# Fanuc Robot Specification

## Global Common

## SD-1040

ISSUED March 9, 2017
REVISED January 29, 2024

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# Annex

# 1. General

## 1.1 Scope

This specification contains principles, guidelines, and requirements for the design, redesign, and implementation of robotic work cells containing one or more FANUC robots for use in process or manufacturing at Nexteer Automotive.

Nomenclature in this specification is as follows:

- Shall – indicates requirement.
- Should – indicates recommendation.
- May – indicates permission or allowance.

NOTE: Changes since the last revision are highlighted.

## 1.2 Purpose

The purpose of this specification is to establish common robotic work cells to Nexteer Automotive's Manufacturing Community which includes Operators, Skilled Trades, Engineering, Safety Personnel and Equipment Suppliers. This specification will provide the knowledge, tools, and methods to achieve safe, robust robotic work cells.

## 1.3 Informative Reference

See Annex A for a list of informative references. Users of this document shall consult applicable Federal State, and Local laws, regulations, and Standards in addition to those listed in Annex A.

## 1.4 Application

The requirements of this specification shall be applied to all new Machinery & Equipment (M&E) and Manufacturing Systems containing one or more FANUC robot systems.

## 1.5 Deviations

Any deviations from this specification shall be addressed during the Design Review or Machine Risk Assessment development with alternative solutions documented and approved by the Nexteer Purchasing Engineer, Controls Engineer, Robotics Engineer, and H&S Representative. Any approved deviations shall only apply to that specific instance and is not considered a change to this specification or acceptable for future M&E purchases.

# 2. Robot Selection and Installation

## 2.1 Selecting a Robot

The Supplier is required to analyze work cell requirements to determine max payload and reach dimensions required for the application. Suppliers shall use the FANUC Payload Checker to ensure the selected robot can handle the intended payload. The payload checker can be downloaded as part of the Nexteer FANUC Robot Toolkit from the Nexteer Data Exchange site. The appropriate robot model shall be selected from Nexteer Automotive Specification SD-007 Approved Components List.

Robots shall be appropriately selected for region installation:

- North American robots have a serial number of F-xxxxxx.
- European robots have a serial number of E-xxxxxx.
- Asia-Pacific robots have a serial number of M-xxxxxx.

## 2.2 Required Options

Nexteer requires all incoming robots to include specific options. A detailed list of requirements is listed in Nexteer Specification SD-007 Approved Components List. Depending on the individual applications, additional options may also be needed.

## 2.3 Purchasing a Robot

Once a robot model has been selected with size and options verified with FANUC, the Nexteer Purchasing Engineer shall purchase the robot. The robot will be shipped to the Supplier for installation / integration. If the Supplier of the machine receives better pricing discounts than Nexteer, the Supplier may purchase the robot directly from FANUC. In the case of the Supplier purchasing the robot, the Purchasing Engineer shall insure each robot is assigned an asset tag number and documented per Section 8 of this document.

## 2.4 Robot Installation

Each robot shall be installed in accordance with FANUC installation requirements.

The robot baseplate shall be from FANUC , or an exact match of their drawings, and shall include the proper datum features.

Tie-Bars (locating jigs) should be used to position the robot in relationship to the other machines / objects within the work cell.

Each robot controller shall be mounted at a minimum of 203mm (8”) from the floor.

# 3. Programming

Robot programs shall be clearly structured, well commented, and clearly named. Program instructions that are no longer needed, but remain remarked, shall be removed. Programs that are empty, or just contain comments, shall be deleted. Background programs may be used when applicable. KAREL programs may be used; however, the Supplier shall provide all source code for any KAREL programs used to facilitate support and troubleshooting requirements.

## 3.1 Robot Libraries and Setup

Nexteer has developed a FANUC robot startup package which is available on the Nexteer Data Exchange at www.nexteerdataexchange.com. The startup package includes the following:

- **Program Libraries**
  - The program libraries include the robot programming structure, which is representative of how all programming is to be completed. These programs will need to be completed by the Supplier based on application requirements.
- **Payload Checker**
  - The payload checker allows for an analysis of the End of Arm Tooling (EOAT) with and without a load (part). The checker will indicate if the Payload, Center of Gravity (CG), and Inertia of the EOAT are appropriate for the robot. The checker will convert the given parameters into payload data which may be used by the programmer as inputs for robot payload schedules.
- **Robot Toolkit**
  - The Nexteer FANUC Robot Toolkit is an Excel workbook that can be used to fulfill many of the requirements in this specification by using the toolkit's various setup features. The Toolkit generates a 'NXTR_Config' KAREL program file that can be compiled in FANUC's Roboguide software. The compiled NXTR_Config KAREL program provides a user interface on the teach pendant for configuring the robot per Nexteer's base configuration, and for commenting based on the user inputs into the Toolkit. It also provides the option to configure I/O per the requirements of this specification, and can generate a .L5X file for import of PLC UDT's into Rockwell PLC software. This will help to align the PLC I/O with the robot I/O. Instructions for the Robot Toolkit's use are in the Robot Toolkit.

    NOTE: A FANUC Command file (.cm) is also provided in the startup package that will configure system variables and I/O per the requirements of this specification. This file may be used when FANUC Roboguide software is not available.

- **Background Program**
  - Nexteer's standard background program, NXTR_BG.TP, shall be ran in BG Logic on all robots. The background program provides a heartbeat signal to the PLC using Nexteer's robot logic routine. If the background program is not running, the robot will be put into a fault condition by the PLC. Existing programming within the background program shall not be removed. However, additional programming may be added to the background program when warranted by the application.

## 3.2 General Programming Requirements

### 3.2.1 New User Frames / User Tools

Utilizing robot world frames is preferred. User frames shall be used only when necessary, such as when the machine or fixture within the cell is not aligned with the robot world frame. The Z positive axis shall be taught such that it is normal to the surface / object (see below example picture). Any user frame that is used should have its origin, X&Y direction, labeled on the machine wherever it is possible.

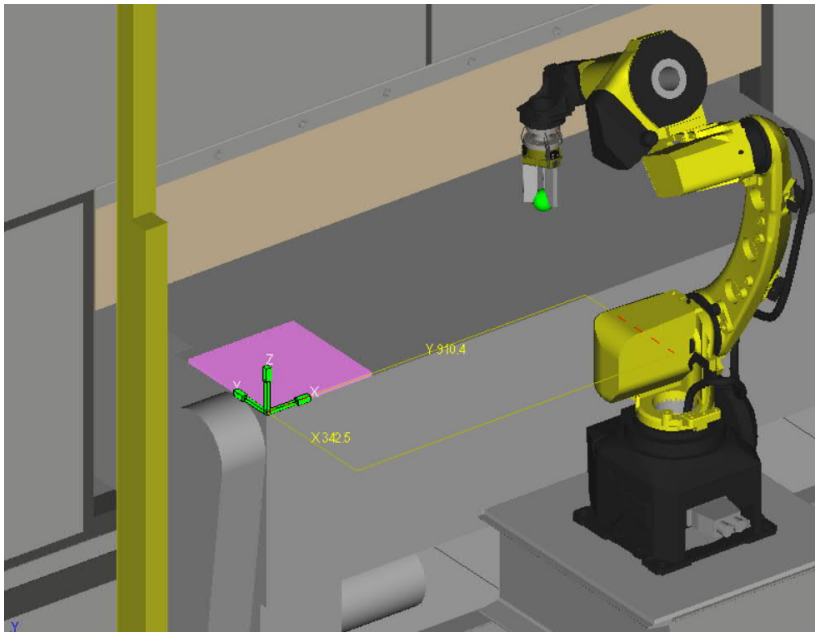


Figure 3.2.1 – User Frame Example

User tools shall be defined on all robot applications. If possible, each tool or feature shall be labeled with the corresponding user tool number. If there are multiple tools, then each tool shall have a defined User tool number associated with it.

If a user frame or tool is used, the supplier shall provide any necessary tooling or fixtures to set up the user frame or tool TCP. Example: Pointer set for teaching user frame or tool. In addition to the tooling or fixtures required for teaching, procedures shall be supplied on how to teach each user frame and tool.

### 3.2.2 Use of Position Registers (PR)

Robot targets shall be position registers to allow for sharing of positions in robot recovery routines. For applications that require large amounts of targets, example dispensing, program points may be used.

- PR[1:Home] and PR[2:Maintenance] shall be the main "HOME" and "MAINTENANCE" positions with a representation in Joint Configuration.
- All perch type positions shall be in Joint representation.

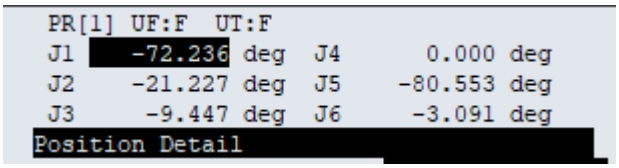


Figure 3.2.2 – Joint representation example

### 3.2.3 Motion Offsets

Offsets are motion modifiers used to offset position points, whether the points are internal program points (P[]'s) or position registers (PR[]'s), by adding the position point and the offset data. Motion offsets shall be used, for example, during picking and placing operations. This ensures the approach point will remain aligned with the pick or place point in the event they are retaught.

