iC-PD 3948
PHASED ARRAY SINE ENCODER

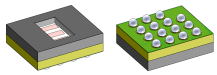
FEATURES

- Compact, 5-channel optical encoder with differential scanning and analog sine/cosine outputs:
  2048 CPR with index, 1 CPR absolute, size ⌀ 39 mm
- Blue-ready and IR capable high-definition phased array design for excellent signal matching
- Reduced cross talk due to moderate track pitch
- Ultra low dark currents for operation up to high temperature
- Low-noise amplifiers with high transimpedance gain
- Short-circuit-proof, low impedance voltage outputs for enhanced EMI tolerance
- Space saving optoQFN and optoBGA packages
- Low power consumption from single 4.1 to 5.5 V supply
- Operational temperature range of -40 to +125 °C
- Sampling with evaluation kit and code disc:
  PD2S 39-2048 (glass 1 mm)
  OD ⌀ 39 mm, ID ⌀ 18.0 mm, optical radius 17.5 mm

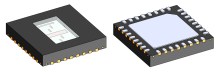
APPLICATIONS

- Incremental sine encoders with commutation information
- Motor feedback
- AC servo and BLDC motor systems

PACKAGES

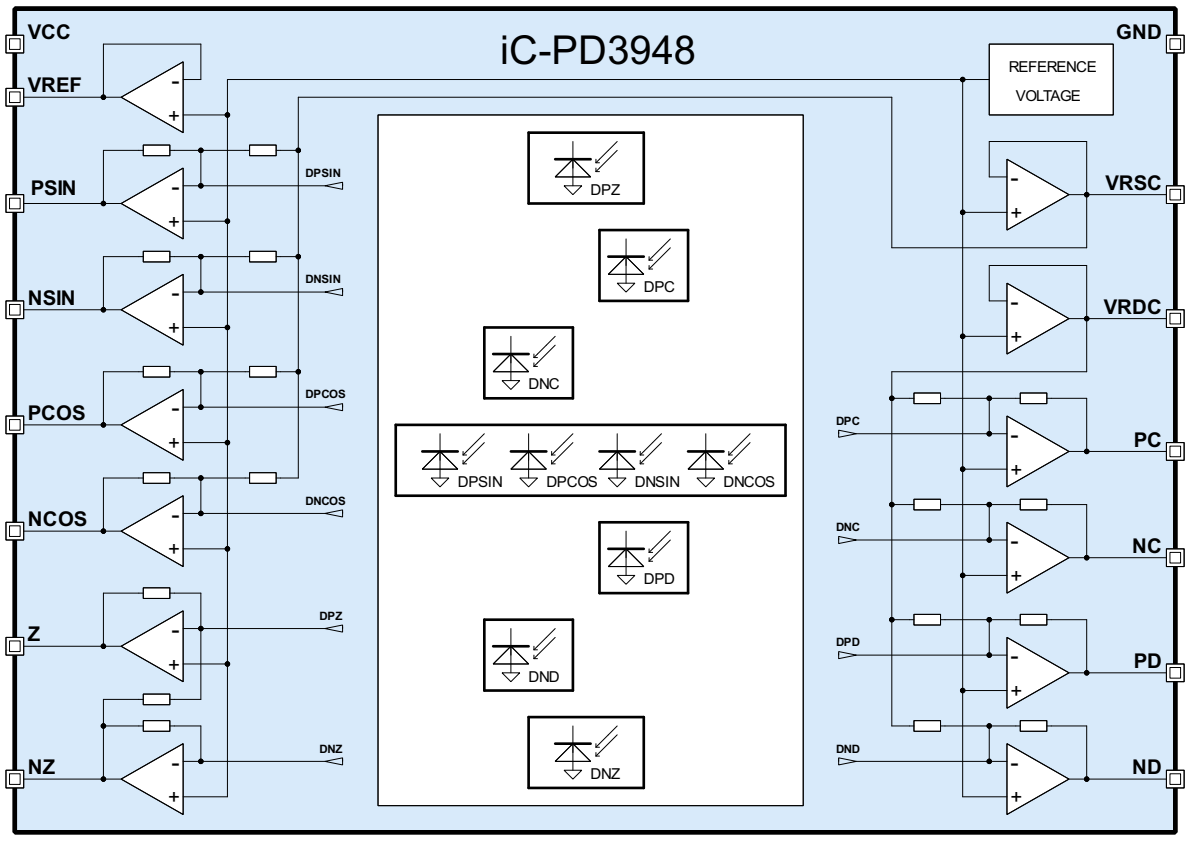


15-pin optoBGA
6.2 mm x 5.2 mm x 1.7 mm
RoHS compliant



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

BLOCK DIAGRAM



DESCRIPTION

iC-PD3948 is an advanced optical encoder IC featuring monolithically integrated photosensors arranged as an *HD Phased Array*, providing excellent signal fidelity at relaxed alignment tolerances.

