

## **Six Axis F/T Sensor User's Manual**

This document is the user's manual for the six axis force/torque sensor from Sunrise Instruments (SRI, [www.srinsensor.com](http://www.srinsensor.com)). The manual includes the principle, performance specification, installation and usage of the F/T sensor.

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## 2. Introduction

SRI is a leading manufacturer of 6 axis force/torque sensor. In addition to China market, significant portion of our products are sold to Europe and North American. Most of the automotive manufacturers are currently using the force sensor manufactured at SRI in their crash test labs. SRI is the supplier for ABB, Foxconn, and many leading robot manufacturers. SRI products are widely used by academic research institutes and manufacturers for industrial products.

SRI have a well-established production line and a testing laboratory for the 6 axis F/T sensor that is certified to ISO 17025. The sensors that are manufactured and certified at SRI meet international standards.

We have 12 product series, and approximately 200 product models. The product lines include intelligent floating grinder, one to six axis force/torque sensor, robot joint torque sensor and data acquisition system.

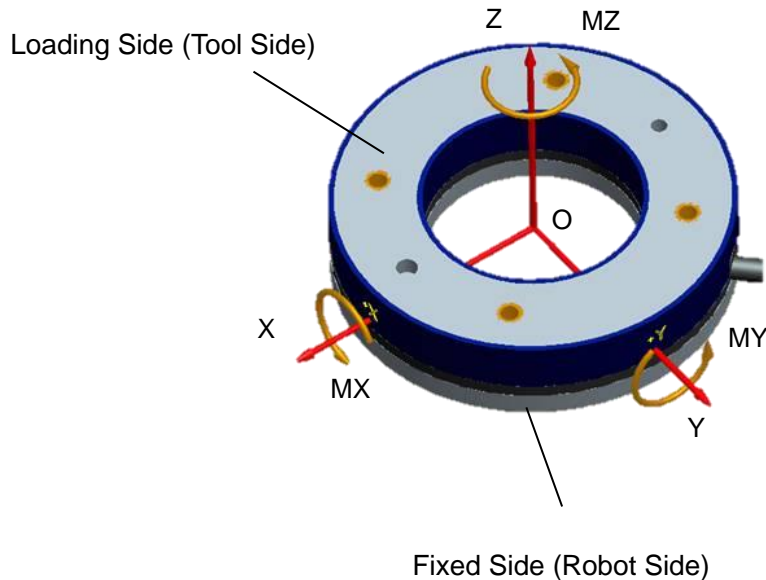
## 3. Engineering Principle of the Sensor

### 3.1 Principle

Six axis F/T sensor is a special type of loadcell, which measures three forces ( $F_x$ ,  $F_y$  and  $F_z$ ) and three moments ( $M_x$ ,  $M_y$  and  $M_z$ ) about its neutral coordinate system (OXYZ).

We can imagine that a 6 axis F/T sensor is divided into two portions – mounting side (mounting to a robot) and loading side (mounting to tool). When a load (force or moment) is applied to the tool side and the robot side is fixed, the sensor flexure undergoes small deformation. The resistance of the strain gauges on the sensor flexure will change accordingly, which is then converted into proportional voltage output.

The force and moment outputs of a six axis F/T sensor always refer to the neutral coordinate system. The neutral coordinate is typically located at the geometric center of the sensor, and its specific location can be found in the specification sheet of each sensor. The specification sheet can be downloaded from SRI website ([www.srisensor.com](http://www.srisensor.com)).



### 3.2 Decoupling Methods

For the SRI F/T sensors, there are two decoupling methods – matrix decoupled and structurally decoupled.

#### Matrix Decoupled:

There are 6 to 12 data channels for a matrix decoupled F/T sensor. The output data channels are “coupled”. For example, when a force  $F_z$  is applied, there may be outputs from all channels. To obtain three forces ( $F_x$ ,  $F_y$  and  $F_z$ ) and three moments ( $M_x$ ,  $M_y$  and  $M_z$ ), all channel data need to be pre-multiplied by a decoupled matrix.

M37XX series, M38XX series and M35XX series are matrix-decoupled F/T sensor.

