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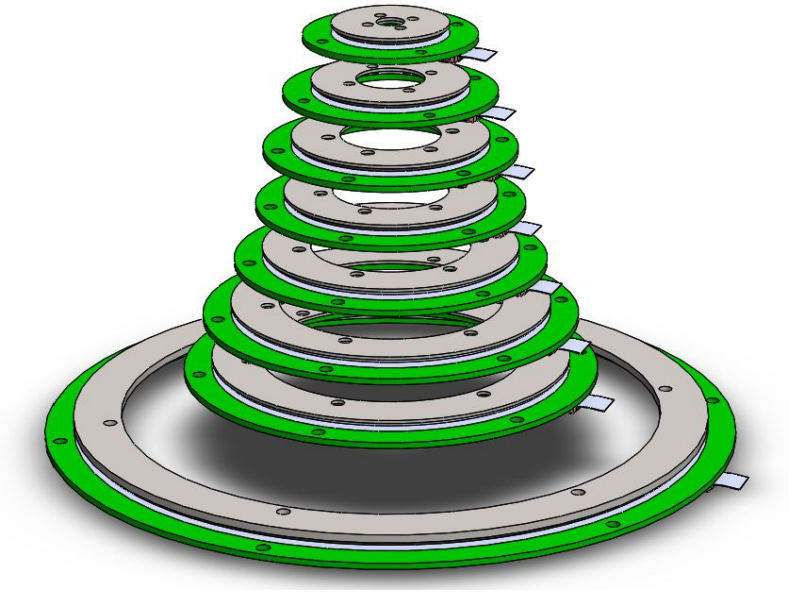
“AFE” Series

Absolute Frameless Encoder

Based on Giant Magneto Impedance (GMI) Principle



Preliminary Datasheet

2020-09

Technical data subject to change

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1. Giant Magneto Impedance Encoder

1.1. General considerations

The Giant Magneto Impedance phenomenon is known since 1930 and its main application was measuring extremely weak magnetic fields.

With its proprietary GMI technology (patent granted), FLUX GmbH Austria is the first encoder manufacturer which implemented this physical principle in position measurement systems.

The Giant Magneto Impedance (GMI) is a completely different physical phenomenon than the magnetoresistance and Hall effect which are usually applied in position measuring systems.

Magnetoresistance and Hall effect phenomenons can be explained by the Lorentz force that changes the flow of charge carriers (direct current) in a conductor, when it is placed in an external magnetic field. Consequently by changing the flow path in a conductor of direct current, the resistance of the path changes. The sensors based on these principles have some disadvantages like: position hysteresis (also known as backlash in a drive system), punctual scanning, low signal to noise ratio and relative low accuracy thus limiting their use mostly to “low end” applications. These disadvantages are specific to all types of magnetoresistance sensors: anisotropic (AMR), giant (GMR), tunnel (TMR).

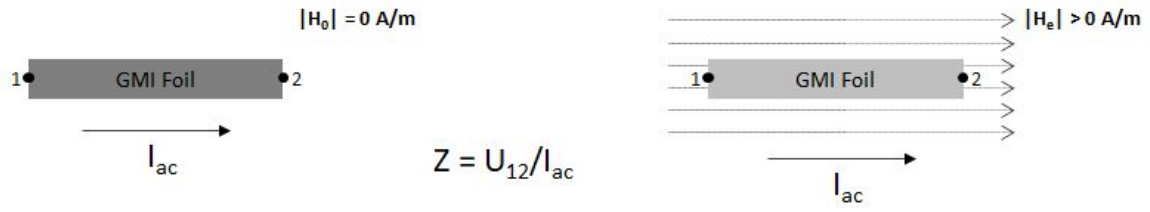
The Giant Magneto Impedance is based on the skin-effect. An external magnetic field changes the permeability and consequently the skin depth of a ferromagnetic material with GMI properties which is passed by an alternating current.

The most notable advantages of this principle are:

- no position hysteresis / backlash
- scanning area over the entire circumference of a rotary measurement system
- high signal to noise ratio
- high accuracy
- large mounting tolerances

1.2. Giant Magneto Impedance principle

A GMI foil is a thin conductive ferromagnetic metallic foil. The impedance "Z" of a GMI foil changes when applying an external magnetic field like in Fig. 1.



no magnetic field: $|H_0| = 0$ A/m within magnetic field: $|H_e| > 0$ A/m

Fig. 1. GMI foil in no respectively in external magnetic field

For a given frequency of the measuring alternating current (I_{ac}) the foil impedance (Z) in lower magnetic fields ($|H_0| \sim 0$ A/m) is bigger than the impedance of the foil when placed in a higher magnetic field ($|H_e| > 0$ A/m):

$$Z(|H_0|) > Z(|H_e|)$$

the depth of the flowing domain depends on the resistivity of the material influenced by the presence of the magnetic field.

