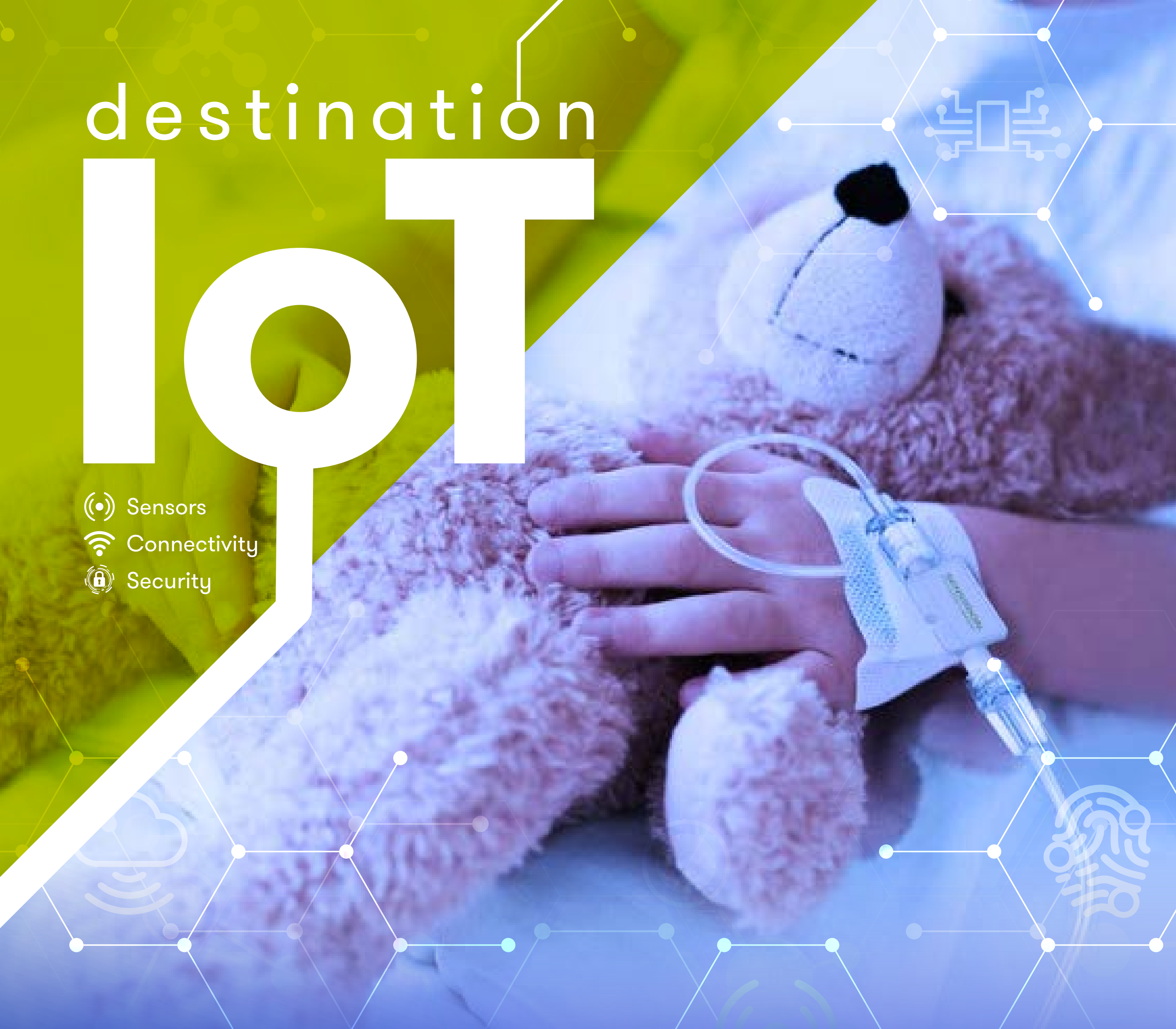

destination

IoT

Sensors
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DOCTOR SENSOR

Measuring biosignals in medicine

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Figures: Sensirion

Doctor Sensor
Measuring biosignals in medicine

Information that can be derived from the organism by means of sensors is called biosignals. They show an image of the state of human health. Their recording, processing and evaluation are important for diagnostics, monitoring, therapy and prevention. Biosignals can be detected invasively or non-invasively, inpatient, during surgery or close to the patient. RS offers various sensor components for the development of medical devices, research projects and prototype designs.

