

# iC-PT...H Encoder blue® Series

## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 1/14

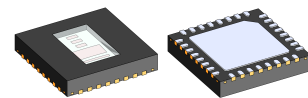
### FEATURES

- ◆ For code discs of  $\varnothing$  33 mm: [iC-PT3320H](#), [3348H](#), [3325H](#)
- ◆ Compact, high resolution incremental encoder ICs with up to 2500 CPR (native) and 10,000 CPR (interpolated)
- ◆ Monolithic *HD Phased Array* with excellent signal matching
- ◆ Moderate track pitch for relaxed assembly tolerances
- ◆ Low-noise signal amplifiers with high EMI tolerance
- ◆ Pin-selectable operating modes:  
analog, compared (x1), interpolated (x2, x4)
- ◆ Pin-selectable index gating:  
ungated (1 T), B-gated (0.5 T), AB-gated (0.25 T)
- ◆ Complementary quadrature outputs: A, B, Z and NA, NB, NZ
- ◆ Commutation signal outputs: U, V, W
- ◆ Short-circuit-proof, current-limited, +/- 4 mA push-pull
- ◆ Analog signal output for ease of alignment and resolution enhancement by external interpolation
- ◆ LED power control with 40 mA high-side driver
- ◆ Low power consumption from single 3.5V to 5.5V supply
- ◆ Operating temperature range of -40 °C to +120 °C
- ◆ Evaluation kits with LED and code disc available for sampling

### APPLICATIONS

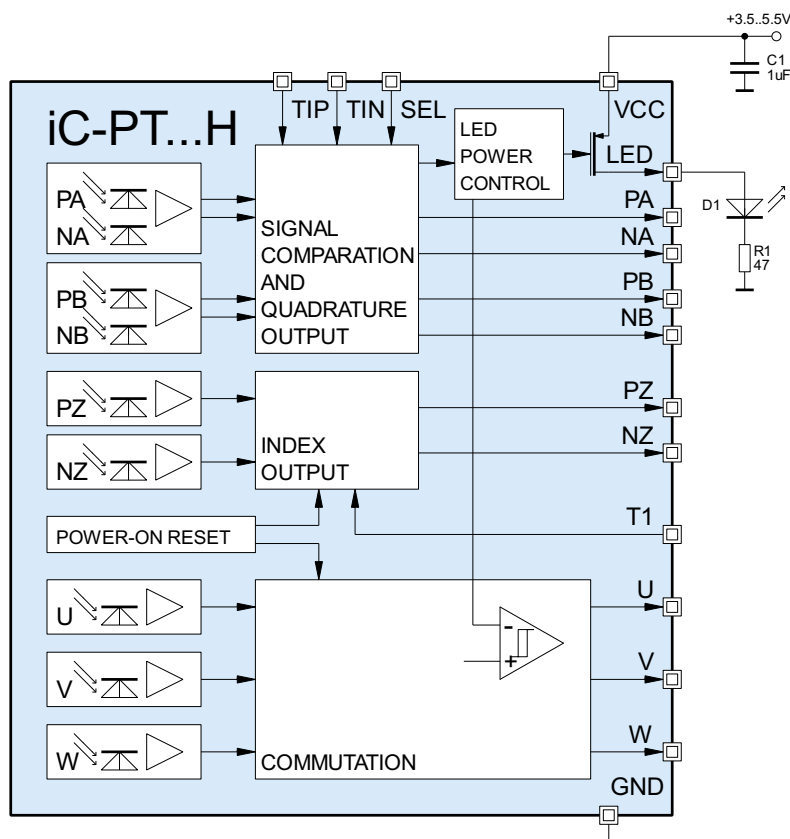
- ◆ Incremental encoder
- ◆ Brushless DC motor commutation
- ◆ Industrial drives

### PACKAGES



32-pin optoQFN  
5 mm x 5 mm x 0.9 mm  
RoHS compliant

### BLOCK DIAGRAM



### DESCRIPTION

The iC-PT H-series represents advanced optical encoder ICs featuring integrated photosensors arranged as an *HD Phased Array*, providing signal fidelity at relaxed alignment tolerances.

Its typical application are incremental encoders for motor speed control and commutation. To this end, the devices provide differential A/B tracks, a differential index track and three more tracks to generate block commutation signals.

Where the optical radius and the native cycles per revolution (CPR) are determined by the device version, the adaption to the motor polecount is carried out by the code disc, for instance with 4 CPR and 90 degree phase shift to operate 4-phase brushless motors<sup>1)</sup>.

Encoder blue<sup>®</sup> series devices feature *blue-enhanced* photosensors requiring the application of a LED with short wavelength, preferably iC-TL46. An outstanding jitter performance is the key benefit due to the improvements in signal contrast.

Low-noise transimpedance amplifiers, arranged in a paired layout to ensure excellent channel matching, are used to convert the scanner's signals into voltages of several hundred millivolts<sup>2)</sup>.

Precision comparators with hysteresis generate the digital signals subsequently, either native or interpolated, which are then output by differential  $\pm 4$  mA push-pull drivers.

The built-in averaging LED power controller with its 40 mA driver permits a direct connection of the encoder LED. The received optical power is kept constant regardless of aging effects or changes in temperature.

