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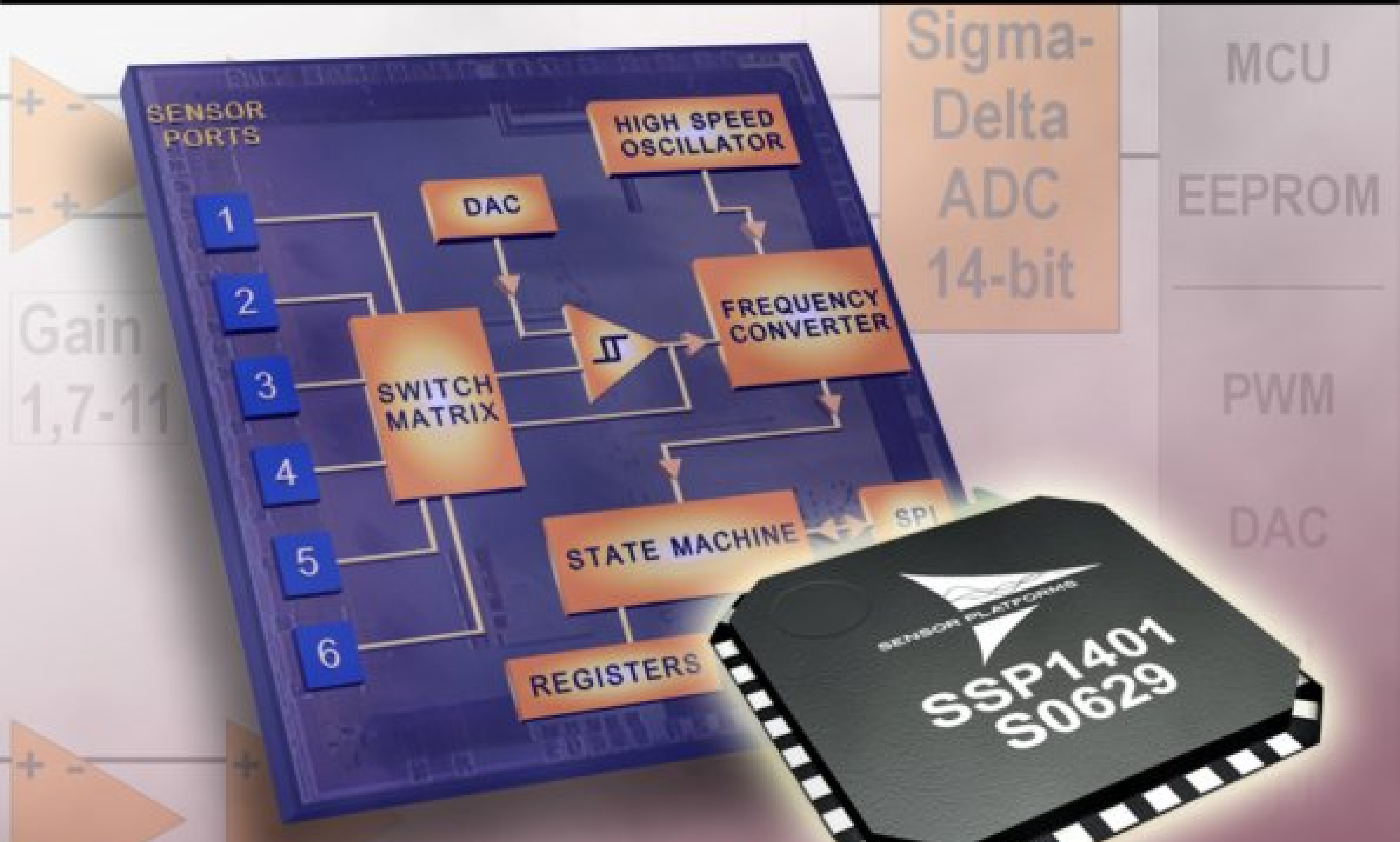

