MGL Avionics

SP-9 AHRS and magnetometer

User and installation manual

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About this document

This document describes installation and usage for the SP-9 AHRS (Attitude Heading Reference System) and magnetometer (electronic compass) for connection to MGL Avionics flight instrumentation systems.

Before you begin – Read this !

The SP-9 is a high grade AHRS with exceptional performance. Incorrect or inadequate quality of installation can seriously degrade the performance of this system. Please read and understand the installation requirements outlined in this document.

Note: The magnetometer part of the AHRS will not work correctly until a calibration in its installed environment has been performed and the heading returned may show very large errors until calibration has been completed successfully. If the magnetometer will not be used, this calibration does not have to be performed as the attitude related part of the AHRS is not dependent on the magnetometer.

Connectivity

The SP-9 is designed to be connected to the XTreme, Enigma, Voyager, Odyssey and iEFIS instruments from MGL Avionics.

The SP-9 units may be used with systems designed by third parties. Please consult relevant documentation of your third party system.

Interface

The SP-9 provides three interfaces:

CAN bus: This is a two wire bus system allowing multiple devices to transfer data over a common data bus. This is the preferred way of connecting the SP-9 and is supported by all newer MGL systems.

RS232: This interface is used mostly for third party applications and is also used for factory diagnostics, calibration and testing. It is not used for any MGL Avionics systems.

Airtalk: This legacy interface is a shared, single wire low data rate connection and is used for legacy device support as well as some basic attitude and heading indicators.

It is possible to use any combination of these interfaces at the same time but only one interface must be used for any given equipment – in other words, if your equipment supports both Airtalk and CAN for example, only one of these interfaces must be connected to the SP-9 (you would likely choose the CAN bus in this case).

The SP-9 magnetometer

The SP-9 contains a fully compatible SP-6 magnetometer. To the connected equipment the built in SP-6 appears as a separate device.

Please note that it is not always possible to use the built in SP-6 magnetometer due to mounting location constraints. It is often not possible to find a location in a small aircraft that is suitable for both the AHRS as well as the magnetometer.

The AHRS should be installed in a location free of vibration and other mechanical alignment disturbance close to the center of rotation of the aircraft while the magnetometer must be installed in a location where it is able to measure the Earths magnetic field with as little disturbance (deviation) as possible.

The SP-9 solves this possible dilemma by switching the internal SP-6 off should an external SP-6 be connected to the same CAN bus.

The AHRS does not require the magnetic field information and this information is not used in the attitude solution. Therefore there is no degrading of the attitude solution in case magnetic field information is not present or unusable.

SP-9 Installation with respect to built in SP-6 equivalent or external SP-6

The most critical decision to make before installing your SP-6 is to decide on a good location inside your aircraft. Special care needs to be taken to prevent exposure of the SP-6 to significant magnetic disturbances – especially in aircraft containing steel (ferrous metal) structures. Such locations are unsuitable.

Aluminum, brass, fibre glass and carbon fibre are examples of materials that will NOT disturb the magnetic field. Ferrous metals and conductors carrying currents will distort the magnetic filed. The disturbance cased by Stainless Steel will depend on the grade of the Stainless Steel used. Although non magnetic in its highest grade form, many grades will be magnetic as they are not pure. Test with a small magnet if unsure. If the magnet sticks, it is a problem.

We recommend that you do a basic survey using a small hand held hiking compass inside your aircraft to help locate strong disturbances. Note that you must orientate your aircraft on several headings and repeat the process to find a good location – doing this on just a single heading is seldom successful.

Your aim is to find a location that will give you a heading error of less than 10º on any heading in normal flight attitude. Only in this case will you be able to use the built in compensation and alignment functions to eliminate the remaining errors properly. If you start with a large error, perhaps 15º or larger, you have little chance of calibrating this error out. Rather find a better location.

In extreme cases, consider locating the SP-6 outside the fuselage, perhaps in a wing tip. The wires running to the SP-6 can be lengthened if required.

When attempting to find a suitable location for your SP-6, be aware of the following:

Avoid any areas that have iron based metals in close or relatively close proximity.

Avoid proximity of instrumentation containing magnets (many electrical "needle" based instruments contain magnets). Some automotive type GPS antennae contain strong magnets. These magnets can often easily be removed.

