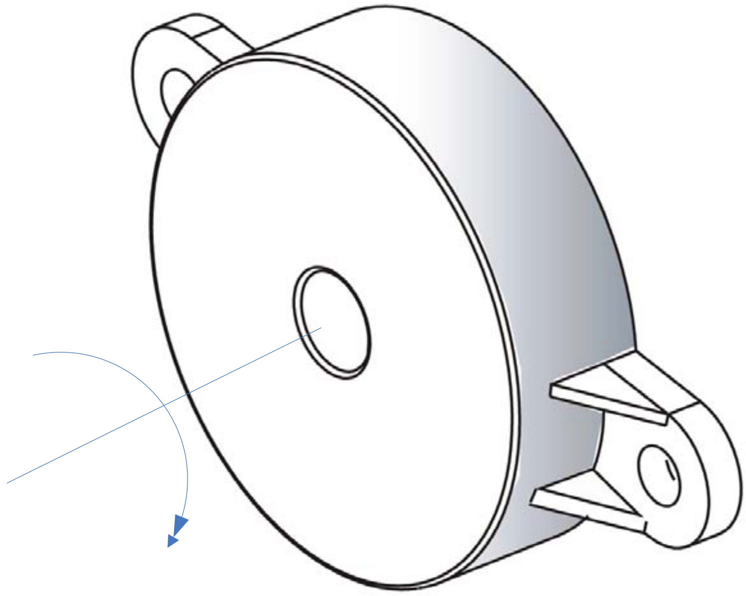
MANUAL FOR A3030 SERIES ENCODERS



**Draft**

**CS**

**11 October 2006**

# CONTENTS

# 1 Summary of the encoder and its applications

## 1.1 Basic Purpose

The A3030 series of encoders is designed to fill a gap between the precision of optical encoders and the simple robustness of Hall-effect sensors. The encoders are precise to 1 part in 1000 (10bits or ±0.3°) and can resolve to 1 part in 4000 (12bits or ±0.1°) at shaft speeds up to 100rpm. They can operate in a chemically hostile environment or where there is liquid under pressure or dust or where a metal casing with shaft seals would present problems. Its life is likely to be well in excess of a decade.

Its attributes are:

- Chemical and mechanical robustness with no metal nor shaft seals
- Indefinite life with no wearing parts
- Non-contact – can operate through non-magnetic bulkheads of plastic or wood or metal
- Absolute angle value (i.e. not incremental)
- Precision and full 360° operation
- Will operate with imprecise shaft alignment
- Output in digital or analogue or both at the same time
- Low cost

*And especially*

- Programmable ‘smart’ commands give pre-processed outputs and decisions:
    - Digital
    - Analogue
    - Set-point
    - Servo

## 1.2 Method of Operation

The encoder senses the direction of a magnetic field. The field is placed in the environment of the encoder usually by a small permanent magnet attached to a shaft. The encoder measures the magnetic angle of this magnet and then performs calculations and logic and transmits answers by both digital and analogue means.

## 1.3 Application examples

Oil or water in tanks – through tank walls
Position of hydraulic systems in waste management
Position of processes elements in chemical or food machinery
Level of hot oil in a machine sump

Engine throttle position command or feedback
Industrial or outdoor command lever controls
Salty angle sensor – trim tabs on boats
Agricultural high dust environments – combined harvesters
Satellite dish positioning systems (eg in Servo mode)

## 2 Connections and definitions

### The Magnetic Field

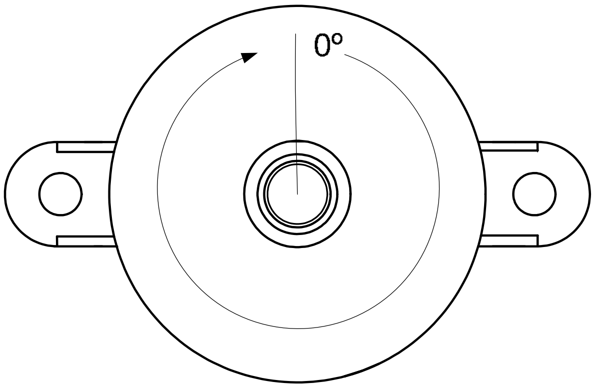
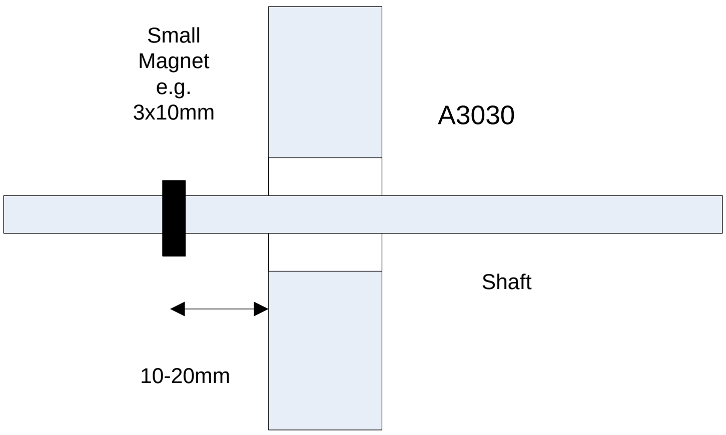



Fig 1 Positive Magnetic Angle increases clockwise when viewed from the top.

We chose the magnetic field to be in the region of 10mT. This design choice is based on the balance between the advantages of a small field and those of a strong field. Such a field is easily set up by a small bar magnet such as AlNiCo 3mm dia x 10mm long and placed about 15mm from the surface.
Ferrite can be used in corrosive environments.




