

# **MAE 263B**

## **Dynamic and Robotic**

Denso Robot Instructions  
**READ BEFORE USING THE ROBOT!!!**

# Manually Controlling the Robot

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## *Instructions for Manual Control the Denso Robot*

### **1. Read this document before attempting to use the Denso robot**

This document provides an overview of many of the fundamental aspects of operating and controlling the Denso robot. **You should read this manual before attempting to operate the robot!**

### **2. What you will have in the work cell**

- The Denso robot (manipulator) on the work table
- The Denso robot controller
- A pneumatically actuated gripper of some type mounted to the end of the robot arm

Note: This document makes reference to WINCAPS. This is a software package supplied by Denso that allows you to develop code for the robot in an offline mode. It also allows for a very robust simulation of the robot. This document does not cover WINCAPS.

### **3. Step-by-step Instructions**

#### **3.1. Powering on the Robot**

Nobody should power-on the robot unless the following procedures are followed:

- **EYE PROTECTION MUST BE WORN AT ALL TIMES**
- The course instructor, one of the course teaching assistants (TAs), or a Washburn Shop lab monitor must be present when operating the robot
- Know where the **EMERGENCY STOP** (E-Stop) buttons are located
- Press [Emergency stop] button on the tech pendant
- Carefully watch the robot during the startup process and be prepared to press an E-Stop button if the robot moves in an unexpected way

Press “-” display side of power switch of the controller shown in the figure below until it clicks. Power lamp (the leftmost of three pilot lamps) turns on. The other two pilot lamps, “Automatic mode” and “Error”, briefly flash immediately after turning on.

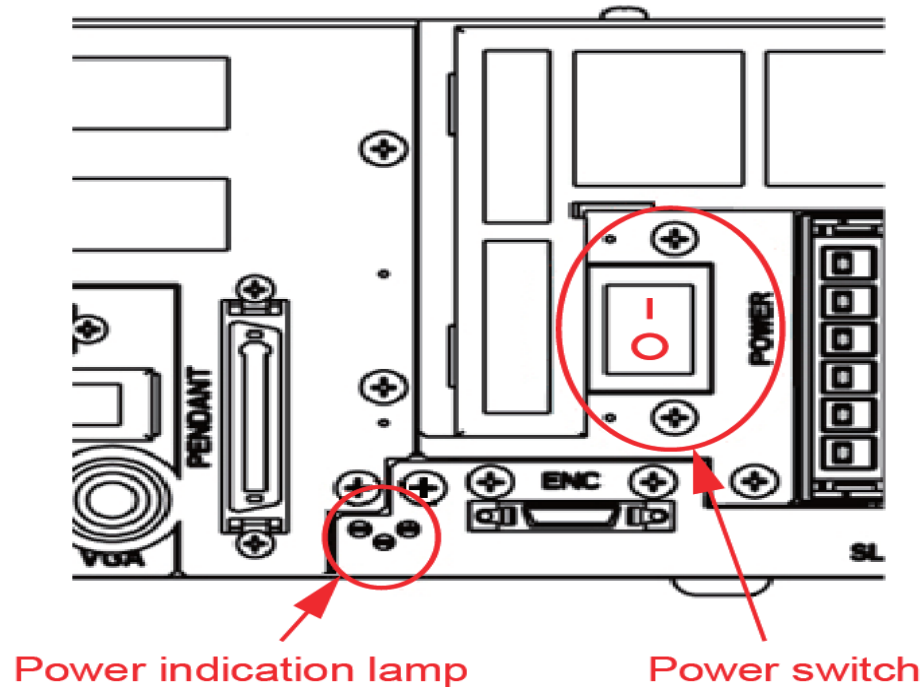


Figure 1 – Turning on the power switch

### 3.2. Turning OFF the robot

Following the follow steps to turn off the robot if the operation of robot is all completed.

- (1) If MOTOR lamp is flashing, press MOTOR key to turn off motor. MOTOR lamp is embedded in MOTOR key. MOTOR lamp turns off

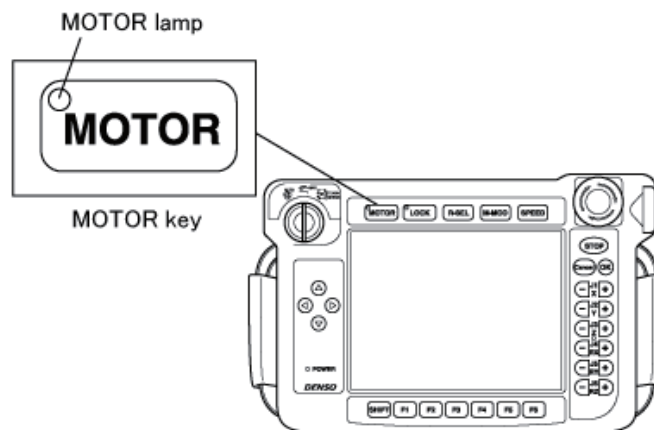
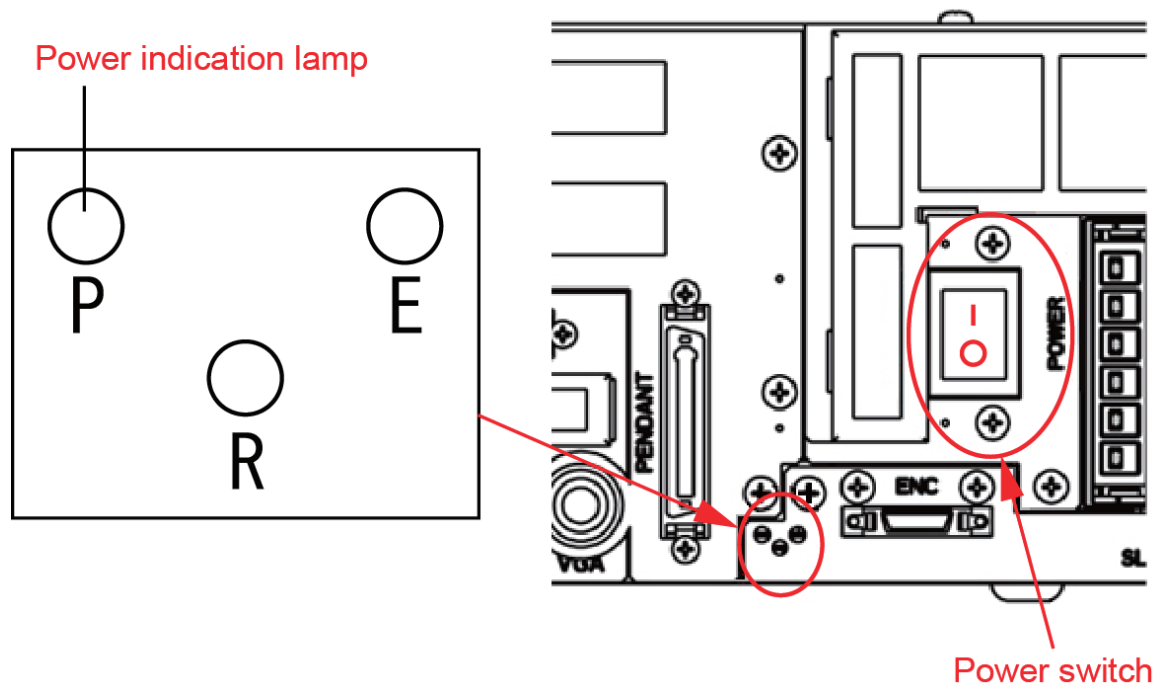


Figure 2 – Turning off the robot (stage 1)

- (2) Press down the power switch of the robot controller. Press lamp (the leftmost of three pilot lamps) turns off.



