

JR3

**EXTERNAL SENSOR ELECTRONICS
WITH SERIAL DATA OUTPUT**

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

5963B 13 October, 2003

TABLE OF CONTENTS

CHAPTER 1 OVERVIEW

General	1 - 1
Sensor	1 - 1
Electronic System	1 - 1
Receiver	1 - 2

CHAPTER 2 INSTALLATION AND CONFIGURATION

Physical mounting of Components	2 - 1
Sensor.....	2 - 1
Electronic System.....	2 - 1
Power Supply.....	2 - 1
Interconnecting Cables.....	2 - 2
Receiver.....	2 - 2
Grounding	2 - 2
System Interconnection.....	2 - 2
Sensor.....	2 - 2
Serial Data	2 - 2
Power.....	2 - 3
Analog Output.....	2 - 3

CHAPTER 3 SYSTEM SETUP AND ADJUSTMENT

Hardware Options	3 - 1
Disassembly.....	3 - 1
Electronic Enclosure	3 - 1
Sensor Body	3 - 1
Adjustment and Calibration.....	3 - 2
Sensor.....	3 - 2
Electronic system	3 - 2
8 Channel Offset.....	3 - 2
6 Channel Offset.....	3 - 3

Analog Filters.....	3 - 3
Full scale.....	3 - 4
Full scale jumpers.....	3 - 5
Shunts.....	3 - 5
Vex.....	3 - 6
Gain Trimpots	3 - 6
Jumper Table.....	3 - 7

CHAPTER 4 CONNECTOR AND CIRCUIT BOARD DETAILS

Sensor End Panel	4 - 1
Power End Panel	4 - 1
Circuit Board Layout.....	4 - 2

CHAPTER 5 DECOUPLING MATRIX

Decoupling Matrix	5 - 1
Manual Calculation	5 - 2
Software Example.....	5 - 2

SYSTEM OVERVIEW

The **JR3** Multi - Axis Force - Torque Sensor System can completely define the loading at the location of the sensor by measuring the forces on three orthogonal axes, and the moment or torque about each of the axes. The system consists of the six degree of freedom sensor body, the electronics system, one of several different receiver systems and interconnecting cables. Optionally, a separate power supply may be used.

Output is in the form of a high-speed synchronous serial data stream which must be connected to a **JR3** serial force-torque sensor receiver. Non calibrated analog signals in the approximate range of + 10 V to - 10 V are also provided. Calibrated analog output is an option.

Sensor

JR3 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. The **JR3** sensors used with external electronic systems are monolithic designs containing no electronic components. Foil strain gages in full Wheatstone bridge configuration sense the loads applied to the sensor at multiple points in the sensor. The analog strain gage data is returned to the electronics unit through the sensor cable.

The reference point for all loading data is the geometric center of the sensor. The axes on the **JR3** sensor are oriented as shown on the drawing for your specific sensor. The forces and moments are related by the Right Hand Rule. The standard **JR3** point of view is "robot view, applied load."

Sensor load specifications and a detailed drawing showing the mechanical interface are provided with the sensor.

Electronic System

The **JR3** electronic system with high-speed serial data output consists of an enclosure housing a circuit board with amplifier, signal conditioning, analog to digital conversion and serial data output circuits.

Signals from the sensor are amplified and combined to provide signals representing the force and torque loads for each axis. Fourth order low pass Butterworth filters reduce high frequency noise and prevent

aliasing at the Analog to Digital converter. The cutoff frequency of the filters may be changed as needed. The low pass filters may be bypassed completely for the analog data outputs.

The analog data is converted to 16 bit digital numbers and transmitted at high speed along with the sensor calibration data to one of several different **JR3** receivers. Standard systems provide non-calibrated, analog output in the approximate range of + 10 V to - 10 V.

Optionally, the system may be ordered with calibrated analog output. In this case a Sensor Specification Sheet with the analog sensor calibration matrix is provided. See chapter 5 for information about the use of the calibration matrix for analog output.

