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35 HA

Optical Absolute Encoder

User Handbook

Industrial Components Group

CONTENTS

INTRODUCTION

THE 35HA OPTICAL ABSOLUTE ENCODER

This 20 bit absolute encoder has been designed with the computer user in mind. It is however straightforward to interface the 35HA to traditional hardwired logic and descriptions of how to do this are given in sections II and III. For users who do not which to become involved in the design of the electrical interface and power supply, an interface box is available. This will handle up to seven encoders and display their position in angular units, on its own display or on a remote display and will also interface in a simple manner with other systems.

GENERAL DESCRIPTION

The encoder 20 bit output is made up of two sections:– (a) The most significant bits are from an absolute encoder. (b) The least significant bits are from a sine wave encoder which produces sine and cosine signals as a function of the shaft position. These sine and cosine signals are fed into a microprocessor which calculates where in the waveform the encoder lies. The absolute data and sine wave data are then combined by the microprocessor into a twenty bit data word (See Fig.1). It is necessary to exercise the encoder over a few degrees at switch-on to achieve full accuracy, because of the way in which the sine wave encoder operates.

In high accuracy measuring devices a problem exists in predicting the delay time through the system. This encoder solves the problem by allowing the user to sample the current position of the encoder without the need to latch externally. This frees the system designer of much of the responsibility for real time control.

In many applications it is important to know the level of confidence that can be placed in the measuring device. A faulty device may allow a machine to exceed its safe limits of operation, or an expensive component that is being machined may be damaged. Many designers are therefore forced to add limit switches or to include a back-up measuring device. In the 35HA encoder this problem is solved by incorporating self testing features which generate an error code should the present readings be unreliable or the device fail to function.

It is essential to use a digital serial format to transmit 20 bits of data and 4 bits of error code over any significant distance, since parallel working would be unwieldy when handling this amount of information. When using a serial link at a high data rate the time delay penalty introduced is not significant when compared with other delays in the system.

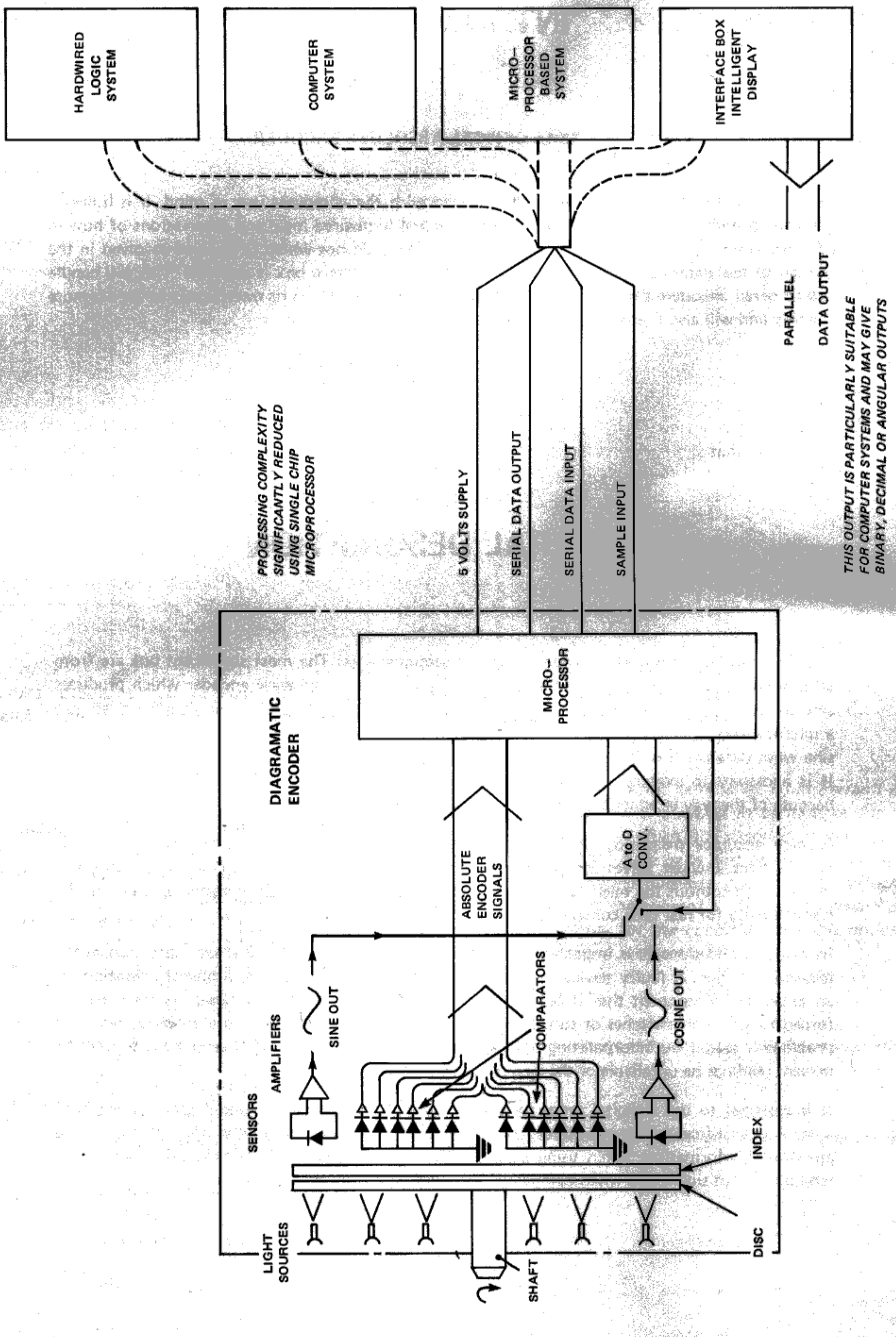


FIG.1 ENCODER PRINCIPLE OF OPERATION

I MECHANICAL DETAILS

I.0 Introduction

The 35HA encoder is a high accuracy, rotary optical measurement instrument which can resolve to 1.2 arc seconds, repeatable to 5 arc/sec and is accurate to 10 arc seconds. It is essential therefore when designing a system which uses this encoder to its full accuracy, that care is taken in the mounting and driving of the device. The effects of thermal expansion, vibration and torsional windup may otherwise falsify the final measurement. If the full resolution of the 35HA encoder is to be used, then these effects are even more important.

I.1 Encoder Drive System

Care must be taken to make the drive system torsionally stiff so that the torque of the encoder bearings of 100gm cms (1.4oz ins) and the acceleration forces required by the inertial mass of the encoder and associated drive system do not cause significant wind up. It is recommended that shafts should be at least 12mm ($^3/_8$") diameter and less than 100mm (4ins) long. Thick wall tube of substantially larger diameter is to be preferred. The wind up due to the maximum bearing torque, of a 12mm shaft 100mm long is approximately 2 arc seconds.

I.2 Couplings

The drive should be connected to the encoder by a compliant metal bellows coupling. This type of coupling copes with axial and angular misalignment, and should be fitted so that it does not load the shaft by more than the values given in the specification: PYF 900).

The torsional stiffness of bellows couplings is normally specified and this allows the errors expected from the torsional loads to be predicted. The torsional stiffness can also be taken as a guide to the errors that can be expected from coupling misalignment, errors that are unfortunately not specified by bellows coupling manufacturers.

