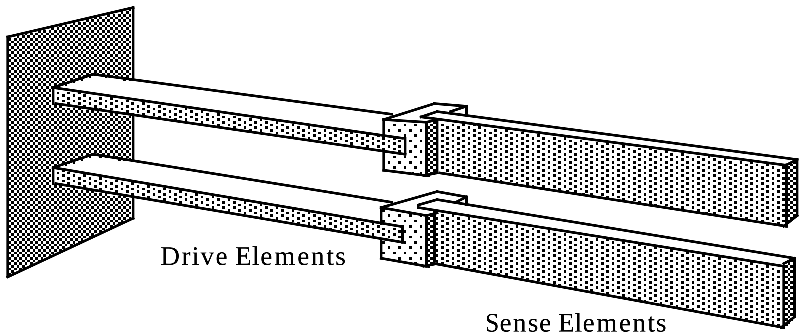
Angular Rate Sensor Manual



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INTRODUCTION

The Watson "tuning fork" angular rate sensor represents a significant advancement in inertial sensor technology and holds U.S. patents 4,628,734 & 4,479,098. It is a highly accurate device, with many advantages over rate gyros and other types of angular rate sensing devices. This manual describes operation of the Watson sensor and provides useful application information for the system designer.

DISCLAIMER

The information contained in this manual is believed to be accurate and reliable. Since Watson Industries cannot know all of the possible uses for its products, it makes no warranty concerning the suitability of its products for a particular application. It is the responsibility of the user to test and to determine whether a Watson Industries' product is suitable for his/her application.

Watson Industries warrants only that its products will meet its specifications for the duration of the warranty. There is no warranty concerning suitability of use, nor any other expressed or implied warranties. Watson Industries' sole liability is limited to repair or replacement of any product which fails to meet its specifications while under warranty coverage. Watson Industries will not be liable for incidental or consequential damage of any kind.

Suggestion of uses should not be taken as inducements to infringe upon any patents.

PRODUCT DESCRIPTION

The Watson Industries angular rate sensor is an entirely solid-state, single axis sensor. It provides an analog output voltage which is proportional to the angular rate about its sensing axis. At zero angular rate, the output is zero volts (plus a bias). Full scale angular rates produce an output of +10 or -10 volts, dependent upon direction of rotation. Full scale outputs are available from 30°/sec to 3000°/sec. See page 3 for standard models. A dual power supply, providing regulated +15 and -15 volts, is required. Custom units with different sensitivities and/or output formats are available. Power converters are also available to allow the sensor to operate from different supply voltages.

THEORY OF OPERATION

The **Watson Industries** angular rate sensor utilizes piezoelectric vibrating beam technology to produce an inertial sensor with no moving parts. The actual transducer consists of two pairs of piezoelectric bender elements as shownon the front cover. Since each pair operates identically, only the operation of element pair number one will be described.

