HEWLETT PACKARD

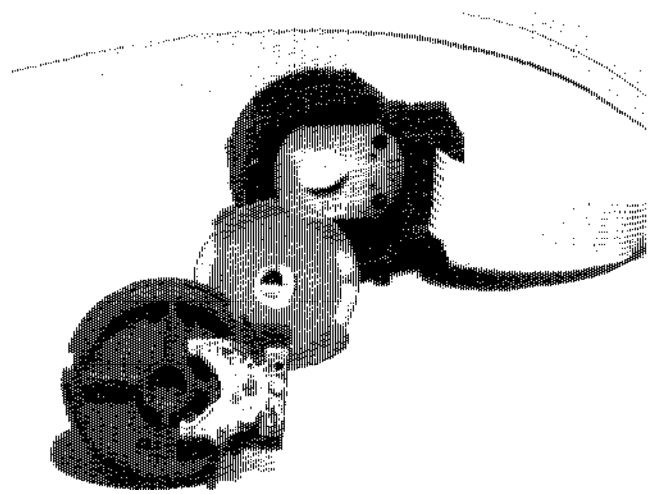
28 mm DIAMETER TWO AND THREE CHANNEL INCREMENTAL OPTICAL ENCODER KIT

HEDS-5000 SERIES

TECHNICAL DATA MARCH 1988

Features

- SMALL SIZE — 28 mm DIAMETER
- 100-512 CYCLES/REVOLUTION AVAILABLE
- MANY RESOLUTIONS STANDARD
- LOW INERTIA
- QUICK ASSEMBLY
- 0.25 mm (.010 INCHES) END PLAY ALLOWANCE
- TTL COMPATIBLE DIGITAL OUTPUT
- SINGLE 5V SUPPLY
- WIDE TEMPERATURE RANGE
- INDEX PULSE AVAILABLE



Description

The HEDS-5000 series is a high resolution incremental optical encoder kit emphasizing reliability and ease of assembly. The 28 mm diameter package consists of 3 parts: the encoder body, a metal code wheel, and an emitter end plate. An LED source and lens transmit collimated light from the emitter module through a precision metal code wheel and phase plate into a bifurcated detector lens.

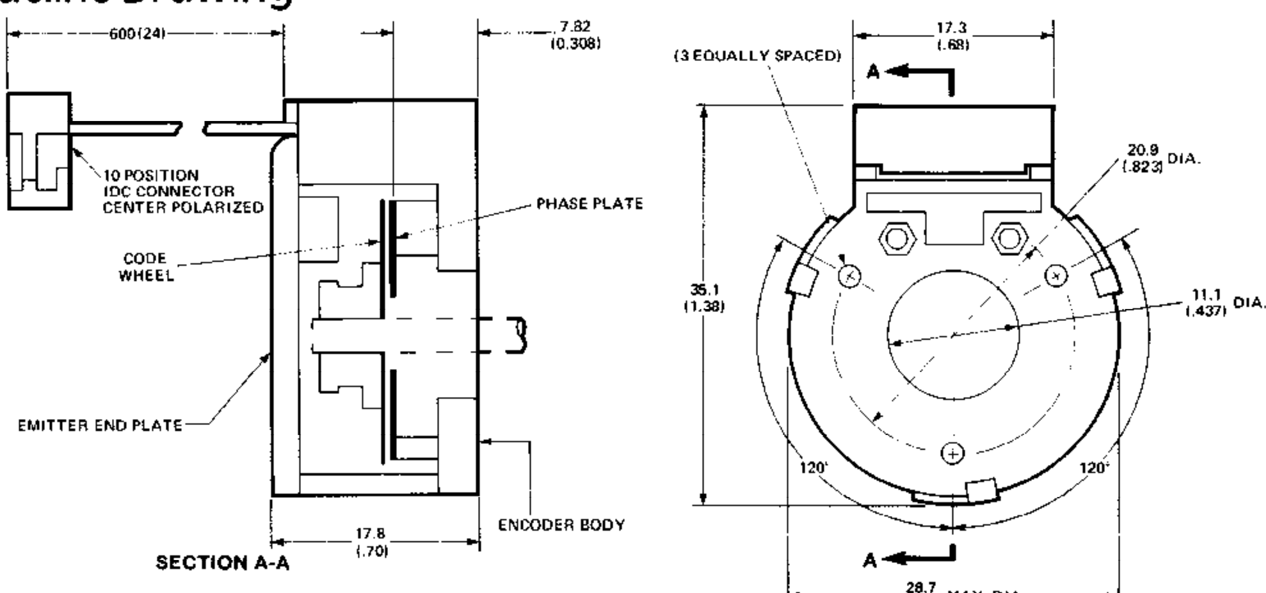
The light is focused onto pairs of closely spaced integrated detectors which output two square wave signals in quadrature and an optional index pulse. Collimated light and a custom photodetector configuration increase long life reliability by reducing sensitivity to shaft end play, shaft eccentricity and LED degradation. The outputs and the 5V supply input of the HEDS-5000 are accessed through a 10 pin connector mounted on a .6 metre ribbon cable.