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Contents

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Development of Ultrasonic Transmission-Mode Tomography for Water-Particles Flow

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Abstract: This paper describes the hardware development of the ultrasonic tomography via transmission-mode method and it covers some of the investigations carried out in the research including modeling, construction of ultrasonic sensing techniques and the measurement results. *Copyright © 2010 IFSA.*

Keywords: Ultrasonic, Solid-Particles, Tomography

1. Introduction

Ultrasonic is the study of sound propagated at frequencies beyond the range of human audibility, which is above 18 kHz. Ultrasonic techniques are very widely used for the detection of internal defects in materials, but they can also be used for the detection of small cracks. Ultrasonic is used for the quality control inspection of finished components. The techniques are also in regular use for the in-service testing of parts and assemblies [1].

The ultrasonic tomography consists of three types of sensing techniques namely the transmission-mode, reflection-mode and the diffraction-mode method [2, 3]. It involves the application of non-invasive ultrasonic sensors to obtain the information in order to develop the concentration map of the dynamic characteristics of process vessels in industries. This information together with the concentration map will derive the result to the mass flow rate, which will then provide the quantity of flowing volume in process vessels [4, 5].

In the study of tomography the physical principle of a sensing system depends on the reconstructed image of the cross sectional distribution of the constituent parameter. It is evaluated by arraying ultrasonic sensors non-invasively on the surface of the vessel. By using the electronic circuits to interface, the data captured can be processed and analyzed by the computer to reveal the information of the internal dynamic characteristics [6].

2. Hardware Construction

The ultrasonic waves propagate within the range of 18 kHz to 20 MHz. Higher frequency produces higher acoustic energy and therefore smaller wavelengths can be obtained which is suitable in smaller particulate sensing system. The relationship between the frequency and the wavelength is given as below:

$$v = f\lambda \tag{1}$$

where v is the speed of sound; f is the frequency, and λ is the wavelength.

As the sizes of the particles are not critical, the frequency of 40 kHz is chosen. Two methods were being used to generate the ultrasonic waves. They are by using continuous signal and by pulses [6]. Both methods will work with the ultrasonic sensor and the output of the sensor is similar. Using a continuous signal will provide continuous impact on the crystal but the interval of the oscillating diaphragm can be estimated by using the pulses.

The receivers' signals are quite small and therefore amplification to a higher voltage level is needed before the *signal conditioning circuit* is applied and it depends on the data acquisition system requirements in order to perform further analysis. In this paper, the results of the signal conditioning circuit will be discussed. The block diagram of the ultrasonic tomography system is shown in Fig. 1.

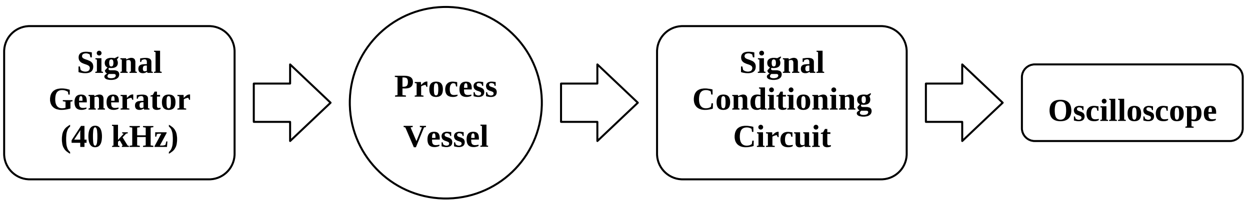

Fig. 1. Block diagram of an ultrasonic tomography system.

The system designed is based on the ability of the sensor transmissions and receptions using transmission-mode method. The development of the system includes mounting eight ultrasound sensors non-invasively, designing the ultrasound signal generator, designing the receiver and the signal conditioning circuit and designing switching device by using microcontroller unit. Fig. 2 shows the hardware block diagram of the ultrasonic tomography designed.

