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Low-power 3D magnetic sensing

A 3D magnetic sensor with low power consumption and high magnetic accuracy has multiple applications for the consumer and industrial markets

The new 3D magnetic sensor TLV493D-A1B6 offers accurate three-dimensional sensing with extremely low power consumption in a small six-pin package. With magnetic field detection in the x, y, and z directions, the sensor reliably measures three-dimensional, linear and rotation movements. Applications include joysticks, control elements, multifunction knobs, anti-tampering for e-meters, and any other application that requires accurate 3D measurements in combination with low power consumption.

While conventional linear Hall sensors, Hall switches and angle sensors only detect magnetic field components that are oriented perpendicularly to the surface of the chip (GMR angle sensors detect only the planar oriented field component), the TLV493D-A1B6 sensor enables the simultaneous detection of the x, y and z coordinates of the magnetic field (Figure 1). By providing the magnetic field components of all three axes, customers get a holistic, three-dimensional picture of the magnetic field at the sensor. Any movement by the magnet will change at least one magnetic field component, which will be detected by the 3D sensor.

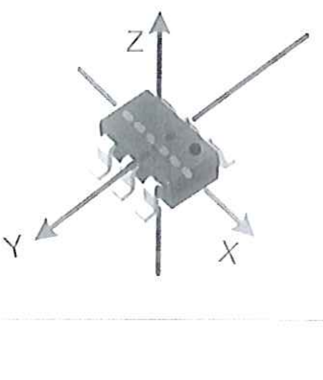

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Figure 1: **3D sensor principle of the TLV493D-A1B6**

The TLV493D-A1B6's three-dimensional sensing capabilities are achieved by integrating vertical and horizontal Hall plates on the sensor chip. Vertical Hall plates are sensitive to the planar oriented field components from the x and y directions. Horizontal Hall plates are sensitive to the perpendicular oriented field component – the z direction.

One of the main targets when developing the sensor was to achieve low power consumption. The use of innovative design technologies like the low power oscillator pushed the power consumption of the sensor to a record low range of some nano-amperes (7nA in power-down mode). Concentrating the development on the core requirements, accurate 3D magnetic sensing and low power consumption resulted in a small piece of silicon that fits in a small package. The TSOP-6 package is only 2.9mm x 1.6mm in size, smaller than any other 3D magnetic sensor on the market today.

Due to reduced cost and high reliability, the TLV4963-A1B6 can be used in applications to replace potentiometer and optical solutions. With contactless position sensing and a high temperature stability of the magnetic threshold, system concepts become smaller, more accurate and robust.

The TLV493D-A1B6 sensor provides a digital output via a standard I²C interface, which enables a high communication speed, bus mode and bidirectional communication between sensor and microcontroller.

TLV493D-A1B6 is RoHs compliant and JESD47 qualified, to enable customers' systems to fulfill the highest quality standards and various environmental regulations.

Architecture and key features

The sensor architecture is designed and engineered with three main function units (Figure 2)

