

# The XV-9000 series gyro-sensors for vehicle attitude sensing application

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Epson Toyocom Corporation developed a series of compact, reliable gyro-sensors (angular rate sensors) that withstand temperatures as high as 125°C. Called the XV-9000 series, the new gyro-sensors are designed for vehicle attitude sensing applications in the automotive industry. (Figure 1).

Gyroscopic sensors measure angular rate (in degrees per second), which indicates the amount of rotation per unit of time. Gyroscopic sensors and accelerometers are often confused with one another, but the distinction between them is important. Whereas accelerometers measure changes in the acceleration in linear motion of an object, gyro-sensors measure the angular rate (velocity) of rotational movement. Triple-axis gyroscopic sensors and triaxial accelerometers can be used in combination to measure two different physical quantities along six axes, thus capturing the motion of an object in three dimensions. (Figure 2)

### Main Specifications

Product Specifications			XV-9100LV	XV-9300LV	Condition
			XV-9100LP	XV-9300LP	
Supply voltage	V <sub>DD</sub>	V	4.75 to 5.25		
Operation temperature	T <sub>OPR</sub>	°C	-40 to +125		
Scale factor	SO	mV/(deg/s)	20	6	25 °C, V <sub>DD</sub> = 5V
Rate range	I	deg/s	±100	±300	25 °C
Output at quiescent	VO	V	V <sub>DD</sub> /2		25 °C
Current consumption	I <sub>DD</sub>	mA	5.5 typ.		no-loaded
Bandwidth	BW	Hz	10	50	-3 dB point
Sensing Axes & External Dimensions			XV-9xxxLV	XV-9xxxLP	
Sensing axis		-	Z	X	
External dimensions		mm	7.2 x 6.8 x 3.3	9.5 x 5.0 x 7.2	

**Figure 2. XV-9000 series specifications**

Epson Toyocom's gyro-sensors exhibit excellent temperature-frequency characteristics and low noise, features that have enabled them to facilitate advances in numerous applications. One example is image stabilization in digital cameras. Image stabilization technology, which improves image quality by correcting for camera shake, is becoming standard on most digital cameras. Optical image stabilization uses gyroscopic sensors to detect vibration (camera shake) when photos. A lens or image sensor is then shifted in such a way as to counteract the motion of the camera. The number of shutter speed steps is one of the indicators used to express correction capability. A one-step correction means that the amount of blur will be the same as if no correction were applied, even if shutter speed is reduced by a factor of 2. Systems that use our gyro-sensors are now capable for four-step correction, which equates to shutter speeds that are 16x slower. This represents a 2X or better performance improvement compared to previous systems.

Our gyroscopic sensors are used in more than just camera image stabilization. Their use is spreading into broader applications, such as dead-reckoning for car navigation systems, motion-based game controllers and 3D mice, as well as attitude control for robotic vacuum cleaners and RC helicopters.

While gyro-sensors have broad and growing applicability, we are now setting our sights on electronic stability control (ESC) for vehicles. ESC senses a loss of steering control and sideways slips by monitoring steering, acceleration, and braking and by comparing this information against information on the vehicle's actual direction, as sensed by on-board gyroscopic sensors and accelerometers. When ESC detects a loss of steering control, it may apply the brakes to one or more wheels or reduce or increase engine torque to the wheels so as to bring the vehicle back in line with the driver's intended direction. Research indicates that ESC could reduce the number of traffic accidents by 30% or more. This finding has prompted many countries to consider legislation that would gradually make ESC mandatory on vehicles. The United States is requiring ESC on all new vehicles under 4.54t, effective September 2011. In Europe, ESC is to become mandatory for all new models sold from November 2011 and all new cars sold from November 2014. Japan has not yet approved legislation but is showing signs of moving down the same path as Europe.