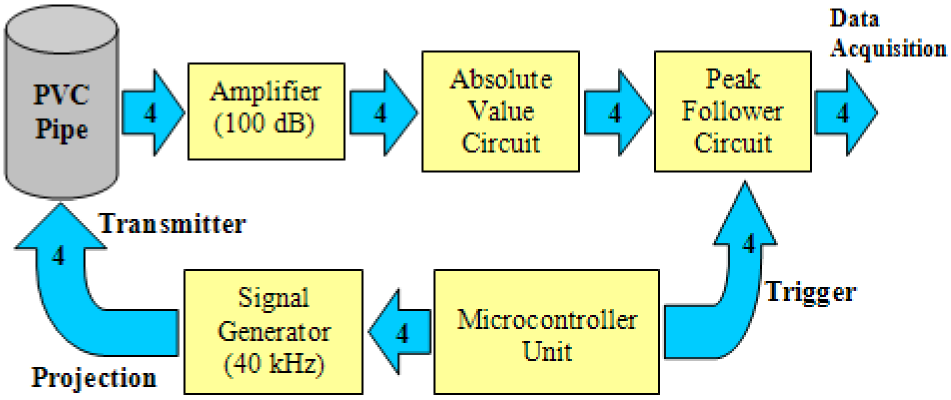

Fig. 2. Hardware block diagram for ultrasonic tomography.

2.1. Sensor Fabrication Technique

Research carried out by Khor [7] was four pairs of ultrasonic sensors that were mounted permanently inside the vertical pipe flow. He investigated the amplitude behavior by comparing it in air and in liquid by using two types of ultrasonic sensor, which are open type and enclosed type. The result is based on the differentiation of particles drop through the pipe. As the size of the particles dropped is increased, the amplitude of the received signal will decrease due to the barrier along the path from the transmitter.

Since using the ultrasonic method in air is very inefficient due to the mismatch of the sensors' impedance compared to air's acoustic impedance [8, 9], an acoustic coupling is needed between the sensor's surface and the outer pipe wall. The acoustic coupling is needed to match the acoustic impedances between the two different medium and it will provide the optimum transference of acoustic energy from the transmitter to the receiver. Besides, the coupling will also provide a free-air region between the sensor's surface and the outer pipe wall. This is because in the air, the acoustic energy will be scattered and thus, none of the signal could emit through the pipe. *Glycerin* is a type of fine grease and has been chosen as the couplant. It was sandwiched between the sensor's surface and the outer pipe wall as shown in Fig. 3.

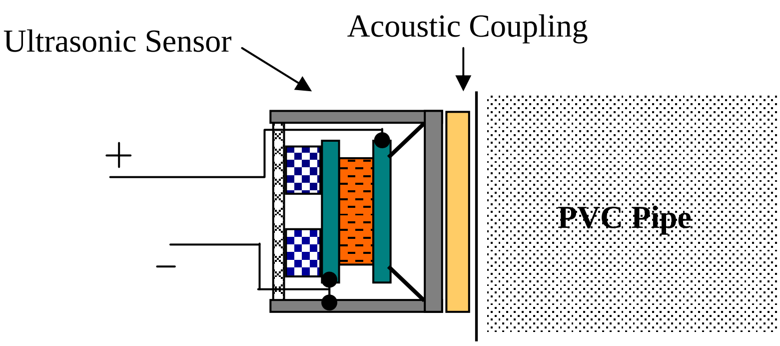

Fig. 3. Ultrasonic sensor mounted on the surface of a pipe wall.

2.2. Ultrasonic Sensor Arrangement

After carrying out a few investigations, the PVC pipe is chosen. Although the steel pipe is able to swing at higher amplitude (as shown in Table 1) of the ultrasonic waves but it is quite thin and therefore any impact on the steel pipe will interfere with the propagated signals. By using the PVC pipe, the ultrasonic waves will probably be absorbed and thus, the signals received will be smaller but it can be increased by increasing the amplifier gain. Fig. 4 shows the ultrasonic sensors arrangement on the PVC pipe.

