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International Frequency Sensor Association (IFSA).
SENSOR+TEST 2007:
Exhibition and Conference Report

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1. A Glance at Exhibition

SENSOR+TEST 2007 exhibition and conference took place from 22 to 24th May at the Nuremberg Exhibition Centre. 610 companies (manufacturers and representatives) from 25 countries exhibited their products and services to visitors on an exhibition area on 23,000 m² divided into three halls including an action area, where visitors seen and tested sensor and measuring technology live, for example, as automotive testing. Sensors applications in an automotive industry was one of the major application demonstrated in 2007. The unique Action Area at SENSOR+TEST 2007 was looking like an international auto- or high-tech auto tuning show and it is no doubt that it was most attractive “hot“ and best visited exhibition’s spot.

The participation of numerous companies from overseas underlined the strong international flavour of this major European annual sensors exhibition. The exhibitors welcomed about 8,600 visitors from different countries to their stands, which is 15 % more than the previous year.

Of course, it is not possible to give a review of all products and services from all exhibitors in this editorial article. Let me to be focused on most innovative, latest developments in the area of frequency (period, duty-cycle, pulse width modulated (PWM)), digital, smart sensors and systems. Detailed descriptions of all mentioned in this article sensors products are available in appropriate sensors sections (see web links at the end of articles) at Sensors Web Portal (http://www.sensorsportal.com).

First of them it was my great pleasure to see a lot of IFSA members among exhibitors in this year and take an unique opportunity to examine latest products from this well growing, high technological area.

At the fist time Melexis (Belgium) exhibited a new generation optical sensors MLX75304 with frequency output and extended dynamic range 120 dB: 0.1 … 100k lux designed for many applications such as automotive, office equipment, consumer goods, industrial machines, healthcare equipment, etc. [1].
Another optical sensor with frequency output was demonstrated by *Hamamatsu Photonics*. Their light-to-frequency converter photo IC S9705 has a square wave output (50% duty ratio) with frequency directly proportional to light intensity incident on the photodiode [1]. The CMOS level output allows direct connection to a microcontroller or other IC circuits, for example, to the Universal Frequency-to-Digital Converter (UFDC-1 [2] or UFDC-1M-16 [3]). The sensor has frequency output range from 0.1 Hz (dark frequency) to 1 MHz.

Robust and reliable integrated inductive position sensor PO1607, speed and direction sensor PO1210 in ultra-thin packages (3.6 mm and 1.6 mm respectively) were exhibited by *POSIC (Switzerland)* [4]. Sensors do not need magnetic target no bias magnet and is insensitive to magnetic disturbance. The sensors have 0 to 40 kHz frequency range output signal with 40-60% duty cycle, which is dependent on the rotor distance.

*Micronas GmbH (Germany)* introduced its Hall-effect sensors HAL® 710/730 with direction detection. The sensor has both: count and direction outputs [4]. It is also necessary to mark the HAL 85x programmable Hall-effect sensors with arbitrary output from the *Micronas* catalog [4]. It has both programmable output formats: PWM or serial Biphas-M. Due to sensor’s programming options, the HAL 85x can be used in contactless potentiometers, rotary position measurement, level measurement, linear position detection, magnetic field detection, etc.

Series of 8-, 10-, 12-bit, 360° magnetic rotary encoders with absolute and/or incremental outputs (AS5030, AS5035, AS5040, AS5045 and AS5130) were exhibited by *Austriamicrosystems (Austria)*. All encoders have pulse width modulated output with duty-cycle proportional to angle or outputs with number of pulse proportional to revolution. The AS5045 has a programmable PWM output. In addition to the pulse width modulated output these sensors also have serial digital outputs [4].

Rotation speed sensors 94 409 and 94 220 were introduced by *AB Elektronik GmbH (Germany)*. Both sensors have 0 … 7 500 Hz frequency range [4].

