# iC-PXL3212
REFLECTIVE INCREMENTAL ENCODER IC



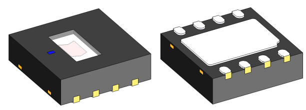
## FEATURES

- Lensless, reflective opto-encoder iC, compact, high-resolution, incremental
- Native optical resolution of 152 LPI
- Monolithic HD Phased Array with excellent signal matching
- *EncoderBlue*®: System-on-chip design with embedded blue LED for excellent signal quality
- LED power control
- Low-noise signal amplifiers with high EMI tolerance
- 3 pin-selectable operation modes: Digital A/B (x16 or x64 interpolated) and analog output
- Differential quadrature outputs A+, A-, B+ and B- (short-circuit-proof, current-limited, +/- 4 mA push-pull)
- Differential analog outputs COS+, COS-, SIN+ and SIN- (Vdc = 1.5 V, Vpp = 2 V, permissible load current 1 mA)
- Extended operating temperature range of -40°C to +125°C
- Low power consumption from single 4.5 V to 5.5 V supply
- Compact optoDFN mold package

## APPLICATIONS

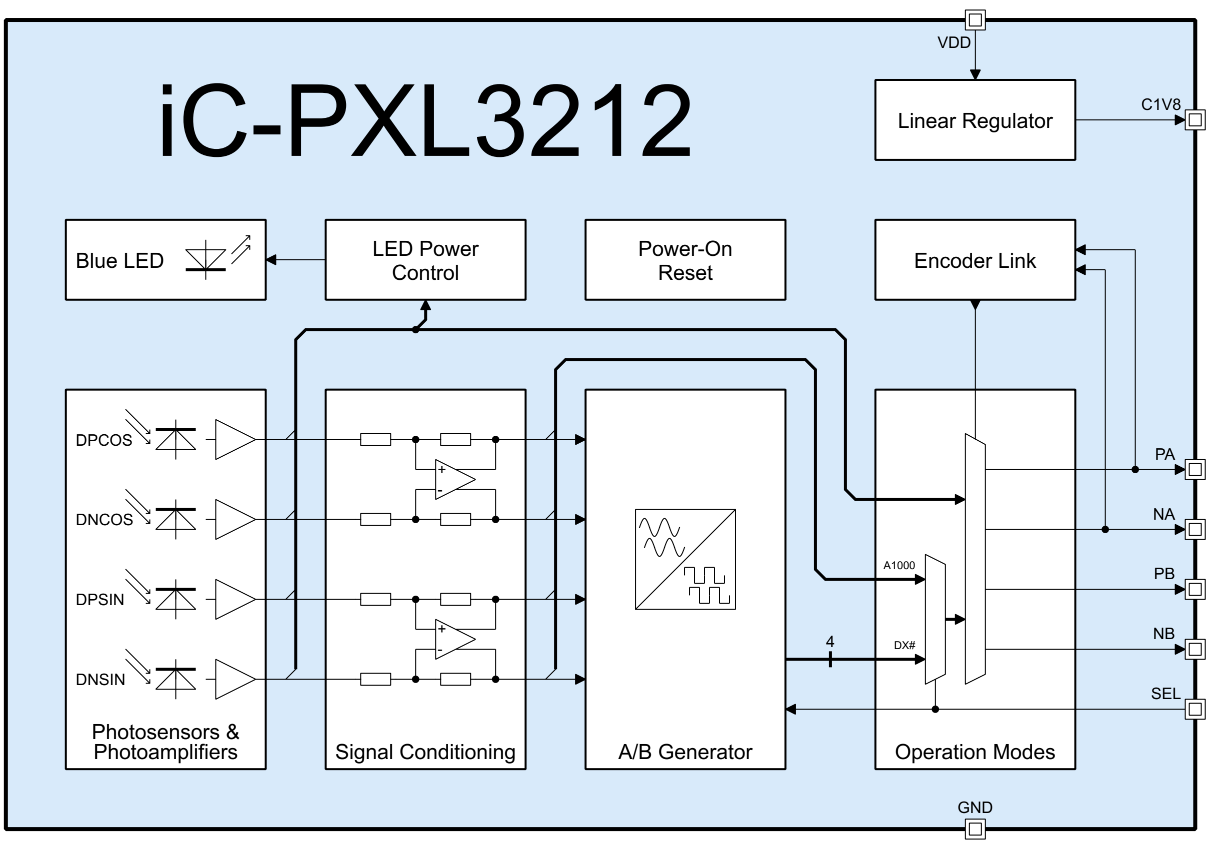
- Incremental encoders
- Miniature motors and actuators
- X-Y and linear stages
- Factory automation robots
- Consumer robots

## PACKAGES



8-pin optoDFN
3 mm x 3 mm x 0.9 mm
RoHS compliant

## BLOCK DIAGRAM



## DESCRIPTION

iC-PXL3212 is an advanced optical, reflective, lensless encoder iC featuring integrated *HD Phased Array* photosensors and a blue LED chip. It provides high signal quality with relaxed alignment tolerances. Differential digital A/B outputs with interpolation or analog COS/SIN outputs are available. Typical applications are incremental encoders for motor control.

