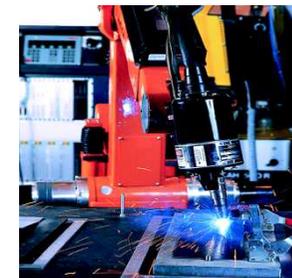




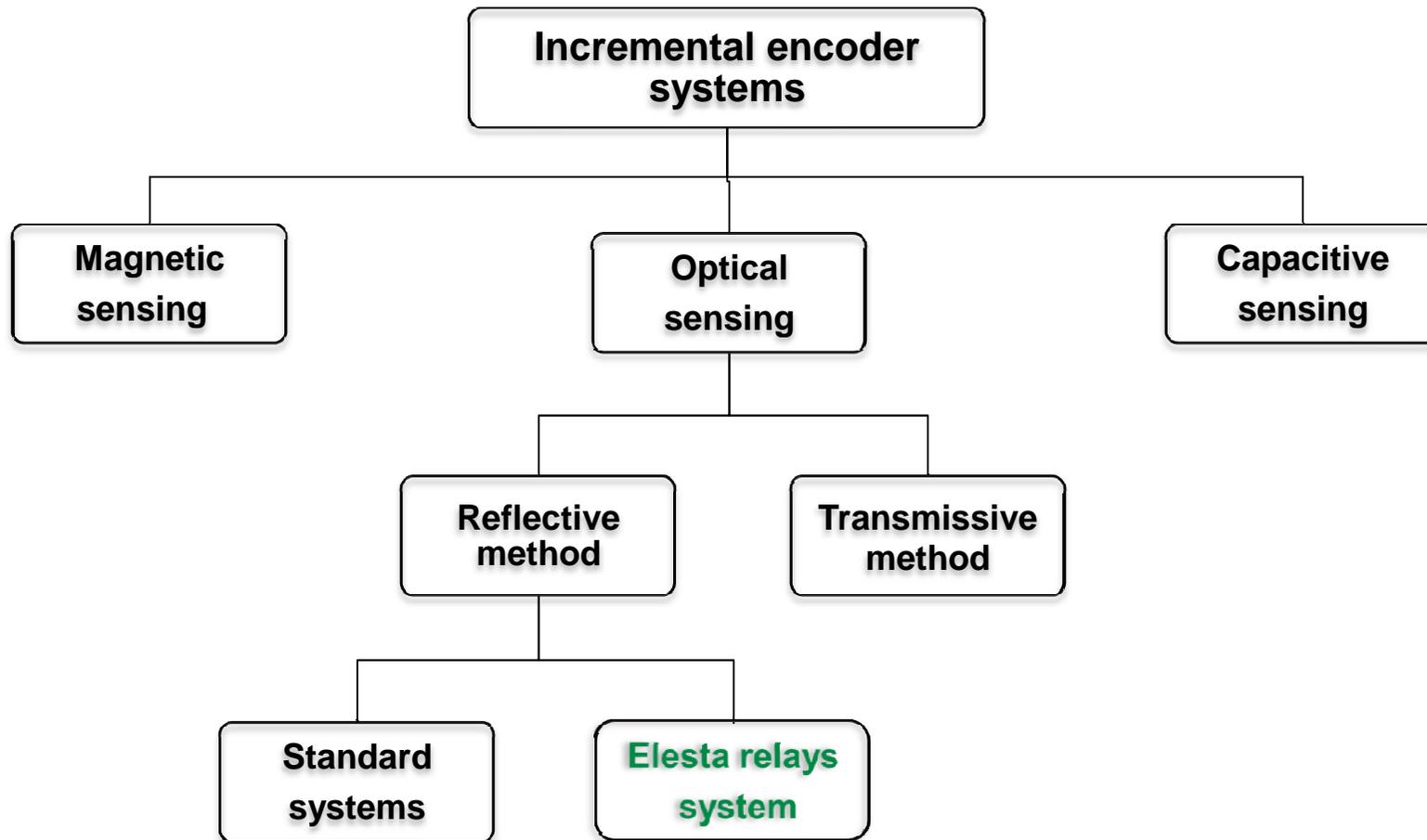
**ELESTA relays GmbH**

## **Incremental Optical Encoders**



# Basic operational principles

## Incremental encoder system classification

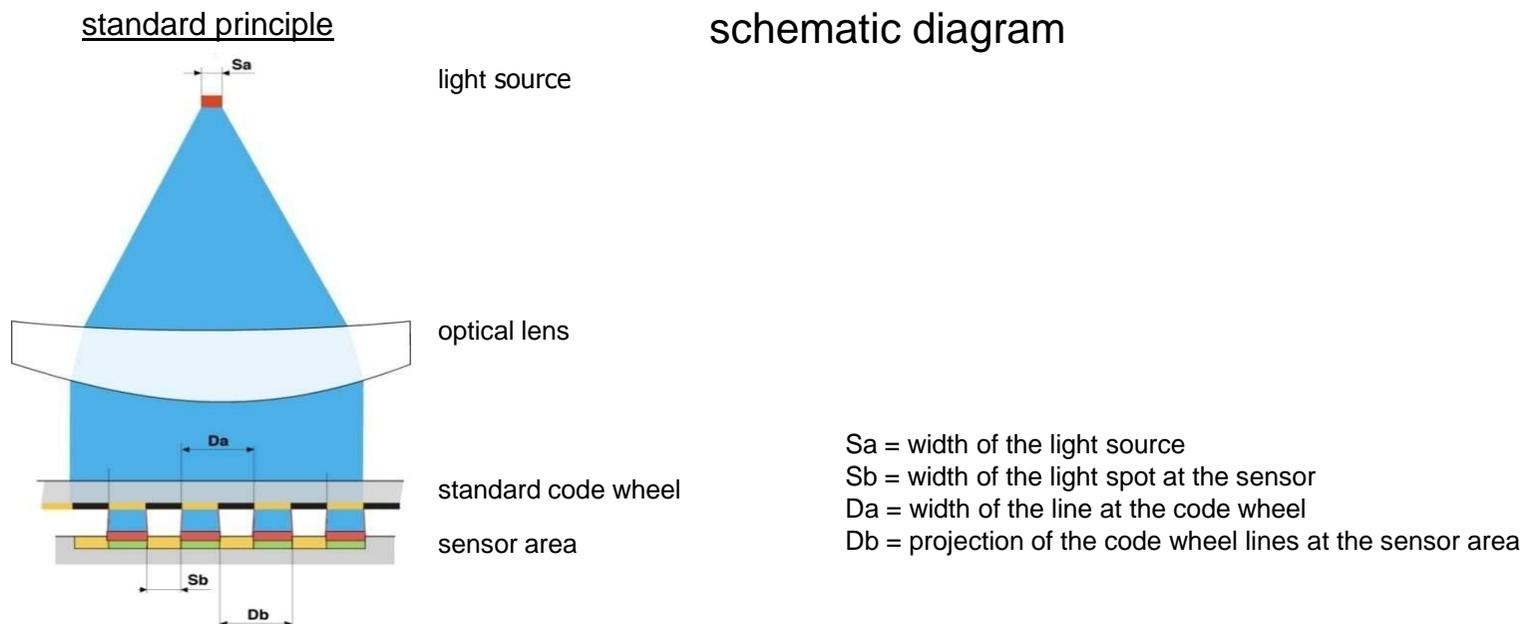


# Basic operational principles

## Transmissive method

The typical optical system, housed in a transmission code wheel encoder, consists of three main optical elements: Light source, code wheel and light sensor. Generally these three optical elements are aligned along the same optical axis.

The performance of transmissive encoders is highly dependent on mechanical tolerances and requires high precision optical parts. Likewise these factors complicate system assembly and performance. The