EUROPEAN SPALLATION SOURCE

Proposals for Feedback Test Items (Absolute Linear Encoder)

In-kind project NIK5.3#5

Test Package for Linear Motion Technology

Thomas Gahl, ESS - MCAG

Project Kick-Off Meeting, FZ Juelich,
21st November 2017

Overview absolute linear encoders

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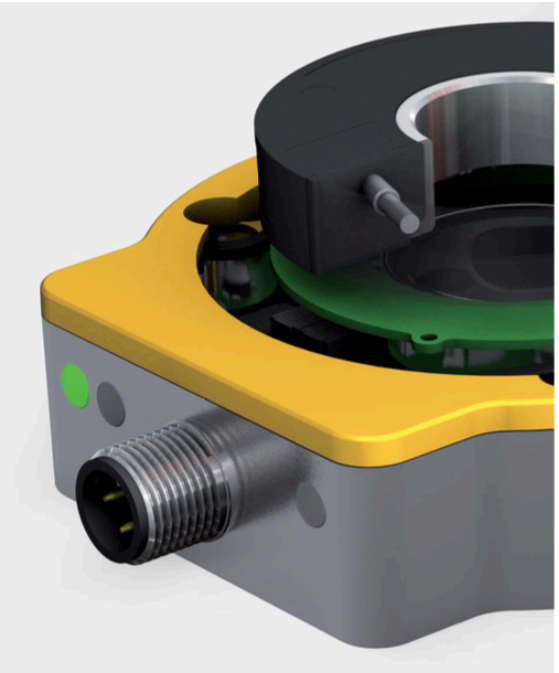
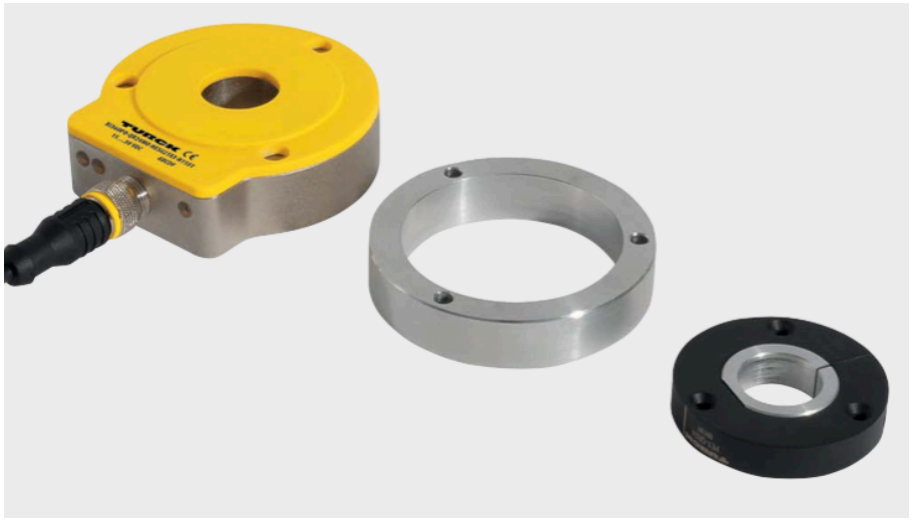
- Inductive Linear Encoder TURCK Li-Q25L (SSI)
- Inductive encoder TWK (SSI)
- LVDT (Analog)
- Magnetolinear RLS (SSI, BissC)
- Inductive+magnetic NEWALL (SSI)

TURCK contactless encoder Ri-QR24 / Li-Q25L

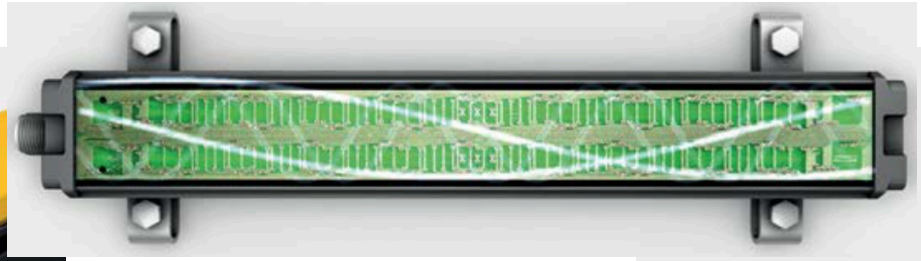
- Turck inductive encoder Ri/Li are using basically the same technology than Zettlex IncOder™ or LINTRAN™ models.
- Supplier is Turck GmbH, Mühlheim, Germany, http://www.turck.com/
- Truly single turn (360°) + pseudo multiturn absolute measurement of angular and linear displacements.
- Encoders come with build-in electronics for signal conditioning and digital SSI or analog 0-10V/4-20mA signal interfaces.





Absolute Inductive Encoders – Turck Li-Q25L

- Coil geometry with low-precision (m) and high precision (n) system (m < n).
- Measuring ranges from 25 to 1000mm
- Highly sealed housings, permanent protection to IP67/IP69K.
- Distance target to encoder 0 to 4 mm
- Highest resolution 1µm, repeatability 18/36 µm for 500/1000mm range

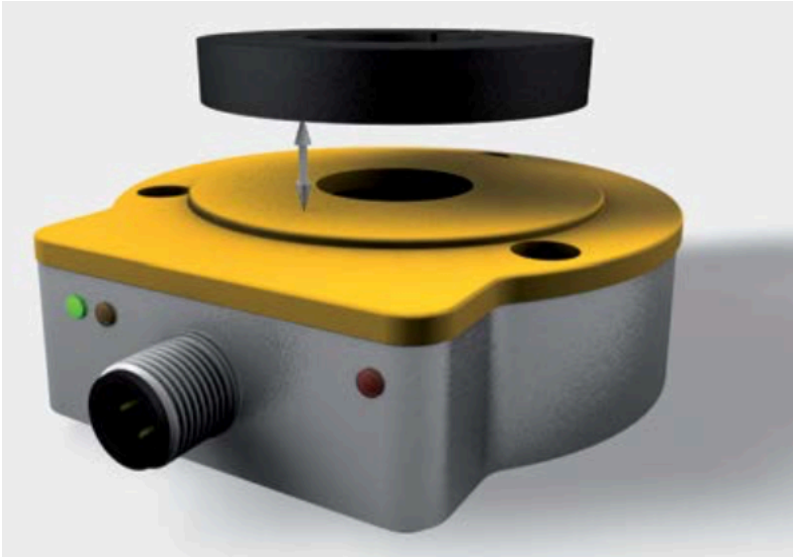


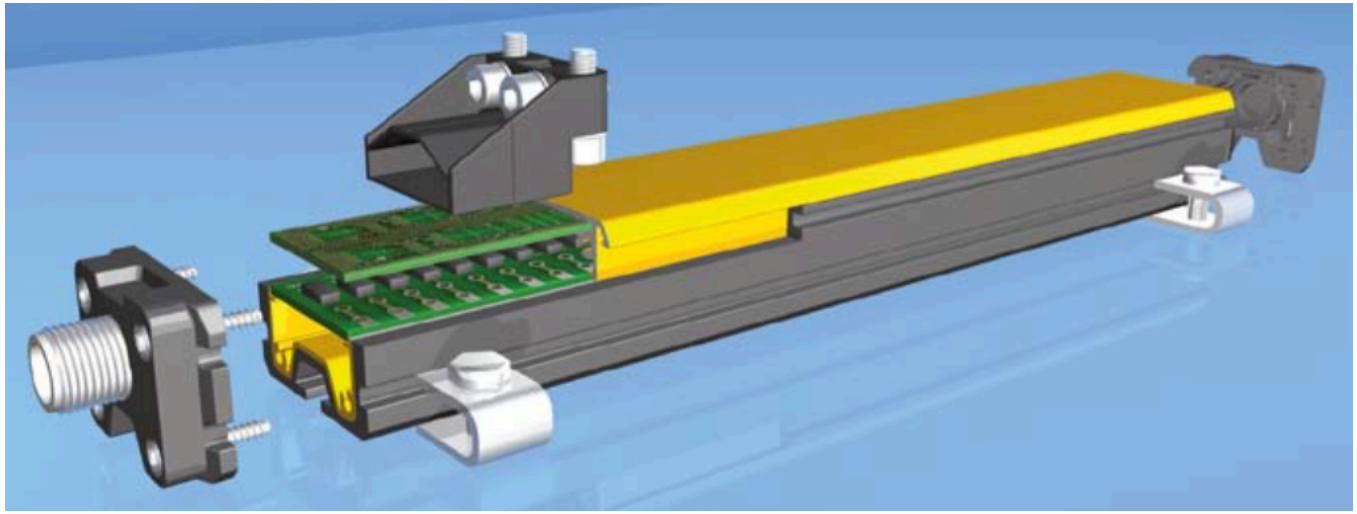
More details on Turck Ri/Li encoder in talk MCA # 39 ”Inductive Encoder”

Turck Ri/Li - Construction

The sensor system consists of a powered stator with emitter and receiver coil systems that are manufactured as printed circuit coils and a passive target (resonator). The measuring process is completely contactless and wear-free.

The electronics are implemented on two board levels. The PCB on which the sensor element is positioned is located directly under the active face; the electronic circuit for the signal evaluation on the other hand, is housed one level below it.





