

Report No.: EW-B-	Version:	Product:	Serial-No.:
Requested by:			
Distribution list:			
Report title: S-350 with Gyro Integration			
Author:			Report date:

S-350: 2 Axis Optical Sensor with Integration of Gyro for Automatic Calculation of Slip Angle Relative to the Vehicle Center of Gravity

1. Introduction

In vehicle dynamics most measured signals refer to the center of gravity (COG) of the vehicle. This concerns especially the velocity vector as well as the body slip angle that characterize the motion of a vehicle.

CORREVIT S-type sensors are able to measure velocity in two axes but usually they are not easily mounted under the vehicle at the COG. Pimarily they have to be mounted either in front or back respectively at one side of the vehicle.

It is logical to understand that while cornering you will measure different velocities whether the sensor is mounted at the inside or outside of the curve.

If the exact position of the CORREVIT sensor in the COG coordinate system is known a correction of the sensor signals can be calculated, but therefore an additional signal – the yaw rate – is necessary.

The yaw rate can be measured by gyroscope sensors. Since the vehicle body can be assumed to be stiff and therefore the angular rate has the same value at every point of a vehicle, the mounting position of a gyroscope is not of importance. Of course the sensitive sensor axis has to be parallel to the vehicle vertical axis.

2. Calculation

2.1 Pure rectilinear vehicle motion

Fig. 1 shows a vehicle in rectilinear motion. In this case the velocity components measured by the sensor are identical with the vehicle velocity \vec{v} .

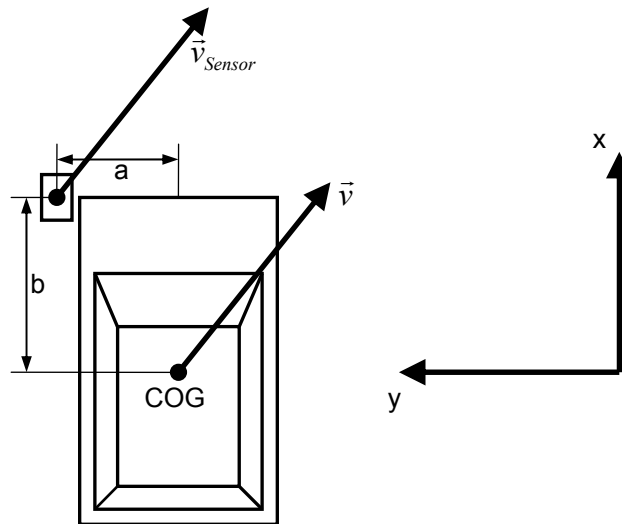


Fig. 1: Rectilinear vehicle motion

$$\vec{v} = (v_{long}, v_{trans}, 0) = \vec{v}_{Sensor} = (v_{Sensor,x}, v_{Sensor,y}, 0)$$

The figure also shows the common convention for the vehicle coordinate system (ISO 8855), in which the x-axis points to the front of the vehicle, the y-axis to the left, and the z-axis upwards (right hand system).

2.2 Pure yaw

With a pure yaw motion around the center of gravity as rotational center. (Fig. 2) the vehicle velocity should be "0". As the sensor is not mounted in the COG it will measure a velocity that is dependent on the yaw rate $\dot{\Psi}$ and the position in relation to the COG. When the position of the sensor in the COG system is

$$\vec{r} = (b, a, 0)$$

the velocity that the sensor measures can be calculated as follows:

$$\vec{v}_{yaw} = \dot{\Psi} \times \vec{r} = (0, 0, \dot{\Psi}) \times (b, a, 0) = (-\dot{\Psi} \cdot a, \dot{\Psi} \cdot b, 0)$$

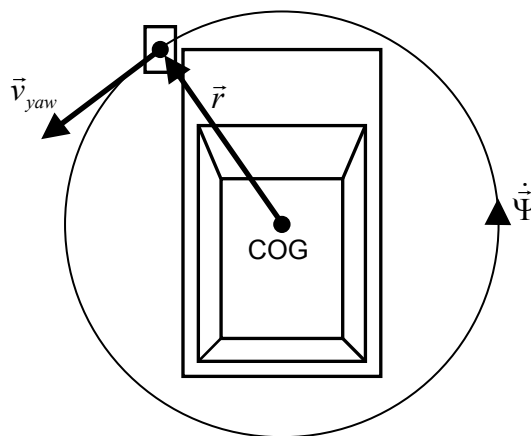


Fig. 2: Pure yaw motion

2.3 Superposition

What the CORREVIT sensor is measuring in reality is the superposition of COG velocity \vec{v} and the velocity caused by yaw \vec{v}_{yaw} .

$$\vec{v}_{Sensor} = \vec{v} + \vec{v}_{yaw}$$

$$\vec{v}_{Sensor} = (v_{Sensor,x}, v_{Sensor,y}, 0) = (v_{long} - \dot{\Psi} \cdot a, v_{trans} + \dot{\Psi} \cdot b, 0)$$

Thus the longitudinal and transversal components of the vehicle velocity are:

$$v_{long} = v_{Sensor,x} + \dot{\Psi} \cdot a$$

$$v_{trans} = v_{Sensor,y} - \dot{\Psi} \cdot b$$

The body slip angle becomes:

$$\beta = \arctan \frac{v_{trans}}{v_{long}} = \arctan \frac{v_{Sensor,y} - \dot{\Psi} \cdot b}{v_{Sensor,x} + \dot{\Psi} \cdot a}$$

3. Signal integration of the Gyro

With the new CORREVIT S-350 two axes sensor we have the possibility to do the signal integration to calculate the slip angle relative to the vehicle center of gravity within the electronics box of the sensor. The S-350 is equipped with two analog inputs where a gyroscope sensor can be connected.

