

# Encoders Frequently Asked Questions

## Q: What is a differential line output?

A: Differential output refers to the fact that each channel has a complement channel, i.e. Channel A and Channel A not. A differential line driver is used to help increase noise immunity. It also allows you to sink or source more current than a Totem-pole output. A differential line driver will work with either a sinking or sourcing circuit. It can also help in increasing the distance that a signal is transmitted.

## Q: What is an open collector output?

A: An open collector output is an NPN transistor. An NPN transistor allows the sinking of current to common. It can be thought of as a switch that allows the circuit to be connected to common after the load. This means that a source is required for the output to work. A supply through a load must be connected to the output, otherwise the NPN transistor is simply creating a path to common, (i.e., a dry contact). Therefore, if you were to measure the voltage at the output of an open collector that is not connected to some supply, you would not see a change in voltage. The voltage should be measured across the output load to determine if the open collector is working properly.

## Q: What is a Totem-pole output?

A: A Totem-pole output, sometimes referred to as a push-pull output, is a bipolar output with active devices that are controlled such that, as the resistance of one increases, the resistance of the other decreases; so that according to the relative states of the two active devices, the output voltage can swing between levels approaching the two supply voltages. The term 'totem-pole output,' as commonly used, does not include three-state outputs.

## Q: What is a quadrature output?

A: Quadrature output refers to the use of two output channels (A and B) separated by 90 degrees of phase shift. The fact that the signals are 90 degrees out of phase allows a controller to determine the direction of rotation, i.e. if channel A leads B then the encoder is spinning one direction, if B leads A then the other. See the channel timing charts for a graphical view of this concept. Remember that each channel

provides the rated PPR for each encoder. For example: with a 100 PPR encoder, there are 100 pulses per revolution from channel A, and 100 pulses from channel B. This is a total of 200 pulses if your controller can count both channels (X2 logic). Some controllers can count the rising edge and the falling edge of each pulse (on both channels) thereby increasing the effective resolution by a factor of four (X4 logic), and counting 400 edges per revolution on a 100 PPR quadrature encoder. This doesn't mean that there are 400 pulses coming from a 100 PPR quadrature encoder.

## Q: Why do I need a pull-up resistor?

A: A pull-up resistor is used to *pull* the logic high voltage level up to the level of the operating voltage. This is useful when the output of the open collector is not reaching the voltage level needed to indicate a logic high signal or when noise is present on the signal line. When a logic high signal is present, its voltage level will be approximately that of the operating voltage for an open circuit. The difference is due to the voltage drop across the pull-up resistor. This is not necessarily true if the load is referenced to ground. Pull-up resistors are also used to convert sinking devices to sourcing devices, which inverts the pulse train.

## Q: What is the difference between X2 and X4 logic?

A: Some devices that are commonly interfaced to encoders (controllers, counters, displays) can detect more events per revolution than the rated PPR output of a quadrature encoder signal. Because a quadrature encoder provides two channels of pulses, a controller that counts the pulses on both channels can count twice (X2) the PPR output of a given encoder. For example, a controller with X2 logic can count 240 pulses per rev. from a 120 PPR encoder. Some controllers can count the rising edge and the falling edge of each pulse (on both channels) thereby counting four times (X4) the PPR rating of the encoder (or 480 edges per revolution in our example). It's important to remember that a quadrature encoder produces two channels of pulses at a given PPR. X2 or X4 logic refers to how the controller (or other device) interprets those pulse streams.

## Q: Is shielded cable needed?

A: YES. The use of shielded cable is highly recommended. This is especially true for areas in which large amounts of electrical noise exist. If you are having any noise problems, or suspect that you might, then use a shielded cable.

## Q: How do I set my calibration constant?

A: The calibration constant can be simplified by selecting the correct pulses per revolution (PPR). When choosing your calibration constant, remember: the closer to 1, the better. The value of the calibration constant is your best resolution per pulse of the encoder.

