JR3

INSTALLATION MANUAL
FOR
FORCE - TORQUE SENSORS
WITH EXTERNAL ELECTRONICS

***JR3,* Inc.**
22 Harter Ave.
Woodland, CA 95776

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CHAPTER 1
SENSOR OVERVIEW

The ***JR3*** sensor is a monolithic aluminum (optionally stainless steel or titanium) device Instrumented with metal foil strain gages which sense the loads imposed on the sensor. The strain gage signals are connected to the external amplifier and signal conditioning equipment through the sensor cable. In the external electronic system the strain gage signals are amplified and combined to produce signals representing the force and moment loads for all axes.

Sensors are produced in a wide variety of load ratings and bolt patterns. The physical size of the sensor varies, depending on factors such as force and moment ratings and required mounting dimensions. A drawing of your specific sensor and a detailed specification sheet is provided with your sensor.

The axes on standard ***JR3*** sensors are oriented with the X and Y axes in the plane of the sensor body, and the Z axis perpendicular to the X and Y axes. The reference point for all loading data is the geometric center of the sensor. When viewed from the Robot Side of the sensor the forces and moments are related by the Right Hand Rule.

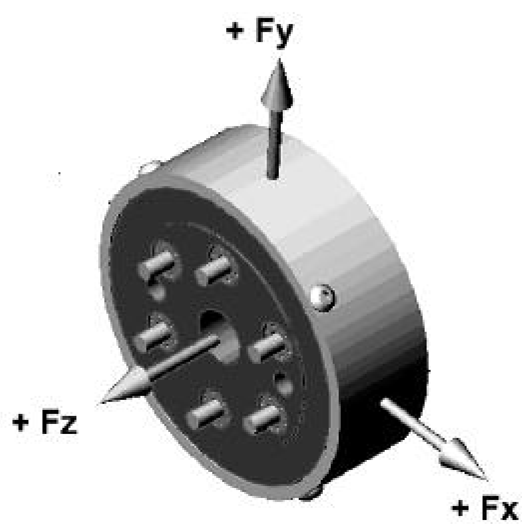

Fig. 1–1
SENSOR AXIS ORIENTATION FROM ROBOT SIDE

CHAPTER 2
INSTALLATION

This chapter provides general instructions for installing the force - torque sensor with your own equipment. Because of the wide variety of possible applications of the sensor, it is not possible to provide detailed instructions for your exact application. If additional information is needed, contact ***JR3***.

PHYSICAL MOUNTING OF SENSOR

CAUTION: THE SENSOR IS A PRECISION MEASURING DEVICE, AND MAY BE DAMAGED IF PROPER PRECAUTIONS ARE NOT OBSERVED WHEN IT IS MOUNTED.

Refer to the sensor specification sheet and drawing for detailed information about the rated capacity and mounting bolt pattern of your specific sensor. The sensor drawing also shows the positioning of the axes on the sensor. Install the sensor with the axes in the desired orientation. Use particular care when handling and installing sensors having low force and torque ratings.

Most ***JR3*** sensors use captive button-head bolts to mount the sensor. The bolts are tightened with a hex key (provided with the sensor) through the bolt holes in the tool side of the sensor. DO NOT TURN ONE SENSOR BOLT ALL THE WAY IN AT A TIME. In many cases these bolts will protrude from the sensor even when fully retracted. If these bolts are tightened one at a time, the sensor can be damaged. Turn each bolt in a few turns at a time, then go to the next bolt until the sensor mounting surface is flat against your mounting surface. Then tighten the bolts in a sequence, moving from side to side. Torque these bolts in two or more stages until the torque recommended on the sensor interface drawing is reached.

BOLT TORQUE

The tables give torque values recommended by the bolt manufacturer to avoid damage to heads for the most commonly used bolt sizes. These values are for the captive button head screws used in standard sensors, other types of bolts may have different ratings. We recommend that sensor mounting bolts be torqued to the lower of the sensor's rated full scale torque, or to these values.