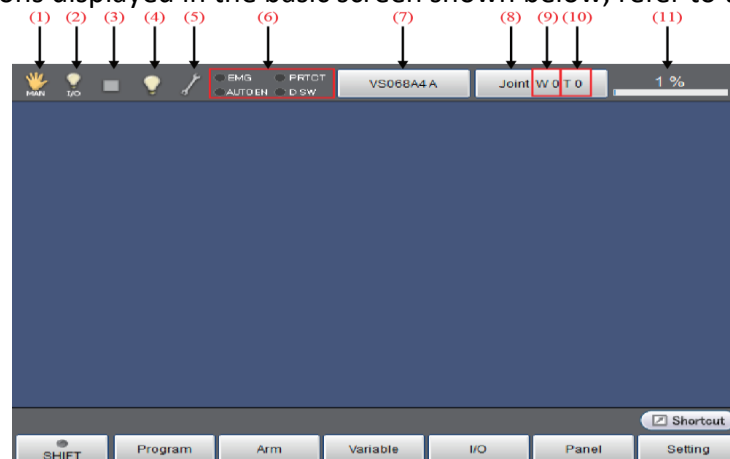
**Figure 3 – Turning off the robot (stage 2)**

### 3.3. Using the Tech Pendant














The Tech Pendant is a multi-function user interface to the Denso robot controller. You should familiarize yourself the main parts of the Denso Pendant as shown in figure below.














#### Icons

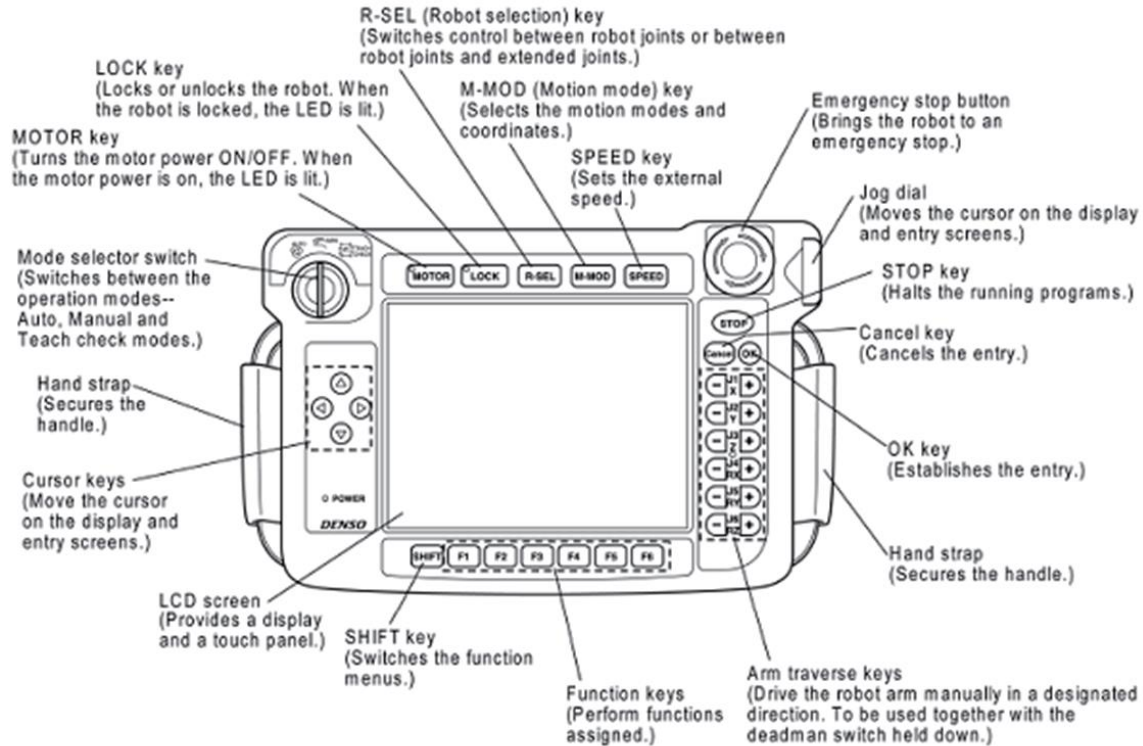
For details of icons displayed in the basic screen shown below, refer to the following list.



**Figure 4 Basic screen**

No.	Name	Description	
(1)	Move mode		Auto mode
			Manual mode
			Teach check mode
			Mode is not selected
			Direct mode
			Transmitting to PC
			Receiving from PC
			Read data in USB memory
			Write data into USB memory
			VirtualTP/RemoteTP is connected.
(2)	Executable Token		Arbitrary
			COM
			EtherNet

			I/O
			Teach Pendant
(3)	Program running		Program is under suspension
			Program is executing
			Supervisory task is executing
			Program and supervisory task are executing
			Message output (Display when PrintMsg command execution)
			Vicinity of the singular point (Sound the warning alarm when in the vicinity of the singular point)
(4)	I/O status/Arm status		Pseudo input unused and I/O lock unused (Note)I/O lock:Limit I/O communication with external devices
			Pseudo input used or I/O locked
			Virtual fence or Exclusive control is enabled.
			Normal
(5)	System state		Abnormal <ul style="list-style-type: none"> <li>Battery warning</li> <li>Encoder system is down</li> <li>Catastrophic failure(When level 5 error is occurred)</li> </ul>
(6)	Switch input state	EMG	Emergency stop state
		AUTOEN	Auto enable state
		PROTECT	Protective stop state
		DSW	Deadman switch state
(7)	Robot selection button		Select and display the robot type
(8)	Move mode		J : Each axis P : Display X-Y mode T : TOOL
(9)	Work coordinate		Display the selected work number.
(10)	Tool coordinate		Display the selected tool number.
(11)	Velocity button		Setting and display of the external speed.



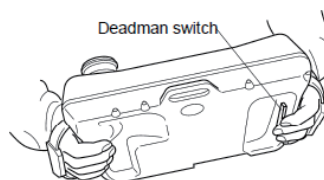
**Figure 5: Location of various controls on the Tech Pendant**

### How to hold the Teach Pendant

The Teach Pendant is typically operated while being held in the hand as shown in Figure below. Hold tech pendent with both hands to operate.

The function of deadman switch is to stop the robot automatically and safely when operator cannot perform normal operation due to the unexpected fainting or death during the manual operation of robot using teach pendant. Deadman switch is a 3-position switch that is designed to recognize the following three operation state.