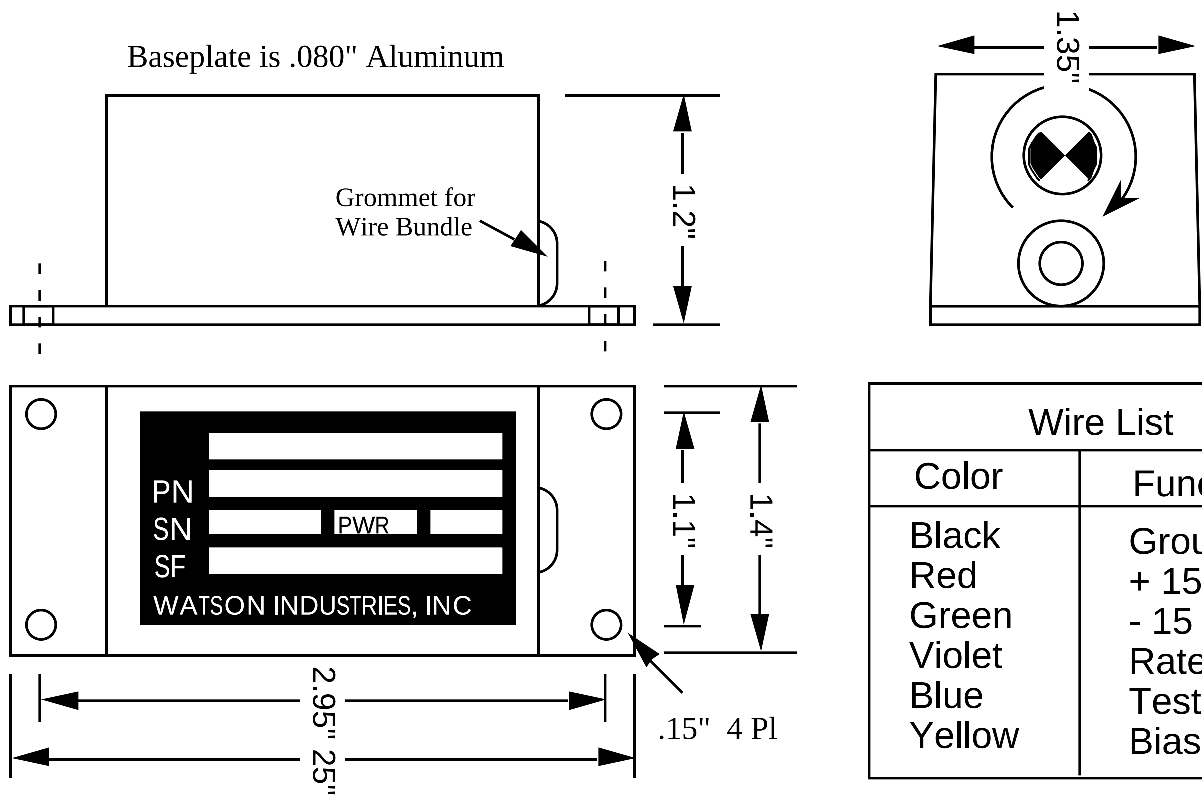
The two piezoelectric bender elements are mounted end to end but rotated at a 90° angle. The element fastened to the base is resonantly driven such that the sense element swings a reciprocating arc. Under zero angular rate conditions on the sense axis (the long axis of the assembly), the motion of the sense element does not produce bending of the element, and therefore, does not produce a signal. When a rate of rotation exists, however, conservation of angular momentum causes rate to be transferred into the perpendicular plane and cause bending of the sense element. A signal is thus produced which magnitude is proportional to the angular rate, and which phase is dependent upon the direction of rotation.

Unfortunately, angular rates are not the only source of sense element bendings. External vibrations and accelerations can deflect the sense element, as can acoustical energy which is radiated from the drive element and reflected by its environment to the sense element.

Using a “tuning fork” configuration (i.e., the use of two pairs of piezoelectric elements) greatly reduces these problems. In this configuration, the two drive elements are driven with identical amplitude and frequency, but are driven l80° out of phase. This accomplishes two objectives: first, there is a nodal plane created midway between the two element pairs. On this node, vibration from the two drive elements essentially cancels, producing a net zero vibration. Solid mounting to the supporting structure is done at this node, which prevents transmission of acoustical energy. If no energy is transmitted, there is none to be reflected back to the sense elements, making the sensor virtually insensitive to its mounting.

The second advantage of the “tuning fork” configuration is that it greatly improves immunity to external vibration. When an angular rate exists, the sense elements vibrate l80° out of phase. However, when an external vibration is present, it causes the sense elements to vibrate in phase. Thus, by subtracting the two sense element signals, the sensor response is enhanced for angular rate motions, with almost total common-mode rejection of external vibration.

The Watson Industries’ angular rate sensor relies upon sophisticated electronics, both to resonantly drive the element assemblies and to demodulate, filter and amplify the sense signals.



Wire List	
Color	Function
Black	Ground
Red	+ 15 VDC
Green	- 15 VDC
Violet	Rate Output
Blue	Test Output
Yellow	Bias Adjust

Figure 2. ARS-C1X1-1A Drawing and Wire List

MECHANICAL INSTALLATION

_______The Watson Industries Angular Rate Sensor is a rugged device and, in most applications, does not require shock mounting to protect it from damage. A rigid mounting is therefore often desirable: however, in many applications a soft mount is preferable.

If a rigid mounting is desired, the sensor may be fastened to its supporting structure via the four holes in its mounting plate. Refer to Page 3 or 7 for dimensional details. This installation will hold the sensor in an accurate alignment with adequate mechanical isolation for many applications.

The Watson Angular Rate Sensor requires vibration isolation in high vibration environments (to prevent damage) and in environments where fundamental or harmonic vibrations excite the drive resonance of the unit (approximately 325 ±20 Hertz).

Symmetry: The sensor will respond 5to motions on a scale that increases with frequency (i.e., 0.1 degree displacement over 1 second = 0.1 degree per second, but the same displacement of 0.01 second = 10 degrees per second). Rotation motions will be introduced ina soft mount if the mount does not apply forces uniformly at the center of mass.