The angle sensor QUADRO-R® for 360° rotation with PWM output was presented also by *DIS Dewit Industrial Sensors (The Netherlands)*. It has a round sensing head and is mounted in compact square polycarbonate housing with a well secured cable or connector. Thanks to its right-angled sides, it has a very high rigidity. The vulnerable electronics is protected by a flexible filling compound. As a result, the sensor is highly resilient to shock and vibration.

There was also the angle sensor DS04 from *Polycontact (Switzerland)*, which can be with voltage or PWM output. It has a freely programmable measurement range (0°- 360°) with ± 2° absolute error and 0.01° resolution and developed for automotive applications.

A programmable conductometric precision inclinometer with PWM and digital (I²C, RS232) outputs was presented by *BFiOPTiLAS GmbH (Germany)*. It can have 1- or 2-axis and ±2°, ±5°, ±10°, ±15°, ±25°, ±45° range.
The D Series of inclinometer was exhibited also by Measurement Specialties, Inc. (EMEA Headquarters, France). This programmable sensor has ±5° to ±30° range, ±0.03° to ±0.4° absolute error and PWM, RS232 and analog output.

Advanced programmable dual, single and 2x single axis linear PWM output tilt modules EZ-Tilt-2000-DX, EZ-Tilt-2000-SX, EZ-Tilt-5000-SX and EZ-Tilt-5000-SX Null/VIB are exist in the B+L Industrial Measurements GmbH (Germany) exhibitor’s catalog. All modules have 12-bit resolution.

South Korean company Korea Digital Co., Ltd. have presented the Sensecube’s CO2 sensor module KCD-AN for OEM applications. The module has PWM, analog and digital serial outputs. It has 0 … 2000 ppm, 0 … 5000 ppm and 0 … 10 000 ppm measuring range options with ±(50 ppm+3 % reading), ±(100 ppm+3 % reading) and ±(200 ppm+3 % reading) accuracy at + 25°C [5].

The CO2 ENGINE™ model K22-PWM from SenseAir (Sweden) is a CO2 sensor module designed to be built into stationary ventilation equipment, such as window vent or duct exhaust actuators, serving as a linear transmitter of CO2. The sensor module measures ambient gas CO2 concentrations at two seconds intervals. Measured CO2 concentration is filtered and is transmitted to the PWM output. The PWM output continues to keep the last valid value in the case of measurement fault detected. Measurement range is from 0 to 2 000 ppm, accuracy ± 75 ppm + 5% of measured value.

An exhibitor – Sensortechnics GmbH (Germany) included in their catalog (Edition 13) that was distributed during the SENSOR+TEST 2007 exhibition an information about pressure sensors for air and non-corrosive gases ASDX/ASDXL…D4 (0…1 to 0…7 bar) and HSD (500…1080 mbar). The fist sensor has 410…3686 counts (total accuracy ±0.5 …2.0 % FS) on its output and the second – 3200…29500 counts (total accuracy ±0.25 % FS).

microFAB Bremen GmbH (Germany) exhibited its surface-mount capacitive absolute pressure sensor PE1.3N/PE8.0T-3.0SQ with 8.0 bar measuring range. The sensors interfacing should be further simplified in case when a microcontroller or the UFDC ICs [2, 3] will be presented within design. Some possible readout strategies such as discrete capacitance-to-frequency and capacitance-to-time interval converter circuits were demonstrated.

Sensor Technology Ltd. (UK) had in their catalog the RWT310 series torque transducers with integral electronics for non-contact rotary torque measurement. It has TTL level, square wave output signal [6].

Data acquisition products including boards for frequency-time parameters of sensors output signals were exhibited by some companies including National Instruments (USA), Meilhaus Electronic GmbH (Germany), IOtech (USA) (represented by Synotech Sensor and Meßtechnik GmbH (Germany) at the exhibition, Jäger Copmutergesteuerte Meßtechnik GmbH (Germany), ADDI-DATA GmbH (Germany) and MicroControl GmbH & Co.KG (Germany) [7]. The last one demonstrated its µCAN.4.ci-BOX module, which can work with frequency signals form 1 Hz to 500 kHz with ±0.1 Hz resolution and high speed CAN interface 2.0A and 2.0B.