*Blue-enhanced* photosensors are adapted to the short wavelength of the embedded blue LED, and provide low-jitter outputs due to improved signal contrast. The unique assembly technology of the blue LED emitter and the sensors results in a low optical crosstalk.

Low-noise photoamplifiers, arranged in a paired layout to ensure excellent channel matching, are used to convert the sensor signals into voltages of several hundred millivolts. Subsequent fully-differential signal conditioning amplifiers provide optimal signal levels for interpolation.

Three operation modes are selectable via tri-level input SEL: Differential digital A/B outputs with interpolated resolution (x16 or x64) or differential analog COS/SIN outputs suitable for external interpolation.

The built-in LED power control keeps the analog amplitudes constant regardless of aging effects, varying temperature or changing air gap (iC vs. code disc).

iC-PXL3212 features a low power consumption and runs at single-sided supplies of 4.5 V up to 5.5 V.

**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.

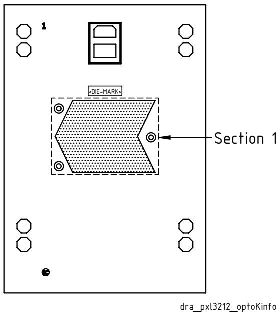
Equally, standard molding materials used for IC packages can show visible changes induced by irradiation, among others when exposed to light of shorter wavelengths, blue light for instance. Such surface effects caused by visible or IR LED light are rated to be of cosmetic nature, without influence to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

## CONTENTS

## PACKAGING INFORMATION

### SENSOR LAYOUT

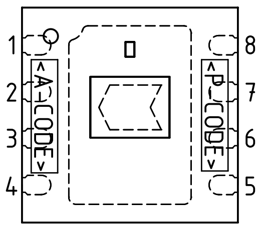



**AOI CRITERIA**

| <Die Mark> | <Section> | <Area Class>[1] |
|---|---|---|
| iC-PXL3212 | 1 | A20 |

[1] Inspection class for the optical inspection of detector areas. Refer to Customer Information # 27 for description.

