ABSOLUTE ENCODER

for AEROSPACE and Hi-Rel APPLICATIONS

MR-Encoder with reluctance tooth-wheel Nonius-rings

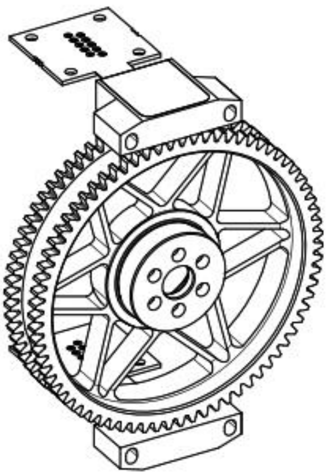
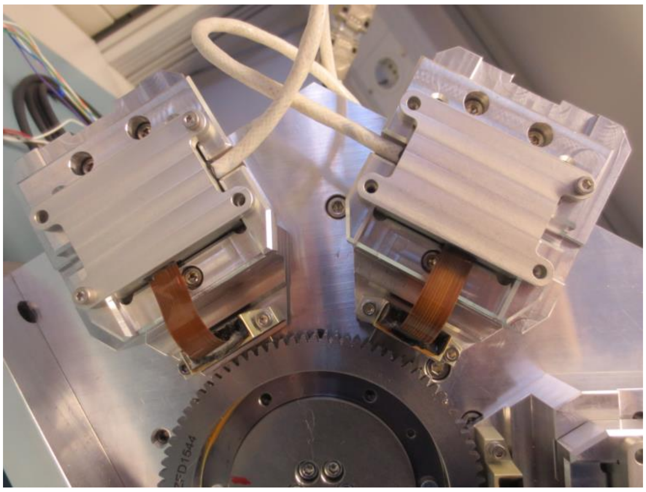



Figure 1. MACCON MR-Encoder Assemblies

CHARACTERSISTICS

The MACCON MR-Encoder has been developed for the measurement of absolute position in extreme physical environments, such as aviation- and space applications, with a resolution up to 19 Bits. The MR-Encoder consists of one reading head and one measurement wheel (see Fig. 1 with one additional redundant sensor head)

Summary of the benefits of the MR-encoder reading heads:

- The sensor head is fully passive with NO integrated electronics and is based on the **GMR** effect (Giant Magneto-resistance)
- Due to its simplicity and passive structure the MR encoder head is highly robust and reliable
- Encoder rings can be scaled to fit the application; hollow-shaft designs can be easily implemented
- Highly flexible with regard to positioning and mounting of the reading head(s)
- Accurate, light and low power consumption
- Measurement is absolute over 360° (temporary position loss can be immediately corrected) due to analogue cosine and sine position signals of the reading heads.
- Duplication of reading heads allows direct implementation of multiple redundancy (see Fig. 1)
- Insensitive to environmental influences, such as radiation fields and vacuum condition, as well as to temperature, vibration and shock.
- An optional external signal conversion box (SSI and SPI) can be connected to the reading head analogue signals for the conversion to SSI and SPI absolute position.

TYPE DESIGNATION

Measuring ring:

S-MR-076-14-75/74C-XXX

- S = Sensor
- MR = (G)MR type
- -076 = Ring outer diameter in mm (tooth tips) (see Fig. 2)
- -14 = Ring width in mm (including both N and N-1 tracks) (see Fig. 2)
- 75 = Number of teeth or cycles on N-track
- 74 = Number of teeth or cycles on (N-1)-track
- C = Cycles
- XXX = Customer modifications

Currently available types**:**

- S-MR-076-14-75/74C-XXX
- S-MR-092-14-91/90C-XXX
- S-MR-038-14-37/36C-XXX

For ring diameters larger than 92mm, the absolute range of the encoder must be reduced to 180° or 120°. The minimum ring diameter is 38mm.

