Encoder IC PR5201-XX

Incremental Sensor IC for Optical Encoders
with additional reticle for highest flexibility

For higher flexibility at lower production volumes, PR5201 uses a reticle to adapt the photodiodes of the encoder IC to different resolutions of A, B and Z channel and different track radii.

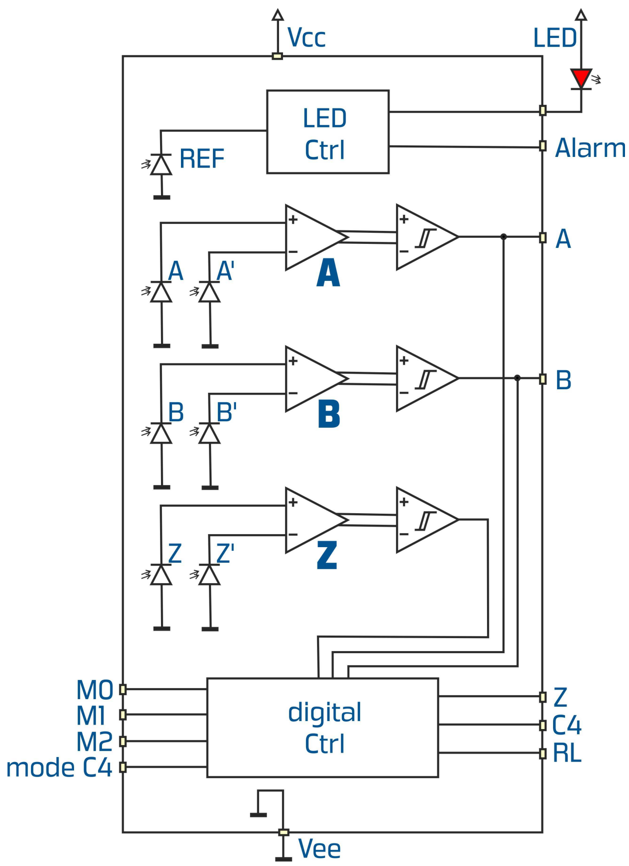
APPLICATIONS

- incremental rotary encoders
- linear scales
- Chip-on-board or QFN package for flexible use for in a wide range of applications
- wide temperature range (-40°...125°C) for operation in rough environments

FEATURES

- sharp Z channel pulse, generated by an innovative method
- A/B channel resolution from 100 to more than 10,000
- adaptable to different track radii
- ungated and gated Z channel (synchronisation with A/B channel)
- rotation direction indicator
- output with 4-fold pulse density, triggered at each A or B phase change
- LED current control using a reference channel and alarm for insufficient light intensity due to ageing LED

BLOCK DIAGRAM



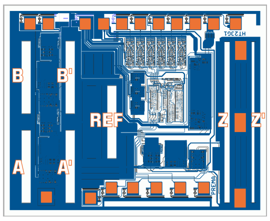
Encoder IC PR5201-XX

Different Packaging Solutions for Individual Requirements

PACKAGES

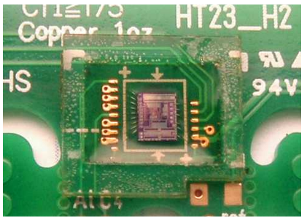
The PR5201 is offered with 3 packaging solutions to meet individual requirements. PREMA Semiconductor GmbH delivers the incremental encoder IC as bare dice, on modified/standard PCBs or in QFN packages suitable for different maximum temperatures.

a) IC as bare dice – PR5201-**BD**



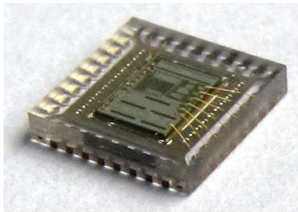
Encoder ICs can be delivered as bare dices (2.245 µm x 3.285 µm) on tested and inked wafers, or singulated dices on adhesive film

b) Chip-on-board – PR5201-**CB**



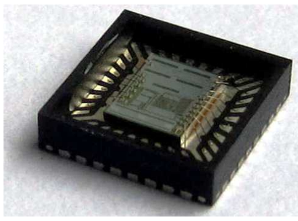
PR5201-CB are mounted on PCBs (standard/customized). A special assembly technique allows a quick assembly of the reticle.

c) QFN-32L 5x5 – PR5201-**TM**



The QFN package consists of transparent mold compound only.

d) QFN-32L 5x5 – PR5201-**OC**



A pre-molded QFN package with a special transparent filler material that is suitable for operation up to 125°C ambient temperature.