By using low-noise amplifiers with a transimpedance gain of typically 1 MΩ for the S/C sensors or 2 MΩ for the C/D sensors, the output signal levels reach a few hundred millivolts even in low light conditions.

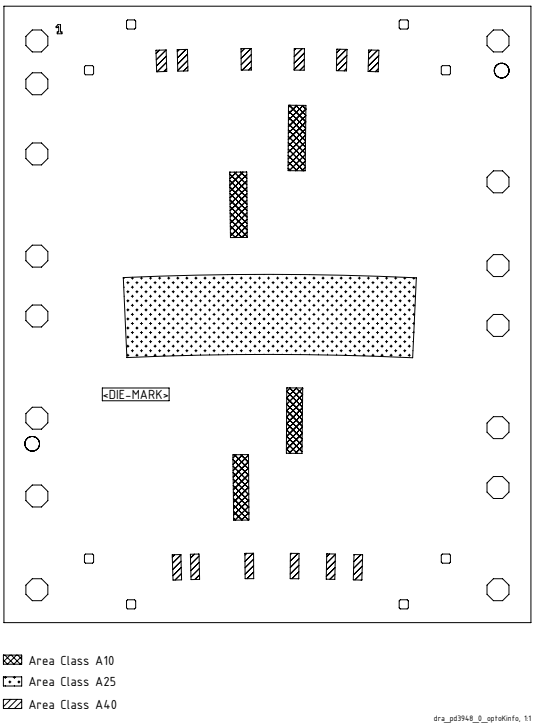
As the pin names would suggest, iC-PD3948 is typically used as a sine encoder for motor feedback systems. For this application, iC-PD3948 provides sine and cosine signals with both a high resolution of 2048 CPR (at S/C, accompanied by an index signal at Z/NZ), and a low resolution of 1 CPR (at C/D).

All code disc signal tracks are evaluated differentially, whereas the high resolution sine signals are scanned by a phased array of multiple photosensors. iC-PD3948 features a purpose-built amplifier layout to obtain excellent matching of paired signals.

The spectral sensitivity ranges from visible blue to near infrared light, with the maximum sensitivity close to a wavelength of 680 nm. Illuminated by a typical encoder LED, such as iC-TL46 (460 nm) or iC-SD85 (850 nm), an LED current of less than 10 mA can be sufficient to operate the sensor, proving beneficial to the LED's endurance at high operating temperatures in industrial drive applications.

PACKAGING INFORMATION

PAD LAYOUT
Chip release Y1 (2.88 mm x 3.37 mm)



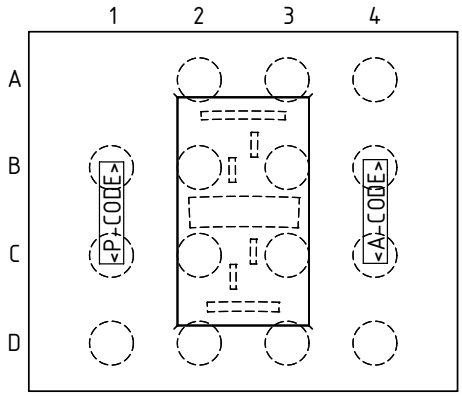
PAD FUNCTIONS

No.	Name	Function
		Refer to the description of pin functions.

