SKF SENSOR BEARINGS

Meeting with Segments

Kulpsville & Frankfurt

July 2000

Encoders. What, why, where and how?

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What are encoders?

Encoders come in many different shapes – and under many different names.

Incremental Encoder, Rotary Encoder, Rotary Pulse Generator are just a few of the more common names for the measuring function that we call Encoder.

Common for all Rotary Encoders (there are also Linear Encoders) is that they rotate and that they output **information about the rotation**. The Sensor Bearing is a Rotary Encoder

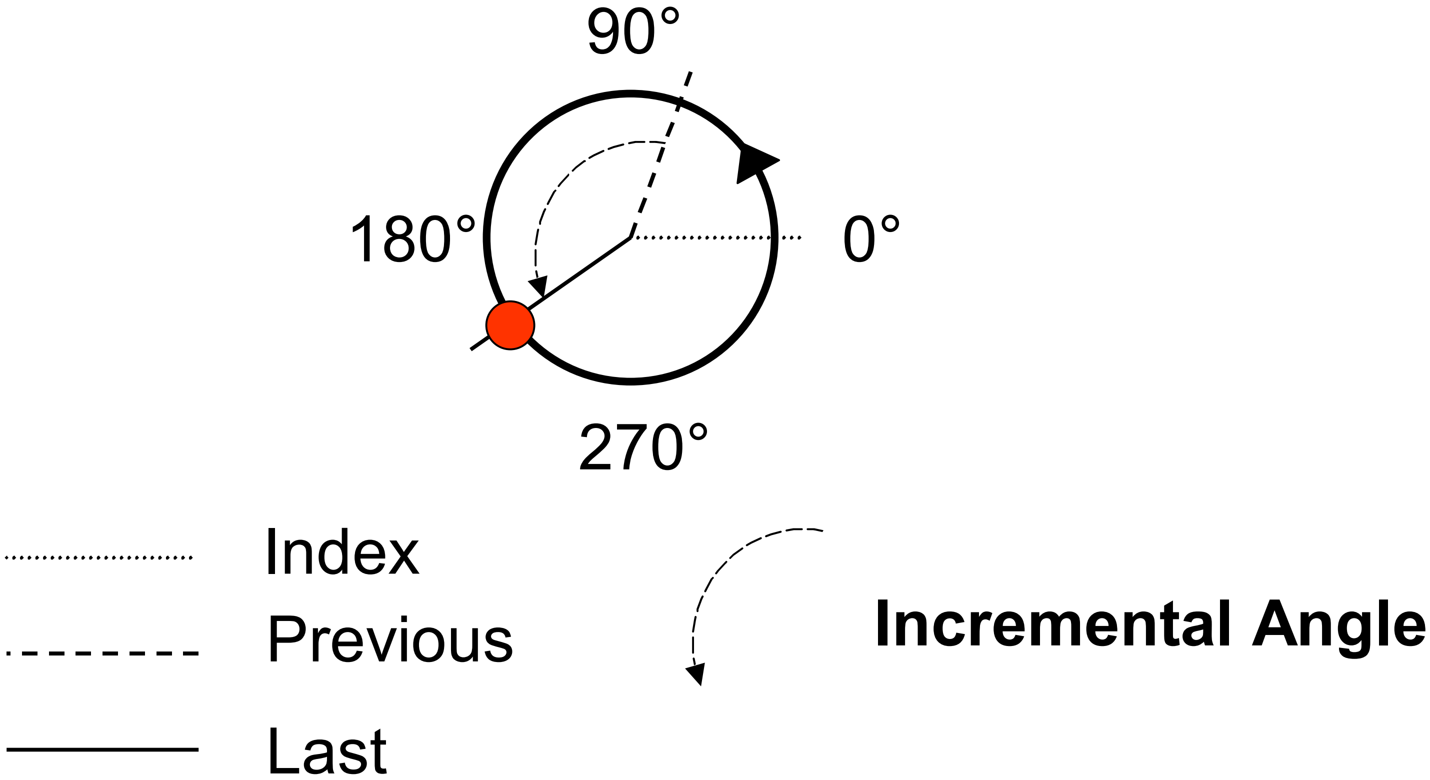
What are encoders?