ABSOLUTE MAXIMUM RATINGS

Parameter		Min	Typ	Max	Units
V_{CC} (supply voltage)		-0.3		14	V
V_{PIN} (voltage @ other pins)		-0.3		V_{CC}+0.3	V
Operating Temperature	PR5201-BD/OC PR5201-CB/TM	-40 -40		125 85	°C °C
Storage Temperature Range	PR5201-BD/OC PR5201-CB/TM	-55 -40		150 100	°C °C
T_J (Junction Temperature)	PR5201-BD/OC PR5201-CB/TM	-40 -40		150 100	°C °C
Electrostatic Discharge (ESD) Protection @ all pins		4			kV

Encoder IC PR5201-XX

Electrical Characteristics

V_{CC} = 5 V, T_J = -40...125°C (unless otherwise noted)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
V_{cc}	Supply voltage		3		6	V
I_{CC}	Supply current (no load)	digital outputs LO digital outputs HI Tj=27°C		2.7 2.5		mA
Digital outputs A, B, Z, C4, RL, Alarm						
f_{OUT}	Output frequency	A, B C4, RL, Alarm			300 1200	kHz kHz
V_{Sat}(Lo)	Saturation voltage LO	I = 1.3 mA			0.3	V
I_{SC}(Lo)	Short-circuit current LO	V = V_{CC}	2		16	mA
V_{Sat}(Hi)	Saturation voltage HI	I = 1.3 mA			1	V
I_{SC}(Hi)	Short-circuit current HI	V = 0 V	-14		-1,6	mA
f_{OSC}	Quantisation frequency of 4x pulses		1.2	2	2.8	MHz
t_{4xW}	Width of 4x pulse		200		500	ns
t_{4xD}	Delay of 4x pulse		500		2000	ns
t_{AW}	Width of alarm-pulse		350		700	ns
t_{4D}	Delay time of alarm-pulse		600		1500	ns
Programming pin mode_C4						
V_{Lo}	mode_C4 Lo state voltage		0		0.3	V
V_{Hi}	mode_C4 Hi state voltage		Vcc-0.3		Vcc	V
R_{open}	mode_C4 permissible load for open	to Vcc or Vcc	500			kOhm
Programming pins M0, M1, M2						
V_{Lo}	Lo state voltage		0		0.3	V
R_{open}	permissible load for Hi	to Vee	500			kOhm

Encoder IC PR5201-XX

Electrical Characteristics

V_{CC} = 5 V, T_J = -40...125°C (unless otherwise noted)

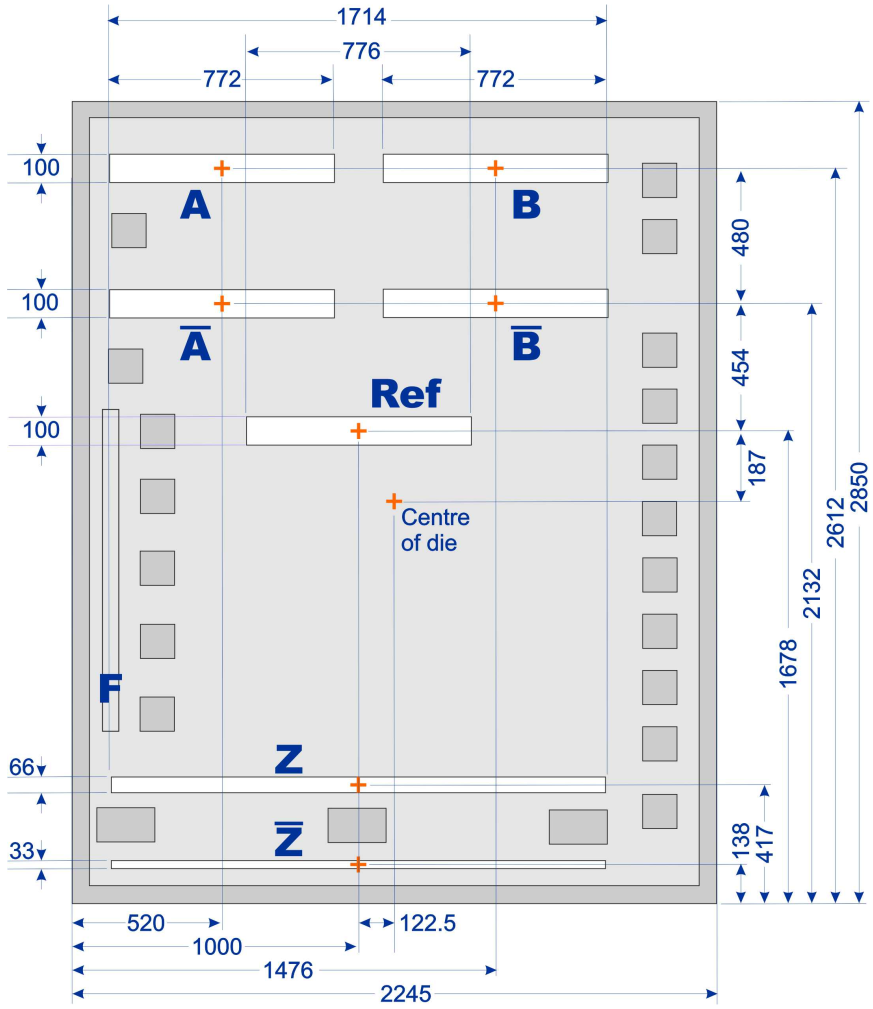
Symbol	Parameter	Conditions	Min	Typ	Max	Units
Test circuit inputs T, TnA, TnB, TnZ						
V_{TP}	No test mode activated		-0.3		0.3	V
Photosensors						
λ_{ar}	Spectral application range	Se(λar)=0.25*λpk	500		950	nm
λ_{peak}	Peak sensitivity			800		nm
LED Current Control						
I_{LED}	LED current control range	V @ pin LED = 2 V	15			mA
I_{SC}	Short-circuit current	V @ pin LED = V_{CC} Tj=27°C		30		mA

Test pins are used for chip test only. Their use is not further described in this document.

