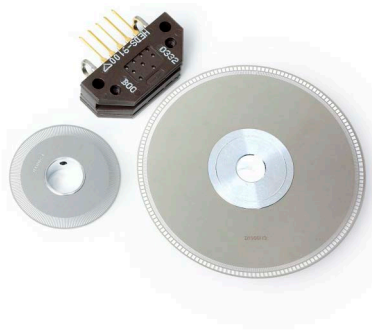
Data Sheet

HEDS-9040/9140

Three-Channel Optical Incremental Encoder Modules



Description

The HEDS-9040 and HEDS-9140 series are three-channel optical incremental encoder modules. When used with a code wheel, these low-cost modules detect rotary position. Each module consists of a lensed LED source and a detector IC enclosed in a small plastic package. Due to a highly collimated light source and a unique photodetector array, these modules provide the same high performance found in the HEDS-9000/9100 two-channel encoder family.

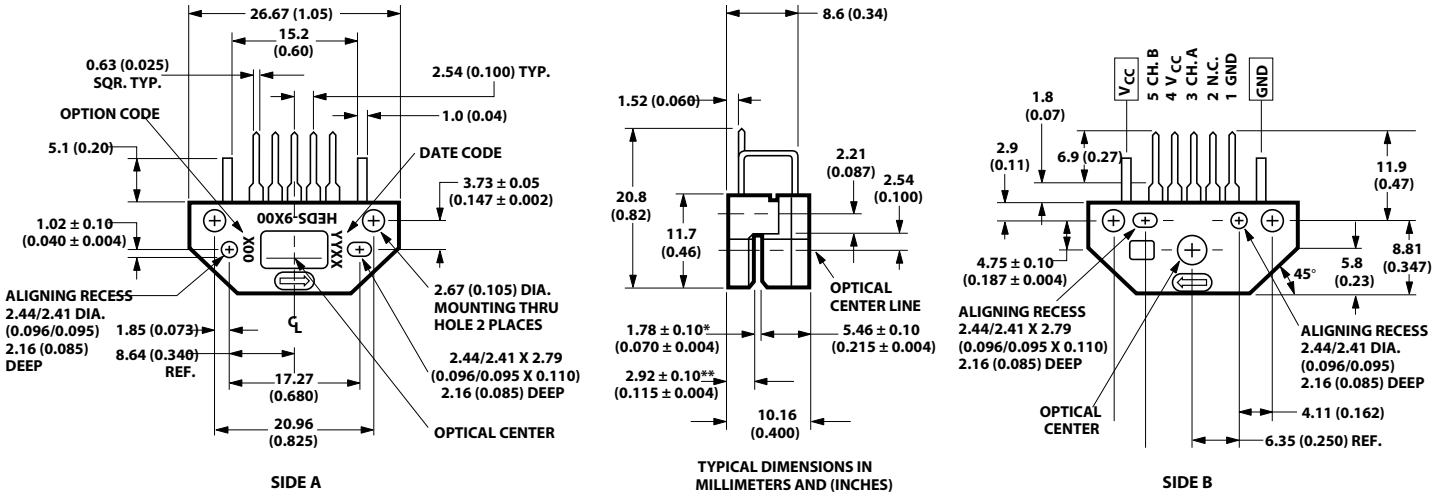
Features

- Two-channel quadrature output with index pulse
- Resolution up to 2000 counts per revolution (CPR)
- Low cost
- Easy to mount
- No signal adjustment required
- Small size
- –40°C to 100°C operating temperature
- TTL compatible
- Single 5V supply

ESD Warning: Take normal handling precautions to avoid static discharge.

Package Dimensions

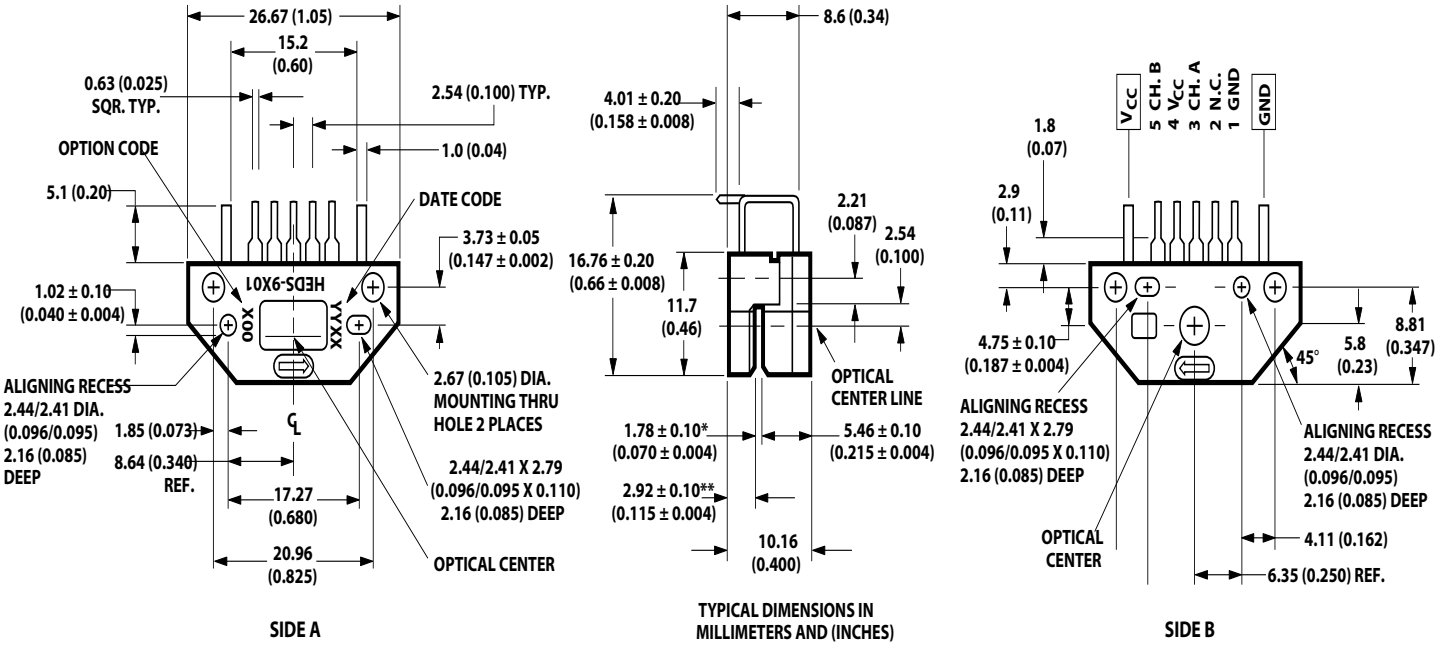
HEDx-9xx0 Option



* GAP MEASUREMENT TO THE SURFACE WINDOW = 1.68 ± 0.10 (0.066 ± 0.004)

** HEIGHT TO THE WINDOW = 3.02 ± 0.10 (0.119 ± 0.004)

HEDx-9xx1 Option



* GAP MEASUREMENT TO THE SURFACE WINDOW = 1.68 ± 0.10 (0.066 ± 0.004)

** HEIGHT TO THE WINDOW = 3.02 ± 0.10 (0.119 ± 0.004)

The HEDS-9040 and 9140 have two-channel quadrature outputs plus a third-channel index output. This index output is a 90 electrical degree (°e) high true index pulse that is generated once for each full rotation of the code wheel.

