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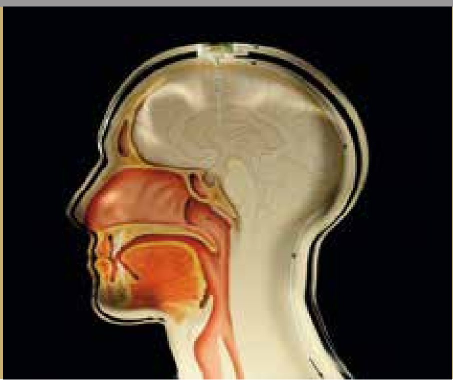

1 *Shunt sensor position in the drainage system.*

2 *Handheld reader unit measuring.*

IMPLANTABLE SENSOR TO MEASURE LIQUOR PRESSURE OF A VENTRICULAR DRAINAGE SYSTEM

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The human brain is filled with cerebrospinal fluid (CSF), which is produced in the ventricles. Patients suffering from normal pressure hydrocephalus (NPH) produce more CSF as they resorb. This leads to an increase of the intracranial pressure (ICP) in the skull, what may cause progressive enlargement of the head, convulsion, tunnel vision and mental disability due to shortage of oxygen and nutrients. To reduce the intracranial pressure, the implantation of a drainage system (shunt) which removes excessive CSF, e.g. into the abdominal cavity, is necessary.

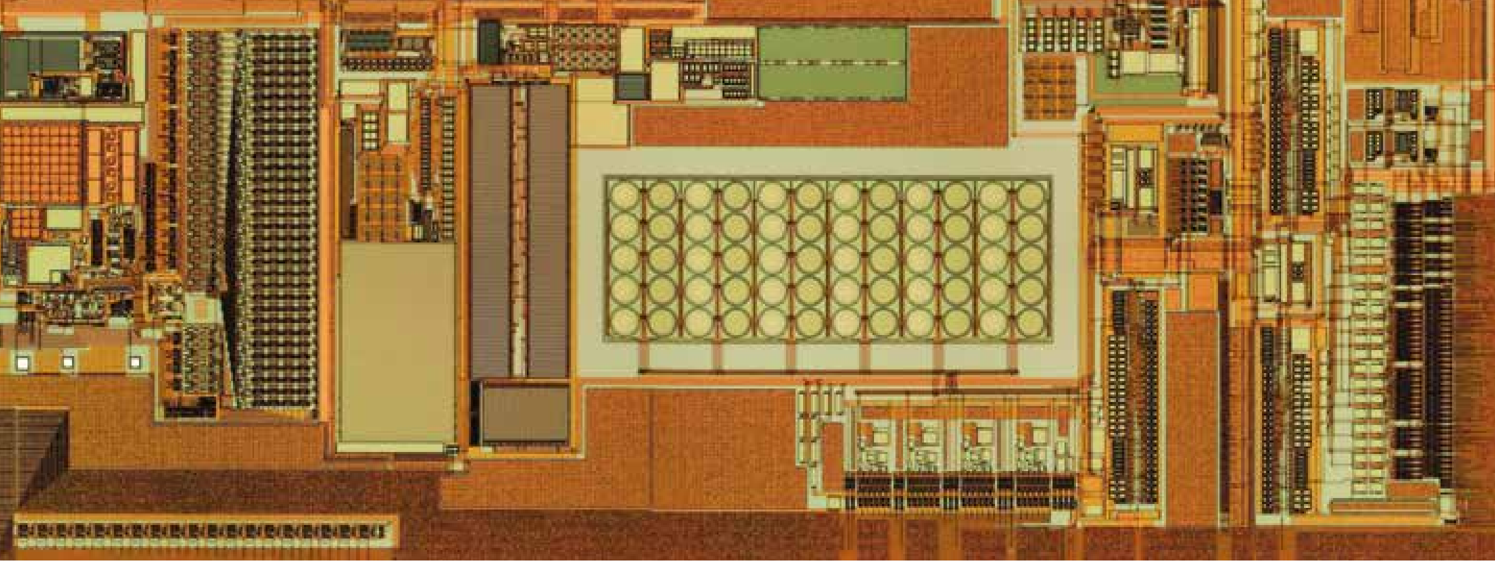
Development

In corporation with the companies Aesculap AG and Christoph Miethke GmbH & Co KG a system was developed for wireless measurements of the cerebrospinal fluid pressure in the shunt. The system is approved for use as a long-term implant in humans.