The biological signals of the body can be detected via sensors, e.g. as temperature, volume or voltage changes and converted into acoustic, electrical and mechanical signals, among other things. Electrical signals are detected via electrodes as current, resistance or voltage. Mechanical signal changes can be detected as pressure, force or movement. Thermal signals can be measured as temperature or amount of heat. Chemical gases, liquids or other substances can be quantified e.g. by concentration. Body sounds and speech are among the acoustic signals. There are corresponding sensors and signal processing components for all types of signals.

Bioelectrical signals	Biomechanical signals	Biothermal signals	Biochemical signals	Bioacoustic signals	Bio-optical signals
• Current • Resistance • Voltage	• Pressure • Force • Motion • Flow	• Temperature • Heat	• Concentration • ph-value • Smell	• Noise • Language • Echo	• Colour • Light

Table 1. Different biosignals

Regardless of the type of sensors and the signals acquired, processing, analysis and evaluation take place after signal acquisition. For this purpose, stochastic processes, frequency domain representations and filters are used. Table 2 shows the signal processing chain. The individual components are often already integrated into complete units - e.g. in so-called front-ends. Such an assembly then performs several of these functions.

Table 2: From biosignal to feedback

Under current - capture bioelectrical signals

Bioelectrical signals are detected in the ECG (electrocardiogram) of the heart, in the EEG (electroencephalogram) of the brain or in the EMG (electromyography) of muscles. Signal acquisition is carried out via special electrodes on humans, the more complex part of the process is signal processing. For this purpose, analog front-ends are used, which contain the sensor and the signal conditioning blocks or complete designs with connections and software.

One procedure is the ECG, in which the electrical activity of the heart is measured via electrodes directly on the body. Minimal electrical changes are recorded (measured in the microvolt range), which provide conclusions about the condition of the heart muscle. The devices are adapted to the respective application. There are ECG machines for resting, long-term or stress examinations.

