FLUXGATE WORLD
subsystems

A4025 OEM FLUXGATE INCLINOMETER/COMPASS
USER MANUAL

November 2007
A4025 manual 02-03.doc
Release 1.0.B
Hardware version 2

Table of Contents

1. Introduction and description of fluxgate inclinometer/compass.

1.1 Description of Compass

The Autonnic A4025 is a complete sub-system for measuring pitch and roll and also includes a compass. It can be used for all kinds of positioning or safety indicating system, satellite or solar positioning, RADAR 'North-up' or autopilot, platform angle and camera pan and tilt. It delivers **pitch** and **roll** and **heading** serial data in one of several selectable forms and has analogue outputs too.

The A4020 contains a fluxgate surrounded by high-precision interface circuits which, together with the special clockwise/anticlockwise and offset nulling sequence allow a microprocessor to acquire a binary value from two orthogonal sensors of the Earth's magnetic field. The processor calculates the vector from these values, uses a calibration table to correct for local field disturbance errors, offsets the result and then presents the data in a manner which has been requested. Such requests alter the frequency of the data, the degree of filtering and the offset value. Calibration sequences for both pitch and roll and heading can also be commanded.

It can be supplied in 2 different versions:
35 ° or 45°
And with pins either up(A) or down(B).

1.2 Description of Inclinometer

The inclinometer is an added function to that of the compass. It uses the compass technology. Autonnic have patented the use of the floating-core fluxgate magnetometer with a vertical field for use, among other things, as a two-axis inclinometer. The unit is operated as a compass twice in succession; the first time measures the Earth's filed. The second time a field is added which runs through the axis of the component (i.e. normal to the plane of the circuit board). Any component of this field which is not symmetrical causes a proportional (with a sine function) addition to that just measured from the Earths field. The first measurement (the 'background' field – A in Fig 1) is then vector subtracted from the second combination reading - B.

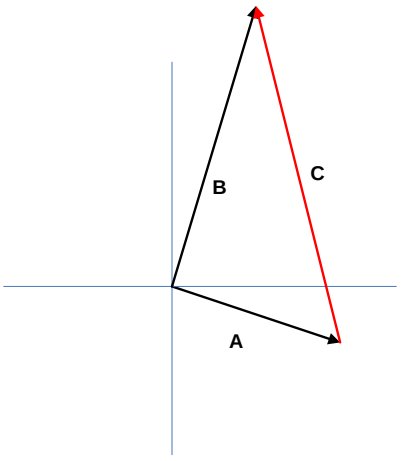

Fig 1

The result, C, is due solely to that of the applied field, represents the pitch and roll and is immune to external magnetic fields. But the first measurement, A, is of only those fields and is the compass output.

In this manual the following convention is used for direction of movement:

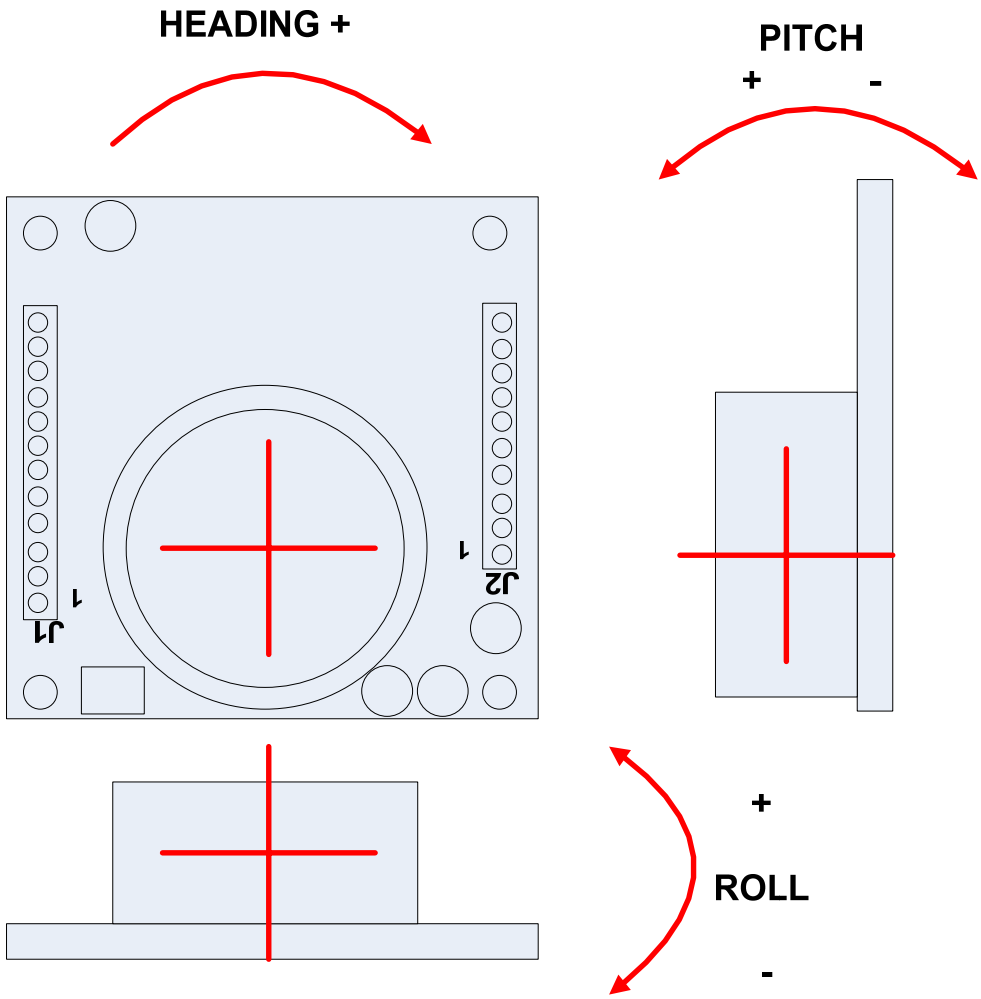

Fig 2

1.3 Connections

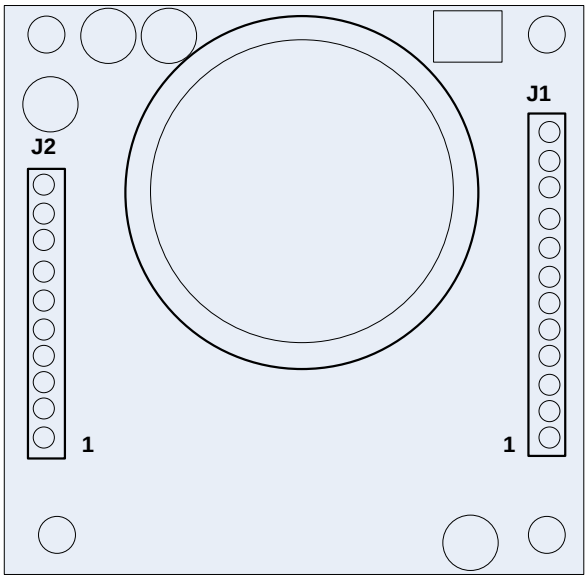

Fig 3

J1	**Header Block**		
Pin	**In or Out**		
1	P	GND	Supply and signal ground
2	I	/AC	not Start compass auto-calibration
3	I	/SZ	not Set zero heading
4	I	/BRC	not Change bit-rate (not implemented)
5	I	/SD	not Shut-down
6	O	/CE	Cal status output
7	I	ANI	Analogue Input
8	O	SO	Serial output
9	I	SI	Serial input
10	O	NMEAO	RS422 / NMEA-0183 O/P (+)
11	I	NMEAI-	RS422 / NMEA-0183 I/P (-)
12	I	NMEAI+	RS422 / NMEA-0183 I/P (+)

