A Discussion of Encoder Technology's Converter and Impedance Detector Technology

An Alternative to Traditional Position Sensors

ENCODER TECHNOLOGY

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Abstract

This paper investigates a relatively new technology for obtaining position information, the INDUCTCODER and its associated sensor to digital or analog converters. Operating principles, advantages, limitations and typical specifications are discussed, including a comparisions to other technologies.

Introduction

Engineers desiring a solution for their postion sensing needs are quite familiar with the traditional market offering. Encoders, resolvers, potentiometers, lasers, and hall effect devices are all possible candidiates. Their costs and attributes are generally understood.

By categorizing these technologies, important characteristics which determine suitability for a particular applications are seen.

Position sensors can be divided into two general groups, incremental (pulsed output) and absolute (direct read). Incremental sensors are an inexpensive method of producing high resolution feedback but the inherent nature of counting pulses creates an opportunity for noise or lost counts. When coupled with the need to establish a home position, incremental sensors lose much of their appeal other than low cost.

Absolute sensors, traditionally have been a more costly solution. High resolution devices tended to be large in size, more fragile and often less reliable because of the need for additional circuitry or contact designs..

Potentiometers are common for low duty cycle applications, but use a wiper which must contact a resistive element. This constant friction induces wear and limits life.

Absolute encoders, another option, use plastic or glass disks with LED emitters and dectectors to produce position infomration. At higher resolutions the masks used to create interference patterns allow so little light to pass, that reduced output of LEDs over time makes the design problematic.

Resolvers produce two AC signals which vary in magnititude by coupling a reference signal on the sensor shaft to stationary secondary coils. This design is more robust but requires a precision made sensor and expensive converter electronics.

While each of these sensors has a loyal following, there are many high volume applications which are not well satisfied by these traditional sensor technologies.

The Inductcoder

This section describes a new sensor technology generically referred to as Inductcoder. (*Note: although this term applies specifically to the rotary form, for the purposes of this document it will be used interchangably for types.*)

Inductcoders are rugged, absolute position sensors consisting of a detector and converter. Inductcoders are relatively new devices which make use of a unique detector and conversion concept and custom ASICs to create another option for design engineers.

In its most basic form rotary Inductcoders have four coils and a rotating eccentric which form the detector. *Figure 1.* is an example of a typical minature Inductcoder detector.

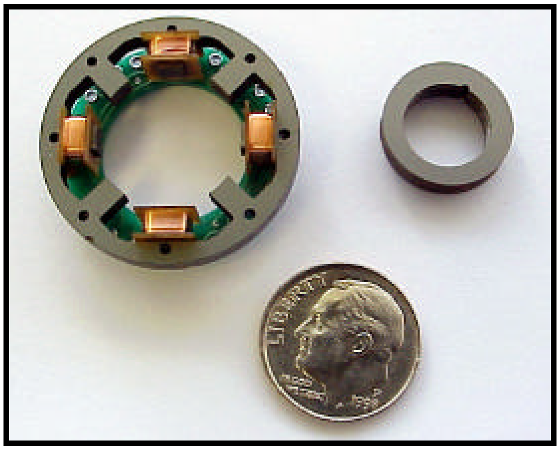


Figure 1. Detector Components

In this configuration the rotor is a simple ferrous eccentric stamping or powdered metal component. The stator assembly contains 4 differentially wound minature coils and a small circuit board to facilitate wiring.

These components are used in conjuction with our proprietary Converters to produce numerous output formats. Presently parallel binary, ABZ encoder emulations, bus compatible structures, UVW commutation and analog outputs are available. *Figure 2.* depicts a few of our converter options. These chip level products are normally used in large volume applications where cost and space are key factors. It is possible to obtain both position information and secondary outputs such as encoder or communtation signals simultaneously.

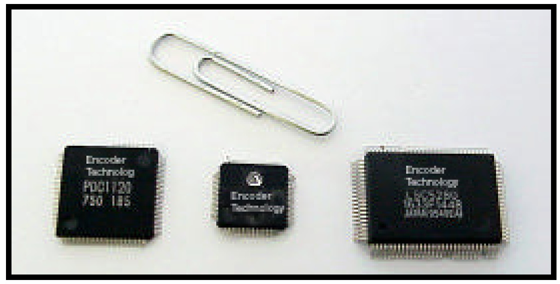


Figure 2. Converter ASICs

Board level converters, *Figure 3.*, allow easy integration into lower volume applications. ET Ltd produces various board level converters with the same output options as our chip solutions. These products are contain most necessary discrete componets and can be readily installed in systems with electronic controls.