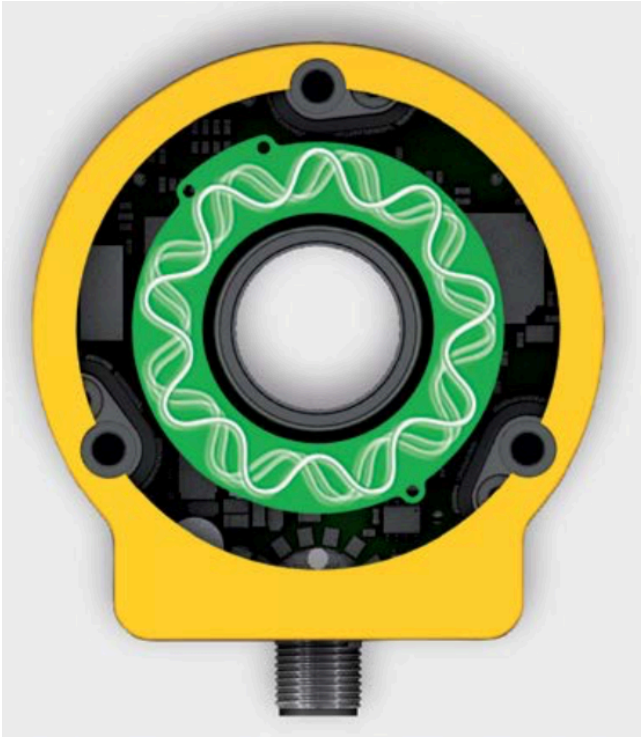
A special coil arrangement ensures that stable resonance coupling is implemented in a defined distance range, and that the sensor signal does not change if there is any lateral movement or a change in distance.

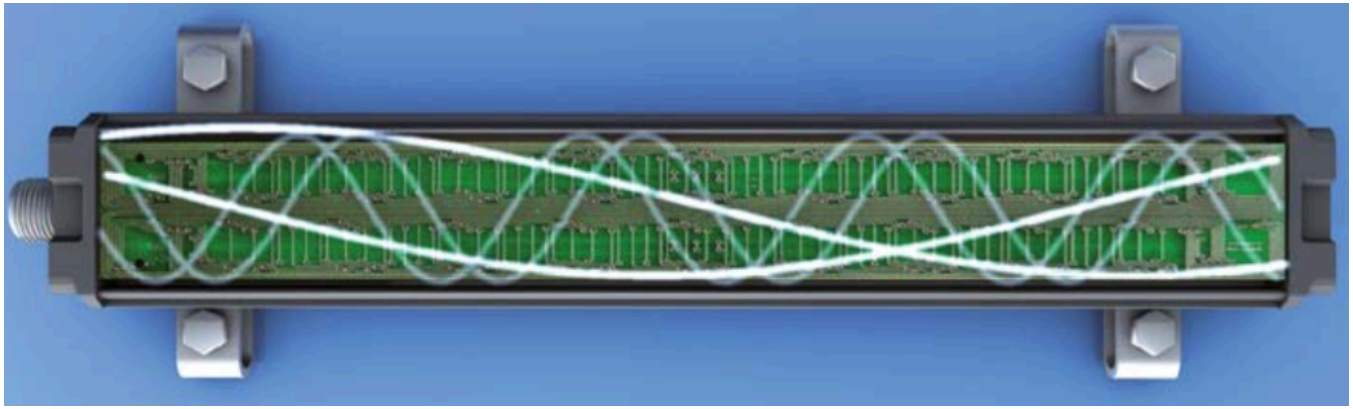
InducTurck Ri/Li - Measuring Principle

The measuring principle of the new encoders is based on an inductive resonance coupling circuit. The emitter coils are excited with a high-frequency AC field and form with the positioning element (resonator) an inductive resonance coupling circuit.

The geometry of the receiver coils is designed so that different voltages are induced in the coils depending on the position of the positioning element, and thus determine the sensor signal.

The sensor is provided with a low-precision and a high-precision receiver coil system in order to increase its measuring speed and accuracy.



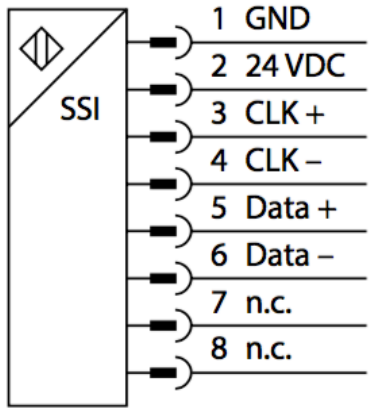


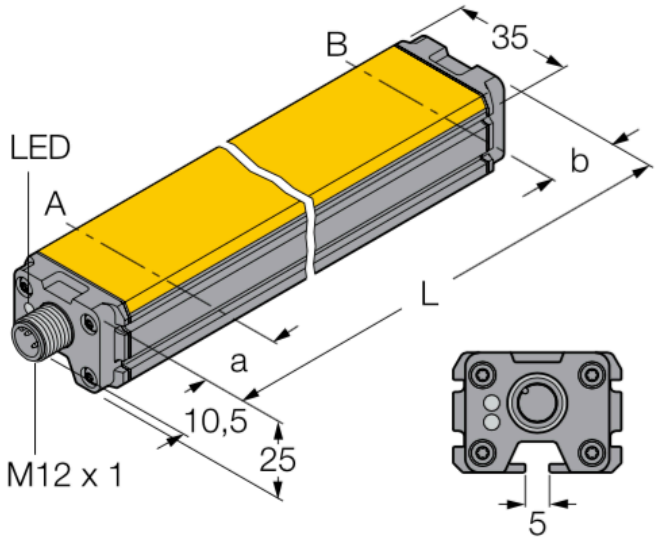
Turck Li-Q25L – Data Sheet

EUROPEAN SPALLATION SOURCE

Measuring range specifications	
Max. measuring range	100, 200, … 1000 mm
Blind zone a	29 mm
Blind zone b	29 mm
System	
Resolution	0.001 mm
Repeatability	18 µ (Li100…Li500), 36 µ (Li600…Li1000)
Linearity deviation	≤ 0.035 % of full scale
Temperature drift	≤ ± 0.0001 %/K
Ambient temperature	-25…+ 70 °C
Electrical data	
Operating voltage	15…30 VDC
Residual ripple	≤ 10 % U_{PP}
Rated insulation voltage	≤ 0.5 kV
Short-circuit protection	yes
Wire breakage / reverse polarity protection	yes/yes (voltage supply)
Output function	SSI, 25 bit Gray coding
Sampling rate	1 kHz
Current consumption	< 50 mA
Housing style	
Housing style	rectangular, Q25L
Dimensions	profile 35 x 25 mm, length L = meas. length + 58 mm
Housing material	aluminium
Material active face	plastic, PA6-GF30
Connection	male M12 x 1
Vibration resistance	55 Hz (1 mm)
Shock resistance	30 g (11 ms)
Protection class (IEC 60529/EN 60529)	IP67

Wiring diagrams





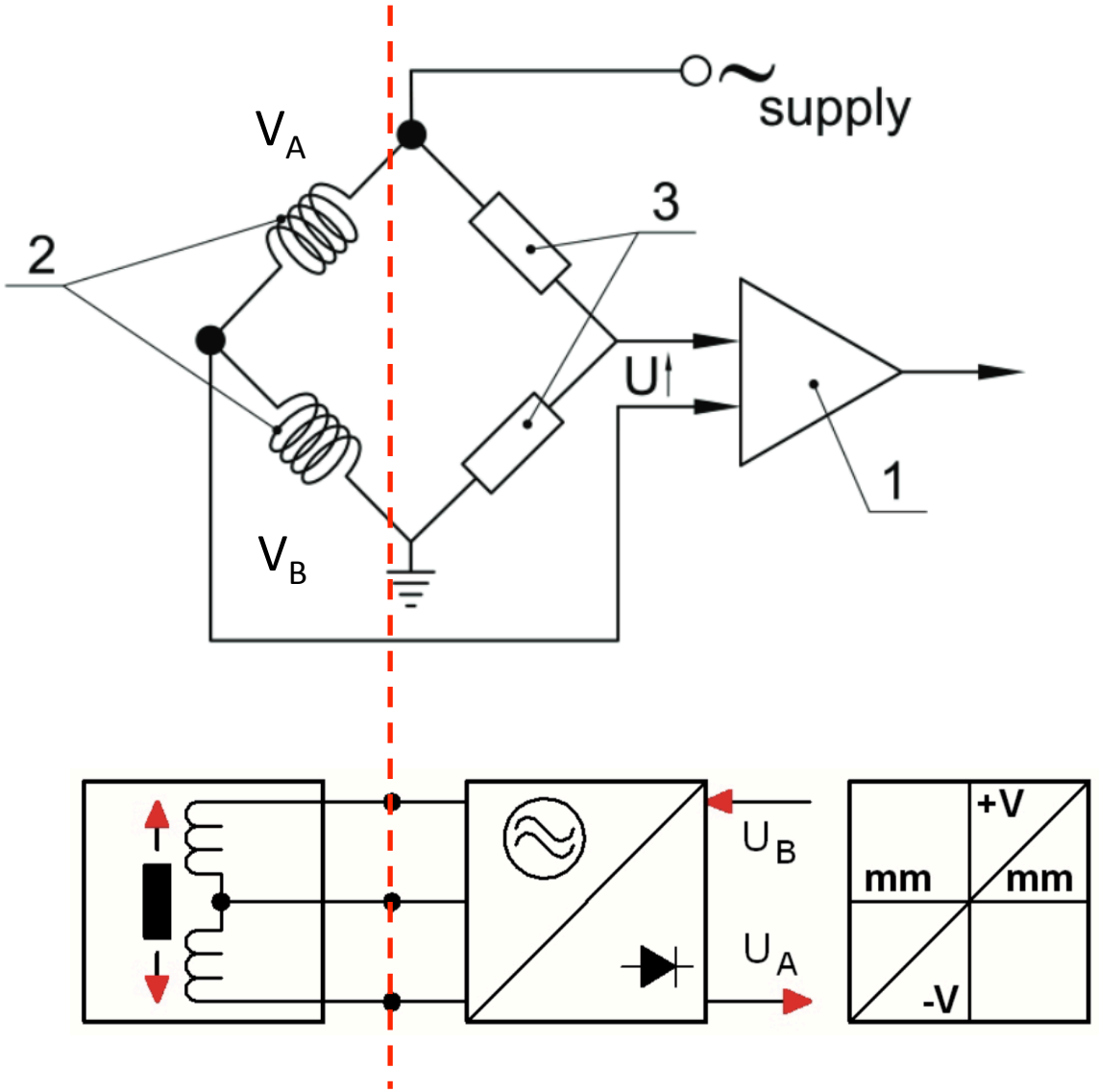
Absolute Inductive Encoders – Turck Ri/Li

- Pros:
  - High resolution, high repeatibility
  - Multiturn capability (Ri)
  - Flexible fixing on different shaft sizes (Ri)
  - Short blind zones on both ends of the encoder (Li)
  - High EMC immunity
  - Only passive target, all electronics in the stator
  - Good for classical harsh environment (shock, vibration, EMC, dust, oil etc.), IP67 per default
  - Large mounting tolerances for gap between stator and rotor (0 to 1.5/4mm)
  - Standard industrial interfaces (SSI etc.)
- Cons:
  - No separation of electronics possible (for potential use in radiation and high temperature areas)
  - Performance in very high DC magnetic fields needs to be tested.

