

## **Encoder Outputs Shouldn't Fail**

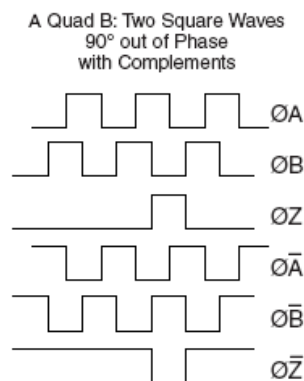
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Seems obvious, doesn't it, that the heartbeat of your process shouldn't stop, leaving you without speed or distance feedback? If you wanted open loop performance, you wouldn't have installed an encoder at all! But outputs do stop working for many OEMs and industrial users, leaving them with a complex troubleshooting problem: Where did their encoder feedback system go wrong?

This article explores methods of correcting encoder output problems. These problems can be eliminated at the design and implementation phases. Also, some troubleshooting guidance for existing installations is provided.

### **Getting Squared Away on Encoder Outputs:**

The dominant encoder & tachometer system used worldwide utilizes two square wave quadrature signals. These signals are 5-24VDC, typically with complementary or negative outputs, often abbreviated "A Quad B" output, with optional Z (marker) output. This system provides both speed and direction indication: Frequency (pulses per second) output is proportional to speed. The A signal leads B for movement or rotation in one direction, while B leads A for movement or rotation in the opposite direction. Counting pulses indicates total distance traveled.



The challenge for the encoder user (and manufacturer) is to successfully carry the square wave output back to the controller undistorted and without interruption, at the voltage level required by the controller for proper operation.

### **So What Goes Wrong?**

For starters, lots of things. The trick of getting square waves to travel accurately down a cable back to the controller through real-world industrial conditions is a lot harder than it seems.

### **Round-Off Problems:**

Encoders create crisp, precise square waves; drives and PLC's read these signals perfectly, counting and timing these signals to determine the next speed or distance output required. However, in the real world, cable impedance and capacitance, bad connections, and weak output circuits mean that the signals that started their journey as perfect square waves inside the encoder end up looking more like rounded sine waves or worse by the time they reach the controller.

Long cables in particular are a serious challenge: Think of them like a jump-rope with a child at each end. When one end is wiggled up and down in a precise on/off pattern, a wave travels from one end to the other. The longer and heavier the jump-rope, the harder it becomes to wiggle the rope to get the wave to travel. Likewise, higher frequencies are a problem; wiggling the rope faster and faster takes more and more energy to make crisp, precise waves.

In all of these cases, the encoder output signals, like the wave, end up weaker and weaker, and more rounded. The controller at the other end can no longer count the pulses, nor can it determine direction. The problem may be intermittent...slight variations may allow the signal to function, and replacement of the encoder with an identical model might seem to work...but only for a while.

The trick here is picking an output with enough bi-directional power to drive the square waves up and down the cable at the full output frequency. The worst offenders are the CMOS driver chips, such as the 8830, 88C30, 26LS31, etc. However, open collector outputs, such as 3904, 7406 and 7273 have the same problem. Even the de-facto standard 7272 line driver is available from some vendors in limited versions that may drop out after 30 meters or less.

When selecting an encoder, specify high-power line drivers, such as the 4469 and 4125 or dedicated discrete component designs. Or for shorter runs, be sure to select a fully rated 7272 to replace open collector designs wherever possible. These high power output versions can replace their weaker cousins with no wiring changes.



Avtron HS35M with fully protected 4125 5-15V high-power outputs

### **Short-Cuts and Cross-Talk May Cause Trouble:**

Encoder outputs were derived from computer circuits; they resemble RS232 and RS422 signals electrically. This means that the original circuits designed for encoder outputs were not designed to be short-circuited. With the realities of wiring on live machines and solder-type connectors, replacement or rewiring under power is an ugly reality. Many line drivers will fail when shorted. Many encoders end up with blown output circuits, victims of short-circuited wiring.

Also, encoder wires are typically going to the same place as the electric motor power leads. The high voltage on power leads can often induce high voltage noise onto the encoder cables. This can either confuse the controller by overwhelming the encoder signal, or worse, induce enough voltage to destroy the encoder outputs or controller inputs.

Select encoders with fully short-circuit protected outputs: Some models' outputs cannot be connected to ground, others to +V, and some fail if outputs are cross-connected. Ensure your encoder provides "transient protection" so that external surges don't destroy outputs. Use a high quality, individually pair shielded signal cable to keep noise out.



Avtron HS35A with fully protected 5-24V fully rated 7272 driver

**Don't run encoder and drive wiring in close proximity; especially avoid parallel motor power and encoder signal wiring.**

### **Maybe You Are Moving Too Fast:**

Industrial encoders typically have seals to keep out contamination. These seals make heat as the shaft spins against them; this heat adds to the ambient heat inside the encoder, and may cause the outputs to generate less current, or even shut down intermittently.

Select a manufacturer that fully rates the encoder for full output at maximum speed; many models are de-rated above 1800 RPM. This shows up as a de-rating of the encoder temperature range, but it means that output current is limited at higher speeds.

### **Here's Where the Red Light Comes On:**

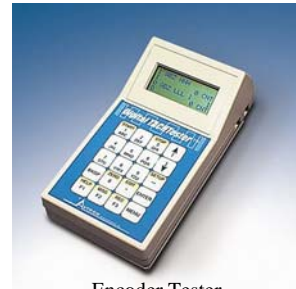
Once the controller can no longer accurately count or measure the encoder or tachometer pulses, most will stop the process and indicate "loss of encoder" or "loss of quadrature." A few will keep running, open loop, but will flag the operator that the process performance will suffer. At this point, the frantic search for the failure begins: Is it the encoder? Is it the cabling? Has the input board to the controller failed? Is the logic faulty inside the controller?

At this point, most users simply replace every component in the system until the problem is solved. Because the encoder is often easy to replace, it is swapped first. However, this often doesn't permanently solve the problem. Encoder manufacturers report over 50% of the returns of units reported "bad" have no detectable fault or problem, even under strict, repetitive testing. A "fresh" unit might seem to work fine, but if the outputs are underrated for the application, problems will resurface later.

Many of the intermittent problems described above can be corrected by initially selecting an encoder with high-power outputs, with full short circuit and transient protection; these models should also be used to replace older units with problems.

## You Need Good Tools:

To troubleshoot an encoder system fully is beyond the scope of this article, but there are some keys to success. An oscilloscope is the engineer's tool for encoder signals, but understanding the results requires a lot of training and experience. The best tool is an encoder tester. A tester should be able to power and test the encoder in-place. A good tester can generate signals back to the controller to enable the user to simulate an encoder signal, to test the wiring and the controller input board. This tester should give simple numerical go/no go feedback on the encoder signals, such as phase output and separation, min and max, whether all channels are present, etc.



Encoder Tester

Many encoder manufacturers offer training classes to assist customers in installation and troubleshooting of encoders.

In brief, pick products with fully rated and protected outputs with adequate power, use proper wiring techniques and cabling and ensure you have good tools on hand. This will ensure your encoders keep providing the heartbeat to keep your process machinery running strong.

For more information about this article or encoders & tachometers in general, contact:

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