When such a GMI foil is placed above a magnetic scale coded with alternating polarity domains, areas with lower (darker) and higher (lighter) impedance arise like in Figure 2.

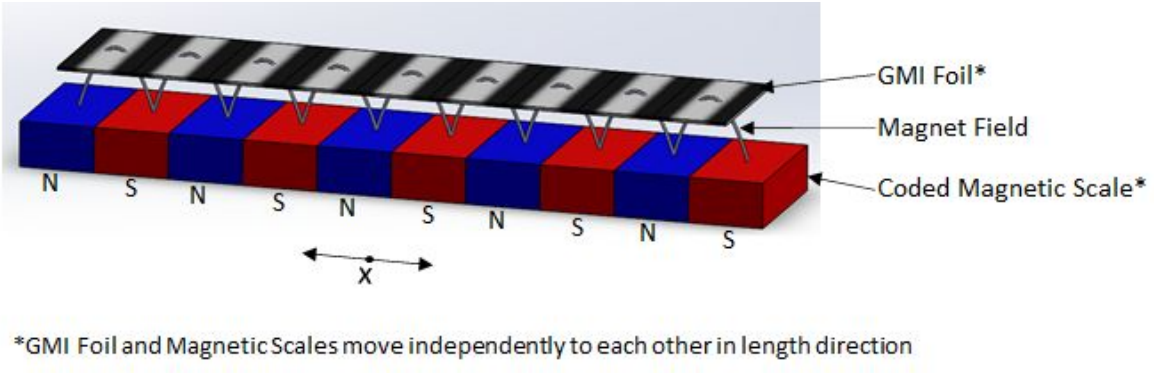


Fig.2. Areas with lower and higher impedance in a GMI foil

The position of the area with:

- low $Z(|H_e|)$ - lighter color
- high $Z(|H_0|)$ - darker color

impedance in the GMI Foil changes with respect to the relative position of the magnetic scale in the direction of measurement "x".

A position depending electrical signal can be generated by acquiring the impedance of the areas $Z(|H_0|)$ and $Z(|H_e|)$ by the means of using a coil system like in Figure 3.

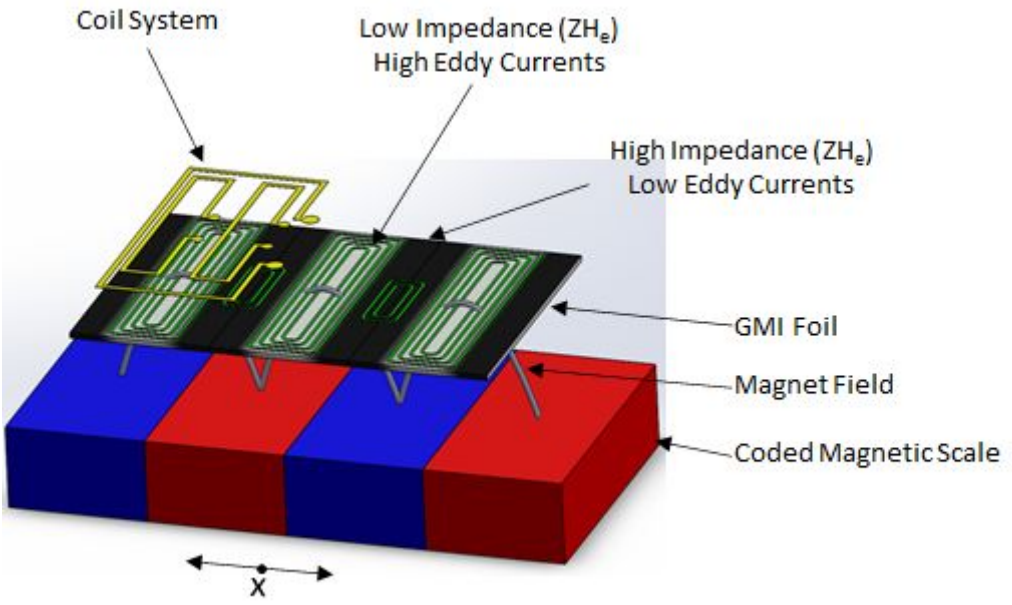


Fig.3. Coil System for impedance measurement

The emitter coil (E) is connected to a high frequency alternating current source in range of 1 up to 10MHz. The time variable magnetic field generated by the emitter coil induces eddy currents in the GMI foil. The eddy current amplitude and position will be determined by the impedance of the area below the coil system:

- area with low impedance (lighter color): eddy currents with high amplitude
- area with high impedance (darker color): eddy currents with low amplitude.

