A Wireless Data Processing System Constructed of SAW Devices and Its Applications to Medical Cares

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Abstract

A wireless data system is constructed with the use of SAW-based transmitter and receiver, which have recently been conceived dedicatedly for short range RF link applications. In order to realize the portability as well as to reduce the power consumption, an ASIC architecture is devised to be incorporated with the transmitter/receiver so as to implement the intermittent drive and communication protocol. By means of the sophisticated drive and protocol mechanism, the wireless data system is applied to the monitoring facilities in medical cares, i.e. the wandering prevention of patients with senile dementia and the 24-hour observation of portable electrocardiographs.

I. INTRODUCTION

A conventional wireless data terminal, composed mostly of discrete components, might have a volume of more than 30-50 cc and waste power at least of the order of 10 mW, which can never be of portable use. However, with advances of short range, unlicensed RF (radio frequency) links, different applications have been required, which include wireless security systems, remote entry systems, wireless bar code readers, wireless computer links, and so forth[1].

In order to achieve high performance and miniaturization in such wireless communications and high-speed computing applications, the SAW (surface acoustic wave) device technology has been unified with the IC technology. Thus, according as a wide variety of low-power wireless applications, such as automotive keyless entry, remote utility meter reading, wireless data links, etc., are growing rapidly, the use of SAW devices is accelerated due to the advantage of the technology to enhance reliable performance, small size, long battery life, and regulatory compliance.

To cope with conventional inductor/capacitor-stabilized super-regenerative receivers with their inherent problems of poor stability, little frequency selectivity, and poor sensitivity, the so-called SAW-stabilized super-regenerative receivers and SAW-stabilized super-heterodyne receivers have been developed, and more recently another new type of receivers, called amplifier-sequenced hybrid receivers, have been conceived to address the shortcomings of previous receiver architectures in short range RF link applications[2].

By using a pair of commercially available SAW-stabilized transmitter and receiver in conjunction with an ASIC module additionally devised for intermittent drive and the communication protocol, a wireless data system can be constructed of base-stations and an IC-card type of portable terminals, which is intended to be applied dedicatedly to the monitoring for medical cares.

The present paper outlines an ASIC architecture for the intermittent drive and communication protocol to be incorporated with the transmitter and receiver, and then describes a wireless data terminal with the use of these transmitter/receiver and ASIC module. The main focus is put on how to enhance the terminal performance and portability to be exploited for the 24-hour monitoring of patients with portable electrocardiographs.

II. ACTIVE DATA CARRIER AND PROTOCOL MECHANISM

Our main theme is to construct a wireless data system composed of base stations and an IC-card type of portable terminals, which is intended for medical cares. To this end, we propose a wireless data terminal ADC (Active Data Carrier) as outlined in Fig. 1. In this diagram, Selector is to switch the terminal into either the transmitting phase or the receiving phase. To achieve the portability, ASIC Module is devised to be incorporated with SAW-based Transmitter and Receiver, which is in charge of not only communication protocol but also intermittent drive. Thus the total system performance depends primarily on this ASIC Module. Fig. 2 shows a block diagram of the Module, which is composed of functional units; (i) System Controller, (ii) Receiver Controller, (iii) Transmitter Controller, and (iv) Electrocardio-

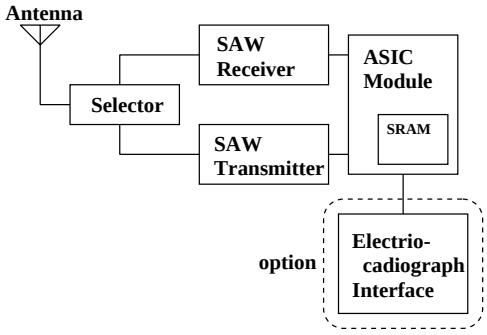

Fig. 1 Block diagram of ADC.

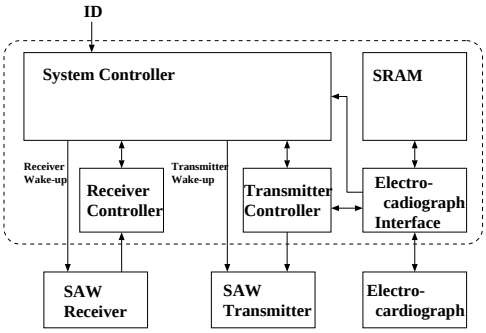

Fig. 2 Block diagram of ASIC Module.

graph Interface, which are outlined as follows.

