Electro Cam Corp. PLμS Controls Div.

PS — 4256 / 4456
ABSOLUTE GRAY CODE ENCODER

PS-4456/4457 (NEMA 4X)

PS-4256/4257 (NEMA 12)

Easily Interfaced to PLCs Using Standard Digital DC Inputs

Or Directly to Gray Code Modules*

Features

- Absolute 8 Bit Output
- Rugged Construction
- 3/4" Shaft with Ball Bearings
- NEMA 12 or NEMA 4X

Applications

- Packaging Machines
- Pick and Place Operations
- Assembly Machines
- Food Processing Equipment
- Indexing Equipment

General Information

Sinking† or Sourcing† Output — The encoders are available with Sinking† or Sourcing† outputs. Be sure to order the type that is compatible with the control's input circuits. The use of fast response DC inputs is recommended to minimize missed fast pulsing encoder outputs.

NEMA 4X Option — The NEMA 4X version of the encoder includes a stainless steel enclosure and shaft, double sealed ball bearings, and conformal coating on both sides of the internal circuit board. This version should be ordered for applications which involve washdowns, high humidity or corrosive atmospheres.

* A-B 1771-DL or Similar type modules

† See page 7 for sinking/sourcing definitions

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Why 8 Bit Gray Code?

When wiring an encoder to the PLC, the most important thing to remember is which output is the MSB (Most Significant Bit) and which is the LSB (Least Significant Bit). If the order is reversed, or the output wiring is out of order (transposed wires), the value that you create in the PLC register will not sequence properly.

MSB and LSB are digits of the binary number. An understanding of the different number systems used by logic controllers (binary, hex, decimal, etc.) is essential to know what these codes signify.

- Gray Code is a cyclic or reflected binary code, specifically designed for positioning information. In a Gray Code number only **one-digit** changes at a time. In a binary number, going from one number to the next may have **many of its digits** change.

  The cyclic change is created by the relationship of the 8 pulse disks that turn the encoder OFF and ON. (See Figure 6, page 6.)

- **Most Significant Bit** refers to the binary code (Gray Code) digit that is on the far left when written out. This digit changes the **least** as the binary number goes from 0 to 255.

- **Least Significant Bit** refers to the binary code (Gray Code) digit that is on the far right when written out. This digit changes the **most** as the binary number goes from 0 to 255.

Absolute Position Decoding — The 8 Bit Gray Code signal always represents the current position of the encoder shaft. The PLC cannot get out of sync with the present encoder position — not even when the encoder shaft is turned while power is off to the controller.

8 Bit Resolution (256 increments) — The revolution of the encoder shaft is divided into 256 uniform increments. Each increment is 1.4 degrees wide, which allows any machine position to be known within ±0.7 degrees. This is appropriate resolution for many applications, especially when PLC scan times are taken into account (@ 60 RPM, a 10 mSec scan time equates to 3.6 degrees of motion between scans).

Error Free Decoding — Only one of the bits changes state when the encoder shaft rotates, eliminating the need for sophisticated latching and/or handshaking circuitry between the encoder and the PLC. Standard DC input cards are used to interface with the encoder. The only special programming needed is 8 exclusive-ORed (XOR) ladder rungs.

RPM / Response Considerations

The operating speed and resolution required of the application must be considered when interfacing the Gray Code encoder directly to a PLC or other control device. The scan speed and/or hardware response will cause delays that can reduce the overall system response and resolution. **Where full 8 bit resolution is required at higher speeds, the use of an Electro Cam PLµS (Programmable Limit Switch) is recommended.**

Values might not be true for certain fast response PLC inputs. Faster response times are dependent on hardware.

When machine speed rises above a certain level, several factors need to be considered:

- What is the scan time of the PLC program?
- What is the response time of the input module?
- What is the integer value that is being used, and is it dependent on several of the least significant bits?