The HEDS-9040 is designed for use with a HEDx-614x code wheel, which has an optical radius of 23.36 mm (0.920 inch). The HEDS-9140 is designed for use with a HEDx-5x4x code wheel, which has an optical radius of 11.00 mm (0.433 inch).

The quadrature signals and the index pulse are accessed through five 0.025-inch square pins located on 0.1-inch centers.

Standard resolutions between 256 CPR and 2000 CPR are available. Consult a local Broadcom sales representatives for other resolutions.

Applications

The HEDS-9040 and 9140 provide sophisticated motion control detection at a low cost, making them ideal for high-volume applications. Typical applications include printers, plotters, tape drives, and industrial and factory automation equipment.

NOTE: Broadcom encoders are not recommended for use in safety-critical applications; for example, ABS braking systems, power steering, life support systems, and critical-care medical equipment. Contact a sales representative if more clarification is needed.

Theory of Operation

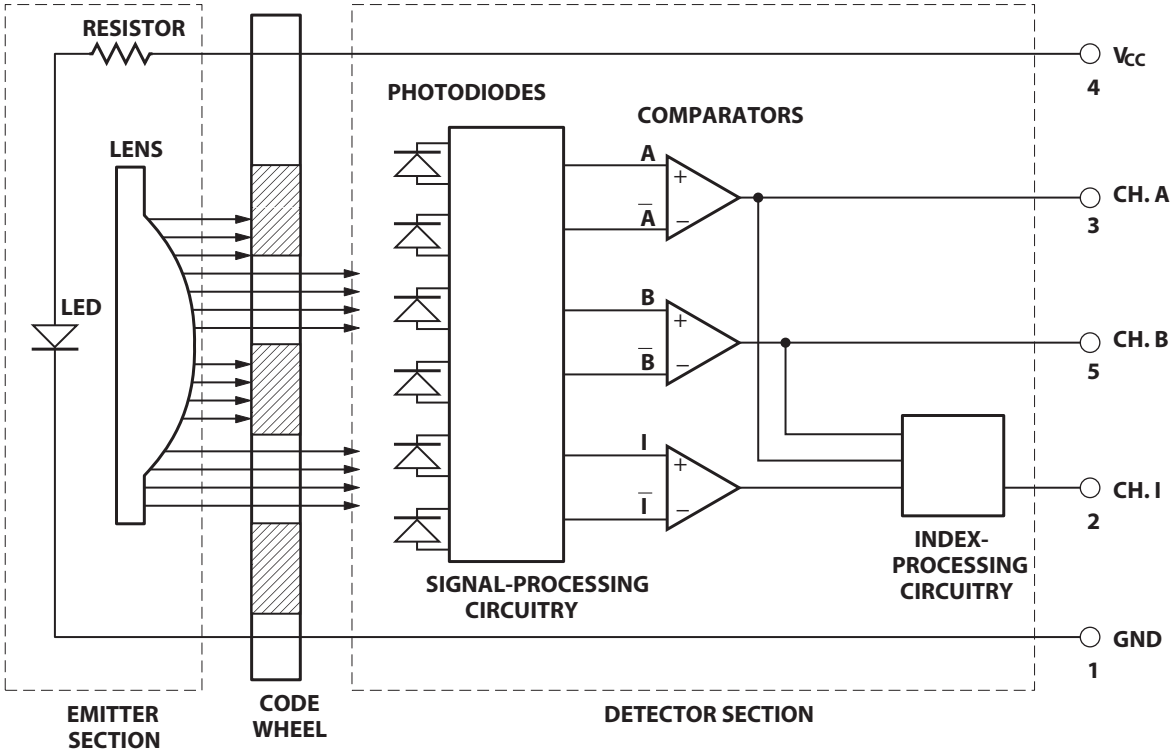
The HEDS-9040 and 9140 are emitter/detector modules. Coupled with a code wheel, these modules translate the rotary motion of a shaft into a three-channel digital output.

As seen in the block diagram, the modules contain a single light-emitting diode (LED) as their light source. The light is collimated into a parallel beam by means of a single polycarbonate lens located directly over the LED. Opposite the emitter is the integrated detector circuit. This IC consists of multiple sets of photodetectors and the signal-processing circuitry necessary to produce the digital waveforms.

