# WHAT IS XTREMESENSE TMR

By Allegro MicroSystems


## ABSTRACT

Many companies around the world are now featuring TMR based products in their respective portfolios, and acknowledging the benefits TMR brings to their offerings. However, because TMR is a relatively new technology, with many new recent participants announcing TMR based products, there are major differences in the implementation and manufacturing of TMR, which can be seen in the final product performance figures. XtremeSense™ TMR is the name of the technology Allegro MicroSystems has developed for the market.


## INTRODUCTION

Some readers might be familiar with AMR, GMR or other available TMR sensors and might incorrectly assume that all TMR sensors are the same. The objective of this document is to help the reader understand how XtremeSense TMR is different from other TMR sensors, both in how it is manufactured to how the performance figures are achieved.

## WHAT IS THE RESOLUTION OF THE SENSOR?

The resolution number refers to the minimum magnetic field step the sensor can resolve. It is determined by evaluating the signal-to-noise ratio (SNR), and it is not to be confused with ADC resolution.

TMR is known for its high sensitivity, which means that to improve SNR, the sensor noise needs to be attenuated. This led to a multi-year internal R&D project that yielded the lowest noise TMR sensors on the market. This low-noise technology appears in all XtremeSense-based sensors and yields industry leading high-resolution numbers such as:

- 5 mA on CT110 Current Sensor, 30 kHz Bandwidth
- 10 mA on CT430 Current Sensor, 1 MHz Bandwidth.
- 0.005 degrees on CT310 Angle Sensor

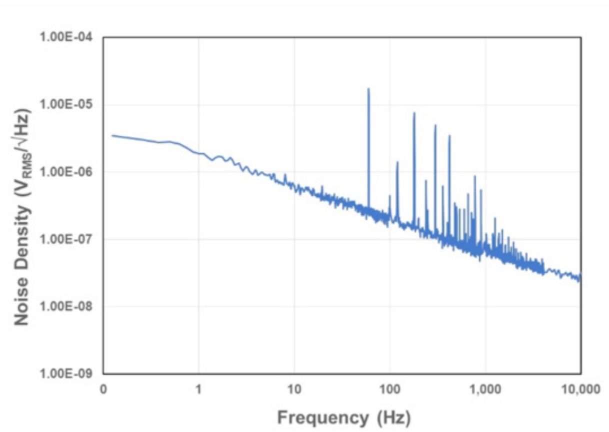


*Figure 1: Sensor resolution*

## HOW MUCH LINEARITY ERROR?

TMR sensors exhibit a hyperbolic tangent response curve to external magnetic fields. This leads to a linearity error that typical TMR sensors exhibit, as shown below.