### PIN CONFIGURATION oDFN8-3x3



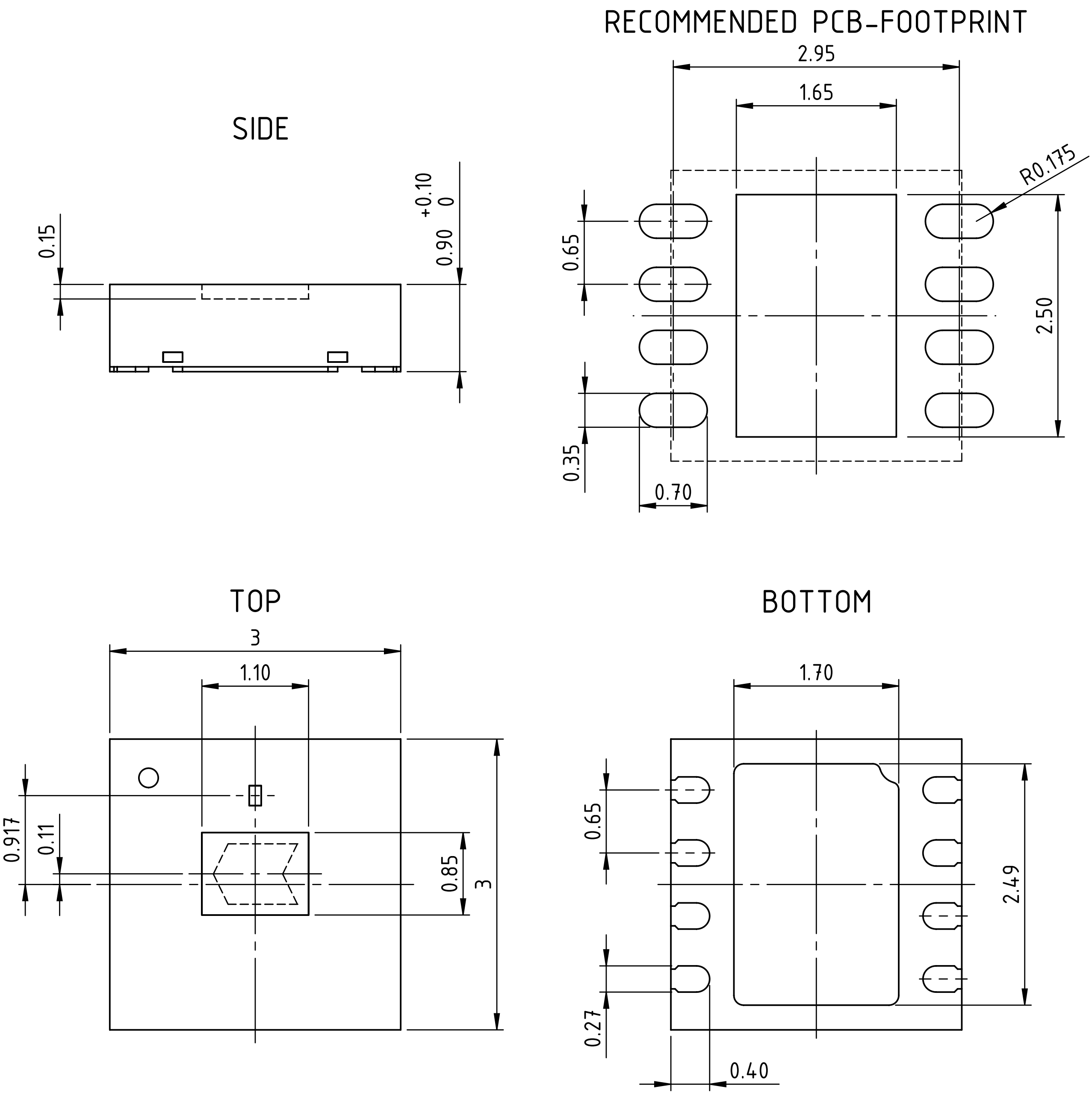

**PIN FUNCTIONS**

| No. | Name | Function |
|---|---|---|
| 1 | PA | Digital Output A+ / Analog Output COS+ |
| 2 | NA | Digital Output A- / Analog Output COS- |
| 3 | PB | Digital Output B+ / Analog Output SIN+ |
| 4 | NB | Digital Output B- / Analog Output SIN- |
| 5 | SEL | Operation Mode Selection Input |
| 6 | C1V8 | Core Voltage Buffer Capacitor (see chapter LINEAR REGULATOR) |
| 7 | VDD | Supply Voltage Input 4.5 V...5.5 V |
| 8 | GND | Ground |
| | BP | Backside Paddle [1] |

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

[1] The backside paddle has to be connected 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-229.
Positional tolerance of sensor pattern: ±70µm / ±1° (with respect to center of backside pad).
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_odfn8-3x3-1_pxl3212_0_pack_1, 15:1

## ABSOLUTE MAXIMUM RATINGS

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

| Item No. | Symbol | Parameter | Conditions | Min. | Max. | Unit |
|---|---|---|---|---|---|---|
| G001 | VDD | Voltage at VDD | Referenced to GND | -0.3 | 6 | V |
| G002 | I(VDD) | Current in VDD | | -20 | 100 | mA |
| G003 | V(C1V8) | Voltage at C1V8 | Referenced to GND | -0.3 | 2.0 | V |
| G004 | I(C1V8) | Current in C1V8 | | -20 | 20 | mA |
| G005 | V() | Pin Voltage, all remaining pins | Referenced to GND | -0.3 | VDD + 0.3 | V |
| G006 | I() | Pin Current, all remaining pins | | -20 | 20 | mA |
| G007 | Vd() | Electrostatic Discharge | HBM, 100 pF discharged through 1.5 kΩ | | 2 | kV |
| G008 | Tj | Junction Temperature | | -40 | 140 | °C |

[1] JEDEC document JEP 155: 500V HBM allows safe manufacturing with a standard ESD control process

