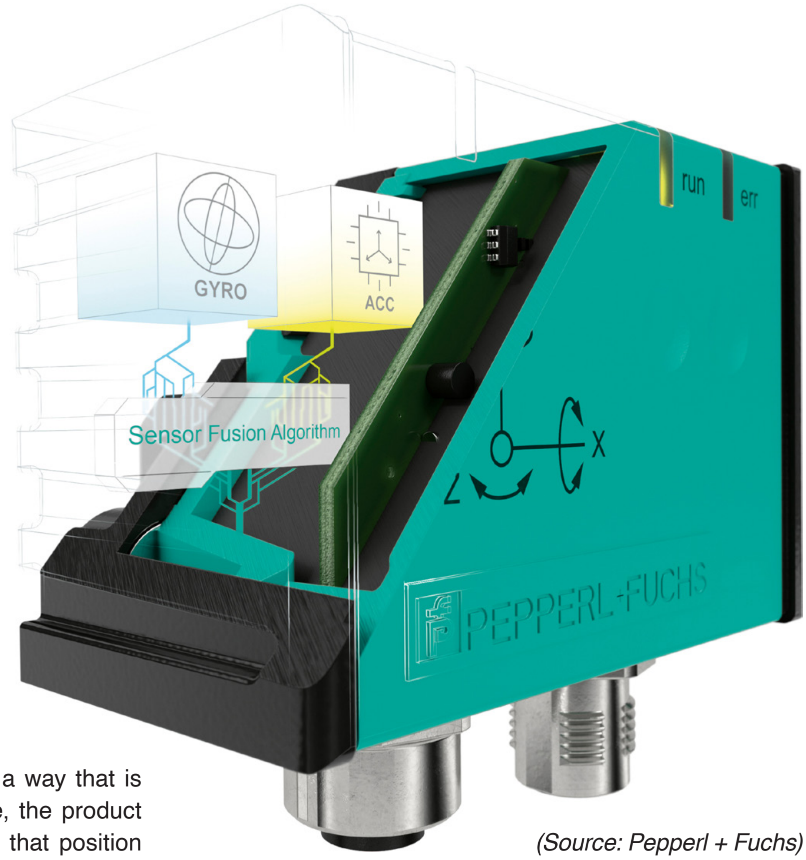
Dynamic inclinometer with angular stability

Pepperl + Fuchs has developed the IMU F99 sensor providing J1939 connectivity. It features reliable inclination values for dynamic applications, because it is able to filter out external interference (e.g. potholes). The software adjustment configurable via the CAN-based interface ensures a high angular quality, even when the driving behavior of machines varies greatly.

Static inclination sensors reach their limits, when used with machines that move dynamically, such as wind turbines, AGVs (automated guided vehicles) as well as construction, agriculture, and forestry machinery. This is because static inclination sensors detect a change in angle based on gravitational acceleration that is always on the same axis. Any additional accelerations triggered, e.g., by braking or travelling over a pothole, cause significant interference, which makes reliable angle measurement impossible.

The IMU F99 dynamic inclination sensor has been developed for this type of dynamic application. At its core, rotation rates and acceleration are both measured in all three spatial directions and are then merged in the smart algorithm to produce an angle value. This makes it possible to achieve a reliable angle output. Nevertheless, it is clear that the different types of machine movements mean that the rotation rate and acceleration need to be merged in a way that is adapted to the particular machine. Therefore, the product comes with adjustment setting capability, so that position measurements can be performed on a wheel loader, bulldozer, crane, etc., using just one device.

The IMU F99 inclinometer also provides the rotation and acceleration rates for each of the three axes in parallel to the angle output. This means that the product can be used in a wide range of applications. For example, the device can be used to determine the rotation speed of wind turbines. At the same time, it can also monitor the blade acceleration rates, which may fluctuate when unwanted ice forms are on the blades. In this way, it is possible to control rotation speed and perform predictive maintenance on the wind turbine.



(Source: Pepperl + Fuchs)

Acceleration sensor and gyroscope

The inertial measurement unit (IMU), combines an acceleration sensor and a gyroscope into a single device. This device is optimized to provide gyroscopic-stabilized inclination and acceleration data as well as rotation rate data. Heart of the IMU is the adaptive sensor fusion algorithm. It is developed and implemented for inclination measurement with effective compensation of external acceleration disturbance.

Triaxial acceleration sensor and triaxial gyroscope outputs are used as input of the fusion system. The adaptive sensor fusion algorithm is designed to compensate the measurement errors by combining accelerometer and gyroscope data adaptively to the current situation. The Figures 1 to 4 show the orientation and assignment of the axis for which the sensor can be used depending on the parameterization of the angle output system.

The IMU measures the acceleration, yaw rate, and angle in each of the three axes. Regardless of the current position of the sensor in space, the acceleration and yaw rate values equal the rotation rate values. A reliable angle output per measuring axis depends on the current position of the sensor in space. A change in angle around the gravitational vector, which is always vertical, can't be measured. If a measuring sensor axis is parallel to the gravitational vector (±5°), then this axis does not provide reliable angle values and must be ignored. The implemented Gravity Flag (GF) offers help for this. The sensor automatically detects whether a sensor axis is parallel to the gravitational vector and shows this in the status of the Gravity Flag (GF). ▷

