Encoding and Code Wheel Proposal for TCUT1630X01

By Sascha Kuhn

INTRODUCTION AND BASIC OPERATION

The TCUT1630X01 is a 3-channel optical transmissive sensor designed for incremental encoder applications. The sensor combines an additional detector to detect a vertical displacement of a code wheel (turn-push detection), and to provide an alternative for the indexing of incremental encoding (see Fig. 1).

In combination with an application-specific code disc or strip, the sensor is ideally suited for a wide range of applications, such as rotary switches, incremental turn switches, speed and motion control systems, and many more.

The integration of three channels in a compact, automotive-qualified (to +110 °C) package also makes the sensor an excellent selection for more complex applications, such as automotive steering wheel encoding, where multiple channels of redundancy are required.

Fig. 1 - TCUT1630X01 Multichannel Optical Sensor

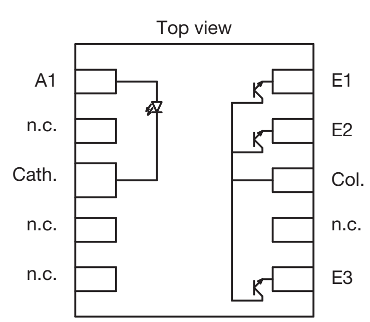


Fig. 2 - Pin Layout

INCREMENTAL ENCODING AND PUSH OR INDEXING

Incremental encoding gives information on relative position and direction of motion. This information can be processed by a microcontroller counting up or down to virtually generate an unlimited number of stages. By knowing the distance between each stage, the relative distance can be determined.

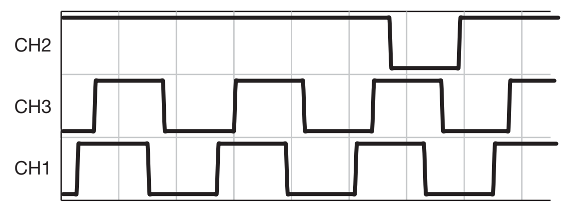


Fig. 3 - Signals CH1 and CH3 Are for Incremental Encoding and Are Equal to E1, E3 in the Pin Layout of Fig 2. CH2 Can Be Used as an Index Channel for Incremental Encoding or as Push Detection for Vertical Displacement of the Code Wheel

CODE WHEEL OPTIONS

The sensor is usable for various code wheel or strip geometries. A variety of technologies are available on the market for generating such code wheels or strips. The most common technologies are summarized in Table 1.

Each code wheel or strip is composed of optical translucent or opaque segments that either block or pass the IR light. The three detector channels will translate the received IR light into electrical signals, which can be further processed by the next stage circuitry.

Fig. 4 shows an example of customary code wheel and strip geometries, with code tracks adapted to the sensor geometry.

Encoding and Code Wheel Proposal for TCUT1630X01

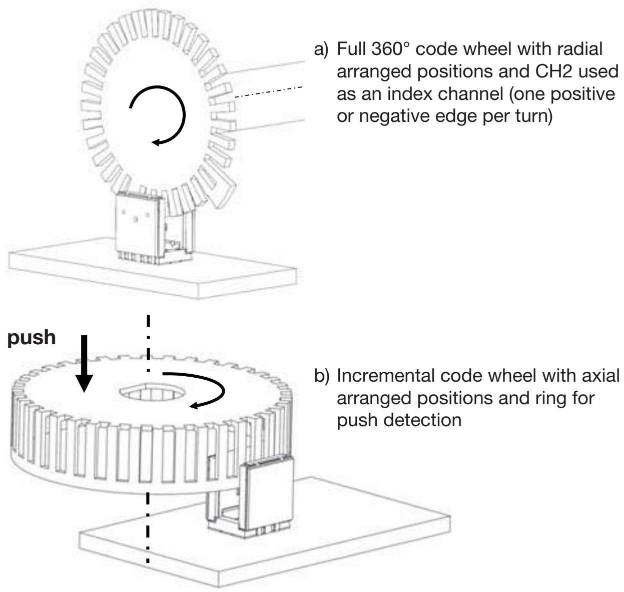


Fig. 4 - Example of Code Wheels

TABLE 1 - TECHNOLOGIES FOR CODE DISK, STRIPS, AND WHEELS			
TECHNOLOGY	COST	ACCURACY	DESIGN FREEDOM
Injection molding	Low	Good	Many geometries are possible, depending on the complexity of the molding tool
Blade punching	Low to high	Good	Difficult for complex geometries
Blade etching	High	Very good	Difficult for complex geometries
Hot foil molding / stamping	Low to high	Medium	Difficult for complex geometries
Foil printing	Low to high	Very good	Limited to plane geometries

Note

- REM: rating based on customer feedback and experience

Table 1 only contains the most common technologies used for this kind of code disc / strip. Another technology not listed, which does have the capability to pass and block IR light and has enough resolution, might also be capable.

DESIGN MARGINS

The chapter "Limitations for Outer Code Wheel Dimensions" reviews the limitations for outer code wheel dimensions in terms of the sensor gap (see Fig. 5). Based on this, proposals are made in the chapter "Vertical Channel Displacement in the Sensor Gap" and "Horizontal Channel Displacement in the Sensor Gap" to find the best encoding structure.

