Denso 6-Axis robot

User Manual

Denso robot

Quanser Inc.
2013

CONTENTS

1 PRESENTATION

1.1 Introduction

The Denso 6-Axis robot shown in Figure 1.1 consists of a Denso VP6242G and a Quanser open-architecture control module which has all the capabilities of an industrial system and is interfaced to QUARC. This module contains 6 amplifiers and built-in FF (feed-forward) and PID (proportional, integral, derivative) controllers. The controllers are operating about each motor at a rate of 4kHz. All the gains in the built-in controller are accessible from QUARC blockset. These blocks also have direct access to the amplifiers current commands in the module. The user can both tune the built-in controller gains in QUARC interface or she/he can design their own controller in Simulink environment and command the amplifier currents directly in a fully open-architecture scenario.

Figure 1.1: The open-architecture 6-axis robot enabled by Quanser

In the fully open-architecture mode, user-defined currents are sent directly to the motors and the operator is responsible for implementing a stable feedback system. **CAUTION: Extra care must be taken when operating the robot in open archetecture mode. The designed or modified controller should always include safety precautions to avoid damage to the robot and the personnel if the controller goes unstable.** The general system description, component nomenclature, specifications, model parameters are given in Section 2.1. Section 3.1 goes through several laboratory requirements and Section 3.2 lists various documents that are referenced in this manual. Wiring of different components and quick setup is also given in Section Section 3.1 and Section 3.2 describes the Kinematics and Jacobian derivation of the 6-Axis robot. An overview of various supplied files with the robot is given in Section 2 of the Open-Architecture Setup Guide. The procedure to run the supplied open-architecture controllers on the actual robot system is discussed in the same section as well.

2 DENSO ROBOT COMPONENTS

2.1 Main Components

To setup the Denso in open-architecture, the following hardware and software are required:

Name	Description
Denso 6-axis robot	Denso robot arm with compact control module as shown in Figure 1.1
PC with QUARC Software	PC with the QUARC-Simulink configuration as detailed in Section 3.2
Force-Torque Sensor	ATI multi-axis force/torque sensor system as described in Section 3.2 [1]

Table 2.1: Main Components of the Denso system

2.2 Denso 6-Axis robot Specifications

The Denso 6-Axis robot system includes the 6 DOF robotic arm and the control module. This document also assumes that the robot includes the optional force-torque sensor. This section summarizes the specifications of the Denso 6-Axis robot encoders and motors. The Denso robot arm has six encoders that measure the angular position of the six motors. The encoders and motors specifications are summarized in Table 2.2. This table lists the encoders resolution, motors gear ratios, motors torque constants, and joints hard stop limits. The joints 2, 3, and 5 are zero when the robot is completely straightened up as depicted in Figure 2.1.

Figure 2.2 demonstrates the world frame 0 and the joint frames which are used to define the kinematics/inverse kinematics and Jacobian matrix.