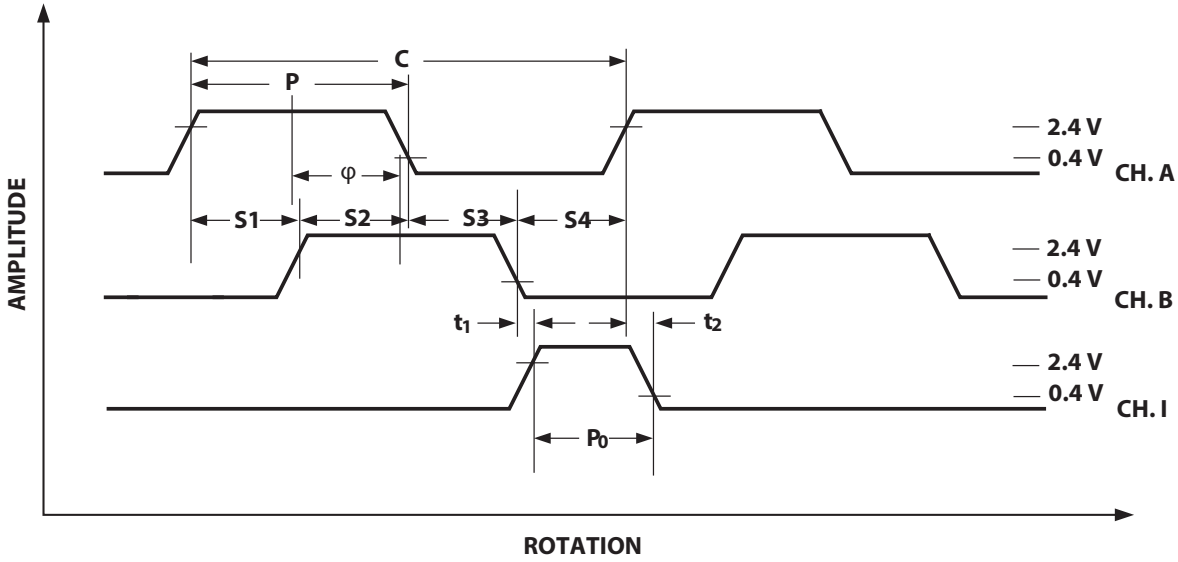
The code wheel rotates between the emitter and the detector, causing the light beam to be interrupted by the pattern of spaces and bars on the code wheel. The photodiodes that detect these interruptions are arranged in a pattern that corresponds to the radius and design of the code wheel. These detectors are also spaced such that a light period on one pair of detectors corresponds to a dark period on the adjacent pair of detectors. The photodiode outputs are then fed through the signal-processing circuitry, resulting in A, $\overline{A}$, B, $\overline{B}$, I, and $\overline{I}$. Comparators receive these signals and produce the final outputs for channels A and B. Due to this integrated phasing technique, the digital output of channel A is in quadrature with that of channel B (90° out of phase).

The output of the comparator for I and $\overline{I}$ is sent to the index-processing circuitry along with the outputs of channels A and B. The final output of channel I is an index pulse P_O that is generated once for each full rotation of the code wheel. This output P_O is a one-state width (nominally 90 °e) high true index pulse that is coincident with the low states of channels A and B.

Block Diagram



Output Waveforms



Definitions

Count (N): The number of bar and window pairs or counts per revolution (CPR) of the code wheel.

One Cycle (C): 360 electrical degrees (°e), one bar and window pair.

One Shaft Rotation: 360 mechanical degrees, N cycles.

Position Error (ΔΘ): The normalized angular difference between the actual shaft position and the position indicated by the encoder cycle count.

Cycle Error (ΔC): An indication of cycle uniformity. The difference between an observed shaft angle that gives rise to one electrical cycle and the nominal angular increment of 1/N of a revolution.

Pulse Width (P): The number of electrical degrees that an output is high during 1 cycle. This value is nominally 180°e or 1/2 cycle.

Pulse Width Error (ΔP): The deviation, in electrical degrees, of the pulse width from its ideal value of 180°e.

State Width (S): The number of electrical degrees between a transition in the output of channel A and the neighboring transition in the output of channel B. There are four states per cycle, each nominally 90°e.

State Width Error (ΔS): The deviation, in electrical degrees, of each state width from its ideal value of 90°e.

Phase (ϕ): The number of electrical degrees between the center of the high state of channel A and the center of the high state of channel B. This value is nominally 90°e for quadrature output.

Phase Error (Δϕ): The deviation of the phase from its ideal value of 90°e.

Direction of Rotation: When the code wheel rotates in the direction of the arrow on top of the module, channel A will lead channel B. If the code wheel rotates in the opposite direction, channel B will lead channel A.

Optical Radius (R_{OP}): The distance from the code wheel's center of rotation to the optical center (O.C.) of the encoder module.

Index Pulse Width (P_O): The number of electrical degrees that an index is high during one full shaft rotation. This value is nominally 90°e or 1/4 cycle.

Absolute Maximum Ratings

Parameter	Symbol	Value
Storage Temperature	T_S	–40°C to +100°C
Operating Temperature	T_A	–40°C to +100°C
Supply Voltage	V_{CC}	–0.5V to 7V
Output Voltage	V_O	–0.5V to V_{CC}
Output Current per Channel	I_{OUT}	–1.0 mA to 5 mA
Shaft Axial Play	—	±0.25 mm (±0.010 in.)
Shaft Eccentricity Plus Radial Play	—	0.1 mm (0.004 in.) TIR
Velocity	—	30,000 RPM [a]
Acceleration	—	250,000 rad/sec^2 [a]

a. Absolute maximums for the HEDS-5140/6140 code wheels only.

Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Temperature	T_A	–40	—	100	°C	—
Supply Voltage	V_{CC}	4.5	5.0	5.5	V	Ripple < 100 mV_{p-p}
Load Capacitance	C_L	—	—	100	pF	2.7-kΩ pull-up
Count Frequency	f	—	—	100	kHz	Velocity (rpm) × N/60
Shaft Perpendicularity	—	—	—	±0.25	mm	6.9 mm (0.27 in.) from the mounting surface
Plus Axial Play	—	—	—	(±0.010)	(in.)	
Shaft Eccentricity Plus	—	—	—	0.04	mm (in.)	6.9 mm (0.27 in.) from the mounting surface
Radial Play	—	—	—	(0.0015)	TIR	

NOTE: The module performance is guaranteed to 100 kHz but can operate at higher frequencies. For the HEDS-9040 #T00 at operation below 0°C and greater than 50 kHz, the maximum Pulse Width and Logic State Width errors are 60°e.

Encoding Characteristics: HEDS-9040 (Except #T00), HEDS-9140 (Except #B00)

Encoding characteristics are over the recommended operating range and recommended mounting tolerances unless otherwise specified. Values are for the worst error over the full rotation of the HEDS-5140 and HEDS-6140 code wheels.

Parameter		Symbol	Min.	Typ.[a]	Max.	Units
Cycle Error		ΔC	—	3	5.5	°e
Pulse Width Error		ΔP	—	7	30	°e
Logic State Width Error		ΔS	—	5	30	°e
Phase Error		Δϕ	—	2	15	°e
Position Error		ΔΘ	—	10	40	Min. of arc
Index Pulse Width		P_O	60	90	120	°e
CH. I Rise After	–25°C to +100°C	t_1	10	100	250	ns
CH. B or CH. A Fall	–40°C to +100°C	t_1	–300	100	250	ns
CH. I Fall After	–25°C to +100°C	t_2	70	150	300	ns
CH. A or CH. B Rise	–40°C to +100°C	t_2	70	150	1000	ns

a. The module is mounted on a tolerance circle of ±0.13 mm (±0.005 in.) radius referenced from the module side A aligning recess centers. 2.7-kΩ pull-up resistors are used on all encoder module outputs.