LIMITATIONS FOR OUTER CODE WHEEL DIMENSIONS

For code wheels with radial arranged position encoding (see Fig. 4 a) and Fig. 4 b)), the limiting factor is the detented positions, which need to be arranged circumferentially around the code wheel. Therefore, in this case the limiting factor is not the sensor geometry. Instead it is the geometry and tolerances of the code wheel itself.

For code wheels with axial arranged positions, some limitations are due to the width of the TCUT sensor (see Fig. 5).

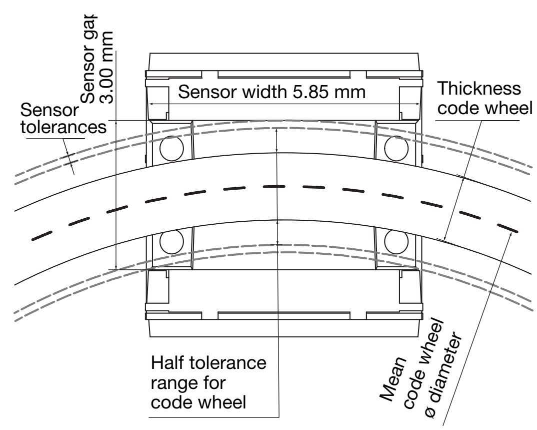


Fig. 5 - Code Wheel Design for Axial Arranged Encoding Positions. The Picture Shows the TCUT Sensor From the Top View With an Encoder Ring Arranged in the Center of the Sensor

In Fig. 5, within the sensor gap the tolerances of the sensor and of the code wheel need to be considered (see dotted lines). Furthermore, the thickness of the code wheel and the sensor width determine the minimum allowed code wheel diameter (see Table 2).

Table 2: example of code wheels with axially arranged encoding positions within the sensor gap. The minimum code wheel diameter is calculated by the geometrical conditions in Fig. 5.

Encoding and Code Wheel Proposal for TCUT1630X01

TABLE 2		
TOLERANCE RANGE CODE WHEEL	THICKNESS OF CODE WHEEL	MINIMUM CODE WHEEL DIAMETER (CALCULATED)
± 0.5 mm	1.4 mm	> 32 mm
± 0.5 mm	1 mm	> 16 mm
± 0.5 mm	0.7 mm	> 12 mm
± 0.3 mm	1 mm	> 11 mm

Note

- Sensor parameters: tolerance of sensor = 0.15 mm, nominal gap of sensor = 3 mm, nominal width of sensor = 5.85 mm

VERTICAL CHANNEL DISPLACEMENT IN SENSOR GAP

The TCUT1630X01 includes one emitter illuminating the three transistors on the detector dome side. When looking at the side of the sensor through the gap (see Fig. 6), the detectors are arranged at different heights. The detectors E1 and E3 are arranged at the same height on the top for incremental encoding applications. The detector E2 is arranged further down in the sensor gap for additional applications (refer to the chapter "Incremental Encoding and Push or Indexing"). Therefore, the optical axis of the three channels has a slope in the sensor gap (see Fig. 6).

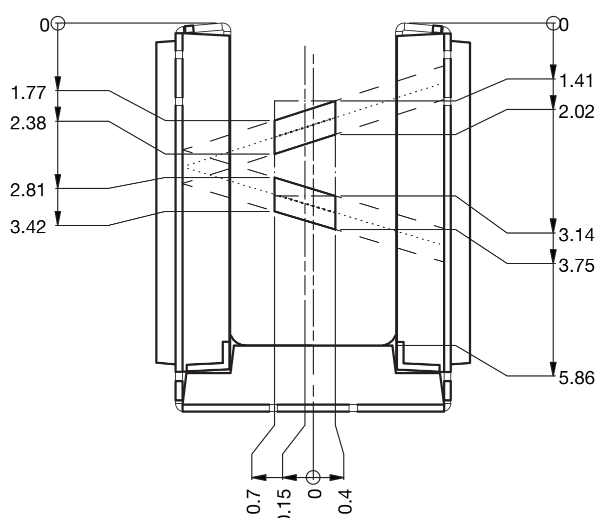


Fig. 6 - Range for Each of the Channels in Vertical View on the Sensor

Fig. 6 helps as a first step in finding a suitable code wheel design. Furthermore, it can be used to check if additional assembly tolerances (code wheel, PCB, sensor soldering on the PCB) will cause any cross-talk issues or any unwanted partial shading of the other channels. Boxes within each of the channels are the active optical regions used for optical encoding (light blocking and light passing features). Features outside do not influence the optical encoding application.

HORIZONTAL CHANNEL DISPLACEMENT IN SENSOR GAP

In the TCUT1630X01, the distance between the apertures of E1 and E3 is 0.8 mm. E2 is positioned in the center of the sensor. In Fig. 7, the position of the optical axis is shown from the top view.

