Four **Groundbreaking** Sensor **Innovations**

Finalists for the AMA Association for Sensors and Measurement Innovation Award 2021

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The AMA Association's Innovation Award 2021 offers a prize of 10,000 Euros to one creative inventor who has developed outstanding innovative solutions to measure non-electrical quantities electrically. This year 29 teams participated, from which four finalists have been selected.

The judges examine each entry's level of innovation, originality of the solution, and market relevance. The prize is awarded to the sensor's developers, not the companies they work for or institutions they attend. The judging panel consists of industry experts drawn from universities, research institutions, and industry. Prof. Andreas Schütze (Saarland University) heads up the panel.

126 to 182 GHz FMCW Radar System

Radar waves are a standard non-contact method of measuring distances and ranging. Two different principles are in common use. The first method transmits short radio pulses of a fixed frequency to estimate the distance to a reflective target by measuring the time between the pulse transmission and its received echo. A second method uses a Frequency Modulated Continuous Wave (FMCW) signal. The signal reflected from the target will be of a slightly different frequency to the signal currently transmitted. This frequency difference is a measure of the distance. In cases where the reflective object consists of layers with varying refractive indices, the wave is reflected at each boundary interface, making it possible to measure the thickness of the layers.

Existing systems using this technique transmit in the 75 to 85 GHz band, relying upon a 4 GHz modulation bandwidth, rather than the rarely used and theoretically maximum possible modulation bandwidth of 10 GHz. Such systems can measure with a resolution down to approximately 1 mm. The system developed by Timo Jaeschke and his team at the 2Pi Lab in Bochum uses the frequency band from 126 to 182 GHz. A modulation bandwidth of 56 GHz increases the measurement resolution by a factor of 5.6 to 14. By employing a few further system tweaks, accuracy down to the single-digit µm range is possible.

The transmitter, receiver, and signal processing modules are all fabricated onto a single chip (**Figure 1**). The semiconductor material used here is silicon-germanium (SiGe, Infineon) that can handle much higher frequencies than a pure silicon device. Specific applications for this device are mainly in the industrial sector, such as in the non-contact measurement of the wall thickness of plastic pipes, coatings, and more.

Gas measurement with significantly improved linearity

A semiconducting metal oxide sensing element is used in many inexpensive devices to measure gas concentration. This element's electrical resistance changes as the gas is

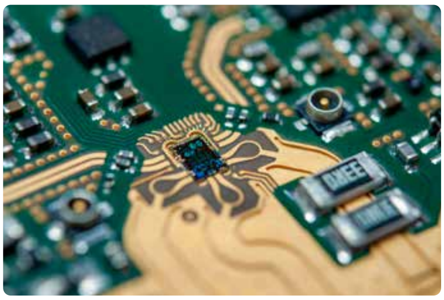

Figure 1: SiGe radar chip uses ultra-wide frequency range from 126 to 182 GHz (Image: 2Pi Labs).

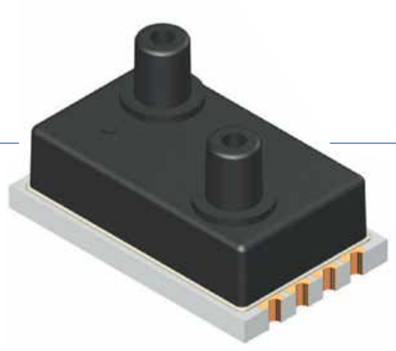

Figure 3: Multiple gas sensors in one housing measure the individual components in a gas blend (Image: First Sensor).

Figure 4: A multi-sensor solution measures all the relevant parameters to monitor the beer brewing process (Image: Endress + Hauser).

absorbed onto its surface, increasing or decreasing according to the type of gas (oxidizing or reducing). Such sensor's typically use tin dioxide (SnO_2), but other materials, often doped with additives, are also common. Selectivity for individual gases can be achieved using appropriate surface coatings. One disadvantage of this type of sensor is its non-linear characteristics which necessitate a fairly complex calibration process.

