ALTHEN
SENSORS & CONTROLS

CRS39A SERIES

High Performance MEMS Gyroscope

CRS39A provides the optimum solution for applications where bias instability, angle random walk and low noise are of critical importance.

At the heart of the CRS39A is Silicon Sensing's VSG3QMAX vibrating ring MEMS sensor which is at the pinnacle of 15 years of design evolution and the latest off a line which has produced over 30 million high integrity MEMS inertial sensors. The VSG3QMAX gyro sensor is combined with precision discrete electronics to achieve high stability and low noise, making the CRS39A a viable alternative to Fibre Optic Gyro (FOG) and Dynamically Tuned Gyro (DTG).

CRS39A has been designed for mounting within a 25mm inside diameter cylinder.

Two on board temperature sensors and the resonant frequency of the MEMS enable additional external conditio-ning to be applied to the CRS39A by the host, enhancing the performance even further.

CRS39A provides improved performance and hysteresis over the established CRS39-03.

CRS39A has 3 resonant frequency variants:

CRS39A	Rate Range	Frequency Output
CRS39A-V	±25°/s	< 27.37kHz
CRS39A-L		27.37 - 27.83kHz
CRS39A-M		> 27.83kHz

FEATURES

- Proven and robust silicon MEMS vibrating ring structure
- FOG-like performance
- DTG-like size and performance
- Low Bias Instability (0.03°/h)
- Excellent Angle Random Walk (0.004°/√h)
- Ultra-low noise (<0.006°/s rms, 10 Hz)
- Optimised for low rate range environments (e.g. North Finding)
- Precision analogue output
- Temperature range from -10°C to +110°C
- High shock and vibration rejection
- Two temperature sensors and MEMS frequency output for precision thermal compensation
- RoHS compliant
- Improved hysteresis
- Lower current compensation than CRS39-03

APPLICATIONS

- Drilling equipment and guidance
- Rail track monitoring
- Gyro-compassing and heading control
- Autonomous vehicles, UAVs and ROVs
- Robotics