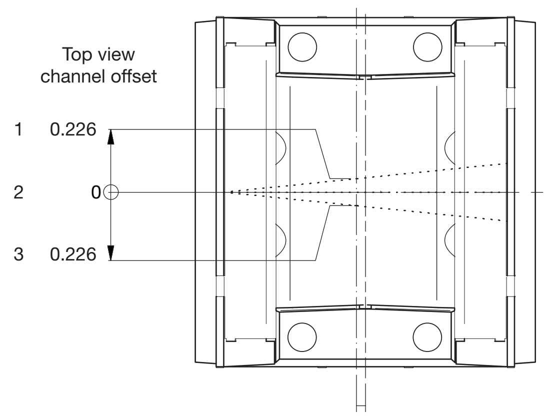


Fig. 7 - Top View of the TCUT1630X01 With Optical Axes of all Four Channels

APPLICATION

The main application for the TCUT1630X01 is to use the sensor as an incremental encoder at CH1 and CH3, and CH2 can be used for push detection or as an indexing channel (see Fig. 4).

CODE TRACK PROPOSAL - TURN AND PUSH

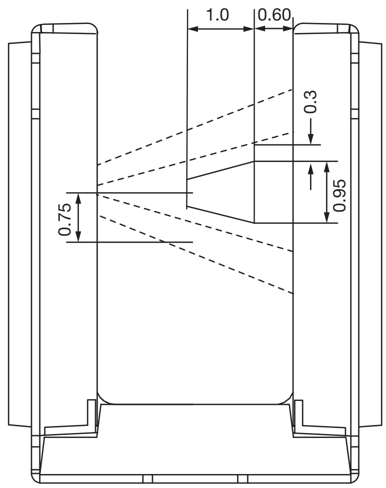
In Fig. 8, a code wheel or strip is designed with an incremental encoding code track. Below the code track, a push detection feature has been added to the code wheel to detect vertical displacements within the sensor gap.

The active optical region of CH1 and CH3 is always within the code track of incremental encoding. If the code wheel or strip is not pushed (as shown in Fig. 8 a)), CH2 is not blocked. The code wheel or strip moves downwards in Fig. 8 a) when it is pushed (also see Fig. 4).

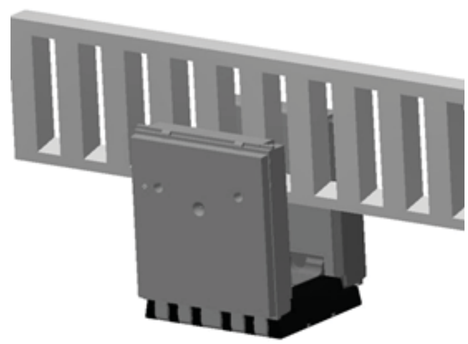
At a downwards movement of 0.75 mm (by push), the outer ring of the code wheel is blocking CH2. But incremental encoding is still possible with a pushed code wheel.

The design for a code wheel or strip should start at the cross-section view in Fig. 8 a). Once the cross-section design of the code wheel or strip is fixed, its 3D shape can be completed.

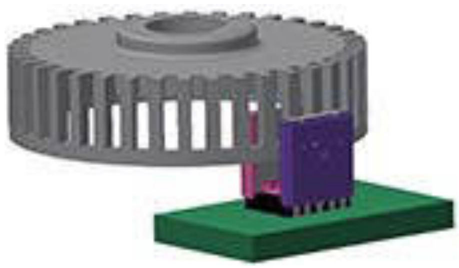
Encoding and Code Wheel Proposal for TCUT1630X01



a) Cross-section view of incremental code track and push detection - direction of movement is perpendicular to the drawing area above



b) Corresponding code strip



c) Corresponding code wheel

Fig. 8 - Side of the TCUT1630X01 With a Proposal for a Code Wheel With Push Detection (light blocking ring at the lower end of the wheel)

CODE TRACK PROPOSAL - INDEXING

In the chapter "Code Track Proposal - Turn and Push", the CH2 is used for push detection. Another application is to use the channel as an indexing channel (Fig. 3 and Fig. 4).

In this case, the upper code track is the same as for incremental encoding. The lower CH2, however, will be blocked or unblocked during rotation or movement of the code track. The code tracks in Fig. 9 do not change its position relative to the three channels (in the x-z-plane).

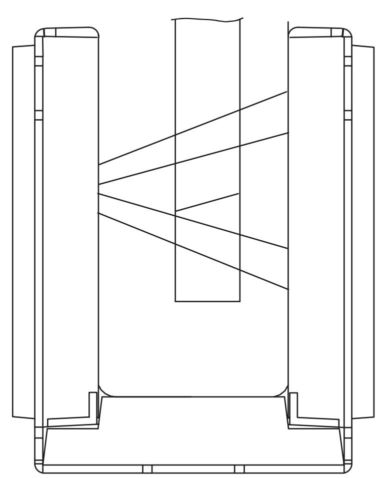


Fig. 9 - Side of the TCUT1630X01 With a Proposal for a Code Wheel With an Indexing Channel (in accordance to the proposal in Fig. 4 a))

For hardware- and application-related info, please also see the application note "Hardware Description and Design-In Proposals for Single and Dual SMD Transmissive Sensors" (www.vishay.com/doc?84873).