ELIMINATING PHANTOM MOVEMENT IN ENCODER APPLICATIONS

October 2006

This paper discusses how false movement signaling can occur in the encoder signal lines as a result of mechanical vibration and electrical noise. This results in "inexplicable" false readings for position and speed in robotic systems and is unavoidable in complex, multi-axis motion control systems. The Terminator multimode electronic filter addresses the problem by acting on both, the causes and the symptoms, to remove the effects of noise and vibration and to fully regenerate the encoder signals to reflect the correct position and speed.

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The Incremental Encoder

The encoder is one of the most effective position sensors and has been widely used over the past thirty years in applications involving speed and position automation. It is available in many forms and the most common type measures relative displacement by generating two pulsing signals for every base unit of length (or increment step) moved.

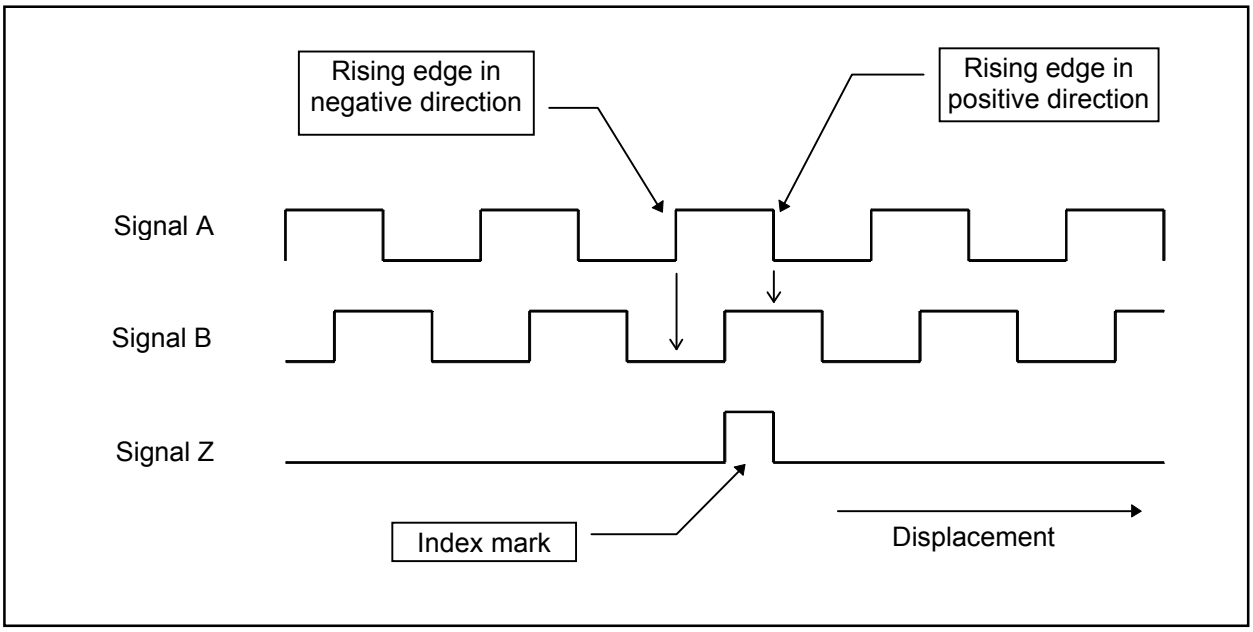

Figure 1. Incremental encoder signaling. The encoder position is obtained by incrementing or decrementing a counter after sampling B on the rising edge (positive change) of A. Signal Z is a reference once-per-turn signal.

The two signals (usually marked “A” and “B”) are phased 90 degrees apart in space (quadrature) and repeat a characteristic number of times in each encoder cycle (the number of pulses per revolution). They usually drive an accumulating hardware or software counter where the sum increases or decreases depending on the direction of movement. When the displacement signal is taken from one output (say “A”), the displacement direction is derived from the state of the other output (“B”) at the positive transitions of A. Because of the signals’ space quadrature property, a change in counting direction can be effected by logically inverting one of the signals or swapping signals A and B (Figure 1).

Typically, a referencing index point is also available as a once-per-turn pulse from a third output (usually “Z”).

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Phantom Movement due to Vibration and Other Mechanical Causes

Mechanical displacement causes the signals A, B and Z to take their expected form and state. However, when vibrational displacement occurs around a change in state of A and within the signal period, signal B is repeatedly sampled at the same point and so the accumulated count increases steadily in one direction when there is no net displacement (Figure 2).