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DIMENSIONS

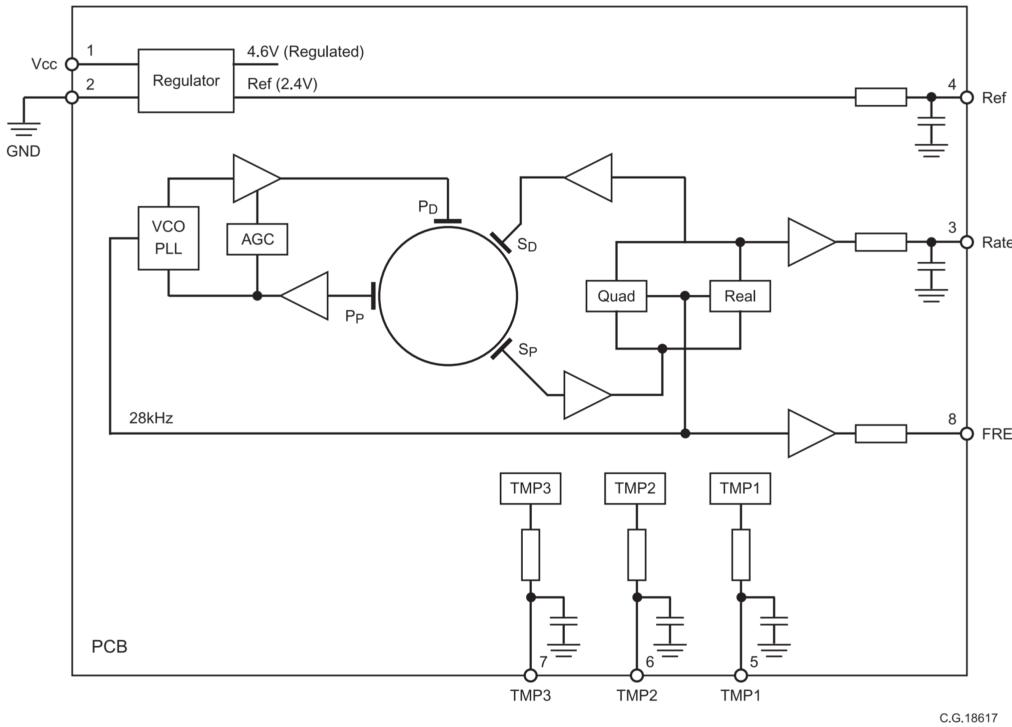
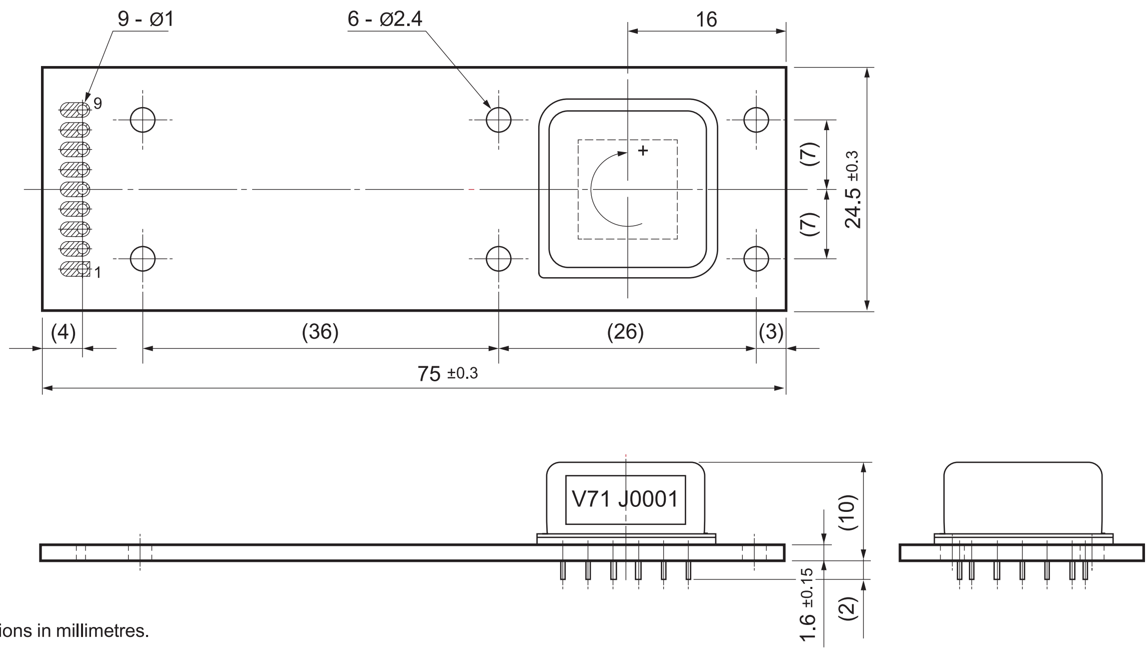


Figure 1.1 CRS39A Functional Block Diagram



All dimensions in millimetres.

C.G. 18885

Figure 1.2 CRS39A - Overall Dimensions

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SPECIFICATION

Unless otherwise specified the following specification values assume Vdd = 4.9 V to 5.25 V and an ambient temperature of +45°C. 'Over temperature' refers to the temperature range -10 to +110°C.