Scan Time / Maximum RPM / Degrees Per Scan

Scan Time	Max RPM	Deg / Scan @ 30 RPM	Deg / Scan @ 100 RPM	Scan Time	Max RPM	Deg / Scan @ 30 RPM	Deg / Scan @ 100 RPM
1 mSec	234	0.18	0.60	20 mSec	11	3 6	12.0
5 mSec	46	0.9	3.0	25 mSec	9	4.5	15.0
10 mSec	23	1.8	6.0	30 mSec	7	5.4	18.0
15 mSec	15	2.7	9.0	40 mSec	5	7.2	24.0

The table above indicates the maximum RPM that the encoder can be turning for all 256 positions to be decoded each revolution for the corresponding scan time. Exceeding the indicated RPM will result in encoder shaft positions being skipped by the control. It is acceptable to skip encoder positions when 8 bit resolution is not required. Worst case output response = 2 Scans + Hardware response.

Figure 1

Refer to the above chart to compare machine RPM to the values listed on the chart. If speed exceeds the value, the PLC will not "see" certain Gray Code values. Miscalculation of the output value will occur.

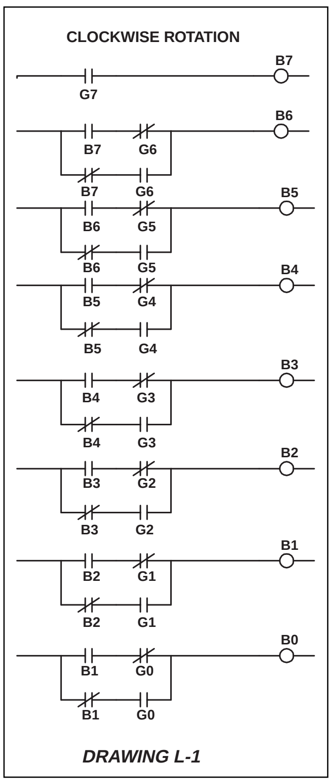
If a bit is on for 30 µSec, and the scan time is 10 mSec, the processor will not see that bit (or combination of bits). If the input module's response time is longer than the bit, or bits on time, the module will not react to the input. All of these factors show up as non-sequencing position values, or outputs that are not performing properly.

Decoding Gray Code?

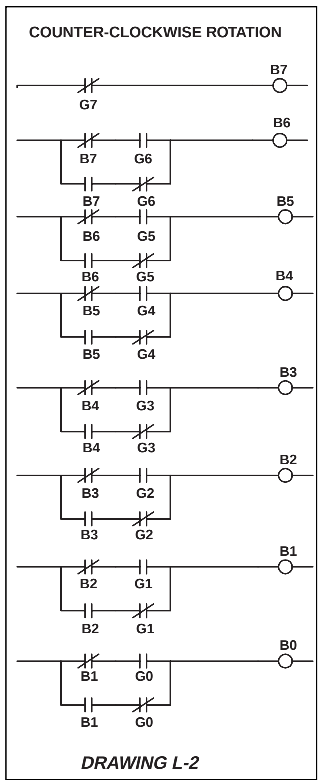
The Ladder Programming examples shown below apply for all Gray Code Encoder models. The examples show how to convert the 8 Bit Gray Code output signal (G0-G7) of the encoder to a binary number (B0-B7) during each scan of the PLC. The value of the Binary result will always be in the range of 0 - 255 because the 8 bit encoder divides each revolution into 256 uniform increments. Ladder rungs which follow the conversion can compare the rotary position value to known positions for control of machine devices that must operate at specific positions within the overall machine cycle. The rotary position of the machine cycle can also be used to gate input sensors and shift register functions.

Converting Gray Code to Binary involves a sequence of "Exclusive OR" operations. It is simple to program this same conversion logic in other programming languages besides ladder logic. In addition to decoding the rotary position of the encoder, controls with arithmetic capability can be programmed to perform direction reversal, position offset and re-zero functions, as well as convert the position value to degrees for ease of monitoring and setup.