BE AWARE OF THE FORCE AND TORQUE RATINGS OF THE SENSOR WHEN TIGHTENING TOOL-SIDE BOLTS. Refer to the Sensor Load Ratings not the Electrical Load Settings. When tightening the mounting bolts on the tool side of the sensor forces and torques are exerted on the sensor. Be certain not to exceed the force or torque ratings of the sensor when tightening the mounting bolts on the tool side of the sensor

English screws:

Size & Pitch	Recommended Tightening Torque
4-40	7 inlb
6-32	12 inlb
8-32	23 inlb
10-24 10-32	45 inlb
¼-20 ¼-28	100 inlb
5/16-18 5/16-24	190 inlb (16ftlb)
3/8-16 3/8-24	300 inlb (25ftlb)
½-13 ½-20	1000 inlb (83ftlb)

Metric screws:

Size & Pitch	Recommended Tightening Torque
M3x.5	1.25 Nm (11 inlb)
M4x.7	2.9 Nm (25 inlb)
M5x.8	5.9 Nm (52 inlb)
M6x1.0	10 Nm (88 inlb)
M8x1.25	24 Nm (210 inlb)
M10x1.5	48 Nm (425 inlb)
M12x1.75	84 Nm (740 inlb)
M16x2.0	207 Nm (1800 inlb)

Fig. 2-1
Torque Values for *JR3* Sensor Mounting Screws

MOUNTING SURFACES

The sensor surfaces are precisely machined to be extremely flat. The plates or flanges to which the sensor is bolted should be as flat as possible, preferably within .0005" (half thousandth). Because of its compact size, the sensor is sensitive to the boundary conditions at the mounting surfaces. For this reason it is necessary that the mounting surfaces be stiff relative to the loads imposed. The mounting plate thicknesses shown in the table are recommendations for typical situations. Your particular application may require thicker mounting plates or be able to use thinner mounting plates.

Sensor Fx, Fy Load Rating in pounds	Aluminum Plate Thickness	Steel Plate Thickness
15	1/2"	3/8"
25	1/2"	3/8"
50	3/4"	1/2"
100	7/8"	5/8"
250	1 1/4"	7/8"
500	1 1/2"	1"

Fig 2-2
Recommended Mounting Plate Thickness

When mounting the sensor, or mounting a device to the sensor, be certain that no components are attached in such a way as to allow part of the load to pass around the sensor. No part attached to the "tool" or "load" side of the sensor should touch anything attached to the "robot" or "fixed" side of the sensor, or the sensor's protective canister, since it is attached to the "robot" or "fixed" side. If contact of this type is made, part of the load may be transmitted around the sensor resulting in false load readings.

There is a small gap between the protective canister and the face of the sensor on the tool, or load, side of the sensor. Be certain that no solid material or particles are allowed to lodge in the gap. If any solid is lodged in the gap, part of the load can be transmitted around the sensor resulting in false load readings. If the sensor environment makes it likely that fluids or particles could enter the gap, a bellows or compliant booting is recommended.

CABLE ROUTING

Cable routing must allow for all possible movement of machinery. Do not allow stretching, crushing or excessive twisting of the cable. Where cable flexing is essential, it should be spread over a loop or length of cable rather than concentrated in a single spot.

CHAPTER 3
ELECTRICAL INTERFACE

Most sensors for use with external electronic systems utilize a DE19-P connector. Other connectors or other means of connection are available by special order.

SENSOR INTERFACE SIGNALS

The strain gage bridges require a source of excitation voltage and produce low level output signals representing the loads imposed at various points in the sensor. These signals are signals are amplified and combined in the external electronic system to produce signals representing the force and moment loads for all axes.

Pin	Signal	Pin	Signal
1	AH+	10	AV-
2	AH-	11	BV+
3	BH+	12	BV-
4	BH-	14	CV+
5	CH+	15	CV-
6	CH-	16	DV+
7	DH+	17	DV-
8	DH-	18	-Vex
9	AV+	19	+Vex

Pin 13 is not used

Fig 3-1
SENSOR CONNECTOR PIN ASSIGNMENTS

Sensors configured to provide strain gage outputs directly representing the forces and moments are available. These sensors utilize a different connector and different pin assignments. Refer to the data sheet provided with these sensors for details on connecting them.

SENSOR CABLE

Standard sensor cables for most ***JR3*** sensors with external electronics is made from Belden type 9812 cable. Details of the cable construction depend on the specific electronic system used. Special cables are available to meet the needs of unusual installations.

GROUNDING

As with any sensitive electronic system, improper grounding can cause problems. The electronic system and the equipment the sensor is mounted on should be connected to the same ground. In unusual situations, where there is a severe noise source near the sensor, it may be necessary to add a heavy ground connection between the sensor mounting surface and the receiver electronic system or utilize a different sensor cable.

RECEIVER ELECTRONIC SYSTEM

Different external electronic systems can be used with ***JR3*** sensors. They amplify the low level signals from the sensor and combine the signals to provide loading data for all axes. Models to provide analog or digital output signals are available. See the manual provided with your electronic system for details about that system.