- Offset, PR[x]
  - Offset instructions are used to offset the position point with respect to the active UFrame.
- Tool Offset, PR[x]
  - Tool Offset instructions are used to offset the position point with respect to the active UTool.

### 3.2.4 Argument Registers (AR)

When argument registers are used, a comment shall be provided in the called program describing the function of each argument register. If the called program is a KAREL program, then the calling program shall contain the comments describing the function of the argument register.

### 3.2.5 Numeric Registers (R)

Each numeric register shall only be used for a single function across all programs. Each numeric register shall have a name describing its function.

### 3.2.6 Collision Detection

Collision detection shall be used anytime a robot or robot tooling is interfacing with peripheral equipment. Collision detection requires accurate payload and center of inertia information to properly function.

### 3.2.7 Use of Reference Positions

Each used reference position shall be assigned to a Digital Output (DO). Examples: Infeed Perch, Outfeed Perch, etc.

Required reference Positions:

- Ref Pos 1 - “Home” shall be assigned to DO[253]
- Ref Pos 2 - “Maintenance” shall be assigned to DO[254]

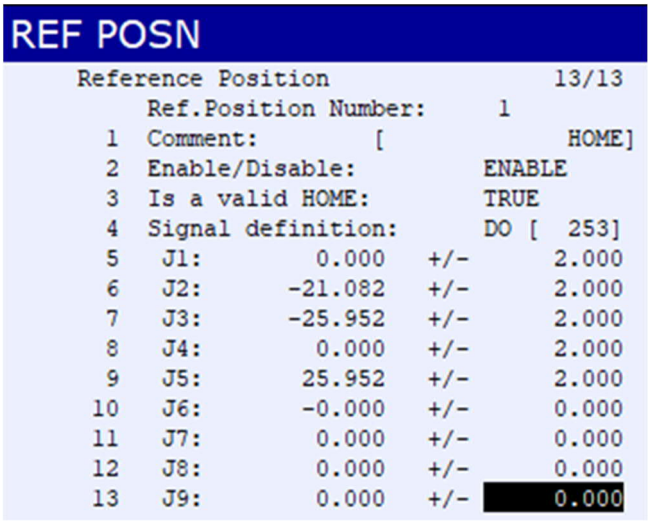


Figure 3.2.7 – Reference position example

### 3.2.8 User Alarms

User Alarms shall be used to notify personnel and the PLC of an error that has occurred while the robot was running. For example, when a camera that is providing part location information to a material handling robot cannot detect a part, the robot would call a User Alarm. The severity of the User Alarm is dependent on the reason for the alarm condition. Figure 3.2.7 (b) shows severity values along with an action description.

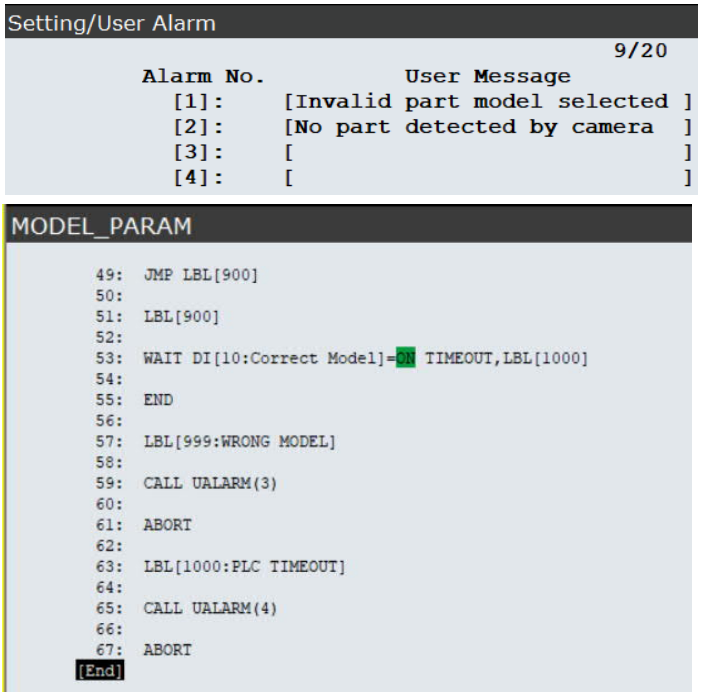


Figure 3.2.8 (a) – User Alarm usage

| Value | Action |
|---|---|
| 0 | No action |
| 2 | Pause program |
| 3 | Abort program with error |
| 4 | Stop program motion |
| 6 | Pause program and stop its motion |
| 8 | Cancel program motion |
| 10 | Pause program and cancel its motion |
| 11 | Abort program and cancel its motion |

16 added to any value causes servomotors to be turned off.

32 added to any value causes the action to apply to all programs and all motions.

64 added to any value requires a Cold start to reset the controller.

Figure 3.2.8 (b) – User Alarm severities

### 3.2.9 Recovery

A robot recovery process shall be provided to enable recovery of the robot from any stop condition in the normal operating space. Recovery shall only be initiated through the operator panel HMI. The logic initiated by the “Return All Motions” button on the HMI shall also initiate the Recovery procedure in the robot. It is up to the Supplier to determine the correct sequence of recovering the robot along with the other motions in the cell. Use of the teach pendant is only allowed to recover from abnormal situations such as a collision.

The recovery program shall comply with the methods stated within this Section and be as simple as possible. The methods listed are used to find the location of the robot within the restricted space. Once the location has been determined, any motion process can be used to move the robot into a safe position. Once in the safe position the robot shall move to a valid home position. The recovery library is a combination of all methods listed below.

Consulting with Nexteer Robotics CSE is highly recommended prior to creating a recovery strategy.

- Dual Check Safety (DCS) Zone(s) Method

  The robot's current location is associated with the defined DCS zone(s) which were created in the robot. Each zone has an associated DI. These DI statuses can be used in the Recovery program to determine subsequent motions to define a clear path home.

- Cartesian Coordinate Method

  The robot's current location is compared to known X, Y, and Z coordinates. The robot then travels on a clear, unobstructed path at a velocity that is appropriate for the robot's current location. Once the robot has reached safe perch type position, the robot shall proceed to the home position on a predetermined path.

- Joint Angle Method

  The robot's current location is compared to known joint angles. The robot then travels on a clear, unobstructed trajectory at a velocity that is appropriate for the robot's current location. Once the robot has reached safe perch type position, the robot shall proceed to the home position on a predetermined path.

- Reference Position Method

  The robot's current location is associated with the defined area(s) that were created by means of creating Reference position(s) with specific joint tolerances. Each Reference position has an associated DO. These DO statuses can be used in the Recovery program to determine subsequent motions to define a clear path home.

Prohibited Recovery Methods (Unless agreed upon by Nexteer Robotics CSE)

- Register Tracking
- Active User Frame (Can be used once robot location has been found)

### 3.2.10 Code Structure

Robot start signals shall use the Program Number Select (PNS) method. All programs shall run through one Main looping program that shall be identified as PNS0001. The Main program shall be divided into smaller subprograms, for example: "Pick_Conveyor" or "Gripper_Close". The preferred approach, as demonstrated in Nexteer's robot logic routine, is that these subprograms be called in the Main program based on the status of Digital Input signals. The

main looping program shall not contain motion instructions. Additional PNS signals may be used for discrete tasks cycle (e.g. camera calibration program).

Required PNS Programs:

- PNS0001 – Main Program
- PNS0002 – Recovery (Home) Program
- PNS0003 – Maintenance Position Program

## 3.3 Robot Speed

### 3.3.1 Override speed

The override speed shall be set using the "OVERRIDE=R[190:Robot Speed]" instruction within the looping section of the Main Program, ensuring it is executed after each task/subprogram is completed. Placement of the instruction in this location allows for the robot speed to be lowered during Auto cycle for troubleshooting purposes, while setting the robot speed back to normal operating speed at the start of the next Main program loop. In certain instances, an additional Override instruction setting the robot to the required speed for the application may need to be placed directly prior to a process step, such as dispensing, so part quality is not affected by the change in override speed. Register R[190:Robot Speed] shall be set with a predefined Group Input (GI[1:Robot Speed]); this instruction is included in the most current Nexteer NXTR_BG background program.

### 3.3.2 Recovery speed

To prevent any potential damage to the robot and peripheral equipment, the recovery speed must be considerably slower than the normal operating speed. During the recovery process, the override speed shall remain at the normal operating speed. Reduced speeds can be achieved by adjusting the speed of motion instructions to a lower value within the recovery program. Registers may be used to designate the speed of motion instructions. Once the robot has reached a known perch location, it is possible to increase the recovery speeds.

### 3.3.3 DCS Speed Check

When deemed necessary by the Machine Risk Assessment, DCS Speed Check shall be implemented to limit the robot's speed to the same speed value used for any safe distance calculations.

## 3.4 Program Naming and Commenting

### 3.4.1 Program Naming

Naming shall be relevant to the task being performed. Common examples are shown below for reference only.

- Pick_1234
- Drop_Model1
- Load_Short
- Unload_Long

### 3.4.2 Register and I/O Naming

Naming shall be relevant to the purpose of the element. Common examples are shown below for reference only.