However, the promised market of data acquisition systems for frequency-time domain sensors output signals is still not fill-in. Until now, there are not any available DAQ board, system or module, which can cover all existing so-call quasi-digital sensors and transducers (with frequency, period, duty-cycle, time interval, PWM, phase-shift, pulse number outputs). As usually, existing and demonstrated at the SENSOR+TEST 2007 exhibition DAQ boards and systems for such parameters had narrowed frequency range and functionally, and/or very big relative measuring error (± 0.1 %) or reference error (0.01 %), which exceeds in many cases the sensor’s relative error. Such giants as National Instruments with their NI 6601, NI 6602, NI 6624 Counter/Timer conditioners with 0.0055 % oscillator (reference)
stability and Meilhaus Electronic with ME-1400 counter and digital I/O board were not exclusions. The Counter/Timer conditioners NI 6608 from National Instruments has much better oscillator stability 75 ppb, good high frequency range up to 80 MHz (125 MHz with prescaler), but low frequency range and real quantization error in the whole frequency range are still open questions.

The exclusive products - 2-channel high performance one chip data acquisition systems UFDC-1 and UFDC-1M-16 from SWP, Inc. (Canada) shown in [7] are exception to the rule but unfortunately this company was not an exhibitor in this year. However, it is no any doubts that this market gap will be fill-in in the nearest future by companies who will start to produce data acquisition systems, boards and modules based on these innovation chips.

Nevertheless the TEDS sensors market is growing slowly (revenues in this market totaled $27.6 million in 2006, and estimates this to reach $40.9 million in 2013 according to Frost & Sullivan [8]), a European company MESSRING Systembau MSG GmbH (Germany) exhibited in this year the 6-channel data acquisition unit M=BUS® Logger 6C with IEEE 1451 Transducer Electronic Data Sheet (TEDS).

Many manufacturers and representatives at SENSOR+TEST exhibited sensors and transducers with both: analog (or frequency, PWM, duty-cycle) and digital output. It is really a good tendency in some last years, which expand sensors applications and customers’ possibilities to use such products in an appropriate manner. Speaking about digital output it is necessary to notice that RS232, RS422, RS485, I²C, SPI and CAN buses and interfaces are very popular as usually. Many exhibitors also demonstrated sensors with digital USB output, for example, digital pressure transducers GS4200-USB from ESI Technology Ltd. (Great Britain) [9]; innovative high precision USB temperature measurement systems ITS-TC, ITS-RH4 and ITS-RTD from Isabellenhutte Heusler GmbH & Co (Germany), which have been developed based on a special thermocouple type or RTD in connection with the high precision data acquisition system ISA-ASIC.

An interesting related product CAPmeter – a USB interface for 1 or 2 capacitive sensors was also demonstrated by JLM Innovation (Germany) developed in collaboration with the University of Tübingen.

Other relatively new interfaces such as AS-Interface for sensors and actuators were realized in interfacing circuits, for example, A²SI and ASI4U ICs and presented by ZMD AG (Germany) and Austriamicosystems (Austria) that demonstrate a new generation AS-Interface slave device - AS2702, which supports AS-Interface bus systems with up to 62 slave modules [10]. ZMD also has in its catalog automotive sensor signal conditioners ICs ZMD31035 and ZMD31030 with a Local Interconnect Network (LIN) bus compatible interface. The ZMD31030 IC has also PWM output option for bridge sensor signal.

The lost-cost sensor signal conditioner ZMD31010 and fast automotive sensor signal conditioner ZMD31150 from ZMD AG (Germany) have a digital ZACwire™ one-wire interface. The ZMD31150 has also I²C and analog outputs.

