Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 746-747

B-9-1 (Invited)

Ultralow-power CMOS/SOI Circuit Technology for Ubiquitous Communications

Y. Kado, Y. Matsuya, S. Mutoh, J. Terada, H. Morisawa, Y. Sato, T. Douseki and H. Kyuragi

NTT Microsystem Integration Labolatories
3-1, Morinosato Wakamiya, Atsugi-shi, Kanagawa 243-0198, Japan

1. Introduction

Conventional communication services have provided voice communication between two persons on the basis of a phone set to which a telephone number has been assigned. We have been investigating the extension of conventional human-to-human communication by voice to communication between a person and various kinds of objects [1]. Our approach is to develop an ultra-compact device that endows a sensor and actuator with close-range wireless communication capabilities and can be attached to various real-world objects (people, things, environments). This device is named the Stick on Communicator and abbreviated as StiC in this paper.

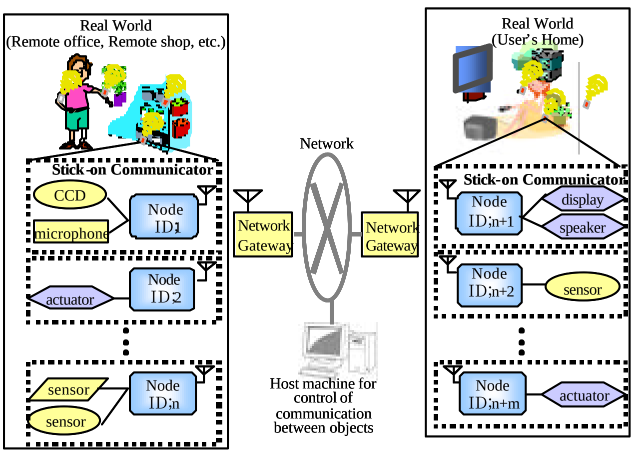

Fig. 1 Ubiquitous Communication System

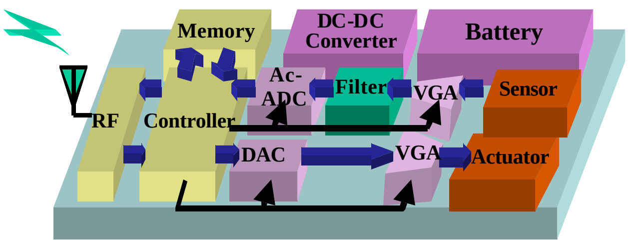

Fig. 2 Configuration of Stick-on Communicator

2. Ubiquitous Communication System

An example of a ubiquitous communication service system is illustrated in Fig. 1. Each StiC device is connected to a network for two-way communication via a parent device (network gateway). A host machine that controls communication between objects on the network connects the StiCs that are attached to various objects and establishes channels for communication with them.

The StiCs have basic functions for sending their unique IDs and positional information to the network, and those equipped with sensors can also send the data from their sensors. This makes it possible, for example, to obtain real-time sensing information from a remote office or store while at home. On the other hand, StiCs that are equipped with actuators can act on objects in the real world according to instructions from the network [1]. The key to implementation of the ubiquitous communication environment described above is the realization of an ultra-low-power StiC. A block diagram of the StiC is shown in Fig. 2 [2].

3. StiC configuration and low power consumption requirements

The relationship between battery capacity and continuous use time with StiC power consumption as a parameter is shown in Fig. 3. The battery capacity axis in the figure shows the capacity range of the thin, coin-type lithium batteries that can be used to power the StiC. For these batteries to be used continuously for one year, the average power consumption must be less than 100 μW, and reduction to the level of several tens of microwatts is desirable. On the other hand, we can see from the figure that if the activity rate for intermittent operation is in the range from 1% to 0.1% and the power consumption during operation is 10 mW or less, the average power consumption is reduced to 100 μW and long-term operation of one year or more comes into the range of possibility. However, power consumption during sleep mode must be less than about 10 μW.

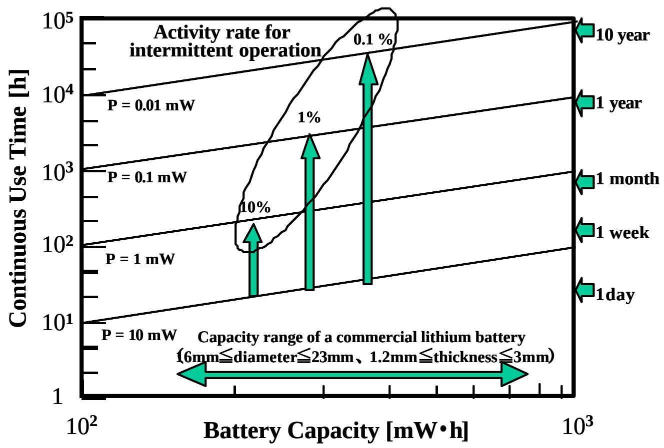

Fig. 3 Relation between battery capacity and continuous use time

4. Achieving low power consumption with a low-power CMOS/SOI analog circuit

An effective way to reduce StiC power consumption during operation to 10 mW or less is to achieve low-voltage operation for each of the blocks shown in the configuration diagram of Fig. 2. In particular, a combination of fully-depleted (FD type) SOI devices, which have excellent low-power operation characteristics [3], and low-voltage circuit technology makes it possible to reduce the operating voltage to 1 V for the RF module [4], to from 0.5 to 1.0 V for the baseband signal processing analog circuit module [5][6], and to 0.5 V for the digital module [7]. Furthermore, the stable 0.5 to 1.0 V power supply from a lithium ion battery allows the realization of from 85 to 90% efficiency in the DC-DC power conversion circuit combined with FD-SOI devices. The characteristics of the FD-SOI devices that are advantageous for low-voltage analog circuit operation and the circuit technology for implementing low-voltage operation in each block of the StiC are presented in Fig. 4.