Linear Differential Inductance Transducer (LDIT) - Inductive Half Bridge

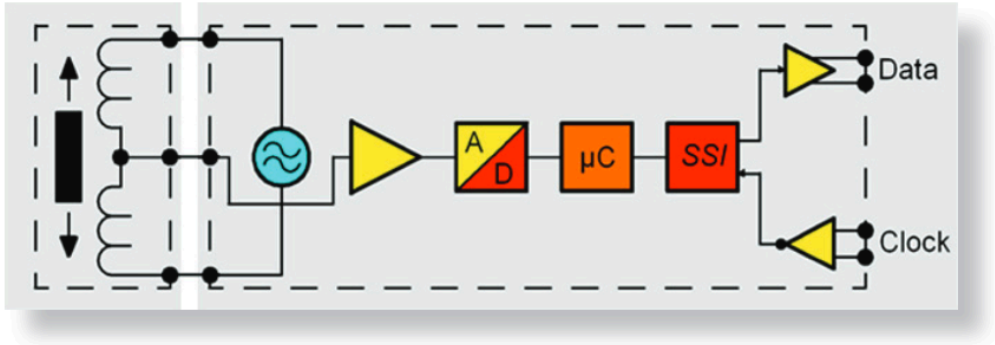
The Half Bridge transducer forms half of a Wheatstone bridge circuit (2), which enables change from null to be readily determined. The other half of the bridge (3) is built into the amplifier (1).

When the core is in a central position, the two signals V_A and V_B are equal. As the core is displaced, the relative inductance of the two windings changes producing a complimentary change in V_A and V_B.



LDIT- TWK IE-25 series

+



Technical Properties

- Encoder heads with 2 to 120mm measuring range (series IW10, IW 120)
- Separate electronics with signal processing and absolute encoder interface
- 12bit resolution, linearity 0.25% or 0.5% FSO
- SSI-interface (125 kHz, 13bit), binary coding

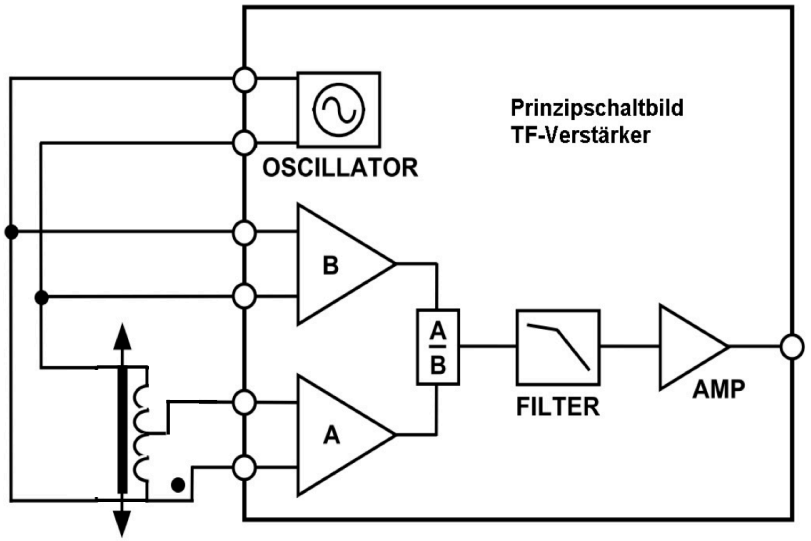
LDIT– Messotron WLH/WLG-series

+

q.bloxx A106

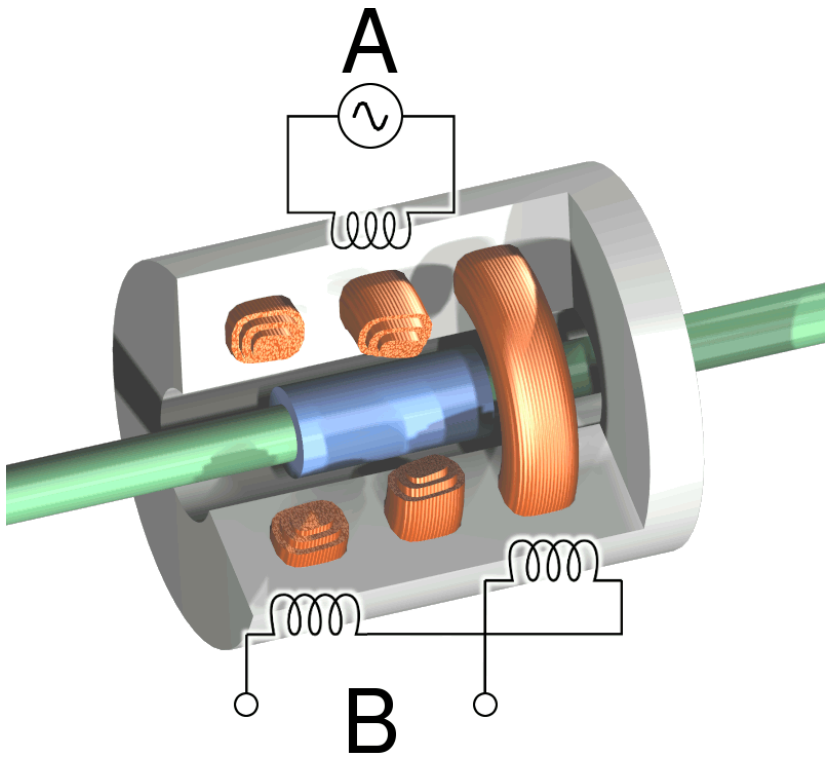
Technical Properties

- 2 to 500 mm measuring range
- Separate electronics with signal processing and absolute encoder interface
- For carrier frequency 2 to 10 kHz
- Linearity 0.1 to 0.5% FS
- Analog output (2 – 10V, 4 – 20mA)



LVDT

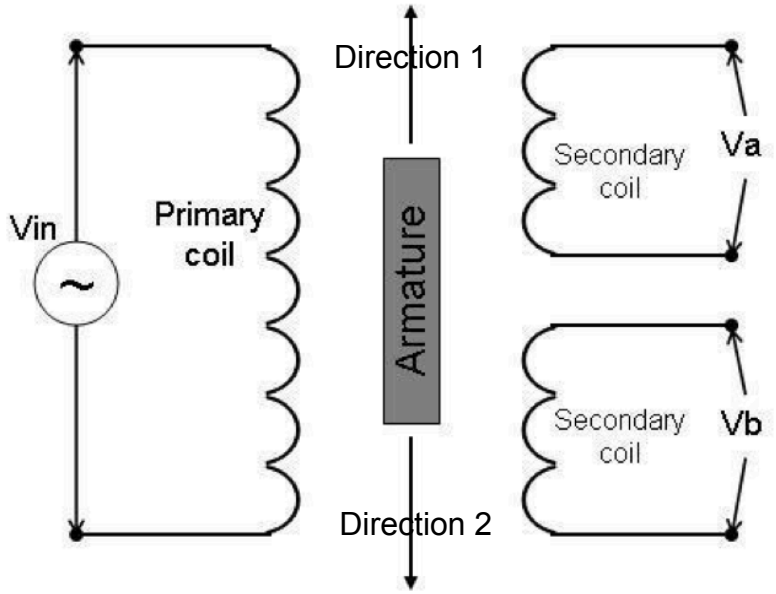
- An LVDT, or Linear Variable Differential Transformer, is an absolute displacement transducer based on the difference-inductive principle.
- It converts a linear displacement or position from a mechanical reference (or zero) position in the middle of the travel range into a proportional electrical signal containing phase (for direction) and amplitude information (for distance).



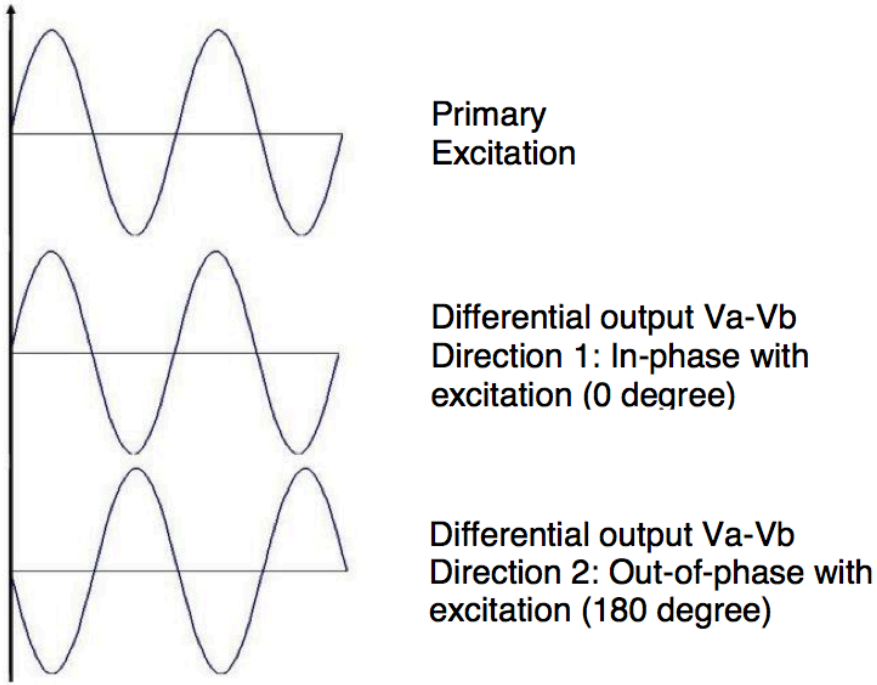
Difference-inductive sensor principle

In a difference-inductive or differential transformer sensor the coupling between primary and secondary coils is modulated by a moving ferromagnetic or electrically conducting object. The primary coil of the transformer generates an AC magnetic field. The two secondary coils are arranged and wired in a differential configuration that is perfectly symmetric with respect to the primary coil.

