Product overview / Technical basics

Kübler

You will find comprehensive information about the basic technical knowledge relating to our products on our homepage, at the address
www.kuebler.com/basics

Encoders	Introduction	

Encoders can be used in applications, where length, positions, speed or an angular position are measured. They transform mechanical movements into electrical signals and can be divided into incremental and absolute measuring systems.

Incremental encoders generate pulses, where the number of pulses can be a measure of speed, length or position.

In absolute encoders, every position corresponds to an unique code pattern. No reference runs after starting-up are necessary as with incremental systems. Safety is increased and the time taken for reference runs is saved.

In principle we can supply all encoders, whether with a solid shaft or in a hollow shaft version.

Using a hollow shaft encoder saves up 30 % of costs and up to 50 % of the required space compared to a shaft encoder. This is achieved by avoiding additional couplings, brackets and other assembly aids.

To mount a hollow shaft encoder it just needs to be pushed onto the shaft, clamped, and in the simplest case prevented from rotating by using a cylinder pin. Moreover, in principle, hollow shaft encoders require less installation depth.
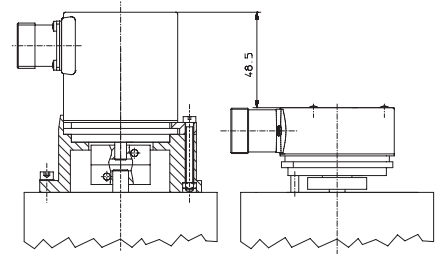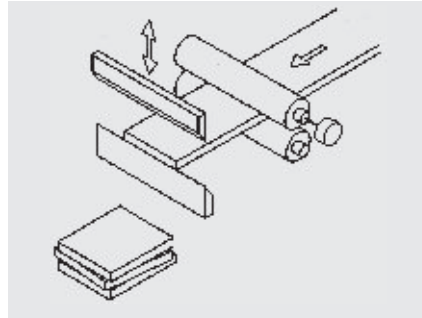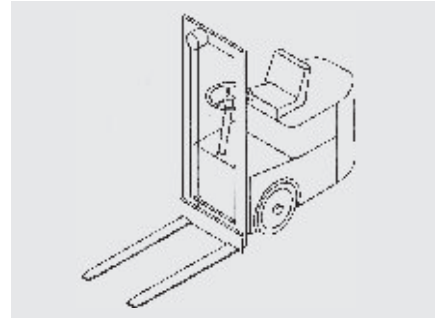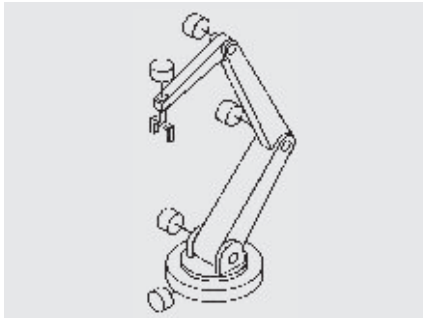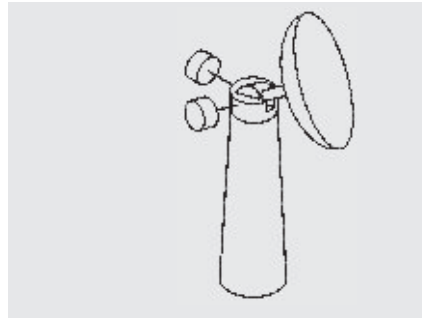

Application examples

Angular measurement
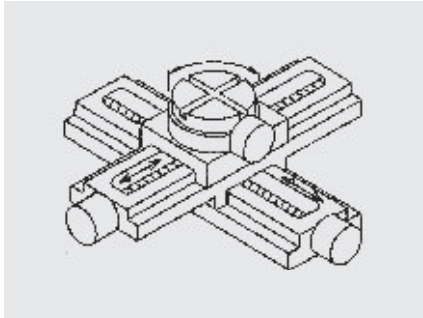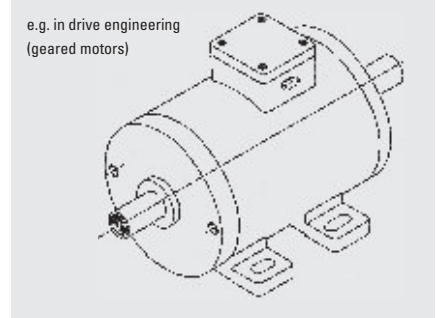

Positioning

Detecting of fork's position

Detecting of position

Angular measurement

Velocity measurement

e.g. in drive engineering
(geared motors)

Basics

| Encoders	Functional principle	

Assembly and function

Optical scanning (incremental)

A disc fitted with a grating, having a code pattern of slits and bars, is mounted so that it can rotate between an LED and a receiver.

The light emitted by the LED is modulated by the mask and grating and then strikes the receiver, which produces a signal proportional to the luminosity.

When the disc rotates this signal has a shape that approximates to a sine wave.

Receiver
Mask
LED
Grating
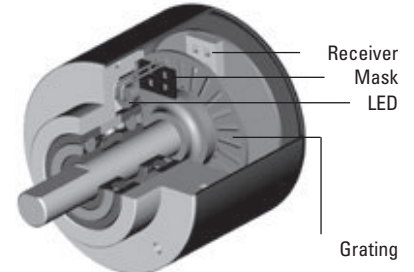
Optical scanning (absolut)

The light that is emitted by an LED is modulated by a code pattern, which is applied to a rotating disc; this is scanned by a special Kübler Opto ASIC. A unique bit pattern is assigned to each position and this is generally available as Gray Code.

The advantage, compared with incremental encoders, lies in the fact that any movement of the shaft whilst voltage is not applied is immediately detected when power is re-applied, ensuring the correct position is always available.

Magnetic scanning

The magnetic field created by a rotating permanent magnet is scanned by a sensor ASIC. Each angular position has underlying field vectors, which are converted by the ASIC into incremental signals.

Depending on the version, this signal will be emitted as an incremental signal or in absolute form as a SSI, 0 ... 10 V, 4 ... 20 mA signal or as a fieldbus signal.

Magnet

magn. Sensor ASIC
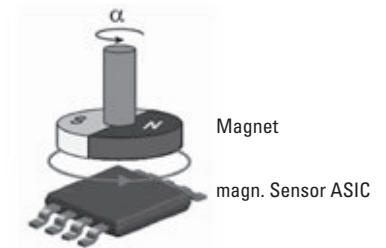
Limes rotary / Limes ring

The Limes rotary magnetic measuring systems are suitable for machines and plants where installation space is tight.

The bearingless and non-contact measuring principle allows error-free operation in environmental conditions that require a high IP protection level (up to IP69k) or high rotary speeds.

Basics

Encoders	Incremental encoders	

Processing of the signals (optical, incremental encoders)

The sine wave signals are then processed in a specially designed electronic circuitry. Most controllers require square-wave signals on their input.

The signals are therefore pre-processed accordingly in the encoder and made available using various output circuits depending on the application.

Number of channels

Encoders with one output channel:

Encoders with one output channel are used where no direction sensing is needed, e.g. speed control or length measuring.

Encoders with two output channels:

Applications, where the direction of rotation should be sensed, e.g. positioning, require encoders with two channels A and B being shifted 90° out of phase. By detecting the phase shift, the direction can be determined.

- Shaft turning clockwise, top-view of shaft / for hollow shaft encoders, viewing the flange
- Inverted signals available
  t_r = rise time
  t_f = fall time
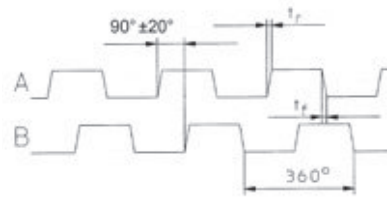
Encoders with three output channels:

In addition to the two channels A and B a zero pulse is available, which occurs once per revolution and is usually used for the reference run (zero point calibration) of a machine.

