MGL Avionics
SP-2 Magnetometer
SP-4 AHRS

User and installation manual

About this document

This document describes installation and usage for the SP-2 magnetometer (electronic compass) and SP-4 AHRS (horizon reference system) for connection to MGL Avionics flight instrumentation systems.

Connectivity

These units are designed to be connected to the following MGL Avionics instruments:

AV-1 Smart Single

AV-2 Maxi Single

Ultra H

Ultra HXL

Enigma

Odyssey

Further to this, these units may be used with compatible systems made by third parties. Please consult relevant documentation with your third party system.

Interface

The SP-2 and SP-4 units make use of the MGL Avionics propriety airtalk link which is based on ordinary RCA audio or video cables for ease of installation.
Airtalk is a low speed, low EMI (electrical noise) connection intended to be used with MGL Avionics equipment data links containing modest data rates.
Airtalk is a multi master link allowing several items to share a single connection. In particular, within context of this document, it is often required to share a single airtalk link between both SP-2 and SP-4 to form a full AHRS system.

The SP-2 magnetometer

The SP-2 magnetometer is a three axis, tilt compensated electronic compass system. It outputs magnetic heading information.

Tilt compensation is performed by deriving the attitude of the SP-2 sensor using on-board accelerometers which are used to vector the direction of gravity. The magnetic field is measured using three magnetometers which are mounted perpendicular to each other resulting in three magnetic force vectors.
Using three magnetic force vectors and knowledge of attitude allows calculation of magnetic heading even if the SP-2 is not mounted exactly horizontal.

There are limitations to this method. During turns the accelerometers will give incorrect indications due to centrifugal forces acting on the SP-2. This will result in incorrect heading readouts during the turn. However, compared to an ordinary mechanical compass, the heading is still usable as it tends to show heading changes in the correct manner (even if heading if not 100% correct) and will allow you to fall out of the turn on the intended heading. The moment you are flying straight, the heading is instantly correct. This is in contrast to a normal mechanical compass which tends to over or under swing and may need considerable settling time.

As alternative, if you have a SP-4 AHRS connected to the same airtalk link as the SP-2, you can set the SP-2 to "gyro mode" for attitude data. This would be done in your connected instrument as part of the compass mode setup. MGL equipment refers to this as 3DG mode (3D gyro vs 3D accelerometer mode as 3DA).

If your SP-2 is set to gyro mode and horizon data is being received, your SP-2 will use the gyro derived horizon rather than the built in accelerometers for tilt compensation. In this case, heading is correct even during turns. Be aware that in this mode, should your horizon be incorrect due to exceeding maximum rate of turns or prolonged maneuvering, your heading will be incorrect too.

We recommend that for normal aircraft operations you leave the SP-2 in normal accelerometer mode (3DA). In this case the SP-2 heading can be used even if the horizon is unreliable. With many aircraft, attitude can be maintained by relying on compass heading and slip indication if no valid horizon information is available.

SP-2 Installation

The most critical decision to make before installing your SP-2 is to decide on a good location inside your aircraft. Many aircraft, in particular those based on steel structures very significant magnetic deviation is present in many locations. Such locations are unsuitable.

We recommend that you do a basic survey using a small hand held hiking compass inside your aircraft to help locate areas of high deviation. 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 10 degrees 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 20 degrees or larger, you have little chance of calibrating out this error. Rather find a better location.

In extreme cases, consider locating the SP-2 outside the fuselage, perhaps in a wing tip.

When attempting to find a suitable location for your SP-2, 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).

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 ferro metallic fasteners such as nuts and bolts.

Be suspicious of stainless steel – 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.

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-2 (once it is connected and operating) and observe the effect on your heading. You may be surprised !

The SP-2 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.

The SP-2 is normally connected to a 12V or 24V DC power system. Power consumption is modest at less than 50mA. Power supplies must be protected from transient events that raise voltage levels above 35V (these events can be caused by solenoids and starter motors and other electrical gear). Exceeding a voltage of 35V positive or 100V negative will destroy the SP-2.