ratio between the surface area **Sa** of the light source and the illuminated surface area **Sb** on the sensor depends on the optics only. A suitable lens system is inserted between light source and code wheel to collimate the incident light on the code wheel. Only light falling on transparent areas is transmitted towards the sensor. It is clear that the initial light intensity is substantially reduced by the code wheel. The light intensity arriving at the light sensor determines the magnitude of the electrical signals generated by the sensor. The total optical path length in a transmission system further reduces the light intensity at the light sensor.

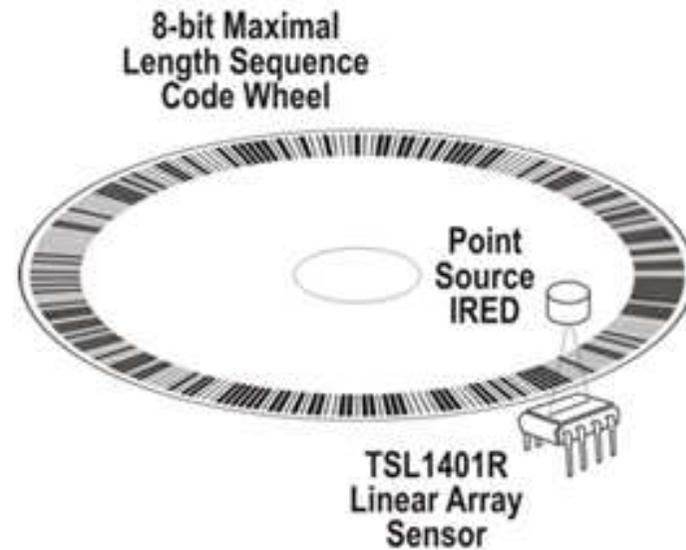
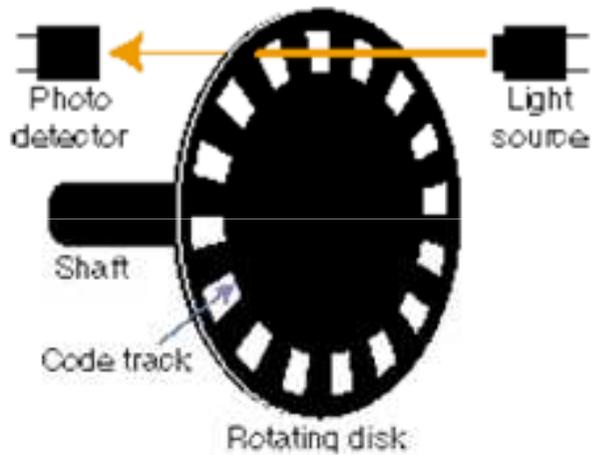