A standard selection of shaft sizes and resolutions between 100 and 512 cycles per revolution are available. Consult the factory for custom resolutions. The part number for the standard 2 channel kit is HEDS-5000, while that for the 3 channel device, with index pulse, is HEDS-5010. See Ordering Information for more details. For additional design information, see Application Note 1011.

Applications

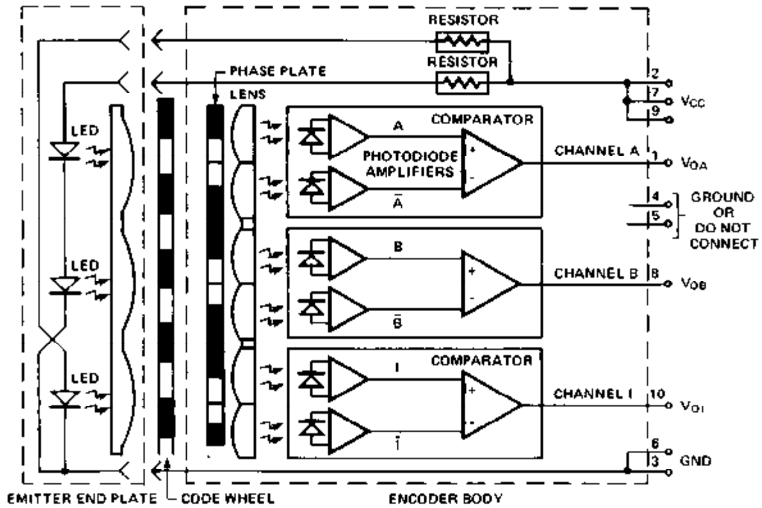
Printers, Plotters, Tape Drives, Positioning Tables, Automatic Handlers, Robots, and any other servo loop where a small high performance encoder is required.

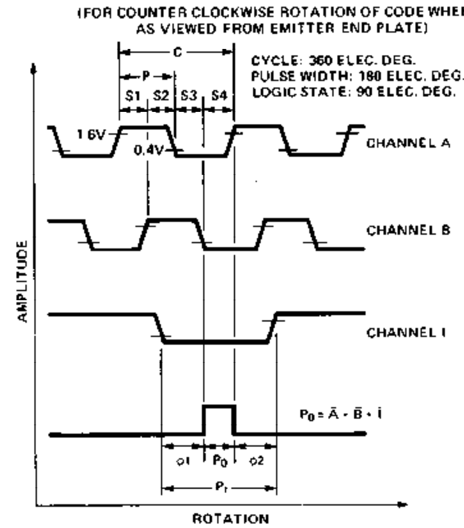
Outline Drawing



TYPICAL DIMENSIONS IN MILLIMETRES AND (INCHES)

Block Diagram and Output Waveforms





Theory of Operation

The incremental shaft encoder operates by translating the rotation of a shaft into interruptions of a light beam which are then output as electrical pulses.

In the HEDS-5XXX the light source is a Light Emitting Diode collimated by a molded lens into a parallel beam of light. The Emitter End Plate contains two or three similar light sources, one for each channel.

The standard Code Wheel is a metal disc which has N equally spaced apertures around its circumference. A matching pattern of apertures is positioned on the stationary phase plate. The light beam is transmitted only when the apertures in the code wheel and the apertures in the phase plate line up; therefore, during a complete shaft revolution, there will be N alternating light and dark periods. A molded lens beneath the phase plate aperture collects the modulated light into a silicon detector.

The Encoder Body contains the phase plate and the detection elements for two or three channels. Each channel consists of an integrated circuit with two photodiodes and amplifiers, a comparator, and output circuitry.

The apertures for the two photodiodes are positioned so that a light period on one detector corresponds to a dark period on the other ("push-pull"). The photodiode signals are amplified and fed to the comparator whose output changes state when the difference of the two photocurrents changes sign. The second channel has a similar configuration but the location of its aperture pair provides an output which is in quadrature to the first channel (phase difference of 90°). Direction of rotation is determined by observing which of the channels is the leading waveform. The outputs are TTL logic level signals.

The optional index channel is similar in optical and electrical configuration to the A and B channels previously described. An index pulse of typically 1 cycle width is generated for each rotation of the code wheel. Using the recommended logic interface, a unique logic state (P_0) can be identified if such accuracy is required.

The three part kit is assembled by attaching the Encoder Body to the mounting surface using three screws. The Code Wheel is set to the correct gap and secured to the shaft. Snapping the cover (Emitter End Plate) on the body completes the assembly. The only adjustment necessary is the encoder centering relative to the shaft. This optimizes quadrature and the optional index pulse outputs.

