iC-PNE Series

OCTAL NONIUS PHASED ARRAY ENCODERS

preliminary

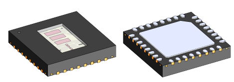
FEATURES

- Compact, high resolution absolute encoder ICs for up to 25 bit singleturn resolution (with nonius interpolation)
- For code discs of ∅ 26 mm, ∅ 33 mm, ∅ 39 mm
- Monolithic 3-channel *HD Phased Array* with excellent signal matching
- Moderate track pitch for reduced cross talk
- Ultra low dark currents for operation up to high temperature
- Low noise amplifiers with high transimpedance gain
- Enhanced EMI tolerance by low impedance differential, short-circuit-proof, analog sine/cosine outputs
- Embedded octal sector detection by 4 digital tracks from 1.8 V upwards (4-bit Gray code)
- Low power consumption from single 4.1 to 5.5 V supply
- Operational temperature range of -40 °C to +125 °C
- Space saving optoQFN package (RoHS compliant)
- Evaluation kits with LED and code disc available for sampling

APPLICATIONS

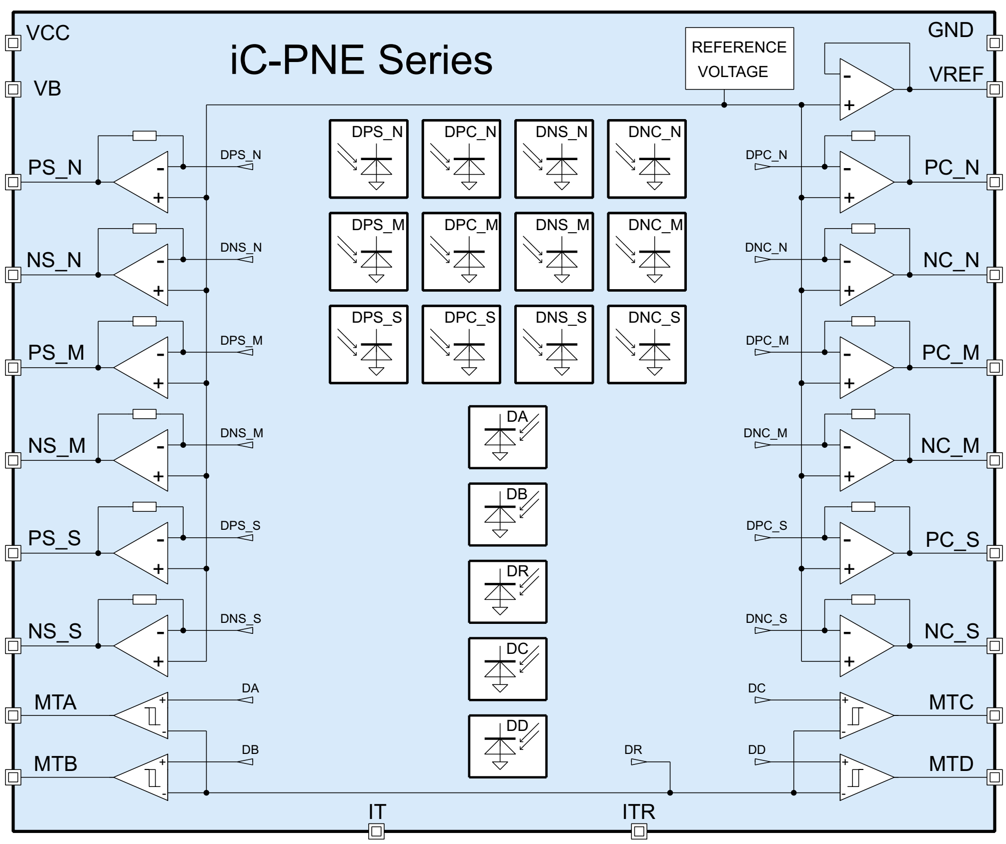
- Absolute position encoders
- AC servo feedback

PACKAGES



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

BLOCK DIAGRAM



DESCRIPTION

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

Its precision sine/cosine output signals allow a high-resolution interpolation by subsequent devices: a singleturn position can be resolved with up to 25 bit utilizing the 3-channel nonius interpolation of iC-MNF. For this, iC-MNF employs its MT interface to read the revolution count as well as the sector information prepared by an external logic or MCU.