Softness: The cut-off frequency (Fc) should be as low as practicable in order to get the best isolation. Shock mounts are a second order resonant system and attenuate at -6db per octave (i.e., Fc(180 Hz) = -6db; Fc(90 Hz) = -12db; Fc(45 Hz) = -18db, etc.). Note that -18db is attentuation to 1.47%

Damping: The resonance of the shock mount will have a peak that will multiply the exciting displacement if low damping is provided. This is not a significant problem if the displacement does not hit the "stops" and the symmetry is good enough to prevent significant rotational motions from the high linear motions. Open cell foam products are best for damping.

Rotational Stiffness: The linear and rotational resonances of a system are independent. Good rotational coupling can be maintained in a soft linear mount. This is done by providing a "wide stance" so that the low forces of a soft mount are multiplied by a long moment arm in coupling to the rotational inertia of the sensor.

Figure 3 shows two methods of mounting that can be applied to any of the Watson products for vibration isolation. The center page shows the packaging outline for the vibration mounting available from Watson Industries.

The sensitive axis of the sensor is the axis perpendicular to the orietnation label. Rotation in the direction indicated by the arrow will produce a positive output voltage. Rotation in the opposite direction will produce a negative voltage.

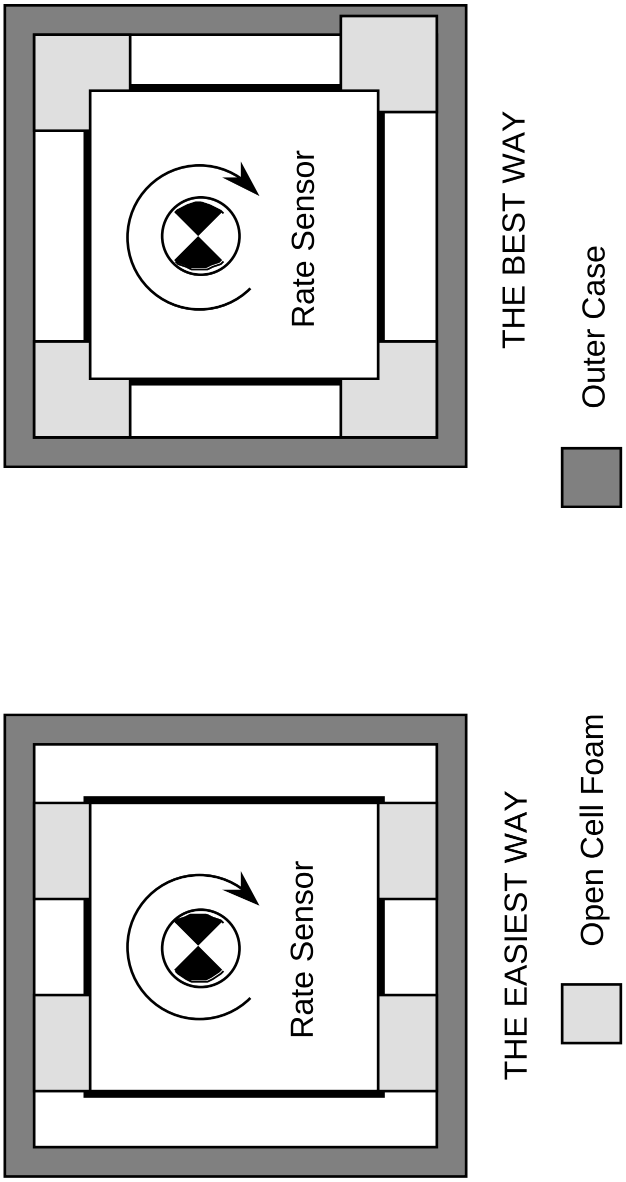


Figure 3. Vibration Isolation Geometries

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ANGULAR RATE SENSOR SPECIFICATIONS

Power Supply Requirements	+15VDC, 10 mA Maximum -15VDC, 10 mA Maximum
Output	±10VDC RANGE ANALOG
Models X: # of Axes (1,2,or 3) Y: 1 - Standard Unit 2 - Vibration Package	ARS-CX2Y-1A, 3°/Sec/Volt ARS-CX3Y-1A,10°/Sec/Volt ARS-CX4Y-1A, 30°/Sec/Volt Scales Available to 1000°/Sec/Volt
System Frequency	325 Hz ± 20 Hz
Scale Factor Error	2%
Resolution	Limited by Noise
Linearity Error	< 0.1% Full Scale
Temperature Offset	ARS-CX2Y-1A, 6°/Sec P-P Max All Others - ±5% of Full Scale
Warmup Drift	Less Than 2% of Full Scale
Frequency Response	DC to 50 Hz
Output Noise	ARS-CX2Y-1A < 0.05 °/Second (RMS) ARS-CX3Y-1A < 0.1°/Second (RMS) ARS-CX4Y-1A < 0.3°/Second (RMS)
Operating/Storage Temperature	-20°C to +50°C
Shock	200 g's
Reliability	50,000 Hours MTBF (Typical)
Weight	
Vibration Package	50 Grams (1.76 oz.)
Standard Unit	85 Grams (3 oz.)