Reading head:

S-MR-3.14-MA-XXX

- S = Sensor
- MR = (G)MR type
- 3.14 = Ring pitch in mm (distance between tooth tips)
- MA: Material
  AL: Aluminum (standard) (lamination example: SURTEC 650)
  TI: Titanium
- XXX = Customer modifications

TECHNICAL DESCRIPTION

Ring and Reading Head

The data given here is for one encoder ring and <u>one reading head</u>, sufficient to measure absolute position. Data is given for the encoder ring type: S-MR-076-14-75/74C

• Ring outer diameter, OD	76mm
• Ring inner diameter, ID	25mm
• Ring width	14mm
• Reading head dimensions	32 x 21.5 x 7.5mm, without ribbon-cable
• Reading head air-gap	0.5mm nominal (0.4 - 0.6mm for signal level adjustment)
• System OD (for two heads)	92mm circle (ring OD + 2 measuring heads + airgap)
• Reading head mass	<20g
• Measurement wheel mass	<120g
• Permissible eccentricity	0.03mm TIR
• Cycle length (pitch)	3.142mm
• No. of tracks	2 (N and N-1 cycles)
• No. of cycles (C)	75 (N) and 74 (N-1)
• Resolution	>18Bit (with signal conversion box). Resolution scales with the diameter of the ring

- Expected accuracy — Dependent on NONIUS-Implementation and Setup. With Signal Conversion Box >14Bit (>16Bit with fingerprint compensation and Signal Conversion Box)
- Supply voltage — 5Vdc nominal
- Supply current Icc (@5Vdc) — 9mA (see below)
- Reading head interface — Sine/Cosine analogue (8 wire) + Vcc + GND (see Fig. 2, 3)
- Signal output — 120mV pk/pk. (dependent on airgap) (the temp. dependence shown below can be compensated by the signal conversion box)
- Signal offset — <20% of signal output pk./pk. (see below)
- Temperature range (storage) — - 50°C to +125°C (ring unlimited)
- Temperature range (operation) — - 40°C to +85°C (ring unlimited)
- Radiation resistance (TID) — >120kRad
- Operation in vacuum verified for — <1.3e-5bar

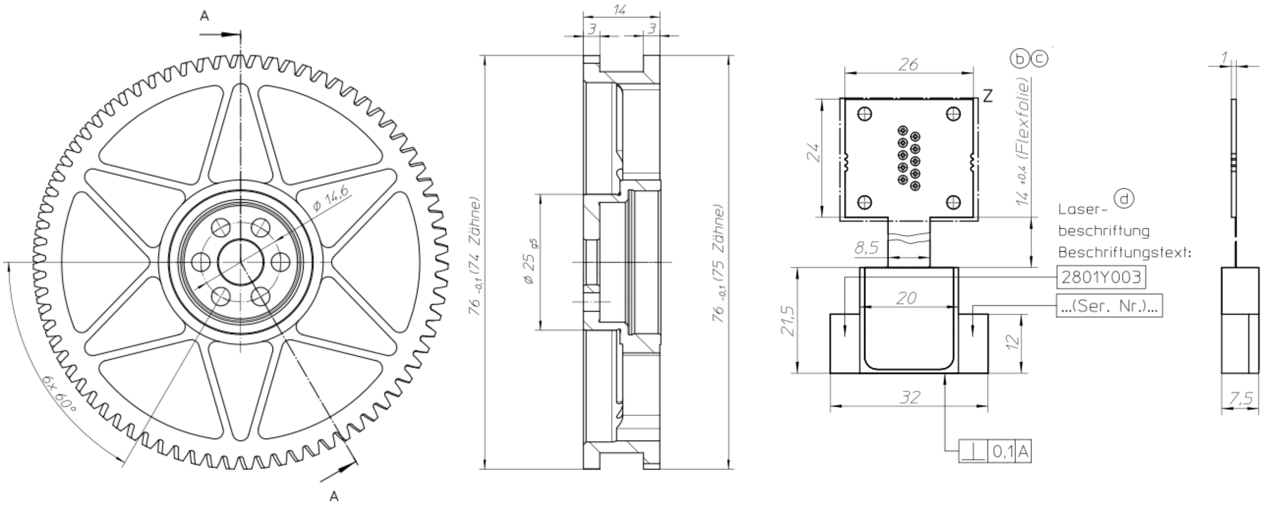
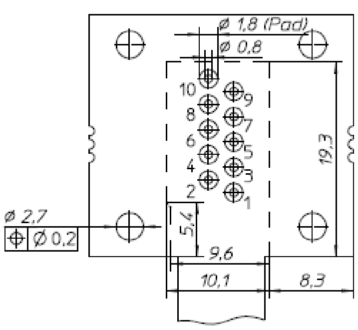
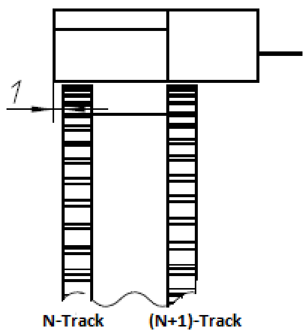