Models DDN & DDP

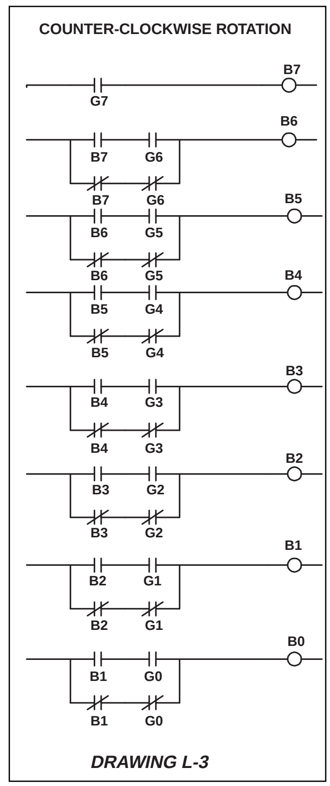


DRAWING L-1

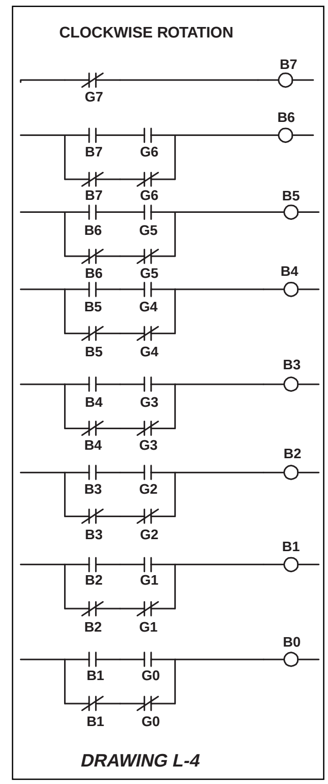


DRAWING L-2

Model DDH



DRAWING L-3



DRAWING L-4

Use a **limit** test function to program a pulse in the PLC. The limit test uses a test reference (in this case the integer register that the Gray Code is going into), and compares it to see if it is between a **lower limit** and an **upper limit**. If the integer value is between the lower limit (ON setpoint), and the upper limit (OFF setpoint), the rung is **true** and an output is turned on. If the integer value does not fall between the upper and lower limits, the rung is false, and nothing happens.

For every output pulse to occur, a different limit test must be programmed with the appropriate limits. **Reminder**: The limit values are position values, not degrees.

Gray Code — Error Free Decoding

The Gray Code chart below *(Figure 2)* shows the bit patterns that are used to represent all 256 encoder positions. It can be seen on this chart that from any position to any adjacent position, only 1 bit changes state. This ensures that the encoder inputs can be read by the control at any point in time (even during a transition) without error.

Consider the following comparison to Binary Code:

INC	DEG	GRAY CODE	BINARY
127	178.6	01000000	01111111
128	180.0	11000000	10000000

When Gray Code advances from increment 127 to 128, only 1 of the 8 bits changes state — bit 8. When Binary Code advances from increment 127 to 128, all 8 bits change states. Sampling the Binary bits during this transition could result in a very large decoding error. Sampling the Gray Code bits during this transition would yield either 127 or 128, depending only on bit 8.

Refer to the table below to understand the relationship between the ***increment*** (integer), ***degrees*** and ***binary numbers***. Use this table as a guide for setup and troubleshooting your Gray Code system.

- INC (increment) column represents the integer value to which the Gray Code is equal. The increments are 0 to 255 (256 total) that repeat or cycle. (At 255, the next number change is 0, increment to 255, then repeat the cycle over again).
- DEG (degree) column represents the actual degree position that the Gray Code is indicating.
- Gray Code column shows the Gray Code value for that particular position. This Gray Code binary number is the same as the Gray Code inputs status, 1 = ON and 0 = OFF.

Because the Gray Code value is also a graphic representation of the input status, it is an invaluable tool in checking the position or troubleshooting.

8 Bit Gray Code Table

INC	DEG	GRAYCODE
0	0.0	00000000
1	1.4	00000001
2	2.8	00000011
3	4.2	00000010
4	5.6	00000110
5	7.0	00000111
6	8.4	00000101
7	9.8	00000100
8	11.3	00001100
9	12.7	00001101
10	14.1	00001111
11	15.5	00001110
12	16.9	00001010
13	18.3	00001011
14	19.7	00001001
15	21.1	00001000
16	22.5	00011000
17	23.9	00011001
18	25.3	00011011
19	26.7	00011010
20	28.1	00011110
21	29.5	00011111
22	30.9	00011101
23	32.3	00011100
24	33.8	00010100
25	35.2	00010101
26	36.6	00010111
27	38.0	00010110
28	39.4	00010010
29	40.8	00010011
30	42.2	00010001
31	43.6	00010000
32	45.0	00110000
33	46.4	00110001
34	47.8	00110011
35	49.2	00110010
36	50.6	00110110
37	52.0	00110111
38	53.4	00110101
39	54.8	00110100
40	56.3	00111100
41	57.7	00111101
42	59.1	00111111
43	60.5	00111110
44	61.9	00111010