## THERMAL DATA

| Item No. | Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| T01 | Ta | Operating Ambient Temperature Range | | -40 | | 125 | °C |
| T02 | Ts | Permissible Storage Temperature Range | | -40 | | 125 | °C |
| T03 | Tpk | Soldering Peak Temperature | tpk < 20 s, convection reflow<br><br>MSL 3 (max. floor life 168 h at 30 °C and 60 % RH); Refer to Handling and Soldering Conditions for details. | | | 245 | °C |
| T04 | Rthja | Thermal Resistance Chip to Ambient | Package mounted on PCB according to JEDEC standard | | 50 | | 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: VDD = 4.5..5.5 V, Tj = -40..140 °C, unless otherwise noted

| Item No. | Symbol | Parameter | Conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|---|
| **General** | | | | | | | |
| 001 | VDD | Permissible Supply Voltage | | 4.5 | | 5.5 | V |
| 002 | I(VDD) | Supply Current | Photoamplifiers within op. range, no load, f()e = 5 kHz, 1.5 mm air gap<br>Mode A1000<br>Mode DX16<br>Mode DX64 | | <br>20<br>24<br>25 | | <br>mA<br>mA<br>mA |
| 007 | f()e,mx | Maximum Permissible Sine/Cosine Frequency | | | | 240 | kHz |
| 008 | a()e,mx | Maximum Permissible Sine/Cosine Acceleration | | | | 100 | $10^6$ rade/s$^2$ |
| **Tri-Level Input SEL** | | | | | | | |
| 101 | V() | Pin-Open Voltage | | 40 | 50 | 60 | %VDD |
| 102 | Vt()lo | Threshold low | | 10 | | | %VDD |
| 103 | Vt()med | Threshold medium | | 40 | | 60 | %VDD |
| 104 | Vt()hi | Threshold high | | | | 90 | %VDD |
| 105 | Vt()hys | Threshold Hysteresis medium/high or low/medium | | | 10 | | %VDD |
| 111 | Rpd() | Pull-Down Resistor | V(SEL) = VDD | 130 | 200 | 280 | kΩ |
| 112 | Rpu() | Pull-Up Resistor | V(SEL) = 0 V | 130 | 200 | 280 | kΩ |
| **Digital Outputs A+, A-, B+, B-** | | | | | | | |
| 201 | fout()ab,mx | Maximum A/B Output Frequency | | 3.6 | | | MHz |
| 202 | AArel | A/B Duty Cycle Variation | Mode DX16, f()e = 128 Hz<br>Mode DX16, f()e = 2.56 kHz<br>Mode DX64, f()e = 128 Hz<br>Mode DX64, f()e = 2.56 kHz<br>See also Figure 1 | | 1.7<br>0.7<br>2.8<br>0.9 | | %<br>%<br>%<br>% |
| 203 | HysD | Digital A/B Hysteresis | | | 1.406 | | °e |
| 204 | Ttd()min | Minimum A/B Transition Distance Time | | 56.25 | 62.5 | 68.75 | ns |
| 205 | Isc()lo | Short-Circuit Current low | V() = VDD | | | 120 | mA |
| 206 | Isc()hi | Short-Circuit Current high | V() = 0V | -120 | | | mA |
| 207 | Vs()lo | Saturation Voltage low | I() = 4 mA<br>See also Figure 2 | | | 0.4 | V |
| 208 | Vs()hi | Saturation Voltage high | Vs()hi = VDD - V(), I() = -4 mA<br>See also Figure 2 | | | 0.4 | V |
| **Analog Outputs COS+, COS-, SIN+, SIN-** | | | | | | | |
| 301 | Vout()ac | AC Signal Amplitude | | | 1000 | | mV |
| 307 | Vout()dc | Output Signal DC Level | | 1.35 | 1.50 | 1.65 | V |
| 312 | Iout()mx | Permissible Load Current | | -1 | | 1 | mA |
| 315 | C()mx | Permissible Capacitive Load | | | | 50 | pF |
| **LED Power Control** | | | | | | | |
| L01 | Iop() | Permissible LED Current | Except startup | 0.5 | | 30 | mA |
| L03 | Ictrl() | Controlled LED Output Current | Refer to Table 2 for details | | 5..10 | | mA |
| L05 | Iop()mx | Maximum LED Current | | 30 | | 70 | mA |
| **Power-On Reset** | | | | | | | |
| P01 | VDDon | Turn-on Threshold VDD (power-on release) | Increasing voltage at VDD<br>LED Current and Photocurrent Amplifiers within op. range | | | 3.95 | V |
| P02 | VDDoff | Turn-off Threshold VDD (power-down reset) | Decreasing voltage at VDD<br>LED Current and Photocurrent Amplifiers within op. range | 3.00 | | | V |
| P03 | VDDhys | Threshold Hysteresis VDD | VDDhys = VDDon - VDDoff | 200 | 300 | 600 | mV |

**ELECTRICAL CHARACTERISTICS: Figures**

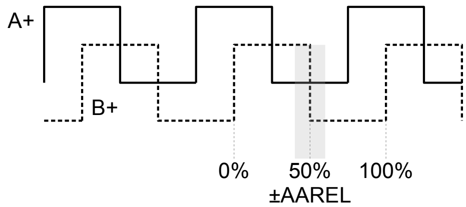



Figure 1: A/B Duty Cycle Variation (AAREL).