The field generated of the primary coil induces in each of the secondary coils a voltage. When the symmetry of the magnetic field is not disturbed, the voltage in each of the secondary coils Va, Vb is the same, (Va-Vb) = 0.

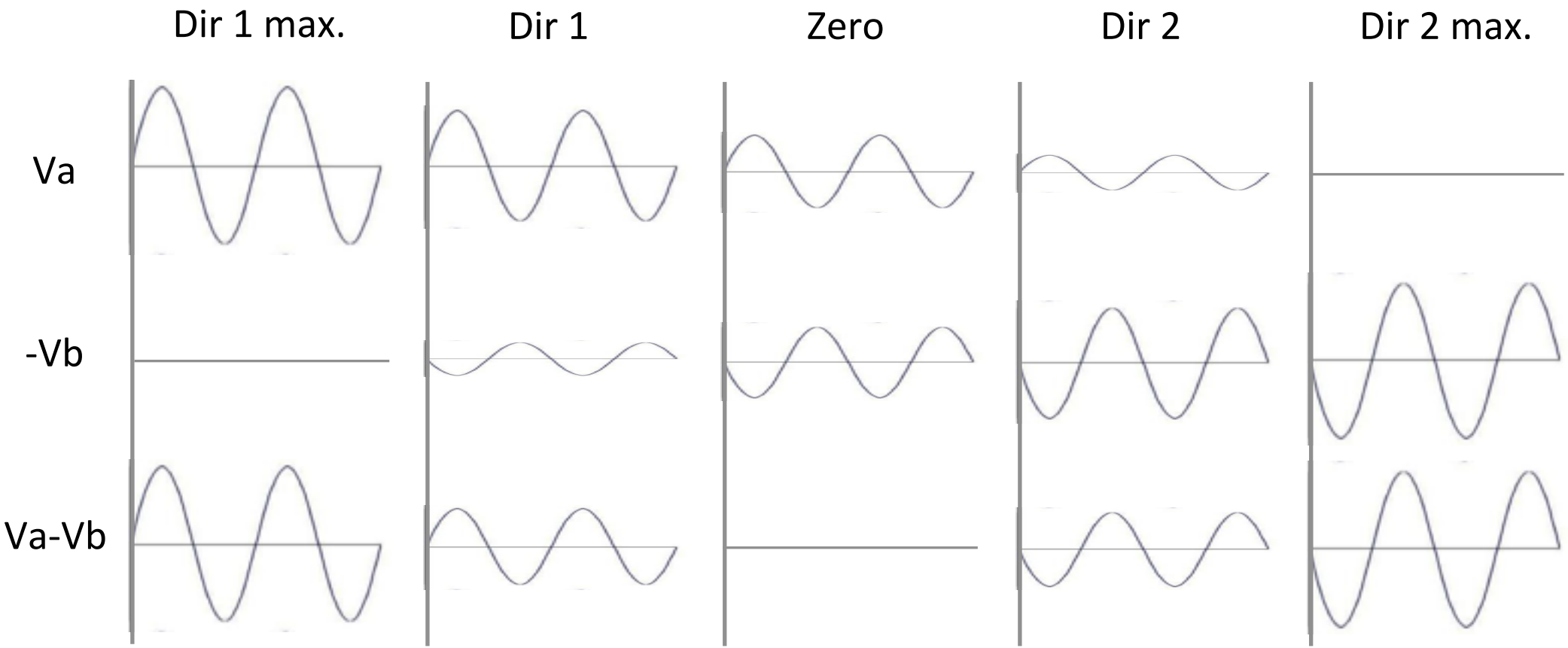


LVDT Schematic



LVDT waveforms

Difference-inductive sensor principle



Coupling between the coils and the induced voltages Va, Vb in the secondary coils is changing symmetrical according to the position of the ferromagnetic object. The resulting differential signal (Va-Vb) is modulated in amplitude (= distance from zero) and phase (with respect to the excitation voltage) pointing into direction 1 (0°) or 2 (180°).

Advantages: Only one signal conditioning channel, noise picked up in both coils will not compromise the measuring result

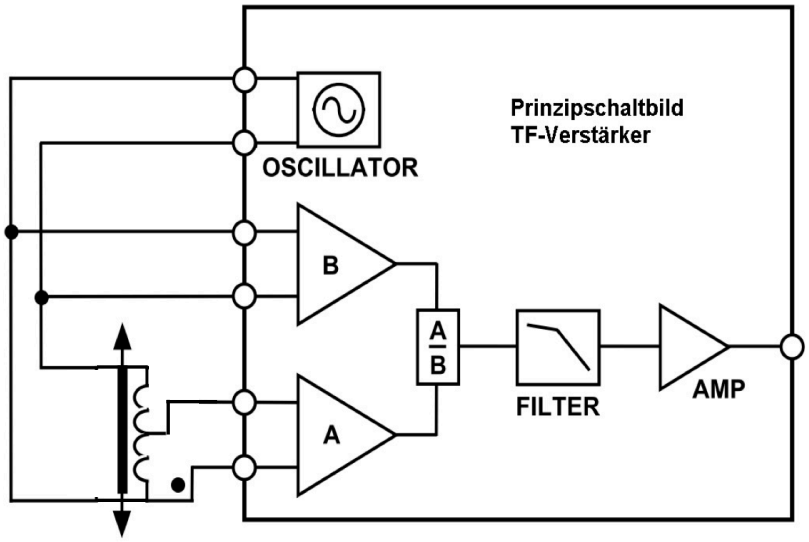
LVDT + Messotron amplifier

+

q.bloxx A106

Specification for LVDTs:

- max. travel range: 200 to 500mm
- no integrated electronics
- separate connections for both sec. coils (a total of 6 wires)
- harsh environment (vacuum, radiation, high temperature)
- guided version?, non guided version?

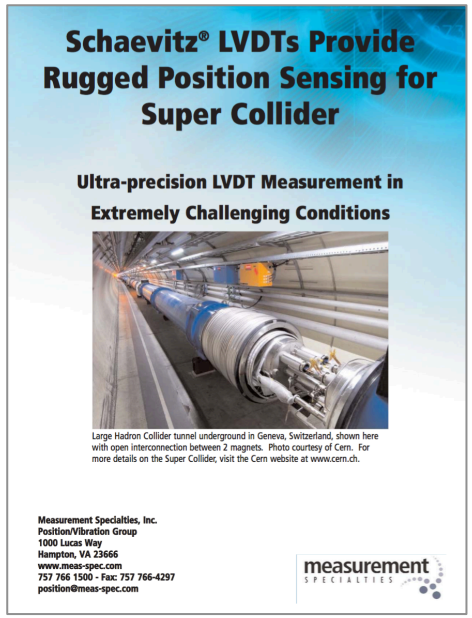


LVDT suppliers

- ASM
- EddyLab
- Kavlico
- MacroSensors (=TE)
- Measurement Specialties (MEAS) (=TE)
- Messotron
- Micro-Epsilon
- Moog
- Penny+Giles
- Schaevitz (=TE)
- Sensonics
- Solartron
- Stellar Technology Inc (STI) (=LORD)

LVDT – Schaevitz (CERN customized)

- **Challenging Environmental Specifications**
- PT-100 Resistance Temperature Detector (RTD) inside each LVDT
- 50 Mgray radiation resistance
- High EMI immune
- Ratiometric design & testing, corrosion-proof
- Temperature coefficient of sensitivity <50 ppm per °C
- Linearity ranging from 0.1 to 0.04%
- Must operate with varying cable lengths from 50 to 750 meters
- ±40 mm stroke in a 200 mm long package
- Integral 1-meter shielded cable
- Sensitivity > 15 mV/V/mm, (in the differential mode)



LVDT - ASM

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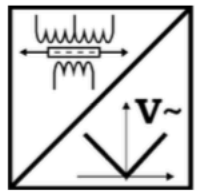
LIN-Serie
LVDT-Positionssensoren

ASM®
Automation
Sensorik
Messtechnik

Sensoren für hohe Temperaturen und hohe Radioaktivität

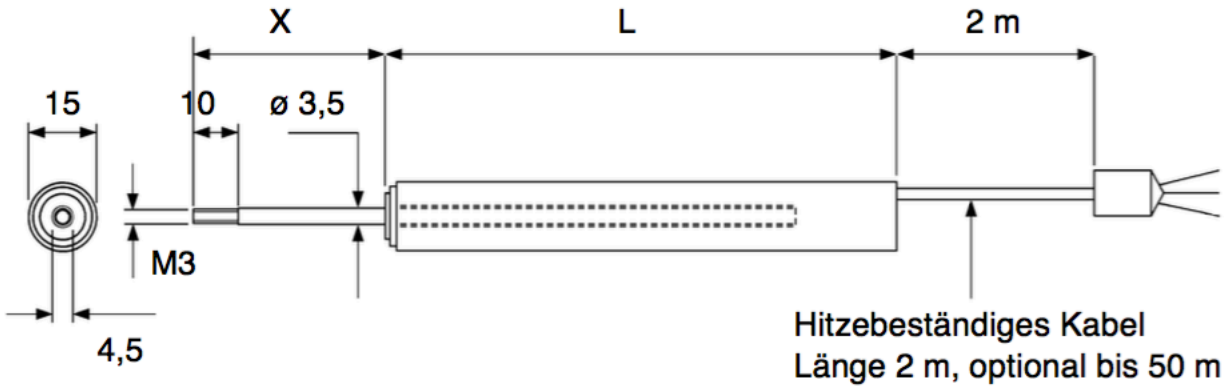
- **Meßbereich: ±5 mm bis ±25 mm**
- **Ausführung mit ungeführtem Anker**
- **Ausführung als Taster**
- **Gehäuse aus Edelstahl**
- **Betriebstemperatur: -220 °C bis +600 °C**
- **Umgebungsdruck: bis 200 bar**
- **Radioaktive Strahlendosis: bis 100.000 MegaRad**