Avoid proximity to autopilot servo motors, electric fuel pumps and other electric motors.

Avoid proximity to any wiring containing electrical supply currents (the currents will cause a magnetic field to build up around the cable).

Avoid any proximity to ferrous metallic fasteners such as nuts and bolts.

Avoid or a least be mindful of proximity to luggage storage areas (example the "glove box"). If ferrous metallic items like car keys are stored in these areas, the magnetic field will be disturbed depending on the location and orientation of the disturbance source.

Be aware that the Earth magnetic field is very weak and is easily disturbed by any of the above items. If you want to experiment to find out just how easy it can be disturbed, move a screwdriver close to the SP-6 (once it is connected and operating) and observe the effect on your heading. You may be surprised!

The SP-6 will in all cases faithfully show the direction of the magnetic field passing through it, even if this is not the direction of the Earth magnetic field at your location.

Mounting the SP-9 with respect to the magnetometer

Mount the SP-9 in a position that is not affected by ferrous metals (including nuts and bolts). Mount the SP-9 using plastic, brass or aluminum fasteners. As alternative, consider industrial quick release fasteners such as self-adhesive Velcro or similar systems.

Try to mount the SP-9 in such a way that it will be horizontal or close to horizontal during normal cruise flight. The internal tilt compensation is effective to about 60º pitch and bank but additional errors can still be introduced. These however are very negligible if only small amounts of tilt are present.

If and external SP-6 is being installed in conjunction with a SP-9, the two sensors MUST be mounted with the same pitch and roll angles. If this is not done, significant heading errors of the SP-6 will result as it will base its calculations on incorrect attitude.

SP-9 magnetometer in-flight calibration

The SP-9 is calibrated in flight using a set of basic maneuvers. The SP-9 needs to be placed into calibration mode for this procedure. This is done through functions provided in the display systems.

The details are described in the SP-6 user manual available for download at www.MGLAvionics.co.za

SP-9 AHRS

The SP-9 AHRS is based on highly advanced micromachined ring gyroscopes. Three of these are used to form a “strap down” gyroscopic system. Relative rotation rate measurements between the three major axis of alignment are used to update a quarternion representation of the aircraft's attitude.

Ring gyros are particular robust with respect to mechanical disturbances such as vibrations and G-force loadings due to their self-compensating nature. This also makes them show excellent behavior to temperature variations – a traditional problem area for MEMS gyros.

High quarternion update rates ensure correct response to rapid rotations without lag while extremely high numerical resolution of the many calculations required minimizes the effect of numerical drift caused by rounding errors.

While the gyros measure rotation, a total of six accelerometers are used to measure Earth gravitational and acceleration forces in order to align the quarternion to the Earth reference frame.

Three Orion class accelerometers provide extremely accurate and drift free acceleration measurement while a further three high range accelerometers are employed to cover the range from 10G to 16G.