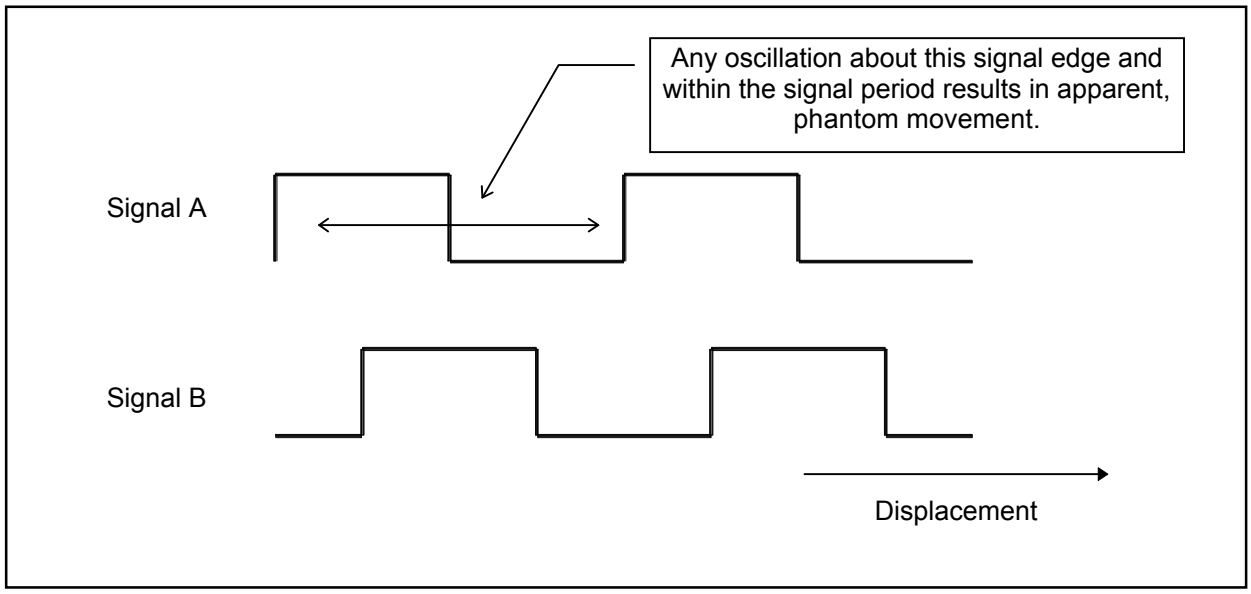

Figure 2. Phantom displacement created by mechanical oscillation.

Miscounting also occurs during normal operation when displacement changes direction around the change in state of A. In this case the accumulated sum changes by one integer count and in relation to the frequency of changes of direction, the robotic system gradually drifts losing its position accuracy.

The situation becomes even more complex and unpredictable when the indexing signal Z, typically counting full revolutions or marking the homing position, falls within this oscillation amplitude.

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Phantom Movement Caused by Electronic Noise and Interference

The industrial environment in which an encoder is required to operate is characterized by the existence of many differing sources of noise. Various techniques are used to deal with this problem, such as the use of shielded cable, differential or symmetrical output signaling, input stage hysterisis and quadrant signal analysis.

Unavoidable interference is caused in many ways and is the result of the high energy, high frequency and complex waveform currents driving the motors of the modern robotic multi-axis system. Noise is propagated and conducted by all the parts in each drive-motor axis. The waveform harmonics interfere in many ways (for example from the motor windings to the motor body then to the attached encoder body and to the encoder signals themselves) and always distort the A, B, Z signals.

