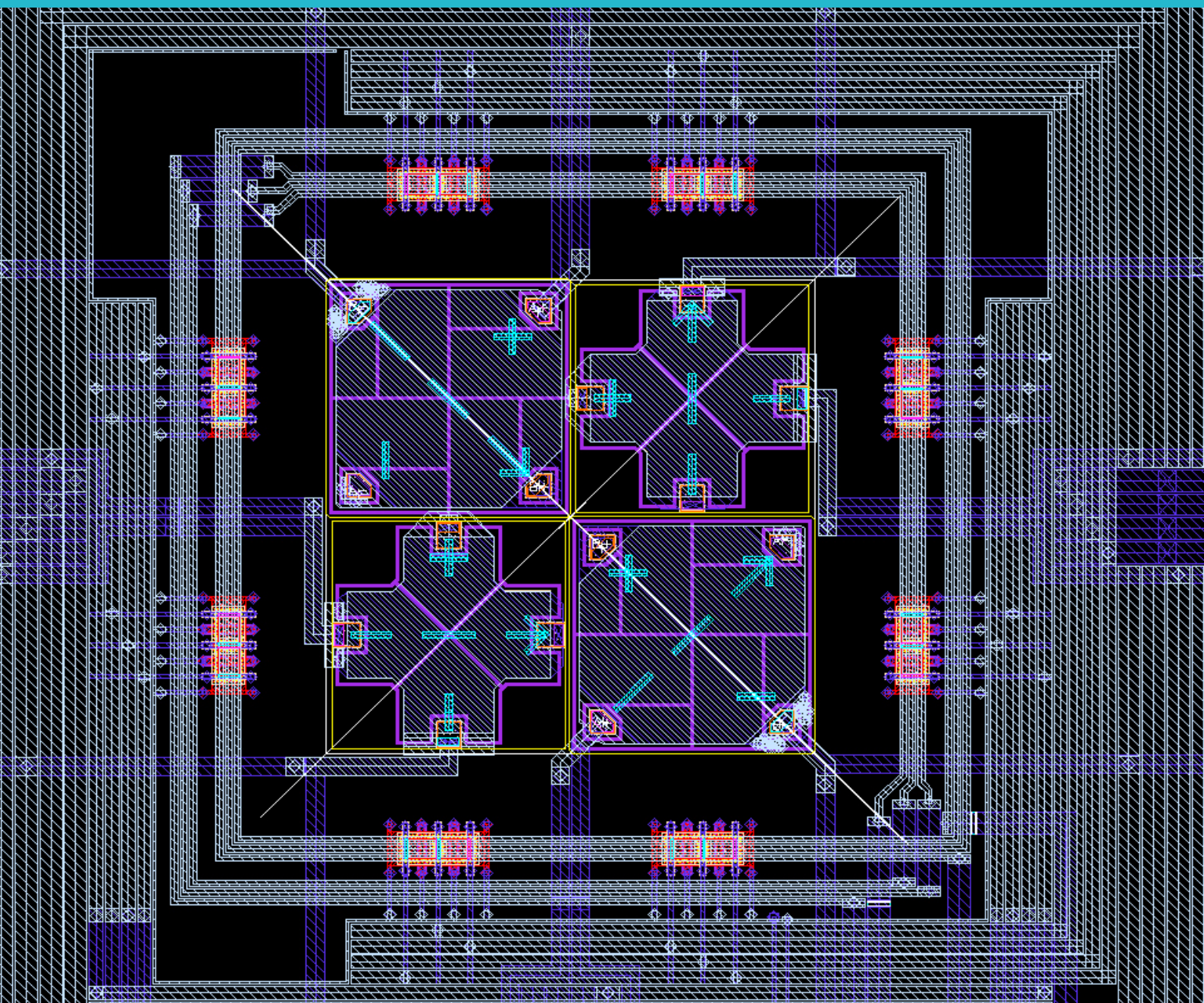
Fraunhofer
IIS

FRAUNHOFER INSTITUTE FOR INTEGRATED CIRCUITS IIS

INTELLIGENT 3D MAGNETIC FIELD SENSOR TECHNOLOGY



HALLinONE®
ONE SENSOR – MANY ADVANTAGES

INTEGRATED 3D MAGNETIC FIELD SENSOR TECHNOLOGY

INEXPENSIVE SENSOR PRODUCTION THROUGH STANDARD CMOS PROCESS

TEMPERATURE COMPENSATION NOT REQUIRED

ROBUST AGAINST INTERFERING EXTERNAL MAGNETIC FIELDS THROUGH GRADIENT EVALUATION

INTEGRATION OF MAGNETIC PIXEL CELLS

VECTORIAL MAGNETIC FIELD MEASUREMENT IN A SINGLE POINT

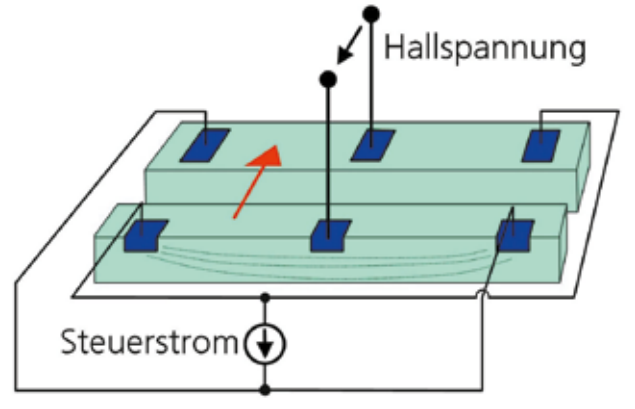
ANGLE BASED AND GRADIENT BASED EVALUATION

INTEGRABLE CUSTOMER-SPECIFIC ELECTRONICS

HALLinONE® – 3D MAGNETIC FIELD SENSOR TECHNOLOGY ON ONE CHIP

The integrated 3D Hall-sensor technology HallinOne® allows 3-axis magnetic field measurement with one sensor chip to realize low-cost contactless position measuring systems. While conventional Hall sensors are sensitive only to magnetic fields which are perpendicular to the chip surface, the sensor also responds to magnetic fields parallel to the chip surface. The sensor chip has a separate sensor for each of the three magnetic axes. The digitalization of the measured values is integrated in the sensor chip. It is possible to connect the chip directly to a computer or microcontroller. The HallinOne® sensor can be produced at low cost in large quantities without any additional process steps in standard CMOS technology, leading to a low selling price.

The figure below shows the essential part of the sensor element, the perpendicular single sensor. It illustrates how a vertical Hall sensor can be realized in standard CMOS technology.



The red arrow indicates the direction of the magnetic field to be measured. If the Hall element is supplied with control current according to the depicted voltage source, Hall voltage proportional to the adjacent magnetic field is generated between the two contacts in the middle.

