Rotary Encoders

■ ENCODER TYPES

Incremental encoders

An incremental encoder is an encoder type that indicates motion and the direction of movement. The incremental encoder serially outputs pulses corresponding to the angle of shaft rotation. This type of encoder does not output pulses when the shaft is at rest. An incremental encoder is connected with a counting device to form a system which can count the pulses and convert this into a measure of the shaft movement.

An incremental optical encoder consists of five components: the light, incremental disk, mask, photo detector assembly, and signal processor. The disk of an incremental encoder is divided into precisely positioned slots or marks. The number of slots determines the encoder's number of pulses per revolution or its resolution. If a disk were divided by 1000 slots, then after 250 counts the shaft would have rotated 90 degrees.

The incremental encoder can be classified into the single phase type (channel A output only), which can be used to determine the amount of rotation or speed by looking at the interval between pulses, and the quadrature encoder (channels A and B output), which can also detect the direction of the shaft rotation (i.e., clockwise or counterclockwise). A type with a zero index (Z channel) output indicates a reference once per revolution to correct errors within each revolution. Higher resolution (two to four times better) is obtained by counting both the leading and trailing edges. Channel A and B generate pulses with 90° shifted phase.

Absolute encoders

An absolute encoder is an encoder type that outputs a unique code for each shaft position. Unlike the incremental encoder, no counter is needed to count the number of pulses and the rotation angle can always be known. The absolute encoder outputs a signal when the shaft is rotating or at rest.

An absolute encoder's disk differs from an incremental encoder because the internal disk has several concentric tracks. Each track has an independent light source. The outputs of each of the tracks make up a unique binary signal for a particular shaft position.

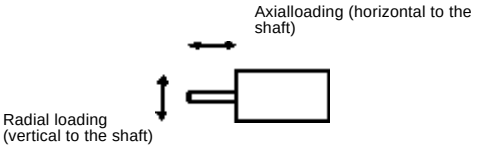
The absolute encoder offers no position loss when power is off and eliminates the need of a home position or reference starting point. The absolute encoder signal is not affected by noise from switching devices, and does not require fine adjustment of the shaft. Moreover, even if the coded signal output by the encoder cannot be read because the shaft is revolving too quickly, the correct rotation angle is registered when the revolution speed decreases. In addition, the encoder is free from chattering that may result from vibration of the application equipment.

■ SHAFT COUPLER

A flexible type coupler to control shaft alignment errors which cause premature wear of encoder products.

■ SHAFT LOADING

Shaft loading is the maximum load that can be exerted on the shaft. Shaft loading is classified into "radial loading" and "axial loading" according to the direction that the load is applied. Shaft loading has a direct effect on the bearing life.



■ BINARY CODE

Binary code is a basic code for digital signal processing and consists of numerals 0 and 1 only. It is, however, difficult to change two or more digits simultaneously when a number represented by binary code changes. Consequently, the reading timing is very delicate, which may occasionally cause a read error.

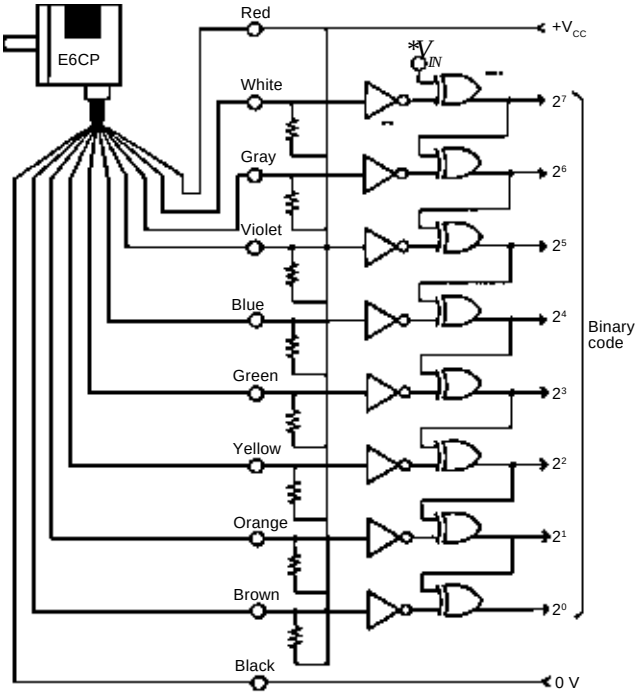
■ GRAY CODE

As shown in the table, only one digit changes when a number represented by Gray code changes. Gray code output, therefore, hardly ever has a read error and is employed in many rotary encoders (absolute type) and electronic balances