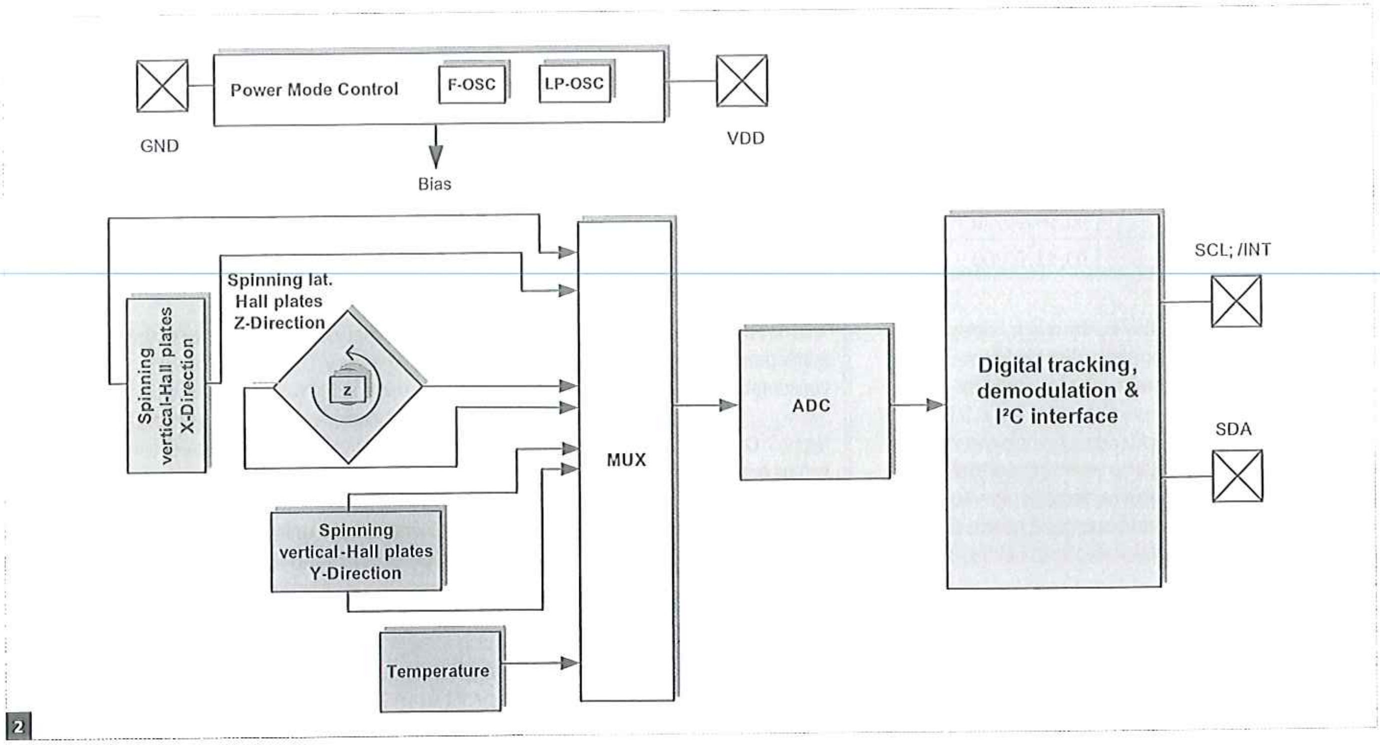


Figure 2: **Block diagram of the TLV493D-A1B6 with the main function units: power mode control system, sensing part and I²C interface**

– power mode control unit, sensing unit and communication unit.

The power mode control unit is responsible for power distribution in the integrated circuit (IC). It also handles the startup of the sensor.

The sensing unit contains the vertical and horizontal Hall plates and a temperature sensor. It also measures the magnetic field in the x, y and z directions. Each x, y and z Hall plate is connected sequentially to a multiplexer, which is connected to the analog-to-digital converter (ADC). The temperature sensor is also connected to the multiplexer and can be used as an additional option. The overall current consumption decreases by approximately 25% when temperature measurement is deactivated.

The communication unit, containing the I²C interface and register files, can be accessed by the microcontroller in any power mode in order to read register values. The values for the three axes and the temperature are stored in separate registers. The interface confirms to the I²C fast mode specification (400Kbps), but with a specific electrical setup, data rates of 1Mbps and more are possible. Following the guidelines of the I²C protocol, the sensor is able to operate in an I²C bus with other devices. The standard bus address of the TLV493D-A1B6 sensor is a factory setting. During power up, this address can be changed via the address pin. The new address is valid during operation and can only be restored to its factory setting by removing the power supply.

For 3D magnetic sensing the TLV493D-A1B6 provides 12-bit data resolution for each measurement direction. This allows a high data resolution of 0.098mT per last significant bit, so even the smallest magnet movements can be measured.

Linear magnetic field (B) measurements of Bx, By and Bz are possible for the wide linear field range of ±150mT. This enables the customer to measure and cover a long magnet movement. The large operation scale also makes the magnet circuit design easy, robust and flexible.

By using vertical Hall plates for both planar magnetic field components (x and y directions), the sensor achieves excellent magnetic matching of ±2%. This enables accurate angle measurement.

When targeting industrial and consumer applications, TLV493D-A1B6 can be operated on a supply voltage from 2.3-3.5V, and at a temperature of -40°C to +125°C.

Flexible power modes enable lowest current consumption

The sensor provides an interrupt signal to the connected microcontroller after each measurement cycle. The microcontroller can now read the magnetic and temperature values from the registers. The sensor interrupt signal can be used to wake up a microcontroller system in

Table 1				
Mode	Byte $_{hex}$ 0,1,2,3: mode settings	Update Rate / Hz	Idd / μA (25°C)	Remark
Power Down	-	-	0.007	default after power on
Ultra Low Power	00, 01, 00, 00	10	10	temp measurement
Low Power	00, 05, 00, 40	100	100	temp measurement
Fast Mode	00, 06, 00, 00	10000	3700	temp measurement
Master controlled	00, 13, 00, 00	variable up to f = 5kHz	2000	temp measurement

sleep mode. Because the system is in sleep mode and is only active during the reading phase, the overall system power consumption can be reduced dramatically.