# Basic operational principles

## Transmissive method



### Example for standard principle



# Basic operational principles

## Reflective method – standard principle

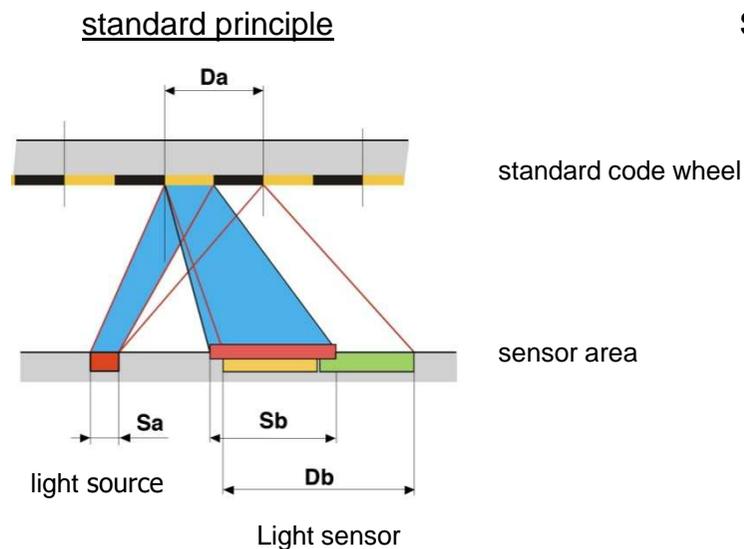
The design of a reflective code wheel is very similar to that of a transmissive code wheel. The obvious difference is that code lines are reflective and opaque and not transparent and opaque. This design enables the designer to position the light source and the light sensor next to each other on the same side of the code wheel encoder.

### Advantage:

Reduction in physical size of encoders thus smaller designs possible.

### Disadvantage:

The ratio of the optical signal registered on the sensor to the signal emitted by the light source is poor. The reason being that the illuminated area **Sb**, on the sensor, is larger than the illuminated area **Sa** of the light source.



schematic diagram

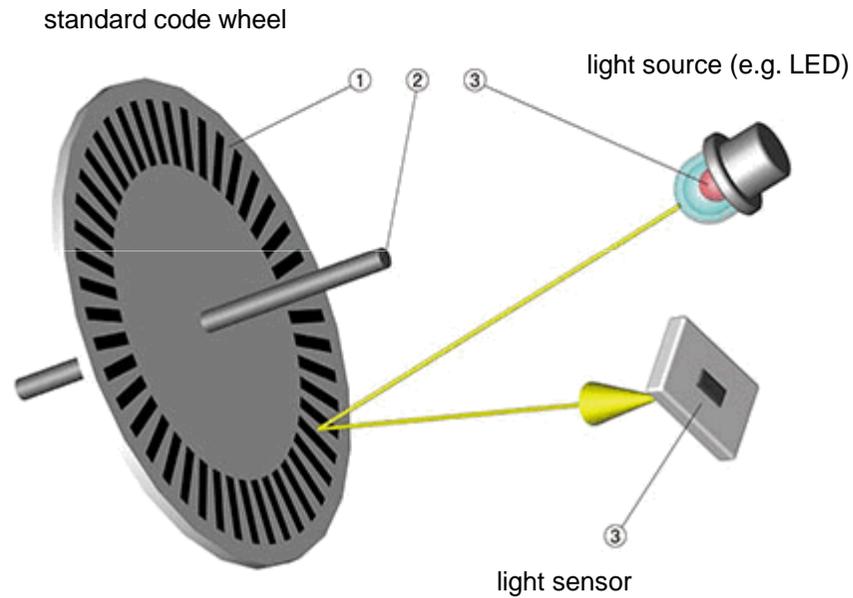
Sa = width of the light source  
 Sb = width of the light spot at the sensor  
 Da = width of the line at the code wheel  
 Db = projection of the code wheel lines at the sensor area