Figure 2. Drawings of typical MR-Encoder ring, S-MR-076-14-75/74C and MR-Reading head, S-MR-3.14-TI (with short ribbon-cable)



Pad	Signal
1	COS2-
2	COS1-
3	COS2+
4	COS1+
5	SIN2-
6	SIN1-
7	SIN2+
8	SIN1+
9	GND
10	UB



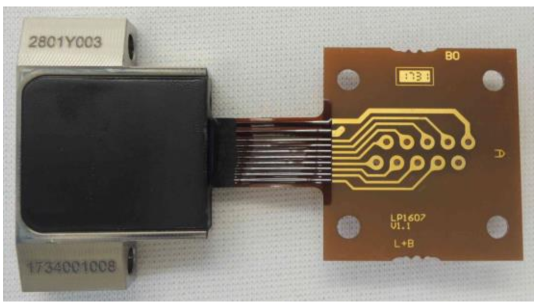
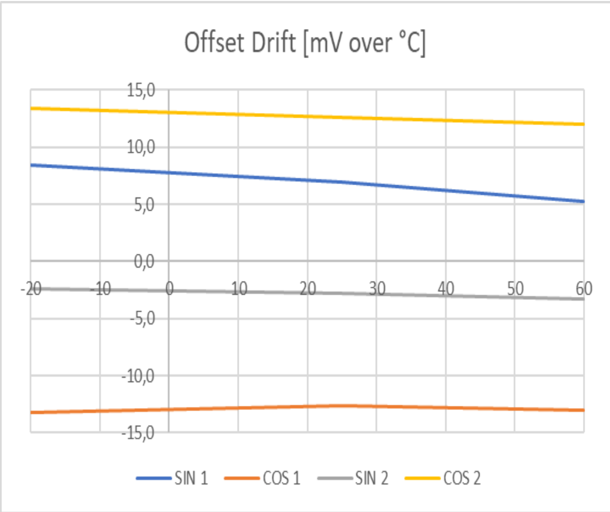
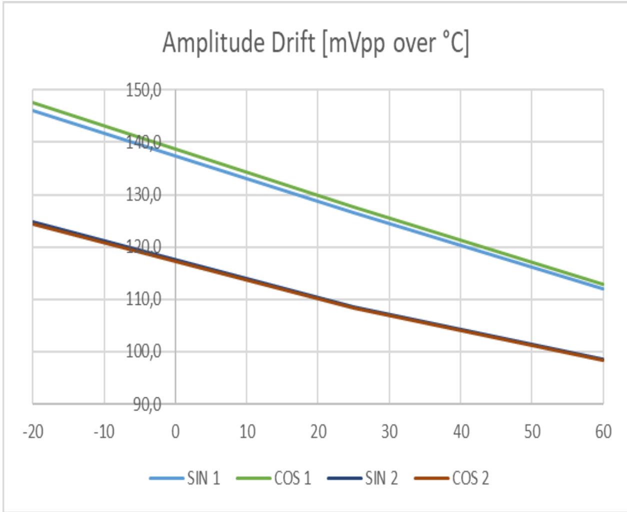
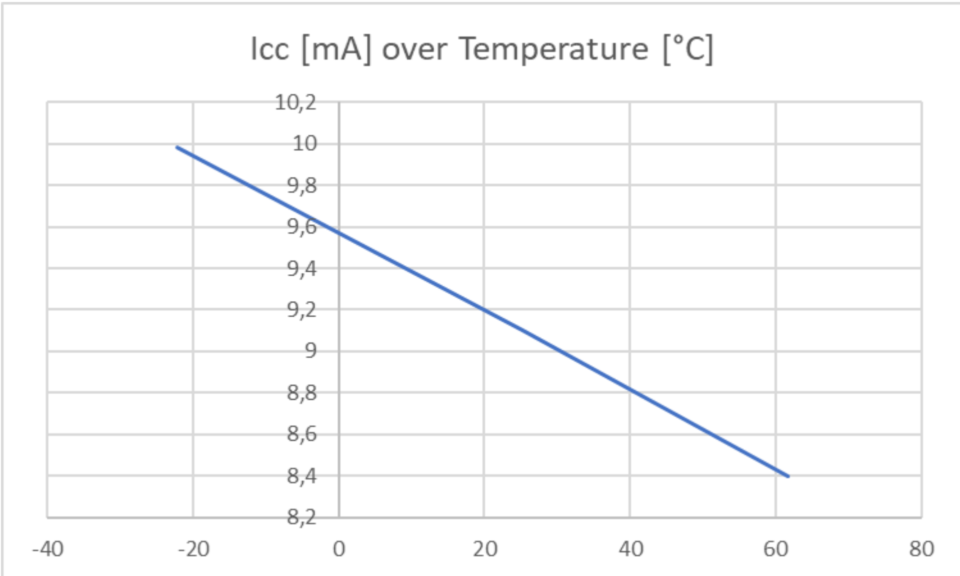