<Die Mark> iC PD3948 Y1

<Area Class> Inspection class for the optical inspection of detector areas. Refer to Customer Information # 27 for description.

PIN CONFIGURATION
oBGA LSH2C (6.2 mm x 5.2 mm)



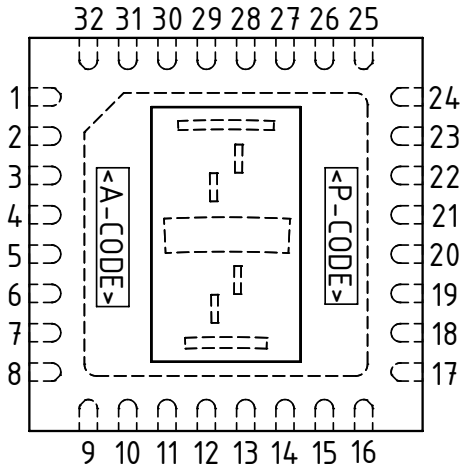
PIN FUNCTIONS

No.	Name	Function
A2	VCC	+4.1...5.5 V Supply Voltage
A3	VREF	Reference Voltage Output
A4	GND	Ground
B1	PSIN	Sine Track +
B2	NSIN	Sine Track -
B3	VRDC	C/D Track Reference
B4	VRSC	S/C Track Reference
C1	PCOS	Cosine Track +
C2	NCOS	Cosine Track -
C3	NC	C Track -
C4	PC	C Track +
D1	Z	Z Index Signal
D2	NZ	Z Index Track -
D3	ND	D Track -
D4	PD	D Track +

Note: All signal and reference outputs are analog voltage outputs.

IC top marking: <P-CODE> = product code, <A-CODE> = assembly code (subject to changes);
For dimensional specifications refer to the relevant package data sheet, available separately.

