DATA SHEET

# PAM7941

## Axial 360 degree absolute Encoder

The Sensor Kit PAM7941 consists of the 360 degree absolute sensor module EAM7941 and a two-track axial magnetic disc.
In combination of both components you will get a true-power-on position measurement system with an resolution up to 21 bit.

By default the module communicates via a SPI-Interface. Other established interfaces like SSI or BiSS-C will be optionally available.

Due to it's axial magnetic disc and the compact, very flat sensor module the system is ideally suited for use in robot joints or flat motors.

With the proven MR-sensor technology and integrated correction algorithms the PAM7941 is a very robust and reliable solution with a high accuracy and repeatability.

### Features

- Singleturn absolute
- Up to 21 bit resolution
- Calibration algorithms
- SPI communication interface
- True-power-on
- Wide temperature range from –40°C up to +105°C

### Product Overview

| Article Name | Description |
|---|---|
| EAM7941USQ-DA-KA | Axial 360 degree absolute sensor module |
| MWC0254FAU-KA | Magnetic disc with axal magnetization |

### Quick Overview

| Symbol | Parameter | min. | typ. | max. | Unit |
|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage | 4.5 | 5.0 | 5.5 | V |
| $I_C$ | Current consumption [1] | 70.0 | 75.0 | 80.0 | mA |
| $Res_{Single}$ | Resolution Singleturn | - | 21 | - | bit |
| $Res_{Multi}$ | Resolution Mutliturn | - | 17 | - | bit |
| d | Working distance | 0.2 | 0.25 | 0.3 | mm |
| Acc | Accuracy [2] | - | ±0.01 | - | deg |
| $T_{amb}$ | Operating temperature | -40 | - | +105 | °C |

[1] without load

[2] after self-calibration routine

### Advantages

- Very flat design (axial)
- High accuracy
- Robust and reliable

### Applications

- Off-axis applications
- Robotic joints
- Automated Guided Vehicles
- Flat electro motors

### Block diagramm

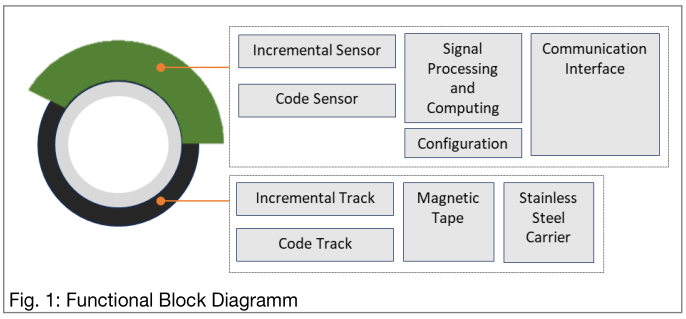



Fig. 1: Functional Block Diagramm

ESD

## Functional Description

**Sensor Module**
The sensor module uses an incremental sensor and sensor array to determine absolute position information over an angular range of 360 degree. The sensor array consists of several sensors that read a serial coding of the magnetic measuring scale. The incremental sensor delivers the fine position and the controller unit of the sensor module calculates the absolute position information over 360 degree from both sensor information.

**Magnetic Disc**
The magnetic disc is magnetized with two magnetic tracks with different encoding. The inner track consists of a serial encoding and is an essential part for the formation of the absolute position. The outer track is an incremental magnetization with alternating north and south poles. This track contributes to the high accuracy of the system.

**Special Feature**
The signal processing of the sensor system has integrated algorithms that allow automatic adjustment of the sensor parameters. In addition, the system provides an auto-correction algorithm that uses look-up table to dramatically increase the absolute accuracy of the system.

## Electrical Data

$T_{amb}$ = 25°C, $V_{CC}$ = 5.0 V; unless otherwise specified

| Symbol | Parameter | Conditions | min. | typ. | max. | Unit |
|---|---|---|---|---|---|---|
| $V_{cc}$ | Supply voltage | | 4.5 | 5.0 | 5.5 | V |
| $F_{SPI}$ | Position Refresh Rate | | - | 200 | - | kHz |
| $F_{Int}$ | Samplingrate | | - | 120 | - | kHz |
| I | Current | $V_{CC}$ = 5.0 V | 70.0 | 75.0 | 80.0 | mA |
| $T_{op}$ | Operating temperature | | -40 | - | +105 | °C |
| $T_{storage}$ | Storage temperature | | -40 | - | +105 | °C |
| $ESD_{HBM}$ | ESD tolerance according to HBM | HBM; 100 pF discharge @1.5 kΩ | - | - | 2000 | V |
| FIT | FIT-Rate | | - | 263 | - | x$10^9$ h |
| MTTF | Mean time to failure | at 55° C | - | 434 | - | years |

