RS data

Optical shaft encoder

Stock number 631-632

An optical shaft encoder producing two phase shifted outputs (to enable detection of direction of rotation), plus a sync. pulse once per revolution.

Each output produces one hundred pulses per revolution enabling accuracies of better than 1 degree to be achieved with a suitable decoding circuit.

The encoder can be used in most applications where the position or speed of a rotating shaft needs to be known, such as machine tool control, robotics, position sensors for feedback control on valves etc.

Absolute maximum ratings

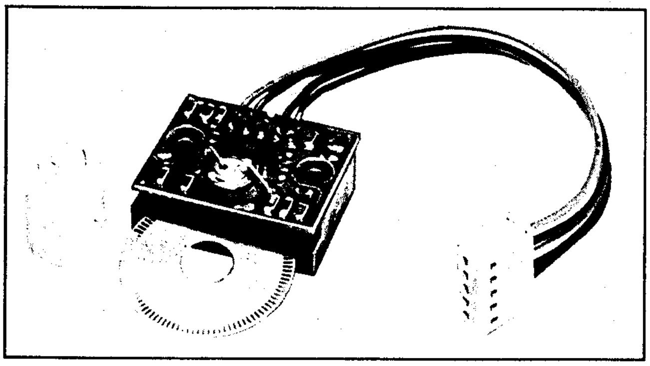
Supply voltage ____ 6V dc
Current consumption ____ 50mA
Operating temperature range ____ 0 to +70°C
Storage temperature range ____ −20°C to +80°C

Connector pin allocations

1. Red (V_{CC}) 2. Black (Ground) 3. Yellow (A output) 4. Blue (B output) 5. Orange (Sync.)

Features

- Can be used to determine speed, direction of rotation or position of a shaft
- Capable of better than 1 degree resolution
- Modular system, can be easily fitted to motor shafts etc.
- Compact size, enabling unit to be fitted in confined spaces
- Uses SMC technology.



Electrical characteristics at 25°C, V_{OUT} = +5V, R_L = 10kΩ

Parameter	Min.	Typ.	Max.	Units
Pulses per output (per revolution)		100		
Phase shift between A and B outputs	70	90	110	°
Output signal A & B (see Figure 1)	1.0			V
Sync. pulse output (see Figure 2)				
Low level			0.5	V
High level	1.0			V
Operating frequency			20	kHz
Equivalent disc speed			12,000	rpm

Mechanical characteristics at 25°C

Parameter	Min.	Typ.	Max.	Units
Allowable run out on disc			0.1	mm
Allowable concentricity disc to shaft			0.1	mm
Disc outer diameter	26.98	27.00	27.02	mm
Disc hole diameter	7.95	8.00	8.05	mm
Disc thickness		0.1		mm
Allowable angular misalignment disc to encoder datum face			5	°
Shaft size (when using the hub supplied)	4.00		6.50	mm
	0.157		0.250	in
Disc material	Stainless steel			
Hub material	Polyacetal homopolymer (Delrin)			

Introduction

The RS shaft encoder kit comprises three parts; the encoder module, disc and a hub.

The encoder contains an LED which acts as an illumination source for the three photodectors providing the A, B and Sync outputs, and an amplifier to produce the output signals.

The very thin, lightweight, disc is the only moving part. The disc contains 100 slots around its circumference which corresponds with the A and B photo-detectors and a single slot which corresponds with the sync. photo-detector.

The hub is made from Delrin and has been designed to accept the disc which should be attached by bonding. The hub provides an easy and convenient method of securing the disc to the shaft, without the need for the shaft to be machined.

The central hole through the hub is 4mm in diameter, this may be enlarged to a maximum of 6.5mm if required. An M3 grub screw is provided to fix the hub to the shaft.

Alternatively the disc may be bonded directly to a suitable dimensional shaft using multibond adhesive.

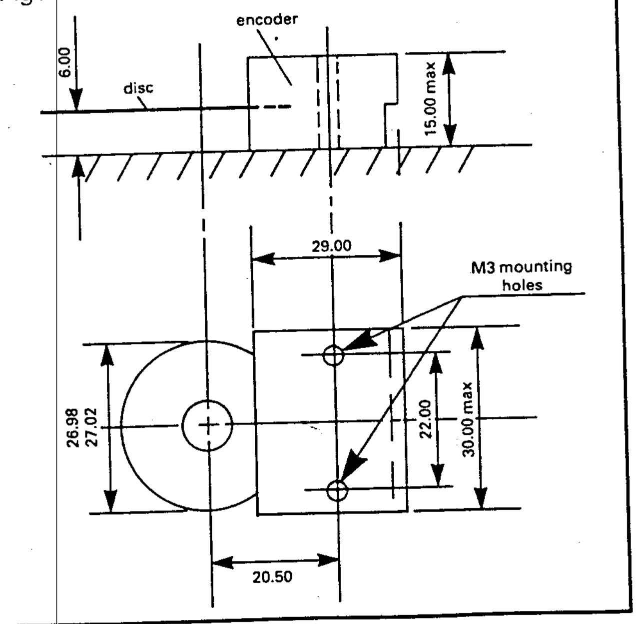
Care should be exercised when handling the disc as damage can easily occur. Under no circumstances should any attempt be made to machine the disc.

