

## ENCODER DATA SHEET

### L690ER OPTICAL RESOLVER® SERIES ABSOLUTE POSITION ENCODERS

#### Features:

- Resolution to 0.077 arcsec (24-bits)
- Accuracy to 0.618 arcsec rms
- LED illuminators
- Wide air gap
- Self-contained electronics
- Serial output with differential driver
- High speed interrogation
- Hand shake interface
- Heavy duty preloaded bearing pairs
- Compatible with BEI's Ultra-Loc® System



#### Options:

- Parallel with or without differential drivers
- Solid, Hollow or Through shaft
- Single 5Vdc input
- Couplers
- Extended temperature
- Vacuum-rated materials

These compact absolute encoders, with a single LED illuminator per station and self-contained electronics, are available from 19 to 24 bits, natural binary code. Every transition is tested on BEI's unique, state-of-the-art, computer based automatic accuracy tester. The L690ER family features high speed interrogation, up to 524,288 Hz, with a handshake interface to eliminate the need for buffer storage. Typical applications include radar, optical and laser tracking systems and astronomical telescopes. Modifications can be made for spacecraft application to incorporate parts, materials and processes with space heritage. Space applications include high gain antennas and payload pointing.

*Approved for general release.*

## SPECIFICATION 5.034A

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## 1.0 GENERAL:

The BEI L690ER Series High Speed Extended Resolution Encoders are absolute position binary encoders providing resolutions to 24-bits and accuracies to 0.618 arc seconds rms in a 6.00 inch diameter package. These encoders are available for operation from +5V and  $\pm 12$ VDC (L690ER) or a single +5VDC power supply (5VL690ER). This encoder series utilizes an extension of BEI's patented Optical Resolver interpolation technique in conjunction with BEI's Dual Ramp Resolver technique to provide the highest resolution in this package size available.

These encoders employ a single coarse LED read station and dual fine LED read stations placed 180 degrees apart to cancel disk runout due to bearing error or shaft loading. All read stations utilize grating optics to provide a minimum of 0.015 inch clearance spacing between the code disk and the optical components, which translates to greater tolerance of vibration and loading.

The L690ER encoders contain all electronics necessary to produce up to 24-bit natural binary output word. Outputs are TTL compatible and will sink up to 12 mA. Data samples are taken at an internal rate 524,288 Hz. A marker signal indicates data updates, rising 0.48  $\mu$ sec prior to and falling 0.48  $\mu$ sec after update. Data may be held to allow for slow transfer by using the HOLD\ and HLDA handshake signals.

## 1.1 DESIGN FEATURES:

- Ultra-high resolution in a 6 inch package. Divides circle into up to 16,777,216 parts.
- Guaranteed monotonic and accurate to specification by 100% testing. Full resolution and accuracy at speed.
- LED optical stations for high reliability.
- Dual read station error cancellation for high accuracy. Available in solid shaft, hollow shaft, or through shaft options.
- 400 Series stainless steel construction.
- Heavy duty preloaded bearing pairs standard on all models.
- Handshake interface eliminates the need for buffer storage.
- High current output drivers standard on all models.
- High speed interrogation — up to 524,288 Hz.

- Low data sampling jitter (120 n sec) to preserve data accuracy during "read-on-the-fly" measurements.
- Available with parallel, serial differential, or parallel differential outputs.
- Available for operation from single 5V power supply.

## 2.0 APPLICATIONS:

An absolute position shaft angle encoder is an analog-to-digital angular measurement device that divides the circle into a specific number of discrete shaft positions. The absolute encoder differs from incremental shaft angle encoders in that it provides a complete digital output word for each discrete shaft position, rather than up/down position. This means that no external memory or counting circuit is required, nor is it necessary to move the shaft to a "home" position after initial power-up to determine actual shaft position.

L690ER series encoders provide binary angular division in the range of 2,097,152 ( $2^{21}$ ) to 16,777,216 ( $2^{24}$ ) positions per revolution, depending on the specific model number. These encoders are intended for applications such as telescopes, mirror positioners, precision grinding machines, angular gauges, or any application requiring ultra high resolution and accuracy.