Table 1. Maximum sensor output voltage for steel and PVC pipe after being amplified at 100 dB.

Pipe	**Maximum voltage (V)**
Steel	5.80
PVC	4.46

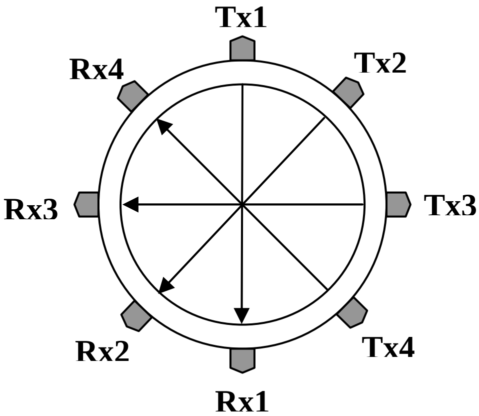

Fig. 4. Ultrasonic sensors arrangement.

2.3. Ultrasonic Signal Generator

Pulses at 40 kHz per channel are generated by using a microcontroller unit. The pulses are then sent to four-ultrasound transmitter's channel after being amplified. Fig. 5 shows the block diagram of the ultrasound signal generator.

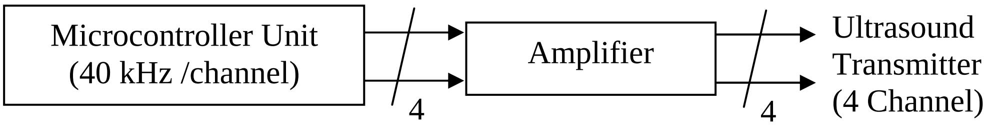

Fig. 5. Block diagram of the ultrasound signal generator.

2.4. Signal Conditioning Circuit

The signal conditioning circuit consists of three elements, the amplifier, the rectifier and the peak detector. The receiver signal will be amplified with the gain of 100 dB and then being rectified by using *Absolute Value Circuit.* The most suitable peaks are then triggered and sampled by the *Peak Detector Circuit*. It is necessary to capture the peak voltage and hold it for approximately 4 μs for data acquisition processing. Compared to the RMS converter, the peak values desired would be mixed up and being missed.

Fig. 6 shows the signal conditioning block diagram while Fig. 7 shows the corresponding output signals.

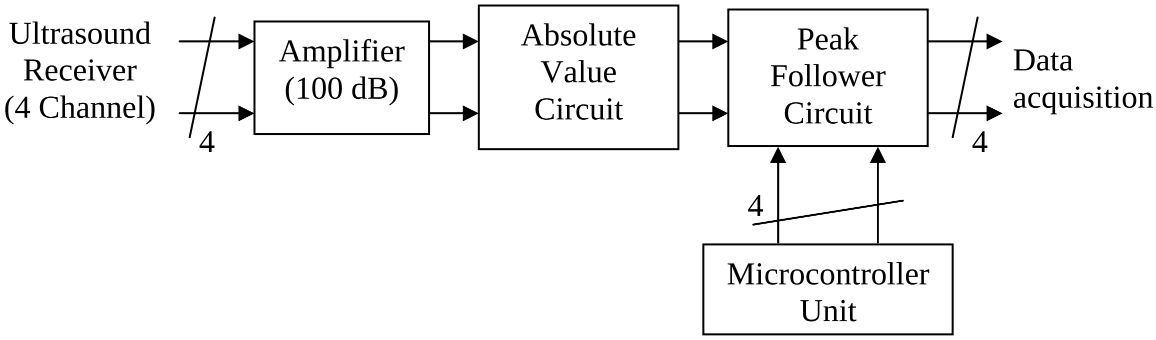

Fig. 6. Block diagram of the signal conditioning circuit.