The phase angle between the two outputs A and B is nominally 90°C. A leads B when the unit is rotating in a clockwise direction when viewed from the shaft and, if the direction of rotation is reversed then B will lead A. Thus a phase detector can be used to determine direction of rotation, and this information together with a pulse count will give absolute position.

Mounting details

The encoder body incorporates two holes suitable for M3 bolts (as shown in Figure 1) to facilitate encoder fixing.

Figure 1. **Encoder assembly dimensions**



The device must be securely mounted and free from vibration otherwise signal quality and performance may suffer.

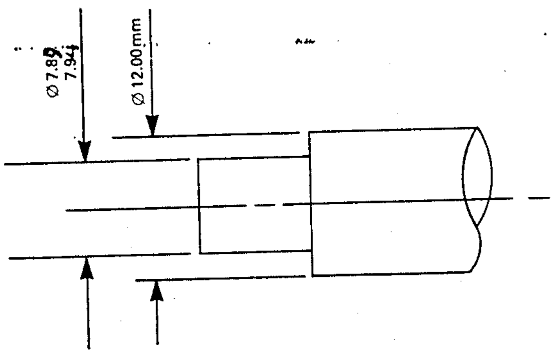
The disc can only be fixed to the hub, or a shaft, by bonding.

For most applications bonding is the easiest and most effective method of fixing as the lightness of the disc will produce minimal stress, even under severe acceleration or braking conditions.

Care should be exercised when handling the disc as damage can easily occur. The bonding method of fixing is outlined later in this Data Sheet.

When directly mounting the disc on shaft the dimensions detailed in Figure 2 should be used.

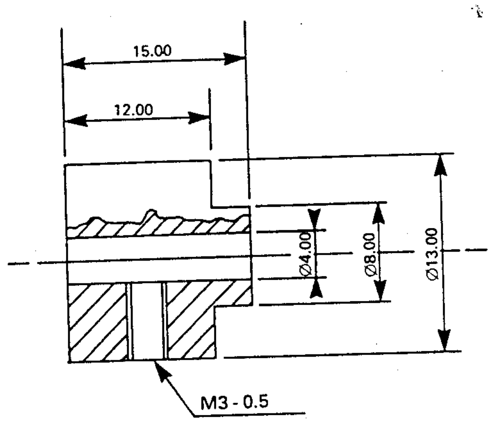
Figure 2 **Shaft dimensions for direct mounting**



The disc must slide easily onto the shaft and a sufficient area should be left to ensure a bond of adequate strength.

The hub supplied has been designed to fit a 4mm shaft but can be machined, to a maximum of 6.5mm, for larger shafts. The hub is made from polyacetal homopolymer (Delrin) which can be machined easily, for dimensions see Figure 3.

Figure 3 **Mounting hub dimensions**



Bonding

Extreme care must be taken during bonding not to damage the disc or get stray adhesive in the slots.

The disc and the hub must be carefully cleaned using a suitable solvent cleaner such as RS 555-134. RS multi-bond acrylic adhesive (555-847) should be used for the joint. Apply a thin coating of adhesive to the Delrin hub and activator to the stainless steel disc. The hub and disc can then be assembled and put aside to set for at least 2 hours.

The joint will only achieve full strength after a period of 24 hours, however, after 2 hours the joint will have achieved approximately 50% of its final strength and may be handled.

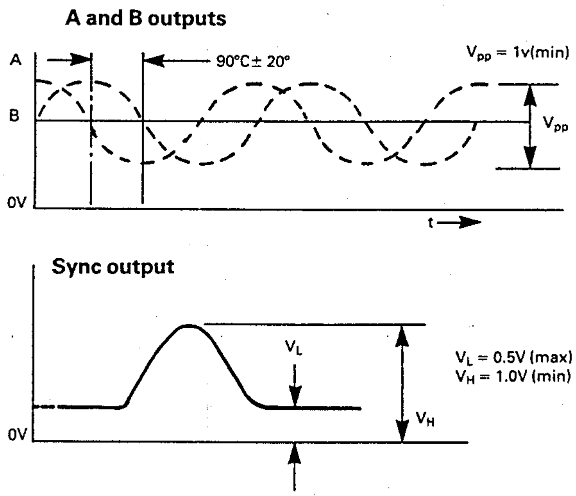
Sufficient adhesive should be used to provide a small fillet when the components are assembled. The excellent peel strength of the multi-bond acrylic adhesive, together with this fillet greatly increase the strength of the joint.