#### Structurally Decoupled:

There are six output channels for a structurally decoupled sensor. Data channels are independent from each other. For example, when a force  $F_z$  is applied, there is only

one channel (Fz) that has output. The forces (Fx, Fy and Fz) and moments (Mx, My and Mz) are equal to the output voltage of each data channel divided by the corresponding sensitivity, respectively.

M33XX series and M39XX series are structurally decoupled F/T sensor. The specification sheet has the information if a sensor is matrix or structurally decoupled.

**Structurally decoupled**

**Not Structurally decoupled**

THE OUTPUT IS POSITIVE WHEN THE LOAD IS APPLIED TO THE TOOL SIDE PER COORDINATE AS SHOWN. ALL CHANNELS ARE STRUCTURALLY DECOUPLED. EMBEDDED AMPLIFIER INCLUDED.

THE OUTPUTS ARE NOT STRUCTURALLY DECOUPLED. A 6x6 DECOUPLED MATRIX IS PROVIDED TO OBTAIN EACH COMPONENT.

SPECIFICATIONS						
POWER SUPPLY (V)	±15V					
OVERLOAD CAPACITY (XF S.)	1000					
LOWEST FREE AIR RESONANT FREQ. (HZ.)	700					
CROSSTALK - NO ADJUSTMENT (XF S.)	5					
CROSSTALK - WITH ADJUSTMENT (XF S.)	2.5					
NON-LINEARITY (XF S.)	1.0					
HYSTERESIS (XF S.)	1.0					
OPERATING TEMP. RANGE (°C)	-40 TO +125					
COMPENSATED TEMP. RANGE (°C)	10 TO 70					
MASS (KG)	1.25					

SPECIFICATIONS						
POWER SUPPLY (V)	+24V(DI)ZOM					
OVERLOAD CAPACITY (XF S.)	400					
FREE AIR RESONANT FREQ. (HZ.)	1500					
CROSSTALK (XF S.)	2.5					
NON-LINEARITY (XF S.)	0.5					
HYSTERESIS (XF S.)	0.5					
OPERATING TEMP. RANGE (°C)	-40 TO +100					
COMPENSATED TEMP. RANGE (°C)	10 TO 70					
MASS (KG)	0.56					

LEMO PIN ASSIGNMENT						
PIN #	FUNCTION	PIN #	FUNCTION	PIN #	FUNCTION	
1 & 2	GND	7	+FX	12	-MX	
3	+15V	8	-FY	13	+MY	
4	-15V	9	+FZ	14	-MZ	
5	+FX	10	-FZ	15	+MZ	
6	-FX	11	+MX	16	-MY	

SUNRISE INSTRUMENTS  
www.srisensor.com

SIX AXIS LOADCELL WITH OL STOPS & AMP  
D104MM F16SN, 1P65

UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN MM

M3314A

SUNRISE INSTRUMENTS  
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SIX AXIS CIRCULAR LOAD CELL, COUPLED  
D91MM F200N, ANALOG OUTPUT, 1P65

UNLESS OTHERWISE SPECIFIED  
DIMENSIONS ARE IN MM

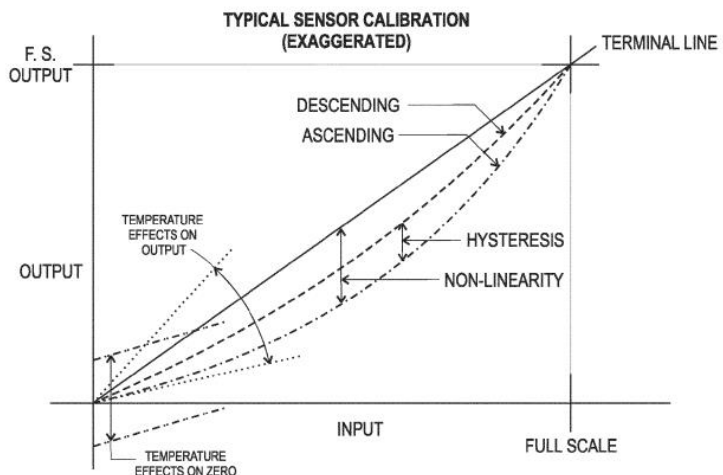
M4325K

**4. Specification Definitions**

SRI six axis F/T sensor follows the definitions as defined in SAE J2570-2000. SAE stands for the American Society of Automotive Engineers. SRI testing laboratory is certified to ISO 17025, as shown below.