**This type of encoders are used in low technology environments and products.**

# Basic operational principles

## Reflective method – standard principle

### Example for standard principle



# Basic operational principles

## Reflective method – new patented sensing system



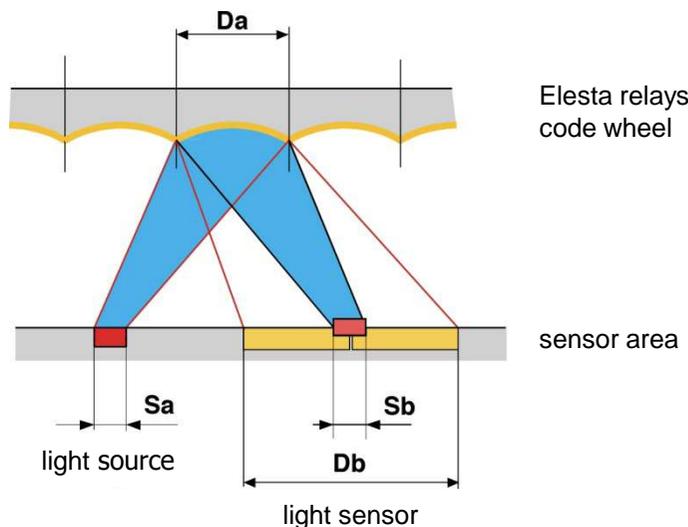
### Principles of the new Elesta Relays patented sensing system:

Light source, light sensor and electronic processing circuitry are on the same substrate, facing the code wheel. The code wheel is similar to a standard reflective code wheel except that the reflective surfaces are optically shaped to focus the incident light on the active area of the sensor and there are no opaque lines.

#### Advantages:

- Smaller physical size
- The surface area **Sa**, of the light source is identical to the surface area **Sb** illuminated on the light sensor
- The optical signal transfer efficiency is improved. This in turn improves the quality of the output signals of the sensor. The input signals to the processor are therefore improved.
- Lower current consumption.

Elesta relays principle



schematic diagram

Sa = width of the light source  
Sb = width of the light spot at the sensor  
Da = width of the line at the code wheel  
Db = projection of the code wheel lines at the sensor area

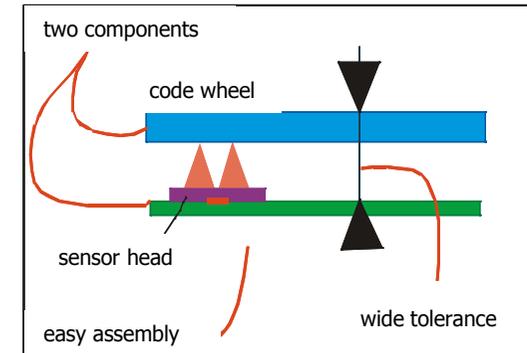
# Elesta relays GmbH - Encoder

## Comparing system parameters



### Improved efficiency

The reduction in optical path length between, light source and light sensor, in addition to the high reflectivity of the optical surface of the code wheel, improved the optical efficiency of the encoder. Nearly 100% of the emitted optical signal is available to be converted into electrical signals by the light sensor. This allows the use of lower intensity and more energy efficient LEDs with identical light sensors.



### High resolution

The light focusing capability of the new code wheel design improved the sensitivity of reflective wheel encoders. The energy efficiency was improved by a factor of up to two. With lower signal noise the signal processing is improved, culminating in improved resolution of the system. A factor of four to six times improvement in the signal resolution was achieved and enables high precision encoding, even at high rotational speeds.

### Relaxed specification with no performance loss

The positional tolerances of the optical system in the Elesta encoder are less critical than in any of the other reflective or transmission systems. Variations of 0.3mm to 1.5mm in the optical path length between code wheel and electro-optical system can be tolerated without any observed degeneration in the performance. This was experimentally verified for an Elesta system with a 128 line code wheel in mid rotational speed range.

# Elesta relays GmbH - Encoder

## Comparing system parameters



### Higher signal precision

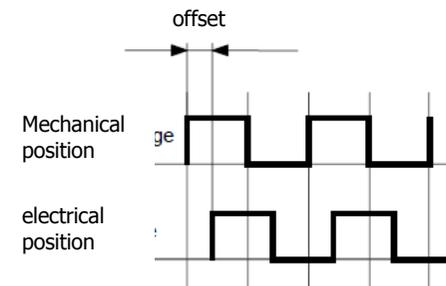
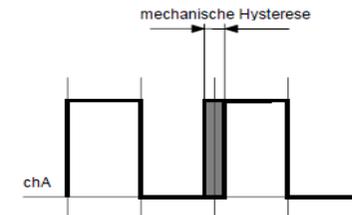
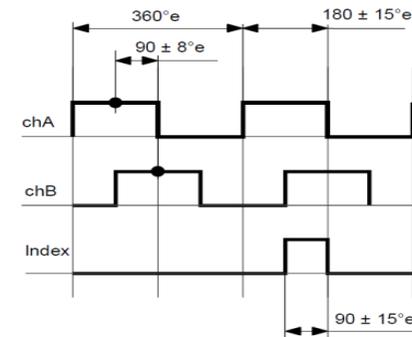
A decrease in signal parameter errors such as in the Width Error or the Phase Error can only be achieved if the quality of the signals are improved. The requirement for signal quality improvement are jitter free stable input signals from the light sensor to the processor. The Elesta system achieves values of less than  $\pm 5 e^\circ$  on  $90 e^\circ$ . This is substantially better than the  $\pm 40 - 50 e^\circ$  error quoted for comparable systems.