Output Codes Table

Decimal	Binary				Gray			
	2^3	2^2	2^1	2^0				
0	0	0	0	0	0	0	0	0
1	0	0	0	1	0	0	0	1
2	0	0	1	0	0	0	1	1
3	0	0	1	1	0	0	1	0
4	0	1	0	0	0	1	1	0
5	0	1	0	1	0	1	1	1
6	0	1	1	0	0	1	0	1
7	0	1	1	1	0	1	0	0
8	1	0	0	0	1	1	0	0
9	1	0	0	1	1	1	0	1
10	1	0	1	0	1	1	1	1
11	1	0	1	1	1	1	1	0
12	1	1	0	0	1	0	1	0
13	1	1	0	1	1	0	1	1
14	1	1	1	0	1	0	0	1
15	1	1	1	1	1	0	0	0

Use the circuit on the right to convert Gray code into binary code



Note:
* Gray code can be converted into positive logic binary code when the V_{in} terminal is connected to 0 V.
** Inverter
*** Exclusive OR

■ INSTALLATION PROCEDURE

1. Place coupler on the shaft.
Do not tighten the set screws on the coupler at this point.

2. Fasten the encoder into position.
Insert the shaft into the coupler to the depth shown below.

Shaft coupler	Insertion depth
E69-C04B	5.2 mm (0.21 inch)
E69-C06B	5.5 mm (0.22 inch)
E69-C68B	6.8 mm (0.28 inch)
E69-C10B	7.1 mm (0.28 inch)
E69-C610B	7.1 mm (0.28 inch)

3. Fasten both sides of the coupler.
Tighten the set screws on the coupler with the torque shown below.

Shaft coupler	Tightening torque
E69-C04B	2.5 kg-cm (2.17 in-lbs.)
E69-C06B	2.5 kg-cm (2.17 in-lbs.)
E69-C68B	2.5 kg-cm (2.17 in-lbs.)
E69-C10B	4.5 kg-cm (3.91 in-lbs.)
E69-C610B	4.5 kg-cm (3.91 in-lbs.)

4. Connect power supply and input/output lines.
Make sure you turn off the power supply when wiring.

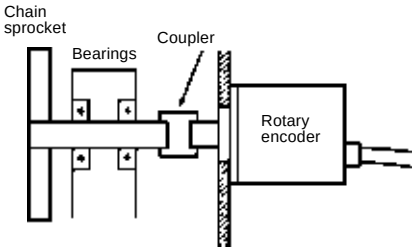
5. Turn on the power and check outputs.

■ INSTALLATION PRECAUTIONS

• Make sure that the encoder is not subjected to oil or water. If oil or water enters the encoder, malfunctions may occur.

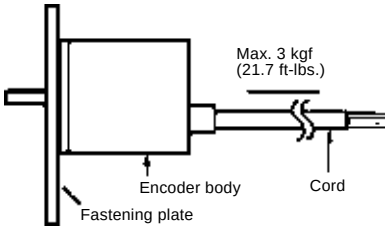
• Rotary encoders consist of precision parts. Their functions may be damaged if dropped. Be very careful in handling encoders.

• When joining to a chain, timing belt or gears, include a coupler and bearings before the encoder.