The electronic system may optionally be ordered with two different sets of full scales, selectable by moving six jumpers on the circuit board. In many situations this will allow the same sensor and electronic system to be used for different purposes requiring different sensitivities.

Receiver

The serial data from the electronic system can be connected to one of several different receivers. Refer to the manual provided with your receiver for details on the proper connection and usage of your receiver.

INSTALLATION AND CONFIGURATION

PHYSICAL MOUNTING OF COMPONENTS

Sensor

Refer to the sensor manual for information about installing the sensor. The sensor specification sheet and the drawing for your specific sensor provide detailed specifications.

Electronic System

The electronic system enclosure should be firmly mounted using the screw holes provided in the enclosure base. Avoid mounting the electronics enclosure in areas with high levels of mechanical vibration. Allow adequate access to the connectors at each end of the enclosure. If the electronic system case temperature exceeds 65° C it may be necessary to provide a flow of air to cool the electronics system.

Locate the electronic system to allow for easy access, especially if you ordered the option for two sets of full scales or if you anticipate the need to adjust the zero offsets frequently to match changes to apparatus attached to the sensor.

Power Supply (optional)

All current **JR3** receiver systems can provide power to the electronic system via the 8 conductor serial data cable. Use of a separate external power supply is optional.

JR3 power supply P/N 1405 requires no specific installation. Connect the AC power cable to an appropriate power outlet; connect the DC output cable to electronic system connector J3. Avoid mounting the power supply in areas with high levels of electromagnetic noise or mechanical vibration. Allow room for the cables at each end of the power supply. If the ambient temperature at the mounting location is above 40° C it may be necessary to provide a flow of air to cool the power supply.

If a power supply other than JR3 P/N 1405 is used refer to the section on power supply connection in this chapter and to chapter 4 for connector pinouts. Follow the manufacturers recommendations regarding mounting and other conditions.

Interconnecting Cables

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.

Receiver

The serial data from the electronic system can be connected to one of several receivers. Refer to the manual provided with your receiver for details on the proper installation of your receiver.

Grounding

As with any sensitive electronic system, improper grounding can cause problems. It is not unusual for different electrical circuits, particularly in an industrial setting, to have ground conductors that measure up to several volts between them. When these different ground conductors are connected, significant currents may flow. If excessive ground currents flow through ground conductors in system interconnecting cables, noise may be introduced in the **JR3** system. For this reason, the electronics, power supply and the equipment the sensor is mounted on should be connected to the same ground point. Grounding options for the analog output are discussed later in this chapter.

SYSTEM INTERCONNECTION

Sensor

Connect the sensor to the electronic system using the provided sensor cable. Connect the smaller, 19-pin connector to the sensor, and the larger 26-pin connector to J1 on the electronic system. If the sensor cable is replaced, or if the length of the cable is changed, be sure to check and if needed, adjust the excitation voltage. Refer to chapter 3.

Serial Data

8-pin modular phone jack J4 is the serial data and power connector. It can connect only to a **JR3** receiver/processor or other **JR3** equipment. An appropriate 8 pin cable is provided with the electronic system, if the cable must be replaced it is important use a cable with identical wiring

cable. This type of cable is available in two different configurations, use of the wrong cable is likely to damage both the electronic system and the receiver to which it is connected.

If serial data and power connector J4 is used to provide power the internal power jumpers (JP4) must be in the "MODULAR" position. This is the default position when the electronic system is shipped. See the circuit board layout drawing on page 4-2.

Power

Power may be supplied via either of two connectors. When using the digital output, the system is connected to a **JR3** receiver/processor and power is normally supplied by the receiver/processor via connector J4. Optionally, power connector J3 can be used to connect an external power supply.

The power connection is selected by moving the jumpers at JP4. The electronic system is shipped with jumpers JP4 set for power via the serial data and power connector J4, the jumper location labeled "modular." If the J3 power connector is used, move the jumpers at JP4 to the location labeled "DE9P."