In Figure 4 the differential receiver coils (R+), (R-) generate an output signal proportional to the difference of the eddy current intensities of each impedance area. This electrical signal is conditioned and processed by the evaluation electronics and outputted as position information.

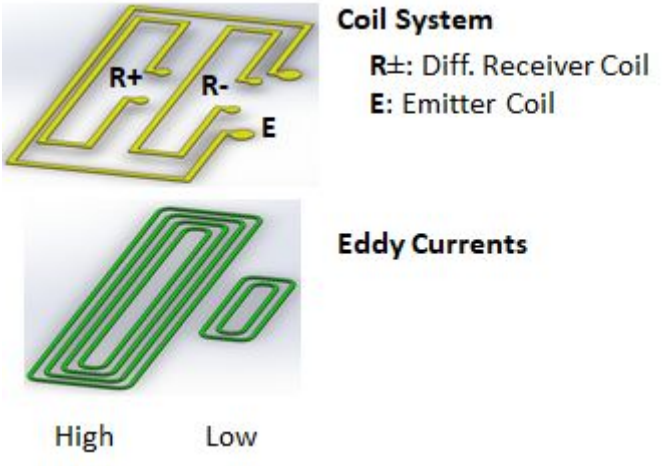
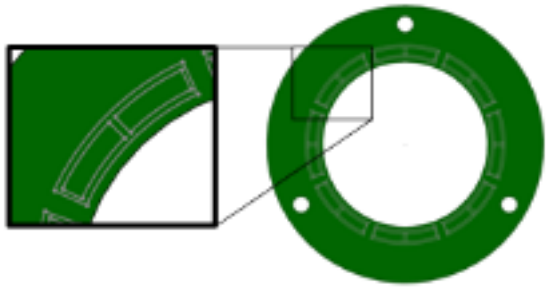
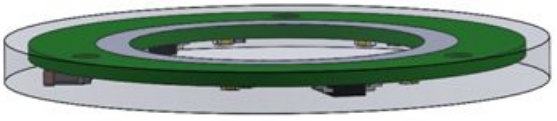


Fig.4. Coil system and induced eddy currents

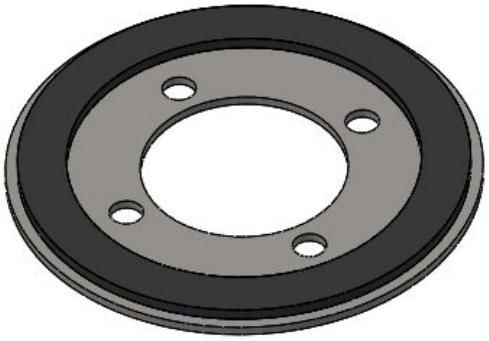
1.3. Axial Frameless Encoder (AFE)

1.3.1. Axial Readhead (ARH) built-up

The emitter and receiver coils are integrated as traces into a standard PCB: 	Above the coils, a thin GMI foil is bonded on the PCB: 
Assembling of analog-digital electronics for signal processing and interpolation including buffers for the output interface: 	On request, the system can be integrated in an IP67 housing: 

1.3.2. Axial Coded Ring (ACR) built-up

The absolute coded ring is precisely magnetized with a special method and equipment developed by FLUX GmbH to achieve the highest accuracy



1.3.3. Absolute Frameless Encoder (AFE) built-up

The absolute AFE (Figure 5) rotary encoder with axial GMI scanning consists of two components:

- Rotor part (ACR) - thin metal ring with magnetic coded area
- Stator Part (ARH) - printed circuit board with sensor (coil array and GMI foil) and evaluation electronic with absolute serial output interface

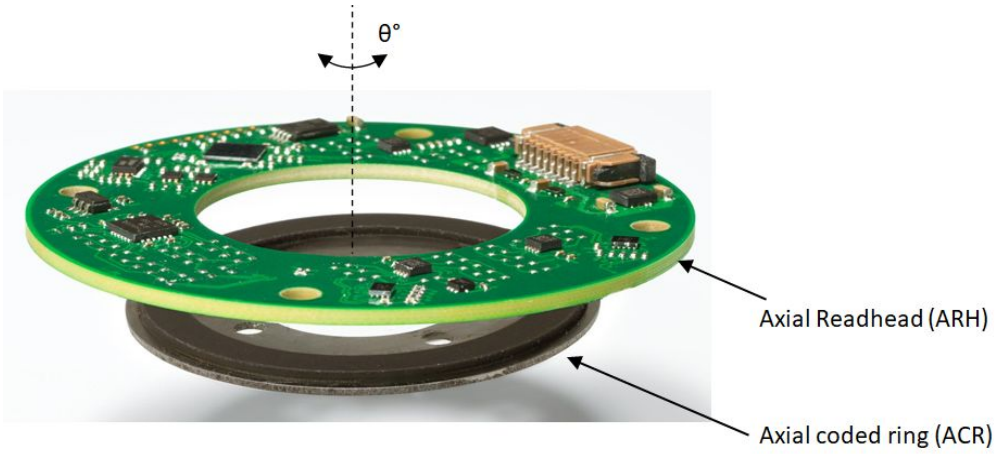


Fig. 5. Absolute Frameless Encoder - Size 039

In Figure 6 one of the mounting options, with fasteners is presented.