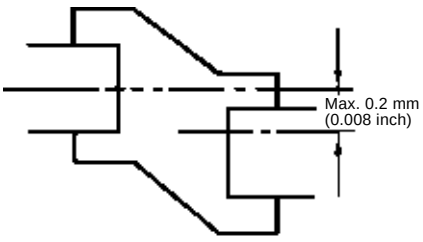
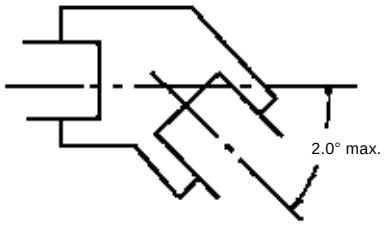
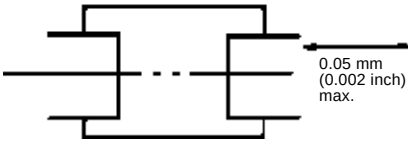
• Keep the tightening torque below 5 kg-cm (4.3 in-lbs.) when fastening the rotary encoder to a coupler.

• Do not pull the wiring at a force greater than 3 kgf (21.7 ft-lbs.) when the main encoder is fastened and wired.



• Do not use a hammer to force the coupler on the shaft. Refer to the shaft insertion depth information above.

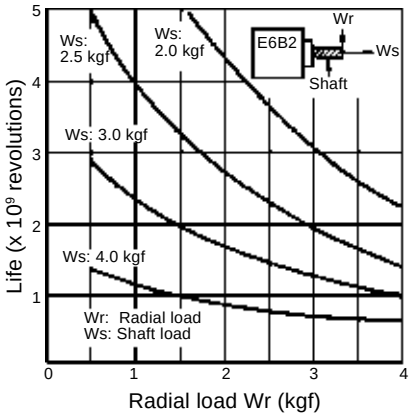
• Large mounting deviations (eccentric centers or angles) may cause an excessive load on the encoder's shaft, resulting in damage or drastically reduced life expectancy. Take care not to place excessive loads on the shaft. Refer to the following illustrations when applying a coupler.

Description	Example and maximum rating
Decentering tolerance	
Declination tolerance	
Displacement tolerance in the shaft direction	

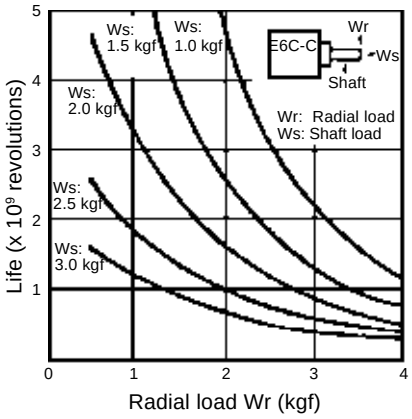
■ BEARING SERVICE LIFE

The following graphs show the life expectancy of the bearing with radial and shaft loads imposed on the bearing.

E6B2



E6C-C



■ WIRING AND CONNECTIONS

• Exercise extreme caution when wiring the encoder since wiring errors may result in serious damage to the internal elements of the encoder. Be especially careful when wiring the power source.

• Do not run the encoder cable in the vicinity of power or high-tension lines. Induced noise may result in a malfunction or even damage to the encoder.

• When the encoder cable is extended, rise and fall times may be lengthened due to the effects of distributed capacitance. If this presents problems, use a waveform-shaping device such as a Schmitt trigger to improve the signal.

• It is recommended that the encoder cable be as short as possible to reduce the effect of induced noise. The cable length is especially important when the encoder is used to input signal to an IC.

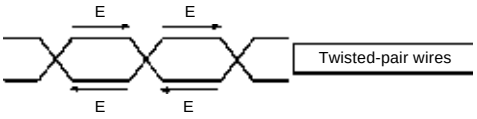
• If a surge is generated by the power supply that feeds the encoder, connect a surge absorber to the power supply.

• The encoder may generate unwanted pulses immediately after (about 0.1 second) the power is turned on or off. Therefore, make sure that the encoder starts operating after a delay of 0.1 second after power up. Likewise, it is necessary to arrange that the encoder is stopped 0.1 second before power is turned off.

■ EXTENSION OF LINE DRIVER OUTPUT

Be sure to use a twisted-pair cable to extend a line driver cord. Use an RS-422A receiver for the receiver side.