In CeCalWin Pro software the correction of the sensor signals v , v_l , v_q and β can be activated (Fig. 3).

The dimensions a and b that locate the CORREVIT sensor in the COG coordinate system and the resolution of the gyroscope sensor has to be entered. Most silicon capacitive gyroscopes have a bias voltage of 2.5 V that can easily be calibrated by pressing the button "Offset Correction".

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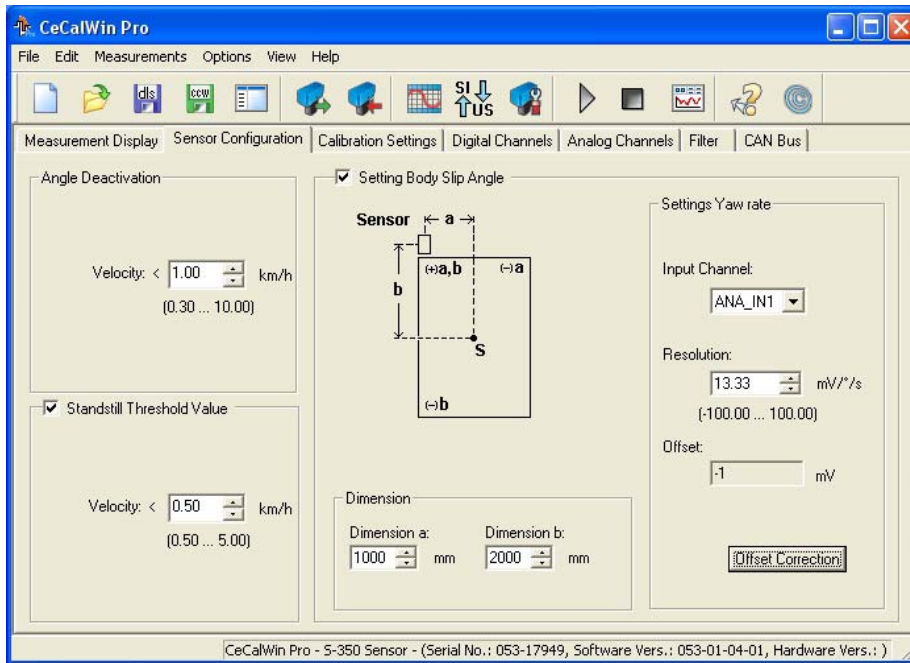


Fig. 3: Configuration of the signal correction in CeCalWin Pro software

Fig. 4 Shows a comparison of data with the slip angle relative to the center of gravity and the data relative to the sensors mounting position at the front right of the vehicle. This test was carried out during low speed cornering.

During the cornering the Slip angle relative to the mounting position shows a big variation between -12° and 22° . The Slip angle relative to the center of gravity signal only shows little variations between -3.1° and 1.6° as expected at low velocities without drifting. The velocity signal without correction shows higher values in left turns and lower values in right turns while the signal with corrections shows a steady behavior.

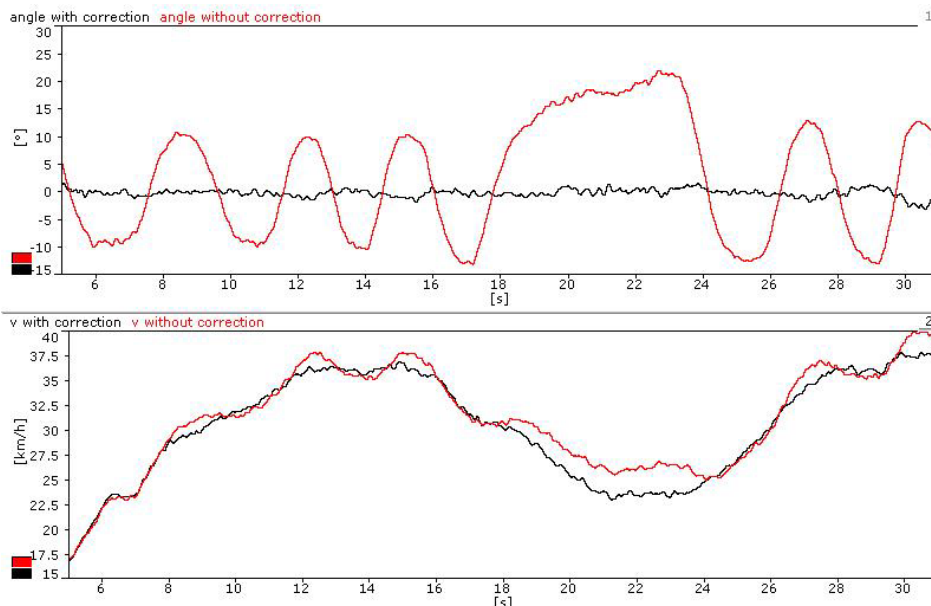


Fig. 4: Comparison of the signals angle and velocity with and without gyro integration

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