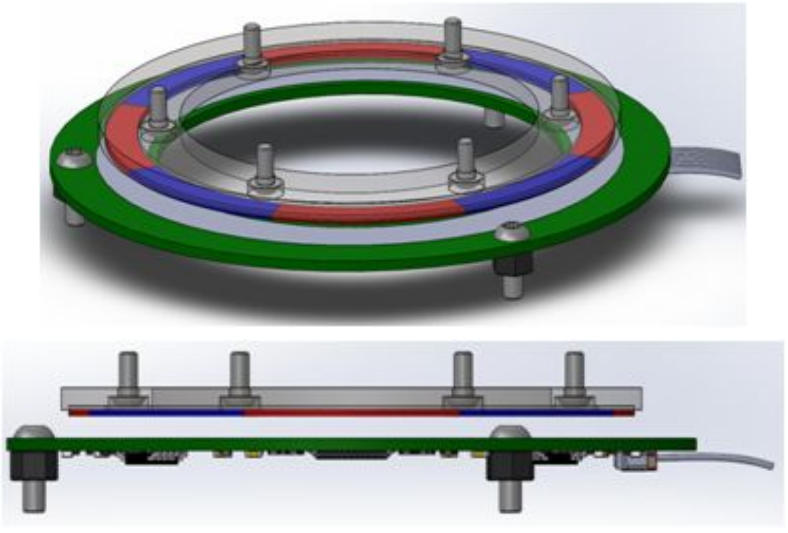


Fig.6. AFE Standard mounting type with fasteners

1.4. Absolute Frameless Encoder Overview

AFE Size 080

- **virtually no limitation for the GMI encoder principle**
- **scalable system to any desired dimension**
- **miniature size**
- **large hollow shaft**
- **360 degree (holistic) scanning**
- **no hysteresis / backlash**
- **high accuracy**
- **high resolution**
- **wide mounting tolerances**

2. Encoder Specification

AFE size/Outer diameter	029	039	049	053	064	080	090	160
System data								
Type	Axial, frameless, true absolute encoder							
Maximum Resolution	18 bits	19 bits	19 bits	19 bits	20 bits	20 bits	20 bits	21 bits
Accuracy for "Standard" Precision Class	0.16°	0.08°	0.08°	0.08°	0.04°	0.04°	0.04°	0.02°
	576"	288"	288"	288"	144"	144"	144"	72"
Accuracy for "High Accuracy" Precision Class	0.08°	0.04°	0.04°	0.04°	0.02°	0.02°	0.02°	0.01°
	288"	144"	144"	144"	72"	72"	72"	36"
Hysteresis	none							
Repeatability	1 bit							
Position update rate	< 1 microsecond							
Maximum speed	10'000 rpm (higher on request)							

Electrical data	
Supply voltage	4 .. 6 Vdc, other ranges on request
Current Consumption	max. 90 mA @ 5Vdc

Mechanical Data	
Dimension	see Chap.3., others on request
Nominal Air-Gap	0.5 mm
Axial Air-Gap tolerances	±0.5 mm
Eccentricity tolerance	±0.5 mm