- PR[1:Home]
- R[3:Current Infeed]
- DI[1:Part Ready]
- DO[1:At Perch Pos]

### 3.4.3 Comments

Commenting inside the program shall be required. Multi-lng Remark is preferred as it allows for more than 32 characters. Comments shall briefly describe the step currently being performed by the program. Message instructions shall not be used.

### 3.4.4 Headers

"PNS0001" program shall contain a header which contains the following information:

- Integrating company's name, address, and phone number.
- Name, address, and phone number of any subcontractors involved in the programming.

Example Main Program Header:

```
-- Machine Builders Inc.
-- 123 Main Street
-- Hometown, IN  USA
-- 555 -555-5555
--
-- Programmed by:
-- Robot Automation Inc.
-- 456 Main Street
-- Hometown, IN  USA
-- 555-555-4444
```

All other programs shall contain a header with a brief description of the task to be performed by the program.

Example Program Header

```
-- Close Robot Gripper
```

## 3.5 Payload and Inertia

Accurate payload, center of gravity, and moment of inertia data is critical to proper robot performance. Suppliers shall be responsible for providing this information and setting up the proper motion profiles for the robot; both with and without parts. The active Payload schedule shall change based on robot control of parts and automatic EOAT changes.

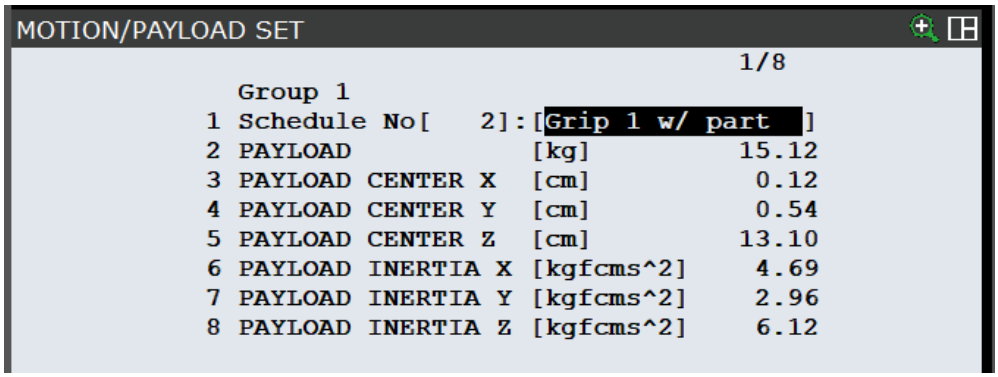


Figure 3.5 (a) – Payload schedule example

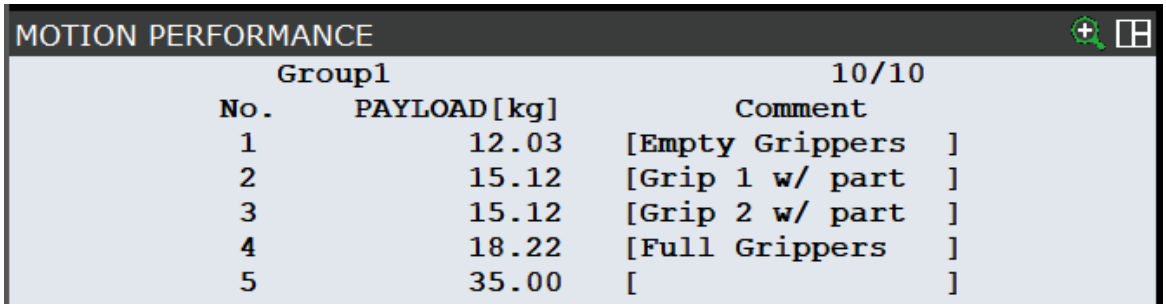


Figure 3.5 (b) – Multiple payload schedules

# 4. Robot Integration

Control of robot signals shall be managed by the PLC of the machine being tended by the robot(s). The robot shall not be used as the cell controller.

## 4.1 Robot Configuration

### 4.1.1 Communication Adapter

All Nexteer robot controllers are required to communicate with the machine or cell controller PLC using Ethernet/IP protocol. The Supplier is required to request robot IP address information from Nexteer.

The provided IP address shall be set to Port #2 (Port CD38B) of the robot controller. The Supplier is required to configure the robot(s) Ethernet/IP connection with the provided IP address of the PLC.

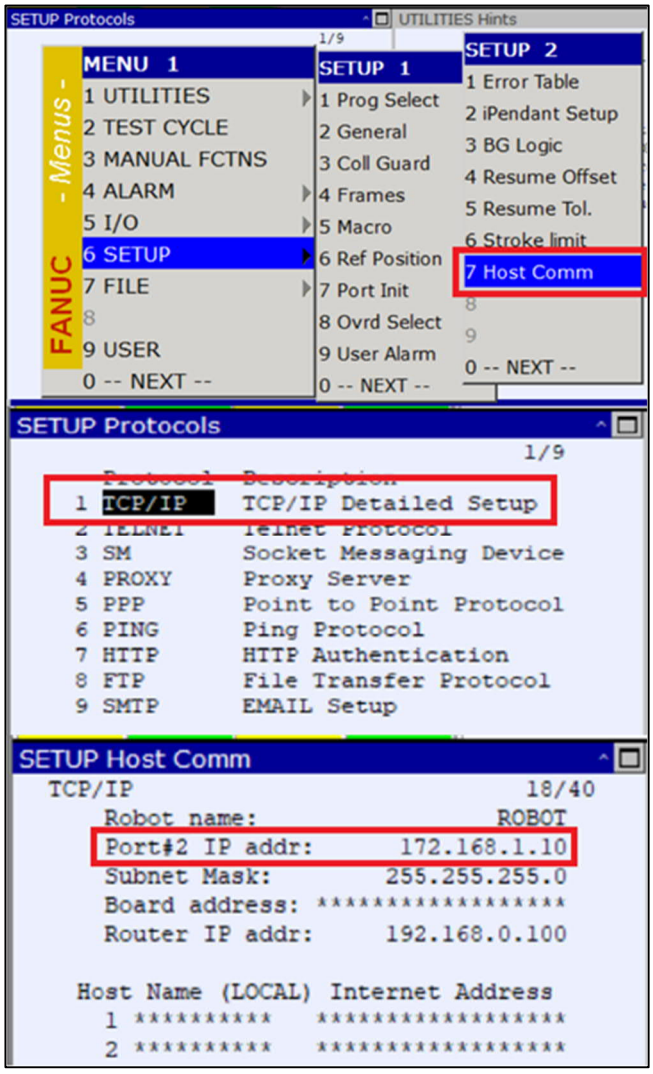


Figure 4.1.1 (a) – IP address assignment

The Supplier is required to configure the Ethernet/IP connection parameters for robot I/O Input Size, Output Size, and RPI (ms) rate matching the configuration of the robot module in the PLC. The required settings for these values are:

- Input Size: **32** (16-bit words)
- Output Size: **32** (16-bit words)
- RPI (ms): **32 ms** (default)

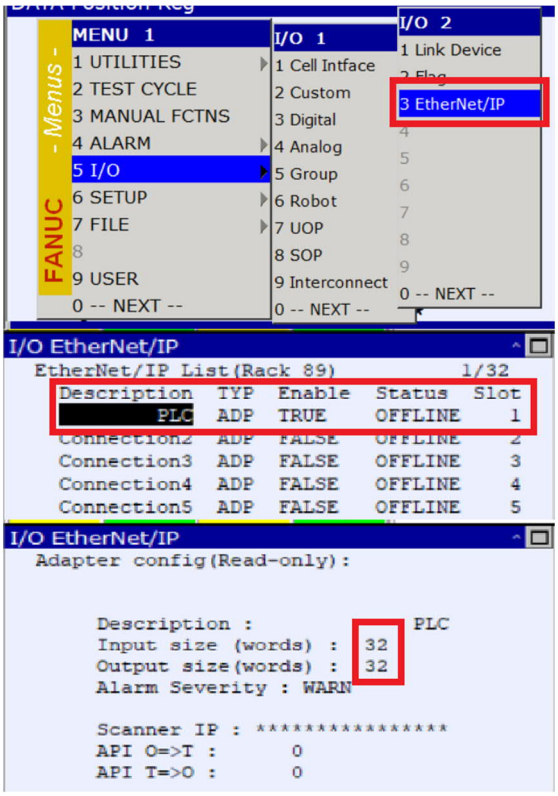


Figure 4.1.1 (b) – Input/Output size configuration

### 4.1.2 I/O Configuration

Nexteer utilizes a standard configuration for Digital I/O, User Operating Panel (UOP), and Group I/O data signals. This standard configuration is a starting point for organization and predefined signals. Some predefined signals are not in use and can be implemented if needed. See Annex A for a list of predefined signals. The unassigned Group I/O signals can be modified as required for the application. The standard I/O configuration as well as the predefined signals align with the Nexteer PLC logic and PLC configuration. Mapping overlap of different I/O types is not allowed. I/O Interconnect ES->DO signals shall be configured per Figure 4.1.2 (d).

