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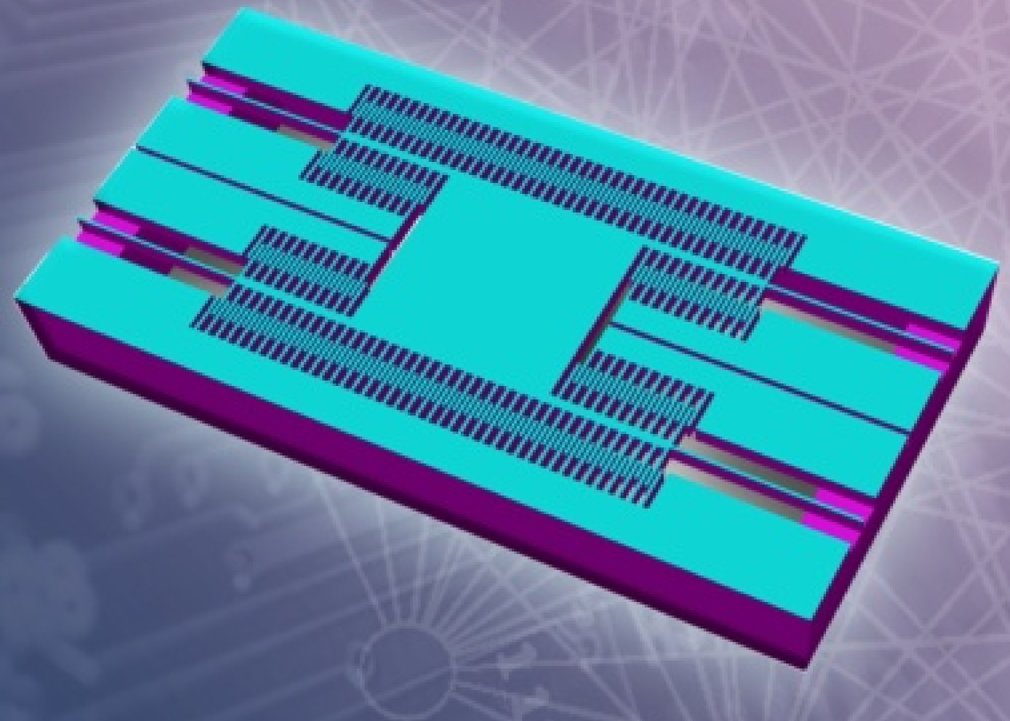

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DSP Sensorless Controller of Switched Reluctance Motor-Generator Approaching to AM Modulation

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Abstract: In this paper, a new method for sensorless starting and controlling of Switched Reluctance Motor-Generator (SRMG) is presented. The method uses Amplitude Modulation (AM) technique. The controller is used to control a new SRMG by two separated layers of 4 stator poles and 2 rotor poles. A DSP processor generates digital signal firstly which is then changed to low voltage sinusoidal signal by a digital to analog convertor (D/A). The signal is then given to the field-assisted windings of each phase of the motor. The response of the winding to the signal which includes the rotor location data is sampled which is after filtering and AM demodulation given to an analog to digital convertor (D/A). Then, the digital data is analyzed by the DSP and the rotation commands are generated and transmitted to the SRGM phase drivers. In the paper, the controller sections are explained and at the end, the performance results are presented. *Copyright © 2012 IFSA.*

Keywords: Switched Reluctance Motor-Generator, Sensorless, AM Modulation, DSP.

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1. Introduction

There are lots of Electric motor species with different features and performance. For many of years, researchers have looked for efficient and affordable motors with adequate maintenance properties and also high speed and power. Switched Reluctance Motor (SRM) had these parameters but requiring power electronic control circuits and also semiconductor devices caused that SRM wasn't used till recent decades.

The basic note in SRM controlling is to have the location and the angle of the rotor to the stator poles. There are some direct and indirect methods to find out the location [1]. Direct methods, in which sensors are used, on one hand, decrease the reliability of the control system in different situations and on the other hand, increase the cost and also the wiring [2, 3]. Indirect methods are more favorable these days. In the methods obtaining the rotor location data is done by using the winding parameters like flux, inductance and anti driving voltage.