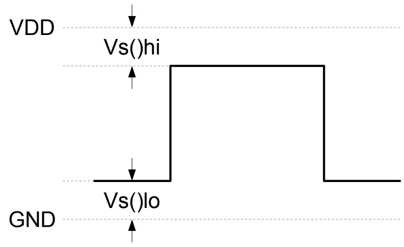



Figure 2: Digital Levels (Vs()hi/lo).

## DEFINITIONS

### Direction of Movement

Figure 3 defines the positive direction of movement and illustrates exemplary output signals.

In A1000 operation mode COS+ leads SIN+, while A+ leads B+ in DX# operation modes.

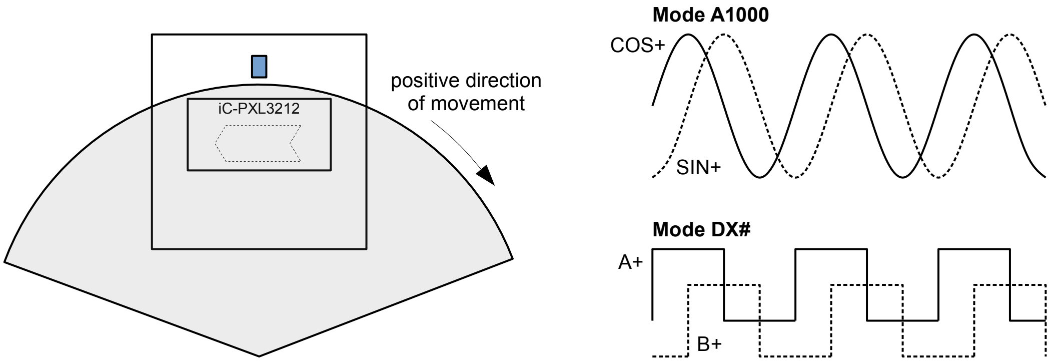



Figure 3: Definition of positive direction of movement.

### Mechanical and Electrical Degrees

An exemplary code disc with 16 cycles per revolution (CPR) is shown in Figure 4. A full revolution of the code disc is defined as 360 mechanical degrees (°m).

The code disc in this example has to be moved by $\frac{360^\circ m}{16} = 22.5^\circ m$ to generate a full sine/cosine period. Each period represents 360 electrical degrees (°e).

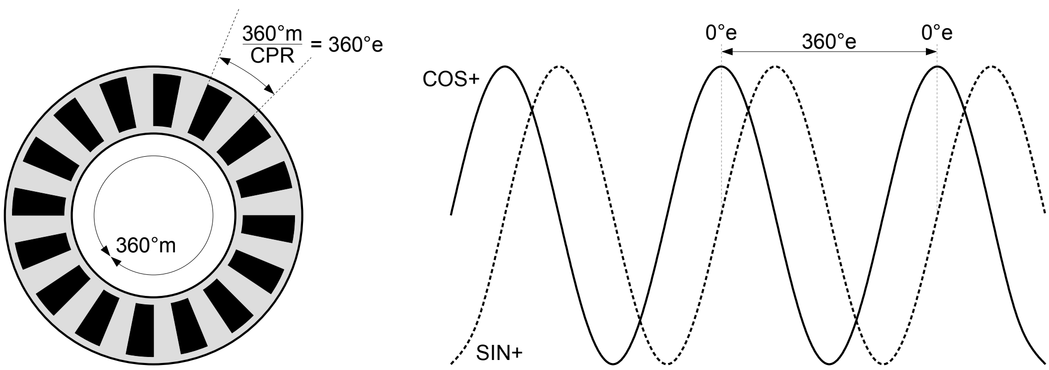



Figure 4: Definition of mechanical and electrical degrees.

If radians are used instead of degrees, the definition of radm and rade is equivalent to °m and °e.