JR3 power supply P/N 1405 has a DC output cable which connects to electronic system connector J3. If you are not using the **JR3** power supply, refer to the input/output connection, page 4-1, for the pinout of this connector. A low noise power supply capable of providing + and - 12 VDC to 15 VDC at 250 mA is required for analog output. For digital output + 8 to +9V at 300 mA is also required. Switching type power supplies are not recommended.

When an external power supply is used analog ground and digital ground should be connected at only one point. This connection can be in your power supply, in your external equipment such as a data acquisition system or in the JR3 electronic system. If you chose to make the analog ground to digital ground tie in the JR3 electronic system install jumper JP10, remove JP10 when the connection is made in other equipment.

Analog Output

The analog output of the standard serial data electronic systems is not calibrated. Each axis may have a different load to voltage relationship and cross coupling effects are not removed. These outputs can be used for simple system checkout and uncalibrated tests where use of the digital data is not desired.

Sensors can be ordered with calibrated analog output. If you have calibrated analog output refer to your sensor specification sheet for the calibration matrix for your specific system. Refer to chapter 5 for information about the use of the calibration matrix.

The analog output signals are available at connector J2. Refer to the input/output connection page for the pinout of this connector.

There are 2 different ground connections possible. In almost all cases pin 9, the direct power supply common should be used for the ground connection. In some situations connection can be made to pin 7.

Pin 7 is a driven ground connection, that is, ground buffered by an opamp. Use of this connection may help reduce noise in the presence of ground loops or current in ground due to a difference in the ground voltages. Do not connect pin 7 to the remote ground.

SYSTEM SETUP AND ADJUSTMENT

HARDWARE OPTIONS

All internal jumpers and adjustments not specifically discussed in this section are not considered user serviceable, and should not be changed by the user without further instructions from **JR3**.

DISASSEMBLY

Electronics Enclosure

CAUTION STATIC DISCHARGE: The electronics enclosure contains components which can be damaged by electrostatic discharge. Use static precautions when disassembling the enclosure and handling the circuit boards and components inside.

To open the electronics enclosure, disconnect the serial data cable (J4) and the power cable (J3) if used. Remove the four screws mounting the end panel with the analog data (J2), and sensor (J1) connectors. Gently pull the panel away from the enclosure sliding the circuit board out of the enclosure.

When reassembling the electronic system be certain the circuit board is installed in the correct slot. Numbering the grooves from the top of the enclosure, the board is in slot 3 with the component side up.

Sensor Body

DO NOT DISASSEMBLE OR ATTEMPT TO REMOVE THE SENSOR COVER. There are no adjustments or user serviceable components located inside the sensor. The internal strain gauge components and wiring are extremely delicate. Unauthorized disassembly of the sensor will void your warranty, and may result in damage requiring costly repair and rework.

ADJUSTMENT AND CALIBRATION

Sensor

The sensor has no adjustments. Calibration of the sensor requires specialized equipment. User calibration in the field is not recommended. Contact **JR3** for additional information.

Electronic System

Several adjustments can be made to the electronic system. The offset adjustments affect the no load voltage output of the amplifier, but do not affect accuracy. Offsets may be adjusted to set the zero load output to a value the user desires, typically, this will be zero volts, but for some purposes a different setting may be desired. The Gain and Vex (excitation voltage) adjustments will affect the overall accuracy and should not be adjusted unless there is a definite indication they are in error. The Gain and Vex trimpots are sealed to help prevent accidental changes. Gain trimpots are not present if the system was ordered with the option for jumper selected full scales.

Some functions are selected by moving jumpers, instructions for using these jumpers are given in this chapter. A list of jumpers and their functions is on page 3-7.

Offset Adjustment

The offset adjustments set the system zero point output with no load applied. The zero load output may change by up to 20% of full scale when the sensor mounting bolts are tightened. Attachment of your apparatus or structural components will also change the output due to their weight.