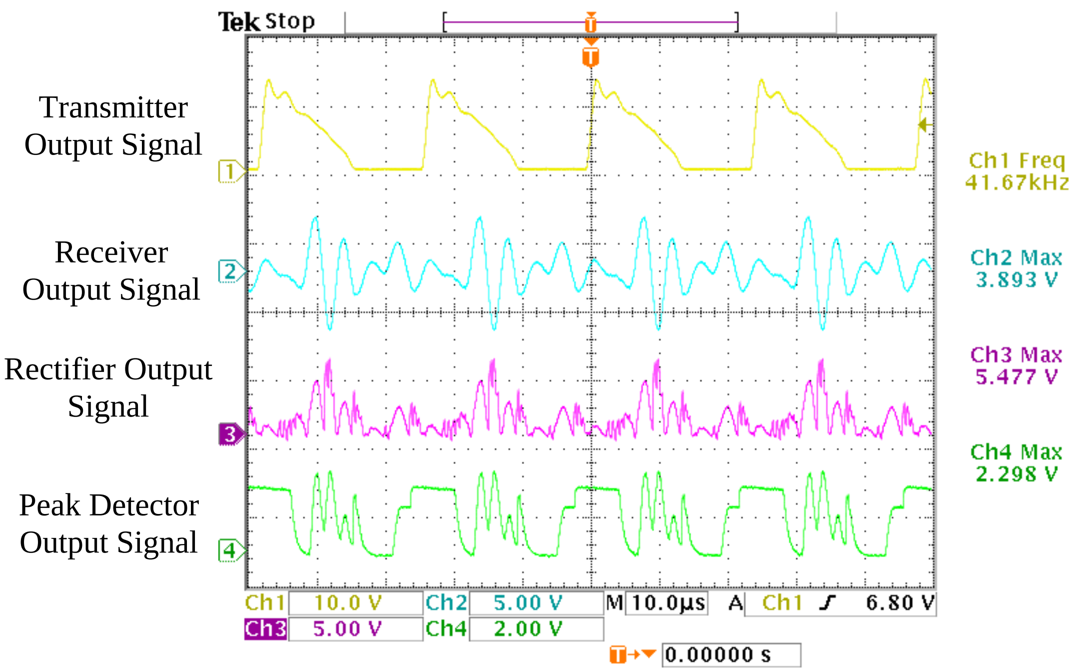

Fig. 7. Output signal of the signal conditioning circuit.

3. Results and Discussions

The investigation is based on the transmission and the reception on a pair of ultrasonic sensor that is mounted circularly on the surface of PVC pipe. The experiment is done by placing a PVC rod in the pipe containing water. The rod is assumed as the particles flowing in the pipe. The attenuated signals due to the moving part in the pipe were investigated. The receiver's signals are then captured using a digital oscilloscope. The results for the experiments are shown in Table 2. From the output signals captured, the reference voltages for each receiver can be represented in Fig. 8.

From Fig. 8, it shows that there is a difference between the sensor reference voltages although no object exists in the pipe. Most probably, the difference is due to the imperfection acoustic coupling that was attached between the sensors and the pipe wall. Besides, the sensor surface has to be kept perpendicular to the pipe wall, so that the transmitted acoustic energy will beam perfectly through the pipe. Another reason is the sensors are mounted manually. Thus, during arraying ultrasonic sensors on the pipe surface, the position could have been shifted from the desired position and this causes the acoustic energy received to be disrupted.

Table 2. Results for the experiments.