## Magnetic Data

$T_{amb}$ = 25°C; unless otherwise specified

| Symbol | Parameter | Conditions | min. | typ. | max. | Unit |
|---|---|---|---|---|---|---|
| $H_{ext}$ | Field strength | | - | - | - | kA/m |
| $N_{Pole}$ | Number of poles | | - | 254 | - | - |
| $L_{Pole}$ | Magnetic Pole length | | - | 0.625 | - | mm |
| $T_{amb}$ | Ambient temperature | | -40 | - | +105 | °C |

## Mechanical Data Magnetic Disc [1)]

$T_{amb}$ = 25°C; unless otherwise specified

| Symbol | Parameter | Conditions | min. | typ. | max. | Unit |
|---|---|---|---|---|---|---|
| | | Magnetic Disc | | | | |
| $D_{out}$ | Outer diameter of the disc | | - | 53.0 | - | mm |
| $D_{in}$ | Inner diameter of the disc | | - | 30.0 | - | mm |
| H | Hight of the disc | | - | 2.0 | - | mm |
| $V_{rot}$ | Rotational speed of the disc | | - | - | 10000 | $min^{-1}$ |

[1)] more details in Fig. 4

## Mechanical Data Sensor Module [2)]

$T_{amb}$ = 25°C; unless otherwise specified

| Symbol | Parameter | Conditions | min. | typ. | max. | Unit |
|---|---|---|---|---|---|---|
| | | Sensor Module | | | | |
| $D_{out}$ | Outer diameter of the module | | - | 74.0 | - | mm |
| $D_{in}$ | Inner diameter of the module | | - | 36.0 | - | mm |
| H | Hight of the module | | - | 3.35 | - | mm |
| $d_{mech}$ | Working distance | | 0.2 | 0.25 | 0.3 | mm |

[2)] more details in Fig. 5

## Performance Data

$T_{amb}$ = +25°C, $V_{CC}$ = 5.0 V, unless otherwise specified

| Symbol | Parameter | Conditions | min. | typ. | max. | Unit |
|---|---|---|---|---|---|---|
| Acc | Accuracy [3)] | | - | ±0.01 | - | deg |
| Rep | Repeatability | | - | ±0.002 | - | deg |
| $Res_{Single}$ | Resolution Singleturn | | - | 21 | - | bit |
| $Res_{Multi}$ | Resolution Multiturn | | - | 17 | - | bit |
| Hys | Hysteresis | | | tbd. | | deg |

[3)] after self-calibration routine

## Absolute Maximum Ratings

The ratings do not imply opening conditions; functional operation is not guaranteed. Beyond these values damage may occur.

| Symbol | Parameter | Conditions | min. | max. | Unit |
|---|---|---|---|---|---|
| $V_{CC}$ | Supply voltage | Referenced to GND | -0.3 | 5.5 | V |
| $ESD_{HBM}$ | ESD tolerance according to HBM | HBM; 100 pF discharge @1.5 kΩ | - | 2000 | V |

## Pinout of the sensor module

| Pad | Symbol | Parameter |
|---|---|---|
| 1 | $V_{CC}$ | Supply Voltage |
| 2 | GND | GND |
| 3 | $TEMP_{PIN1}$ | Temperature sensor PIN 1 |
| 4 | $TEMP_{PIN2}$ | Temperature sensor PIN 2 |
| 5 | $SPI_{SCK}$ | SPI Clock |
| 6 | $SPI_{SS}$ | SPI Slave Select |
| 7 | $SPI_{MISO}$ | SPI Slave Out |
| 8 | $SPI_{MOSI}$ | SPI Slave In |

