GENERAL INFORMATION

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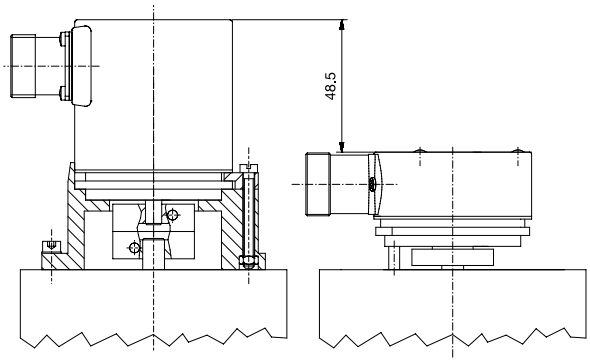
Rotary Measurement Technology

Introduction:

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

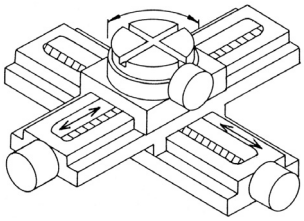
Incremental encoders generate pulses, where the number of pulses can be a measure of speed, length or position. In absolute encoders, every position corresponds to a unique code pattern, so that the actual position is recognized.

Turck can supply all encoders, whether its a solid shaft or hollow shaft version. Using a hollow shaft encoder saves up to 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.

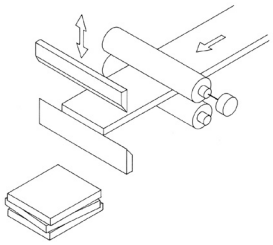


Application Examples:

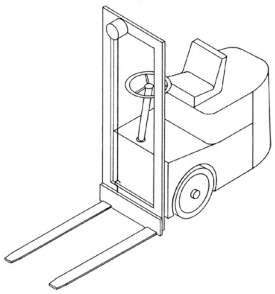
Positioning



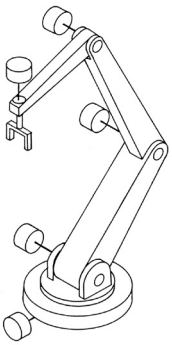
Length Measurement



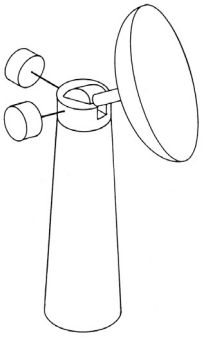
Detecting a Fork's Position



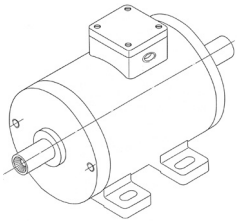
Detecting Position



Angular Measurement



Velocity Measurement
e.g., in drive engineering (geared motors)



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Rotary Measurement Technology

Approvals:

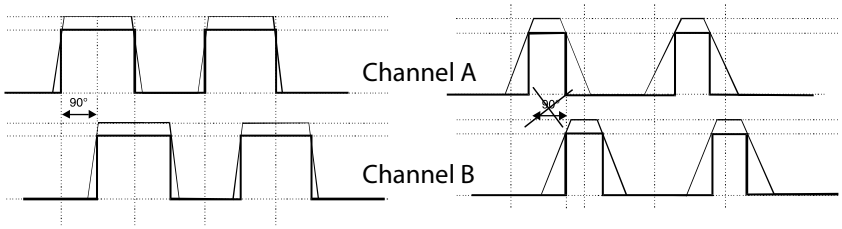
Most Turck products carry UL (Underwriters Laboratories Inc.) approvals. Turck products comply with RoHS standards.

Aging Compensation:

LEDs inevitably lose power over a period of time. As a result, the output signal degrades. The phase shift between channel A and B of 90° also degrades, and the direction of rotation may no longer be detected. A special electronic circuit built into the Turck specific ASIC prevents this effect.

Signals of a new encoder or encoders with aging compensation:

Signals of an older encoder without aging compensation:



Benefit: The aging compensation circuit ensures the same signal, even after many years of operating time. Machine downtime is reduced dramatically, while reliability is increased.

Temperature Compensation:

This specialized circuit ensures that the quality of the signal will stay on the same high level over the whole working temperature range.

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

Current Consumption:

The values for current consumption in this catalog 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 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 +Ub 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 day-to-day industrial environments do not lead to the encoder being permanently damaged.

Environmental Conditions:

A significant influence on the lifetime of the encoder is set by the environment in which the encoder is operating. For example, the ambient temperature, expected shaft load, and possible grade of dust/dirt and humidity/liquids. The support design and the use of high quality components makes our encoders suitable for applications in rough conditions. Many references from customers including Bosch, Siemens, and Bombardier are proof of this high quality.

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Rotary Measurement Technology

Temperature:
Definition according to
DIN standards 32 878

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 that the encoder can withstand without getting damaged.

Dirt/Dust and Humidity/Water:

An ingress protection (IP) classification according to EN 60529 describes how the encoder is protected against particles and water. The first digit following IP defines the size of the particles. The higher the number, the smaller the particles. The second digit defines the resistance against water. The higher the number, the higher the water pressure can be. Turck encoders have a protection up to IP67.

Protection Against Particles (first digit):

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

IP69k acc. to DIN 40050 Part 9: protected against high-pressure water/steam jet cleaning

Protection Against Particles (second digit):

0	Not protected
1	Protected against vertically falling drops of water
2	Protected against falling drops of water up to 15° from vertical
3	Protected against water sprayed up to 60° from vertical
4	Protected against water sprayed from all directions, limited ingress permitted
5	Protected against low pressure jets from all directions, limited ingress permitted
6	Protected against strong jets of water (e.g., for use on ship decks), limited ingress permitted
7	Protection against the affects of immersion between 15 cm and 1 m
8	Protected against long periods of immersion under pressure

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Designation of Colors:
to DIN standard 757

Abbreviation	Color
BK	black
BN	brown
RD	red
OG	orange
YE	yellow
GN	green
BU	blue

Abbreviation	Color
VT	violet
GY	gray
WH	white
PK	pink
GD	gold
TQ	turquoise
SR	silver

Bearing-Lock:

Bearing-Lock: The proven Bearing-Lock construction with an additionally mechanical protected shaft seal.


Bearing-Lock

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Rotary Measurement Technology - Encoders

Installing Encoders:

Encoder shafts and 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)

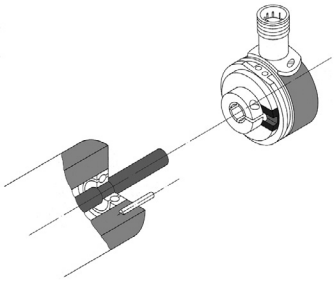
These load factors have a direct effect on the life expectancy of the shaft bearings and on the quality of the signal. For this reason, Turck provides a wide variety of accessories that should be used to compensate for these forces. For encoders with a solid shaft, this is generally done by using shaft couplings between the drive shaft and the encoder shaft. The solution with hollow shaft encoders is to use flex couplings, fixing brackets, or torque stops between the encoder bracket and the mounting surface. Not using a coupling 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 flex couplings that are available from Turck are used, then no problems will occur. For solid shaft encoders, the maximum permitted axial and radial loads are shown in the appropriate technical data.

Mounting Examples for Hollow Shaft Encoders:

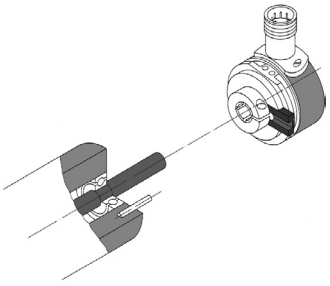
Mounting a hollow shaft encoder with torque stop and pin is easiest and fastest. Standard hollow shaft encoders are equipped with the torque stop.

Application: If axial play is less than 0.5 mm and a resolution of up to 2500 ppr (if no pulse doubling is used).



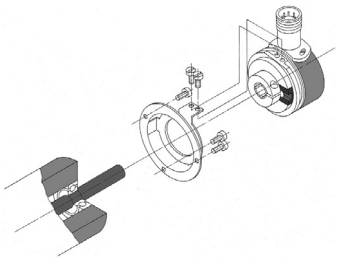
Mounting of a hollow shaft encoder with extended torque stop and long pin.