I.3 Wind up Error

It is adviseable to calculate the allowable compliance for each system, using the equations in Table 1, the encoder torque and angular inertia, in conjunction with the likely maximum angular acceleration and the bellows coupling data. Utilisation of the full resolution will normally mean that the total compliance of the drive system and coupling should not exceed 0.6 arc secs/100g cm (0.43 arc sec/oz in) and the angular acceleration, assuming that the angular inertial of the encoder is the main component, should not exceed 2 radians per second per second. (95 r.p.m. per second) respectively. If higher angular accelerations are experienced when high accuracy is required then stiffness should be increased accordingly.

Table 1

Typical Parameters	Practical metric units	Imperial Measure	S.I. Units
Bearing Torque	100 g cm	1.4 oz ins	.0098 NM (Newton metres)
Inertial mass	400 g cm^2	2.2 oz ins^2	40X10^{-6} Kgm^2 (kilogram metres ^{2})
Resolution Angle	1.2 arc seconds	.00033 deg.	2.18 μR (micro radians)
Angular speed	60 r.p.m.	1 r.p.s.	6.3 RS^{-1} (radians per sec)
Angular acceler.	60 r.p.m.p.s.	1 r.p.s.p.s.	6.3 RS^{-2} (radians per sec^2)
Compliance	1 arc sec/100 gm cms	0.71 arc sec/oz in.	0.49 mR (NM)$^{-1}$ (milli radians per Newton metre)

I .3.1 **Equations (in S.I. units)**

Wind up Torque (NM) = Inertial mass (Kg M^2) X Angular acceleration (RS^{-2}) + Bearing torque (NM)

Wind up Angle (R) = Wind up Torque (NM) X Coupling and drive system compliance (R $(NM)^{-1}$)

I .4 **Mounting the Encoder**

The encoder should be fitted firmly to a rigid flat face. This should align the encoder shaft and the rotational axis of the device to be measured within the limits demanded by the bellows coupling. To assist in this there are four flat mating surfaces square to the encoder shaft, at the fixing holes, and a spigot diameter that is concentric to the shaft. See specification* for details. All mating surfaces should be clean and flat at the time of assembly to prevent undue buckling of the encoder structure.

In high accuracy systems, the encoder mounting is critical. Unlike the drive system is is difficult to predict the errors that are likely to result from the effects of temperature, vibration and shock and it is therefore adviseable to make the mounting structure as stiff as possible.

I .5 **Vibration and Shock**

Vibration and shock cause errors in two ways. Firstly by creating a sideload on the bearings by accelerating the mass supported by them. This mass is the sum of the bearing supported mass of the encoder and the part of the system coupling supported by the bearings. This sideload may cause the encoding disc to move inside the encoder relative to the reference sensors and cause errors in reading that may lower the operational accuracy level of the encoder, see specification and table 1 for permissible loads. Shock and excessive vibration can result in short term errors that if severe will cause a "Type 0" error to be set in the output data which will clear after 256 encoder cycles, approx 500 mS. (See IV 0.1).

The second source of error due to vibration is when the structural rigidity of either the encoder mounting or drive coupling is not adequate. Most problems are due to the lack of rigidity of the mounting since the masses involved are higher and the attachment usually less direct.

It is adviseable to mount the encoder on a box structure since a plate attached by one or two sides only can result in structural resonance. Resonances can be damped by the use of a compliant but lossy material, such as rubber, in the mounting arrangement and can be prevented by using a naturally "dead" material such as cast iron or granite. Twist of the drive coupling due to the shaft oscillation is unlikely to cause errors since the coupling tends to isolate the encoder from the drive but transverse flexing can change the load applied to the encoder bearings.

The best solution is to isolate the system from any source of vibration of shock.

I .6 **Temperature Effects**

The materials used in the structure should have the same coefficient of linear expansion, and ideally that of the stainless steel of the encoder (11 p.p.m./^{o}C). Differential expansion can cause errors in two ways. Firstly it can cause rotation of the encoder support or coupling, either directly or by redistributing the stress in the structure. Secondly thermal cycling can cause creep of mating surfaces which can change the relative position of the encoder and the drive system. The ideal solution is to operate the equipment at a constant temperature

I .7 **Summary**

The precautions outlined above may appear difficult to meet, but it should be remembered that they only apply when the full accuracy, repeatability and resolution of the encoder are required.

* Specification No. PYF 900

II ELECTRICAL INSTALLATION

II .0 Introduction

The cable from the encoder has ten wires grouped in pairs, surrounded by a screen grounded at the encoder. Two pairs are for power supply use and three pairs are available for transmitting the data from the encoder and controlling it. The encoder requires only a single 5V supply and all data receivers and transmitters conform to RS422A with serial data in a standard UART format.

The cable is fitted with a standard 15 way miniature Cannon "D" connector with jackscrews. See specification for details.

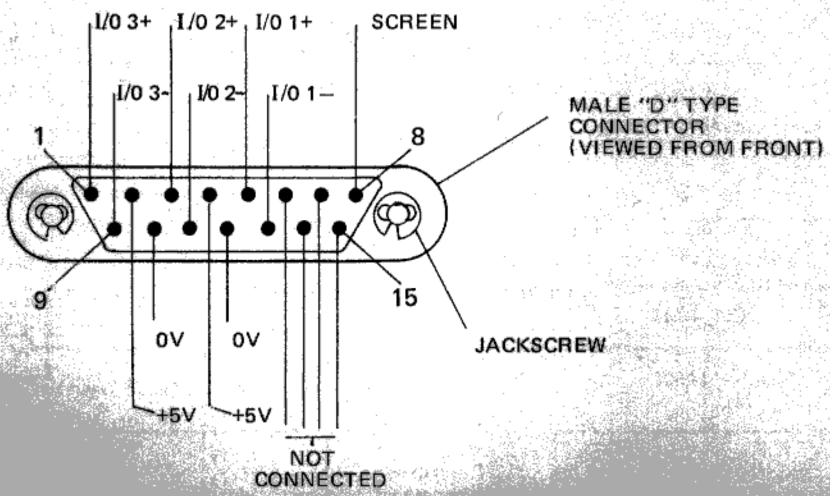


FIG.2 TYPE 'D' CONNECTOR (VIEWED FROM FRONT)

II .1 Power Supply

The encoder requires a 5V supply stable to within 250mV at the encoder and capable of supplying 800mA. The supply must rise from 0.5V to supply voltage within 40mS to cause the encoder to reset.

Standard 7 strand, 0.2mm wire has a resistance of 0.092Ω per metre. The doubling effect of supply and ground gives a voltage drop of about 150mV per metre at the rated maximum current. For this reason the encoder is supplied with two pairs of supply leads linked together in the encoder. These may be used in one of two ways. Either they can be wired in parallel so halving the total wire resistance and hence halving voltage drop, or one pair can be used to supply the power to the encoder while the other pair feeds back to the voltage sense inputs of the power supply. Using the sensing method it is recommended that the power supply incorporates overvoltage protection which operates at 7V to avoid accidental damage to the encoder electronics. The maximum permitted voltage drop in the cable is therefore approximately 1.5V.