Various operating modes are selectable at multi-level input SEL<sup>3)</sup>: digital output with native (x1) or interpo-

lated resolution (x2 or x4), analog output or mixed analog/digital output; the latter combines an output of sine/cosine signals with comparated UVW commutation signals. During analog operation the amplified signal voltages are available at the outputs for inspection and monitoring of encoder assembly, or to feed external interpolation circuits.

Index gating is also pin-selectable at input T1<sup>3)</sup>: the options are ungated, respectively T-gated if using interpolated output, B-gated and AB-gated.

All devices run at single-sided supplies from 3.5 V up to 5.5 V and feature a low power consumption.

#### iC-PT33xxH Encoder blue<sup>®</sup> Series

Optical radius 14.5 mm, code disc  $\varnothing$  33.0 mm;  
Native CPR: 2000, 2048, 2500.

<sup>1)</sup> Standard on code discs available for sampling.

<sup>2)</sup> Operating point varies by device version and CPR.

<sup>3)</sup> For ease of replacement, iC-PT H-Series pin functions are backwards compatible to iC-PT series ICs (except for iC-PT3325 which does not feature pin T1).

Encoder blue is a trademark of iC-Haus GmbH.

#### General notice on materials under excessive conditions

Epoxy resins (such as solder resists, IC package and injection molding materials, as well as adhesives) may show discoloration, yellowing, and surface changes in general when exposed longterm to high temperatures, humidity, irradiation, or due to thermal treatments for soldering and other manufacturing processes.

Equally, standard molding materials used for IC packages can show visible changes induced by irradiation, among others when exposed to light of shorter wavelengths, blue light for instance. Such surface effects caused by visible or IR LED light are rated to be of cosmetic nature, without influence to the chip's function, its specifications and reliability.

Note that any other material used in the system (e.g. varnish, glue, code disc) should also be verified for irradiation effects.

# iC-PT...H Encoder blue® Series

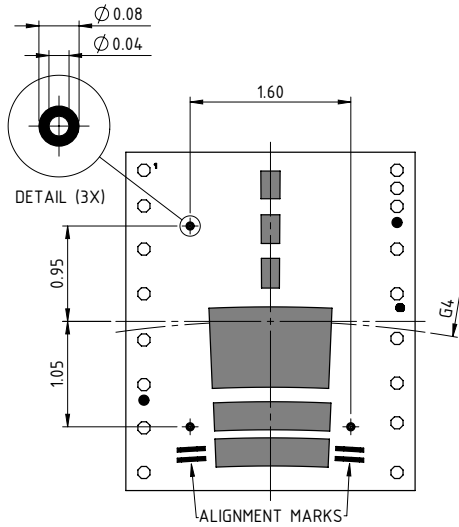
## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 3/14

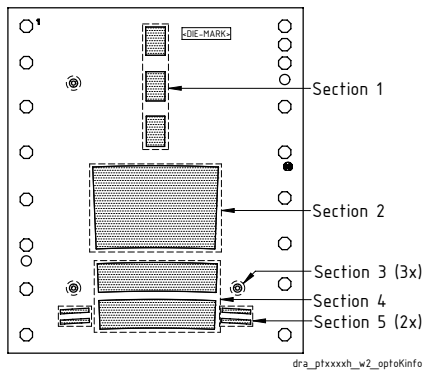
### PACKAGING INFORMATION

#### CHIP LAYOUT



Chip layout example for chip release W2 featuring alignment markings.  
Grey sections represent sensor layout areas; fill factors vary.

#### SENSOR LAYOUT



#### AOI CRITERIA

<Die Mark>	<Section>	<Area Class> <sup>1</sup>
iC PT3320H W2	1, 4, 5	A40
	2, 3	A25
iC PT3348H W2	1, 4, 5	A40
	2, 3	A25
iC PT3325H W2	1, 4, 5	A40
	2, 3	A25

<sup>1</sup> Selection class for the optical inspection of detector areas. Refer to [Optical Selection Criteria](#) for further description.

# iC-PT...H Encoder blue® Series

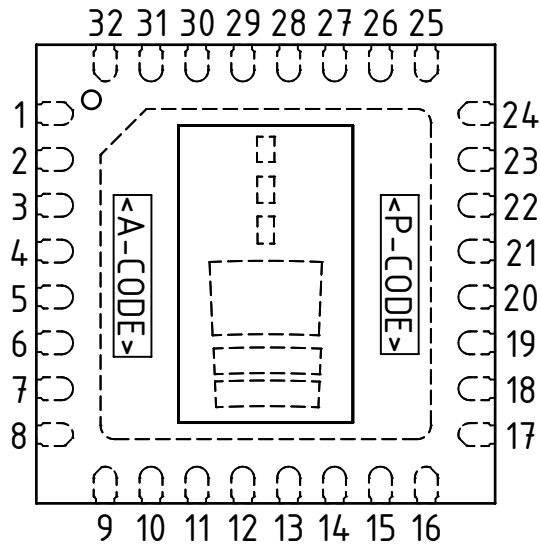
## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 4/14

### PIN CONFIGURATION

oQFN32-5x5 (5 mm x 5 mm)