3.0 REQUIREMENTS:

## 3.1 MECHANICAL:

TABLE 1  
MECHANICAL SPECIFICATIONS

	<u>Solid Shaft</u>	<u>Hollow Shaft</u>	<u>Through Shaft</u>	
3.1.1 Encoder Outline:	Fig. 4	Fig. 5	Fig. 6	
3.1.2 Weight (max.)	9.6	10.1	10.9	lb
3.1.3 Starting Torque (max.)	4.0	6.0	4.0	oz-in
3.1.4 Running Torque (max.)	3.0	4.0	3.0	oz-in
3.1.5 Rotor Moment of Inertia	0.07	0.11	0.08	oz-in-sec <sup>2</sup>
3.1.6 Slew Speed (max.)	15,000	15,000	15,000	rpm (note 1)
3.1.7 Angular Accel (max.)	50,000	50,000	50,000	rad/sec <sup>2</sup> (note 1)
3.1.8 Shaft Runout	0.0005	0.0005	0.0005	in
3.1.9 Shafting Loading, Axial (max.)	15.0	15.0	15.0	lb
3.1.10 Shaft Loading Radial (max.)	10.0	10.0	10.0	lb

Note 1: Maximum velocities and accelerations shown above are mechanical limits. For maximum operating conditions, see Table 2.

## 3.2 ELECTRICAL CHARACTERISTICS:

### 3.2.1 Output Formats:

24-bit (max) parallel w/hold input (single ended or differential pairs)  
 24-bit (max) serial (differential pairs)

#### 3.2.1.1 Outputs, Single Ended:

Logical "1": +2.0 V min @ I<sub>out</sub> = -12 mA  
 Logical "0": +0.4 V max @ I<sub>out</sub> = 12 mA  
 Rise & Fall Times: 100 n sec max

#### 3.2.1.2 Differential (each line):

Logical "1": +3.8 V ± 0.5 V open circuit  
 Logical "0": 0 to +0.4 V open circuit  
 Output Impedance: 75 ohms max

### 3.2.2 Marker Pulse Output, Parallel Options Only:

Pulse Width: 0.95 usec ± 0.1%  
 Frequency: 524,288 Hz ± 0.1%

### 3.2.3 Inputs:

#### 3.2.3.1 Single Ended Inputs:

Logical "0": 0.8 V max @ I<sub>I</sub> = -4.1 mA max  
 Logical "1": 2.0 V min or open circuit (2.0 K pull-up to +5 VDC)

#### 3.2.3.2 Differential Inputs:

Logical "0": -0.2 V min differential  
 Logical "1": +0.2 V min differential  
 Common Mode Voltage: ±15 V max  
 Input Loading: 6.0 K Ohms min in parallel with  
 (0.01 uF in series with 180 Ohms)

### 3.2.4 Power Requirements:

#### L690ER Models:

+5 VDC ± 5% @ 1.5 A max.  
 +12 VDC ± 5% @ 200 mA max.  
 -12 VDC 5°/0 @ 200 mA max.

#### 5VL690ER Models:

+5 VDC ± 5% @ 3.0 A max.

### 3.2.5 Connectors:

(Parallel output):

J1 power DA15P (See Table 3a.)

J2 signal DC37P (See Table 3b.)

(Serial Output):

J1 Signal & Power DB25P (See Table 4)

(Differential Parallel):

J1 Power MS27508E12A35P (See Table 5a)

J2 Signal MS27508E18A35P (See Table 5b)

### 3.2.6 Signal Definitions:

D1-D24	Encoder data outputs, active high. D1 ( $2^{-1}$ rev) is most significant bit (MSB).
MKR	Marker pulse output- indicates data updates. Pulse Width = 0.95 usec. Starts 0.48 usec before data is updated. Inverse of MKR may be used as "Data Valid." Not available with serial output option.
HLD\	Hold input, active low on single ended input models, not used on serial models. Assertion of this input causes a data sample to be taken (indicated by MKR pulse) and the data to be held until HLD is released. Hold will be acknowledged by the HLDA signal going high. Data is sampled between 600 nsec before and 120 nsec after HLD\ goes low, with internal interrogation active, 0 to 120n sec with internal interrogation inhibited.
HLDA	Hold Acknowledge output, active high, not used on serial models. HLDA goes high upon assertion of HLD\ after data sample has been taken. HLDA is reset upon HLD\ returning high. Maximum time HLD to HLDA — 1.55 usec.
READ	Read differential input. (Serial models only) 0.5 fisec pulse on this input starts interrogation sequence. Data may be shifted out on receipt of RDY signal or 1.55 usec after application of READ.
RDY	Ready differential output. (Serial models only) This output signifies that data is ready for output.
DCLK	Data Clock input. (Serial models only) Application of clock pulses on this input causes output data to be shifted out LSB first.

