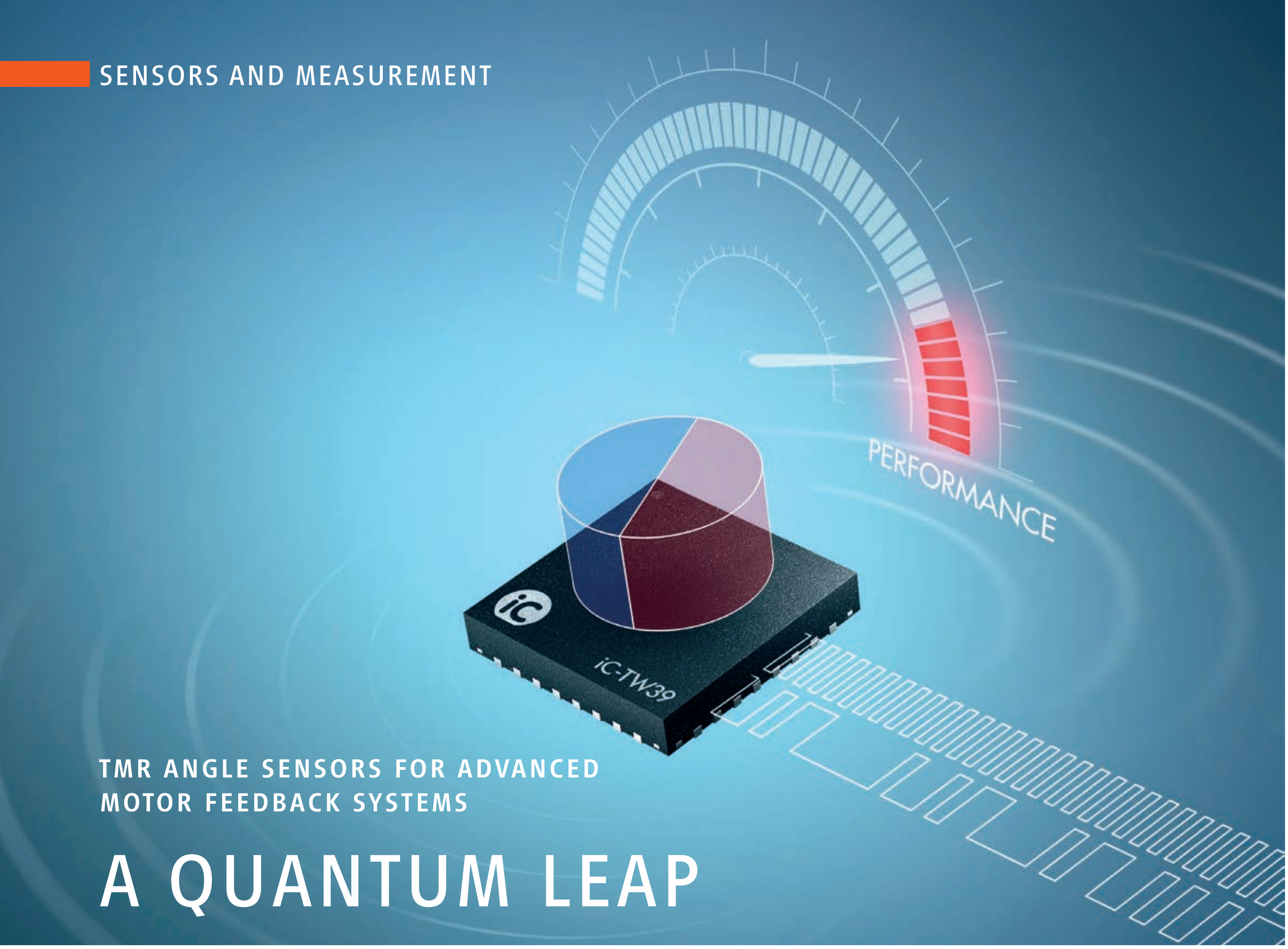


TMR ANGLE SENSORS FOR ADVANCED MOTOR FEEDBACK SYSTEMS

A QUANTUM LEAP

Magnetic position sensors measure absolutely, contactless and wear-free. They impress with their insensitivity to dirt or moisture and allow uncomplicated encoder design. In terms of resolution and accuracy, TMR technology brings a decisive quantum leap for modern motor feedback systems – with simultaneous cost advantages. We present a new TMR angle sensor with the performance level of optical encoders.