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



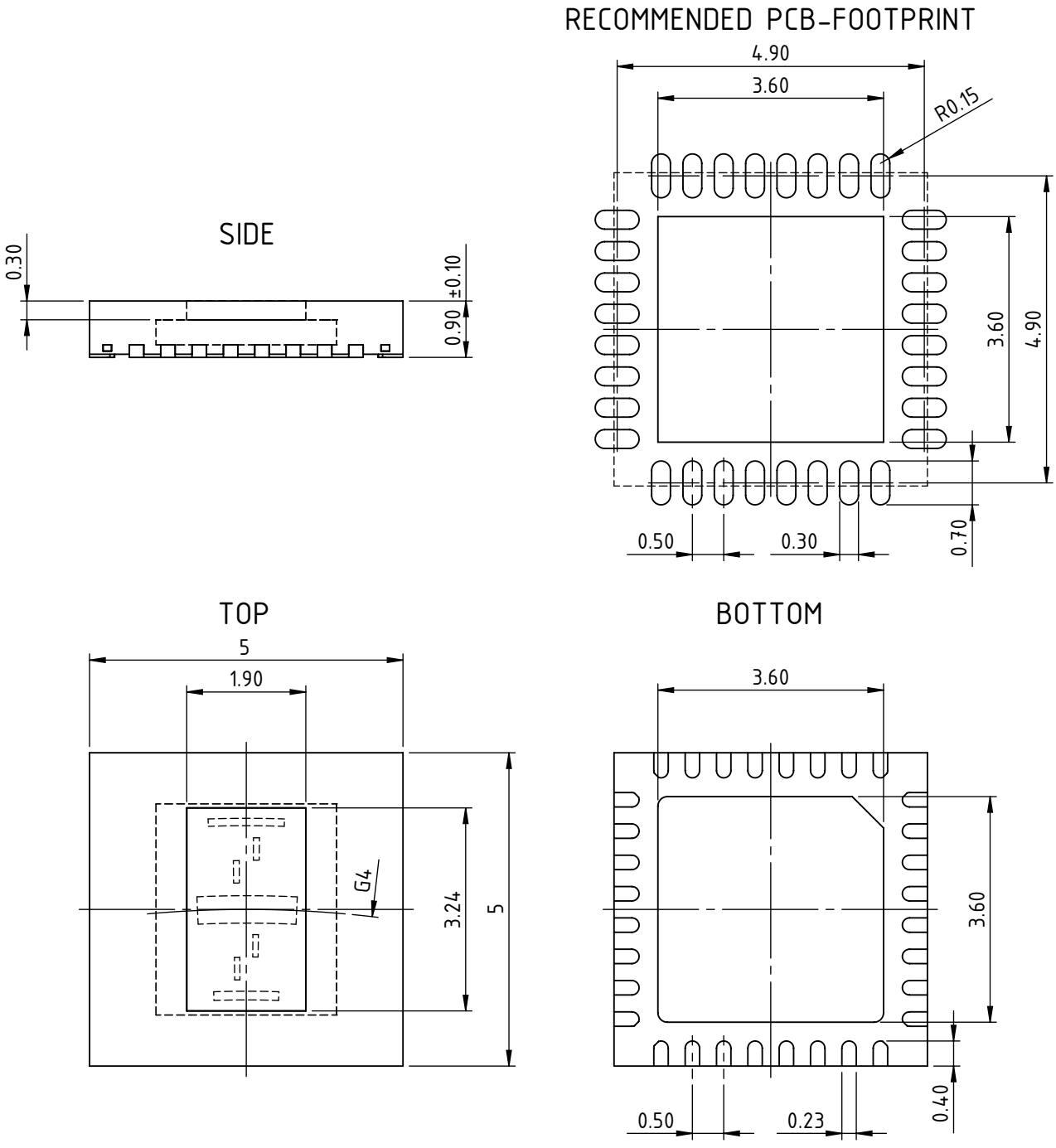
PIN FUNCTIONS

No.	Name	Function
1	VCC	+4.1...5.5 V Supply Voltage
2	VREF	Reference Voltage Output
3	PSIN	Sine Track +
4	NSIN	Sine Track -
5	PCOS	Cosine Track +
6	NCOS	Cosine Track -
7	Z	Z Index Signal
8	NZ	Z Index Track -
9..16	n.c.[1]	
17	ND	D Track -
18	PD	D Track +
19	NC	C Track -
20	PC	C Track +
21	VRDC	C/D Track Reference
22	VRSC	S/C Track Reference
23	n.c.[1]	
24	GND	Ground
25..32	n.c.[1]	
	BP[2]	Backside paddle

Note: All signal and reference outputs are analog voltage outputs.

IC top marking: <P-CODE> = product code, <A-CODE> = assembly code (subject to changes); dashed lines are used for visible or hidden outlines.
[1] Pin numbers marked n.c. are not connected.
[2] 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. 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/reticle.

drb_pdxx-oqfn32-2_pack_1, 10:1

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	Min.	Max.	Unit
G001	VCC	Voltage at VCC		-0.3	6	V
G002	I(VCC)	Current in VCC		-20	20	mA
G003	V()	Pin Voltage, all signal outputs		-0.3	VCC + 0.3	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		2	kV
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 package oBGA LSH2C	-40 -40		125 110	°C °C
T02	Ts	Storage Temperature Range	package oQFN32-5x5 package oBGA LSH2C	-40 -40		125 110	°C °C
T03	Tpk	Soldering Peak Temperature	package oQFN32-5x5 tpk < 20 s, convection reflow tpk < 20 s, vapor phase soldering MSL 5 A (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
T04	Tpk	Soldering Peak Temperature	package oBGA LSH2C tpk < 20 s, convection reflow tpk < 20 s, vapor phase soldering TOL (time on label) 8 h; Please refer to customer information file No. 7 for details.			 245 230	 °C °C
T05	Rthja	Thermal Resistance Chip to Ambient	package oQFN32-5x5 surface mounted to PCB according to JEDEC 51		40		K/W

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, Tj = -40...125 °C, unless otherwise noted.