### Lower switching hysteresis

Shorter rise and fall times, decreased positional sensitivity and reduced switching hysteresis are achieved. The angular deviation between the true position of the drive shaft and the measured position of the drive shaft was accordingly reduced. The width of the switching hysteresis is inversely proportional to the precision of the encoder. The Elesta encoder achieves a precision of  $0,03 \times 360 e^\circ$ . It is therefore possible to achieve higher positional accuracy with an Elesta encoder, with a code wheel with a lower number of encoding lines, than on comparable encoders using code wheels with a higher number of lines.

### Smaller offset

The offset is defined as the difference between the true mechanical position and the apparent position indicated by the electronic measurement. This is determined by the quality of the electrical signals, which in turn is determined by the optical signal quality. It should be clear that the lower sensitivity of the Elesta encoder for the distance between code wheel and sensor is responsible for decrease in value of the offset.



# Elesta relays GmbH - Encoder

## Comparing system parameters



### **Steep signal slopes**

The inherent electrical capacity of the outputs of the encoder determines the slope of the signals. The implementation of CMOS outputs on the ASIC ensures that the rise and fall times of the signals are very short. CMOS outputs have a lower capacity than most other outputs. Rise and fall times below 300ns are achievable. Due to this design feature the Elesta encoder is capable of fault free operation at high rotational speeds.

### **Simplified assembly**

An uniqueness of the Elesta encoder is the large tolerance of up to 1.5mm on the positioning of the code wheel relative to the sensor head. There are no complicated and expensive alignment requirements or tools to enable a client to install the single components in a custom designed housing.

# Elesta relays GmbH - Encoder

## Comparing system parameters



### **Reduced angular error**

Although electrical and mechanical angular errors are equivalent, it is important to note what is specified when comparing different systems with one another. Data sheets may quote the angular error in electrical degrees (e°) or mechanical degrees (°) or both. The Elesta encoder achieves an angular error up to ten times smaller than comparable systems.

### **Illustrative examples**

#### **Example 1**

A manufacturer quotes a mechanical angular error of  $\pm 0,2^\circ$ .  
With 128 lines on the code wheel this is equivalent to a phasing tolerance of  $\pm 26e^\circ$ .

#### **Example 2**

A manufacturer quotes a phasing tolerance of  $\pm 45e^\circ$ .  
With 128 lines on the code wheel this is equivalent to a mechanical angular error of  $\pm 0.35^\circ$ .

#### **Example 3**

The angular error on the Elesta relays system is  $\pm 5e^\circ$ .  
With 128 lines on the code wheel this is equivalent to a mechanical angular error of  $\pm 0.04^\circ$ .

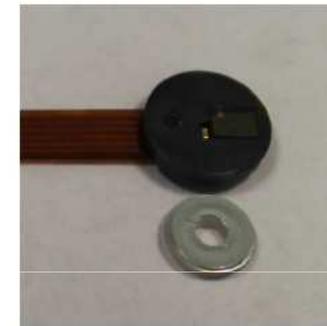
# Elesta relays GmbH - Encoder

## Basic design



- A unique code wheel design which allows the code wheel to be mounted on a solid shaft.
- The light source, light source electronics, light sensor, light sensor electronics and an ASIC are mounted on a single circuit board. The ASIC functions as a processor to digitalize the pulses in the A, B and Z signals. Multiple operational modes can be selected.
  - In channels A and B the signals are identical but with a phase difference of  $90^\circ$ . The Z channel is the indexing channel with a single pulse for every revolution.
  - In a further selectable mode only the signals in channel A are processed for determining the rotational angle. The signal in channel B indicates the direction of rotation. The Z channel is again the indexing channel with a single pulse for every revolution.
- In the present design a code wheel with a diameter of 6mm and 128 lines is implemented. This code wheel generates 128 pulses per revolution. The 128 pulses can be interpolated to 256 usable pulses. The interpolation is performed either externally or internally.
- Elesta relays GmbH are able to supply encoders in standard housings. Easy integration into systems such as motors, gear boxes etc. is possible.