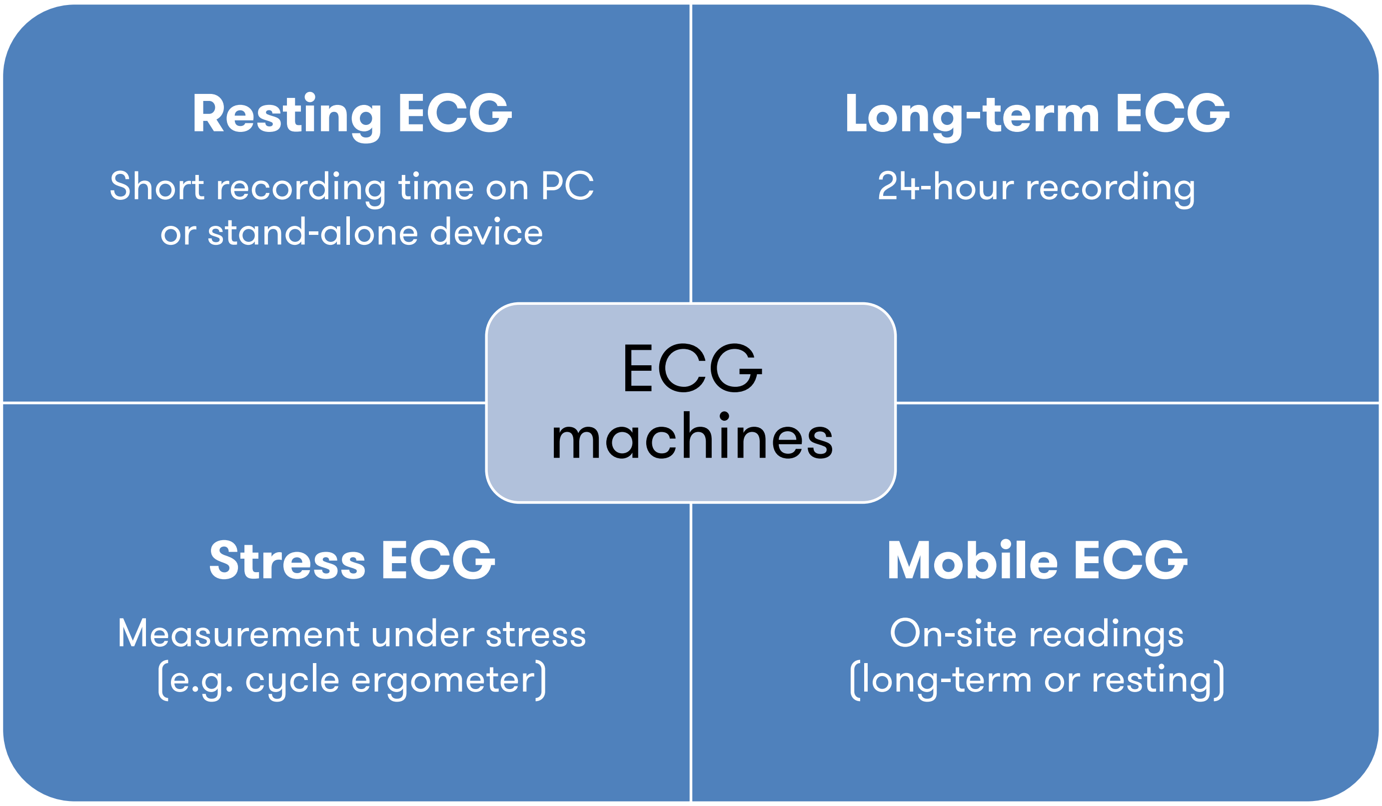

Table 3. The ECG procedure detects bioelectrical signals from the heart muscle

RS

Developer Kits

For developers, development kits are offered for prototype design. Under the name ECG 3 click, there is a complete solution for an ECG application from MikroElektronika, which is based on the MAX30003 analog front end (AFE) from Analog Devices/Maxim Integrated. Inside is a single-channel biosensor with various options for heart rate and ECG monitoring. The kit has a 3.5mm electrode connector and is supported by a mikroSDK compatible software library.

Fig. 4. The click board is suitable for use on a system with a microbus connection and is used for prototyping. (Image: RS Components)

The EMG Click board from the same manufacturer measures the electrical activity generated by the skeletal muscles. It is therefore a module for electromyography. On board are an MCP609 operational amplifier from Microchip and the MAX6106 voltage reference from Analog Devices/Maxim Integrated. The whole thing runs on a 5V power supply and is intended for prototyping.

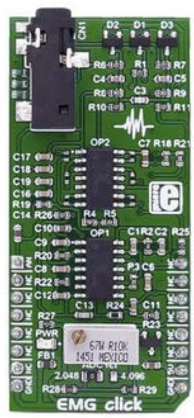

Fig. 5. EMG-Click is a prototyping board and not a medically approved component (Image: RS Components)

The manufacturer's Click EEG board is also designed for prototyping. It makes it possible to monitor brain activity by amplifying weak electrical signals from the brain. This is necessary so that they can be sampled by a host MCU. For this purpose, the precision instrument amplifier INA114 from Texas Instruments is used. The board can be used with silver chloride electrodes and is supported by a library for software development.

Fig. 6. With this board you gain an insight into brain activity (Image: RS Components)

Sensors for biomechanical signals

Sensors for biomechanical signals include pressure, force, motion and flow sensors. So-called flow sensors are used for respiratory applications. This makes it possible, for example to measure breathing air in ventilators. A sensor measures air, oxygen and mixed flows with high accuracy. Reliability and long-term stable operation without recalibration are important. The “flow” is the gas flow (e.g. in litres of gas) that flows per second through a pipe cross-section.

Ventilation and inhalation devices are used, for example in resuscitation and emergency care, in oxygen and nebuliser therapy, in ventilation filters, anesthesia face masks, suction systems and CPAP systems (Continuous Positive Airway Pressure; supports spontaneous breathing with a permanent overpressure). The respiratory flow is measured as close as possible to the patient (proximal).

The Sensirion SFM3200 flow sensor is a digital flowmeter suitable for inspiratory flow measurements. It has a dynamic measuring range from -100 to 250 SLPM (standard litres per minute). The design of the flow channel leads to a low-pressure drop through the flow housing of the sensor. A bidirectional measurement mode with an internally linearised and temperature-compensated signal is implemented via a thermal sensor element. The module works with 5V and is certified according to ISO5356-1:2004. It has an I2C interface and is suitable for air (non-condensing), N2, O2 and other non-aggressive gases. It is used in anaesthesia, in drug dosing, for respiratory flow measurements or breath measurements.

Fig. 7. The sensors are designed for a maximum pressure of 1.07 bar. (Image: RS Components)

Differential pressure sensors can be used to detect the pressure drop in flow lines. This allows flow rates in ventilators to be determined, which is useful for stationary and mobile ventilators.