Encoder IC PR5201-XX

Photodiodes – Sizes and Locations

Sizes and locations of photodiodes are indicated in the diagram below.



Remarks:

- A, Ā and B, B̄ are the locations of A and B channel photodiodes, respectively.
- Z and Z̄ are the locations of the Z channel photodiodes
- Ref is the reference channel photodiode to measure the illumination on the chip.
- F is fiducial marking for easier alignment of the photodiode. (It is not a photodiode.)
- The crosses mark the centres of the photodiodes.
- Die dimensions are taken from the centre of scribe line.

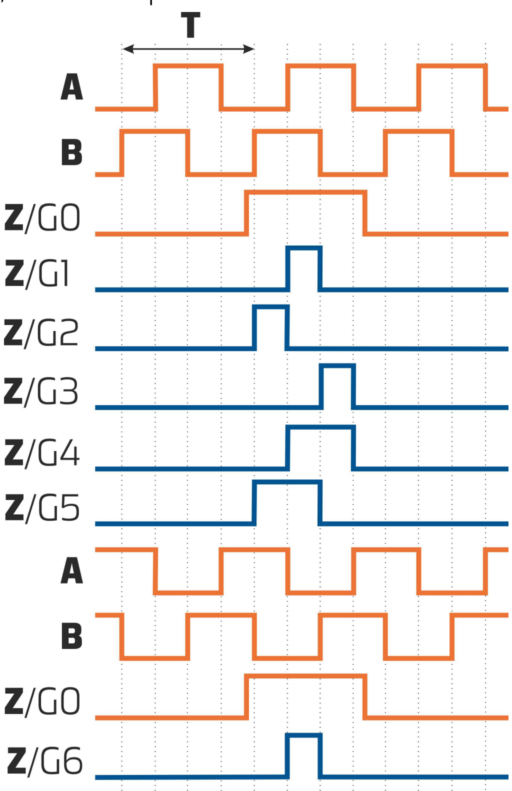
Encoder IC PR5201-XX

Z Pulse Gating Modes G0-G6

Together with a reticle assembled on top of PR5201, the rotating code disk produces a time sequence of bright and dark patterns on the photosensors A, $\overline{A}$, B and $\overline{B}$. PR5201 amplifies the differential signals from photodiodes A and $\overline{A}$, and B and $\overline{B}$, respectively.
The output signal is formed from the differential signals by means of a comparator.
While the A and B outputs are periodic and ideally have a phase shift of 90° against each other, the Z signal is used as an index pulse that occurs once per revolution.

Z PULSE GATING MODES G0-G6

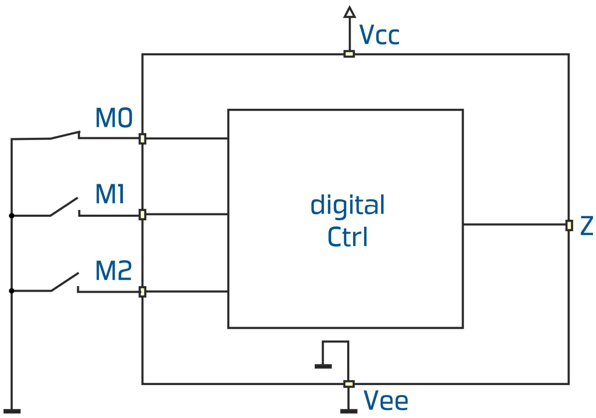
To prevent the variation of the Z-pulse length, it can be synchronized ("gated") with the A and B channel in six different modes G1 ... G6.
In addition, the ungated signal is available in mode G0.
The mode selection is made through a three bit selector, by connecting the M0, M1 and M2 pins either with Vee (Lo) or leaving them open (Hi).
The following diagram shows all gating modes in comparison, and how they are set through M0, M1 and M2 pins.



Remark: In mode **G6**, a proper Z pulse is achieved only with a disk with different phase between Z and A/B pattern than shown in the upper part of this image.

mode	M0	M1	M2	condition	pulse width
G0	Hi	Hi	Hi	ungated	$^3/_4 ... 1^1/_2\,T$
G1	Lo	Hi	Hi	$Z \wedge A \wedge B$	$^1/_4\,T$
G2	Hi	Lo	Hi	$Z \wedge \overline{A} \wedge B$	$^1/_4\,T$
G3	Lo	Lo	Hi	$Z \wedge A \wedge \overline{B}$	$^1/_4\,T$
G4	Hi	Hi	Lo	$Z \wedge A$	$^1/_2\,T$
G5	Lo	Hi	Lo	$Z \wedge B$	$^1/_2\,T$
G6	Hi	Lo	Lo	$Z \wedge \overline{A} \wedge \overline{B}$	$^1/_4\,T$

EXAMPLE FOR SELECTING GATING MODE G1

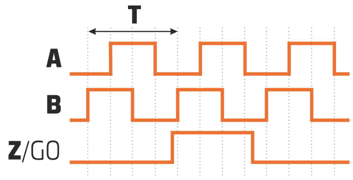


M0 = Lo, M1 = Hi, M2 = Hi

Encoder IC PR5201-XX

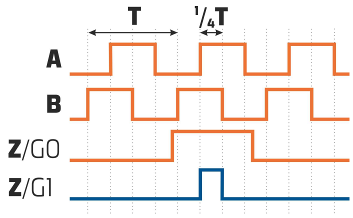
MODE G0

Programming: M0 = Hi, M1 = Hi, M2 = Hi
Z signal logic combination: ungated
Z pulse width: typically $^3/_4$ T...$1^1/_2$ T, depending on optical adjustment and resolution.