HALLinONE®
INTEGRATED 3D MAGNETIC FIELD SENSOR TECHNOLOGY IN STANDARD CMOS

Characteristics

Due to the different sensor geometries necessary to measure vertical and tangential magnetic fields, the Z-axis has different characteristic values than the axes X and Y.

Sensor for the Z-axis:

Sensitivity:	ca. 200 mV/T
Noise (@800 Hz):	11 nV/sqr (Hz)
Offset (without compensation):	< 2 µV (≈ 10 µT)

Resolution:	
Δf = 100 Hz:	0,6 µT
Δf = 1 kHz:	2 µT
Δf = 10 kHz:	6 µT

Sensors for axes X and Y:

Sensitivity:	ca. 40 mV/T
Noise (@800 Hz):	20 nV/sqr (Hz)
Typ. Offset (without compensation):	< 20 µV (≈ 500 µT)

Resolution:	
Δf = 100 Hz:	6 µT
Δf = 1 kHz:	20 µT
Δf = 10 kHz:	60 µT

At the current state of technology the magnetic field in the Z-direction can be measured with higher accuracy than presently the X-axis and Y-axis. Sensors have further potential for improvement in the measurement of tangential magnetic fields.

Temperature Response

The magnetic sensitivity of silicon Hall sensors decreases in higher temperature ranges. The sensitivity of the HallinOne® sensor for instance decreases by about 30 percent at temperatures rising up to 100 degrees Celsius.

Angle measurements (see also application example "Joystick" on page 9) do not require temperature compensation, since the magnitude of the magnetic field has no influence on angle calculations. A reference source current can constantly measure the sensitivity of the sensor during operation. If certain applications do require temperature compensation, the measured values can be corrected by the reference source current. All circuit parts necessary for reference measurement are integrated in the chip, except for the external reference resistor.