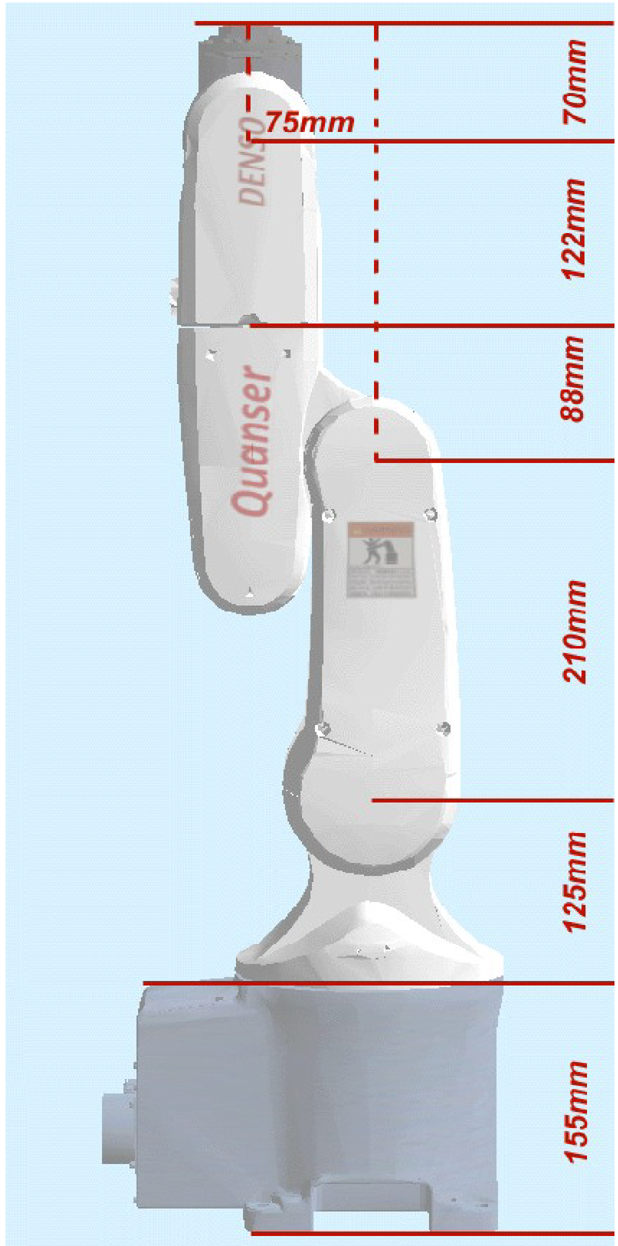

Figure 2.1: The link lengths are displayed in milimeters.

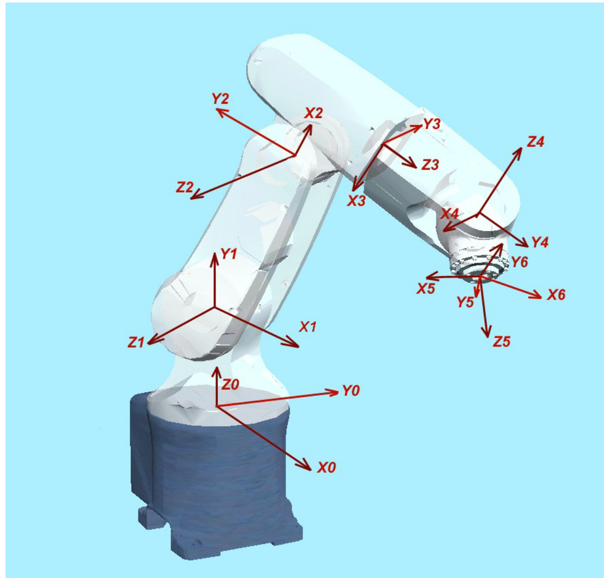

Figure 2.2: World frame and join frames used for kinematics calculation.

Motor/Encoder Starting with Base	Motor Gear Ratio	Encoder Calibration (count/deg)	Torque Constant N.m/Amp	Joint maximum stop limit (deg)	Joint minimum stop limit (deg)
1	120:1	43690.666670	0.38	160	-160
2	160:1	58254.222220	0.38	120	-120
3	120:1	43690.666670	0.22	160	20
4	100:1	36408.888890	0.21	160	-160
5	100:1	36408.888890	0.21	120	-120
6	100:1	36408.888890	0.21	360	-360

Table 2.2: Motor and encoder calibration specifications for Denso 6-Axis robot VP6242G

3 DENSO ROBOT CONFIGURATION AND SETUP

■ **Caution: If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.**

3.1 Denso robot prerequisites

There are several Denso manuals that need to be consulted prior to controlling the system in open-architecture mode. This document does not go through many basic robot operations that are covered in the Denso robot manuals. To successfully carry out this laboratory, the prerequisites are:

1. In order to install theDenso 6-Axis robot system the user must carefully study references 4, 5, and 6. This document goes though how to install, test, and wire the system for open-architecture implementation.
2. If the multi-axis ATI force/torque sensor with corresponding data acquisition board is used, make sure you read through References 1 and 7 for installation and other information. Section 4.2 here describes how to mount and wire the ATI F/T sensor on the Denso robot arm.
3. The user should be familiar with using QUARC to control and monitor the robot in real-time and to design a controller through Simulink. See References 2 and 3 for more details.
4. The information for the serial port PCI card are provided in reference 8.
5. The information for installation and communication with optional Faulhaber Linear Actuator is given in reference 9 (Optional).

3.2 References

1. Multi-Axis ATI Force/Torque Sensor(CD1).
2. QUARC User Manual (type doc QUARC in Matlab to access).
3. QUARC Installation Guide(CD2).
4. Denso Robot General Information(CD3).
5. Denso Robot Safety Precautions(CD3).
6. Denso Robot Installation and Maintenance Guide(CD3).
7. National Instruments 16bit Data Acquisition Board(CD4).
8. Serial Port Card Installation Guide(CD6).
9. Tool Faulhaber Linear Actuator(CD7) (Optional).

3.3 Open-Architecture System Setup

Section 3.4 gives an overview of open-architecture connections. The force/torque sensor installation is outlined in Section 4.2 followed by the wiring needed for open-architecture operation in Section 4.1. Homing the robot arm from its crouched position is also explained in the latter section.

3.4 Overview of Open Architecture Teleoperation System (Optional)

In open-architecture mode, the encoder sensors as well as the actuators in the system are connected to the PC through the Quanser control module. This is shown in Figure 3.1. In this mode, the controller algorithm is designed in Simulink and implemented with QUARC instead of using Denso own controller. QUARC generates real-time code from a Simulink model and targets it on the processor of a PC. Figure 3.1 demonstrates the components involved in a single PC bilateral teleoperation setup. The main components are a PC,

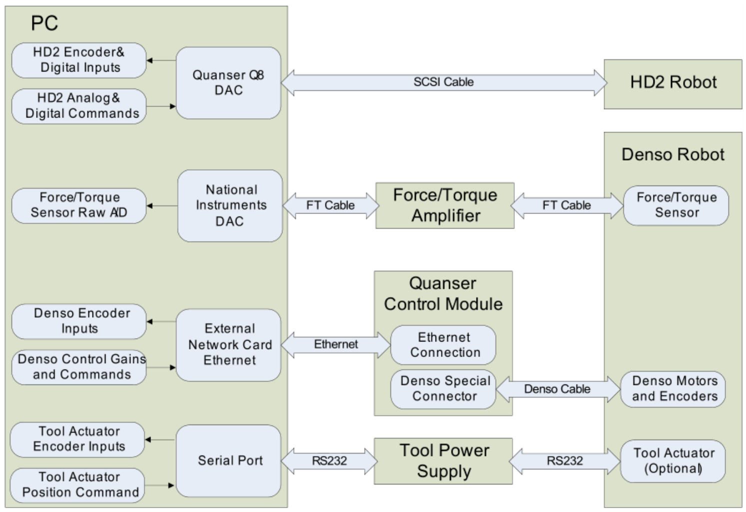

Figure 3.1: Open Architecture Teleoperation System Overview (Single PC).

master robot (Quanser HD2), slave robot (Denso 6-Axis robot), and force/torque sensor. The F/T sensor is mounted on the Denso robot end-effector and wired to the data acquisition board in the PC through the amplifier and special, optional cables. Quanser control module contains the amplifiers and embedded controllers for the Denso arm. It is connected to the specialized network card in the PC through Ethernet cable. The HD2 robot utilizes a SCSI cable to make this onnection. In case a tool is delivered with the robot then the RS232 cables are required to wired the tool electronics box to the PC and the Denso robot back panel. It should be mentioned that the Quanser control module should preferably be connected to the specialized external network card in the PC. Figure 3.2 demonstrates the components involved in a double PC bilateral teleoperation. PC No.1 (Master PC) communicates with the master robot and transmits the commands to the Slave PC (PC No.2/Denso PC) over the communication network. The slave PC (Denso PC), on the other side, communicates with the slave robot and measures the force/torque sensor data and sends the measurements back to the master PC over the communication network.

