SmarAct METIRIO Encoder
ENCODER EVALUATION KIT

SmarAct | metrology

Abstract
This document contains information on how to setup, and use the **ENCODER** EVALUATION **KIT** and its components. It further describes a step by step process to adjust the **METIRIO** Encoder for optimized signals.

ABBREVIATIONS

EEK	**ENCODER** EVALUATION **KIT**
EES	**ENCODER** EVALUATION **SLIDE**
EEM	**ENCODER** EVALUATION **MODULE**
EEP	**ENCODER** EVALUATION **PROGRAM**
MTP	Multiple-Times Programmable (Memory)
RAM	Random Access Memory

INTRODUCTION

The **ENCODER** EVALUATION **KIT** is an standalone equipment accommodating all necessary electrical, mechanical and optical functions for encoding positional information. Its main purpose is to facilitate the alignment and adjustment process of the **METIRIO** Encoder during installation and testing. The 4 main components are described in the following:

ENCODER EVALUATION SLIDE

Figure 1. ENCODER EVALUATION SLIDE

The **EES** is a pre-mounted mechanical component comprising a guide rail, a sensor strip and a slide onto which the **METIRIO** Encoder embedded in its A1 housing can be attached via two screws.
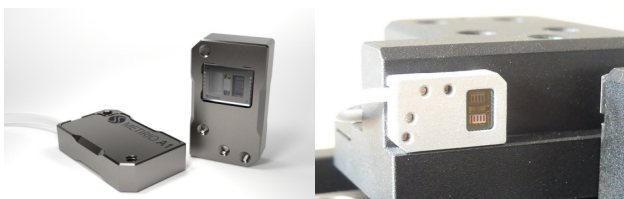
METIRIO A1

Figure 2. METIRIO A1 and mounted to EES

METIRIO Encoder in A1 housing.

ENCODER EVALUATION MODULE

The **EEM** is an electronic box whose architecture is based on the **MCS**2 technology. The electronic is fully adapted to communicate and interact efficiently with **METIRIO** Encoders and allows streaming of analog signals with a rate of up to 50 kHz to a connected PC. A **METIRIO** A1 encoder can be directly connected to the D-Sub 15 female connector. The pins are described in table 1. For more details refer to the Encoder User Manual, chapter Technical Data. Additionally, the analog signals (sine, cosine and reference) can be observed on the BNC connectors with the **METIRIO** Encoder own rate of 500 kHz.

Figure 3. ENCODER EVALUATION MODULE side views

ENCODER EVALUATION PROGRAM

The **EEP** is a software package that runs on Windows PC. It connects to the **EEM** to communicate with the **METIRIO** Encoder in order to read and write settings from the encoder's RAM and MTP memory. Furthermore it shows the encoder's main output signals (Sine, Cosine and Reference) in two graphs:

1. Lissajous figure

2. Position resolved

Pin	Description	Pin	Description
1	n.c.	9	n.c.
2	n.c.	10	SCL (in/out)
3	n.c.	11	SDA (in/out)
4	GND	12	U_{sin-} (in)
5	U_{sin+} (in)	13	U_{cos-} (in)
6	U_{cos+} (in)	14	U_{Ref-} (in)
7	U_{Ref+} (in)	15	V_{DD} (out)
8	PD (out)	Housing	Shield

Table 1. *Pin description of D-Sub 15 female connector of the* **EEM**
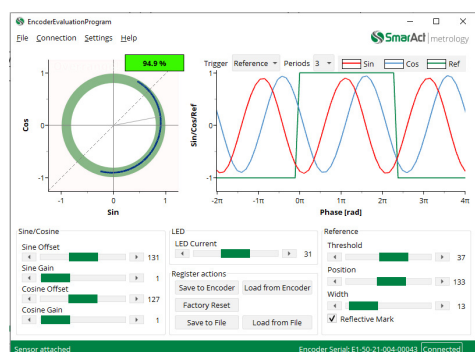

Figure 4. **ENCODER** *EVALUATION* **PROGRAM**

Further Components

- Power Supply 12 V, 2 A

- USB Cable

- PC running Windows 10 or 11 (not included)

SETUP OF EEK

In the following, the operation functions of the **EEP** are illustrated using the **EES**. Any arbitrary motion control system can be utilized instead given the **METIRIO** Encoder parameter space.