Application: Especially recommended if there is a large axial play. Due to the larger mounting radius of the pin, the resolution can be higher (up to 3600 ppr, if no pulse doubling is used).



Mounting of a hollow shaft encoder with a flex coupling.

Application: For higher resolution or if no pin can be used due to mechanical restrictions. No restrictions on resolution.



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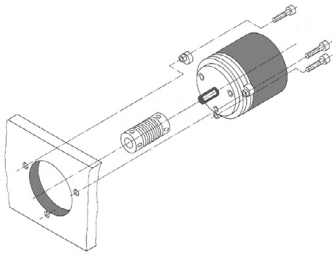
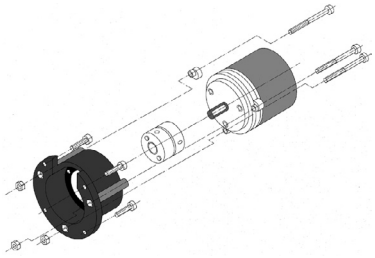
Rotary Measurement Technology - Encoders

Mounting Examples for Shaft Encoders with Servo Bracket:

Mounting with fastening eccentrics and coupling (to reduce shaft overload).

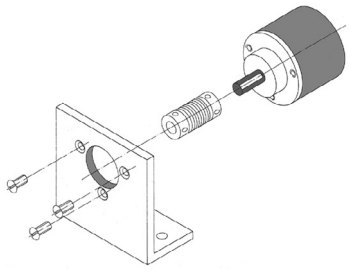


Mounting with assembly bell, fastening eccentrics and coupling (to prevent shaft overload and to insulate the encoder thermally and electrically).

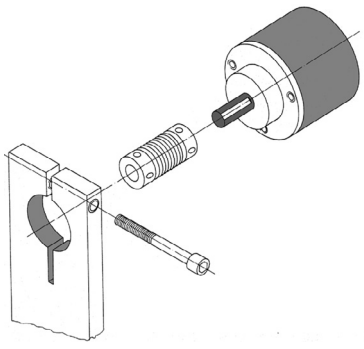


Mounting Examples for Shaft Encoders with Clamping Bracket:

Mounting with an angular bracket and coupling (to reduce shaft overload).



Mounting with a commonly used clamping device and coupling (to reduce shaft overload).



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Rotary Measurement Technology - Encoders

Loading of Encoder Shaft Bearings Using Coupling Forces:

With all spring couplings (shaft coupling, flex 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, 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 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 dependent on it being mounted in such a way that it has freedom to move radially and 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:

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

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	010

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 around the shaft (all shaft couplings, many flex couplings) and asymmetrically mounted couplings (many flex 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). These deviations are dependent on the amount of the radial play and the distance of the torque stop locating point from the drive shaft.

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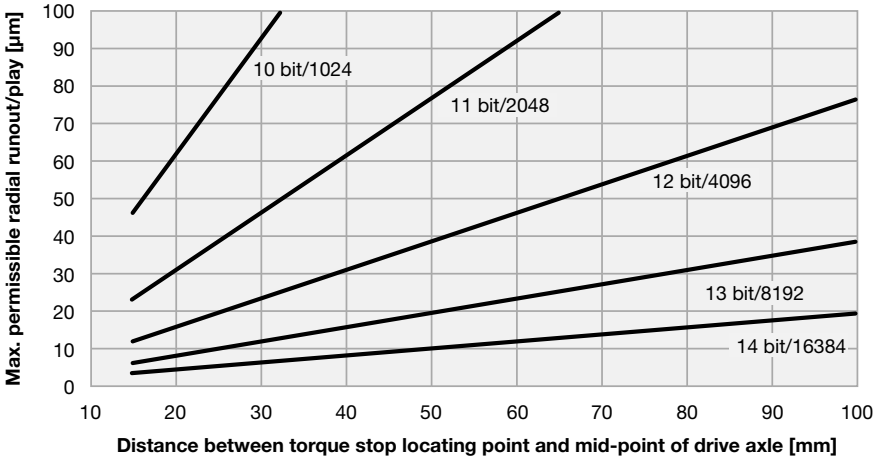
Rotary Measurement Technology - Encoders

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

The relationship is shown in the following diagram:



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 pre-stressing and angular acceleration. Turck encoders are designed to 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 are exceeded, the encoder shaft must be isolated from the radial load by selecting an appropriate shaft with its own bearings that can absorb the forces. Turck offers suitable bearing blocks and bearing boxes for this purpose (please refer to the page G1, Accessories in this catalog).

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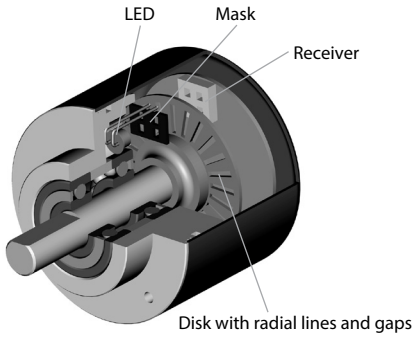
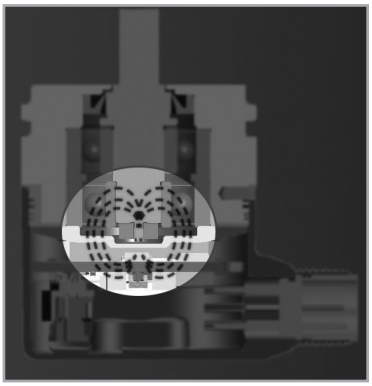
Rotary Measurement Technology - Incremental Encoders

Incremental Encoders Assembly and Function:

Optical Scanning
The optical encoder operates on the Moiré Fringe principal of optics. Light from the LED passes through the code disk, the mask, and onto the photo receiver. The photo receiver outputs a sine wave which corresponds to the flashing light pulses from the LED. The sine wave is then converted to a square wave by the receiver circuitry.



Magnetic Scanning
In addition to optical encoders, Turck offers encoders that use magnetic technology to create a robust incremental encoder. The magnetic field of the permanent magnet is rotated over the magnetic ASIC sensor that a covert the changing magnetic fields into incremental encoder signals.



Incremental

Mechanical Advantages of Turck Encoders:

Sturdy bearing construction: "Bearing-Lock design"
- Interlocked bearings, large bearing span and strong outer bearings ensure stability when subjected to vibration.
- Ideal for outdoor use thanks to its solid die-cast housing and radial shaft seal, as well as IP67 protection rating and a temperature range from -40 to 185 °F (-40 to 85 °C).

Processing of the Signals:

The sine wave signals are processed in an electronic circuitry, usually a Turck specific ASIC. This is necessary because most controllers require digital signals with a certain voltage level. Signals are pre-processed in the encoder by the output circuit depending on the application.

Selecting an Incremental Encoder:

When selecting a suitable incremental encoder, refer to the general selection criteria shown on page G1, Accessories.

Multiplication of Pulses:

The resolution of a two channel encoder can be multiplied by two or four using special edge detecting.

An encoder with physically 5,000 pulses per revolution can generate 20,000 pulses per revolution using this technique.

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Rotary Measurement Technology - Incremental Encoders

Inverted Signals:

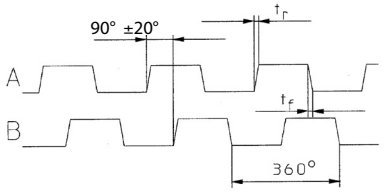
When used in environments with high electrical noise and/or very long cable distances, it is recommended to use encoders with inverted (complementary) signals. These signals are available with RS422 and sine wave outputs. Turck also offers push-pull outputs.