INC	DEG	GRAYCODE
45	63.3	00111011
46	64.7	00111001
47	66.1	00111000
48	67.5	00101000
49	68.9	00101001
50	70.3	00101011
51	71.7	00101010
52	73.1	00101110
53	74.5	00101111
54	75.9	00101101
55	77.3	00101100
56	78.8	00100100
57	80.2	00100101
58	81.6	00100111
59	83.0	00100110
60	84.4	00100010
61	85.8	00100011
62	87.2	00100001
63	88 6	00100000
64	90.0	01100000
65	91.4	01100001
66	92.8	01100011
67	94.2	01100010
68	95.6	01100110
69	97.0	01100111
70	98.4	01100101
71	99.8	01100100
72	101.3	01101100
73	102.7	01101101
74	104.1	01101111
75	105.5	01101110
76	106.9	01101010
77	108.3	01101011
78	109.7	01101001
79	111.1	01101000
80	112.5	01111000
81	113.9	01111001
82	115.3	01111011
83	116.7	01111010
84	118.1	01111110
85	119.5	01111111
86	120.9	01111101
87	122.3	01111100
88	123.8	01110100
89	125.2	01110101

INC	DEG	GRAYCODE
90	126.6	01110111
91	128.0	01110110
92	129.4	01110010
93	130.8	01110011
94	132.2	01110001
95	133.6	01110000
96	135.0	01010000
97	136.4	01010001
98	137.8	01010011
99	139.2	01010010
100	140.6	01010110
101	142.0	01010111
102	143.4	01010101
103	144.8	01010100
104	146.3	01011100
105	147.7	01011101
106	149.1	01011111
107	150.5	01011110
108	151.9	01011010
109	153.3	01011011
110	154.7	01011001
111	156.1	01011000
112	157.5	01001000
113	158.9	01001001
114	160.3	01001011
115	161.7	01001010
116	163.1	01001110
117	164.5	01001111
118	165.9	01001101
119	167.3	01001100
120	168.8	01000100
121	170.2	01000101
122	171.6	01000111
123	173.0	01000110
124	174.4	01000010
125	175.8	01000011
126	177.2	01000001
127	178.6	01000000
128	180.0	11000000
129	181.4	11000001
130	182.8	11000011
131	184.2	11000010
132	185.6	11000110
133	187.0	11000111
134	188.4	11000101

INC	DEG	GRAYCODE
135	189.8	11000100
136	191.3	11001100
137	192.7	11001101
138	194.1	11001111
139	195.5	11001110
140	196.9	11001010
141	198.3	11001011
142	199.7	11001001
143	201.1	11001000
144	202.5	11011000
145	203.9	11011001
146	205.3	11011011
147	206.7	11011010
148	208.1	11011110
149	209.5	11011111
150	210.9	11011101
151	212.3	11011100
152	213.8	11010100
153	215.2	11010101
154	216.6	11010111
155	218.0	11010110
156	219.4	11010010
157	220.8	11010011
158	222.2	11010001
159	223.6	11010000
160	225.0	11110000
161	226.4	11110001
162	227.8	11110011
163	229.2	11110010
164	230.6	11110110
165	232.0	11110111
166	233.4	11110101
167	234.8	11110100
168	236.3	11111100
169	237.7	11111101
170	239.1	11111111
171	240.5	11111110
172	241.9	11111010
173	243.3	11111011
174	244.7	11111001
175	246.1	11111000
176	247.5	11101000
177	248.9	11101001
178	250.3	11101011
179	251.7	11101010