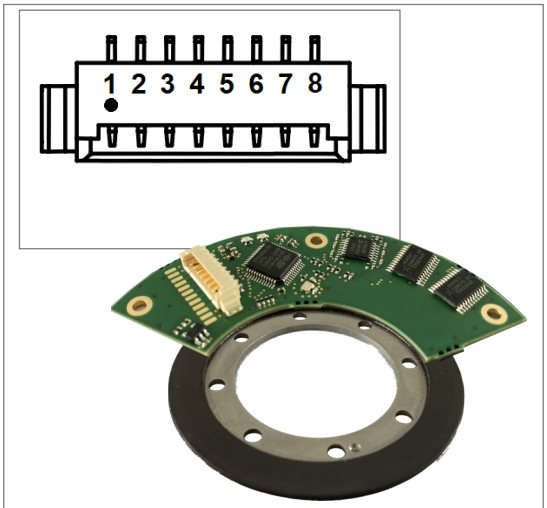
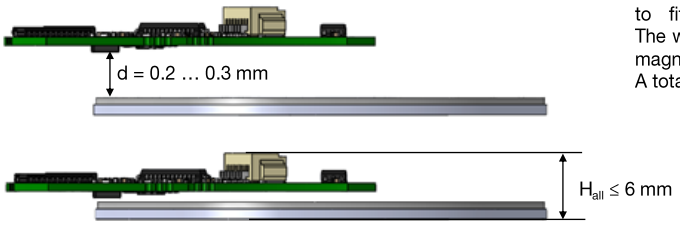



Fig. 2: Pinout of the sensor module

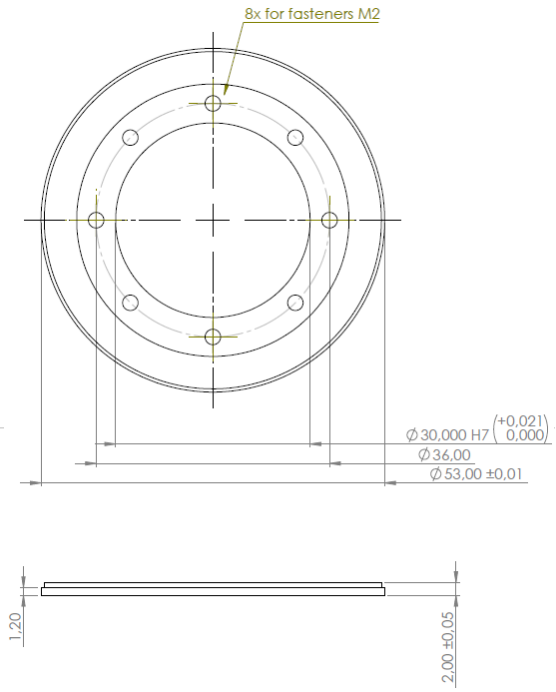
## Application Information




When mounting, make sure that the sensors are adjusted to fit the respective track on the magnetic disc. The working distance between the sensor module and the magnetic disc has a tolerance range of 100 µm. A total height of less than 6 mm can be realized.

Fig. 3: Alignment of the sensormodule and magnetic disc

## Dimensions



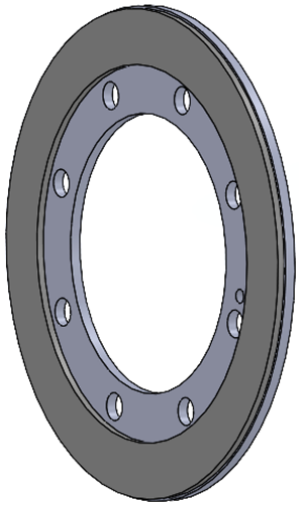
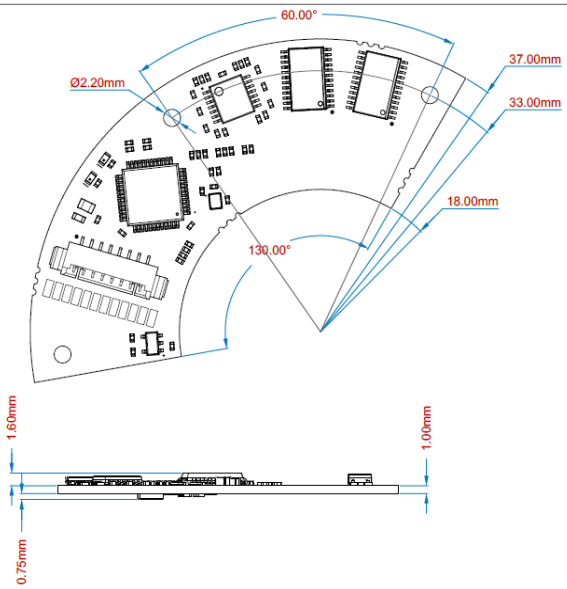