In the above diagram the shaft is shown going through the A3030 but not all applications will need that. The A3030 measures the angle of the small magnet whatever it is attached to and even if it is the other side of a non-magnetic barrier.

All measurements are based on the **Magnetic Angle (MA).**

## Connections

The 5 wires are detailed in Fig 2:

| *Wire* | *I/O/S* | *Colour* | *Function* | *Abbreviation* |
|---|---|---|---|---|
| 1 | Supply | Brown | +ve supply voltage 8-15v | V+ |
| 2 | Supply | Black | -ve supply and signal common | GND |
| 3 | Input | Blue | Serial digital command input | SI |
| 4 | Output | Green | Output A – either serial digital or analogue | A |
| 5 | Output | Grey | Output B - analogue | B |

Fig 2 Connection Table

All serial data is asynchonous at 9600b/s and uses the levels 0v(space) and +5v(mark) with 1 stop bit.

# 3 Commands

## 3.1 Basic Form of Command

The commands are serial data strings which the A3030 parses and executes. All strings whether from or to the encoder are ASCII characters and are always at a data rate of 9600.

## 3.2 Structure of Command

A command has a **start**, **operator**, optional **operand** and an **end**. For example:

`$Ae<CR><LF>`

| | |
|---|---|
| `$` | is the start |
| `A` | is the operator |
| `e` | is the operand – there could be several |
| <CR><LF> | the end. |

## 3.3 Execution

Any command is executed shortly after the <LF>. This timing is important as it often involves the Magnetic Angle (MA). In the example above the command is to set the analogue channel A to have an Output Angle of zero *at the MA prevailing when the command is executed.*

There is a delay which is short and varies with what the processor in the encoder has to do and what it was engaged in at the time the command was sent. The safest way to avoid errors is to have MA stationary at the time of the command.

# 4 Mode Non-Specific Commands

The encoder measures a magnetic angle. This is then error corrected and becomes the Magnetic Angle (MA) which is the basis for all the output functions.
The angle sensing process and hence all other processes take place at the Update Rate set by the U command. The encoder takes more supply current at faster rates.
For Servo Mode a rapid rate is probably needed.
For digital display purposes the recommended rate is 3/s.
Very low rates are suited to logging slowly changing systems.

## 4.1 Uu eg `Uc<cr><lf>`

The Update Rate 'u' is sent as a lower case ASCII character which set the magnetic angle sampling rate according to the following table. All values have a basic clock rate of 10Hz and the maximum value is 6553.5s

| u | Rate value | Interval | | Typical Use |
|---|---|---|---|---|
| | units | Decimal | Hex | |
| a | 1 | 100ms | 1 | Servo |
| b | 3 | 300ms | 3 | Digital display |
| c | 5 | 500ms | 5 | Digital display |
| d | 10 | 1s | A | Display (a or d) |
| e | 50 | 5s | 32 | Display (a or d) |
| f | 100 | 10s | 64 | Display and logging –fast events |
| g | 150 | 15s | 96 | Display and logging -fast |
| h | 200 | 20s | C8 | Display and logging -fast |
| i | 300 | 30s | 12C | Display and logging -medium |
| j | 600 | 1m | 258 | Display and logging -medium |
| k | 1500 | 2.5m | 5DC | Display and logging -medium |
| l | 3000 | 5m | BB8 | Display and logging -medium |
| m | 6000 | 10m | 1770 | Display and logging -slow |
| n | 9000 | 15m | 2328 | Display and logging -slow |
| o | 18000 | 30m | 4650 | Display and logging -slow |
| p | 36000 | 1h | 8CA0 | Display and logging -slow |

The A3030 will reply:

**#hhhh** where hhh is the interval in Hex with leading zeros

## 4.2 R

The Request for Serial Number causes the encoder to send a string on Output A of the form:

**#ssss<cr><lf>**

but only if the encoder is operating this output channel as a digital output. If the encoder is currently sending a value the command will be executed at the end of the transmission of this string. Otherwise the Serial Number is sent immediately.

## 4.3 Sssss

The encoder can be programmed with a 4 decimal digit serial number sent as ASCII. The encoder will send **#ssss<cr><lf>** as though it had just been sent an R command but only if the encoder is operating this output channel as a digital output.

## 4.4 Qaaaabbbb

The Q operator commands the A3030 to calculate the checksum ss in its memory between memory addresses aaaa and bbbb inclusive. It will reply:

**#Qaaaabbbbss**

## 4.5 Naaoooopppppqqqqrrrrss

The N operator is for loading the calibration table. It is followed by a two hex digit address (either 0,4,8,C,10,14,18,1C or 20) to show which starting angle the next four data points correspond to. 0° is always 0° and is always the same. The value of aa= 0 is a starting angle of 40°, 4 = 80° and so on. Each 10° point will have a calibration value when all have been sent. The calibration values are oooo, pppp, qqqq and rrrr.
Every time the N command is correctly received the A3030 will respond with **#M.**

## 4.6 K

The encoder will send a string **#Kss** in response to the K command. The string is the 2 hex characters of the CHECKSUM generated from the contents of the calibration table.

# 5 Mode – Digital

In this mode, output A sends serial data. Output A can be either analogue or digital. Output B is always analogue

### 5.1 Dr

After being sent the D command followed by the r operator, Output A will send strings of the form:

**#ddd.d<cr><lf>**

This is the *digital default mode* for channel A with the update rate at u=1, any offset will be cleared and the span set to full 360°.

