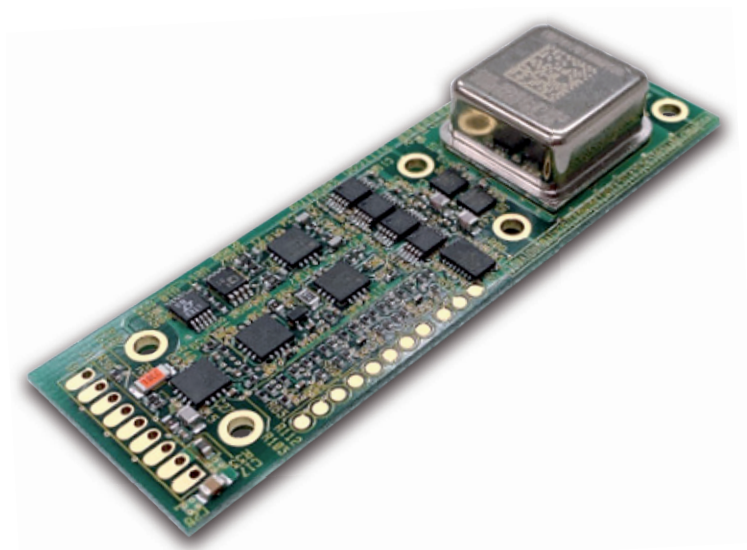


# CRS39A Series Technical Datasheet

High Performance MEMS Gyroscope



## Features

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

## Applications

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

## 1 General Description

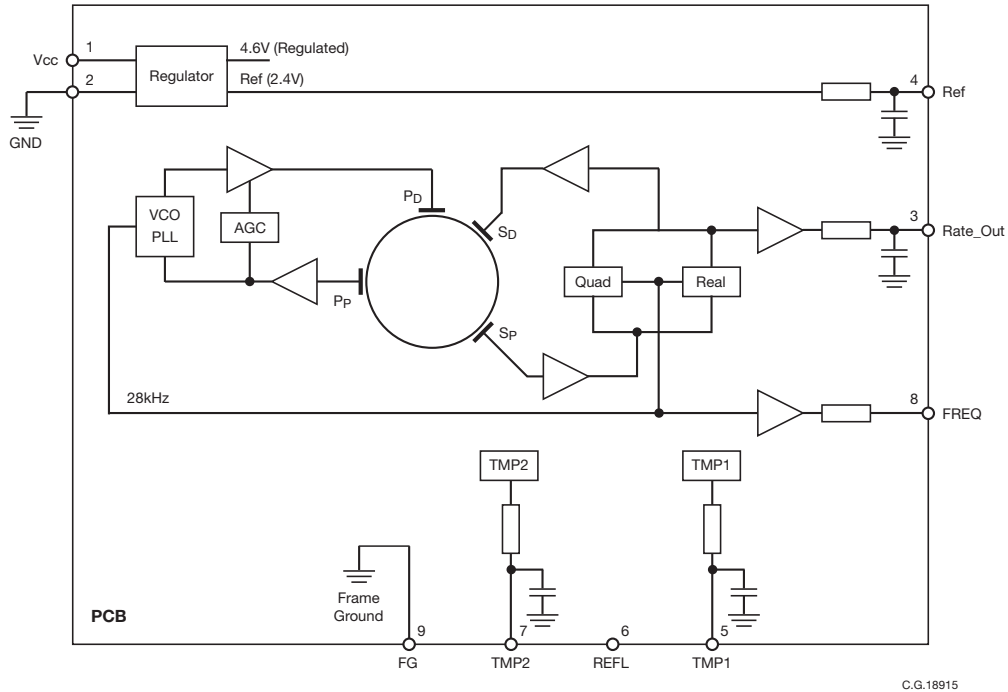
CRS39A provides the optimum solution for applications where bias instability, angle random walk and low noise are of critical importance.

At the heart of the CRS39A is Silicon Sensing's VSG3Q<sup>MAX</sup> vibrating ring MEMS sensor which is at the pinnacle of 15 years of design evolution and the latest of a line which has produced over 30 million high integrity MEMS inertial sensors. The VSG3Q<sup>MAX</sup> 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.