Index Pulse Considerations

The motion sensing application and encoder interface circuitry will determine the necessary phase relationship of the index pulse to the main data tracks. A unique shaft position can be identified by using the index pulse output only or by logically relating the index pulse to the A and B data channels. The HEDS-5010 allows some adjustment of the index pulse position with respect to the main data channels. The position is easily adjusted during the assembly process as illustrated in the assembly procedures.

Definitions

Electrical degrees:

1 shaft rotation = 360 angular degrees
= N electrical cycles

1 cycle = 360 electrical degrees

Position Error:

The angular difference between the actual shaft position and its position as calculated by counting the encoder's cycles.

Cycle Error:

An indication of cycle uniformity. The difference between an observed shaft angle which gives rise to one electrical cycle, and the nominal angular increment of 1/N of a revolution.

Phase:

The angle between the center of Pulse A and the center of Pulse B.

Index Phase:

For counter clockwise rotation as illustrated above, the Index Phase is defined as:

$$\Phi_I = \frac{|\phi_1 - \phi_2|}{2}.$$

ϕ_1 is the angle, in electrical degrees between the falling edge of I and falling edge of B. ϕ_2 is the angle, in electrical degrees, between the rising edge of A and the rising edge of I.

Index Phase Error:

The Index Phase Error ($\Delta\Phi_I$) describes the change in the Index Pulse position after assembly with respect to the A and B channels over the recommended operating conditions.

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Storage Temperature	T_S	-55	100	°Celsius	
Operating Temperature	T_A	-55	100	°Celsius	See Note 1
Vibration			20	g	See Note 1
Shaft Axial Play			.50 (20)	mm(1inch/1000) TIR	
Shaft Eccentricity Plus Radial Play			.1 (4)	mm(1inch/1000) TIR	Movement should be limited even under shock conditions.
Supply Voltage	V_{CC}	-0.5	7	Volts	
Output Voltage	V_O	-0.5	V_{CC}	Volts	
Output Current per Channel	I_O	-1	5	mA	
Velocity			30,000	R.P.M.	
Acceleration	α		250,000	Rad. Sec^{-2}	

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Units	Notes
Temperature	T	-20	85	°Celsius	Non-condensing atmos.
Supply Voltage	V_{CC}	4.5	5.5	Volt	Ripple < $100mV_{p-p}$
Code Wheel Gap			1.1 (45)	mm (inch/1000)	Nominal gap =
Shaft Perpendicularity Plus Axial Play			0.25 (10)	mm (inch/1000) TIR	0.63 mm (.025 in.) when shaft is at minimum gap position.
Shaft Eccentricity Plus Radial Play			0.04 (1.5)	mm (inch/1000) TIR	10 mm (0.4 inch) from mounting surface.
Load Capacitance	C_L		100	pF	

Encoding Characteristics

The specifications below apply within the recommended operating conditions and reflect performance at 500 cycles per revolution (N = 500). Some encoding characteristics improve with decreasing cycles (N). Consult Application Note 1011 or factory for additional details.

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes (See Definitions)
Position Error - Worst Error Full Rotation	$\Delta\Theta$		10	40	Minutes of Arc	1 Cycle = 43.2 Minutes See Figure 5.
Cycle Error - Worst Error Full Rotation	ΔC		3	5.5	Electrical deg.	
Max. Count Frequency	f_{MAX}	130,000	200,000		Hertz	f = Velocity (RPM) x N/60
Pulse Width Error - Worst Error Full Rotation	ΔP		16		Electrical deg.	T = 25° C, f = 8 KHz See Note 2
Phase Sensitivity to Eccentricity			520 (13)		Elec. deg./mm (Elec. deg./mil)	mil = inch/1000
Phase Sensitivity to Axial Play			20 (.5)		Elec. deg./mm (Elec. deg./mil)	mil = inch/1000
Logic State Width Error - Worst Error Full Rotation	ΔS		25		Electrical deg.	T = 25° C, f = 8 KHz See Note 2
Index Pulse Width	P_I		360		Electrical deg.	T = 25° C, f = 8 KHz See Note 3
Index Phase Error	$\Delta\Phi_I$		0	17	Electrical deg.	See Notes 4, 5
Index Pulse Phase Adjustment Range		±70	±130		Electrical deg.	See Note 5

Mechanical Characteristics

Parameter	Symbol	Dimension	Tolerance	Units	Notes
Outline Dimensions		See Mech. Dwg.			
Code Wheel Available to Fit the Following Standard Shaft Diameters		2 4 3 5	+.000 −.015	mm	
		5/32	+.0002 −.0005	inches	
		1/8 3/16 1/4	+.0000 −.0007	inches	
Moment of Inertia	J	0.4 (6 x 10^{-6})		gcm^2 ($oz\text{-}in\text{-}s^2$)	
Required Shaft Length		12.8 (.50)	±0.5 (±0.02)	mm (inches)	See Figure 10. Shaft in minimum length position.
Bolt Circle		20.9 (.823)	±0.13 (+.005)	mm (inches)	See Figure 10.
Mounting Screw Size		1.6 x 0.35 x 5 mm DIN 84 or 0-80 x 3/16 Binding Head		mm inches	

Electrical Characteristics When operating within the recommended operating range.