## LINEAR REGULATOR

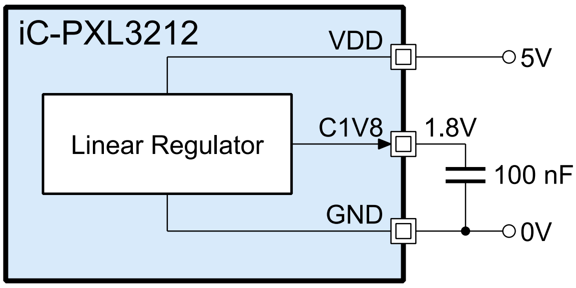



Figure 5: Core voltage buffer capacitor at C1V8.

An integrated linear regulator generates the digital core voltage of 1.8 V from VDD. To ensure a stable regulated voltage, an external buffer capacitor of typ. 100 nF is required at pin C1V8, as depicted in Figure 5.

The core voltage is for internal use only and must not be used to supply additional circuitry. Sensing pin C1V8 with high impedance, e. g. for safety reasons, is permitted.

Capacitor types suitable for filtering high-frequency interferences are recommended, e. g. ceramic capacitors.

## OPERATION MODES

iC-PXL3212 features three operation modes, as summarized in Table 1. They are selectable via tri-level pin SEL, which may be connected to a voltage below Vt()lo (SEL = *L*), a voltage above Vt()hi (SEL = *H*) or a voltage between the specified values of Vt()med (SEL = *M*). The function is undefined for any other voltage.

For SEL = *M* it is recommended to use an external voltage divider. Alternatively, when pin SEL is left unconnected, the iC itself biases the input at 50% VDD.

Static pin voltage at SEL is required during operation. Changing the configuration of SEL during operation requires a power cycle.

| Pin SEL | Mode | Description | Pin PA | Pin NA | Pin PB | Pin NB |
|---|---|---|---|---|---|---|
| *H* | DX64 | Differential digital A/B (x64 interpolation) | A+ | A- | B+ | B- |
| *M* | DX16 | Differential digital A/B (x16 interpolation) | A+ | A- | B+ | B- |
| *L* | A1000 | Differential analog COS/SIN (Vout()dc $\pm$ Vout()ac) | COS+ | COS- | SIN+ | SIN- |

Table 1: Operation modes and pin functions selectable by pin SEL.

## A/B GENERATOR

### Resolution

Differential quadrature signals with interpolated resolution are provided by the A/B Generator.

Figure 6 illustrates the signal outputs for both digital modes around the sine/cosine position of 0°e.

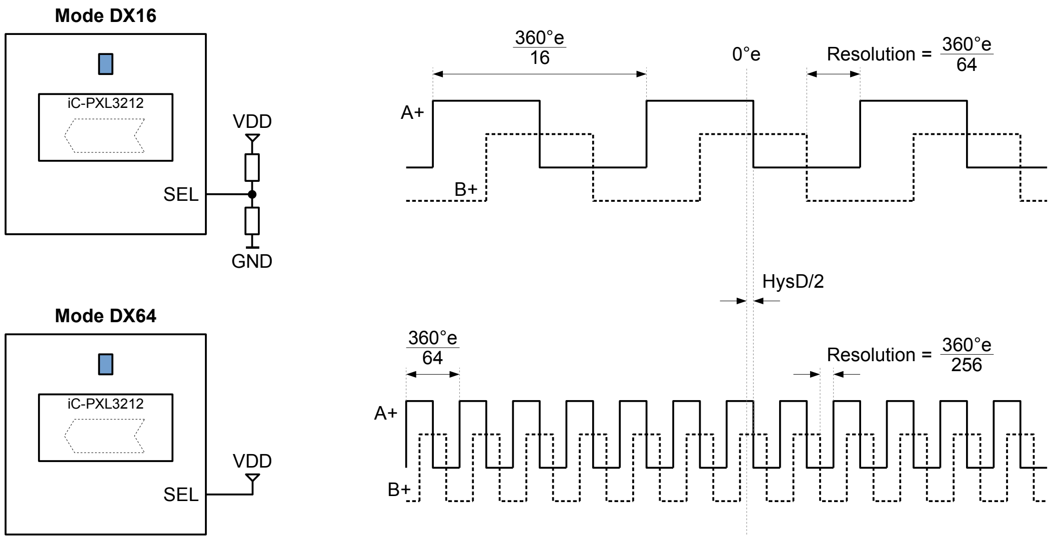



Figure 6: Digital outputs in modes DX16 and DX64 for positive direction of movement.

### Digital Hysteresis

Independent of the operation mode, the A/B outputs of iC-PXL3212 feature a digital hysteresis of $\mathrm{HysD} = \frac{360°e}{256}$, which is 1 LSB of the resolution in mode DX64. As illustrated in Figure 7, the digital hysteresis avoids spurious switching of the A/B outputs at the reversing point, when the direction of movement changes, e.g. from positive to negative or vice versa.