Integration

The multidimensional magnetic field sensors in HallinOne® are part of an extensive sensor library. Using the library, the customer has the opportunity to realize complete systems for magnetic field measurement, including signal processing, in one application specific integrated circuit (ASIC). Particularly analog-to-digital converters (ADC), digital-to-analog converters (DAC), microcontrollers, interfaces together with any other digital logic plus sensors can be integrated in one chip. The benefits are potential price advantages and a high level of protection against unauthorized replica. Further advantages are the small space requirements of 3D sensor technology as well as an increased reliability due to reduced external connections. It is also possible to combine complex systems with various sensors on one chip by combining the magnetic field sensor elements with e. g. light-, force-/torison- or temperature sensors.

HALLinONE® ALLOWS BETTER PRODUCTS WITH NEW TECHNOLOGY

HIGH-PERFORMANCE WASHING MACHINES THROUGH INTELLIGENT 3D MAGNETIC FIELD SENSOR TECHNOLOGY

Optimized operation and control processes in washing machines through intelligent control – now possible with HallinOne® technology. The 3D magnetic field sensor developed by Fraunhofer Institute for Integrated Circuits IIS in cooperation with Robert Seuffer GmbH & Co KG optimizes the performance of washing machines.

Sensor Requirements:

- Positioning of the laundry drum
- Determination of the load weight
- Detection of imbalances
- Prevention of excessive use of mechanical components

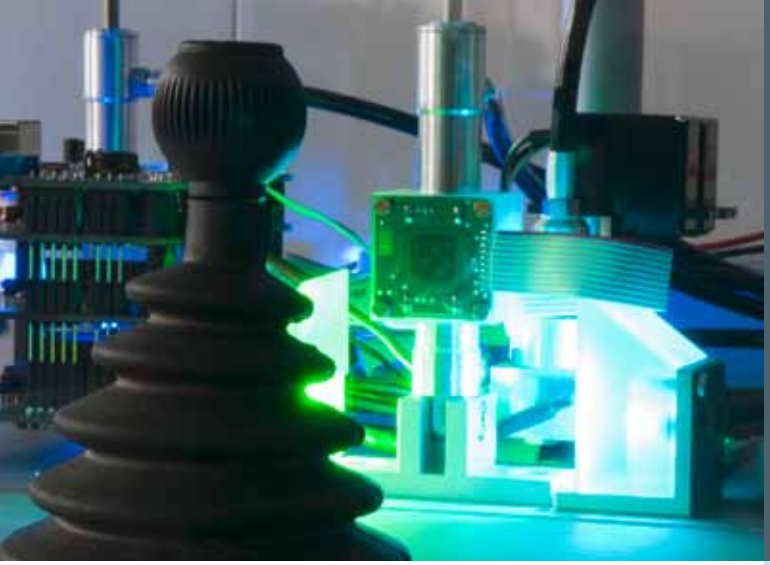
The 3D magnetic field sensor HallinOne® allows for 3-axis measurement of any magnetic field at one spot in the washing machine.

Sensor Characteristics:

- Contactless angle measurement
- Integrated 3D magnetic field sensor technology
- Resolution as rotation angle sensor better than 0.1 degree
- Cost-effective sensor production through standard CMOS process
- Integrable in customer-specific electronics

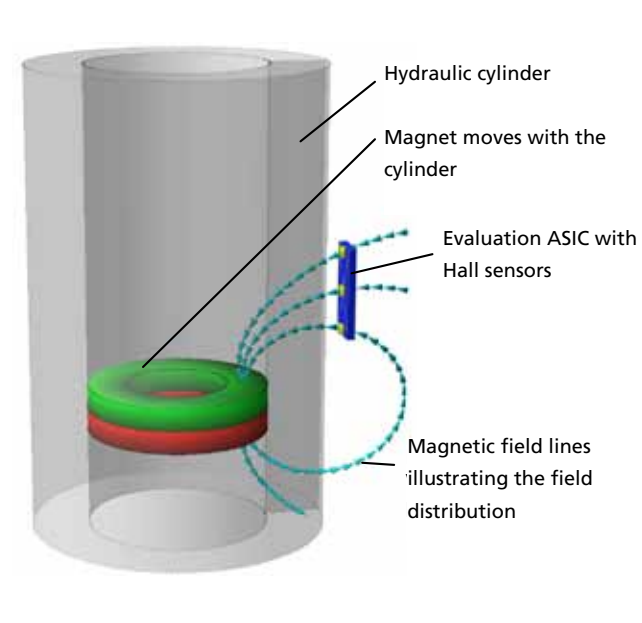
Customer Benefits through 3D Magnetic Field sensor Technology in Washing Machines:

- Efficient use of detergent
- Optimized use of drum bearings
- Higher spin speed
- Spinning with imbalance compensation
- Increased volume capacity



LINEAR POSITIONING WITH 3D MAGNETIC FIELD SENSORS IN STANDARD CMOS

HallinOne® provides sensors, which can measure all the three axes of a magnetic field practically punctiform. Linear positioning uses two or three (depending on the evaluation method) of those so-called pixel cells to determine the position. Gradient based and angle based evaluation allow for robust positioning. Neither temperature changes nor homogenous noise fields can cause inaccurate measurement results. This approach is not more expensive than conventional approaches since the sensors are integrated in the evaluation chip.



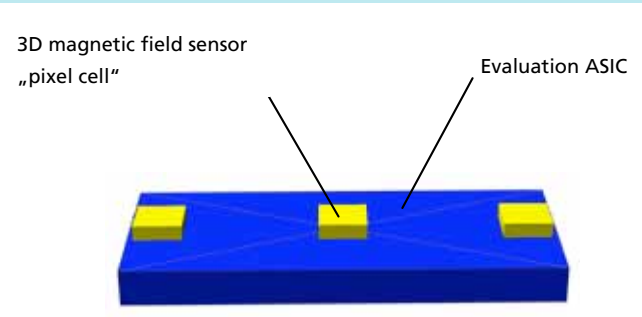
Example for linear positioning at cylinders

Position Sensors

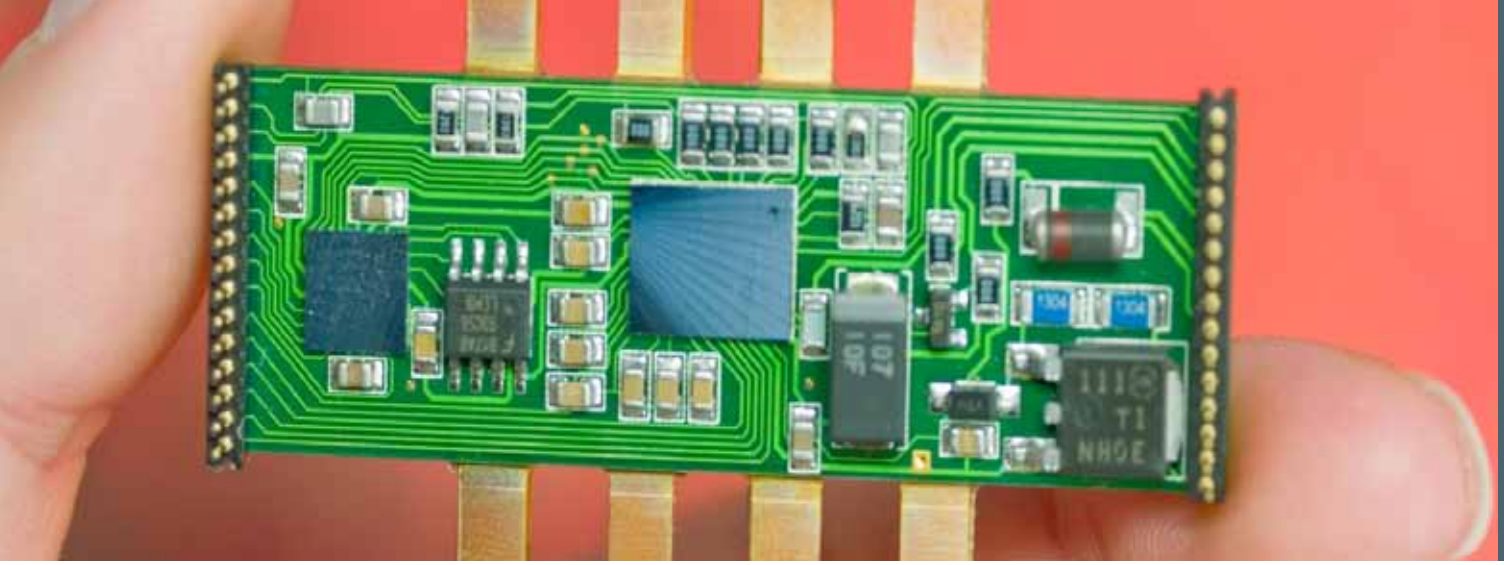
There is a vast field of industrial applications for position sensors, especially in vehicles and automated manufacturing plants. The technological development of the magnetic position sensors are leading the way from simple angle and distance sensors to multidimensional, robust, intelligent sensor systems.

