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Roles and Expectations for LSI and MEMS Technologies in the IoT Era

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Abstract

The spread of the IoT makes it possible to realize cyber-physical systems that combine the real world and cyber space. In view of this trend, the current state of the research and development of the key devices that will have an impact on business will be presented along with an overview of the role of LSI and MEMS technologies. It also describes nanowatt-level wireless sensor node circuit technology and sensor platform circuit technology.

1. Introduction

With the explosive spread of smart phones and wearable devices, it is expected that it will become possible to attach various maintenance-free sensor nodes to all things in the future. As the IoT (Internet of Things) continues to expand, cyber-physical systems (CPS) that fuse cyberspace and the real world are starting to become a reality. This is also referred to as the Fourth Industrial Revolution, which will culminate around 2030. LSI and MEMS technologies serving as enablers of the creation of new services are expected to play important roles in this revolution.

Here, from the standpoint of a circuit research engineer, the current state of the research and development of the key devices that will have an impact on business will be presented, along with an overview of the role of LSI technology. In various technology fields, the style of R&D management, which oversees device integration, information processing technology, and the internet layer structure, becomes important. Specifically, there are mainly three important issues: 1) the fusion of materials, devices, and circuits; 2) their relationship with computer technologies operating on the cloud, such as for big data analysis; and 3) cooperation with network technology that links sensor nodes to the cloud. This paper describes a nanowatt-level wireless circuit technique for ultralow-power sensor nodes [1-3] and presents a sensor platform circuit technique that easily achieves various sensing functions by means of the fusion of transducers and sensor interface circuits [4].

2. Nano-watt level wireless circuit technique for ultra-low-power sensor nodes

Figure 1 shows the configuration and a photograph of the nanowatt-level wireless sensor node we developed. Solar energy is charged to a capacitor, which is good for low-current charging from a small solar battery. When a vibration is detected, the charged energy is supplied to the wireless IC. The IC generates and transmits the ID signal. Thus, the sensor node can detect motion, such as something being dropped or lifted. Each device is mounted on two 5 × 5 mm printed circuit boards. The devices are stacked three dimensionally to reduce total volume [5]. The nanowatt wireless chip was fabricated in a 0.18-µm CMOS process. The current consumption becomes ~3 mA when the pulse signal is generated and ~100 µA when it stops. Thus, the energy efficiency is 625 pJ/bit. When we transmit 100 bits per second, the total power consumption is less than 62.5 nW. Therefore, the RF transmitter based on pulse OOK achieves nanowatt-level power consumption. Figure 2 shows a battery-driven nanowatt wireless node with a micro controller. Instead of an RF filter, the node uses filtered envelope signal generated from the chip to reduce RF

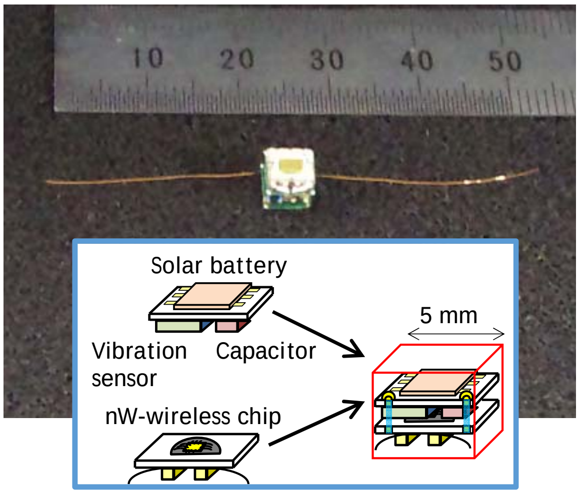

Fig. 1 nW-level wireless sensor node and photograph.

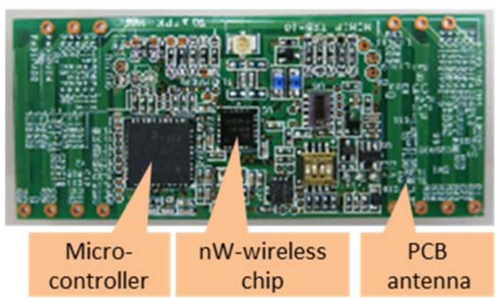

Fig. 2 Battery-driven nW-wireless sensor node.

bandwidth. In accordance with Japan's regulations, it transmits over distances of more than 10 m at 315 MHz. This is useful for a short-term monitoring system, such as one with a one-second interval. The node can stay activated for ten years without maintenance.