### PIN FUNCTIONS

No.	Name	Function
1	VCC	+3.5 V...+5.5 V Supply Voltage
2	LED	LED Controller, High-Side Current Source Output
3	PA	Push-Pull Output A+ / Analog Sin+ <sup>1</sup>
4	NA	Push-Pull Output A- / Analog Sin-
5	PB	Push-Pull Output B+ / Analog Cos+
6	NB	Push-Pull Output B- / Analog Cos-
7	PZ	Push-Pull Output Z+ / Analog Z+
8	NZ	Push-Pull Output Z- / Analog Z-
9..16	n.c. <sup>2</sup>	
17	SEL	Op. Mode Selection Input: 100% VCC = x2 interpolated 75% VCC = ABZ analog, UVW digital 50% VCC (or pin open) = all analog 25% VCC = x4 interpolated 0% VCC = x1 compared (native res.)
18	W	Push-Pull Output W / Analog W
19	TIN	Negative Test Current Input <sup>3</sup>
20	V	Push-Pull Output V / Analog V
21	TIP	Positive Test Current Input <sup>3</sup>
22	U	Push-Pull Output U / Analog U
23	T1	Index Gating Selection Input: lo = 0.5 T (B-gated), hi = 1 T (ungated/T-gated), open = 0.25 T (AB-gated)
24	GND	Ground
25..32	n.c.	
	BP	Backside Paddle <sup>4</sup>

IC top marking: <P-CODE> = product code, <A-CODE> = assembly code (subject to changes);

<sup>1</sup> Capacitive pin loads must be avoided when using the analog output signals.

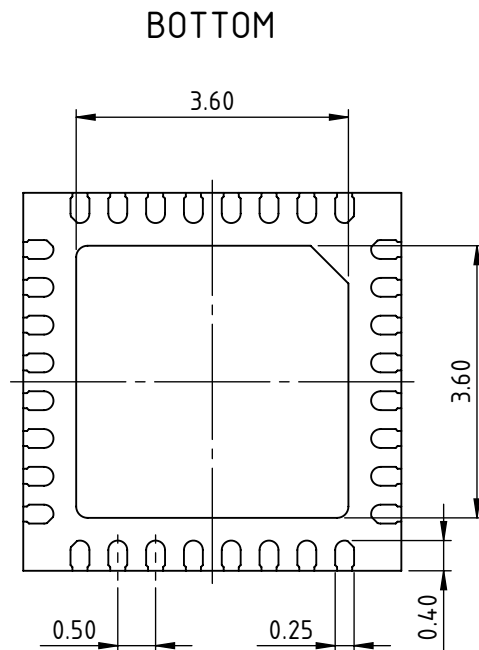
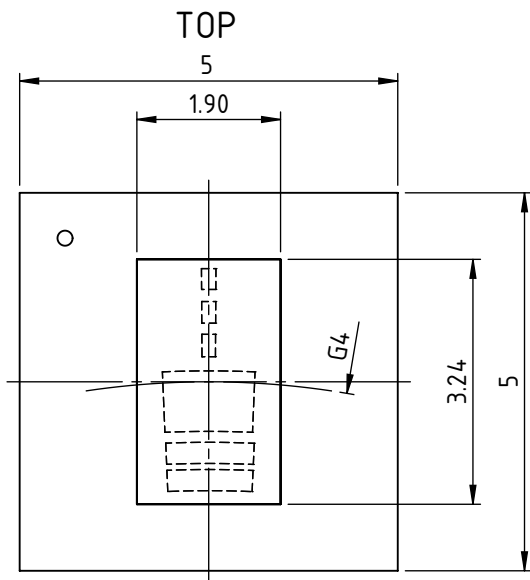
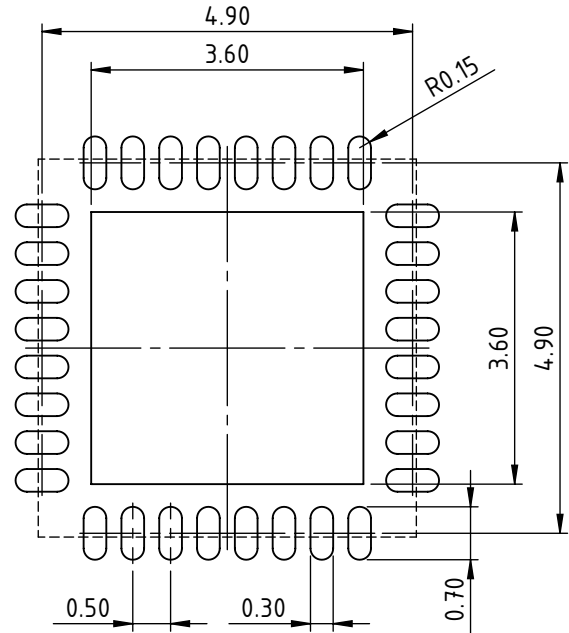
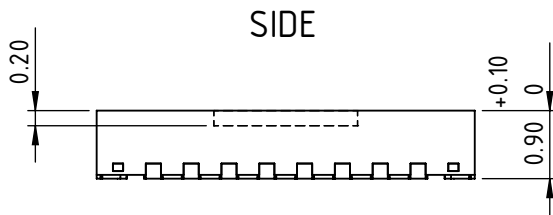
<sup>2</sup> Pin numbers marked n.c. are not connected.