Gyro Output Parameter	Minimum	Typical	Maximum	Notes
Dynamic Range	±25°/s			–
Scale Factor at 45°C	79.6mV/°/s	80.0mV/°/s	80.4mV/°/s	–
Scale Factor Variation Over Temperature (w.r.t. 45°C)	–	±0.15%	±0.5%	–
Scale Factor Non-Linearity	–	–	±0.05%	–
Bias at 45°C	–	–	±10mV	w.r.t. Ref
Bias Over Temperature (w.r.t. 45°C)	–	±60°/hr	±250°/hr	–
Bias Drift	–	10°/hr	–	1hr after power on at 25°C
Bias Run to Run	–	0.5°/hr	–	1min on/1min off, 10 times, at 25°C
Bias Hysteresis	–	20°/hr	–	–
Angle Random Walk	–	0.004°/√hr	–	at 25°C
Bias Instability	–	0.03°/hr	–	at 25°C
Quiescent Noise	–	0.006°/s rms	0.01°/s rms	3 - 10Hz at 25°C
	–	0.03°/s rms	0.05°/s rms	Wide band at 25°C
Bandwidth	15Hz	25Hz	35Hz	-3dB point at 25°C
Reference Output (Ref)	2.370V	2.400V	2.430V	w.r.t. REFL
Start Up Time	–	–	1s	–
Temperature Output Parameter				
TMP1, TMP2 voltage at 45°C	-1.16V	-1.06V	-0.96V	w.r.t. Ref
Temperature Sensor Scale Factor	-13.7mV/°C	-11.7mV/°C	-0.70mV/°C	–
Frequency Output Parameter				
Frequency output	27.0kHz	28.0kHz	29.0kHz	V, L, M - Type
Frequency Temperature Coefficient	-0.90Hz/°C	-0.80Hz/°C	-0.70Hz/°C	–
Physical				
Mass	–	15 grams	–	–
Cross Axis Sensitivity	–	1.2% (0.7°)	3.5% (2°)	at 25°C
Environmental				
Temperature (Operating)	-10°C	–	+110°C	–
Temperature (Storage)	-40°C	–	+130°C	–
Shock (Operating)	–	–	250g×1.7ms	at 25°C
Shock (Non-operating)	–	–	1000g×1.0ms	at 25°C

ELECTRICAL CHARACTERISTICS

Parameter	Minimum	Typical	Maximum	Unit	Notes
Supply Voltage	4.9	5.0	5.25	V	–
Current Consumption	–	30	40	mA	–