- (1) If switch is not pressed or pressed lightly→ Switch is off
- (2) If switch is pressed with medium pressure→ Switch is on
- (3) If switch is pressed too hard→ Switch is off



**Figure 6: Holding the Tech Pendant**

### 3.4. Coordinate Systems

#### Overview

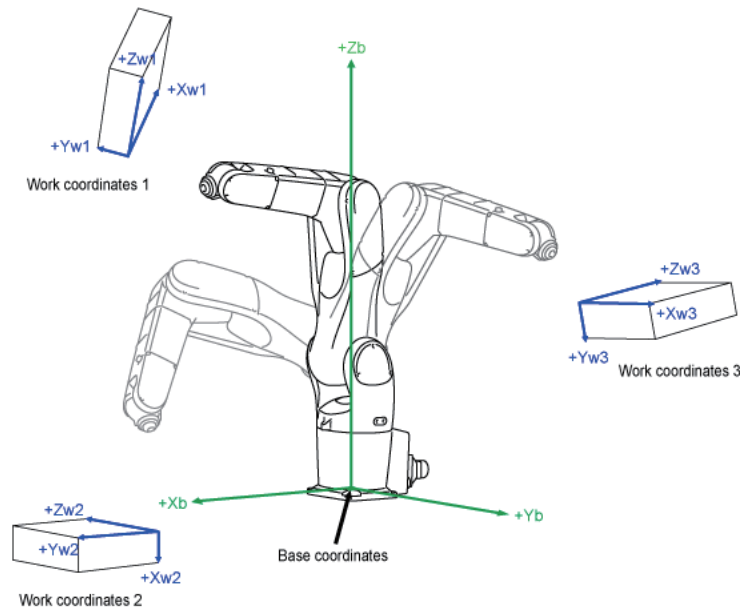
This section provides an introduction to the coordinate systems used mostly for offline programming.

#### Base Coordinates

Base coordinates are 3-dimensional Cartesian coordinates with its origin at the center of the robot base. "Base" of the robot is a part where the first axis of the robot is installed. It has components  $X_b$ ,  $Y_b$  and  $Z_b$  which are identical with  $X$ ,  $Y$  and  $Z$  in  $X - Y$  mode.

#### Work Coordinates

Work coordinates are 3-dimensional Cartesian coordinates defined for each operation space workplace. The origin can be defined anywhere and as much as needed. Work coordinates are expressed by the coordinate origin ( $X$ ,  $Y$ ,  $Z$ ) are corresponding to the base coordinates and the angles of rotation ( $R_X$ ,  $R_Y$ ,  $R_Z$ ) around  $X$ ,  $Y$  and  $Z$  axes of base coordinates. Up to seven work coordinates can be defined and assigned work coordinates #1 to #7. If work coordinates are not defined, base coordinates go into effect.

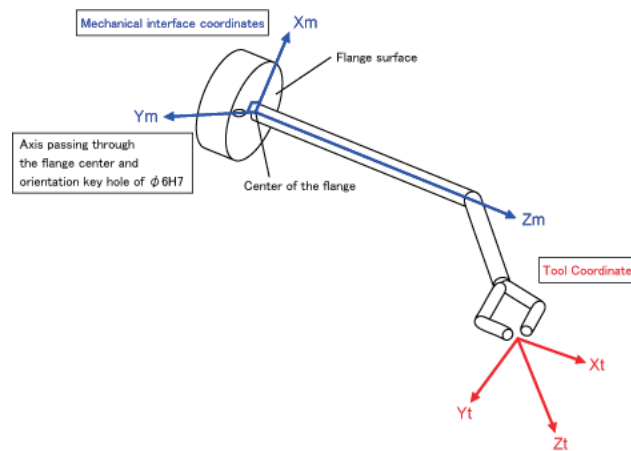


**Figure 7: Base coordinates and Work coordinates**



## Tool Coordinates

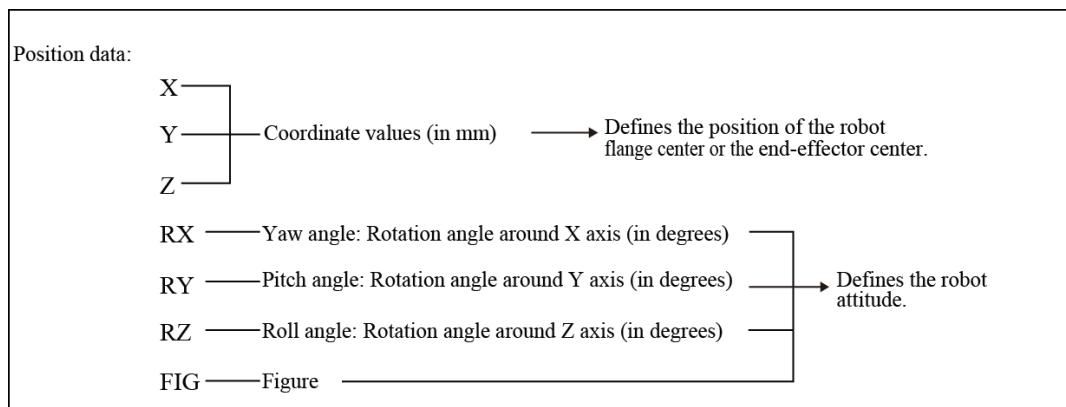
A tool mounting surface at the end of the robot arm is called a flange. Three-dimensional Cartesian coordinates whose origin at the center of the flange center are called mechanical interface coordinates. The tool coordinates are 3-dimensional Cartesian coordinates whose origin at the end of the tool mounted on the flange. Based on the origin of the mechanical interface coordinates, the tool coordinates define the offset distance components and axis rotation angles. The figure below represents VM robots.



**Figure 8: Tool coordinates for VM robots**

## Position Data

Position data refers to a set of data which includes RX, RY and five components of base coordinates. Of these five components, three are robot flange center coordinates and two are current robot attitude components, as shown below.



**Figure 9: Position data**

## Components of Position Data

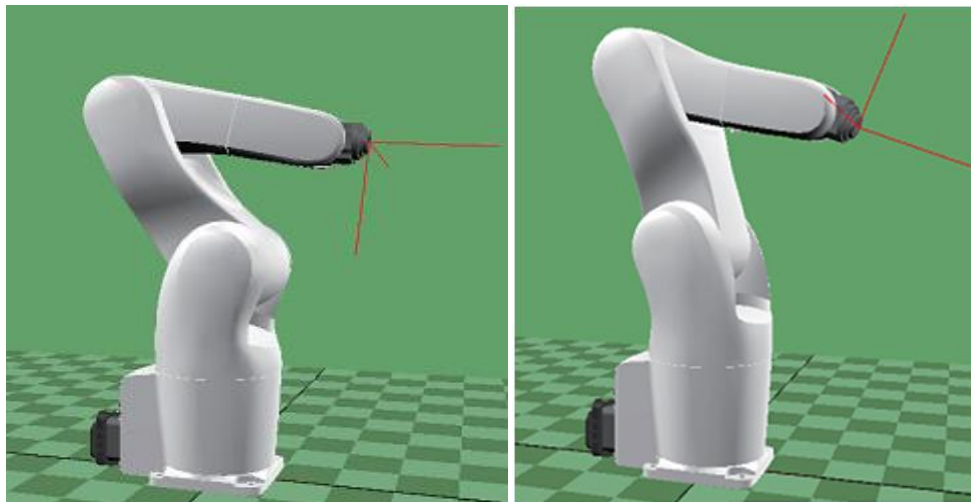
A set of X, Y and Z coordinate values represents the position of the robot flange center expressed in base coordinates in units of mm.

The yaw angles, pitch angles and roll angles which are expressed by RX, RY and RZ, refer to rotation angles around the respective axes of the base coordinate system defined by the mechanical interface coordinate system whose origin is at the center of the flange surface. These angles are expressed in units of degree. With respect to the positive (+) direction on axes of the base coordinates, clockwise rotation is treated as positive (+).

You should always preserve the rotation order of RZ, RY and RX. Changing it will cause the robot to take a different attitude in spite of the same rotation angle defined.

## Shoulder Figure

A shoulder figure is defined by a set of the values of the 1<sup>st</sup>-, 2<sup>nd</sup>-, and 3<sup>rd</sup>- axis components. The robot can take two different shoulder figures-Left handed(LEFTY) and Right-handed(RIGHTY).