WATSON INDUSTRIES, INC.

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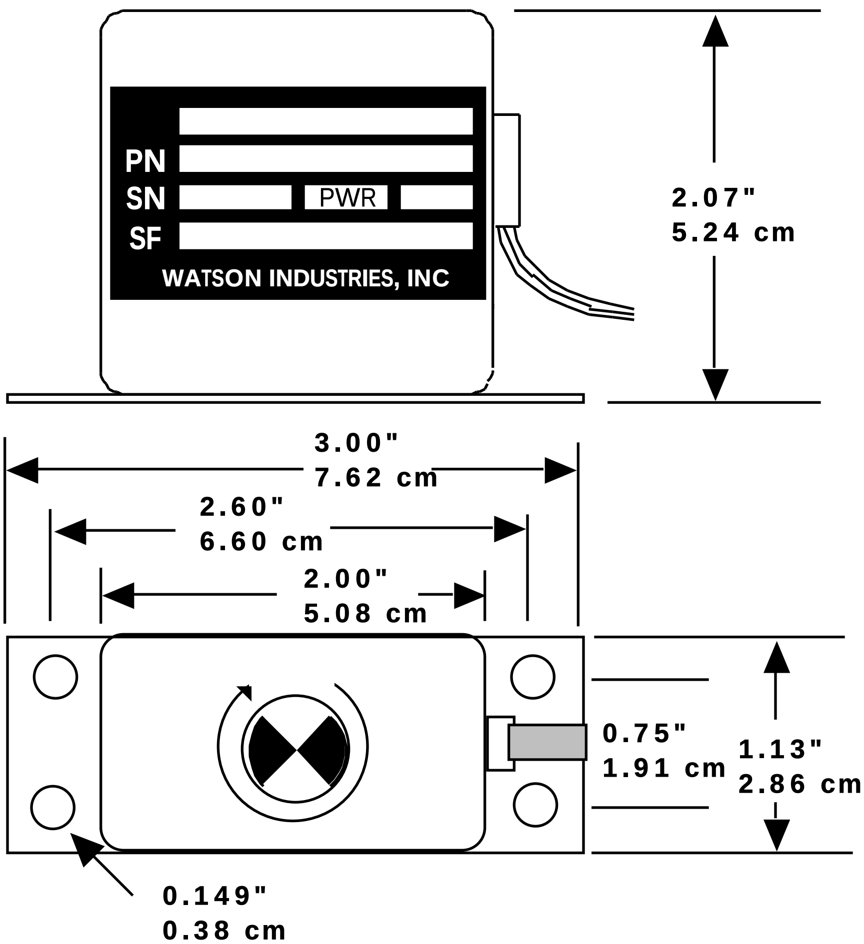
ARS-C1X2-1A
DRAWING AND WIRE LIST

BLACK	GROUND
RED	+15VDC
GREEN	-15VDC
VIOLET	SIGNAL OUTPUT
YELLOW	ZERO INPUT BIAS



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CALIBRATION

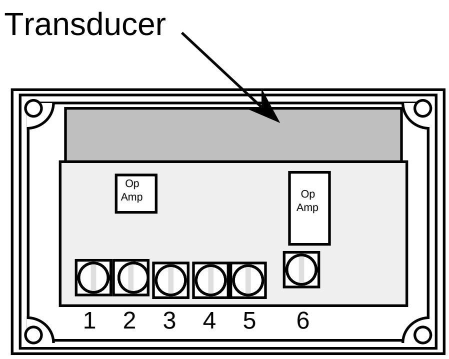
The only calibration which the user should attempt are those for zero offset and scale factor (gain).

ZERO

The Zero pot (pot #2-Figure 4) should be used only to re-zero the output to remove bias changes due to aging or high/low temperature operation. Large offsets in bias should be accomplished with the bias lead (the yellow wire). The bias input has a 10 KW input impedance and will offset the zero at a scale of ±1 volt output change for every ±1 volt bias input.