The typical application of iC-PNE devices are absolute position encoders for motion control and drive applications.

iC-PNE scans 8 tracks in total, whereof 3 analog tracks feature phased-arrays of multiple photosensors, each per track, generating positive and negative going sine signals, as well as positive and negative going cosine signals. An excellent matching and common mode behavior of the differential signal paths is obtained by a paired amplifier design. Due to a typical transimpedance gain of 1 MΩ, the output signal level reaches a few hundred millivolts at low light conditions already.

Additionally, 5 digital tracks are implemented for absolute position scanning, providing sector detection for repeated Nonius scales. For example, the standard code disc for iC-PNE repeats the Nonius scale after 45 degrees, i.e. 8x per revolution, and provides a 4-bit Gray code for differentiation.

Sector detection can be used already at low supply voltages from 1.8 V up; the power consumption is low unless other sections are biased. Full operation requires a single-sided supply of 4.1 V to 5.5 V.

iC-PNE2612
Optical radius 11.0 mm, code disc ∅ 26.0 mm;
(8x 63/64/60 CPR)

iC-PNE2648 EncoderBlue®
Optical radius 11.0 mm, code disc ∅ 26.0 mm;
(8x 255/256/240 CPR)

iC-PNE3312
Optical radius 14.5 mm, code disc ∅ 33.2 mm;
(8x 63/64/60 CPR)

iC-PNE3348 EncoderBlue®
Optical radius 14.5 mm, code disc ∅ 33.2 mm;
(8x 255/256/240 CPR)

iC-PNE3912
Optical radius 17.5 mm, code disc ∅ 39.2 mm;
(8x 63/64/60 CPR)

iC-PNE3948
Optical radius 17.5 mm, code disc ∅ 39.2 mm;
(8x 255/256/240 CPR)

EncoderBlue® devices feature *blue-enhanced* photosensors requiring the application of a LED with short wavelength of about 460 nm, preferably iC-TL46. An outstanding signal performance is the key benefit due to the improvements of optical contrast.

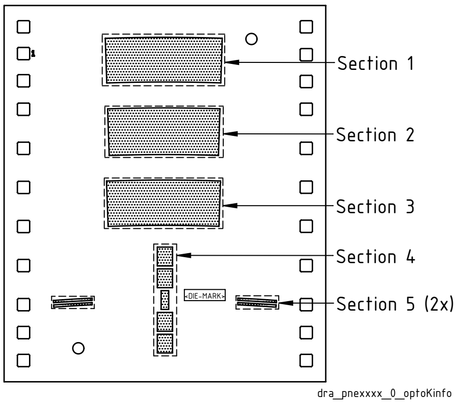
General notice on materials under excessive conditions
Epoxy resins (such as solder resists, IC package and injection molding materials, as well as adhesives) may show discoloration, yellowing, and surface changes in general when exposed longterm to high temperatures, humidity, irradiation, or due to 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.

PACKAGING INFORMATION

SENSOR LAYOUT



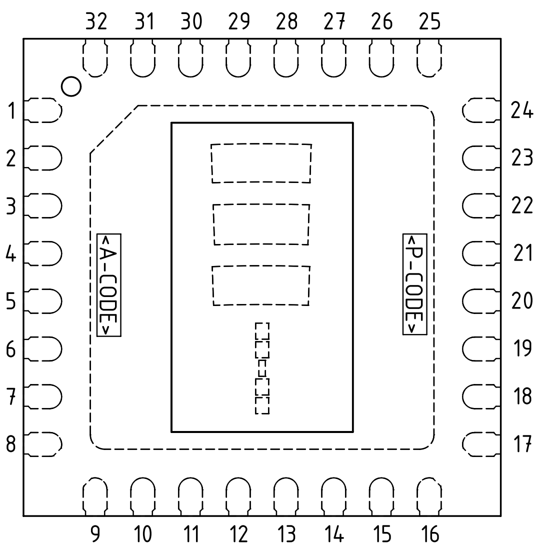
Chip layout example. Grey sections represent sensor layout areas; fill factors vary.