		No Rod Placed, V_1 (V)	Rod Placed, V_2 (V)	Attenuated, V_1 - V_2 (V)
12 mm Diameter	Tx1-Rx1	2.9	1.2	1.7
	Tx2-Rx2	2.0	0.6	1.4
	Tx3-Rx3	3.1	1.6	1.5
	Tx4-Rx4	2.8	2.0	0.8
26 mm Diameter	Tx1-Rx1	2.9	1.2	1.7
	Tx2-Rx2	2.3	0.6	1.7
	Tx3-Rx3	3.1	1.6	1.5
	Tx4-Rx4	2.8	2.0	0.8
60 mm Diameter	Tx1-Rx1	2.9	1.2	1.7
	Tx2-Rx2	2.3	0.4	1.9
	Tx3-Rx3	3.1	1.0	2.1
	Tx4-Rx4	2.8	1.6	1.2

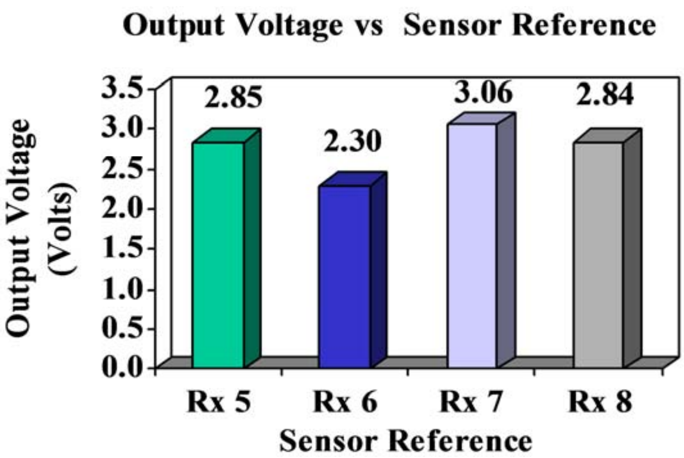

Fig. 8. Receiver reference voltages.

When a PVC rod is placed in the pipe, the voltage for each sensor will be reduced because the rod is blocking the transmitted signal from being projected to the receiver. As seen from the experiment, a different rod diameter produces a different receiver value and somehow the receiver values are identical for a certain diameter of a rod tested. Fig. 9 shows the summary for those signals captured.

Fig. 9 shows that the received signal is almost identical to each of the receivers for every rod tested. The signals are being reflected and thus the acoustic energy that propagated from the transmitters to the receivers has been attenuated.

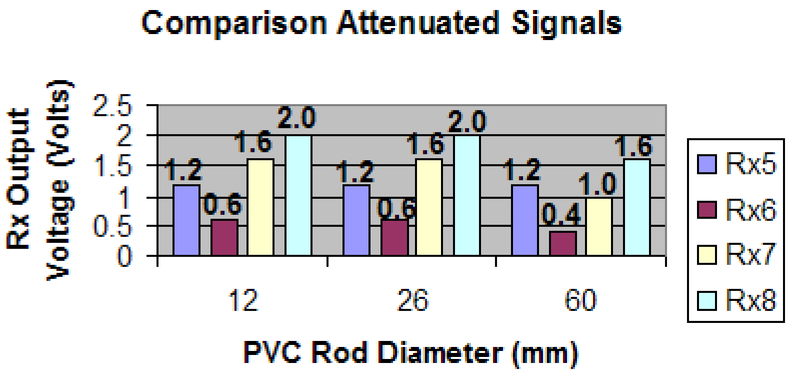

Fig. 9. Receiver signals with different diameter of PVC rod.

An assumption of straight-line wave propagation has been made. In order to apply this assumption, the size of a particle should be bigger than one-half the wavelength (λ). Thus no matter how small the particles dropped, as long as the wavelength could be blocked then the information of the particulate sensing of a water-particles flow will reveal to the concentration map development

References

[1]. Xu, L., Han, Y., Xu, L. A., & Yang, J. Application of Ultrasonic Tomography to Monitoring Gas/Liquid Flow, *Chemical Engineering Science,* Vol. 52. 1997, pp. 2171-2183.

[2]. Gai, H. Ultrasonic Techniques for Flow Imaging, University of Manchester, *Ph. D. Thesis*, 1990.

[3]. Williams, R. A., & Beck, M. S., Process tomography-principles, techniques and applications, *Butterworth-Heinemann*, Oxford, UK, 1995.