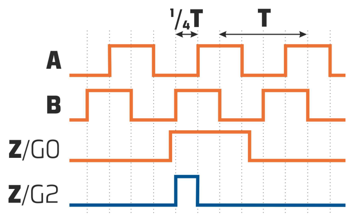
MODE G1

Programming: M0 = Lo, M1 = Hi, M2 = Hi
Z signal logic combination: $Z \wedge A \wedge B$
Z pulse width: $^1/_4$ T



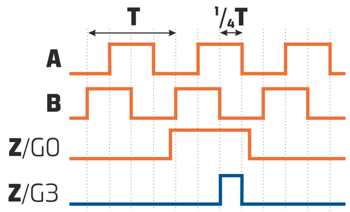
MODE G2

Programming: M0 = Hi, M1 = Lo, M2 = Hi
Z signal logic combination: $Z \wedge \overline{A} \wedge B$
Z pulse width: $^1/_4$ T



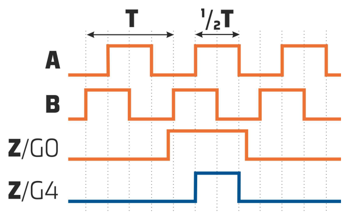
MODE G3

Programming: M0 = Lo, M1 = Lo, M2 = Hi
Z signal logic combination: $Z \wedge A \wedge \overline{B}$
Z pulse width: $^1/_4$ T



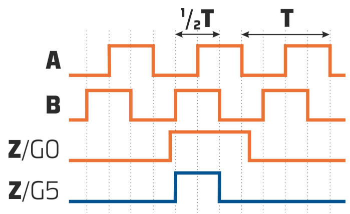
MODE G4

Programming: M0 = Hi, M1 = Hi, M2 = Lo
Z signal logic combination: $Z \wedge A$
Z pulse width: $^1/_2$ T



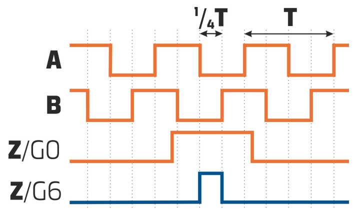
MODE G5

Programming: M0 = Lo, M1 = Hi, M2 = Lo
Z signal logic combination: $Z \wedge B$
Z pulse width: $^1/_2$ T



MODE G6

Programming: M0 = Hi, M1 = Lo, M2 = Lo
Z signal logic combination: $Z \wedge \overline{A} \wedge \overline{B}$
Z pulse width: $^1/_4$ T



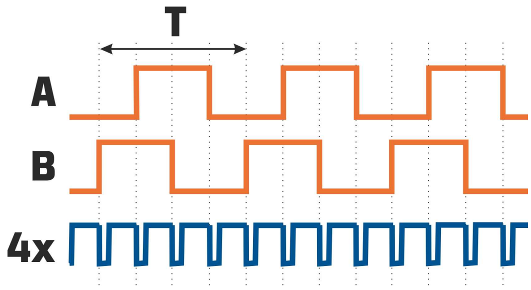
Encoder IC PR5201-XX

Using RL and C4 Signals

For easier use with some digital systems, PR5201 offers an alternative set of output signals. In addition to A and B signals, it provides a clock signal 4x that comes with every T/4 period, plus an information indicating the direction of rotation.

4x PULSES

4x pulses are triggered with each rising or falling edge of A or B channel; hence their frequency is four times the frequency of A or B.
E.g. a code disc with 2048 lines per revolution produces 8192 4x pulses per revolution.



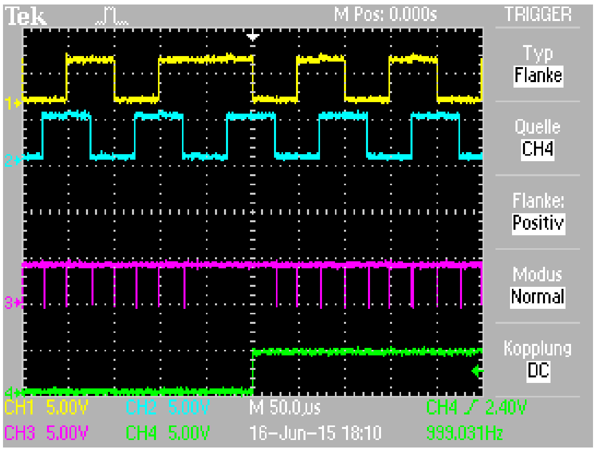
Unlike A, B and Z, 4x pulses have a fixed length, independent of the rotation frequency. The image on the left illustrates one typical 4x pulse (magenta), which is typically 300 ns long.
4x pulses are not synchronised with the A or B edges, but with an internal clock (see "quantisation frequency"). This causes a delay between the triggering event and the 4x pulse.

Due to the synchronisation, the 4x pulse can jitter within one quantisation period. In the example shown on the left, the minimum delay is 730 ns, the maximum is 1170 ns.
If at high speeds the pulse sequence becomes too fast to be resolved, the Alarm output is activated (see chapter "Alarm pin".)