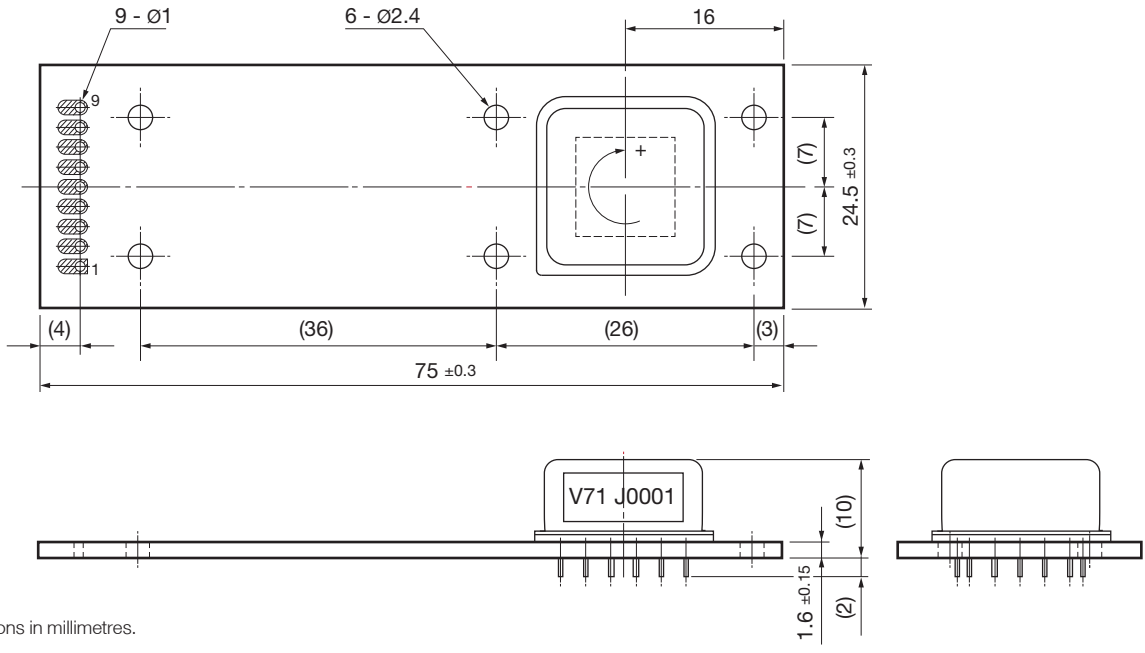
Two on board temperature sensors and the resonant frequency of the MEMS enable additional external conditioning to be applied to the CRS39A by the host, enhancing the performance even further.

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



C.G.18915

**Figure 1.1 CRS39A Functional Block Diagram**



All dimensions in millimetres.

C.G. 18885

**Figure 1.2 CRS39A - Overall Dimensions**

## 2 Ordering Information

CRS39A-01M, L or V  
 ↳ Resonant (Operating) Frequency

**Figure 2.1 Ordering Part No. Definition**

CRS39A-01 is available with three different resonant (operating) frequencies designated; M, L and V. There is no difference in the function, performance or interface between these parts.

For multiple axis applications the required resonant frequencies should be ordered, as CRS39A-01M, CRS39A-01L or CRS39A-01V.

Rate Range	Frequency Output kHz	Designation	Ordering Part No.
±25°/s	>27.83	M	CRS39A-01M
±25°/s	27.37 - 27.83	L	CRS39A-01L
±25°/s	<27.37	V	CRS39A-01V