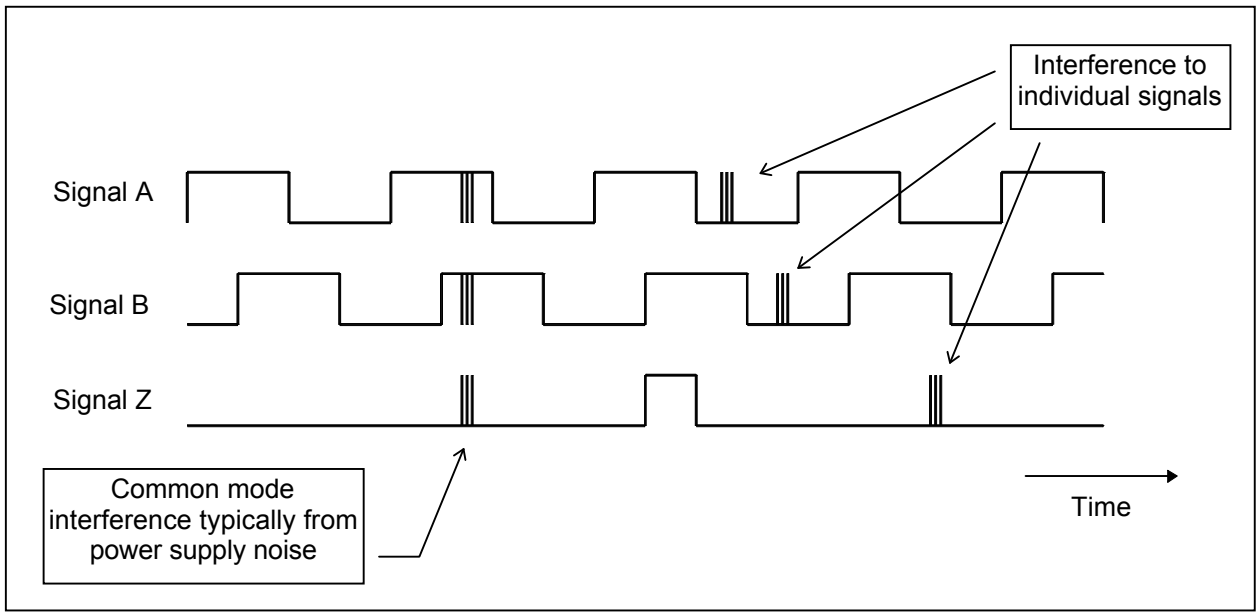

Figure 3. Typical waveforms of electronic noise (waveforms at constant speed).

Figure 3 shows the two main types of interference: common mode affecting all channels simultaneously and differential mode affecting one line only. Common mode interference is usually caused by disturbances and interference in the encoder power supply and affects all the signals. In the worst case, the system completely loses its position and has to be restarted.

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Differential noise distorts one of the signals in relation to the others. In the case of noise in A displacement pulses are generated while noise in B causes the counted direction to be wrong when sampled on A's positive edges. Interference in Z is particularly catastrophic. In cases where Z is used as the reference point (home) for the whole system, the accumulated sum is zeroed and as a result the system loses its position completely.

The situation is further complicated by the timing and the sequence in which the different types of interference occur, usually in an indefinite, unpredictable and uncontrollable manner. The system sensitivity to interference increases with the use of long cables where the signal waveform is further distorted and the signals reach the counter skewed and unsynchronized. Finally, in the usual case of a multi-axis drive system, the encoder receives interference from many and different sources simultaneously and in all possible combinations arising from system operation.

In all cases and irrespective of the source of the noise, the result is always the same: position drift, measurement accuracy degradation and the partial or complete loss of position and speed data in the robotic system. And as more than one noise generating mechanism may be active at a given time, all causes and their symptoms must be addressed to ensure reliable and robust operation.

The Terminator Multimode Electronic Filter

Our Terminator line of electronic filters effectively solve all the above problems by addressing at the same time both, the causes and the effects of all noise types, in an encoder installation.

Multimode Terminator Filter EFxx.

They feature an independent power supply for the encoder and galvanically isolate the input and output stages. The outputs are the result of DSP processing and logical analysis which completely recreate the inputs without the interference.

Further information is available at the company's site **www.cognitoquam.gr**.

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Terminator Multimode Filter EFxx Feature Summary	
Dual voltage 115/230 VAC twin isolated supply	The twin supply powers the two internally isolated, input and output, filter sections. It can power the monitored encoder with regulated 5 VDC or unregulated 10-12 VDC.
Galvanically isolated input and output stages	The galvanic isolation interrupts unavoidable and inevitable system ground loops eliminating related noise as well as protecting the input stage of the driven controller from high voltage transients. The galvanic barrier features 5 V/ns dV/dt immunity.
Four selectable modes of digital filtering	1. Unfiltered: the outputs are buffered replicas of the inputs, 2. Filtered: the encoder inputs are processed for electronic noise only, 3. Recovered x1: the encoder inputs are processed for electronic noise and analyzed for mechanical position to recover corrupted motion sequences. The outputs are in quadrature format and the mark (or index) channel is processed for electrical noise. 4. Recovered x4: Same as the Recovered x1 mode, but with output resolution quadrupling. The output signals are a clock/direction pair at four times the input frequency instead of the quadrature format.
Test mode	Depending on the chosen mode and sampling frequency, the filter outputs simulate the function of a 1024 ppr encoder.
Direction reversal	One of the encoder channels can be complemented to effect a direction reversal, thus saving the rewiring/reconnection of the encoder signals.
Supply, signal and worn/faulty encoder indication	Five LEDs indicate the status of the power supply, the three encoder channels and the presence of out-of-sequence signaling, typically caused by a worn or faulty encoder.
DIP switch selectable options	All operational parameters and functions are set/reset via DIP switches.
Selectable sampling frequency	The encoder signals are DSP processed at selectable frequencies to interface to slower equipment or tune out problem noise sources in particularly difficult applications.
Three types of EIA422 termination	Standard DC, AC and none.
Input, output and speed options	Models differ on input/output type and processing speed capability (next page).
Cast aluminum enclosure	IP65 protection and high noise immunity