Fig.4: Dimensions of MWC0254FAx-KA



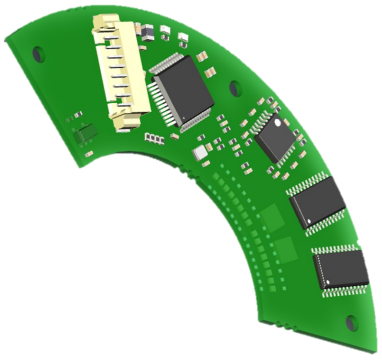



Fig.5: Dimensions of EAM7941

## Performance Graphs

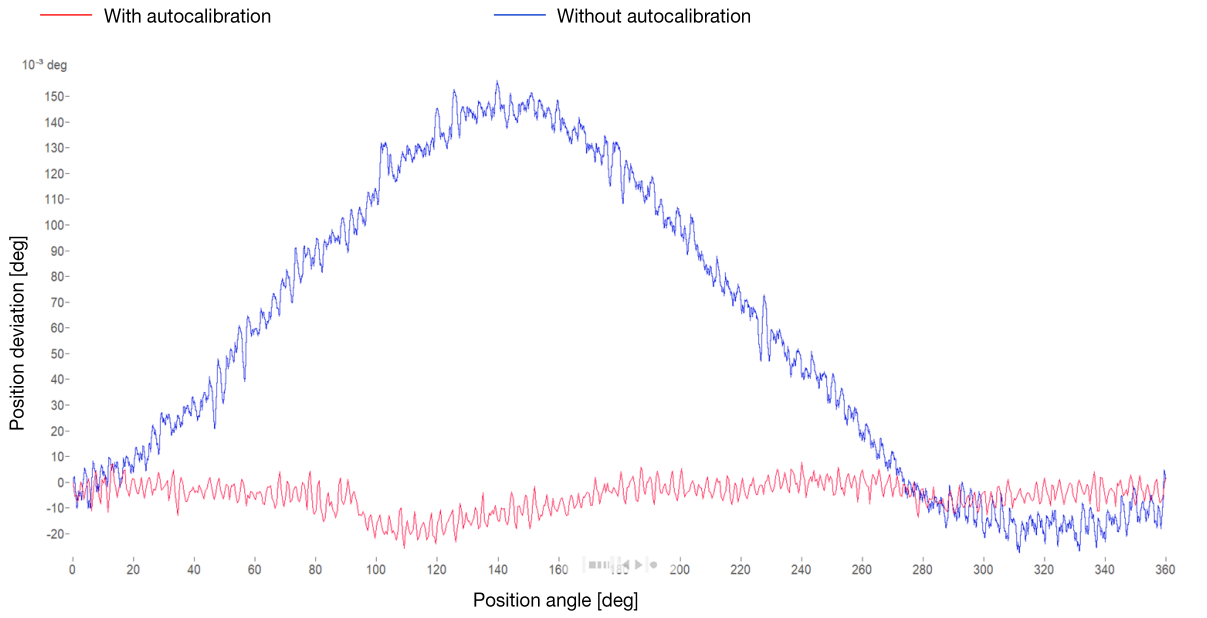



Fig. 6: Absolute accuracy (unidirectional) with and without autocalibration

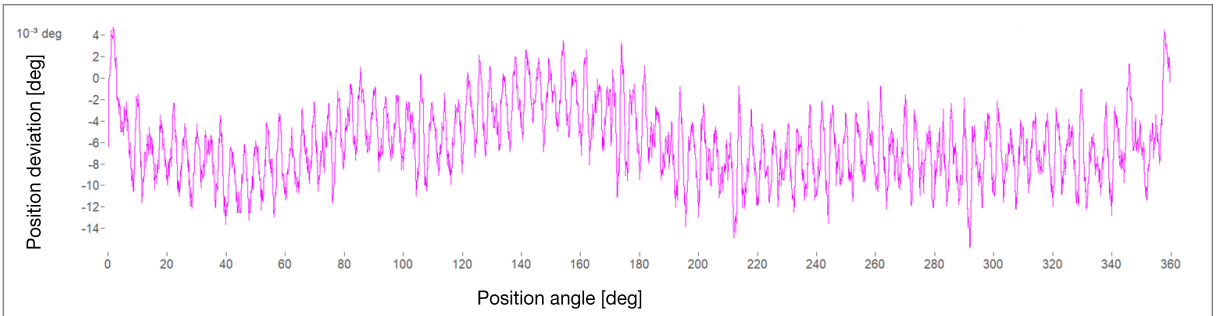


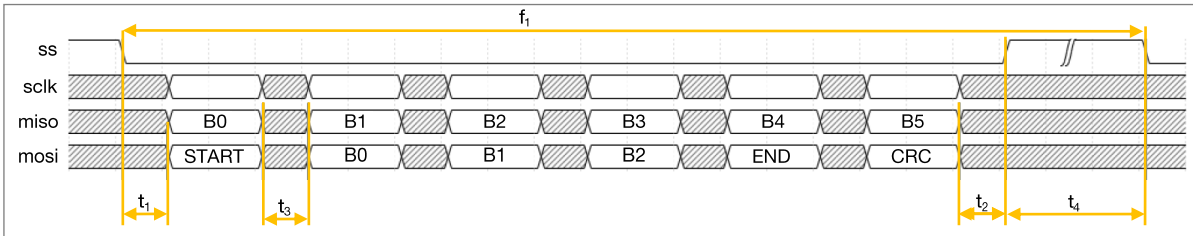

Fig. 7: Absolute accuracy (unidirectional) with autocalibration

## SPI interface

The following chapter describes how the SPI interface is working and how it is possible to receive the position information of the sensor.

The signal conditioning IC operates in slave mode, so it is not possible to start communication itself.

**The interface is compatible to the most typical microcontroller families in SPI mode 0.**




| sclk | 0.98 | 1.96 | 3.91 | 7.82 | MHz |
|---|---|---|---|---|---|
| $t_1$ min | 4 | 4 | 4 | 4 | µs |
| $t_2$ min | - | - | - | - | µs |
| $t_3$ min | - | - | - | - | µs |
| $t_4$ min | 2 | 2 | 2 | 2 | µs |
| $f_1$ max | 16.3 | 28.7 | 47.7 | 71.2 | kHz |

SPI-Mode: 0
Clock Phase: 0
Clock Polarity: 0
SS: active low

If calibration status or single turn position command is transmitted to encoder, the data response will be prepared and transmitted in the next frame. If default SPI output frame should be sent, the actual encoder position is transmitted within the same transmission.

Fig. 8: SPI transfer