**Optical Encoder ER6**



**Typ ER 6**

# Elesta relays GmbH - Encoder

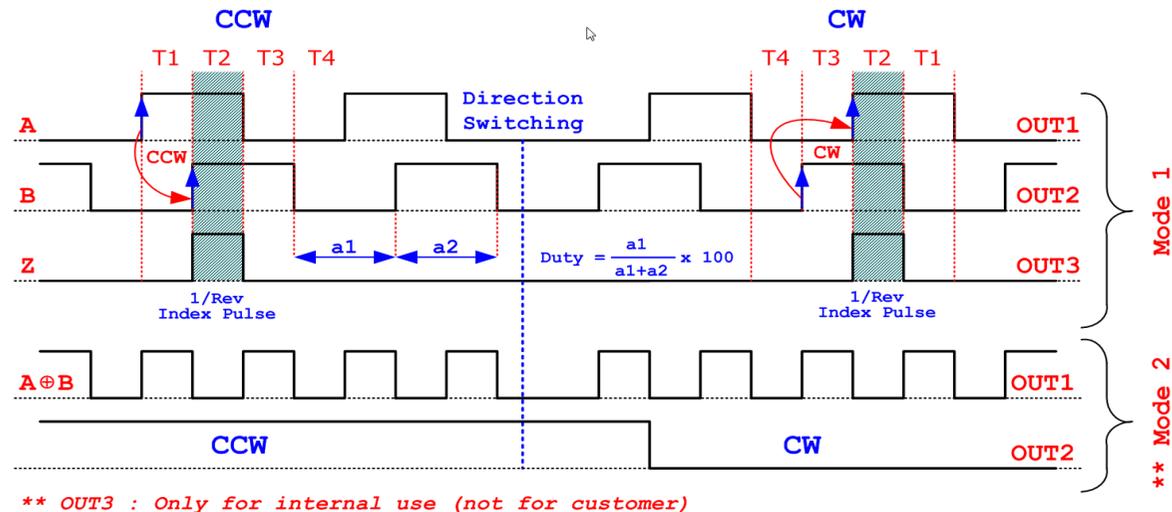
## Operational mode selection



- In the present design two different operational output modes can be selected.

**Mode 1:** Two 90° out of phase square wave outputs A and B and a square wave output Z. Signal A at OUT1, Signal B at OUT2 and the indexing signal Z at OUT3

**Mode 2:** Two different signals are available at OUT1 and OUT2. An internal EXOR circuit generates 256 pulses per revolution at OUT1. At OUT2 the rotational direction is indicated by a low level signal for clockwise rotation (CW) and a high level signal for counter clockwise rotation (CCW).



- It is possible to program the ASIC to change the displayed number of output signals per revolution. The standard setting for this parameter is 1 and displays the full compliment of 128 generated pulses. Three optional settings allows the selection of a reduction factor of 2, 4 or 8. This selection then displays either 64, 32 or 16 signals per revolution accordingly.

# Elesta relays GmbH - Encoder

## Selected application examples



### Determining the rotational speed (revolutions / min)

1. Measuring the number of pulses in the Z channel (1 Pulse per revolution)  $\text{Rotational speed} = \text{Number of Z-pulses} / \text{minute}$
2. Determining the time between two consecutive Z-signals,  $\text{Rotational speed} = 1 \text{ minute} / \text{Time difference}$
3. Counting the number of pulses per minute at OUT1 or at OUT2  $\text{Rotational speed} = (\text{Number of pulses} / 128) \text{ per minute}$
4. Determining the duration of a pulse at OUT1 or at OUT2
5. 1 Revolution equals the duration of the pulse x 128  $\text{Rotational speed} = 1 \text{ minute} / (\text{Duration of the pulse} \times 128)$

### Determining the angular position

The rotational angle can be determined with high precision due to the high precision of the square waves at the output of the encoder. This is performed by means of the following procedure.

### Translating the electrical angle ( $e^\circ$ ) into a mechanical angle $\alpha$ ( $^\circ$ )

The distance between two consecutive lines on the code wheel is equivalent to the period of the pulse. The period of a pulse is  $360e^\circ$ .

$360^\circ (\text{Mechanical}) / \text{Number of lines on the wheel} = \text{Angle / line in mechanical}^\circ$

$\alpha = 360^\circ \times 1 \text{ Line width} / \text{Number of lines on the wheel}$  (For 128 lines the angle covered by one line equals  $2,81^\circ$ )

The signals at OUT1 und OUT2, with their phase difference of  $90e^\circ$ , thus enable the measurement of the angular position to a quarter of the value determined above. (The time delay between the rising slope of A and the rising slope of B.) It is therefore possible to determine the angular position within  $0.7^\circ$

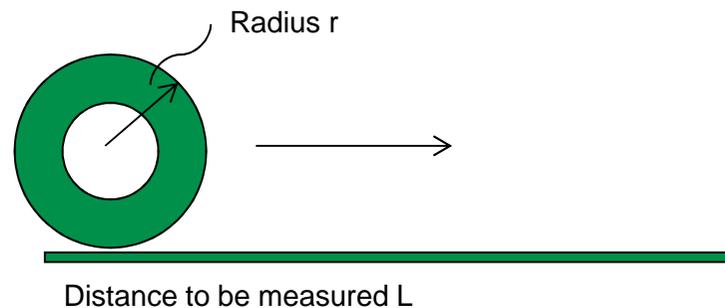
# Elesta relays GmbH - Encoder

## Selected application examples



### Measuring distances

Due to the high precision of the Elesta system and the precision of the square waves, it is possible to determine distances with relative high accuracy.