What information is there about rotation?

- Incremental angle
- Total angle from index point
- Total number of turns
- Instantaneous speed
- Mean speed
- Angular acceleration

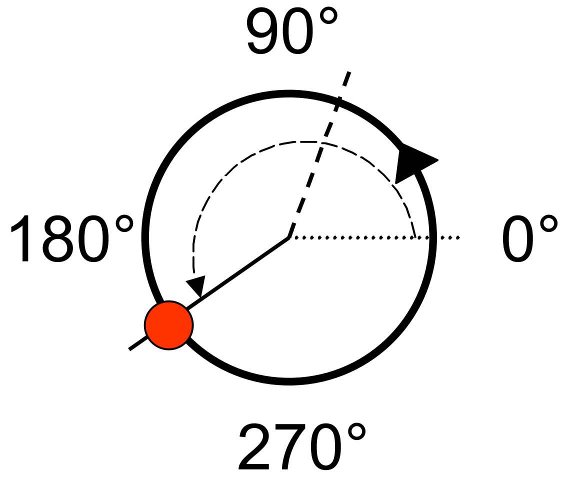
What are encoders?

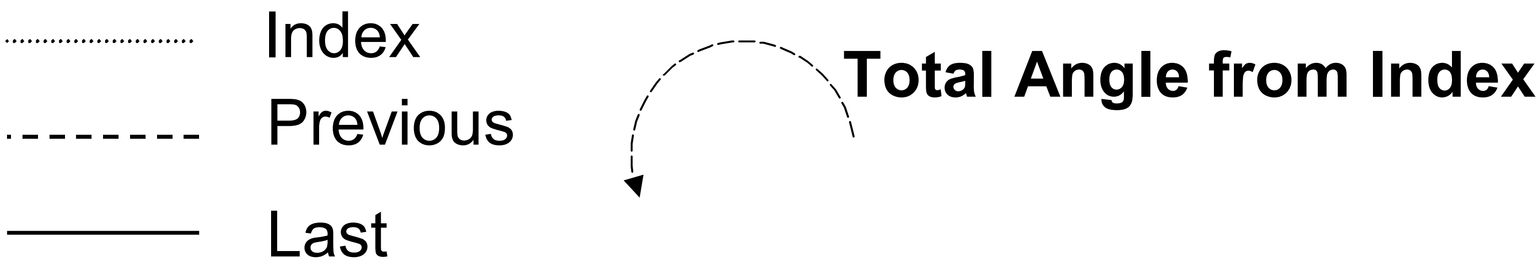
Incremental Angle is the change since last measurement.



What are encoders?

Total Angle from the Index Point





What are encoders?

Number of turns. That is fairly obvious. Isn’t it? Or is it?

•Counted since when?

•Counted in what direction?

•Accumulated movement?

•Net movement?

It all depends. There are no obvious answers to these questions.

What are encoders?

Mean Speed is the speed (in RPM, RPS, radians/s or pulses/second) that one gets when measuring over an extended time interval.

What Interval?

That depends. In a car it could be a minute. In a Paper Machine it could be ten seconds. It depends. There are no general rules. It could even be an hour. Or anything, really.

What are encoders?

Instantaneous speed is the speed measured over an infinitely short interval.

Mathematically, the definition is:

$$\omega = \lim d\varphi/dt \quad (dt\ldots0)$$

The problem is: when time gets short, there are no pulses to count.

So the interval usually is a lot more than zero. Usually tens of milliseconds. Even hundred milliseconds.

What are encoders?

Acceleration is the change in speed between two measurements.

$$\alpha = \lim d\omega/dt \quad (dt \ldots 0)$$

The problem with short times gets even more pronounced here. That is because the result is the difference between two differences. You can't have too short times or your resolution goes down the sink.

Solution: More PPR (or reciprocal techniques)

What are encoders?