Item No.	Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Total Device							
001	VCC	Permissible Supply Voltage		4.1		5.5	V
002	I(VCC)	Supply Current	no load, photocurrents within op. range		12	16	mA
003	Vc()hi	Clamp-Voltage hi at all pins	Vc()hi = V() - VCC; I() = 4 mA	0.6		2	V
004	Vc()lo	Clamp-Voltage lo at all pins	I() = -4 mA	-1.2		-0.3	V
Photosensors							
101	λar	Spectral Application Range	Se(λar) = 0.25 x S(λpk)	400		950	nm
102	λpk	Peak Sensitivity Wavelength			680		nm
103	Aph()	Radiant Sensitive Area	S/C track (DPSIN, DNSIN, DPCOS, DNCOS) C/D track (DPC, DNC, DPD, DND) Z track (DPZ, DNZ)		0.076 0.031 0.039		mm^2 mm^2 mm^2
104	S(λ)	Spectral Sensitivity	λ_{LED} = 740 nm λ_{LED} = 460 nm, 850 nm		0.5 0.3		A/W A/W
106	E()mx	Irradiance For Maximum Signal Level	λ_{LED} = 740 nm, Vout() not saturated; S/C track C/D track Z track	 6.0 8.0 12	 12 15 21	 18 24 36	 mW/cm^2 mW/cm^2 mW/cm^2
Photocurrent Amplifiers							
201	Iph()	Permissible Photocurrent Operating Range	S/C track and Z track C/D track	0 0		1120 560	nA nA
202	η()r	Photo Sensitivity (light-to-voltage conversion ratio)	λ_{LED} = 740 nm; S/C track, Z track C/D track	0.1 0.2	0.16 0.32	0.3 0.6	V/µW V/µW
203	Z()	Equivalent Transimpedance Gain	Z = Vout() / Iph(); S/C track, Z track C/D track	0.67 1.34	1.0 2.0	1.36 2.72	MΩ MΩ
204	TCz	Temperature Coefficient of Transimpedance Gain			-0.12		%/°C
205	ΔZ()pn	Transimpedance Gain Matching Of Paired Amplifiers	P.. channel vs. corresponding N.. channel	-0.2		0.2	%
206	ΔVout()pn	Signal Matching	no illumination, any output to any output	-35		35	mV
207	ΔVout()pn	Signal Matching	no illumination, P vs. N path per diff. channel	-2.5		2.5	mV
208	fc()hi	Cut-off Frequency (-3 dB)		240	360	560	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	illumination to E()mxr, linear gain	2.0			V
302	Iout()mx	Permissible Max. Output Current		-100		250	µA
303	Vout()d	Dark Signal Level	no illumination, load 20 kΩ vs. +2 V;	560	770	1000	mV
304	Vout()acmx	Maximum Signal Level	Vout()acmx = Vout()mx - Vout()d	1.48	1.96	2.35	V
305	Isc()hi	Short-Circuit Current hi	load current to ground	100	420	800	µA
306	Isc()lo	Short-Circuit Current lo	load current to IC	250	480	700	µA
307	Ri()	Internal Output Resistance	f = 1 kHz	70	110	180	Ω
Signal References VRSC, VRDC							
401	Vout()	Reference Voltage	I() = -100...+250 µA	560	770	1000	mV
402	Isc()hi	Short-Circuit Current hi	current to ground	100	420	800	µA
403	Isc()lo	Short-Circuit Current lo	current to IC	250	480	700	µA
404	Ri()	Internal Output Resistance		70	110	180	Ω
Reference Voltages VREF							
501	Vout()	Reference Voltage	I(VREF) = -100 µA...+300 µA	560	770	1000	mV
502	dVout()	Load Balancing	I(VREF) = -100 µA...+300 µA	-10		+10	mV
503	Isc()hi	Short-Circuit Current hi	current to ground	600	1100	1600	µA
504	Isc()lo	Short-Circuit Current lo	current to IC	0.5	4.5	10	mA