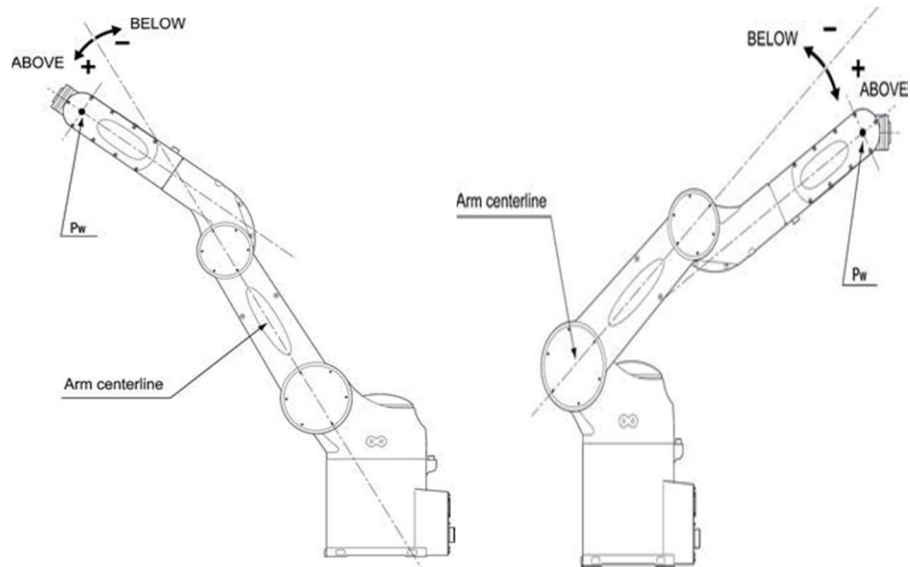


**Figure 10: Shoulder Figure**

## Elbow Figure

The centerline of the arm link (connecting the shoulder with elbow) is defined as the boundary between ABOVE and BELOW. If point Pw exists in the + side of the centerline, the figure is ABOVE; if point Pw exists in the – side, it is BELOW. In the figures shown below, the boundary is drawn with alternate long and short dash lines. The left of the

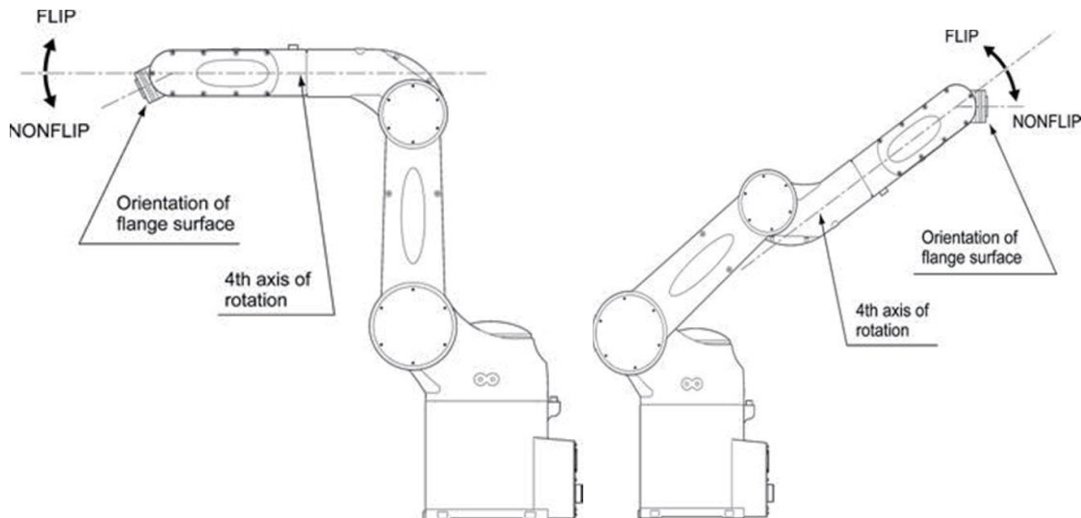
Figure 11 represents the boundary for LEFTY, the right of the Figure 11 represents the boundary for RIGHTY.



**Figure 11: Elbow figure**

## Wrist Figure

The rotary axis of the 4<sup>th</sup> axis is defined as the boundary between FLIP and NONFLIP. If the normal line on the flange surface tilts up the rotary axis of the 4<sup>th</sup> axis, the figure is FLIP; if it tilts down the rotary axis, it is NONFLIP. In the figures shown below, the boundary is drawn with alternate long and short dash lines.



**Figure 12: Wrist figure**

### **3.5. Speed selection and Manual Mode**

#### **What is the manual mode?**

In manual mode the manipulator movement is under manual control. The enabling device must be pressed to activate the motors of the manipulator, that is, enabling movement.

The manual mode is used when programming and for program verification. In some robots, there are two manual modes, the manual reduced speed mode and the manual full speed mode.

#### **Safety in manual mode**

When in manual mode the manipulator is operated with personnel in close proximity. Maneuvering an industrial manipulator is potentially dangerous and therefore maneuvers should be performed in a controlled fashion.

#### **What is the manual reduced speed mode?**

In manual reduced speed mode the movement is limited to 250 mm/s. The enabling device must be pressed to activate the motors of the manipulator.

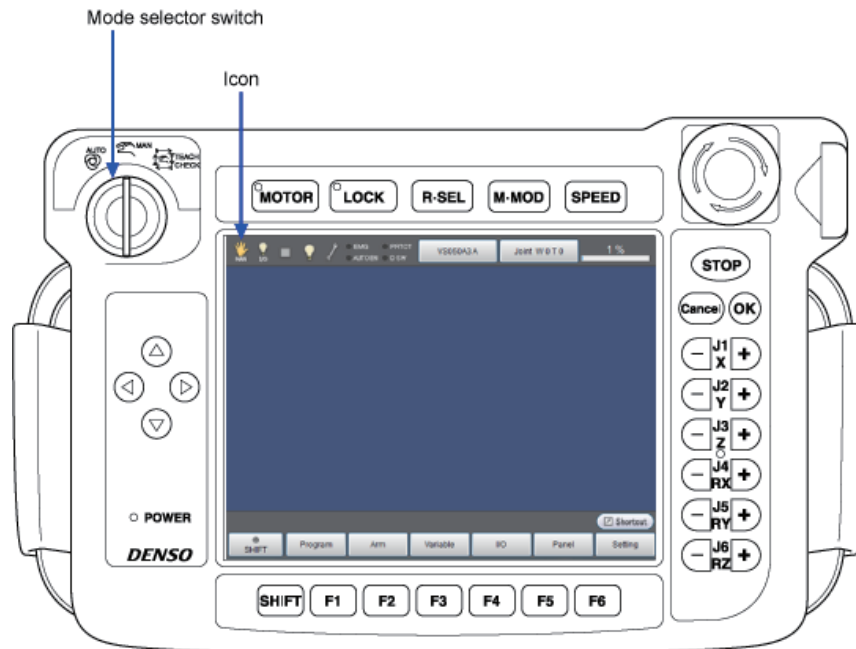
#### **Switching to Manual Mode**



At the start, set the reduced ratio of the programmed speed to 20% or less. If you run the robot manually at high speeds from the beginning, you may mistakenly strike the robot against the surrounding objects.