In order to determine the distance travelled the geometrical relationship between radius, angle and circumference of a circle is applied..

Example: Radius = 20mm,  
Number of lines on the code wheel = 128.  
Number of recorded pulses = 240

Formula:  $L = 2\pi r \times \text{Number of pulses} / 128 = 2 \times 3,14 \times 20\text{mm} \times 240 / 128$

Result: The distance travelled  $L = 235,5\text{mm}$  with a resolution of 0.5mm.

# Elesta relays GmbH - Encoder

## Data sheet



### Technical Data

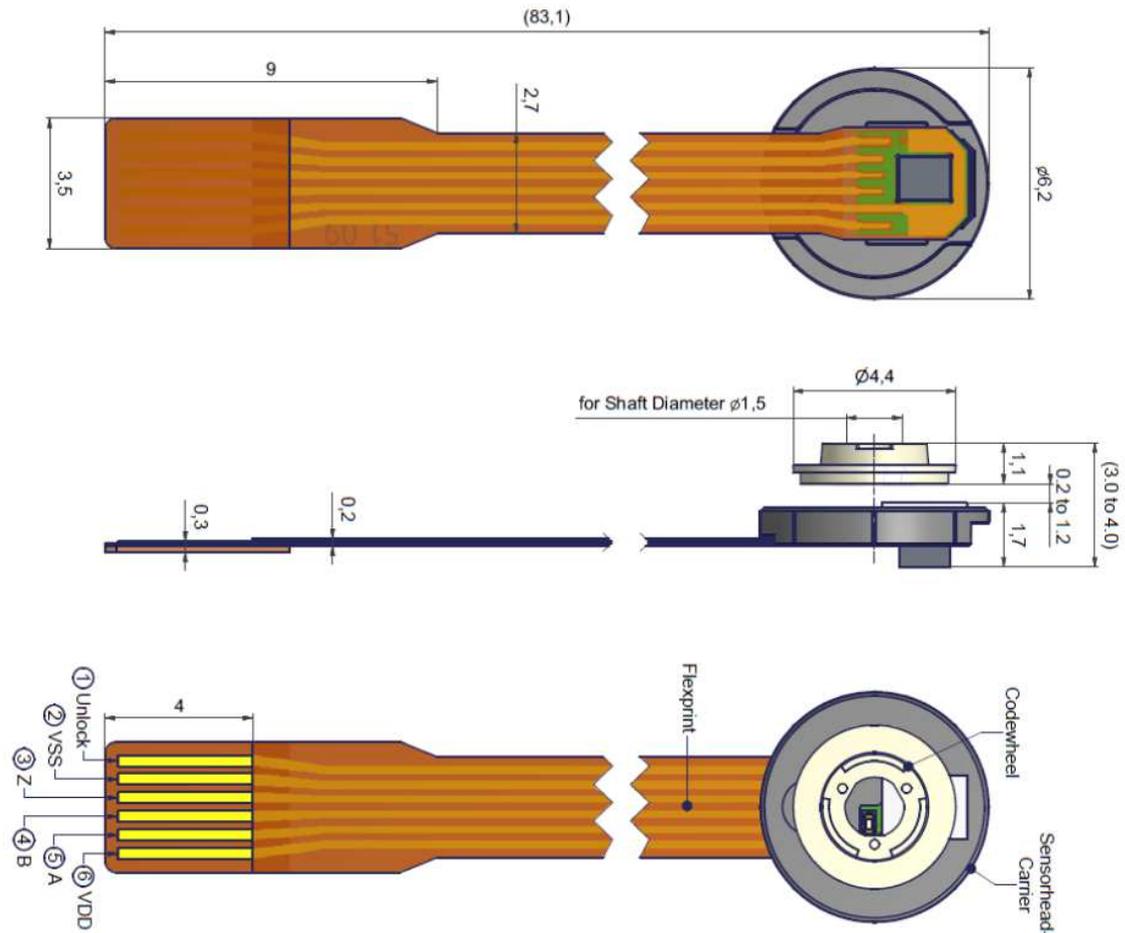
Electrical data (after Calibration)	unit	min	typ	max
Supply voltage	V	3	5	6
Supply current	mA	2	4	6
Power Dissipation	mW	6	20	36
Output short circuit current with GND @ OUT = 1	mA	-	20	30
Output short circuit current with VDD @ OUT = 0	mA	-	20	30
Output drive current (Output Voltage ~ 4.5V)	mA	-	2.5	-
Speed	RPM	-	24'000	-
Frequency (rise time dependent)	kHz	-	1000	-
Signal rise time (R <sub>L</sub> =1kΩ, C <sub>L</sub> =47pF, C <sub>osc</sub> =12pF)	ns	-	300	-
Signal outputs (3 channels), CMOS/TTL compatible	-	-	A, B, Z	-
Duty cycle for A and B	%	45	50	55
Phase error between A and B (90°e)	%	0	5	10
Operating temperature	°C	-20	-	85
Storage temperature	°C	-20	-	85
Burst			on request	
ESD			on request	
Isolation values			on request	