Number of Channels:

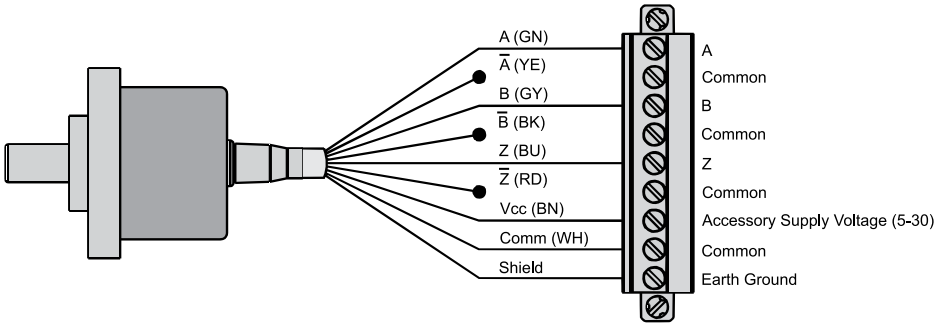
Encoders with one output channel:
Encoders with one output channel are used where no direction sensing is needed (e.g., speed control or length measuring).

Encoders with two output channel:
Applications to sense the direction of a rotation require encoders with two channels (A and B) being shifted 90° out of phase. By detecting the phase shift, the direction can be located.

- Shaft turning clockwise, top-view of shaft
- Inverted signals available
- 0-pulse is linked with channel A and B; tr = rise time, tf = fall time



Single ended connection:



Complements (A not, B not, Z not) should never be tied to common or to each other. The unused wires should be tied back and insulated to prevent them from touching Vcc, common or any other signal wires or driver damage can occur.

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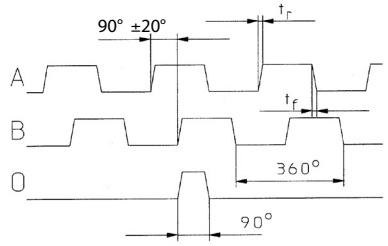
Rotary Measurement Technology - Incremental Encoders

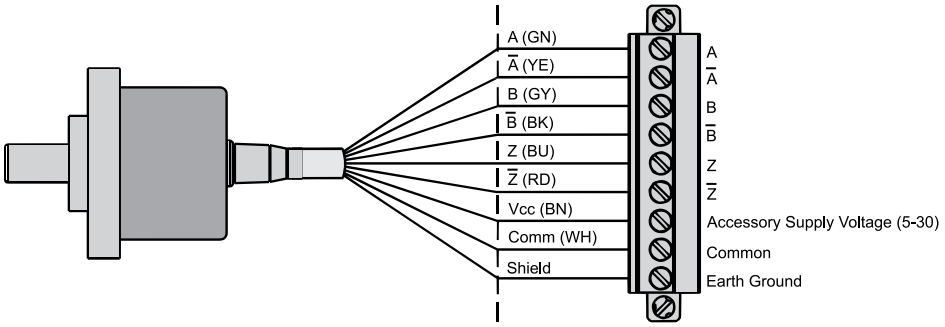
Number of Channels:

Encoders with three output channels:
In addition to two channels, a zero signal that appears once per turn is also available. This can be used as a reference signal during the first revolution after power up.

- Shaft turning clockwise, top-view of shaft
- Inverted signals available
- 0-pulse is linked to AND with channel A and B; tr = rise time, tf = fall time



Differential Wiring:



For general industrial environments where there are no large motor or drives present, the standard M12 Eurofast® cordset with non-twisted pair conductors will suffice. In heavy industrial environments, or when used on AC vector motors, M12 Eurofast cordsets with twisted pairs should be used.

Resolution - Measuring Wheel:

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:
U = 200 [mm]

Accuracy of the system:
G = 0.1 [mm]

Wanted: Resolution of the encoder:
A = ? [pulses/revolution]

$$\text{resolution} = \frac{\text{circumference}}{\text{accuracy}} = \frac{U}{G}$$

Sensor Outputs:

The sensor outputs are used if the distance from the encoder to the control unit is very long and the voltage supply at the encoder could drop due to this long distance.

The input impedance of the sensor inputs (Controller) is very high, and the voltage drop on the sensor output line is almost zero. Due to this, it is possible to detect the actual supply voltage of the encoder (e.g., 4.2 V instead of 5 V). Based on this information, the controller will increase the voltage supply to, for example, 5.8 V. This feature is generally available on selected 5000, 5800 and A02H encoder models. Please refer to the selection guides for more information on this feature.

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Rotary Measurement Technology - Incremental Encoders

Pulse Frequency:

The required pulse frequency can be calculated based on the number of pulses per revolution (ppr) and the speed (rpm). The maximum pulse frequency is listed for each encoder. The pulse frequency can be from 300 kHz to 800 kHz.

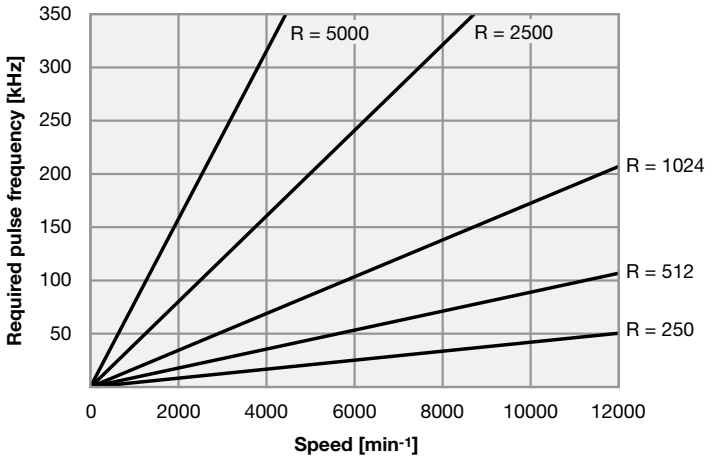
Example:
How to calculate the required pulse frequency f_{max}:

Given: speed
n = 3000 RPM
Resolution of the encoder
R = 1000 ppr

$$f_{max} = \frac{n \times R}{60}$$

The required pulse frequency is 50 kHz. Now you can compare this result with the data of the encoder you would like to choose.

This diagram can be used as a quick guide for the most common resolutions:



Outputs and Voltage Supplies (overview):

Turck offers a wide range of possible outputs and voltage supplies for any application:

Output	Inverted Signals	Voltage Supply
RS422	Yes	5 VDC
RS422	Yes	10-30 VDC or 5-30 VDC
Push pull output	No	10-30 VDC or 5-30 VDC
Push pull output	Yes	10-30 VDC or 5-30 VDC
Push pull (7272)	Yes	5-30 VDC
Sine wave voltage output	Yes	5 VDC
Sine wave voltage output	Yes	10-30 VDC

If the encoder is used in an environment with high electrical noise and long cables, it is recommended to use inverted signals.

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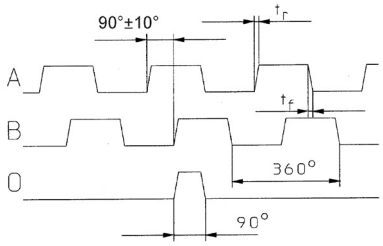
Rotary Measurement Technology - Incremental Encoders

Digital Outputs:

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

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



There are two possible outputs available to transmit the signals, RS422 (TTL compatible) or push-pull (PNP or NPN). 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 distance from the encoder to the receiver unit
- The sensitivity against electrical noise or other interference

Available Output Drivers:

The IC-DL is a fast line driver with six independent channels and ideal for 10-30 VDC control circuits. It can transmit a push pull signal with inverted signals up to 250 meters. An IC-DL encoder can be used as a differential line driver, a sinking output or a sourcing output. The push-pull output stages have been designed to cope with a high driver power of typically 100 mA at 30 VDC and are compatible with TIA/EIA RS-422 standard. The outputs are current-limited and short-circuit-proof. The output channels can be shorted and are protected by a thermal overload circuit that detects the short and reactivates the output when the short circuit is removed.

The 7272 output driver is capable of transmitting digital encoder signals to 30 meters, and allows interfacing to drives, PLCs, discrete counters, etc. Depending on its physical connection to a device, this driver can be used as a differential line driver, a sinking output, or a sourcing output. This driver can provide voltage levels equal to the encoders supply voltage (up to 30 V), and can sink or source 40 mA of current. This device is also referred to as a push-pull driver. The outputs are short circuit protected by utilization of internal current limiting and thermal shutdown during overload. Caution: only one channel can be shorted at a time.

The 7272 is a replacement for the following IC's: 4469, 88C30, 8830, and 26LS31. The 7272 will also replace open collector outputs with internal pull up resistors.