Some Greek symbols were used. The standard use is:

φ Is the symbol for angle, degrees or radians

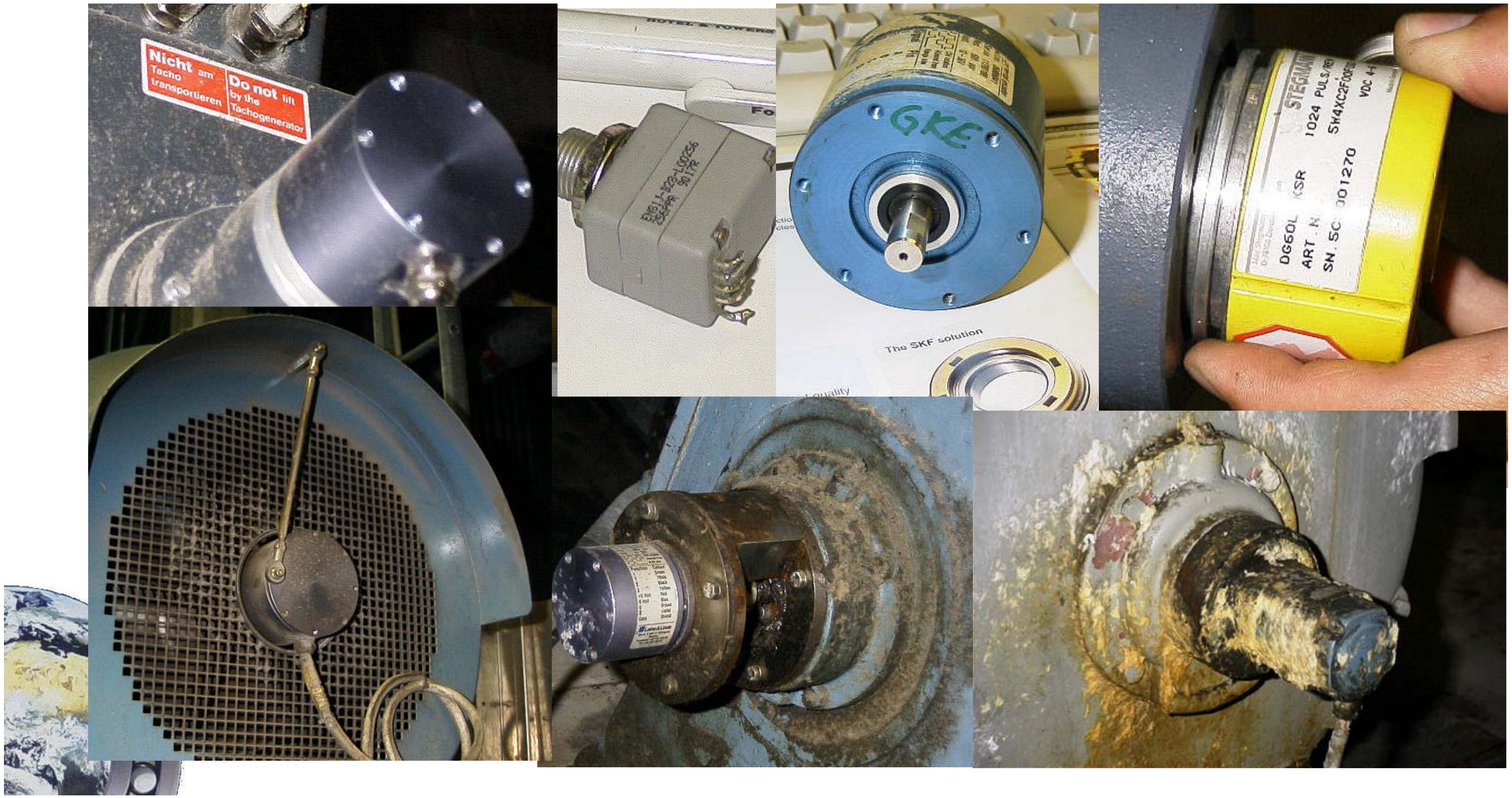
ω Is the symbol for speed, RPM or rad/sec

α Is the symbol for acceleration, rad/s^2

These are the more common symbols in Europe, they are also seen in the US. Please note that these symbols and units are used for rotation only. Linear movement uses *s*, *v* and *a* for length, speed and acceleration.

What are encoders?

The easy answer is. These are Encoders:



Why encoders?