ISO17025 Certificate



Typical testing data curve (from SAE J2570-2001)

#### **4.1 Full Scale Capacity**

Full scale capacity refers to the intended maximum loads (forces and moments) that are applied to the sensor. This must be defined for calculating other parameters in these specifications.

#### **4.2 Output at Full Scale (F.S.)**

When load (force or moment) is applied to the sensor at full scale, the channel output is called output at full scale, in the unit of mv/V or V.

#### **4.3 Sensitivity**

Sensitivity is equal to the output at full scale divided by the full scale.

#### **4.4 Crosstalk**

Effect on the reading of an unloaded transducer axis when a load equal to the full-scale capacity of a secondary axis is applied to that secondary axis. Expressed as a percentage of full-scale capacity of the unloaded axis.

#### **4.5 Free Air Resonance**

The frequency at which a transducer resonates, when suspended freely in air by a single wire and impacted with a hard surfaced body. This test shall be done while monitoring the channel output to insure each channel's fundamental output frequency shall be equal to or greater than the specified frequency.

#### **4.6 Hysteresis (% of Full Scale Capacity)**

The maximum deviation between ascending and descending output readings taken at the same load point, expressed as a percentage of full scale capacity. Refer to above figure for graphical representation.

#### **4.7 Non-Linearity (% of Full Scale Capacity)**

The maximum deviation of a transducer output reading from the terminal line, expressed as a percentage of full scale capacity (the terminal line is defined as a straight line connecting a transducer zero load reading and its full scale reading). Refer to above figure for graphical representation.

#### **4.8 Decoupled Matrix**

For a coupled output sensor, the three forces and three moments are equal to the product of a matrix and the output voltage (in mv/V or volt). The matrix is called "decoupled matrix". The matrix is 6X6 when the sensor has 6 output channels, or 6X12 when the sensor has 12 output channels.

#### **4.9 Zero offset**

The output voltage (in mv/V or Volt) when no load is applied to the sensor. Due to the gravity effect, the zero offset may change when the sensor is placed on a table from horizontally to vertically.

#### **4.10 Accuracy**

The accuracy of the sensor relates to non-linearity, hysteresis and crosstalk.

#### **4.11 Resolution**

The minimum load that the sensor can differentiate is called resolution. Resolution is typically much higher than accuracy. In addition, resolution is also related to the data acquisition system and how the resolution is measured and how the data is interpreted.

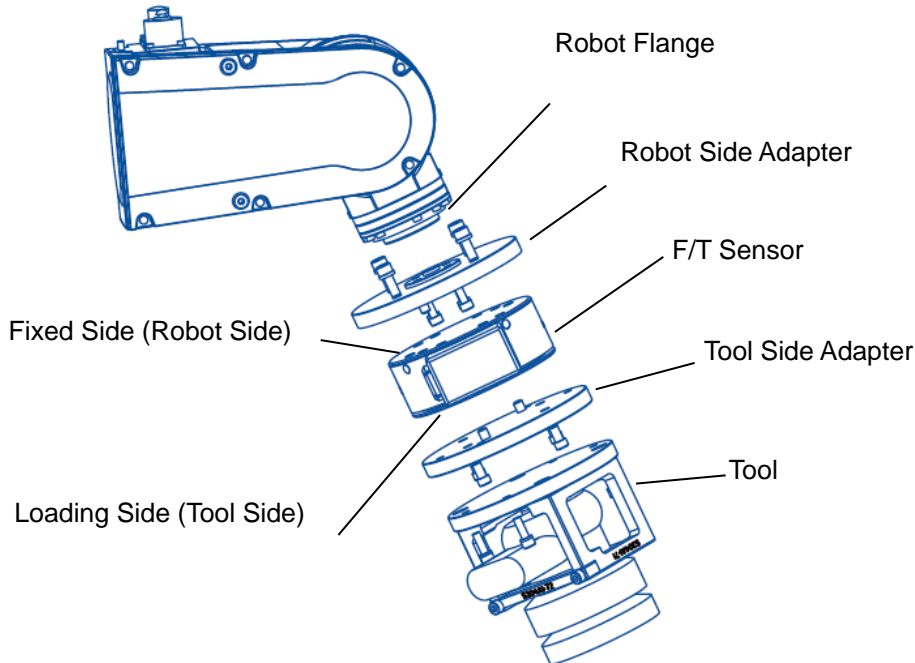
SRI defines the resolution as the minimum load that sensor can differentiate when the load is suddenly removed from the sensor. SRI interface box M8128 is used for this testing. The sampling rate is set to 100Hz.