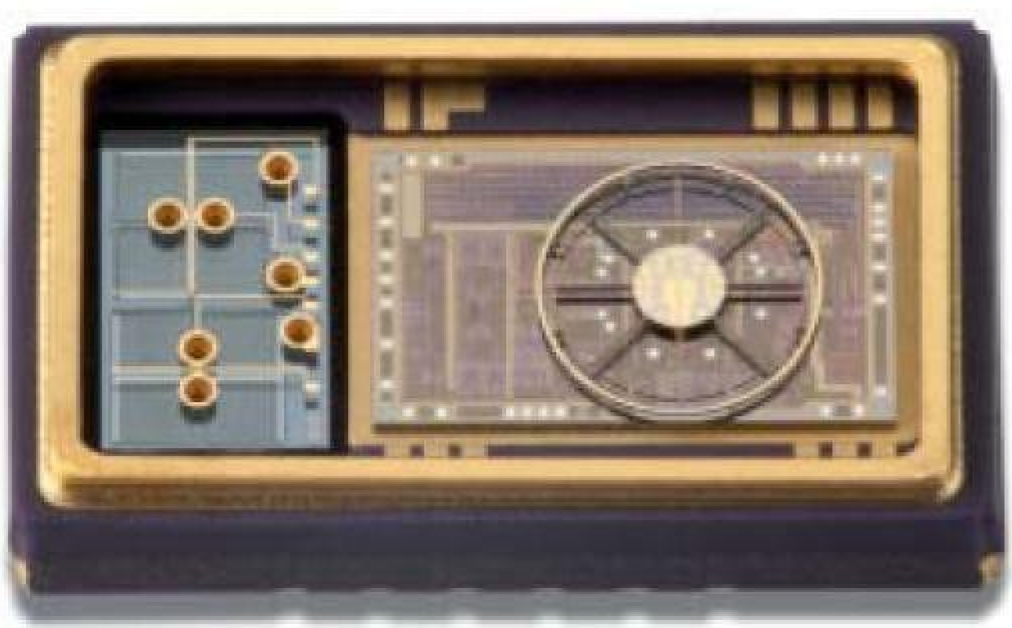


Image of the ring gyroscope system on the right, mounted onto the semiconductor chip containing interface electronics. This presents a true marvel of micro-engineering. The area on the left with a bue tint is the highly accurate Orion class accelerometer. The SP-9 contains three of these devices.

If available, velocity information such as from pitot static or GPS systems are also included in the mathematical solution to further aid the attitude solution. This aiding information is automatically transferred to the SP-9 by the connected equipment. The SP-9 AHRS does not rely on this information to be present and will continue to operate at slightly reduced overall performance should this information not be available.

SP-9 installation from an AHRS perspective

The SP-9 must be rigidly fixed to your airframe (i.e. it must not move relative to your airframe).

The AHRS must be aligned correctly to your airframe. The horizon picture you are seeing on your display is not that of your aircraft but that of the AHRS.

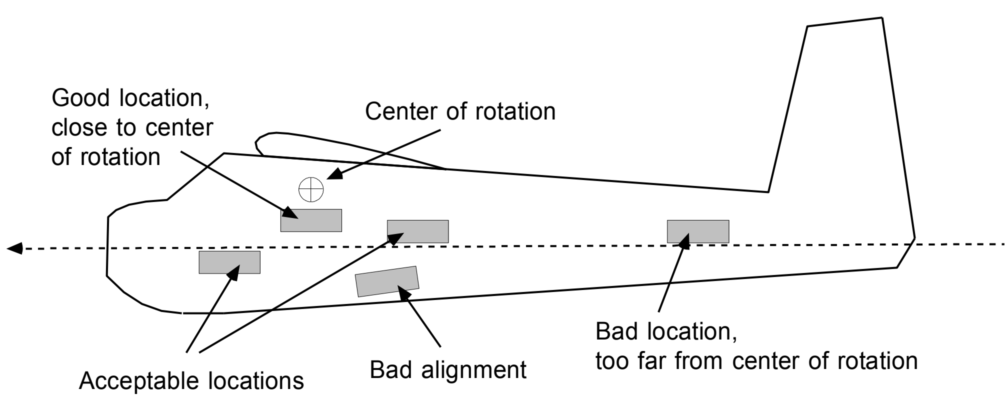
Any undesired movement must be kept away from the AHRS as this will degrade the attitude solution.

Vibration, such as caused by an engine is poison to an AHRS. Vibration contains many linear and rotational movements at high frequency, many above the maximum rate of rotation that can be measured by the gyros. If your AHRS is exposed to engine vibration it will significantly reduce the performance of your system. Read this part again – it is the single biggest factor that you must understand. Use any means possible to mount the SP-9 such that vibration is minimized as far as possible.

Temperature. Avoid exposing your AHRS to extreme temperatures, both hot and cold. Also avoid rapid temperature changes. The gyros react badly to temperature changes. Your SP-9 contains an internal heating element that will try and maintain a constant internal temperature of about 35º Celsius to assist in this matter.

Location. The ideal location for the AHRS is in the center of rotation of your aircraft. This is seldom possible though. However, try and find a location that is as close as possible to the center of rotation. Any significant distance from the center of rotation (more than say 5ft) will cause the accelerometers to read incorrect information. For example: Consider that you have installed the SP-9 some distance behind the center of rotation. If your aircraft yaws, the X axis accelerometer will think that you are banking due to the centrifugal forces created by the yaw.