Quantum effect meets sensor technology: the iC-TW39 angle sensor from microelectronics specialist iC-Haus, is a universal TMR-based sensor for incremental and absolute measuring systems, also with multiturn interface. The first thing catching the eye is the distance of only 2 mm to the magnet, which significantly simplifies handling – similar to optical reflective systems.

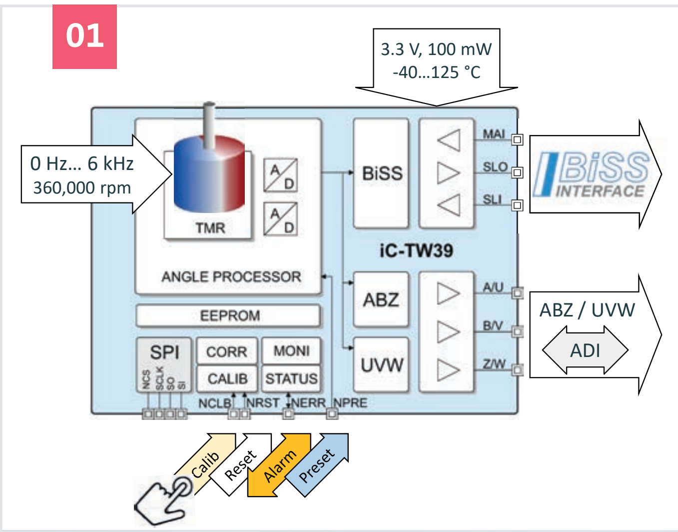
Basically, TMR angle sensors are magnetic sensors for detecting the magnetic field direction of a magnet (TMR = Tunneling Magneto Resistance). They convert magnetic information into electrical signals. They are extremely precise and reliable, have good temperature characteristics and extremely low power consumption. Thus, they can be used in a wide variety of industrial applications, including current, displacement, length and angle of rotation measurements and are therefore used in numerous applications, including in the automotive industry, robotics and consumer products such as mobile devices.

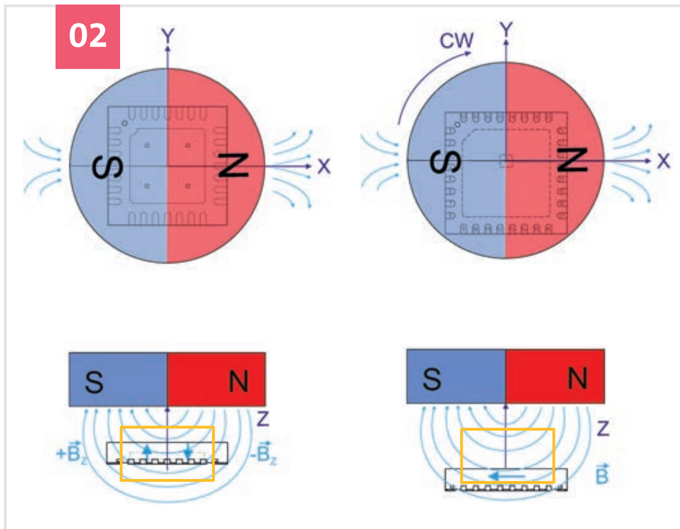
CALIBRATION AT THE PUSH OF A BUTTON

To achieve optimum angular accuracy within practical mounting tolerances, the angle sensor automatically calibrates the TMR sensor signals and compensates for primary signal errors. In addition to one-touch calibration, permanent auto-corrections are optionally available to compensate for offset drift due to temperature, for example, and to maintain measurement accuracy. An adjustable digital monitoring of the uncorrected residual errors allows reporting inadmissible – or implausible – deviations to the control system.