MODE_C4 SETTING

Other than A and B, 4x alone does not contain information about the direction of rotation. This makes it necessary to provide this status in a different way.
For compatibility with different digital systems, these signals can be provided in three different ways at pins C4 and RL, selectable through the mode_C4 pin.
The mode can be set by connecting the mode_C4 pin either to Vcc, Vee, or leaving it open.

mode_C4 connect to	Direction of rotation	Signal at C4-pin	Signal at RL-pin
open	A follows B	4x	Lo
open	B follows A	4x	Hi
Vcc	A follows B	4x	Hi
Vcc	B follows A	Hi	4x
Vee	A follows B	Hi	Lo
Vee	B follows A	Hi	Hi

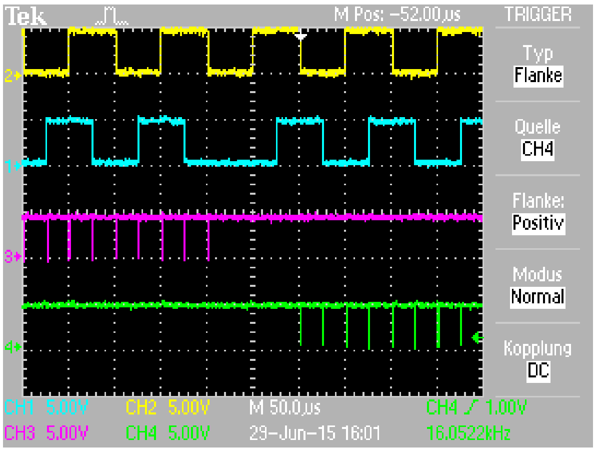


1 (yellow):	A	2 (blue):	B
3 (magenta):	C4	4 (green):	RL

MODE_C4 = OPEN

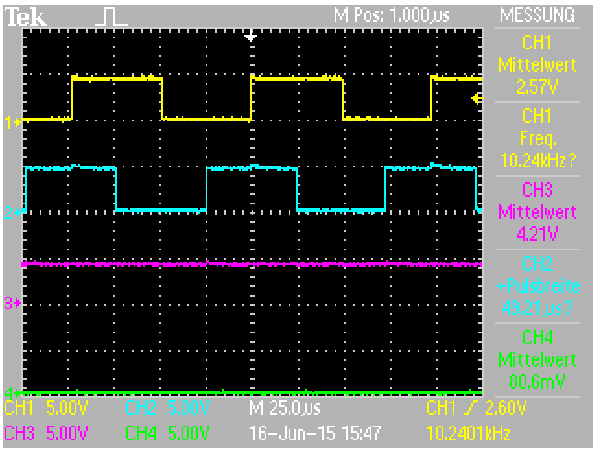
C4 pin provides the 4x signal.
RL = Lo if "A follows B"
RL = Hi if "B follows A"

To avoid erratic signals for an encoder jittering around a static position, the RL signal is changed only after the second edge in the new direction. 4x pulses resume only after the next phase change after RL has changed its status.
When using 4x to count the absolute position, the two skipped pulses cause an offset by two digits between a left turning and a right turning encoder. If needed, this offset may be corrected by the software of the counter.
As the RL phase change is synchronized with the internal clock, there may be an additional delay time.



MODE_C4 = Vcc

This mode is provided for systems expecting up and down counting signals at different inputs.
If "A follows B", 4x is obtained at the C4 pin, and the RL pin is Hi.
If "B follows A", 4x is obtained at the RL pin, and the C4 pin is Hi
Similar to the detailed description above, there is an absolute offset of two digits between left and right turning encoders.



MODE_C4 = Vee

In this mode, the logic state of RL (green) indicates the sense of rotation, while C4 (magenta) is unused and always Hi.
In contrast to the modes described above, the sense of direction is indicated immediately, as it is not synchronized with the quantisation clock.
4x signals are not available in this mode, which is intended for direct evalutation of A and B signals.

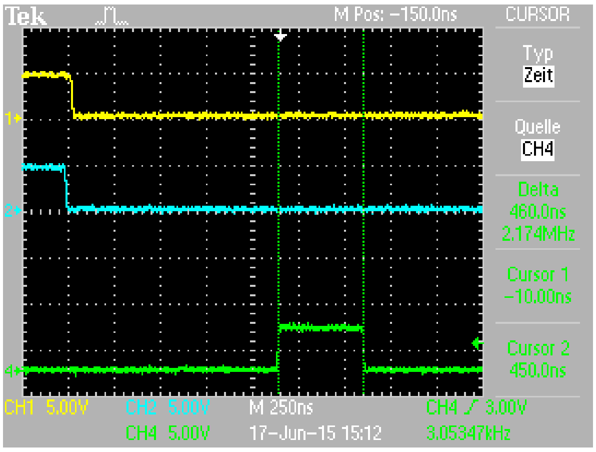
Encoder IC PR5201-XX

Alarm Signal

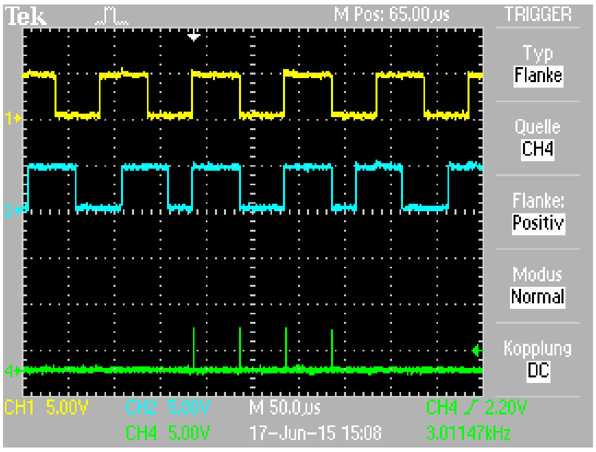
The Alarm pin is activated in two cases:

a) illumination level at reference photodiode too low
b) rotation speed too high for 4x pulses to be resolved

This chapter only deals with condition (b).