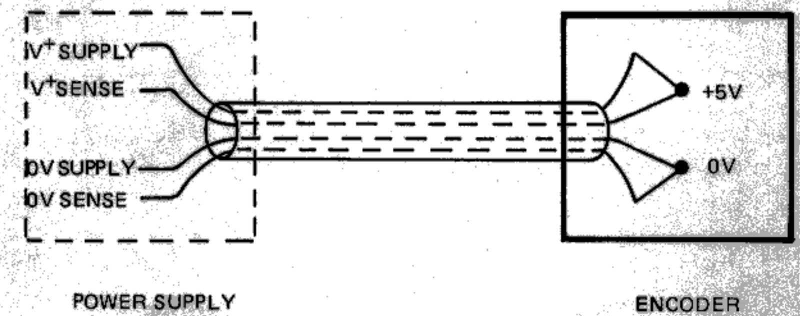


FIG.3 ENCODER WIRING

If power is to be transmitted over any significant distance, and not supplied locally, heavy duty wire should be used.

A multi-encoder power supply may be configured by starring the supply wires and starring the sensing wires from the encoder in one junction box using equal lengths of wires (for equal resistances) to each encoder.

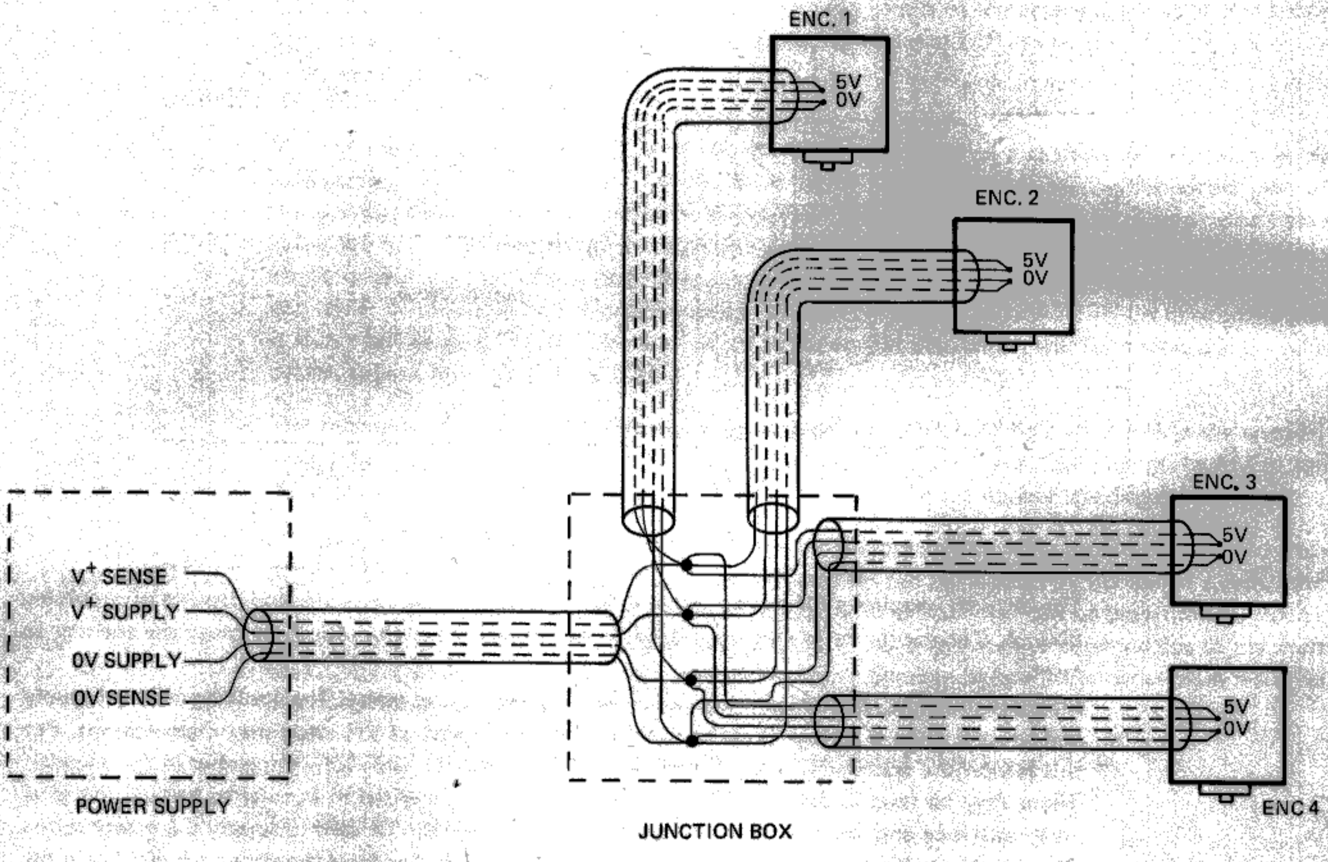


FIG.4 STARRED MULTI–ENCODER POWER SUPPLY

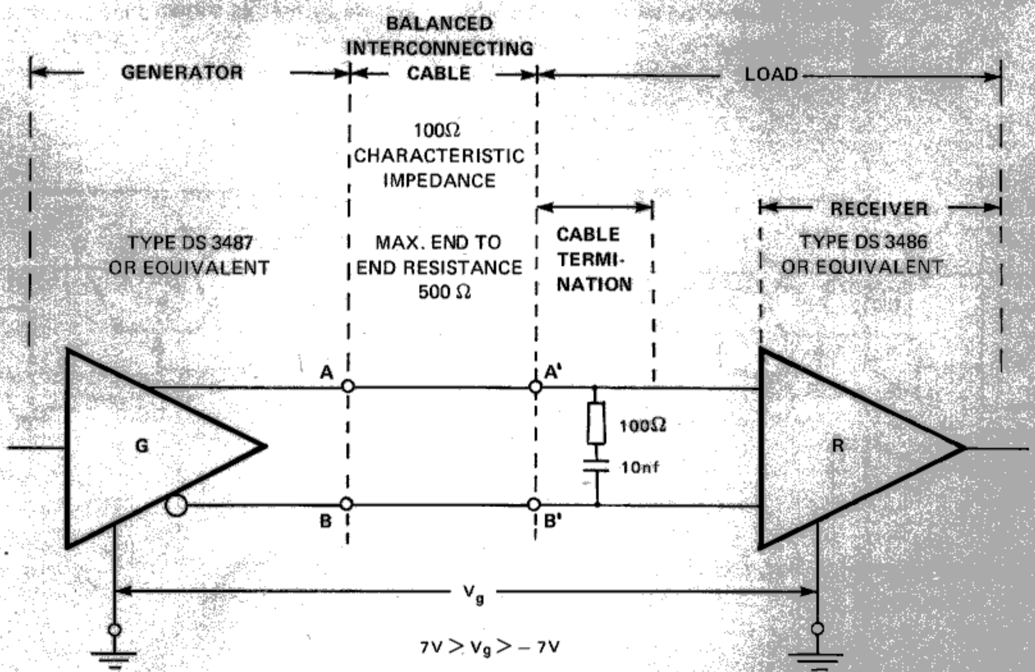
II .2 RS 422A Interface

The encoder is fitted with differential line receivers and transmitters which meet the requirements of RS 422A. This method of data transmission is less well known than RS 232 but it has several advantages, of which the most important are: the use of a single +5V supply, differential driving (which doubles the effective voltage swing), elimination of ground shift, and together with twisted pair cable, cancellation of noise.

High speed data may be transmitted reliably over distances in excess of 1000 metres.