The complexity of the design task for magnetic positioning systems is closely correlated with the number of degrees of freedom and the sensor complexity. Hence, simulation support during system design is not only a sensible measure regarding costs, but indispensable at already two degrees of freedom.

Fraunhofer IIS developed the HallinOne® technology for multidimensional Hall sensors integrated in one CMOS IC. The Fraunhofer IIS division in Dresden created a design environment for HallinOne® sensors, which allows the simulation of components but also entire systems during the early design phase.



Schematic structure of the evaluation ASIC with three integrated magnetic pixel cells



HALLinONE® – THE TECHNOLOGY OF THE FUTURE

CURRENT SENSORS

Technology

Current sensors measure the electric current created by the magnetic field using Hall elements, which can be realized in a standard CMOS process.

The high sensitivity of the sensors and their ability to compensate offsets and temperature dependence with integrated electronics allow to forego /to pass on elements like ferrit cores, which concentrate the magnetic field. This way hysteresis and saturation effects can be avoided and a simple design as well as a high level of integration capability achieved.

Two magnetic field sensors are necessary to measure current since external magnetic fields, like the earth field, can be compensated only this way. The used Hall elements measure only the Z-component of the magnetic field, which is perpendicular to the chip surface. While the Z-components of external noise fields have the same value and sign in both sensors, they have opposite signs in a field created by electric current. This way the current in the conductor can be measured without interference. The integration of both sensors in one chip allows a compact design and an exact reproducibility of their geometry. A single calibration measurement can compensate the positioning mistakes of the conductor, which is not integrated in the chip.

APPLICATION EXAMPLE – JOYSTICK

The 3D magnetic field sensor can be used for the contactless record of the current position of a joystick.

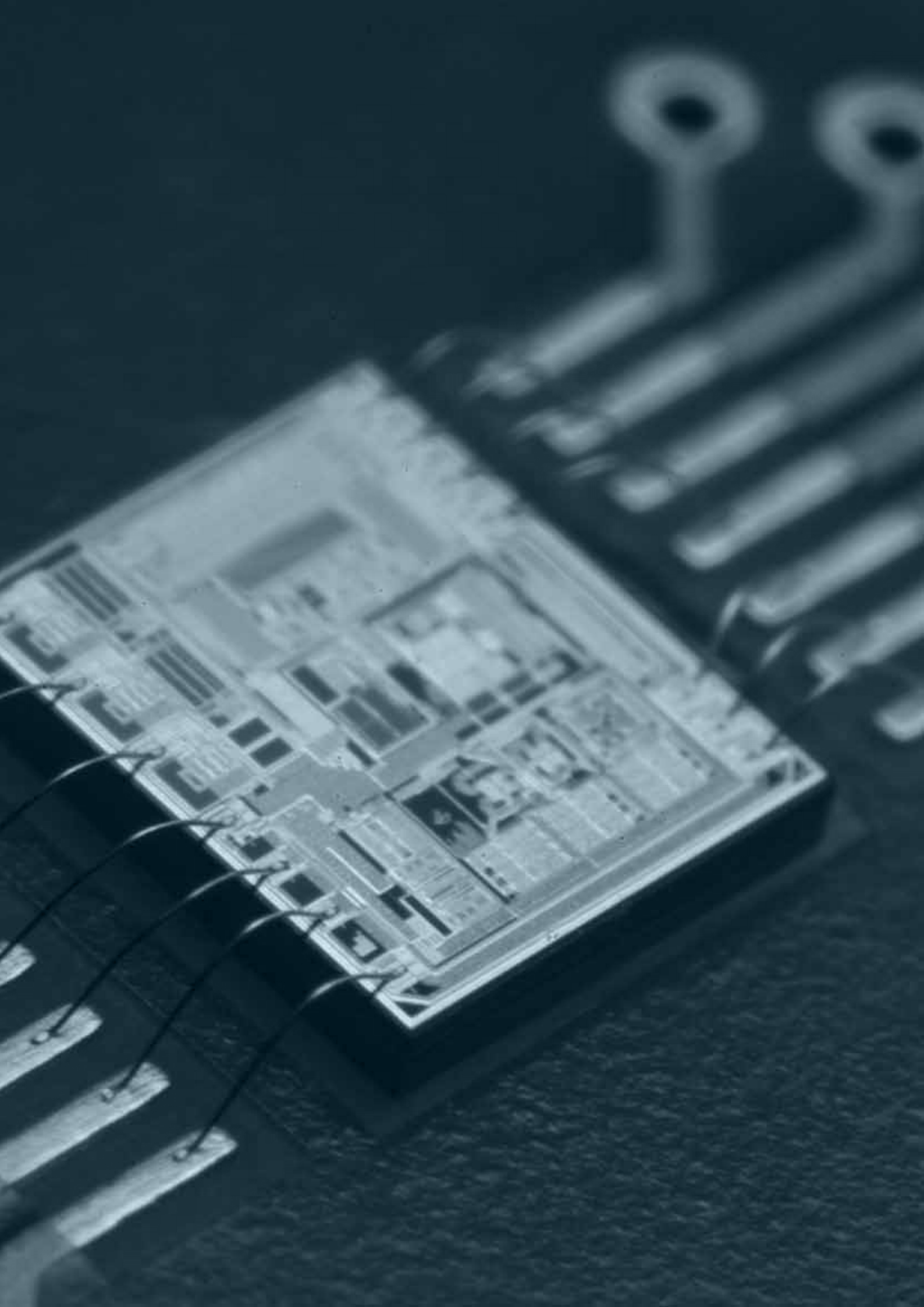
A permanent magnet is mounted to the lower end of the lever whose orientation is measured continuously in relation to the sensor chip underneath. All three spacial directions of the measured magnetic field are used to define the direction of the joystick above the field generated by the magnet. Electrical connections to the moving part of the joystick are not required allowing for a high-end and robust joystick which can even be employed in a humid or unclean environment. It is possible to adjust the distance between the magnet and the sensor chip to realize an analog or digital button on the joystick. In this case, the temperature compensation for the magnetic field values should be activated to ensure a stable absolute value of the magnetic field.