- **Digital I/O:** Bit 1-256 (32 bytes)
  **Note:** If mapping to rack 36 for DCS zone status, use range DI[500-512] per below.

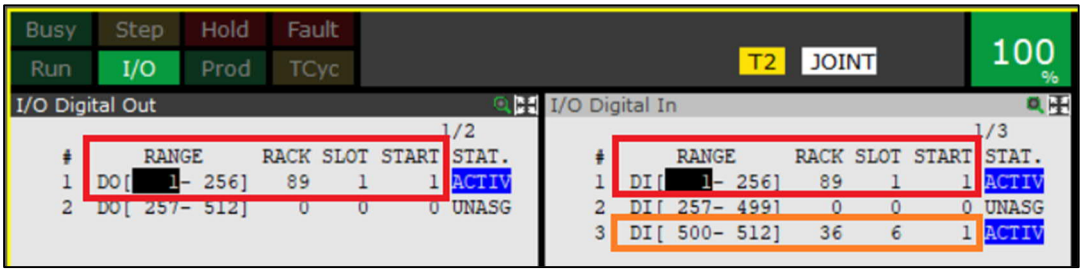


Figure 4.1.2 (a) – Digital I/O configuration

- **UOP Output Signals:** Bit 257-277
- **UOP Input Signals:** Bit 257-275

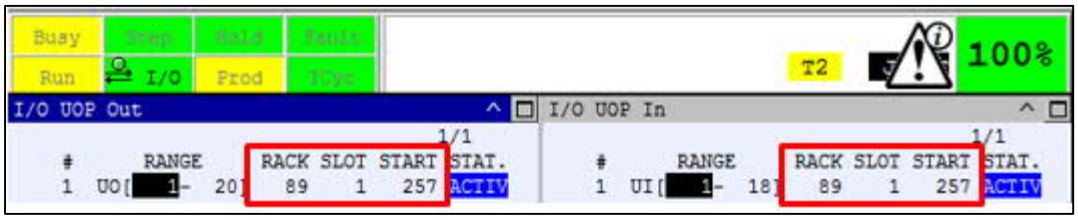


Figure 4.1.2 (b) – UOP configuration

- **Reserved Bits (Output):** Bit 278-288
- **Reserved Bits (Input):** Bit 276-288

- **Group Outputs:** 289-320, 353-512 (configurable for the application) 321-352 (16 bytes)
  **Note**: GO[1-4] total number of points must be 32 for proper output of DCS signature to PLC via GO[5-6].
- **Group Inputs:** 289-296 (8 bytes), 297-499 (configurable for the application)

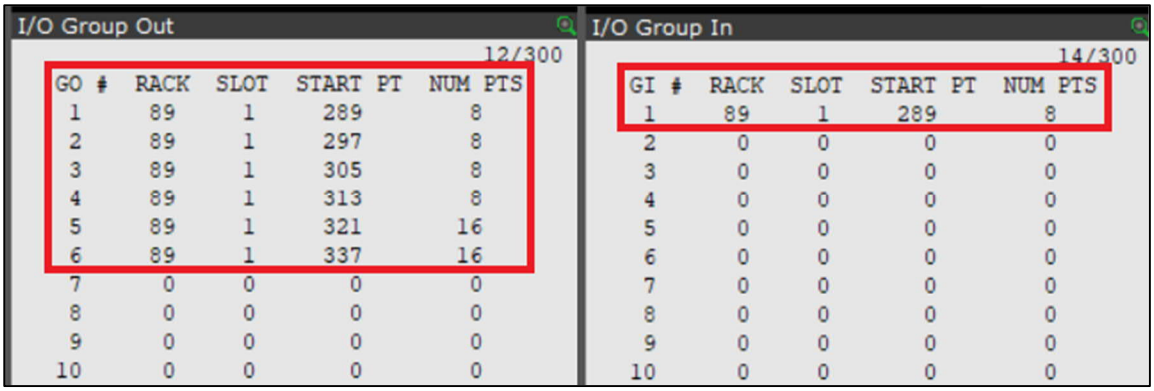


Figure 4.1.2 (c) – Group I/O configuration

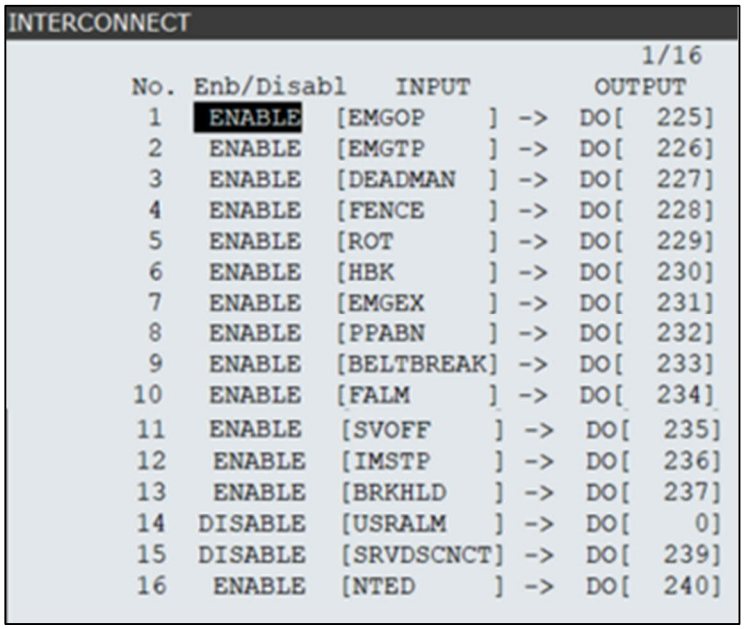


Figure 4.1.2 (d) – I/O Interconnect ES->DO Configuration

### 4.1.3 PLC / HMI Configuration

Nexteer provides a standard robot logic routine and HMI screen used for controlling and monitoring each configured robot integrated with the machine or cell. The routine and HMI screen are available in the "PLC HMI Library Files folder" at www.nexteerdataexchange.com. It will be necessary to modify the logic in this routine to meet the requirements of the application.

### 4.1.4 Robot Module Configuration

The robot ethernet connection is required to be configured in the PLC controller. It is recommended to use the latest FANUC Robotics ethernet module profile available for Rockwell Automation Studio5000 software.

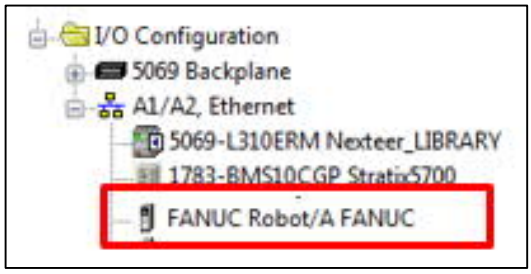


Figure 4.1.4 (a) – Robot Ethernet Module

In order to properly transfer the required Digital I/O, UOP, and Group I/O signals, the module properties shall be configured as follows.

The Input and Output Assembly Instances shall be configured with 64 bytes of data each. The data aligns with the I/O configuration in the robot. See **Annex A** for details on these signals.

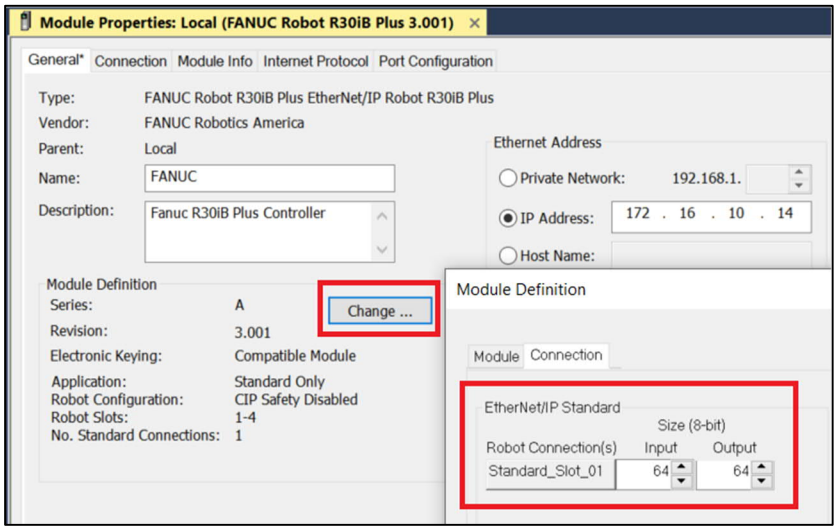


Figure 4.1.4 (b) – Ethernet Module Input/Output Size

### 4.1.5 Import the Standard Robot Routine (R36_Robot_FANUC)

It is recommended that the Supplier export the latest **R36_Robot_FANUC** routine version from the Nexteer PLC logic library file and then import the routine into the appropriate program.

The import configuration dialog will appear. Ensure that Operation is set to Create by entering a unique value for the Final Name. This will only need to be modified if there is an existing R36_Robot_FANUC routine in the program, perhaps due to more than one robot integrated with the PLC.