Electrical Characteristics over Recommended Operating Range Typical at 25° C .

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Supply Current	I_{CC}		21	40	mA	HEDS-5000 (2 Channel)
			36	60		HEDS-5010 (3 Channel)
High Level Output Voltage	V_{OH}	2.4			V	I_{OH} = -40μA Max.
Low Level Output Voltage	V_{OL}			0.4	V	I_{OL} = 3.2 mA
Rise Time	t_r		0.5		μs	C_L = 25 pF, R_L = 11K Pull-up
Fall Time	t_f		0.2			See Note 6
Cable Capacitance	C_{CO}		12		pF/metres	Output Lead to Ground

NOTES:

1. The structural parts of the HEDS-5000 have been tested to 20g and up to 500 Hz. For use outside this range, operation may be limited at low frequencies (high displacement) by cable fatigue and at high frequencies by code wheel resonances. Resonant frequency depends on code wheel material and number of counts per revolution. For temperatures below -20° C the ribbon cable becomes brittle and sensitive to displacements. Maximum operating and storage temperature includes the surface area of the encoder mounting. Consult factory for further information. See Application Note 1011.
2. In a properly assembled lot 99% of the units, when run at 25° C and 8 KHz, should exhibit a pulse width error less than 35 electrical degrees, and a state width error less than 45 electrical degrees. To calculate errors at other speeds and temperatures add the values specified in Figures 1 or 2 to the typical values specified under encoding characteristics or to the maximum 99% values specified in this note.
3. In a properly assembled lot, 99% of the units when run at 25°C and 8 KHz should exhibit an index pulse width greater than 260 electrical degrees and less than 460 electrical degrees. To calculate index pulse widths at other speeds and temperatures add the values specified in Figures 3 or 4 to the typical 360° pulse width or to the maximum 99% values specified in this note.
4. After adjusting index phase at assembly, the index phase error specification ($\Delta\Phi_I$) indicates the expected shift in index pulse position with respect to channels A and B over the range of recommended operating conditions and up to 50 KHz.
5. When the index pulse is centered on the low-low states of channels A and B as shown on page 2, a unique P_O can be defined once per revolution within the recommended operating conditions and up to 25 KHz. Figure 6 shows how P_O can be derived from A, B, and I outputs. The adjustment range indicates how far from the center of the low-low state that the center of the index pulse may be adjusted.
6. The rise time is primarily a function of the RC time constant of R_L and C_L. A faster rise time can be achieved with either a lower value of R_L or C_L. Care must be observed not to exceed the recommended value of I_{OL} under the worst case conditions.

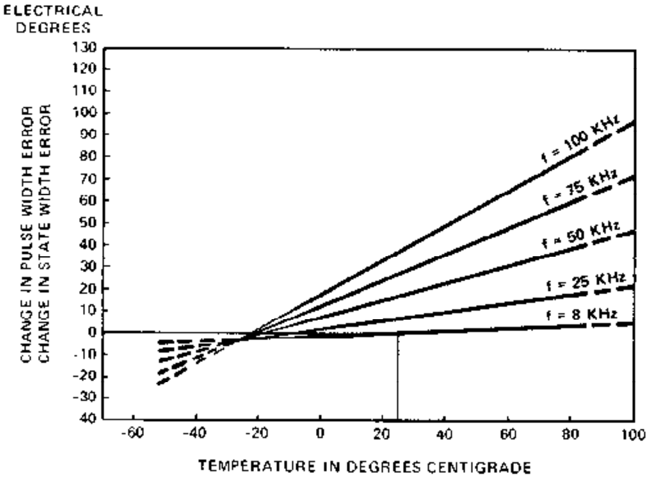


Figure 1. Typical Change in Pulse Width Error or in State Width Error due to Speed and Temperature

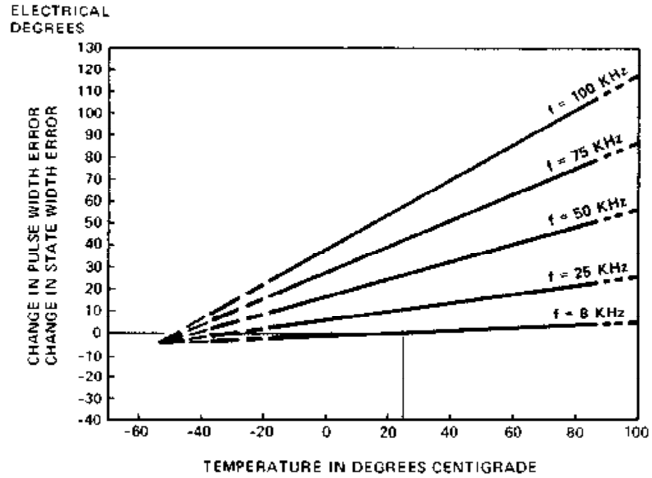


Figure 2. Maximum Change in Pulse Width Error or in State Width Error Due to Speed and Temperature

