The XV-9000 Series of Gyro Sensors for Vehicle Attitude Sensing

XV-9000 series products

What is a gyro sensor?

A gyro sensor measures angular velocity which is the amount of rotation per unit of time in degrees per second. Acceleration sensors, or accelerometers, are often confused with gyro sensors. A gyro sensor measures the angular velocity of an object's rotational motion. An accelerometer measures changes in the velocity of an object's linear motion. Since they measure two different physical quantities, these sensors can be used in combination (three gyro-sensors on three axes and three accelerometers on three axes) to capture the motion of an object in three dimensions.

Epson gyro sensors

Epson's gyro sensors have contributed to the evolution of many different applications because of their excellent temperature characteristics and low noise. Well-known applications include car navigation, remote controllers for home video game systems, 3D PC mice, autonomous vacuum cleaners, and hobby applications.

Epson’s gyros are widely used for optical image stabilization in digital cameras. These systems work by using gyro sensors to detect and compensate for camera shake and shifting the lens or image sensor thus reduce blurring caused by the movement of the camera. Optical image stabilization performance is measured in stops, where each stop of correction means that you will get the same amount of blur as when no correction is applied with double the shutter speed. Systems using Epson's gyro sensors achieve four-stop correction (16X shutter speed), which is at least double the performance of competing systems.

Seiko Epson has also developed commercial gyro-sensors for vehicle attitude sensing for both electronic stability control (ESC) and rollover detection. The company's XV-9000 series of gyro sensors are engineered to meet the strict temperature, reliability, and quality requirements of the automotive industry. In this edition of Technical Notes, we explain this series of gyro sensors.

Figure 1: The XV-9000 series of gyro sensors for vehicle attitude sensing.
Pictured: CD package (bottom left), LV package (top right), and LP package (top left)

Parameter	Unit	XV-9100CD XV-9300CD	XV-9100LV XV-9300LV	XV-9100LP XV-9300LP	Conditions
Detecting axis	-	Z		X	-
Operating temperature range	ºC	-40 to +105	-40 to +125		-
Supply voltage	V	5.0+/-0.25			-
Current consumption	mA	5.8 Typ.			No load
Rate range	º/s	+/-100 (XV-9100) +/-300 (XV-9300)			-
Scale factor	mV/(º/s)	0.004 x V_{DD} (XV-9100) 0.0012 x V_{DD} (XV-9300)			-
Scale Factor variation over temperature	%	+/- 5			Ta = +25ºC
Bias	V	0.5 x V_{DD}			-
Bias variation over temperature	º/s	+/- 5 (XV-9100) +/- 20 (XV-9300)			Ta = +25ºC
Nonlinearity	%FS	+/- 0.5			-
Frequency response	Hz	50			-3dB point
Output Noise	(º/s) p-p	1.0 Max. (XV-9100) 3.3 Max. (XV-9300)			-
Cross axes	%	+/-5.0			-
Built-in Self Test	-	Yes			-
External dimensions	mm	5.0 x 5.0 x 1.4	6.8 x 7.0 x 3.3	9.5 x 5.0 x 7.0	-

Table 1: General specifications of the XV-9000 series

Electronic Stability Control

Gyro sensors are essential in electronic stability control (ESC) systems, which improve vehicle safety by sensing when a vehicle is skidding and intervening to control braking and engine torque. Skidding is detected by comparing the driver's actions (e.g., steering, acceleration, and braking) and the direction of the vehicle (measured by gyro sensors and accelerometers).

Studies show that ESC can reduce crashes by more than 30%, so many countries around the world are making them compulsory for all vehicles. The United States requires ESC for all new passenger vehicles under 4.54 tons sold in or after September 2011. Europe requires that ESC be introduced for all new models sold in or after November 2011 and for all new vehicles sold in or after November 2014. Japan requires ESC systems on all new models sold in or after October 2012 and on specified vehicle models sold from October 1, 2014.

Electronic stability control depends on several types of sensors, including gyro sensors. These gyro sensors – like all components used in automotive systems, and particularly those that involve safety – are subject to a number of special requirements that ordinary consumer components are not. They must be extremely reliable, they must withstand high temperatures, such as those generated in brake units, and they must be accurate even when subjected to shock and vibration.

Seiko Epson's XV-9000 series gyro sensors are engineered for use in electronic stability control and rollover protection systems and can be used to detect yaw or roll for either application.

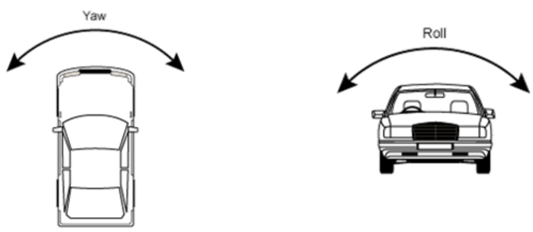

Figure 2: Vehicle yaw rate and roll rate

Features of the XV-9000 Series

The XV-9000 series boasts the following five features.

