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Low Power SoC Integrated Circuits Design for the Wireless Medical and Health Care Applications

Zhihua Wang

Institute of Microelectronics, Tsinghua University, Beijing 100084, China
Phone: +86-10-62781991, Fax: +86-10-62771130, E-mail: Zhihua@tsinghua.edu.cn.

1. Introduction

Wireless medical and health care applications are emerging as one of the major driving forces for today's semiconductor industry. On the other hand, the advanced integrated circuit, as the enabling technology to implement those implantable/portable medical devices, is bringing up a new revolution in the personal medical/healthcare area. Now days, information technologies provide a wealth of services for people, at the same time, it bring an unprecedented business opportunities for the information industry. The current health care cycle is data centralized care routine. It is efficient for curative care but introduces much disturbance for patient. The critical weak point is that it is expensive. To reduce the medical and healthcare cost, we should take advantage of information technologies and to establish a novel patient centric distributed care routine by witch the sense of discomfort, medical tests and/or monitoring, the diagnostics and part of the treatments can be carried out in the home of a patient. So as to minimum disturbance to daily life of a patient and reduce the cost. In order to achieve such distributed care routine, there have a urgent requirement for the medical devices that can achieve a complete, accurate and reliable testing and monitoring of the status of patient. By this requirement, the global medical devices industry is becoming a fairly large, intensely competitive and highly innovative.

In this presentation, the system architecture of typical wireless medical and health care applications will be discussed, followed by detailed analysis for the design requirements and challenges. The key design considerations to implement the building blocks of ultra-low power CMOS IC's for those applications will be examined, including the sensor interface, signal processing, wireless transceivers, embedded controllers and the most critical power management. Three design examples will be given to illustrate how those design principles are applied to the ultra-low-power IC's dedicated for specific applications of total knee/hip replacement surgery, capsule endoscope systems.

2. Technology enablers and architecture of a wireless medical and health care systems

The medical devices industry is divided into different segments such as Cardiology, Oncology, Neuro, Orthopedic, Aesthetic Devices and Healthcare IT ("HCIT"). The patient centric distributed care routine need HCIT with a kernel of portable medical monitoring systems which can provide a reliable and seamless monitoring and can be integrated into patients daily life routine. In addition, an ambulatory data analysis system which can execute a real-time data analysis and even diagnostics is needed to increase the efficiency of health-care delivery. Of course, it is ideal if a close loop including a smart drug delivery and/or stimulation systems for preventive care can be implemented.

Figure 1 is the architecture of a typical wireless medical/health care system which is composed of one/multiple smart sensing/intervention devices (SID's) and a portable base station (PBS) which has the functions to communicate with SIDs and to connect to the wide area network.

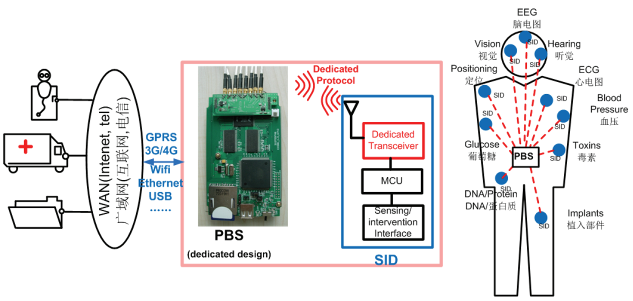

Figure 1. A wireless medical/health care system

3. The consideration of design a PBS in wireless medical and health care systems

For the design of a PBS, two approaches can be used to achieve the main functions. A PBS can be designed based on existing platform for example, a smart phone or a PAD computer. The communication between PBS & SID's relied on a standard protocol, Bluetooth for example. It has the advantages of no hardware design for PBS, a great connectivity to 2G/3G/4G communication networks and a very short ramp-to-market time. But it is hardly achieve the optimization of the performance for SID and could not achieve low power for the long tine operation by using a battery power.

A dedicated design of PBS chips in contrary is proposed to achieve an optimal performance for SID's. The communication between PBS & SID's is a dedicated protocol. The typical function blocks for a PBS SoC consist of a wireless transceiver, a signal processor and/or controller, local memory, power management and interfaces including Ethernet/GSM/3G/USB/802.11.x. For the application of PBS, a multi-band multi-mode multi-rate transceiver is needed which is an application-optimized transceiver for various SID's. Table 1 lists the specifications of PBS SoC which have compromised considerations about the flexibility, connectivity to network and diversity of SID's, power consumption, etc.