## MOSI command frames

| Start | CMD0 | CMD1 | CMD2 | END | CRC | Description | Return |
|---|---|---|---|---|---|---|---|
| 0x00 | 0x00 | 0x00 | 0x00 | 0x00 | 0x00 | Default output frame | Default |
| 0x42 | 0x10 | 0x00 | 0x00 | 0x7E | 0xFB | Trigger linear and non-linear calibration (sequentially), and turn both on. | Default |
| 0x42 | 0x11 | 0x00 | 0x00 | 0x7E | 0x66 | Trigger linear calibration (and turn it on) | Default |
| 0x42 | 0x12 | 0x00 | 0x00 | 0x7E | 0xDC | Turn linear calibration on | Default |
| 0x42 | 0x13 | 0x00 | 0x00 | 0x7E | 0x41 | Turn linear calibration off | Default |
| 0x42 | 0x14 | 0x00 | 0x00 | 0x7E | 0xB5 | Trigger non-linear calibration (and turn it on) | Default |
| 0x42 | 0x15 | 0x00 | 0x00 | 0x7E | 0x28 | Turn non-linear calibration on | Default |
| 0x42 | 0x16 | 0x00 | 0x00 | 0x7E | 0x92 | Turn non-linear calibration off | Default |
| 0x42 | 0x17 | 0x00 | 0x00 | 0x7E | 0x0F | Untrigger calibration | Default |
| 0x42 | 0x18 | 0x00 | 0x00 | 0x7E | 0x67 | Untrigger linear calibration | Default |
| 0x42 | 0x19 | 0x00 | 0x00 | 0x7E | 0xFA | Untrigger non-linear calibration | Default |
| 0x42 | 0x20 | 0x00 | 0x00 | 0x7E | 0x94 | Set zero position | Default |
| 0x42 | 0x21 | 0x00 | 0x00 | 0x7E | 0x09 | Calibration status | Status |
| 0x42 | 0x42 | 0x00 | 0x00 | 0x7E | 0x6D | Singleturn position (32 bit) | Position |