The twisted-pair wires as shown in the following illustration are suitable for RS-422A signal transmission. Normal mode noise can be eliminated by twisting the wires because the generated electrical forces on the lines cancel each other.

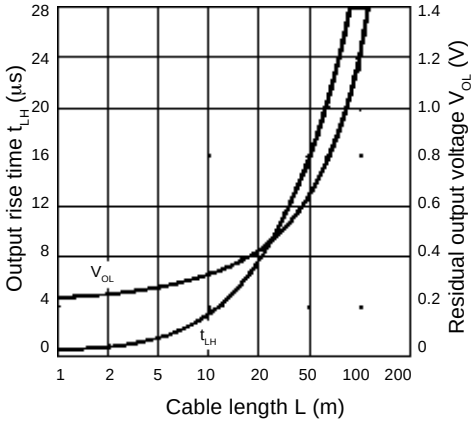


■ CORD EXTENSION

The rise time of each output waveform will increase when the cord is extended. This affects the phase difference characteristics of phases A and B.

The rise time varies with the resistance of the cord and the kind of cord as well as the length of the cord.

The residual output voltage will increase according to the length of the cord.



Conditions:

Rotary encoder:	E6B2-CWZ6C (2,000 pulses/revolution)
Load voltage:	5 VDC
Load resistance:	1 kΩ (The residual output voltages were measured with a load current of 35 mA.
Frequency:	100 kHz
Cord:	Dedicated cord

■ PREVENTIVE MISCOUNTING

If the operation of the encoder is topped near a signal's rising or falling edge, a wrong pulse may be generated, in which case the encoder will miscount. In such a case, use an increment-decrement (reversible) counter to prevent miscounting.

■ ENCODER CONNECTION COMPATIBILITY

E6A2 Incremental Encoders

Part number	E6A2-CS3E, E6A2-CW3E, E6A2-CWZ3E	E6A2-CS3C, E6A2-CW3C, E6A2-CWZ3C	E6A2-CS5C, E6A2-CW5C
TTL, LSTTL devices	Directly connectable	Connectable	Not connectable
CMOS	Directly connectable	Connectable	Connectable
Sensor controller S3D8	Connectable	Directly connectable	Directly connectable
Digital counter H7BR	Directly connectable	Directly connectable	Directly connectable
Digital counter H7ER	Directly connectable	Connectable	Connectable
SYSMAC C-Series high-speed counter	Directly connectable	Directly connectable	Directly connectable

E6B2, E6C-C, E6D Incremental Encoders

Part number	E6B2-CWZ3E	E6B2-CWZ6C	E6C-CWZ3E	E6C-CWZ5C	E6D-CWZ1E	E6D-CWZ2C
TTL, LSTTL devices	Directly connectable	Connectable	Directly connectable	Connectable	Directly connectable	Connectable
CMOS	Directly connectable	Connectable	Directly connectable	Connectable	Directly connectable	Connectable
Sensor controller S3D8	Connectable	Directly connectable	Connectable	Directly connectable	Not connectable	Directly connectable
Digital counter H7BR	Directly connectable	Directly connectable	Directly connectable	Directly connectable	Not connectable	Directly connectable
Digital counter H7ER	Not connectable	Connectable	Directly connectable	Connectable	Not connectable	Connectable
Multiple counter H8PA	Connectable	Directly connectable	Connectable	Directly connectable	Not connectable	Directly connectable
SYSMAC C-Series high-speed counter	Directly connectable	Directly connectable	Directly connectable	Directly connectable	Connectable	Directly connectable
SYSMAC C-Series position control unit	Not connectable	Directly connectable	Not connectable	Connectable	Not connectable	Connectable
Servo positioner	Not connectable	Directly connectable	Not connectable	Connectable	Not connectable	Connectable
Multi-axis positioner	Not connectable	Directly connectable	Not connectable	Connectable	Not connectable	Connectable

