JR3

INSTALLATION MANUAL
FOR
FORCE - TORQUE SENSORS
WITH INTERNAL ELECTRONICS

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TABLE OF CONTENTS

CHAPTER 1
SENSOR OVERVIEW

The **JR3** sensor is a monolithic aluminum (optionally stainless steel or titanium) device containing analog and digital electronics systems. Foil strain gages sense the loads imposed on the sensor. The strain gage signals are amplified and combined to become analog representations of the force loads on the three axes and the moments or torques about the three axes. In most models, the analog data is converted to digital form by electronic systems contained within the sensor. Some models optionally provide analog output instead of digital.

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.
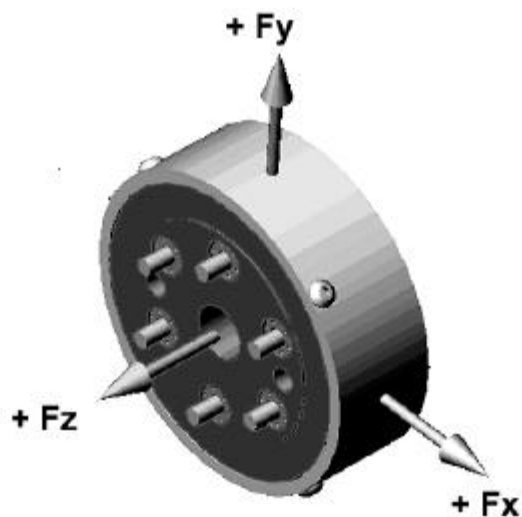

Fig. 1–1
SENSOR AXIS ORIENTATION FROM ROBOT SIDE

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 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
1/4-20 1/4-28	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 with internal electronic systems provide Digital output signals for use with several different *JR3* receiver systems. A few models are optionally available with Analog output.

DIGITAL OUTPUT

Digital output sensors transmit data to the receiver electronics in a synchronous serial format. All low level analog signals and the Analog to Digital (A/D) circuitry are within the sensor body, shielded from electromagnetic interference by the metallic sensor body. Data for all six axes is returned to the receiver at a rate of 8 kHz. Certain sensor models may utilize other data rates.

The data stream also includes feedback monitoring the sensor power supply voltage and information about sensor characteristics and calibration. Transmission of sensor calibration data from the sensor allows sensors to be interchanged with no need for any adjustment of the receiver circuitry. Feedback of the sensor power voltage allows use of long lengths of small gage wire in the sensor cable. Sensor power and data signals can be passed through slip rings with no increase in noise or loss of accuracy.

Standard digital output sensors utilize either a 6 pin RJ-11 or an 8 pin RJ-45 modular style jack depending on the sensor model. Other connectors may be used for special orders. See specifications provided with your sensor for details of connectors other than RJ-11 or RJ-45.

SENSOR CABLE

The cable for most *JR3* digital sensors is a flat modular type cable with RJ-11 (6 pin) or RJ-45 (8 pin) modular plugs. If your sensor does not utilize the flat modular type cable refer to information provided with the sensor for information about the cable.

JR3 digital sensors use a "standard" modular cable, as opposed to a "reverse" cable. The terms "standard" and "reverse" in regard to these cables are the cause of a great deal of confusion and misunderstanding. Therefore figure 3-1 showing the wire arrangement at the 2 ends of our normal 6 wire modular cable is provided to define our cable. The 8 pin cable is similar with the