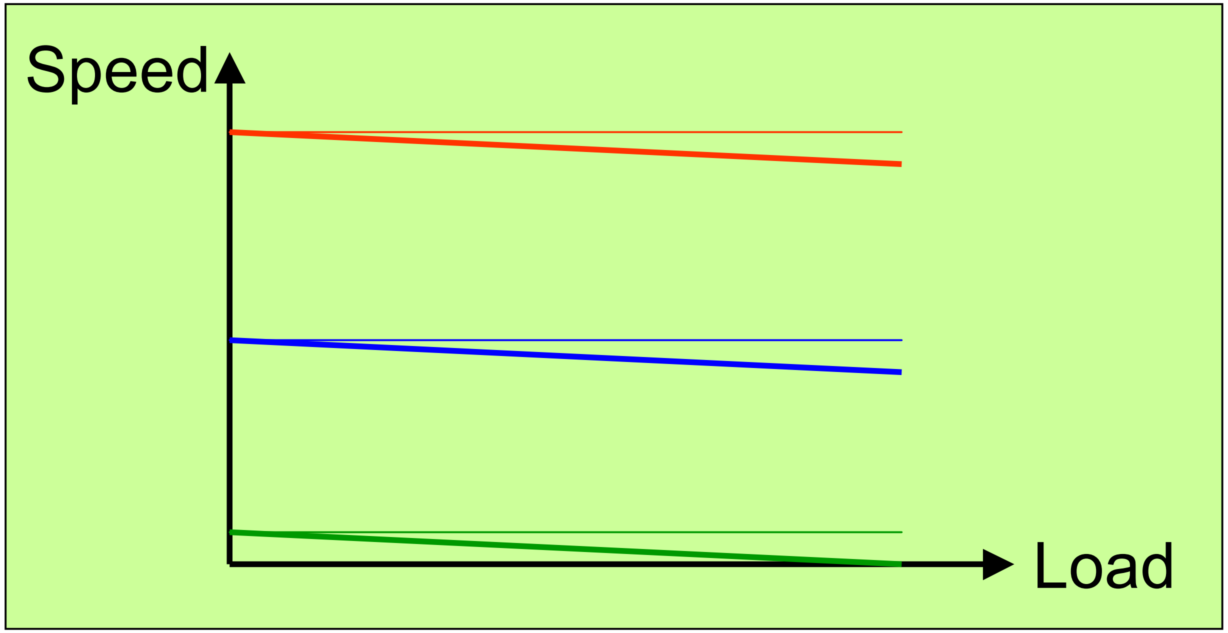
Drive systems have different properties. Most of them are less than ideal and need encoders to keep track of the actual speed.

Among electrical drives there are asynchronous and synchronous AC drives and there are DC drives.

The only drive that does *not* need a speed sensor is the *synchronous* drive. It always stays locked to the actual drive frequency, which is already known to the inverter.

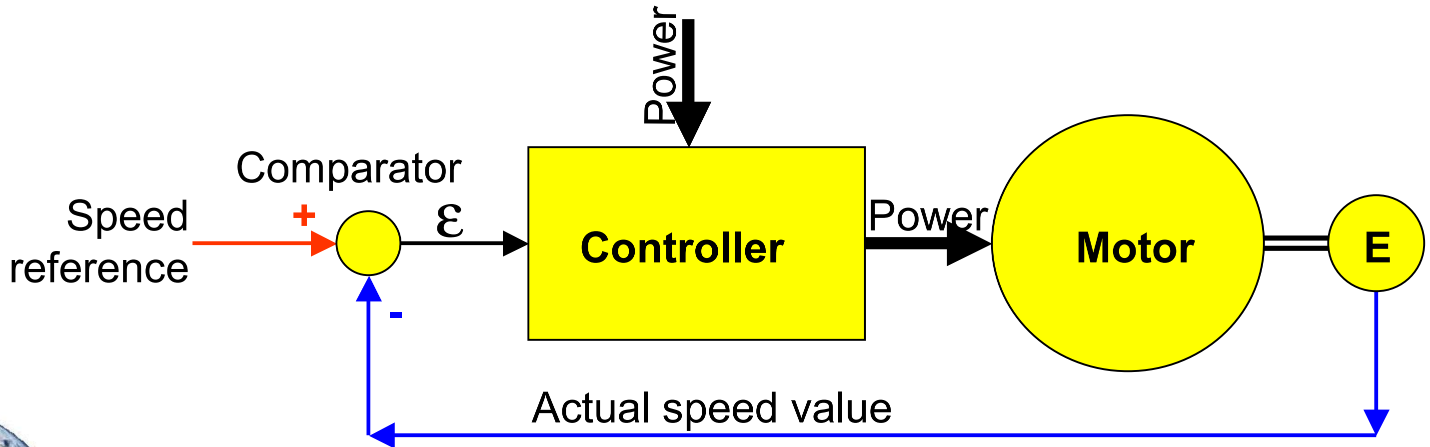
Why encoders?