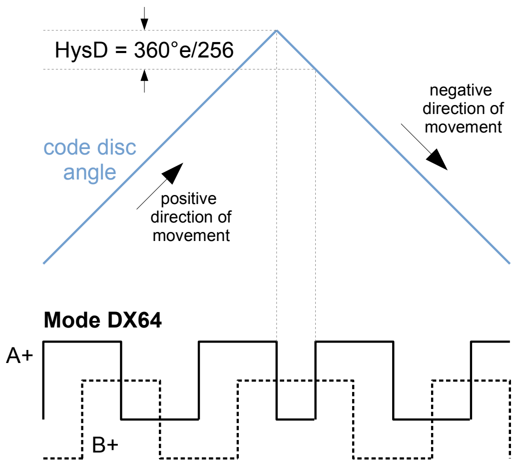



Figure 7: Digital hysteresis (here shown for DX64).

### Minimum Transition Distance Time

The transition distance time is defined as the time between two consecutive A/B edges, as depicted in Figure 8. iC-PXL3212 limits the transition distance time to a minimum of Ttd()min.

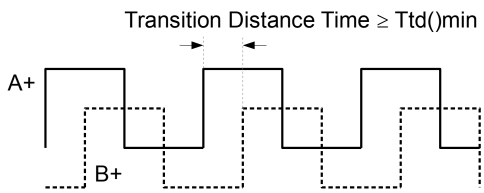



Figure 8: Transition distance time.

If the motor movement would cause faster A/B signals than the minimum transition distance time, the A/B output frequency will be limited accordingly (see fout()ab,mx). In this situation the A/B position increasingly differs from the actual shaft position. If the difference becomes too large, A/B generation will no longer work correctly and incorrect A/B signals will be output, e.g. with incorrect direction.

## SIGNAL CONDITIONING

Fully-differential signal conditioning amplifiers provide optimal analog signal levels for the on-chip interpolation and A/B generation in the digital modes DX#. In mode A1000 these amplified analog signals are output, allowing for inspection and monitoring of encoder assembly.

Moreover, feeding external interpolation circuits is possible. The analog output is illustrated in Figure 9. See Elec. Char. for specified amplitude Vout()ac, DC value Vout()dc, and permissible load current Iout()mx.

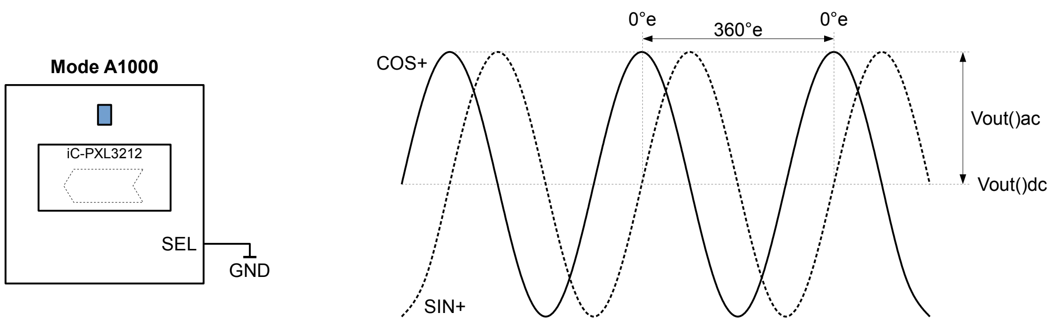



Figure 9: Analog outputs in mode A1000 for positive direction of movement.

## STARTUP

The startup-phase of PXL is indicated by all outputs being tied low by a pull-down current. Afterwards, the function defined by pin SEL is performed.