The 26C31is an output driver capable of transmitting digital encoder signals to 100 meters, and allows interfacing to drives, PLC, discrete counters, etc. Depending on its physical connection to a device, this driver can be used as a differential line driver, a sinking output or a sourcing output. This driver can provide voltage levels to 3.5 V (TTL Level), and can sink or source 20 mA of current. This device is also referred to as a push-pull driver. The outputs are short circuit protected by utilization of internal current limiting and thermal shutdown during overload. The 26C31is a replacement for the 26LS31 and will also replace open collector outputs with internal pull up resistors

The 7273 IC is an open collector driver manufactured by Texas Instruments. This device should be used for short transmission distance (up to 5 meters) and in environments with little or no electrical interference. This driver acts like a switch sinking current to ground. Maximum sinking capability is 20 mA maximum and the maximum voltage applied to the output is 30 VDC. This output is very common for interfacing to discrete counters. This output is equal to: 3904, 7406, 3302, 681, 689.

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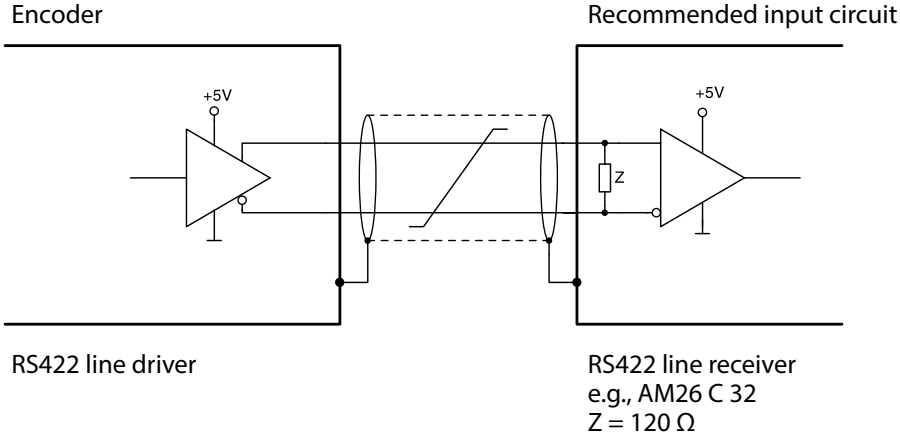
Rotary Measurement Technology - Incremental Encoders

RS422:
Output Circuit and
Recommended Input Circuit



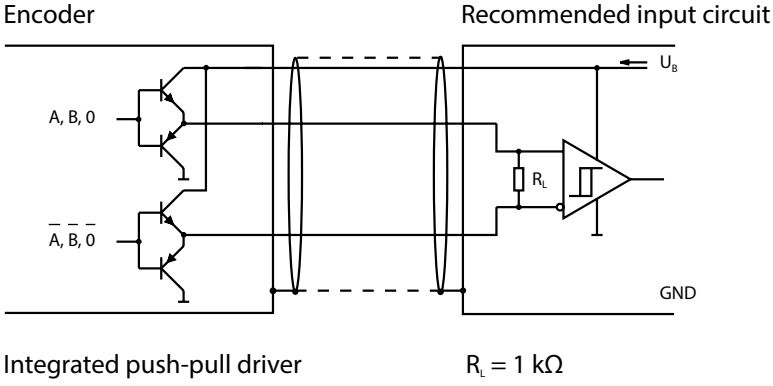
Push-Pull Outputs:

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 up 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 with Inverted Signals:



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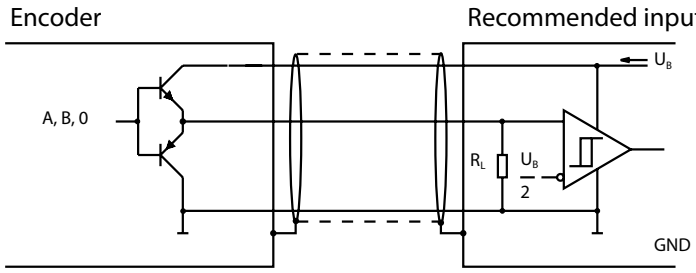
Rotary Measurement Technology - Incremental Encoders

Output Circuit and Recommended Input Circuit Push-Pull Without Inverted Signals:



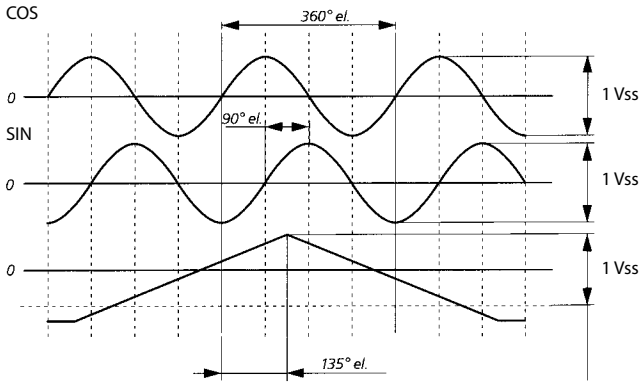
Integrated push-pull driver

R_L = 1 kΩ

Sine Wave Outputs:

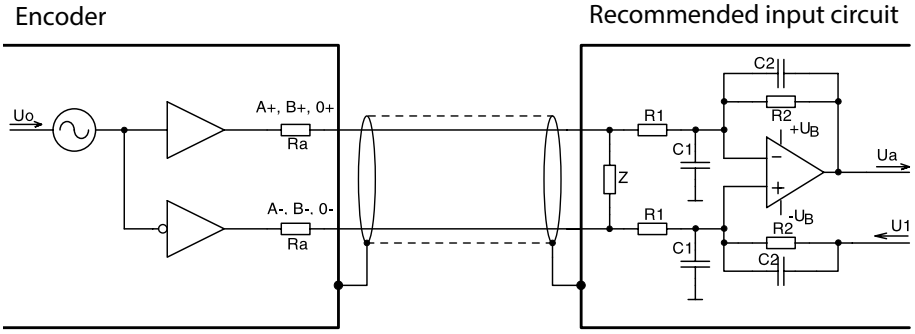
The sine wave signals are available as voltage signals. They can be further processed and multiplied by a factor of 10, 20, 50, 100, 400, 500, 1000 res. binary factors (512, 1024). Due to the interpolation of the two signals, which are 90° out of phase, a very high resolution can be achieved.

This makes these signals useful for applications where very high resolutions are required. Further they are very suitable for digital drives with a very slow and precise movement (e.g., for grinding machines or lifts and elevators).



- Shaft turning clockwise, top view of shaft
- 0-pulse is generated once per turn

Output Circuit and Recommended Input Circuit for Sine Wave Voltage Signals:



R_a = 10 Ω
C_1 = 150 pF
C_2 = 10 pF
R_1 = 10 kΩ
R_2 = 33 kΩ
U_0 = 2.5 V ±0.5 V

Z = 120 Ω
U_1 = U0

OPV: e.g., MC33074

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Rotary Measurement Technology - Incremental Encoders

How Devices Interpret Encoder Signals:

PLC counter cards, discrete counters, and drives require two distinct voltage level states to trigger the input's logic state. The voltage "threshold" levels are defined by each manufacturer and will be included in their operation manuals. The lower voltage level is defined as logic "0" and the higher voltage level is defined as logic "1". The encoders square wave output toggles from logic "0" to logic "1". The PPR (pulses per revolutions) of the encoder defines how many times this will occur per revolution of the encoder, while the encoders output driver determines the voltage threshold levels. The physical communication line between the encoder and these devices will be either single ended or differential. Therefore, it is critical to take care when selecting the encoder's output driver.

Typical Device Voltage Level Triggering Requirements:

	Logic Level "0"	Logic Level "1"
TTL Level	0 V to 0.5 V	2.8 V to 5 V
HTL Level	0 V to 4 V	10 V to 24 V

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:
Push-pull without inverted signals	328 ft (100 m*)	Counter/PLC
Push-pull with inverted signals	820 ft (250 m*)	PLC/IPC [1)]
Push-pull with inverted signals (7272)	98 ft (30 m)	
RS422 with inverted signals	Up to 3280 ft (1000 m) (> 164 ft (> 50 m)*)	PLC/IPC [1)]
Voltage sine with inverted signals	164 ft (50 m)	PLC/IPC [1)]

[1)] IPC = industrial PC
* depends on frequency

Annotations:

- Depending on the application the recommended cable length can be shorter, especially in areas with strong electrical noise.
- Always use shielded cables
- The core diameter of the signal cores should be ≥ 0.14 mm² (26 AWG)
- 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! We strictly recommend the use of the cable types written down in the accessories.