## 3 Specification

Unless otherwise specified the following specification values assume Vdd = 4.9V to 5.25V 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
Angular Rate Range, °/s	<-25	-	>+25	-
Bias at 45°C, mV	-10	-	+10	w.r.t. Ref
Bias Over Temperature (w.r.t. 45°C), °/hr	-250	±60	+250	-
Bias Drift, °/hr	-	±10	-	1hr after power on at 25°C
Bias Run to Run, °/hr	-	±0.5	-	1min on/1min off, 10 times, at 25°C
Bias Hysteresis, °/hr	-	±20°/hr	-	-
Bias Instability, °/hr	-	0.03	-	at 25°C
Angle Random Walk, °/√hr	-	0.004	-	at 25°C
Bandwidth, Hz	15	25	35	-3dB point at 25°C
Scale Factor at 45°C, mV/°/s	79.6	80.0	80.4	-
Scale Factor Variation Over Temperature (w.r.t. 45°C), %	-0.5	±0.15	+0.5	-
Scale Factor Non-Linearity, %	-0.05	-	+0.05	-
Noise, °/s rms	-	0.006	0.01	3 - 10Hz at 25°C
Wideband Noise, °/s rms	-	0.03	0.05	Wideband at 25°C
Start Up Time, seconds	-	-	1.0	-
Cross Axis Sensitivity, %	-	1.2% (0.7°)	3.5% (2°)	at 25°C
Mass, grams	-	15	-	-

## 4 Power Requirements

Parameter	Minimum	Typical	Maximum	Notes
Supply Voltage, Vdd, Volts	4.9	5.0	5.25	–
Current, mA	–	30	40	–
Noise 13.5kHz to 14.5kHz	–	–	0.5mV	Power supply ripple (pk - pk)
Noise 40.5kHz to 43.5kHz	–	–	5.0mV	Power supply ripple (pk - pk)

## 5 Frequency and Temperature Output Characteristics

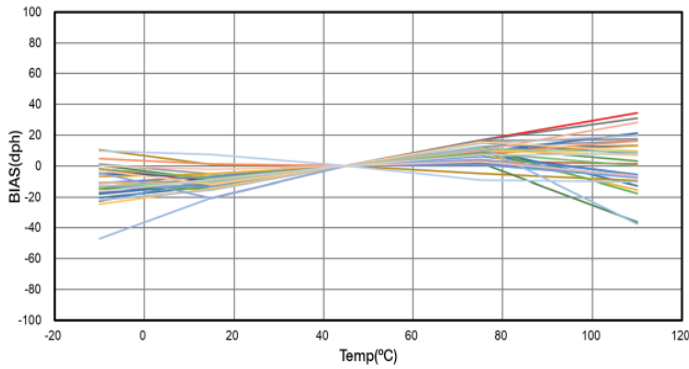
Parameter	Minimum	Typical	Maximum	Notes
Frequency output, kHz	27.0	28.0	29.0	V, L, M - Type
Resonant Frequency Temperature Coefficient, Hz/°C	-0.90	-0.80	-0.70	–
TMP1, and 2, Volts at +45°C	-1.16	-1.06	-0.96	w.r.t. Ref
Temperature Sensor Temperature Coefficient, mV/°C	-13.7	-11.7	-0.70	–

## 6 Operating and Storage Environmental

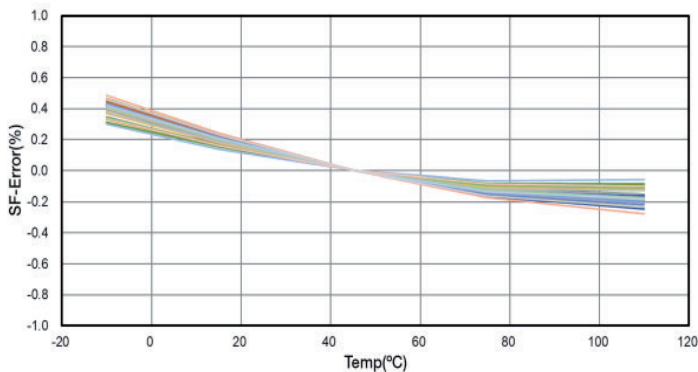
Parameter	Minimum	Typical	Maximum	Notes
Operating Temperature Range °C	-10	–	+110	–
Non-operating Temperature Range °C	-40	–	+130	–
Operational Shock, g	–	–	250gx1.7ms	–
Powered and Non-operational Shock Survival, g	–	–	1,000gx1.9ms	–