The TLV493D-A1B6 provides five power modes that can be selected by the user: power-down mode, fast mode, low-power mode, ultra-low-power mode and master-controlled mode (Table 1). These modes can be configured during operation via the I²C interface.

At power up, the sensor starts in factory configuration. For a short time all function blocks are active. After this the sensor enters power down mode and all functional blocks are off and no magnetic measurement takes place. Power consumption falls to 7nA. Powered by two standard AA batteries (2,400mAh each), the TLV493D-A1B6 sensor could operate for over 27 years in ultra-low-power mode.

In fast mode, the readout is optimized for speed. The measurement sample from the last conversion can be read while the next conversion is being performed. This mode is ideal for applications where fast magnet movements need to be detected, such as in joysticks. The power consumption of the sensor peaks at 3.7mA when operating at a maximum sample rate of 10kHz. This corresponds to approximately 10,000 measurement cycles per second.

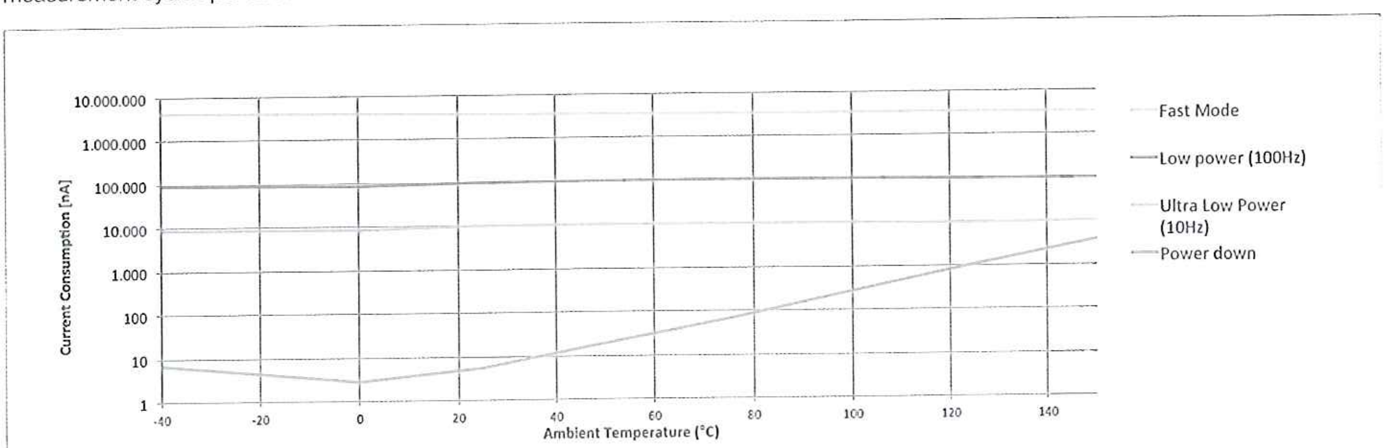
Table 1: **Power modes and their corresponding current consumption with sample rates**

Figure 3: **Current consumption versus temperature**

In low-power mode, the sensor wakes up periodically every 10ms from power-down mode to perform magnetic measurements. Power consumption in low-power mode is just 100μA. This energy efficient mode is ideal for applications such as control elements (multifunction knobs) that may require regular magnetic measurements with low power consumption.

It is possible to get 10 times lower power consumption in ultra-low-power mode. Wake-up cycles are extended to 100ms so that power consumption is reduced to 10μA. Battery-powered applications such as tamper protection in e-meters profit from this mode.

In the master-controlled mode, the sensor can be read out flexibly depending on the application's need. After each measurement the sensor waits for the microcontroller (master) to read the registers. Depending on the application situation, the reading can be taken either immediately or with a delay. As soon as the microcontroller collects the magnetic values, a new measurement cycle is triggered. This mode is especially useful when several TLV493D-A1B6 sensors are connected via the I²C bus to detect large linear movements, in which case the microcontroller decides which sensor data is most relevant and triggers the appropriate sensor. Figure 3 shows the current consumption for the different power modes versus the temperature.