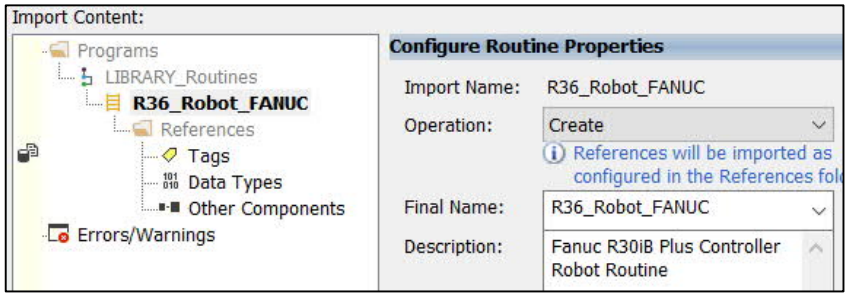


Figure 4.1.5 (a) – Import R36_Robot_FANUC routine

Click on the **Tags** option in the **Import Content** tree. The module tag names will need to be updated to match the name given to the robot module when configuring. The example below has the module named “FANUC”.

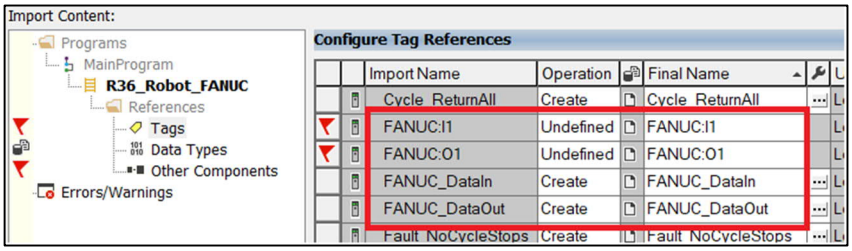


Figure 4.1.5 (b) – Updating Module Tag Names

If there is more than one R36_Robot_FANUC routine, the tag names **Robot**, **Robot_AlarmMsgRead**, and **Robot_WriteREAL** will need to be changed to a unique name representing the robot the routine is interfacing with.

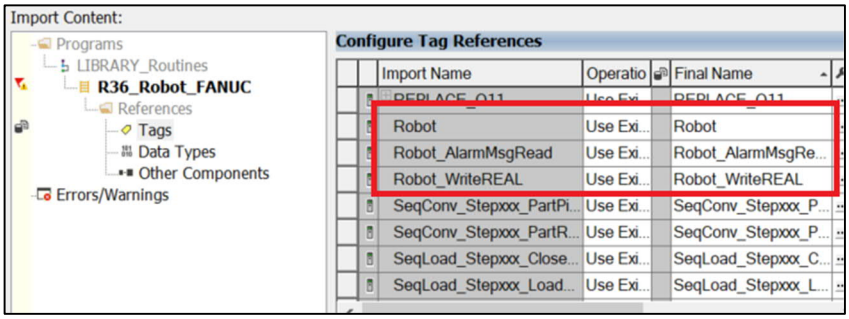


Figure 4.1.5 (c) – Updating Additional Tag Names

This import will create multiple Nexteer standard data types (prefix "**NX_**") and user editable datatypes (prefix "**u_**"). These data types are configured to interface with the Digital I/O, UOP, and Group I/O signals in Nexteer's standard configuration in the FANUC robot. The user editable datatypes have several predefined tags and several spares that may be updated to meet the requirements of the application.

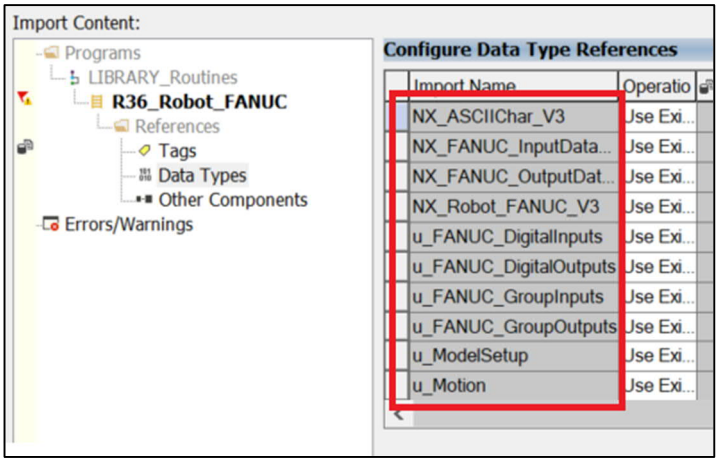


Figure 4.1.5 (d) – Robot UDT's

### 4.1.6 Human Machine Interface (HMI) Screen

The machine or cell controller HMI shall have a separate Robot Screen for each robot being controlled. Nexteer provides a template screen to be used which interfaces directly with the standard **R36_Robot_FANUC** routine tags.

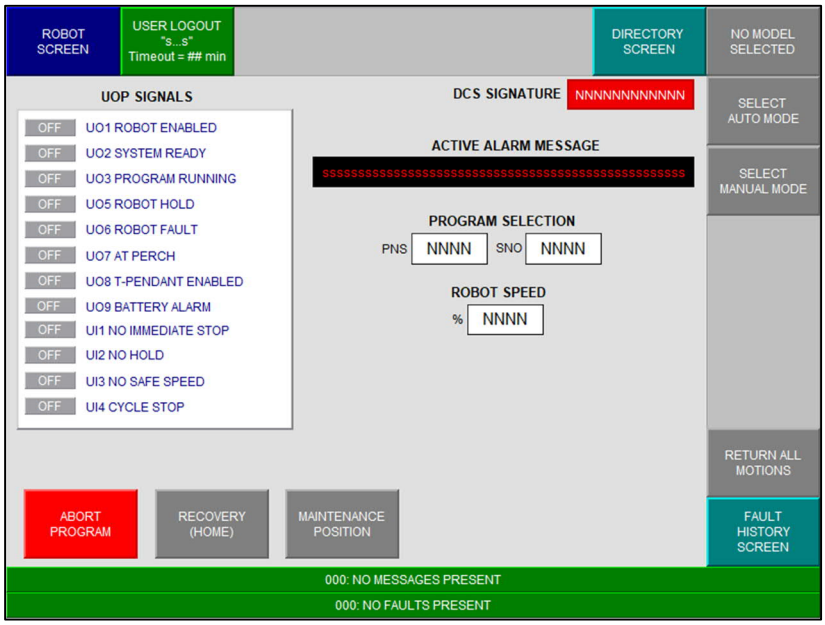


Figure 4.1.6 – HMI robot screen

4.1.7 Functional Operator Buttons

- Recovery (Home)
  - Recovery and returning robot to home position may be used for any stop that does not allow the robot to complete its programmed cycle.
- Maintenance Position
  - Move robot to a maintenance position. This is generally used to provide access to EOAT or peripheral equipment.
- Cycle Stop (provided on Automatic screen)
  - Requests a cycle stop and allows the robot to complete its programmed cycle before stopping. For additional guidance, reference SD-012 (Design-In Health and Safety Specification) and the Machine Risk Assessment.
- Abort Cycle (provided on Automatic screen)
  - Requests an immediate cycle stop and stops the robot wherever it is within the programmed cycle without needing to run out parts; should not be used in place of a cycle stop.

Note: Buttons allowing actuation of robot EOAT are not permitted on HMI screen.

4.1.8 Status and Diagnostic Information

- Program Selection
  - The current PNS and Selected Number Output (SNO) values shall be displayed.
- Robot Speed
  - The robot override speed percentage value shall be displayed. The speed of the robot shall be controlled through the PLC.

    NOTE: Modification of the Override speed using the teach pendant is allowed when required for troubleshooting.
- UOP Status
  - Status indicators shall be provided for all critical UOP signals.
- Active Alarm Display
  - The active alarm shall be displayed in the dedicated banner near the top of the screen and in the machine message banner along the bottom of each HMI screen.
- User Alarm Display
  - The active user alarm shall be displayed in the dedicated banner near the center of the screen and in the machine message banner along the bottom of each HMI screen.
- DCS Signature

- The current DCS signature shall be displayed in the dedicated banner at the top of the screen. This should also be displayed on the Machine Support screen.

- Faults and Messages
  - Robot UOP and Digital Output fault conditions in the robot logic routine shall be programmed in the cell controller fault logic and displayed on cell HMI.
  - Robot Digital Output message conditions in the robot logic routine shall be programmed in the cell controller machine message logic and displayed on cell HMI.

#### 4.1.9 System Variables

A table of specific system variables is provided in Appendix C of this document. These system variables shall be set to the statuses listed in the appendix.

## 4.2 EOAT Control

Robot EOAT control shall be provided by the cell controller PLC. Hazardous output power shall be provided from the appropriate machine control safety circuit based on the Machine Risk Assessment. Reference SD-011 Specification for Safety Circuits and SD-012 Design-In Health and Safety Specification for additional requirements and guidance.

- EOAT I/O signals
  - I/O signals shall be passed between the robot-mounted BNI module and the PLC via ethernet communications.
  - Output signals shall be passed between the robot-mounted BNI module and valve manifold through IO-Link communications.
  - Output power shall be passed between appropriate control circuits and valve manifold as described below.
  - I/O signals shall not be controlled by the robot's EE connector.

EOAT power and signal routing shall be dictated based on robot model as shown below. Reference Figure 4.3 for additional detail.