J2	Header Block		
Pin	**In or Out**		
1	O	ANO4	Analogue Output 4
2	O	ANO1	Analogue Output 1
3	O	ANO2	Analogue Output 2
4	O	ANO3	Analogue Output 3
5			Not to be connected
6			Not to be connected
7			Not to be connected
8			Not to be connected
9	P	+7 to +15v	+ supply
10	P	GND	Supply and signal ground

1.3 Pin functions

Note that most functions are active low (shown as /)

1.3.1 J1

/AC Start autocalibrate

/SZ Set to zero (North)

/BRC reserved for future: Change bit-rate

/SD Shut-down. Reduces consumption

/CE Calibration Status Output

ANI reserved for future: Analogue Input

SO Serial output direct from the micro-controller

SI Serial input direct from the micro-controller

NMEAO NMEA Output. Sourced through 150R to +5v

NMEAIN+ and - Inputs to the photo-diode in the NMEA-0183 opto-isolator input.

1.3.2 J2

ANO1-4 The four analogue outputs. These are not directly from the magnetometers but are normalized by the on-board processor and created using a 10bit D-A

1.4 Power supply.

The compass is compatible with any DC power supply of between 8 and 15 Vdc. Typical supply current during operation is approx. 25mA. The A4025 is protected against reversed polarity.

Care should be taken to make sure the compass is not situated too close to the power supply, as it's accuracy may be affected by either the iron in the mains transformer, or by magnetic field 'noise' from a switching power supply. It is not possible to cover all possible scenarios here, and it remains up to the user to determine the suitability of a possible location for the compass.

1.4.1 Power up

When the unit is powered up full accuracy will not be achieved during the first 10 seconds of operation. The device will send **$P<CR><LF>** on a good power-up.

Auto calibration and/or set heading operations should not be performed during this time.

This constraint does not apply after exit from sleep/shutdown mode.

1.4.2 Power consumption (all at 20 degrees centigrade typical values)

Shutdown mode <3mA
Normal operation average = 30mA peak 70mA
During Compass Auto-calibration average = 55mA peak = 60mA
Allow +/- 10% on the above values
Voltage input +7v min, +15v max

2 Connecting the A4025 to your application.

2.1 To a NMEA-0183 instrument.

The hardware on which the NMEA-0183 standard is based on is a balanced serial protocol called RS422. This means that two wires are need for send and two for receive.

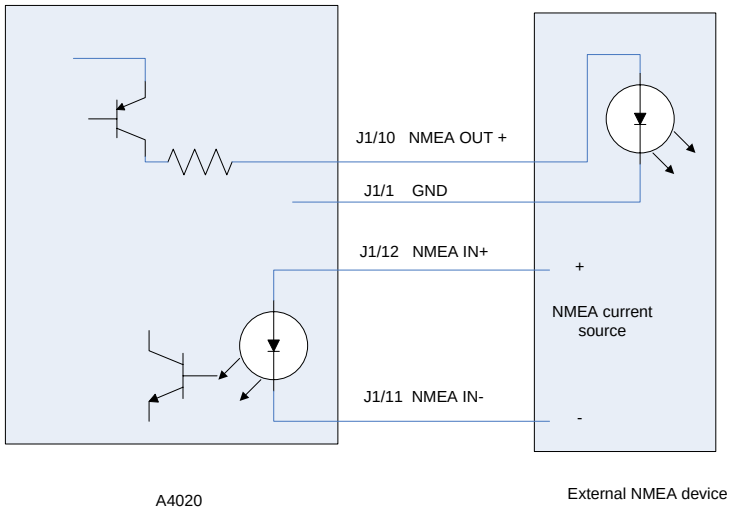

Fig 4

The current in the A4025 is sourced from +5v.
Note that the GND wire is used for the current return path. This might be shared with the NMEA- wire in some installations.