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Rotary Measurement Technology - Absolute Encoders

Design and Function:

Absolute encoders have a disk with a digital coding on concentric tracks. This code is read by a Turck Opto-Asic. A unique bit pattern is assigned to each position.

In the event of a power failure, true position verification is available as soon as power is up again, even if the shaft was rotated while the encoder was powered off. Also, no reference drives after starting-up are necessary, as with incremental systems. Thus, safety is increased and the time taken for reference drives is saved.

Absolute

Mechanical Advantages of Turck Encoders:

Sturdy bearing construction: "Bearing-Lock design"

- Interlocked bearings, large bearing span and strong outer bearings ensure stability when subjected to vibration.
- Ideal for outdoor use thanks to its solid die-cast housing and radial shaft seal, as well as IP67 protection rating and a temperature range from -40 to +185 °F (-40 to +85 °C).

Selecting an Absolute Encoder:

When selecting an absolute encoder, the following parameters should be considered in addition to the recommendations on page B1: supply voltage, type of code and interface (SSI, parallel, fieldbus, 4-20 mA)

Versions:

Singleturn encoders: Depending on the number of divisions, they generate up to 131,072 (17 Bit) unique positions per turn. This corresponds to an angular resolution of 0.0028 (= 0.168'). After one revolution the process re-starts.

Singleturn encoders can be used in applications where revolution is sufficient (e.g., measurement of angles, robotics).

Multiturn encoders: Available with up to 131,072 (17 Bit) definite angular positions per revolution in addition to 16,777,216 (24 Bit) definite revolutions. This corresponds to 2.19 trillion (41 Bit) definite positions.

Multiturn encoders can be used for positioning applications (e.g., automatic storage, retired systems, lift elevators, cranes, and machine tools).

Output Codes:

Decimal	Binary	Gray	BCD
0	0000	0000	0000 0000
1	0001	0001	0000 0001
2	0010	0011	0000 0010
3	0011	0010	0000 0011
4	0100	0110	0000 0100
5	0101	0111	0000 0101
6	0110	0101	0000 0110

Decimal	Binary	Gray	BCD
7	0111	0100	0000 0111
8	1000	1100	0000 1000
9	1001	1101	0000 1001
10	1010	1111	0001 0000
11	1011	1110	0001 0001
12	1100	1010	0001 0010

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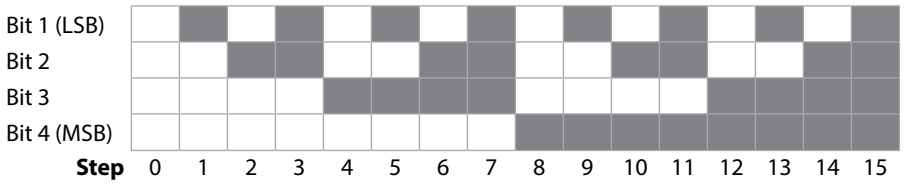
Rotary Measurement Technology - Absolute Encoders

Code Types

Binary Code:

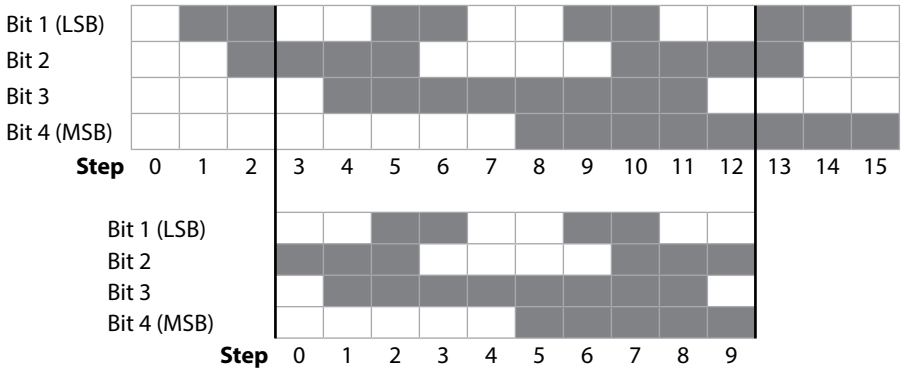
Binary Code can be processed very simply by computer systems. Gray code inside the encoder is converted via the ASIC to binary code. Binary codes have more than one bit transition for each position change. For this reason, optical systems using binary code may cause occasional transition errors. In most applications this does not present a problem due to the absolute nature of the encoder, and the position is normally corrected.



Gray Code:

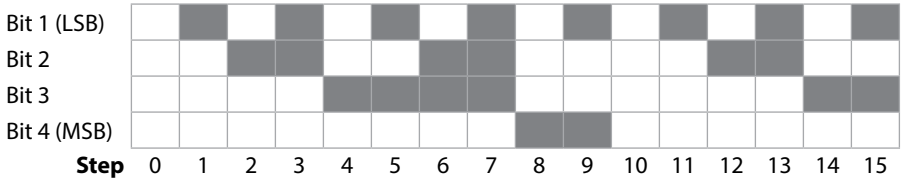
The Gray Code is a single-step code. This indicates that only 1 bit is changed from one position to the next. This leads to a high position reliability. The Gray Code is used to optically read out the position for all absolute encoders.

Gray excess: The extraction of a defined part of the Gray Code leads to the gray excess code. This code enables the generation of non-binary based divisions (e.g., 360, 720, 1000, and 1440).



Reversion of the gray code: The code values increase when the shaft is turning clockwise. If the most significant bit (MSB) is inverted, the code values decrease when the shaft is turning clockwise.

BCD Code:



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Rotary Measurement Technology - Absolute Encoders

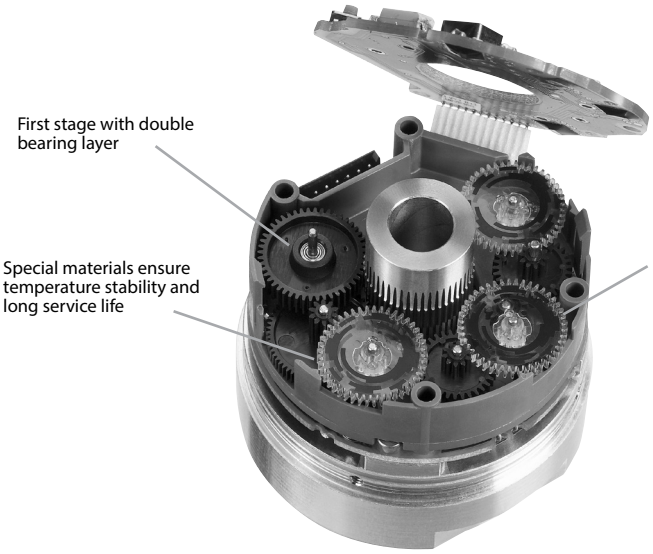
OptoASIC and Intelligent Scan Technology™:

OptoASIC and Intelligent Scan Technology (IST) is the latest development in Absolute encoder technology. The development of an OptoASIC with Intelligent Scan Technology enabled Turck to build the first optical multiturn encoder without gears or magnetic sensors.

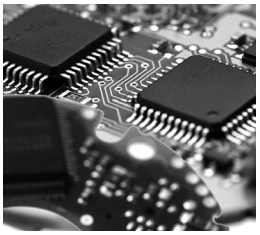
Eliminating mechanical parts like gears allowed Turck to make the encoder smaller than others currently on the market. These encoders offer a total resolution of up to 41 bits, a programmable multiturn encoder with up to 16 million revolutions, and a high-precision single turn with up to 17 bits resolution, all in a 39 mm diameter housing that is up to 45 mm long.

The Multiturn Gear Module (12 bit resolution):

Geared multiturn encoders are the types RM-28, RM-29, RM-35, and RM-36.