INTERFACING

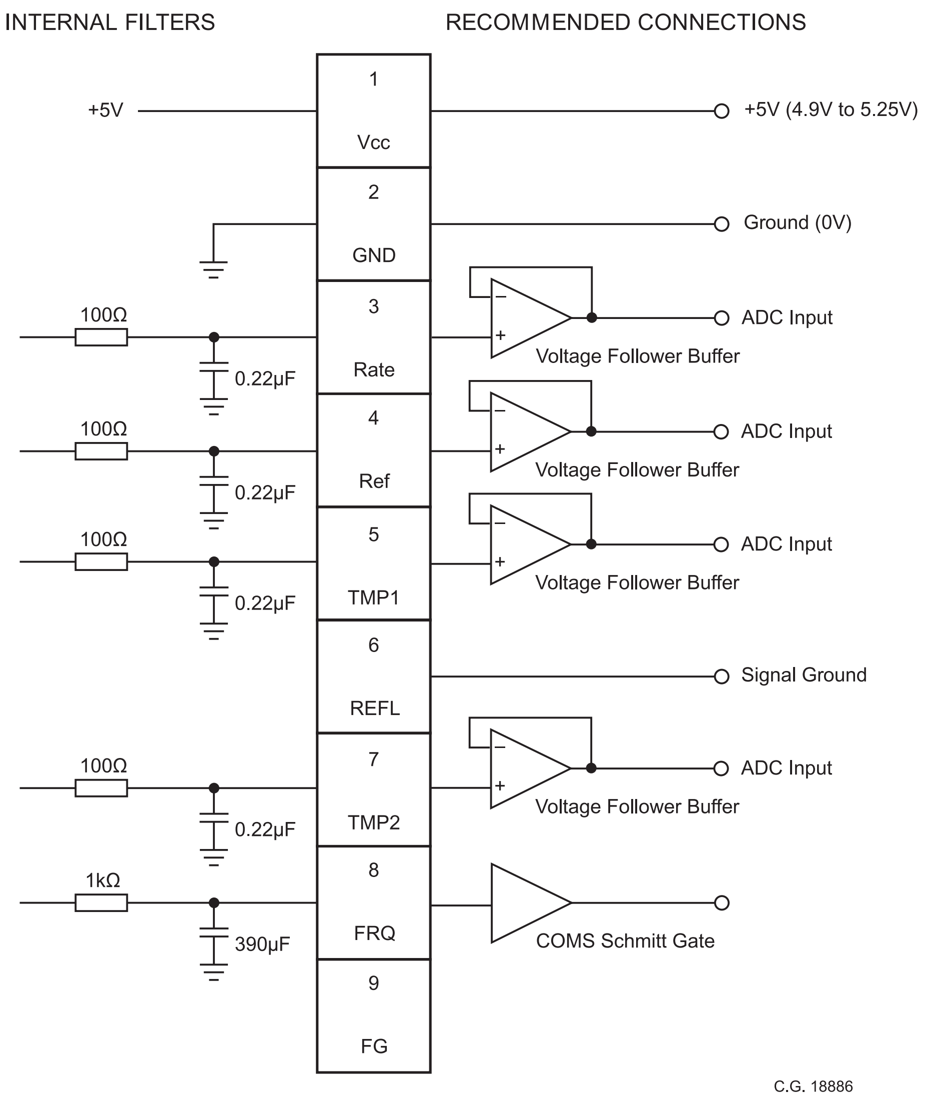

Figure 4.1 Recommended Interfacing

The table below provides connection details

Pin Number	Pin Name	Signal Direction (I/O)	Function
1	Vcc	–	Power supply to sensor
2	GND	–	Power ground
3	Rate	Output	Rate output with respect to Ref
4	Ref	Output	Reference voltage output. Datum for rate , TMP1 and TMP2
5	TMP1	Output	Temperature output 1 with respect to Ref
6	REFL	Output	Signal ground
7	TMP2	Output	Temperature output 2 with respect to Ref
8	FREQ	Output	Second harmonic resonating ring frequency output
9	FG	–	Frame ground (chassis ground), connected to six fixing holes internally

TEMPERATURE SENSORS

The temperature sensors use the LM20B device, internally connected as shown in Figure 4.2.

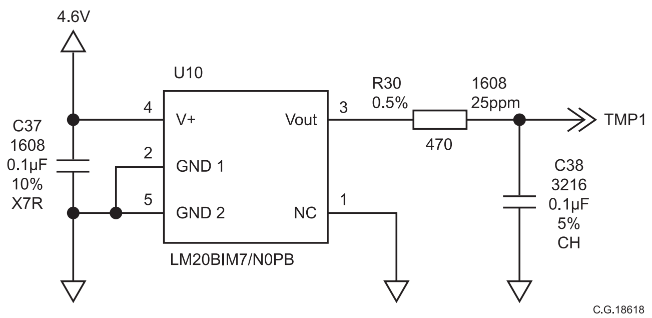

Figure 4.2 Temperature Sensors

The output at 0°C is typically +1.864 V with respect to GND. The temperature coefficient is typically -11.7 mV/°C.

The output can be measured with respect to GND or can be put through a differential input instrumentation amplifi er, referenced to the Ref pin, in which case the offset at 0°C is typically -0.536 V. At +45°C, the output is typically -1.06 V with respect to Ref. The temperature sensors are not intended for use as a thermometer, since they are not calibrated on the Celsius scale. They are intended only as a temperature reference for thermal compensation techniques.

RATE AND REF OUTPUTS

Both the Rate and the Ref outputs are passed through a simple RC low pass filter before the output pins. The resistor value is 100 ohms. The capacitor value is 0.1 µF.

It is recommended that the Rate Output (signal High or +) is differentially sensed using a precision instrumentation amplifi er, referenced to the Ref output (signal Low or -).

The Offset of the instrumentation amplifi er should be derived from the host stage (e.g. derived from the ADC Ref Voltage) or from the signal ground if the following stage is an analogue stage.

FREQUENCY OUTPUTS

This is CMOS Digital (74HC series) compatible digital output at two times the frequency of the sensor head. It is provided to give an indication of the temperature of the MEMS sensor head. The nominal frequency is 28 kHz with a typical temperature coeffi cient of -0.8 Hz/°C.

The signal is protected with a 1kohm resistor before being output from the CRS39. It is recommended that this signal is buffered with a CMOS Schmitt Gate such as 74HC12, or TC7S14F. The signal can be used to accurately measure the temperature of the MEMS structure.

An example of measuring the MEMS temperature is to use a precision crystal oscillator (operating at a very high frequency, for example 20, 40 or 60 MHz) to measure the frequency of the ring by measuring the time (oscillator clock cycles) to count to a defi ned number of ring cycles.

SUPPLY VOLTAGE

Power supply voltage should be maintained between 4.90 V and 5.25 V. This requirement includes any effects resulting from voltage ripple and/or noise.