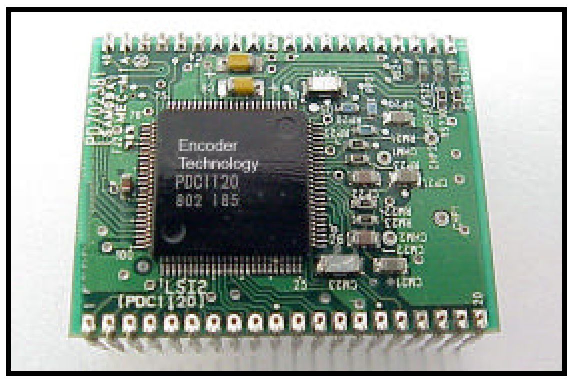


Figure 3. Board Level Converter

The combination of a detector and one of the converter solutions form an Inductcoder. A key advantage to this technology is it packaging flexibility. As mentioned previously, Figure. 1 is an example of a minature rotary detector, but the same principle work equally well in linear form and easily scales up in size.

Examples of various designs are shown in *Figure 4*. Clockwise from top center: 2 1/2 inch rotary, through hole sensor; 1 1/2 inch stroke linear; 3/16 diameter-1/2 inch stroke probe type; 3/32 diamter-1/4 inch stroke minature linear; in cylinder 3 inch stroke; 3/8 diameter minature rotary

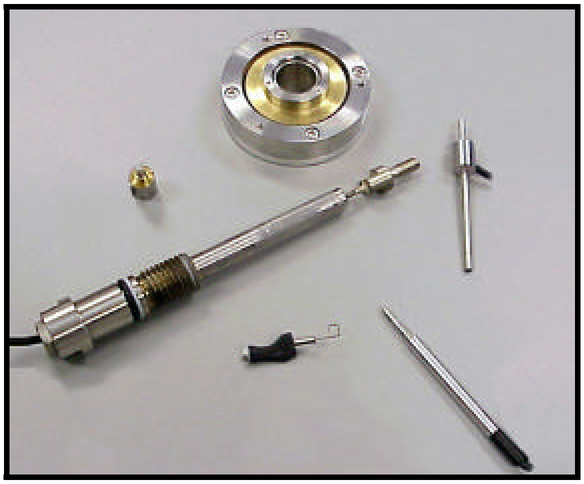


Figure 4. Detector Examples

Theory Of Operation

Two different sensor detection techniques (Separate and Hybrid Coils) are used depending on application requirements.

Separate Coil Technique (Phase to Digital Converter & Variable Transformation Sensor)

In this form our sensors use separate primary and secondary coils. The primary coil is excited with a nominal 1Volt p-p, 10 Khz AC signal generated by a master clock($A\ \mathrm{Sin}\ \omega\tau$). Due to the close proximity of the primary and secondary coils a portion of the excited signal is conducted to the secondary windings. The conduction efficiency is affected by the location of the eccentric rotor to produce an analog voltage of varying magnitude. The coils are positioned and wound to produce two differential signals in phase with our excitation signal, with the following relation to the rotor;

1. $a\ \mathrm{Sin}\ (\theta, \varkappa)\ .\ \mathrm{Sin}\ \omega\tau$
2. $a\ \mathrm{Cos}\ (\theta, \varkappa)\ .\ \mathrm{Sin}\ \omega\tau$

Figures 5. and 6 display these physical and electrical relationships.