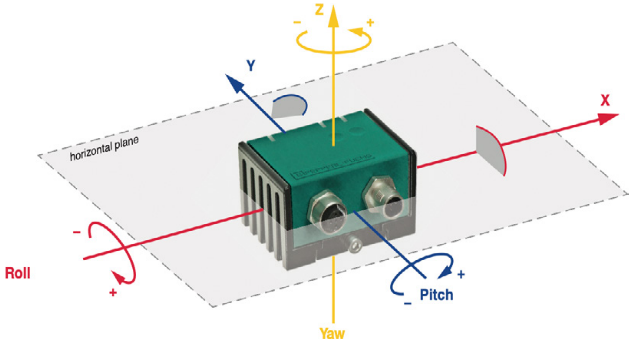


Figure 1: Spatially fixed coordinate system (extrinsic reference to the horizontal plane) for the angles INX or INY (Source: Pepperl + Fuchs)

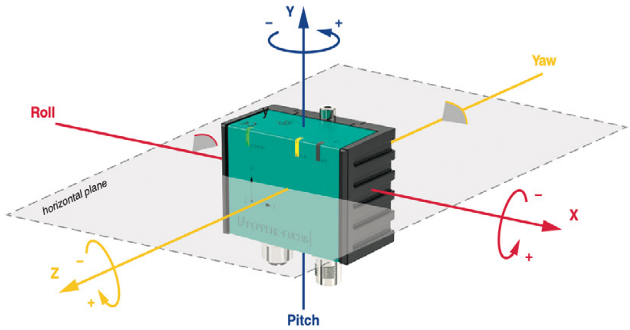


Figure 2: Spatially fixed coordinate system (extrinsic reference to the horizontal plane) for Euler angle (Source: Pepperl + Fuchs)

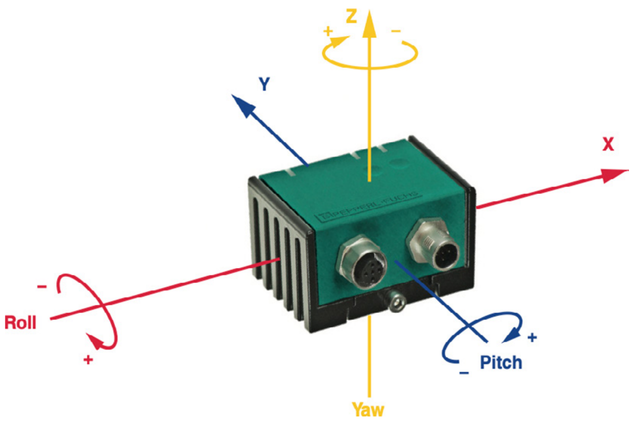


Figure 3: Body fixed coordinate system (intrinsic or co-rotating) for Euler angle zy'x'' (Source: Pepperl + Fuchs)

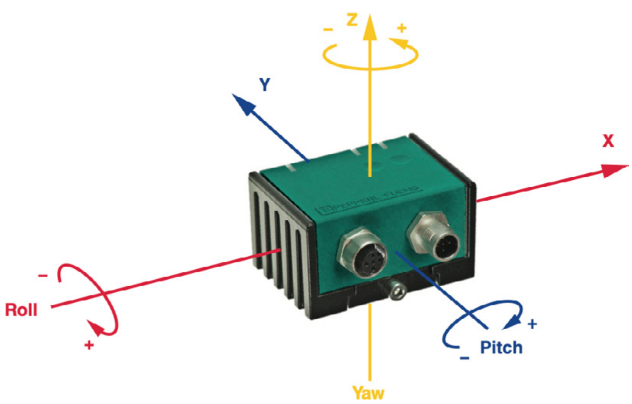


Figure 4: Body fixed coordinate system (intrinsic or co-rotating) for P+F angle INZ (Source: Pepperl + Fuchs)

CANopen profiles mapped to J1939

CiA supports the mapping of device profiles originally developed for the CANopen application layer to the J1939-21 higher-layer protocols. This includes the CiA 510 document specifying the mapping of SDO (service data objects) and EMCY (emergency message) to J1939 parameter groups (PG). This means you can configure and diagnose the J1939 device similar to CANopen. CiA provides additionally a mapping of CANopen-PDOs (process data objects) to standardized PGs. The CiA 406-J document specifies the encoder profile mapping to J1939. The CiA 410-J document does the same for inclinometers, but is not yet released.

The CiA inclinometer base document (CiA 410-B) specifying the process and configuration parameters currently does not support smart inclinometers such as the IMU F99 by Pepperl + Fuchs, for example. If this is desired, the inclinometer profile needs to be improved by means of additional configuration parameters setting the filter options. This would improve device interoperability and partly interchangeability. *hz*

Accordingly, it is always displayed for each angle value as to whether it can be used.

Independent limits can be configured for the X, Y, and Z axes of the acceleration, rotation rate, and angle measurement axis. If these limits are exceeded, this is indicated in the switching status of the Application Flags (AF).

Several selectable output values such as acceleration, rotational speed, inclination (Euler angle, Euler value, quaternions), and programmable filters allow users to adapt the measuring system to the application. Parameterization and data transfer take place via the CAN-based SAE J1939 interface.

The J1939 interface

The CAN interface supports a default bit rate of 250 kbit/s. It implements an application layer compliant with J1939-21. As specified in J1939/81, the sensor supports the dynamic address claiming starting with default address 128. If this feature is not desired, it can be deactivated.

The J1939 inclinometer communicates by means of proprietary Parameter Groups (PG). The payload is similar to the PDOs (process data objects) used in the CANopen variant of this inclinometer. The above-mentioned configuration of the J1939 sensor is performed by means of dedicated PGs. This configuration is mainly the setting of filters, which determines the measured signal filtering. This enables the suppression of vibration frequencies. These vibrations could be triggered by a running engine or gearbox, for example. In this way, the quality of the angle output can be adjusted despite disturbing vibrations. The filter type, the filter order, and the width of a low-pass filter are configurable. The filter settings can be defined in the filter-settings parameters. ◀

hz (based on information by Pepperl + Fuchs)