## 7 Typical Performance Characteristics

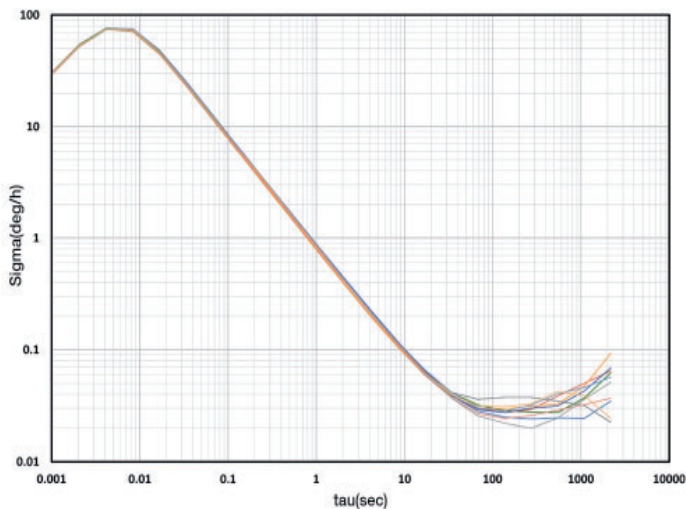
Graphs showing typical performance characteristics for CRS39A are below.



**Figure 7.1 CRS39A Series Bias (45°C)**

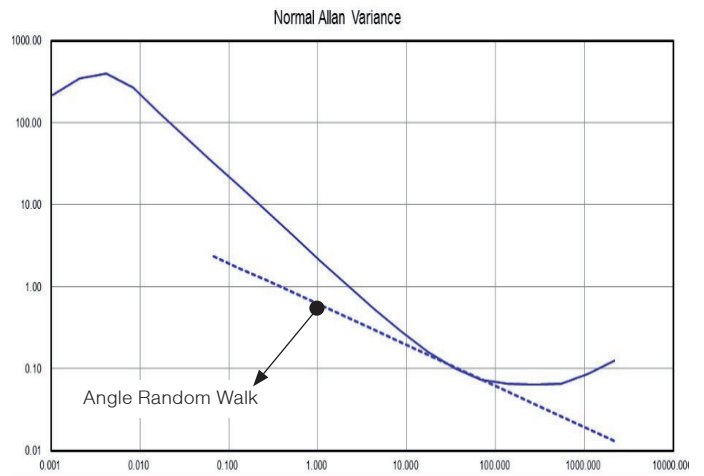


**Figure 7.2 CRS39A Series Scale Factor (45°C)**



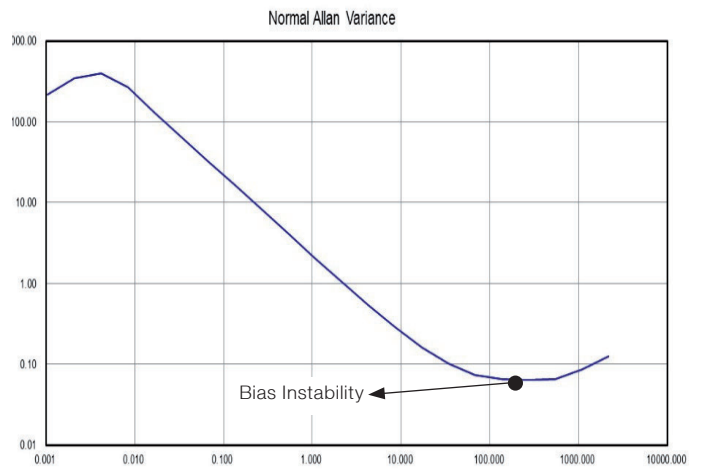
**Figure 7.3 CRS39A Allan Variance**

Angle Random Walk is calculated by finding 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 7.4 Angle Random Walk**