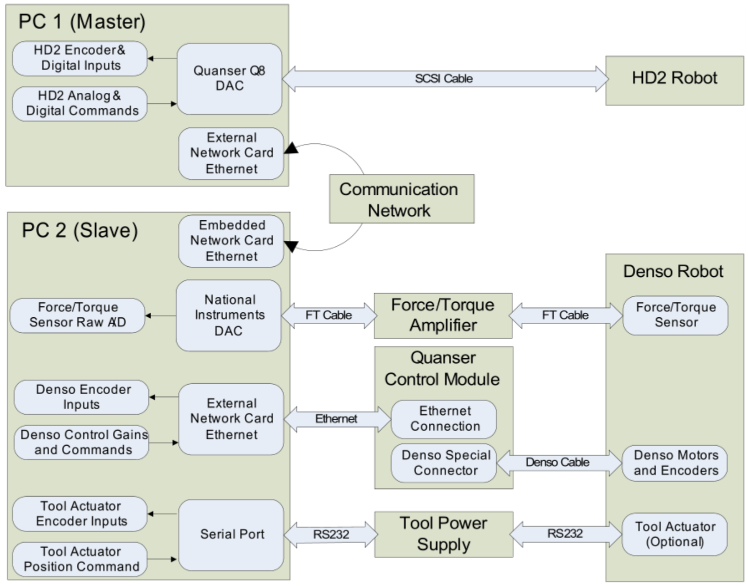

Figure 3.2: Open Architecture Teleoperation System Overview (Double PC).

4 WIRING PROCEDURE FOR THE DENSO 6-AXIS ROBOT

4.1 Open-Architecture Wiring Procedure

This section explains how to connect the PC to the Denso system in order to control the robot in open-architecture mode. It also explains how to interface an ATI force-torque sensor to the Denso robot.. There is a total of 12 sensors in the system. This includes the six motor encoders and the six signals from the analog force-torque device. In case of using the tool a serial connection will provide the user with different information about the tool actuator such as current consumption, encoder data, and temperature. There are seven actuators: six motors in the robot arm, and the servo gripper motor at the end-effector (optional).

■ **Caution:** bf The reader is referred to Section 3.4 for more information on wiring overview. For connecting the HD2 robo t to the maaster PC the reader is referred to HD2 User Manual.

The wiring procedure for the Denso 6-Axis system with two PCs and the force-torque sensor is explained in the following steps. All the required connectors will be available on one PC as well in case of using a single PC setup. Step