2.2 To a PC serial port.

There is a choice: either use the NMEA connections or else connect directly to the micro-controller as shown in Fig 5. This sometimes needs a RS422 to RS232 converter but in most cases the wires can be joined directly as shown in Fig 4.

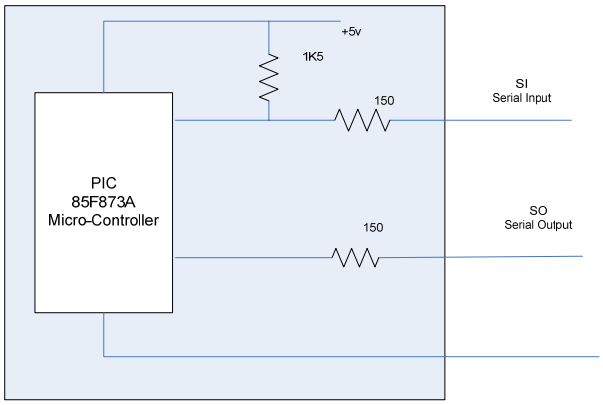

Fig 5

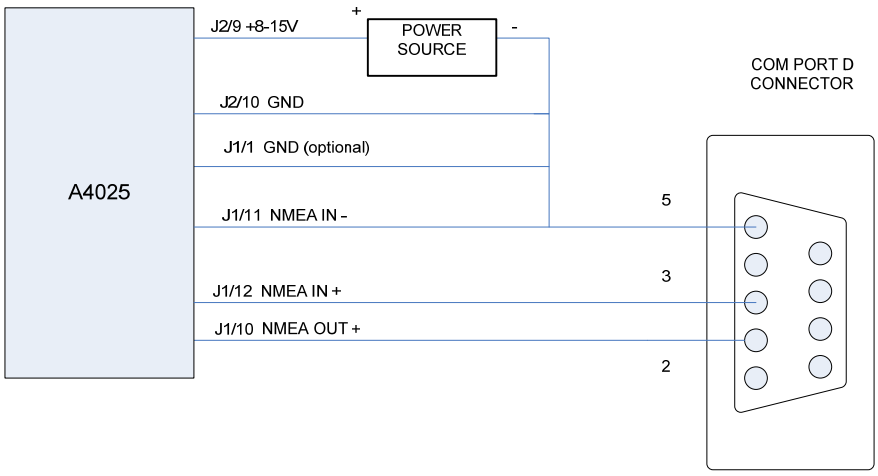

Fig 6

3 Output formats available from the A4025.

3.1 Serial

The serial output format is: 4800 Baud, 8 data bits, 1 stop bit, no parity.

The A4025 sends information using the NMEA-0183 sentence 'HDG': Magnetic Heading, Deviation, and Variation BUT also can add Pitch and Roll in a proprietary way. Note that the information of Deviation and Variation is not sent and so blank fields are defined by consecutive commas.

In the example sentences which follow:

hhh.h is the compass heading in degrees e.g. 047.3

±pp.p is the pitch in signed degrees e.g. +28.2

±rr.r is the roll in signed degrees e.g. -11.8

The sentence may have one of several forms and this is defined by sending a configuration command:

$PATC,IIHDG,CFG,nk<CR><LF>

where **n** is the sentence type and **k** defines the value of **v** as follows:

n=0 : ***$HCHPR,hhh.h,±pp.p,±rr.r,v<CR><LF>***

k=0 : there will be no v field and the direction sentence will include neither checksum nor unit ID serial number.

e.g. ***$HCHPR,hhh.h,+/-pp.p,+/-rr.r<CR><LF>***

k=1 : direction sentence will include a two character checksum.

e.g. ***$HCHPR,hhh.h,+/-pp.p,+/-rr.r,cc<CR><LF>*** where **cc** is the checksum.

k=2 : sends the unit's 4 digit serial number instead of checksum.

e.g. ***$HCHPR,hhh.h,+/-pp.p,+/-rr.r,aaaa<CR><LF>***

where **aaaa** is the decimal serial number.