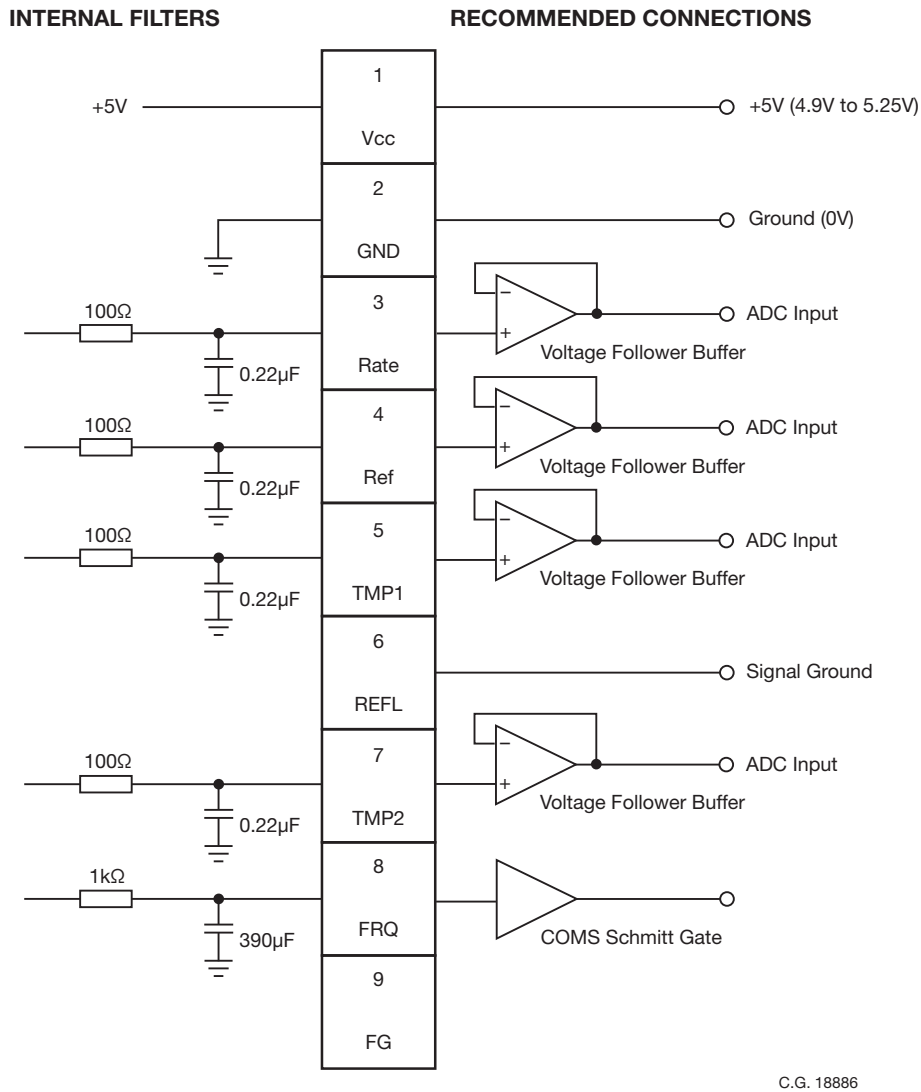
Bias instability value at the lowest point of the Allan Variance curve as shown in Figure 7.5.



**Figure 7.5 Bias Instability**

More data coming soon.

## 8 Other Information



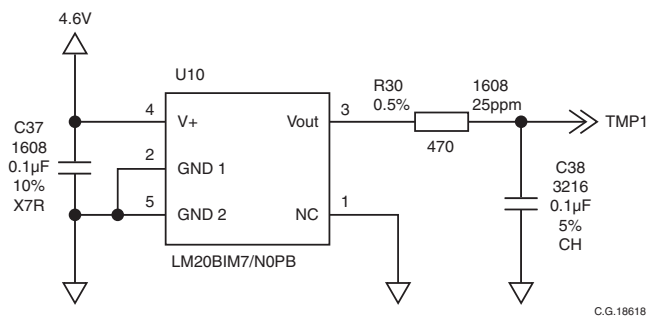
**Figure 8.1 Recommended Interfacing**

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

### 8.1 Temperature Sensors

The temperature sensors use the LM20B device, internally connected as shown in Figure 8.2.