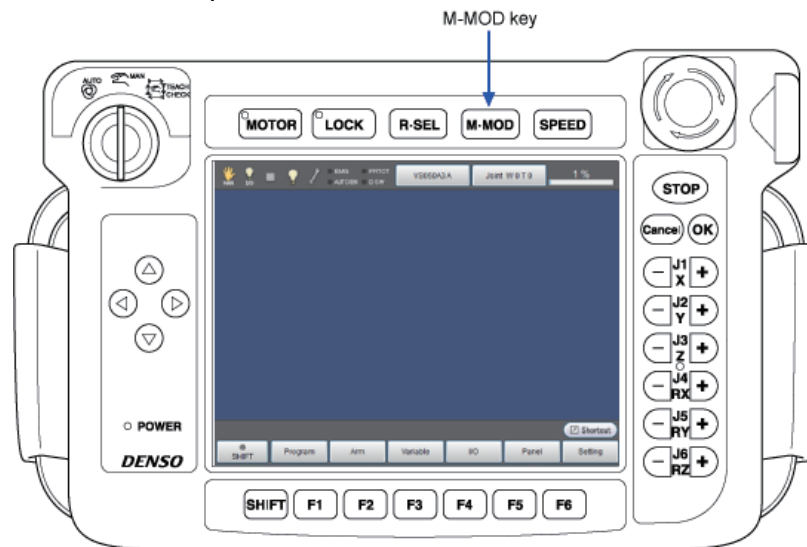
From the teach pendant

(1) Step 1: set the mode selector switch to the MANUAL position.



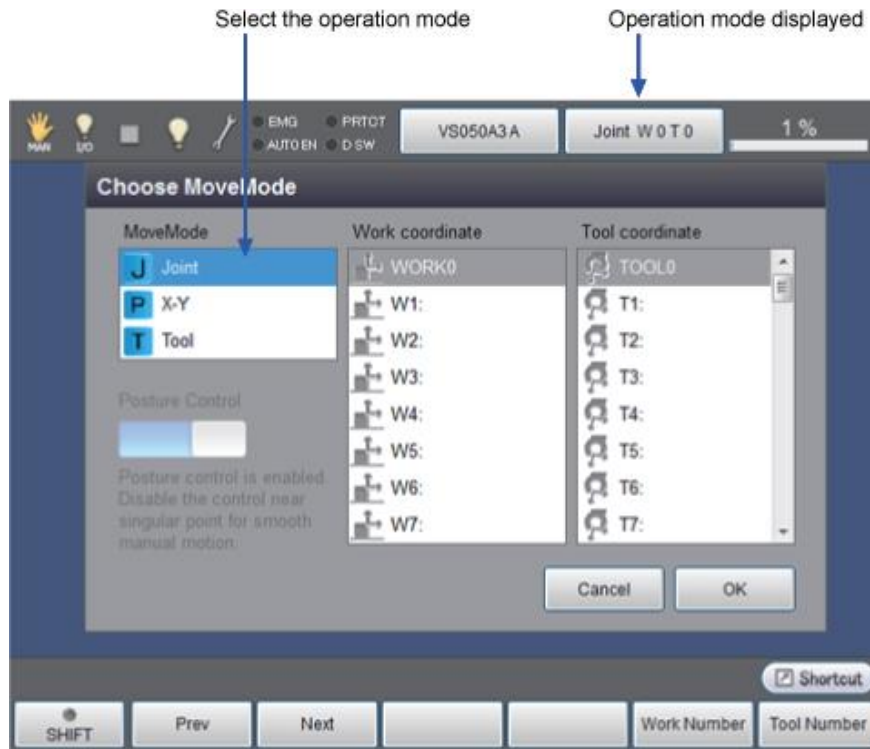
**Figure 13: Step 1 of switching to manual mode**

(2) Step 2: Press the M-MOD key



**Figure 14: Step 2 of switching to manual mode**

(3) Step 3: Select the desired operation mode by using the cursor keys or touching the screen directly, then press the OK key.



**Figure 15: In the mode area of the status bar appears the selected operation mode above**

### Running the Robot Manually

It allows robot operation from teach pendant and mini-pendant, or automatic robot run by turning on the robot controller.

### Turning ON Robot Controller

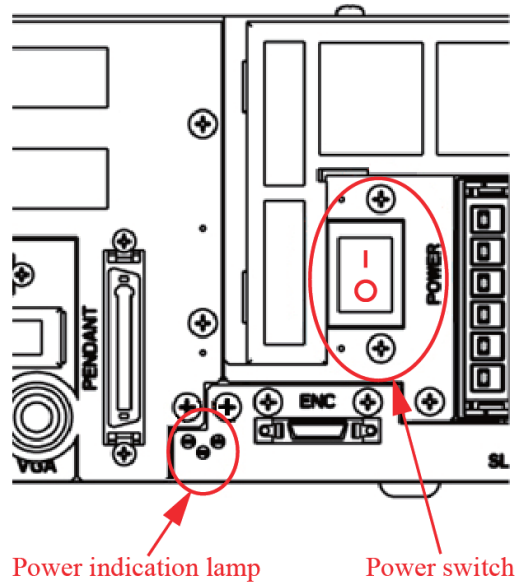
To operate the robot, it necessary to turn on the robot controller. The robot controller controls and supplies all power needed for the operation of robot.

### Operation procedures

Checking that it is safe to proceed

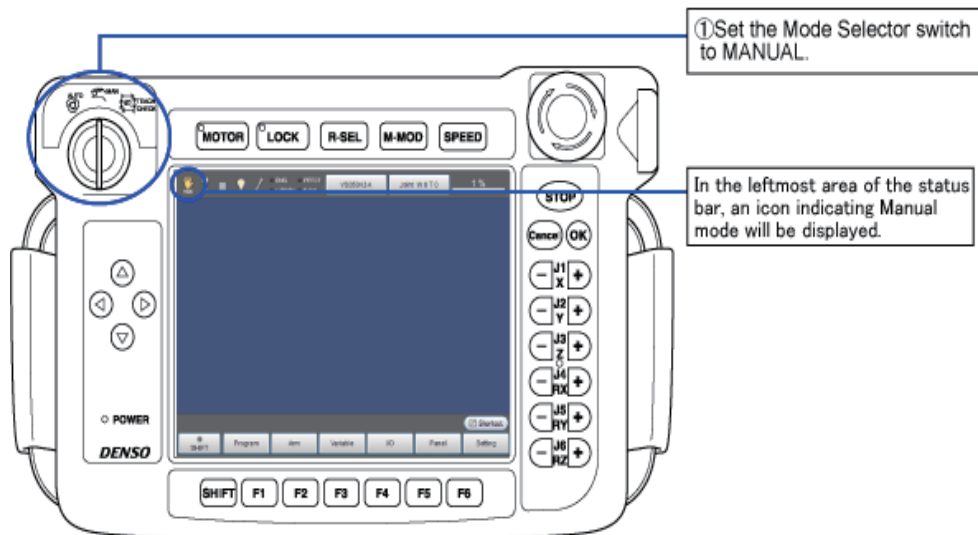
- Check that the robot is installed correctly.
- Check that there is no one within the robot's restricted space.

(1) Step 1: Press " | " display side of the power switch of the controller shown in the figure below until it clicks. Power lamp (the leftmost of three pilot lamps) turns on. The other two pilot lamps, "Automatic mode" and "Error", briefly flash immediately after turning on.