Patented Integrative Technology®:



Integrative Technology, developed and patented, is a package of measures that ensures compact construction, high signal quality, high shock resistance (up to 2,500 m/S^2), high reliability and a high level of immunity to EMC.

This is achieved using an Opto ASIC: a multilayer board, shock resistant and space-saving method of mounting the sensor unit. The use of a highly optimized ASIC interface ensures the integration of several hundred individual components. Components that had previously been needed to balance the system, such as balancing potentiometers, can be dispensed with.

Advantages of Integrative Technology: Singleturn shaft encoders are available with the same dimensions as their incremental correspondents. This allows an easy mechanical substitution.

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Rotary Measurement Technology - Absolute Encoders

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 are now being employed where incremental encoders had dominated, such as with geared motors or 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 electronic counters with electronic data storage. For many years, encoder companies have made both absolute multiturn encoders with gears or without gears, and then criticized each other for the perceived drawbacks to the designs. Turck offers both absolute mutliturn encoders without mechanical gears and with mechanical gears. Not having mechanical gears allows Turck to make more compact absolute multiturn encoders. These encoders require batteries, whereas geared multiturn encoders do not have batteries. Battery life is often a discussion point. Based on how the encoder is actually used, the calculated battery life could be as long as 75 years.

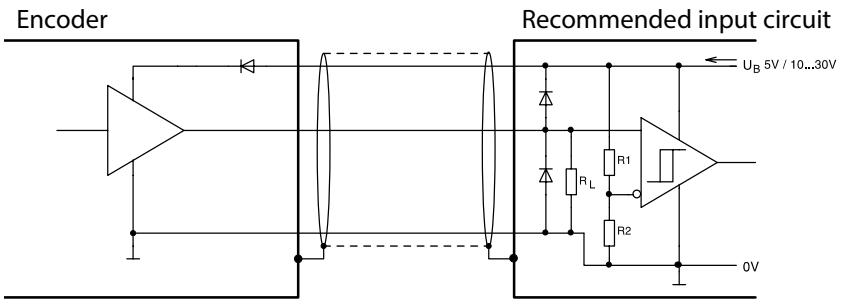
Outputs:

Different interfaces are available to transfer the position data to a controller. Turck offers a variety of outputs detailed in the following sections.

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 Parallel Interface:



Integrated push-pull driver

Synchronous Serial Interface (SSI):

SSI is an industrial standard serial interface between an absolute encoder or sensor and a controller. The SSI protocol uses a clock pulse train from a controller to initiate a gated output from the sensor. Position data is continually updated by the sensor and made available to the shift register. Data is shifted out when the sensor receives a pulse train from the controller. SSI is widely used because of it's simplicity and noise immunity.

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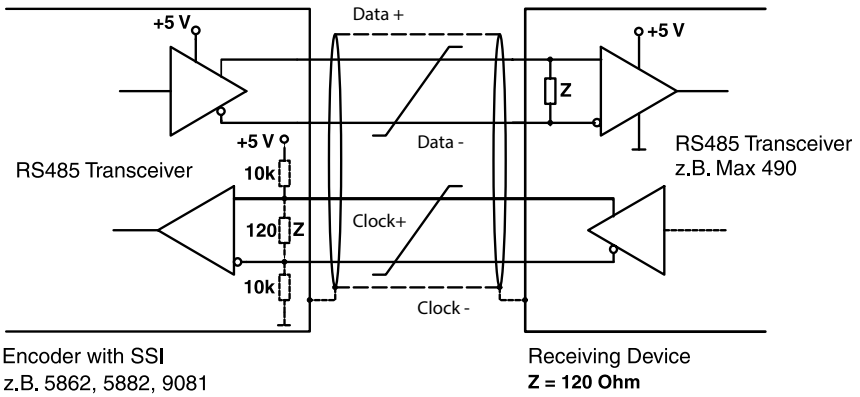
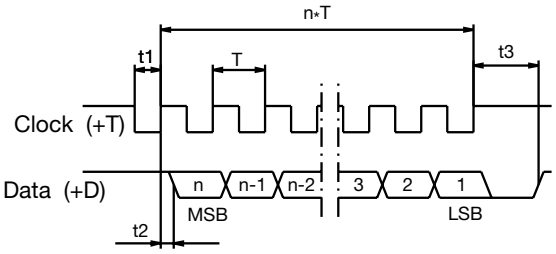
Rotary Measurement Technology - Absolute Encoders

Output Circuit and Recommended Input Circuit for Multiturn Encoders with SSI Output:



Data Transmission SSI:



t1 = T / 2
t2 < 1 / (4 x fmax)
t3 = Monoflop time (see below)
n = Resolution in Bit
$1/f_{max}$ = < T = < 1 / fmin
f_{min} = min. SSI clock rate (see data sheet)
f_{max} = max. SSI 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 is stored in the buffer ready to be sent. With the next rising clock-pulse edge, the data is 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). For example, 14 clock signals are needed for a complete readout of a 13 Bit encoder. After the next positive-going clock-pulse edge, the data line will remain at a low level until the encoder is ready for a new data word. The clock line must stay high for a time longer than the mono flop time, and then can begin a new read-out sequence again with the next falling edge.

Please Note:

Only for type series RS-22, RS-30, RM-41, RM-77, RM-78: Updating the data occurs sequentially with the read-out cycle. Therefore, the data is as up-to-date as the interval time between two read-outs. A periodic read-out of the encoder in the application is 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 Absolute encoders: Updating the data occurs immediately with the first falling edge of the clock signal. The data is 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 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.

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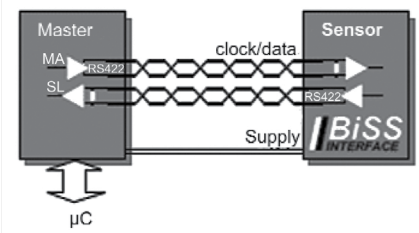
Rotary Measurement Technology - Absolute Encoders

BiSS Interface:

Open, digital sensor interface (BiSS). The bidirectional digital sensor interface (BiSS) assures the communication between the encoder and the measuring device or drive control and can, if required, simultaneously transfer the measured values of up to eight sensors.

For one to eight subscribers the interface master provides the clock signal for the simultaneous capturing of all position data as well as for the subsequent synchronous serial data transmission. Only four unidirectional RS422 data lines are required; the minimal slave electronics is located directly in the sensor ICs.

When the master sends the clock pulse on the line MA, the slave will reply on the return line SL with the captured position data. Commands or parameters are exchanged via a PWM clock sequence, although this is not necessary for the startup of the BiSS protocol.

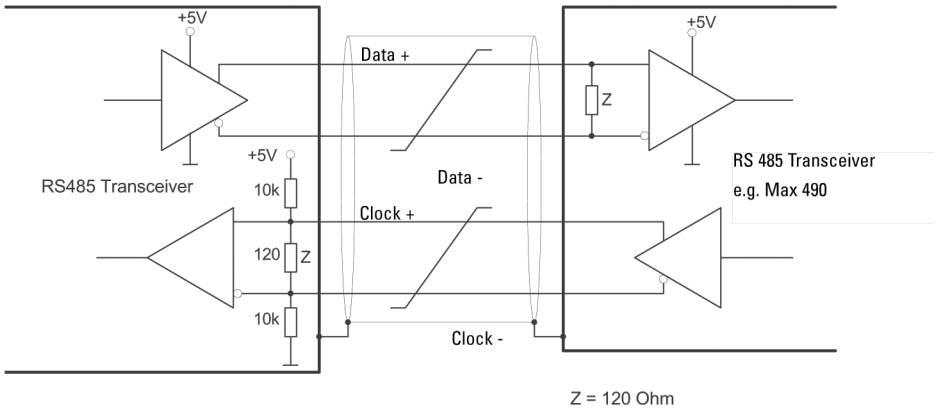


With every data cycle the master learns and compensates for the signal transit times, thus enabling high clock rates up to 10M bit/s even with cable lengths of 100 m. Varying cable conditions, for example due to drag movement, are corrected. The synchronization accuracy between several encoders on a number of axes is less than one microsecond; moreover the master keeps the signal transit times that have been experienced transparent for the controller and thus enables a further optimization.