Typically, the output is set for zero with no applied load, but specific uses may require a setting other than zero.

There are two sets of offset adjustments, the “8 channel offsets” and the “6 channel offsets.” In most situations only the 6 channel offset adjustment will need adjustment once the system has been adjusted after installation.

8 channel offset

The 8 channel instrumentation amplifier offsets will normally need adjustment only if there is a large change in the bolt-up deformation of the sensor, as can occur when it is mounted to a new surface, or if it is necessary to remove the offset caused by a large change in the tool or static load. If the sensor was ordered with electrical full scales substantially lower than the sensor mechanical rating the 8 channel offsets may require adjustment for

moderate changes in the static load. In most situations, only the 6 channel offset adjustment will be needed.

To check the 8 channel instrumentation amplifier offset, bolt the sensor and any device attached to it in place. Refer to the circuit board drawing and locate the 8 channel offset adjustment trimpots and the 8 test points labeled AH, BH, CH, DH, AV, BV, CV, & DV. With one meter lead connected to the ground test point, connect the other lead to each test point in turn. A reading in the range of +/- 1 VDC is acceptable. If necessary, adjust the appropriate trimpot until the offset voltage is in an acceptable range.

Sensors ordered for some specialized applications may specify 8 channel offsets different than 0 V. These sensors have the offsets and the conditions for setting them listed on the sensor specification sheet.

6 channel offset

Before adjusting the 6 channel offset, check the 8 channel offset to verify that it is correct. The 6 channel offset voltage can be checked at either the analog output connector J2 or at the filtered/unfiltered jumper block. Note that if the measurements are made at the jumper block all polarities will be reversed, and the voltage will be 0.9 times the voltage at J2. Refer to the circuit board drawing to locate these test points and adjustments.

NOTE: Be sure to notice that the sequence of the adjustment trimpots is Fx, Fy, Mz, Mx, My, Fz while the jumper block sequence is Fx, Fy, Fz, Mx, My, Mz.

Adjust the appropriate trimpot until all channels are set to the desired voltage (0 VDC is standard). If your application requires a setting other than zero make a note of the settings and the conditions under which they should be set for future reference.

Sensors ordered for some specialized applications may specify 6 channel offsets different than 0 V. These sensors have the offsets and the conditions for setting them listed on the sensor specification sheet.

Analog Filters

A fourth order Butterworth filter with a user selectable cutoff frequency is available for each axis.

The fourth order Butterworth filter attenuates the output above the cutoff frequency at 20 db per octave, providing a significant reduction in the noise

content of the output. A filter introduces a time delay in the data. An approximation of the delay is the reciprocal of the frequency (1/f).

The filter cutoff frequency is selected by changing a plug in resistor network. The circuit board drawing shows the location of the resistor networks on the circuit board. The analog filter selection table lists the resistor networks provided with the system and their associated cutoff frequencies.

Filtered or unfiltered analog output may be selected for each axis by moving the jumper plug for the desired axis to the appropriate position. The unfiltered response of the amplifier is greater than 10 kHz. Refer to the circuit board drawing for the location of the jumper block.

The serial data electronic system Analog to Digital Converter (ADC) is connected to the filtered data. The analog data to the ADC must be filtered to prevent false output due to alias effects. The system is shipped with the filter set to 926 Hz to allow maximum use of the digital filters in the receiver. If a lower analog filter cutoff frequency is selected, the bandwidth of the received digital data is limited by the cutoff of the analog filters.