<sup>3</sup> The test pins TIP and TIN may remain unconnected.

<sup>4</sup> Connecting the backside paddle is recommended by a single link to GND. A current flow across the paddle is not permissible.

**PACKAGE DIMENSIONS**

**RECOMMENDED PCB-FOOTPRINT**



All dimensions given in mm. General Tolerances of form and position according to JEDEC MO-220.  
 Positional tolerance of sensor pattern:  $\pm 70\mu\text{m}$  /  $\pm 1^\circ$  (with respect to center of backside pad).  
 G4: radius of chip center (refer to the relevant encoder disc and code description).  
 Maximum molding excess  $+20\mu\text{m}$  /  $-75\mu\text{m}$  versus surface of glass. Small pits in the mold surface, which may occasionally appear due to the manufacturing process, are cosmetic in nature and do not affect reliability.

# iC-PT...H Encoder blue<sup>®</sup> Series

## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 6/14

### ABSOLUTE MAXIMUM RATINGS

These ratings do not imply operating conditions; functional operation is not guaranteed. Beyond these ratings device damage may occur.

Item No.	Symbol	Parameter	Conditions			Unit
				Min.	Max.	
G001	VCC	Voltage at VCC		-0.3	6	V
G002	I(VCC)	Current in VCC		-20	170	mA
G003	V()	Voltage at all Pins		-0.3	VCC + 0.3	V
G004	I()	Current in PA, NA, PB, NB, PZ, NZ, U, V, W, TIP, TIN, SEL, T1		-20	20	mA
G005	I()	Current in LED		-120	20	mA
G006	Vd()	ESD Susceptibility, all pins	HBM, 100 pF discharged through 1.5 kΩ		2	kV
G007	Tj	Junction Temperature		-40	150	°C

### THERMAL DATA

Operating conditions: VCC = 3.5...5.5 V

Item No.	Symbol	Parameter	Conditions				Unit
				Min.	Typ.	Max.	
T01	Ta	Operating Ambient Temperature Range		-40		120	°C
T02	Ts	Permissible Storage Temperature Range		-40		120	°C
T03	Tpk	Soldering Peak Temperature	tpk < 20 s, convection reflow tpk < 20 s, vapor phase soldering  MSL 5A (max. floor life 24 h at 30 °C and 60 % RH); Please refer to customer information file No. 7 for details.			245 230	°C °C

All voltages are referenced to ground unless otherwise stated.

All currents flowing into the device pins are positive; all currents flowing out of the device pins are negative.

# iC-PT...H Encoder blue<sup>®</sup> Series

## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 7/14

### ELECTRICAL CHARACTERISTICS

Operating conditions: VCC = 3.5...5.5 V, Tj = -40...125 °C, λ<sub>LED</sub> = 460 nm, unless otherwise noted

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>Total Device</b>							
001	VCC	Permissible Supply Voltage		3.5		5.5	V
002	I(VCC)	Supply Current	photocurrents within op. range, no load		6		mA
<b>Photosensors</b>							
101	λar	Spectral Application Range	Se(λar) = 0.25 x S(λpk)	400		700	nm
<b>Photocurrent Amplifiers</b>							
201	Z()	Equivalent Transimpedance Gain	Z = Vout() / Iph(), Tj = 27 °C; for PA, PB, NA, NB for PZ, NZ for U, V, W		0.5 1.25 2...3		MΩ MΩ MΩ
<b>Analog Outputs: PA, NA, PB, NB, PZ, NZ, U, V, W</b>							
301	Vout()mx	Permissible Max. Output Voltage		1.8			V
303	Vout()ac	AC Signal Level	LED iC-TL46		0.2...0.3		Vpp
304	Vout()d	Dark Signal Level	I() < 10 μA	560	770	985	mV
305	Ri()	Output Resistance		250	750	2250	Ω
306	Isc()hi	Short-Circuit Current hi	SEL open, load current to ground	300	1000	1700	μA
307	Isc()lo	Short-Circuit Current lo	SEL open, load current to IC	50	85	130	μA
<b>Comparators</b>							
401	Vt()hys	Switch Hysteresis			24		mV
<b>LED Power Control</b>							
501	Iop()	LED Output Current Control Range		0		40	mA
502	Ictrl()	Controlled LED Output Current	refer to Table 2 for details		5...12		mA
503	Vs()hi	Saturation Voltage hi	Vs()hi = VCC - V(LED); I() = -40 mA			0.6	V
504	Isc()hi	Short-Circuit Current hi	V() = 0 V	-150		-50	mA
<b>Digital Outputs: PA, NA, PB, NB, PZ, NZ, U, V, W</b>							
601	fout	Maximum Output Frequency	x1 compared (native resolution) x2 interpolated x4 interpolated	400 800 1600			kHz kHz kHz
602	AArel	AB Duty Cycle Variation	AC signal according to item 303, compared or interpolated, see Figure 1	-10		10	%
603	Vs()lo	Saturation Voltage lo	I() = 4 mA			0.6	V
605	Isc()lo	Short-Circuit Current lo	V() = VCC	7		70	mA
606	Vs()hi	Saturation Voltage hi	Vs()hi = VCC - V(), I() = -4 mA			0.6	V
608	Isc()hi	Short-Circuit Current hi	V() = 0 V	-70		-7	mA
<b>Operating Mode Selection Input: SEL</b>							
701	Vmod()	Mode Selection (see Figure 2)	x2 interpolated analog ABZ, digital UVW all analog x4 interpolated x1 compared (native resolution)	95 70 45 20 0		100 80 55 30 5	%VCC %VCC %VCC %VCC %VCC
702	Vmod()hys	Hysteresis			10		%VCC
704	V0()	Pin-Open Voltage		45	50	55	%VCC
705	Rpd()	Pull-Down Resistor	V(SEL) = VCC	65			kΩ
706	Rpu()	Pull-Up Resistor	V(SEL) = 0 V	65			kΩ