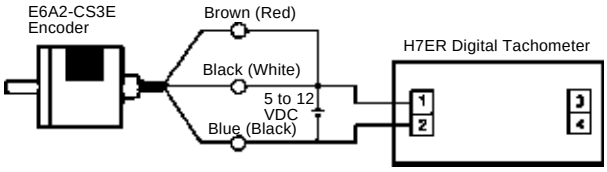
E6CP, E6F Absolute Encoders

Part number	E6CP-AG3C	E6CP-AG5C-C	E6F-AB3C	E6F-AB3C-C	E6F-AG5C-C
TTL, LSTTL devices	Connectable	Not connectable	Connectable	Not connectable	Not connectable
CMOS	Connectable	Connectable	Connectable	Not connectable	Not connectable
SYSMAC C-Series DC input unit	Connectable	Directly connectable	Connectable	Not connectable	Not connectable
Cam positioner H8PR	Not connectable	Not connectable	Not connectable	Not connectable	Directly connectable
Cam positioner H8PS	Not connectable	Directly connectable	Not connectable	Not connectable	Directly connectable

■ CONNECTION EXAMPLES

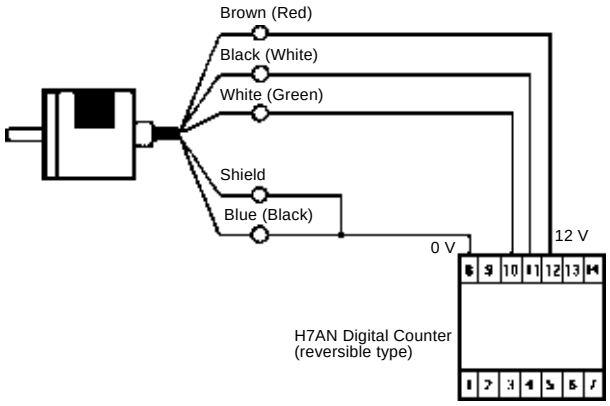
Digital Tachometer H7ER

Applicable models: E6A2-CS3E



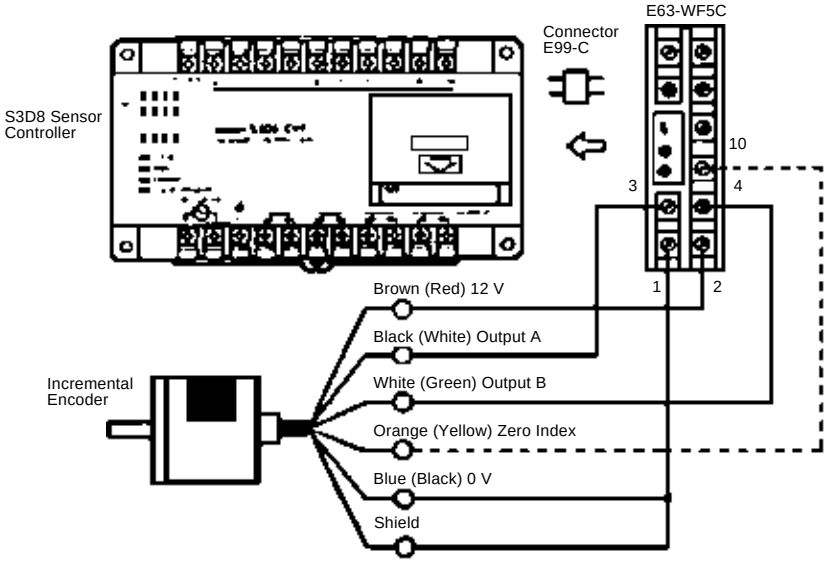
Digital Counter H7AN

Applicable models: E6B2-CWZ3E, E6C-CWZ3E



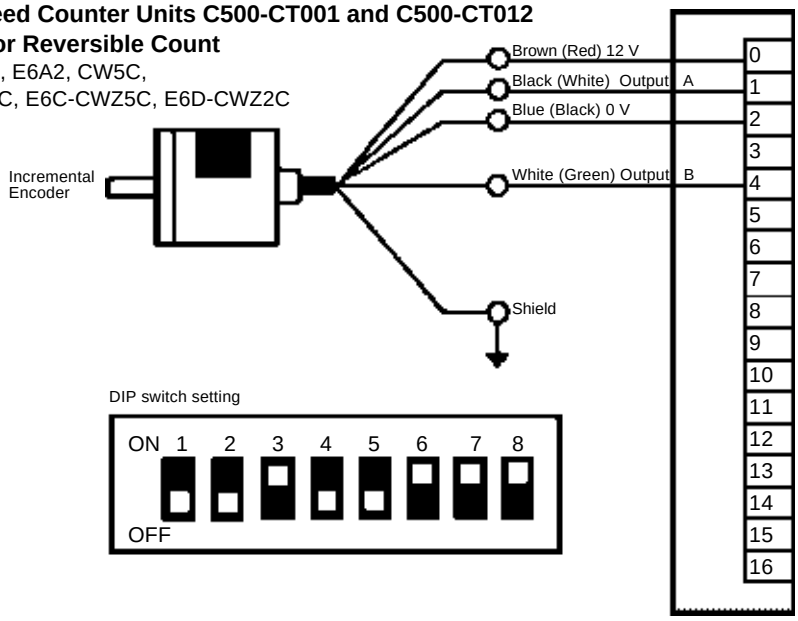
Sensor Controller S3D8 with E63-WF5C Encoder Pulse Director

Applicable models: E6A2-CW3C, E6B2-CWZ3E, E6C-CWZ5C, E6D-CWZ2C



SYSMAC C-Series High-Speed Counter Units C500-CT001 and C500-CT012 Using CW/CCW Detection for Reversible Count

Applicable models: E6A2-CW3C, E6A2, CW5C,
E6B2-CWZ6C, E6C-CWZ5C, E6D-CWZ2C



■ NOMENCLATURE

E6 ① ② ③ ④ ⑤ ⑥

Code	Classification	Meaning	Applicable models
E6	Standard model	E6: Encoder	—
1	Outside diameter	A: 25 mm	—
		B: 40 mm	
		C: 50 mm	
		D: 55 mm	