2. Conference

The SENSOR conferences, held parallel to the fair. The conference committee, chaired by Prof. Dr. Reinhard Lerch from University of Erlangen-Nuremberg, and Prof. Dr. Roland Werthschützky from Technical University Darmstadt, have selected 90 section and 49 poster papers from 19 countries for the three-day programme. Each of the three conference days started off with a plenary presentation, in which one of the selected topics is discussed in detail. Besides the traditional measuring-technology
subjects, such as pressure, flow, etc., the emphasis this year was on industrial development projects, in which new research results have been implemented. The number of presenter papers from each of country is shown in Table 1.

The SENSOR 2007 Conference’s report will be focused on new research results in different frequency output sensors and smart sensors areas as well as industrial development projects in the same fields.

For the first time, the prototype of 2-channel smart universal sensor and transducer interface (USTI) IC as well as its fast version USTI-1M-20 were reported in the paper [11]. It is suitable for practically all existing quasi-digital sensors and transducers. The IC has a high programmable relative error form 1 to 0.0005 %, wide frequency range from 0.05 Hz to 9 MHz (144 MHz with prescaler). The USTI can convert to digital a frequency, period, duty-cycle, duty-off factor, frequencies and periods difference and ratio, time intervals, pulse width and space, absolute and relative frequency deviation, phase-shift, rotation speed and pulse number.

In addition, the USTI has one generation mode (10 MHz frequency output) for calibration purpose and a possibility to convert into digital a resistive and capacitance sensing elements, and resistive bridge parameters. The USTI custom design version can also keeps in its flash memory an IEEE 1451 TEDS for sensors. There are three popular communication interfaces in the IC: RS232, I²C and SPI. The IC has a scalable resolution and non-redundant conversion time from 0.32 s to 0.16 ms for the USTI and from 0.01 s to 5 µs for the USTI-1M-20, which is determined only by the programmable relative error.

Speaking about future smart sensors architectures, it is necessary to mark a presentation from TU Kaiserslautern about dynamically reconfigurable sensor electronics [12]. The concept merges conventional, reconfigurable and evolvable hardware and uses a multiobjective evolutionary optimization to contribute to the development of generic sensor electronics with flexibility and rapid-prototyping as well as fault-tolerance and robustness properties. In the frame of this approach, a special reconfigurable architecture for time-continuous signal processing with selective restrictions in reconfigurability to save chip area, enforce standard circuit topologies, and reduce reconfiguration time was developed by authors. A first CMOS-chip with three amplifier cells has been designed in 0.35 µm technology and tested in-situ in two prototypes.

### Table 1. The number of presenter papers from each of country.

<table>
<thead>
<tr>
<th>No.</th>
<th>Country</th>
<th>Number of Papers</th>
</tr>
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<tbody>
<tr>
<td>1.</td>
<td>Germany</td>
<td>90</td>
</tr>
<tr>
<td>2.</td>
<td>Austria</td>
<td>12</td>
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<tr>
<td>3.</td>
<td>Switzerland</td>
<td>7</td>
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<tr>
<td>4.</td>
<td>Ukraine</td>
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<tr>
<td>5.</td>
<td>France</td>
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<tr>
<td>6.</td>
<td>Russia</td>
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</tr>
<tr>
<td>7.</td>
<td>USA</td>
<td>3</td>
</tr>
<tr>
<td>8.</td>
<td>Armenia</td>
<td>2</td>
</tr>
<tr>
<td>9.</td>
<td>Great Britain</td>
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<tr>
<td>10.</td>
<td>Palestine</td>
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</tr>
<tr>
<td>11.</td>
<td>Belarus</td>
<td>1</td>
</tr>
<tr>
<td>12.</td>
<td>Canada</td>
<td>1</td>
</tr>
<tr>
<td>13.</td>
<td>Czech Republic</td>
<td>1</td>
</tr>
<tr>
<td>14.</td>
<td>Denmark</td>
<td>1</td>
</tr>
<tr>
<td>15.</td>
<td>Italy</td>
<td>1</td>
</tr>
<tr>
<td>16.</td>
<td>Ireland</td>
<td>1</td>
</tr>
<tr>
<td>17.</td>
<td>Japan</td>
<td>1</td>
</tr>
<tr>
<td>18.</td>
<td>Netherlands</td>
<td>1</td>
</tr>
<tr>
<td>19.</td>
<td>Poland</td>
<td>1</td>
</tr>
</tbody>
</table>
In the field of different frequency sensors developments and investigations several papers was presented during three-day conference. For, example, the piezosensor analysis of leucine and isoleucine aqueous solution was described in paper [13] from Voronezh State University (Russia). Nevertheless the piezosensor is not a mass-sensitive sensor in a solution but plays a role of an acoustic sensor, i.e. its output signal is proportional to the properties of the investigated solutions. It was demonstrated that the difference between the quartz oscillation frequency in water and solution is a linear function of the square root out of the product of its viscosity and density. The creation of piezoquartz resonators is a new tendency in analytical technology