	PBS SoC	SID SoC祖
TRX frequency band	Multiband, cover 400/900/2400 MHz ISM bands	Single band for one specific application
TRX data rate	10kbps-3Mbps, reconfigurable	Chosen for application
TRX modulation	ASK, 2FSK, QPSK, MSK, changeable	Chosen for application
MCU programmability	Required	Usually no
WAN connectivity	Required	No
USB &SPI connection	Required	Usually no
Power consumption	Moderately low	Ultra low

Table 1. The specifications of PBS SoC

3. Power management circuit design in a SoC for SID

Under normal circumstances, it will keep several months from a SID being manufactured to it is used by a user. Traditionally, medical devices such as a SID use a reed switch (controlled by magnet) as the power switch as shown in Figure 2. There have serious disadvantages of such reed switches include vulnerable to magnet interferences and leakage current.

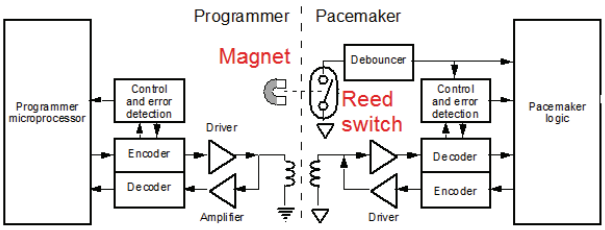

Figure 2. Reed switch by John G. Webster in 1995

A wireless switch based on passive RF receiver for the switch of SID's is proposed [1] by which a zero standby current is achieved. The circuit has the advantages of high tolerance to environment electromagnetic disturbance and no leakage current during standby. In fact, an ID information can even be used to program the medical devices in all kind of application that need to be sealed. Schottky diodes are usually needed to implement the energy recovery circuit (charge pump actually). Unfortunately, a Schottky diode is not available in standard CMOS technology. A CMOS compatible Schottky diode is proposed in de design of the switch circuit by making use of the interface between the metal (contact) and low-doped n-well forms a Schottky junction being achieved.

4. A Reconfigurable Transceiver for PBS and three applications

Figure 3 is the schematic of a reconfigurable transceiver SoC used for PBS. The chip can worked at the frequency bands of 400-450MHz and 2400-2480MHz. It can worked as the different modulation/data rate include OQPSK(3/2/1/0.5/0.25Mbps), MSK(3/2/1/0.5/0.25Mbps) and OOK(50kbps). The chip is manufactured using UMC 0.18um process and finished the measurement.

Making use of the PBS Soc, a various kinds of application was designed and demonstrated. A wirelessly ultra-low-power system for equilibrium measurements in total hip replacement surgery was given in [2], a bidirectional wireless monitoring system of the orthopedic Implants was discussed in [3], and, a wireless capsule endoscope with bidirectional communication was demonstrated in [4]. The single-chip wireless capsule endoscope is targeting a painless gastrointestinal examination by integrating novel low-power circuit techniques. The capsule endoscope system allows a working time of up to 23 hours, far exceeding the previous record. This work was successfully commercialized and the corresponding product was already approved by FDA China.

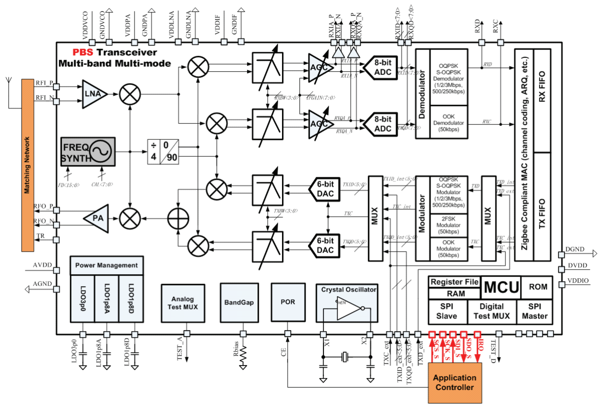

Figure 3. A Reconfigurable Transceiver for PBS

All of those three examples will be detail demonstrated during the presentation.

5. Conclusions

A typical wireless medical/health care system architecture is proposed in tjis presentation. The detail design considerations of the whole system are discussed and a few application results of SoC for total kee/hip replacement surgery, capsule endoscope system are demonstrated in this presentation.

References

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