- Shaft turning clockwise, top-view of shaft / for hollow shaft encoders, viewing the flange
- Inverted signals available
- 0 pulse is linked to AND with channel A and B
  t_r = rise time
  t_f = fall time

Basics

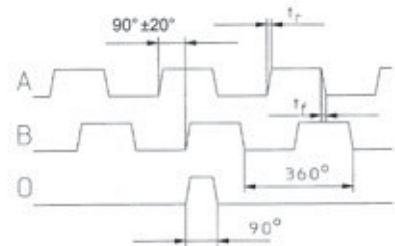| Encoders	Incremental encoders	
Multiplication of pulses	The resolution of a two channel encoder can be multiplied by two or four using special edge detection circuitry.	An encoder with physically 5000 pulses per revolution can generate 20000 pulses per revolution using this technique.
Inverted signals	When used in environments, with a lot of electrical noise and/or if very long cable distances are required, we recommend using encoders with inverted (complementary) signals.	These signals are always available with output circuits of the RS422 type and sine wave outputs or optionally with push-pull outputs.
Resolution	The required angular or linear resolution of a application determines the number of pulses per revolution. Linear movements must first be converted into rotary, for example by means of a spindle. **Example:** An encoder is equipped with a measuring wheel. Every revolution corresponds to a distance of 200 mm (circumference). The accuracy should be 0.1 mm. What is the required resolution (ppr)?	given: • Circumference of the measuring wheel = 200 mm • Accuracy of the system = 0.1 mm wanted: • Resolution of the encoder [ppr] [1] $$\text{Resolution} = \frac{\text{Circumference}}{\text{Accuracy}}$$ The required resolution would be 2000 ppr [1].
Pulse frequency	The required pulse frequency can be calculated as a result of the number of pulses per revolution (ppr) and the maximum speed (rpm). The maximum pulse frequency is shown in the data sheet specifications for each encoder. Generally this is 300 KHz, but can be up to 800 KHz with high-resolution encoders.	**Example:** given: • Speed = 3000 min^{-1} • Resolution of the encoder= 1000 ppr [1] wanted: • Required pulse frequency of the encoder $$\text{Pulse frequency} = \frac{\text{Speed x Resolution}}{60}$$ The required pulse frequency is thus 50 KHz. This can now be compared with the maximum possible pulse frequency of the desired encoder.

This diagram can be used to estimate the required pulse frequency
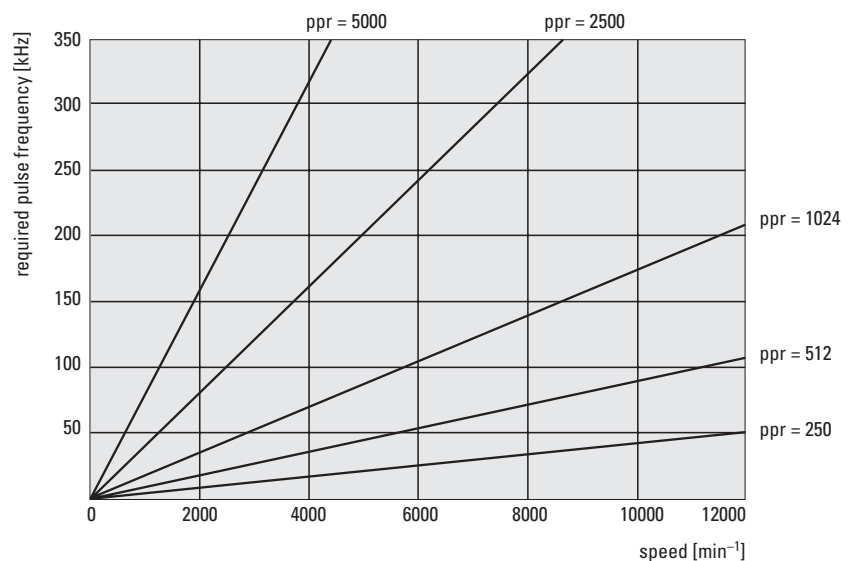
[1] ppr = Pulses per revolution

Basics

Encoders	Incremental encoders	

Sensor outputs

With long cable runs, the inherent resistance of the cables can lead to a situation where insufficient supply voltage is available to the encoder.

Using the sensor outputs of the encoder, the voltage present can be measured and if necessary increased accordingly.

Digital outputs

The sine wave signal from the optical system is first digitised to have square wave signals available.

- Shaft turning clockwise, top view of shaft
- Inverted signals are available
- 0 pulse is linked to AND with channel A and B

To transmit the signals there are two possible outputs available. RS422 (TTL compatible) or push-pull.

When choosing the suitable output for the application the following points have to be considered:

- The corresponding unit / controller the encoder will be connected to
- The required cable length
- The sensitivity against electrical noise or other interference

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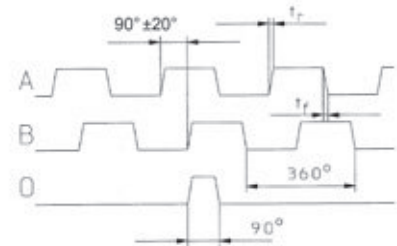
Push-pull outputs (HTL)

Push-pull outputs are suitable for count interface cards, electronic counters or PLC inputs. They are available in two versions:

Push-pull:

- Push-pull with integrated wave impedance adjustment, recommended cable impedance 40 ... 150 Ω
- Recommended for long cable lengths, high pulse frequencies and output voltages to 30 V
- With or without inverted (complementary) signals

Push-pull (7272):

- Universal line driver 5 ... 30 V with low-level (max 0.5 V)
- Recommended for cable lengths up to 30 m
- With inverted signals

Output circuit and recommended input circuit push-pull without inverted signals (HTL)
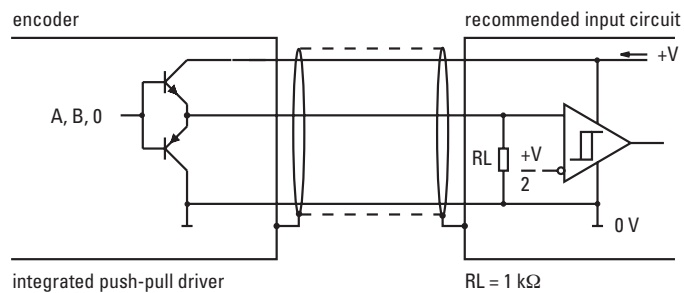
Encoders	Incremental encoders	

Output circuit and recommended input circuit push-pull with inverted signals (HTL)

encoder

A, B, 0

$\overline{A}, \overline{B}, \overline{0}$

Integrated push-pull driver

recommended input circuit

+V

RL

0 V

RL = 1 kΩ
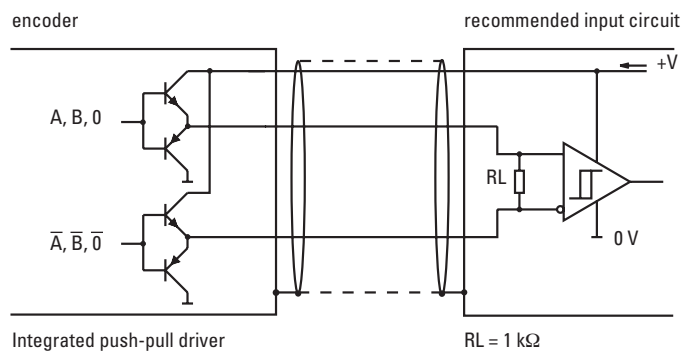
**RS422
Output circuit and recommended input circuit (TTL)**

encoder

+5V

RS422 line driver

recommended input circuit

+5V

Z_0

RS422 line receiver
e.g. AM26 C 32 / Z = 120 Ω
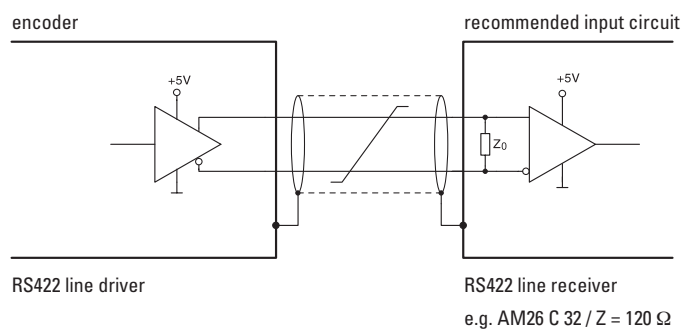
Sine wave outputs

The sine wave signals are available as voltage signals. They can be further processed in the evaluation electronics. Due to the interpolation of the two signals, which are 90° out of phase, a very high resolution can be achieved.