Encoding Characteristics: HEDS-9040 #T00

Encoding characteristics are over the recommended operating range and recommended mounting tolerances unless otherwise specified. Values are for the worst error over the full rotation of the HEDM-614x option Txx code wheel.

Parameter		Symbol	Min.	Typ.[a]	Max.	Units
Cycle Error		ΔC	—	3	7.5	°e
Pulse Width Error		ΔP	—	7	50	°e
Logic State Width Error		ΔS	—	5	50	°e
Phase Error		Δϕ	—	2	15	°e
Position Error		ΔΘ	—	2	20	Min. of arc
Index Pulse Width		P_O	40	90	140	°e
CH. I Rise After CH. B or CH. A Fall	–40°C to +100°C	t_1	10	450	1500	ns
CH. I Fall After CH. A or CH. B Rise	–40°C to +100°C	t_2	10	250	1500	ns

a. The module is mounted on a tolerance circle of ±0.13 mm (±0.005 in.) radius referenced from the module side A aligning recess centers. 2.7-kΩ pull-up resistors are used on all encoder module outputs.

Encoding Characteristics: HEDS-9140 #B00

Encoding characteristics are over the recommended operating range and recommended mounting tolerances unless otherwise specified. Values are for the worst error over the full rotation of the HEDM-504x option Bxx code wheel.

Parameter		Symbol	Min.	Typ.[a]	Max.	Units
Cycle Error		ΔC	—	6	12	°e
Pulse Width Error		ΔP	—	10	45	°e
Logic State Width Error		ΔS	—	10	45	°e
Phase Error		Δϕ	—	2	15	°e
Position Error		ΔΘ	—	10	40	Min. of arc
Index Pulse Width		P_O	50	90	130	°e
CH. I Rise After CH B or CH A Fall	–40°C to +100°	t_1	200	1000	1500	ns
CH. I Fall After CH. A or CH.B Rise	–40°C to +100°	t_2	0	300	1500	ns

a. The module is mounted on a tolerance circle of ±0.13 mm (±0.005 in.) radius referenced from the module side A aligning recess centers. 2.7-kΩ pull-up resistors are used on all encoder module outputs.

Electrical Characteristics

Electrical characteristics are over the recommended operating range.

Parameter	Symbol	Min.	Typ.[a]	Max.	Units	Notes
Supply Current	I_{CC}	30	57	85	mA	
High Level Output Voltage	V_{OH}	2.4	—	—	V	I_{OH} = –200 µA max.
Low Level Output Voltage	V_{OL}	—	—	0.4	V	I_{OL} = 3.86 mA
Rise Time	t_r	—	180[b]	—	ns	C_L = 25 pF, R_L = 2.7-kW pull-up
Fall Time	t_f	—	49[b]	—	ns	

a. Typical values are specified at V_{CC} = 5.0V and 25°C.

b. The t_r and t_f times are 80 ns for the HEDS-9040 #T00.

Electrical Interface

To ensure reliable encoding performance, the HEDS-9040 and 9140 three-channel encoder modules require 2.7-kΩ (±10%) pull-up resistors on output pins 2, 3, and 5 (Channels I, A, and B) as shown in Figure 1. These pull-up resistors should be located as close to the encoder module as possible (within 4 feet). Each of the three encoder module outputs can drive a single TTL load in this configuration.

Mounting Considerations

Figure 2 shows a mounting tolerance requirement for proper operation of the HEDS-9040 and HEDS-9140. The aligning recess centers must be located within a tolerance circle of 0.005-inch radius from the nominal locations. This tolerance must be maintained whether the module is mounted with side A as the mounting plane using aligning pins (see Figure 5) or whether the module is mounted with side B as the mounting plane using an alignment tool (see Figure 3 and Figure 4).

Figure 1: Pull-Up Resistors on HEDS-9x40 Encoder Module Outputs

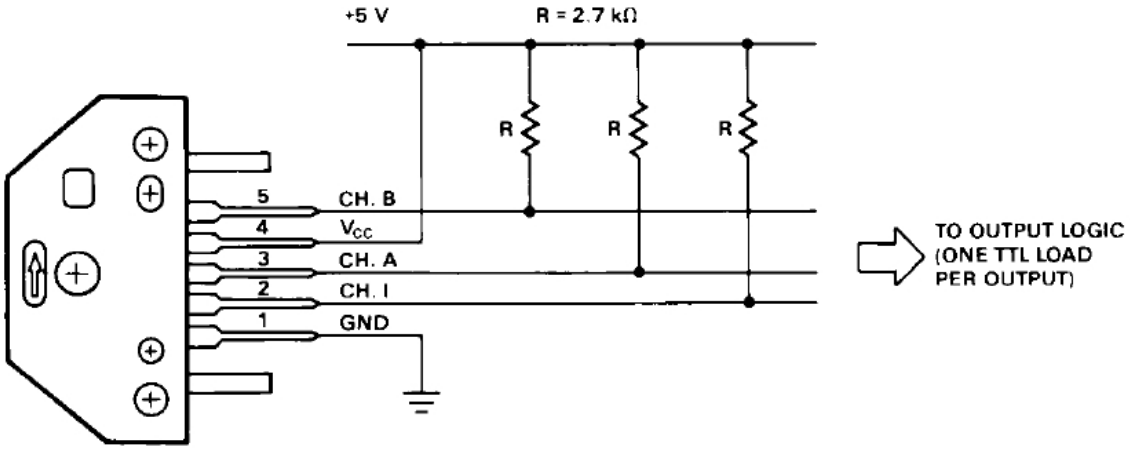
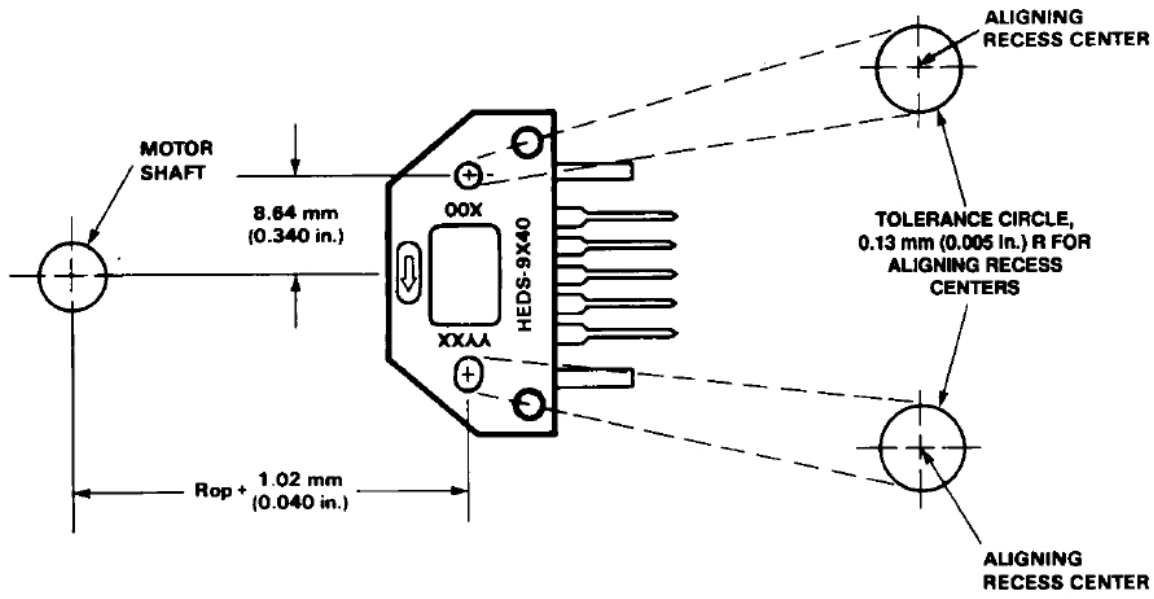