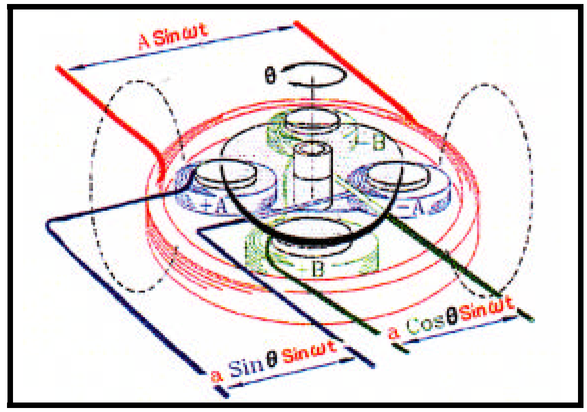


Figure 5. Mechanical Relationships

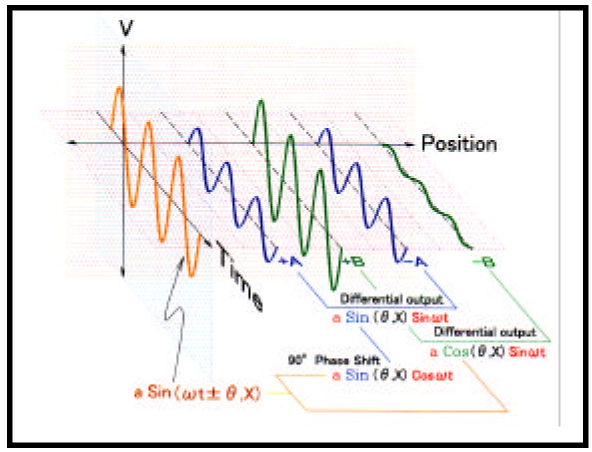


Figure 6. Electrical Relationships

The "$a\ \mathrm{Sin}\ (\theta, \varkappa)\ .\ \mathrm{Sin}\ \omega\tau$" signal is shifted by $\pi/2$ radians in our converter to produce;

3. $a\ \mathrm{Sin}\ (\theta, \varkappa)\ .\ \mathrm{Cos}\ \omega\tau$

When the first and third signals are summed together they produce a synthesized sine wave that is phase shifted by $(\theta, \varkappa)$ compared to the excitation reference. Next a counter within the converter chip is set to zero at the zero crossing point of the reference. The counter value to the zero crossing point of our synthesized signal is proportional to position. This process is repeated for each new cycle of the reference.

Thus, position data is determined by the time difference between our master clock

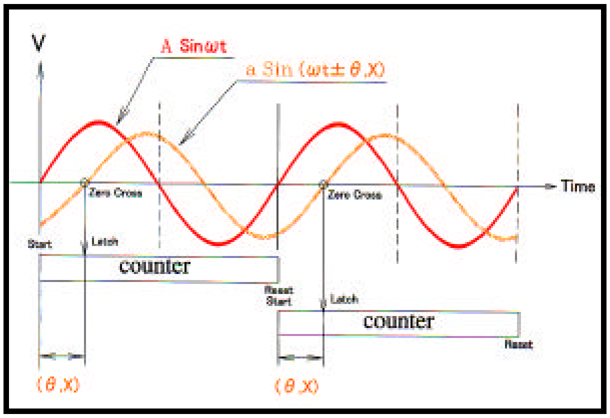


Figure 7. Phase Shifted Signal

controlled reference and the synthesized phase shifted feedback in direct digital form(*Figure 7.*). This data is updated for each cycle of the reference (10,000/sec) and further interpolated up to 1/10,000/sec x 1/128 or roughly every 780 ηsec.

Resolutions up to 16 Bits (65,536) per pitch may be obtained in this fashion. In special cases it is possible to operate at a lower clock frequency to increase output resolution.

Although the previous discussion descibes a simple rotary system, linear devices operate in the same fashion.

Imagine a rotary device which has been cut open and layed flat. In this manner it produces the same signals. Figure 8 describes this technique.

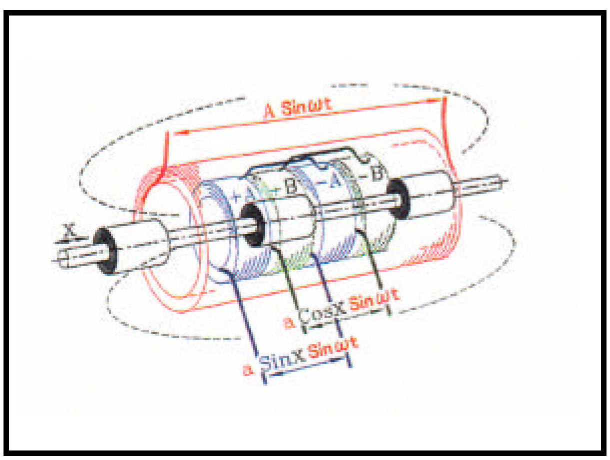


Figure 8. Linear Configuration

Hybrid Coil Technique (Phase to Digital Converter & Impeadance Detector)

This technique utilizes a sensor with a "hybrid coil". Instead of a traditional separate primary and secondary coil configuration, each coil assembly is excited by an AC signal derived from our master clock (*Figure 9.*). The change in magnetic resistance caused by the eccentric produces a corresponding voltage variation.