AOI CRITERIA

<Die Mark>	<Section>	<Area Class>[1]
iC PNE2612		
iC PNE2648		
iC PNE3312		
iC PNE3348		
iC PNE3912		
iC PNE3948		
	1, 3	A25
	2, 4	A16
	5	A40

[1] Selection class for the optical inspection of detector areas. Refer to Optical Selection Criteria for further description.

PIN CONFIGURATION
oQFN32-5x5 (5 mm x 5 mm)

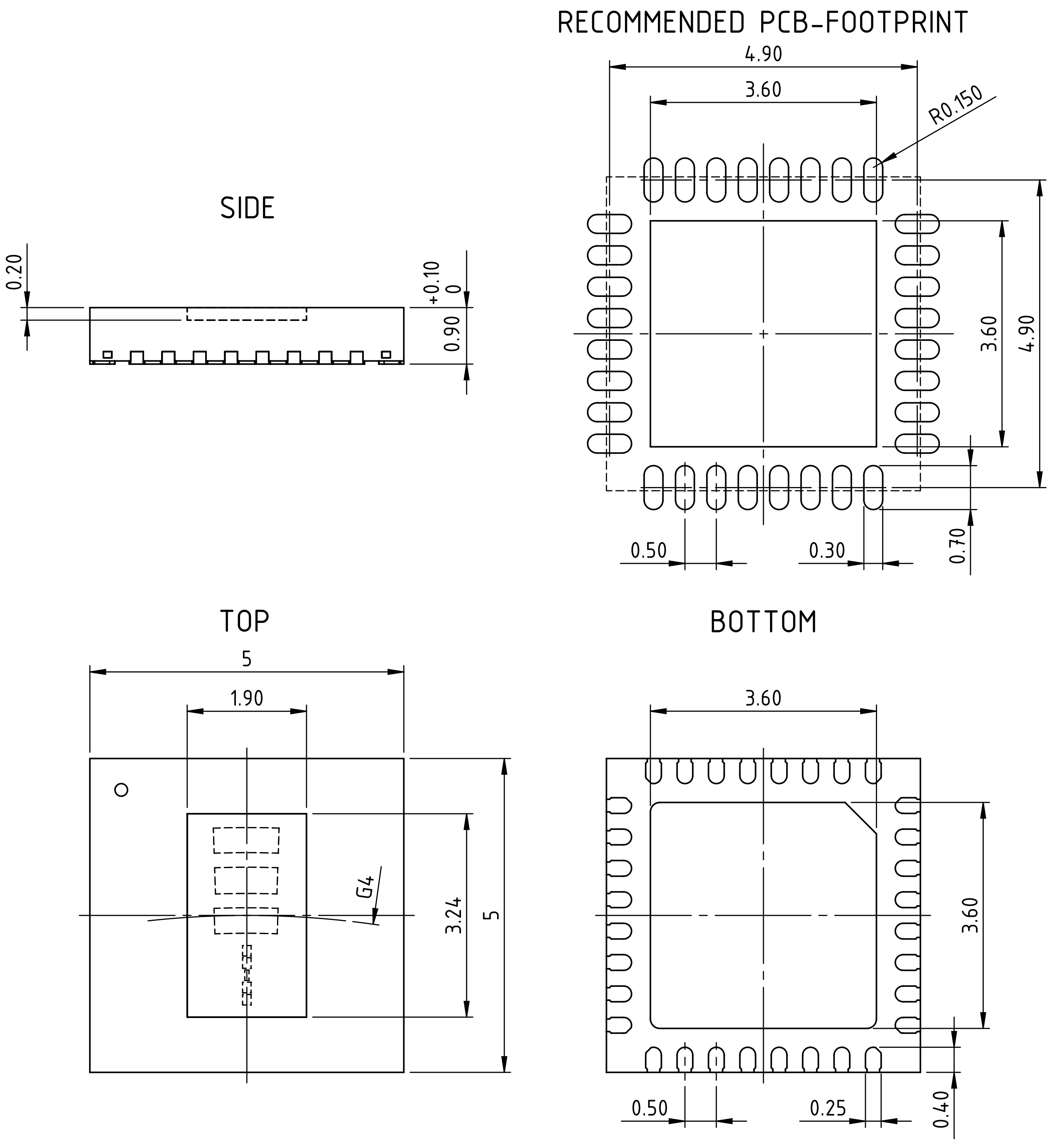


PIN FUNCTIONS

No.	Name	Function
1	VCC	+4.1..5.5 V Supply Voltage
2	VREF	Reference Voltage Output
3	PS_N	N-Track Sine +
4	NS_N	N-Track Sine -
5	PS_M	M-Track Sine +
6	NS_M	M-Track Sine -
7	PS_S	S-Track Sine +
8	NS_S	S-Track Sine -
9	MTD	Digital Output D
10	ITR[2]	Test Input
11..14	n.c.[1]	
15	IT[2]	Test Input
16	MTC	Digital Output C
17	NC_S	S-Track Cosine -
18	PC_S	S-Track Cosine +
19	NC_M	M-Track Cosine -
20	PC_M	M-Track Cosine +
21	NC_N	N-Track Cosine -
22	PC_N	N-Track Cosine +
23	MTB	Digital Output B
24	GND	Ground
25	MTA	Digital Output A
26..31	n.c.[1]	
32	VB	+1.8..5.5 V Digital Supply Voltage
	BP[3]	Backside paddle

IC top marking: <P-CODE> = product code, <A-CODE> = assembly code (subject to changes);
[1] Pin numbers marked n.c. are not connected.
[2] Pin can be left open or connected to ground.
[3] Connecting the backside paddle is recommended by a single link to GND. A current flow across the paddle is not permissible.

PACKAGE DIMENSIONS



All dimensions given in mm. General Tolerances of form and position according to JEDEC MO-220.
Positional tolerance of sensor pattern: ±70µm / ±1° (with respect to center of backside pad).