Figure 2: HEDS-9x40 Mounting Tolerance



Mounting with an Alignment Tool

The HEDS-8905 and HEDS-8906 alignment tools are recommended for mounting the modules with side B as the mounting plane. The HEDS-8905 is used to mount the HEDS-9140, and the HEDS-8906 is used to mount the HEDS-9040. These tools fix the module position using the code-wheel hub as a reference. They will not work if side A is used as the mounting plane.

The following assembly procedure uses the HEDS-8905/8906 alignment tool to mount a HEDS-9140/9040 module and a HEDS-5140/6140 code wheel.

1. Place the code wheel on the shaft.
2. Set the code-wheel height by placing the alignment tool on the motor base (pins facing up) flush up against the code wheel as shown in Figure 3. Tighten the code-wheel setscrew and remove the alignment tool.
3. Insert the mounting screws through the module and thread them into the motor base. Do not tighten the screws.
4. Slide the alignment tool over the code-wheel hub and onto the module as shown in Figure 4. The pins of the alignment tool should fit snugly inside the alignment recesses of the module.
5. While holding the alignment tool in place, tighten the screws down to secure the module.
6. Remove the alignment tool.

Figure 3: Alignment Tool Is Used to Set the Height of the Code Wheel.

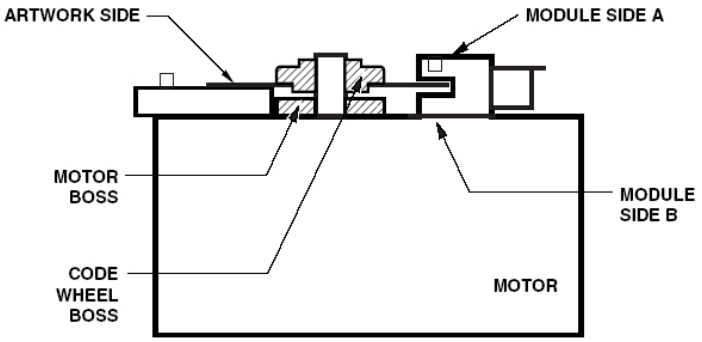
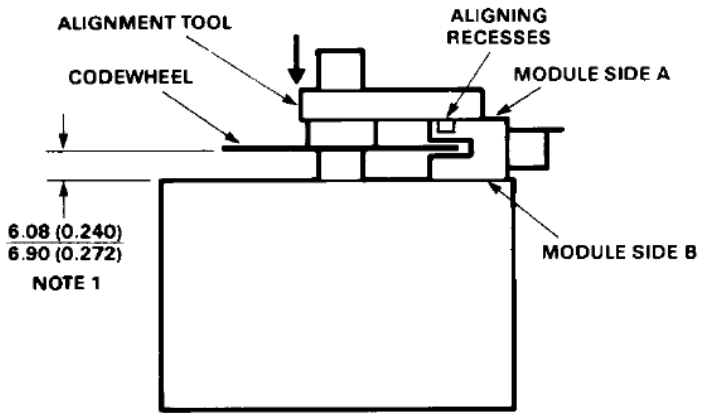


Figure 4: Alignment Tool Is Placed over the Shaft and onto the Code-Wheel Hub. Alignment Tool Pins Mate with the Aligning Recesses on the Module.



NOTE 1: THIS DIMENSION IS FROM THE MOUNTING PLANE TO THE NON-HUB SIDE OF THE CODEWHEEL.

Mounting with Aligning Pins

The HEDS-9040 and HEDS-9140 can also be mounted using aligning pins on the motor base. (Broadcom does not provide aligning pins.) For this configuration, side A must be used as the mounting plane. The aligning recess centers must be located within the 0.005-inch radius tolerance circle as explained in Mounting Considerations. Figure 5 shows the necessary dimensions.