CUTOFF FREQUENCY	PART NUMBER	VALUE (OHMS)
6.3 Hz	4608X-102-105	1.0 M
13 Hz	4608X-102-474	470 k
29 Hz	4608X-102-224	220 k
42 Hz	4608X-102-154	150 k
63 Hz	4608X-102-104	100 k
134 Hz	4608X-102-473	47 k
190 Hz	4608X-102-333	33 k
926 Hz	4608X-102-682	6.8 k

Analog Filter Selection

Full Scale Adjustment

The electronic system is available with either a single full scale setting or with two full scale settings selectable by moving jumpers. Systems with a single full scale setting have adjustable gain trimpots which are factory sealed at calibration. Adjustment of the gain trimpots will affect system calibration

and accuracy. Systems with two full scale settings do not have gain trimpots, the gain settings for each of the two full scales are fixed.

Full Scale Jumper Use

Systems with two sets of full scales have a specification sheet for each set of full scales. The higher set of full scales is selected when the jumpers are installed on the two pins provided; the lower set of full scales is selected when the jumpers are not installed on the two pins. When the lower set of full scales is selected the jumpers may be stored by installing them on one pin only of each pair of pins. It is important that the same set of full scales (high or low) be selected for all axes. If any axis is different large errors are likely to result.

Most receiver/processors utilize the shunt values stored in the electronic system to set the full scales. The shunt values for the lower set of full scales are stored in the electronic system non volatile memory. The system will default to the lower full scales on power up.

If the jumpers are set to select the higher full scales, it will be necessary to load the shunt values for the higher full scales into the proper location in your receiver/processor. This can be done as part of the initialization process of the software you use to read the data. Refer to the manual for your receiver/processor for detailed information.

Shunts

System gain calibration may be checked in the field using the calibrated shunt output for each channel. Turn the system on and allow at least fifteen minutes warm up time. Insure that the sensor will not have any change in the applied loads during the adjustment procedure. . Verify that the + Vex and – Vex voltages are set correctly and adjust them if needed. Verify the eight channel and six channel offset adjustments are set near zero, adjust the offsets if needed.

Refer to the receiver manual for the data location and method of reading the 6 channels of force and torque measurement and the stored shunt values. Read and record the force and torque values and the stored shunt values for each axis. Do not convert the output to engineering units, leave it in the counts as read from the receiver.

Turn the shunts on by installing the shunt jumper on the two pins at jumper JP1. Read and record the output counts for each channel with the shunts on. The difference in counts between shunts off and shunts on should equal the stored shunt counts you recorded for each axis. Significant errors may indicate a problem with the electronic system.

If the system was ordered with calibrated analog output the analog output shunt voltages will be specified on the sensor specification sheet. The shunt voltage is checked at the analog output connector by moving jumper JP1 as described above for the digital output.

NOTE: The Vex (excitation voltage) and Gain adjustments will affect the overall accuracy and should not be adjusted unless there is a definite indication they are in error. The Vex and Gain (if present) trimpots are sealed to help prevent accidental changes.

Vex

The sensor must be connected when the excitation is checked or set. The length of the sensor cable will affect the Vex, use the sensor cable which will be used in normal operation when the Vex is checked or set.

There is a testpoint and an adjustment trimpot for both the + and the - excitation voltages. Refer to your sensor specification sheet to determine the excitation voltage for your sensor. Refer to the circuit board drawing and locate the test points. Connect an accurate voltmeter to ground and the appropriate test point. Set the + Vex to plus one half the excitation and the - Vex set to minus one half the excitation. Measure the voltage from the + Vex test point to the - Vex test point. This voltage should equal the specified Vex.

Gain Trimpot Adjustment

If significant errors are present in a system with gain trimpots you may be able to adjust the gain to reduce errors. Read the output change using the shunt jumper as described above.