Pressure Sensor and Sensor Readout Electronics

The integrated capacitive pressure sensor of the transponder ASIC, as shown in Figure 3, consists of an array of circular pressure sensitive and pressure insensitive elements. The capacitor of a pressure sensor is formed by a fixed electrode in the substrate and a second electrode as a deflectable membrane of polycrystalline silicon above. The cavity under the membrane is obtained by anisotropic etching and later vacuum sealing. The diameter of one element is approx. 100µm and the capacitive change between minimal and maximal pressure is approximately 50fF.

A differential C/V converter transforms the capacitance of the pressure sensor into a voltage signal. This signal is A/D converted by a RSD (Redundant Signed Digit) cyclic A/D converter into a digital 13 × 2 bit data



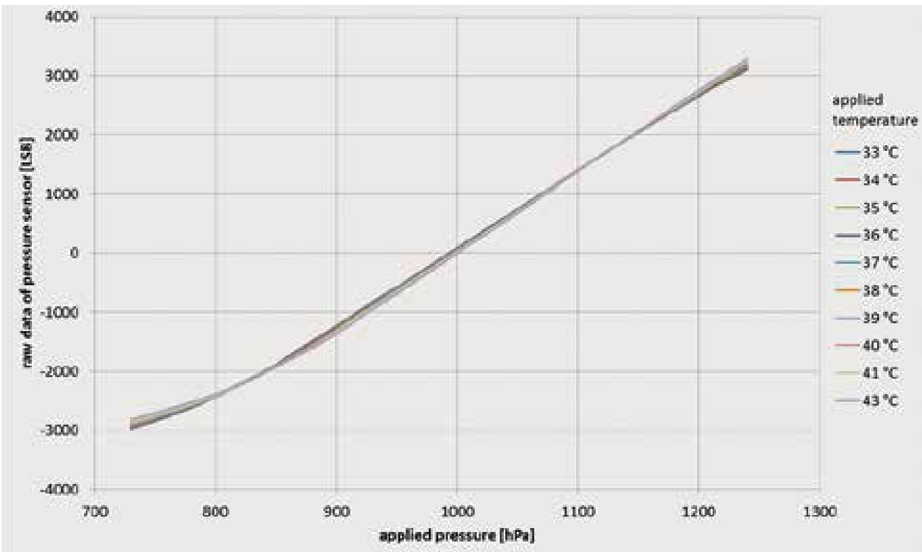
stream. The cyclic conversion algorithm is based on the conventional restoring numerical division principle. The conversion of the capacitance is adjustable in offset and gain to compensate fabrication related tolerances of the pressure sensor parameters. The C/V converter and the A/D converter are realized in a switched capacitor technique. A typical pressure curve for raw sensor data is shown in Figure 4.

Transponder System

The complete transponder system, as shown in Figure 2, consists of a passive transponder equipped with the described pressure sensor and readout electronics, and a reader device which powers the transponder by an electromagnetic field and receives back information from the transponder. In this transponder system, load-modulation is used to transmit data from the transponder to the reader. The transmitted data package comprises of the sensor readout data, calibration data, a unique identification number and a checksum for data validation. The reader unit calculates the measured pressure and temperature out of the received data by a fixed formula. To overcome the damping caused by the metal encapsulation of the implant the handheld reader was designed with a high quality factor of the transmitter coil, to optimize the performance regarding reading distance and battery lifetime.

Note: The illustrations and information presented herein are not the specifications of a medical product but examples of a Fraunhofer IMS pressure sensor system.

Parameter	**Value**
Sensor transponder ASIC size (l, w, h)	9.4 mm, 2.5 mm, 0.73 mm
Pressure range	733 – 1233 hPa
Pressure sensor accuracy	2.66 hPa
Pressure sensor sample rate	44 Hz
Temperature range	20 – 45 °C
Temperature sensor accuracy	0.5 K
Temperature sensor sample rate	22 Hz
Operation distance	0 – 5 cm
Reader HF-frequency	133 kHz



3 *Pressure and temperature transponder ASIC.*

4 *Typical raw pressure curve of a complete in metal encapsulated sensor.*