### 5.2 Dm

This is for the servo mode and the A channel responds in a similar way to that commanded by the r operator except that the A3030 will respond with an output string in the form:

**$Bddd.d<cr><lf>** NOTE the standard response is **#** not **$B**

The purpose of the m operator is to cause the sending of the data in a form in which a second encoder will accept it as a command for servo slave purposes (**see Section 8**).

### 5.3 Dz

Set channel A to digital zero.
Sets the DA to zero. This is the same as adding an offset i.e.:

DA = MA - offset.

The offset is the value of MA at the instant the command is sent. If the MA was 103.4 at the instant that the encoder received Az then DA = 0 and the value transmitted would be:

**#000.0<cr><lf>**

This value is maintained until changed by another command.

### 5.4 Dc

The current position is used as the digital END point in a CLOCKWISE direction (+MA) from the setting of the START (see 5.3)

The command also sets the DA to 100.0

After being sent the D command followed by the c operator, Output A will send strings of the form:

**#ddd.d<cr><lf>**

Where d is the decimal value of the current Digital Angle (DA) in the range 000.0 to 100.0.

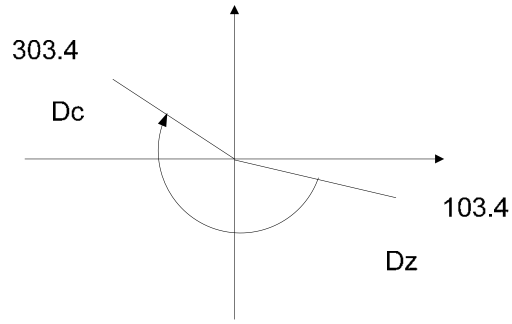
In either case the string is sent at the Update Rate.

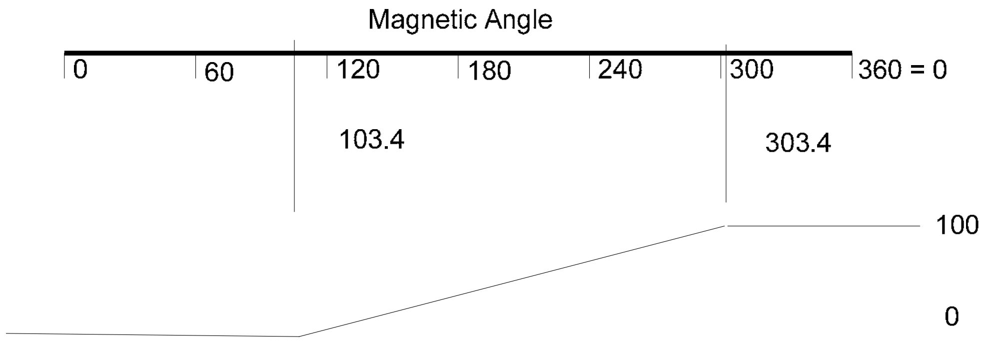
The purpose is to scale the digital output to represent a percentage value for display on panel meters. Also for logging where the angle itself is of no direct interest but its representation as a percentage of some system displacement is.

The 360° digital output is changed so that 100.0 is maintained for increased MA indefinately. Similarly, if the input angle is rotated in the anti-clockwise direction the output will decrease to 000.0 and then stay at this value.

NOTE the EXCEPTION in the case of more than 360° of turn. The A4030 does not maintain a whole revolution count so that all values are internally maintained in MODULO 360 values.

For example:




If the MA for Start (the sending of Dz) was 103.4° and the MA when the Dc was set was 303.4° (this angle having been realised by clockwise rotation) then the scaling will be exactly 1 unit of output = 2° of rotation.

If the shaft is turned clockwise beyond 360°, the output remains at 100 however many revolutions are included. But as soon as the shaft is turned anti-clockwise and reaches 303.4° the output will start to fall.

Similarly if the shaft is turned anticlockwise by several revolutions the output will stay at 0 but will start to rise when turning clockwise after it reaches 103.4°.

## 5.5 Resolution

Note that resolution will change significantly. The MA is resolved to 0.1° and this will represent larger fractions as the range 0 to 100 is compressed to a smaller and smaller physical angle. The minimum range is 10° at which value the resolution is 1°. Such small ranges are not recommended as small disturbances appear significant.

Resolution Table

| Resolution in degrees | DA range |
|---|---|
| 0.1 | 360 |
| 0.2 | 359-180 |
| 0.3 | 179-120 |
| 0.4 | 119-90 |
| 0.5 | 89-72 |
| 0.6 | 71-60 |
| 0.7 | 59-52 |
| 0.8 | 51-45 |
| 0.9 | 44-40 |
| 1.0 | 39-10 |

## 5.6 Da

This is the same as the Dc command except that the digital output from 0 to 100.0 is scaled anticlockwise from the point at which the Dz command was sent. The shaft magnet must be turned to the new position and then the command sent so as to define the MA for the 100.0 value.

After being sent the D command followed by the a operator, Output A will send strings of the form:

**#ddd.d<cr><lf>**

Where d ASCII characters are decimal values of the current Digital Angle (DA) but in an anticlockwise direction from the Start point.

The string is sent at the Update Rate.

The exception of Section 5.4 applies here too.

### 5.7 Dh

This command requests that the A3030 send the current value of the MA in the form:

**#hhhh<cr><lf>**

Where dddd is the hex value of the current MA. It is resolved to 15 bits (about 1 part in 30,000) and so the range is from 0 to 7FFF.