Further they are very suitable for digital drives with a very slow movement, e.g. for grinding machines or lifts and elevators.

- Shaft turning clockwise, top view of shaft
- 0 pulse is generated once per turn
  (only with 5804 / 5824)

360° el.

COS
0
1 Vpp

90° el.

SIN
0
1 Vpp

0
1 Vpp

135° el.
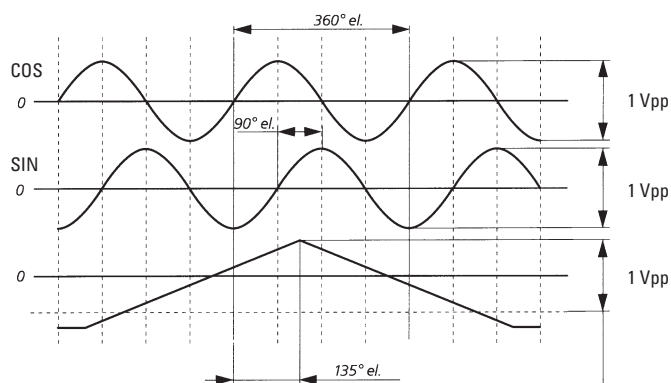
Output circuit and recommended input circuit for sine wave voltage signals

encoder

U_0

A+, B+, 0+
Ra

A-, B-, 0-
Ra

recommended input circuit

C2
R2
R1
C1
+V
−V
Ua

Z

R1
C1
R2
C2
U1

$R_a = 10\ \Omega$
$C_1 = 150\ pF$
$C_2 = 10\ pF$
$R_1 = 10\ k\Omega$
$R_2 = 33\ k\Omega$
$U_0 = 2.5\ V \pm 0.5\ V$

$Z = 120\ \Omega$
$U_1 = U_0$

operation amplifier:
e.g. MC33074

Encoders	Incremental encoders	
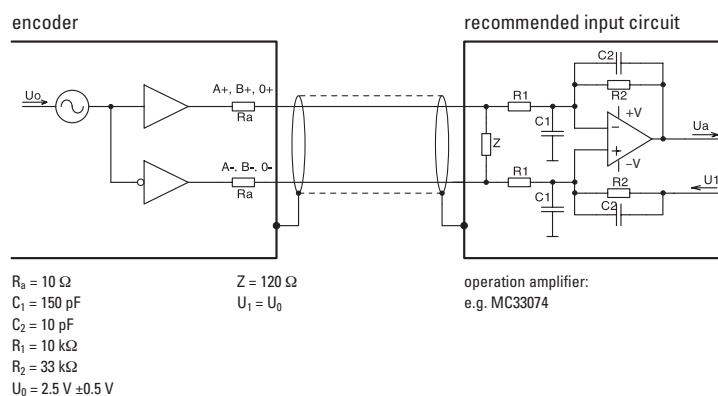
Cable lengths for incremental encoders

Depending on the output circuit and the electrical noise the following cable lengths are recommended:

Output circuit	max. cable length	Encoder connected to e.g.
Push-pull without inverted signals	100 m [1]	Kübler counter/SPS
Push-pull with inverted signals	250 m [1]	SPS/IPC [2]
Push-Pull with inverted signals (7272)	30 m	
RS422 with inverted signals	up to 1000 m (> 50 m dep. on frequency)	SPS/IPC [2]
Voltage sine with inverted signals	50 m	SPS/IPC [2]
Sine wave 1 Vpp	50 m	10 ... 30 V DC

Annotations:

- Depending on the application the recommended cable length can be shorter, especially in areas with a high level of electrical noise.
- Always use shielded cables - the shield should be connected at both the encoder and controller ends!
- The core diameter of the signal cores should be > 0.14 mm^2
- The core diameter of the voltage supply cores should be large enough depending on the cable length, that the voltage supply of the encoder is high enough and the signals do not go below the minimum levels!

[1] Depends on frequency
[2] IPC = industrial PC

Basics

Encoders	Absolute encoders	

Versions

Singleturn encoders

Depending on the number of divisions they generate unique positions per revolution. After one complete revolution the process re-commences at the start position.

They are suitable for angular measurement over a maximum of one turn of the shaft (=360°), for example in robotics, with cam controllers and in other controlled rotary motion.

Multiturn encoders

Up to 17 bit unique angular positions per revolution are provided. In addition the number of revolutions is detected. Up to 4096 (12 bit) unique revolutions can be made available on the output.

Multiturn encoders are suitable for angular measurement over more than one turn of a shaft, for example with longer traverse paths, such as high rack storage areas, cranes or machine tools.

Code types

Binary code

The Binary code can be processed very easily by computer systems. When using optical read-out, errors may occur, because the change from one bit to another on the different concentric tracks

(LSB, LSB+1...) is not exactly synchronized. Due to this, without any correction of the code, the position information could be wrong.
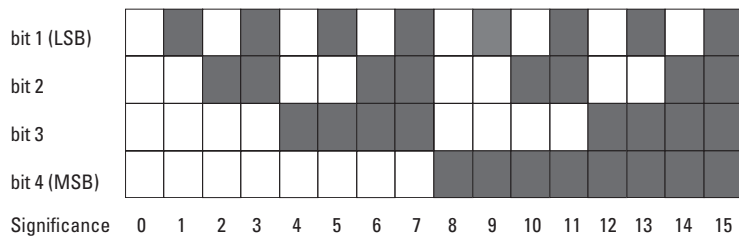
Gray code

The Gray Code is a single-step code, which guarantees that from one position to the next only 1 bit changes.

This leads to reliable scanning of the code and consequently of the positions.

Symmetrically capped Gray code (Gray-Excess):

If a particular section of the complete Gray Code is extracted, this results in the so-called Gray Excess Code

This permits even-numbered divisions, such as 360, 720, 1000, and 1440.
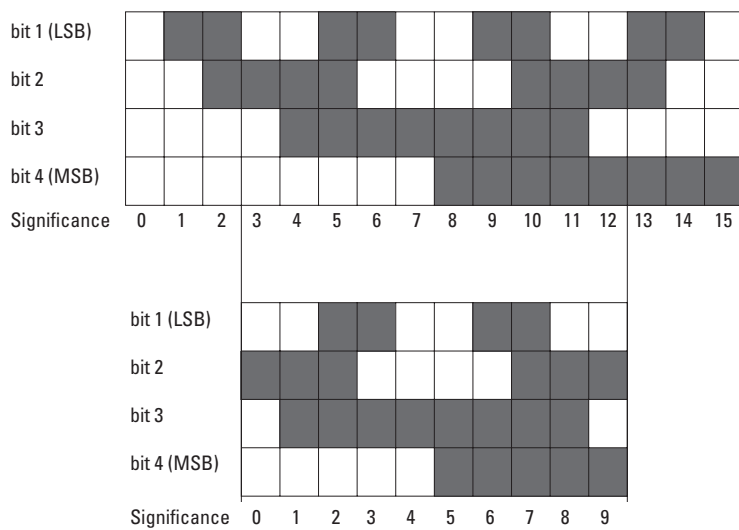
Reversion of the Gray code

The code values increase when the shaft is turning clockwise.

The Gray code is reversible, i.e. if the most significant bit (MSB) is inverted, the code values decrease when the shaft is turning clockwise.

Encoders	Absolute encoders	

The mechanical Sendix multiturn stage with gear

- Multiturn gear with purely optical scanning technology. Completely resistant to magnetic fields.

- First stage with double bearing layer.

- Special materials ensure temperature stability and long service life.

- Through hollow shaft diameter up to 14 mm
  - up to 15 mm as blind hollow shaft.

- Specially developed gear teeth allow for very high rotational speeds and eliminate wear.

The patented electronic Sendix multiturn stage with Intelligent Scan Technology™

Firstly all the single and multiturn functions of the encoder are integrated on an Opto ASIC.