Mounting the SP-2

Mount the SP-2 in a position that is not affected by ferro magnetic metals including nuts and bolts. Mount the SP-2 using plastic, brass or aluminum fasteners. As alternative, consider industrial quick release fasteners such as self-adhesive Velcro or similar systems.

Try and mount the SP-2 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 60 degrees pitch and bank but additional errors can still be introduced. These however are very negligible if only small amounts of tilt are present.

SP-2 deviation compensation

It is normal to have small amounts of deviation in an aircraft compass installation. Deviation is caused by nearby hard or soft iron and other effects.

With a traditional mechanical compass small magnets are placed or rotated in close proximity to the compass to correct for most of the deviation. It is quite possible to do the same with an electronic compass but there is another way. Objects causing deviation tend to modify the strength of the magnetic field in their proximity. This can be used to help compensate for the deviation in many cases.

Consult your display device's manual on how to enter and leave deviation compensation mode.

Warning: Only proceed with deviation compensation if your deviation is relatively small (perhaps a maximum of 10 degrees). Large deviation can seldom be corrected significantly this way – your only option is to either remove the offending source (such as a iron bolt perhaps) or to find a better location for your SP-2.

Deviation compensation consists of entering deviation compensation mode and rotating your aircraft through at least one full 360 turn on the ground. The SP-2 must during this procedure remain horizontal to the Earths surface. If you have a tail dragger, lift the tail while you perform this maneuver.

Once the turn is completed you need to end the deviation compensation procedure. It is also possible to clear any deviation compensation and return the unit to factory calibration.

Note: Be aware that many concrete reinforced aircraft aprons or runways may contain significant amounts of iron which may make it impossible to perform any meaningful deviation compensation on these surfaces. Also, do not attempt to calibrate your compass inside a hanger that contains significant amounts of iron based metals as part of the construction.

SP-2 alignment

Your SP-2 includes a second method to calibrate directly to the four major cardinal headings North, South, West and East. Consult your display instruments manual for details on how to use this function.

The procedure requires that you have exact transits to the cardinal headings that you can use as reference. Note that you need magnetic headings. Use a small survey or good hiking compass to find suitable transits.

This calibration is intended to be performed after normal deviation compensation to eliminate remaining deviation or to be used on its own if you only need to correct for very small deviation and the normal procedure does not fully compensate for any errors.

Align your aircraft with the cardinal heading you wish to calibrate and select the heading to calibrate (view your display instruments manual on how to do this).

This method works well if small deviations need to a compensated for (less than 10 degrees)

and the normal method will not work due to the characteristic of the magnetic field at the SP-2 location.

The SP-2 will create a smooth interpolation between the four calibration headings.

SP-2 general discussion

The SP-2 is based on Honeywell magetoresistive sensors. These sensors are very sensitive to magnetic fields and are able to measure tiny field variations. However, the sensors also have large undesired error components caused by temperature and aging.

The design of the SP-2 uses techniques developed at MGL Avionics to cancel out most error components allowing accuracies of up to 1 degree to be obtained and maintained by continuously monitoring and correcting sensor performance. These are techniques developed over the last three generations of compass systems designed by MGL Avionics. The SP-2 being our forth generation system.

As a result the SP-2 maintains excellent temperature performance even over an unusually wide range of temperatures.

All analog signal processing is done using laboratory grade instrumentation amplifiers coupled to a 16 bit data acquisition system to allow unprecedented resolution and accuracy during measurement of the small sensor output signals.

SP-2 specifications

Weight: 40 grams (+ standard connector cable 25 grams)

Power supply: 7.5V-28V DC, 50mA. Reverse polarity protection.

Magnetic sensors: Magnetoresistive, three axis

Measurement headroom: 3:1 based on field strength at magnetic equator

Accuracy: 1 degree typical, sensor horizontal, no external deviation (clean field performance)

Tilt compensation: Accelerometers or external gyro derived horizon data feed

Tilt compensation range: +/-60 degrees with accelerometers, +/-90 degrees depending on external horizon data.