2. The SRGM Structure

The SRGM was first fabricated by Dr Afjei in 2009 [4]. Its rotor structure is shown in Fig. 1. It includes two separated layers of 4 stator and 2 rotor salient poles which combine a 2 phase SRGM. A fixed reel is used between the two separated stators in the structure for generator state. A cutting structure of SRGM is shown in Fig. 2.

Fig. 1. SRMG rotor structure.

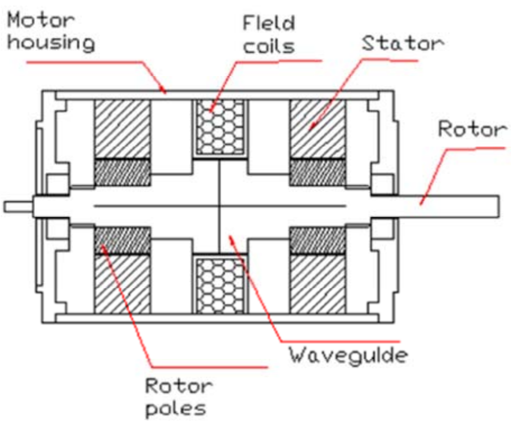

Fig. 2. Cutting structure of SRGM.

2.1. DSP Processor Board and its Features

In this section, the detail information of the DSB processor board which is used in the project is declared. [5- 10]

The board which is named TMS320C6416 TDSK is produced by Texas Instruments Company. The TMS320C 6414 32 bit DSP processor is used in the board which is able to operate in 1 GHz clock frequency. The board block diagram is presented in Fig. 3. It includes SDRAM, Flash memory, CPLD, etc. The CPLD is used to configure the registers, accessories boards, dip switches and LEDs. The processor communicates with a 16 MB SDRAM on a 64 bit port and 128 MHz speed. The flash memory used in the board has 512 KB memory which is able to be used as program memory as well.

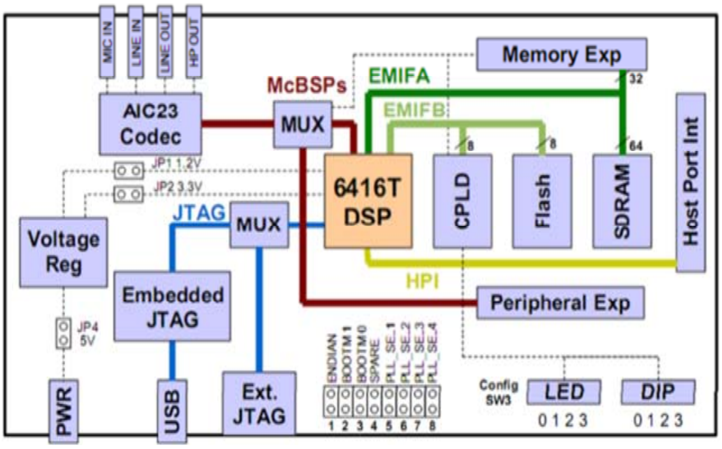

Fig. 3. The DSP processor board block diagram.

2-2. Controller block diagram

Fig. 4 shows how the SRMG controlling is done with the presented control algorithm.

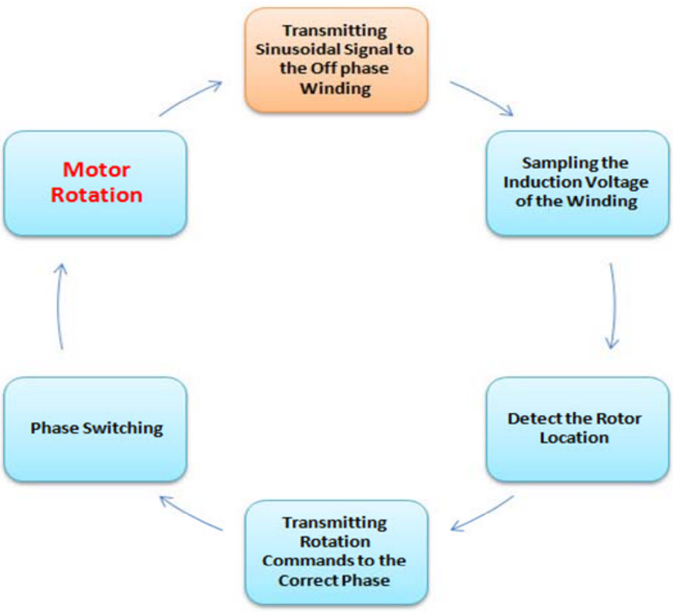

Fig. 4. The controller block diagram.