n=1 : ***$HCHDG,hhh.h,,,,<CR><LF>***

n=2 : ***$HCPNR,±pp.p,±rr.r<CR><LF>***

n=3 : ***$,±pp.p,±rr.r<CR><LF>***

n=4 : ***$,±pp.p<CR><LF>***

n=5 : ***$,±rr.r<CR><LF>***

n=6 : ***$,hhh.h<CR><LF>***

n=7 : ***$,xxxx,yyyy, ±pp.p,±rr.r <CR><LF>***

n=8 : an alternating pair of sentences:
$HCHDR,hhh.h,,,,*cc<CR><LF>
And ***$YXXDR,A,±pp.p,D,aaaa,A,±rr.r,D,aaaa*cc<CR><LF>***

n=9 and higher are reserved.

For other serial commands see section 5

3.2 Analogue Format

The four outputs are arranged as PITCH, ROLL, REF and LINEAR as follows – with the output value shown in volts :

ANO1 = ANO3 ± Pitch where Pitch is represented as 1bit of a 9bit output with 2.5v reference. i.e. 30° is 2.5+(2.5 x 300/512) = 3.086v

ANO2 = ANO3 ± Roll where Roll is represented as 1bit of a 9bit output with 2.5v reference. i.e. -24.6° is 2.5-(2.5 x 246/512) = 2.019v

ANO3 = 2.5 Use this as the common signal for ANO1 and ANO2

ANO4 = Linear compass using 13.89mV per °. (0-4.998v = 0 – 359.9°)

4 Calibration

4.1 Why the compass needs calibrating.

When any compass is installed the magnetic characteristics of the whole installation affect the way the Earth's field reaches the detector inside the device. Each individual installation will be different and so the A4020 is equipped with an auto-calibration routine which corrects for these installation distortions.

4.2 Why the inclinometer needs calibrating

Each magnetometer and its supporting electronics is slightly different. The magnetic output is linearised and calibrated at zero (level) and then at each of the 4 calibration points of ±35° for each of the axes Pitch and Roll

4.3 Starting Compass calibration.

The calibration process can be started in either of two ways:

- A NMEA-0183 command (section 5) can be sent to initiate the process.

OR

- The /AC pin can asserted low. This can be done with a resistance to GND of not more than 10K

The process consists of rotating the whole installation in the Earth's field so that both permanent magnets and induced magnets are corrected. The method used is the single turn at a constant rate and this rate should be in range 60 to 180 seconds for the full 400 degrees needed. The whole arrangement is turned at constant angular velocity because the method relies on applying a correction when the heading measured is uneven with time.

There is another method, which Autonnic has evaluated, which is to treat errors as arising from distortion due to magnetic objects. This is the classical compass swinging approach. The ideal error plot is a circle with no offset from the origin. Permanent magnets ('hard') have the effect of shifting the centre from the origin and induced magnets ('soft') modify the circle into an ellipse. Then results of our investigation show that there is always a residual error due to magnetic objects behaving exactly according to the model outlined. Autonnic are aware that the need for a constant angular velocity is onerous but it provides very low residual error – less than 0.5°.

Note that the calibration is different if the unit is mounted upside-down and must be done with the unit in its final mounted position. The essential point of the calibration is remove the influence of external magnetic components in the vicinity – the nearby pieces of iron and steel.

The output /CE is asserted low during this process and is provided so that the status can be monitored. /CE can be used to operate an LED drawing a current of not more than 20mA from a +5v (maximum) supply.

4.4 Aborting a bad calibration.

If the process is faulty in any way – such as would happen if the manoeuvre cannot be completed, the process can be terminated by the NMEA command listed and the original factory default (linear) table is restored.

The status is available either:

- by observing the /CE pin (If this process does not succeed the pin will toggle at approximately 0.5s low and 0.5s high).