Figure 3. Encoder ring and close-up of reading head (short ribbon-cable)

Reading Head Characteristics (example of one reading head)







Sensor head supply current Icc at 5Vdc supply voltage

SIGNAL CONVERSION BOX

TYPE DESIGNATION

S-MR-2-XXX-YYY-SCB

- S = Sensor
- MR = (G)MR type
- 2 = dual channel
- XXX = SSI, SSI interface; XXX= INC, Incremental encoder
- YYY = 030, 300mm cables (open ended); YYY = Customised, t.b.d.
- SCB = Signal Conversion Box
- Temperature range (operation): -40°C to +85°C
- Radiation resistance (TID): 15kRad
- Shock and vibration resistant
- Operation in vacuum verified for <1.3e-5bar

DESCRIPTION

The MACCON signal conversion box can process the differential sensor head analogue signals from two reading heads and converts them to serial, digital data (SSI and SPI format). The two signal conversion circuits in the box are fully independent and isolated from each other.

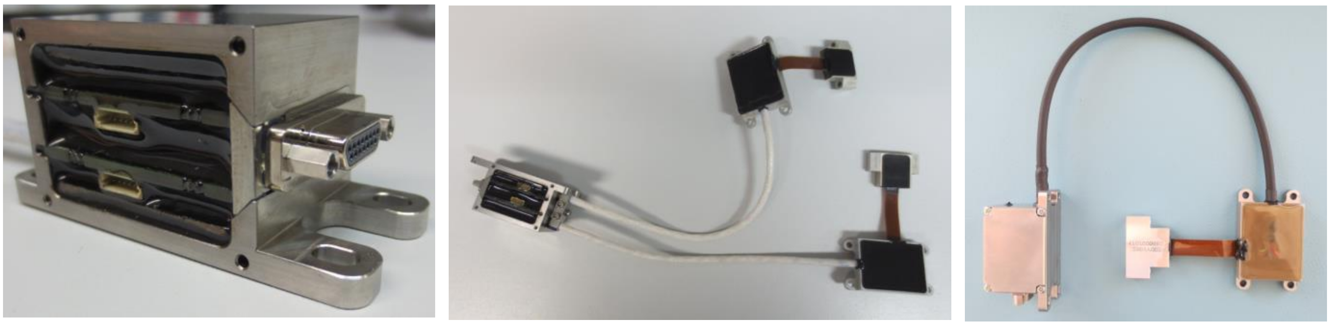


Figure 4. Signal Conversion Box (open, showing configuration interfaces) [left side]
Converter Box with interface box to reading heads, [center and right]

Features:

- Signal conversion electronics with 4 differential ADCs per sensor head
- Sin/Cos Nonius conversion
- Serial digital output, SSI and SPI or incremental encoder
- 2 independent sensor head channels in one box for redundant reading

Dimensions:

• Dimensions:	40 x 30 x 28.5mm
• Mass (without connection box and cables):	180g
• Connector, controller side	ITT Cannon MDM-15PH003M2-A174 (15 pin)
• Cable, sensor side; two cables	300mm long (or specify)

The reading head is fitted with a short flat-band cable and contact interface PCB. As a customized option MACCON can supply reading head(s) directly attached to interface boxes (60g) and the signal conversion electronics (see Fig. 4).