With multiturn versions the optical sensor technology can achieve a resolution of up to 41 bits.

Furthermore, the new Intelligent Scan Technology ensures 100% magnetic insensitivity.

Mechanical or electronic gears?

Absolute singleturn and multiturn encoders have established themselves as the standard method for measuring linear displacement or angular position.

With absolute encoders a reference trip is no longer needed after system start-up or a power-down. Multiturn encoders in particular are now being employed, where previously incremental encoders had predominated, for example with geared motors or in lifts.

Today all manner of multiturn encoders are available in a variety of designs.

As a rule the manufacturers offer either mechanical gears for 'counting turns', or swear by electronic counters with electronic data storage. They are critical of any other technology.

The fact is however: it is not a case of which is better or worse; each technology has its advantages and drawbacks.

Only the actual application can decide.

Intelligent Sensing Technology

A new operating principle, based on a non-contact multiturn stage, eliminates the system drawbacks linked with the encoders with mechanical gear or with the usual electronic gear technology.

Advantages
- High operational safety
- Compensation of high EMC disturbances thanks to logical filters and a novel operating principle of the system
- Free of wear

| Encoders	Absolute encoders	

Outputs

To transfer the position data to a controller, different interfaces are available.
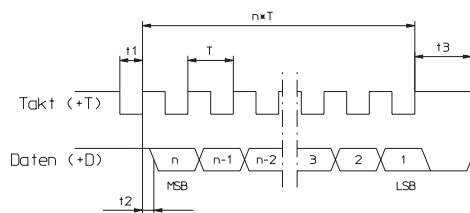
Synchronous serial interface (SSI)

Compared to the parallel interface, the SSI interface needs less components and the EMC characteristics are much better.

In addition less lines are needed for transmission and the possible cable length is much longer.

Output circuit and recommended input circuit

9081

Z = 120 Ohm
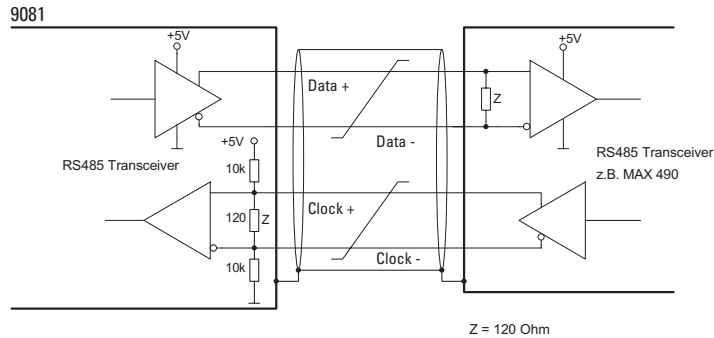
Data transmission SSI

t_1 = T / 2

t_2 < 1 / (4 x fmax)

t_3 = Monoflop time (see below)

n = Resolution in bit

$1/ f_{max} \leq T \leq 1 / f_{min}$

f_{min} = min. clock rate (see data sheet)

f_{max} = max. clock rate (see data sheet)

At rest, the clock and data lines are at a high level. With the first falling clock-pulse edge, the current encoder data are stored in the buffer ready to be sent. With the next rising clock-pulse edge, the data are transmitted bit by bit, starting with the MSB. The transfer of a complete data word requires n+1 rising clock-pulse edges (n=resolution in bit), e.g. 14 clock signals for a complete readout of a 13 bit encoder.

After the last positive-going clock-pulse edge the data line will remain for the duration of the monoflop time t3 at a low level, until the encoder is ready for a new data word. The clock line must stay high for at least as long, and then can begin a new read-out sequence again with the next falling edge.

Please note!

Only for type 5850, 5870 and 9081:

The updating of the data occurs synchronously with the read-out cycle. So, the data are as up-to-date as the interval time between two read-outs.

A periodic read-out of the encoder in the application is therefore recommended, using appropriately short cycle times, so that current position values are constantly maintained. It is not possible to read out the same data word several times.

Monoflop time of the encoder: t3 = max. 40µs

Only for the new Sendix absolute encoders:

The updating of the data occurs immediately with the first falling edge of the clock signal. The data are thus always up-to-date. If a repeated read-out of the same data word is desired, then a new clock sequence must be started within the time interval t3. If the clock sequence is terminated before the necessary number of clock pulses, needed for a complete readout of the data word, has been transmitted, then after a further time interval t3 the data line will go high again and signal that the last read-out sequence has been aborted. It will also indicate that it is ready for a new data word to be sent. Monoflop time of the encoder: t3 = see data sheet.

Basics

Encoders	Absolute encoders	

BiSS interface

Point-to-point communication

- Bidirectional isochronous connection between drive, converter and sensor.
- Purely digital link for maximum performance, reliability and safety in transmission.
- Reduction of hardware, installation and maintenance work.

Advantages at a glance

- Flexible.
- Fast and safe.
- Cost-effective and non proprietary / Open source.
- Fully digital and bidirectional.
- Suitable for motor feedback systems.
- Plug and Play.
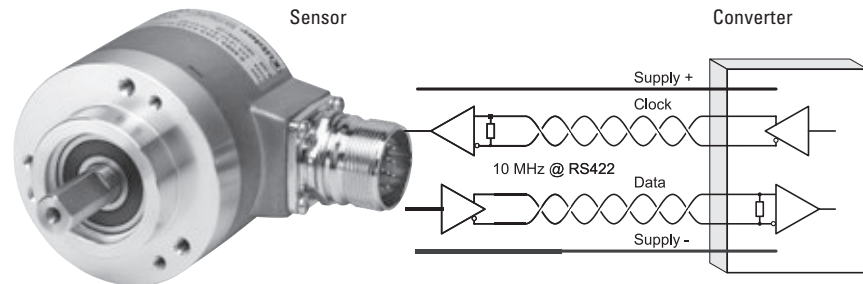
Extended possibilities with BiSS

- Motor data and maintenance information can be stored and read out easily in the encoder.
- Condition monitoring through register communication.

Easy supplementing of the BiSS master function

- The existing standard control hardware can mostly be used also for BiSS.
- Extension by firmware update is in most cases possible.
- BiSS as a real alternative to existing, RS422 or RS485-based interfaces.
- Fast and simple BiSS master implementation with free-of-charge BiSS IPs on processors and FPGAs.

Details about our BiSS interface can be found on our website at: www.kuebler.com/service/biss_en.pdf.

Basics

| Encoders	Absolute encoders

Parallel output

This type of transfer is very fast. All bits of a position are transferred simultaneously each via a separate line.

Output circuit and recommended input circuit

encoder   recommended input circuit

Integrated push-pull driver
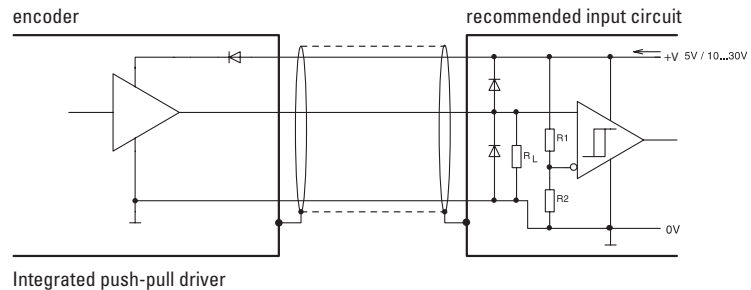
Analogue output 4 ... 20 mA

Output circuit and recommended input circuit

encoder   recommended input circuit
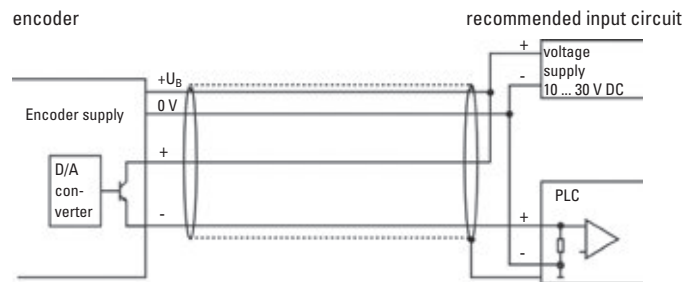
Cable lengths

The following maximum cable lengths are recommended, depending on the output circuitry and any noise sources present

Interface and output circuit	max. cable length	Connected to
Parallel CMOS / TTL	2 m	SPS / IPC [1]
Parallel push-pull (HTL)	100 m	SPS / IPC [1]
SSI	up to 1000 m [2]	SPS / IPC [1]
RS422 / RS485	1000 m	SPS / IPC [1]
Analogue 4 ... 20 mA	200 m	

Annotations:

- Depending on the application the max. allowed cable length can be shorter, especially in areas with strong electrical noise
- Always use shielded cables; the cable shield should be connected at both the encoder and controller ends.
- The core diameter of the signal cores should be ≥ 0.14 mm^2

- The core diameter of the voltage supply cores should be large enough depending on the cable length, that the voltage supply of the encoder is high enough and the signals do not go below the minimum levels!