CRS39A does not have protection for input or reverse voltages larger than the specified limits, shown in section 2. It is therefore recommended that reverse or over voltage protection is implemented in the host system.

SOLDERING

CRS39A should not be exposed to temperatures greater than specifi ed in section 3. This includes, for example, refl ow during soldering or sub assembly operations.

Bias Characteristic

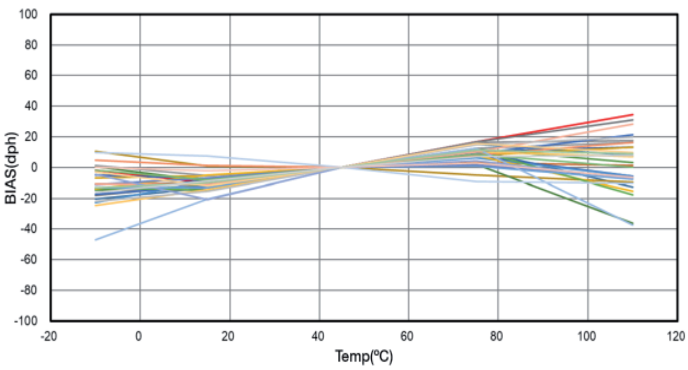

Figure 5.1 CRS39A Series Bias (45°C)

Scale Factor Characteristic

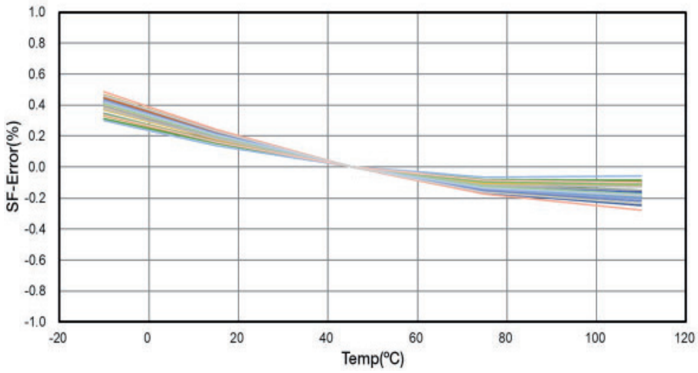

Figure 5.2 CRS39A Series Scale Factor (45°C)

Allan Variance Curve

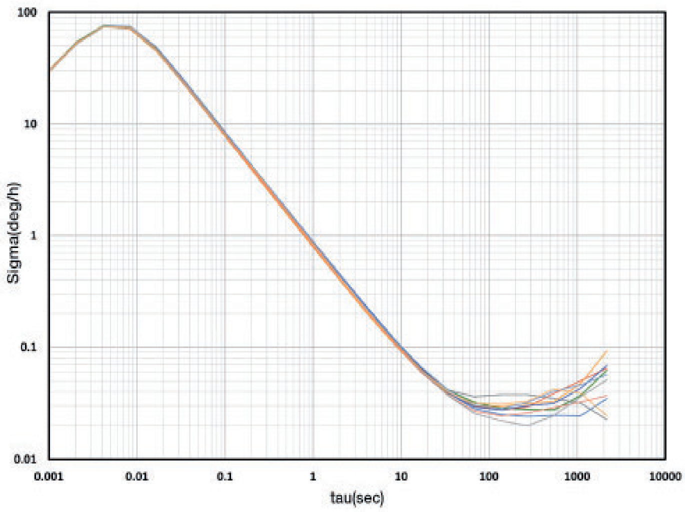

Figure 5.3 CRS39A Allan Variance

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ANGLE RANDOM WALK

Angle Random Walk is calculated by fi nding the value at the intersection of the -0.5 slope (drawn tangentially to the AV curve) and the 1s point along the x axis. This value is then divided by 60.