The Bourns Precision Sensor (BPS) range includes MEMS pressure sensors with analog or digital outputs (I2C) and configurable connectors. They can be used for medical devices at low or medium risk of use. These are applications in patient monitoring devices, calibration pressure sensors for low differential and overpressure values as well as CPAP devices (Continuous Positive Airway Pressure) or spirometers.

Fig. 8. Bourns' BPS110 series pressure differential sensor measures 12.7mm x 13.8mm x 8.4mm. (Image: RS Components)

Honeywell's ABP series are piezoresistive silicon pressure sensors with digital or ratiometric analog output for reading pressure over the entire specified pressure and temperature range. There are variants with digital or analog output as well as in SMD, DIP or leadless SMT packages. The sensors are suitable for medical applications such as CPAP, blood pressure and patient monitoring and ventilators. Pressure measurements can be realised between 60mbar and 10bar.

Fig. 9. Honeywell's piezoresistive pressure sensor operates at 3.3 VDC or 5 VDC (Image: RS Components)

A question of temperature - biothermal signals

In the medical field, temperatures are measured in direct contact with the body surface or contactlessly with so-called infrared thermometers. NTC thermistors (Negative Temperature Coefficient), digital temperature sensors, temperature probes or, in the case of the non-contact measuring method, infrared sensors are used for this purpose.

NTC thermistors can be used to measure surface temperatures. The change in the electrical resistance in a conductor is determined depending on the temperature. With NTC temperature sensors, the electrical resistance decreases as the temperature rises. The components are autoclavable (steam sterilisation) for medical technology.

TE Connectivity's MEAS MBD series NTC thermistor probes are soldered to a silver-plated 30 AWG copper solid wire with PVDF insulation. They can be used for small medical probes and localised temperature sensing.

Fig. 10. The NTC thermistor is 56mm long and operates with a tolerance of +/-0.2% (Image: RS Components)

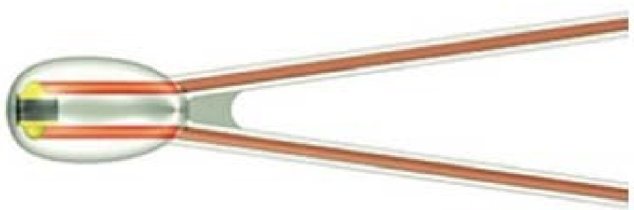

Fig. 11. Epocs' B57550G1 series NCT hot conductors have a stable and heat-resistant encapsulated glass construction. (Image: RS Components)

Infrared temperature sensors are used for contactless temperature measurement. Body temperature detection on the ear, forehead or other parts of the skin is possible.

The sensors of the Omron D6T series are based on an infrared sensor that measures the surface temperature of the target object without contact using a thermopile. This absorbs the radiated energy of the object. The D6T 4×4 sensor can measure the temperature of a face from up to one metre away and achieves a temperature inaccuracy of ±0.2°C for fever detection.

Fig. 12. The Omron D6T thermal MEMS (Micro-Electro-Mechanical-Systems) sensors use special ASIC technology to achieve the necessary immunity to interference. (Image: RS Components)

Even with thermopiles, a temperature can be measured from a certain distance. TE Connectivity's TS3XX thermopiles are temperature sensors that measure surface temperatures contactlessly. The sensor consists of a chip with a series of micro-thermocouple elements, a reference ambient temperature sensor and an infrared filter window. All elements are housed in a hermetically sealed metal housing. The sensor has a voltage output proportional to the thermal infrared energy entering the sensor through the filter window. The measuring range is -40 to 300°C.

Fig. 13. The thermopiles are housed in hermetically sealed TO-5 or TO-18 packages. (Image: RS Components)

The blood glucose controllers

One of the applications for chemical biosignal acquisition are sensors for the determination of blood glucose levels. The sensors for this are invasive (e.g lancet devices), minimally invasive (e.g. patch measuring devices) or non-invasive. The latter variant is based on optical methods (infrared light) and is intended more for home equipment such as fitness watches.

There are also methods of spectroscopy (for example: https://www.diamontech.de) for non-invasive use. A beam of light is directed from a sensor onto the skin to heat glucose molecules there. From the measured heat developed, the blood sugar value is calculated.

The company Alphabet (Google parent company) had even researched until 2018 on a sensor that was supposed to measure blood sugar via the tear fluid of the eye via contact lens. In the end, however, no reliable values could be generated here.