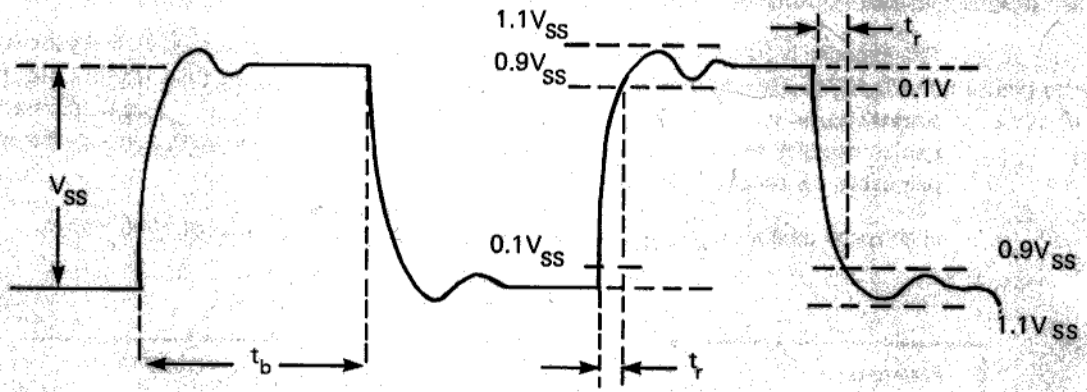
Table 2

Parameter	RS422	RS232
Mode of operation	Differential	Single Ended
Number of drivers and receivers allowed on line	1 Driver 10 Receivers	1 Driver 1 Receiver
Maximum cable length (ft.)	4000	50
Maximum data rate (Baud /sec)	10M	20K
Driver Load	100Ω	3KΩ–7KΩ
Output Load in high 'Z' state	± 100uA max	300Ω
Receiver Sensitivity	± 200 mV	± 3V



V_g = Ground Potential Difference
A, B = Generator Interface Points
A',B' = Load Interface Points

FIG.5 CONNECTIONS AS DEFINED BY EIA STANDARD RS–422A



t_b = Time duration of the unit interval at the applicable data signalling rate

$t_r \leqslant 0.1t_b$ when $t_b \geqslant 200$ns

$t_r \leqslant 20$ns when $t_b \leqslant 200$ns

V_{SS} = Difference in steady state voltages

$V_{SS} = \left| V_t - V_t \right|$

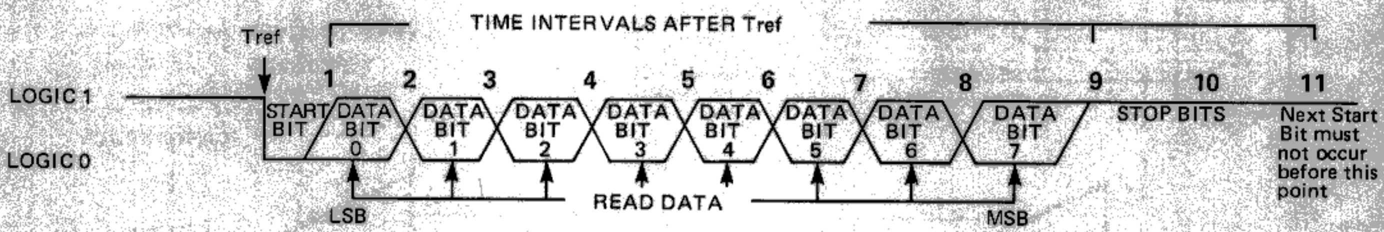
V_t = Differential Voltage $2V \leqslant V_t \leqslant 6V$

FIG.6 SIGNALS AS DEFINED BY EIA STANDARD RS–422A

II 2.1 UART Format

A suitable UART is Intersil Type IM6402.

The data is configured in the standard serial data format as shown below where all time intervals are equal to the reciprocal of the baud rate.



Note that the timing error from Tref. should be < 2%

FIG.7 UART FORMAT

III WIRING UP THE ENCODER

III .0 Introduction

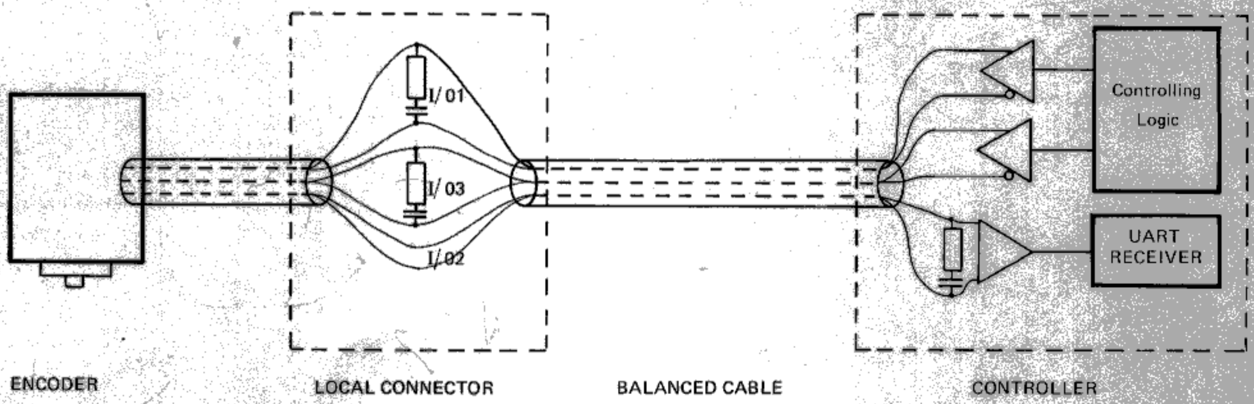
It is recommended that cable of 100Ω nominal impedance be used, as required by RS 422A. If long distances are involved this cable should be special data cable or twisted pair ribbon cable. Over shorter distances ordinary ribbon cable, preferably sheathed and screened, is sufficient provided that signal pairs are separated from adjacent signal pairs by 0V or 5V conductors (see Appendix 2 for suitable suppliers).

If the cable is longer than 3 metres it must be terminated. Termination cannot be provided inside the encoder because of wiring options, and therefore must be fitted in a junction box as indicated in the diagrams. If 100Ω cable is used, the terminating resistors should be 100Ω. A 10nF capacitor has been added in series with the resistors (see fig.5) to reduce the power requirement of the drivers and to prevent ringing without affecting the impedance matching requirements. This capacitor must be fitted when more than one encoder is being used to allow the pull up and pull down resistors to be effective (See III .4, III .5).

III .1 Connecting the encoder in simple mode 1 (see IV .1)

In this mode the continuous transmission of data by I/02 is enabled by I/03.

Switch Positions	C, D, E, F (according to Baud rate required, see table 3).
Cable Requirement	Power supply wires. Two or three balanced pairs of wires depending on whether I/0 1 is being used or not.
I/0 1	Optional sample facility (see IV 0.2). If not used connect the +ve input to 5V and the -ve input to 0V. We recommend that if the power supply uses sense wires, the inputs should be connected to these rather than the supply wires.
I/0 2	Continuously transmits data when I/03 is high.
I/0 3	Enables the transmitting of data by I/0 2.