#### **4.12 Overload Capacity**

The maximum possible load a sensor can take is called overload capacity. The overload capacity ranges from 1.5 to 10 times of the sensor capacity, which is defined in the specification sheet. Select a sensor model with the capacity (not overload capacity) of about 120% to 200% of the possible maximum loads (forces & moments). Note that the overload capacity of the sensor cannot be considered as typical "capacity", since it is designed for accidental usage when mis-handling.

## 5. Mechanical Installation

The sensor dimensions and mounting holes are shown in the specification sheet. The following example illustrates how the sensor is mounted to a robot and a tool.



Note: If there are dowel holes on the sensor mounting surfaces, dowel pins should be used for mating the sensor to the adaptor

## 6. Electrical Connection

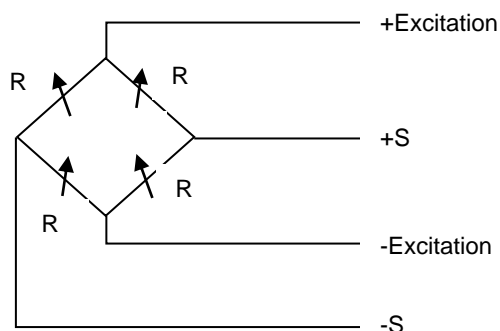
There are three types of output from SRI F/T sensors, where the output type is specified in the specification sheet.

- Low voltage output – the +signal and -signal of the strain gauge bridge inside the sensor are directly wired to output cable (e.g. M35XX series). The output is typically proportional to the excitation voltage. Therefore, the output voltage is typically divided by the excitation voltage to obtain mv/V.
- High voltage output with embedded amplifier – the low voltage signals from the strain gauge is amplified before wired to external cable (e.g. M33XX series).
- Digital output version: Data acquisition system is integrated inside the sensor. The communication buses include RS232, CAN, Ethernet and/or EtherCAT (e.g. M4325N).



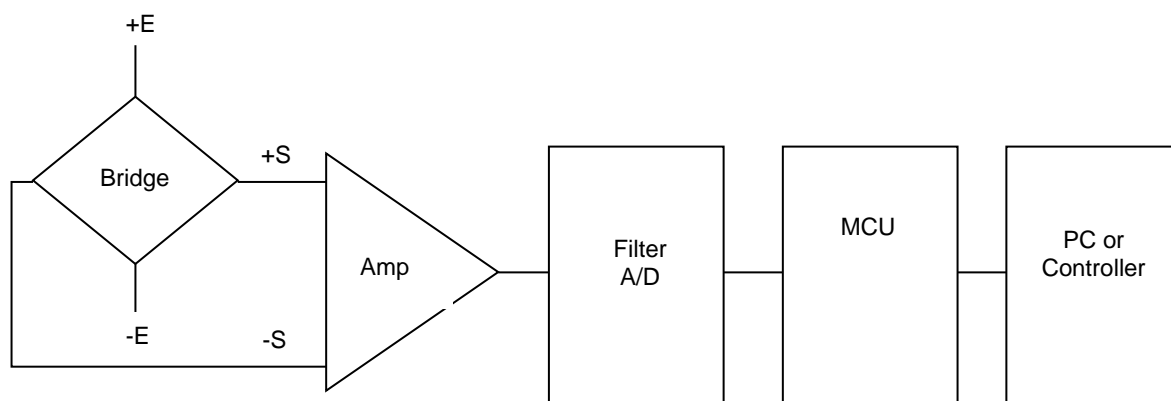
### 6.1 Low Voltage Output Sensor

Low voltage output sensor has a full strain gauge bridge. The overall flow chart as