### ELECTRICAL CHARACTERISTICS

Operating conditions: VCC = 3.5...5.5 V, Tj = -40...125 °C, λ<sub>LED</sub> = 460 nm, unless otherwise noted

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
<b>Index Gating Selection Input: T1</b>							
801	Vgate()	Gating Selection (see Figure 3)	ungated (1 T with interpolation) AB-gated (0.25 T) B-gated (0.5 T)	82 32 0		100 68 18	%VCC %VCC %VCC
802	Vgate()hys	Hysteresis			10		%VCC
804	V0()	Pin-Open Voltage	for index length 0.25 T (AB-gated)	45	50	55	%VCC
805	Rpd()	Pull-Down Resistor	V(T1) = VCC	65			kΩ
806	Rpu()	Pull-Up Resistor	V(T1) = 0 V	65			kΩ
<b>Test Inputs: TIP, TIN</b>							
Z101	Ipd()	Pull-Down Current	test mode not active, V() = 0.4 V	60	100		μA
Z102	It(on)	Test Mode Activation Threshold			130	190	μA
Z103	V()test	Test Pin Operating Voltage	test mode active, I() = 200 μA		1.5		V
Z104	I()test	Permissible Test Current	test mode active	10		1000	μA
Z105	CR()	Current Ratio I()test/Iph()	test mode active, I() = 200 μA		1000		

### ELECTRICAL CHARACTERISTICS: Diagrams

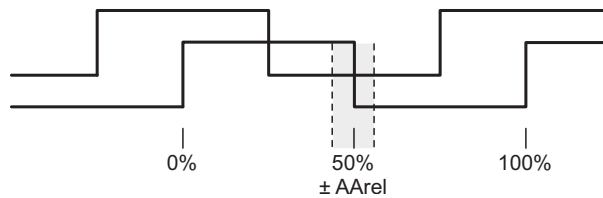


Figure 1: Definition of AB duty cycle variation.

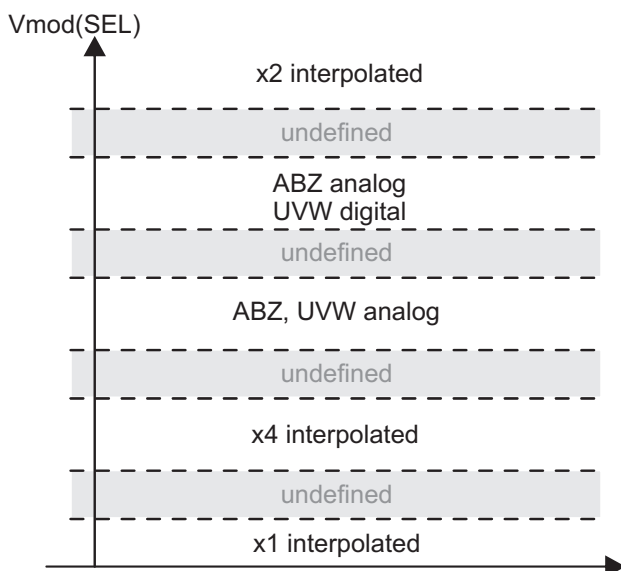


Figure 2: Operating mode selection at pin SEL.

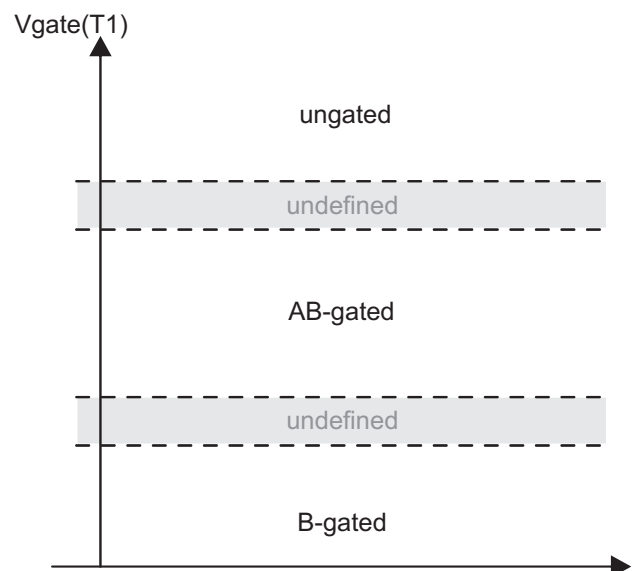


Figure 3: Index gating selection at pin T1.