100.000 Mrad = 1Ggy !!, or is it
100.000 krad = 1Mgy?
to be confirmed !!



LVDT - ASM

Ungeführter Anker



LIN-Serie	Meßbereich [mm]	Betriebs-temperatur [°C]	max. Temperatur [°C]	Gehäuselänge L [mm]	elektr. Nullpunkt X [mm]	Linearität [%]
LIN 52	±5,0	220	300	105	20	< ±0,5
LIN 56	±5,0	600	700	105	20	< ±1,0
LIN 152	±15,0	220	300	182	40	< ±0,5
LIN 156	±15,0	600	700	182	40	< ±1,0
LIN 252	±25,0	220	300	284	60	< ±0,5
LIN 256	±25,0	600	700	284	60	< ±1,0

LVDT - TE

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RoHS

XS-ZTR SERIES

Extreme environment LVDT

SPECIFICATIONS

- **Cryogenic/high-temperature operation**
- **Gamma and neutron radiation resistant**
- **2500 PSI [172 bar] operating pressure**
- **100% inorganic material construction**
- **Stroke ranges of ±0.1 and ±0.25 inch**
- **Hermetically sealed**
- **Stainless steel housing**
- **Imperial or metric threaded core**

The XS-ZTR is made exclusively from inorganic materials, specifically selected for their compatible expansion coefficients in order to minimize thermally induced stresses. The coil windings are of ceramic insulated precious metal alloys, while all seams and joints are either welded or brazed with high temperature alloys. The leads are sheathed in stainless steel, with conductors composed of nickel with magnesium oxide insulation. These cables can be terminated to a sealed header or connector if required.

LVDT - TE

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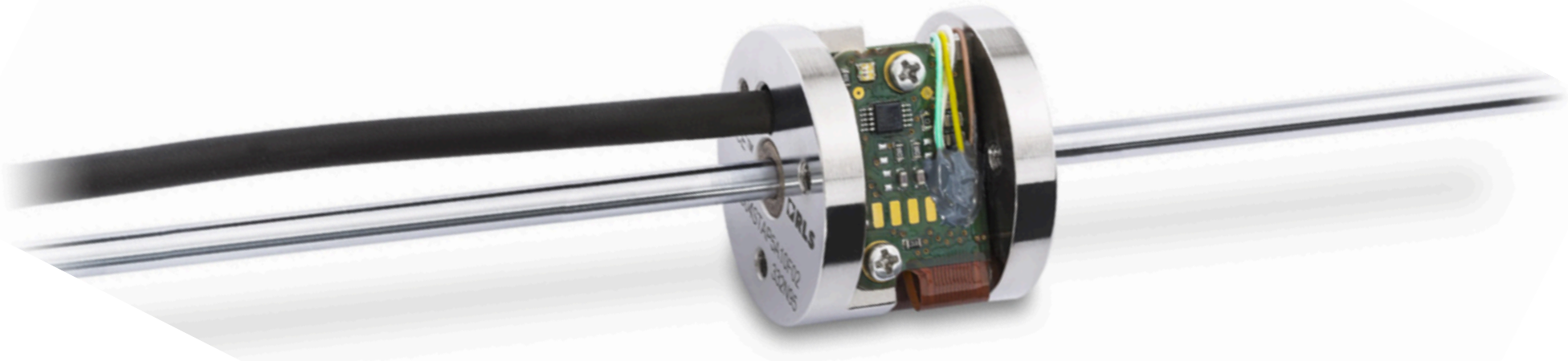
Parameter	XS-ZTR 100	XS-ZTR 250
Stroke range	±0.10 [±2.54]	±0.25 [±6.35]
Sensitivity V/V/inch [mV/V/mm]	1.3 [51]	0.3 [12]
Output at stroke ends (*)	130mV/V	75mV/V
Phase shift	-8°	+20°
Input impedance (PRIMARY)	95Ω	100Ω
Output impedance (SECONDARY)	250Ω	80Ω
Non-linearity (Room temperature only)	±0.5% of FR maximum	
Input voltage	3 VRMS sine wave	
Test input frequency	2.5kHz	
Input frequency range	400Hz to 5kHz	
Null voltage	0.5% of FRO maximum	

ENVIRONMENTAL SPECIFICATIONS & MATERIALS	
Operating temperature	-320 to +1020°F [-195 to +550°C]
Non-operating temperature	-455 to +1200°F [-270 to +650°C]
Radiation resistance Total integrated neutron flux: Gamma-ray total integrated dose:	 3×10^{20} NVT or 3×10^{24} n/m^2 maximum 10^{11} rad or 10^9 Gy maximum
Operating pressure	2,500 psi [172 bar] maximum
Shock survival	10 g (11ms half-sine)
Vibration tolerance	10 g up to 2KHz
Housing material	AISI 304 Series stainless steel

Magnetolinear Encoders

- Magnetolinear encoders (LinACE™) are based on reading a structure with different magnetic permeability in a rod.
- Supplier RLS, Slovenia
- Absolute measurement of linear displacements
- Magnetolinear encoders come with build-in electronics for signal conditioning and digital signal interfaces like SSI, BiSS-C or CAN.



Magnetolinear - Construction

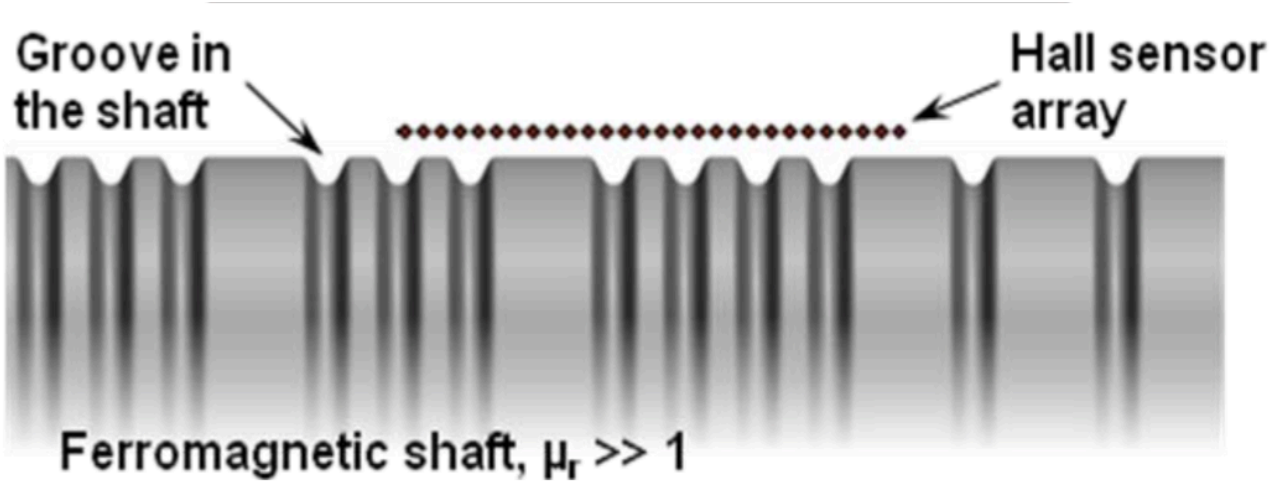
The LinACE™ encoder consists of a sliding encoder readhead module and a solid steel encoder shaft which eliminates the need for a separate measurement system in motion applications;

with numerous implications for design, complexity, cost-effectiveness and even feasibility of motion systems requiring accurate absolute position encoding.

Magnetolinear – Measuring Principle

The LinACE™ technology is based on absolute code written into an information carrier in the form of regions with different magnetic permeability representing a pseudo-random binary sequence (PRBS absolute code).

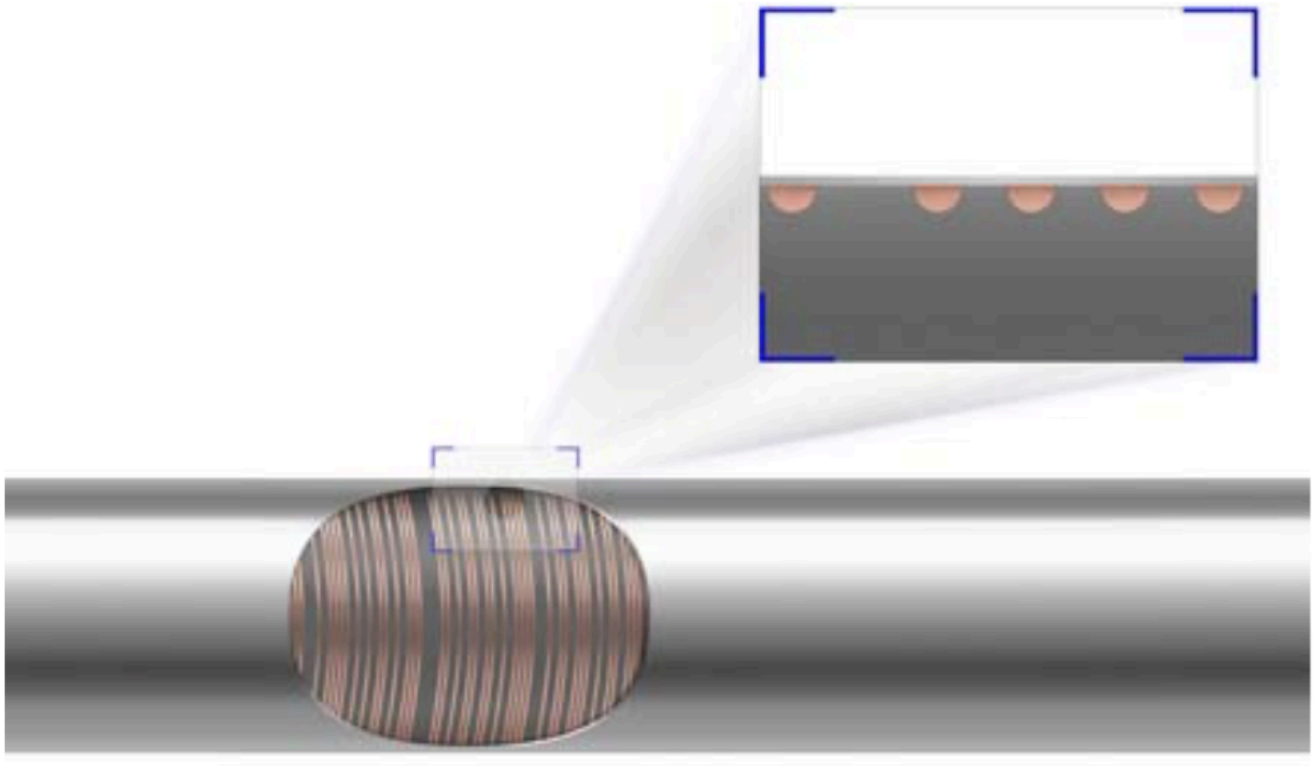
The structure is then read by an array of Hall sensors integrated in a single silicon die.