INC	DEG	GRAYCODE
180	253.1	11101110
181	254.5	11101111
182	255.9	11101101
183	257.3	11101100
184	258.8	11100100
185	260.2	11100101
186	261.6	11100111
187	263.0	11100110
188	264.4	11100010
189	265.8	11100011
190	267.2	11100001
191	268.6	11100000
192	270.0	10100000
193	271.4	10100001
194	272.8	10100011
195	274.2	10100010
196	275.6	10100110
197	277.0	10100111
198	278.4	10100101
199	279.8	10100100
200	281.3	10101100
201	282.7	10101101
202	284.1	10101111
203	285.5	10101110
204	286.9	10101010
205	288.3	10101011
206	289.7	10101001
207	291.1	10101000
208	292.5	10111000
209	293.9	10111001
210	295.3	10111011
211	296.7	10111010
212	298.1	10111110
213	299.5	10111111
214	300.9	10111101
215	302.3	10111100
216	303.8	10110100
217	305.2	10110101
218	306.6	10110111
219	308.0	10110110
220	309.4	10110010
221	310.8	10110011
222	312.2	10110001
223	313.6	10110000
224	315.0	10010000

INC	DEG	GRAYCODE
225	316.4	10010001
226	317.8	10010011
227	319.2	10010010
228	320.6	10010110
229	322.0	10010111
230	323.4	10010101
231	324.8	10010100
232	326.3	10011100
233	327.7	10011101
234	329.1	10011111
235	330.5	10011110
236	331.9	10011010
237	333.3	10011011
238	334.7	10011001
239	336.1	10011000
240	337.5	10001000
241	338.9	10001001
242	340.3	10001011
243	341.7	10001010
244	343.1	10001110
245	344.5	10001111
246	345.9	10001101
247	347.3	10001100
248	348.8	10000100
249	350.2	10000101
250	351.6	10000111
251	353.0	10000110
252	354.4	10000010
253	355.8	10000011
254	357.2	10000001
255	358.6	10000000