1) Low noise and excellent stability in a small form factor due to the use of piezoelectric material (Quartz) and Epson's patented double-T hammerhead structure
2) Sensing elements and an element support structure that make the gyro-sensors insensitive to the effects of shock and vibration
3) Capacity for high-temperature operation which enables mounting in brake units
4) High reliability with a BIST monitor to alarm failures at any given time and at startup
5) J-lead pins used for superb joint reliability (LV package, LP package)

Low sensitivity to shock and vibration is especially important for automotive safety, so these features deserve an explanation. Figure 3 shows the sensor element. The sensor element is symmetrical with respect to its center and the center area is a fixed by mounting. Since the element is supported at this fixed-point center of gravity, it is able to remain stable when exposed to external forces.

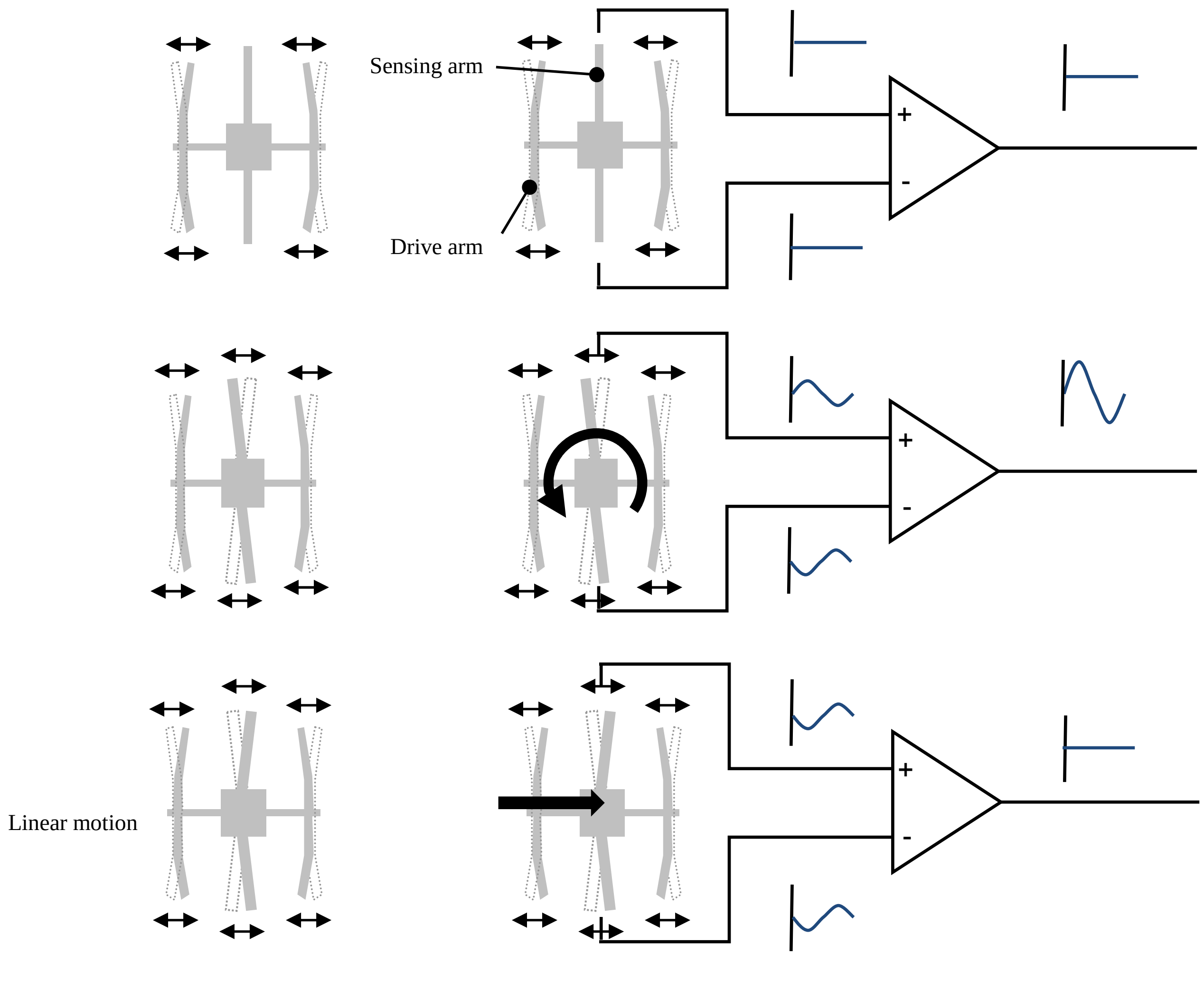

Fig. 3 Sensor element movement during rotational motion and linear motion

Next, let's examine the operation in line with the actual sensing flow. First, when power is supplied to the sensor, an inverse piezoelectric effect causes the drive arms to begin vibrating. When the drive arms are vibrating and the sensor is rotating, Coriolis forces are produced in the drive arms. The sensing arms are subjected to flexure vibration proportional to the Coriolis forces. Flexure of each sensing arm produces an electrical charge due to the piezoelectric effect. As a result, the sensor element outputs an electric signal proportional to angular velocity.

