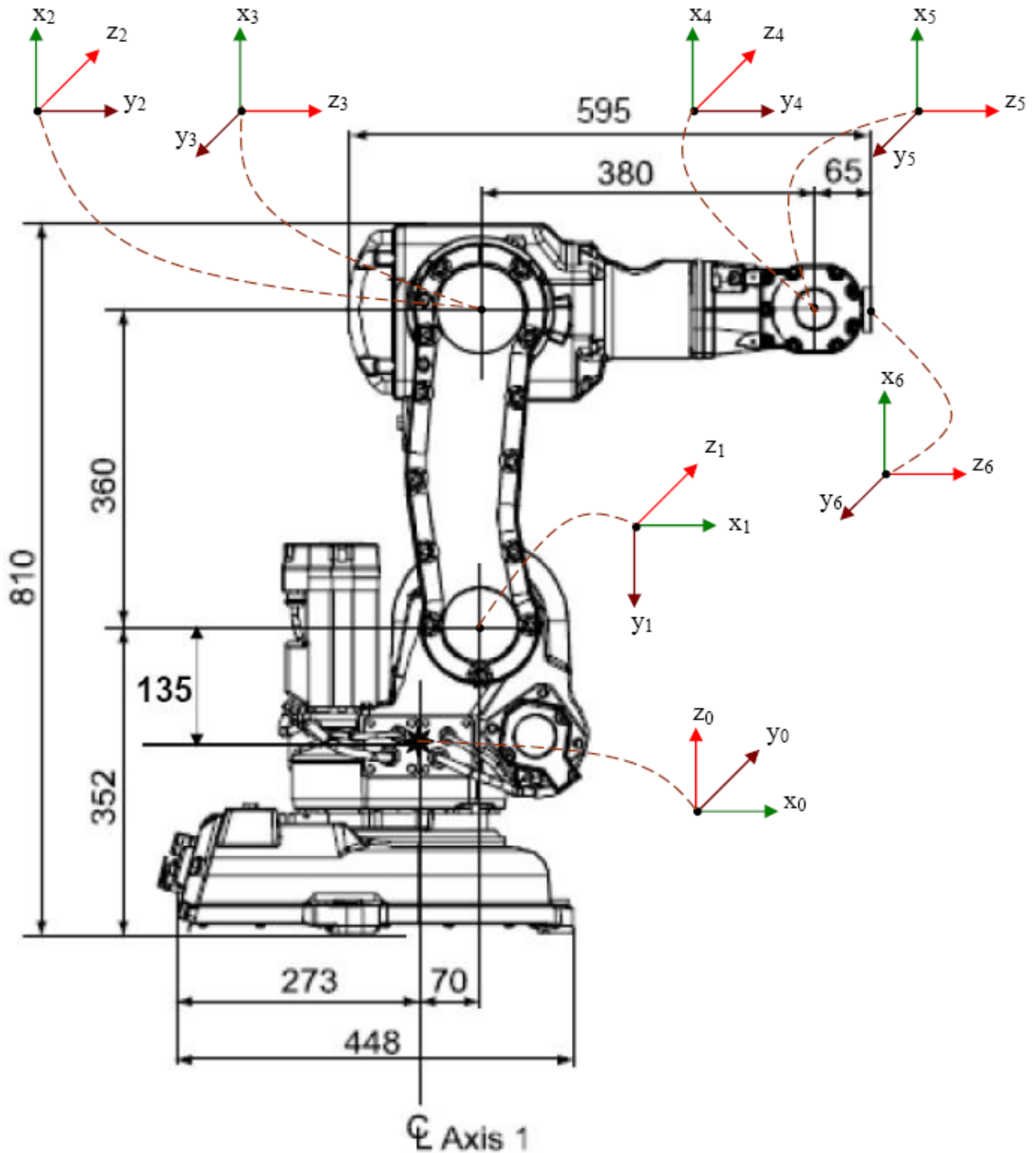


Fig. 5 Link co-ordinates of the robot

Link	θ_i	r_i	d_i	α_i
1				
2				
3				
4				
5				
6				

Table 2 Kinematic parameters

Trial		1	2	3
Joint Angles (degree)	Joint 1	+90	+45	-45
	Joint 2	0	+15	-10
	Joint 3	+30	0	+15
	Joint 4	0	+20	0
	Joint 5	0	0	+45
	Joint 6	0	0	-90
Actual Tool position (Flex pendant reading)	X			
	Y			
	Z			
Calculated Tool position (mm)	X'			
	Y'			
	Z'			

Table 3 Verification of forward kinematics