Figure 5: Mounting Plane Side A

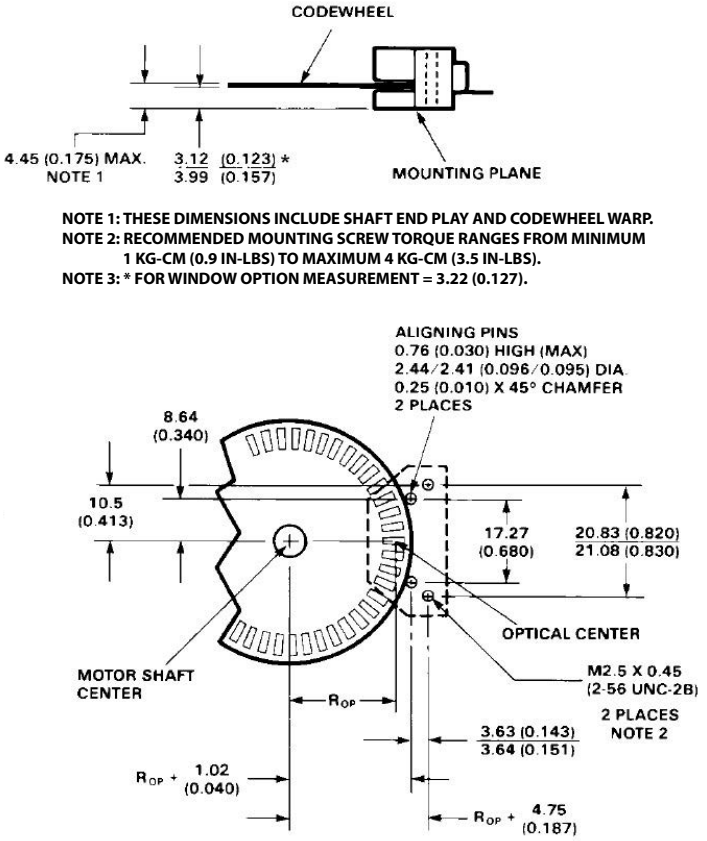


Figure 6: HEDS-6140 Code Wheel Used with the HEDS-9040

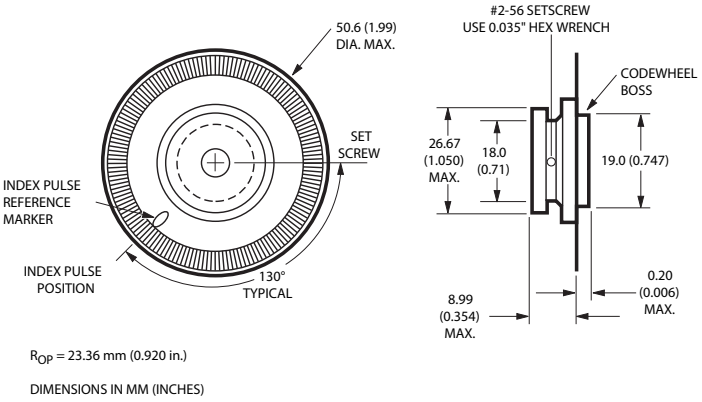


Figure 7: HEDM-614x Series Code Wheel Used with the HEDS-9040 #T00

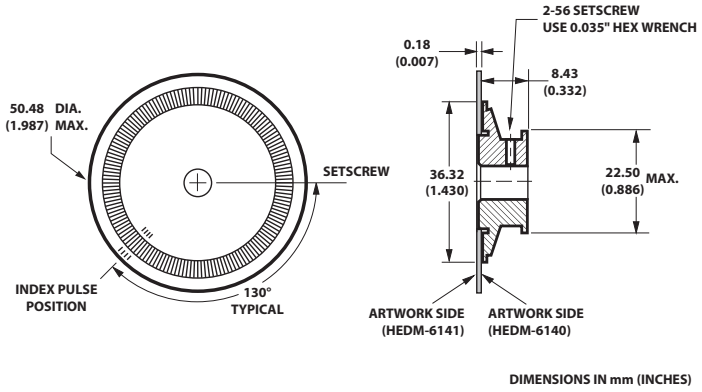
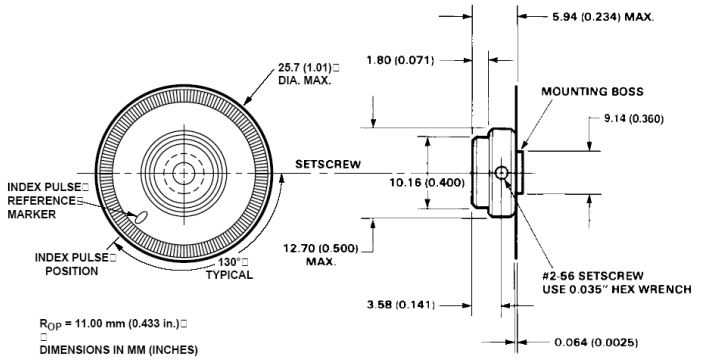


Figure 8: HEDS-5140 Code Wheel Used with the HEDS-9140



Orientation of Artwork for HEDS-9040 Option T00 (2000 CPR, 23.36-mm Rop) and HEDS-9140 Option B00 (1000 CPR, 11.00-mm Rop)

The index area on the HEDS- 9040 option T00 (2000 CPR) and the HEDS-9140 option B00 (1000 CPR) encoder module has a nonsymmetrical pattern as does the mating code wheel. In order for the index to operate, the right-reading side of the code-wheel disk (the artwork side) must point toward side A of the module (the side with the connecting pins). See Figure 6 and Figure 8.

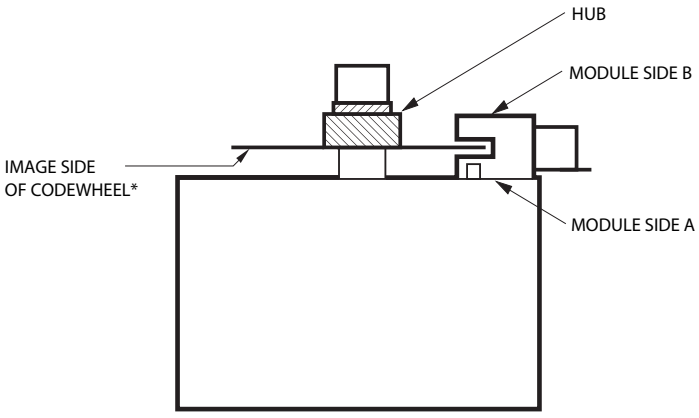
Because the encoder module can be used with either side A or side B toward the mounting surface, Broadcom supplies two versions of film code wheels for use with the option T00 3-channel module and the option B00 3-channel module:

- Code-wheel HEDM-6140 option Txx and HEDM-5040 option Bxx have the artwork side on the hub side of the code-wheel/hub assembly and work with side B of the module on the user's mounting surface.
- Code-wheel HEDM-6141 option Txx and HEDM-5041 option Bxx have the artwork side opposite the hub side and work with side A of the module on the mounting surface.

These options refer to Figure 7.

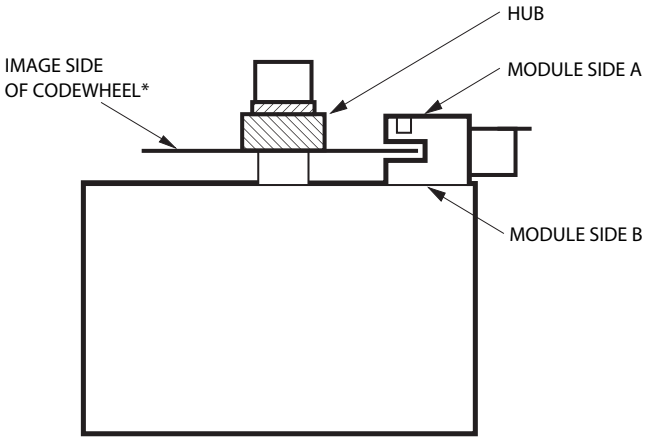
For the index to operate, these parts must be oriented as shown in Figure 9 and Figure 10.