G4: radius of chip center (refer to the relevant encoder disc and code description).
Maximum molding excess +20µm / -75µm 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.

dra_oqfn32-5x5-4_pnexxxx_0_pack_1, 10:1

ABSOLUTE MAXIMUM RATINGS

Beyond these values damage may occur; device operation is not guaranteed.

Item No.	Symbol	Parameter	Conditions	Min.	Max.	Unit
G001	VCC, VB	Voltage at VCC, VB		-0.3	6	V
G002	I(VCC), I(VB)	Current in VCC, VB		-20	20	mA
G003	V()	Pin Voltage MTA, MTB, MTC, MTD all other signal outputs		-0.3 -0.3	VB + 0.3 VCC + 0.3	V V
G004	I()	Pin Current, all signal outputs		-20	20	mA
G005	Vd()	ESD Susceptibility, all pins	HBM, 100 pF discharged through 1.5 kΩ CDM (JEDEC Standard No. 22-C101F)		2000 750	V V
G006	Tj	Junction Temperature		-40	150	°C
G007	Ts	Chip Storage Temperature		-40	150	°C

THERMAL DATA

Operating conditions: VCC = 4.1...5.5 V

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
T01	Ta	Operating Ambient Temperature Range	package oQFN32-5x5	-40		125	°C
T02	Ts	Storage Temperature Range	package oQFN32-5x5	-40		125	°C
T03	Tpk	Soldering Peak Temperature	package oQFN32-5x5; tpk < 20 s, convection reflow tpk < 20 s, vapor phase soldering MSL 5A (max. floor life 24 h at 30 °C and 60 % RH); Refer to Handling and Soldering Conditions 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.

ELECTRICAL CHARACTERISTICS

Operating conditions: VCC = 4.1...5.5 V, VB = 0 V, Tj = -40..125 °C, unless otherwise stated.