Tilt compensation maximum error component at 60 degrees pitch or bank, any heading: 5 degrees.
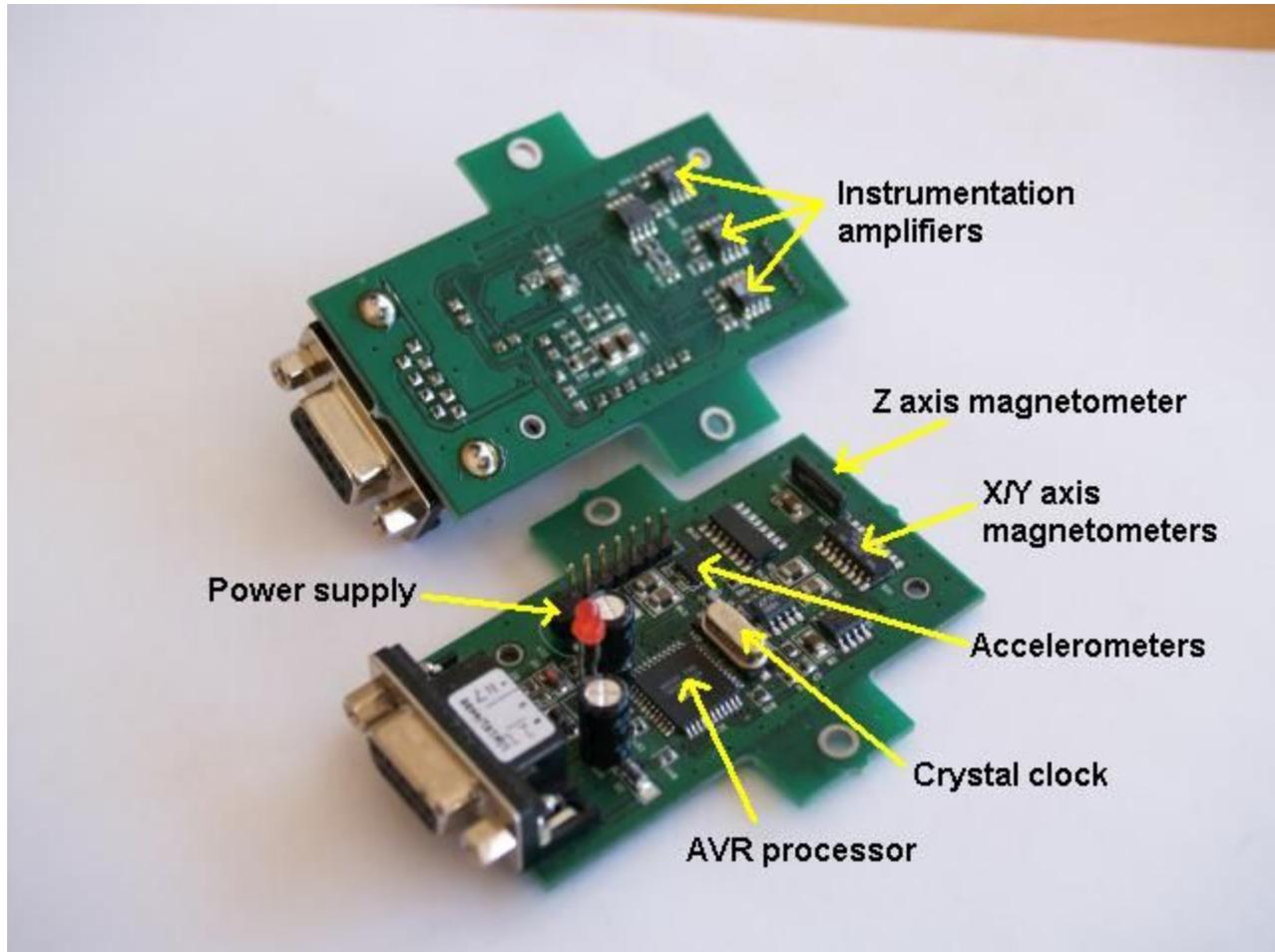
SP-2 basic operating modes: 2D (two axis), 3D accelerometer, 3D gyro.

Maximum permissible G-force loading (any axis): 30 G.

Interface: MGL Avionics airtalk compatible.

Inside the SP-2

The SP-2 is based on a two layer double sided component PCB using mostly SMD components.

SP-4 AHRS

The SP-4 AHRS is MGL Avionics's fourth generation AHRS system. It is also the smallest and lightest, yet it packs an incredible system:

3 Analog Devices MEMS gyros, three Analog Devices high performance MEMS accelerometers, a high performance Linear Technologies 16 bit data acquisition system and a powerful ARM7 32 bit microprocessor system.

SP-4 AHRS explained

Before you proceed with installation of your SP-4 system, it is wise to study how the SP-4 AHRS works so you can understand how to perform the installation for maximum possible performance of the system.

While the SP-4 is much cheaper than a traditional AHRS system as installed in military aircraft or airliners, the very same principles of operation are used and the same restrictions and limitations are present. More than with any other system in your aircraft, the performance of the AHRS is directly related to the quality and correctness of your installation.

The SP-4 is a "strapdown AHRS", a term used for a system that is not based on the traditional spinning body gyroscope (vacuum or electric gyro) but rather uses three separate gyroscopic devices to measure rotation rates around each of the three major axis. This is combined with three accelerometers that measure linear acceleration in the same three axis.

So how does it work ?

The gyros cannot know where the Earth surface is in relation to your aircrafts attitude. The accelerometers can do this – but only if your aircraft is not accelerating, deceleration or changing direction of flight. In principle, the accelerometers can give us the information we need if you average them over a long time (much longer than your average maneuver, like a turn would take). But of course that would give you a very slow result that is all but unusable. Enter the gyros – using a sophisticated piece of mathematics, it is possible to work out using turn rates around three axis how the horizon (that we know from the accelerometers) is changing in the short term. Unfortunately, while the gyros are very good at giving a good result following through a few maneuvers, accumulated measurement errors will eventually

cause the calculated horizon to drift out of true. The interesting part is that this applies to any and all strapdown systems, regardless of how expensive the gyros are – it may just take a little longer until the errors become a problem.

So how does this affect us ? The system will work fine if we allow the accelerometers opportunity to correct any error that has accumulated during a maneuver that relied on only the gyros to calculate the movement of the horizon relative to your aircraft.

In practice, with careful and clever design of the software in your AHRS, your AHRS will work fine for normal flight which would normally consist of much straight and level inter spaced with relatively short maneuvers (such as a turn). During the straight and level parts of the flight, the information from the accelerometers is dominant in determining your attitude while during any maneuver (or turbulence induced rotations) the gyros become dominant.

Should you be flying a continuous maneuver without ever giving the AHRS a change to re vector Earths gravity, your horizon will eventually drift out.

Just how long this takes is dependent on two factors: The quality of the system as a whole (including the expensive gyros) AND the quality of your installation.

SP-4 installation

The AHRS must be rigidly fixed to your airframe (i.e. It must not move relative to your airframe).

The AHRS must be aligned correctly with 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 corrupt the horizon due to additional calculations and hence additional, small errors.

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 you to mount the SP-4 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-4 contains an internal heating element that will try and maintain a constant internal temperature of about 35 degrees C 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 distance from the center of rotation will cause the accelerometers to read incorrect information. For example: Consider that you have installed the SP-4 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. Undue 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.

SP-4 mounting

The SP-4 can be mounted by means of the two rubber isolated flanges using metric 3mm or equivalent fasteners.

Alternatively, industrial quick release fasteners such as self adhesive Velcro strips can prove to be an easy option.

Should mounting require vibration absorption, a suggested technique would require the SP-4 to be mounted on a heavy base plate (consider lead or other heavy material). This base plate would then be mounted onto a soft rubber sheet of sufficient thickness. In turn the rubber sheet would then be mounted to a suitable surface on the aircraft.

The consistency of the rubber sheet must be chosen such that the SP-4 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-4.

Good location, close to center of rotation

Center of rotation

Acceptable locations

Bad alignment

Bad location, too far from center of rotation

SP-4 operational options

Your SP-4 ships with internal filters set to default states which is likely all you need. These filters have been designed to optimize performance for the average aircraft and installation.

What is a filter ?

A filter in this context is a software algorithm that takes various factors like time and sensor signals and processes these depending on some criteria. Your SP-4 contains many such filters.

Why should you change a filter setting ?

Not all aircraft are created equal and not all installations are created equal. It is possible that higher performance can be achieved if you have a very good installation (no vibration, aircraft with smooth flight in turbulence etc). In a case like this it may be better to reduce the dominance of the accelerometers and favor the gyros. The reverse may also be true – consider a helicopter that is badly affected by rotor introduced vibrations that cannot be isolated from the AHRS – in a case like this, it may be better to favor the accelerometers.

The bump filter

Your SP-4 ships with this filter set to "medium".

Select "lower" or "lowest" to favor the gyros, "higher" or "highest" to favor the accelerometers.

You will notice, the higher the filter setting, the faster the horizon will correct to the accelerometer derived horizon after an upset (such as exceeding maximum rate of turn).

Consult your display units documentation for instructions on how to change this filter setting. Note: Not all display units may include this function.

The slew filter

Your SP-4 will use velocity of your aircraft in order to optimize some algorithms in order to be able to better judge some of the sensor data.

Velocity information may be derived from airspeed (true airspeed is required) or from a GPS receiver. Instruments that provide this information to the SP-4 currently include the Stratomaster Ultra HXL, Enigma and Odyssey.

The slew filter is used if external velocity information is not available. In this case the algorithms operate in a reduced velocity compensation mode in very defined situations only. You use the slew filter to effectively tell the AHRS the speed that you will be flying most likely (normally your cruise speed).

Lowest – 50 mph

Lower – 70 mph

medium – 100 mph

higher -150 mph

highest – 200 mph and higher

Select the value that describes your normal operating speed (true airspeed) best.

Consult your display units documentation for instructions on how to change this filter setting.

SP-4 general operation

The SP-4 would normally be switched on with the aircraft stationary. It quickly finds and stabilizes current gyro bias and sets the horizon from the information measured by the accelerometers. This process typically takes up to 15 seconds. If Bump filter settings are set very low, it can take a bit longer for the horizon to track correctly.

Maximum accuracy is achieved a few minutes after startup if at a relatively cold ambient temperature, less time is needed if you are operating on a warm summer day. The SP-4 contains a built in heater element to speed up heating to operational needs (35 degrees 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 24V DC.

Should power be cycled in flight, the SP-4 will track the horizon very quickly after startup if the aircraft is held in non-accelerated flight (such as straight and level).

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 360 degrees). As you turn out straight, the horizon should be instantly correct. If not, check your installation – something is upsetting the SP-4.

SP-4 for blind flight operations (IFR flights)

The SP-4 is not intended, certified or rated for professional level IFR usage. The SP-4 is to be used as VFR reference only.

Should you find yourself in a position where you are forced to use the SP-4 as reference without any other available option proceed as follows:

Place the aircraft in straight and level flight at a speed that results in best overall stability. Usually this is less than the rated cruise speed and below maneuvering speed.

Check your compass heading if you have an electronic compass such as the SP-2. You will be using the compass heading as backup to the horizon. Check your slip indicator (you should have a slip indicator display derived from the accelerometers in your SP-4). You will be using the slip indicator as backup as well.

Ensure that you are in a stable flight with the ball centered and on the desired heading. Crosscheck your position with GPS. You need to know exactly where you are and where you are going.

You need to ascertain that you will regain VFR flight conditions before hitting the ground !

When you descend into the cloud your sole aim is to maintain heading, wings level and ball centered. Check your VSI to ensure that you descend at the required rate. Only use engine power to control your descent. Crosscheck your airspeed with your pitch attitude. Watch your rate of turn indicator (if you have one). You don't want to turn.

Do not maneuver. Your most reliable instruments are the slip indicator, compass (if SP-2) and airspeed. Your horizon is secondary at this stage.

Remain in this attitude until you break free of cloud.

Note: This procedure is very dangerous and should never be attempted without training. Be aware that you may encounter severe turbulence inside the cloud that you will not be able to counter and that may render your horizon information invalid due to drift or exceeding of maximum rate of turns that the AHRS can measure. In this case your only options are related to using the SP-2 heading with help of airspeed and slip indicator. Even so, recovery from unusual attitudes using these indicators may be impossible.

Depending on the natural stability of your aircraft, it may be best to allow the aircraft to regain normal flight regime: Stick neutral to slightly forward, engine power low, rudder center and wait...

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, the predecessor of your SP-4.
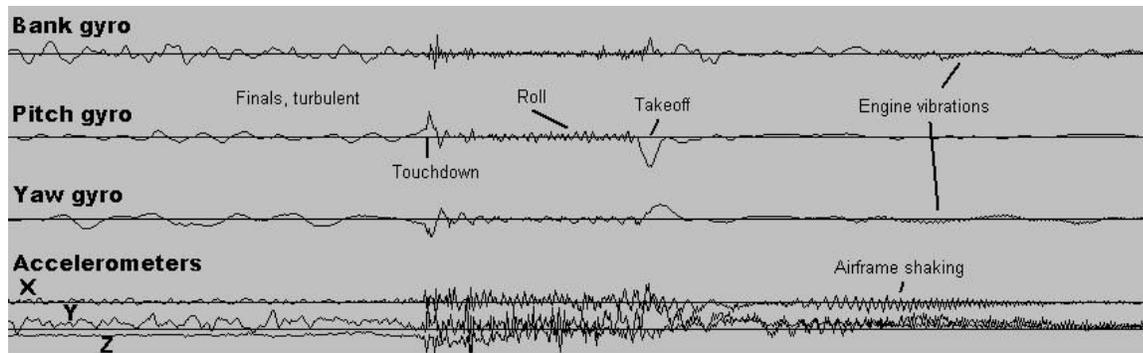
The SP-3 was installed on a ultralight aircraft, no provision was made to dampen any engine or airframe vibrations. The SP-3 was simply taped to one of the airframe members. The resulting horizon display was correct thoughout the flight. This serves to give an indication of the abilities of the SP-3 firmware.
The data obtained during this flight was made available by the SP-3 set to mode four data output (Raw data, 40 samples per second).

Interpreting this data, you can observe large inputs from the three gyros during finals. The very light aircraft was exposed to significant turbulence until the point of touchdown. Also interesting are the large pitch accelerations (Y axis) during this phase of flight. Accelerations in the X axis (roll) and Z axis (yaw) where relatively small.
The landing was performed on a concrete runway that is quite smooth. Nevertheless it is apparent that large accelerations are present during the landing roll and subsequent take-off. The aircraft did not have benefit of any form of shock absorbers. The gyros are also outputting rate of turn information during this phase suggesting a relatively rough runway. The point of take-off is easy to recognize, a large pitch rate of turn signals the exact point of rotation.
climb out thereafter is relatively smooth with only minor bank input from the pilot. Notice however the large vibration amplitudes recorded by the accelerometers. These are typical effects of airframe shaking and the engine running at full power.
Interesting is also the yaw output directly at take-off. The aircraft did in fact yaw as the wheels left the ground due to a cross-wind.