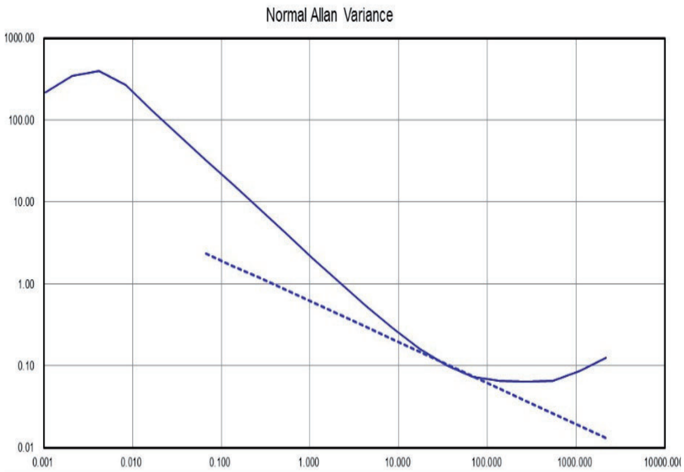

Figure 5.4 Angle Random Walk

BIAS INSTABILITY

Bias instability value at the lowest point of the Allan Variance curve as shown in Figure 5.5.

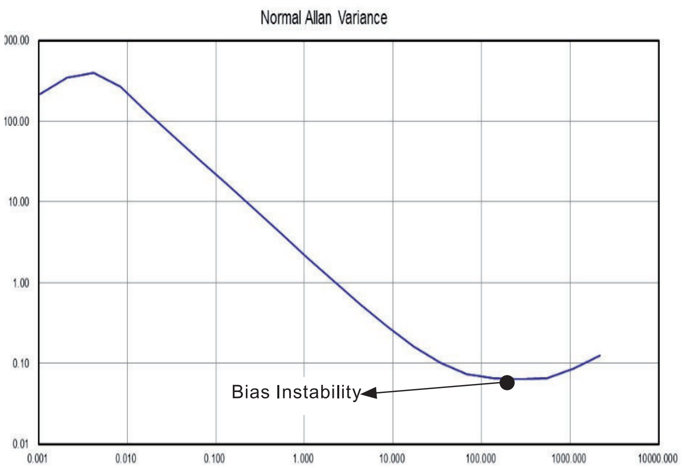

Figure 5.5 Bias Instability

NOTICE

Specifications are subject to change without notification for the purpose of product improvement.

FAILURE MODE FOR RATE SENSOR OUTPUT

Output	Failure Mode	Observation
1	Sensor output saturated (High)	Sensor output saturated (+2V)
2	Sensor output saturated (Low)	Sensor output saturated (-2V)
3	Bias shift	Continue rate output
4	Scale Factor shift	Continue rate output
5	Increased noise	Continue rate output
6	Start up time delay	No effect for rate output

RATE OUTPUT WHEN OVER RANGE INPUT

If CRS39A is operated outside of its specifi ed angular rate range, the sensor will not be damaged but the output will saturate. Once the over range is removed CRS39A will return to its normal operational state within 2 seconds.

SENSOR HEAD (U1) CAN PACKAGE VOLTAGE SUPPLY

Note: The metal package of CRS39A's sensor head is electrically connected to REF (2.4 V).

SHOCK AND VIBRATION

The long rectangular profile of the CRS39A makes it susceptible to resonances when used in an environment with high shock or vibration levels. In these circumstances it is recommended that, as well as using the 6 attachment points, an additional mounting method, such as support along the PCB edge, is used.

DISPOSAL PROCESSING

In case of scrap, this unit should be disposed of as industrial waste.

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SILICON MEMS RING SENSOR (GYRO)

At the heart of the CRS39A is Silicon Sensing's VSG3QMAX vibrating ring MEMS sensor which is at the pinnacle of 15 years of design evolution and the latest off a line which has produced over 30 million high integrity MEMS inertial sensors. The VSG3QMAX gyro sensor is combined with precision discrete electronics to achieve high stability and low noise, making the CRS39A a viable alternative to Fibre Optic Gyro (FOG) and Dynamically Tuned Gyro (DTG).

The silicon MEMS ring is 6 mm diameter by 100 µm thick, fabricated by Silicon Sensing Systems using a DRIE (Deep Reactive Ion Etch) bulk silicon process. The ring is suppor-ted in free-space by sixteen pairs of 'dog-leg' shaped symmetrical legs which support the ring from the sup-porting structure on the outside of the ring.