Power. Last but not least – make sure your power supply is stable and provides sufficient voltage AT ALL TIMES. Electrical noise on the supply is not a good thing and will degrade performance – the AHRS has to measure extremely small signals to be accurate. A noisy electrical environment does not help.



Location and Mounting of the SP-9

Important:

The gyros used in the SP-9 have exceptional resistance to the effect of vibrations. However this should not be taken as a reason to relax mounting requirements of the SP-9 unit. Please treat the SP-9 the same as you would treat a $100.000 AHRS system in order to gain advantage of its potential performance.

SP-9 mounting

The SP-7 can be mounted by means of the four bolt holes in the flanges.

Alternatively, industrial quick release fasteners such as self adhesive Velcro strips can prove to be an easy option. This form of mounting the SP-9 onto a sturdy airframe member such as a wing spar box has proven to work very well. The velcro also allows simple repositioning of the SP-9 should that be required.

Should mounting require heavy duty vibration absorption, a suggested technique would require the SP-9 to be mounted on a heavy base plate (consider lead or other heavy material). This base plate would then be mounted using rubber mounts.

The consistency of the rubber must be chosen such that the SP-9 does not readily move on its own relative to the airframe if exposed to airframe shocks but is flexible enough to prevent vibrations from being transmitted mechanically to the SP-9. This is very important as any rapid movement, even if very small, relative to the airframe will degrade performance.

Under no circumstances mount the SP-9 onto the skin of the airframe, regardless of the skin material. Skins tend to be exposed to severe buffeting and this transfers into the SP-9 severely degrading performance.

SP-9 general operation

The SP-9 would normally be switched on with the aircraft stationary. It quickly finds and stabilizes current gyro biases and sets the horizon from the information measured by the accelerometers. This process typically takes less than 15 seconds.

Maximum accuracy is achieved a few minutes after startup if at a relatively cold ambient temperature. Less time is required if you are operating on a warm summer day. The SP-9 contains a built in heater element to speed up heating to operational needs (35º Celsius internal). This heater will operate at less effectiveness if your power supply voltage is low. The heater is intended to operate at full efficiency between 12 and 20V DC.

Should power be cycled in flight, the SP-9 will track the horizon very quickly after start-up if the aircraft is held in non-accelerated (such as straight and level) flight.

The horizon should track well in straight and level flight, even with relatively severe aircraft motion caused by turbulence. The horizon should not show any noticeable error after flying a complete rate one turn (two minutes for 360º). As you turn out straight, the horizon should be instantly correct. If not, check your installation – something is upsetting the SP-9.

Multiple SP-9 devices in a system

It is possible to connect up to 4 SP-9 devices on a single CAN bus. In this case it is required that each SP-9 is set to a unique CAN bus device address.

MGL EFIS systems provide a function under the Horizon setup menu → Advanced options to set the device address.

This is a once-off installation task. Connect ONE SP-9 at a time to the CAN bus and set its address (choices are AHRS 1,2,3 and 4).

If you have multiple AHRS systems connected (which may include lower cost SP-7 units) the AHRS information shown on the display is that of the lowest AHRS address (usually address 1). Should this device fail the next higher AHRS takes over.

For system testing you have the option of forcing the use of a particular AHRS device. In some MGL systems you have an AHRS diagnostics function which allows you to view each connected AHRS.

SP-9 for blind flight operations (IFR flights)