# 6 Mode 2 – Analogue

Note that both Output A can be analogue and B is always analogue. In either case the output voltage range is from 0 (GND) to +5volts. [More precisely the value is resolved to 10bits so the maximum is 4.995v and 1 bit = 5mV]

In the Analogue Mode the voltage always changes linearly with MA –though it could either increase or decrease with respect to a positive MA direction of rotation. We introduce the notional value of Analogue Angle which is a version of the MA and could be offset and or scaled.

## 6.1 Ar
Or Br

For Output A the Ar command changes it from a digital output to analogue. When the command is sent the analogue range defaults to 0 offset and full range. i.e. the output is 0 when the MA=0 and +5v when the MA = 359.9°.

The command Br has the effect of initialising the B output in the same way. Fig 2 shows how either output would behave after the command.

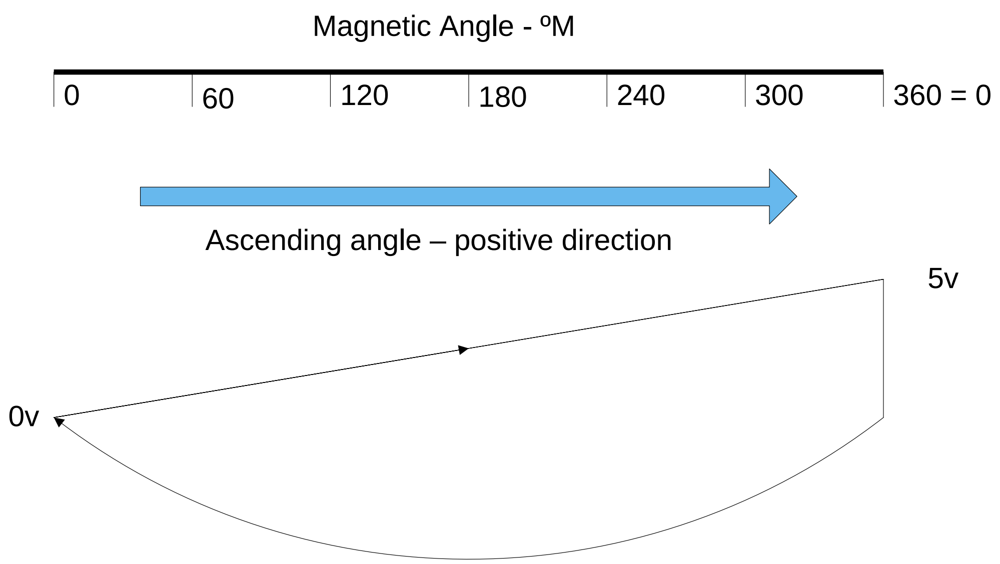



Fig 2 Output A or B before the r operand.

6.2 Az
or Bz

The analogue range is set to start at the value of the MA when the command was executed. Fig 3 shows an example.

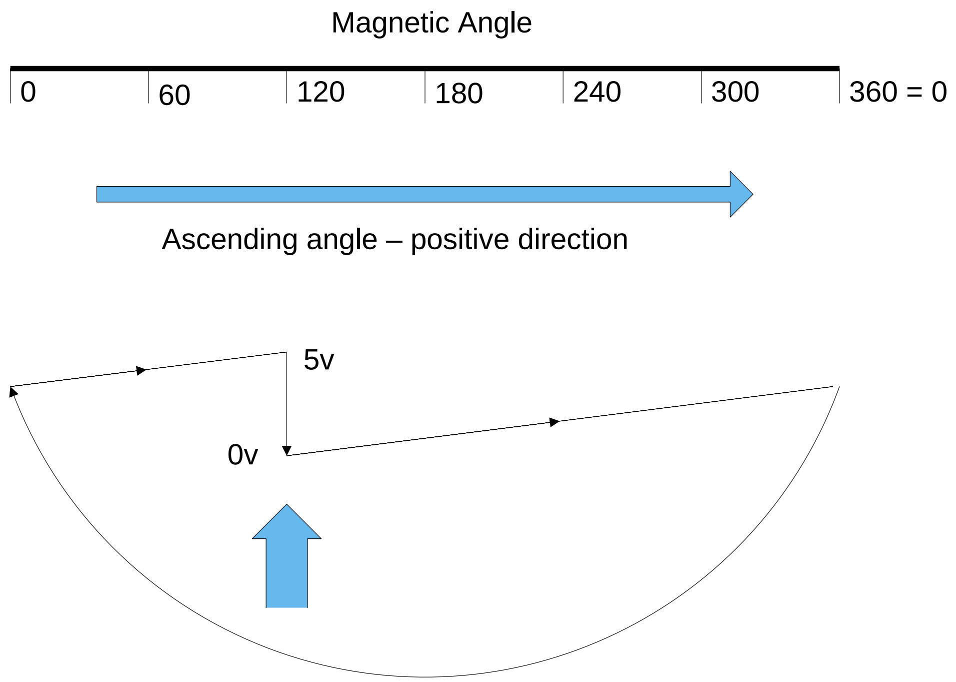



Fig 5 The effect of sending Az or Bz when the MA is 120°

The offset is not dependant on the direction of travel.

6.3 Ac
or Bc

Either output A or B can be set to the maximum value by the ‘c’ operand. The effect is directional. The analogue ramp is rising when the shaft rotation is in the direction of Positive MA – clockwise.