At first, a high frequency low voltage signal is generated and given to the field-assisted windings after amplification causing a flux is produced in the rotor. The flux movement in a closed loop path creates induction voltage in the motor phases which is sampled then by the processor. The voltage consists of the rotor location data which is detected by the processor. The rotation commands are produced then and transmitted to the motor. The cycle is repeated again [11-16]. In this paper the AM demodulation technique is used to detect the rotor location data from the phase induction voltage.

2.3. Power Electronic Section

The power electronic section turns each phase voltage on or off due to the processor commands which causes the motor rotating.

The starting circuit of the presented designing has two switches in each phase. Each phase winding of the motor is located between the switches (Fig. 5).

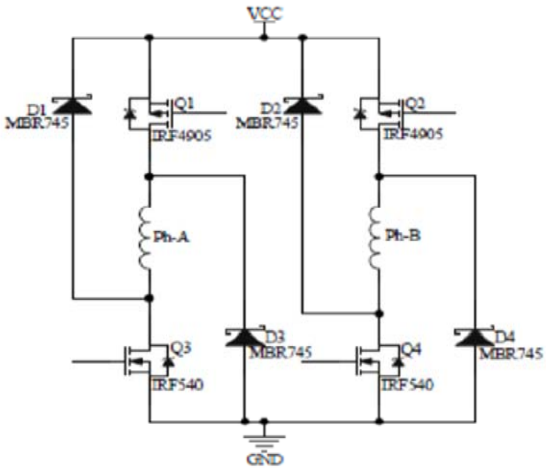

Fig. 5. The starting circuit.

An IRF 4905 P-channel and an IRF 540 N-channel MOSFET are used in each phase as power switches. Since the presented motor has 2 phases, 4 MOSFETs are used in the circuit. As it's shown in the Fig. 5, the sources of the P-channel MOSFETs are connected to the power supply and their drains are connected to the phases winding. The sources of the N-channel MOSFETs are connected to the ground of the power supply and their drains are connected to the phases winding.

Two MBR745 Schottky diodes are used to discharge the winding energy in each phase.

The TSC426 and TSC427 MOSFET drivers are used to transmit the processor command signals to the MOSFETs gate.

2.4. Power and Digital Isolator

The isolator section is designed to separate the digital and power sections in order to protect the components in the digital section from the harmful effects and fluctuations of the power electronic section. So on one hand, isolator trans is used and on the other hand, in order to protect the sampling and digital circuit from the probable high voltage signals, two zener diodes are connected to each other as Fig. 6. As it's shown in Fig. 7, an opto-isolator is used to isolate the DSP processor commands from the power electronic section. The resistant R1 is put to limit the given current of the DSP. The zener diode and resistant R2 are put to guaranty the output voltage which is given to the MOSFET driver.

Isolating and amplifying the high frequency sinusoidal signal, is done by the circuit shown in Fig. 8. The isolating is done with the Trans. The DSP generated signal amplitude is about 4 V which is proper for the field-assisted windings but since limitation in the DSP output current, a current amplifier is required. The current amplifier is shown in Fig. 8 as well which is connected after the Trans.

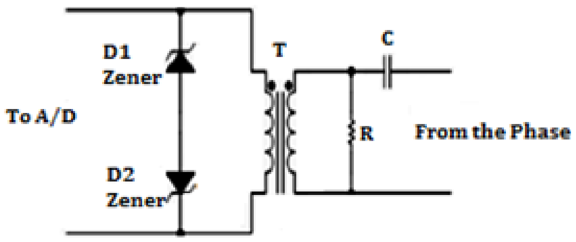

Fig. 6. The power and digital isolator.

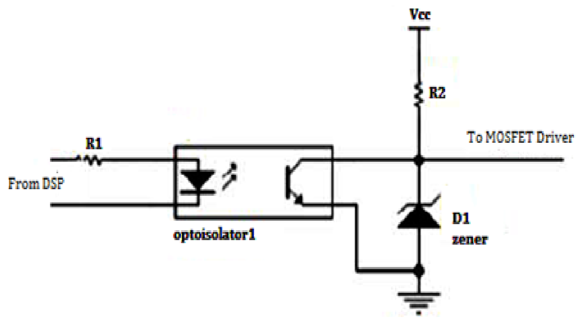

Fig. 7. The DSP commands isolator.