Notes:

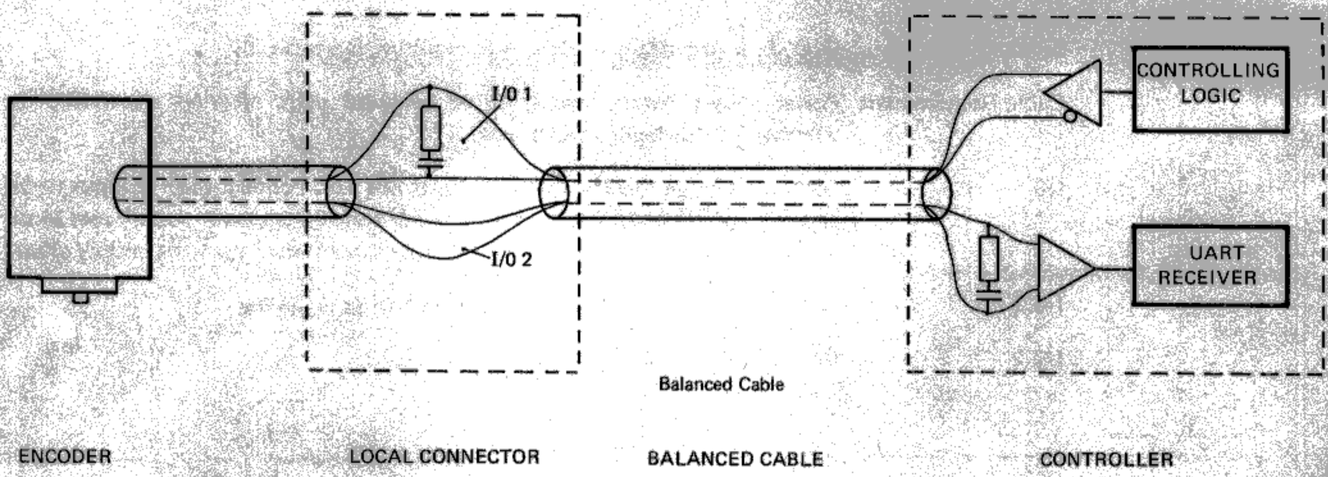
1. *Power supply wires not shown.*
2. *I/0 1 is optional*

FIG.8 SIMPLE MODE 1

III .2 **Connecting the encoder in simple mode 2 (see IV .1)**

In this mode when I/0 1 is switched from logic '1' to logic '0' a sample of the encoder position is taken and transmitted.

Switch Position	8. (See table 3).
Cable Requirement	Power supply wires. Two balanced pairs of wires.
I/0 1	Sample facility (see IV 0.2). Sample taken when I/0 1 is switch from logic '1' to logic '0'.
I/0 2	Transmits data from sample taken when I/0 1 was switched from logic '1' to logic '0'.
I/0 3	Not used. Connect the +ve input to 5V and the -ve input to 0V. We recommend that if the power supply uses sense wires, the inputs should be connected to these rather than to the supply wires.



1. Power supply wires not shown

FIG.9 SIMPLE MODE 2

III .3 Connecting the Encoder in Intelligent Mode, One Encoder (see IV.2)

Switch positions 1 to 7, 9, A, B (according to Baud rate and address, see table 3).

Cable requirement Power supply wires. Two or three balanced pairs of wires depending on whether I/0 1 is being used or not.

I/0 1 Optional sample facility (see IV 0.2) which is enabled by bit 6 of the control byte. If not used connect the +ve input to 5V and the -ve input to 0V. We recommend that if the power supply uses sense wires, the inputs should be connected to these rather than to the supply wires.

I/0 2 Serial output. This output must always be active, this is done by setting bit 1 of the control byte high.

I/0 3 Serial input.

Control Byte

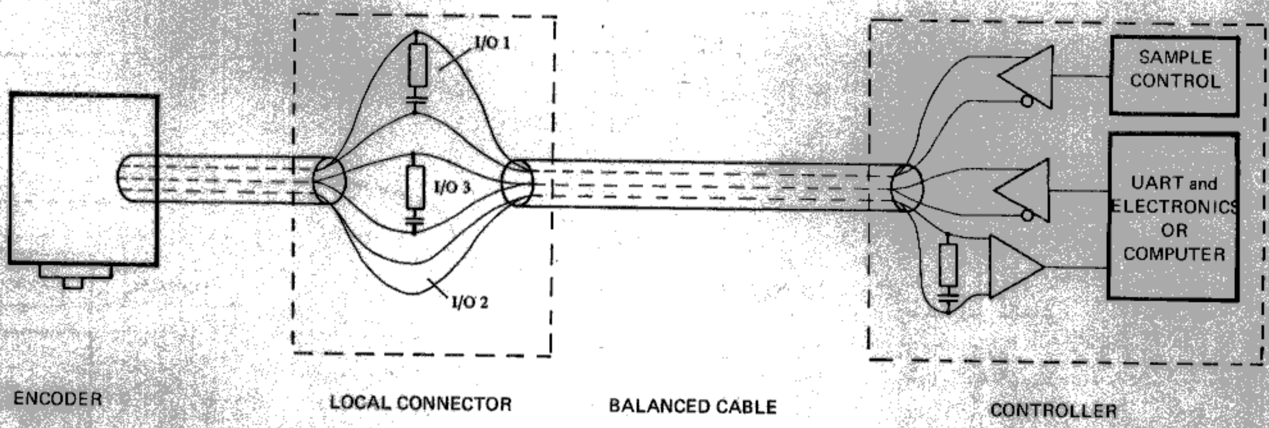
7	6	5	4	3	2	1	0
0	X	0	0	0	X	1	0

X means user-definable

a) Bit 1 must be set high to allow the serial output to be always active.

b) If bit 2 is high a checksum response is sent (see IV 2.3).

c) Bit 6 enables I/0 1.



1. Power supply wires not shown
2. I/0 1 is optional

FIG.10 INTELLIGENT MODE: ONE ENCODER

III .4 Connecting the Encoder in Intelligent Mode, Many Encoders

Note:– *Pull up and pull down resistors of about 1KΩ are required in the controller to prevent false start bits being recognised by the controllers receiving UART. Also the encoders should be as close to each other as possible. If they do have to be some distance apart (>2 metres) extra terminating resistors should be fitted to* I/0 2 *(see Fig.11).*

Switch position 1 to 7, 9, A, B (according to Baud rate and address, see table 3).

Cable requirement Power supply wires. Two balanced pairs of wires if I/0 1 is not used, three if used.

I/0 1 Optional sample facility (See IV 0.2) which is enabled by bit 6 of the control byte. If not used connect the +ve input to 5V and the -ve input to 0V. We recommend that if the power supply uses sense wires, the inputs should be connected to these rather than to the supply wires.

I/0 2 Serial output. Note that pull up and pull down resistors should be fitted at the controller. I/0 2 must be at high impedance when not transmitting data, and this is done by setting bit 1 low in the control byte.

I/0 3 Serial input.