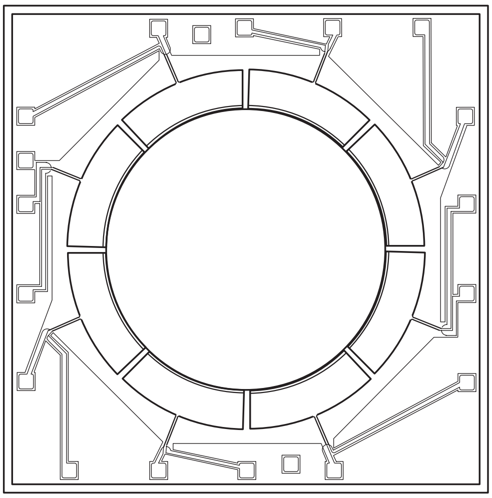

Figure 7.1 Silicon MEMS Ring

The bulk silicon etch process and unique patented ring design enable close tolerance geometrical properties for precise balance and thermal stability and, unlike other MEMS gyros, there are no small gaps to create problems of interference and stiction. These features contribute signifi cantly to CRS39A's bias and scale factor stability over temperature, and vibration immunity. Another advantage of the design is its inherent immunity to acceleration induced rate error, or 'g-sensitivity'.

GLOSSARY OF TERMS

ADC	Analogue to Digital Converter
ARW	Angular Random Walk
BW	Bandwidth
C	Celsius or Centigrade
DAC	Digital to Analogue Converter
DPH	Degrees Per Hour
DPS	Degrees Per Second
DRIE	Deep Reactive Ion Etch
EMC	Electro-Magnetic Compatibility
ESD	Electro-Static Damage
F	Farads
hr	Hour
HBM	Human Body Model
Hz	Hertz, Cycle Per Second
k	Kilo
MEMS	Micro-Electro Mechanical Systems
mV	Mili-Volts
NEC	Not Electrically Connected
NL	Scale Factor Non-Linearity
PD	Primary Drive
PP	Primary Pick-Off
RC	Resistor and Capacitor filter
s	Seconds
SF	Scale Factor
SMT	Surface Mount Technology
SOG	Silicon On Glass
SD	Secondary Drive
SP	Secondary Pick-Off
T.B.A.	To Be Announced
T.B.D.	To Be Described
w.r.t	With respect to
V	Volts

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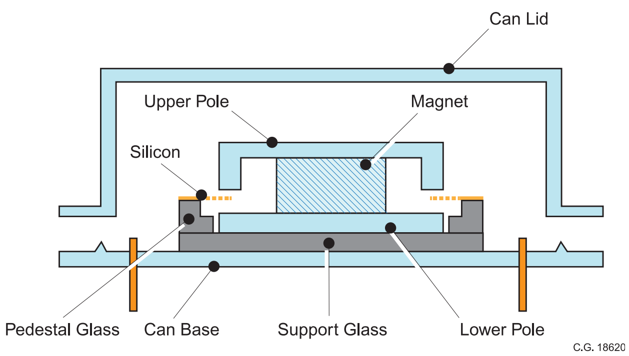

Figure 7.2 MEMS Sensor Head

SILICON MEMS RING SENSOR (GYRO)

The ring is essentially divided into 8 sections with two conductive tracks in each section. These tracks enter and exit the ring on the supporting legs. The silicon ring is bonded to a glass pedestal which in turn is bonded to a glass support base. A magnet, with upper and lower poles, is used to create a strong and uniform magnetic fi eld across the silicon ring. The complete assembly is mounted within a hermetic can with a high internal vacuum.

The tracks along the top of the ring form two pairs of drive tracks and two pairs of pick-off tracks. Each section has two loops to improve drive and pick-off quality.

One pair of diametrically opposed tracking sections, known as the Primary Drive PD section, is used to excite the cos2⊖ mode of vibration on the ring. This is achieved by passing current through the tracking, and because the tracks are within a magnetic fi eld causes motion on the ring. Another pair of diametrically opposed tacking sections is known as the Primary Pick-off PP section is used to measure the amplitude and phase of the vibration on the ring. The Primary Pick-off sections are in the sections 90° to those of the Primary Drive sections. The drive amplitude and frequency is controlled by a precision closed loop electronic architecture with the frequency controlled by a Phase Locked Loop (PLL), operating with a Voltage Controlled Oscillator (VCO), and amplitude controlled with an Automatic Gain Control (AGC) system. The primary loop therefore establishes the vibration on the ring and the closed loop electronics is used to track frequency changes and maintain the optimal amplitude of vibration over temperature and life. The loop is designed to operate at about 14 kHz.