Figure 2

Wiring

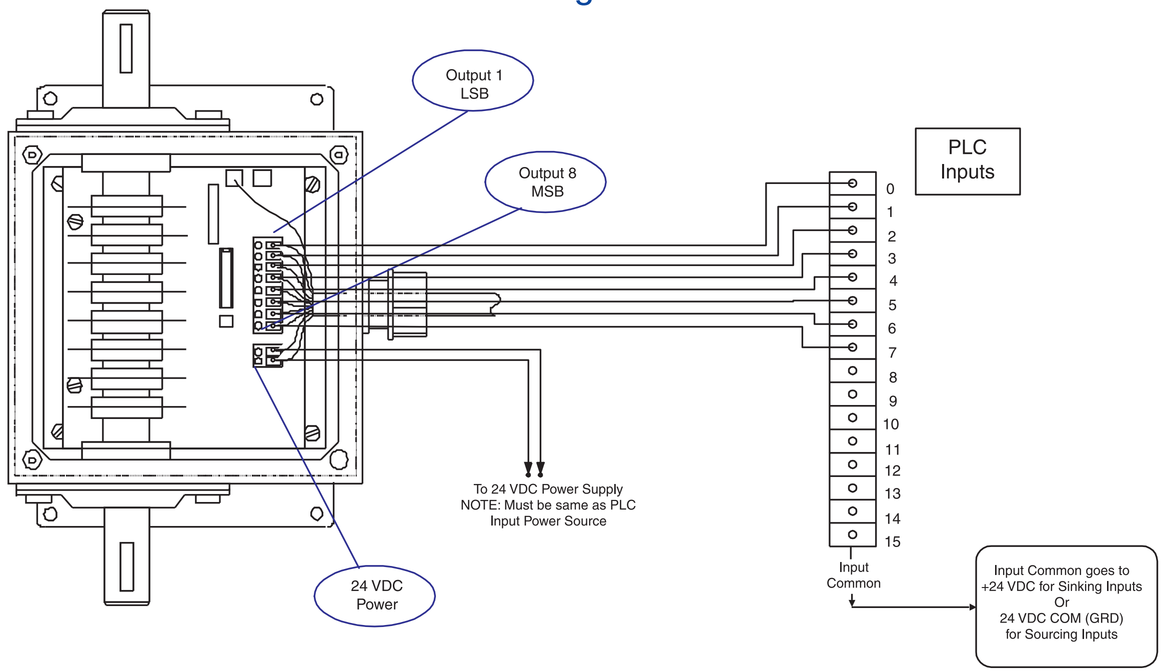


Figure 3

Dimensions

NEMA 12

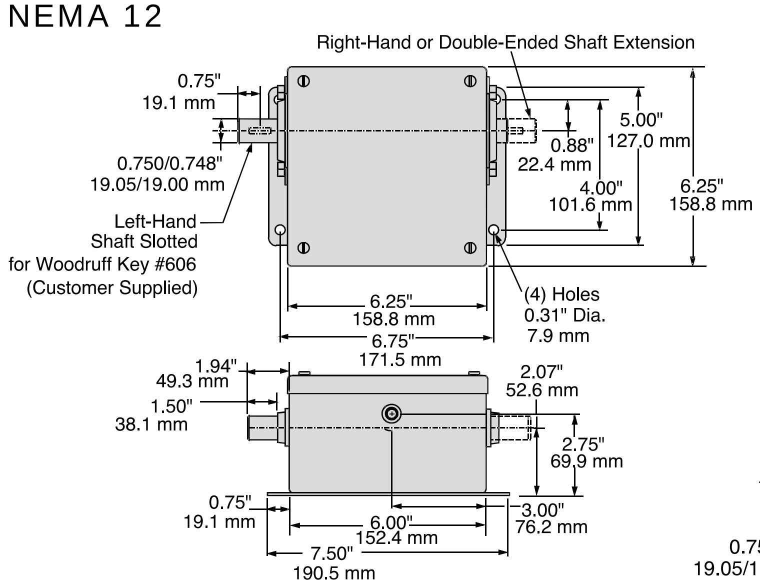


Figure 4

NEMA 4X

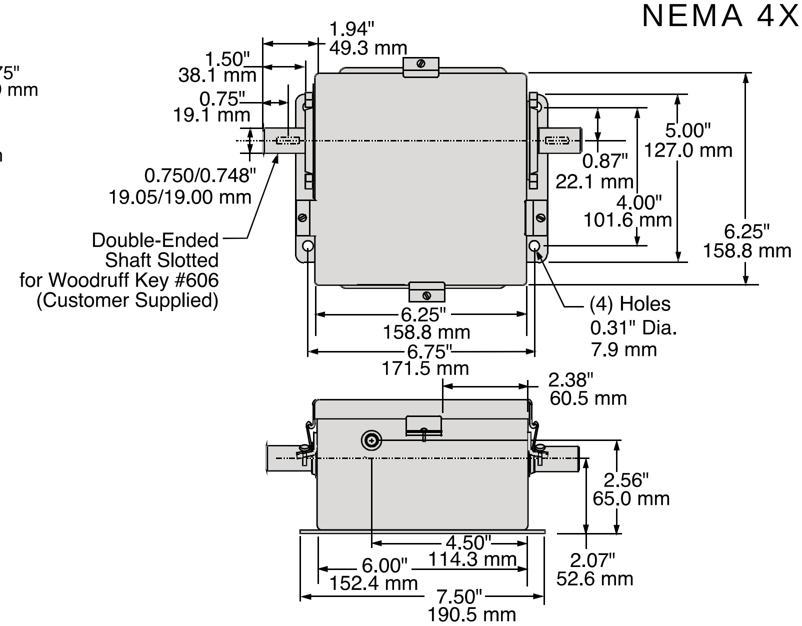


Figure 5

Specifications

General	NEMA 12	NEMA 4X
Ambient Temp.	0 - 60 Degrees C	0 - 60 Degrees C
Enclosure	JIC - 16 Ga Steel	JIC - 16 GA Stainless
Shaft Dia. / Material	3/4" Stainless Steel	3/4" Stainless Steel
Bearings	3/4" Sealed Ball Bearing	3/4" Double Sealed Ball
Conformal Coating	Component Side of PCB	Both Sides of PCB

Electrical	Sourcing†	Sinking†
Input Voltage	12 - 30 VDC	12 - 30 VDC
Output Voltage	12 - 30 VDC	3 - 30 VDC
Output Current (each bit)	50 mA	50 mA
Output Logic Type	High True	Low True or High True