All other drives are more or less imperfect. The speed tolerance is several percents. It is also load dependent.



Why encoders?

A speed sensor (encoder or tacho generator) is needed to feed back the actual speed to the controller which adjusts its output to bring speed to the set value (”speed reference”)



ε = speed error

E = Speed sensor i.e. encoder or tacho generator

Why encoders?

By using a good encoder and a good control system, it is possible to achieve speed tolerances down to 0,01 percent of full scale value. Static.

Dynamics count, too. So you need the information fast. The feed-back is needed once every ten milliseconds, often better.

Why encoders?

A few examples (from ABB Handbok Industri) show what one expects from a modern drive system.

Scalar Control w/o encoder:

Momentreglering	
Upplösning	1:1000
Olinjäritet	+/- 12%
Repeterbarhet	+/- 4%
Stigtid för momentsvar	150 ms

Vector Control w/o enc:

1:1000
+/- 4%
+/- 1%
10-20 ms

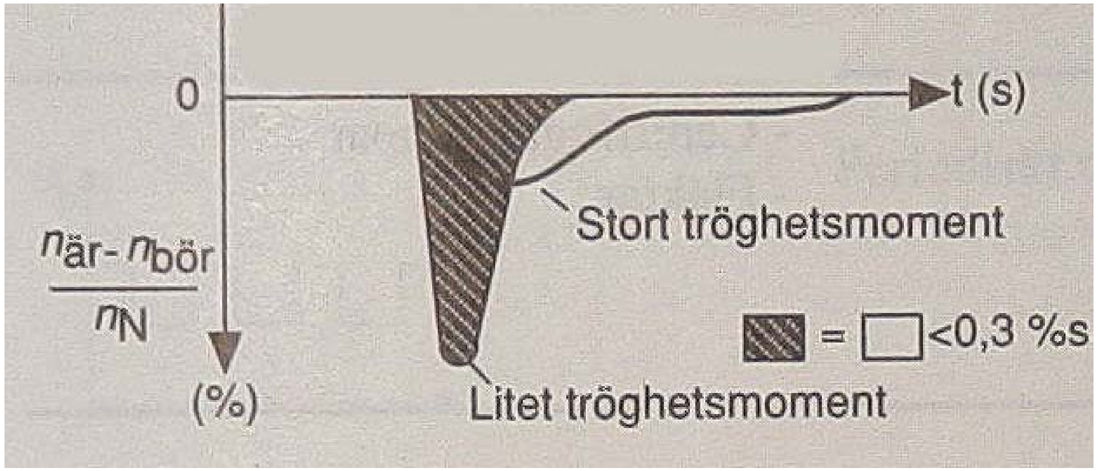
Speed Control with encoder:

Varvtalsreglering (varvtalsåterkoppling med pulsgivare)	
Upplösning	1:20000
Varvtalsområde (n_{min}/n_{max})	1:40
Statisk noggrannhet	+/- 0,01%
Dynamisk noggrannhet	3%s

Why encoders?

There is a difference between static and dynamic tolerance.

ABB explains what dynamic tolerance is in Handbok Industri:



Why encoders?

Conclusion

Encoders are needed to measure rotational speed and/or rotational angle.

Two primary uses are:

- Pure measurement for surveillance or logging purposes
- As a feed-back element to improve the performance of a hydraulic motor or an AC or DC motor in conjunction with a suitable controller

Where encoders?

Encoders are found in all machinery where speed is critical and needs to be controlled or supervised.

- Paper mills
- Steel mills
- Machine tools
- Transportation
- Forest machinery
- Process industry
- And many more areas

Where encoders?