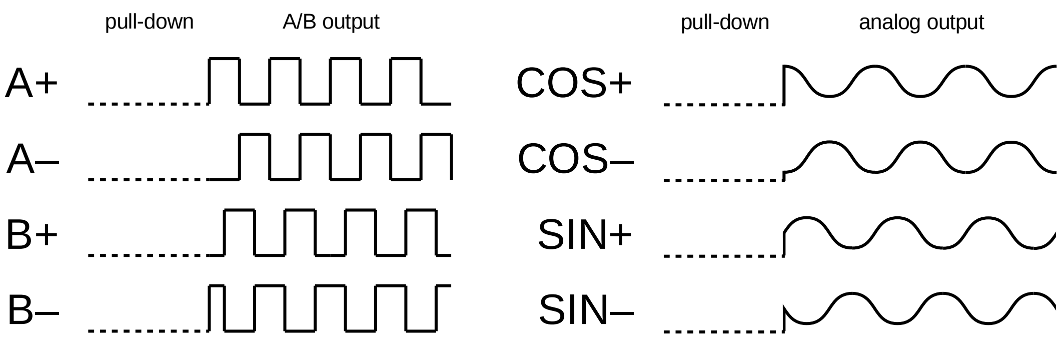



Figure 10: Startup-Phase for digital and analog output

## LED POWER CONTROL

iC-PXL3212 regulates the current through the integrated blue LED, keeping the analog signal amplitudes constant regardless of aging effects, varying temperature or air gap change (iC vs. code disc).

In case of a large code disc displacement or if no code disc is present, a maximum current is sent through the LED (see Elec. Char. Iop()mx).

When the code disc and the iC-PXL3212 are exactly aligned, the LED current is significantly reduced and depends on the code disc type and air gap (see Table 2 for typical overall supply current values).

## SAFETY ADVICE

Depending on the mode of operation, these devices emit highly concentrated visible blue light which can be hazardous to the human eye.

Products which incorporate these devices have to follow the safety precautions given in IEC 60825-1 and IEC 62471.

## HANDLING ADVICE

Because of the specific housing materials and geometries used, these LED devices are sensitive to rough handling or assembly and can thus be easily damaged or may fail in regard to their electro-optical operation. Excessive mechanical stress or load on the LED surface or to the glass window must be avoided.

## LIST OF ACRONYMS

**AOI** Automated optical inspection
**CPR** Cycles per revolution
**EMI** Electromagnetic interference
**ESD** Electrostatic discharge
**HBM** Human-body model
**HD** High definition
**IR** Infrared
**LPI** Lines per inch
**LSB** Least significant bit
**RPM** Revolutions per minute

## DEVICE OVERVIEW

| Device | CPR | Code Disc | | Supply Current / mA | | Max. RPM | |
|---|---|---|---|---|---|---|---|
| | Native | P/O Code | Type | 1.5 mm[1] | 2.0 mm[1] | DX16 | DX64 |
| **∅ 32 mm** | | | | | | | |
| iC-PXL3212 | 512 | PX02S | F | 24 mA | 33 mA | 24000 | 6000 |
| **∅ 36 mm** | | | | | | | |
| iC-PXL3212 | 625 | PX03S | F | 24 mA | 33 mA | 24000 | 6000 |
| **∅ 30 mm** | | | | | | | |
| iC-PXL3212 | 500 | PX04S | F | 24 mA | 33 mA | 24000 | 6000 |

Type M = Metal
Type P = Polycarbonate
Type F = Film
Type [ ] = Glass

Device and code disc availability on request.

Table 2: Device overview

[1] Air gap (iC vs. code disc)

## DESIGN REVIEW: Notes On Chip Functions

| iC-PXL3212 Z, Z1 | | |
|---|---|---|
| **No.** | **Function, Parameter/Code** | **Description and Application Hints** |
| | | None at time of printing. |

Table 3: Design review

## REVISION HISTORY

| Rel. | Rel. Date[1] | Chapter | Modification | Page |
|---|---|---|---|---|
| A1 | 2021-12-10 | | Initial release | all |

| Rel. | Rel. Date[1] | Chapter | Modification | Page |
|---|---|---|---|---|
| B1 | 2023-12-22 | all | Removed details about Encoder Link and added reference to corresponding application note | all |
| | | ELECTRICAL CHARACTERISTICS | Operating conditions: Tj changed to -40..140 °C<br>202: Changed to typ. values at exemplary sine frequencies<br>301: Changed to typ. value<br>312: Removed | 7 |
| | | DEVICE OVERVIEW | Discs added | 14 |
| | | DESIGN REVIEW: Notes On Chip Functions | Added chapter | 14 |



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

## ORDERING INFORMATION

| Type | Package | Options | Order Designation |
|---|---|---|---|
| iC-PXL3212 | 8-pin optoDFN,<br>3 mm x 3 mm,<br>0.9 mm thickness<br>RoHS compliant | | iC-PXL3212 oDFN8-3x3 |
| Evaluation kit | Kit with<br>iC-PXL3212<br>PXL1M (61mm x 64 mm)<br>PX02FS Code Disc | | iC-PXL3212 EVAL PXL1M |
| Mother board | Adapter PCB<br>(80 mm x 110 mm) | incl. ribbon cable | iC-PR EVAL PR2M |

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