FURTHER FIELDS OF APPLICATION

For the first time all three axes of the magnetic field can be measured practically punctiform and at low cost with the integrated 3D magnetic field sensor. This opens a wide range of new applications compared to conventional magnetic field sensors:

- Magnetic switches with one or more axes on a single chip
- Multiaxial magnetic field measurement, characterization of permanent magnets
- Linear motion in machine tools with suppression of external fields through gradient evaluation
- Contactless potentiometers on one single chip
- Proximity switches with high operating distances (up to approx. 15 cm)
- High-precision position measurement using multidimensional magnetic scales
- Rotation angle measurement with high resolution and / or high distance to the magnet
- Off-axis rotation angle measurement with absolute values as well as gradient based
- Fraunhofer IIS, in cooperation with Micronas GmbH, developed a gradient Hall sensor for complex applications and operation in high temperature ranges up to 170 degrees Celsius. The sensor can also be used for applications in engine construction.

This way, the entire signal processing and evaluation and the sensors can be integrated in one chip, customized for individual customer requirements. These inexpensive system-on-chip solutions provide unmatched competitive advantage in the marketplace.



THAT IS HALLinONE®:

HIGH-PRECISION LATERAL MAGNETIC FIELD SENSORS BASED ON HALL-EFFECT TECHNOLOGY

VERTICAL MAGNETIC FIELD SENSOR (INTEGRATED 3D SENSOR ON CMOS)

NOISE OPTIMIZED SENSOR SIGNAL PROCESSING FOR MAGNETIC FIELD SENSORS

INTEGRATED SELF TEST, SELF MONITORING AND SENSITIVITY CALIBRATION

MAGNETIC GRADIENT SENSORS

MAGNETIC “COLOR” CAMERA

OUR EXPERTISE – YOUR BENEFIT:

DEVELOPMENT OF CUSTOMIZED 3D MAGNETIC FIELD SENSORS AND CURRENT SENSORS (IN STANDARD CMOS TECHNOLOGY)

MEASUREMENT AND SIMULATION OF MAGNETIC FIELDS

SINGLE-CHIP INTEGRATION OF OPTICAL AND MAGNETIC SENSORS

MIXED-SIGNAL IC DESIGN, INTEGRATION OF ULTRA-LOW CURRENT RADIO RECEIVERS AND RADIO TRANSMITTER ASICS, WAKE-UP RECEIVER

CUSTOMER SUPPORT FOR SERIES PRODUCTION AND SMALL VOLUME PRODUCTION

10/2009 K.Dembowski

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