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1) IPC = Industrial PC
2) Depends on clock frequency:
   at 100 kHz L_{max} approx. 250 m; at f = 250 kHz L_{max} approx. 50 m

Encoders	Installing encoders	

Encoders shafts and in turn their bearings are subjected to loads for a variety of reasons:

- Installation tolerances when mounting the encoders (radial and angular displacement)
- Thermal changes, e.g. linear expansion of the drive shaft
- Effects of wear, e.g. radial runout of the drive shaft or vibrations

These load factors have a direct effect on the life expectancy of the shaft bearings and on the quality of the signal.

Facilities must therefore be provided during installation to compensate for these forces. For encoders having a solid shaft this is generally done by using shaft couplings between the drive shaft and the encoder shaft. The solution with hollow shaft encoders is to use stator couplings, fixing brackets or torque stops between the encoder flange and the mounting surface.

Not making use of a coupling but instead rigidly mounting the shaft and the encoder housing generally leads to unacceptably high loads on the bearings; the ensuing wear will cause the encoder to fail prematurely.

In order to avoid permanent damage of the encoder, certain bearing loads should not be exceeded. If hollow shaft encoders are correctly installed and the torque stops or stator couplings that are available from Kübler are used, then no problems should occur. For solid shaft encoders the maximum permitted axial and radial loads are shown in the appropriate technical data.

Mounting options for hollow shaft encoders

Hollow shaft encoder with torque stop and pin

(easiest and fastest mounting)
Standard hollow shaft encoders are equipped with the torque stop (cylindrical pin not supplied).
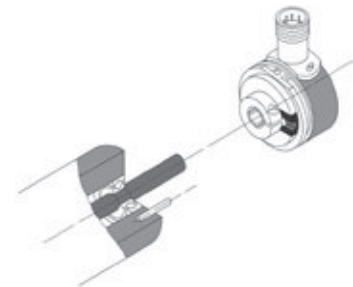
Extended torque stop and long pin
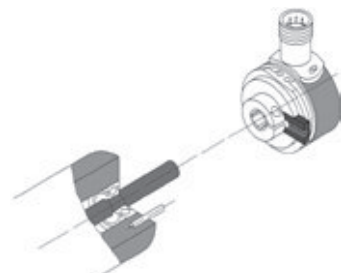
Stator coupling
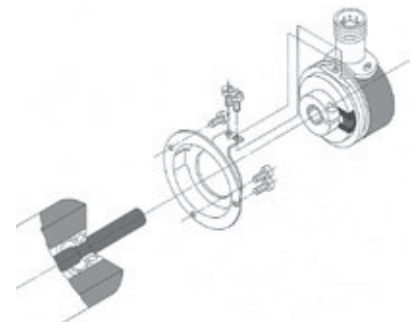
Encoders	Installing encoders	

Mounting examples for shaft encoders with synchronous flange

Fastening eccentrics + coupling

(to reduce shaft overload)
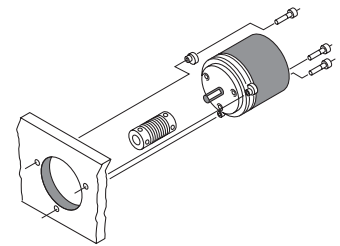
Assembly bell, fastening eccentrics + coupling

(to prevent shaft overload and to isolate the encoder thermally and electrically)
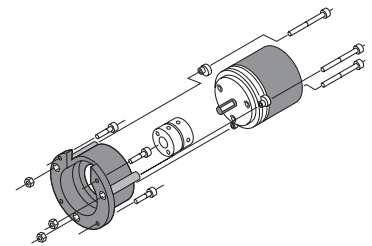
Mounting examples for shaft encoders with clamping bracket

Angular bracket + coupling

(to reduce shaft overload)

Clamping device + coupling

(to reduce shaft overload)

Encoders	Installing encoders	

Loading of encoder shaft bearings using coupling forces

With all spring couplings (shaft coupling, stator coupling, fixing bracket), alignment and axial errors are converted to a force that corresponds to the spring constant of the coupling.

This force has to be absorbed by the encoder shaft bearings. When installing an encoder, this should be done with as little force as possible, i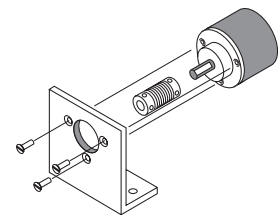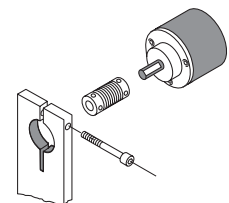.e. without any unnecessary initial tension on the coupling. If this is adhered to, then with all Kübler couplings adequate tolerance compensation is guaranteed for the whole service life of the encoder bearings.

This force does not occur with torque stops for hollow shaft encoders, where the encoder is prevented from turning also by means of a pin or rod.

Although the encoder is prevented from rotating due to a rigid interlock, the encoder is still free to move in any other direction. This is of course dependent on it being mounted in such a way that it has freedom to move radially and especially axially (thermal linear expansion of the drive shaft!).

Possible errors in accuracy due to couplings

1. Deviations in accuracy caused by torsion of a spring coupling (in particular shaft couplings)

This deviation in accuracy is defined by the torque to be transmitted (bearing friction and mass moment of inertia) and by the torsional spring constant of the torque stop.

The following applies:

$$\text{Max. error (degree)} = \frac{\text{max. torque [Ncm]}}{\text{torsional spring constant [Ncm/Grad]}}$$

The following table serves to estimate the ratio between such an error and the smallest increment of an encoder:

Relationship between the resolution of an encoder in bit and the smallest increment in angular degrees:

Resolution	binary	10 bit	11 bit	12 bit	13 bit	14 bit	17 bit
	ppr	1024	2048	4096	8192	16384	131072
Increment	degrees	0.352	0.176	0.088	0.044	0.022	0.0028
	degrees:min:sec	0:21:06	0:10:33	0:05:16	0:02:38	0:01:19	0:00:10
	sec	1266	633	316	158	79	10

2. Deviations in accuracy caused by radial play in the drive shaft with asymmetrical mounting of the couplings

Here one has to differentiate between couplings that are mounted in an axially symmetrical manner round the shaft (all shaft couplings, many stator couplings) and asymmetrically mounted couplings (many stator couplings, all mounting brackets and pin-based torque stops).

With asymmetrical couplings deviations in accuracy can arise due to radial movements of the drive shaft (radial runout/play); this is determined by the system. These deviations are dependent on the amount of the radial play and the distance of the torque stop locating point from the drive shaft.