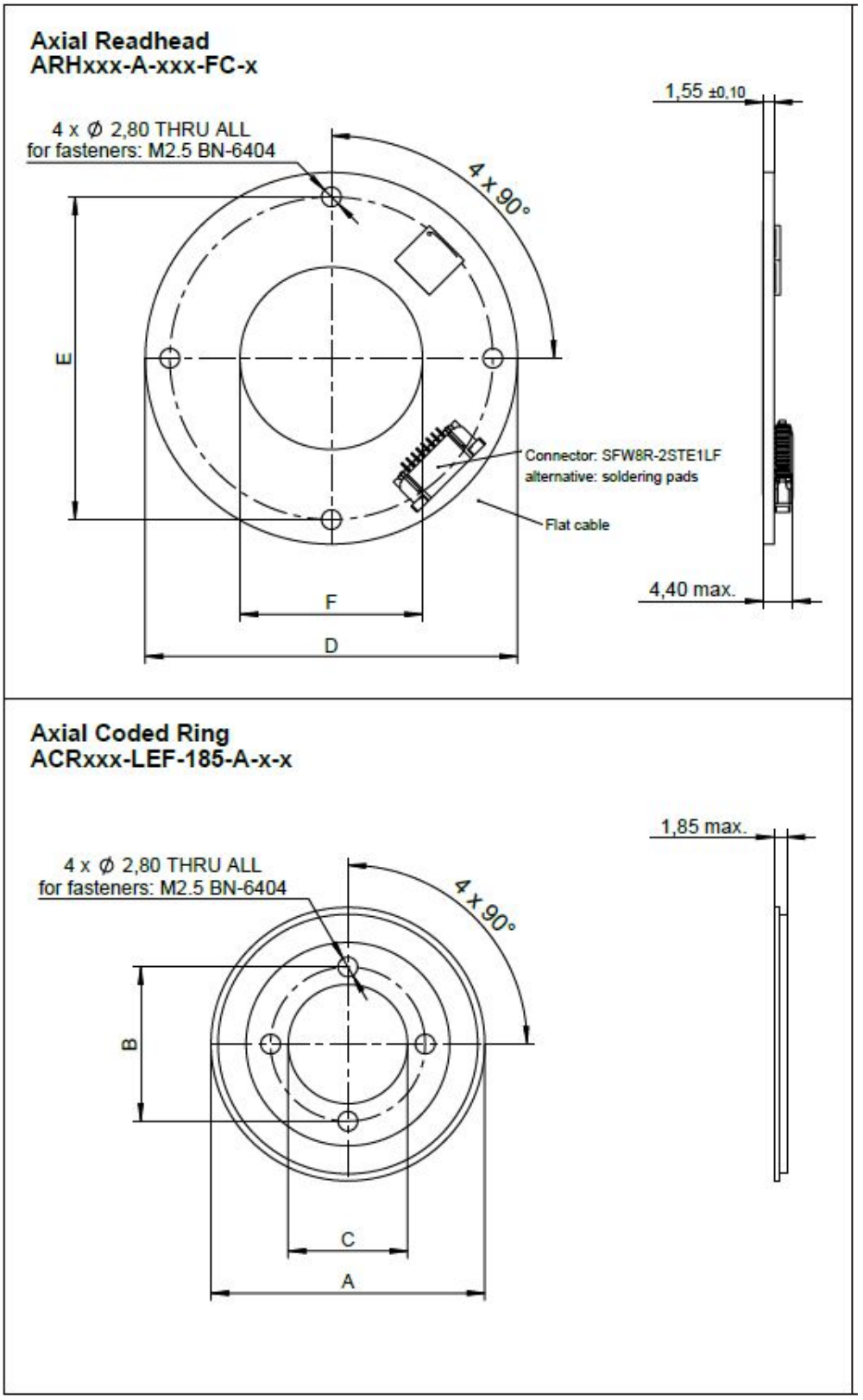
Environmental Data	
Operating Temperature	Industrial: -20°C .. +85°C Extended: -40°C .. +105°C
Storage Temperature	Industrial: -20°C .. +85°C Extended: -40°C .. +150°C(1)
Humidity	non-condensation for non-IP67 encoders
IP67	on request

(1) Not for Connecter Type “FC” - FPC or/and Diagnosis LED option.
For FPC connector and Diagnosis LED max Storage Temperature is +85°C

Output interfaces	
SSI	Available versions: SSI00. See Chap.4
BiSS/C	in work
Others	on request

3. Assembly drawings

3.1. AFE-29 up to AFE-039



Dimensions and mounting drawings: AFExxx

Dimensions and tolerances in mm.