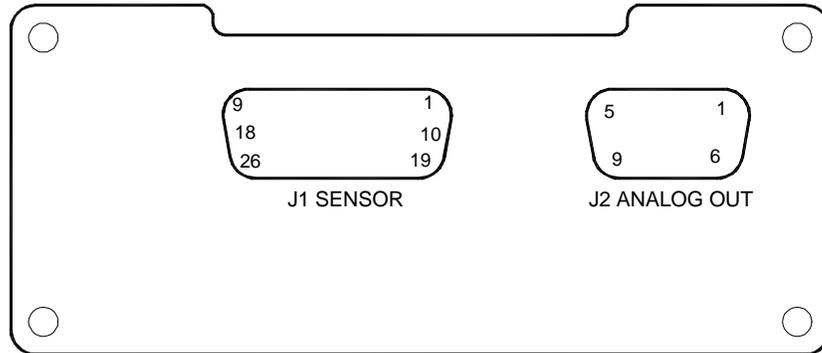
Refer to the drawing showing adjustment and test point location and adjust the gain trimpot for the axis with error. Changing the gain adjustment may change the 6 channel offset, it is necessary to re-check the zero point after each gain adjustment before checking shunt change. Repeat this procedure until the shunt output is correct. This adjustment is not possible in systems with two sets of full scales selected by moving jumpers.

Jumper	Function	Default Position
JP1	Shunts on	Off
JP2	Analog Filtered/Unfiltered	Filtered
JP3	Transmitted Channels	0 - 7
JP4	Power source select	Modular
JP5 – JP9	Not Present	N/A
JP10	Agnd – Dgnd tie	Off
JP11	Fx full scale	Low Full Scale (Jumper Off)
JP12	Fy full scale	Low Full Scale (Jumper Off)
JP13	Mz full scale	Low Full Scale (Jumper Off)
JP14	Mx full scale	Low Full Scale (Jumper Off)
JP15	My full scale	Low Full Scale (Jumper Off)
JP16	Fz full scale	Low Full Scale (Jumper Off)

JP11 thru JP16 present only for jumper selected full scales

Jumper Functions

CONNECTOR AND CIRCUIT BOARD DETAILS

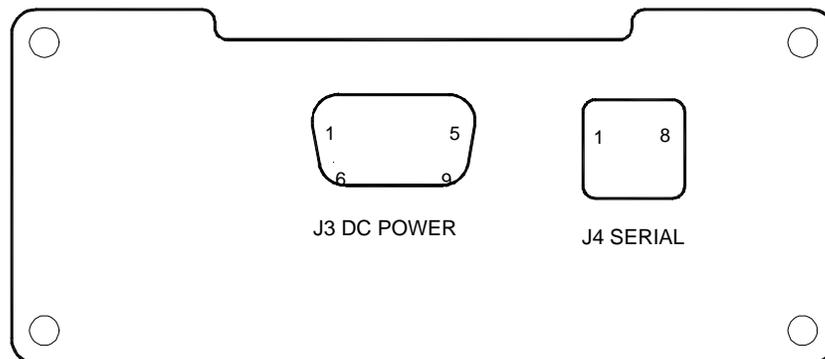


SENSOR END PANEL

1 Do Not Use	10 Do Not Use	19 Vex +	1 Fx
2 Vex + Return	11 Vex -	20 Do Not Use	2 Fy
3 Vex - Return	12 Do Not Use	21 Do Not Use	3 Fz
4 DV -	13 DV +	22 Shield	4 Mx
5 CV -	14 CV +	23 AH -	5 My
6 BV +	15 BV -	24 AH +	6 Mz
7 AV +	16 AV -	25 BH -	7 Gnd. Out
8 DH +	17 DH -	26 BH +	8 NC
9 CH +	18 CH -		9 Gnd.