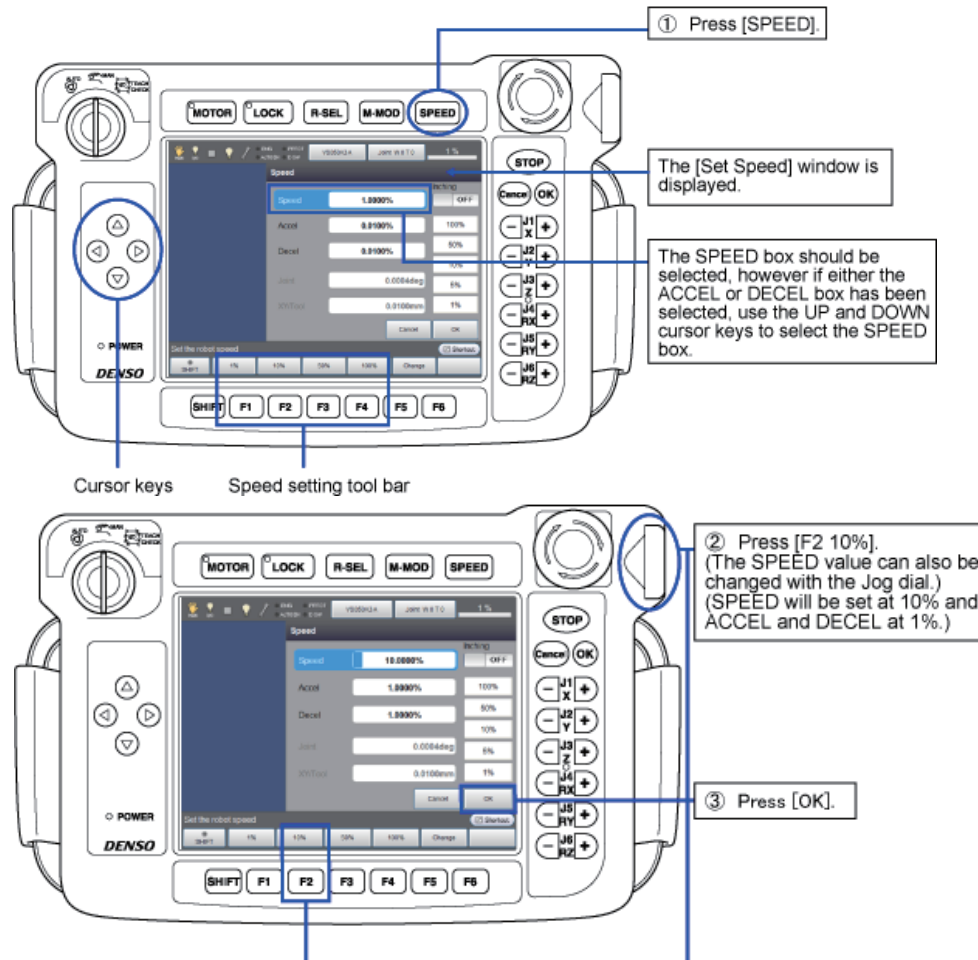
**Figure 16: Step 1 of running the robot manually**

(2) Step 2: Set the mode selector switch to the MANUAL position



**Figure 17: Step 2 of running the robot manually**

### (3) Step 3: Set the speed and acceleration



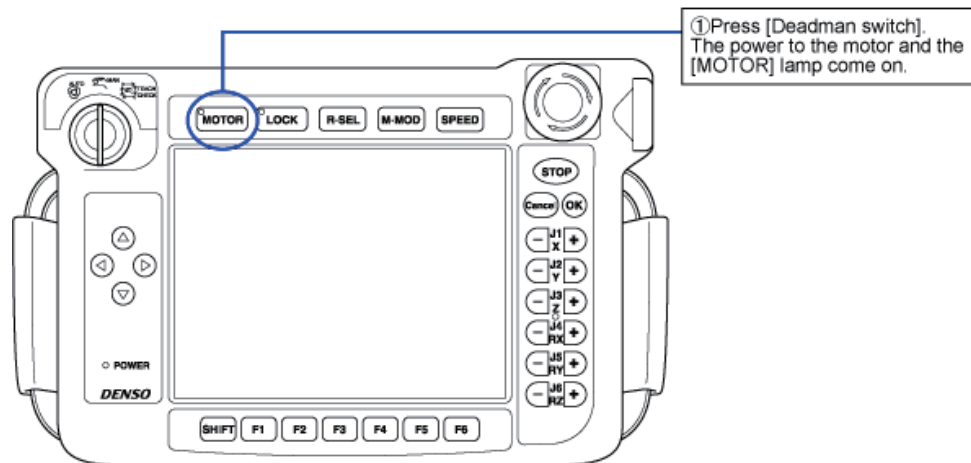
At the beginning, leave these settings as they are, as you will be running the robot slowly to ensure safety. The settings can be changed later on, after you have become accustomed to running the robot with the teach pendant.





**Figure 18: Step 3 of running the robot manually**

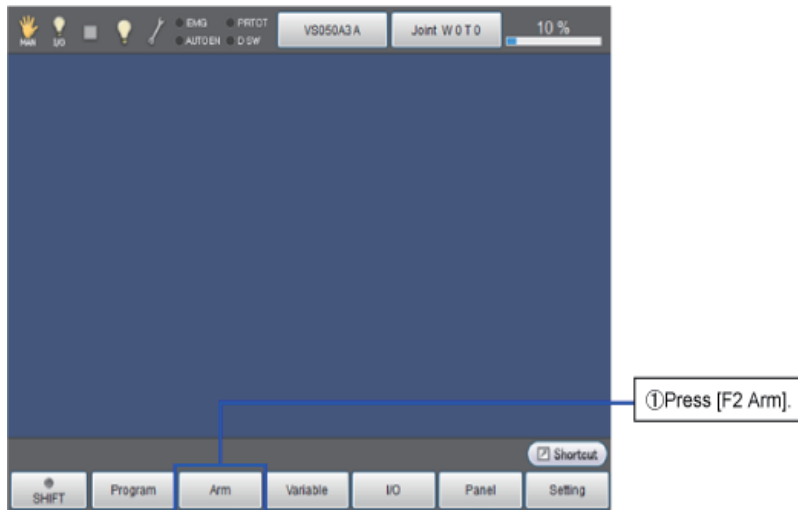
(4) Step 4: Press the dead man switches



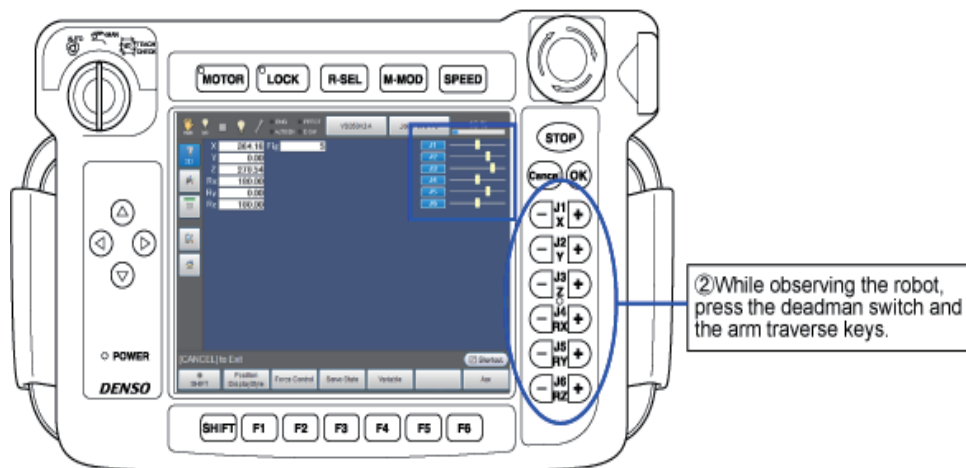
**Figure 19: Step 4 of running the robot manually**

(5) Step 5: Move each arm of the robot manually. When this operation is performed, the robot arm will move. Any workers should leave the robot's restricted space.