DIR	Direction Control input. A High or open circuit condition on this input causes the encoder to display increasing count in the clockwise direction as viewed from the shaft end. A low causes the count direction to be counterclockwise.
RES	Resolution output. This signal at a logical 0 indicates that the encoder is operating at full resolution. A logical 1 on this line indicates that encoder angular speed exceeds maximum speed for full resolution and that output data are truncated by six bits.
INT\	Internal interrogation control. Not used on serial models. A logic high or open circuit on this input allows the encoder to self interrogate at 524.288 KHz. A low applied to this input will inhibit internal sampling of the encoder. Data samples will then be forced by bringing HLD1 low.
+5V	Power input. Unit requires +5 VDC $\pm$ 5%.
+12V	Power input. Unit requires +12 VDC $\pm$ 5%.
-12 V	Power input. Unit requires -12 VDC $\pm$ 5%.
GND	Ground. Power and signal return.
CASE	Case ground. Should be used for shield termination. Must be connected to GND at one point in the system. Case ground is isolated from GND within the encoder.



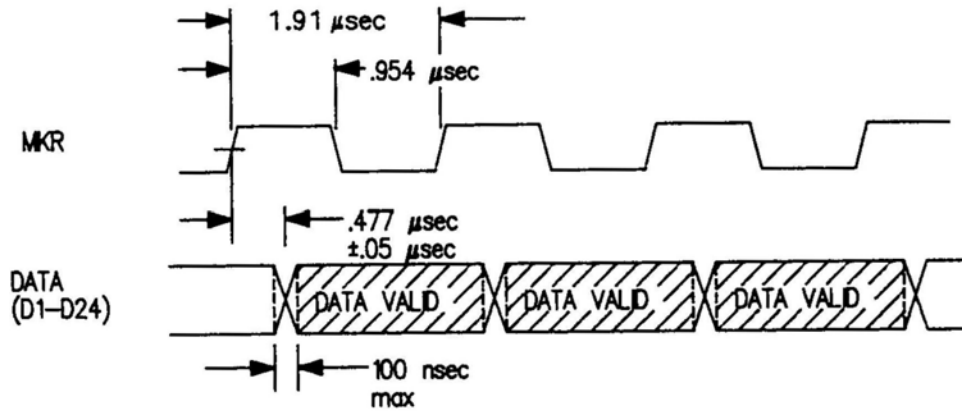


FIGURE 1, OUTPUT TIMING

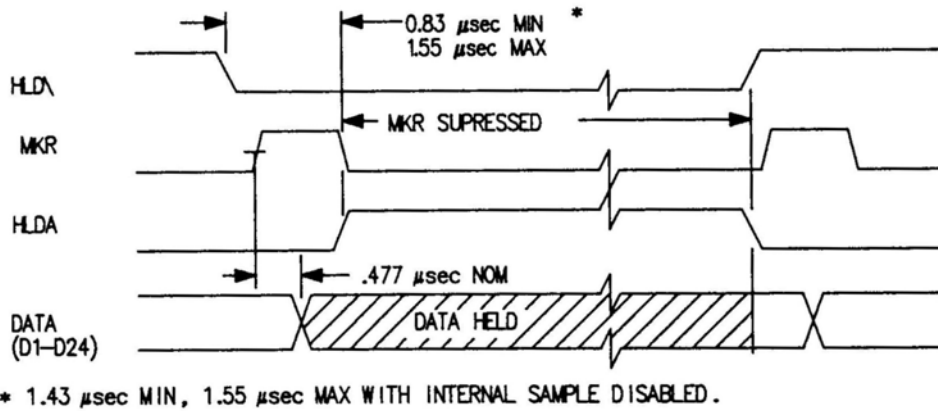


FIGURE 2, HLD – HLDA TIMING

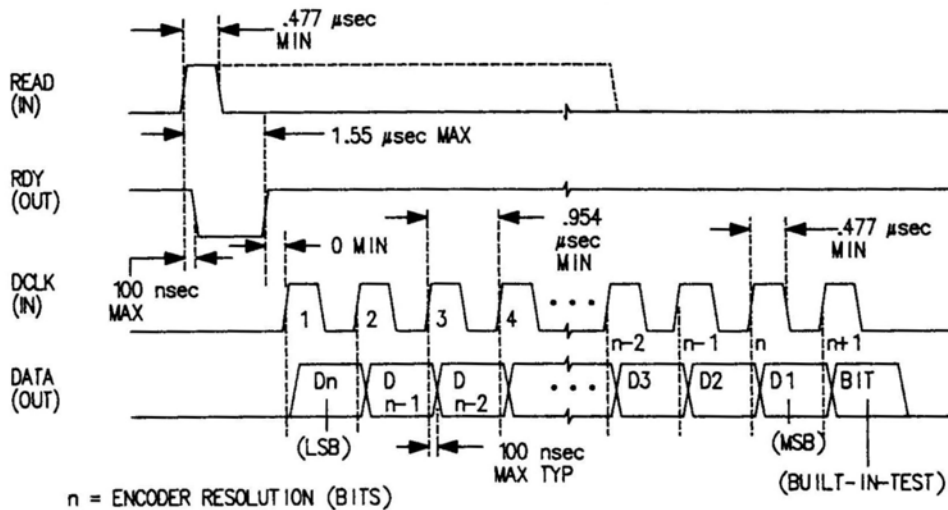


FIGURE 3, SERIAL DATA TIMING

## 3.3 ENVIRONMENTAL:

## 3.3.1 Thermal:

Operating Temperature

Standard range: 0 to +55° C

Extended range: -40 to +75° C

Storage Temperature: -40 to +85° C

3.3.2 Altitude: 70,000 ft. max

3.3.3 Humidity: 98% RH max (non-condensing)

3.3.4 Vibration: 0.01 in. double amplitude 5 to 20 Hz; 2 g pk, 20 to 500 Hz  