SP-4 specifications

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

Weight: 45 grams (+ standard connector cable 25 grams)

Power supply

Input voltage range: 7.5V to 24V DC regulated preferred for maximum performance. 12V is suggested operating voltage.
Current consumption:
Heater off: 40mA
Heater on: 80mA at 12VDC input voltage.
Internal, maintained temperature: 35 degrees C.

Sensor technology:
Gyros: MEMS
Accelerometers: MEMS
Mechanical alignment error total: <1 degree.

Gyro specifications:
Maximum rate of turn around any axis: 170 degrees/second typical.
Bandwidth: 10Hz
Drift short term: <1 degree/Minute. Condition: Error correction off, temperature stable, no movement.
Drift long term <15 degrees/30 Minutes, same conditions as above.
Random noise performance: <0.1 degrees/Second typical.
Drift specifications are obtained using built in bias tracking code, this data can be verified by the user if optional Windows based interface program is used.
Nonlinearity: better than 1% FS, best fit.

Accelerometer specifications:
+/- 6G, any axis.
Temperature drift: <0.02 G/degree C.
Linearity: Better than 1% FS, best fit.

Analog to digital conversion:
16 bit, all signals.
Gyro raw sample rate: ~2500/second (each gyro).
Gyro oversample rate: 64.
Accelerometer raw sample rate: ~300/second (each axis).
Accelerometer oversample rate: 8.

Attitude calculations:
Quaternion system, IEEE Single floating point, normalized.
No attitude angle restrictions in any axis.
Quaternion update rate: 40/Second.
Euler angle extraction rate: 10/Second.

Latency, normal output message:
50 mS average.

Latency, raw data output message:
12 mS average.

SP-4 output data

Consult the SP-4 OEM manual for message formats and message type selection.

Available data (depending on message chosen):

Stabilized horizon as Euler angles: bank, pitch and yaw.

Rate of turn relative to horizon

Quaternion data

Total G-Force (G-Force irrespective of direction of force)