1. Make sure everything is powered off before making any of these connections. This includes turning off your PC and the Denso control module.
2. It is assumed that a data acquisition board is installed for the Force/Torque sensor in the PC that is used to measure the F/T sensor data.
3. Connect the 68-pin SCSI ribbon cable (No.2 in Figure 4.6), from the SCSI connector on the back panel of the PC to the appropriate connector on the force- torque sensor power supply box given in Figure 4.6. This carries the analog force and torque signals from the F/T sensor to the data acquisition board on the PC.
hline **In case of using an HD2 device on the same PC there will be two SCSI connectors on the back of the PC. Extra care should be taken to avoid misplacing the cables with similar shapes. The operator should follow them labels on the SCSI connectors on the PC.**
4. Wire the male side of the transducer cable (No1 in Figure 4.6 and Figure 4.5) to the "From F/T" connector on the force-torque sensor power supply, as illustrated in Figure 4.6. Connect the other side of the cable (with the holes) to the actual F/T sensor connector shown in Figure 4.5. This cable powers the F/T sensor and carries its force and torque raw analog signals in order to be interfaced to the PC.
5. Connect the E-Stop cable to the corresponding connector on the Quanser control module (No.4 in Figure 4.2 and Figure 4.3).
6. Connect the Denso robot special cable (No.3) from the back panel of the 6-Axis robot to the appropriate connector on the Quanser control module as depicted in Figure 4.1 and Figure 4.2.
7. Connect the Ethernet cable from the network card connection on the back of the slave PC to the right connector on the control module as shown in Figure 4.2.
hline **It is highly recommended that the Ethernet cable from the Quanser control module be connected to the PCIX network card as opposed to the embedded network card.**
8. Connect the RS232 cable (No.6 in Figure 4.7) from the serial port connector on the back of the slave PC to the labelled connector on the Quanser electronics box.
9. Connect another RS232 cable (No.7 in Figure 4.7) from the Quanser electronics box (labelled "Robot") to the corresponding connector on the back panel of the Denso robot in Figure 4.1.
10. If there is only one PC used then the Ethernet cable (connector 5 in Figure 4.2) and RS232 cable (connector 6 in Figure 4.7) should be wired to their corresponding connectors on the same PC. Also, the Force/Torque sensor and its PCI DAC board should be moved to the same PC.

11. After all the connections are made, in order to place the Denso robot in home position the user should run the executable file named *Denso_Homing_VMode.rt-windows*. This file should be executed in the PC which is assigned to the Denso robot and connected to the Quanser control module through the Ethernet connection.

Cable	Cable Type	From	To	Function
1	Special ATI Cable	"From F/T" Connector on F/T Power Supply	Force-Torque Sensor	Power the F/T sensor and carries its analog input signals to the power supply.
2	SCSI 68-pin	SCSI "Analog Input" Connector on the PC	"To HIL" Connector on FT Sensor Power Supply	Carries analog signals from the F/T sensor to the NI board.
3	Denso Robot Interface Cable	Denso Robot back panel	The Connector on Quanser control Module	Transmits the signals to and from the control module to the Denso robot.
4	6-Pin mini din cable	E-stop Push Button	The Connector on Quanser Control Module	Transmits the Amplifier Enable Signals from the E-stop button to the control module.
5	Ethernet Cable	Ethernet Connector on the Network Card in the Slave PC	Ethernet Connector on the Denso Control Box	Carries the Data between the PC and Quanser Control Module
6	RS232	Serial Port Connector on the back of slave PC	RS232 Port Connector on the Quanser Tool Electronics Box (Label PC)	Carries the data between the PC serial port and Quanser tool electronics box.
7	RS232	RS232 Port Connector on the Quanser Tool Electronics Box (Label Robot)	RS 232 Port connector on the back panel of the Denso robot.	Carries the Data and power between the Quanser tool electronics box and the tool controller on the Desno arm.

Table 4.1: Denso Open-Architecture Wiring Summary

Figure 4.1: Denso robot back panel

Figure 4.2: Quanser controller interface box

Figure 4.3: E-Stop Push Button

4.2 Installing the Force-Torque Sensor (Optional Package)

This section explains how to install the force-torque sensor at the end-effector of the robot arm, as shown in Figure 4.5. The ATI force-torque sensor has six analog outputs to measure the XYZ force, and XYZ torque. As shown in Figure 3.1, only the force and torque data are fed back to the NI board Analog Input Channels 0-5. Follow this procedure:

1. Make sure the robot is homed before starting this procedure, as detailed in Step 11 of Section 4.1 and in Section 7.3.1, located in the lab guide. In home position joints 1, 2, 4, and 6 are at zero and joints 2 and 5 are at 90 degrees.
2. In Home configuration, the Y label on the F/T sensor is along the X Axis in the global frame (see Section 6) and the X label on the F/T sensor is along negative direction of the Y Axis in the global frame.
3. Align the four screw holes of the force-torque sensor with the sensor holding plate (bottom plate in Figure 4.5).