Radislav Potyrailo and his team at General Electric in Niskayuns (USA) have developed a significant improvement in these sensors' capability. The chip shown in **Figure 2** excites the sensor dielectric with an AC signal and measures its impedance characteristics. Across a specific frequency range, the imaginary value of the sensor's impedance (Z") provides a linear response over a wide range of gas concentrations. This dielectric excitation approach uses specific frequency ranges to evaluate sensor output. This is achieved by following the front shoulder (high- or low-frequency) of the spectral peak obtained from dielectric relaxation measurements of semiconducting metal oxide sensor materials (n- or p-type, respectively) as they are exposed to various gas concentrations. Compared to conventional chemiresistors, this novel method expands the dynamic range of gas detection, improves sensor baseline stability, and significantly reduces, or eliminates, humidity and ambient temperature effects.

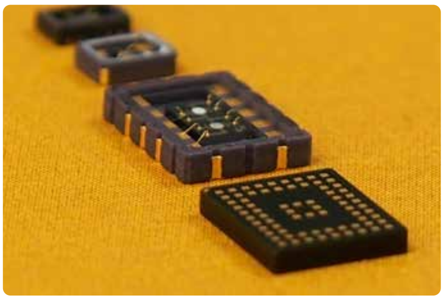

Figure 2: AC operation provides metal oxide gas sensors linear characteristics (Image: General Electric).

Analysis of complex gas mixtures

Many different sensor principles are used to measure gas flow through a pipe. However, most of these sensor types are only sensitive to one specific gas, delivering incorrect readings when used with a different gas type. When the gas is a blend of two or more gases and gas concentration levels fluctuate, measurement problems often occur. One example of this is natural gas which, depending on the gas field, may contain very different proportions of the main component methane and other biogas (dependent on the raw material from which it is produced). As the gas concentration levels vary, measurements become unreliable.

When such gas blends are to be used industrially – to fuel engines, heating systems, or chemical plants – it's crucial to accurately determine the gas composition so that processes can be controlled more precisely. In combustion, the gas blend's calorific value is critical when a process temperature needs to be precisely maintained. It is important to employ sensors that can determine the gas blend's composition as it flows through a pipe (mass flow against time). Several sensors are employed to determine the blend's properties to tackle this issue since a single sensor cannot be used. As a result, a unique characteristic 'fingerprint' can be assigned to each blend of gas.

A new sensor developed by Oleg Grudin, Head of Development at First Sensor in Berlin, now solves the problem by combining several different sensor types into a single housing (**Figure 3**). The variables measured are pressure, temperature, density, viscosity, and thermal conductivity of the gas. The associated software analyses the individual sensors' primary measurement signals to determine the proportions of individual gas types, the quantities flowing through them per unit of time (in kg/s), and other variables such as the calorific value for combustible gases. The sensor does not employ any moving parts, has a fast (20 ms) response time, and draws just a few mW of power. Its application areas include industrial processes, natural gas and biogas production, and medicine (such as the delivery of anesthetic gases and respiratory ventilation).

Fermentation control via Cloud-linked sensor

The process of brewing beer uses natural materials that are subject to a certain degree of variability. To ensure consistent taste and quality, it's necessary to monitor and control the fermentation process constantly. A variety of sensors are typically employed to measure critical variables.

Tobias Brengartner at Endress + Hauser SE + Co KG in Maulburg has assembled all the necessary sensors into a single housing. The InQGuard Brew QWX43 (**Figure 4**) is a multi-sensor system combining several different sensor functions in a robust stainless steel housing that is very practical to use. The primary sensor element is a piezo-electrically excited tuning fork with a natural resonant frequency of around 1 kHz. The density of the medium in which the sensor is used directly affects the Q factor of this resonant element. The same piezo elements are used to measure the transit time of ultrasonic pulses in the liquid medium, providing a measure of its compressibility. The sensor is also equipped with two Pt1000 temperature sensors. Raw sensor values are sent to the E + H cloud service, where custom algorithms interpret the measurements. These determine parameters such as alcohol content, sugar concentration, original wort, solids, level of fermentation, and some other factors relevant to the production of consistent brewing results.

To whom of these four finalists the prize will be awarded shall be revealed on the first day of the 'SENSOR+TEST' event held on May 4th, 2021 that, this year, out of necessity, will be online only.

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