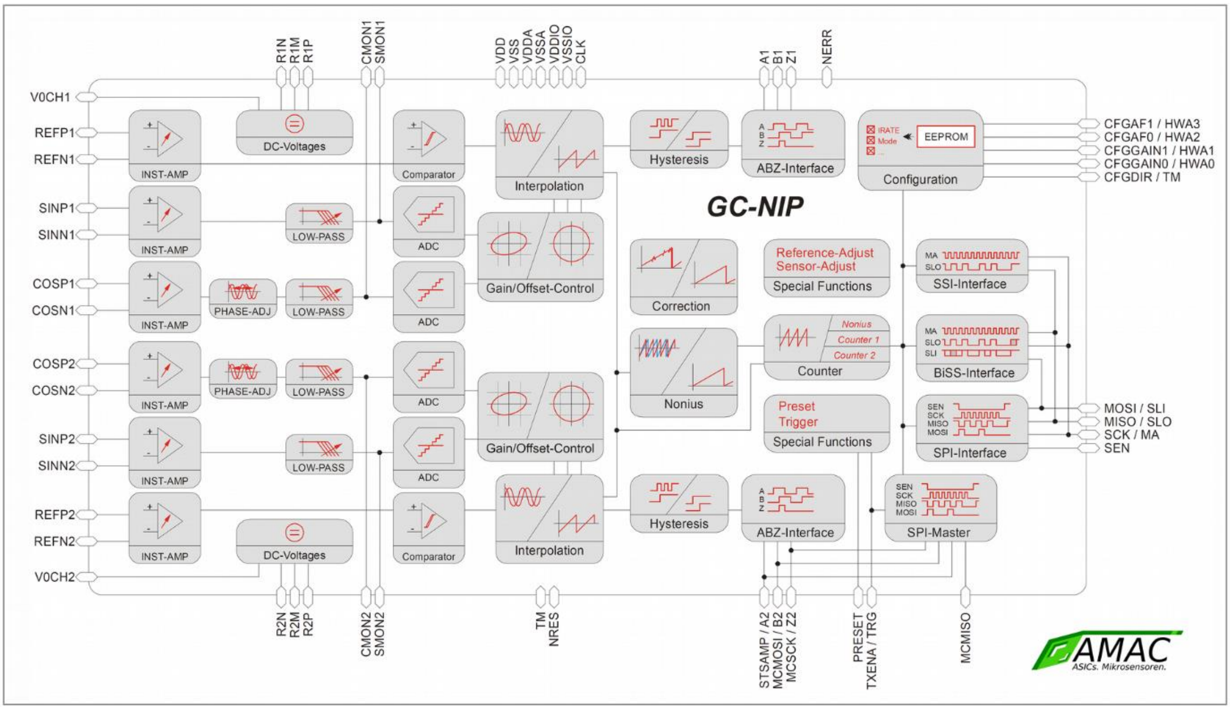


Figure 5. Internal circuit of Signal conversion electronics (one reading head/ conversion electronics)