This encoder is doing duty in a paper mill. The environment is humid, hot, dirty and the mission is critical. A typical paper machine runs for six weeks between each eight hours ”pit stop” when maintenance is done.

Where encoders?

A typical paper machine needs somewhere between 30 and 100 speed controlled drives – and the same number of encoders.

This one is well protected and works in a clean environment. The problem here is the vibration level.

How encoders?

Encoders take on many shapes. There are simple plastic encoders that are used as input devices in instruments.

And there are precision encoders that need special care and skills to preserve the high precision.

How encoders?

There is also the plain vanilla encoder. Like the Leine & Linde encoders. L&L shown here. 500 PPR.

How encoders?

Encoders use several different principles to measure rotational speed:

•Disk with slots and a LED/phototransistor combination. Low resolution, 100 – 256 PPR maximum

•Disks with sputtered pattern, a slit plate and LED/phototransistor. High resolution possible

•Magnetic pattern and Hall sensors or magneto-resistors

•There are also resolvers, which are wound little electrical machines. Robust, loved by military people

How encoders?

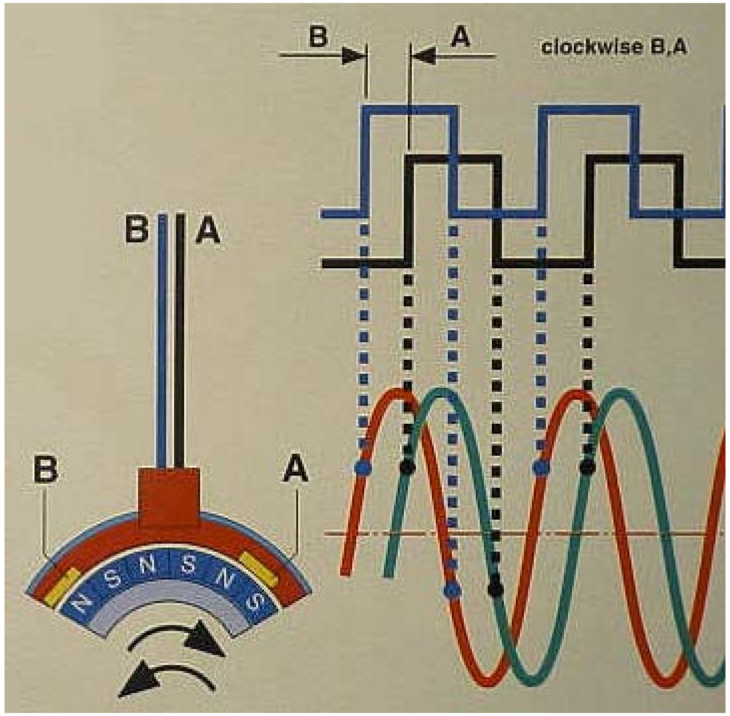
The SKF Sensor Bearing is a compact addition to the standard bearing.

It represents an extreme form of added value. No housing, no extra bearings, no mechanical coupling, no alignment problems.

The resolution is rather poor by today's standards, but there is more than one way to improve that.

How encoders?

The SKF Sensor Bearing utilises a magnetic ”scale ring” and hall effect sensors to detect the periodic flux and to convert it into electrical signals.



How encoders?

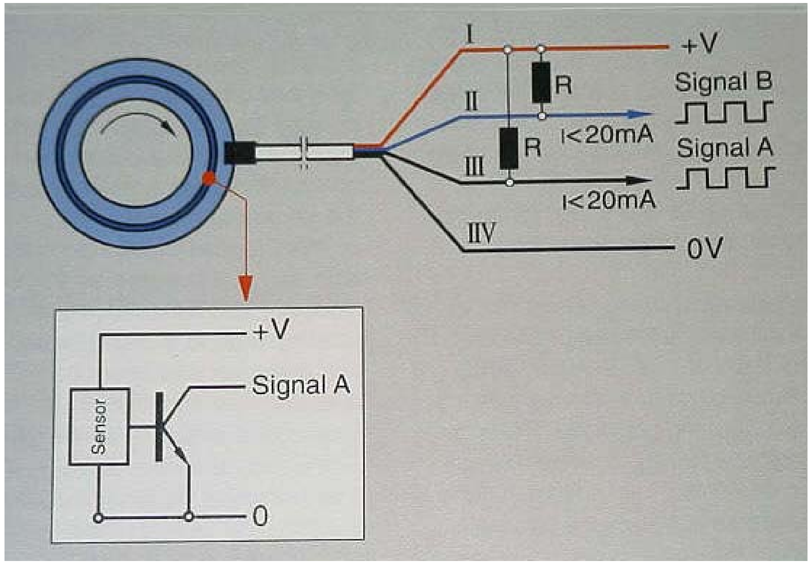
Once electrical, the sky is the limit.