If the disc is to be attached to a steel shaft the same procedure should be used.

Electrical outputs

The electrical output waveforms are shown in Figure 4. The phase relationship between the A and B output waveforms is dependent on the direction of rotation. The frequency of A and B depends on the speed of rotation.

Figure 4 **Electrical outputs**



Moving the encoder relative to the disc will change the phase angle between the A and B outputs. The encoder body, or disc, should be adjusted to ensure the phase difference is as near 90° as possible.

The flying lead is terminated by an inter PCB cable socket and will mate with PCB plugs 467-576 and 468-096.

Application notes

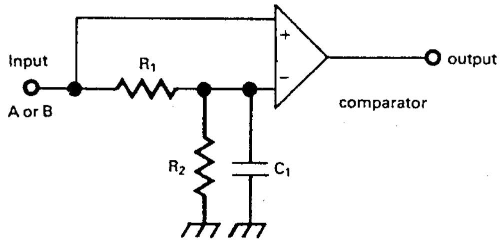
Using the shaft encoder as a speed sensor

Although capable of determining position the encoder may be used as a speed sensor.

The unit produces 100 output pulses per shaft revolution, thus, accurate speed readings can be readily obtained. Additionally the large number of pulses per revolution enables the speed of slow moving shafts to be quickly determined. Figure 5 shows a circuit suitable for this application.

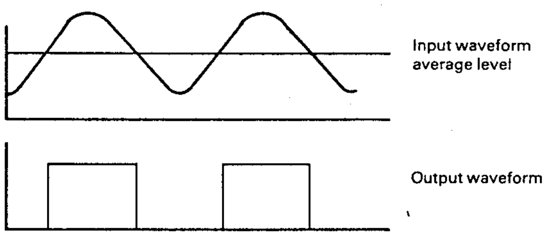
The incoming signal from the shaft encoder is filtered by the low-pass network R_1, C_2 to remove the ac component and leave only the dc level.

Figure 5 **Simple shaft speed decoding circuit**



The signal is then compared with the dc level, the resultant output being a square wave. The square wave will be 'high' when the shaft encoder pseudo sinusoidal output is above the average level as shown in Figure 6.

Figure 6 **Waveforms of input and output in Figure 5**



Resistor R_2 has two functions, firstly it ensures the comparator output is low when there is no input, and secondly, by setting a threshold level it improves noise immunity.

The circuit shown in Figure 5 requires no setting-up, as would a conventional circuit, but it will not work at very low frequencies. This approach would not therefore be suitable for positional sensing.

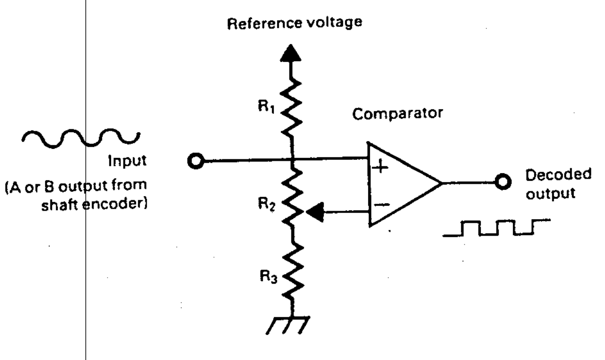
Positional sensing decoder circuit

In order to determine absolute position a circuit which can respond to the level of the A and B signals, down to zero speed, is required.

The simplest way to achieve this is to use a comparator, however, as the circuit must be able to respond to all frequencies a low pass filter cannot be employed.

Figure 7 shows a typical solution to this problem. Resistors R_1, R_2 and R_3 form a potential divider chain which provides a stable voltage equal to the dc level of the output from the shaft encoder.

Figure 7 **Position sensing decoder**



R_2 must be adjusted for optimum performance and a stable reference voltage supply must be used.