CHAPTER 4
CALIBRATION MATRIX

All multi-axis sensors have some degree of cross coupling, a condition where a force or moment load on one axis produces a change in the indicated load of other axes. Each ***JR3*** sensor is individually calibrated, with loads applied to each axis. The calibration data is used to generate a calibration and decoupling matrix, which is used to convert the output voltages to force and moment loading data in engineering units.

DIGITAL OUTPUT ELECTRONIC SYSTEMS

Sensor electronic systems with digital output store the matrix in non-volatile memory. When the sensor or electronic system is connected to the receiver the data is automatically downloaded in the first few seconds of operation. The receiver then applies the matrix to the sensor data stream without user intervention.

ANALOG OUTPUT ELECTRONIC SYSTEMS

When analog output electronic systems are used, the calibration matrix is provided on the Sensor Specification Sheet for your sensor. Sensors ordered with special calibration features may be provided with more than one matrix.

The six by six calibration matrix is multiplied by the six element voltage (column) vector. The result is calibrated force and moment data in the units specified on the Sensor Specification Sheet.

$$\begin{array}{c} \mathrm{Fx} \\ \mathrm{Fy} \\ \mathrm{Fz} \\ \mathrm{Mx} \\ \mathrm{My} \\ \mathrm{Mz} \end{array} \begin{bmatrix} A_{1,1} & A_{1,2} & A_{1,3} & A_{1,4} & A_{1,5} & A_{1,6} \\ A_{2,1} & A_{2,2} & A_{2,3} & A_{2,4} & A_{2,5} & A_{2,6} \\ A_{3,1} & A_{3,2} & A_{3,3} & A_{3,4} & A_{3,5} & A_{3,6} \\ A_{4,1} & A_{4,2} & A_{4,3} & A_{4,4} & A_{4,5} & A_{4,6} \\ A_{5,1} & A_{5,2} & A_{5,3} & A_{5,4} & A_{5,5} & A_{5,6} \\ A_{6,1} & A_{6,2} & A_{6,3} & A_{6,4} & A_{6,5} & A_{6,6} \end{bmatrix} \mathrm{X} \begin{bmatrix} V_{FX} \\ V_{FY} \\ V_{FZ} \\ V_{MX} \\ V_{MY} \\ V_{MZ} \end{bmatrix} = \begin{bmatrix} \mathrm{Load}_{FX} \\ \mathrm{Load}_{FY} \\ \mathrm{Load}_{FZ} \\ \mathrm{Load}_{MX} \\ \mathrm{Load}_{MY} \\ \mathrm{Load}_{MZ} \end{bmatrix}$$

CALIBRATION MATRIX

OUTPUT VOLTAGE VECTOR

CALIBRATED LOADS IN ENGINEERING UNITS

Fig. 4-1
CALIBRATION MATRIX MULTIPLICATION

MANUAL CALCULATION:

Matrix calculations are most easily done with a computer, but they can, of course, be done manually. As an example, to find the decoupled, calibrated, Fx load reading using the raw analog voltages multilpy the Fx row ($A_{1,n}$) by the analog channel readings in volts. This gives the calibrated, decoupled, output in the units which were specified when the sensor was ordered.

$$(A_{1,1} \text{ X } V_{FX}) + (A_{1,2} \text{ X } V_{FY}) + (A_{1,3} \text{ X } V_{FZ}) + (A_{1,4} \text{ X } V_{MX}) +$$

$$(A_{1,5} \text{ X } V_{MY}) + (A_{1,6} \text{ X } V_{MZ}) = Load_{FX}$$

To find the loads for other axes, follow the same procedure using $A_{2,n}$ for Fy, $A_{3,n}$ for Fz, etc.

SAMPLE COMPUTER CODE FOR DECOUPLING:

A brief Pascal procedure showing one possible way of programming a computer for the decoupling matrix multiplication is shown below. This procedure can easily be implemented in other programming languages.

```
TYPE
   matrix = ARRAY[0..5,0..5] OF real;
   vector = ARRAY[0..5] OF real;

PROCEDURE mult (mat : matrix; vecIn : vector; VAR vecOut : vector);
VAR
  row : integer;
  col  : integer;

BEGIN
  FOR row := 0 TO 5 DO
    BEGIN
       vecOut [row] := 0;
       FOR col := 0 to 5 DO
          vecOut [row] := vecOut [row] + vecIn[col] * mat [row, col];
    END;
END;
```

Fig. 4-2
MATRIX SOFTWARE EXAMPLE