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Total Device							
001	VCC	Permissible VCC Supply Voltage	regular operation	4.1		5.5	V
002	I(VCC)	VCC Supply Current	no load, Vout() < Vout()mx		13	20	mA
Photosensors							
101	λar	Spectral Application Range	Se(λar) = 0.25 x S(λpk)	400		950	nm
102	λpk	Peak Sensitivity Wavelength			680		nm
104	S(λ)	Spectral Sensitivity	λ_{LED} = 460 nm λ_{LED} = 740 nm λ_{LED} = 850 nm		0.3 0.5 0.35		A/W A/W A/W
Photocurrent Amplifiers							
201	Iph()	Permissible Photocurrent Operating Range		0		1120	nA
202	η()r	Photo Sensitivity (light-to-voltage conversion ratio)	λ_{LED} = 460 nm with EncoderBlue® λ_{LED} = 740 nm λ_{LED} = 850 nm		0.3 0.5 0.35		V/µW V/µW V/µW
203	Z()	Equivalent Transimpedance Gain	Z = Vout() / Iph()	0.7	1.0	1.4	MΩ
204	TCz	Temperature Coefficient of Transimpedance Gain			-0.12		%/°C
205	ΔZ()pn	Transimpedance Gain Matching	inside channel: P vs. corresponding N output, or sine vs. cosine output	-3		3	%
206	ΔVout()pn	Signal Matching	signal average to signal average of Master vs. Nonius, Master vs. Segment, Nonius vs. Segment channel	-40		40	mV
207	ΔVout()pn	Dark Signal Matching	no illumination; inside channel, any output vs. any output Master channel outputs vs. VREF	 -2.5 -2.5		 2.5 2.5	 mV mV
208	fc()hi	Cut-off Frequency (-3 dB)			400		kHz
209	VNoise()	RMS Output Noise	illuminated to 500 mV signal level above dark level, 500 kHz band width		0.5		mV
Signal Outputs							
301	Vout()mx	Permissible Max. Output Voltage	refer to Figure 1, VCC > 4.3 V VCC > 4.1 V	2.0 1.8			V V
302	Iout()mx	Permissible Max. Load Current		-100		250	µA
303	Vout()d	Dark Signal Level	no illumination, I() $\leq$ 50 µA	600	900	1150	mV
304	Isc()hi	Short-Circuit Current hi	load current to ground	100	420	1300	µA
305	Isc()lo	Short-Circuit Current lo	load current to IC	250	480	700	µA
306	ton()	Power-On Settling Time	VCC = 0 V $\rightarrow$ 5 V			100	µs
Reference Output VREF							
401	VREF	VREF Reference Voltage Output	I(VREF) = -100...+300 µA	600	900	1150	mV
402	TC()	VREF Temperature Coefficient			-1.3		mV/°C
404	Isc()hi	VREF Short-Circuit Current hi	load current to ground	200	420	2000	µA
405	Isc()lo	VREF Short-Circuit Current lo	load current to IC	0.5	4.5	10	mA
Digital Outputs MTA, MTB, MTC, MTD and Supply VB							
601	VB	Permissible VB Supply Voltage		1.8		5.5	V
602	I(VB)	Supply Current in VB	MTA...MTD not loaded; VB = 1.8...3.6 V VB > 3.6 V			300 350	µA µA
603	ton(VB)	VB Power-Up Settling Time for MTA, MTB, MTC, MTD Operation	VB = 0 V $\rightarrow$ 1.8 V, without illumination; refer to Figure 2			10	µs
604	Vs()hi	Saturation Voltage hi at MTA, MTB, MTC, MTD	Vs()hi = VB - V(), I() = -130 µA			0.4	V
605	Vs()lo	Saturation Voltage lo at MTA, MTB. MTC, MTD	I() = 200 µA			0.4	V

ELECTRICAL CHARACTERISTICS

Operating conditions: VCC = 4.1...5.5 V, VB = 0 V, Tj = -40..125 °C, unless otherwise stated.