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The available EFxx models are offered in a range of options:

- **Two speed versions**: Standard and High. The maximum quadrature input frequency which can be processed by the filters depends on the filter mode as follows:

Maximum Quadrature Input Frequency Capability per Filtering Mode				
Speed Version	**Unfiltered**	**Filtered**	**Recovered x1**	**Recovered x4**
Standard	10 MHz	1.5 MHz	1.2 MHz	375 kHz
High	10 MHz	3.0 MHz	2.4 MHz	1.5 MHz

- **Two types of encoder input interface**: Dedicated differential EIA422 and Universal 5 V (differential EIA422 and single-ended NPN, PNP, push-pull, TTL), and

- **Two types of output signal**: Universal 5 V (differential EIA422 and single ended NPN, PNP, push-pull, TTL) and 8-28 VDC single ended push-pull (sink and source).

Multimode Encoder Filter Model Selection Table					
Model	**Single-ended 5 V input (all types)**	**Differential EIA422 input**	**Universal 5 V output (EIA422 and all single-ended types)**	**Single-ended 8-28 V output (all types)**	**High Speed Option Available**
EFDO02		√	√		√
EFU502	√	√	√		√
EFSO02	√	√		√	

Multimode Encoder Filter and Accessories Ordering Information	
Model	**Description**
EFDO02-ALU-H	High speed Terminator Multimode encoder signal filter, EIA422 inputs, Universal 5 V (EIA422 and single ended NPN, PNP, push-pull, TTL) outputs.
EFDO02-ALU-S	Standard speed Terminator Multimode encoder signal filter, EIA422 inputs, Universal 5 V (EIA422 and single ended NPN, PNP, push-pull, TTL) outputs.
EFSO02-ALU-S	Standard speed Terminator Multimode encoder signal filter, Universal 5 V (EIA422 and single ended NPN, PNP, push-pull, TTL) inputs, 8-28 VDC single ended push-pull outputs.
EFU502-ALU-H	High speed Terminator Multimode encoder signal filter, Universal 5 V (EIA422 and single ended NPN, PNP, push-pull, TTL) inputs and outputs.
EFU502-ALU-S	Standard speed Terminator Multimode encoder signal filter, Universal 5 V (EIA422 and single ended NPN, PNP, push-pull, TTL) inputs and outputs.
DISVO00	3 ch. EIA422 to 8-28 VDC Single Ended Voltage Output Interface (accessory to repeat EIA422 signals to external monitoring equipment etc).
XFR400230	Control Voltage Supply Transformer, 90VA, 400/230 VAC (accessory to provide power from 3x400 VAC lines).

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Cognito Quam Profile

Cognito Quam Electrotechnologies Ltd. (established in 1990) is an engineering company specializing in industrial electronics and their application. The company expertise covers all aspects of applications for the factory environment namely measurement (transducers and sensors), data processing and communication, control and actuation, automation and robotics and power and energy electronics.

The company has contributed and been involved in the design and development of the following technologies, machinery and devices:

- Thermal load control and management,
- Robotic interfaces and protocol converters,
- Adaptive panel controllers,
- Robotics controllers,
- Variable speed fan drives,
- Olive oil processing rejects control equipment (FAIR contract),
- Low Voltage and EMC CE marking compliance devices and equipment for production lines,
- Portable dioxine-furan instrumentation (SMT contract),
- Three-phase programmable soft-starters,
- Hard real time job scheduling systems,
- Hard real time industrial distributed data systems (Brite-EuRam subcontract),
- Calibration rig and supplies for power meters,
- Electrical utility Hall effect energy and power meters,
- Industrial data networks,
- Battery chargers and UPS inverters,
- Solar power air conditioning telemetry and control systems (Thermie subcontract)
- Small switching power supplies,
- Multi-port communication PC cards,
- Ship oily water separators, and
- Modem controllers.

Cognito Quam's research and development services are available in integrating its products in industrial systems or individual products as well as in the design of new and challenging devices and equipment. As such, Cognito Quam cooperates closely and supports its customers in their endeavours for a better product.

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