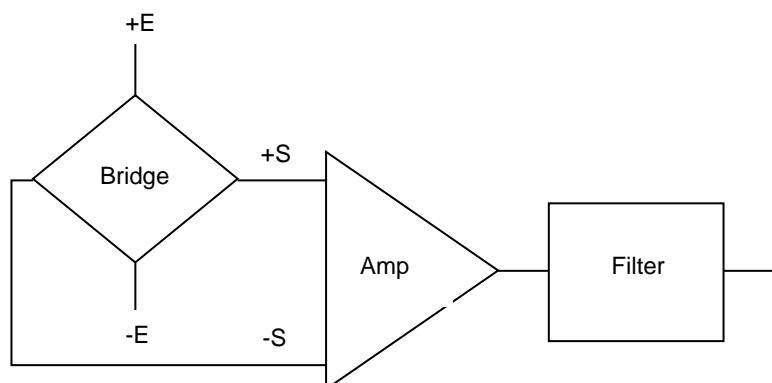
shown above. Note that SRI has matching amplifier M830X that can convert the low signal voltage into high voltage. In addition, SRI interface box M8126/M8128 can convert the analog signals from the sensor with low voltage output into digital, with communication RS232, CAN, Ethernet and/or EtherCAT.

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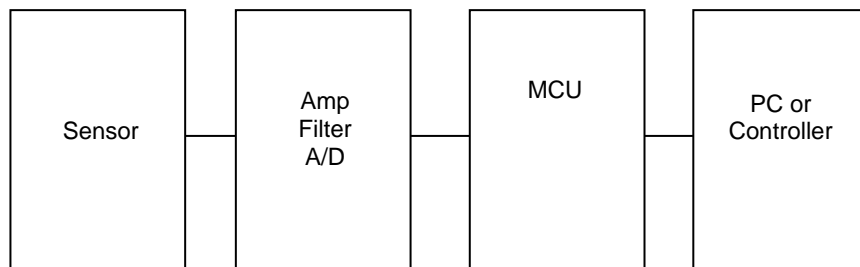


### 6.2 Embedded Amplifier Sensor

The sensor has embedded amplifiers, as shown below::



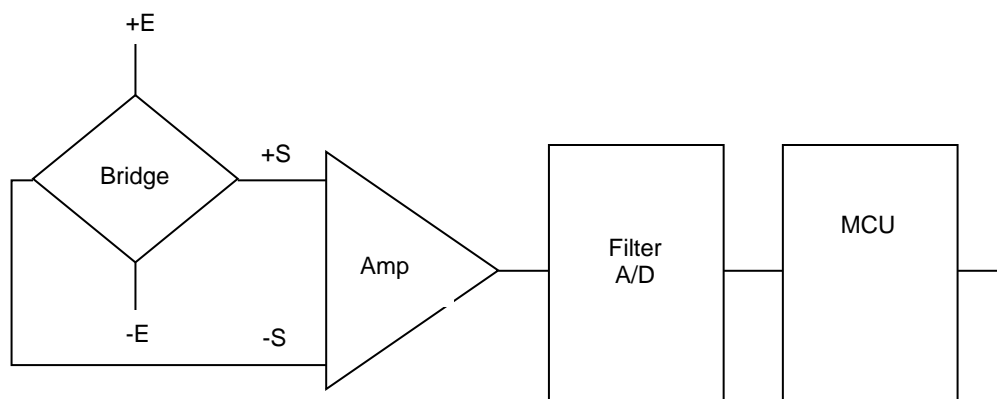
Example of external circuitry as below:



Note that SRI interface box M8126/M8128 can convert the analog signals from the sensor with embedded amplifier sensor into digital, with communication RS232, CAN, Ethernet and/or EtherCAT.

### 6.3 Digital Output Sensor

Data acquisition system is integrated inside the sensor. The communication buses



include RS232, CAN, Ethernet and/or EtherCAT.

External circuitry is shown below:

