Stratomaster Maxi Single

AV2 airtalk link computer

Application A/C-3

The AV-2 is a 3.5" format instrument. It is intended for connection to an airtalk data link. A downloadable application program determines the functionality of this instrument.

This document describes the application A/C-3. This application is intended to provide an interface to the MGL Avionics compass and gyroscopic sensor packages SP-2, SP-3h and SP-3hc.

The A/C-3 application provides one of four user selectable operating modes:

a) Compass with four different types of display (requires SP-2 or SP-3hc)
b) Horizon with or without slip indicator (requires SP-3h or SP-3hc)
c) Turn and Bank indicator (requires SP-3h or SP-3hc)
d) Combined compass and horizon display with bank indicator and optional slip indicator (requires SP-3hc)

General

This document describes installation of the following systems:

AV-2 with SP-3h	Artificial horizon
AV-2 with SP-2	Advanced digital compass
AV-2 with SP-3hc	Artificial horizon and advanced digital compass “combo”
AV-2 with SP-3h and SP-2	Artificial horizon and advanced digital compass

Please be aware that it is possible to connect more that one AV-2 system to the sensor packages for example you may want to separate the compass and horizon.
You can also mix displays with AV-1 units (these are 2.25” displays). For example you may want a 3.5” horizon but a 2.25” compass.

The Stratomaster AV-2 unit is based on a passive viewing system intended for data available on an airtalk link, a simple to use local area data network for sharing of data between instruments on an aircraft.
The AV-2 unit is a 3.5” instrument. It is passive as it does not itself contain any sensors. The duty of the A/C-3 application program is to display data as selected by the pilot of the aircraft. The A/C-3 application fulfills the requirements of either Artificial horizon, Turn and Bank display or the advanced compass system.

The SP sensor package is available in four versions:
SP-1: Two axis compass.
SP-3h: Artificial horizon / Turn and Bank
SP-2: Advanced compass
SP-3hc: Both artificial horizon/Turn and Bank and advanced compass in one unit (also referred to as a “combo”).

The artificial horizon (attitude indicator).

The SP-3h and SP-3hc units implement a “strapdown” AHRS or inertial attitude system. This system is fundamentally different from the common vacuum or electrical gyro based artificial horizons found in most aircraft today.
With a strapdown system there are no moving parts and electronic versions of the old fashioned “spinning top” gyros move with the aircraft. With the older gyro systems the gyro itself would remain aligned with the earth while the aircraft effectively revolved around the gyro.
Strapdown AHRS systems are very complicated and require high levels of sensor integrity, excellent electronic hardware and fast computers to handle the high rate of mathematical calculations required to determine the position of the horizon.
Strapdown AHRS systems are attitude “estimators”. The combined outputs of rate integrating gyroscopes (three of them at right angles to each other) are used to arrive at a calculated attitude. Systems like this do not know what the actual attitude is, they only know how the attitude changes. In order to provide a useful attitude display, the calculated attitude is corrected by means of a “gravity direction” detector. For this three accelerometers at right angles aligned in the X-Y-Z axis are used.
In principle, the calculated gyro attitude is “drifted” towards the attitude as calculated from the accelerometers. However, this is greatly qualified by evaluating the current dynamics of the rate sensors to determine if the accelerometer readings can be considered reliable. For example, should you be flying a balanced turn, the readings from the accelerometer will be wrong. The accelerometer can only be trusted if you are flying straight and level.

Until very recently, no affordable electronic sensors existed that could be used to determine the rate of turn around an axis, three of which are required to make an electronic AHRS. Systems like these remained the domain of the military that could afford the use of expensive laser gyro systems. Systems like these have been the cornerstone of precision navigation systems in aircraft and submarines.

Resonating, coriolis effect sensors became available in the early 90's. These were used in camera stabilizers and later in upmarket automotive applications such as skid sensors and roll detection.
These early sensors where not good enough to be used in an artificial horizon system. However, development has not stopped and we have reached a point where more sophisticated sensors have become available. While sadly still far from the excellent qualities of a laser gyro, they can nevertheless be used with some clever design and special attention to limitations and error corrections.

Righting of the calculated horizon is done by means of a dual axis accelerometer. This device is used to correct any errors that may have accumulated by maneuvering of the aircraft whenever conditions suggest that the accelerometer readings are reliable.

The SP-3 sensor package implements a true standalone AHRS, able to function independently of an airdata computer system or GPS. It also does not require a magnetometer system, although such is provided in the SP-3hc.

The system in the SP-3 units is based on three dual resonator gyro chips which are very resistant against effects of acceleration forces and vibration, a big problem with nearly all other available coriolis force sensors. Regardless of this, installation of any AHRS system in an aircraft must be done with great care so that maximum isolation exists from acceleration effects not related to roll, pitch or yaw. It should also be noted that vibration itself is a form of movement that can be detected by the AHRS and this can lead to false measurements.
In particular, it is very important to isolate the AHRS from engine vibrations as it will react to vibrations that are of a frequency close to the operating frequency of the gyros.
In the case of the SP-3 system, this frequency is 14Khz. While engines tend to produce frequencies much lower than this, smaller harmonics may be produced at certain revolutions that fall into this frequency range. More on this subject in the installation section of this manual.

A/C-3 Features and functions in Horizon or Bank & Turn mode

The horizon mode features the following additional functions over and above the normal horizon display:

Slip indictor.

A "step on the ball" slip indicator can be enabled to appear below the horizon display. The source of information for this indicator is derived from the accelerometer aligned with the pitch axis of the aircraft, i.e. the acceleration forces acting in the direction of the wings.

Pitch leveler function.

Should your aircraft fly "nose up" or "nose down" due to trim, you can level the pitch as displayed on the horizon at the touch of a button.

Fast righting function.

This function is used should the horizon display be toppled (i.e. indicating incorrectly by a large amount) due to excessive maneuvering, exceeding maximum rates of turn, yaw or bank or rapid and large temperature changes that exceed the internal compensation rate.
A one touch function is available that indicates to the instrument that you are flying straight and level and that gravity tracking may be accelerated to ensure rapid realignment of the horizon.

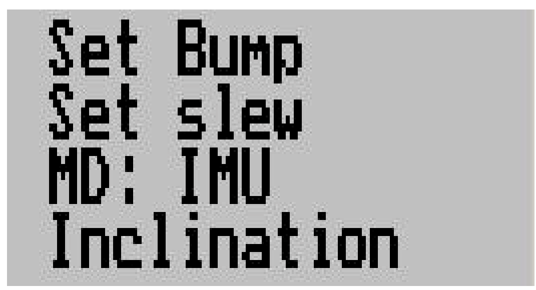
Extended range of operation.

Bank operates over a full 360 degree range allowing limited use of the horizon for aerobatics, providing maximum published roll, pitch and yaw rates are not exceeded. Maximum rates under normal operation are approximately 165 degrees per second, valid for all three axis simultaneously. Depending on conditions maximum rates may reach 180 degrees/second.
No caging of the electronic gyro system is required during excessive maneuvering or aerobatics, unlike systems based on mechanical gyros. Simply right the horizon when you are done or let the horizon right itself which will happen during straight and level flight.

The A/C-3 menu system in Horizon or Bank & Turn Mode

Press the Menu key to enter the menu. The Menu key is the left-most button. You can move forward and backwards in the menu by using the + and – keys. To change or select a menu item, move the highlight to the desired item and then press the Select key. To end an edit or function, press the Menu key again.

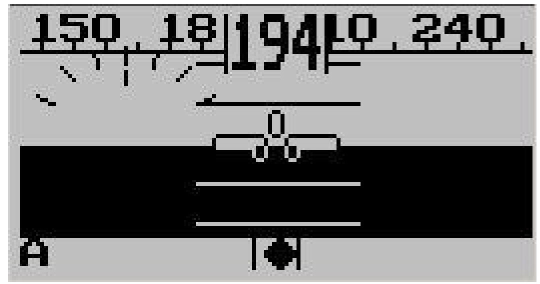
To exit the menu and continue normal operation, press the Menu button again.



Mode …

This function allows you to select operation of the A/C-3 as artificial horizon, Turn and bank or compass or a combined horizon and compass. The menu system will change according to your selection.
Note: if you have purchased the SP-3hc sensor package with two or three AV-1 or AV-2 displays, it is possible to setup either of the AV units to display either the artificial horizon, Turn and bank or the compass. This allows you to use any combination of horizon, turn and bank or compass displays.
You can connect further AV-1 or AV-2 units should you require this for a dual cockpit layout. Up to six AV units can be configured to give you 2 x Horizon, 2 x Turn and bank as well as 2 x Compass.

Slip Yes/No



Select if you would like to enable a slip indicator to be shown underneath the horizon display. The slip indicator operates in the same fashion as the well known “step on the ball” indicator in traditional cockpits.

Note: In Bank and turn mode the slip indicator is always enabled, regardless of this setting.

Contrast …

This function allows you to change the display contrast to your liking. You can select values from about 20 to 45. (can vary depending on display type).

Backlight …

This function allows you to switch the display backlight on or off.

Set Bump

This function allows you to select a fudge factor used in the operation of the system. In particular, this selection affects at which point the system changes from accelerometer mode to gyro mode.
Smaller aircraft or turbulent conditions may benefit from a larger factor while larger aircraft or calm conditions benefit from a smaller factor.
As a guideline, when flying straight and level in relatively turbulent conditions (bumpy conditions), you should see that the system is switching to accelerometer mode frequently. If the system spends most of its time in gyro mode with little opportunity for the accelerometer to correct for errors, then the displayed horizon will start to show an incorrect horizon. In such a case you should select a larger bump factor.
A good selection is when you can verify that the horizon remains reliable while the system remains at least 50% of its time in accelerometer mode (straight and level flying only).

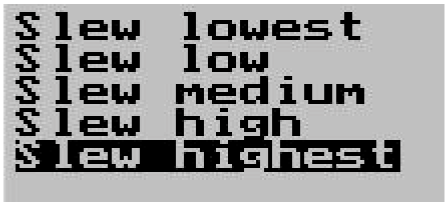
We suggest that you start with a setting of “medium”.

Once you have found a suitable setting for your aircraft, you will probably not change it again.

Please note, as you enter this function, the display does not show the current setting as this is contained in the SP-3 unit. Choose a setting using the + and – keys and then press the Menu/Select key to send the new setting to the SP-3 unit.
This setting can be changed in flight at any time.

Set Slew factor

This function presents you with a small menu. You can send one of five settings to your SP-3. This function will only work if you have a SP-3 connected. The setting is stored in the SP-3, the highlighted entry that is shown is NOT the setting in the SP-3, only the setting that you want to send to the SP-3. The SP-3 stores the setting in permanent memory, the setting is not lost if you remove power from the unit.



Like the “Bump” filter, the “Slew” filter also has five settings:
Lowest, Low, Medium, High, Highest.

This filter setting affects the speed at which error corrections take place. Good settings are usually Low or medium.

This filter setting interacts somewhat with the Bump setting. Should you find your installation tends to accumulate errors quickly (for example you may have unavoidable vibration affecting the sensors), set the error correction speed higher.
Do not set the error correction speed unnecessarily high as this may degrade your systems ability to correctly detect very slow entries to banks.

Finding the right filter values

Once good filter values are found, they are rarely if ever changed.
Good filter value selection will result in the system remaining in accelerometer mode (indicated on your screen) for most of the time during straight and level flight.
Slow entries into banks are the most critical factor, so try these in calm conditions. Bump factor too high or Slew factor too high (or both too high) may result in bad detection of this maneuver.
Select the Slew factor such that any errors that have accumulated during a full 360 turn at 30 degrees of bank are corrected quickly after you roll out straight and level.

MD …

Here you can select the type of attitude calculations you want to use.
The choice is between “IMU” and “Mattitude”. The display shown indicates the current mode of operation if you have the SP-3 connected.
Please read the documentation on the SP-3 for detail of which mode you should choose.
“Mattitude” is an experimental system at this point in time, “IMU” is the normal way a strapdown artificial horizon works.
“Mattitude” will not work correctly if your aircraft has a significant effect on the direction and strength of the measured Earth magnetic field.
Please note that before you can use this mode, you have to set the magnetic inclination at your location (described below).

Attitude determination modes

The SP-3hc unit provides the user with a choice of two different modes to obtain aircraft attitude (bank and pitch).

IMU attitude determination

This mode is the traditional IMU consisting of three gyros and three accelerometers. Gyros provide rate of turn information while the accelerometers are used to vector gravity in order to compensate for gyro drift and also to set the initial orientation of the quaternion.

Magnetometer based attitude determination

→ lease note: The "Mattitude" system is experimental and has been included for experimentation purposes only.

This method uses the magnetic vector direction in three dimensions to obtain a relative attitude that can be used as bases for determining attitude relative to the earth surface.
The SP-3hc will automatically obtain the magnetic inclination (dip angle) regardless of its own tilt relative to the earths surface. This measurement needs to be done very accurately. The SP-3 will perform this measurement about once every 10 seconds provided the aircraft is providing a stable enough platform. (benign flight conditions).
The magnetic inclination does not change by a large amount over a large distance, however small local variations of the inclination angle do occur in some locations and it is these variations that the SP-3hc will attempt to track.
The SP-3hc provides a function that allows the user to set the default magnetic inclination. This functions needs to be used at least once and may have to be repeated should the SP-3hc be operated in an area with a different magnetic inclination.
No knowledge of the inclination angle is required by the user during this process as the SP-3hc is capable of measuring this angle.

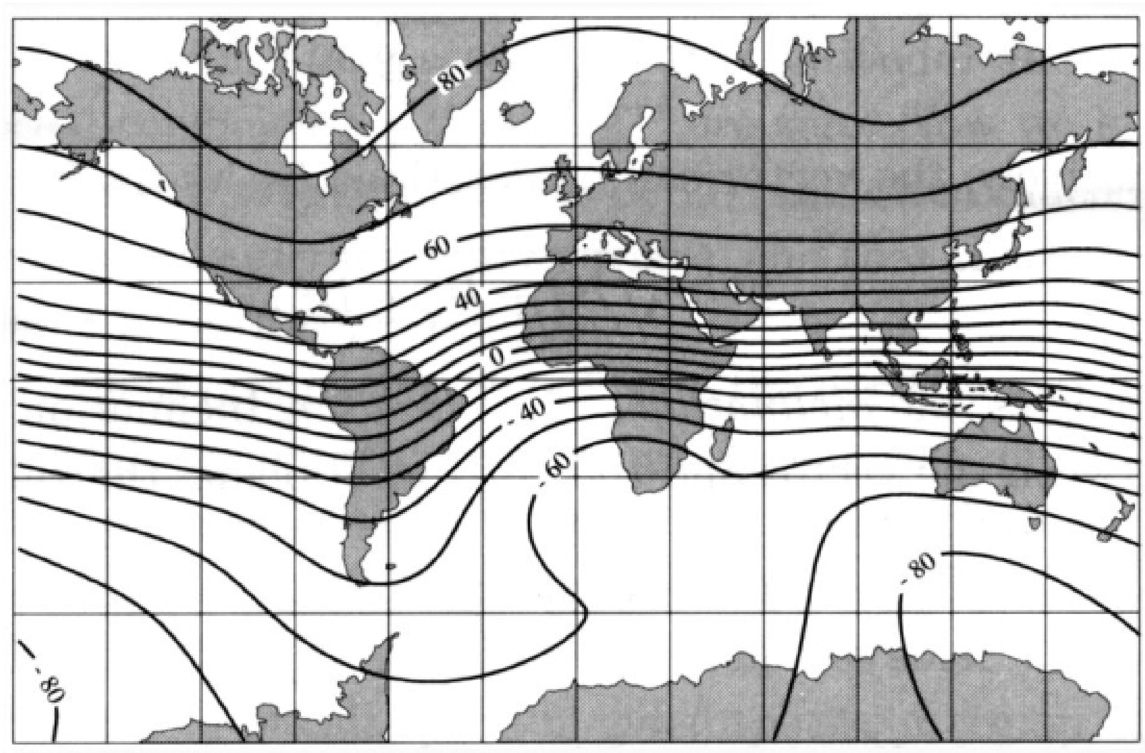
Set inclination

Use this function to set the magnetic inclination at your location. The aircraft has to be steady and stationary. Ensure that you have moved away from metallic structures such as aircraft hangers or reinforced concrete aprons.
Selecting this function will return the angle of inclination (zero degrees is straight up/down, as you would get at the magnetic poles). The SP-3hc needs to be connected for this.

The inclination is only needed if you want to use the "Mattitude" mode. Should you move to an area with a different angle of inclination, you should repeat the procedure.

Note: Set the inclination only after you have performed the deviation compensation.

Compare the angle derived with what it should be, should you not get an acceptable result, you may have to relocate the SP-3 as it is measuring a magnetic field with significant deviation, probably due to metal effect of your aircraft.



Map of the Earth showing isobar lines of magnetic inclination.

The advanced compass

The SP-2 and SP-3hc contain a three axis precision magnetometer.
The sensor package is divorced from the actual display unit. This allows the placement of the sensor package in a location inside the aircraft that is relatively undisturbed by magnetic influences.
The compass display unit (AV-2 Smart Single) can be located at the convenience of the pilot without the need to take magnetic influences into account.

This magnetic compass system contains no moving parts and produces no magnetic field of its own. Magnetic heading information is based on measurements of low level magnetic fields on three sensors, opposed 90 degrees to each other. The system uses the latest available magneto resistive technology available as used in modern commercial aviation applications.

Three sensors are used so the magnetic field can be measured in three dimensions. This allows the construction of a tilt compensated compass, providing the direction of gravity is known.
With this system, information on the direction of gravity is available either from an accelerometer (3D A mode) or an artificial horizon (3D G mode).
It is also possible to operate the compass in a 2D mode in which case it behaves like our SP-1 compass model. In this case the Z axis of the earth magnetic field is ignored and the compass needs to be placed horizontal to the earth surface for accurate reading.

A/C-3 Features and functions in Compass mode

The A/C-3 application in compass mode presents the following features and functions:

Selectable displays.

The A/C-3 provides 5 user selectable display types, including a graphical emulation of a vertical compass rose. All graphical heading displays are direction correct, i.e. you steer in the direction of a desired heading as indicated on the screen to intercept this heading.

“From” heading.

The A/C-3 includes a “From” heading indicator function, course steering indicators, and user programmable variation allowing indication of magnetic or true heading.

Course steering.

A course steering indicator is available with left/right indication of required heading change to intercept the course.

Deviation compensation.

A simple to use deviation compensation procedure can be used to eliminate most deviation effects caused by stray magnetic fields caused by on board ferro-magnetic materials and electrical currents. No known magnetic transits are required for this procedure.

Fast heading determination.

The A/C-3 uses a sophisticated acquisition algorithm allowing the display of instantaneous heading information without any delay. Unlike a normal, mechanical compass, the A/C-3 does not suffer from over or under swing, settling time or friction. It is possible to consider usage of the

A/C-3 as a replacement for expensive, gyro based directional indicators (DI) combined with ordinary magnetic compasses.

High resolution.

The A/C-3 provides outstanding, professional level performance to single digit accuracy and a single degree resolution.

Universal application.

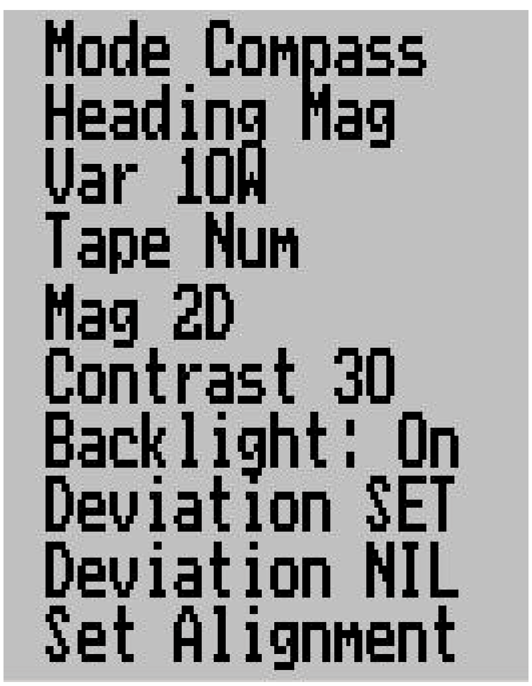
The A/C-3 works anywhere on earth, no special versions for northern or southern hemisphere are required. Acceptable performance can be obtained very close to the magnetic poles, even with a very small horizontal magnetic field component.

The A/C-3 menu system in Compass Mode

Press the Menu key to enter the menu. The Menu key is the left button. You can move forward and backwards in the menu by using the + and – keys. To change or select a menu item, move the highlight to the desired item and then press the Select key (second key from left). To end an edit or function, press the Menu key again.

To exit the menu and continue normal operation press menu.
Note, all changes you have initiated during your session will only be remembered by the instrument if you exit the menu back to the main screen.

Exception: All actions related to deviation compensation are stored as performed.



Mode …

This function allows you to select operation of the A/C-3 as artificial horizon, Turn and bank, compass or combined horizon/compass system. The menu system will change according to your selection.

Note: if you have purchased the SP-3hc sensor package with two or three AV-2 displays, it is possible to setup either of the AV-2 units to display either the artificial horizon, Turn and bank or the compass. This allows you to use any combination of horizon, turn and bank or compass displays.
You can connect further AV-1 or AV-2 units should you require this for a dual cockpit layout. Up to six AV units can be configured to give you 2 x Horizon, 2 x Turn and bank as well as 2 x Compass.

Heading Mag / True

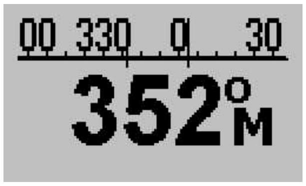
Select if you would like the instrument to display magnetic or true heading.
If you select true heading, you need to enter the correct magnetic variation for your location. You can find your local variation on aeronautical or maritime charts.
The heading displays will be augmented with °M or °T depending on the mode you have selected.

Var …

Enter the magnetic variation of your location. This is only used if you would like the instrument to display true heading. True heading is the heading relative to the geographic north pole. Magnetic heading is the heading relative to the magnetic north pole.
Variation is expressed in degrees east or west.
Please note that should you move a long distance, you may have to update the variation setting. This setting may be ignored if you only use the magnetic heading display option.

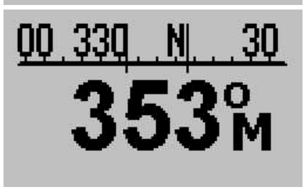
Tape …

Select the type of display you would like. Your options are:



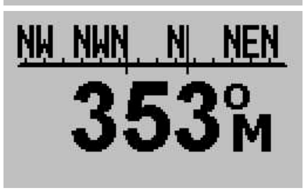
NUMERIC

The heading tape shows headings as numbers in degrees



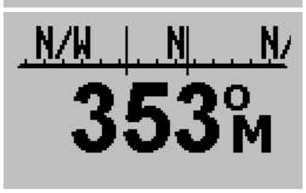
MIXED

The heading tape shows headings as number in degrees except for the four major cardinal points which are shown as N,S,E and W.



CARD1

The heading tape shows headings as major and minor cardinal points.
N,NEN,NE,ENE,E,ESE,SE,SES,S,SWS,SW,WSW,W,WNW,NW,NWN



CARD2

The heading tape shows headings as major and intermediate cardinal points: N,N/E,E,S/E,E,EW,W,NW

ROSE

The display shows a graphic representation of a vertical compass card.

Mag …

Select the mode you would like your compass to operate under.

2D – this mode selects a two axis compass system. This has no tilt compensation.
3D A – this mode selects a three axis compass system. Tilt compensation by means of gravity vectoring via accelerometers.
3D G – this mode selects a three axis compass system. Tilt compensation by means of information supplied by an artificial horizon.

SP-3hc can be used with any of the above modes.
SP-2 can be used in modes 2D or 3D A. 3D G is available if an external artificial horizon is connected.
SP-1 can only be used in 2D mode.

Each mode has advantages and disadvantages over other modes. Briefly, these are outlined in the table below:

Mode	Advantage	Disadvantage
2D	Most accurate as long as compass remains level. Not affected by turns or acceleration provided compass remains level during turns.	Large heading errors when compass is tilted. The magnitude of these errors is dependent on the heading, type of tilt (pitch and/or bank) as well as location on Earth.
3D-A	Self-contained tilt compensated compass. Will compensate for most tilt errors up to 60 degrees of tilt.	Cannot correctly compensate for tilt during any form of turn due to centrifugal forces acting on the accelerometers.
3D-G	Can provide for accurate heading even during turns as tilt compensation is based on gyro derived horizon.	Can show very large errors should the horizon information be invalid which could have a number of causes such as exceeding operational limitations of the horizon system.

Contrast …

This function allows you to change the display contrast to your liking. You can select values from about 20 to 45. (can vary depending on display type).

Backlight …

This function allows you to switch the display backlight on or off.

Deviation SET

Enters the deviation acquisition mode. Please read the text on the procedure to use.

Deviation NIL

Clears any previous deviation compensation and returns the instrument to factory calibration.

Set Alignment

This function is used after you have performed the deviation compensation as described in the chapter below.
The purpose of this function is to increase the achievable accuracy of the compass by setting two calibration points for the major North/South and East/West axis.

Align your aircraft exactly on a north/south heading, pointing north. Use another compass outside of the aircraft to ensure that you are aligned exactly on the north/south axis.
Select the North/South + or North/South – functions and use the select key until the heading is shown as 000 degrees.

Once you have done this, point the aircraft facing exactly south and verify the heading. If not exactly 180 degrees, use the functions again.
Find the best possible compromise between north and south.

Repeat the above procedure for the east/west heading.

This function, if used properly can lessen any remaining deviation that may be present after you have performed the prescribed compass swing (deviation compensation in the next chapter).
If you cannot find a successful setting using both methods, examine your installation location more closely. Perhaps you have an interfering metal part nearby. You may need to choose a different location to mount the compass sensor.

Note: In difficult circumstances it may not be possible to find a location for the sensor inside the fuselage of your aircraft. This may be particularly true for aircraft based on tubular steel frames. In this case you need to locate the compass sensor inside the wing (perhaps in a wing-tip).
Applications like this cannot use the SP-3hc package as it is not possible to operate the gyros so far away from the center of rotation of the aircraft.
In this case you need to split the functions into separate sensor packages, for example you may choose either SP-1 or SP-2 for the compass and the SP-3h for the horizon.

Using the deviation compensation feature

When you install your compass sensor package, it may be surrounded by several items or materials that in some way change the strength and direction of the earth magnetic field that your sensors are measuring. If left unattended, this may contribute to considerable errors in the heading as indicated by your instrument.
Due to the magnetic sensor not being based on a magnetic item (such as a magnetic needle) as in a normal compass, the effect of deviation is lessened a little. This is because the needle in a magnetic compass will be attracted by iron, even if the offending iron has no effect on the magnetic field (i.e. does not change the field direction or strength in a hypothetical case).

Deviation needs to be corrected if you intend using the compass for navigational purposes. The procedure for this is traditionally called a “compass swing”. Often, two small magnets are placed close to the compass in an effort to correct some of the larger errors. Smaller, remaining errors are then noted on a “deviation chart” and this is placed next to the compass for future reference.

With the SP-1,2 and 3, a very simple method can be used to correct for most of the deviation that may be present in your aircraft or vehicle.
However, before you start, ensure that the sensor package is installed as far away as possible from any of the following:

a) Ferro magnetic materials such as Iron, many steels and soft magnetic materials such as ferrites. Any magnets must by located as far away as possible from the sensor package. This includes electromagnets as used in solenoids, electrical motors and relays.
b) Cables containing large electrical currents. DC currents will cause magnetic fields around the cables which will lead to deviation. AC currents cause fluctuating magnetic fields that may reduce your compass resolution.
c) Be aware that some lower grades of stainless steel may be ferro magnetic.

If in any doubt, use a small magnet to test any metals surrounding the sensor package.
We recommend to mount the sensor package using glued on strips of velcro material. This allows for easy alignment of the sensor package horizontal to the earth magnetic field.

Never perform the deviation compensation procedure or a compass swing if your aircraft is placed on a reinforced concrete apron or tarmac. The steel that may have been used to reinforce may have a very significant effect on the strength and direction of the magnetic field at your location.

To start the deviation compensation procedure, enter the menu and select “Deviation SET”. You will see the display on the right:

Place your aircraft in flight attitude. For example, if you own a tail-dragger, raise the tail. Some tricycle gear aircraft may need to raise the nose gear slightly. The object is to place the sensor package as close to horizontal attitude relative to the earth’s surface as you can.
Press the “+” key or have an assistant do this for you if you are busy holding up your aircraft’s tail. You will get the display on the right:

Proceed as instructed and turn the aircraft through a full 360 degrees at least once. Allow this procedure to take some time, perhaps a minute. You can proceed to turn your aircraft though two or even more turns but you need to fully complete at least one turn.
If you like, you can press the “-“ button during this procedure to see the actual numeric data obtained from the magnetometers. You will see the instrument tracking minimum and maximum values for each sensor and you can see the current values.
Once you have completed your turn(s), press “+” again to inform the instrument that you have finished.
Your instrument will at this point calculate a best possible fit of the sensor data to a 360 degree arc taking the relative strengths and offsets of the magnetic field into account.
This procedure can result in remarkably good overall performance of your compass.

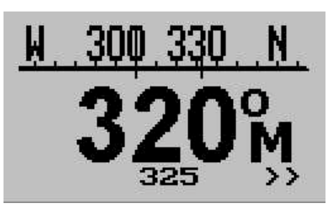
Please note: After this procedure has been completed, you may have to verify the compass performance by performing a normal compass swing. Should any deviation remain, you need to note this on a deviation card and place this card next to the compass.
This may be a legally required procedure in your country for your aircraft class. Please check your relevant regulations.

Deviation compensation and compass swing may need to be repeated from time to time as the magnetic properties of metals in your aircraft may change over time.

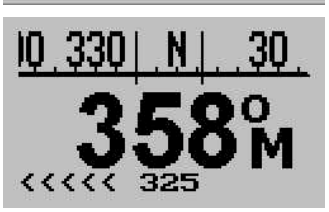
Using the course steering indicator

To activate the course steering indicator, steer the required heading and then press the “+” key. The compass will display:

“+” pressed at a heading of 325 degrees.
Currently the heading equals the course to steer as shown below the heading. No steering indicators show.



The current heading is 320 degrees, course indicators show the need to steer slightly to the right to intercept the course.



In this picture the heading is 358 degrees. Steering indicators show that a large correction to the left is required to intercept the course.

Each “>” or “<” equals 2 degrees of heading error.
To cancel the course steering function, simply press the “+” button again.

The reverse course (From heading) display

Press the "-" button to activate the reverse course display. This display remains active for about 4 seconds before reverting to the normal heading display.

Heading stability issues

You may find short term fluctuations of the heading occurring. These tend to be very small and are typically less than one degree. This could still cause the heading to fluctuate occasionally by a single degree. These fluctuations occur naturally in the earths magnetic field and can also be caused by nearby electrical equipment such as radios, lamps or electronic instrumentation or computers, even ignition systems of engines. The AV-2 is specifically designed for fast response and thus may show residual fluctuations of the magnetic field that are impossible to filter out without causing delays in the update of the heading information.
Each measurement interval of 0.5 seconds consists of a computational evaluation of 12.000 individual measurements of the magnetic field at the magnetometer sensors.

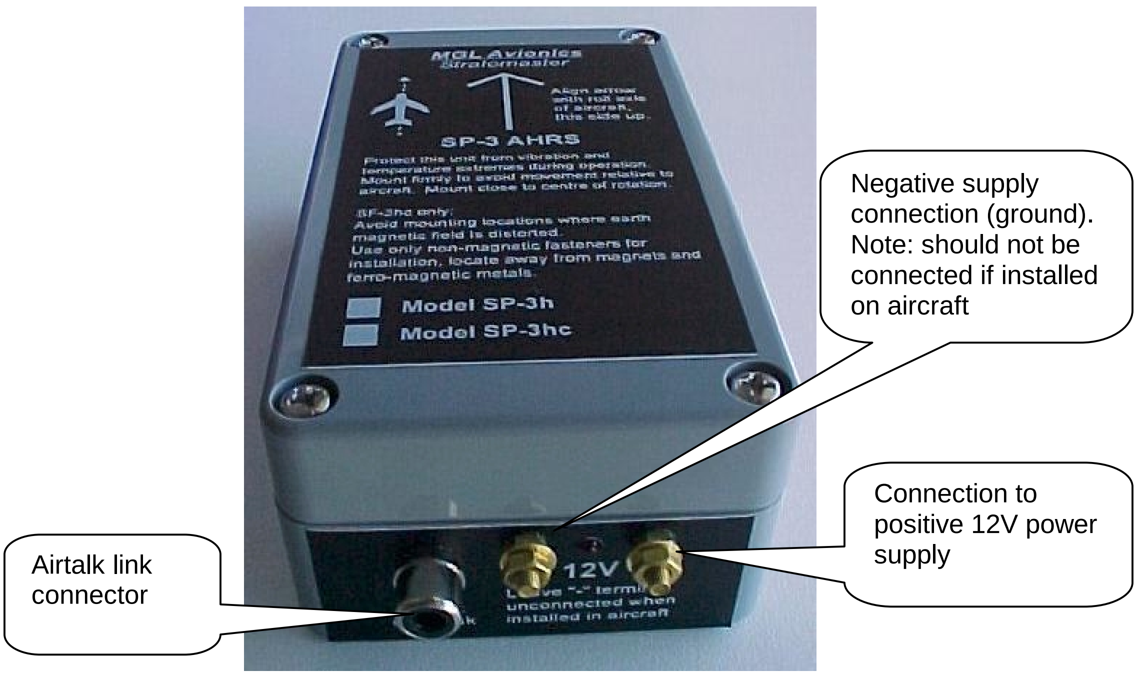
SP-1,2,3 sensor package

The SP sensor packages contain the gyro, accelerometer and magnetic sensors and a dedicated micro processor system. The unit performs all required measurements and computations depending on the application. Output of the processed information is via airtalk link.

Connection between the sensor package is done via a standard airtalk cable. This cable is compatible with ordinary RCA audio or video cables that are easily obtainable from electronic appliance vendors and supermarkets. You can use low cost cables, there is no advantage in using expensive, gold plated cables and connectors.

The sensor package needs to be connected to a +12V DC power supply using the RED cable attached to the SP unit. No ground (or minus) connection is required as this will be established when you plug the unit into the AV-2 display.

A small, red LED will flash indicating that the unit is powered and is transmitting information.



Should the SP unit not be connected to the AV-2, the AV-2 will display the following message:

Technical specifications:

Display temperature range (operational): -20 to +80 degrees C
Supply voltage: +8 to +18V. +24/28V with optional pre regulator.
Supply current AV-1: 40mA/120mA (backlight off/on)
Supply current SP-3x: 100mA

Technical data SP-3hc sensor package. Other versions of these, delete items not applicable.

IMU (Inertial measurement unit)

Technology: Three axis gyro plus two axis accelerometer. Third axis accelerometer for special applications available as option.
Gyro type: Coriolis force sensing using vibrating structure. Manufactured using MEMS technology.
Accelerometer: MEMS technology.
Gyro Bias drift: 1 degree/Minute typical (Note: without accelerometer error compensation, gyros only).
Recommended temperature range for operation: 10-30 degrees C. Other temperature ranges are possible providing sensor package is allowed to acclimatize and adjust after power up. Alternatively, sensor package can be user calibrated for a different temperature rage (See offset calibration).
Accelerometer drift: 1 degree per 10 degree C temperature change. Horizontal position may be set to zero by user.
Startup time: Instantaneous if in recommended temperature range. Up to 30 seconds typical if outside of this range. Manual "fast set" available.
Maximum rate of turn: 165 degrees/second. Each axis simultaneously. Up to 180 degrees/second typical when operated in recommended temperature range (not guaranteed, typical specification).
Resonance frequency of gyros: 14Khz.

Magnetometer (Compass)

Technology: Magneto resistive, 2 axis and 3 axis modes.
Compass resolution: 1 degrees.
Compass accuracy: 2 degrees (2D mode) 3 degrees (3D mode) plus +/-1 digit. Typical figures.
Condition: After correct deviation compensation procedure in zero magnetic disturbance environment at a temperature of 25 degrees C.
Compass stability: 2 degrees average short term fluctuation. Condition: Zero magnetic interference from any external magnetic source, very low solar magnetic storm activity.
Measurement interval: 0.25 seconds.
Maximum time to stable heading after large heading change: 0.5 to 1.0 seconds depending on relation of movement to measurement interval.

Weight: SP-x unit approximately 150 grams.
Weight of AV-2 display units: Approximately 180 grams each.

Warranty:
MGL avionics warrants their products for a period of one year from date of purchase against faulty workmanship. Warranty is limited to the replacement of faulty components and includes the cost of labor. Shipping costs are for the account of the purchaser.

Note for operation on supplies with inductive loads:

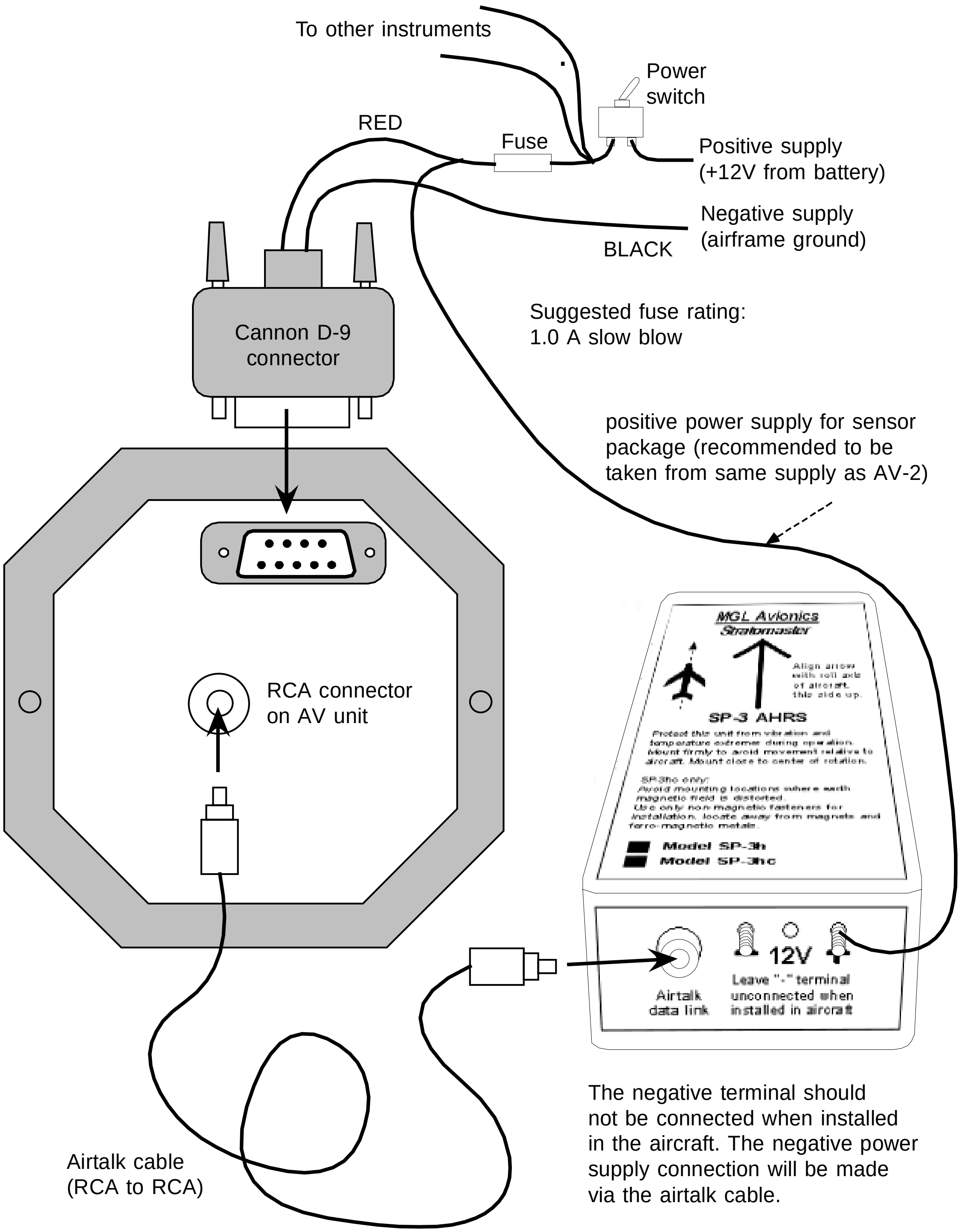
Any operation of electronic instrumentation on power supplies that are subject to high voltages caused by operation of inductive loads (starter motors, solenoids, relays) are required to be fitted with suitable protection.

All Smart Singles are guaranteed to withstand temporary over voltage up to 40V without additional protection. We recommend that measures are taken to prevent voltage transients in excess of this limit.
MGL Avionics recommends the fitting of a fuse in line with a 33V transorb (available from MGL Avionics at low cost) to protect electronic instruments, radios and intercom systems. Only one such arrangement is required for a cluster of instruments.
Please note that product warranty excludes damages caused by unprotected, unsuitable or incorrectly wired electrical supplies.

This instrument is not certified by the FAA. Fitting of this instrument to certified aircraft is subject to the rules and conditions pertaining to such in your country. Please check with your local aviation authorities if in doubt.
This instrument is intended for ultralight, microlight, homebuilt and experimental aircraft.

Operation of this instrument is the sole responsibility of the pilot in command (PIC) of the aircraft. This person must be proficient and carry a valid and relevant pilots license. This person has to make him/herself familiar with the operation of this instrument and the effect of any possible failure or malfunction. Under no circumstances does the manufacturer condone usage of this instrument for IFR flights.

Installing the AV-2 and wiring of the SP-x sensor package



The above drawing shows the required system wiring for an installation requiring one AV-2 display. Should you be installing more than one AV-2 units, use standard RCA splitter cables to create more nodes on the airtalk cable.
Connect the supply terminals to your aircrafts power supply (you need a dropping resistor or pre-regulator for 24/28V systems).
Install suitable power supply protection if you have a supply that can contain large voltage transients such as can be created by starter motors and solenoids.

Ensure that the supply voltage will not drop below 8V during operation as this may result in incorrect displays.

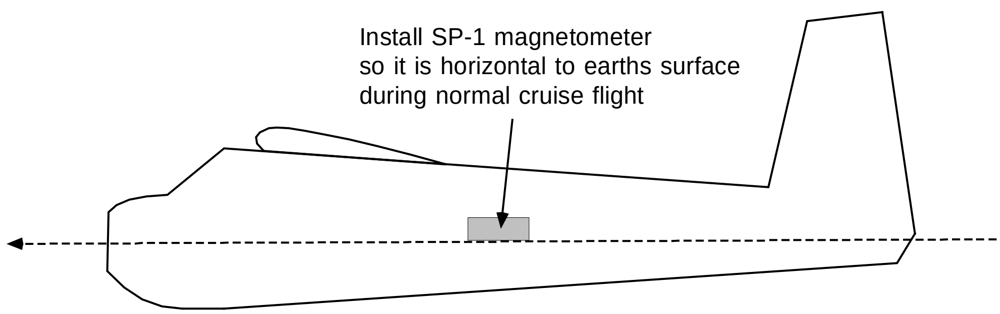
Physical installation of the SP-x sensor package

This section is split into requirements for the compass and IMU (artificial horizon). Should you have the SP-3hc sensor package, you must take both sections into account.
Please study the installation requirements carefully. The quality of your installation has a direct relation to how well your system operates.

Installing the compass (Sensor packages SP-1, SP-2, SP-3hc)

The sensor package must be installed such that it is in a horizontal position during normal cruise flight. This is a very important requirement for maximum possible accuracy of the system.
Ensure that you do not have any magnetic materials close to the sensor package.
We recommend ordinary velcro tape for installation as this allows you to easily adjust the orientation of the sensor package. Velcro tape is available in a self-adhesive form but you can glue normal velcro strips onto airframe and sensor housing using contact adhesive.
Should you choose to mount the sensor package using other hardware, ensure that you use only non-magnetic fasteners and materials such as plastic, aluminum, brass or high grade stainless steel. Use a small magnet to test any material if in doubt.

Horizontal installation is particularly important for the two-axis SP-1 system. However, we recommend that you also install the other systems horizontally as these systems can be operated in a two-axis mode as well.
For maximum accuracy, the tilt compensated compasses SP-2 and SP-3hc should be installed so that during all power settings they will not pitch more than +/-15 degrees of the horizontal.



Suggested installation locations for various aircraft:

3 axis aircraft:

Fuselage or wing. Find a location that is as far away as possible from ferro-magnetic materials.

Trikes:

Trike frames operate over a large range of pitch due to power settings. Trikes should ideally fit our SP-2 or SP-3hc tilt compensated compass models.
However, it is possible to use the MAG-1 if the SP-1 sensor package is installed inside the wing, perhaps along the center keel. While the trike frame experiences large pitch changes, the wing undergoes relatively small pitch changes.
If you install the SP-1 inside the wing, please ensure that it will not be damaged during wing folding.

It is important to mount the SP-1 as close to horizontal to the earths surface during ordinary cruise flight as you can. The more effort you spend on this, the more accurate your heading information will be on all headings.

Perform the deviation compensation procedure as outlined in this manual after you have installed the sensor package.
If you own a tail dragger, you must raise the tail to flight position and rotate though 360 degrees as least once.
For a trike, raise the nosegear to flight position and rotate the trike through 360 degrees. Ensure that you bar position is in the same position it would be during cruise flight if the sensor package is mounted in the wing.
For a three axis tricycle gear aircraft, it may be sufficient to simply taxi the aircraft though 360 degrees if you would fly with the nose wheel not significantly higher than the rear wheels.

Alternate, in-flight deviation compensation procedure:
Place instrument in deviation compensation mode, ensure sensor package is horizontal to Earth's surface.
Fly a **very shallow** 360 turn keeping any bank or pitch angle to an absolute minimum (less than 5 degrees), during the turn, straighten out periodically during the turn (every 10 to 20 degrees).
Once completed, perform another turn in the same manner but the opposite direction.
When done, leave the deviation compensation mode as described.
Perform this procedure during calm weather conditions to aid you in flying such that no drastic bank or pitch angles will be present during this procedure.

If you plan to use your compass for navigation, please ensure that you perform a normal compass swing after you have completed the installation and deviation compensation. Create a deviation card showing any remaining deviation for the major and minor cardinal points and place this card next to the compass display.
This may be a legal requirement for the aircraft category you are using.

Installing the IMU (SP-3h and SP-3hc sensor packages)

Installation of the IMU (inertial measurement unit) is critical to performance of this unit. A bad installation is guaranteed to result in a system that does not function properly.

A low cost IMU operates in exactly the same way that a $100.000 inertial navigation system does. As a result, you need to understand the installation requirements and you have to take great care in providing a suitable installation.

In particular the following have to be taken into account:

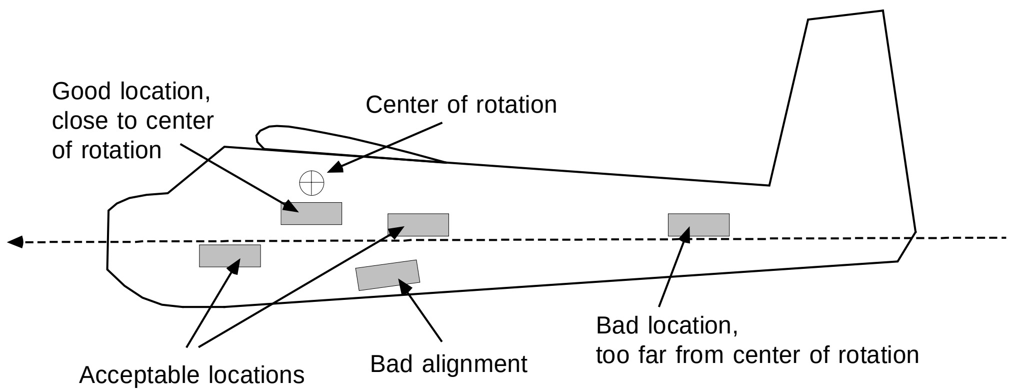
a) Location of the IMU must be as close to the center of rotation of your aircraft as possible. Reason: A bad location will introduce accelerations during Yaw, Pitch or Bank. This will interfere with the ability of the accelerometer to vector gravity.

b) The IMU must be protected from rapid temperature changes. The IMU is able to operate over a fairly wide temperature range but care must be taken that temperature changes occur gradually. Reason: Rapid temperature changes may exceed the ability of the gyro bias drift tracking to compensate for temperature changes.

c) The IMU must be protected from engine, propeller or rotor vibrations. Reason: vibrations are movements that contain both linear and rotary components. These movements will be detected by the accelerometer as well as gyros and this can severely degrade performance as the system is swamped with false information. In addition, frequency components that are in the same band as the operating frequency of the gyros will lead to immediate, large bias drift that signals false rotation to the electronics of the IMU.

d) The IMU must be aligned with the aircraft. Reason: The IMU measures your aircrafts pitch, bank and yaw to calculate the orientation of your aircraft with the horizon. If the IMU is not aligned with your aircraft, then, for example, the Yaw gyro may in fact measure some of the pitch and bank, the same with the other gyros. In this case all calculations will be invalid and the horizon will rapidly show large errors. Your IMU has been measuring signals that are not related to your aircrafts actual movement.

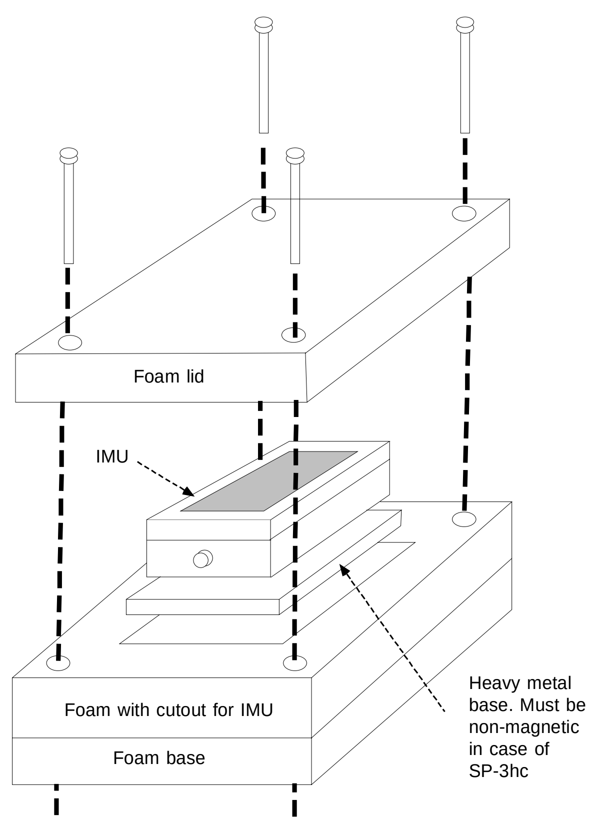
Let us start with the location of the IMU.
The drawing below shows some examples of locations assuming a fairly standard fuselage layout. The IMU should be located as close as possible to the center of rotation which tends to coincide closely with the center of mass of your aircraft.
Often it is not possible to place the IMU exactly at this location. Choose a location as close as you can that is practical.



The drawing also gives an example of a bad alignment. Please try and locate the IMU such that it is aligned with the aircrafts axis of travel at cruise power setting.

Providing a suitable solution to both temperature and vibration isolation is relatively simple. Of course, this if highly individual to your aircraft type and mounting position, so the solution presented here should be seen as a generic suggestion.

A soft foam such as used as fill material for furniture or bedding is ideal and we can use it for both thermal isolation and anti-vibration mount. As the IMU has a very low weight, we need to provide it with a heavy mounting plate to help absorb the vibrations. In case you have the SP-3hc with compass, we suggest to use a plate made from brass, copper or simply cast from lead. In case of the SP-3h you can use steel or iron.
Once closed up, the IMU is well protected against rapid temperature changes as well as vibrations.



Using RCA cables.

The airtalk link uses easily available RCA video or audio cables. You can connect the SP-x sensor package to up to six AV-1 units. You can use ordinary RCA cables and splitter cables for this. You can also make up your own cables. However, use only suitable, shielded cable. Thin 75 ohm video cable works best.

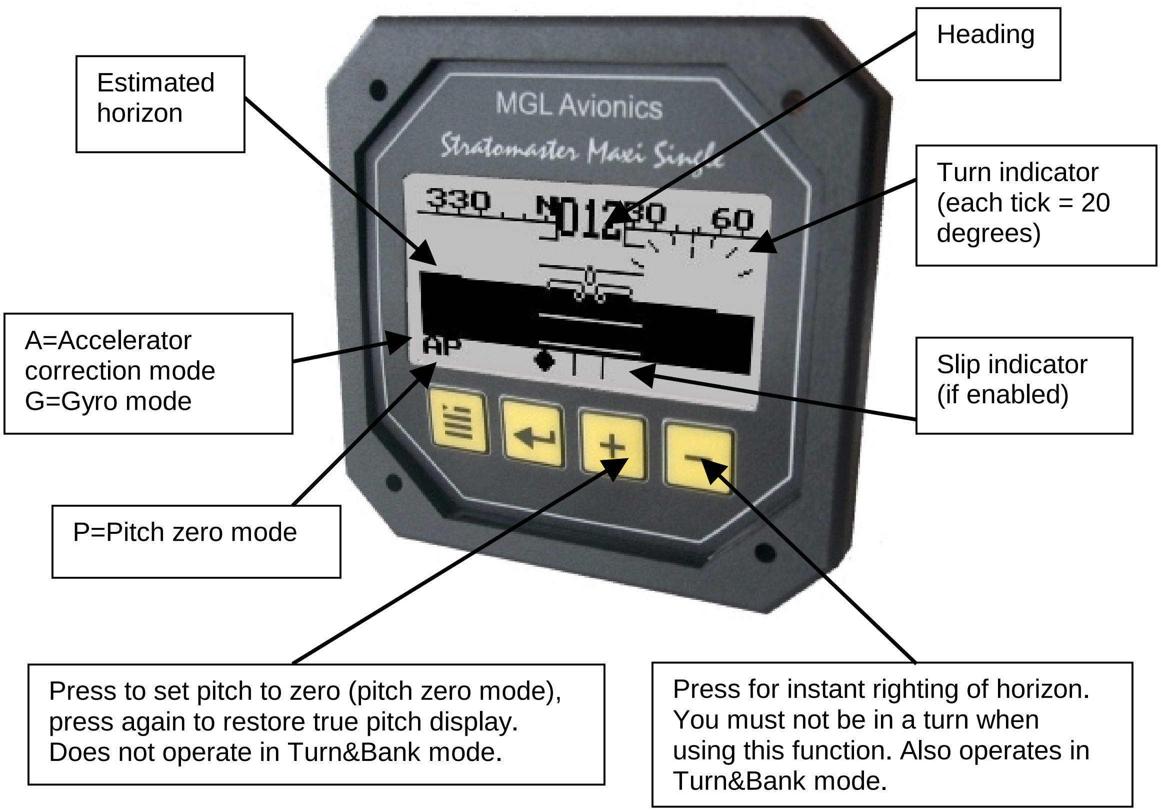
The cable can be extended to a length of up to six meters, allowing convenient placement of the SP-x sensor package.

Slightly bend the outside tabs on the RCA connectors inwards to ensure a tight fit of the connectors. For critical applications, use very high quality connectors and secure the connectors an cables so they cannot separate by accident.

Operating the Artificial horizon

The horizon is designed to erect itself rapidly whenever possible. This means that during ordinary flight you do not interact with the unit.
The horizon may loose accuracy. This may have several causes:

a) You have exceeded the maximum allowable turn rate on one or more axis (165 degrees/second)
b) Continuous maneuvering without giving the unit a chance to correct for errors. In this case gyro drift will eventually cause a noticeable error of the horizon
c) The IMU is subject to vibration from an engine. Often you will find this will have an effect only at very specific engine RPM
d) The IMU is subject to rapid temperature changes or is operating outside of the recommended temperature range (consider re-setting offsets in this case).
e) The IMU Bump factor is set incorrect for your aircraft. Try a different setting.



In order to correct the horizon display, you need to fly straight and level. The horizon will correct itself in this case given some time (about 15 seconds to a minute depending on severity of the error and your “slew” setting). You can also press the “-“ key to force an immediate correction. You must fly straight and level for this to work correctly.

You will notice a small character on the top left of the display. This character will be one of two:

a) The letter “A”. The IMU is in accelerator mode. The accelerator has been given authority to right the horizon.

b) The letter “G”. The IMU is in gyro mode. You are busy turning through one or more of the aircrafts axis. The accelerator has no noticeable effect on the calculated horizon.

The Bump factor for your system is correctly set if you see the “A” at least 50% of the time while you are flying straight and level. Increase the factor (higher) to give the accelerator a greater chance to operate. The accelerometer is used to correct gyro drift and if never allowed to operate, your horizon will soon show errors due to drift.

Power and trim changes will affect the pitch display of the horizon. You can set the horizon to zero by pressing the “+” key. To get back to the real horizon, press the “+” key again. To show that you are in “pitch zero” mode, the character “P” is shown in the top left corner of the display.

Operating the IMU in a test setup

Before you install the IMU, it is advisable to rig a small test setup so you can get a feel for how it operates. This is quite easy to do.
Use a 12V power source (Note: do not use a cheap battery charger, these do not output a filtered DC voltage). Use a battery or regulated power supply. You need to supply about 200mA for one AV-2 display unit and the IMU (less if the IMU does not have a compass, such as the SP-3h).

Connect everything up as shown in the installation drawing. Connect +12V to both the IMU (red cable) and the terminal marked +12V on the AV-2. Connect the battery negative to the “-“ terminal of the AV-2. Finally use a standard RCA to RCA video or audio cable to connect the IMU to the AV-2.

Place the IMU on a flat surface such as a table. After power has been applied, you should see the A/C-3 application log on screen for a few seconds. If the horizon application does not appear, enter the menu and select the horizon application.
You should now see the horizon. It may show bank or pitch movement for a short while if the temperature is significantly different from the calibration temperature. After a few seconds the horizon should be stable. Press the “-“ key on the A/C-2 if required to right the horizon or wait until the horizon is level.

Now, pick up the IMU with your hand and move through typical flight maneuvers. You can bank and pitch the IMU. Take care to do this at the typical rates that an aircraft would do these maneuvers. It is very easy to exceed the maximum rate of turn for the gyros by hand.
Note how the gyro/accelerator mode indicator in the top left hand corner of the display changes if you turn or hold the IMU steady.
Now, deliberately introduce a horizon error. This can easily be done by doing a fast movement exceeding about 170 to 180 degrees per second (i.e. half a turn per second). Do this in the bank or pitch axis.
Place the IMU on the table when you have a definite error and watch the horizon correct itself. This will happen during straight and level flight if your Bump factor has been set correctly for your aircraft.

You will notice that it takes a larger amount of turn rate to switch into gyro mode if the Bump factor is higher but that it takes longer for the accelerometer to correct for errors. The reverse is true for smaller Bump factors. Note that the gyros are never "disabled". The horizon is always calculated from the gyro information. The accelerometer is given more or less authority to alter the horizon if it is deemed safe to do so. It is generally safe to do if you are flying straight and level. Small yaw movements, or bank and pitch changes during straight and level are tolerable.

Using the IMU in flight

The pilot in command of the aircraft has to be aware of the following:
The SP-3 sensor packages are not certified by the FAA or any other agency for use during IFR (instrument flight rules).
This implies that any such flight that uses the SP-3 IMU as reference for either heading, turn&bank or horizon is **illegal**. Do not do it !

Following is a set of guidelines should you choose to ignore the above statement. This is by no means to be seen as any form of recommendation by the MGL Avionics or its appointed distributors to allow or recommend such flights.

1) Flying in IMC (IFR) conditions requires practice and an understanding of the functions and limitations of any instruments used as reference for such flights. It is foolish to attempt to fly any aircraft blind without extensive training for such flights.
2) Train yourself before attempting any IFR flights, even if this is illegal. Train in VFR (visual flight rules) conditions by flying only with reference to the instruments. Have a qualified co-pilot watch over your progress while you are training. Do not train for IFR flights without a second pilot that has visual contact to the Earth horizon on board.
3) Only ever attempt to use the instruments in an emergency if you have no other option, and only if you are proficient in their use.

In order to fly though an area of limited visibility:

1) Ensure that you will have visual airspace when exiting the area of limited visibility. It is of no use if a cloud extends to ground level or to a mountain.
2) Maintain straight flight, slowly descending or level as required. Do not maneuver.
3) If you have to turn, turn shallow (25 degrees bank angle or rate one turn). Only turn 90 degrees at a time then level out for a short time to allow the horizon to correct for any errors. Ensure that the horizon goes into accelerometer mode to correct errors. Verify that you are not turning by looking at the compass heading.
4) Be aware that turbulence may decrease the accuracy of your horizon display if maximum turn, bank or pitch rates have been exceeded or other factors have contributed to an error of the horizon display.
5) If you have a digital compass from the MGL Avionics range, set it to 2D or 3DA mode and use the course steering function to help you maintain a straight path. This way you have a backup should the horizon become invalid for whatever reason.

Diagnosing the cause of horizon display errors

One of the most common horizon display errors is caused by unsuitable “bump” factor settings related to the type of aircraft you fly or conditions you are flying in.

Setting too high:

Horizon behaves well in straight and level flight through turbulence.
Horizon does not indicate correct bank if a bank is entered very gradually. The horizon display remains level.

Here is what happens in the above case:
While you are entering very slowly into a bank, the SP-3 unit remains in accelerator mode as the output signals from the gyros are very small, below the “bump” factor. These signals are ignored. The accelerometer will indicate that you are level provided your slow entry into the bank is a entry into a coordinated turn.

When you now roll back to straight and level with the horizon shown incorrectly, the roll is often done at a faster rate activating the gyros. The result of this is that the horizon is now displayed banked when you are in fact level.

I your SP-3 unit is allowed to remain in accelerometer mode for a short while, the horizon will correct itself. Alternatively, press the “-“ key to set the horizon level instantly.

Try a lower “bump factor” to allow detection of gradual entries into the turn.

Setting too low:

The main result of a too low setting of the “bump factor” is that the horizon will drift out as the SP-3 sensor is not able to switch into accelerator mode and remains in gyro mode. The error will accumulate faster if you are flying through turbulence.

In this case you need a higher “bump factor”.

Suggested method of finding a good “bump factor”:

In calm weather conditions, fly a series of slow entries into turns. Select a bump factor low enough so that these turns are shown correctly on the horizon.
Fly straight and level through a turbulent stretch. Select a bump factor high enough so the horizon will still display correctly after a minute or two. A good location for this is usually during the last part of finals before touchdown as your aircraft starts buffeting due to ground turbulence.
Find a setting that fits your aircraft best for both extremes.
The smaller your aircraft, the more critical this setting becomes as your aircraft will react more violently to turbulence.
A good setting to start with is usually “medium”. Larger aircraft and helicopters may choose a “lower” setting while often ultralight aircraft need a setting of either “medium” or “higher”.
The settings of “lowest” and “highest” are seldom, if ever used and are only provided in case of extreme operating conditions.