The BiSS protocol classifies each subscriber into various data areas: sensor data, multi-cycle data and register data. These data areas are laid out differently with respect to the possibility of accessing them and to their transmission performance, which covers a wide variety of sensor applications. A bidirectional communication parameter for configuring the device, and if need be for so-called OEM parameters, is placed in the register data area. Data that change slowly, such as speed of rotation or motor temperature, occupy the multi-cycle data area, whereas data that change quickly occupy the sensor data area.

This means that there is no problem in achieving control cycle times under 10 MHz even for data words up to 64 bit. Enough space is available for redundancy, and as a rule is used for implementing a CRC (cyclic redundancy check). As they are only framed by a start and a stop bit, the sensor data is transferred at the best possible user data rate; a single multi-cycle data bit is optional. Similarly detected and triggered, the multi-cycle data bits form a second inband protocol and contribute to the redundancy of the sensor data. Permanent monitoring of the drive status and operation is possible without interfering with the controller cycle. Specific device developments by individual users are not restricted or made more expensive by a need to be compatible with other BiSS products. A BiSS subscriber is described with only a few parameters, and an XML device description file that comes with the product simplifies the startup of the controller.

Output circuit and recommended input circuit for absolute encoders with a BiSS output



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Rotary Measurement Technology - Absolute Encoders

Cable Length:

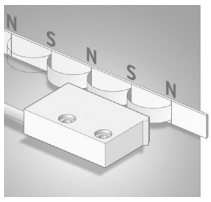
The following maximum cable lengths are recommended, depending on the output circuitry and any noise sources present.

Interface and output circuit:	Max. cable length:	Connected to:
Parallel CMOS/TTL	6.5 ft (2 m)	SPS/IPC [1]
Parallel push-pull	328 ft (100 m)	SPS/IPC [1]
SSI	up to 3,280 ft (1,000 m) [2]	SPS/IPC [1]
RS422 /RS485	3,280 ft (1,000 m)	SPS/IPC [1]
Analog 4-20 mA	656 ft (200 m)	

[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

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 core diameter of the signal cores should be ≥ 0.14 mm2
- 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! We strictly recommend the use of the cable types written down in the accessories.

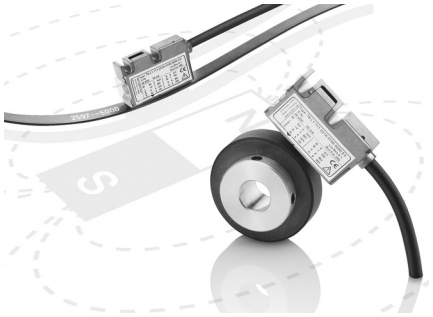
Magnetic Measuring System Up to 50 m Measuring Length Up to 0.005 mm Resolution:



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 two mm. Repeat accuracy is very high.

Where is Our Linear Measurement 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 until 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 can fit around very large shafts. The maximum length of the magnetic band is 50 m.

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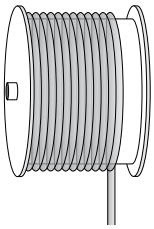
Linear Measurement Technology

Draw Wire Systems:



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.

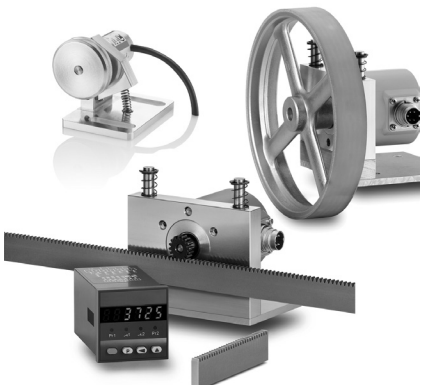
Thus, draw wire systems convert linear motion into rotary motion. This is then measured with encoders. Our spectrum ranges from miniature draw wire versions to models capable of measuring 40 m.

- Specially for demanding applications
- With analog sensors (0-10 V, 4-20 mA, potentiometer) or encoders (incremental, absolute, fieldbus)
- Measuring lengths from 250 mm up to 40,000 mm
- High travelling speed
- High acceleration
- Simple wire fixing using clip
- Quick mounting
- Diamond-polished ceramic guide
- Titanium anodized aluminum housing
- Dynamic spring traction by means of a constant force spring, long service life, approx. 2 million complete cycles.

Length Measuring Kits:

*unlimited length resolution up to 0.1 mm

Turck provides the measuring wheel, encoder and counter from one source, all in one complete kit. This kit saves you time and effort, as there is no need to assemble the component parts.



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IP Protection Class

IP		Dust Protection						
		0_ Unprotected	1_Objects ≥50 mm	2_Objects ≥12.5 mm	3_Objects ≥2.5 mm	4_Objects ≥1.0 mm	5_Dust Protected	6_Dust Tight
Water Protection	0_Unprotected	IP00	IP10	IP20	IP30	IP40	IP50	IP60
	_1 Dripping Water		IP11	IP21	IP31	IP41	IP51	IP61
	_2 Dripping Water on 15° slant		IP12	IP22	IP32	IP42	IP52	IP62
	_3 Spraying Water			IP23	IP33	IP43	IP53	IP63
	_4 Splashing Water				IP34	IP44	IP54	IP64
	_4K Splashing Water High Pressure				IP34K	IP44K	IP54K	IP64K
	_5 Jet Water						IP55	IP65
	_6 Intense Jet Water						IP56K	IP66K
	_7 Temporary immersion							IP67
	_8 Continuous immersion as specified by manufacturer							IP68
	_9K Water at high pressure/ Steam jet cleaning							IP69K

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Ingress Protection Classes- IEC 60529

First ID Number	Protection from penetration of…	Requirements
0	Unprotected	N/A
1	Solid Foreign Particles Ø50 mm	No full penetration of sphere with Ø50 mm
2	Solid Foreign Particles Ø12.5 mm	No full penetration of sphere with Ø12.5 mm
3	Solid Foreign Particles Ø2.5 mm	No penetration of rod with Ø2.5 mm
4	Solid Foreign Particles Ø1.0 mm	No penetration of wire with Ø1.0 mm
5	Dust	Dust may only penetrate in such quantity that function and safety are not impacted
6	Dust	No penetration of dust

Second ID Number	Protection from penetration of…	Requirements
0	Unprotected	N/A
1	Dripping water	Vertically falling drips may not cause any damage
2	Dripping water when the enclosure is in a slanted position of up to 15°	Vertically falling drips may not cause any damage
3	Spraying water	Spraying water, which is sprayed in a perpendicular angle of up to 60° may not cause any damage
4	Splashing water	Water splashing against the enclosure from every direction may not cause any damage
4K	Splashing water with increased pressure	Water splashing against the enclosure from every direction and with increased pressure may not cause any damage
5	Jet water	Water which is hosed against the enclosure from every direction may not cause damage
6	Intense jet water	Water which is hosed against the enclosure with high intensity may not cause any damage
6K	Intense jet water with increased pressure	Water which is hosed against the enclosure with high intensity and increased pressure may not cause any damage
7	Temporary immersion in water	Water may not enter the enclosure in such quantity as to cause damage when the enclosure is held under water for a set period of time using predetermined pressure (1 m for 30 min)
8	Continuous immersion in water	Water may not enter the enclosure in such quantity as to cause damage when the enclosure is held under water for a set period of time using predetermined pressure (Turck standard is 6' of water, and other chemicals, for a period of 24 hours)
9K	Water at high-pressure/steam jet cleaning	Water which is directed against the enclosure from every direction with extremely high pressure may not cause any damage (14 to 16 l/min at 8,000 to 10,000 kPa)

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Warranty Terms and Conditions

RISK OF LOSS

Delivery of the equipment to a common carrier shall constitute delivery to the Purchaser and the risk of loss shall transfer at that time to Purchaser. Should delivery be delayed due to an act or omission on the part of the Purchaser, risk of loss shall transfer to the Purchaser upon notification by Turck Inc. that the order is complete and ready for shipment.