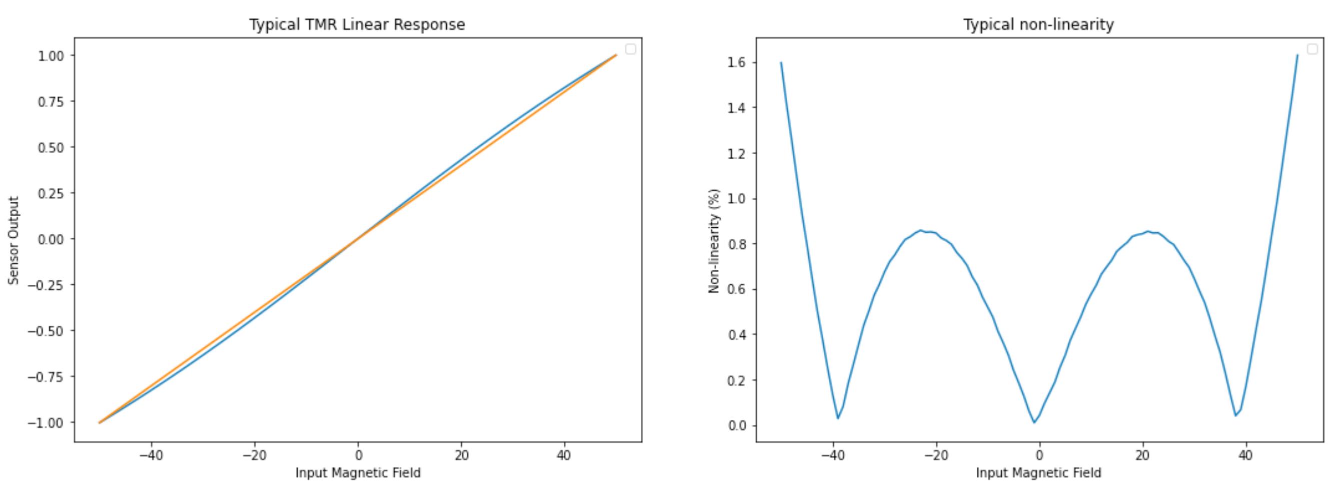


*Figure 2: Typical TMR linearity error*

Naturally, the higher the magnetic field amplitude, the further on the response curve the sensor is, and the less linear the response is.

While the sensor is not saturated, it loses the great linearity numbers found in the center of the response curve. The challenge, then, is to extend the linear range of the sensor without sacrificing other parameters.

XtremeSense TMR provides less than 0.1% linearity error shown on the graph below; this 0.1% linearity number is only matched by costly closed-loop systems.

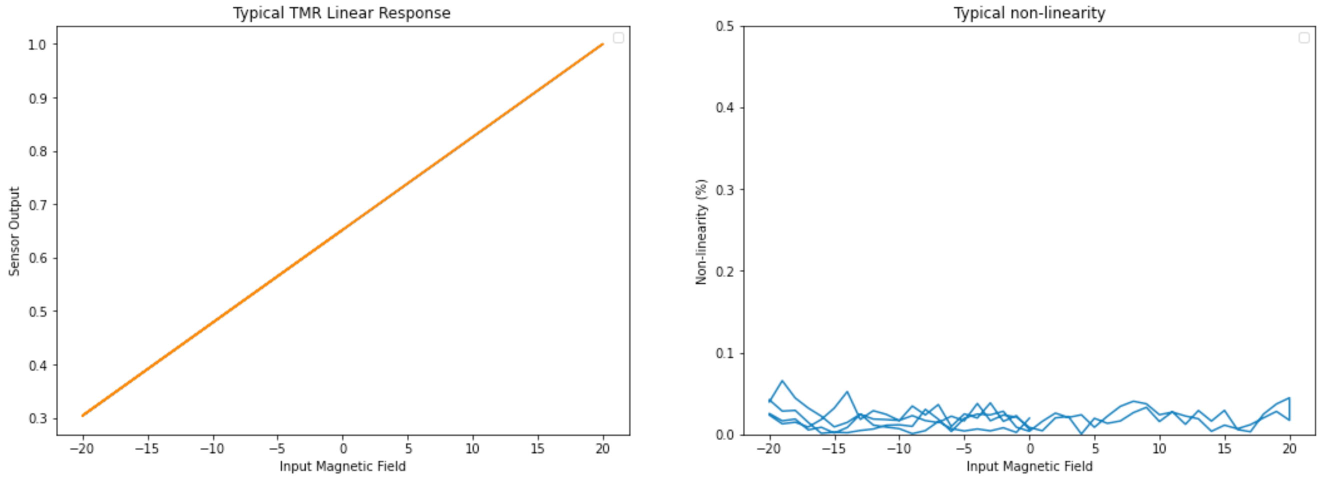


*Figure 3: XtremeSense TMR linearity error*

# IS THERE ANY MAGNETIC HYSTERESIS?

Commonly known as the "memory effect", hysteresis is found in all ferromagnetic materials. This behavior is, however, unwanted in linear sensors and angle sensors. The figure below shows a typical hysteretic response curve that generates unwanted offsets and change of sensitivity. This however is not the case on XtremeSense based sensors.