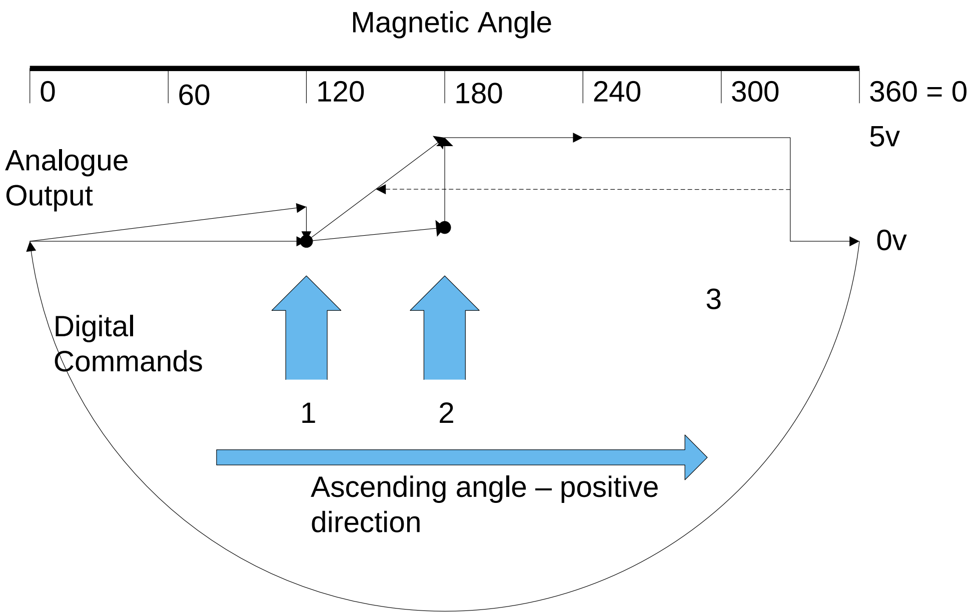



Fig 5 Effect of z and c operators on either A or B

In Fig 5 the shaft is turned slowly in the positive direction. At some time when the MA is 120° the c operator is sent – position 1 in Fig 5.
The analogue value falls to 0v. Further increase in input angle increases the voltage at the original slope of 5v spread over 360°. But when the shaft has turned to an MA of 180° the e operator is sent which forces the output immediately to 5v.

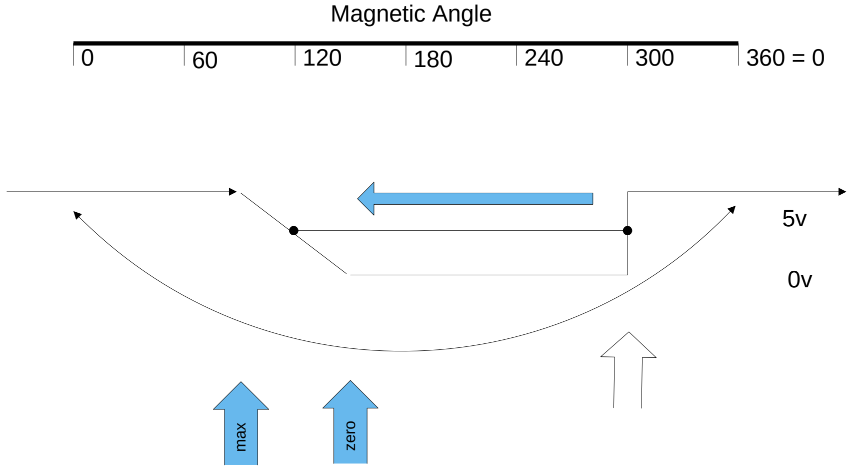
6.4 Aa
Or Ba

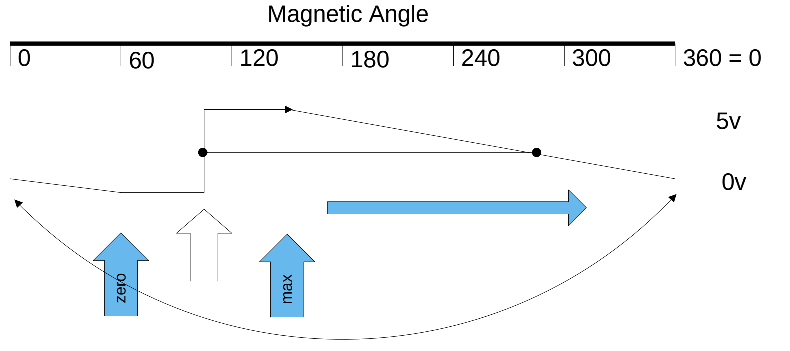
Conversely the ramp is rising with decrease in MA if the ‘a’ is sent following ‘z’ when the shaft rotation is in the direction of Negative MA – i.e. anticlockwise.

## 6.5 Resolution

NOTE that the range of analogue values is compressed to 60° between 120° and 180°. The remainder of the Magnetic circle is handled as follows:
The mid-point is calculated – in this case 150° - and 180° added to it – in this example this comes to 330°. At this MA the Output changes from full (5v) to zero (0v). In this way the analogue output is scaled over a defined range of shaft angle.

Note that the analogue output is derived from a digital value of MA and is resolved to 10bits. This means that the analogue resolution is maintained only as low as a range of 102.4°. Below this range the analogue resolution cannot be matched by the digital resolution and falls. For the example of Fig 5 the digital range for the full expression of analogue values is only 60° containing 600 points; in this case the analogue resolution will be only 9bits as the Magnetic Angle cannot be resolved to 1024 points within this range.



# 7 Mode 3 - Set-Point

The Set-Point Mode is designed for control and limit outputs. Either Output A or B can operate in the Set-Point Mode. The two outputs are independent. Either or both can be set with Set-Point Commands.