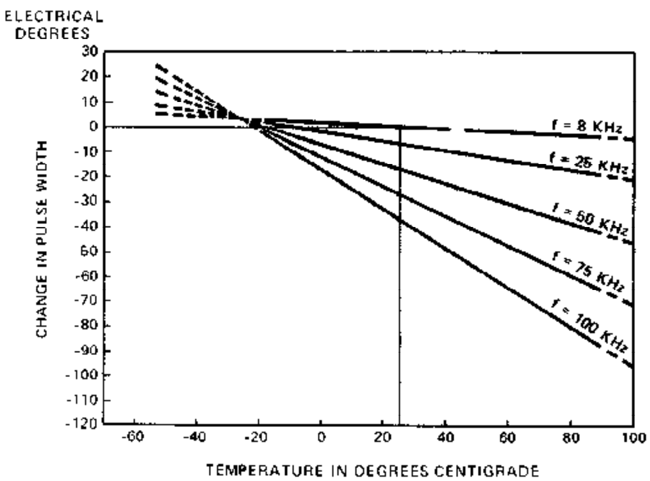


Figure 3. Typical Change in Index Pulse Width Due to Speed and Temperature

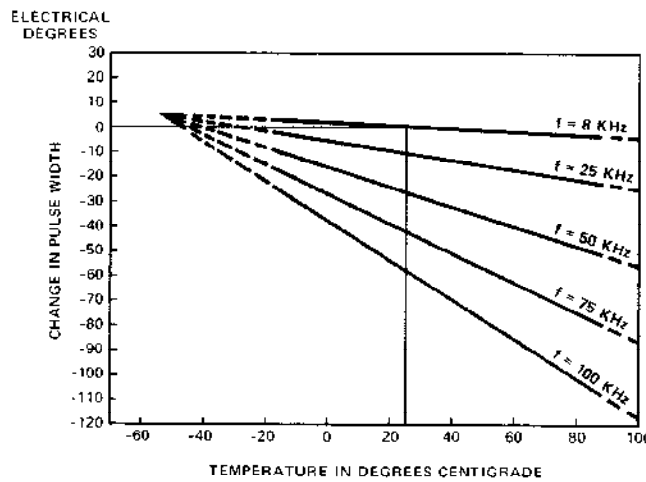


Figure 4. Maximum Change in Index Pulse Width Due to Speed and Temperature

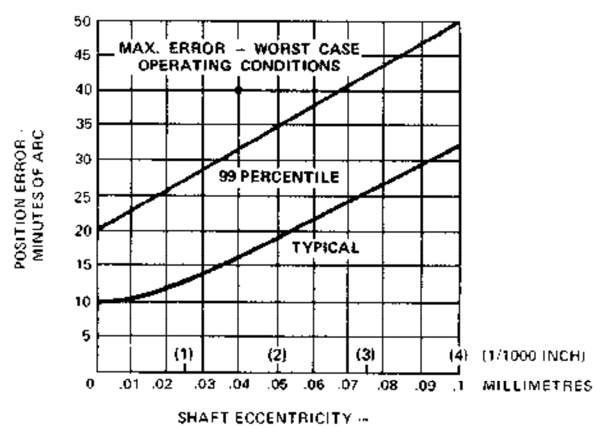
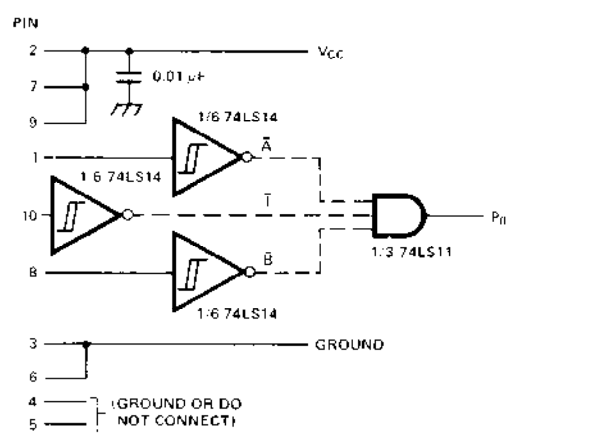
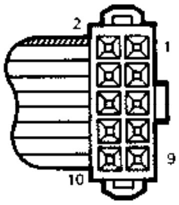


Figure 5. Position Error vs. Shaft Eccentricity



DASHED LINES REPRESENT AN OPTIONAL INDEX SUMMING CIRCUIT.
STANDARD 74 SERIES COULD ALSO BE USED TO IMPLEMENT THIS CIRCUIT.