Use it as is.

Network it.

Bluetooth it.

WAP it.



The beauty of the Sensor Bearing

Let’s look at a few applications with ordinary encoders and tacho generators. You will find that there is a lot more to an encoder than just buying one.

In fact, most users experience that adapter rings, flexible couplings and extra protective means cost a lot more than the encoder itself.

Then, there is the vulnerability of the external encoder. A key point that often means more than pricing and fitting costs.

The beauty of the Sensor Bearing

We are looking at the Non Drive end of a DC motor. We see the motor frame, an adapter ring (or flange). There is also an Encoder (Stegmann 1024 PPR) and a couple of hands unscrewing the three fixing screws with washers that keep the Encoder in place.

You need no Adapter Rings with a Sensor Bearing!

The beauty of the Sensor Bearing

The Encoder is being removed from the adapter ring. You can see the typical ”servo flange” that is popular with this kind of equipment. You have to be very careful here! It is very easy to loose one of those little springs or washers that might exist inside.

There’s nothing to drop with a Sensor Bearing!

The beauty of the Sensor Bearing

We were lucky. Nothing dropped. The funny shape inside is a spring that is part of a flexible coupling that is needed to absorb angular and radial misalignment and thermally induced shaft movements. The spring is bolted to a disc, which in its turn is fastened to the motor shaft end with a hexagonal screw.

So much easier with a Sensor Bearing!

The beauty of the Sensor Bearing

The Encoder and the mating half of the flexible coupling.

The two pins are supposed to engage in the two holes in the spring. The problem is that you cannot see if they really have done that. It works most of the time, though. But it leaves you with a feeling of uncertainty.

No uncertainty with a Sensor Bearing!

The beauty of the Sensor Bearing

Wait a minute! A SPRING!? That is not good if you want to stay out of truble in a highly dynamic drive. A spring always means trouble. Resonances, for instance.

No springs in the signal path with a Sensor Bearing!

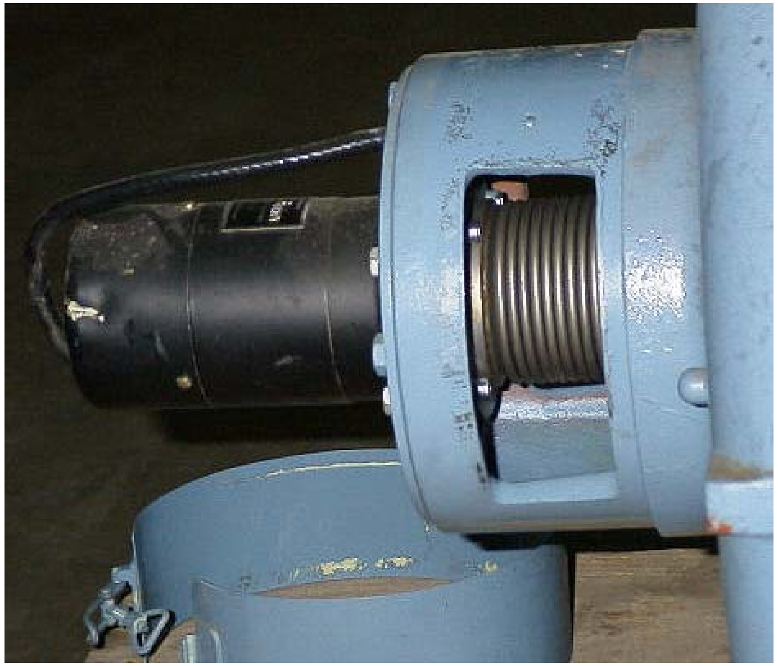
The beauty of the Sensor Bearing

Tacho Generators are used as speed feedback elements in many drive systems. This is a French one. Radio Energie, DC tacho.