### DIGITAL OUTPUT SIGNALS

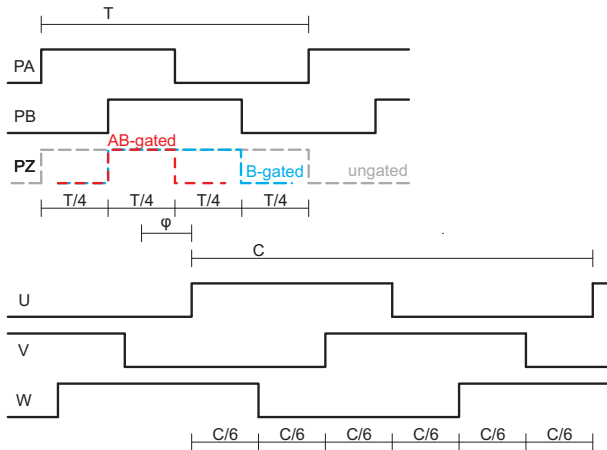


Figure 4: Encoder quadrature signals and motor commutation signals.

iC-PT H-series devices determine the optical radius and the native cycles per revolution for the quadrature outputs by its phased array design.

The U, V, W commutation signals can be configured independently of the device: the pulse count, period length and phase shift is determined by the code disc.

Standard code discs available for sampling provide 4 CPR each for U/V/W, with a period length of 90 degrees (C). A phase shift of 0 degrees ( $\varphi$ ) between U and Z edges must be considered during alignment. Ideally, the rising edge of U meets the index Z.

For detailed specifications, refer to the relevant code disc datasheets, available separately.

### ANALOG OUTPUT SIGNALS

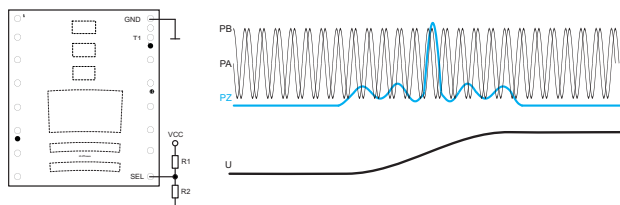


Figure 5: Example of analog ABZ / analog UVW (pin SEL = 50% VCC)

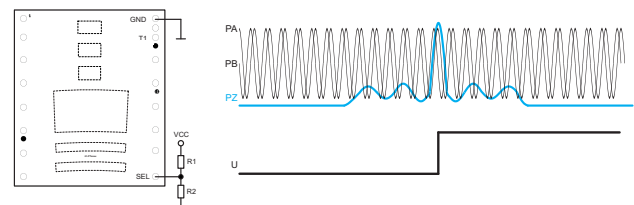


Figure 6: Example of analog ABZ / digital UVW (pin SEL = 75% VCC)

The iC-PT H-series features 5 principle operation modes which are selectable by the voltage applied to pin SEL. A voltage divider as suggested by Table 1 is the easiest way to obtain this.

SEL	R1 <sup>1)</sup>	R2 <sup>1)</sup>	Operation Mode
100 % VCC	0 $\Omega$	open	x2 interpolated
75 % VCC	2.7 k $\Omega$	8.2 k $\Omega$	analog ABZ, dig. UVW
50 % VCC	4.7 k $\Omega$ (open)	4.7 k $\Omega$ (open)	all analog
25 % VCC	8.2 k $\Omega$	2.7 k $\Omega$	x4 interpolated
0 % VCC	open	0 $\Omega$	x1 compared

1) Exemplary values.

Table 1: Selection of operation mode by pin SEL.

If input SEL is left open, the IC biases its input at 50% VCC and analog output signals are available for test and alignment.

Analog output signals may also be used to increase the encoder's resolution by connecting an external interpolation IC. In this case the analog signals are required permanently, so that noise immunity should be improved by wiring pin SEL to an external reference providing VCC/2.

Setting 75 % VCC may be considered to obtain analog signals at PA/PB/PZ and NA/NB/NZ outputs feeding the external interpolation IC, together with digital signals at U/V/W directly connecting a line driver. Special attention to the PCB layout should be paid to avoid cross talk; analog and digital lines should be separated carefully.

### INDEX GATING AND INTERPOLATION

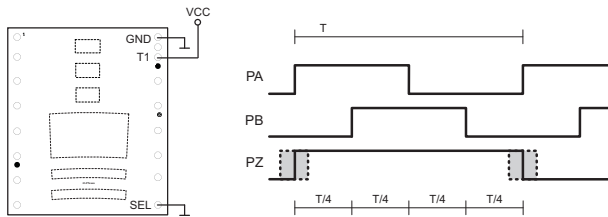


Figure 7: Ungated index (T1 = high),  
x1 compared (SEL = low).

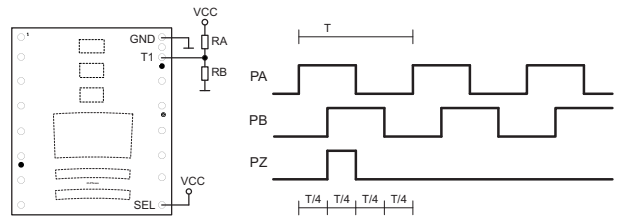


Figure 12: AB-gated index (T1 = open or VCC/2),  
x2 interpolated (SEL = high).