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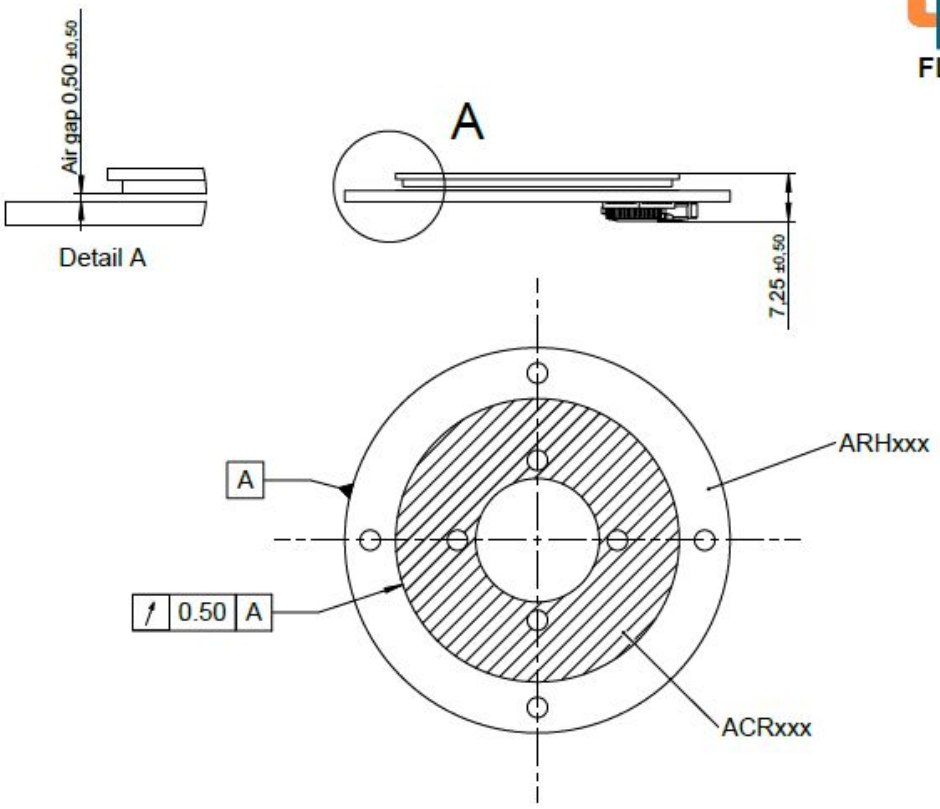
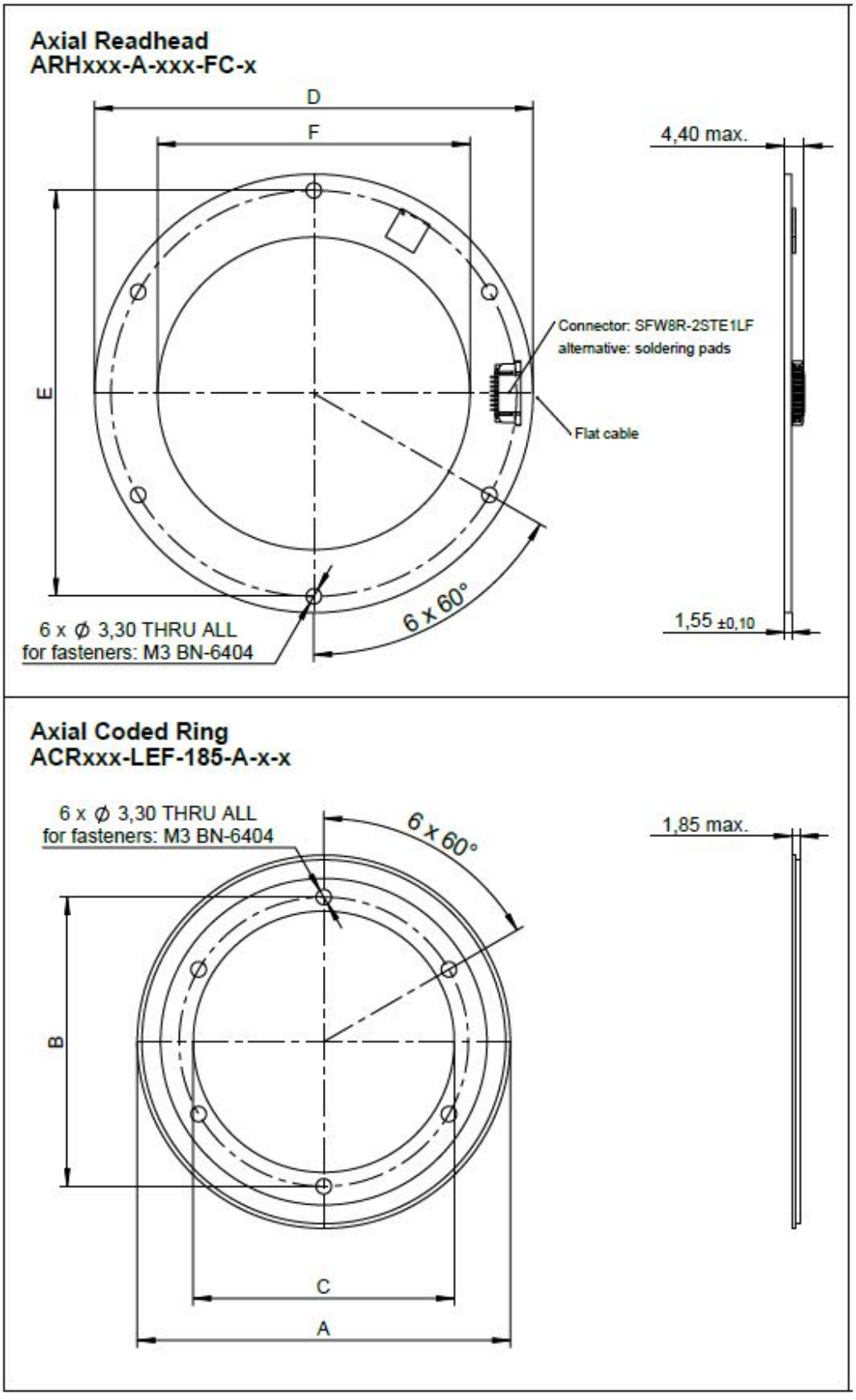


	Ring			Readhead		
	A	B	C	D	E	F
AFE029	⌀29	⌀12	⌀7	⌀43	⌀36	⌀16
AFE039	⌀39	⌀22	⌀17	⌀53	⌀46	⌀26

Note: Preliminary specifications. Subject to change without notice.