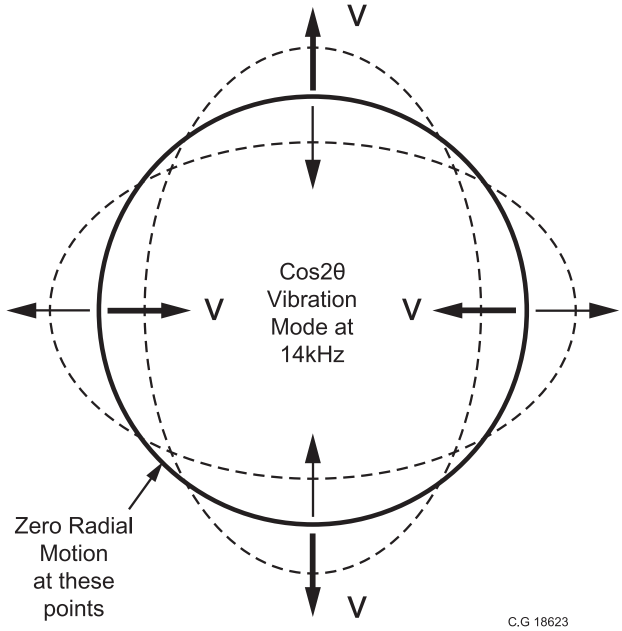

Figure 7.3 Primary Vibration Mode

Having established the cos2⊖ mode of vibration on the ring, the ring becomes a Coriolis Vibrating Structure Gyroscope. When the gyroscope is rotated about its sense axis the Coriolis force acts tangentially on the ring, causing motions at 45° displaced from the primary mode of vibration. The amount of motion at this point is directly proportional to the rate of turn applied to the gyroscope. One pair of diametrically opposed tracking sections, known as the Secondary Pick-off SP section, is used to sense the level of this vibration. This is used in a secondary rate nulling loop to apply a signal to another pair of secondary sections, known as the Secondary Drive SD. The current applied to the Secondary Drive to null the secondary mode of vibration is a very accurate measure of the applied angular rate. All of these signals occur at the resonant frequency of the ring. The Secondary Drive signal is demodulated to baseband to give a voltage output directly proportional to the applied rate in free space.

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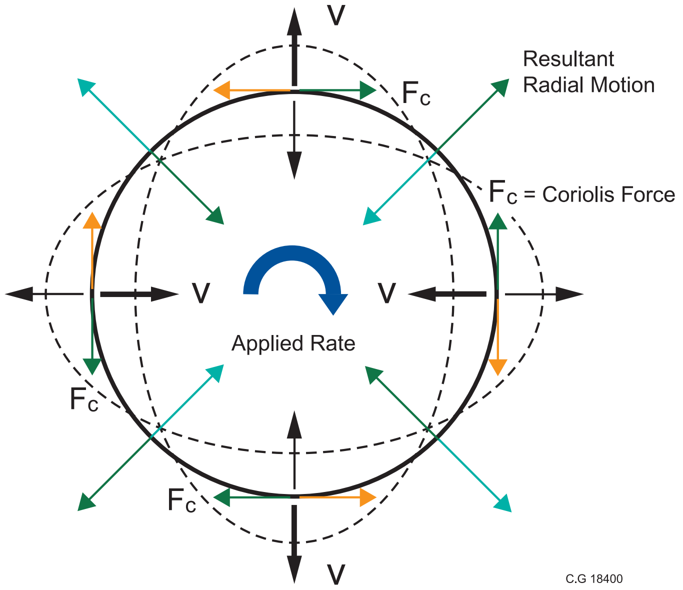

Figure 7.4 Secondary Vibration Mode

The closed loop architecture on both the primary and secondary loops result is excellent bias, scale factor and non-linearity control over a wide range of operating environments and life. The dual loop design, introduced into this new Sensor Head design, coupled with improved geometric symmetry results in excellent performance over temperature and life. The discrete electronics employed in CRS39A, ensures that performance is not compromised.

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