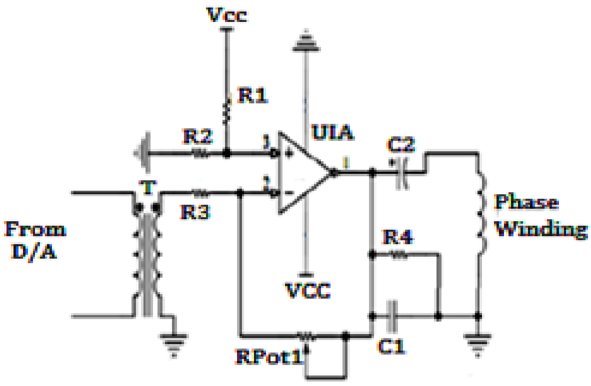

Fig. 8. The amplifying and isolating circuit for the DSP output signal given to the field-assisted windings.

2.5. D/A and A/D Sections

These sections which are inside the DSP processor are convertors of the analog to digital signals and the reverse. In this paper a 16 bit D/A is used to generate 3 kHz sinusoidal analog signal from the digital data. The signal is then given to the field-assisted windings of the motor. (Fig. 9)

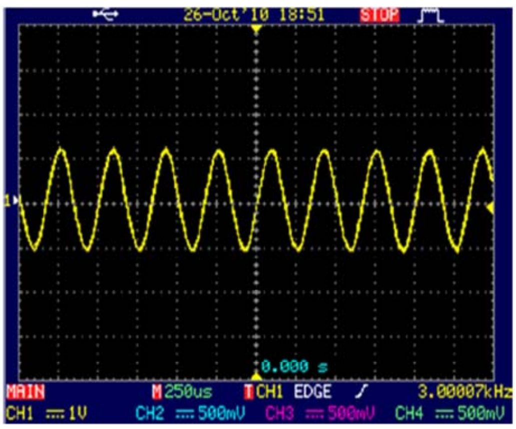

Fig. 9. 3 kHz sinusoidal analog signal generated by D/A.

An accurate 16 bit A/D is used to sample the low voltage induction voltage (0.2 V p-p) which is produced under the effect of the given sinusoidal signal in the winding. According to the Nyquist theory, for a signal reconstruction, the signal sampling frequency should be at least double of the signal frequency itself. The sampling frequency in this paper is 48 kHz which is 16 times faster than the signal frequency.

2.6. Filtering and Demodulation

The DSP processor is the main device of the whole control system which produces the high frequency sinusoidal sample signal, runs the A/D and D/A sections, generates the commands, etc.

The DSP processor has two main sections: digital band pass filter (BPF) and AM demodulator.

Since switching in the control circuit and the motor rotation, a lot of noises are generated in the motor phase and the induction voltage changes steadily during the motor rotation. So, before analyzing the sampled signal, it should be firstly filtered and then demodulated to be an analog signal and free of any noises.

A digital 2 order BPF is designed in the DSP. The filter frequency and time response to step, shock and slope pulses are presented in Fig. 10 and Fig. 11.

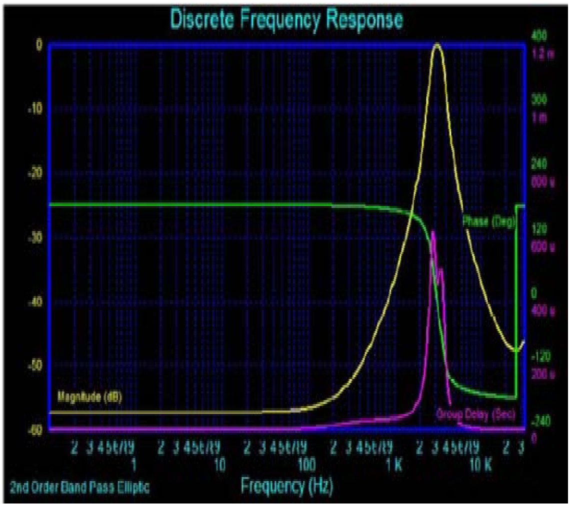

Fig. 10. Step, shock and slope frequency response.