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
606	ton_LED	Recommended Illumination Time	Gray-code scanning by DA to DD sensors: Iph(DA to DD) = 100...260 nA, Iph(DR) = 180 nA See Figure 3 and note on verification.	3			µs
607	tp1()	Output Validity at MTA, MTB, MTC, MTD	see Figure 3; output stable for readout after LED on			3	µs
608	tp2()	Output Validity at MTA, MTB, MTC, MTD	see Figure 3; output stable for readout after LED off	0.2			µs
610	Iph()ofs	Photosensor Offset Current	I(DA, DB, DC, DD) vs. I(DR)	-5		+5	nA
611	Iph()hys	Equivalent Photosensor Input Hysteresis	difference of hi←→lo switching points at MTA, MTB, MTC, MTD	0.3		8	nA
Device Specific: iC-PNE2612							
V101	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.063 0.021		mm^2 mm^2
V102	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 740 nm, Vout() not saturated		1.6		mW/cm^2
Device Specific: iC-PNE2648							
V201	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.063 0.021		mm^2 mm^2
V202	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 460 nm, Vout() not saturated		1.6		mW/cm^2
Device Specific: iC-PNE3312							
V301	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.058 0.019		mm^2 mm^2
V302	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 740 nm, Vout() not saturated		1.7		mW/cm^2
Device Specific: iC-PNE3348							
V401	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.046 0.015		mm^2 mm^2
V402	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 460 nm, Vout() not saturated		2.2		mW/cm^2
Device Specific: iC-PNE3912							
V501	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.070 0.023		mm^2 mm^2
V502	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 740 nm, Vout() not saturated		1.4		mW/cm^2
Device Specific: iC-PNE3948							
V601	Aph()	Radiant Sensitive Area	sensors of N/M/S tracks sensors of MTA to MTD tracks		0.060 0.020		mm^2 mm^2
V602	E()mxr	Irradiance For Max. Signal Level	λ_{LED} = 740 nm, Vout() not saturated		1.5		mW/cm^2

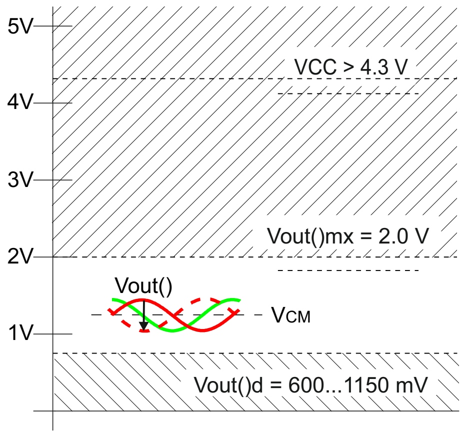


Figure 1: Permissible maximum output voltage range and example of typical output voltage.

Note: With a state of the art optical path and assembly of the encoder, the operating range for the signal output at MTA to MTD may be extended to 1/3 of the nominal illumination level (i.e. LED current at 33 %).

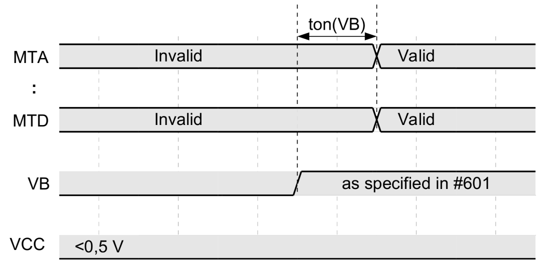


Figure 2: Outputs MTA to MTD operated from auxiliary supply VB.

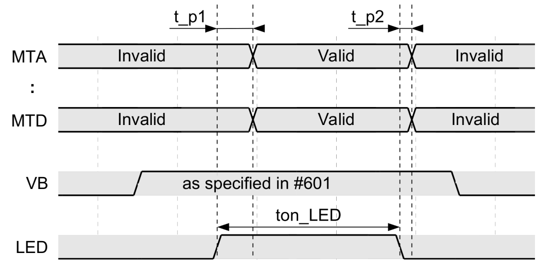


Figure 3: MTA to MTD output validity depending on LED flash.