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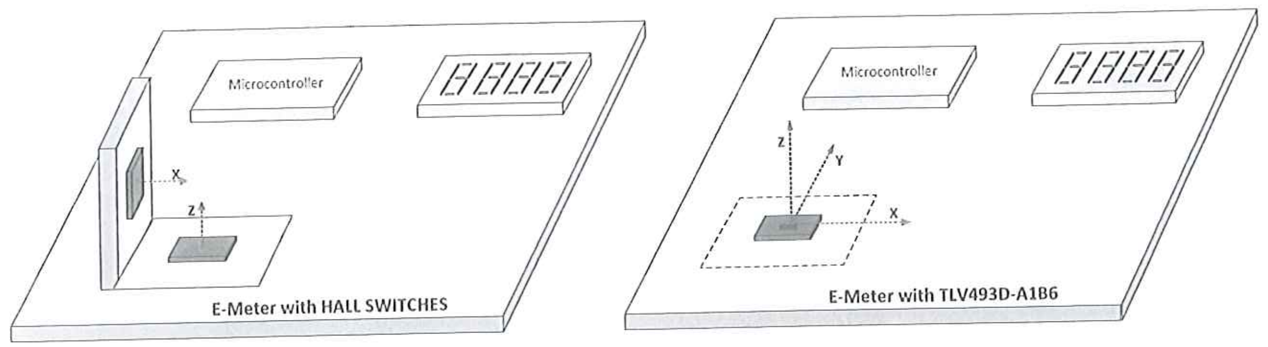

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Figure 4: **The TLV493D-A1B6 is ideal for the tampering protection in smart e-meters**

Application: tampering protection of e-meters

Traditional electricity meters have no ability to detect or deal with tampering because they only measure energy based on the voltage and current flowing between the in/out terminals. In such meters, tampering has become very easy and detection is hard. However, electronic meters deployed today have the ability to detect tampering and take appropriate action.

Magnetic interference is probably the commonest and easiest way to tamper a with meter. Magnetic current sensors such as a current transformer (CT) are most susceptible to this interference. A powerful permanent magnet, when placed on the case close to the CT, produces a strong magnetic field that quickly saturates the core, thereby rendering the current sensor useless. The current reading would then be zero and so would the energy reading.

The conventional approach to implementing magnetic sensing for tamper protection is based on two Hall sensors, one soldered to the relevant printed circuit board (PCB) and the other vertical to it on a separate small PCB (Figure 4). This approach comes with some disadvantages, including cost-intensive mechanical construction, calibration, tuning and high power consumption.

With the new 3D sensor there is no extra PCB necessary and therefore system complexity is reduced, leading to higher reliability. In addition, the TLV493D-A1B6 fulfills all the other demands for this kind of application, including offering a large field range, high resolution, temperature measurement, very low power consumption, digital output, no additional components, a small package and low costs. The sensor not only provides a fixed switching level, but also information about the constant magnetic field strength. Thus the anti-tampering level can be easily defined by software.

Joysticks and control elements

Accurate 12-bit resolution and the fast communication speed put the TLV493D-A1B6 in the top position for joystick applications. Non-contact magnetic sensing, high temperature stability and basically no aging effects allow the design of a novel generation of joysticks for industrial applications (man-machine interface).

Furthermore the new 3D sensors enable cost-effective and energy-efficient control elements – such as their user-friendly turn-push buttons – in white goods and home appliances. In addition to this, accurate angle measurements and a small system architecture enable the design of a new haptic end-user experience.

Evaluation board and free software

To enable a fast design and to reduce engineering time, customers can order a cheap evaluation board online (www.infineon.com/sensors2go). The 3D Magnetic Sensor 2Go evaluation board uses a TLV493D-A1B6 sensor and the Infineon XMC1100 Industrial Microcontroller ARM Cortex-M0. Together with the attached magnet and the provided sensor software, the first measurements can be taken within minutes. Using the XMC1100 as the microcontroller also offers the possibility of using the free development platform DAVE to develop a sensor system.

Summary and outlook, focusing on the automotive industry

The TLV493D-A1B6 sensor provides precise and energy-efficient 3D magnetic sensing for various applications. Flexible operation modes enable dedicated and scalable system designs with a wide measurement range for accurate position sensing, while the current consumption is kept to the lowest level.

Engineering samples of the TLV493D-A1B6 are available. Volume production is expected to start in January 2016. To serve customers in the automotive market, Infineon will conduct a full AEC-Q100 qualification on the sensor. Volume production for the automotive qualified TLE493D-A1B6 is expected for mid of 2016.

This first 3D sensor from Infineon marks the starting point for a 3D magnetic sensor portfolio. More 3D sensor versions will be introduced in the upcoming months. ■