The relationship is shown in the following diagram:

Maximum permissible radial runout to achieve an accuracy >1/2 LSB when using an asymmetrical 1 point torque stop

Distance between torque stop locating point and mid-point of drive axle [mm]

Basics
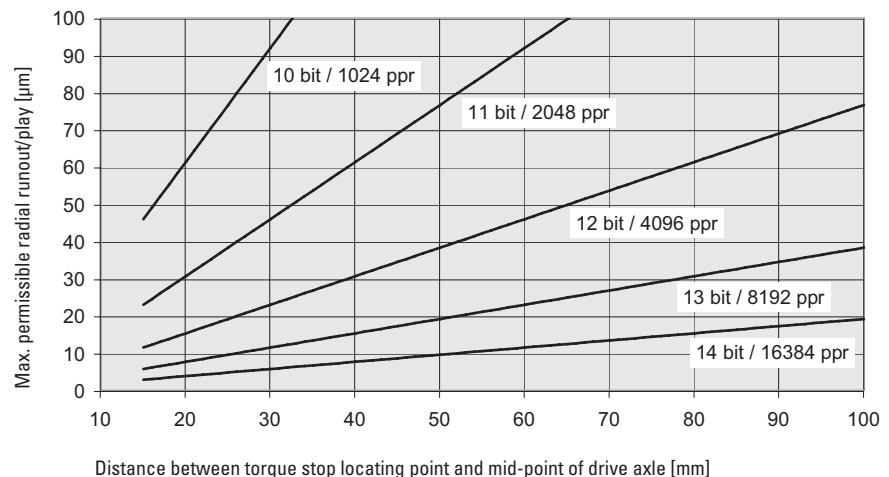
Encoders	Installing encoders	

Particular shaft loading due to toothed-wheels, gear-pulleys and similar elements

Measuring wheels, toothed wheels or gear pulleys, which are mounted directly on the encoder shaft, exert radial forces on the latter, dependent on prestressing and angular acceleration.

Kübler encoders are designed so that they can absorb these forces to a great extent. The maximum permissible load capacity of the shaft is shown in the technical data for the encoder.

If these load values may be exceeded in a particular application, then the encoder shaft must be isolated from the radial load by interposing an appropriate shaft with its own bearings that can absorb the forces.

Kübler offers suitable bearing blocks and bearing boxes for this purpose (please refer to the ‚Accessories' section in the catalogue).

Isolation insert

Thermal and electrical isolation of the encoders.

Isolation inserts prevent currents from passing through the encoder bearings. These currents can occur when using inverter controlled threephase or AC vector motors and considerably shorten the service life of the encoder bearings. In addition the encoder is thermally isolated as the plastic does not transfer the heat to the encoder.

Basics

Encoders	Functional Safety

Incremental and absolute encoders for Functional Safety

Further information about Functional Safety can be found in our catalogue "Functional Safety" or at:

www.kuebler.com/safety

Safe incremental encoder function

In order to achieve safe incremental information with the encoder, the controller must monitor the validity of the analogue, 90° phase-shifted sine/ cosine signals with the help of the function:
$\sin^2 + \cos^2 = 1$

Safe mechanical connection

A 100% reliable mechanical connection is required for a safe function in the applications. Suitably sturdy fixing elements can help eliminate the risk of faults.

Compliance with Safety standards

According to EN ISO 13849-1, EN ISO 13849-2 and EN 61800-5-2 up to SIL3/PLe/Cat.4 the following safety functions can be implemented with the encoder:

Safe absolute encoder function

In order to obtain safe information with the encoder regarding the absolute position, the controller counts the incremental pulses and compares the result with the absolute positions also provided by the encoder.

Acronym	Designation	Function
SSX	Safe Stop 1 or 2	Monitoring of the braking ramp and switch-off of the motor after standstill (SSI) or monitoring of the braking ramp and SOS after standstill (SS2). Corresponds to Stop Category 1 or 2 acc. DIN EN 60204-1.
SOS	Safe Operating Stop	Monitoring of the standstill of the active motor.
SLA	Safely Limited Acceleration	Monitoring of the exceeding of an acceleration limit value.
SLS	Safely Limited Speed	Monitoring of a speed limit value.
SLT	Safely Limited Torque	Monitoring of a torque / force limit value.
SLP	Safely Limited Position	The exceeding of a position limit value is monitored.
SEL	Safe Emergency Limit	Safe monitoring of the minimum and maximum position or of the allowed position range. Optional monitoring of the speed / position limit curve for minimizing the worst-case overtravel.
SLI	Safely Limited Increment	The respect of a specific step value during the movements is monitored.
SDI	Safe Direction	Monitoring of the unintended direction of movement of the motor.
SBC	Safe Brake Control	Safe control and monitoring of an external brake.
SCA	Safe Cam	A safe output signal is generated when the motor position is in a specified range.
SSM	Safe Speed Monitor	A safe output signal is generated when the motor speed is lower than a specified value.
SAR	Safe Acceleration Range	Monitoring of the respect of the acceleration of the motor within specified limit values.
ECS	Encoder Status	Error status of the speed / position sensor.
PDM	Position Deviation Muting	Muting of the deviation monitoring in 2-sensor operation.

Basics

| Linear measuring systems | Technology |

Magnetic measuring system (incremental)

up to 90 m measuring length, up to 0.005 mm resolution

Kübler plus

The idea:

A magnetic sensor is guided across a magnetic band without coming into contact with it. The changes in polarity on the magnetic band are counted and intermediate values are interpolated. Our engineers have fine-tuned the system to such a degree that resolutions up to 0.005 mm are possible.

The system is not affected by dust, shavings or humidity and is resistant to many liquids and to oil.

Assembly is easy - the magnetic band just has to be glued into place. There are no problems for calibration.
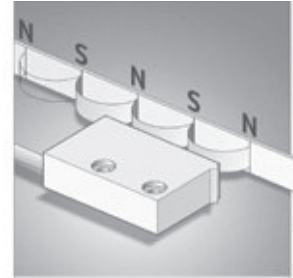
The distance between the sensor and the magnetic band can be up to 2 mm.

Repeat accuracy is very high.

Where is our Limes system used?

The measuring system offers an economical alternative to optical systems in applications where the high accuracy of the glass rules is not absolutely necessary but where up till now no other suitable alternative has been available.

Because of its rugged construction the measuring system can now be used even in tough industrial environments.

The system is not affected by vibration nor is it damaged if subjected to high shock loads.

Our flexible magnetic band offers a further interesting area of application, due to the fact that it can be fitted round very large shafts.

The maximum length of the magnetic band is 90 m!
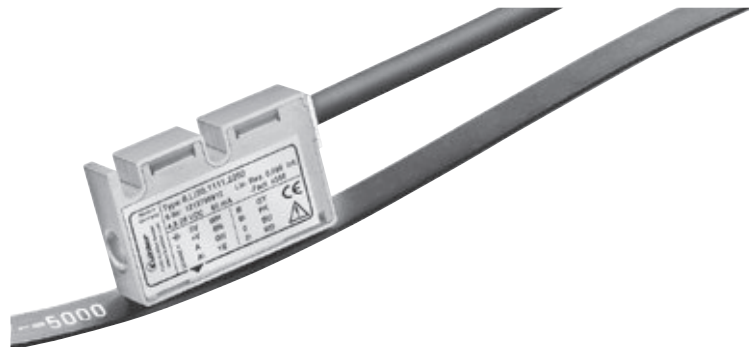
Linear measuring systems

Technology

Magnetic measuring system Limes (absolute)

up to 8 m measuring lenght, up to 0.001 mm resolution
up to 20 m measuring lenght, up to 0.01 mm resolution

The LA series are absolute length measuring systems. Sensor and translator and interpolation unit are together in one housing. The magnetic tape of the BA series is paste up to a plain area. The sensor can be mounted with a max. of 0.2 / 1.5 mm distance to the magnetic tape with reduced measuring accuracy.

Different interfaces are available (SSI, CANopen (DS406)).

Typical applications are handling systems, conveyor and storage technology, hydraulic presses, stamping machines, casting machines, linear slides, linear drives and pick and place systems.

Overview of features:

- No reference necessary.
- Direct contact free measurement.
- Distance between sensor and magnetic tape can be between 0.1... 0.2 / 1.5 mm
  –> Distance not OK = LED glow red.
- Up to 8 / 20 m measuring length.
- High resolution 1 / 10 µm.
- Repeat accuracy +/- 1 µm.
- Inured against dirt.

Functional principle

A hall sensor and a magneto-resistive impedance measuring bridge are guided over a two-track magnetic tape with a fine-interpolation trace and an absolute trace.

Together with the sensor line the absolute track provides an absolute value and the fine-interpolation trace provides together with the interpolation electronic the measuring systems high resolution.

Figure 1

Shows two magnetic traces, with north pole and south pole magnetization.