April 2020, v00

3.2. AFE-049 up to AFE-160



Dimensions and mounting drawings: AFExxx

Dimensions and tolerances in mm.

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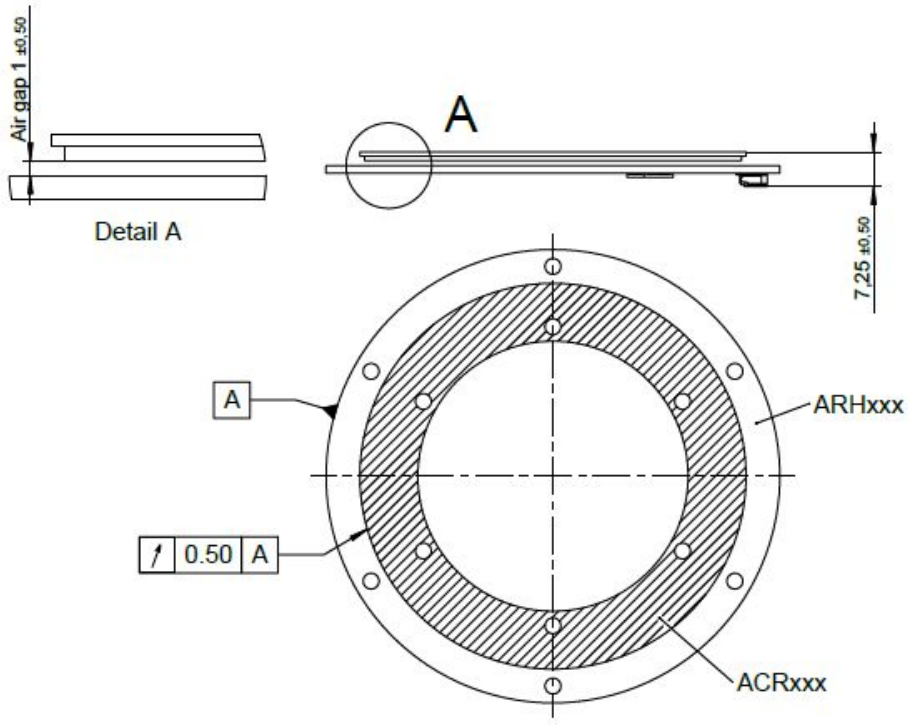
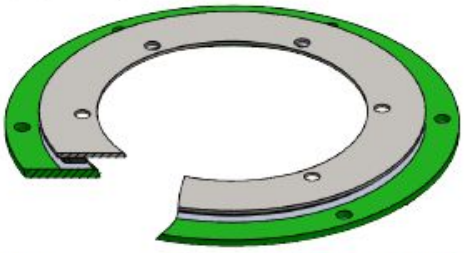


	Ring			Readhead		
	A	B	C	D	E	F
AFE049	⌀49	⌀31	⌀25	⌀63	⌀56	⌀36
AFE053	⌀53	⌀35	⌀29	⌀67	⌀60	⌀40
AFE064	⌀64	⌀46	⌀40	⌀78	⌀71	⌀51
AFE080	⌀80	⌀62	⌀56	⌀94	⌀87	⌀67
AFE090	⌀90	⌀72	⌀66	⌀104	⌀97	⌀77
AFE160	⌀160	⌀142	⌀136	⌀174	⌀167	⌀147



Note: Preliminary specifications. Subject to change without notice.