Hysteresis is a known limitation that reduces the scope of possible xMR based products. The figures below show the raw hysteresis of an XtremeSense linear sensor. The hysteresis numbers of XtremeSense TMR are so low that they are inconsequential.

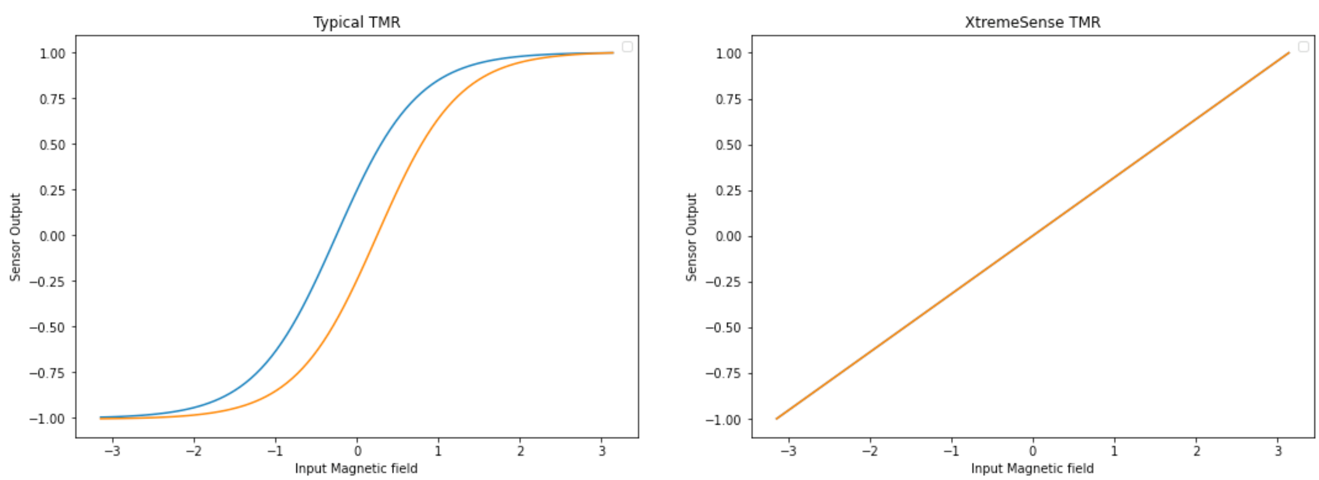


*Figure 4: Magnetic hysteresis of typical TMR devices vs XtremeSense TMR*

It is important to note that some Hall-effect sensors include a ferromagnetic concentrator, which generates magnetic hysteresis. An example of this is shown below:

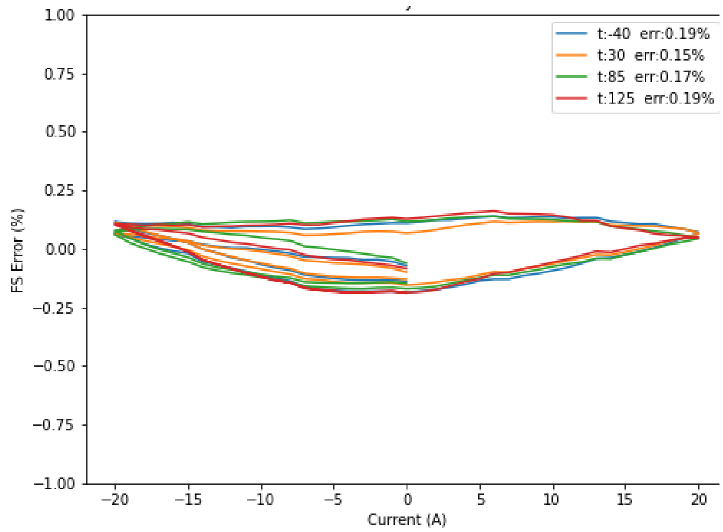


*Figure 5: Ferromagnetic concentrators generate magnetic hysteresis*

## HOW WILL THE SENSOR RESPOND UNDER CROSS-AXIS MAGNETIC FIELDS?

An ideal linear magnetic sensor should pick up the magnetic field in its sensitivity axis and be completely blind to orthogonal fields, also called cross-axis fields.