J1 SENSOR

J2 ANALOG OUT

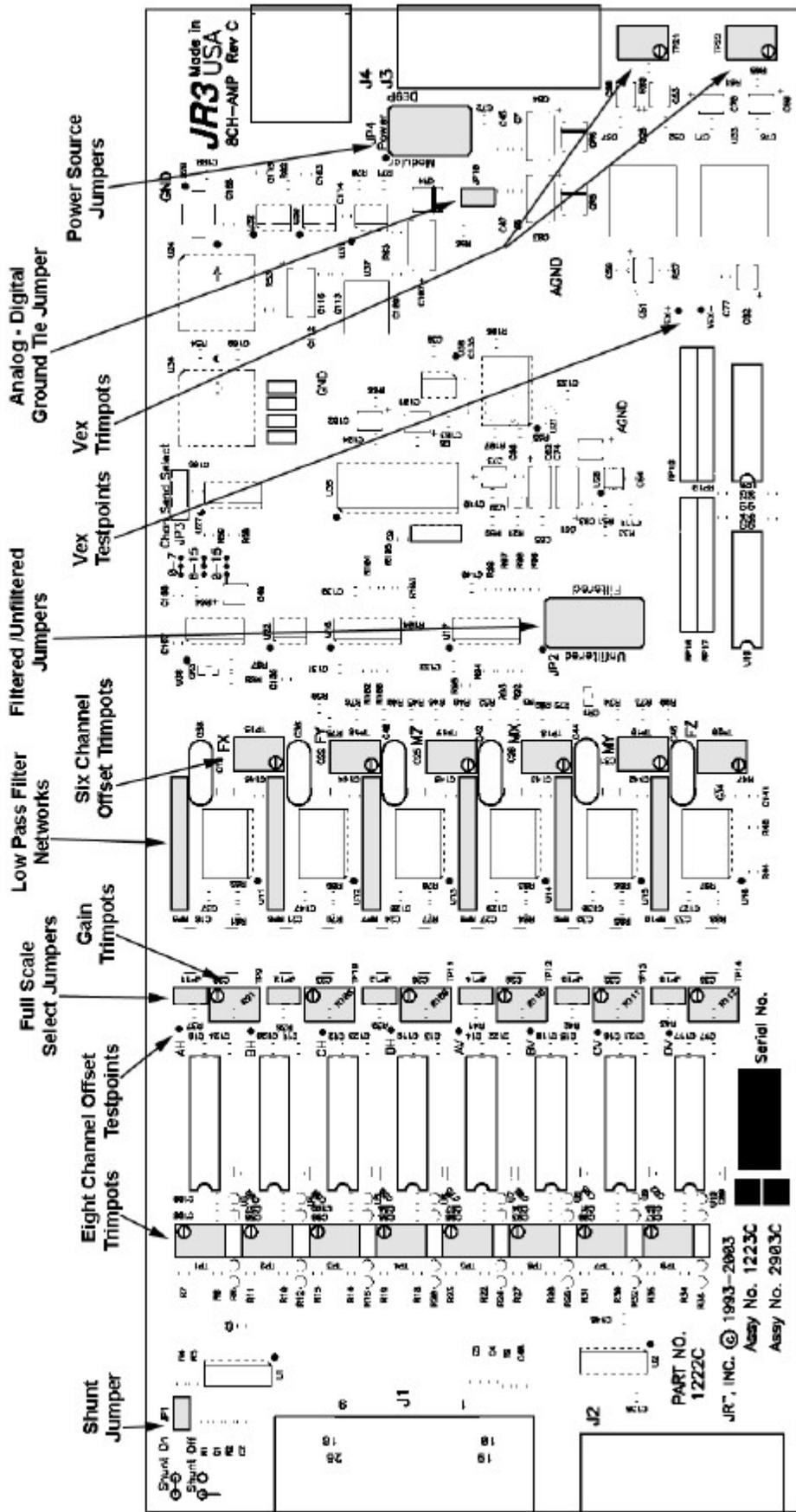


POWER END PANEL

1 + 8 VDC	1 - 12 VDC
2 Dig. Gnd.	2 Dclk +
3 NC	3 Dclk -
4 NC	4 + 8 VDC
5 NC	5 Gnd.
6 NC	6 Data +
7 + 12 VDC	7 Data -
8 - 12 VDC	8 + 12 VDC
9 Ana. Gnd. (12 VDC return)	