Magnetolinear - Measuring Principle

Coding structure is applied as grooves in the carbon solid steel shaft with high relative permeability.

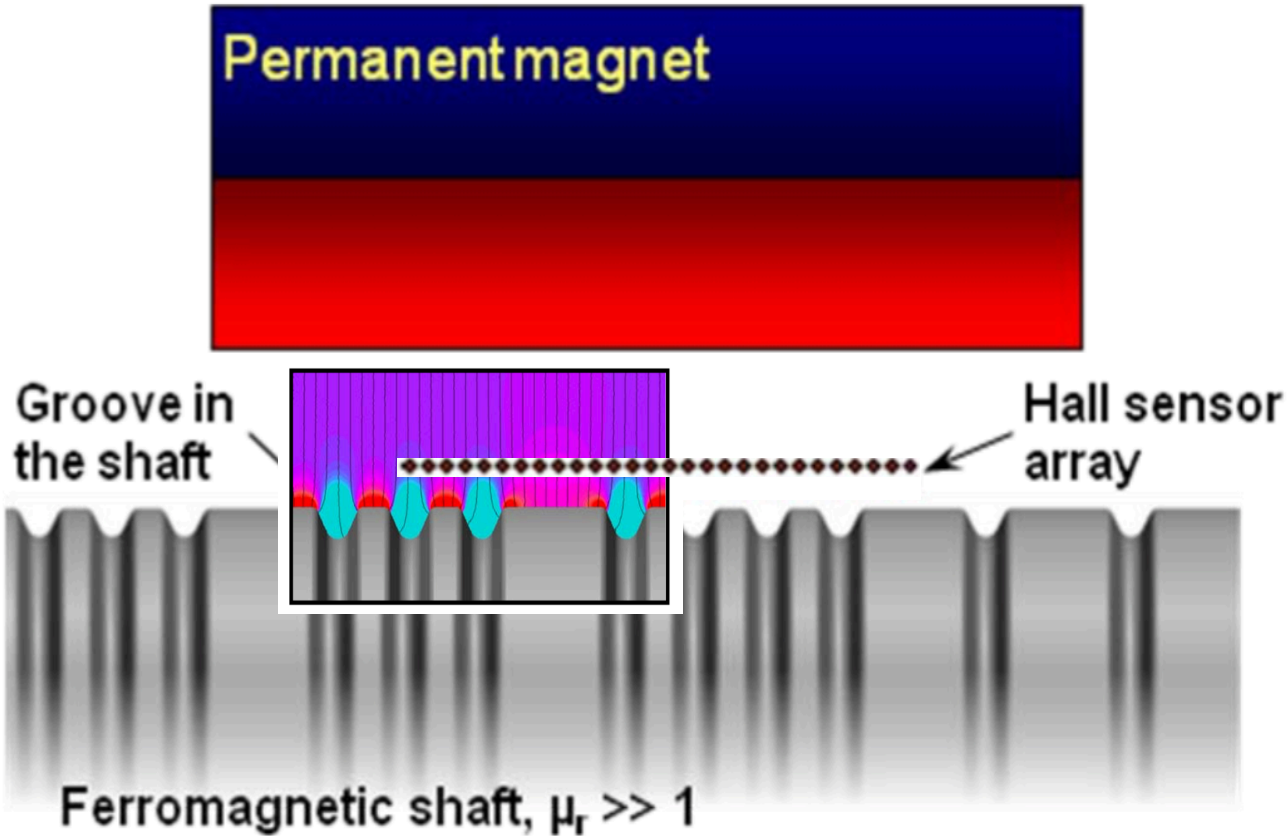
Grooves may be filled with hard chrome, copper or any other material with low permeability by galvanic or thermal spraying process.



Magnetolinear - Signal Conditioning

Using a bias magnet, differences in magnetic permeability modulate magnetic field density, which is detected and converted to electrical signals by a Hall sensors array integrated in a single-silicon-die ASIC.

Generated electrical signals are processed using algorithms including Fourier transform to calculate position based on millimeter-scale bit length down to sub-micrometer resolutions.



Magnetolinear – Data Sheet

EUROPEAN SPALLATION SOURCE

Technical specifications

System data		
Maximum shaft overall length	500 mm (320 mm for shaft diameter 4 mm)	
Shaft diameter	4 mm, 8 mm and 12 mm	
Shaft linear expansion coefficient	~11 × 10^{-6}/K	
Maximum speed	5 m/s	
System accuracy	±5 µm – for shaft overall lengths up to 125 mm ±10 µm, ±20 µm, ±50 µm – for shaft overall lengths up to 500 mm (in both cases readhead and shaft are not exchangeable) ±100 µm – readhead and shaft are exchangeable (start of measuring length can be any value bigger than zero)	
Hysteresis	Less than unit of resolution	
Repeatability	Better than unit of resolution	
Electrical data		
Supply voltage	4 V to 6 V – voltage on readhead. Consider voltage drop over cable (see page 4).	
Set-up time	5 ms (after switch-on)	
Power consumption	Typ. 115 mA, max. 150 mA	
Mechanical data		
Material type	Shaft	EN 1.1203 / AISI 1055 or EN 1.0601 / AISI 1060 30 µm to 40 µm Hard chrome coating 800 HV to 1100 HV
	Readhead	CuZn37Mn3Al2PbS, nickel coated
	Sliding bearing	Sint-A51 bronze impregnated with standard oil Sint-A51 bronze impregnated with low temperature oil

Preliminary product information
LinACE™ absolute shaft encoder
29th September 2016

BETA SAMPLES AVAILABLE

RLS®

LinACE™ absolute linear shaft encoder

LinACE™ is an extremely robust absolute linear cylindrical encoder system designed for direct integration into hydraulic, pneumatic, electromechanical actuators and linear motors as a feedback element for position or velocity.

The LinACE™ encoder system consists of a sliding encoder readhead and a solid steel shaft acting as a measuring standard.

By replacing the main shaft of the actuator or one of the guide shafts with LinACE™ hard chrome plated shaft the encoder becomes part of the actuator and provides measuring in the axis of movement. The readhead can replace the existing sliding bearing eliminating the need for an external encoder and thereby reducing space consumption.

The encoders come in asynchronous serial RS422, PWM, SSI, BiSS and CAN proprietary output variants and offer a range of selectable resolutions from 50 µm to 0.5 µm with speeds up to 5 m/s.

The LinACE™ encoder has a built-in advanced self-monitoring function, continually checking several internal parameters. Error reporting, warnings and other status signals are available on all digital interfaces and visualised with the on-board LED.

The encoder is insensitive to external magnetic fields, operates from –30 °C to +85 °C and is resistant to shock and vibration. The encoder position is retained even if the shaft rotates while moving backwards and forwards.

The LinACE™ encoder system is suitable for integration into electric, hydraulic and pneumatic actuators for motion control in industrial and medical applications. Custom design service for OEM integration is also available.