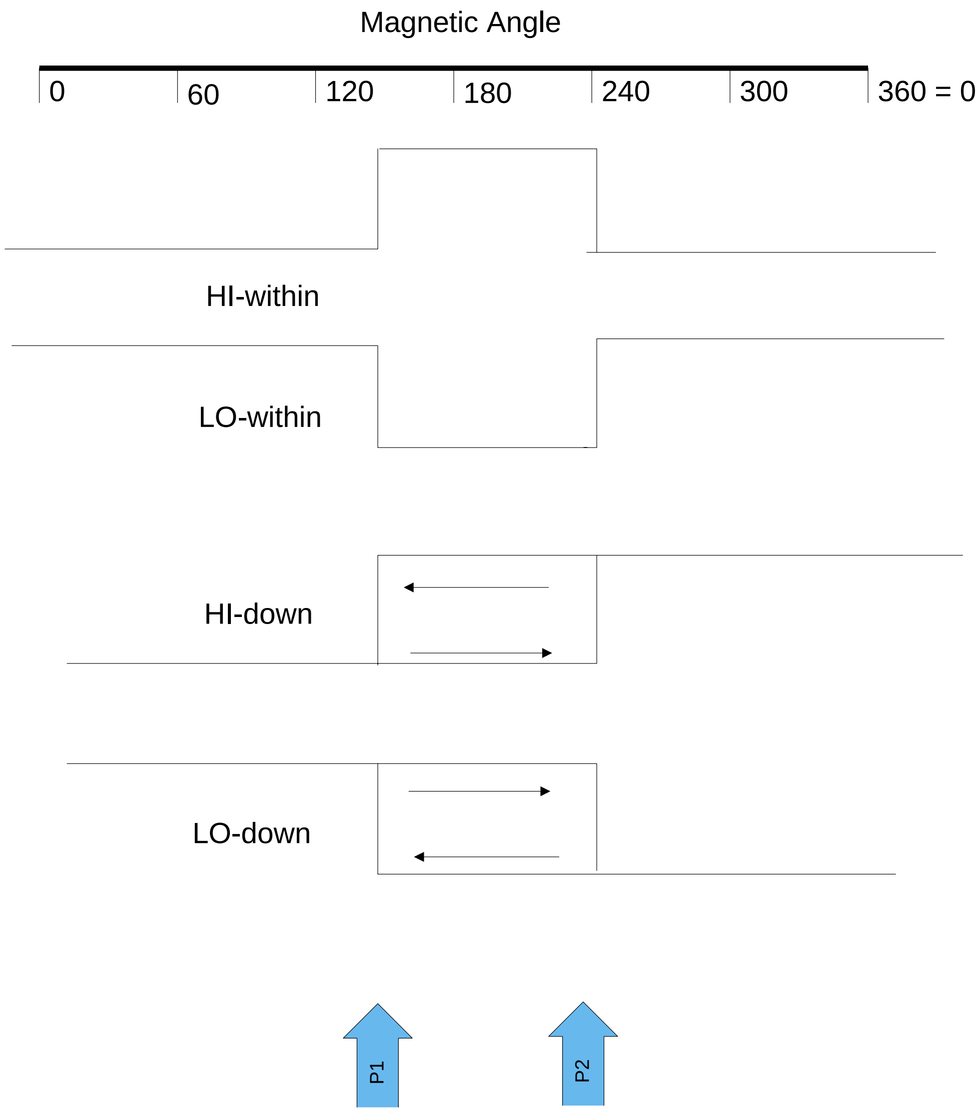



Fig 6 The four sub-modes of Set-Point commands

## 7.1 Start and End

### 7.1.1 As or Bs

The start command is send when the input shaft angle is at the most anticlockwise end of the desired band – P1 in Fig 6.

**Note that the two channels A and B are independent and that the values of P1 and P2 can be different for each channel.**

### 7.1.2 Ae or Be

These are sent to signify that the shaft has been turned to the most clockwise end of the band – P2 in Fig 6

## 7.2 The four set-point modes

SetPoint mode defines the state of an output as one of the following four:

| State | Output A | Output B |
|---|---|---|
| HI-within | Ahi | Bhi |
| LO-within | Alo | Blo |
| HI-down | Ahd | Bhd |
| LO-down | Ald | Bld |

These each describe the state between two points P1 and P2 which are set by sending As or Bs for P1 and Ae or Be for P2.

When MA is at the most anti-clockwise place send the s command to send the channel to P1. When it is in the new more clockwise place send the  command for P2.

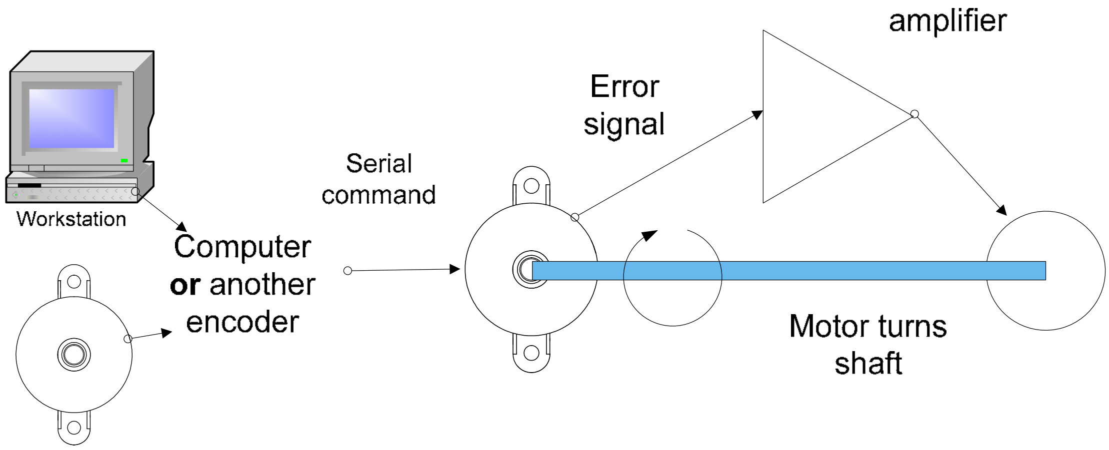
The diagram shows the 4 states which can be expressed as follows:

| | |
|---|---|
| HI-within | HIGH when P1<MA<P2 else LOW |
| LO-within | LOW when P1<MA<P2 else HIGH |
| HI-down | Set LOW when P1> MA<br>Set HIGH when P2<MA |
| LO-down | Set HIGH when MA>P1<br>Set LOW when MA<P2 |

NOTE that in the last two sub-modes there is no change to the output when P1<MA<P2. In this region the value remains as set when MA had a value outside this region.

The purpose is to create **hysteresis** for as the MA falls (anti-clockwise rotation) the output does not change state at the same angle.  This hysteresis is useful in control applications.

# 8 Mode 4 – Servo




The final Mode described is to use the encoder as a Servo Sub-System. The analogue outputs are fixed in this mode. Output B is used to operate a linear type of control and output A serves as a reference mid-point for +ve and –ve control.

The input is a digital value of where the shaft is supposed to be. This data can originate either from a computer or from another A4030.

## 8.1 Bvvv.v

Output B has its mid-scale analogue value set to the digital value of vvv.v. In this case vvv.v is the Magnetic Angle. [Mid-scale is 2.495v]

The purpose is to alter the mid-point so that shaft angles which are either side of the value of v cause the analogue voltage on output B to be proportional to the error angle. The constant of proportionality can be set by a range command – see 8.2.

8.2 B+yyy
or B-yyy

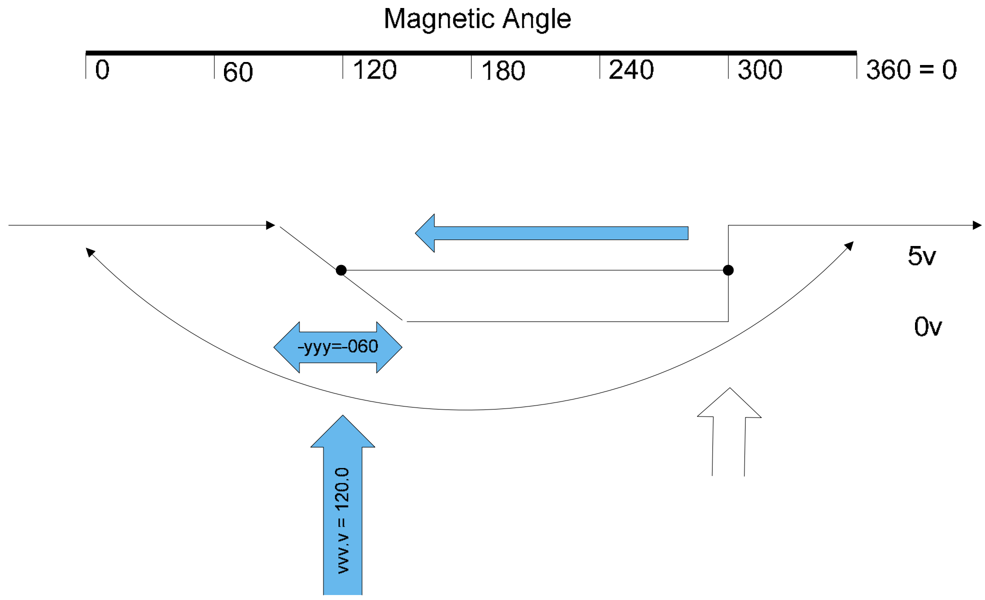



Fig 8 Servo Mode with range set at -60°, centred at 120°

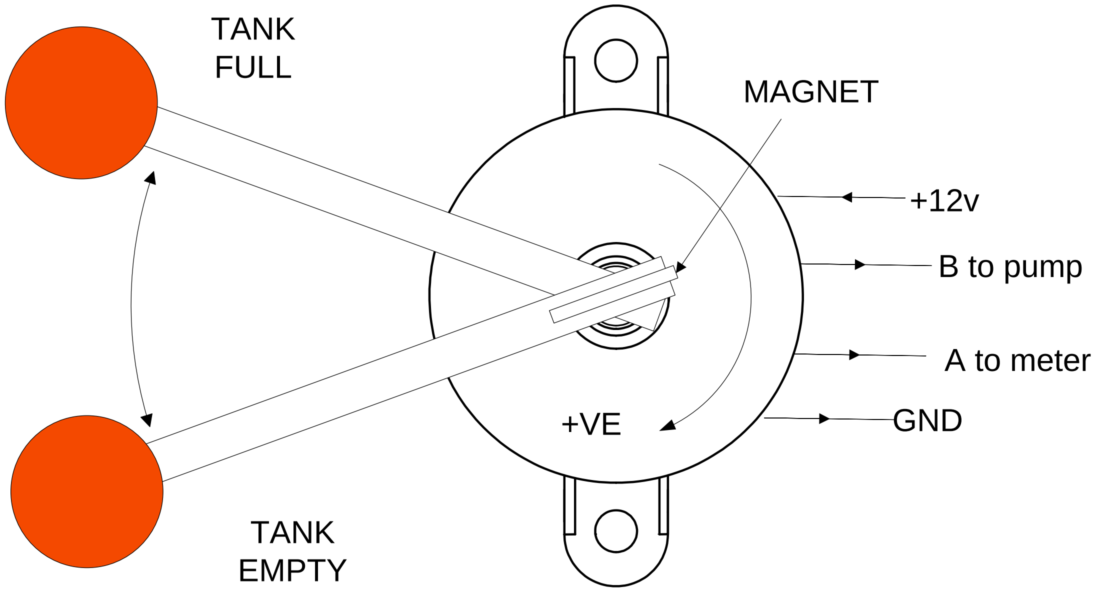
The sign of the range command is to set the slope of the analogue output to be either +ve or –ve with increasing MA. In Fig 8 the –ve symbol has set the output to rise with decreasing MA.
Note that as in the analogue command the output of the B channel changes from 0 to 5v opposite (by 180°) to the v value commanded. In Fig 8 the v is commanded at 120° so the transition takes place at 300°.