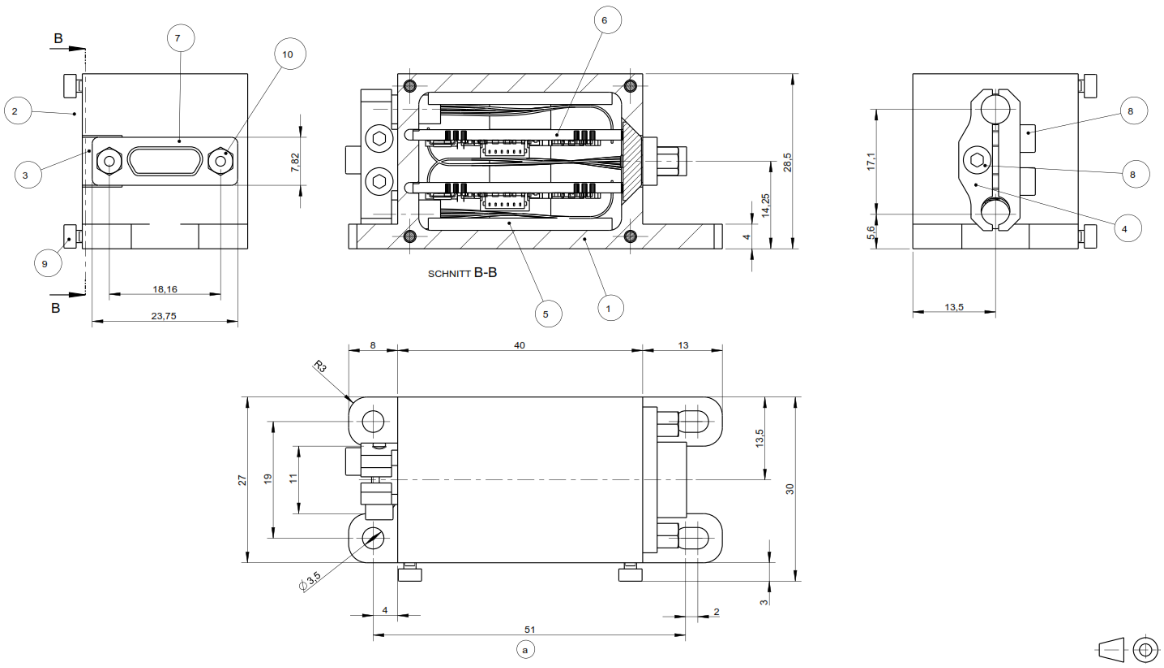


Figure 6. Drawing of Conversion Electronics Box (one side open)

TECHOLOGY & MODE of OPERATION

This encoder operates by exploiting the change of magnetic field, when the air-gap between a small permanent magnet and a ring, having a cyclic sine-wave profile (salient teeth are distributed around the ring with a constant pitch length) and being of ferromagnetic material, caused by rotation of the ring. The field change is detected by a GMR resistive sensor film (GMR = Giant Magneto-resistance effect).

Each sensor track consists of two Wheatstone bridges, each made up of 4 GMR resistors, which experience Sine and Cosine resistance variations due to the changing magnetic field (See Fig. 7). These resistance variations are detected by observing the voltage difference between the center-taps of two arms of the Wheatstone bridges; both are covered with a bias permanent magnet and fed with a common voltage. This configuration automatically suppresses common-mode interference and the influence of supply voltage changes.

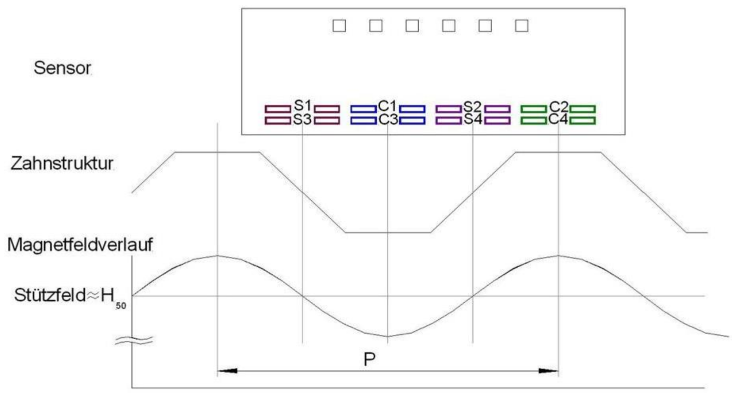


Figure 7. Working Principle of the GMR resistor

The sensor itself just provides analogue voltage outputs (one sine and one cosine channel per track).