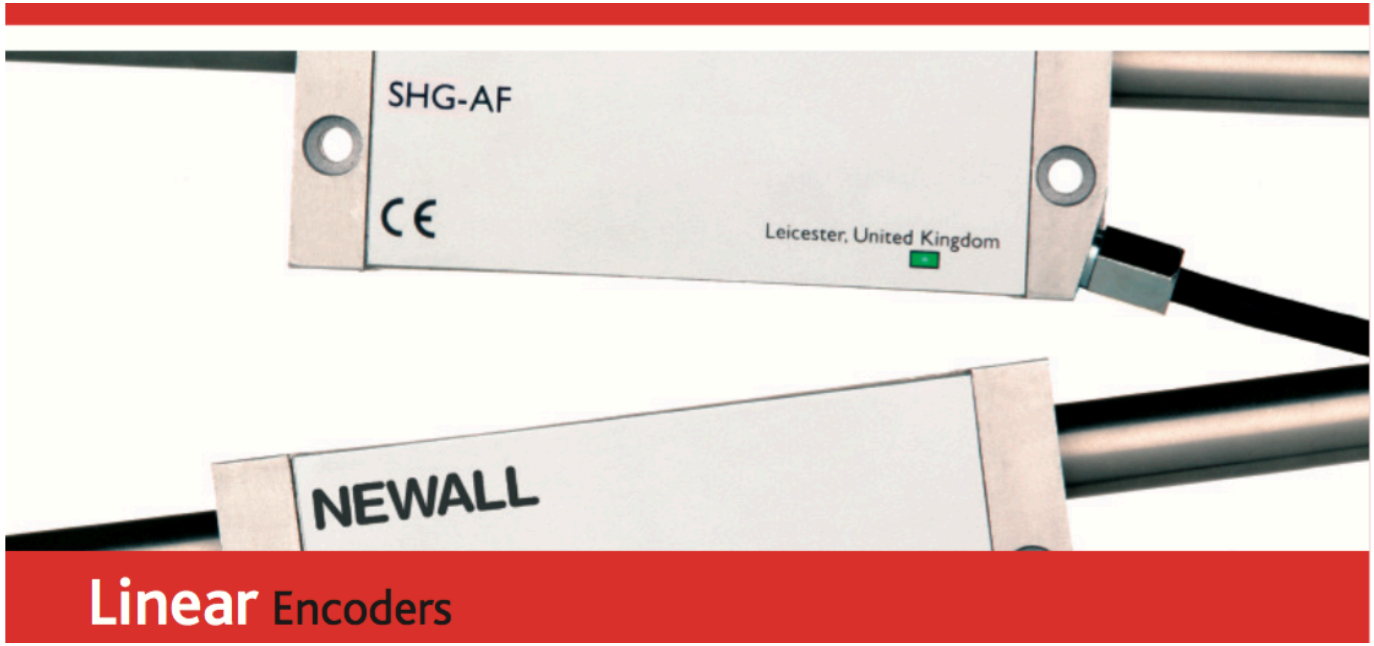
- True absolute system
- Encoder for direct integration into an actuator
- No magnetically induced position hysteresis
- Resolutions up to 0.5 µm
- Lengths up to 500 mm (320 mm for shaft diameter 4 mm)
- Speeds up to 5 m/s
- Built-in self-monitoring
- Integrated status LED
- Asynchronous serial RS422 communication, PWM, SSI, BiSS and CAN proprietary interface
- Non-magnetised hard chrome plated shaft
- Shaft insensitive to stray magnetic fields

A RENISHAW® associate company

RLS LinACE

Inductive & Magnetic Linear Encoders

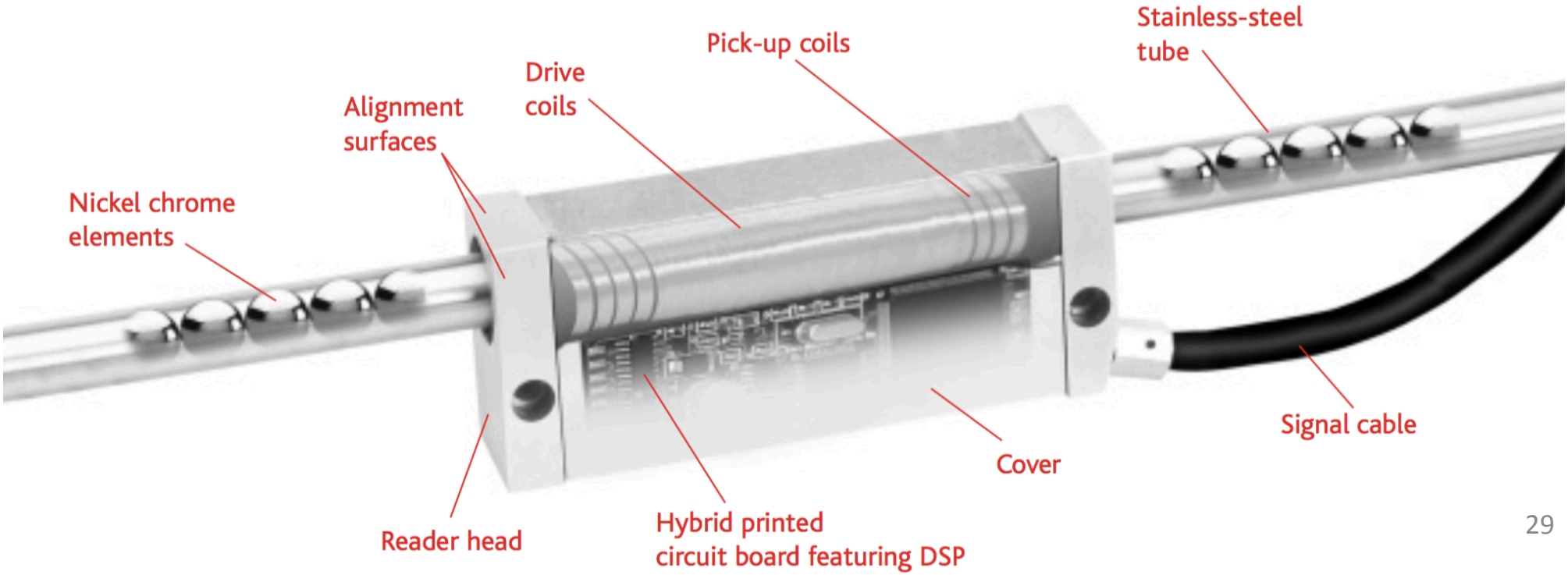
- Newall linear encoders SHG are combining a high resolution inductive incremental reading with a magnetic absolute reading based on a pseudo-random code. Both inductive and magnetic targets are incorporated in the rod.
- Supplier Newall, Leicester, UK
- Absolute measurement of linear displacements
- Encoders come with build-in electronics for signal conditioning and digital signal interfaces like SSI or asynchron RS232.



Inductive incremental sensor - Construction

Newall's SHG linear encoder are made up of two main assemblies; the reader head and the scale.

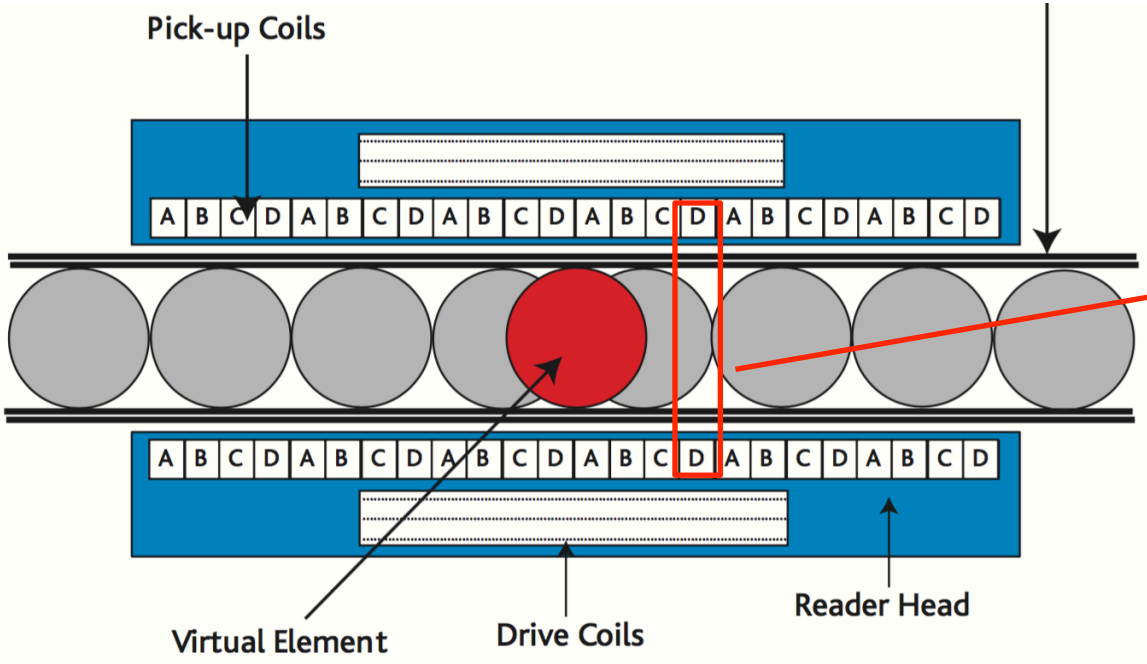
The scale is a stainless steel tube, housing a column of precision nickel chrome elements (12.7 mm balls) representing the encoders pitch. The reader head, which fits around the scale, moves in a linear motion along the scale length, comprising an assembly of drive and pick-up coils and electronics.



Inductive incremental sensor – Measuring Principle

There are six sets of pick-up coils with four identical windings A to D that are spaced at intervals of one pitch. As a result of this spacing each coil in a set is positioned over an identical part of an adjacent element. Coils with the same letter designation are connected together in series to enhance the induction amplitude.

Over the pick-up coils is the drive coil excited with frequencies of 1 to 10 kHz. The elements within the scale cause the permeability of the scale to vary periodically over a pitch. The voltages induced in each of the sets of pick-up coils vary according to the relevant positions of the coils to the underlying elements.



The amount of Cr-Ni in the core is determining the permeability (and thus the voltage in the pick-up coil)

Inductive incremental sensor – Signal conditioning

The amplitude of the induced signals varies with displacement along the scale (Figure 2a). The coils are spaced such that when one set of coils is at a maximum, (e.g. set A) another set spaced one half an element pitch away (set C) will be at a minimum. These coil pairs are combined differentially to produce standardised Sin/Cos signals that vary with displacement (Figure 2b).

After demodulation the output voltage of the signal is indicating an absolute displacement within one pitch of 12.7mm.