The current position can be checked by the teach pendant. To display the current position on the screen, press [F2 Arm]. This is optional, so you can operate robots' arms without displaying current position.

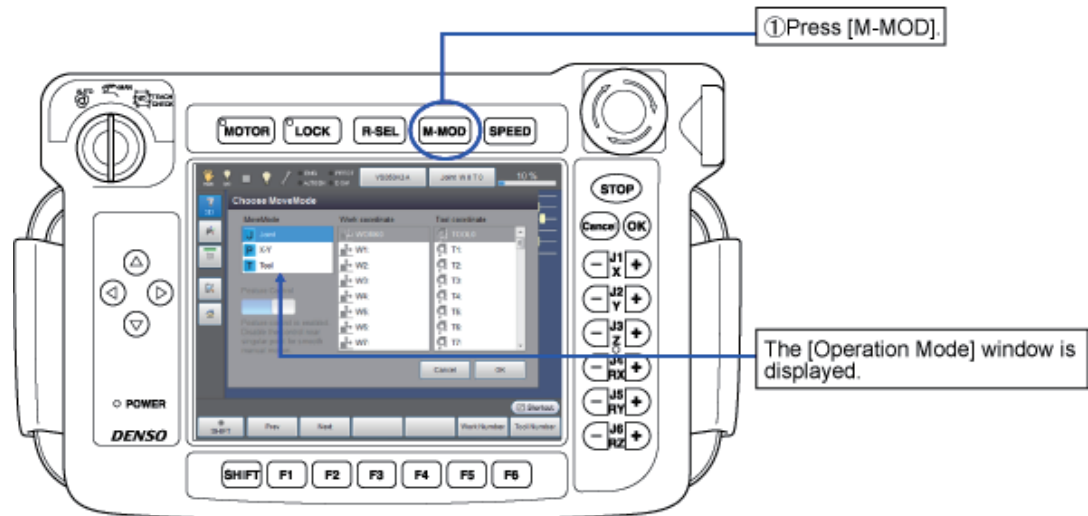


The arm corresponding with the operation of the J1 to J6 (6-axis robot) arm traverse keys will move. Current position against full stroke length of each axis are displayed.

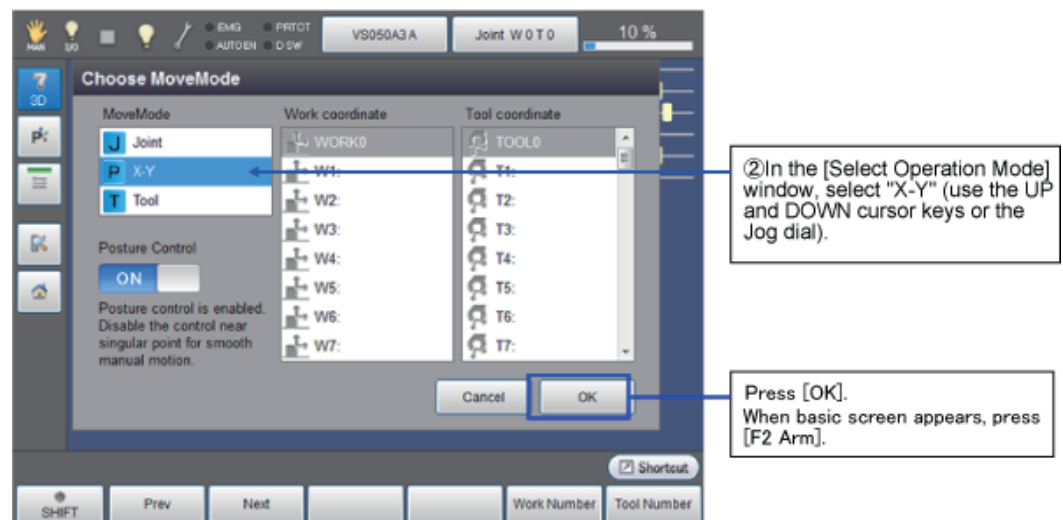


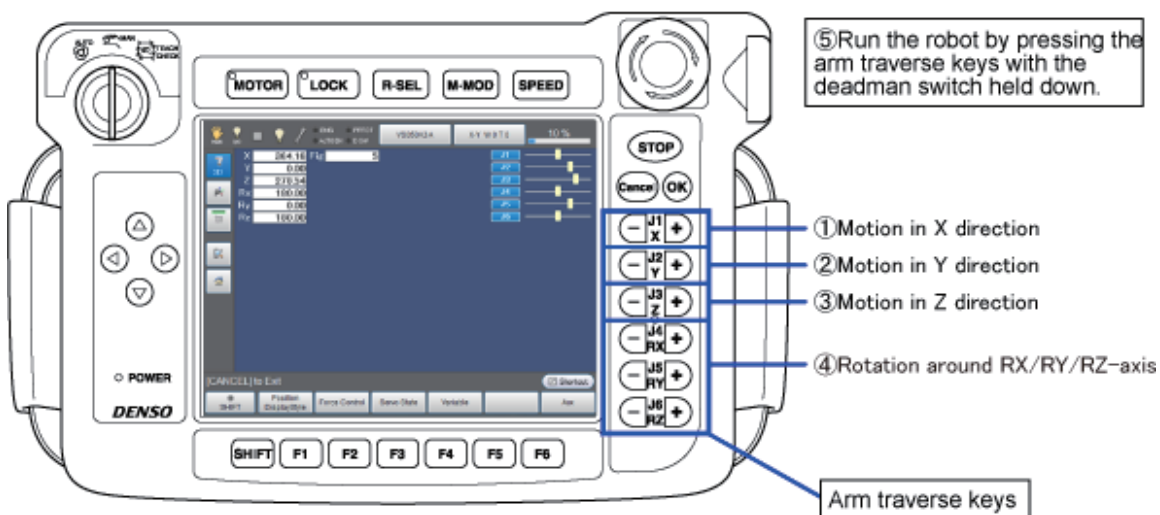
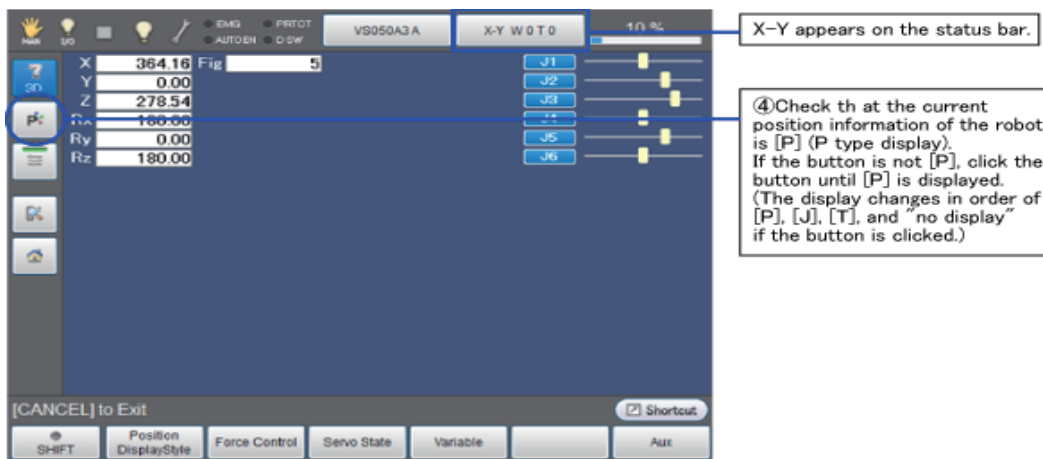
**Figure 20: Step 5 of running the robot manually**

(6) Step 6: Select Manual mode to run the robot manually



In this section, running the robot in X-Y mode.