April 2020, v00

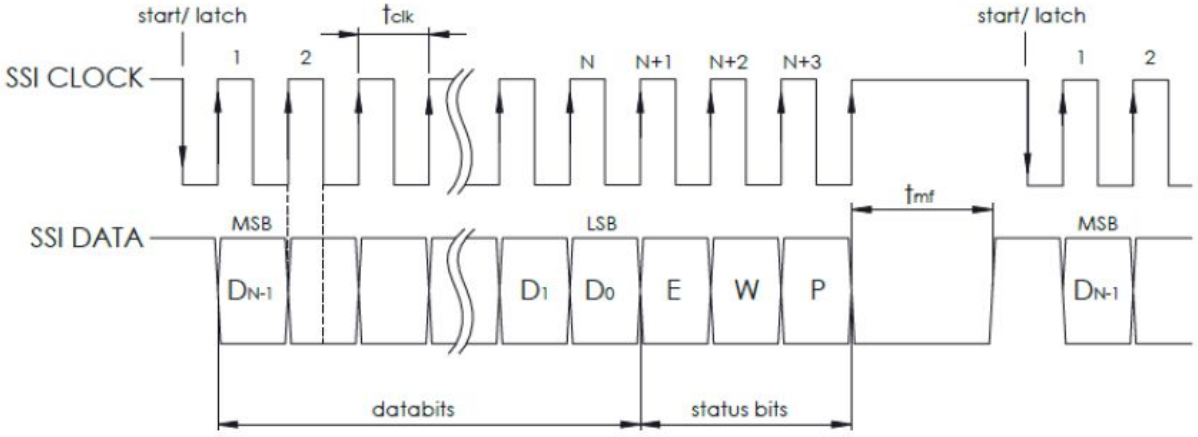
4. Interface description

4.1. SSI00

The synchronous serial interface *SSI* is an unidirectional point to point communication channel. The transmission of the sensor output signal *SSI DATA* is synchronized by the common clock signal *SSI CLOCK*. The *DATA* and *CLOCK* signals are transmitted according the RS-485 (EIA-485) standard, driven by RS-485 buffers.

Parameter	Note	Min.	Typ.	Max.	Unit
Clock frequency f_{clk}	data update on rising clock edge	0.2	tba	1	MHz
Monoflop time t_{mf}			30		µs
Total number of bits			28		bit
Number of databits N			25		bit
Number of status bits S	Error E (active high) Warning W (active high) Parity P (even)		3		bit

The data transmission and position latch starts on falling edge clock, the serial data update occurs on rising clock edge.



4.2. INC00

tbd

4.3. BIS00

tbd

5. Commissioning and Debugging

5.1. Mounting and commissioning

The AFE encoders must be mounted with respect to the mounting tolerances presented in Chapter 3, "**Assembly drawings**".

AFE encoders require no calibration nor additional commissioning procedures.

After mounting and powering up the AFE encoders are ready to provide over the interface position with high accuracy and high resolution.

5.1. Debugging

The AFE encoders are equipped with a status LED[(2)]

LED Color	Status	Recommended actions
No color	System is not (correctly) Powered-Up.	Check wiring connection to the motion controller
Green	Normal Operation	
Red	Encoder is in Error State	Check if the current mounting tolerances are correct
Yellow	Encoder recovered from an Error State and currently is in Normal Operation	Check if the current mounting tolerances are correct Check the power supply, ground and shielding concept of the wires and machine

[(2)]Except high temperature applications. Please contact FLUX for more information.

6. Pinout and Wiring

6.1. Connector

6.1.1. Option “FC”

Manufacturer	**Amphenol ICC (FCI)**
Manufacturer Part Number	SFW8R-2STE1LF
Description	8 Position FFC, FPC Connector Contacts, Top 0.039" (1.00mm) Surface Mount, Right Angle

6.1.2. Option “SD”

Manufacturer	**n.a.**
Manufacturer Part Number	n.a.
Description	PADS for wire soldering

6.2. Pinout

Pin No.	Signal	Function
1	Vdd	Encoder Supply Voltage
2	GND	Encoder Power Ground
3	n.c.	Do not connect
4	n.c.	Do not connect
5	SCLK+	Serial Clock +
6	SCLK-	Serial Clock -
7	SDATA+	Serial Data +
8	SDATA-	Serial Data -

7. Optional features

tbd

8. Ordering code

8.1. Axial Coded Ring

ACR	**029**	**-FEF-185**	**-A**	**-S**	**-I**
Axial Coded Ring	Diameter [mm]	Material & Thickness	Mounting Type	Accuracy	Temperature Range
	029	**FEF-185**	**A** - fasteners	**S** - standard	**I** - industrial
	039	**FEF-305**		**H**- high	**E** - extended
	049				
	053				
	064				
	080				
	090				
	160				

8.2. Absolute Readhead

ARH	**029**	**-A**	**-S**	**16**	**-SSI00**	**-FC**	**-I**
Axial Readhead	Diameter [mm]	Mounting Type	Accuracy	Resolution [Bits/Rev]	Output Interface	Connector Type	Temp. Range
	029	**A** - fasteners	**S** - standard	**15**	**SSI00**	**FC** - FPC	**I** - industrial
	039		**H** - high	**16**	**INC00**	**SD** - Solder	**E** - extended
	049			**17**	**BIS00**		
	053			**18**			
	064			**19**			
	080			**20**			
	090			**21**			
	160			**22**			

9. Version history

All data are subject to change without notice.

Date	Version	Comments
2020-02-27	00	First built
2020-09-01	02	

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