8.3 Am

Sets A to a fixed voltage of 2.5 [2.495v]. Used as a mid-point analogue reference for the B output to control the servo-motor direction.

# 9 APPLICATIONS

## Tank Filling




1 Place the float arm at 'TANK EMPTY' and send the commands: **Az** followed by **Bs**

2 Then place the float arm at 'TANK FULL' and send the commands: **Ac** followed by **B1d**

Result 1: Output B goes high (to +5v) when the tank is empty and can be connected to drive a pump. The LO-down programming gives the encoder hysteresis so that the pump goes on if the arm goes below empty and stays on until the tank is full.

Result 2a: Output A is now scaled 0-5v over the normal operating range and can be used to show how full the tank is. Output A will remain at 0v if the tank is less than empty and similarly will not go more than +5v if the tank is more than full.

OR

Result 2b: The A channel could be set so send a Digital value from 000.0 to 100.0 over the same range by sending Dz at EMPTY followed by Dc when FULL

# 10 REFERENCES


1 A3030-00 Data Sheet

2 AN-01 What is a Fluxgate?

# 11 COMMAND TABLE

Encoder software release 0.3
10th Aug. 2006

Serial communication : 9600bps, no parity 8 bits 1 stop bit.
(Please note : a communication interface will be required if connect to a PC.)

All commands and replies ended with CR & LF. All command characters are case sensitive and do not suppress any zero.

**Commands :** **encoder reply :**

$R : send serial number #ssss

$Sssss : set serial number #ssss

$Uu : set update rate #hhhh

$Naabbbbccccddddeeeess : load calibration table #M if data been accepted.
where
aa - start address (in hexadecimal) (0x00, 0x04, 0x08, 0x0C, 0x10, 0x14, 0x18, 0x1C or 0x20)
bbbb; cccc; dddd; eeee 14 bits data (in hexadecimal) for 4 memory locations
ss - 2-character hexadecimal checksum (XOR between $ and ss)

$K : query calibration table checksum #Khh (hex value of checksum)
XOR of memory content of calibration table (i.e. location between 0x1700 and 0x1723 inclusive)

## Ch.A digital output

$Dr : set Ch.A to digital default settings #ddd.d
(#000.0 to #359.9)
(update rate 100mSec, std serial format, reset offset, span 360 degree mode.)

$Dm : $ output format, span 360 degree mode. $Bddd.d ($B000.0 to $B359.9)

$Dz : zero Ch.A / set current position as Start point. #000.0

$Dc : set current position as End point, span CW #ddd.d
(#000.0 to #100.0)
$Da : set current position as End point, span ACW #ddd.d
(#000.0 to #100.0)
$Dh : output MA data (15 bits hex value). #hhhh
(#0000 to #7FFF)

## Ch.A analogue output

$Ar : set Ch.A to analogue default settings (reset offset, span 360 degree mode).

$Az : zero Ch.A / set current position as Start point.

$Ac : set current position as End point, span CW mode.

$Aa : set current position as End point, span ACW mode.

$As : set current position as Start point.

$Ae : set current position as End point.

$Ahi : analogue High within mode.

$Alo : analogue Low within mode.

$Ahd : analogue High-down mode.

$Ald : analogue Low-down mode.

$Am : fix output as 2.5volt.

## Ch.B analogue

$Br : set Ch.B to analogue default settings (reset offset, span 360 degree mode).

$Bz : zero Ch.B / set current position as Start point.

$Bc : set current position as End point, span CW

$Ba : set current position as End point, span ACW

B set-point
$Bs : set current position as Start point.

$Be   : set current position as End point.

$Bhi  : analogue High within mode.

$Blo  : analogue Low within mode.

$Bhd : analogue High-down mode.

$Bld  : analogue Low-down mode.

## B servo

$Bm  : fix output as 2.5volt.

$B+yyy : set span angle range (do NOT suppress any zeros).

$B-yyy :  set span angle range (do NOT suppress any zeros).

$Bvvv.v : set mid scale angle to vvv.v(do NOT suppress any zeros).
If the span angle range is +, then the span is CW.  If the span angle range is – the the span is inverted for CW direction.

## Error reply

If a command is not accepted, an error code will be sent in the form of $Xa

where a =
- 0   : un-recognise command
- 1   : data missing
- 2   : data out of range / program address too low
- 3   : data out of range / program address too high
- 4   : data value error / program sentense checksum error
- 9   : programming write error.

*End*
*CS*