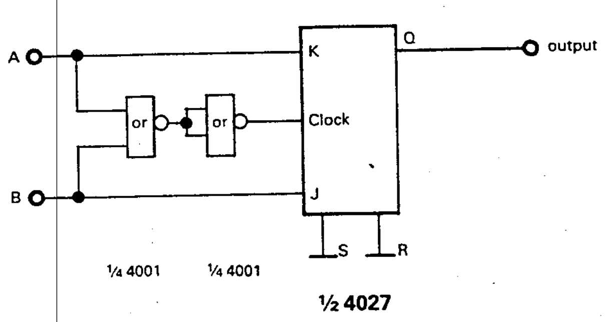
The decoded output pulses can be counted to establish the angle moved by the disc.

Direction indication

In order to determine direction of rotation, the phase lead, or lag, of the A output with respect to the B output needs to be determined.

The circuit shown in Figure 8 is a phase detector making use of the 90° phase difference between the decoded A and B outputs of the encoder, and provide an output indicating direction of rotation.

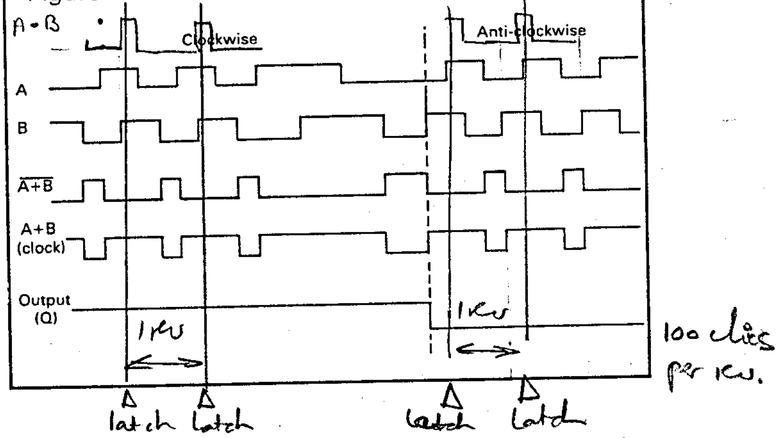
Figure 8 **Direction indicator**



The circuit uses a J-K flip-flop to determine which of the A or B signals goes high first. The clock signal is derived from the A and B inputs via two NOR gates.

Figure 9 shows the waveforms associated with the direction indicator, note that the clock signal remains unchanged when the direction of rotation is reversed.

Figure 9 **Direction indicator waveforms**



From the 4027 truth table it can be seen that the output (Q) will go high if K is high and J is low on the positive going edge of the clock pulse.

From the waveforms in Figure 9 it can be seen that on the positive edge A is high and B is low. As shown in Figure 8 A is connected to the K input of the flip-flop and B to the J input. At this point the output of the flip-flop will be high.

When the shaft is rotating in an anti-clockwise direction output B leads A, thus on the positive edge of the clock pulse J is high and K low making the output low.

The output from the flip-flop can be used to control the count direction of an up-down counter, for determining position.

Although the circuit uses 4000 series CMOS logic, other families may be used.

Improving accuracy

Although the shaft encoder only produces 100 pulses per revolution, the two outputs which are phase shifted by 90° can be employed to achieve accuracies of better than 1°.

This is made possible by counting the edge of both pulses, rather than counting the pulses themselves.

As there are two outputs, each with two edges, four times the number of pulses can be produced giving four times the resolution.

The circuit shown in Figure 10 uses a 4538 dual monostable which incorporates positive and negative edge triggering.

The circuit waveforms are shown in Figure 11.

Figure 10 **Edge detecting circuit**

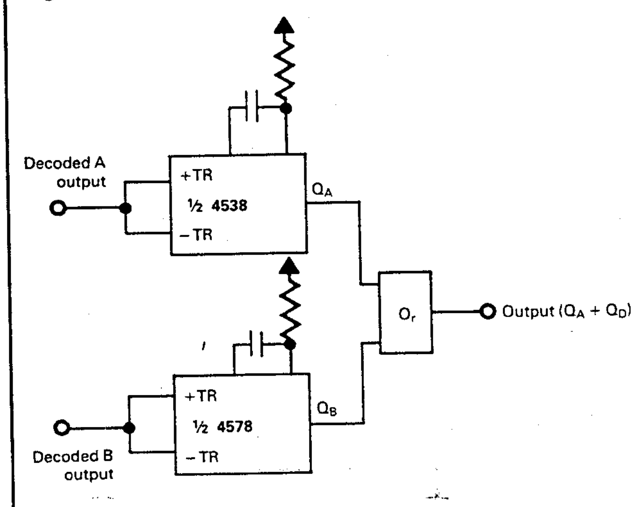


Figure 11 **Edge detector waveforms**