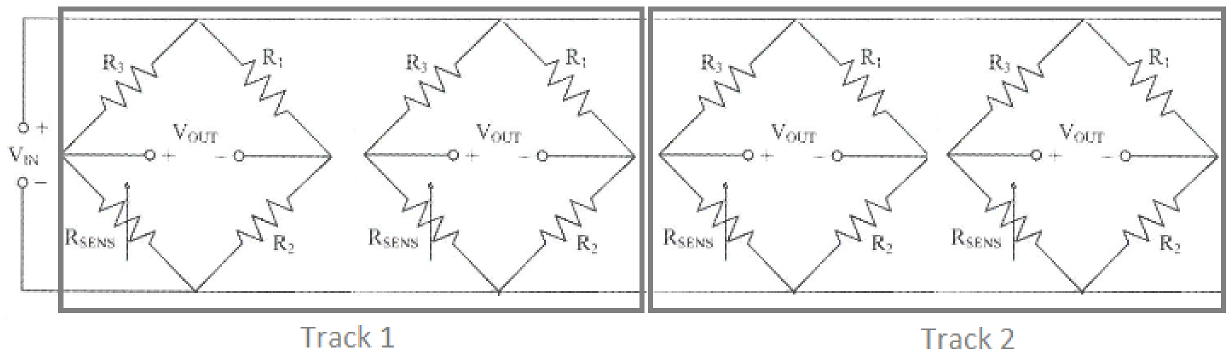
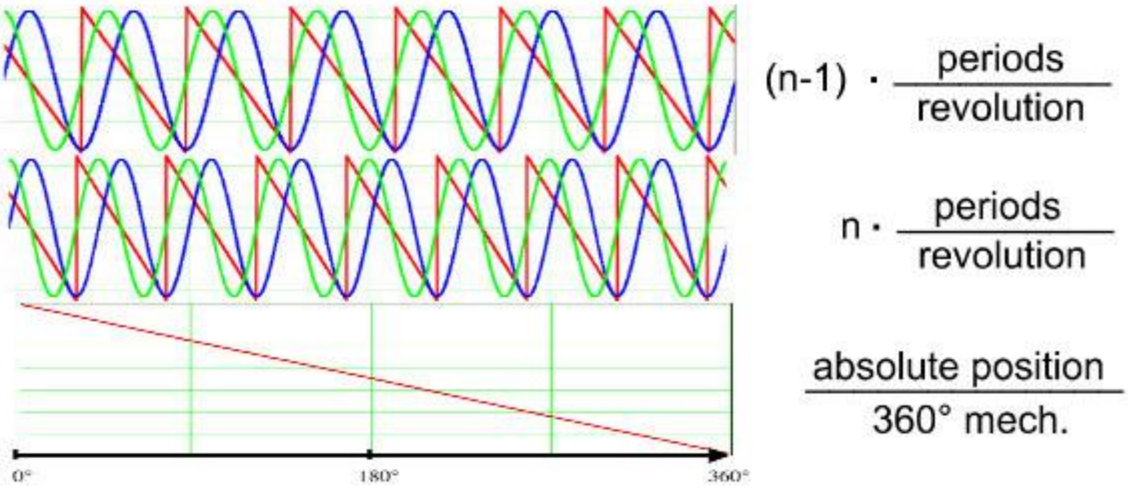


Figure 8. Two Wheatstone bridges for one sensor track (in total two tracks)

One sensor unit is integrated for each track which leads to a total number of two sensor units per reading head. These observe the two tooth tracks of the ring, which are physically separated due to the different number of teeth per track. The two adjacent reluctance patterns deliver a different number of electrical cycles (N and N-1). The two tracks are needed to allow absolute position to be detected over 360. The single cycle offset per revolution delivers uniquely different pitch position values from the two tracks within every cycle during 360° rotation of the ring. Signal processing is necessary to compute the absolute angular position. Two or more identical but physically and functionally independent sensor heads can be used for redundancy purposes.



llustration of Nonius Principle (N, N-1)

Overview of MR-Technology in SPACE

- “Spirit” and “Opportunity” Space rovers (Maxon Motor)
- MERTIS on Bepi Colombo (Kayser Threde; OHB)
- MACCON has further experience in space-rated sensors from the programs: Meteosat scanner (Eumetsat), LCT on TeraSAR, GEO et al., MHS on FY3.
- Curiosity” (Aeroflex/NASA) – in mission: Over 20 MR position sensors are used on this space vehicle.

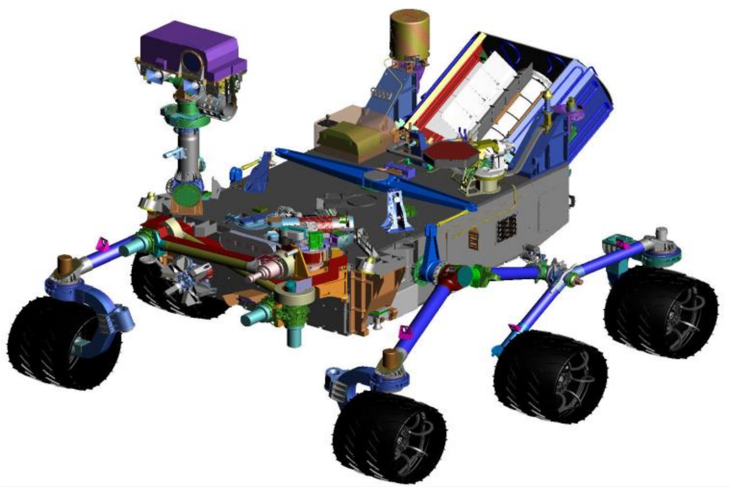


Figure 9. CURIOSITY Mars Rover; See: https://www.nasa.gov/mission_pages/msl/index.html

Disclaimer: Technical details in this datasheet are subject to change. An individual qualification program is recommended for each specific space mission

Total Ionizing Dose (TID) Test

Utilized Source: Co-60. **Applied documents** (ESCC Basic Specification No. 22900, MIL-STD-750-1A, …)
Conditions: Specimens were active.