1. Mount the **METIRIO** Encoder to the slide of the **EES** using two screws, see Figure 2.

2. Install the **EEP** on the desired PC using the installer provided.

3. Connect the **METIRIO** A1 and the PC to the **EEM** as shown in Figure 5. Use the 12 V Power Supply to power the **EEM**. To turn it on push the power button on the front panel. Use only the cables and Power Supply delivered by SmarAct Metrology.

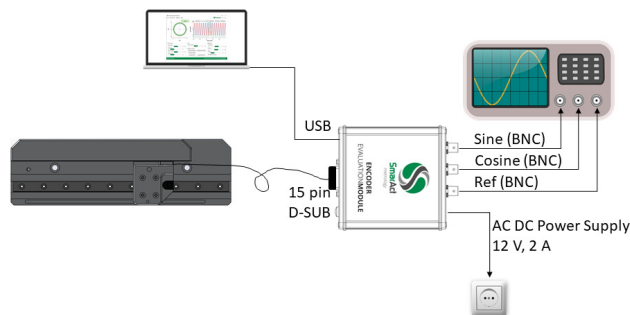4. Optionally, connect an oscilloscope to the **EEM** using BNC cables to monitor the signals directly.

Figure 5. **ENCODER** *EVALUATION* **KIT** *connection diagram*

USING THE EEP

Connecting to an EEM

The **EEP** automatically establishes a connection to the first available **EEM** it finds. The connection state is highlighted in the status bar in the lower right corner of the UI. Additionally, clicking on the state connects or disconnects the **EEM** relative to the present state. A connection wizard is available in the menu bar under the item *Connection*, listing all existing **EEM**s that can be connected or disconnected, respectively.

The attachment or detachment of a **METIRIO** Encoder to or from the **EEM** is automatically processed, and the GUI initialized accordingly. The serial number of the current operating **METIRIO** Encoder is shown in the status bar left of the connection state. Upon attachment of a **METIRIO** Encoder, its settings are loaded from the memory as the current values of the corresponding controls.

Display of Signals

The Sine, Cosine and Reference signals from an attached **METIRIO** Encoder are displayed in the two graphs simultaneously. The data is acquired with a rate of 50 kHz which is the maximum rate of the **EEM**.

Lissajous Figure

In the left graph the Sine and Cosine signals are shown in a Lissajous figure. It is most useful for providing feedback during the adjustment of the **METIRIO** Encoder. The green ring is a guidance for a range of good signal settings. Additionally, the amplitudes and offsets of the signals are used to calculate a signal strength which is depicted in the top right corner of the graph. The background color of the signal strength also indicates the quality of the signal in the range of red (bad) to dark green (good). The color fades if the **METIRIO** Encoder has not been moved recently, signaling that the value might require validation.

If the signals are on or outside of the unit radius, an overrange warning is triggered because the signals could potentially be truncated, see Figure 6.

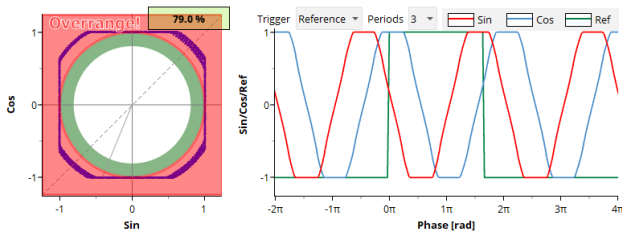The presence of a reference mark is shown with a cyan colored background.

Figure 6. *Overrange warning due to too high LED brightness*

Triggered Position

In the right graph the Sine, Cosine, and Reference signals are outlined as function of the current position. The position value is the accumulated phase calculated from the Sine and Cosine signal during the movement of the **METIRIO** Encoder. The mode of the graph can be chosen with the *Trigger* selection above the graph. In the *Reference* mode, new data is only filled into the graph on moving across a reference mark which will then be displayed in the center of the graphs range. The latest signal periods are shown in the *Phase* mode recording best the movement of the **METIRIO** Encoder along the axis.

The range of the phase axis can be selected with the *Periods* drop-down list to 3, 15 or 40 periods.

Because of the limited data rate of maximal 50 kHz by the **EEM**, moving the encoder very fast leads to under sampling of the Sine and Cosine signals. Consequently, the phase can no longer be reliably calculated without the risk of skipping periods. In this case no signals will be plotted in the graph.