The piezoelectric effect and reverse piezoelectric effect are crystal properties. The piezoelectric effect is the appearance of an electric potential across a crystal when the crystal is subjected to mechanical pressure, and the electric potential is dependent on the pressure applied. Conversely, the reverse piezoelectric effect is the appearance of mechanical distortions in the crystal itself when an electric field is applied to the crystal. Many gyro sensors use the piezoelectric effect, but Epson's gyro sensors are made from single crystals, and therefore have better stability.

Now let's consider the behavior of a sensor subjected to linear motion, for example when lateral linear motion is applied to the vibrating drive arm. The application of lateral linear motion produces flexure vibrations of the same phase in both sensing arms, but because the amplifier is differential, this effect is cancelled and the gyro is therefore immune to acceleration (translatory motion).

Next, we explain the vibration resistance and shock survivability of the XV-9000 series. The left graph in Figure 4 shows sensor output when frequencies of 10 to 3000 Hz are applied at 10Gs of acceleration. The frequency of the applied acceleration is plotted on the horizontal axis. The sensor's acceleration sensitivity (acceleration equivalent of the voltage output per 1G) is plotted on the vertical axis. The measured results show no aberrant output at any frequency. The right graph of Figure 4, meanwhile, shows sensor output when the major shock of 500G is applied. The horizontal axis shows the response time, and the shock was applied at the 0-second point. Again, the sensor's output is not aberrant even when exposed to a high G-force of 500Gs. This demonstrates the superior vibration resistance and shock survivability of the Epson XV-9000 series.

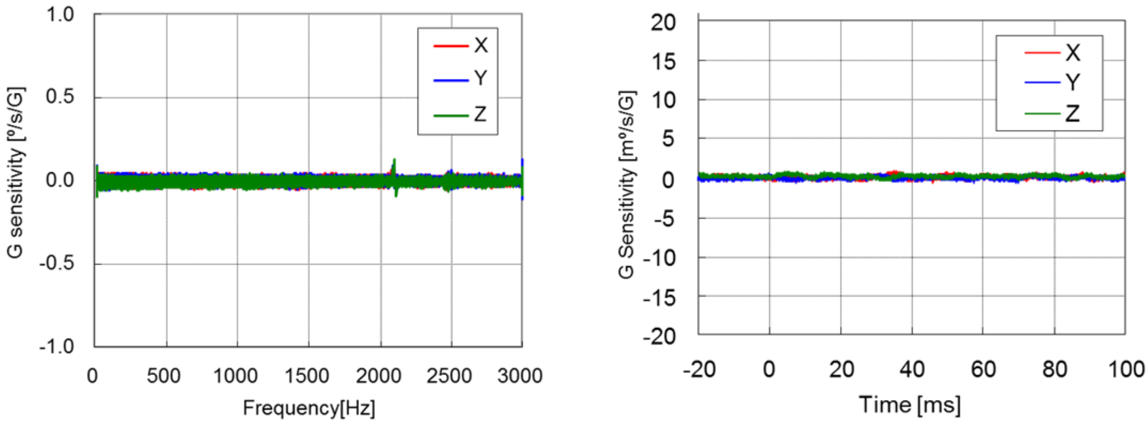

Figure 4: Low vibration sensitivity (left) and low shock sensitivity (right)

Extreme erroneous output suppression

In addition to the inherent vibration resistance and shock survivability of the sensor elements themselves, the gyro sensors in the XV-9000 series have built-in signal processing circuitry that minimizes aberrant output resulting from vibration and shock. This enables the use of a simple structural design for the gyro sensor mounting system and improves overall system stability.

Epson is committed to pursuing the potential of its crystal gyro-sensors in a wide range of applications, from cameras, hobbies, video games and other consumer products, to vehicle control and safety systems.

Please visit the following Epson Website for detailed product specifications.

Epson Website

http://www5.epsondevice.com/en/sensing_device/product/gyro/xv9100_9300lv_lp.html

http://www5.epsondevice.com/en/sensing_device/product/gyro/xv9100_9300cd.html