SCALE FACTOR

Changes in scale factor require use of a calibrated turntable. Set the turntable rate to equal the desired full scale ARS output, then adjust the gain pot (pot #6-Figure 4) until the ARS output reads ±10 V (depending on direction of rotation). After adjusting rate, re-zero the output, if necessary, using pot #3. If the desired rate cannot be reached in the range of pot #4 unit must be returned to factory for a bias resistor change.



Potentiometers	
Pot #1:	T Adjust
Pot #2:	Zero offset(Bias)
Pot #3:	Temperature Compensation
Pot #4:	F Adjust
Pot #5:	BPF Gain
Pot #6:	Scale Factor

Watson Industries recommends that only the factory adjust pots 1, 3, 4, and 5. Pot #6 requires the use of precision angular rate table.

Figure 4. ARS Potentiometer Locations

ELECTRICAL CONNECTIONS

All electrical connections to the sensor are made through the 6-wire (5-wire in vibration packages) bundle. Refer to Page 3 or 7 for color coding information. The blue test wire is not available in vibration packaging.

Power Connections: ground (black), +15 VDC (red), -15 VDC (green). Each input voltage should be within ±5%. Higher voltages may cause component damage, while lower voltages may cause faulty operation, especially at low temperatures. The power inputs should be well filtered; power line noise may cause noise to appear on the outputs. Current draw is approximately 10mA from each supply with no loading on the outputs.

Outputs: Both the signal and test outputs are protected by 1 KW series resistors and will not be damaged by intermittent short circuits. These resistors protect the circuit from ringing caused by the capacitive loading of long test leads.

Signal output (violet): The output is 0-VDC at zero angular rate and ±10 VDC at full scale angular rate. Approximately 20% over range is available.

Test output (blue): The Test output is derived from the drive crystal oscillator circuitry. It can be used to ascertain proper operation of the drive circuitry. However, because the test output cannot detect sense circuit failures, a proper reading does not insure correct operaiton of the entire sensor. The blue test output is only available by special request in vibraiton mount packages.

Under normal operating conditions, the test output should be a low distortion sine wave with frequency of 350 Hz ±10%. The AC component should have an amplitude of 3.5 VRMS ±20% and the DC component should be less than ±0.20 VDC.

On an oscilloscope, the oscillation period should be 2.5 to 3.3 msec. The amplitude should be 7.0 ±l.5 V P-P and there should be only a slight amount of distortion on the sine wave. No high frequency ringing should be visible.

External zero input (yellow): This wire can be used to provide a DC bias for the output signal. The circuit will allow the output to be biased over a range of approximately ±13 volts before saturation occurs. The bias input has a 10 K input impedance and will offset the zero at a scale of ±1 volt output change for every ±1 volt bias input.

WARRANTY

Watson Industries, Inc. warrants to the original purchaser this product to be free from defective material or workmanship for a period of one full year from the date of purchase. **Watson Industries**' liability under this warranty is limited to repairing or replacing, at **Watson Industries'** sole discretion, the defective product when returned to the factory, shipping charges prepaid, within one full year from the date of purchase. The warranty described in this paragraph shall be in lieu of any other warranty, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose.

Excluded from any warranty given by **Watson Industries** are products that have been subject to abuse, misuse, damage or accident; that have been connected, installed or adjusted contrary to the instructions furnished by seller, or that have been repaired by persons not authorized by **Watson Industries**.

Watson Industries reserves the right to discontinue models, change specifications, price or design of this product at any time without notice and without incurring any obligation whatsoever.

The purchaser agrees to assume all liabilities for any damages and/or bodily injury which may result from the use or misuse of this product by the purchaser, his employees or agents. The purchaser further agrees that seller shall not be liable in any way for consequential damages resulting from the use of this product.

No agent or representative of **Watson Industries** is authorized to assume and **Watson Industries** will not be bound by any other obligation or representation made in connection with the sale and purchase of this product.

SERVICE

All service is performed at the factory. In order to insure prompt service, please call or write to **Watson Industries** at the following address prior to returning a unit for repair:

Watson Industries, Inc.
3041 Melby Road
Eau Claire, Wisconsin 54703
ATTENTION: Service Department
Telephone : (800) 222-4976

All sensors returned under warranty will be repaired or replaced at the option of Watson Industries at no cost to the customer other than shipment of the defective unit to Watson Industries.

In the case of units not under warranty, a flat repair fee will be charged. This fee can be determined by calling or writing to Watson Industries.

Recalibration service can be obtained for a flat fee. Please call or write to Watson Industries for details.

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