Encoder Setting Controls

The **METIRIO** Encoder settings can be changed with the controls below the graphs and are directly applied to the **METIRIO** Encoder. They are grouped in settings for the Sine and Cosine signals, LED brightness, and reference signal.

Each parameter and its range is represented by a slider. The current value is noted on the right side of the corresponding slider. Due to the PCs system settings, the minimum step size for the slider might be too large to be able to set every value. For a precise adjustment, the arrow buttons left and right of the slider provide a step size of one.

A special case are the parameters *Width* and *Position* for the reference mark because they control two coupled thresholds. Since one threshold needs to be higher than the other the range of each individual slider depends on the other one and is dynamically adapted.

The only parameter not represented by a slider is the type of the reference mark, which can be set with the check box *Reflective Mark* to reflective (checked) or absorbing (unchecked).

METIRIO Encoder Memory Management

The **METIRIO** Encoder has two types of internal memory.

1. RAM

   With the **EEP**-sliders of the , it is possible to interact directly with the encoder RAM. Setting the RAM will immediately affect the encoder performance, e.g. changing the Sine gain or LED brightness. However, these settings are not permanent and get lost upon power cycling the encoder.

2. MTP

   The MTP is used to store permanently all settings of the encoder. After power cycle, all RAM values will be reset to the values previously stored in the MTP. Changes of settings in the RAM will not influence the MTP.

With the group of buttons *Register actions* the memory of the encoder, meaning all register at once, can be affected.

The RAM is saved to MTP with the *Save to Encoder* button. Loading settings from the MTP into the RAM is carried out with *Load from Encoder*. Caution - the values in the RAM are overwritten and not recoverable. The RAM settings can also be saved to a file on the PC with the button *Save to File* and again loaded into the RAM with the button *Load from File*.

With the *Factory Reset* button the RAM is reset to the default values representing a stable but not adjusted state.

Messages

In the status bar on the left, messages about changing system status, warnings, and problems are highlighted.

Changing status refers to connection and disconnection of of the **EEM** or the **METIRIO** Encoder. In case the connection to the **EEM** is lost e.g., because of turning it off or unplugging the USB cable a warning will be shown.

In addition a log file is saved in the installation folder.

Menu

In the menu at the top, except for the program exit, more functions can be found that are dedicated for advanced users.

The connection wizard has already been described. Under the *Help* item the software version of the **EEP** is documented. The *Settings* item opens the *Advanced Settings Wizard*.

Advanced Settings

LED Control Loop

Switching the Enabled status will set the encoder to the *Control Loop* mode. Then the encoder automatically adapts the brightness of the LED to the *Setpoint* requested with the slider. The control for the *LED Current* is consequently disabled.

This mode is not recommended. Please contact SmarAct Metrology for further advise.
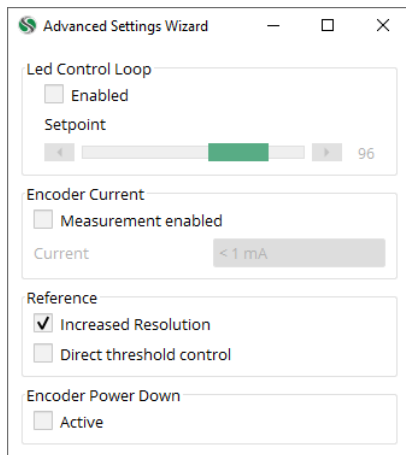
Figure 7. *Advanced Settings Wizard*

Encoder Current
This mode shows the current consumption of the encoder. If the value is grayed out, it is not valid.

Reference Increased Resolution
This mode is per default enabled.
If disabled, it allows for adjustment the width and position of the reference mark with greater steps size over a larger range.

Reference Direct Threshold Control
For advanced users: The setpoints of the left edge and the right edge of the TTL pulse of the reference mark can be changed separately if enabled. The *Width* and *Position* controls are swapped to the *Threshold* controls.
Normally this mode is disabled.