**Figure 8.2 Temperature Sensors**

The output at 0°C is typically +1.864V 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 amplifier, referenced to the Ref pin, in which case the offset at 0°C is typically -0.536V. At +45°C, the output is typically -1.06V 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.

## 8.2 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 $\mu$ F.

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

The Offset of the instrumentation amplifier 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.

## 8.3 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 28KHz with a typical temperature coefficient of -0.8Hz/°C.

The signal is protected with a 1kohm resistor before being output from the CRS39A. 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 60MHz) to measure the frequency of the ring by measuring the time (oscillator clock cycles) to count to a defined number of ring cycles.

## 8.4 Supply Voltage

Power supply voltage should be maintained between 4.90V and 5.25V. 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 4. It is therefore recommended that reverse or over voltage protection is implemented in the host system.

## 8.5 Rate Output when over Range Input

If CRS39A is operated outside of its specified 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.

## 8.6 Sensor Head (U1) CAN Package Voltage Supply

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

## 8.7 Input Protection

CRS39A does not have reverse or over voltage protection on any input.

## 8.8 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.

## 8.9 Disposal Processing

In the event of disposal, CRS39A should be disposed of as industrial waste and in accordance with local regulations.

## 8.10 Notice

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



## 9 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	Millivolts
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

## 10 Part Markings

Each CRS39A series has a unique label on the SGH03 sensor; the large through-hole metal can device.

The label shows 8 characters: VVRYSSSS.

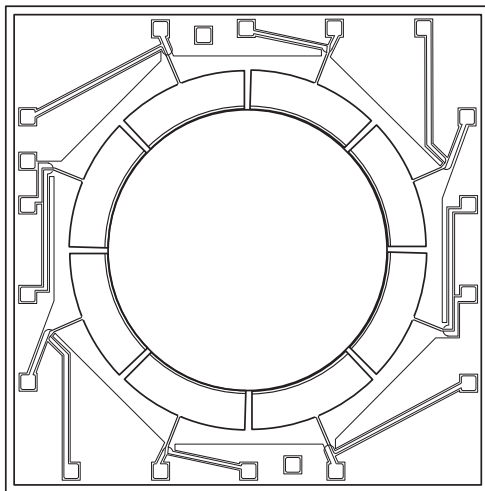
Product	ID	Range %s	ID	Year	ID	Serial Number
	VV		R		Y	SSSS
CRS39A-01M	M7	±025	1	2020	K	SSSS
CRS39A-01L	L7	±025	1	2021	L	SSSS
CRS39A-01V	V7	±025	1	2022	M	SSSS

For example, V71K0001 indicates a low frequency part (V7), with a rate range of ±025%/s (1) and was manufactured in 2020 (K). The serial number of the device is 0001.

### 11 Silicon MEMS Ring Sensor (Gyro)

At the heart of the CRS39A is Silicon Sensing's VSG3Q<sup>MAX</sup> vibrating ring MEMS sensor which is at the pinnacle of 15 years of design evolution and the latest of a line which has produced over 30 million high integrity MEMS inertial sensors. The VSG3Q<sup>MAX</sup> 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).

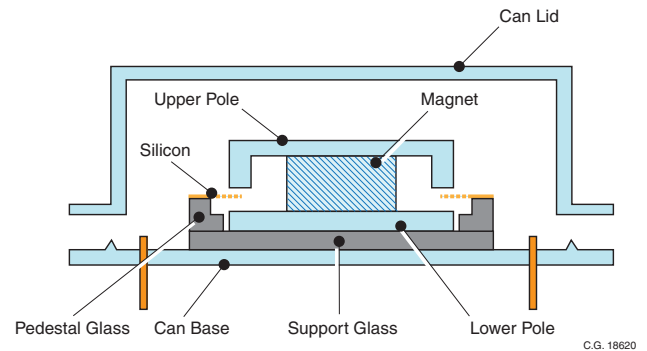
The silicon MEMS ring is 6mm diameter by 100µm thick, fabricated by Silicon Sensing Systems using a DRIE (Deep Reactive Ion Etch) bulk silicon process. The ring is supported in free-space by eight pairs of symmetrical 'dog-leg' shaped legs which support the ring from the supporting structure on the outside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



C.G. 18619

**Figure 11.1 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 significantly 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'.