Since the non-invasive method of blood glucose monitoring has many advantages and the population increasingly suffers from diabetes, many developments are underway here. For easy control at home with smartphone, watch or fitness module, you can also get by with lower accuracies than in hospital situations.

Traditionally, blood glucose levels can be determined optically. Chemical substances react in a test strip with the applied blood. A colour change occurs, which is captured, analysed and output as a result by the measuring instrument. Another variant is amperometric measurement, in which glucose in the blood is converted into so-called metabolites by an enzyme. The resulting current flow is measured and the result is determined.

Smart noses

Sensors that act as “intelligent noses”, for example, can learn to smell artificially. In medicine, this could be used, for example, to detect a Covid-19 disease from the air a person breathes.

Electronically reproducing the human sense of smell can therefore be useful. A research project funded by the Volkswagen Foundation called “Olfactorial Perceptronics” deals with this topic. For this purpose, a study (Crown) is currently being carried out, in which research is being carried out on human olfactory perception.

Researchers of Karlsruhe Institute of Technology (KIT) have already developed an electronic nose with an artificial sense of smell. It can detect different types of mint and can initially be used for pharmaceutical quality control.

Fig. 14. It doesn’t look like a nose at all: a combination of sensors and materials enables the artificial sense of smell. (Photo: Press photo Amadeus Bramsiepe, KIT)

Bosch Sensortec has implemented a digital nose that also uses AI methods (AI: artificial intelligence) as a 4-in-1 gas sensor. The MEMS sensor can be used to simultaneously measure gas, humidity, temperature and air pressure. The sensor's AI capabilities, BME AI-Studio software tool, and an Adafruit-compatible design kit support the development. A device could, for example detect bad breath or body odour. The BME688 sensor is specifically designed for mobile and portable applications.

Fig. 15. The B680 is housed in an LGA package with dimensions of 3mm x 3mm x 0.93mm with 8-pin metal lid. (Image: RS Components)

Scientists at TU Dresden want to develop an electronic nose as part of the EU-funded project "Smart Electronic Olfaction for Body Odour Diagnostics" (SMELLODI) with seven partners from Germany, Israel and Finland. The intelligent electronic sensor systems could be used, for example for implants and aids for people with olfactory disorders.

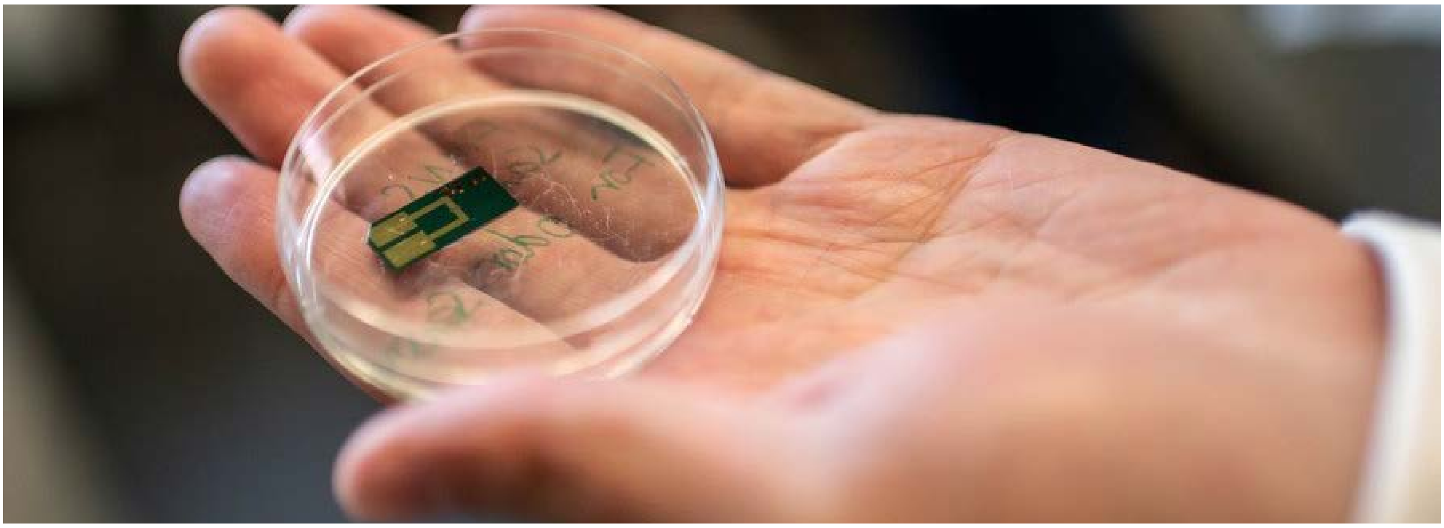

Figure 16. The plan is to develop intelligent electronic sensor systems that can distinguish and digitally transmit healthy body odours that have been altered by illness. (Photo: Press photo TU Dresden, Antonie Bierling)