Encoder Power Down
The **METIRIO** Encoder can be powered down with the *Active* checkbox to stop current consumption. This is a power cycle, meaning that the current RAM settings are lost. On reactivation, the settings are loaded from the MTP in to the RAM. The *Save to Encoder* can be used to store the RAM settings to MTP before hand.
If this mode is active, a warning in form of a button is displayed in the status bar *Deactivate Power Down*, which is also a short cut to deactivate the power down, see Figure 8.
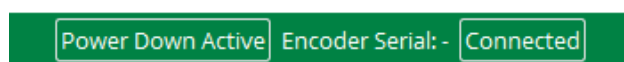

Figure 8. *Status bar if power down is active*

ADJUSTMENT OF A METIRIO ENCODER

The adjustment of a **METIRIO** Encoder consists of the following steps. It is advised to abide to this order if adjusting a **METIRIO** Encoder for the first time.

1. Mounting

2. Mechanical alignment with default settings

3. Electrical adjustment of incremental signals

    (a) LED brightness

    (b) Sine and Cosine offset

4. Electrical adjustment of reference marks

    (a) Window

    (b) Width

    (c) Position

5. Storage to Encoder memory or file

The steps are described in more detail in the following sections.

Mounting
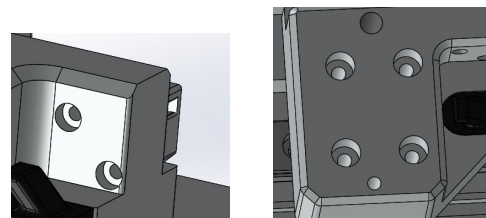Mount the encoder via two M1.6 screws to the slide.

Figure 9. *Mounting point for* **METIRIO** *A1 and slide loosening screws*

Mechanical Alignment
1. Turn on the **EEM** and start the **EEP** to observe the signals of the Encoder.

2. Press the *Factory Reset* button to start the adjustment with the default Encoder settings.

3. Loosen the four M3 screws to give some degrees of freedom fort the encoder alignment.

Figure 10. *Mounted* **METIRIO** *A1*

4. Move the encoder back and forth along the axis and over a reference mark of the scale. Ensure the slide is loose to adjust the rotation and the distance to the sensor scale by pulling and twisting the slide.

5. Monitor the signals and try to align the system for good signals.
A weak signal is small in diameter and distorted in shape.
A good signal is perfectly round and has a maximum diameter. Adjust distance and rotation of the Encoder with respect to the sensor scale.
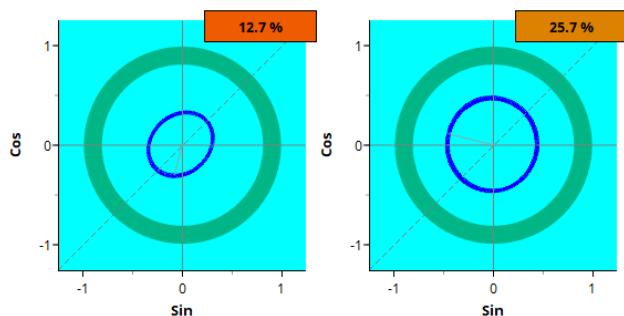

Figure 11. *Weak, distorted signal before alignment; larger diameter, round signal after alignment*

Notice:
With the default factory settings, it is unlikely to reach a perfect signal strength. Continue the mechanical alignment process until no further increase in the signal strength is achived. A local maximum in circle diameter and a perfect round circle indicates the best possible signal strength with regard to the sensor scale and mechanics.

6. Tighten the screws to lock all degrees of freedom while maintaining the signal strength.

Electrical Adjustment

1. Increase the LED brightness with the slider or button for *LED Current* to achieve a maximum signal strength.
Since the signal can slightly change during travel over the entire length, move the slider over the entire length of your sensor scale to guarantee no overranges.

2. Adjust the Sine and Cosine Offset to center the signal. Check again the entire travel range.
Usually there is no need to adjust Sine and Cosine Gain. It is suggested to leave these values close to zero. They are for fine tuning only or to avoid increasing the LED brightness for any reason.

A signal strength above 75 % is well suitable for high precision position measurements.
The shape of the signal is preferred to be small but round, rather than elliptical or showing overranges. However, a perfect signal to noise ratio necessitates resuming the fine-tuning procedure until the process results in values above 90 % over the entire travel range and without any overrange events.

Congratulations! You have done the incremental Signals.