XtremeSense sensors exhibit minimal sensitivity to cross-axis fields as shown below.

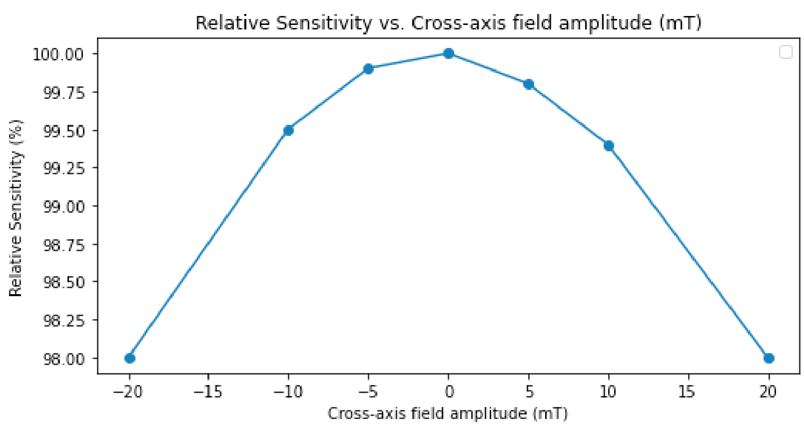


*Figure 6: Relative sensitivity vs Cross-axis field amplitude*

## WHAT HAPPENS IF A STRONG MAGNETIC FIELD IS APPLIED TO THE SENSOR?

Contrary to the majority of xMR sensors on the market, XtremeSense sensors are designed to survive any magnetic field amplitude without permanent damage. Material development, deposition conditions and process engineering are essential elements to achieve this feat.

In the case of linear sensors based on XtremeSense technology, while the sensor does not irreversibly fail and comes back into normal operating conditions once the strong magnetic field is eliminated, there can be an offset shift. Because of nature of this offset shift, which is stable and irreversible, combined with the rarity of such event, an offset recalibration is typically recommended to eliminate the performance impact on total accuracy.