[4]. Beck, M. S., Selection of sensing techniques, in R. A. Williams, & M. S. Beck, Process tomography - principles, techniques and applications Process Tomography: Principles, Techniques and Applications, *Butterworth-Heinemann*, Oxford, 1995, pp. 41- 48.

[5]. Warsito, Ohkawa, M., Kawata, N., Uchida, S., Cross-Sectional Distributions of Gas and Solid Holdups in Slurry Bubble Column Investigated by Ultrasonic Computed Tomography, *Chemical Engineering Science*, Vol. 54. 1999, pp. 4711-4728.

[6]. Hoyle, B. S. and Xu, L. A., Ultrasonic sensors, in Williams, R. A. and Beck, M. S. (Eds.) Process Tomography: Principles, Techniques and Applications, *Butterworth-Heinemann*, Oxford, 1995, pp. 119-149.

[7]. Khor, Kah Yen, Comparison Between Air and Liquid Using Ultrasonic Sensor in Process Tomography, *B. Sc. Thesis*, Universiti Teknologi Malaysia, 2002.

[8]. M. H. Fazalul Rahiman, R. Abdul Rahim, Z. Zakaria, Design and Modelling of Ultrasonic Tomography for Two Component High Acoustic Impedance Mixture, *Sensors & Actuators: A. Physical,* Vol. 147, Issue 2, 2008, pp. 409-414.

[9]. Mohd Hafiz Fazalul Rahiman, Zulkarnay Zakaria, Ruzairi Abdul Rahim, Wei Nyap Ng, Ultrasonic Tomography Imaging Simulation of Two-Phase Homogeneous Flow, *Sensor Review*, Vol. 29, Issue 3, 2009, pp. 266-276.

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. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc.

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;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

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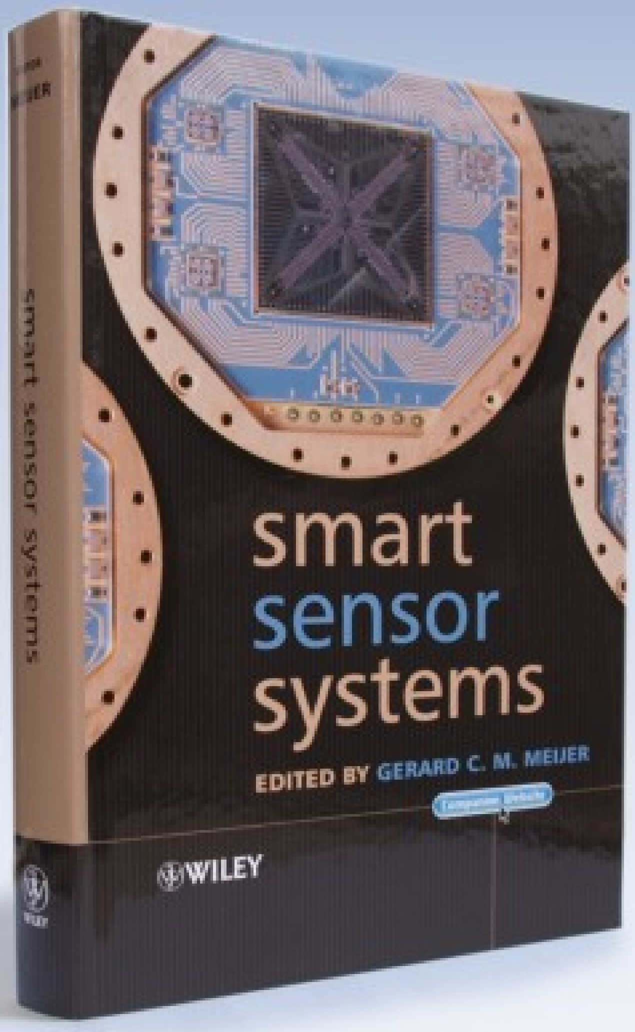
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