		F: 60 mm	
2	Series	No indication: Metal housing	—
		2: Updated series	E6A2, E6B2
		P: Plastic housing	E6CP
3	Encoder type	A: Absolute type	E6C2-A, E6CP, E6F
		C: Incremental type	E6A2, E6B2, E6C2-C, E6D
4	Output method	Incremental encoders W: Reversible (square wave) S: Single type	E6A2, E6B2, E6C2-C, E6D
		Absolute encoders N: Binary code B: BCD code G: Gray code	E6CP, E6C2-A, E6C-M, E6C-N E6F
5	Reference point	Z: With origin output	E6B2, E6C2-C, E6D
		No indication: No origin output	E6A2
6	Supply voltage	1: 5 VDC	E6D
		2: 12 VDC	E6D
		3: 5 to 12 VDC	E6A2, E6B2, E6C2-C, E6CP, E6F
		4: 24 VDC	E6A
		5: 12 to 24 VDC	E6C2-A, E6C2-C, E6C-M, E6C-N, E6CP
7	Output form	6: 5 to 24 VDC	E6B2, E6C2-C
		C: NPN open collector output	E6A2, E6B2, E6C2-A, E6C2-C, E6C-M, E6C-N, E6CP, E6D, E6F
		E: NPN resistive load output	E6B2, E6C2-C, E6D
		G: Complementary output	E6C2-C
		X: Line driver output	E6B2, E6C2-C
		B: PNP open collector output	E6C2-C

■ OUTPUT PHASES AND RESOLUTION

Incremental encoders

Housing OD (mm)	Output phase	Resolution: 10 100 500 1000 2000 6000
25	A, A/B, A/B/Z	**E6A2**
46	A/B/Z	**E6B2**
55	A/B/Z	**E6D**
56	A/B/Z	**E6C2-C**

Absolute encoders

Housing OD (mm)	Resolution: 256	360	500	720	1024	2048	4096
50	**E6M**					x	x
	E6N x		x				
56	**E6C2-A** x				x		
	E6CP x						
60	**E6F** x	x					

Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

Omron:
E63-WF5C