- M-10 and Larger robots
  - The ASi connector shall be utilized to route hazardous and non-hazardous power internally between the robot base and arm. The internal ethernet pass-through shall be utilized to provide ethernet communication for IO-Link and any other robot-mounted devices utilizing ethernet communication.
- LR Mate and SCARA
  - Robot hazardous and non-hazardous power shall travel externally on the robot from the base to the EOAT due to the lack of ASi connector functionality on these robot models. The internal ethernet pass-through shall be utilized to provide ethernet communication for IO-Link and any other robot-mounted devices utilizing ethernet communication.

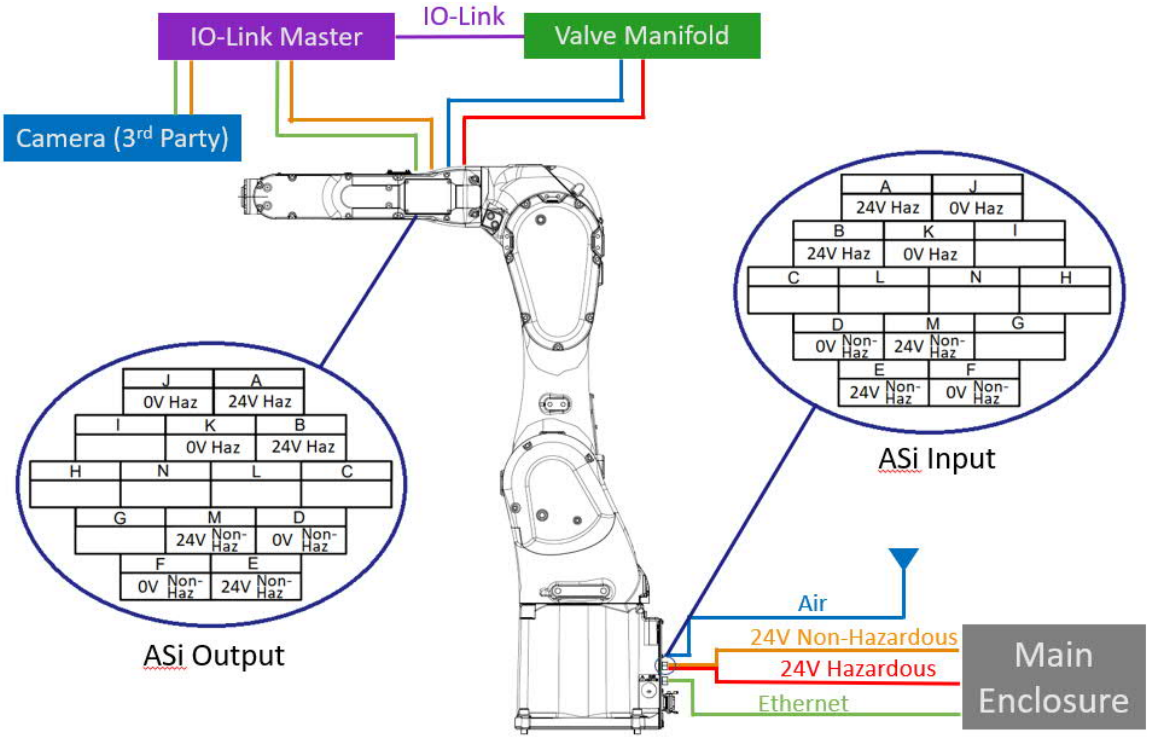


Figure 4.2 – Robot EOAT Architecture

# 5. Vision-Guided Robots

Vision systems shall only be used to guide robots to increase the accuracy of pick and place positions, or to find randomly oriented components. Approved 2D and 3D vision systems for vision-guided robot applications are listed in SD-007. The Nexteer equipment destination facility should be notified of the proposed vision system to provide guidance on preferences. The Nexteer Robotics CSE shall approve vision systems and processes prior to their purchase. Cameras mounted to the robot shall be assigned a UTOOL.

## 5.1 Vision Systems

- iRVision
  - Integrated vision system provided by Fanuc for 2D and 3D applications.
- 3rd Party Vision Systems (through Robot)
  - 2D or 3D Vision system communicating directly to the Robot through ethernet. Socket messaging shall be used to write position or offset data to robot registers along with other functions, i.e. calibration.
- 3rd Party Vision Systems (through PLC)
  - 2D Vision system communicating through the PLC to the robot through ethernet. Explicit messaging shall be used to write position or offset data to robot registers.

## 5.2 Calibration

A calibration grid shall be supplied by the integrator to calibrate the vision system. The calibration grid shall be provided with a fixture, if necessary, to position the grid in the same relative location as the initial calibration. A calibration procedure shall be documented and supplied by the integrator.

# 6. Work Cell Safety

## 6.1 General Work Cell Layout

All robots must be observable from an HMI location while functional operator buttons are utilized. Additional HMI's may be necessary to meet this requirement.

## 6.2 General Safety

Refer to Nexteer Automotive Specifications SD-011 Specification for Safety Circuits and SD-012 Design-In Health and Safety Specification for general safety requirements.

**NOTE:** Providing external 24V power to the robot E-stop board should only be implemented on applications that require provisions to allow cell E-stop operation while robot controller is powered off.

## 6.3 Guarding

Robotic cell guarding requirements for material handling applications are listed in SD-012 Design-In Health and Safety Specification Section 10.

Suppliers shall review cell layout and any specific floor plan restrictions that could affect placement of guarding with the Nexteer Purchasing Engineer. Examples: support beams, walkways, building equipment, and ductwork.

## 6.4 Dual Check Safety (DCS)

### 6.4.1 General Requirements

DCS Position / Speed check shall be used to create a restricted space of robot motion and to protect peripheral equipment, at a minimum. Suppliers should be trained in DCS use by FANUC or a certified FANUC trainer. DCS User models shall be set up and used for EOAT and any production parts to ensure the robot, EOAT, and parts are accounted for in the DCS zones. All DCS zones used for safety shall have a Stop Category of 0. If the application uses a tool change system, then the DCS User models shall change with respect to the active EOAT. The DCS password shall remain the factory default password. All DCS zones, passwords, and safety I/O setup shall be documented per Section 8 of this document. All DCS zones shall be commented appropriately.

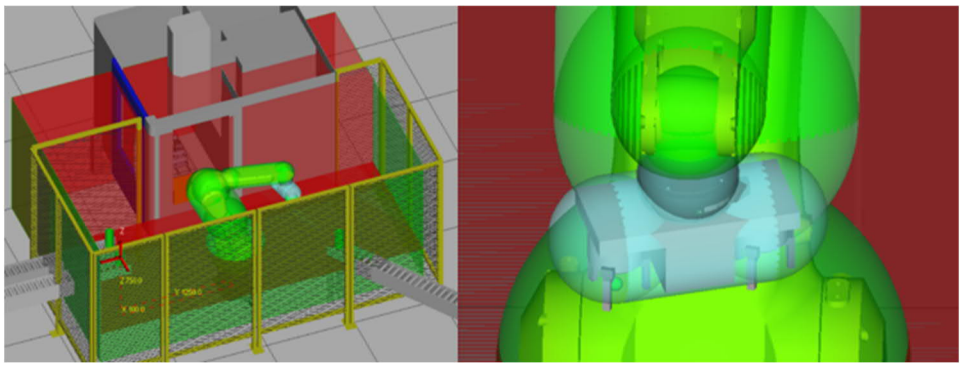

Figure 6.4.1 – DCS robot and user models

### 6.4.2 Restricted Space

Creation of a restricted space is required for all robot applications where the robot, including EOAT and parts, can reach cell safeguarding. Establishment of the restricted space shall conform to SD-012. Any DCS zone(s) created for establishing the robot's restricted space shall be assigned a Stop Type of Stop Category 0 and shall be commented with the name "Operating Zone."

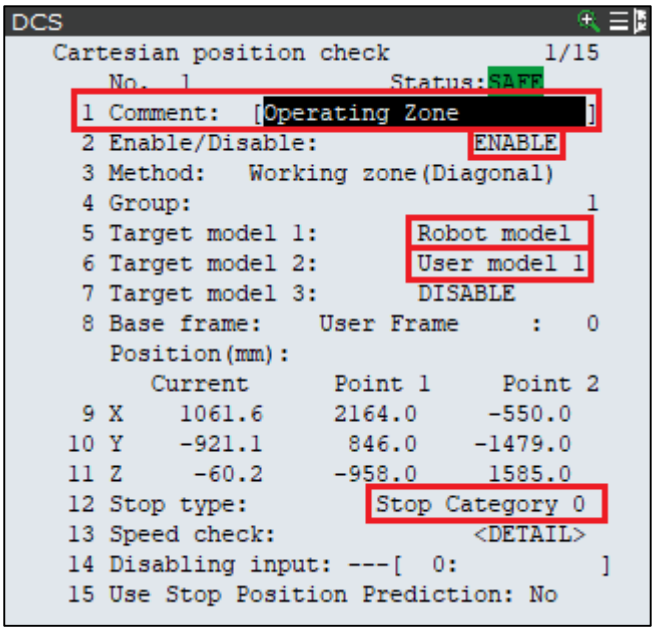


Figure 6.4.2 – DCS 'Operating Zone' zone configuration

### 6.4.3 DCS Signature

During initial DCS setup, the DCS signature must be confirmed in the "Signature number" menu. The robot monitors the Previous and Current signature numbers for DCS. When a change has been made to DCS, a new Current signature number is generated. If the Current and Previous signatures do not match, the Signature Change Annunciation output will turn off, signifying a change has been made to at least one DCS parameter. The DCS signature annunciation shall be set to DO[246]. The DCS signature itself shall also be sent to the PLC via Group Output. This is accomplished by setting the system variable $DCS_CRC_OUT.$START_GRP[1] to a value of '5'. The Group Outputs used for the DCS Signature will then align with Nexteer's robot logic routine.