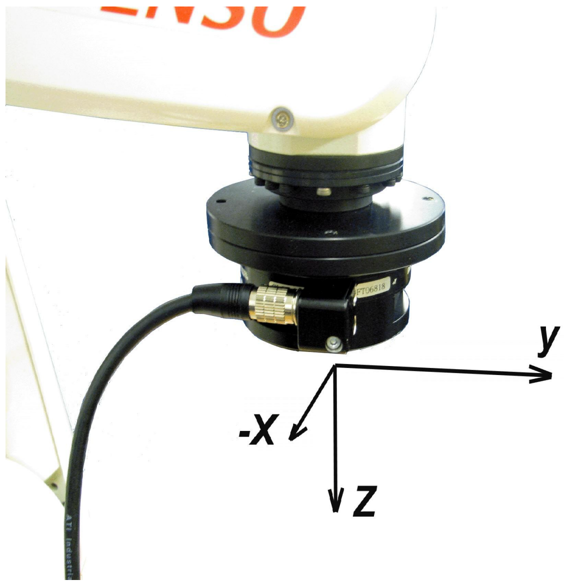

Figure 4.4: Force-torque sensor mounting orientation. The sensor coordinate frame is shown in the figure.

4. Loosely screw the four screws until they are snug.
5. Using a 5/32 in. hex key, tighten the cap screws into the F/T sensor.
   Do not tighten the screws too tightly or you may damage the sensor or alter its readings!
6. Align the four screw holes on the middle of the top plate in Figure 4.5 with those of the robot end-effector and tighten the four screws.
7. Align the force-torque sensor plate with the end-effector plate.
8. As depicted in Figure 4.5, make sure the +X label on the F/T sensor is facing opposite direction of the “-X Axis” in Figure 4.5 and the +Y label is along the “Y Axis” of the frame displayed in Figure 4.5.
9. Loosely screw the four screws until they are snug.
10. Using a 3/16 in. hex key, tighten the four screws to into the F/T sensor.
    Do not tighten the screws too tightly or you may damage the sensor or alter its readings!
11. Go through the force-torque sensor cable wiring procedure described in Section 4.1

Figure 4.5: Force-torque sensor on Denso arm

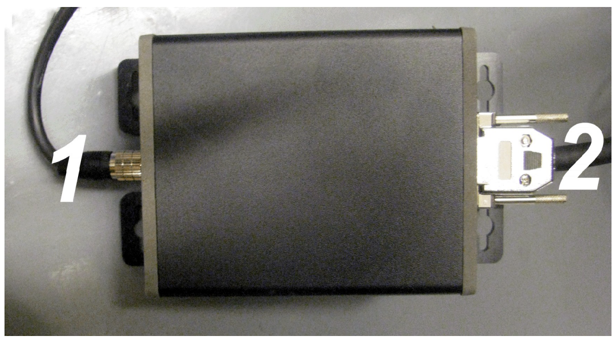

Figure 4.6: Force-torque sensor power supply

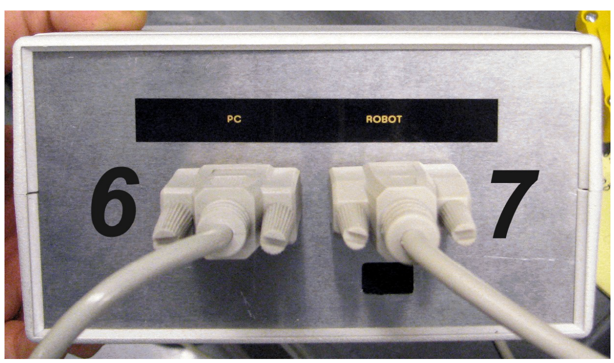

Figure 4.7: End- Effector Tool Electronics Box