APPLICATION CIRCUITS

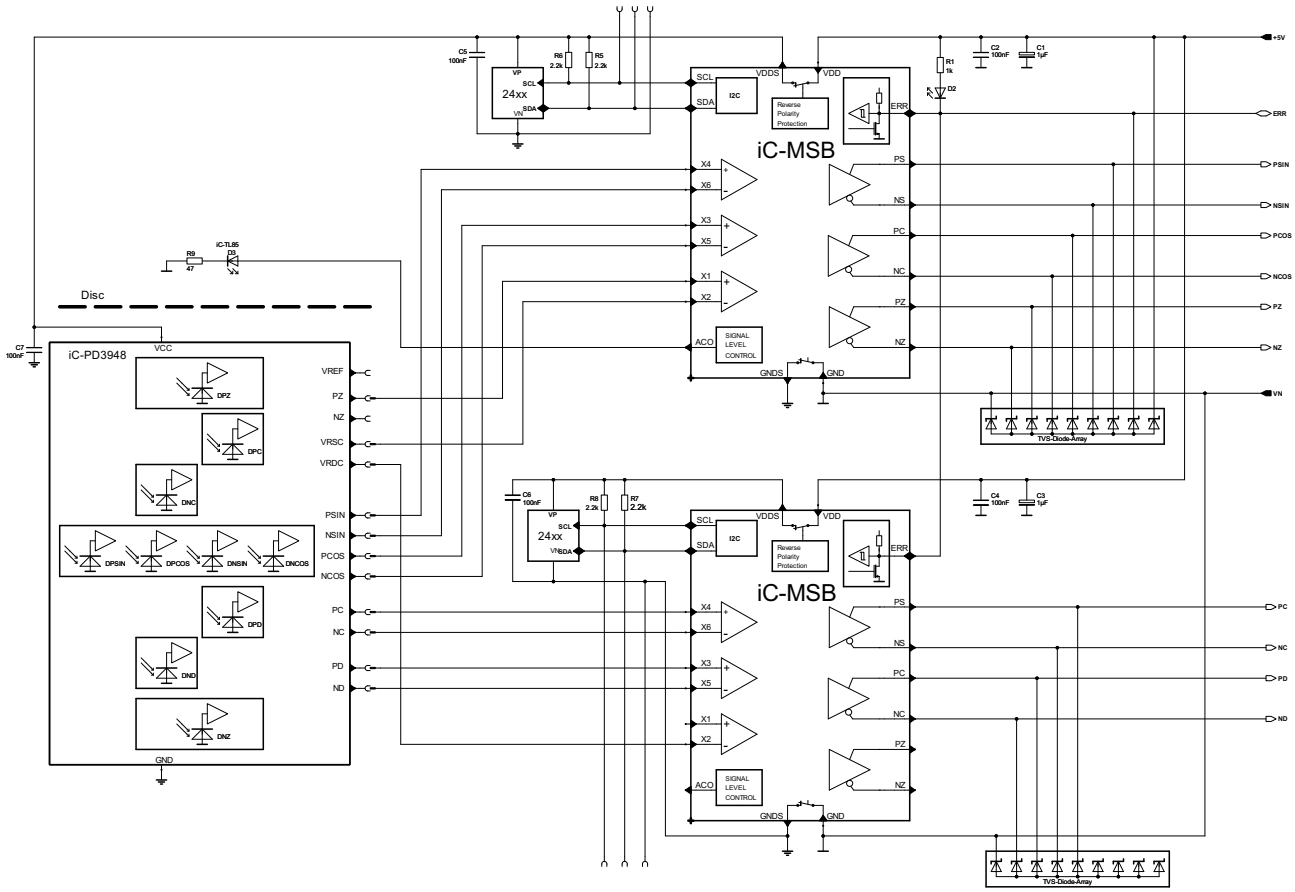


Figure 1: Application example of a motor feedback encoder utilizing two iC-MSB devices.
Sine square plus cosine square LED power controlling by iC-MSB maintains the differential 1 Vpp signal of the S/C channel featuring 2048 CPR. The C/D channel with 1 CPR is initially also calibrated to 1 Vpp differential, but experiences variation due to LED power controlling. This variation can be neglected at speeds below 1,500 rpm, as iC-PD3948 does not run into cut-off frequency.