The fine interpolation trace encloses alternately north and south pole traces with a distance of 1 / 5 mm, these are scanned with resistance bridges and provide a resolution of 0.001 / 0.01 mm. The absolute value provides the sensor line with 16 single Hall sensors, these sensors are scanning the code sections of the north and south poles. The absolute value on the magnetic tape recurs every 8 / 20 m.

Fig. 1: Coding

Interpolation trace
Not magnetised area
Absolute trace

Basics

| Linear measuring systems	Technology

Draw wire systems

Measuring length up to 40 m,
Resolution up to 0.1 mm

Kübler plus

The idea:

At the core of a draw wire encoder is a drum mounted on bearings, onto which a wire is wound. The winding takes place via a spring-loaded device. The number of revolutions is measured by means of an encoder. If the circumference of the drum is known, then the length can be calculated from it.

- Specially for demanding applications
- With analogue sensors (0 ... 10 V, 4 ... 20 mA, potentiometer) or encoders (incremental, absolute, fieldbus)
- Measuring lengths from 250 mm up to 40000 mm
- High travelling speed
- High acceleration
- Dynamic spring traction by means of a constant force spring, long service life
- Simple wire fixing using clip
- Quick mounting
- Diamond-polished ceramic guide
- Titanium anodised aluminium housing
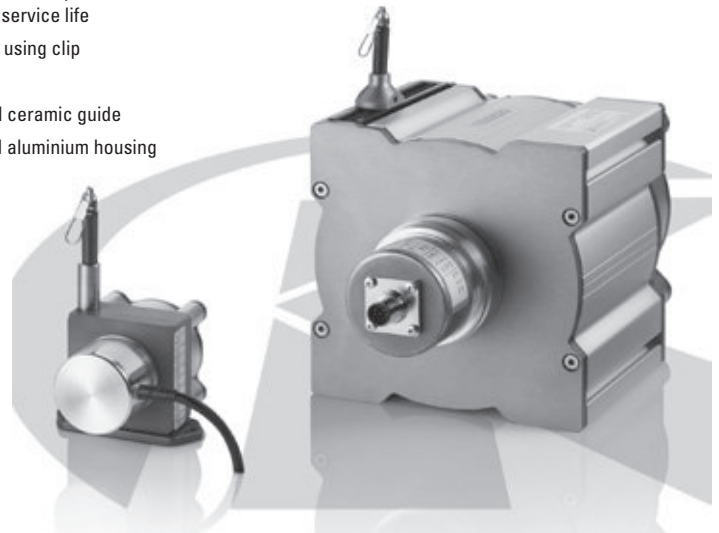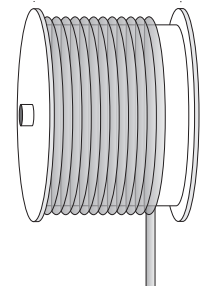
Length measuring kits

We have taken our expertise from the fields of sensor and counting technology and applied this to length measuring kits.

We will supply you the measuring wheel, the encoder and the counter – all from one source. Plug in and go – saves you time and effort – no need to assemble the component parts.

We supply the complete kits.

Inclinometers	Technology

Inclinometers

The 1 and 2-dimensional inclinometers are used for measuring inclinations in the ranges of ±10°, ±45°, ±60° and 0-360°.

To ensure high accuracy, the zero point and the limit values of the measuring range are factory-calibrated at a temperature of 25°C.

These inclinometers are based on the MEMS technology (Micro Electro-Mechanical Systems). They can be used for a wide range of different applications such as:

- Machines and automats
- Vehicles and planes
- Harvesting, agricultural and construction machinery
- Transport equipment

Basics
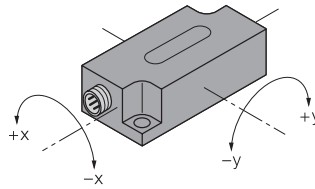
Connection technology	Introduction / Cables and connectors

The idea behind our connection technology system

Kübler plus

Connection technology from Kübler = system safety!

All the products in the connection technology section have been tested and approved with the relevant compatible Kübler sensors.

They ensure the full functionality and high signal quality of our sensors.

Your benefit:

- Elimination of connection errors
  – no laborious fault finding

- Optimal shielding
  – avoids EMC problems

- Shorter installation times
  – saves time, cuts costs

- No time-consuming search for the right connector or cable
  – saves time, eliminates errors

Introduction

All products of chapter connection technology have been tested and released in relation with the corresponding compatible Kübler sensors.

They ensure the full functionality and high signal quality of our sensors - this guarantee is supported by our competent customer service.

Your advantage:

- Prevents from misconnections
  - No time-consuming search for errors

- Optimal shielding
  - Prevents from EMC problems

- Shorter mounting times
  - Time- and thus cost-savings

- No time-consuming search for the suitable connector or cable
  - Time-savings and error prevention

Material information - cables

PVC

- Suitable for average mechanical stresses in the area of packaging machines and assembly and production lines.

- Good resistance against acids and alkalis and thus predestined for use in the food and beverage industry.

- Limited friction resistance and partial resistance to oils and chemicals.

PUR

- Flexible, PVC, silicone and halogen-free control cable with PUR cable jacket and polypropylene wire insulation.

- The cable is oil-resistant and non-flammable according to VDE 0472, and it is resistant to chemicals, hydrolysis and microbes.

- Temperature resistance from -30°C to + 90°C.

- Use is possible in trailing cable carriers with a bending radius equal at least to 10 x D.

- Thanks to its resistance to welding sparks, this cable is very well adapted for flexible use in the area of robotics, machine tools and metal cutting production.

Material information - connectors

Two material groups are used for the connectors described in the catalogue:

Metals for contacts and housings

- Contacts:
  metal, CuZn, gilded

- Connecting nut /compression screw:
  metal, CuZn, nickel-plated

Plastics for insulator and housing

- Contact carrier:
  plastic, TPU, black

- Body:
  plastic, TPU, black

- Seal:
  plastic, fluorine rubber (FKM/FPM) FPM/FKM or nitrile-butadiene rubber (NBR)

| Connection technology	Introduction / Cables and connectors	

Coding of the M12 x 1 connectors

The connectors are coded to guarantee protection against polarity reversal. This coding is achieved by means of a peg or a notch in the contact carrier.

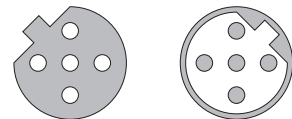Kübler connectors make a distinction between A, B or D coding.

A-coding

Female connector with coupling nut: Coding notch
Male connector with external thread: Coding peg
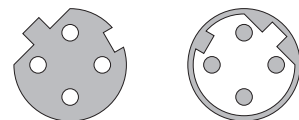Use: CANopen and 8-pin connector
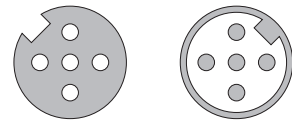
B-coding

Female connector with coupling nut: Coding peg
Male connector with external thread: Coding notch
Use: Profibus

D-coding

Female connector with coupling nut: Coding peg and Coding notch

Male connector with external thread: Coding peg and Coding notch

Use: Profinet and EtherCAT

Shielding

With round connectors, care must be taken to connect carefully the shielding braid of the cable to the shield connection of the connector.

An all-round contact (360°) is optimal.
Good (in practice often sufficient) shielding values are also reached by connecting the shielding braid firmly to the electrically conductive housing. Connectors purely out of plastic, without metal sleeve, providing no contact for the shielding braid, are not sufficient.

Furthermore, a proper contact with the mating connector is also important, as well as a good contact of the mating connector with the chassis of the equipment.

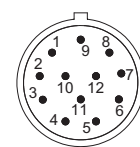"Allround" shielding
with Kübler cordsets

Counting direction cw/ccw

The counting direction of the connectors is indicated by cw for a clockwise arrangement and ccw for a counter-clockwise arrangement. The connector is always viewed from the mating side.

Top view of mating side

Counting direction cw
(e.g. female connector)

Counting direction ccw
(e.g. male connector)

Basics

Optical fibre signal transmission	General information

Description

The system is made up of an optical fibre transmitter and an optical fibre receiver.