## Q: How do I choose the pulses per revolution (PPR)?

A: When choosing the PPR value of the encoder, you should follow a few simple rules. Make sure that you do not choose a PPR that will exceed the maximum input frequency of the controller (or whatever device the encoder is driving). To calculate the max frequency of the encoder signal (in Hz): simply multiply the speed that the encoder will spin (in revs/sec) by the PPR of the encoder (don't forget to take X2 or X4 logic into account if it applies for your application). Try to choose a PPR that is an even multiple of the value you are trying to measure or display. For example, if one revolution of the encoder equates to 12 inches of travel, you might choose a 1200 PPR encoder. This can eliminate or simplify the need for a calibration constant or scaling factor and more importantly, it eliminates the possibility of accumulating a rounding error over many cycles of the encoder. In this example you would be able to measure the travel to a resolution of 1/100 of an inch. You should also consider any 2x or 4x counting logic in your controller. If your controller can "see" pulses on both the A and B channels (2x logic), then it will count 2400 pulses for every 12 inches of travel in our example. If the controller counts both the leading edge and the trailing edge of each of the pulses on both channels (4x logic), then it will count 4800 edges per revolution and your effective resolution would increase to 1/400 of an inch per count.

*FAQs continued on next page*

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Pushbuttons/  
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Process

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Wiring

Power

Circuit  
Protection

Enclosures

Appendix

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# Encoders Frequently Asked Questions

## **Q: How accurate will an encoder be in my application?**

A: Encoders can provide a very accurate indication of rotational position, but it's impossible to say how accurate a given encoder will be in a real-world application. Mechanical inaccuracies and electrical issues such as noise, or lost counts can affect the accuracy of any system. A good rule of thumb is to design the system to measure from 2 to 5 times more resolution than your desired accuracy. For example: if you wish to accurately measure movement of 1/100th of an inch, you should select an encoder that can deliver at least 200 counts per inch of resolution. In a rotary application - if you need accuracy within 6 degrees, select an encoder that can deliver at least 120 counts per revolution ( a resolution of 3 degrees) to your controller.

## **Q: How far away can I place my encoder from my system?**

A: There is no set answer to this question. Many factors play a role in determining the maximum length of cable that can be used to connect the units together. The largest problem with running long lengths of cable is that the cable becomes more susceptible to noise. This is due to the capacitance of the cable, the cable acting as an antenna, and the loss of power through the cable. The maximum distance of cable can be achieved by following some basic wiring principles. Do not run the cable near objects that create a lot of electrical noise. This includes AC motors, arc welders, AC power lines, and transformers. Use twisted pair cabling when using the signal and its complement, and shielded cabling when running any type of signal. Use the highest voltage available for the output voltage. For example, if the encoder will output 5 to 24 volts, then use 24 volts. Use an open collector or differential line driver output with a differential receiver so that the maximum amount of current can be sink/sourced. If you are using the encoder as an input to more than one controller, use a signal amplifier. This is also a good way to help increase the distance a signal can travel. Typical maximum distances for a differential line driver are around 100ft., or more when using a differential input, and for an open collector the distance is around 35 ft.

## **Q: Why use an absolute encoder?**

A: An absolute encoder has each position of the revolution uniquely numbered. This means that instead of an output of pulses, you get an output that is a specific value in a binary format. This is very useful when exact positioning is a must. If the power should be lost, the actual value of the position will be known when power is restored, since each location in an absolute encoder's revolution is a unique binary value. The exact position will be known even if the controller loses power and the process is moved.

## **Q: What is gray code?**

A: Gray code is a form of binary. The difference between gray code and binary is the method of incrementing to the next number. In gray code, only one digit may change states for every increment. This means the count sequence would look something like this: 0, 1, 3, 2, 6, and 7. This is different than standard binary, where the sequence would be 0, 1, 2, 3, 4, and 5.

Gray code is used to prevent errors as transitions to the next state occur. An example of how an error could occur would be when both values in the sequence were true. This can occur due to the timing sequence and the capacitance of the cable. The transition from 0011 to 0100 could cause 0111 to be generated. With gray code this is not possible.

## **Q: How do I convert gray code to binary?**

A: The conversion from gray code to binary is simple.

Step 1: Write the number down and copy the left most digit under itself.

Step 2: Add the highlighted binary digit to the gray code immediately up and to the right of it. So, 1 plus 1 is 0 dropping the carried digit. Write the result next to the binary digit just added. Drop all of the carried digits.

Step 3: Repeat Step 2 until the number is completed.

## **Q: What is a sinking or sourcing Input?**

A: Sinking and sourcing inputs simply refer to the current flow in a transistor. This means that they require a voltage and a load to operate. A sinking input requires the voltage and load to be present before connecting it to the circuit. This means that it is "sinking" the current to ground for the circuit. A sourcing input must be before the load in the circuit. This means that it is "sourcing" the current to the circuit. Voltage and a load must be present in either case to detect a voltage change at the input. The same is true for sinking or sourcing outputs.