Irradiation Sequence		50 Gy, 100Gy, 150Gy, 300Gy, 600Gy, 1000Gy, 1200Gy at room temperature
Step	**Test specimen type**	**Description**
1	S-MR-3.14-AL S-MR-2-SSI-030-SCB	Dstep = 50 Gy (5 krad), Dtotal = 50Gy (5 krad) +/- 10%, Drate = 0.7mGys^-1
2	S-MR-3.14-AL S-MR-2-SSI-030-SCB	Dstep = 50 Gy (5 krad), Dtotal = 100Gy (10 krad) +/- 10%, Drate = 0.7mGys^-1
3	S-MR-3.14-AL S-MR-2-SSI-030-SCB	Dstep = 50 Gy (5 krad), Dtotal = 150Gy (15 krad) +/- 10%, Drate = 0.7mGys^-1
4	S-MR-3.14-AL	Dstep = 150 Gy (15 krad), Dtotal = 300Gy (30 krad) +/- 10%, Drate = 0.7mGys^-1
5	S-MR-3.14-AL	Dstep = 300 Gy (30 krad), Dtotal = 600Gy (60 krad) +/- 10%, Drate = 0.7mGys^-1
6	S-MR-3.14-AL	Dstep = 400 Gy (40 krad), Dtotal = 1000Gy (100 krad) +/- 10%, Drate = 0.7mGys^-1
7	S-MR-3.14-AL	Dstep = 200 Gy (20 krad), Dtotal = 1200Gy (120 krad) +/- 10%, Drate = 0.7mGys^-1

The “reading head” (S-MR-3.14-AL) was tested successfully to step 7 (120krad). The “signal conversion box” (S-MR-2-SSI-030-SCB) was tested successfully to step 3 (15krad); a failure occluded shortly before Step 4 completion (30krad); higher levels possible through radiation screening).

Random Vibration Test

Test specimen type: S-MR-3.14-AL, S-MR-3.14-TI, unmolded sensor (raw PCB of S-MR-3.14) and S-MR-2-SSI-030-SCB. **Conditions**: Specimens were passive; Room Temperature; Three directions (X, Y, Z).

Frequency (Hz)	(g^2/Hz)	Test Profile
20	0.02	1
90	0.30	
130	20.00	
170	20.00	
170	20.00	2
220	10.00	
295	2.00	
400	0.08	
630	0.08	
700	1.00	
920	1.00	
1200	12.00	
1200	12.00	3
1300	15.00	
1300	15.00	4
1400	15.00	
2000	0.02	

Shock Test

Test specimen type: S-MR-3.14-AL, S-MR-3.14-TI, unmolded sensor (raw PCB of S-MR-3.14) and S-MR-2-SSI-030-SCB. **Conditions**: Specimens were passive; Room Temperature; Three directions (X, Y, Z).

Frequency [Hz]	SRS-Levels (Q=10) OUT OF PLANE [g]
100	31
270	111
400	183
665	351
1000	598
2000	533
2001	377
10000	357

Thermal Life Test - Constant Temperature

Test specimen type: S-MR-3.14-TI

Test Condition:
Constant temperature of 125°C (+10°C)
Test duration > 2000h
Conditions: Specimens were passive

Thermal Life Test - Cycling Temperature

Test specimen type: unmolded sensor (raw PCB of S-MR-3.14)

Cycle:
Upper temperature T_o: +140°C +5K/-0K
Lower temperature T_u: -60°C +0K/-5K
Time of duration at T_o: 20 minutes
Time of duration at T_u: 20 minutes
Time of change T_o<->T_u: <10 seconds
Number of Cycles: 200

Conditions: Specimens were passive

Thermal Vacuum Test

Test specimen type: S-MR-3.14-AL and S-MR-2-SSI-030-SCB

Cycle:
Upper temperature T_o: +85°C +5K/-0K
Centre temperature T_c: 25°C +2.5K/-2.5K
Lower temperature T_u: -40°C +0K/-5K
Time of duration at each temperature > 30min

Conditions:
Vacuum condition < 1.3e-5bar
Cycles: 3
Specimens were active; position measurements were performed at each temperature level