per MIL-E-5400T paragraph 3.2.24.6.1, Fig. 2-1, Curve II

3.3.5 Shock: 15g for 11 msec, per MIL-E-5400T, paragraph 3.2.24.6.1

4.0 QUALITY ASSURANCE PROVISIONS:

100% inspection of solder and workmanship.

100% inspection and test of electrical and mechanical parameters.

5.0 RESOLUTION AND ACCURACY:

TABLE 2  
ENCODER BASIC MODEL NUMBERS

MODEL	RESOLUTION		ACCURACY (RMS)		N (CYC/REV)	MAX SPEED ( $W_R$ ) FOR FULL RES. (DEG/SEC)	MAX OPERATE SPEED (DEG/SEC)
	BITS	SEC	BITS	SEC			
L696ER	24	0.077	21	0.618	16,384	22.5	90
L695ER	23	0.154	21	0.618	8,192	45	180
L694ER	22	0.309	20	1.24	4,096	90	360
L693ER	21	0.618	19	2.47	2,048	180	720

- NOTES:
1. For 5 Volt single power supply option, add "5V" prefix to basic model number.
  2. Least significant seven bits are truncated at speeds above  $W_R$ .
  3. Higher accuracy available.

6.0 CONNECTOR PIN DEFINITIONS:

TABLE 3a  
J1 POWER CONNECTOR  
PARALLEL  
TYPE DA15P

PIN	FUNCTION	PIN	FUNCTION
1	+12V *	9	GND
2	- 12V *	10	GND
3	+5V	11	GND
4	+5V	12	
5		13	
6		14	
7		15	CASE
8			

\* Pin not used on "5V" models.

TABLE 3b  
J2 SIGNAL CONNECTOR  
PARALLEL  
TYPE DC37P

PIN	FUNCTION	PIN	FUNCTION
1	D1 (MSB)	20	D2
2	D3	21	D4
3	D5	22	D6
4	D7	23	D8
5	D9	24	D10
6	D11	25	D12
7	D13	26	D14
8	D15	27	D16
9	D17	28	D18
10	D19	29	D20
11	D21	30	D22
12	D23	31	D24 (LSB)
13	HLD\	32	HLDA
14		33	
15	MKR	34	MKR\
16		35	RES
17	INT\	36	BIT
18	DIR	37	CASE
19	GND		

TABLE 4  
J1 SIGNAL & POWER CONNECTOR  
L690ER ENCODERS  
(SERIAL)  
TYPE DB25P

PIN	FUNCTION	PIN	FUNCTION
1	DATA	14	DATA\
2	DCLK	15	DCLK\
3	READ	16	READ\
4	RDY	17	RDY\
5		18	
6	DIR	19	GND
7		20	
8	RES	21	RES\
9	GND	22	GND
10	GND	23	GND
11	+5V	24	+5V
12	+12V*	25	CASE
13	-12V*		

\* Pin not used on "5V" models.