Figure 6. Recommended Interface Circuit



PINOUT

PIN #	FUNCTION
1	CHANNEL A
2	V_{CC}
3	GROUND
4	N.C. OR GROUND
5	N.C. OR GROUND
6	GROUND
7	V_{CC}
8	CHANNEL B
9	V_{CC}
10	CHANNEL I

NOTE: REVERSE INSERTION OF THE CONNECTOR WILL PERMANENTLY DAMAGE THE DETECTOR IC

MATING CONNECTOR
BERG 65-692-001 OR EQUIVALENT

Figure 7. Connector Specifications

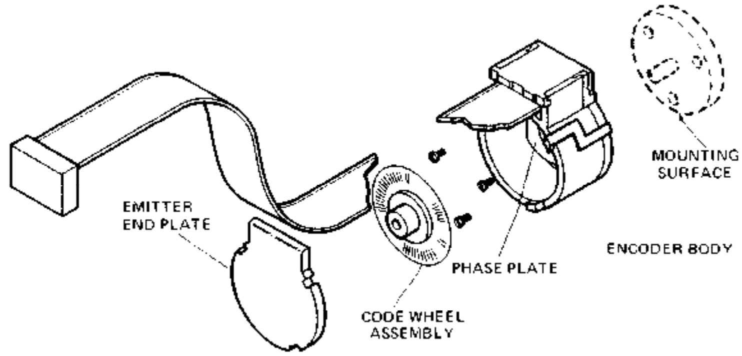


Figure 8. HEDS-5000 Series Encoder Kit

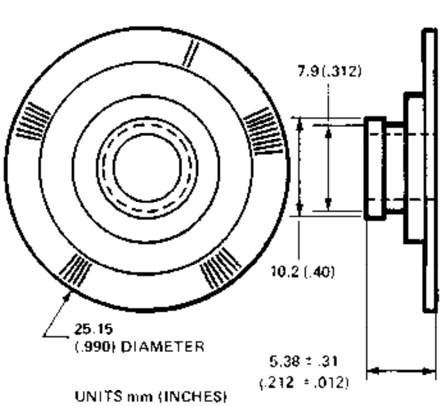


Figure 9. Code Wheel

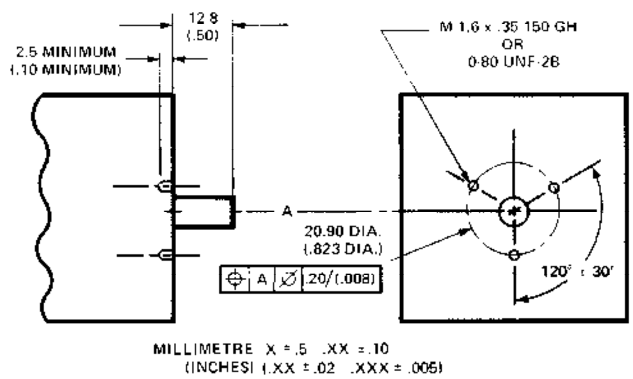


Figure 10. Mounting Requirements

Ordering Information

HEDS-5 ☐ ☐ ☐
OPTION* ☐ ☐

RESOLUTION (CYCLES PER REVOLUTION)

C – 100 CPR	G – 360 CPR
D – 192 CPR	H – 400 CPR
E – 200 CPR	A – 500 CPR
F – 256 CPR	I – 512 CPR

NOTE: OTHER RESOLUTIONS AVAILABLE ON SPECIAL REQUEST.

SHAFT DIAMETER

01 – 2 mm
02 – 3 mm
03 – 1/8 in.
04 – 5/32 in.
05 – 3/16 in.
06 – 1/4 in.
11 – 4 mm
12 – 6 mm
14 – 5 mm
00 – USE WHEN ORDERING ENCODER BODIES

PRODUCT TYPE

0 – 28 mm COMPLETE KIT
1 – 28 mm CODE WHEEL
2 – 28 mm ENCODER BODY
3 – 28 mm EMITTER END PLATE*

OUTPUTS

0 – 2 CHANNEL DIGITAL
1 – 3 CHANNEL DIGITAL

MECHANICAL CONFIGURATION

0 – 0.6 m (24 in.) CABLE

*NO OPTION IS SPECIFIED WHEN ORDERING EMITTER END PLATES ONLY.

Shaft Encoder Kit Assembly **See Application Note 1011 for further discussion.**

The following assembly procedure represents a simple and reliable method for prototype encoder assembly. High volume assembly may suggest modifications to this procedure using custom designed tooling. In certain high volume applications encoder assembly can be accomplished in less than 30 seconds. Consult factory for further details. Note: The code wheel to phase plate gap should be set between 0.015 in. and 0.045 in.

WARNING: THE ADHESIVES USED MAY BE HARMFUL. CONSULT THE MANUFACTURER'S RECOMMENDATIONS.

READ THE INSTRUCTIONS TO THE END BEFORE STARTING ASSEMBLY.