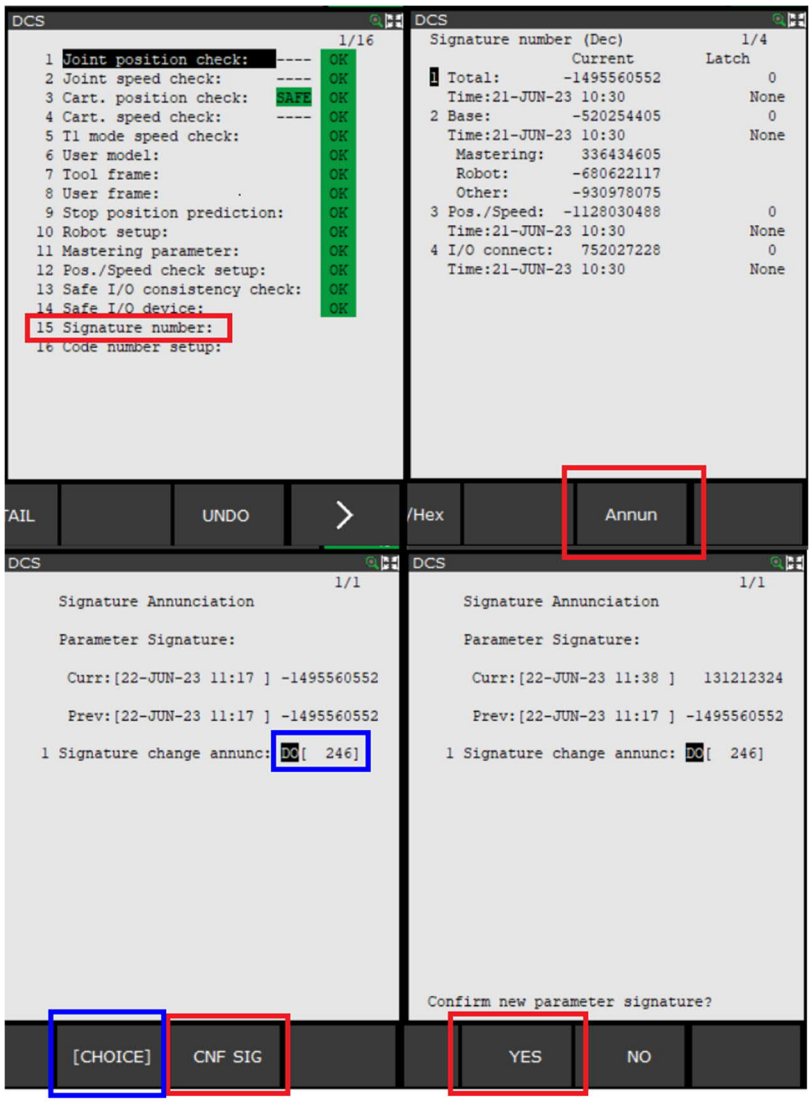


Figure 6.4.3 – DCS Signature setup and confirmation

## 6.5 Robot Disable

A robot disable circuit shall be provided for all full-body access robotic cells where the operator can place their entire body between the safeguarding and the robot. The circuit shall be integrated into the FANUC controller to remove power to the robot servo motors.

A robot disable switch, lockable only in the OFF position (i.e. rotary disconnect), shall be readily accessible wherever the Operator can request to enter the robot cell, such as each Operator control station or cell access point.

Reference Nexteer Specification SD-011 and SD-012 for additional information.

## 6.6 Enabling Device for Multiple Operators in a Cell

A handheld enabling device (3-Position) shall be provided for each person required to be inside the safeguarded area when teaching a robot. The FANUC teach pendant provides this enabling device for the Operator holding the pendant.

Reference Nexteer Specification SD-011 and SD-012 for additional information.

## 6.7 Teach Mode Selection for Cells with Multiple Robots

A teach mode selection circuit shall be provided on all robot cells with multiple robot systems within the same safeguarded area where the restricted spaces overlap. The teach mode selection shall only allow one robot to be in teach mode at a time.

Reference Nexteer Specification SD-011 and SD-012 for additional information.

## 7. Qualification

Prior to MQ1, an All of Above robot backup of each robot shall be supplied to the assigned Nexteer Robotics CSE for review. The backup intended for final submittal shall be taken from the physical robot to be used in production, not a virtual robot.

## 8. Runoff

Refer to Nexteer Automotive Specifications SD-001 (General Manufacturing and Equipment Specifications) and SD-002 (Manufacturing Equipment Statistical Qualification Requirements) for general qualification requirements in addition to the requirements below.

### 8.1 Mastering

Suppliers shall demonstrate the robot is mastered properly in alignment with each axes' zero-position witness mark. Supplier shall also perform the Set Quick Master Reference mastering procedure before shipment of the robot.

### 8.2 Dual Check Safety (DCS)

When DCS is implemented, the Supplier shall provide locations and purpose of DCS zones. Functions of all DCS zones shall be tested at runoff.

### 8.3 Faults / Recovery

The Supplier shall provide a complete robot process fault list.

Recovery shall be verified by stopping the robot at various positions within the cycle and observing that the robot recovers without operator intervention. This can be accomplished multiple ways. For example, pressing the "HOLD" button on the teach pendant and then pressing "ABORT PROGRAM" on the HMI robot screen.

## 9. Documentation/Deliverables

The following items shall be provided by the Supplier to the Nexteer Robotics CSE prior to MQ1:

- Nexteer FANUC Robot Toolkit workbook with completed "Required Documentation" sheet (at a minimum).
- Zip file containing robot's core software (when core software received with robot from FANUC).
- Source code of any Karel programs used.

The following items shall be placed inside the robot controller cabinet by the Supplier before shipment:

- FANUC core software thumb drive (when core software thumb drive received from FANUC).
- Robot master count sheets.

Additionally, all documentation provided by robot manufacturers shall be provided to Nexteer by the Supplier.

# A. Robot / PLC Interface Signals

## A.1 Digital Inputs / Outputs

Digital Inputs: DI[1]…[256] = Spare available for application specific requirements.

Digital Outputs: DO[1]…[224] = Spare available for application specific requirements.

Digital Outputs: DO[225]…[256] = Predefined Signals. Required signals are marked with an "*". Unmarked signals can be used as needed based on the application.

| OUTPUT # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| DO[225]* | EMGOP | Operator Panel Emergency Stop |
| DO[226]* | EMGTP | Teach Pendant Emergency Stop |
| DO[227]* | DEADMAN | Teach Pendant Deadman Switch |
| DO[228] | FENCE | Fence Open |
| DO[229] | ROT | Robot Overtravel |
| DO[230] | HBK | Hand Broken |
| DO[231] | EMGEX | External Emergency Stop |
| DO[232] | PPABN | Low Air Alarm |
| DO[233] | BELTBREAK | Belt Broken |
| DO[234]* | FALM | Fuse Alarm |
| DO[235] | SVOFF | Servo Off |
| DO[236] | IMSTP | Immediate Stop |
| DO[237] | BRKHLD | Brake Hold |
| DO[238] | UNUSED | UNUSED |
| DO[239] | UNUSED | UNUSED |
| DO[240] | NTED | Non-Teaching Enabling Device |
| DO[241] | BLAL | Battery Low Alarm |
| DO[242]* | COLALARM | Collision Detect Alarm |
| DO[243] | UNUSED | |
| DO[244]* | BG HRTBT | Nexteer BG Program Heartbeat |
| DO[245]* | IN STEP | Robot in STEP Mode |
| DO[246]* | DCSANNUNC | DCS Change Detected |
| DO[247]* | IN AUTO | Robot in Automatic Mode |
| DO[248]* | IN T1 | Robot in Low Speed Teach Mode |
| DO[249] | UNUSED | |
| DO[250]* | InEstop | Robot in Emergency Stop |
| DO[251] | Input Simulated | Digital Input Simulated |
| DO[252] | Output Simulated | Digital Output Simulated |
| DO[253]* | At Home | Robot at Home Position |
| DO[254]* | At Maint | Robot at Maintenance Position |