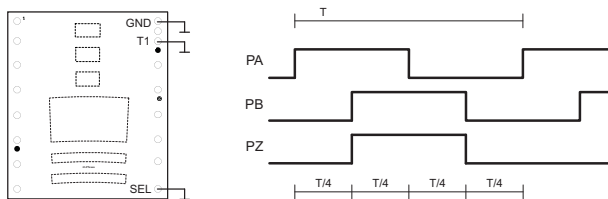


Figure 8: B-gated index (T1 = low),  
x1 compared (SEL = low).

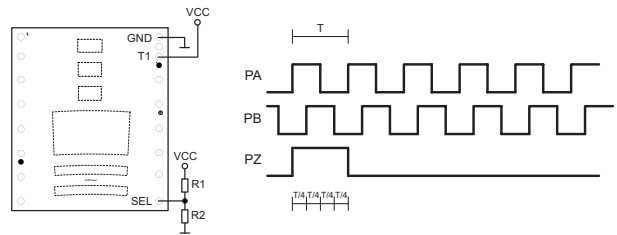


Figure 13: T-gated index (T1 = high),  
x4 interpolated (SEL = 25% VCC).

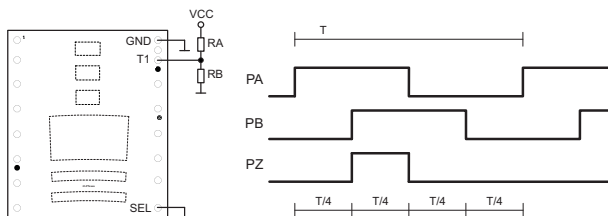


Figure 9: AB-gated index (T1 = open or VCC/2),  
x1 compared (SEL = low).

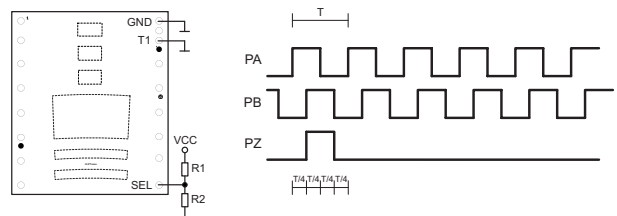


Figure 14: B-gated index (T1 = low)  
x4 interpolated (SEL = 25% VCC).

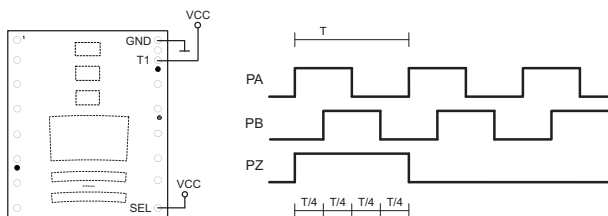


Figure 10: T-gated index (T1 = high),  
x2 interpolated (SEL = high).

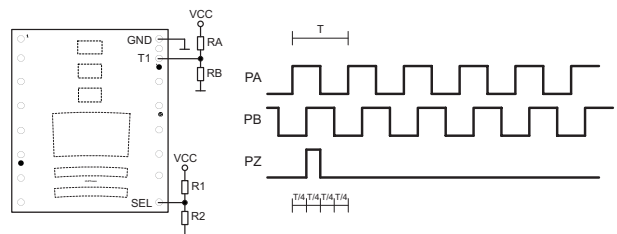


Figure 15: AB-gated index (T1 = open or VCC/2)  
x4 interpolated (SEL = 25% VCC).

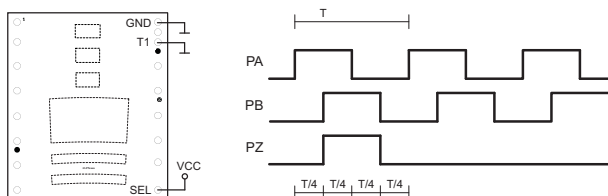


Figure 11: B-gated index (T1 = low),  
x2 interpolated (SEL = high).

### DEVICE OVERVIEW

Device	CPR native	Code Disc P/O Code	Material	Permissible Max. RPM	Typ. LED Current <sup>1)</sup>		Comments
					iC-TL85	iC-TL46	
<b>∅ 33 Series</b>							
iC-PT3320H	2000	PT04HFS 33-2000_4 PT04S 33-2000_4	film glass <sup>2)</sup>	12,000	n/a	9 mA	
iC-PT3348H	2048	PT17HFS 33-2048_4 PT17S 33-2048_4	film glass <sup>2)</sup>	11,700	n/a	8 mA	
iC-PT3325H	2500	PT05HFS 33-2500_4 PT05HS 33-2500_4	film glass	9,600	n/a	3.4 mA	

Device availability on request.

<sup>1)</sup> Controlled LED output current of IC (DC average); according to Elec. Char. No. 502.

<sup>2)</sup> Code disc design made for iC-PTxx series.