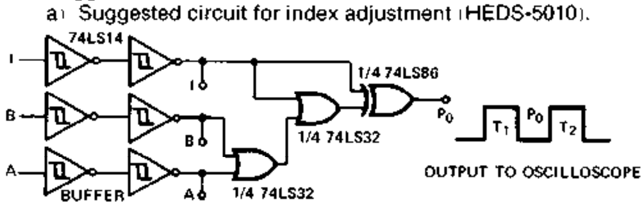
1.0 SUGGESTED MATERIALS

1.1 Encoder Parts
Encoder Body
Emitter End Plate
Code Wheel

1.2 Assembly Materials
RTV — General Electric 162
— Dow Corning 3145
Epoxy—Hysol 1C
Acetone
Mounting Screws (3)
RTV and Epoxy Applicators

1.3 Suggested Assembly Tools
a) Holding Screwdriver.
b) Torque Limiting Screwdriver, 0.36 cm kg (5.0 in. oz.).
c) Depth Micrometer or HEDS-8922 Gap Setter.
d) Oscilloscope or Phase Meter (Described in AN 1011). Either may be used for two channel phase adjustment. An oscilloscope is required for index pulse phase adjustment.

1.4 Suggested Circuits
a) Suggested circuit for index adjustment (HEDS-5010).



For optimal index phase, adjust encoder position to equalize T_1 and T_2 pulse widths.

b) Phase Meter Circuit
Recommended for volume assembly. Please see Application Note 1011 for details.

2.0 SURFACE PREPARATION

THE ELAPSED TIME BETWEEN THIS STEP AND THE COMPLETION OF STEP 8 SHOULD NOT EXCEED 1/2 HOUR.

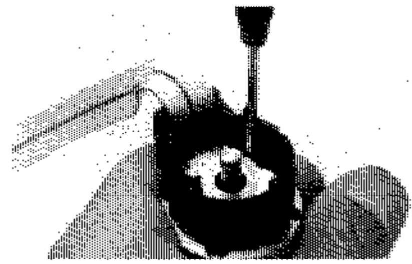
2.1 Clean and degrease with acetone the mounting surface and shaft making sure to keep the acetone away from the motor bearings.

2.2 Load the syringe with RTV.

2.3 Apply RTV into screw threads on mounting surface. Apply more RTV on the surface by forming a daisy ring pattern connecting the screw holes as shown above.

CAUTION: KEEP RTV AWAY FROM THE SHAFT BEARING.

3.0 ENCODER BODY ATTACHMENT

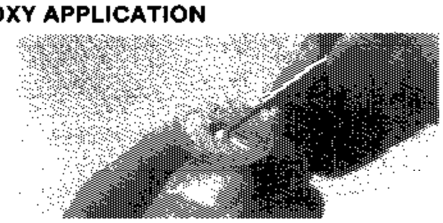


3.1 Place the encoder body on the mounting surface and slowly rotate the body to spread the adhesive. Align the mounting screw holes with the holes in the body base.

3.2 Place the screws in the holding screwdriver and thread them into the mounting holes. Tighten to approximately 0.36 cm kg (5.0 in. oz.) using a torque limiting screwdriver if available (See notes a and b below). Remove centering cone if used.

Notes:
a) At this torque value, the encoder body should slide on the mounting surface only with considerable thumb pressure.
b) The torque limiting screwdriver should be periodically calibrated for proper torque.

4.0 EPOXY APPLICATION



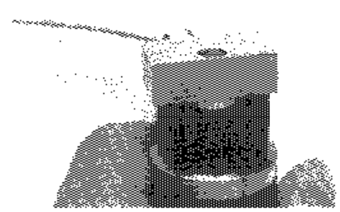
CAUTION: HANDLE THE CODE WHEEL WITH CARE.

4.1 Collect a small dab of epoxy on an applicator.

4.2 Spread the epoxy inside the lower part of the hub bore.

4.3 Holding the code wheel by its hub, slide it down the shaft just enough to sit it squarely. About 3 mm (1/8").

5.0 CODE WHEEL POSITIONING



5.1 Take up any loose play by lightly pulling down on the shaft's load end.

5.2 Using the gap setter or a depth micrometer, push the code wheel hub down to a depth of 1.65 mm (.065 in.) below the rim of the encoder body. The registration holes in the gap setter will align with the snaps protruding from the encoder body near the cable.

5.3 Check that the gap setter or micrometer is seated squarely on the body rim and maintains contact with the code wheel hub.

5.4 No epoxy should extrude through the shaft hole.

DO NOT TOUCH THE CODE WHEEL AFTER ASSEMBLY.

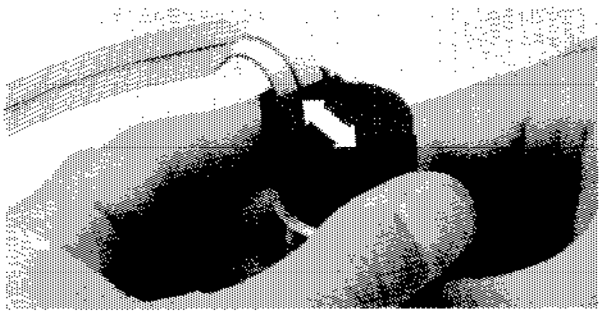
6.0 EMITTER END PLATE

6.1 Visually check that the wire pins in the encoder body are straight and straighten if necessary.

6.2 Hold the end plate parallel to the encoder body rim. Align the guiding pin on the end plate with the hole in the encoder body and press the end plate straight down until it is locked into place.