Gyroscopic sensors are essential for ESC, but gyro-sensors for automotive applications have to meet some special requirements that gyros for ordinary consumer products do not. Since lives depend on them, these gyro-sensors have to be extremely reliable and able to withstand the high temperatures of the engine bay. In addition, they must not output aberrant signals when subjected to the characteristic vibrations and impacts of a vehicle.

Epson Toyocom engineered the XV-9000 series of gyroscopic sensors for use in the automotive industry, in electronic stability control systems (active safety systems) and in rollover protection systems (impact safety systems). These two systems have different sensing axes, the former sensing vehicle yaw and the latter sensing vehicle roll, so Epson Toyocom has readied two package types, each that senses along the axis required by one of the systems.(Figure 3)

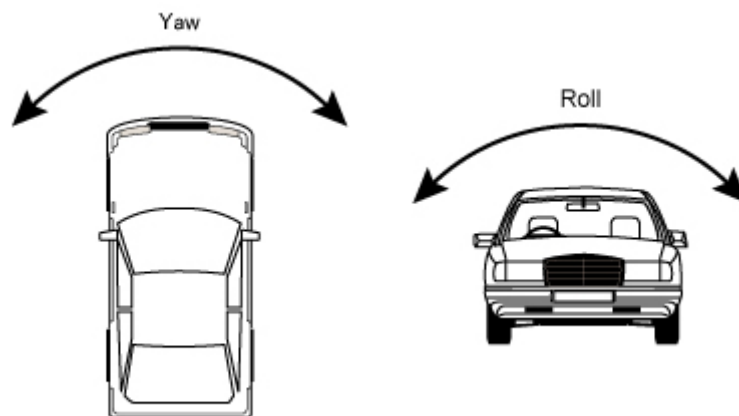


Figure 3. Yaw rate & roll rate sensors

Among the XV-9000 series' outstanding features are:

- 1) Sensing elements and an element support structure that make the gyro-sensors insensitive to the effects of impacts and vibrations
- 2) Ability to operate normally at temperatures up to 125°C, for installation in engine bays
- 3) High reliability ensured by a function that diagnoses failures at any given time and at startup
- 4) Low noise and stable characteristics in a small form factor thanks to crystal sensing elements that employ an original hammerhead structure
- 5) J-lead pins used for superb joint reliability

Low sensitivity to impacts and vibrations are especially important when it comes to vehicle control, so these features deserve an explanation.

The graph on the left in Figure 4 shows sensor output when frequency is changed from 10 to 3000 Hz at 10Gs of acceleration. The frequency of the applied acceleration is plotted on the horizontal axis. The sensor's acceleration sensitivity (an acceleration equivalent of the voltage output per 1G) is plotted on the vertical axis. There is no aberrant output at any frequency. The graph on the right, meanwhile, shows sensor output when the sensor is subjected to a single, greater acceleration (500G). The horizontal axis shows the response time, and the acceleration was applied at the 0-second point. Even when exposed to a high G-force of 500Gs, the sensor's output is not aberrant. (Figure 4).