PREDICTIVE MAINTENANCE

Additional to the serial data output via BiSS with up to 10 MHz, a microcontroller can be connected via SPI to implement additional functions (Fig. 1). For example, the chip‘s residual error values can analyze the motor run to monitor axle bearings in





01 **The TMR angle sensor and its interfaces: for BiSS data output, an accurate and finely resolved singleturn position with up to 24 bits is generated; additionally available is a 24-bit revolution counter as well as commutation or incremental signals in any resolution**

02 **The Hall array (left) evaluates the curved magnetic field lines differentially in the vertical Z direction; the TMR sensor (right), on the other hand, evaluates the field vector in the X/Y chip plane**

the background. This is a highly sought-after extension for Industry 4.0 control systems with predictive maintenance.

FLEXIBLE USE FOR ABSOLUTE AND INCREMENTAL ENCODERS

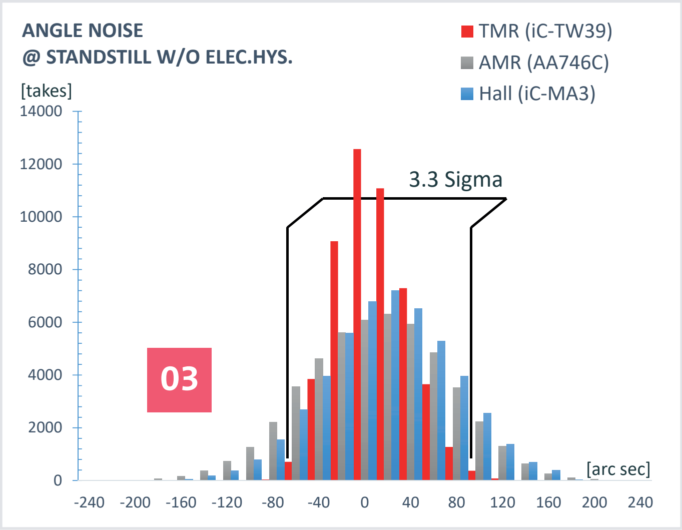
Magnetic Hall encoders have been optimized for a wide variety of applications, so that a broad IC portfolio is available for encoder and motor installation. iC-TW39 extends the possible applications to high-resolution absolute encoders with multiturn interface, via which, for example, a gear evaluation or a battery-buffered number of revolutions can be read in from iC-PVL. The TMR angle sensor is also suitable as a programmable incremental encoder, which can output ABZ signals with any adjustable number of pulses, from 1 to 65536. The AB jitter quality here is at the high level of optical encoders, even at 2500 pulses.

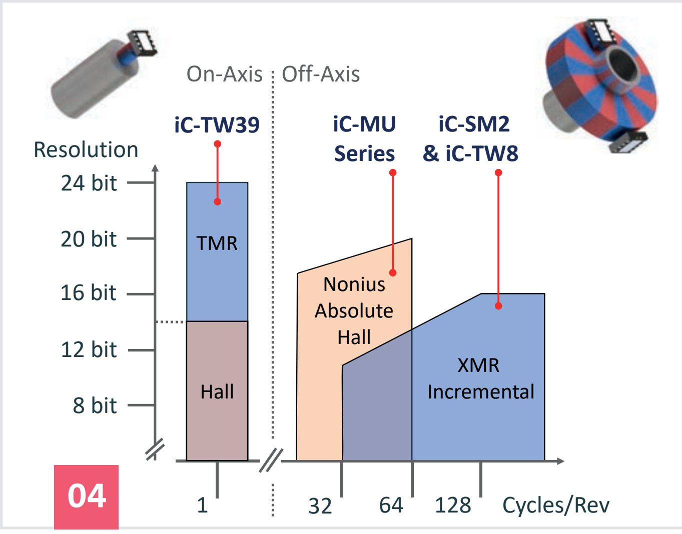
TMR SENSORS VERSUS HALL SENSORS – WHAT YOU NEED TO KNOW