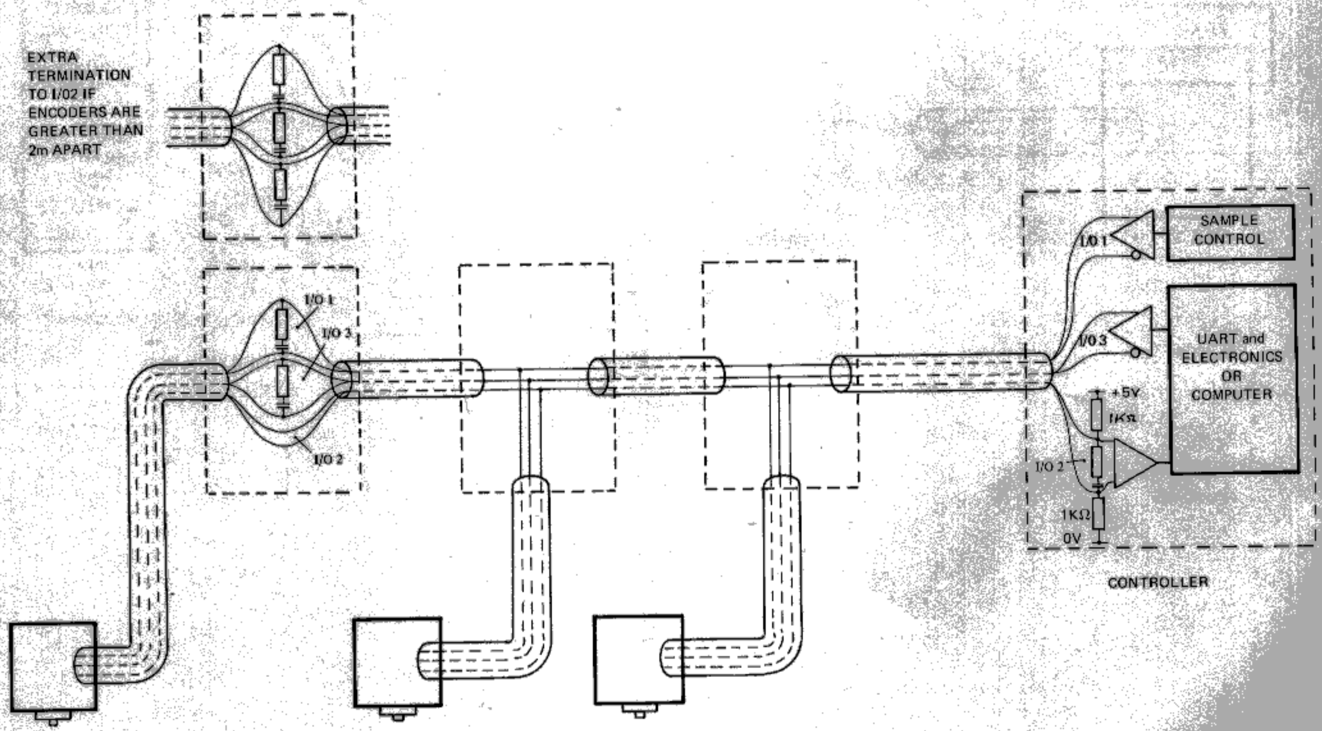
Control Byte

7	6	5	4	3	2	1	0
0	X	0	0	0	X	0	0

X means user definable

a) If bit 2 is high a checksum response is sent (see IV 2.3).

b) Bit 6 enables I/0 1.



1. Power supply wires not shown
2. I/01 is optional

FIG.11 INTELLIGENT MODE: MANY ENCODERS

III.5 Connecting the Encoder in Intelligent Mode, Minimum Wire Configuration

Note:– *The minimum wire configuration is shown below in multi-encoder form. The protocol used allows the data and commands to be multiplexed on the same wires. For this reason the cable must be terminated at each end and fitted with pull up resistors divided between the two ends (see figure 12). This will guarantee that the line stays high when not controlled by an encoder or the controlling device.*

Switch Positions 1 to 7, 9, A, B (according to baud rate and address, see table 3).

Cable requirement Power supply wires. One or two balanced pairs of wires depending on whether I/0 1 is being used or not.

I/0 1 Optional sample facility (see IV 0.2) which is enabled by bit 6 of the control byte. If not used connect the +ve input to 5V and the –ve input to 0V. We recommend that if the power supply uses sense wires, the inputs should be connected to these rather than to the supply wires.

I/0 2 Serial input and serial output

I/0 3 Connected together in junction box.

Control Byte

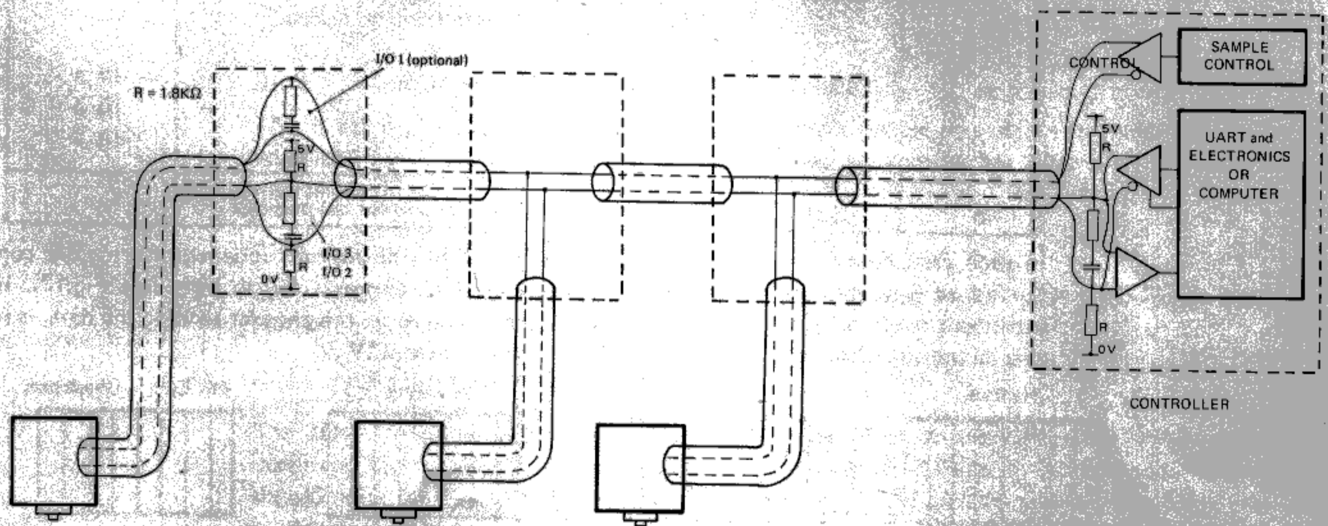
7	6	5	4	3	2	1	0
0	X	0	0	0	X	0	1

X means user definable

a) Bit 0 must be high so that an identification byte is included in any reponse from the encoders.

b) Bit 2. If bit 2 is high a checksum response is sent (see IV 2.3).

c) Bit 6 enables I/0 1.



1. Power supply wires not shown
2. I/01 is optional

FIG.12 INTELLIGENT MODE: MINIMUM WIRE CONFIGURATION

IV COMMUNICATION PROTOCOL

IV .0 Introduction

This encoder can operate with two different communication protocols referred to as "Simple mode" protocol and "Intelligent mode" protocol. The encoder knows which protocol it is dealing with from the position of a hexadecimal switch at the rear of the encoder (see Table 3). This switch is accessed by the removal of a screw. The encoder should be in clean surroundings and the area around the screw be cleaned before the screw is removed to make any switch position change. The screw must be replaced as soon as possible since any particles entering this encoder may affect the accuracy.