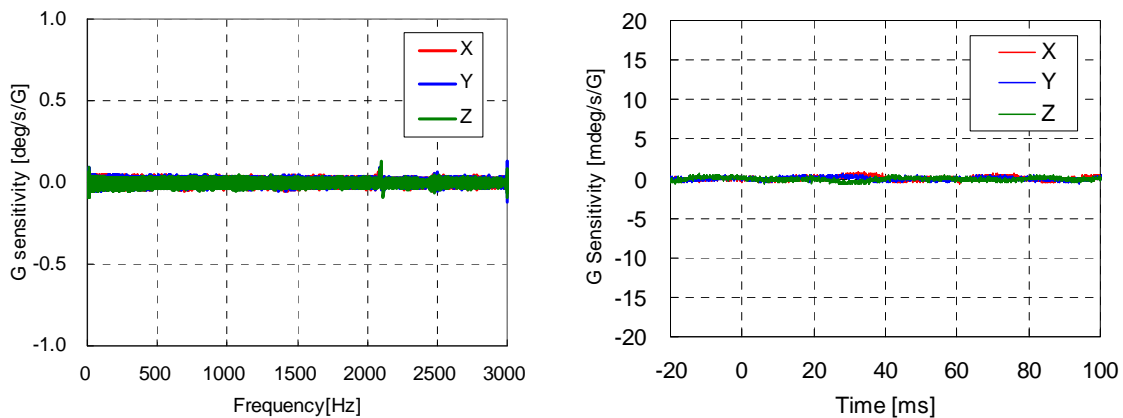


Figure 4. Low impact sensitivity and low vibration sensitivity (Source: ETC)

The unique configuration of the sensor element used by Epson Toyocom is a major reason the sensor is resistant as it is to the effects of acceleration. The figure depicts an illustration of a sensor element. The sensor element is engineered such that it has point symmetry with respect to the center, and the center area is a fixed point. Since the element can be supported at this fixed-point center of gravity, it is able to remain stable when exposed to external forces. Moreover, the element is designed with a symmetrical shape so that, electrically, it is also resistant to the effects of external forces. Next, let's examine the operation in line with the actual sensing flow.