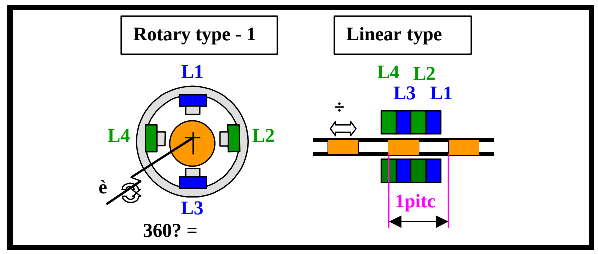


Figure 9. Hybrid Mechanical Configuration

Notice the absence of a seperately excited coil in *Figure 9*. Instead all coils are excited. The rotating eccentric produces a varying resistance in each coil proportionate to the ferrous material position. This in turn produces an output signals of varying magnititude.

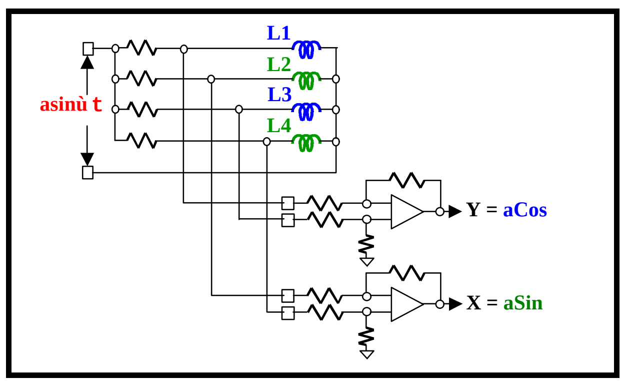


Figure 10. Detecting Circuit

If these signals are differentially connected as indicated in *Figure 10.*, the same mathematical outputs as our seperate coil technique are created. Hence the same converter chips may be utilized.

Advantages of Inductcoder System

Physical

Because Inductcoder detectors are primarily coil assemblies they can be constructed with materials impervious to temperature extremes, dirt, dust and oils. Potting the assembly provides further resistance to environmental contaminates was well as shock and vibration.

Most Inductcoders are designed as integral parts of an existing assembly. In this manner they make use of already existing bearings, eliminating another failure mode.

Inductcoders are non contact sensors with parts which do not touch each other in ways which produce friction. The life expectancy of a detector is measured in decades rather than hours.

Converting from Analog to Digital

Most analog to digital conveters must resolve voltage levels into digital numbers. At low voltages it is difficult to obtain fine resolution and the effects a electric noise become significant. Inductcoder systems sum two differential AC signals together producing an output of relatively constant magnititude at the maximum voltage at all times.

Dealing with Temperature Drift

Most detectors that operate in the analog mode suffer from the effects of temperature changes. Temperature affects resistance and resistance changes voltages. In the Inductcoder system pairs of coils operate in a differential mode and cancel temperature induced errors.

Fast Response

Inductcoder converters operate in an open loop mode and therefore produce very fast update rates. They are fundamentally limited by the Doppler Effect. A single pitch rotary sensor can operate up to 190,000 rpm, where most closed loop design are limited to a maximum of 60,000rpm.

Redundancy

Inductcoders require two signals for proper operation. The presence of both are necessary for correct operation. Detection circuits within the converter identify open or shorted wires and trigger fault signals.

Simple Power Requirements

Inductcoder digital converters operate on a single power supply.

Packaging Flexibility

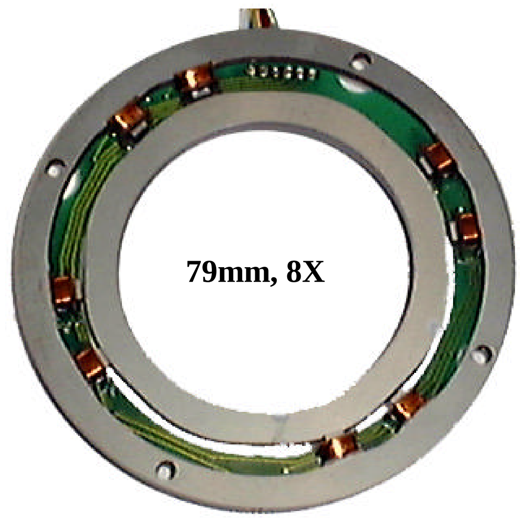
Inductcoder detectors can be produced in both linear or rotary formats. Within these categories multiple pitchs detectors are used to increase resolution. Regardless of the style standard converters can be used.

Rotary Type 10mm, 29mm, 53mm

Linear Sensors

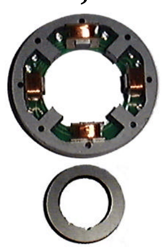
9mm, 1X

20mm, 2X



79mm, 8X

29mm, 1X



29mm, 2X