APPLICATION CIRCUITS

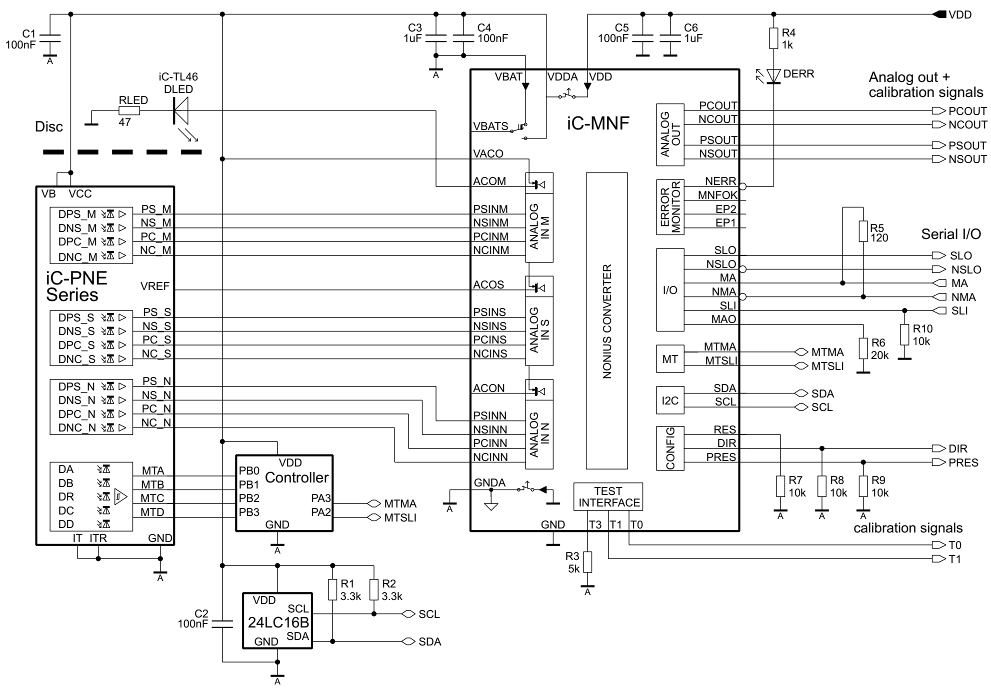


Figure 4: Application example for an absolute singleturn encoder using a controller for Gray binary conversion and SSI output to iC-MNF.

Battery Application with iC-MNF

To realize a battery buffered multiturn application iC-PNE Series supports an additional supply pin VB. A low-cost micro-controller has to power-up the optical front-end and flash the blue LED with a bootstrap circuit. After the short pulse the digital Gray code can be sampled to update the multiturn information. When iC-MNF is powered by the external encoder supply the micro-controller has to convert the parallel octal information into a serial bit stream for the multiturn interface MTMA/MTSLI.

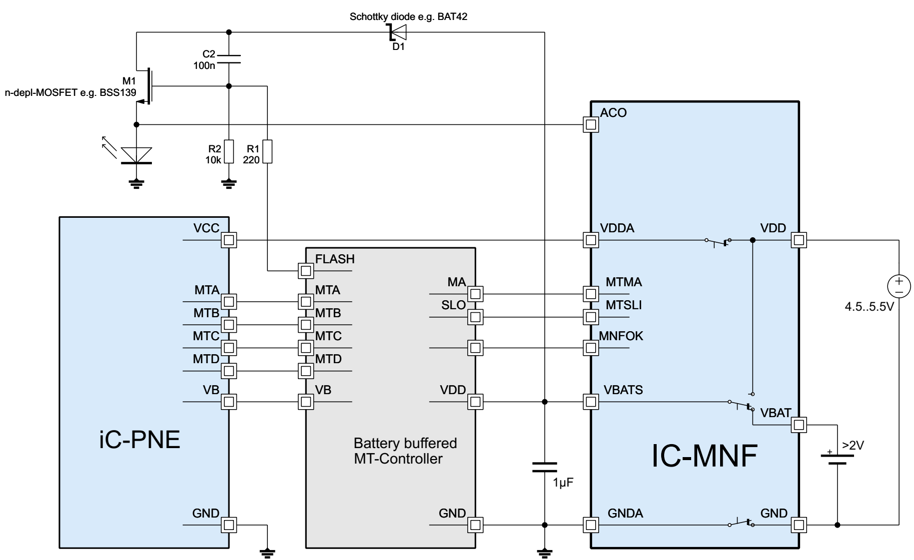


Figure 5: Example circuit enabling battery operation, e.g. when using a blue LED or low-voltage MCU.