Table :– Baud Rate/Interface State/Encoder Address No.
(Switch to change position available at rear of encoder)

Table 3

Switch Position	Baud Rate	Encoder Address No.	Interface State	Wiring up diagrams
F E D C	19,200 9,600 2,400 1,200	– – – –	Simple Mode 1	III .1
9 to B	9,600	1 to 3	Intelligent mode	III .3 III .4 III .5
8	9,600	–	Simple mode 2	III .2
1 to 7	62,500	1 to 7	Intelligent Mode	III .3 III .4 III .5
0	62,500	–	Used by Ferranti for test purposes	N.A.

In each case, data from the encoder is sent out as 20 bits of position code with 4 error bits configured as 3 bytes together with an exclusive– or checksum as a fourth byte (see Fig.13). In intelligent mode only a fifth byte (not shown), which identifies the encoder sending the data, may also be transmitted if requested (see intelligent mode protocol IV .2).

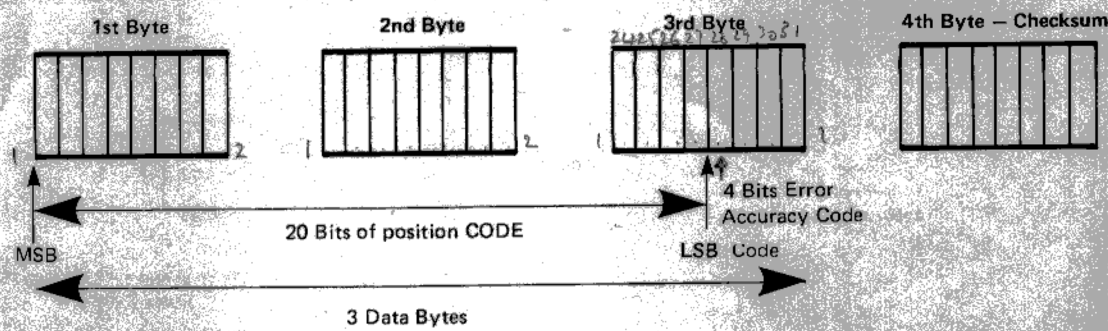


FIG.13 DATA FROM ENCODER

IV 0.1 Error/Accuracy Code

The error/accuracy code is contained in the lower nibble of byte 3. If an error is indicated by bit 3 being high then the 4 least significant data bits are replaced by a fault identifying code.

Bit no.	7 6 5 4	3	2	1 0
	Data if bit 3 low. Error code if bit 3 high.	error	sample	accuracy level;

Bits 0, 1

The encoder gives out a code indicating the accuracy level of the data. See specification for details.

Table 4

Bits 1	0	Accuracy level
0	0	0 Start up
0	1	1 lowest accuracy
1	0	2
1	1	3 highest accuracy

The accuracy code is generated by checks on the waveform from the sine wave encoder. From start up the accuracy level should climb from 0 to 3 as the encoder is exercised slowly. This exercising may be performed over an angle of ±1 degree provided that a total of 5 degrees is moved through.

In most applications the encoder will be operating at less than 10 rpm and hence will be at accuracy level 3. If the speed is increased the accuracy level will decrease one level at a time (see table 4). The accuracy level will increase again as soon as the encoder has rotated through one degree at a lower speed.

A reduction in accuracy level which is not due to an increase in speed may have been caused by vibration or shock (see mechanical details).

Bit 2

This is set if the data transmitted was obtained by a sample instruction (through I/0 1 or by a command byte). This may be used as a check that the encoder has taken a sample when commanded to do so.

Bit 3

Bit 3 is set if an error has occurred inside the encoder, bits 6 and 7 will then contain more information on the type of error and how serious it is.

Bits 4 and 5 are for use during factory testing.

The 35HA continuously checks itself throughout its operation and can decide that an error has occurred. The possible errors are classified into four groups (Table 5). In most applications they should never be seen, the following information is a guide to indicate possible causes and ways of correcting them if they do occur.

Table 5

Bit No. 7	Bit No. 6	Error No.
0	0	0
0	1	1
1	0	2
1	1	3

Error 0 This is the least serious of errors and indicates that only the first ten bits of data are reliable. It may be a temporary fault, due to too much noise getting into the system or to mechanical shock which will correct itself. It this is a common error, check for any sources of noise. The encoder will automatically set error 1 if error 0 persists. Error 0 will normally clear after 256 encoder cycles.

Error 1 This is a more serious error than error 0 and is not self-correcting although the first ten bits are still accurate. A partial reset command, or if this is unsuccessful, a full reset command may eliminate the fault. If both fail the encoder should be returned for examination.

Error 2 This is a run time error and may be caused, for example, by a program crash. No new data is available. Again a partial reset should be tried first (to avoid the need for exercising at start up) followed by a full reset if unsuccessful.

Error 3 This error occurs due to failure of the self test procedure at start up (e.g. due to A–D convertor failure) so that no data is available, the data being replaced by a series of zeros. This may well be due to an incorrect power up time (see II .1) so a reset command should be tried. If this fails return the encoder for examination.

IV 0.2 Sampling

The encoder takes samples of its position automatically every 2 ms with the result ready after 1 ms. A further 0.7 ms minimum is needed to transmit the data at 62.5K baud and, at the more normal 9.6K baud this will be 4.6ms. The data will therefore inevitably be out of date before it reaches the computing device. In slow systems this will not normally matter, but in systems in which a number of encoders inter-relate, or when the shafts rotational velocity is required, the sampling facility of the encoder may be used.

Encoder samples may be taken in two ways. Firstly by a high to low transition of I/0 1 and secondly by a COMMAND BYTE when the encoder is in intelligent mode. In both cases the data resulting from the sample will be identified by bit 2 of the error/accuracy code (See IV 0.1).

The first method gives the highest degree of precision. A delay of between 0 and 6 μs is normal unless the encoder is handling an input command or data output when this figure might, under exceptional circumstances, be extended to 15 μ s.

The resultant reading error can be calculated using the equation:–

$$\text{Reading error (arc secs)} = 21.6 \times 10^{-3} \times \text{encoder speed (rpm)} \times \text{delay time } (\mu s).$$

Which, for example, at 100 rpm with a delay time of 6 μs gives a reading error of just 13 arc seconds.

In the second method, of sending a command byte, the time to process the incoming byte is repeatable to within 6 μs. By sending a "Sample current encoder position" command byte to address 0 a number of encoders can thus be sampled at the same instant to be read later. This sampling method is also useful for accurate speed measurement.

IV .1 Simple Mode Protocol (see III .1, III .2)

The simple mode protocol is configured when the hexadecimal switch at the rear of the encoder is at positions 8, C, D, E or F. (see table 3). If more than one encoder is being used, they must be connected separately. Within this protocol there are two modes of operation; in both cases transmission of data is in the form of 3 bytes followed by an exclusive – or checksum of these three bytes (see fig.13).

In the first mode (configured by switch positions C, D, E, F) data is continuously sent out while I/0 3 is at logic 1 and not when I/0 3 is at logic 0. In this way the byte counters of the receiving computer of electronics can by synchronised with the transmitting encoder. The first byte of data is not distinguished in any way but a correct checksum will indicate that the data is being read correctly.

In the second mode (switch at position 8) a sample of the encoder position is taken as soon as I/0 1 changes from logic 1 to 0 and only the data from this sample is transmitted.