addition of 2 wires. Either end of the cable can connect to the sensor or the receiver/processor.   Note that there is a reversal of pin order between sensor and receiver/processor.
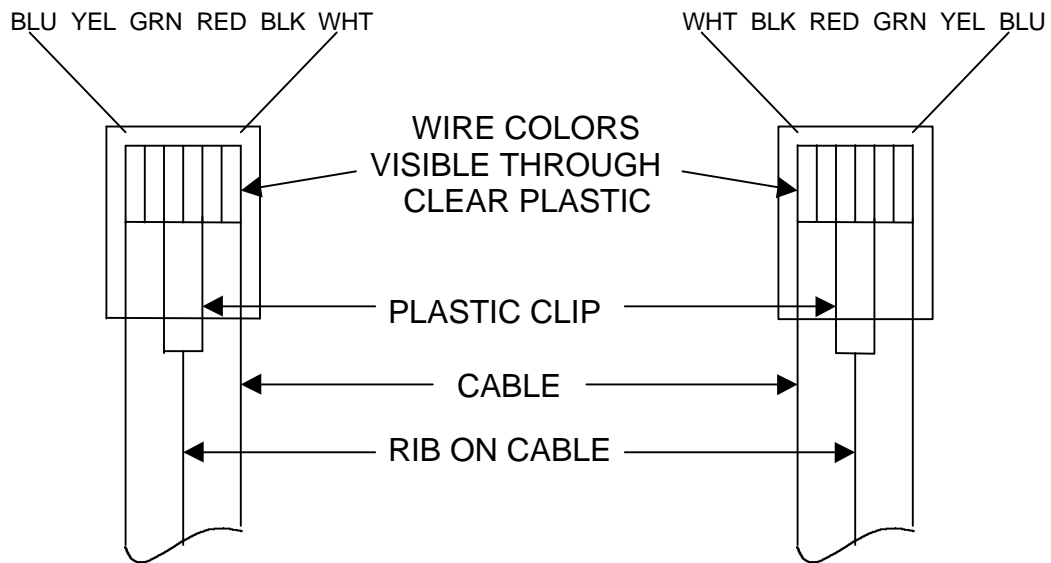
BLU YEL GRN RED BLK WHT   WHT BLK RED GRN YEL BLU

WIRE COLORS
VISIBLE THROUGH
CLEAR PLASTIC

PLASTIC CLIP

CABLE

RIB ON CABLE

Fig 3-1
6 PIN SENSOR CABLE

The sensor uses either a 6 pin 8 pin or 10 pin modular jack depending on the model; receiver/processors use a 10 pin modular jack designed to allow connection of a 10, 8 or 6 pin plug with no damage. When a 6 pin plug is plugged into the 10 pin jack only the central 6 pins are used. There are 2 unused jack pins on each side of a 6 pin plug. Similarly, an 8 pin plug has 1 unused jack pin on either side.
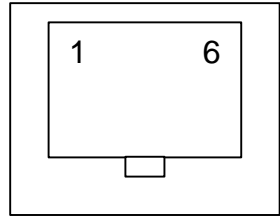
6 pin Sensor Jack
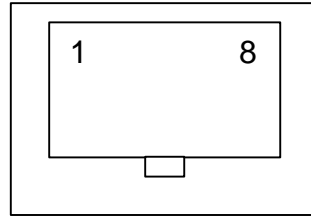
8 pin Sensor Jack

PIN	SIGNAL
1	DCLK +
2	DCLK -
3	+ ~ 8 V
4	PWR COM
5	DATA +
6	DATA -

PIN	SIGNAL
1	- 12 V
2	DCLK +
3	DCLK -
4	+ ~ 8 V
5	PWR COM
6	DATA +
7	DATA -
8	+ 12 V

Fig 3-2
MODULAR SENSOR CONNECTOR PIN ASSIGNMENTS

Note that for the six central pins the function of each pin is identical though the pin numbers are different. This allows a sensor with six pins or a sensor with eight pins to connect to the same receiver electronic system jack.

ANALOG OUTPUT

Standard analog output sensors utilize a DE-9P connector. Other connectors may be used for special orders. See specifications provided with your sensor for voltage requirements and for details of connectors other than DE-9P.

PIN	SIGNAL
1	Fx
2	Fy
3	Fz
4	Mx
5	My
6	Mz
7	+ power
8	– power
9	power and signal common

Fig. 3-3
DE-9P SENSOR CONNECTOR PIN ASSIGNMENTS

Sensors with high level analog output provide an analog voltage for each axis, typically specified as +5 V to -5 V or +10 V to -10 V representing + full load to - full load. Data from analog sensors must be processed using the Calibration Matrix provided with the sensor. Refer to Chapter 4 for information about the decoupling matrix. When digital output sensors are used the receiver electronic system automatically processes the calibration matrix.

GROUNDING

As with any sensitive electronic system, improper grounding can cause problems. The receiver electronics 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.

RECEIVER ELECTRONIC SYSTEM

Several different receiver/processors and electronic systems can be used with *JR3* sensors with serial data output. They receive the serial data from the sensor and provide sensor loading data in the desired form. Different electronic systems allow direct connection to computer and controller back planes, serial or parallel ports.

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 SENSORS

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 SENSORS

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.

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

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.

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

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

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