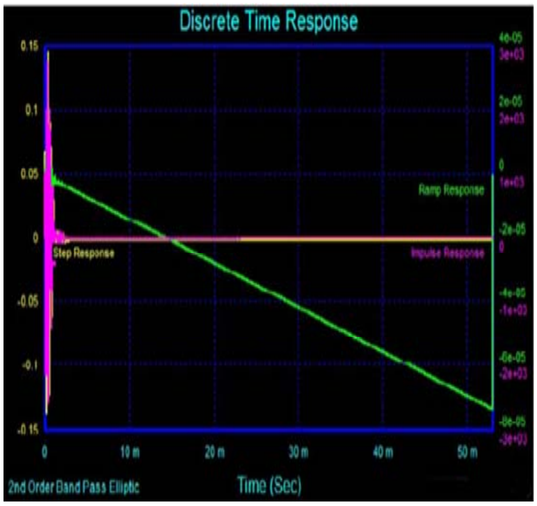

Fig. 11. Step, shock and slope time response.

In Fig. 12, the sampled induction signal is shown before and after the filtering. As it's illustrated, the filtering is done well.

In this paper AM technique is used to demodulate and detect the signal. The induction voltage of the field-assisted windings, before and after the AM detector, is shown in Fig. 13.

3. Controller Performance Results

In this section the controller performance is explained. The rotor and the stator poles in SRM either are aligned or are non-aligned. Non-aligning means there is an angle between the rotor pole and the stator pole. Aligning means the rotor and the stator poles overlap.

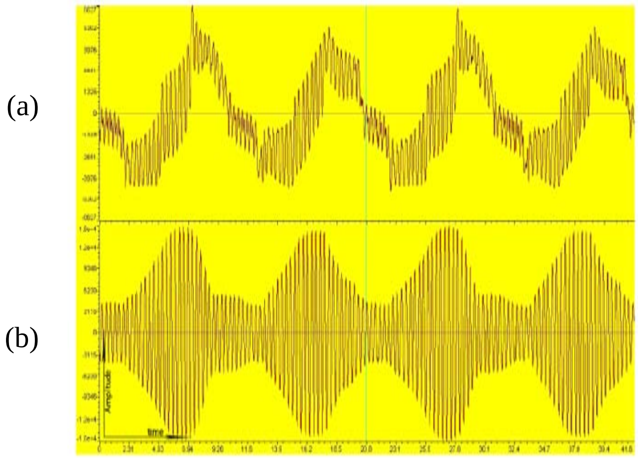

Fig. 12. The input (a) and output (b) of the filter.

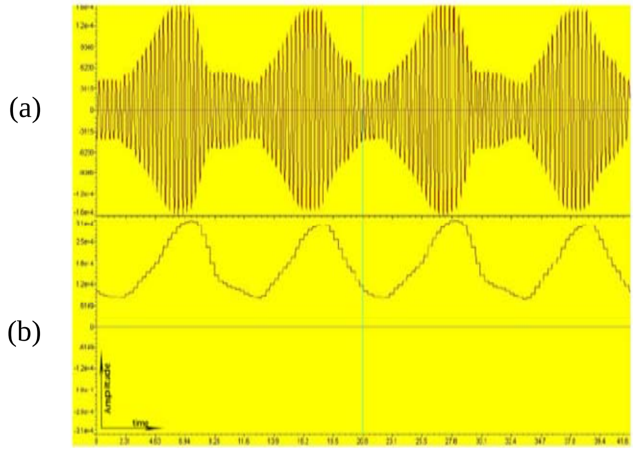

Fig. 13. The input (a) and output (b) of the AM detector.

At the first of a control cycle, the digital data of a 3 kHz signal is generated by the DSP which is given to D/A and the analog signal is produced finally. The signal is given to the field-assisted windings of the motor where the output voltage level depends on the location of the rotor. In fact, the maximum output voltage is occurred when the rotor and the stator poles are aligned and the minimum output is when the poles are completely non-aligned.

The output voltage is sampled with 48 kHz sampling frequency and after filtering and AM demodulation is given to the A/D and then digital data are analyzed in the DSP again and due to the detected location of the rotor, the commands are generated and sent to the MOSFET drivers which turn on the phase that has to be On.

In Fig. 14, a-a' poles are aligned. To start the motor rotating, the b-b' phase has to be turn on which produces flux in b-b' phase winding. According to the electromagnetic rules, the field lines prefer to move in the shortest path with the lowest resistance.