The optical fibre transmitter converts the electrical signals of an encoder into optical fibre signals. A simple glass fibre allows reliable transmission up to distances of 2000 m.

The receiver module converts the optical signals back into electrical signals.

The modules are available in various level and power supply voltage variants.

Main advantages of an optical fibre transmission:

- Insensitivity to electromagnetic interferences and to leakage effects between lines routed parallel
- Significantly higher transmission speeds
- The optical fibre cable can be routed through explosive atmospheres
- Cost and weight savings thanks to reduced cabling work, especially for important cable lengths

Mounting of optical fibre modules

The optical fibre modules can be mounted directly on a TS35 DIN rail (top-hat rail) according to EN 50022.

The installation width for every module is only 19 mm.

Laying and connection of glass fibre cables

Laying the cable is generally easy.

Care must nevertheless be taken to make sure that the bending radius does not become smaller than 30 mm for static laying and 60 mm for dynamic laying.

When connecting the cable, make sure that the bayonet catch is locked and remove the dust protection caps only just before connecting the cable.

Glass fibre cables

The modules can be connected together using 50/125 µm or 62.5/125 µm multimode glass fibre cables with ST/PC type connectors with bayonet catch. Single-mode Simplex patch cables are not suitable.

Kübler offers finished confectioned patch cables adapted to the optical fibre modules as accessories.

They ensure the full functionality and high signal quality of our sensors.

Basics

Kübler

Safety-Lock™

All Kübler encoders are equipped with the Safety-Lock™ bearing structure.

Safety-Lock™

Interlocked bearings, large bearing span and extra strong outer bearings ensure stability when subjected to vibration and tolerance of installation errors. Machine downtime and repairs are eliminated.

Safety-Lockplus™

The proven Safety-Lock™ construction with additional mechanically protected shaft seal.

Kübler plus

HD-Safety-Lock™
= Safety-Lock™ + additional engineering

Floating bearing on the cover-side eliminates internal stress [1]

- Mechanically decoupled sensor unit ensures constant signal quality with large temperature fluctuations and other adverse environmental influences [1]
- Dual seals on the shaft-side – friction seal against humidity, labyrinth seal against dust and water jet ingress
- Very large, highly-robust flange bearings
- Even greater bearing clearance
- Extremely robust flange mounting due to screw-on housing
- Bearing design incorporates integrated isolation (isolating inserts not required), tested up to 2.5 kV for high running accuracy; metal to metal connection for slip free mounting. [2]

[1] for Sendix H100   [2] for Sendix H120

Benefits:

The resistance against adverse environmental conditions is greatly increased – especially against high bearing loads and high temperatures.

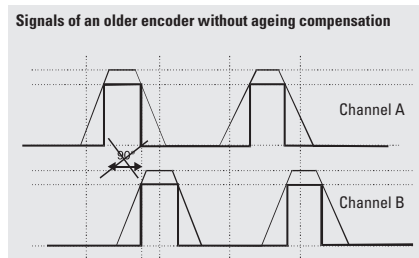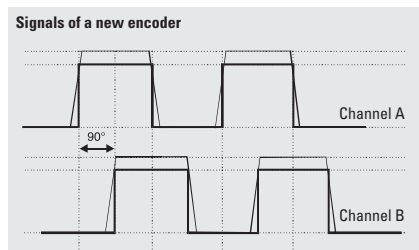|	Safety-Lock™	HD-Safety-Lock™
Stability with vibration	+	++
Robustness against installation errors	++	++
Radial load	80 N	400 N
Axial load	40 N	300 N
Elimination of internal stresses	0	++
Constant signal quality with extended temperatures	+	++
Mechanical protection of the seal	0	++

Encoders	Technologies

Ageing compensation (optical encoders)

Every LED loses some of its luminosity over time. Without ageing compensation the excellent quality of the output signals would suffer. The phase shift of 90° necessary to detect the direction of rotation would be lost. This effect however is prevented by means of special electronic circuitry.

Benefit:

The ageing compensation circuit ensures the same signal, even after many years of operating time.

The downtime of machines will be reduced dramatically and the reliability is increased.

Signals of a new encoder

Channel A

90°

Channel B

Signals of an older encoder without ageing compensation

Channel A

90°

Channel B

Temperature compensation

This circuit ensures that the signal will remain the same over the whole working temperature range.

Benefit:

The positioning accuracy of a machine will not be affected by temperature changes.

Current consumption

The typical values for current consumption given in the catalogue apply for ambient temperature (23°C).

Because of the temperature compensation, the current consumption of the encoder rises with the temperature.

This increase in current is taken into consideration when giving the figure for maximum current consumption. The output currents are dependent on the user's input circuit and are therefore not included in the figures given; these should therefore be calculated and added in.

Short-circuit protection

The outputs of all the encoders are short-circuit protected, provided that the supply voltage is correctly wired. If an output is connected by mistake to 0 V or +U$_B$ or with another output, the device will not be damaged. As soon as the error is corrected, the encoder is ready for use again.

Benefit:

Wiring circuit errors during installation that often occur in the hectic of day-to-day industrial environments do not lead to the encoder being permanently damaged.

Environmental conditions

Kübler plus

The environmental conditions in which the encoder operates can have a significant influence on its service life, for example

- The ambient temperature
- The expected shaft load
- Soiling and humidity
- Noise interference

Thanks especially to the high-quality technology employed in our encoders, they are particularly suitable for use in harsh environments.

Numerous references from our customers, including Bosch, Siemens, Bombardier and from suppliers to the automotive industry, are proof of this.

Bearing life

All Kübler encoders are designed to ensure that their bearings give a long service life. This is subject of course to correct installation and to the load limits for the shaft (shaft encoders) being complied with or, in the case of hollow shaft encoders, being mounted with the appropriate stator couplings or torque stops.

The following diagrams show the expected service life of the shaft encoder bearings depending on the bearing load. The calculations are based on a mixed load, where the axial force components are always half of the radial shaft load.

The use of the torque stops and stator couplings that are offered ensure that the shaft load with the hollow shaft encoders as supplied from the factory is kept very small.

Basics

Encoders	Glossary	
Bit (Binary Digit)	Smallest discrete piece of information. A bit can be allocated to the value 0 or 1.	
ccw (counter clockwise)	Turning the encoder shaft in counterclockwise direction (in view of the shaft side of the encoder).	
cw (clockwise)	Turning the encoder shaft in clockwise direction (in view of the shaft side of the encoder).	
Zero signal	The zero signal is emitted once per revolution, it can be used e.g. as a reference signal during the first revolution after power.	
Temperature	*Working temperature:* Is defined as the environmental temperature, in which the encoder will produce the signals defined in the data sheets.	*Operating temperature:* Is defined as the environmental temperature, in which the encoder can be operated without incurring damage.
Soiling and humidity	The IP classification according to EN 60529 describes how the encoder is protected against particles and water. It is described as an abbreviation "IP" followed by two numbers.	These two tables summarise the most used IP ratings.

Protection against particles (first digit)

The higher the number the smaller the particles.

0	Not protected
1	protected against particles 50 mm and larger
2	protected against particles 12.5 mm and larger
3	protected against particles 2.5 mm and larger
4	protected against particles 1.0 mm and larger
5	protected against dust
6	dust proof

Our encoders have a protection up to IP69k.

Protection against water (second digit)

The higher the number, the higher the water pressure can be.

0	Not protected
1	Protected against vertically falling drops of water
2	Protected against vertically falling drops of water when enclosure is tilted up to 15°
3	Protected against spraying water
4	Protected against splashing water
5	Protected against water jets
6	Protected against powerful water jets
7	Protected against the effects of temporary immersion in water
8	Protected against the effects of continuous immersion in water

9K	acc. to DIN 40050 / Part 9: protected against high-pressure water/ steam jet cleaning

Encoders	Glossary	

Designation of colours to DIN IEC 757

Abbreviation	Colour
BK	black
BN	brown
RD	red
OG	orange
YE	yellow
GN	green
BU	blue
VT	violet
GY	grey
WH	white
PK	pink
GD	gold
TQ	turquoise
SR	silver