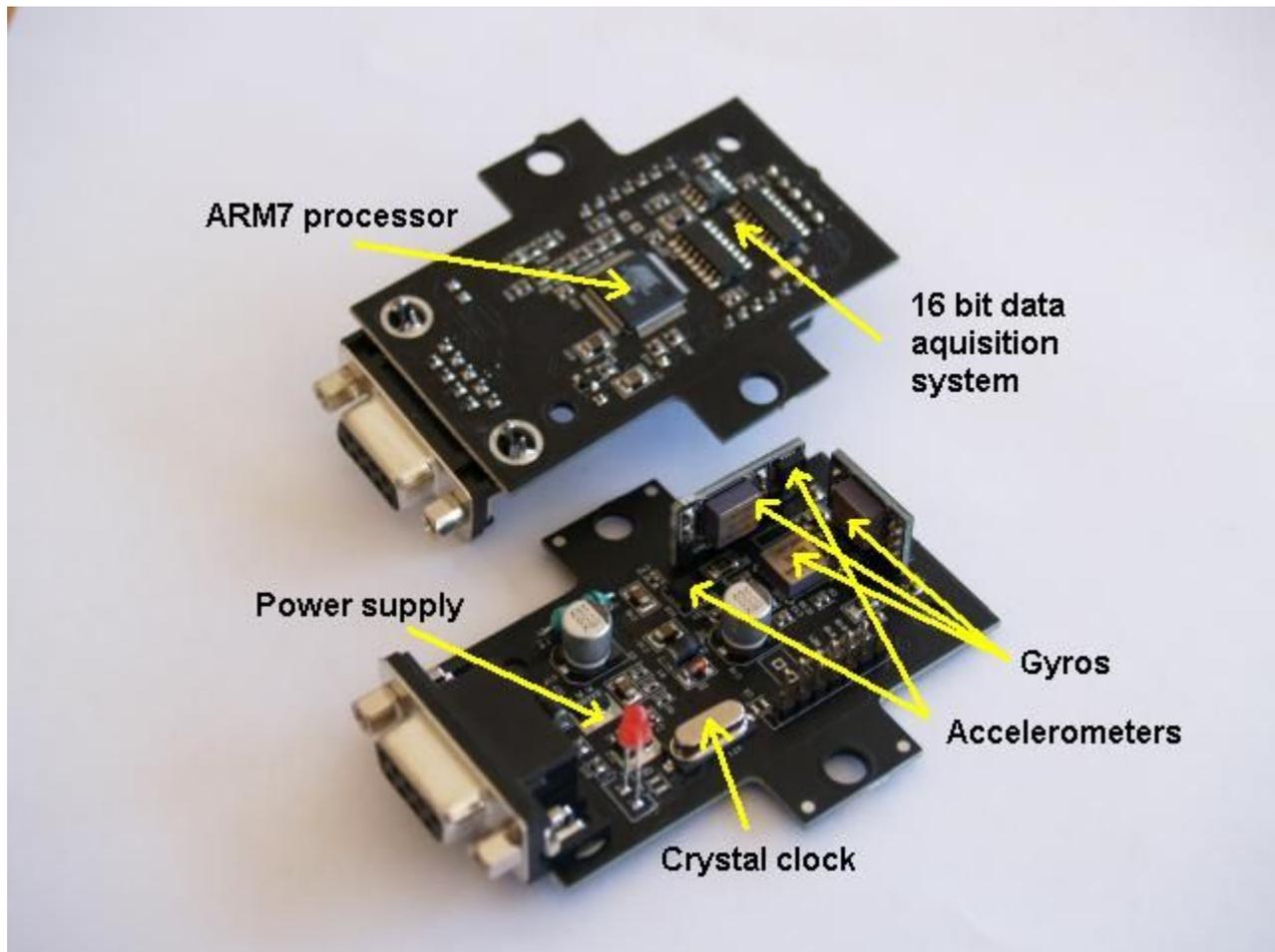Internal temperature

Operating voltage

Mode/operation information

Raw gyro and accelerometer data

Calibration data (data stream containing various information used during sensor calibration at factory).

Inside the SP-4

The SP-4 is based on a high tech six layer PCB with double sided SMD components.

Electrical connections for SP-2 and SP-4

The above image shows the principle components required to connect the SP-2 or SP-4.

The Cannon D-9 connector (with gray shell in this picture) provides a black and red wire as well as a female RCA connector.

The RCA connector connects to the RCA female airtalk connector on your display unit using a standard RCA to RCA audio or video cable. These cables can be obtained at low cost from a variety of outlets and super markets.

We recommend to use relatively good quality cables as we find that some cheap makes may provide intermittent contact or may disconnect easily.

Slightly bend the male connector shields towards the inner conductor to ensure a tight fit. Secure with a heat shrink sleeve or self-adhesive tape.

Power is supplied via the red and black cable. Connect the red cable to your 12V DC source positive (+12V). The black cable does not need connecting as the negative supply connection will be made through the RCA cable to the negative supply of the instrument. The black cable is only needed should the SP-2 or SP-4 be connected to a PC or third party instrument. In this case the black cable should be connected to ground or the power supply negative. If you do not need to connect the black cable, wind it in a tight loop and isolate it using electrical tape.

If you own both a SP-2 and SP-4 you can connect both RCA connectors to a single RCA cable using commonly available RCA splitters. You need to get a splitter that provides two male RCA and one female RCA connector.

Alternatively, you can cut off the female RCA connectors on the SP-2 and SP-4 leaving you with bare wires, red and green in color.

Take a RCA cable of sufficient length and cut off one of the connectors. Connect the two red wires (the two red wires that used to go to the RCA connectors) to the inner conductor of the RCA cable. Connect the two green cables to the outer conductor of the RCA cable. Isolate the two conductors using electrical tape or heat shrink sleeving so they will not short to anything.

On the larger instruments from MGL Avionics, two female RCA airtalk connectors are provided. You can use them both with one RCA cable to each SP-2 and SP-4 or you can use a single cable as described above.

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-2 and SP-4 are 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.

The SP-2 and SP-4 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.