If the rotation speed is so high that A and B signals change within the same quantisation cycle (< 700 ns), resulting in missing 4x pulses, PR5201 triggers the Alarm pin. The screenshot shows an alarm-pulse due to a simultaneous A/B phase change. The pulse is typically 500 ns long. As Alarm is synchronized with the internal clock, the delay to the triggering event can vary, but is about 1.1 μs in this example.



Here, two rising and two falling edges of the A and B signals (yellow and blue) are too close together, causing four alarm pulses (green). For each quantisation period in which an error occurs, one alarm pulse is issued.

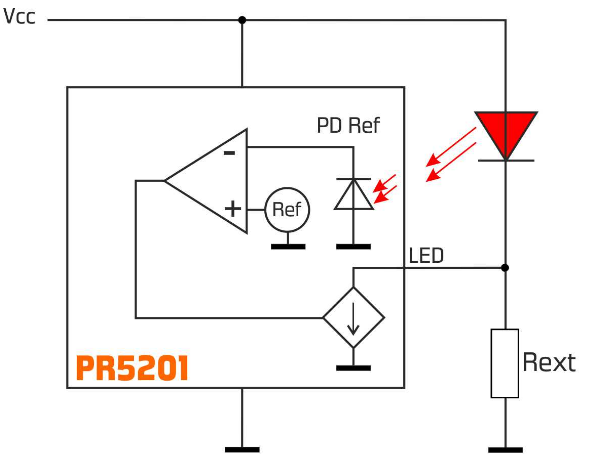
LED Current Regulation

PR5201 uses a reference photodiode to measure the illuminance on the chip.
Through the integrated linear current regulator, this signal can be used to control the LED current to be at the minimum level needed for proper operation, independent of LED ageing.
The LED current needed depends on the LED beam diameter, efficiency, wavelength, and other parameters. Typically LED currents of 5...12 mA will suffice for a high-efficiency LED with 4 mm beam diameter.

LED ALARM

The Alarm pin goes Hi if the illuminance of the Ref photodiode falls below a threshold.
The threshold can be influenced by the width of an aperture over the Ref diode, which is part of the reticle mounted on top of the package.
The LED signal is high as long as the failure condition persists.
The Alarm signal can be used in connection with the internal LED current regulation or with fixed LED current.

INCREASING THE LED CURRENT

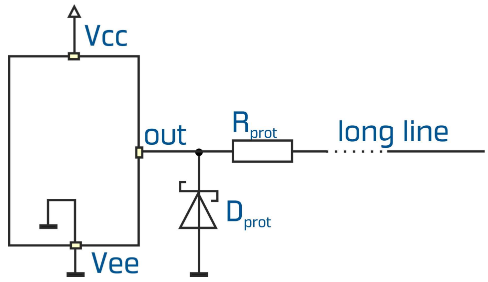


Especially at low supply voltage and when using LEDs with high forward voltage, the current driven by PR5201 may be insufficient.
In this case a constant current can be added to the current regulated by PR5201, by connecting a resistor between the LED pin and Gnd.
In this case, the LED current is given by:

$$I_{LED} = \frac{V_{cc} - V_{LED}}{R_{ext}} + I(LED)$$

Output Driver Latchup Protection

If longer wires are to be connected with the outputs A, B, Z, C4 or RL, it is recommended to protect each output against latchup with the following circuit:



Recommended values are:
R_{prot} > 50 Ohm
D_{prot} type SD130B or equivalent (Schottky type)

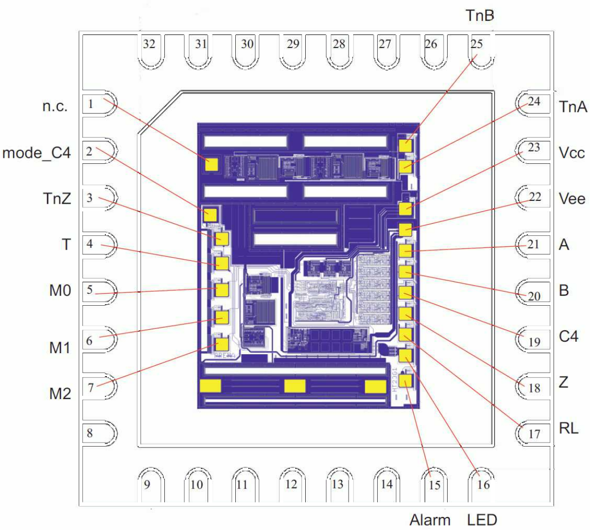
This protection is not required for internal connection on the same PCB, e.g. to line driver or µC.