J3 DC POWER

J4 SERIAL DATA AND POWER



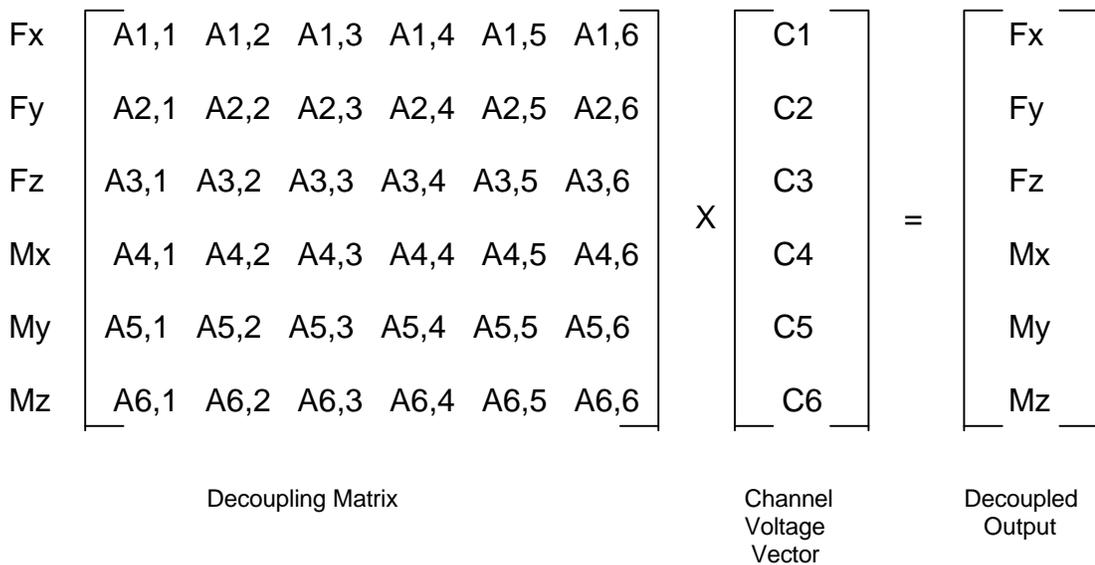
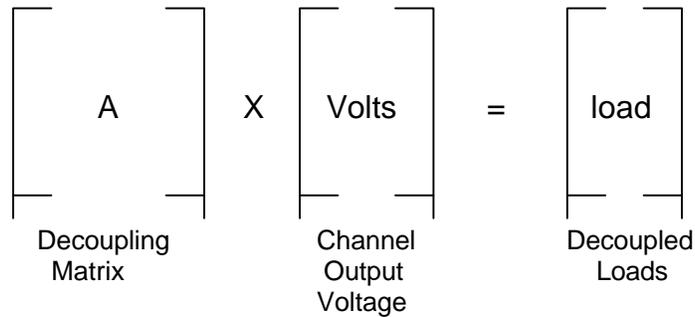
CALIBRATION AND DECOUPLING MATRIX

This chapter is applicable only if the sensor and electronic system was ordered with the optional calibrated analog output.

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

The six by six matrix is multiplied by the six element voltage vector (column). The result is calibrated force and moment data in the units specified on the Sensor Specification Sheet. The matrix multiplication is most easily performed by a computer, although manual computation is possible.

To find the calibrated, decoupled output, multiply the decoupling matrix by the output channel voltage vector. The output must be scaled to the desired units.



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 Mx reading, using the raw analog voltages, multiply the Mx row (A4) by the analog channel readings in volts. This gives the decoupled output as a fraction of full scale (assumes 10V full scale).

$$(A4,1 \times C1) + (A4,2 \times C2) + (A4,3 \times C3) \dots + (A4,6 \times C6) = Mx$$

A brief Pascal procedure showing one possible way of programming a computer for the decoupling matrix multiplication is shown below.

SAMPLE PASCAL CODE FOR DECOUPLING:

```
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;
    END;
```