3. Sensor platform circuit technique by fusion of transducers and sensor interface circuits

The proposed circuit concept is given in Fig.3. In this concept, instead of a specific analog front-end (AFE) for each sensor type or connection configuration, an array of general purpose AFEs is used as a sensor-independent and connection independent interface. Consequently, if the desired sensor type or application is changed after chip fabrication, the hardware can still be used for interfacing. This will increase system flexibility and expandability and thereby reduce design time and cost. Such an approach can be used to interface an array of the same sensors for increased measurement accuracy and reliability. It can also be pushed further by including many heterogeneous sensors in one package (e.g., by using CMOS-MEMS [6]) for an application-independent sensor array module. The user can then use the sensors that match his application and disable other undesired ones or reserve them for future expansion.

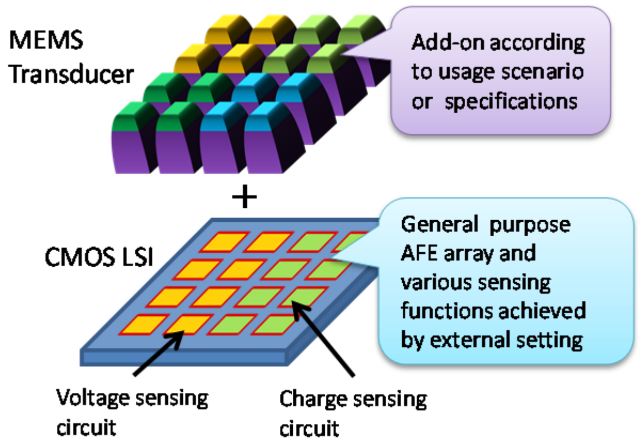

Fig. 3 The concept of the proposed general purpose AFE LSI array for sensor platform circuit techniques.

Figure 4 shows a proof-of-concept of a system that uses a 2 x 2 chip array of the to interface four transducers. The transducers are attached to the opposite side of the sensor readout board by using the bonding pads shown in the bottom photograph. A microcontroller is used to generate the timing signals and communicate with the PC using an RS232 connection. The gain and the offset settings are changed in the PC program and sent serially to the board. The microcontroller then sends the data measured using the proposed circuit to the PC for analysis. The operation of the proposed system was also verified when the PC was replaced with an Arduino board to form a completely mobile sensor node. Although four transducers are used in this board, any number of transducers can be interfaced using the proposed system. This will greatly reduce fabrication and

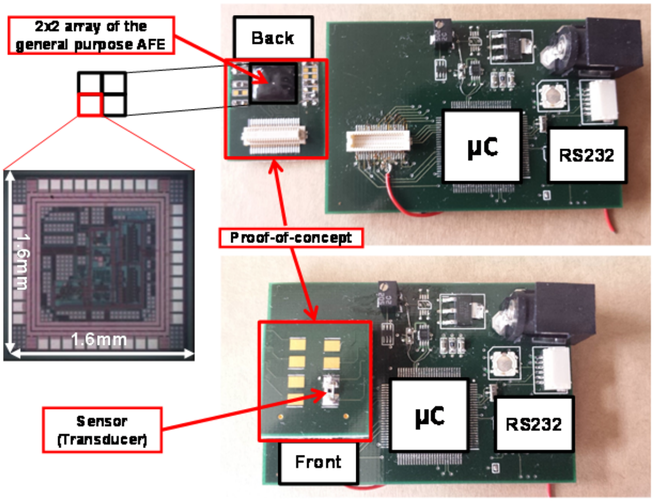

Fig. 4 Proof-of-concept of the proposed circuit that uses 2x2 array of the proposed AFE to interface four sensors along with measurement board.

development costs for sensor nodes as the same circuit can be reused to interface various types of transducers with no hardware redesign.

4. Conclusions

Circuit techniques for ultralow-power sensor nodes and a sensor platform were described. The nodes and platform are useful for IoT devices, which will be used in widely spreading services according to rapidly changing demands. Moreover, in order to meet various service requirements, it is important to consider not only device integration but also information processing and internet technology. Therefore, LSI and MEMS technologies are charged with very important role to generate industrial and economical eco-systems, and are expected to produce the key devices for gathering huge data as a front-end for IoT.

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