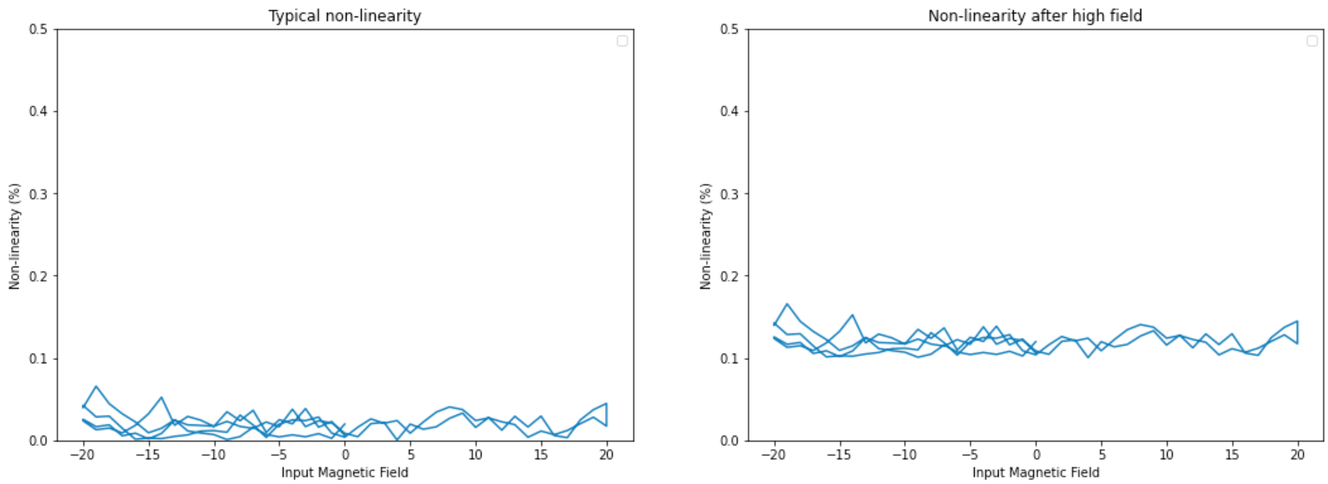


*Figure 7: Offset in nonlinearity after contact with magnetic field*

## HOW MUCH OFFSET/GAIN DRIFT UNDER TEMPERATURE?

XtremeSense TMR was designed to operate in harsh environments including high temperatures of up to 150°C. Both material development and layout topologies have been considered in order to reduce the drift over temperature of both offset and gain.

The gain achieved by XtremeSense TMR allows it to be competitive with Hall-effect sensors, with active temperature compensation. When also combined with active temperature compensation circuitry, XtremeSense TMR based sensors achieve less 40 ppm/C gain drift vastly surpassing similar open-loop Hall-effect based sensors, and matching higher end closed-loop current sensors.

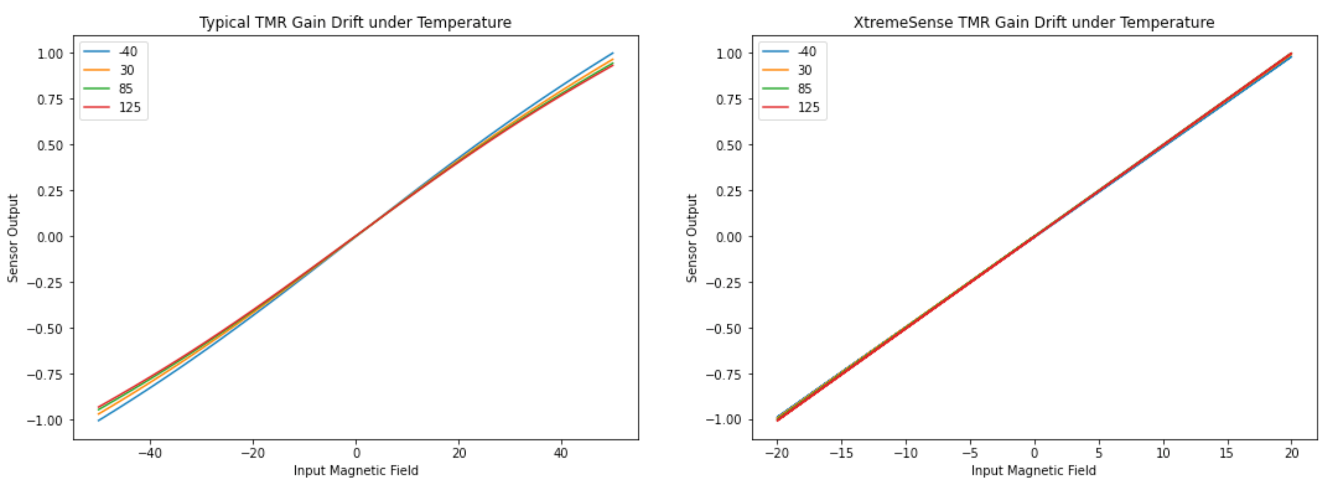


*Figure 8: Gain drift under temperature*

## HOW ARE THESE SENSORS MANUFACTURED?

The manufacturing process is equally as difficult to master as the TMR material development. While some companies and research labs focus solely on the materials, the team has always acknowledged that the integration of XtremeSense TMR in a standard CMOS process is a must for mass-market adoption.