TABLE 5a  
J1 POWER CONNECTOR  
L690ER ENCODERS  
(DIFFERENTIAL PARALLEL)  
TYPE MS27508E-12A35P

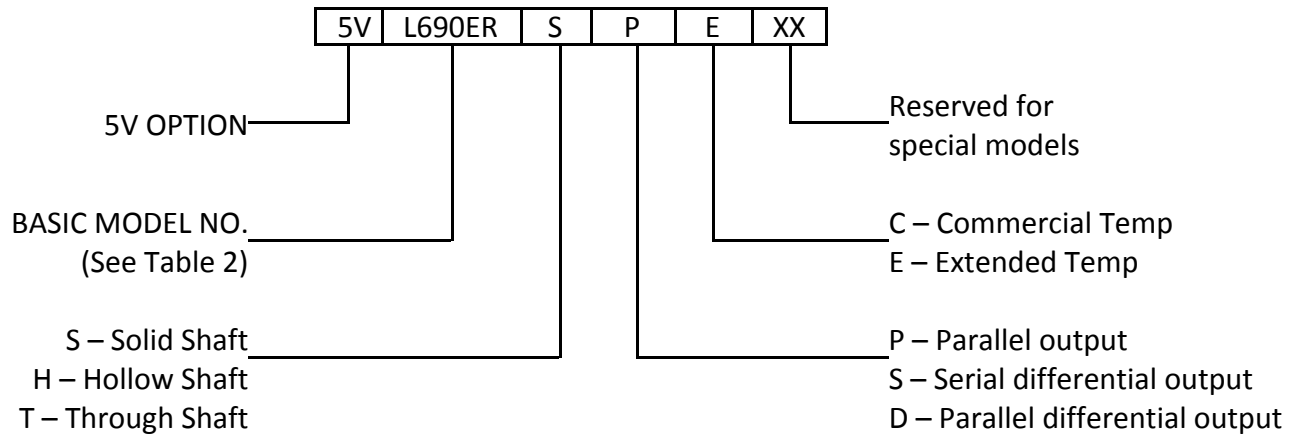
PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
1	+5V	8		15	
2	+5V	9	-12V*	16	
3	+5V	10	-12V*	17	GND
4	+5V	11		18	GND
5		12		19	GND
6	+12V*	13		20	GND
7	+12V*	14		21	
				22	CASE

\* Pin not used on "5V" models.

TABLE 5b  
 J2 SIGNAL CONNECTOR  
 L690ER ENCODERS  
 (DIFFERENTIAL PARALLEL)  
 TYPE MS27508E-18A35S

PIN	FUNCTION	PIN	FUNCTION	PIN	FUNCTION
1	D1 (MSB)	23	D12	45	D23
2	D1/ (MSB)	24	D12/	46	D23/
3	D2	25	D13	47	D24 (LSB)
4	D2/	26	D13/	48	D24/ (LSB)
5	D3	27	D14	49	MKR
6	D3/	28	D14/	50	MKR/
7	D4	29	D15	51	HLD
8	D4/	30	D15/	52	HLD/
9	D5	31	D16	53	HLDA
10	D5/	32	D16/	54	HLDA/
11	D6	33	D17	55	
12	D6/	34	D17/	56	
13	D7	35	D18	57	GND
14	D7/	36	D18/	58	DIR
15	D8	37	D19	59	GND
16	D8/	38	D19/	60	INT/
17	D9	39	D20	61	RES
18	D9/	40	D20/	62	RES/
19	D10	41	D21	63	BIT
20	D10/	42	D21/	64	BIT/
21	D11	43	D22	65	GND
22	D11/	44	D22/	66	CASE

7.0 ORDERING INFORMATION:



Special models are available at additional cost. Contact BEI sales representative for special requirements.