† See page 7 for sinking/sourcing definitions

The 8 Bit Gray Code Encoder Output Chart (*Figure 6*) shows the transitions of each of the 8 bits as the encoder rotates from 0 to 360 degrees. The output bits are phased so that only one bit changes state at each of the 256 increments. The pulse disc which operates bit 0 (least significant) has 64 uniformly spaced slots, bit 1 has 32 uniformly spaced slots, bit 2 has 16 uniformly spaced slots, and so on. The 8 bit output of the encoder is always one of the 256 bit patterns shown in the table on page 4 *(Figure 2)* and always represents the current position of the encoder shaft. For this reason, the control cannot get out of sync with the encoder. High speed count cards that use incremental encoders are NOT absolute and require marker pulses, or other reference signals, for position synchronization.

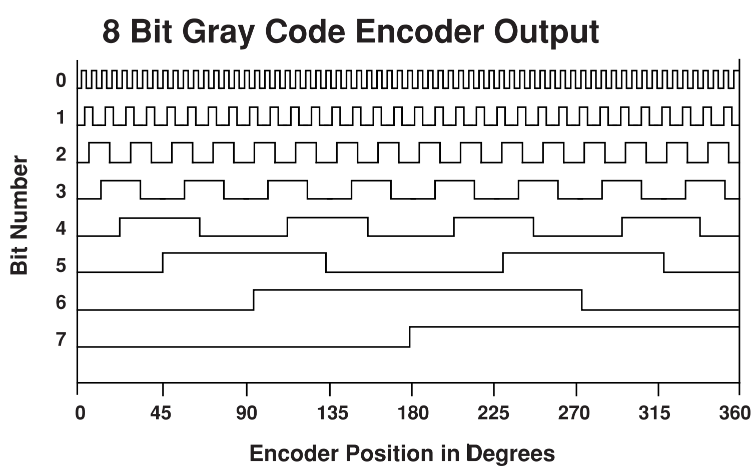


Figure 6

Encoder Part Numbers

1000 RPM MAX	2000 RPM MAX	Output Type	NEMA Rating
PS - 4256 - 12 - DDP	PS - 4257 - 12 - DDP	Sourcing†	12
PS - 4256 - 12 - DDN	PS - 4257 - 12 - DDN	Sinking† (Low True)*	12
PS - 4256 - 12 - DDH	PS - 4257 - 12 - DDH	Sinking† (High True)*	12
PS - 4456 - 12 - DDP	PS - 4457 - 12 - DDP	Sourcing†	4X
PS - 4456 - 12 - DDN	PS - 4457 - 12 - DDN	Sinking† (Low True)*	4X
PS - 4456 - 12 - DDH	PS - 4457 - 12 - DDH	Sinking† (High True)*	4X

***High True** = Current Flow

Low True = No Current Flow

Accessories

PS - 4300 - 03 - XXX (XXX = Length in Feet): 10 Conductor #22 gauge shielded (foil and braid) cable for use with encoders. Cut to specified length, stripped, tinned, connectors attached to shield.

EC - 8001 - XXX - XXX (X's for pitch and # of teeth): Sprocket disengagement clutch allows encoder to be rotated without turning the chain which drives the encoder. Call for more information.

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†SINKING or SOURCING (as pertaining to Electro Cam Corp. products)

Sinking means that when the logic is true and the output (or input device) is ON, the output (or input device) is providing a DC common or ground to the connected device.

Sourcing means that when the logic is true and the output (or input device) is ON, the output (or input device) is providing a +DC voltage to the connected device.

This information is important when interfacing an Electro Cam Corp. product with another electronic device. If you are using an Electro Cam Corp. product input to an Allen-Bradley 1746-IN16 "sinking" input card* or similar A-B device, you have to supply a +DC voltage (Electro Cam Corp. ***Sourcing*** output) to this card, NOT a DC common or ground. In these cases, ***Sinking*** is what the card does with the input voltage; sinks it to common or ground.

* Other manufacturers include, but not limited to: Koyo (formerly GE Series 1, Texas Instruments, or Siemens SIMATIC PLS's) that use descriptions similar to Allen-Bradley.

Electro Cam Corp. is highly experienced in supplying
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