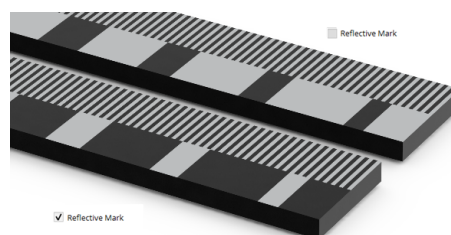**Electrical Adjustment of Reference Marks**

Figure 12. *Scales with reflective and absorbing Reference Marks respectively*

1. Chose the proper type in use:
   - reflective marks (bright on dark or dull background)
   - or absorbing marks (dark on bright background).

   Check the checkbox *Reflective Mark* accordingly.

2. Set the *Trigger* to *Reference* and the *Periods* to 40. Move the encoder back and forth over one reference mark. Keep moving while doing the adjustment.
Note that neither a TTL pulse is visible nor 40 periods yet, but only one edge of the TTL pulse.
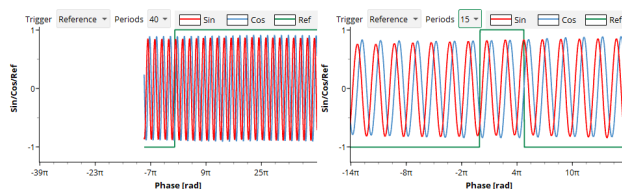

Figure 13. *Start of Reference Mark adjustment; after increasing the threshold and decreasing the width*

3. Increase the *Threshold* until all 40 periods are recorded.

4. Decrease the *Width* until one TTL pulse spans only a couple of periods.

5. Then switch to 15 or even 3 periods.

6. Adjust the *Width* further, so that the width of the reference mark is not much greater than one period of the incremental track.
Condition 1:

$$1.5\,\pi < \text{width} < 2.5\,\pi$$

7. Adjust the *Position*, so that the Sine/Cosine cross is in the middle of the reference mark.
Condition 2:

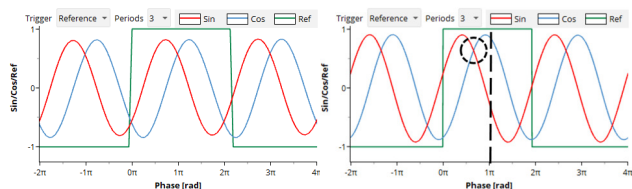Upper cross point closer to $1\,\pi$ than lower one.

Figure 14. *Condition 1 and 2 example*

8. There might be a slight hysteresis between the forward and backward direction.
   Move the encoder back and forth and ensure that the period is located in the center for both directions. Else wise adjust the *Position* slider for a good compromise between both directions. Condition 1 and 2 should hold for both movement directions.
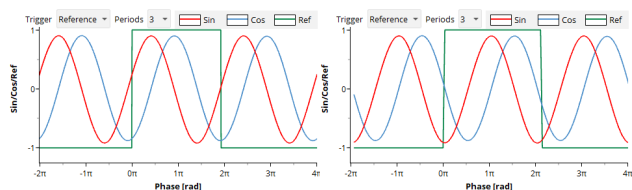

Figure 15. *Forward and backward movement hysteresis*

9. Optional:
   Check the conditions for all reference marks.
   If there are several reference marks (for example distance coded) distributed over the travel range, move the encoder over the entire travel range to check Condition 1 and 2 for all reference marks.

Storage to Encoder Memory or File
Store the settings to the Encoders Memory using the *Save to Encoder* button. The settings will be permanent even after power cycling the encoder.
Additionally, the settings can be stored to a configuration file with the *Save to File* button.

DIRECT SIGNAL OBSERVATION

The stream rate of the EEM is 50 kHz, but the **METIRIO** Encoder is 10 times faster (500 kHz).
For observing **METIRIO** Encoder analog signals with full bandwidth, connect an oscilloscope with BNC cables to the analog output plugs of the **EEM**.

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SmarAct Metrology GmbH & Co. KG develops sophisticated equipment to serve high accuracy positioning and metrology applications in research and industry within fields such as optics, semiconductors and life sciences. Our broad product portfolio – from miniaturized interferometers and optical encoders for displacement measurements to powerful electrical nanoprobers for the characterization of smallest semiconductor technology nodes – is completed by turnkey scanning microscopes which can be used in vacuum, cryogenic or other harsh environments.

We maintain the complete production in house for a high level of customization so that we can always provide you the optimal individual or OEM solution. We also offer feasibility studies, measurement services and comprehensive support to accompany you along your projects.

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