Mechanical data	unit	min	typ	max
Code wheel diameter	mm		4.4	
Code wheel thickness	mm		1.1	
Resolution (code wheel lines)	-		128	
Shaft diameter	mm		1.5	
X, Y position tolerances	mm	-	-	±0.2
Distance between code wheel and light sensor	mm	0.2	0.3	1.2
Shock stability	-		on request	
Vibration	-		on request	
Package type	-		on request	



# Elesta relays GmbH - Encoder

## Data sheet



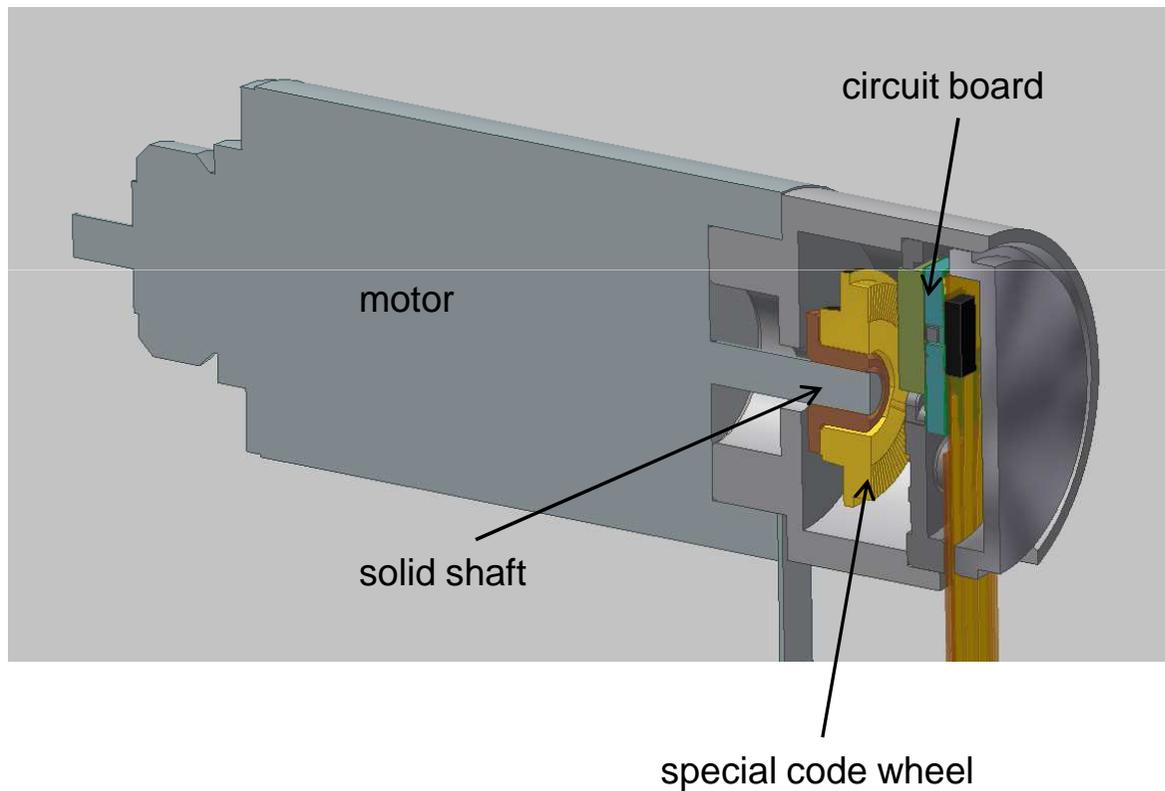
08.04.2013

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# Elesta relays GmbH - Encoder

## Installation example



# Elesta relays GmbH - Encoder

## Market sectors



### Primary users

- Small motor manufacturers
- Valve manufacturers
- Pump manufacturers
- Medical appliance manufacturers
- Rehabilitation appliance manufacturers
- Robot manufacturers
- Remote control manufacturers

### Fields of application

- Robot technology
- Printing technology
- Medical and healthcare appliances
- Process technology
- Aerospace and transport
- Metrology

### Applications

- Dose dispensers
- Actuators
- Positioning systems
- Level control systems
- Rotational speed, angular position and distance measurements
- Potentiometers