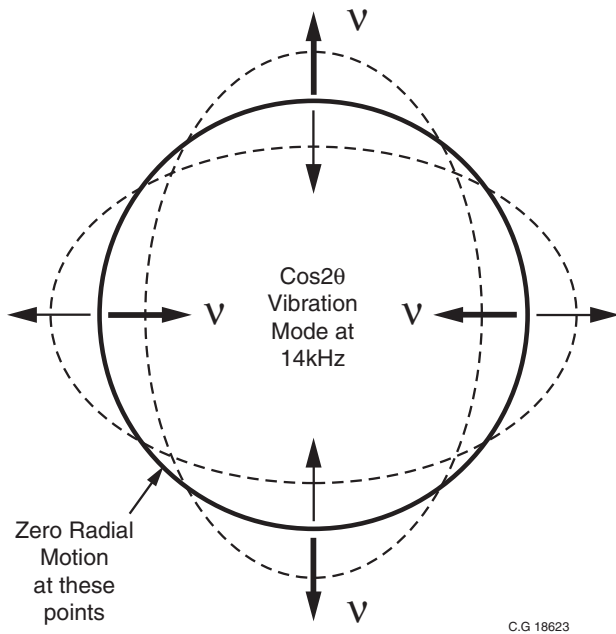
C.G. 18620

**Figure 11.2 MEMS Sensor Head**

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 field across the silicon ring. The complete assembly is mounted within a hermetic can with a high internal vacuum.

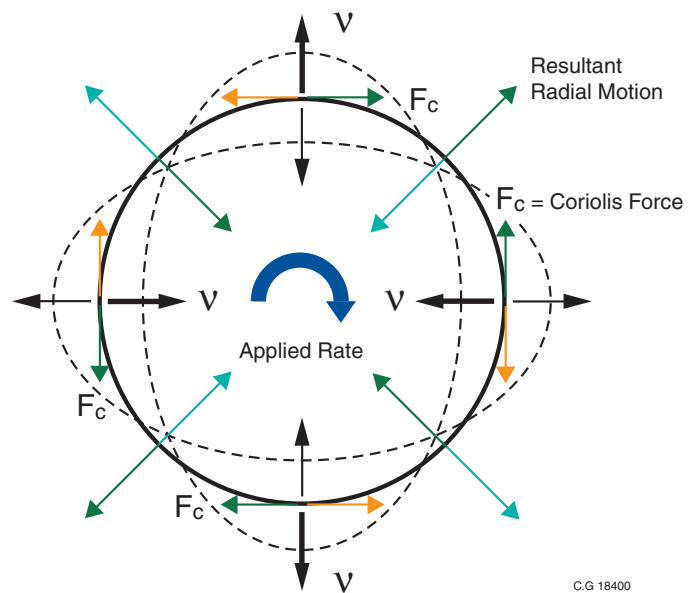
The tracks along the top of the ring form two pairs of drive tracks and two pairs of pick-off tracks. Each section has two loops to improve drive and pick-off quality.

One pair of diametrically opposed tracking sections, known as the Primary Drive PD section, is used to excite the  $\cos 2\theta$  mode of vibration on the ring. This is achieved by passing current through the tracking, and because the tracks are within a magnetic field causes motion on the ring. Another pair of diametrically opposed tracking 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  $90^\circ$  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 14kHz.



**Figure 11.3 Primary Vibration Mode**

Having established the  $\cos 2\theta$  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  $45^\circ$  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.



**Figure 11.4 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.

# CRS39A Series Technical Datasheet

High Performance MEMS Gyroscope



## Notes

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