Encoder IC PR5201-XX

QFN-32L 5x5 TM/OC - Pinning

Beside bare dice (BD) or chip-on-board (CB), the optical encoder PR5201 is offered in a QFN-32L 5x5 package. For different temperature requirements two QFN-32L 5x5 packages are available with a transparent mold compound (TM) or with an open cavity (OC) including a filler material.
Both packages (TM and OC) are pin compatible and use the same footprint.

PIN DESCRIPTION



QFN-32L 5x5 package
(view from top)

Temperature ranges are
QFN-32L 5x5 OC: -40 - +125°C *
QFN 32L 5x5 TM: -40 - +85°C *
* preliminary specification; qualification in progress

OC and TM type packages have a moisture sensitivity level (MSL) of 3.
A lead-free solder profile with a peak temperature of 260°C or less, according to J-STD-020 should be followed.

Samples shipped without moisture barrier bag must be dry-baked according to JEDEC guidelines before soldering. Manual soldering may not be possible or must be done with utmost care.

Direct infrared heating should be avoided; pure convection heating is recommended. There is no experience with gas phase soldering.

Pin No	Pin Name	Pin Function Description
1	n.c.	do not connect
2	mode_C4	mode_C4 (C4 mode select)
3	TnZ	TnZ (test input Z invert)+
4	T	T (test input comp volt)+
5	M0	M0 (gating selection)
6	M1	M1 (gating selection)
7	M2	M2 (gating selection)
8-14	n.c.	not connected
15	Alarm	Alarm (LED alarm)
16	LED	LED (LED current control)
17	RL	RL
18	Z	Z (Z pulse)
19	C4	C4
20	B	B (B channel)
21	A	A (A channel)
22	Vee	Vee
23	Vcc	Vcc
24	TnA	TnA (test input A invert)+
25	TnB	TnB (test input B invert)+
26-32	n.c.	not connected
pad	n.c.	central pad not connected

+ Test pins are for chip test only and not further described in this document. They should not be connected on the PCB.

Chip centre may be offset by up to 50 µm from package centre in any direction.

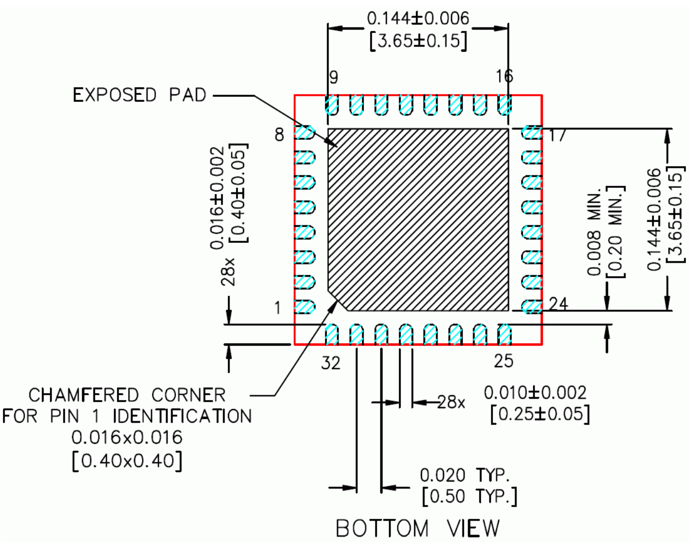
Encoder IC PR5201-XX

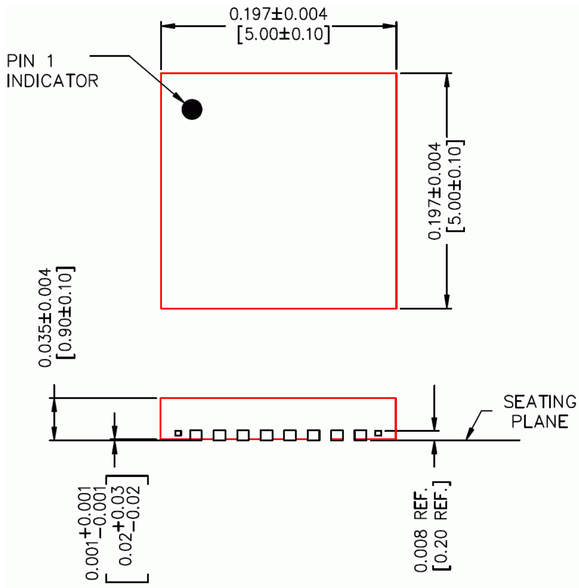
QFN-32L 5x5 TM/OC - Dimensions

Both packages (TM and OC) are pin compatible and use the same footprint

PR5201-TM – A COMPLETE TRANSPARENT QFN-32L-5x5 PACKAGE

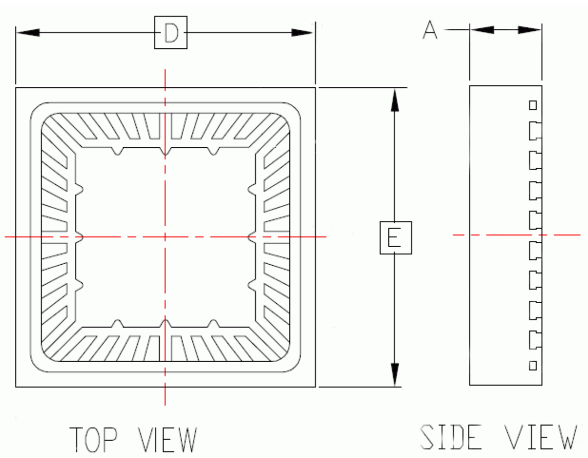
Optical QFN package 32 leads, 5.0 mm x 5.0 mm