Figure 9: Code-Wheel Artwork Orientation for Side B Mounting Configuration



* USE HEDM-6141 # Txx

Figure 10: Code-Wheel Artwork Orientation for Side A Mounting Configuration



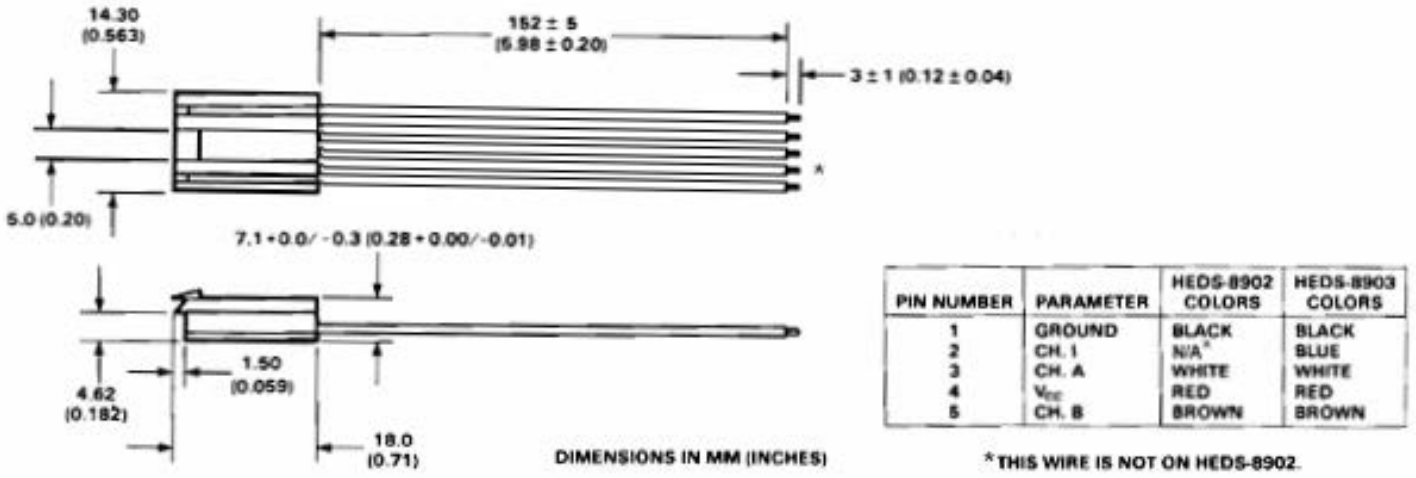
* USE HEDM-6140 # Txx

NOTE: The image side of the code wheel must always face module side A.

Connectors

Manufacturer	Part Number
AMP	103686-4
	640442-5
Broadcom	HEDS-8902 (2 ch.) with 4-wire leads
	HEDS-8903 (3 ch.) with 5-wire leads
Molex	2695 series with 2759 series

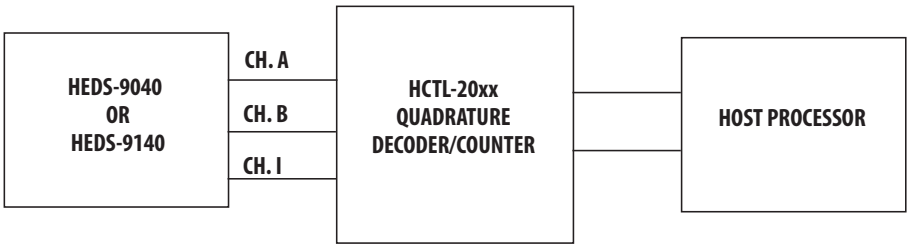
Figure 11: HEDS-8903 Connector

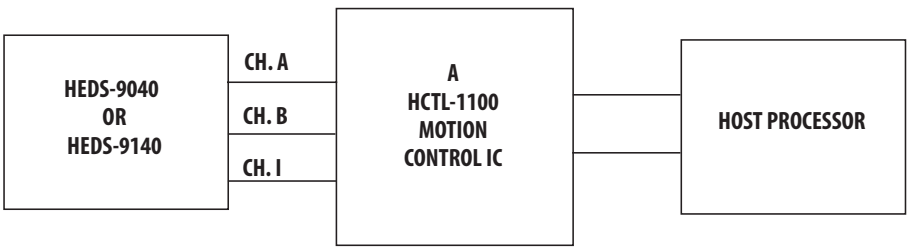


PIN NUMBER	PARAMETER	HEDS-8902 COLORS	HEDS-8903 COLORS
1	GROUND	BLACK	BLACK
2	CH. I	N/A*	BLUE
3	CH. A	WHITE	WHITE
4	V_{DD}	RED	RED
5	CH. B	BROWN	BROWN

*THIS WIRE IS NOT ON HEDS-8902.