6.3 Visually check to see if the end plate is properly seated.

7.0 PHASE ADJUSTMENT



7.1 The following procedure should be followed when phase adjusting channels A and B.

7.2 Connect the encoder cable.

7.3 Run the motor. Phase corresponds to motor direction. See output waveforms and definitions. Using either an oscilloscope or a phase meter, adjust the encoder for minimum phase error by sliding the encoder forward or backward on the mounting surface as shown above. See Application Note 1011 for the phase meter circuit.

7.4 No stress should be applied to the encoder package until the RTV cures. Cure time is 2 hours @ 70° C or 24 hrs. at room temperature.

Note: After mounting, the encoder should be free from mechanical forces that could cause a shift in the encoder's position relative to its mounting surface.

CODE WHEEL REMOVAL

In the event that the code wheel has to be removed after the epoxy has set, use the code wheel extractor as follows:

1 Remove the emitter end plate by prying a screwdriver in the slots provided around the encoder body rim. Avoid bending the wire leads.

2 Turn the screw on the extractor counter-clockwise until the screw tip is no longer visible.

3 Slide the extractor's horseshoe shaped lip all the way into the groove on the code wheel's hub.

4 While holding the extractor body stationary, turn the thumb screw clockwise until the screw tip pushes against the shaft.

5 Applying more turning pressure will pull the hub upwards breaking the epoxy bond.

6 Clean the shaft before reassembly.

8.0 INDEX PULSE ADJUSTMENT (HEDS-5010)

8.1 Some applications require that the index pulse be aligned with the main data channels. The index pulse position and the phase must be adjusted simultaneously. This procedure sets index phase to zero.

8.2 Connect the encoder cable.

8.3 Run the motor. Adjust for minimum phase error using an oscilloscope or phase meter (see 7.3).

8.4 Using an oscilloscope and the circuit shown in 1.4, set the trigger for the falling edge of the I output. Adjust the index pulse so that T_1 and T_2 are equal in width. The physical adjustment is a side to side motion as shown by the arrow.

8.5 Recheck the phase adjustment.

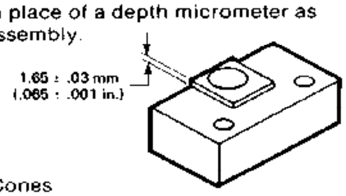
8.6 Repeat steps 8.3-8.5 until both phase and index pulse position are as desired.

8.7 No stress should be applied to the encoder package until the RTV has cured. Cure time: 2 hours @ 70° C or 24 hrs. at room temperature.

SPECIALITY TOOLS — Available from Hewlett-Packard

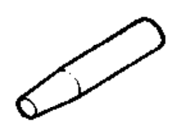
a) HEDS-8920 Hub Puller
This tool may be used to remove code wheels from shafts after the epoxy has cured.

b) HEDS-8922 Gap Setter
This tool may be used in place of a depth micrometer as an aid in large volume assembly.



c) HEDS-892X Centering Cones
For easier volume assembly this tool in its appropriate shaft size may be used in step 3.0 to initially center the encoder body with respect to the shaft and aid in locating the mounting screw holes. Depending on the resolution and accuracy required this centering may eliminate the need for phase adjustment steps 7 and 8.

Part Number	Shaft Size
HEDS-8923	2 mm
HEDS-8924	3 mm
HEDS-8925	1/8 in.
HEDS-8926	5/32 in.
HEDS-8927	3/16 in.
HEDS-8928	1/4 in.
HEDS-8929	4 mm
HEDS-8931	5 mm



d) HEDS-8930 HEDS-5000 Tool Kit
- 1 Holding Screwdriver
- 1 Torque Limiting Screwdriver, 0.36 cm kg (5.0 in. oz.)
- 1 HEDS-8920 Hub Puller
- 1 HEDS-8922 Gap Setter
- 1 Carrying Case

For more information call your local HP sales office listed in the telephone directory white pages. Ask for the Components Department. Or write to Hewlett-Packard: **U.S.A.** — P.O. Box 10301, Palo Alto, CA 94303-0890. **Europe** — P.O. Box 999, 1180 AZ Amstelveen, The Netherlands. **Canada** — 6877 Goreway Drive, Mississauga, L4V 1M8, Ontario. **Japan** — Yokogawa-Hewlett-Packard Ltd., 3-29-21, Takaido-Higashi, Suginami-ku, Tokyo 168. **Elsewhere** in the world, write to Hewlett-Packard Intercontinental, 3495 Deer Creek Road, Palo Alto, CA 94304.

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