## A.2 User Operating Panel (UOP)

User Inputs: UI[1]…[18] = Predefined Signals

| INPUT # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| UI[1] | *IMSTP | No Immediate Stop |
| UI[2] | *HOLD | No Hold |
| UI[3] | *SFSPD | No Safe Speed |
| UI[4] | Cycle Stop | Cycle Stop |
| UI[5] | Fault Reset | Fault Reset |
| UI[6] | Start | Program Resume |
| UI[7] | Spare01 | |
| UI[8] | Enable | Enable |
| UI[9] | PNS1 | Program Number Select Bit 1 |
| UI[10] | PNS2 | Program Number Select Bit 2 |
| UI[11] | PNS3 | Program Number Select Bit 3 |
| UI[12] | PNS4 | Program Number Select Bit 4 |
| UI[13] | PNS5 | Program Number Select Bit 5 |
| UI[14] | PNS6 | Program Number Select Bit 6 |
| UI[15] | PNS7 | Program Number Select Bit 7 |
| UI[16] | PNS8 | Program Number Select Bit 8 |
| UI[17] | PNS_Strobe | PNS Strobe |
| UI[18] | PRODSTART | Production Start |
| - | - | |
| - | - | |

User Outputs: UO[1]…[20] = Predefined Signals

| OUTPUT # | ROBOT COMMENT | DESCRIPTION |
|---|---|---|
| UO[1] | Cmd Enabled | Command Enabled |
| UO[2] | System Ready | System Ready |
| UO[3] | Prg Running | Program Running |
| UO[4] | Prg Paused | Program Paused |
| UO[5] | Motion Held | Motion Held |
| UO[6] | Fault | Robot Faulted |
| UO[7] | At Perch | At Perch Position |
| UO[8] | TP Enabled | Teach Pendant Enabled |
| UO[9] | Batt Alarm | Battery Alarm |
| UO[10] | Busy | System Busy |
| UO[11] | SNO1 | Selected Number Bit 1 |
| UO[12] | SNO2 | Selected Number Bit 2 |
| UO[13] | SNO3 | Selected Number Bit 3 |
| UO[14] | SNO4 | Selected Number Bit 4 |
| UO[15] | SNO5 | Selected Number Bit 5 |
| UO[16] | SNO6 | Selected Number Bit 6 |
| UO[17] | SNO7 | Selected Number Bit 7 |
| UO[18] | SNO8 | Selected Number Bit 8 |
| UO[19] | SNACK | Selected Number Acknowledge |
| UO[20] | Spare01 | |

## A.3 Group I/O Data

Group Inputs: GI[1] = Predefined Signals

Group Inputs: GI[2]+ = Spare available for application specific requirements

| OUTPUT # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| GI[1] | Speed | Robot Speed |

Group Outputs: GO[1]…[4] = Spare available for application specific requirements

NOTE: GO[1-4] must total 32 points for proper output of DCS signature to PLC via GO[5-6].

Group Outputs: GO[5]…[6] = Predefined Signals

Group Outputs: GO[7]+ = Spare available for application specific requirements

| OUTPUT # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| GO[5] | DCS SIGLWR | DCS Signature Lower 16-Bits |
| GO[6] | DCS SIGUPR | DCS Signature Upper 16-Bits |

## B. Robot Registers

B.1 Number Registers

R[1]..[189] & R[191] = Spare available for application specific requirements

R[190] & [192] = Predefined registers

| REGISTER # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| R[190] | Robot Speed | Robot Speed % |
| R[192] | BG Hrtbt Ctr | Background Heartbeat Counter |

B.2 Positions Registers

PR[1]..[2] = Predefined registers

PR[2]…[99] = Spare available for application specific requirements

| REGISTER # | ROBOT COMMENT | PLC DESCRIPTION |
|---|---|---|
| PR[1] | Home | Robot Home Position |
| PR[2] | Maintenance | Robot Maintenance Position |

## C. FANUC System Variables

| Description | Variable | Value |
|---|---|---|
| Use Hot Start | $SEMIPOWERFL | FALSE |
| I/O Power Fail Recovery | $PWF_IO | 1 |
| Restore Selected Program | $DEFPROG_ENB | FALSE |
| Enable UI Signals | $OPWORK.$UOP_DISABLE | 0 |
| Start for Continue Only | $SHELL_CFG.$CONT_ONLY | TRUE |
| CSTOP for Abort | $SHELL_CFG.$USE_ABORT | TRUE |
| CSTOP Abort All | $SHELL_CFG.$CSTOPI_ALL | TRUE |
| PROD_START Depend on STROBE | $SHELL_CFG.$PRODSTARTYP | 0 |
| Detect FAULT_RESET | $SCR.$RESETINVERT | TRUE |
| Use PPABN Signal | $PARAM_GROUP[1].$PPABN_ENBL | FALSE |
| Wait Timeout | $WAITTMOUT | 3000 |
| Receive Timeout | $RCVTMOUT | 3000 |
| Return Top of Program | $PNS_END_CUR | FALSE |
| Max ACC Instruction | $ACC_MAXLMT | 150 |
| Min ACC Instruction | $ACC_MINLMT | 0 |
| WJNT Default Motion | $DEF_WRSTJNT | 0 |
| Auto Display Alarm | $ER_AUTO_ENB | FALSE |
| Force Message | $AUTOMESSAGE | 2 |
| Allow Force I/O Auto | $AUTOMODE_DO | FALSE |
| Allow Change Override Auto | $AUTOMODE_OV | TRUE |
| Signal in AUTO Mode | $CR_AUTO_DO | 247 |
| Signal in T1 Mode | $CR_T1_DO | 248 |
| Signal in E-Stop | $E_STOP_DO | 250 |
| Signal Input Simulated | $INPT_SIM_DO | 251 |
| Signal Output Simulated | $OUT_SIM_DO | 252 |
| Remote/Local Setup | $REMOTE_CFG.$REMOTE_TYPE | 1 |
| UOP Auto Assignment | $IO_AUTO_UOP | FALSE |
| Multi-Program Selection | $SCR.$MULSELENB | TRUE |
| Separate CPU and Encoder Bat Alarms | $BLAL_OUT.$BATALM_OR | TRUE |
| IO Auto Config | $IO_AUTO_CFG | FALSE |
| Liveman Auto Reset | $DMAURST | TRUE |
| Program Select Mode (PNS) | $SHELL_CFG.$SEL_TYPE | 1 |
| Production Start Method (UOP) | $SHELL_CFG.$PROD_MODE | 1 |
| Enet/IP Slot 1 Description | $EIP_CONN[1].$DESC | “PLC” |
| Enet/IP Output Size | $EIP_CONN[1].$PR_SZ | 32 |
| Enet/IP Input Size | $EIP_CONN[1].$CS_SZ | 32 |
| HTTP KAREL | $HTTP_AUTH[2].$TYPE | 3 |
| Port 1 Hostname Description | $HOSTNAME | “ROBOT1” |
| Constant Path | $GROUP[1].$CNSTNT_PATH | TRUE |
| Set DCS Annunc I/O Type | $DCS_SGN.$ANNUNC_TYP | 2 |
| Set DCS Annunc DO Number | $DCS_SGN.$ANNUNC_IDX | 246 |
| Set Start GO for DCS Sig Output | $DCS_CRC_OUT.$START_GRP[1] | 5 |

## D. References

The references used in the development of this specification are listed below.

NOTE: users of this specification shall consult applicable Regional, Federal, State, Country, and Local laws, regulations, and standards in addition to those listed below. Reference the most current version of the specifications / standards listed below.

### International Standards:

ISO – International Standards Organization: www.iso.org

- ISO 10218-1, Robots and Robotic Devices – Safety Requirements for Industrial Robots: Part 1 – Robots
- ISO 10218-2, Robots and Robotic Devices – Safety Requirements for Industrial Robots: Part 2 – Robot Systems and Integration

### American National Standards:

ANSI – American National Standards Institute Website: www.ansi.org

- ANSI B11.1, Machine Tools – Mechanical Power Presses – Safety Requirements for Construction, Care, and Use
- ANSI B11.19, Machine Tools, Safeguarding when referenced by the Other B11 Machine Tool Safety Standards – Performance Criteria for the Design, Construction, Care, and Operation
- ANSI B11.20, Manufacturing Systems / Cells – Safety Requirements for Construction, Care, and Use
- ANSI / RIA R15.06, American National Standard for Industrial Robots and Systems
- ANSI Z244.1, Lockout / Tagout of Energy Sources

### Nexteer Automotive Specifications:

Nexteer Data Exchange Website: www.nexteerdataexchange.com

- SD-004, Electrical Specification for Industrial Machinery, addendum to IEC 60204
- SD-011, Specification for Safety Circuits
- SD-012, Design-In Health & Safety Specification
- SD-014, Pneumatic fluid power – General rules relating to systems, addendum to ISO 4414
- SD-015, Lean Equipment Design
- SD-016, Lean Equipment Controls Design
- SD-017, Design-In Ergonomics Guideline

## RECORD OF REVISIONS

| Revision No | Date | Section | Description |
|---|---|---|---|
| 001 | 09MR17 | ALL | Initial release and approval. |
| 002 | 03JN19 | ALL | Updated. |
| 003 | 04JN20 | ALL | Updated specification per highlighted text. |
| 004 | 29JAN24 | ALL | Full update. |
| 005 | | | |
| 006 | | | |
| 007 | | | |
| 008 | | | |
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