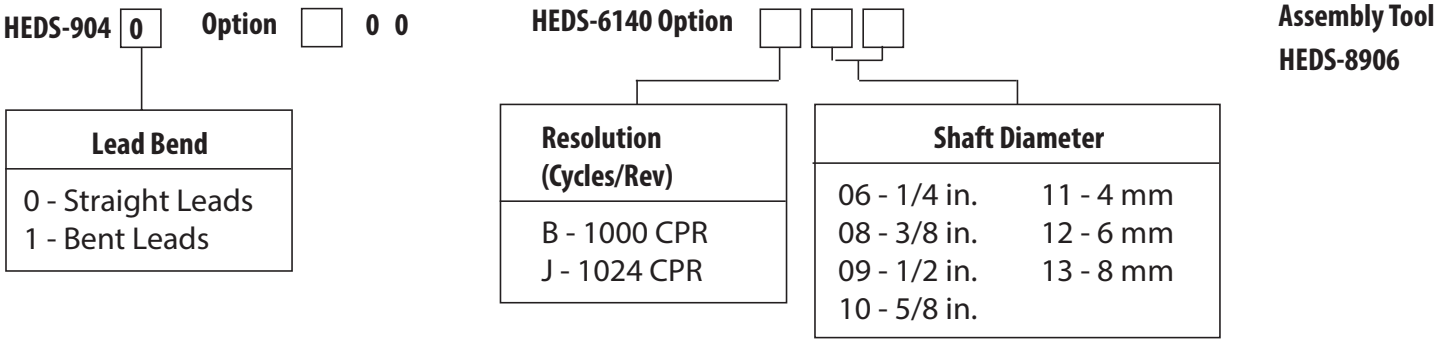
Typical Interfaces



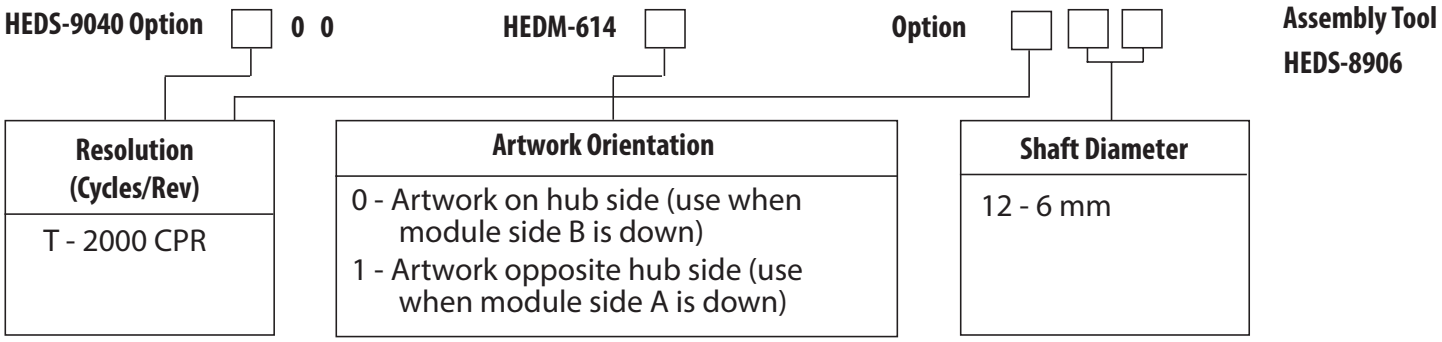


Ordering Information

Three-Channel Encoder Modules and Metal Code Wheels: 23.36-mm Optical Radius



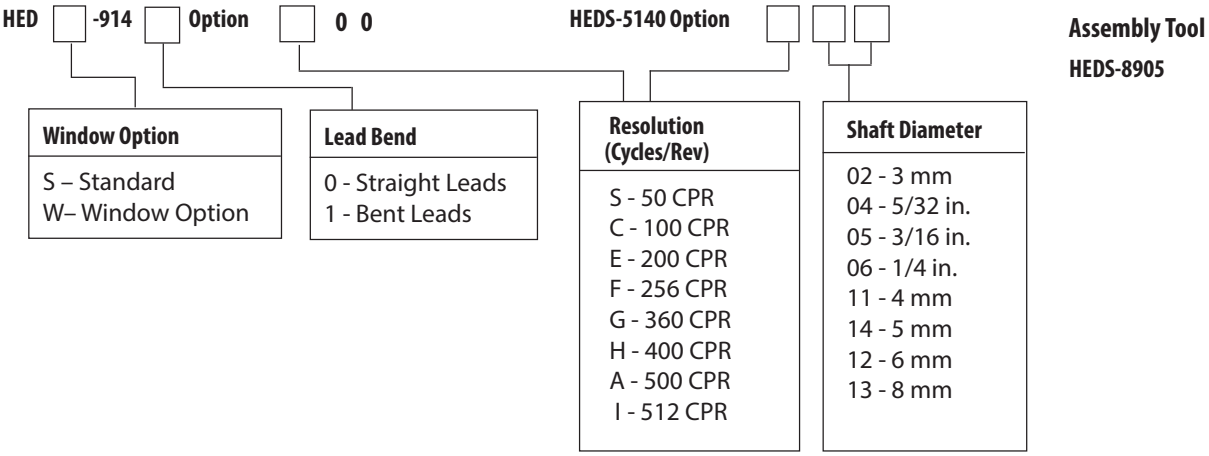
Three-Channel Encoder Modules and Film Code Wheels: 23.36-mm Optical Radius



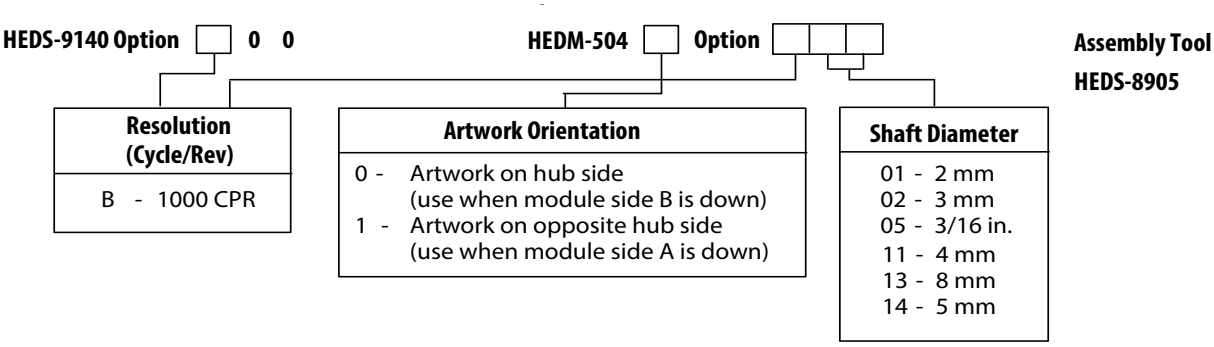
	A	B	C	D	E	F	G	H	I	J	K	S	T	U
HEDS-9040	*									*			*	
HEDS-9041	*													

		01	02	03	04	05	06	08	09	10	11	12	13	14
HEDS-6140	B							*	*	*	*	*	*	*
	J							*		*			*	*
HEDM-6140	T												*	

Three-Channel Encoder Modules and Metal Code Wheels: 11.00-mm Optical Radius



Three-Channel Encoder Modules and Film Code Wheels: 11.000 Optical Radius



	A	B	C	D	E	F	G	H	I	J	K	S	T	U
HEDS-9140	*	*	*		*	*	*	*	*		*			
HEDS-9141	*				*	*	*							
HEDW-9140	*								*					

		01	02	03	04	05	06	08	09	10	11	12	13	14
HEDS-5140	A		*		*	*	*				*	*	*	*
	C				*		*					*	*	
	E						*				*	*		*
	F				*							*		*
	G						*					*		*
	I		*		*		*				*	*	*	*
HEDM-5040	B	*	*			*					*		*	*
HEDM-5041	B	*	*			*					*		*	*

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