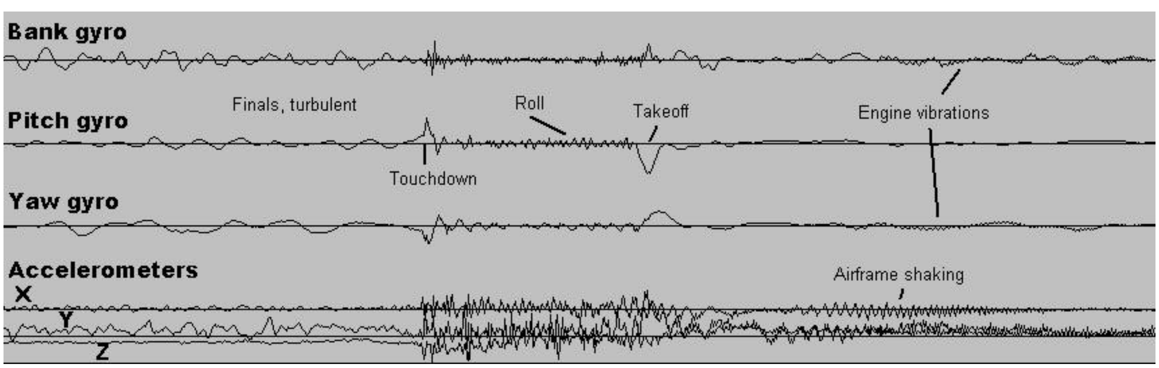
The SP-9 is designed to the requirements set out in TSO-C201 when used with an MGL display device.

The SP-9 is not planned for FAA or EASA certification. The SP-9 is intended for use with uncertified aircraft or aircraft where special permission has been granted or use of such equipment is otherwise permitted.

IFR flight must only be attempted by pilots qualified and trained in IFR procedures including instrument failure modes and flight without visual reference to the horizon in any form.

Typical raw data recording

The image below has been obtained from raw data recorded during a touch and go. This recording was done using an SP-3 AHRS (an early predecessor of the SP-9, information included hare for interest).



The SP-3 was installed on a ultralight aircraft. No special provision was made to dampen any engine or airframe vibrations.

Horizon recovery

The horizon position (attitude) reported by the SP-9 is a result of many measurements and calculations. Certain conditions can lead to an error in the attitude reported. Typical cases are: Exceeding the maximum rate of rotation that can be measured on any axis (300 degrees per second) or “floppy” mounting arrangements where the SP-9 can move rapidly independently from the airframe.

The SP-9 will attempt to “drift” the attitude towards an internally derived attitude based on accelerometer measurements and aiding calculations. This is a slow correction timed such that normal gyroscopic drift (and effects such as the Earth's rotation) are completely compensated for.

Based on internal criteria the system will increase this rate of compensation up to a very high value if there has been an upset (such as exceeding the maximum rate of measurement).

This results in a fast restoration of a valid attitude and resumption of normal operation.

The SP-9 is capable of following an aircraft through a complex series of aerobatic maneuvers without restriction other than maximum rates of measurements. There is no need to “cage” the system as would be required for traditional gyroscopes.

Should any attitude errors accumulate after a period of sustained, unusual flight maneuvers, these are quickly corrected once un-accelerated flight is resumed (including “normal” flight maneuvers such as turning, ascending and descending).

Electrical connections for the SP-9

Pin Number	Pin Description
1,2	Ground (GND) / Battery minus
3	RS-232 Receive (RX)
4	RS-232 Transmit (TX)
5	Airtalk
6,7	Vin / Battery positive / +12V
8	CAN Low
9	CAN High

Cannon D-9 connector pin descriptions for the SP-9

The SP-9 is intended to be supplied by a clean DC voltage that is protected against reverse polarity and surges exceeding the maximum limits as dictated by DO-160. It is recommended to limit any continuous DC supply voltage to less than 18V, although the SP-9 will operate on higher voltage bus systems such as 24/28V systems.

It is suggested to install a 33V transorb plus a 10 000uF capacitor across your power supply wires if there is a possibility of power supply noise or voltage spikes caused by starter motors or other electrical equipment.

The SP-9 is required to be supplied through a fuse or over current protection circuit. It is acceptable to supply both through a single fuse. A fuse rating of 500mA slow blow is recommended for either one or both units. It is accepted practice to share a single circuit breaker or fuse with multiple, related instruments or devices. Ensure the rating of the circuit protection device is suitable for the expected power consumption and start-up current surges.

The SP-9 must be connected to your supply after your main power switch (master switch). The units should not receive power when your master switch is in the “off” position.
Should you be using the CAN bus, please observe CAN bus wiring standards and bus termination rules. A CAN bus uses a twisted pair wire of a single run and two or more devices connect to this using no more than short wiring stubs. Each physical end of the CAN bus is terminated with a 120 ohm resistor (there are never more than two resistors on a bus).
The CAN wires are identified as CAN-high and CAN-low. Each of these wires connects to the corresponding CAN-High or CAN-Low pin on each connected device. The termination resistors are wired between CAN-High and CAN-Low, one on each end of the bus.