Usual Hall encoders evaluate the field running vertically through the chip in its curvature, so that the magnet must be comparatively close. TMR sensors, on the other hand, follow the field vector at a larger distance, allowing greater axial play of the motor axis (Fig. 2). However, the intrusion of an external interference field must be prevented so that the TMR sensor does not evaluate superimposed fields and provide an angular deviation. A ferromagnetic sheet may be sufficient as a shield. In this comparison, the Hall sensor scores with its immunity to interference and its cost-effectiveness due to monolithic integration. It is only a question of noise, bandwidth and

Type of Sensor	Hall	AMR (+ Hall)	TMR
System Components	iC-MA3 & iC-TW29	AA746C & iC-TW29 (iC-PVL)	iC-TW39
Typ. Sensitivity @ 50 mT	5 mV	40 mV	500 mV
Typ. Signal TC @ +100 K	-60 %	-40 %	-15 %
Resolution (Cycles / Rev)	360° (1 cpr)	180° (2 cpr)	360° (1 cpr)
System Hysteresis	±0.2°	±0.2°	±0.04°
Alignment Tolerances	Tough	Small	Relaxed
Stray Field Robustness	Immune	Sensitive	Sensitive
Accuracy (INL)	±0.2°	±0.1°	±0.1°
Noise Free Resol. (3.3 σ)	380"	380"	140"
Position Lag	33.5 µs	1.5 µs	1.5 µs

Table: selected Hall, AMR and TMR sensors in performance comparison - one system each as reference





03 **Due to its high sensitivity, the TMR sensor delivers the lowest angular noise in relation to AMR and Hall systems; this makes a position as reproducible as possible, for example, the zero signal with an output of 2000 AB pulses**

04 **Magnetic encoder solutions in comparison: the low-noise TMR angle sensor achieves high angular resolutions previously reserved for off-axis systems**

permissible measuring delay, respectively, by how much earlier the achievable resolution is limited.

TMR TECHNOLOGY IN PERFORMANCE COMPARISON

To compare the principle sensor performance, the ***table lists*** one system each as a reference, representing Hall, AMR and TMR technology:

- the Hall sensor iC-MA3, which has various filter settings and gain control to output sine and cosine over 360 degrees at 500 mV,
- the PVL3M evaluation board with AMR angle sensor (AA746C from Sensitec),
- and the new TMR-based iC-TW39 angle sensor.

The sensors were been supplied with 3.3 V and evaluated by the iC-TW29 encoder processor, which allows calibration at the push of a button. When comparing the sensitivities, the Hall sensor delivers only a few millivolts at a typical field strength, which are highly amplified on-chip, while the TMR output signal is at least 50 times larger and reaches several hundred millivolts. By comparison, the AMR output signal reaches only 1/12 of the TMR and thus needs to be post-amplified. This can be at the expense of signal-to-noise ratio, package space and cost.

Notable differences exist in sensitivity versus temperature. For example, the temperature coefficient of the output amplitude for the TMR sensor is only about a quarter as large as for the Hall sensor (considered without Automatic Gain Control), and at least twice as good as for the AMR sensor.

In this context, the main problem of many measurements must be evaluated – and that is signal offset. Although AMR and TMR differ only slightly in this respect, the error effect is smaller with TMR because the signal amplitude decreases much less with increasing temperature than with the AMR sensor. Regarding the Hall sensor, an approximately offset-free output is only possible at all because special circuit techniques are used to compensate – otherwise the output offset would be as large as or even larger than the output amplitude.

In terms of alignment, roughly summarized, the Hall sensor must be close to the magnet and be well centered to provide Hi-Fi quality low distortion sine/cosine signals. The advanced AMR sensor AA746C mainly relaxes the air gap, because here already small field strengths from 5 kA/m are sufficient for operation in magnetic saturation. The TMR is also easy to set up and rather tends to condone alignment errors.