All xMR technologies make use of materials, such as nickel, iron, and manganese, that are not standard in CMOS manufacturing. Moreover, the interaction between the TMR layers and the rest of the CMOS circuitry also needs to be considered.

XtremeSense TMR is a CMOS compatible technology; it is deposited between metal layers and does not take up precious space on the substrate, nor does it require keep-out zones.

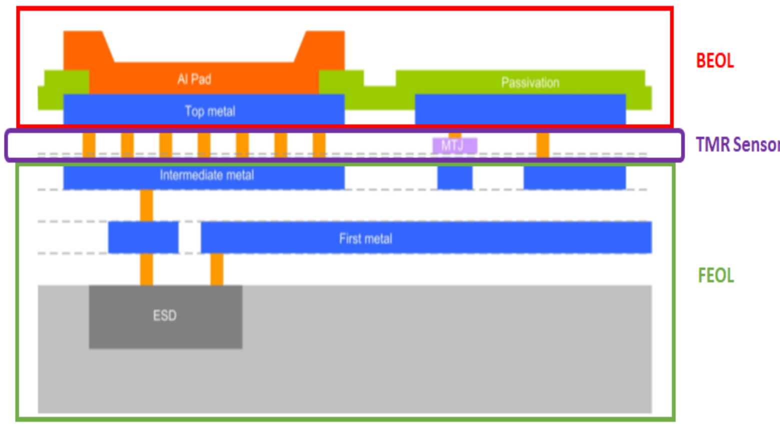


*Figure 9: XtremeSense TMR construction*

The image below illustrates the complexity of a multi-die package versus the simplicity of a monolithic solution that is enabled by XtremeSense TMR technology:

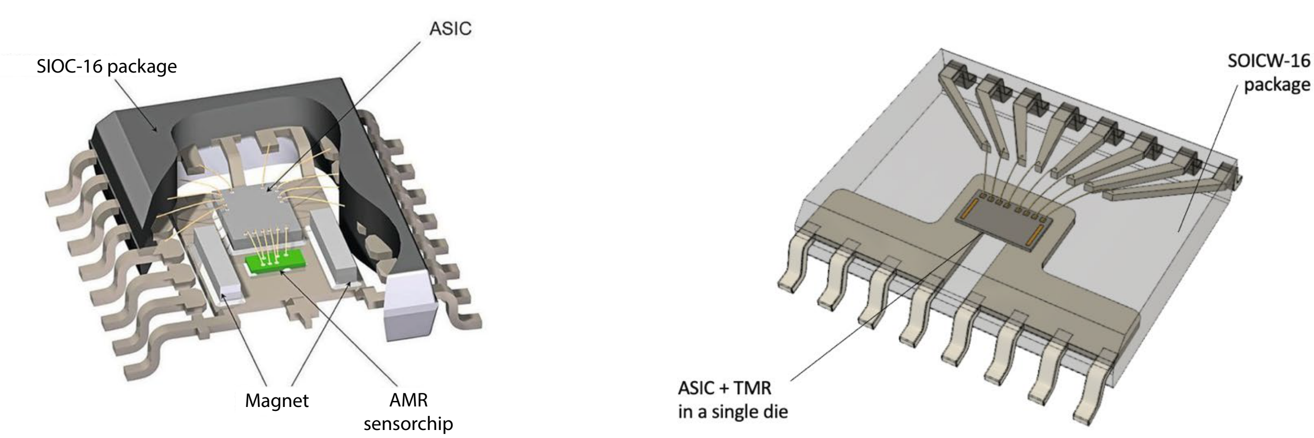


*Figure 10: Multi-die package solution versus single-die package solution with XtremeSense TMR*

*Revision History*

| Number | Date | Description | Responsibility |
|---|---|---|---|
| 1 | December 8, 2023 | Document rebrand and minor editorial updates | Tyler Hendrigan |