Film bulk acoustic resonators (FBARs) for various sensor applications such as gas detection, biosensing viscosity measurements and stress measurements have been demonstrated and discussed in a paper from Siemens’ authors [14]. As it was marked in the paper, an essential advantage of the FBARs in comparison to quartz resonators is the possibility to realize large arrays and the integration of different applications on one chip. Authors shown that the relevant sensor properties such as sensitivity or resolution are in general equivalent or even better for the FBAR if compared with quartz resonators.

Quartz crystal microbalance sensors are also continue to be extensively used widely in different analytical chemistry and biological systems [15-16].

Based on a new concept, i.e. the creation of monolithic structures in langasite, the MEMS for applications at high temperatures was developed and reported by authors from University of Applied Studies and Research (Wernigerode) and Otto-von-Guericke University of Magdeburg [17]. The temperature dependence of the resonance frequency and of the resonator quality factor for cantilevers and membranes were determined. Such MEMS can be used as a gas sensor.

Sven Kuhn from Hottinger Baldwin Messtechnik GmbH (Germany) reported in his paper a contactless torque measuring system with scalable analog and frequency (10 ± 5 kHz, 60 ± 30 kHz) outputs [18].

A good review of acoustic microsensors, its applications and future perspective were given in an invited presentation made by Peter R. Hauptmann from Otto-von-Guericke University of Magdeburg [19]. Author marked that frequency is a mainly used output signal of such sensors, and most interesting frequency range for the technological application of ultrasound lies between 0.1 and 100 MHz.

Authors from microFAB Bremen GmbH (Germany) discussed a miniature capacitive pressure sensors and their flexible, economic systems integration [20]. It was noted that the cost for an integrated sensor system depends highly on the level of complexity of an ASIC read-out as well as the extent of calibration. Examples of low-cost sensor integrations including multivibrator circuit output frequency of which depends on sensors capacitance and simple capacitance-to-time interval converter were given.

3. AMA SENSOR Innovation Award

For the seventh time, the AMA Association for Sensor Technology has sponsored the SENSOR Innovation Award, presented during the SENSOR+TEST 2007. Thirty percent of the submissions in this year were from abroad. The number of applications has also increased in 2007. Out of the 46 submissions, the jury has selected four projects for nomination. Three of the four projects deal with gas analysis and the fourth with the optimization of motor vehicle engines. But unfortunately the jury has missed at least one really revolution sensor related innovation project submitted among 46 applications.
4. Afterworlds

The major sensors exhibition and conference in Europe has clearly demonstrated increased interest in different frequency, period, duty-cycle and other frequency-time signal domain output sensors due to technological innovations and further development of MEMS and IC. It is true for different reported research and development results as well as for exhibited products available on the modern market. SENSOR+TEST 2007 exhibition and conference have given a unique opportunity to see many of them for the first time in May 2007.

References and Web Links


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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in Sensors & Transducers Journal will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In additional, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
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