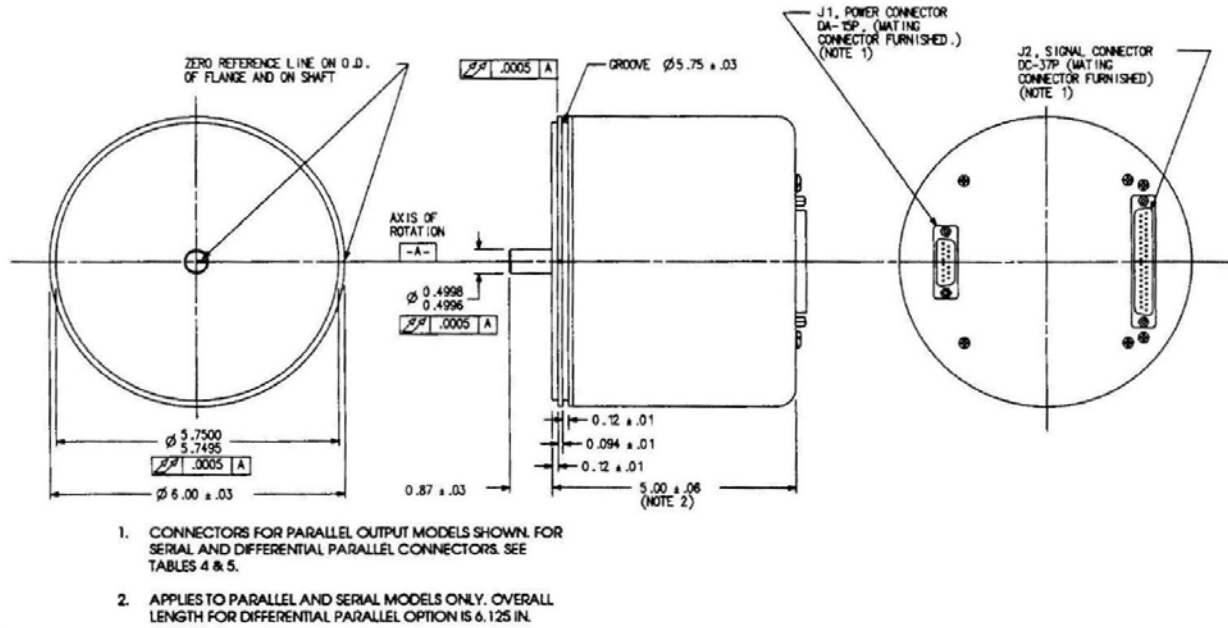


FIGURE 4, OUTLINE, SOLID SHAFT ENCODER

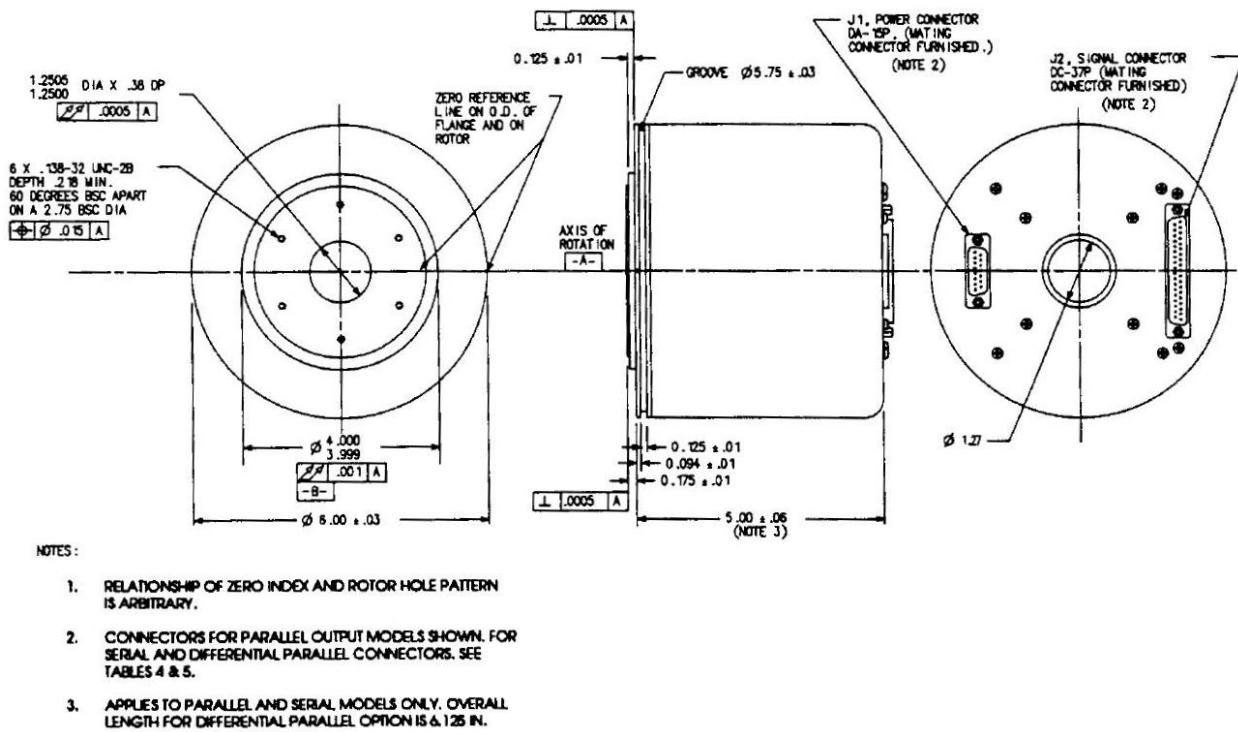


FIGURE 5, OUTLINE, HOLLOW SHAFT ENCODER