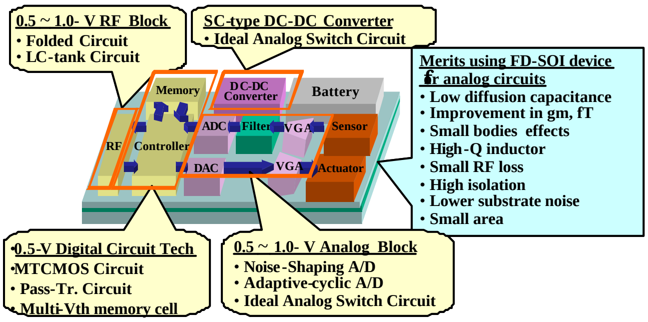

Fig. 4 Merits of FD-SOI devices and low-power CMOS/SOI circuit technology

5. Prospects for long lifetime through intermittent operation of CMOS/SOI circuits

The operating sequence and the estimated power consumption of each block for when the StiC is operated intermittently with an activity rate of 1% are shown in Fig. 5. In the first 5 ms after the power is turned on in the blocks other than the RF block, the analog output signal is acquired from the sensor and converted to a numerical value, and the value is stored. Then the RF module is powered up, and in the next 5 ms the RF circuit is stabilized, communication with the parent device is established, and the data is transmitted. After this 10 ms of operation, the device goes into the sleep mode. When this operation is repeated every second to ensure a good real-time characteristic, the activity rate is 1%.

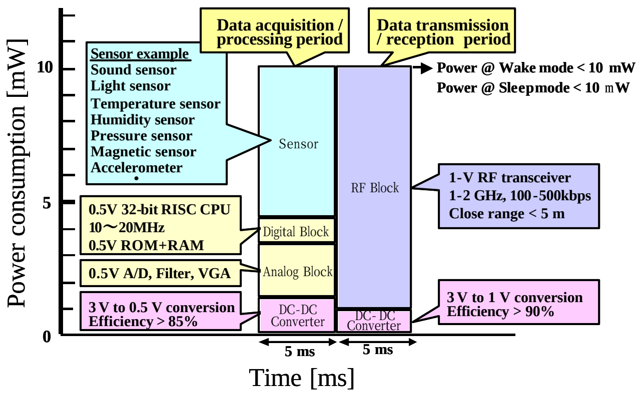

Fig. 5 Intermittent StiC operation and estimated power consumption of each CMOS/SOI circuit block in Fig. 4

In that case, 100 StiC devices can communicate with one parent device (network gateway) by using time division multiplexing access, as shown in Fig. 6. The sensor and the actuator are powered directly from the lithium battery. The digital module and the analog module are powered via the power conversion circuit, which supplies 0.5 V with a conversion efficiency of 85%. The RF module is supplied with 1 V with a 90% conversion efficiency. In addition, the sensor and actuator are assumed to be energy-efficient devices that operate on 3V and about 2 mA of current. For intermittent operation of about 10 ms such as described in this example, evolution toward StiC sensors that operate on natural energy sources like heat and vibration is expected [8].

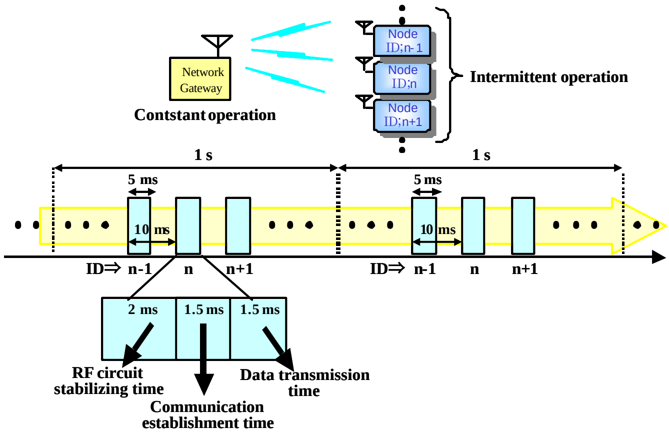

Fig. 6 Sequence for 1:N close-range wireless communication by time division multiplexing access

Conclusions

We have introduced an example of a system that embodies the concept of a ubiquitous communication service and explained the importance of low power consumption in the StiC that will serve as the bridge between the real world and the network for real-time services in which sensor data is acquired every second. An effective solution to the problem of high energy efficiency is to employ the synergy of combining low-voltage analog circuit technology and FD-SOI devices. Taking advantage of that synergy to reduce the power consumption of the StiC during operation to about 10 mW and employing intermittent operation with an activity rate of less than 1% would make it possible to support operation for one year or more with a commercial coin-type lithium battery.

Acknowledgments

This work was supported partly by the New Energy and Industrial Technology Department Organization, Japan.

References

[1] F. Morisawa, et al., Interaction 2003 Digest of Technical Papers, p. 223. (in Japanese)
[2] Y. Kado, et al., NTT REVIEW, Vol. 14, No. 5, pp. 49-55, 2002.
[3] Y. Kado, et al., IEDM Technical Digest, p. 635, 1995.
[4] M. Harada, et al. ISSCC2000 Digest of Technical Papers, pp. 378-379.
[5] J. Terada, et al., Proceedings of 2002 IEEE SOI Conf., pp.126-127.
[6] Y. Matsuya, et al., IEEE JSSC, Vol. SC-22, No. 6, pp. 921-929, 1987.
[7] T. Douseki, et al., 2002 Symposium on VLSI Circuits Digest of Technical Papers, pp. 6-7.
[8] T. Douseki, et al., ISSCC2003 Digest of Technical Papers, pp. 388-389.