Measuring antibiotic levels via the breath

A team of scientists from the University of Freiburg have demonstrated the concentration of antibiotics in the body in breath samples from mammals. For this purpose, a biosensor was developed that could allow personalised dosing of drugs in the future. They are portable paper sensors that fit into common breathing masks. You can continuously monitor biomarkers in the breath.

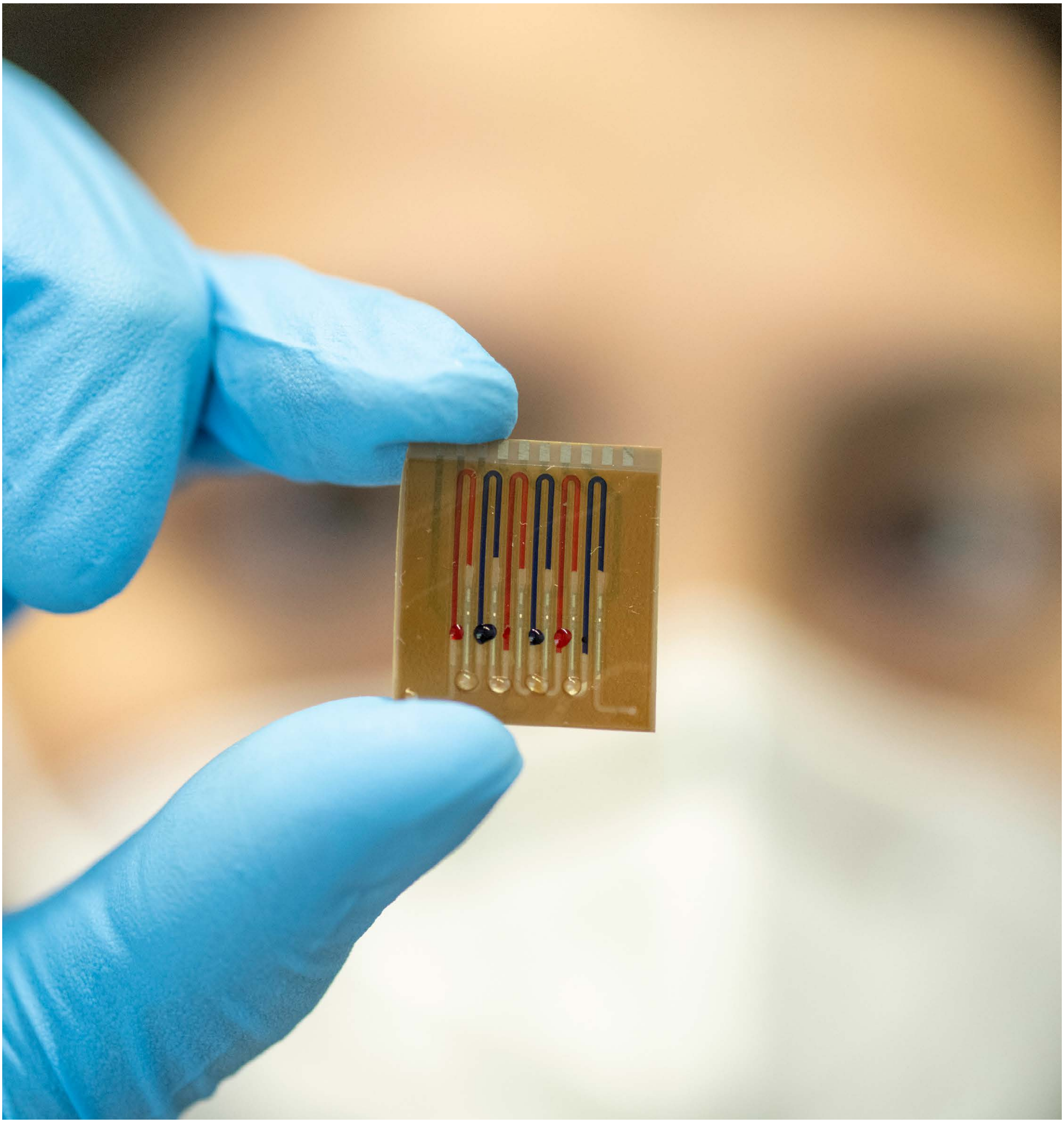

Fig. 17. The microfluidic multiplex biosensor carries proteins attached to a polymer film that can detect antibiotics. (Photo: Patrick Seeger/Press photo Albert-Ludwigs- Universität Freiburg)