OR

- by sending a NMEA request (see section 5). The reply will supply information about the cause of a terminated calibration.

4.5 Calibrating the Inclinometer

This is done with a utility. As with the compass it must be done either right-way-up or upside-down; the calibration for one is not valid for the other. It should not be done inside the final device but on a precision rig which can level and tilt the board with precision. Each unit come factory calibrated and can be purchased as Up or Down. NOTE that the compass calibration does not affect the pitch and roll calibration.

5 NMEA-0183 inputs

The compass can be configured by sending various proprietary sentences to its NMEA-0183 input. Once configured, the compass will remember those settings every time it is powered up.

In the list below the **`normal case`** denote input and the ***`italic case`*** denotes output.

Start Compass Auto-Calibration: Refer to section 4.2. Same as asserting **/AC**

`$PATC,IIHDG,IAC<CR><LF>`

Abort Compass Auto-Calibration: Refer to section 4.3.

`$PATC,IIHDG,XCL<CR><LF>`

Reset compass to factory default: Resets all compass data to factory default values:

`$PATC,IIHDG,OCV<CR><LF>`

Output rate = 100 milliseconds (10 updates/second), output damping = 50 percent, heading offset f= 0 degrees.

Set Reference 'NORTH' heading: Where f is in degrees with a valid range of 000.0 to 359.9

`$PATC,IIHDG,AHD,fff.f<CR><LF>` When f = 000.0 the result is the same as asserting **/SZ**

Set Output update period:

`$PATC,IIHDG,TXP,x.x<CR><LF>`

Valid range is 100 to 3000 milliseconds. This is limited by the maximum data rate of NMEA-0183 output at 4800 baud.

Set pitch roll damping value:

`$PATC,IIHDG,PRD,ddd<CR><LF>`
(replies with the standard acknowledge sentence) where **ddd** is the damping value from 0 to 100 (%).

Set pitch and roll as zero degrees **ie zero inclinometer:**

`$PATC,IIHDG,ZPR<CR><LF>`
`(replies with the standard acknowledge sentence)`

Set pitch roll factory calibration data value:
NOTE this is a factory calibration and should not be changed.

`$PRCALI,XXXX,YYYY,FFFF<CR><LF>`
(replies with the standard acknowledge sentence.

where
XXXX = (1 sign + 13 bits) 2's complement X(pitch) factory zero adjustment value
YYYY = (1 sign + 13 bits) 2's complement Y(roll) factory zero adjustment value
FFFF = (16 bits) adjusted Tilt curve scale factor value
[All values are in special ASCII (i.e. CHR(30 - 3F) corresponding to Hex 0 to F and have to be generated by the proprietary calibration software]

Response:

When any of the above input sentences are received the A4020 will reply with an 'acknowledge' output sentence of the format:

$PATC,HCHDG,ACK<CR><LF>
If any command is not understood the serial reply will be ***$X<CR><LF>***

Request Status: Read out the last compass auto-calibration status.

$PATC,IIHDG,CEC<CR><LF>
The response is a proprietary sentence containing a code, **k**, for the status:

$PATC,IIHDG,CEC,k<CR><LF>

k=0 the last auto-calibration was successfully completed.
k =1 Resetting the calibration data to factory default was completed successfully.
k =2 The autocalibration has been aborted internally due to the rotation being too slow.
k =3 The autocalibration has been aborted internally due to the rotation being too fast.
k =4 The autocalibration has been aborted internally because of rotation inconsistency.
k =5 The autocalibration has been aborted by an external command.

Report unit's serial number:

$PATC,IIHDG,RID<CR><LF>

A special proprietary reply sentence follows:

$PATC,IIHDG,RID,ssss<CR><LF> where **SSSS** is the serial number in ASCII decimal.

6 References

1 A4020 data sheet
2 NMEA-0183 specification

Autonnic Research Ltd Tollesbury Essex CM9 8SE UK
www.autonnic.com www.fluxgateworld.com