IV .2 Intelligent Mode Protocol (see III .3, III .4, III .5)

General

This protocol is designed to interface one master device with up to 15 slaves. However, if the minimum wire configuration is being used the total number of devices is limited to 7. The protocol relies on the fact that the first byte in any transmission is a form of identification byte which is used to specify which device is being addressed and how many bytes of data are to follow. Simple commands may be inserted directly into this first byte in which case there are no bytes to follow and the transmission is complete. These bytes are referred to as command bytes and are distinguished from identification bytes indicating more data to follow by bit 7 low.

Identification Byte to Encoder
Indicating more bytes to follow
Distinguished from a command byte
by bit 7 high.

Bit No.	7	6	5	4	3	2	1	0
	high	No. of bytes to follow			Device address			

Command Byte Format

	7	6	5	4	3	2	1	0
	low	device command			device address			

IV 2.1 Protocol as applied to 35HA

The intelligent mode protocol is configured by the switch at the rear of the encoder (see table 3). The switch, as well as indicating the mode of operation and baud rate, labels the encoder with an address. When a 62.5K baud rate is being used the encoder can have an address form 1 to 7 at 9.6K baud the encoder only has address 1 to 3 available.

In all the identification bytes and command bytes the address 0 has been reserved as an 'address all encoder' instruction. This facility is useful to set up, reset or sample all encoders simultaneously. However, it must be used with caution in multi-encoder systems because a reply cannot be expected from all the encoders at the same time.

The 35HA expects only one byte to follow the identification byte. This byte is known as the 'control byte' and is used to inform the encoder which options are required.

IV 2.2 Control Byte Options

Table 6

CONTROL BYTE	
BIT NO.	FUNCTION
0	IF HIGH, SENDS IDENTIFICATION BYTE IN DATA RESPONSE AND CHECKSUM RESPONSE.
1	IF HIGH, SERIAL O/P ALWAYS ACTIVE. IF LOW, I/0 2 IS HIGH IMPEDANCE WHEN NOT TRANSMITTING DATA (FOR USE WHEN MULTIPLEXING)
2	IF HIGH, CHECKSUM RESPONSE SENT
3 4 5	NOT USED
6	INPUT I/0 1 ENABLED (INTERRUPT)
7	NOT USED

Bit 0 If several encoders are multiplexed in the minimum wire configuration (see III .5) bit 0 must be set high. This indicates that an identification byte should be sent by the addressed encoder with any of its information (data or checksum).

Bit 1 This must be set high when several encoders are multiplexed and whenever the minimum wire configuration is used (see III .4 and III .5). Otherwise it must be low (see III .3).

Bit 2 If set high the addressed encoder will send back to the controller a checksum of the identification and control bytes it has received. This is a useful check to see that an encoder is responding correctly to commands.

Bit 6 As in simple mode protocol, there is a facility for an immediate hardware sample using I/0 1. Bit 6 enables this facility and allows a change of state on I/0 1 logic 1 to logic 0 to generate an interrupt which will immediately sample the encoder position.

The default value for the control byte at start up is

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

IV 2.3 Checksum Response

If no checksum response is requested (i.e. bit 2 is low) no reply is sent by the encoder on receiving the control byte. If a checksum only is requested (bit 2 high) one byte will be sent in reply, this byte consisting of the exclusive or of the identification byte and control byte received by the encoder. If an identification byte has also been requested (bits 0 and 2 are both high) two bytes of reply will be sent by the encoder. The first byte being a form of identification byte (see below) and the second byte again being the exclusive – or of the identification byte and control byte received by the encoder.

Identification byte from encoder sent when bits 2 and 0 of control byte is high. Not included in checksum

7	6	5	4	3	2	1	0
high	no. of bytes to follow			encoder address +8			

Note that this identification byte reply from the encoder is distinguished from any identification bytes sent by the controller. This ensures that this byte is never read by any encoder as an input command.

Table 7

Input		Byte B		Reply
Identification Byte	Control Byte	Control Byte Bits 0	2	
A	B	0	0	No reply
A	B	0	1	A XOR B
A	B	1	0	No reply
A	B	1	1	Identification Byte A XOR B

IV 2.4 Command Bytes

Command bytes are distinguished from identification bytes by bit 7 low. They are completely self-contained, bits 4, 5 and 6 containing the encoder command and bits 0, 1 and 2 containing the address of the encoder to which this command is destined. As with the identification byte, address 0 is reserved for addressing all encoders simultaneously.

Encoder commands

010	Transmit data.
001	Re-transmit last data.
* 100	Sample current encoder position.
* 110	Sample current encoder position and transmit when data is ready.
011	Partial reset.
111	Reset encoder to start up condition.

* Bit 2 of the Error/Accuracy code will be set to indicate that the data is the result of a sample.

The 're-transmit last data' command '001' is useful when an error has occurred (e.g. a checksum is incorrect) so that data which is the result of a sample instruction (through a command byte or I/0 1 is not lost because of a fault in its transmission. When a sample instruction has been used, a useful check that the data being transmitted is a result of this sample is that bit 2 of the 3rd byte is set (see error accuracy code, IV 0.1).

The 'sample current encoder position' command '100' is particularly useful for multiplexed encoders. If the command is used with an address '0', all encoders will take a sample simultaneously. The 'Transmit Data' command can then be sent to each device in turn to collect the data.

There are two reset commands available to deal with problems with the encoder response. The partial reset command '011' should be tried first. If this fails to correct the problem the reset '111' will have to be used. However it should be noted that since the encoder has now returned to its start up condition, the encoder must rotate through 5^{o} at a low speed to bring it up to its full accuracy level. The reset '111' may also be used at start up to ensure correct start up conditions although this should not be necessary..

In order to make sure that an encoder receives either reset command it is suggested that it should be sent eight times. This will eliminate any problem arising from a misreading of an identification byte containing the number of bytes to follow (the maximum number of bytes to follow is seven).

IV 2.5 Data Response

The data response from a command byte consists, as in simple mode protocol, of three bytes of position code and error bits together with a checksum (See Fig.13). However, now the checksum will not be just the checksum of the three data bytes that are transmitted by the encoder, but also of the command byte originally sent to the encoder. If an identification byte has been requested, this is sent along with the three data bytes, but is not included in the checksum.

IV 2.6 Example

The following example shows the use of intelligent mode protocol in controlling two encoders, ENC 1 and ENC 2.

	Byte 1	Byte 2	Byte 3	Byte 4	
Master to all ENCS	0111 0000				Reset all encoders
Master to ENC 1	1001 0001	0000 0100			Set up control of ENC 1.
ENC 1 to master	1001 0101				Checksum is correct
Master to ENC 2	1001 0010	0100 0100			Set up control of ENC 2.
ENC 2 to master	1001 0001				Checksum incorrect.
Master to ENC 2	1001 0010	0100 0100			Try again.
ENC 2 to master	1101 0110				Checksum correct.
Master to all ENCS	0100 0000				Sample all encoder
Master to ENC1	0010 0001				Transmit data from ENC 1
ENC 1 to master	1100 0110	1000 0000	1101 0000	1001 0001	Data & checksum (incorrect)
Master to ENC 1	0001 0001				Retransmit last data
ENC 1 to master	1100 0110	1000 0000	1101 0000	1000 0111	Data & checksum (correct)
Master to ENC 2	0010 0010				Transmit data from ENC 2
ENC 2 to master	1000 0001	0010 0100	1110 1111	0110 1000	Data & checksum (correct)