The Blood Pressure Monitors

Blood pressure measurement determines the force exerted by the blood on the vascular wall of the arteries and veins; it is expressed in millimetres of mercury column mmHg. Blood pressure measurement can be monitored indirectly and bloodlessly or invasively (via an arterial catheter). Piezoresistive silicon pressure sensors are used for invasive blood pressure measurement.

Digital measuring devices (on the wrist or upper arm) determine blood pressure based on the fluctuations in the volume of blood in the arteries. An electronic pressure sensor and a microphone with integrated miniature pump work in the digital blood pressure monitor. The results are presented on a display.

The ear has its finger on the pulse

The blood pressure measurement can also be realised with optical sensors. The CiS Research Institute develops measurement methods and prototypes for testing. In January 2022, the ZIM project (ZIM: Zentrale Innovationspramm Mittelstand) was launched with the name BDMon (in-ear sensor for non-invasive beating-to-beat blood pressure monitoring). Together with the partners PAR Medizintechnik, bluepoint MEDICAL and the Steinbeis Innovation Center, devices are to be developed and verified in this context. The whole thing works on the basis of photoplethysmography (PPG). The contour of the pulse pressure waves is optically detected through the skin surface. Through the analysis, the course of blood pressure can be reconstructed. At the same time, the beat-to-beat variation of blood pressure can be analysed and useful information about the cardiovascular system can be obtained from it.

Fig. 18. The in-ear sensor for non-invasive beating-to-beat blood pressure monitoring (Image: Nadin Jurisch, press image CiS Research Institute)

Pulse oximetry applications

In pulse oximetry, the oxygen saturation of the arterial blood (oximetry) and the heart rate (pulse) are detected non-invasively. Photo-optical sensors measure the blood oxygen level (SpO_2).

The oxygen saturation of the blood indicates in what concentration hemoglobin is loaded with oxygen. Depending on the level of concentrations, the light of certain wavelengths is absorbed very differently. For this purpose, a so-called clip is used, in which the sensors are located, which itself is shielded from light.

Infrared light and red light are emitted through the light source. Hemoglobin without oxygen absorbs infrared light (940nm), haemoglobin with more oxygen absorbs mainly red light (660nm). A photodetector mounted opposite the transmitter measures how much light of both wavelengths has been transmitted. A percentage value can be calculated and displayed from the attenuation of the light intake. The pulse rate is output as a heartbeat per minute. There are these devices for the finger or for the ear.

Fig. 19. A common pulse oximeter is the CMS50D1 from Contec Medical Systems (Image: RS Components)

TE Connectivity's ELM-5002 series optical SMD emitter assembly is used for oxygen level detection. It was developed for medical applications, allows the selection of the peak wavelength and is reflow solderable. The red LED provides 660nm ±3nm peak and the infrared LED can emit 890nm or 950nm.

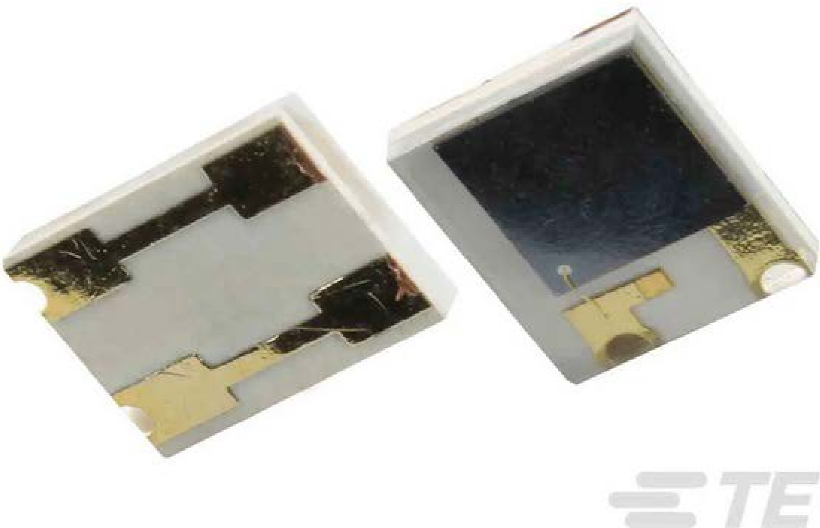

Fig. 20. The biometric 2-pin sensor operates at 1.26V to 5V. (Image: RS Components)