Figure 2a

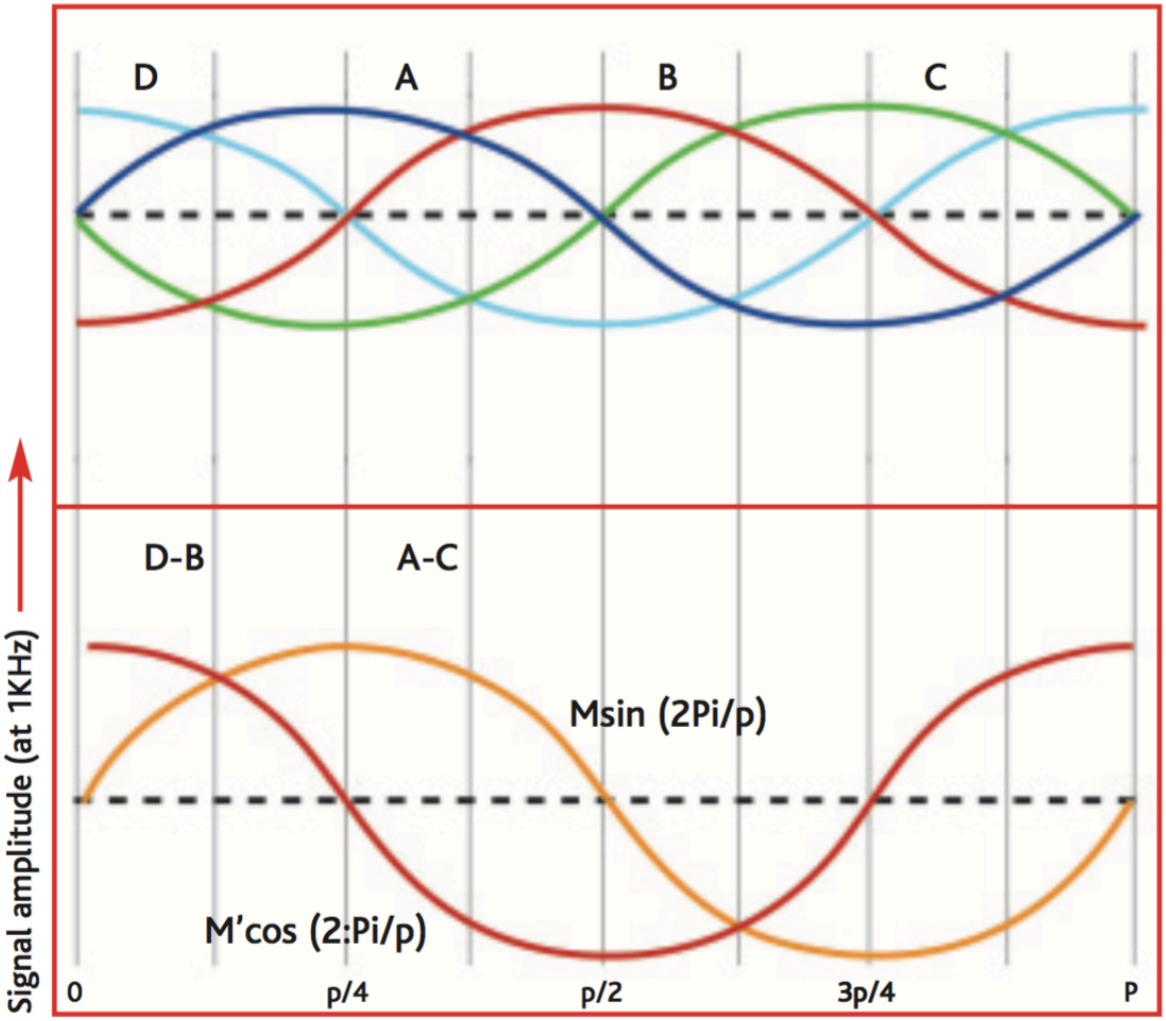
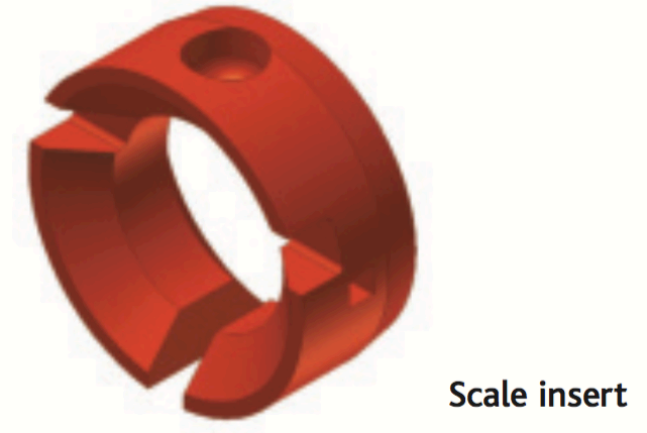


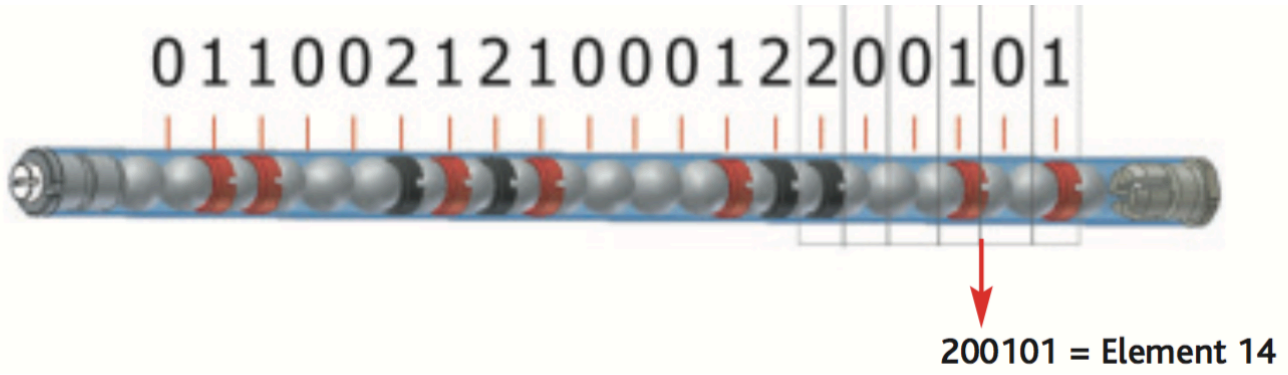
Figure 2b

Inductive & Magnetic – Absolute Measuring Principle

Uniquely coded inserts are placed between the Ni-Cr elements in the scale. The inserts are locked in position as part of the manufacturing process. They contain a small magnetic target that can be detected by a series of hall sensors contained within the reader head. The inserts represent a 3^n code unique for each 12.7mm pitch of the incremental scale thus defining the pitch number.



Scale insert

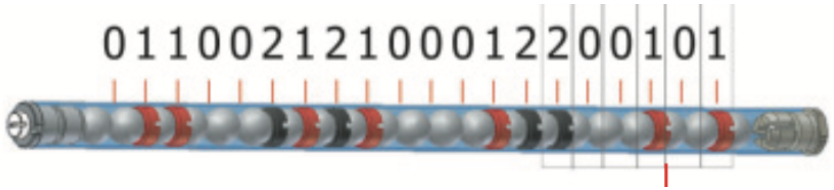


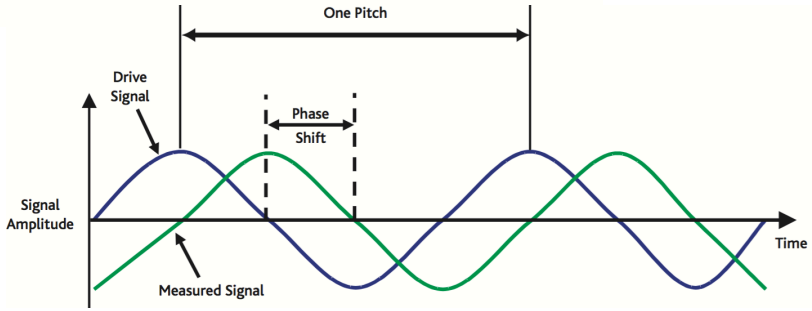
Inductive & Magnetic – Combined Signal Conditioning

The signal conditioning unit in the encoder is combining the interpolated sin/ cos signal of the incremental unit with the pitch no. resulting in a high resolution absolute value.

200101 = Element 14

Absolute Position (mm) = Element No. x 12.7 + Position on current Element





Being a Digital Sound Processor (DSP) based absolute system capable of a high level of processing, the encoders are error mapped during manufacturing against a laser interferometer. This error map is stored in FLASH memory allowing it to be applied in real-time thus resulting in a highly accurate system.

Inductive & Magnetic – Data Sheet

EUROPEAN SPALLATION SOURCE

Specification	SHG-A2, SHG-A4, SHG-AB, SHG-AF, SHG-AG, SHG-AS, SHG-AV
Type	Inductive
Accuracy Grade	±10µm (0.0004in)
Resolutions (µm/m)	1µm
Resolutions (in)	0.00005in
Reference Type	None
Reference Location	Every 10mm via RS422 interface Except SHG-AF & SHG-AV = None
Maximum Traverse Rate	SHG-A2 = 6m/s SHG-A4 = 6m/s SHG-AB = 6m/s SHG-AF = 4m/s SHG-AG = 6m/s SHG-AS = 6m/s SHG-AV = 4m/s limited by SCC200
Maximum Acc. / Dec.	10g / 980m/s (head moving)
Power Supply	5VDC ± 5% <80mA
Shock (11ms)	100g / 980m/s2 (IEC 69-2-6)
Vibration (55-2000Hz)	30g / 294m/s2 (IEC 68-2-27)
Ingress Protection (IP) Level	IP67, fully submersible (IEC 529) - Exceeds NEMA 6
Operating Temperature Range	0 to 55°C (32 to 131°F)
Storage Temperature Range	-20 to 70°C (-4 to 158°F)

Magnetic Field Susceptibility	3mT (30 Gauss)
Radiated Magnetic Field	10mT (100 Gauss)
Overall Cross-Section	53.5 x 28.5mm (2 x 1in)
Scale Material	Stainless Steel
Co-efficient of Expansion	12ppm/°C
Scale OD	15.25mm (0.6in)
Maximum Scale Travel	3500mm (138in)
Maximum Single End Mount Measuring Length	350mm (14in)
Maximum Length between Supports*	1000mm (39in)
Scale Over-Travel Requirements	254mm (10in)
Standard Cable	9 core screened cable with PUR (polyurethane) cover with no armour
Cable Length	0.5m (20in)
Minimum Bend Radius with PUR	25mm (1in)
Maximum Cable Length	18m (708in)
Connector	D Type 15 Pin (IP54, NEMA 6)
EMC Compliance	BS EN 50081-2 & BS EN 50082-2