Motion of the X-Y mode

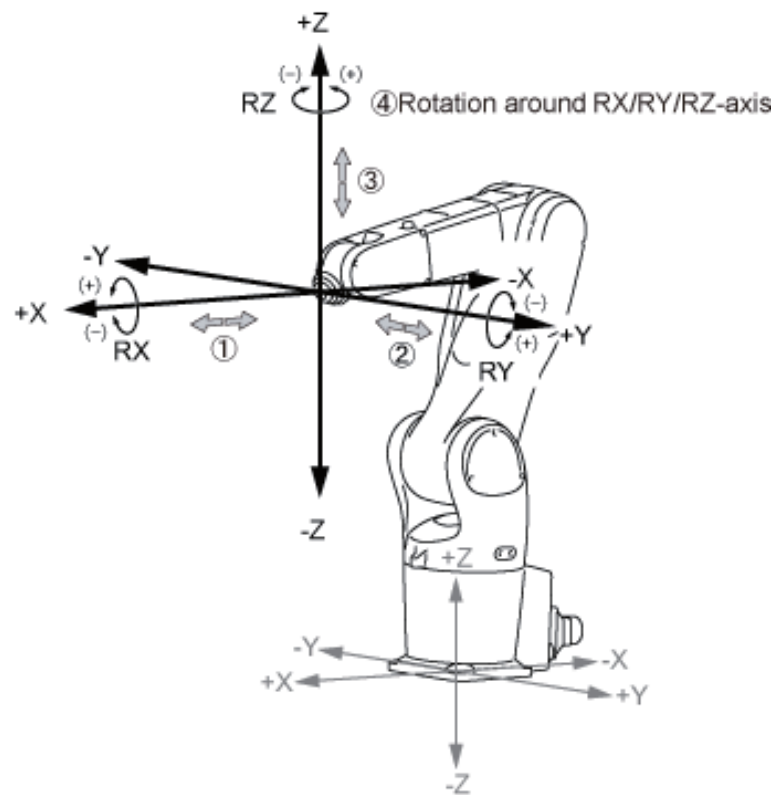


Figure 21: Step 6 of running the robot manually

### 3.6. Gripper Operation

Different grippers are used for different tasks. The four standard grippers are usually used in the project. (Take example of the gripper of ABB robot). The four standard grippers are:

#### Parallel-Finger

The parallel-finger gripper is shown in Figure below.



**Figure 22: Parallel-finger gripper**

As the name implies, the fingers are always kept parallel to each other as they move. The movement of the fingers is also symmetric to the center of the gripper – in other words, both fingers always move in or out the same amount. Note that only the finger mounting blocks are shown above – longer fingers will be provided for the various course-related tasks if needed. If you use this gripper for a custom project, you may need to machine your own fingers. CAD files are available for the finger mounts.

The stroke for this gripper, i.e., the distance between the open and closed positions of the fingers, is 14.4 mm. The holding force varies according to the air pressure used; the total opening grip force is 63 lbf; the total closing grip force is 57 lbf. This is assuming an input air pressure to the gripper of 87 psi (6 bar).

### Angular-Finger

The angular-finger gripper is shown in figure below.



**Figure 23: Angular-finger gripper**

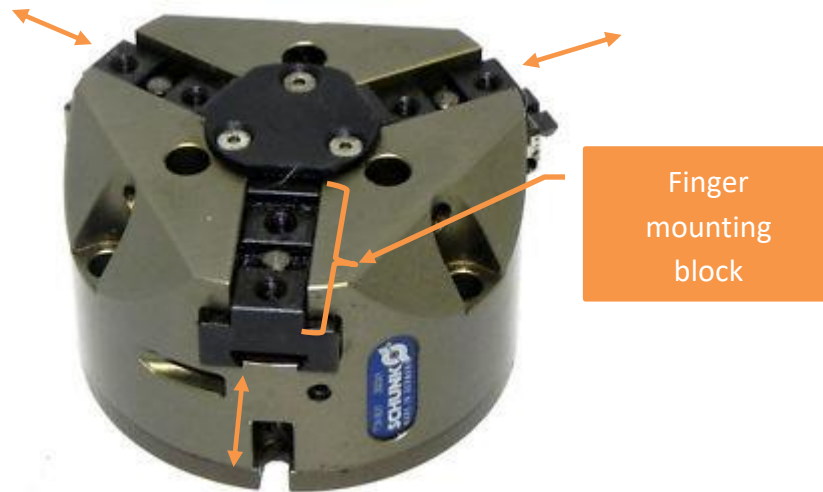
As the name implies, the fingers rotate with respect to each other as they move. Again, the movement of the fingers is symmetric to the center of the gripper – in other words, both fingers always rotate by the same amount.

If you think of the straight-up position of the finger mounts as  $0^\circ$ , the gripper can rotate from  $30^\circ$  outward (as shown in the picture above) to  $-10^\circ$ . Those are total angular displacements – in other words, as shown above, the angle between the two finger mounts is  $30^\circ$ .

The stroke for this gripper, i.e., the angle between the open and closed positions of the fingers, is therefore  $40^\circ$ . The holding torque varies according to the air pressure used; the total closing torque is 28 in-lbf at 20 mm along the tool. This is assuming an input air pressure to the gripper of 87 psi (6 bar). The total opening torque is 32 in-lbf.

## Radial-finger

The radial-finger gripper is shown in Figure below.



**Figure 23 - Radial-finger gripper**

As the name implies, the fingers move radially in and out with respect to the center of the gripper. That movement makes this type of gripper perfect for gripping cylindrical objects (rods, etc.). Note: No actual fingers are shown on the above gripper. What you see are the mounting blocks for the fingers.

## Suction Cup

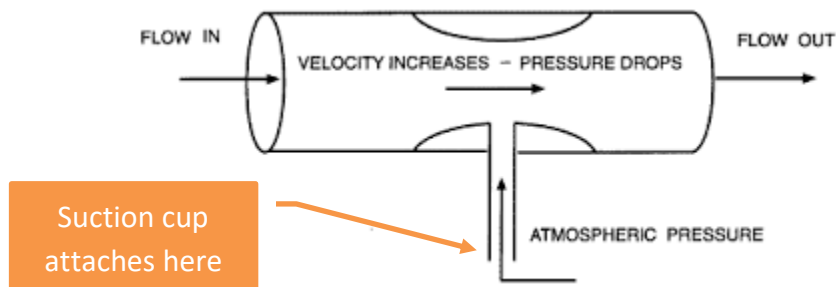
The fourth standard gripper available for use in this course is a pneumatic suction cup. The suction cup is mounted to a 'suspension' as shown in figure below. The suspension allows for some compliance in the Z direction of the gripper. So to use the suction cup, you would have the robot press the cup against the flat surface to be gripped so that the spring in the suspension is compressed a little – then the vacuum is turned on.





**Figure 24 - Suction cup suspension system**

The vacuum is created from the supplied high-pressure air by use of a vacuum generator – also called a venturi. See the diagram in figure below to understand how a venturi works.



**Figure 25: Cross-sectional view of a venturi**