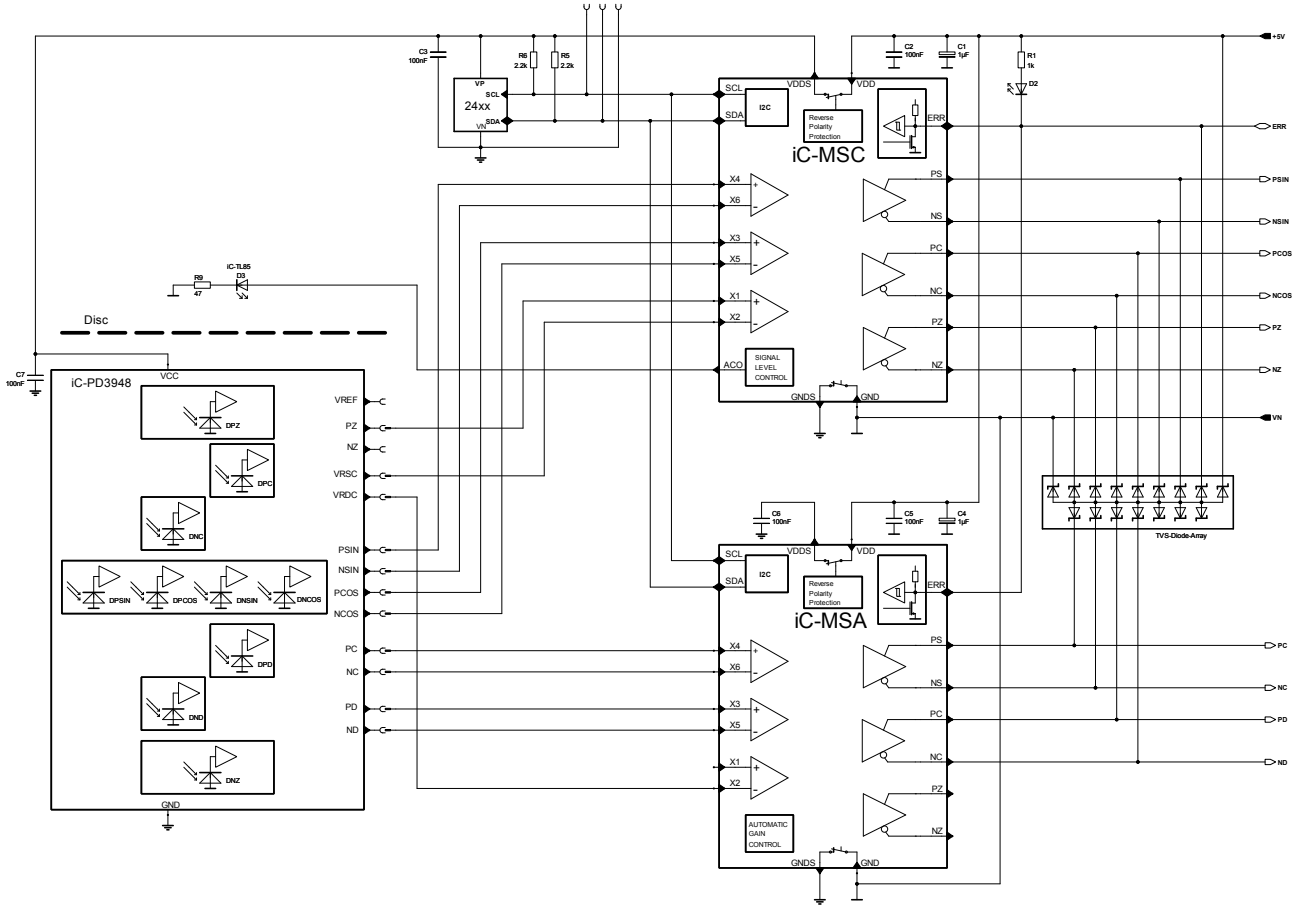


Figure 2: Application example motor feedback encoder utilizing iC-MSC and iC-MSA.
Sine square plus cosine square LED power controlling with optional hysteresis by the advanced iC-MSC maintains the differential 1 Vpp signal of the S/C channel featuring 2048 CPR. The C/D channel with 1 CPR ensures its 1 Vpp differential signal by automatic gain control. In this setup, operation at high rpm speed and beyond iC-MSC's cut-off frequency is possible.

DESIGN REVIEW: Notes On Chip Functions

iC-PD3948.		
No.	Function, Parameter/Code	Description and Application Hints
1		Refer to datasheet release C1, 2014.

Table 4: Notes on chip functions regarding iC-PD3948 chip release 0.

iC-PD3948 Y1		
No.	Function, Parameter/Code	Description and Application Hints
1		Note at time of printing.

Table 5: Notes on chip functions regarding iC-PD3948 chip release Y1.

REVISION HISTORY

Rel.	Rel. Date[1]	Chapter	Modification	Page
B5	2011-03-14	...		

Rel.	Rel. Date[1]	Chapter	Modification	Page
C1	2014-07-31		Refer to datasheet rev. C1	

Rel.	Rel. Date[1]	Chapter	Modification	Page
D1	2019-05-28	FEATURES	Min. supply 4.1 V, operating temp. up to 125 °C	1
		DESCRIPTION	Text update	2
		PACKAGING INFORMATION	Pad layout Y1, inspection criteria added	2