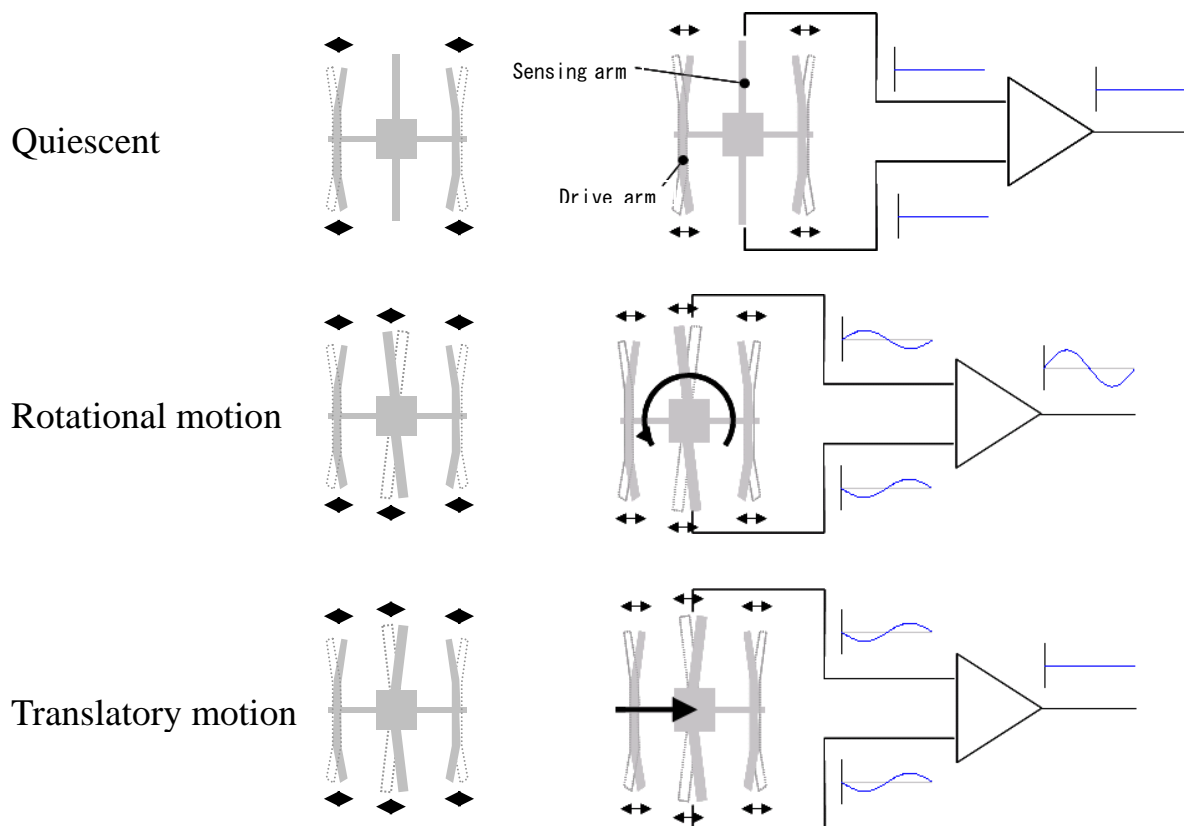


Figure 5. Rotational motion and translatory motion

First, when power is supplied to the sensor, an inverse piezoelectric effect causes the drive arms to begin vibrating. When planar rotation motion is exerted on the paper surface when the drive arms are vibrating, Coriolis forces perpendicular to the driving vibration are produced in the driving arms. The Coriolis forces produce flexure vibration of the opposite phase in the sensing arms. Amplitude corresponding to the angular rate and electrical signals of opposite phase corresponding to the direction of flexure are produced, respectively, in the sensing arms due to the piezoelectric effect. Electrical signals corresponding to the angular rate are amplified by a factor of 2 by differential amplification of the electrical signals of opposite phase that are produced in the upper and lower sensing arms. This is the mechanism by which angular rate (rotational motion) is sensed.(Figure 5)

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. A large number of vibrating gyroscopic sensors use the piezoelectric effect, but Epson Toyocom differentiates its gyro-sensors by selecting single-crystals, which exhibit excellent stability of properties.

Now let's consider the behavior of a sensor subjected to linear motion. As an example, let's see what happens when the vibrating drive arms are subjected to lateral linear motion. The application of lateral linear motion produces flexure vibrations of the same phase in the sensing arms. Amplitude corresponding to the acceleration and electrical signals of the same phase corresponding to the direction of flexure are produced, respectively, in the sensing arms due to the piezoelectric effect. Electrical signals corresponding to the translatory motion are not output but are canceled by employing differential amplification of the electrical signals of the same phase that are produced in the upper and lower sensing arms. This is the mechanism by which aberrant output is avoided even when acceleration (translatory motion) is applied.

In addition to the low sensitivity to vibrations and impacts of the sensor elements themselves, the gyro-sensors in the XV-9000 series have an optimally designed, built-in low-pass filter that strictly minimizes aberrant output resulting from translatory motion.

Gyroscopic sensors that operate normally when exposed to vibrations and impacts without requiring unwanted corrections will increase system stability while simultaneously reducing the need for development resources. Epson Toyocom is committed to demonstrating the potential of its crystal gyro-sensors in a wide range of applications, from cameras, cell phones, video games and other consumer products, to vehicle control and safety systems.

**About Epson Toyocom**

Epson Toyocom Corporation was formed through the integration of the quartz business of Seiko Epson Corporation and Toyo Communication Equipment Co., Ltd. in October 2005. Epson Toyocom follows a “3D strategy” designed to drive both horizontal growth through expansion in three device categories—timing devices, sensing devices and optical devices—and vertical growth through combinations of products in these categories. With this strategy, Epson Toyocom aims to be the leading company in the quartz device industry, selling a wide range of products to customers worldwide, from cellular phones for consumer fields, to industrial fields such as core network systems and automotive systems.

The company's timing devices are extremely accurate, stable crystal products that serve as reference signal sources in all manner of devices. The lineup currently includes products in frequencies ranging from the kilohertz band up to 2.5 GHz range. In the kilohertz range, Epson Toyocom offers tuning forks. At frequencies up to about 100 MHz, Epson Toyocom offers AT-crystal products that use thickness-shear vibration. In the hundreds of megahertz range, the company applies its AT vibration technology to provide crystal products that use an HFF (high-frequency fundamental) or SAW (surface acoustic wave).

Epson Toyocom website : <http://www.epsontoyocom.co.jp/english>

Gyro Sensor Portal Site : <http://www.epsontoyocom.co.jp/english/gyroportal/index.html>

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