DEVICE OVERVIEW

Device	CPR [1] Master	Code Disc P/O Code	Material	OR [2] [mm]	Code Radius begin / end [mm]	Resolution [3] [bit]	Error Tol. [4] [e°]
∅ 26 mm		(disc diameter 26.0 mm, bore hole 11.6 mm)					
iC-PNE2612	8x 64	PNE01S 26-512	glass	10.905	9.4 / 12.4	23	± 19.6
iC-PNE2648 [5]	8x 256	PNE02S 26-2048	glass	10.905	9.4 / 12.4	25	± 9.8
∅ 33 mm		(disc diameter 33.2 mm, bore hole 18.0 mm)					
iC-PNE3312	8x 64	PNE03S 33-512	glass	14.5	13.0 / 16.0	23	± 19.6
iC-PNE3348 [5]	8x 256	PNE04S 33-2048	glass	14.5	13.0 / 16.0	25	± 9.8
∅ 39 mm		(disc diameter 39.0 mm, bore hole 18.0 mm)					
iC-PNE3912	8x64	PNE5S 39-512	glass	17.5	16.0 / 19.0	23	± 19.6
iC-PNE3948	8x256	PNE6S 39-2048	glass	17.5	16.0 / 19.0	25	± 9.8

[1] Signal cycles per revolution of master track.
[2] Optical center radius.
[3] Angle resolution per single turn; interpolated by iC-MNF with 14 bit resolution.
[4] Permissible maximum track-to-track signal phase deviation in electrical degree per master signal cycle.
[5] EncoderBlue®. EncoderBlue is a trademark of iC-Haus GmbH.
Device availability on request.

Table 1: Device overview

DESIGN REVIEW: Notes On Chip Functions

iC-PNExxxx 01, 11, Z		
No.	Function, Parameter/Code	Description and Application Hints
-		None at time of release.

Table 2: Notes on chip functions regarding iC-PNE chip releases 01, 11, Z.

REVISION HISTORY

Rel.	Rel. Date[1]	Chapter	Modification	Page
A1	2022-11-14		Initial release.	

Rel.	Rel. Date[1]	Chapter	Modification	Page
A2	2023-09-12	ELECTRICAL CHARACTERISTICS	Item 402: typ. value Item 608: minimum limit	6
		APPLICATION CIRCUITS	Figure 4 added	9

[1] Release Date format: *YYYY-MM-DD*

ORDERING INFORMATION

Type	Package	Options	Order Designation
iC-PNExxxx	32-pin optoQFN, 5 mm x 5 mm, thickness 0.9 mm RoHS compliant	xxxx = device version	iC-PNExxxx oQFN32-5x5
Code Disc	Glass disc 1.0 mm	nn = design number aa = diameter cc...cccc = master track CPR	PNEnnS aa-cccc
		for iC-PNE2612 (8x 64 CPR) for iC-PNE2648 (8x 256 CPR) for iC-PNE3312 (2x 64 CPR) for iC-PNE3348 (8x 256 CPR) for iC-PNE3912 (8x 64 CPR) for iC-PNE3948 (8x 256 CPR)	PNE01S 26-512 PNE02S 26-2048 PNE03S 33-512 PNE04S 33-2048 PNE05S 39-512 PNE06S 39-2048
Evaluation Kit	Kit with Scanner Module ICnnn (61 mm x 64 mm), LED Module IC274 and Code Disc	xxxx = device version (availability on request)	iC-PNExxxx EVAL PNE1M
Adapter Board	Adapter PCB, connects ICnnn to MNF1D (xx mm x yy mm)		iC544 EVAL IC544

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