		THERMAL DATA	Items T01, T02: oQFN32-5x5 up to 125 °C Item T05: added	5
		ELECTRICAL CHARACTERISTICS	Various items: entries reduced to latest chip release; Item 001: Operating voltage 4.1 V min. Item 003: conditions and limits Item 104: 460 nm added Item 301: limit adapted to min. operating voltage Item 302: added for clarification Item 401; condition supplemented	6
		APPLICATION CIRCUITS	Figure 2: circuit example updated to iC-MSC	8
		ORDERING INFORMATION	Eval kit IC273 and related parts added	10

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

ORDERING INFORMATION

Type	Package	Options	Order Designation
iC-PD3948	32-pin optoQFN, 5 mm x 5 mm, thickness 0.9 mm RoHS compliant		iC-PD3948 oQFN32-5x5
	15-pin optoBGA, 6.2 mm x 5.2 mm thickness 1.7 mm RoHS compliant		iC-PD3948 oBGA LSH2C
Evaluation Kit	Kit with Scanner Module IC273 (61 mm x 64 mm), IR LED Module IC274 and Code Disc PD2S 39-2048		iC-PD3948 EVAL IC273
Code Disc		2048 CPR (S/C) with index, 1 CPR (C/D) absolute, OD ∅ 39 mm, ID ∅ 18.0 mm, optical radius 17.5 mm (glass 1 mm)	PD2S 39-2048
Illumination	Infrared LED module (28 mm x 29 mm) Blue LED module (28 mm x 29 mm)		iC-SD85 EVAL IC274 iC-TL46 EVAL IC274
Mother Board	Adapter PCB (80 mm x 110 mm)		iC277 EVAL IC277

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