Multifunctional platforms

In addition to individual sensors for the respective measurements, there are modules that already combine several functions.

To develop a heart rate and pulse oximetry device, the MAXREFDES117# reference design from Analog Devices (formerly Maxim Integrated) can be used. The optical heart rate module contains a red and an IR LED as well as a power supply. This board is designed for mobile devices and works with Arduino or mbed platforms. As a support, there is already a basic open source heart rate and SpO2 algorithm in the sample firmware.

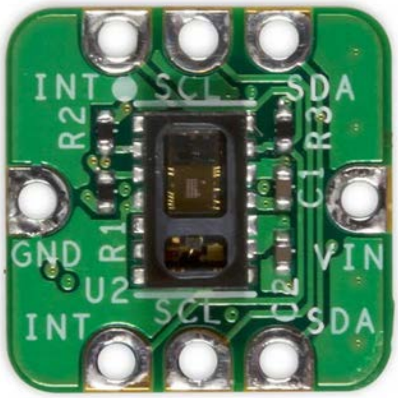

Fig. 21. The optical heart rate monitor and pulse oximetry solution is located on a board measuring 12.7mm x 12.7mm. (Image: RS Components)

The BIOFY Eco1 SFH 7050 health monitoring module from Intelligent LED Solutions contains the SFH 7050 BIOFY sensor from OSRAM Opto Semiconductors. The LED array consists of an FR4 board with built-in thermal management, so no additional heat sink is necessary.

BIOFY-SFH 7050 is an integrated optoelectronic sensor for reflective pulse oximetry. It uses 3 LEDs (red, green and infrared) as well as a photodiode to capture biometric information. It can be used, among other things, for heart rate monitoring and pulse oximetry.

Fig. 22. The BIOFY Eco1 SFH 7050 board has mounting holes for M3 screws and has dimensions of 20.25mm x 13.7mm x 0.9mm. (Image: RS Components)

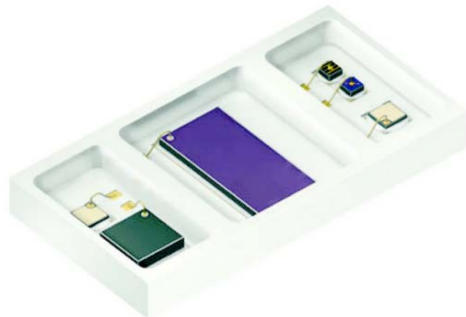

Fig. 23. This is the SFH 7050 BIOFY sensor from OSRAM Opto Semiconductors (Image: RS Components)

Analog Devices' MAXM86161EVSYS (Maxim Integrated) development kit allows you to evaluate the MAXM86161 sensor. This allows integrated optical modules to be implemented for various applications on the body - e.g. in-ear and mobile devices. The sensor detects heart rate, SpO2 (Peripheral Capillary Oxygen Saturation) with the integrated MAX32664GWEC+ biometric sensor hub microcontroller. Real-time monitoring and data logging functions can be implemented. A Bluetooth LE interface is available for wireless data acquisition.

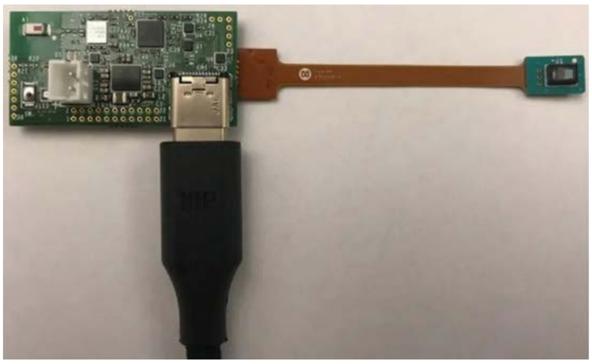

Fig. 24. The development kit is designed for in-ear applications (Image: RS Components)

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