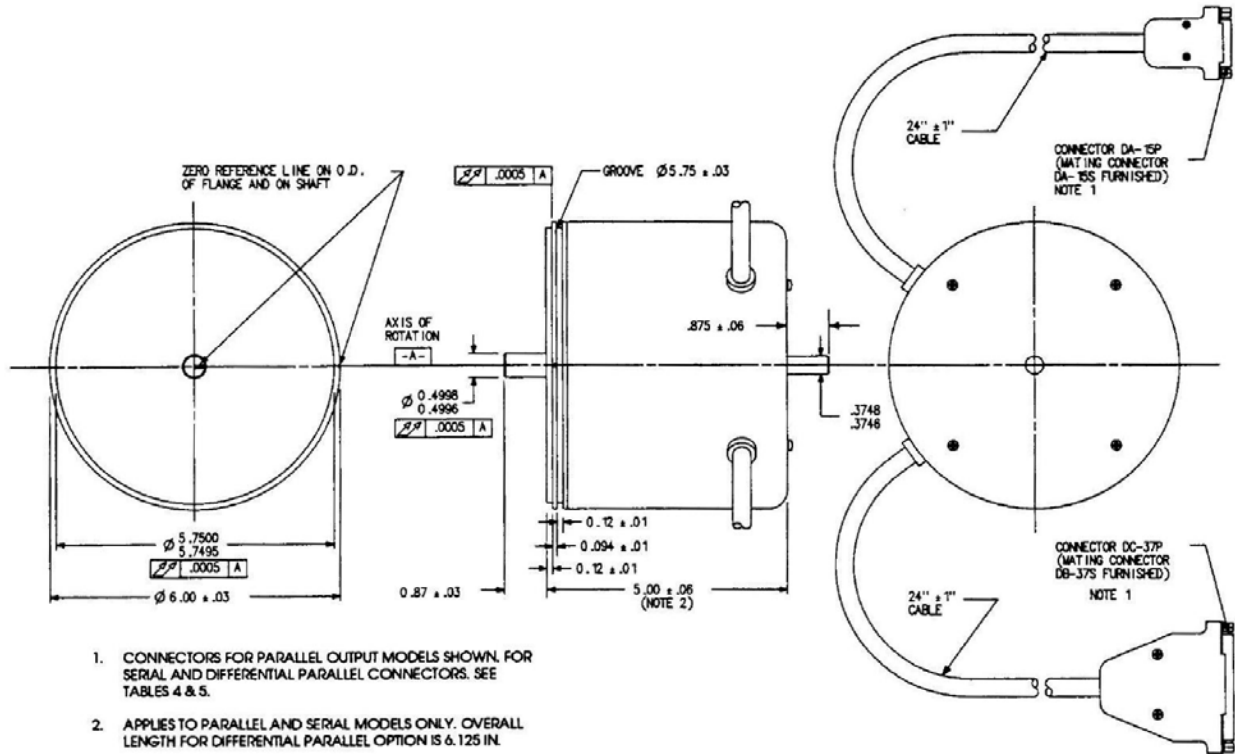


FIGURE 6, OUTLINE, THROUGH SHAFT ENCODER

Specifications Subject to Change Without Notice