> » THE TMR-SENSOR IC-TW39 OFFERS PERFORMANCE THAT REACHES INTO THE DOMAIN OF OPTICAL ENCODERS

DELAY, LINEARITY AND HYSTERESIS

While XMR sensors respond nearly without propagation, Hall systems generally exhibit the greater delay due to the circuitry and deep signal filtering.

In terms of linearity (INL), AMR and TMR perform twice as well as Hall – when using the error correction offered by the evaluation circuitry. The systems were been driven all with the same quality magnet and well centered on axis. Due to INL correction, the iC-TW39 also compensates for the long-wave measurement error and minimizes the angular error on the remaining signal distortions.

Hysteresis is also a property of the technology. Only, an intrinsically hysteresis-free Hall cell is useless, considering that the Hall signals are weak and an amplifier adds noise. Thus, electrical hysteresis will be necessary in the system, for example to quieten the AB output. The same applies to the evaluation of the AMR sensor, whereby this sensor already brings along a hysteresis of around 0.2 °. The TMR sensor has a double advantage here, its own hysteresis is very low, the signal level is high – a minimum electrical hysteresis of 0.04 ° is sufficient for the iC-TW39 to be stabilized.

AMR SENSOR AND TMR SENSOR PERFORM TWICE AS WELL AS HALL ENCODER

The table contains the INL results for the system comparison: AMR and TMR perform twice as well as Hall – using the error correction offered by the iC-TW29 encoder processor. The selection of the magnet plays an important role; size and field quality must be correct and fit the sensor if high-precision angle measurements are to be achieved. Also relevant are the centering of the magnet and the alignment of the sensor to the axis center. Due to INL correction, iC-TW39 can compensate for long-wave measurement errors so that angular errors can be minimized to the remaining distortions.

Information on repeatability can be derived from the noise-free resolution, measurable at standstill without electrical converter hysteresis. Noise-free resolution is, so to speak, the sharpness of the angle that can be reproduced, and it gives a minimum hysteresis that has to be set for a stable angle reading. In this respect, the TMR is unsurpassed, providing a more than 2-fold narrower distribution in the histogram (Fig. 3), due to an angular noise of only 140“. A better filtering of the Hall or AMR systems would be conceivable if one accepts larger latency, however this is often not desired in the application.

BENCHMARKING RESOLUTION AND ACCURACY

The low-noise iC-TW39 TMR angle sensor not only exceeds the angular resolution of all previously known on-axis Hall encoders, but also competes with classic pole wheel encoders (Fig. 4). In off-axis mounting, the through hollow shaft may be advantageous, and higher pole numbers push the resolution – however, the measuring scale is more complex and costly, at the latest when a second track is required for the index or for position calculation (iC-MU Vernier systems). Regardless of the system, correction functions help to improve angular accuracy and compensate for the target's graduation imperfection, although signal noise is the final limiting factor for reproducibility. Here, iC-TW39 offers high bandwidth and low latency similar to optical encoders due to TMR.

A PERFORMANCE IN A CLASS OF ITS OWN

Due to TMR sensor integration, the iC-TW39 offers performance that extends far beyond known Hall encoders into the domain of optical encoders. High mounting tolerances, the permissible axial play of the motor axis, calibration at the push of a button, or a low space requirement are advantages worth mentioning, which are rewarded by higher measuring accuracy and extreme resolutions when the sensor-specific design requirements are taken into account. Furthermore, on account of the temperature sensor and various operational monitoring functions, smarter drive monitoring becomes possible.

Pictures: *iC-Haus*

www.ichaus.de

COMPANY

iC-Haus GmbH
Am Kuemmerling 18, 55294 Bodenheim
Tel.: 0049 6135 - 9292-300
E-Mail: info@ichaus.de

AUTHORS

Dipl.-Ing. Joachim Quasdorf, application specialist for optical encoder sensors and interpolation circuits,
Dipl.-Ing. (FH) Patrick Stahl, sales and applications engineer of encoder ICs and micro systems, both iC-Haus, Bodenheim

FLYER ZUM DOWNLOAD

www.bit.ly/TW39_factsheet_pdf