### Default SPI output frame

| Bits | Description |
|---|---|
| Bit00 - Bit07 | 8 Bit CRC |
| Bit08 | Warning, always low (reserved) |
| Bit09 | High, if position is invalid |
| Bit10 - Bit30 | 21 Bit Singleturn position, left aligned, MSB first |
| Bit31 - Bit47 | 17 Bit Multiturn counter , left aligned, MSB first |

### Fullscale absolute position

| Bits | Description |
|---|---|
| Bit00 - Bit07 | 8 Bit CRC |
| Bit08 - Bit15 | Reserved |
| Bit16- Bit47 | Singleturn position (32 bit), left aligned, LSB first |

### Calibration status

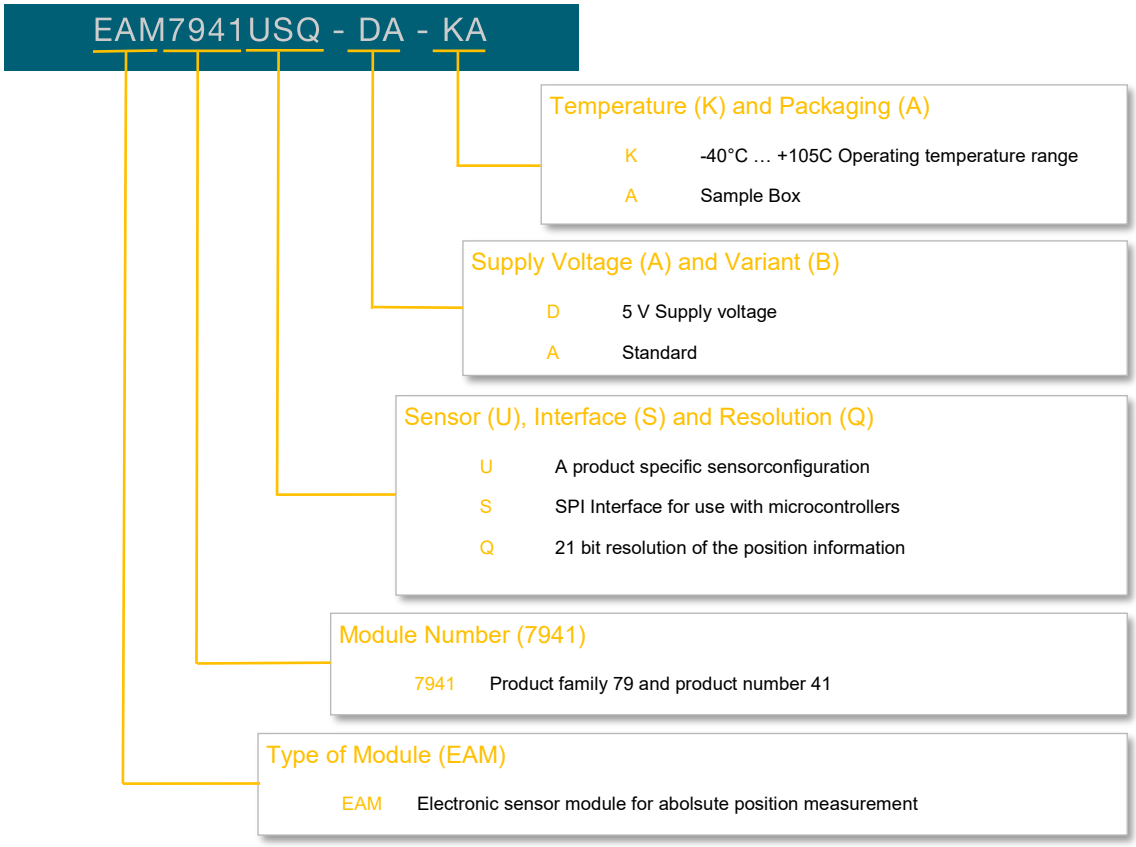
| Bits | Description |
|---|---|
| Bit00 - Bit07 | 8 Bit CRC |
| Bit10 - Bit39 | Reserved |
| Bit40 | Linear calibration active |
| Bit41 | Linear calibration triggered |
| Bit42 | Reserved |
| Bit43 | Reserved |
| Bit44 | Non-linear calibration triggered |
| Bit45 | Non-linear calibration triggered |
| Bit46 | Reserved |
| Bit47 | Reserved |