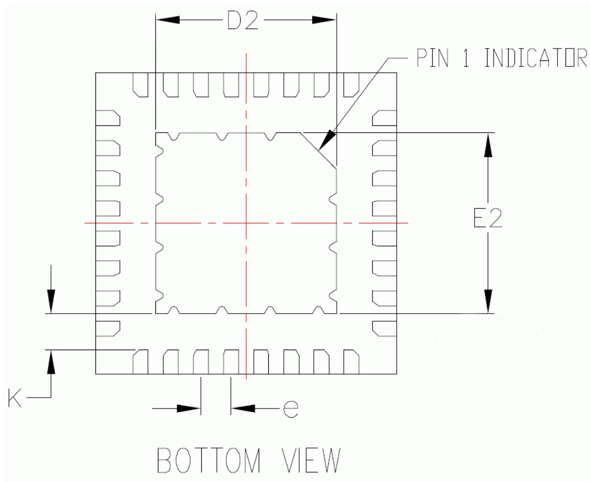




PR5201-OC – OPEN CAVITY QFN-32L-5x5 PACKAGE WITH A TRANSPARENT FILLER MATERIAL

Open Cavity Package QFN 32 leads, 5.0 mm x 5.0 mm





Dimensions [mm]:
A = 1.35 max.
D = 5.0 ± 0.1
D2 = 3.0 ± 0.1

E = 5.0 ± 0.1
E2 = 3.0 ± 0.1
e = 0.50
K = 0.40 ± 0.05

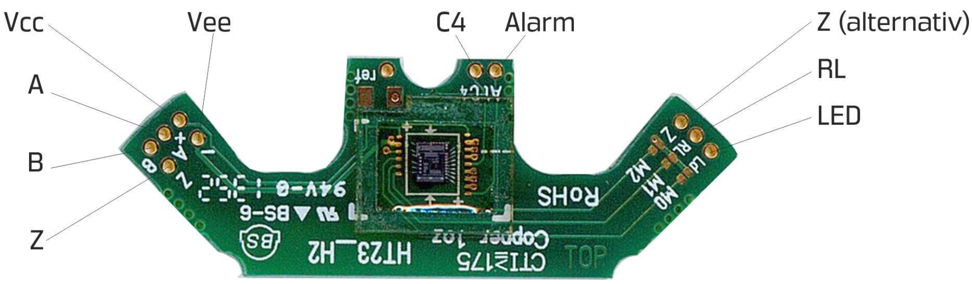
Encoder IC PR5201-XX

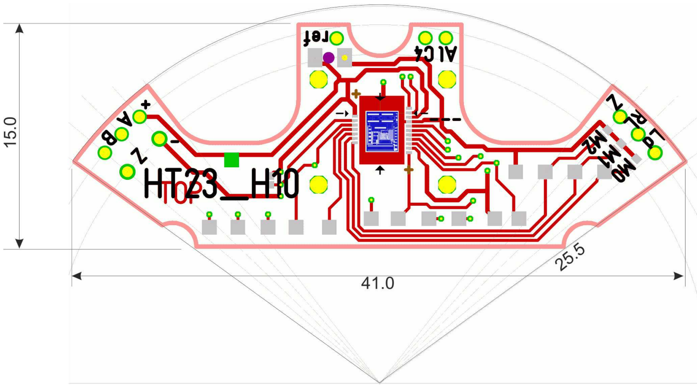
Chip-on-board Technique for Standard and Individual Solutions

The PR5201-CB is offered as Chip-on-board. Some existing solutions are on stock and can be delivered within short time. For individual applications, printed circuit board (PCBs) can also be designed and produced according to your geometrical requirements for shape of the PCB and location of the connectors.

PR5201-CB – CHIP-ON-BOARD TECHNIQUE

The bare die is bonded to the PCB, enclosed by a plastic frame and covered by a silicone material.

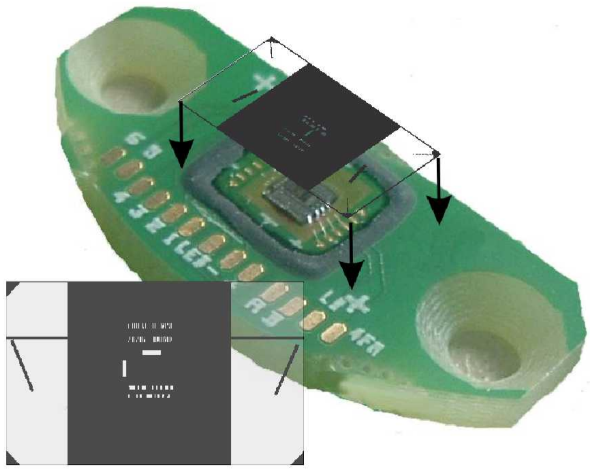




These images show a sample PCB for encoders with inner case diameter of at least 52 mm.

MOUNTING A RETICLE

The reticle can be bonded on top of the frame. An innovative method allows to align the reticle against the photodiodes in PR5201 in a short assembly time.



Notes

Disclaimer

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