APPLICATION NOTE

North Finding

North finding is critical for tactical navigation and target orientation localization. It is used either in fixed static observation systems or in hand-held portable devices. The present application note focuses on the military domain, mainly about scouting operations.
Common north finding modules embed a 3-axis magnetometer. Such a sensor measures the angle between the pointing direction of the system and the magnetic field of the Earth. Magnetometers are cheap and small, however they show some weaknesses. First and foremost, this type of sensors measures the magnetic north, leading to an error to adjust. Secondly, its accuracy is greatly reduced when the sensor is surrounded by magnetic elements.

Advanced north finding modules are using a gyroscopic compass instead of a magnetometer. Gyroscopes measure angular velocity relative to its inertial position. A 2-axis gyroscope can find north, and a 3-axis gyroscope detects the Earth's axis of rotation. There are many types of gyroscopes, based on different principles:

Classic Mechanical - Spinning wheel mounted on a gimbal
Optical – Fiber optic gyros (FOG) and Ring Laser Gyro (RLG), based on the Sagnac effect
Vibrating – Coriolis effect – Hemispheric Resonating Gyros (HRG), Micromechanical Gyros (MEMS)

The gyroscopes measure true north and are not affected by external magnetic fields or surrounding metals but they are affected by Bias drift

Accelerometer Function in System

Accelerometers are combined with gyrocompass for three major reasons. First of all, north finding modules are often exposed to continuous error sources such as temperature drift, vibration, bias offset, and aging. Measurements during a long period of time (more than an hour) becomes less accurate. Therefore, the use of an accelerometer is often required as an auxiliary sensor in order to counter gyrometer errors. The accelerometer reads the value of drift and sends the variation to e.g. a a Kalman filter in order to recalibrate the gyroscope. Another utility of the accelerometers is when a system is rotating without moving, typically a platform at sea. The gyroscope cannot distinguish between the rotation of the system and the Earth: it is melded as one resulting vector.

Figure 1: The STERNA Family Safran Vectronix SA

The angular velocity of the platform is calculated using the accelerometer,
and a derivative electronic circuit. Once obtained, the angular velocity is substracted from the gyroscope's output to acquire the Earth's rotation axis and north direction.

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A third way of exploiting the potential of an accelerometer is to obtain the inclination of the system. Inclinometers are also embedded in north finding devices in order to read the vertical angle between the horizon and the target. For a low range inclinometer, the acceleration is directly related to the angle, by the following formula:

$$a = g \times \sin\varphi$$

Where *a* is the acceleration, *g* the gravity on Earth, and φ the angle between the horizontal and the cantilever. If the angle is small:

$$a = g \times \varphi = 9.81 \times \varphi$$

Accelerometer Performance Grades

The embedded accelerometers must not only respect high safety standards, by measuring reliable data over long periods of time, but also have a small size and a low power consumption. Accelerometers differ in performance classes based on manufacturing technology and performances. Here are the four main grades distinguishing accelerometer performances:

- High End motion control Grade
- Tactical Grade
- Navigation Grade
- Strategic Grade

The following table resumes the specifications[1]:

Class	Accelerometer Technology	Global Bias Accelerometer Accuracy	Corresponding Gyro Technology
Strategic Grade	Quartz Servo accelerometer	< 30 µg	ESG, RLG,
Navigation Grade	Quartz Servo accelerometer, Vibrating Beam	50-100 µg	RLG, FOG, HRG
Tactical Grade	Quartz Servo accelerometer, Vibrating beam, MEMS	1 - 10 mg	RLG, FOG, HRG, Quartz MEMS
High Performance (motion control)	MEMS	10-100 mg	CVG , MEMS
Industrial/ Instrumentation	MEMS	1 g	MEMS

[1] Source from http://www.navlab.net/Publications/Introduction_to_Inertial_Navigation.pdf , slide 10

MS1000 – an optimal MEMS accelerometer for North Finding

Fig.2: MS1000 Accelerometer

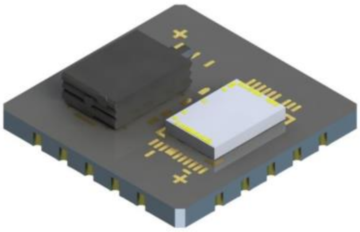

Fig. 3: MS1000 Architecture

As figured in the previous table, Quartz servo accelerometers are high performance sensors that match Strategic, Navigation grade of performances. North finding requires performances of tactical grade, as well as small dimensions of integrated components and a very low power. A range of ±2g and +/-5g correspond for North Finding, as it allows to avoid the majority of the saturation during measurements.

A good example of Tactical grade performances MEMS sensor is a new open loop MEMS accelerometer MS1000, designed by Safran Colibrys for advanced inertial applications. Its initial bias residual modelling error over temperature range -40 to 85 °C will be < 140 µg, a long term bias repeatability will be better than 240 µg and an in-run bias stability (Allan Variance) better than 3 µg (all values are typical and are given for +/-2g range). During north finding system alignment phase turn-on to turn-on bias repeatability of the sensor plays a very important role. MS10002 bias turn-on to turn-on bias repeatability stands for 15 µg for +/-2g range.

MEMS capacitive accelerometers function thanks to two electrodes and a beam that deflects itself by a change of velocity. This effect creates a voltage variation, proportional to the acceleration. The MEMS sensors are known to have both low weight and low power consumption, with good reliability and durability. Colibrys MS1000 accelerometer power consumption is only 2.5 mA, with shock resistance of 1'500g and vibration resistance of 20g rms. The sensor is hermetically sealed to operate correctly even in harsh conditions. A temperature sensor is also embedded to compensate drift as system level.

Colibrys part of Safran Group

Colibrys is a Swiss society specialized in MEMS capacitive accelerometers. In 2012, the company joined the Safran group. Today Safran Colibrys is a part of Safran Electronics & Defense - a high-tech company, holding world or European leadership positions in optronics, avionics, electronics and critical software for both civil and military markets.

Glossary:

- CVG: Coriolis vibratory gyroscope
- DC: Direct current
- ESG: Electrostatic gyroscope
- FOG Fiber optic gyroscope
- GPS: Global positioning system
- HRG: Hemispherical resonating gyroscope
- IMU: Inertial measurement unit
- MEMS: Microelectromechanical systems
- RLG: Ring laser gyroscope

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