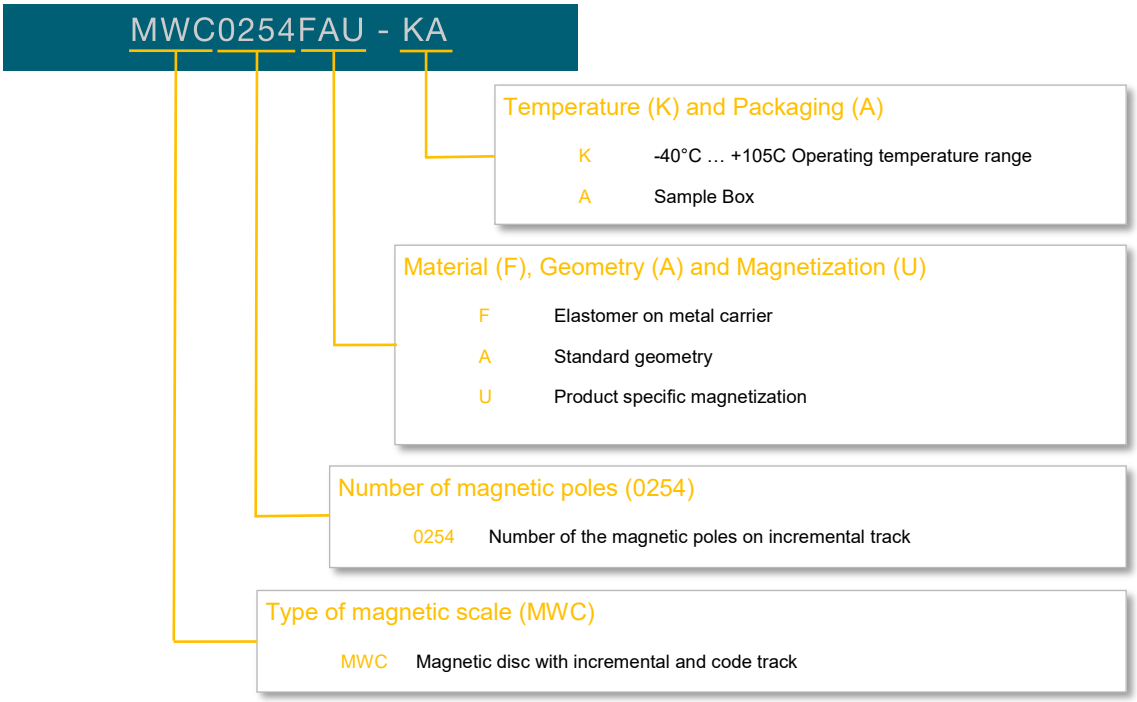
### Calibration

The encoder calibration consists of a linear calibration which calibrates the internal sensor parameters, e.g. amplitude and phase, and a non-linear calibration which minimize position errors caused mainly from magnetic scale and mounting position.
The calibration is started by triggering the linear and/or non-linear calibration, respectively. After starting the calibration, the pole ring must be rotated at least 360 degrees, while the calibration is running. The calibration stops automatically when it is completed. For the non-linear calibration a constant speed is required and is also recommended for the linear calibration. The upper speed limit for calibration is **36 degree per second**.
When both calibrations are carried out individually, a linear calibration must have been carried out before the non-linear calibration is started.

Note, that the calibration can be stopped manually by untrigger the respective calibration. Old calibrations are not overwritten by this action.

## Additional Information on Ordering Code



## General Information

### Product Status

| Article | Status |
|---|---|
| EAM7941USQ-DA-KA | The product is under development. |
| MWC0254FAU-KA | The product is under development. |
| **Note** | The status of the product may have changed since this data sheet was published. The latest information is available on the internet at www.sensitec.com. |

### Disclaimer

## General Information

### Application Information

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### Life Critical Applications

These products are not qualified for use in life support appliances, aeronautical applications or devices or systems where malfunction of these products can reasonably be expected to result in personal injury.

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### Changelist

| Version | Description of the Change | Date |
|---|---|---|
| PAM7941.DSE.03 | Include the SPI-interface description | 04/2024 |
| PAM7941.DSE.02 | Include some more technical data | 10/2023 |
| PAM7941.DSE.01 | Change from target spec to real values | 08/2023 |
| PAM7941.DSE.00 | Original (pp. 1-6) | 04/2023 |

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