Table 2: Device overview

### TEST MODE

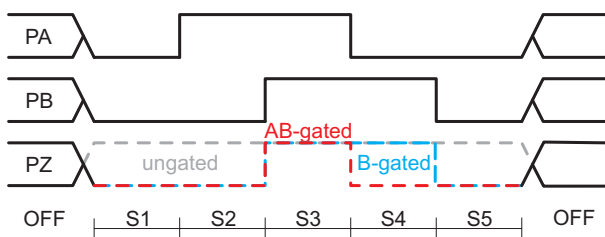


Figure 16: Output states during test mode  
(SEL = low: x1 compared)

State	I(TIP)	I(TIN)	Function	Wiring Instruction
OFF	$I(TIP) \leq 10 \mu A$	$I(TIN) \leq 10 \mu A$	Normal operation	
S1	$I(TIP) \geq 190 \mu A$ $I(TIP) \approx 300 \mu A$	$I(TIN) \geq 190 \mu A$ $I(TIN) \approx 300 \mu A$	Test mode activation (low-level at PA, PB)	Pull-up TIP and TIN by 10 kΩ each to 5V.
S2	$I(TIP) \approx 700 \mu A$	$I(TIN) \approx 300 \mu A$	Force high-level at PA	Add pull-up to TIP of 4.7 kΩ to 5V.
S3	$I(TIP) \approx 700 \mu A$	$I(TIN) \approx 700 \mu A$	Force high-level at PA, PB, PZ	Add pull-up to TIN of 4.7 kΩ to 5V.
S4	$I(TIP) \approx 300 \mu A$	$I(TIN) \approx 700 \mu A$	Keep high-level at PB (and PZ if B-gated)	Disconnect 4k7 pull-up from TIP.
S5	$I(TIP) \approx 300 \mu A$	$I(TIN) \approx 300 \mu A$	(low-level at all outputs)	Disconnect 4k7 pull-up from TIN.
OFF	$I(TIP) \leq 10 \mu A$	$I(TIN) \leq 10 \mu A$	Normal operation	All pull-ups removed.

Table 3: Selection of output states.

### DESIGN REVIEW: Notes On Chip Functions

PT3320H chip release W2 PT3348H PT3325H		
No.	Function, Parameter/Code	Description and Application Hints
		None at time of printing.

Table 4: Design review

### APPLICATION NOTES

Application notes for iC-PT H-series devices are available separately.

### REVISION HISTORY

Rel.	Rel. Date <sup>1</sup>	Chapter	Modification	Page
A3	2014-12-19	...	Initial release of Encoder blue series	all

Rel.	Rel. Date <sup>1</sup>	Chapter	Modification	Page
B1	2016-08-01	DESCRIPTION	General notice added	2
		PACKAGING INFORMATION	Chip layout supplemented, update of drawings (chip rel. W2)	3
		ELECTRICAL CHARACTERISTICS	Item 101: max. value, item 201: typ. UVW gain, item 303: min. value Block Z supplemented for test inputs	7
		TEST MODE	New chapter added	10
		DEVICE OVERVIEW	Table 5: Correction of discs and P/O codes	10
		ORDERING INFORMATION	Glass code disc supplemented	12

Rel.	Rel. Date <sup>1</sup>	Chapter	Modification	Page
C2	2021-10-08	PACKAGING INFORMATION	Sensor layout added for AOI, footnote with hyperlink to customer information	3
		PACKAGE DIMENSIONS	Update of package drawing and footnote	5
		ABSOLUTE MAXIMUM RATINGS	Redundant G008 (Ts) deleted	6
		ELECTRICAL CHARACTERISTICS	Items 302ff moved to 303ff Items 306, 307: added as new items	7
		DEVICE OVERVIEW	iC-PT3325H: LED current corrected	11

<sup>1</sup> Release Date format: YYYY-MM-DD

# iC-PT...H Encoder blue® Series

## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 13/14

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# iC-PT...H Encoder blue® Series

## 6-CH. PHASED ARRAY OPTO ENCODERS



Rev C2, Page 14/14

### ORDERING INFORMATION

Type	Package	Options	Order Designation
iC-PTnnnnH	32-pin optoQFN, 5 mm x 5 mm, 0.9 mm thickness RoHS compliant	nnnn = device version  Encoder blue® devices	iC-PTnnnnH oQFN32-5x5  iC-PT3320H oQFN32-5x5 iC-PT3348H oQFN32-5x5 iC-PT3325H oQFN32-5x5
Code Disc	film disc 0.18 mm  glass disc 1.0 mm	nn = design number aa = diameter xxxx = AB pulse count ID u = UVW pulse count ID  for Encoder blue® devices	PTnnHFS aa-xxxx_u  PT04HFS 33-2000_4 PT17HFS 33-2048_4 PT05HFS 33-2500_4  PT05HS 33-2500_4
Evaluation Kit	Kit with Scanner Module IC273 (61 mm x 64 mm), LED Module IC274 and Code Disc	nnnn = device version	iC-PTnnnn EVAL IC273
Illumination	Blue LED module (28 mm x 29 mm)	assembled with iC-TL46 (460 nm)	iC-TL46 EVAL IC274
Mother Board	Adapter PCB (80 mm x 110 mm)	incl. ribbon cable	iC277 EVAL IC277

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