For short CAN connections (less than 15 feet) in an MGL system it is also permitted to use a single 100 ohm resistor wired at any location on the CAN bus between CAN-High and CAN-Low.

Applications

The SP-9 is intended for use in the following applications:

- Camera stabilization
- Antenna stabilization
- Attitude and heading reference systems
- Short term autonomous navigation
- Dead reckoning reference systems
- UAV applications (autonomous aerial vehicle)
- Autopilot applications
- Almost anything that requires knowledge of attitude…

It remains the responsibility of the customer buying these sensor packs to ensure that the accuracy is sufficient for his application, and that adequate sensor redundancy is in place.

SP-9 specifications

Specifications published in this section are "typical". Individual variations may result in some of these specifications to be better or worse.

Electrical specifications, where applicable, are with unit stabilized at operating temperature.

Weight

Excluding cables:	126 grams

Electrical and Temperature Characteristics

Input voltage range:	8V to 28V DC regulated preferred for maximum performance. 11-14V is suggested as operating voltage.
Current consumption:	100 mA (heater off) at 13.8VDC input voltage 140 mA (heater on) at 13.8VDC input voltage
Temperature Regulation:	35ºC (internally maintained temperature)
Range of high accuracy:	+0 to +40 degrees C ambient temperature
Normal operating range:	-20 to +60 degrees C ambient temperature
Ultimate temperature range:	-40 to +85 degrees C ambient temperature

Accelerometer Specifications

Accelerometers:	MEMS ORION CLASS +/-10G, High G range sensors +/-16G.
Sensor Limits:	+/- 16G (automatic switchover between sensor ranges)
Maximum G-force loading:	30G (any axis)
Orion measurement error:	<0.1% over 0-10G range
High range:	<1% at 16G

Rate Gyroscope Specifications

Gyro class:	IMU grade gyroscopic system
Rate Gyroscopes:	MEMS. Ring gyroscopic element on pedestal.
Maximum rate :	300º/second
Non-linearity:	<0.033% FS
Cross coupling:	<0.25%
Bias instability:	<15 degrees/hr, all compensation switched off. Static condition. <2 degrees/hr, only bias drift compensation active. Static condition.
G force effect:	<0.001 degrees/second/G
Noise:	<0.1 degrees/s rms
Bandwidth:	85Hz

Attitude calculations

Quaternion system, IEEE Double floating point, normalized.
No attitude angle restrictions in any axis.

Quaternion update rate:	100Hz
Euler angle output rate:	20Hz

Latency at output (CAN bus): 0.001s (from quaternion update to TX).
Yaw angle is synchronized with magnetic heading derived from internal or external SP-6

Magnetic sensors

Sensor type:	Magnetoresistive, three axis
Measurement headroom:	3:1 based on field strength at magnetic equator

Accuracy:	+/-1.5º typical, sensor horizontal, clean field after calibration
Tilt compensation:	Performed in external system based on magnetic measurement and attitude.
Tilt compensation range:	+/-90º pitch +/-180º bank depending on algorithms employed.

Temperature compensation

Ring gyroscope system and Orion accelerometer system are calibrated and compensated for the temperature range from -40 to +85 degrees C.
Accuracy figures are based on this temperature range.
For typical temperature ranges (0 to 40 degrees C) accuracy figures tend to be improved by a factor of three on average. Individual variations on a per sensor bases are very small and not considered a major factor.

A small heater is employed to enhance performance at very low temperatures. This heater is switched off if actual gyro device temperatures reach about 35 degrees C. The gyro devices themselves also have a small amount of self heating.

Please keep the enclosure of the SP-9 closed during operation, do not leave it open as this will interfere with internal temperature regulation.

Fault monitoring and reporting

The SP-9 performs an extensive hardware check on startup and continues monitoring of hardware devices during operation for faults.

Any detected faults are reported via the connected display system (EFIS). This includes hardware faults as well as out of bounds power supply conditions.

MGL display systems updated to their current firmware versions are always compatible with the requirements. In case of third party systems please refer to the supplier.