The adapter is there again. Plus an extra flange.

The tacho has taken some beating.

Take no beating with a Sensor Bearing!



The beauty of the Sensor Bearing

If anything breaks here, it won't be the coupling. And look at the adapter! Sturdy. The bellow is well protected by a sleve. But the tacho itself is not protected. (Note the indentation)

Perfect protection with a Sensor Bearing!

The beauty of the Sensor Bearing

An Encoder or a Tacho Generator inevitable makes the motor longer. There is not much you can do about that. Or, perhaps you can?

Someone saved several inches here.

No such problems with a Sensor Bearing!

The beauty of the Sensor Bearing

Aha! A couple of pulleys, a timing belt and a housing.

Why not use a Sensor Bearing instead!

The beauty of the Sensor Bearing

Shure enough! One of these fittings just fell off.

That never happens with a Sensor Bearing!

The beauty of the Sensor Bearing

You need no extra hardware with a Sensor Bearing!

There's nothing to drop with a Sensor Bearing!

No uncertainty with a Sensor Bearing!

No resonances with a Sensor Bearing!

Perfect protection with a Sensor Bearing!

No space problems with a Sensor Bearing!

A sensor bearing stays where you put it!

A Sensor Bearing is for ever!

…and then, much lower cost.

The Sensor Bearing is the industry's best preserved secret. We are going to change that!!

Common objections to the Sensor Bearing

We need more resolution!

Are you sure? Many volume applications don't even need the resolution we can offer today.

It is only servos and high-precision drives that really need high resolution. Many applications that we look at today use standard PLCs with rather slow process inputs. So these applications cannot handle the 10 – 30 kHz pulse frequency that a 1024 PPR Encoder outputs and the customer does not want to buy extra hardware only to handle resolution that he doesn't need.

And remember, these applications are volume applications. Not a mere 50 or 100 piece sale.

Common objections to the Sensor Bearing

We need more resolution! (cont.)

The demands for high resolution is often exaggerated. Siemens – for example – has the following criterium:

$$PPR > 275/RPM_{min}$$

This would mean that a four-pole motor could be run from less than 4.5 RPM (64 PPR) up to 1800 RPM (60 Hz, base speed) and that is a controlled speed range equal to 400:1. More with field weakening.

It is only when you need high speed and low speed in a drive that the resolution gets critical.

Most customers don’t know this. Make sure they understand!

Common objections to the Sensor Bearing

It takes too long time to change!

Think! Why do you change Encoders?

Encoders and Tacho generators are the most vulnerable components that there is today. They get beaten, their little bearings have poor life in the environment they are put to work and bearing currents often kill the encoder bearings first (in fact, encoder bearings are known to save the main motor bearing).

A Sensor Bearing can live as long as the motor itself. So it doesn't matter that it takes some time to change it. You will probably never have to.

If you don't have to change it, why bother about the time it takes?

Common objections to the Sensor Bearing

It is not proven in use!

Oh yes, it is!

The DGBB is an extremely mature product. That is for sure.

Magnetic materials are also proven in use.

So is integrated electronics and Hall elements.

These things have been around for at least fourty years. If that isn’t proven in use…

But, of course, we have to prove that convincingly.

Common objections to the Sensor Bearing

What about EMC?

That’s a point. The Sensor Bearing *can* be improved.

But still. There are hundreds of thousands of Sensor Bearings doing their job out there. In electric motors with intense PWM interference.

True. Some applications need extra care, but that is not a problem. Just sound engineering.

And the next generation will be even less sensitive to EMI.

The Sensor Bearing can be improved with respect to EMC. And the next generation will be improved.

Growth paths

The Sensor Bearing represents a whole new thinking.

It does away with housing, coupling, bearings, shaft and seals. That is 70 - 85 % of the cost of a conventional encoder.

This fact alone points to a host of interesting applications that can take advantage of the Sensor Bearing envelope and mechanical interface. A careful study of today's existing and tomorrow's emerging needs will probably give birth to a whole family of healthy Sensor individuals.