So, the rotor starts rotating in order to align the b-b' poles where the lowest resistance and the shortest path exist. After aligning b-b' poles, the phase is turned off by the DSP command and a-a' phase is turned on and the same cycle is occurred for it. The cycle iteration keeps the motor rotating.

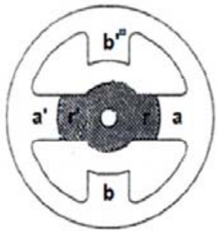

Fig. 14. Aligned and non-aligned poles in a 2 phase SRM.

4. Conclusion

In this paper an AM sensorless control method using DSP processor was presented to control SRGM. The controller circuit elements, sections and details were explained and finally the system performance was illustrated.

DSP processors are strong devices for system controlling and signal processing. They are able to perform complex program with their ultra high frequency. In fact in this paper the assimilating of digital elements and power electronic elements causes an excellent SRGM controller designing.

An important note of connecting digital and power electronic circuits is the isolation. Without proper isolation in these kinds of circuits, the digital elements are not able to have good performance and they may damage.

The Schottky diodes which are used in the starting circuit are so important elements. Without them, in the switching moment, the energy saved in the phase winding is given to the MOSFETs in the form of spikes which are so harmful for MOSFETs and even may not be seen in analog oscilloscopes because they only occur in a moment with a high voltage.

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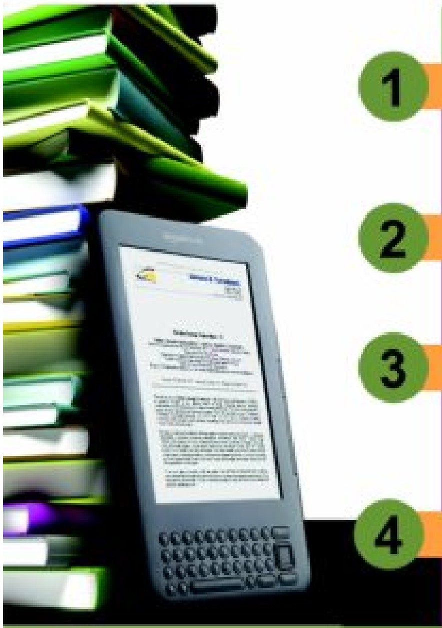

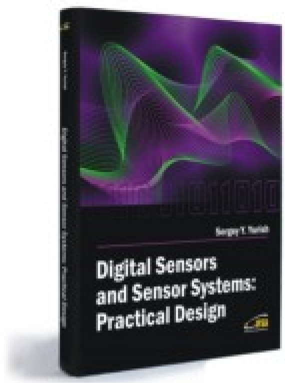
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Digital Sensors and Sensor Systems: Practical Design

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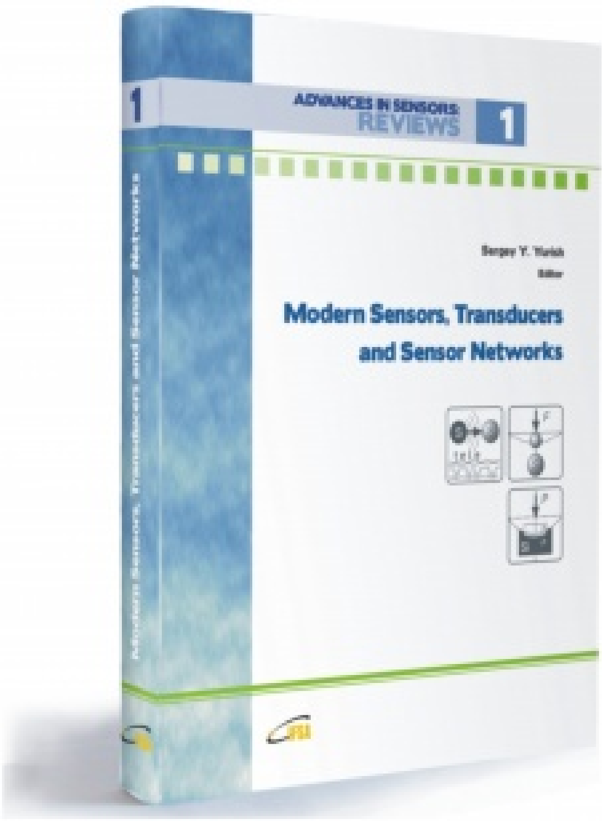

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