WARRANTIES

Turck Inc. (hereinafter "Turck") offers five (5) WARRANTIES to cover all products sold. They are as follows:
1) The **12-MONTH WARRANTY** is available for the products listed - generally those not covered by **LIFETIME**, **5-YEAR**, **24-MONTH** or **18-MONTH** warranty. No registration required.
2) The **18-MONTH WARRANTY** is available for the products listed - generally those not covered by **LIFETIME** or **5-YEAR WARRANTY**. No registration is required.
3) The **24-MONTH WARRANTY** is available for the products listed - generally those not covered by **LIFETIME**, **5-YEAR** or **18-MONTH**. No registration is required.
4) The **5-YEAR WARRANTY** is available generally for the products listed. No registration is required.
5) A **LIFETIME WARRANTY** is available for the products listed. It becomes effective when the accompanying Turck **LIFETIME WARRANTY REGISTRATION** is completed and returned to Turck.

GENERAL TERMS AND CONDITIONS FOR ALL WARRANTIES

- **12-MONTH STANDARD WARRANTY**
- **18-MONTH STANDARD WARRANTY**
- **24-MONTH STANDARD WARRANTY**
- **5-YEAR WARRANTY**
- **LIFETIME WARRANTY**

Turck warrants the Products covered by the respective WARRANTY AGREEMENTS to be free from defects in material and workmanship under normal and proper usage for the respective time periods listed above from the date of shipment from Turck. In addition, certain specific terms apply to the various WARRANTIES.

THESE EXPRESS WARRANTIES ARE IN LIEU OF AND EXCLUDE ALL OTHER REPRESENTATIONS MADE - BOTH EXPRESSED AND IMPLIED. THERE ARE NO WARRANTIES OF MERCHANTABILITY OR OF FITNESS FOR A PARTICULAR PURPOSE FOR PRODUCTS COVERED BY THESE TERMS AND CONDITIONS.

Turck warrants that the goods sold are as described, but no promise, description, affirmation of fact, sample model or representation, oral or written shall be part of an order, unless set forth in these terms and conditions, or are in writing and signed by an authorized representative of Turck. These WARRANTIES do not apply to any Product which has been subject to misuse, negligence, or accident - or to any Product which has been modified or repaired, improperly installed, altered, or disassembled - except according to Turck's written instructions.

These WARRANTIES are subject to the following conditions:
1) These WARRANTIES are limited to the electronic and mechanical performance only, as expressly detailed in the Product specifications and NOT to cosmetic performance.
2) These WARRANTIES shall not apply to any cables attached to, or integrated with the Product. However, the **18-MONTH WARRANTY** shall apply to cables sold separately by Turck.
3) These WARRANTIES shall not apply to any Products which are stored, or utilized, in harsh environmental or electrical conditions outside Turck's written specifications.
4) The WARRANTIES are applicable only to Products shipped from Turck subsequent to January 1, 1988.

ADDITIONAL SPECIFIC TERMS FOR:
(12-MONTH STANDARD WARRANTY) FOR LINEAR DISPLACEMENT TRANSDUCERS, EZ TRACK, RFID PRODUCTS, DRAW WIRE ASSEMBLIES AND SLIP RINGS.

(18-MONTH STANDARD WARRANTY) FOR Q-TRACK INDUCTIVE SENSORS, ULTRASONIC SENSORS, FLOW SENSORS, PRESSURE SENSORS, TEMPERATURE SENSORS, INCLINOMETERS, CABLES AND ALL NON-SENSING PRODUCTS SOLD BY TURCK INC. INCLUDING MULTI-SAFE, MULTI-MODUL, MULTI-CART AND RELATED AMPLIFIER PRODUCTS, RELAYS AND TIMERS.

(24-MONTH STANDARD WARRANTY) FOR ENCODERS EXCLUDING DRAW WIRE ASSEMBLIES.

5-YEAR WARRANTY FOR INDUCTIVE AND CAPACITIVE PROXIMITY SENSORS: THE PERIODS COVERED FOR THE ABOVE WARRANTIES AND PRODUCTS SHALL BE 12 MONTHS, 18-MONTHS, 24-MONTHS AND 5-YEARS, RESPECTIVELY, FROM THE DATE OF SHIPMENT FROM TURCK.

LIFETIME WARRANTY (OPTIONAL - REGISTRATION REQUIRED) FOR INDUCTIVE, INDUCTIVE MAGNET OPERATED AND CAPACITIVE PROXIMITY SENSORS SOLD TO THE ORIGINAL PURCHASER FOR THE LIFETIME OF THE ORIGINAL APPLICATION.

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Warranty Terms and Conditions

THE FOLLOWING TERMS APPLY TO THE LIFETIME WARRANTY IN ADDITION TO THE GENERAL TERMS:

1) This WARRANTY shall be effective only when the LIFETIME WARRANTY REGISTRATION has been completed, signed by the End User and an authorized Turck Representative or Distributor and has been received by Turck no later than six (6) months after installation in the End User's Plant, or two (2) years from the date product was shipped from Turck, whichever is sooner.
2) This warranty is available only to Turck's authorized Representatives, Distributors and to the Original User. (The term "Original User" means that person, firm, or corporation which first uses the Product on a continuous basis in connection with the operation of a production line, piece of machinery, equipment, or similar device.) In the event the ownership of the product is transferred to a person, firm or corporation other than the Original User, this WARRANTY shall terminate.
3) This WARRANTY is applicable only to the Original Application. In the event the machinery, equipment, or production line to which the Product is connected, or on which it is installed, is substituted, changed, moved or replaced, the WARRANTY shall terminate.
4) This WARRANTY shall be valid only if the Product was purchased by the Original User from Turck, or from an authorized Turck Distributor, or was an integral part of a piece of machinery and equipment obtained by the Original user from an Original Equipment Manufacturer, which itself, was purchased directly from Turck or from an authorized Distributor.

PURCHASER'S REMEDIES

This Remedy shall apply to all WARRANTIES. If a Turck Distributor desires to make a WARRANTY Claim, the Distributor shall, if requested by Turck, ship the Product to Turck's factory in Minneapolis, Minnesota, postage or freight prepaid. If the User desires to make a WARRANTY Claim, they shall notify the authorized Turck Distributor from whom it was purchased or, if such Distributor is unknown, shall notify Turck. Turck shall, at its option, take any of the following two courses of action for any products which Turck determines are defective in materials or workmanship.

1) Repair or replace the Product and ship the Product to the Original Purchaser or to the authorized Turck Distributor, postage or freight prepaid; or
2) Repay to the Original Purchaser that price paid by the Original Purchaser; provided that if the claim is made under the LIFETIME WARRANTY, and such Product is not then being manufactured by Turck, then the amount to be repaid by Turck to the Original Purchaser shall be reduced according to the following schedule:

Number of Years Since Date of Purchase by Original Purchaser	Percent of Original Purchase Price To Be Paid by Turck
10	50%
15	25%
20	10%
More than 20	5%

PURCHASER'S REMEDIES SHALL BE LIMITED EXCLUSIVELY TO THE RIGHT OF REPLACEMENT, REPAIR OR REPAYMENT AS PROVIDED AND DOES NOT INCLUDE ANY LABOR COST OR REPLACEMENT AT ORIGINAL PURCHASER'S SITE. TURCK SHALL NOT BE LIABLE FOR ANY CONSEQUENTIAL DAMAGES RESULTING FROM ANY BREACH OF ANY WARRANTY, EXPRESSED OR IMPLIED, APPLICABLE TO THE PRODUCT, INCLUDING WITHOUT LIMITATION, ANY DAMAGES RESULTING FROM PROPERTY DAMAGE, PERSONAL INJURY OR BUSINESS INTERRUPTION.

CONSIDER SAFETY AND PROTECTION PRECAUTIONS

Turck takes great care to design and build reliable and dependable products, however, some products can fail eventually. You must take precautions to design your equipment to prevent property damage and personal injury in the unlikely event of failure. As a matter of policy, Turck does NOT recommend the installation of electronic controls as the sole device FOR THE PROTECTION OF PERSONNEL in connection with power driven presses, brakes, shears and similar equipment and, therefore, the customer should build in redundancy or dual control using approved safety devices for these applications.

GOVERNING LAW

The sale and purchase of Products covered hereby and all terms and conditions hereof shall be governed by the law of the States of Minnesota.

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