System Controller: This unit drives SAW Receiver, SAW Transmitter, Receiver Controller, and Transmitter Controller intermittently for 50 ms per second in the 'idling mode'. When Receiver Controller detects a pulse sequence, hereafter called *ENQ Sequence* (enquiry pulse sequence), which indicates the start of the 'data receiving mode', it has to inform System Controller (i) to drive all the prescribed units, i.e. to switch them from the idling mode into the data receiving mode, and (ii) to continue to drive them until Receiver Controller detects the end of the data receiving mode, and then (iii) to resume the idling mode.

Receiver Controller: First, it should be pointed out that SAW Receiver is usually unstable for 90 ms from the start of drive. Thus, as soon as this Receiver Controller detects ENQ Sequence, it begins to drive all the prescribed units so as to switch them into the data receiving mode, skips all the received pulses for the first 90 ms, then resumes reading received pulses, and as soon as it detects the end of data receiving mode, it switches all the units into the idling mode.

To make the total mechanism operate precisely, a state machine is modeled on a number of specific states, such as *ACK* (acknowledge), *NAK* (negative acknowledge), *ETX* (end of text), *time-out*, *demand for data transmission*, and on the basis of this state machine a protocol scheme is constructed as shown in Fig. 3.

```
   procedure Base_station;
   begin
 1 Issue ENQ; /*ENQ mode*/
 2 Wait until a reply is received or time-out (i.e.
   90ms of the unstable state of SAW Receiver);
   /*ID check mode*/
   if no data then back to ENQ mode;
   case receiving_data of
 3 ID: issue ACK;
 4     if data transmission is not requirement,
 5     back to ENQ mode;
 6 error: issue EOT and back to ID check mode;
   end
 7 Wait until a reply is received or time-out;
   /*data receiving mode*/
 8 if no data then back to ENQ mode;
   case receiving_data of
 9 ETX: back to ENQ mode;
10 data: issue ACK and back to data receiving
         mode;
11 error: issue NAC and back to data receiving
         mode;
   end
   end
```

```
   procedure Terminal();
   begin /*idling mode*/
12 sleep 950ms;
13 Wake-up();
   end
```

```
   procedure Wake-up();
   begin /*data receiving mode*/
14 Wait until a pulse sequence is detected or time-out;
15 if no pulse then back to idling mode;
16 Skip the pulse sequence until ENQ detection
   or time-out;
17 if ENQ is not detected then
         back to idling mode;
18 while ID is not issued successfully then
19  issue ID;
20  Wait until a reply is received or time-out;
21  if no data then back to idling mode;
22  case receiving_data of
23   ECF: Wait T×N ms
        (N: 1!A16, generated by random number table
         T: interval time between each ENQ);
24   ACK: ID transmittion succeed;
25   others:
    end
   end
26 if data is not transmited then
         back to idling mode;
27 while data is not transmit successfully then
28  transmit data;
29  Wait until a reply is received or time-out;
30  if no data then back to idling mode;
31  case receiving_data of
32   ACK: data transmittion succeed;
33   NAC: transmit data again;
34   others: back to idling mode;
    end
   end
35 issue ETX;
   end
```

Fig. 3 Protocol between Basestation and Terminal.

Table 1 Main features.

Technology	$0.6\mu m$ CMOS 3LM
Chip size	$4.59mm \times 4.59mm$
Core size	$1.94mm \times 2.32mm$
Transistors	14,740
Power dissipation	0.98mW (3V, 307.2KHz)

In this protocol a number of typical procedures are specified. For example, while the base station is communicating with a terminal, it should not issue ENQ Sequence (see lines 2-11 in Fig. 3). In addition, although the probability is very low, it may happen that two or more terminals can receive ENQ Sequence simultaneously. In this case, let each such terminal transmit its own ID to the base station, then such ID signals cause a transmission conflict, and hence an parity error, in the base station, and therefore let the base station issue EOT Signal so as to start the timer of each such terminal by using random numbers (see lines 18-25 in Fig. 3).

It should be added that this Controller reads received pulses by the unit of 8-bit data plus 1-bit parity, each to undergo the parity-check.

Transmitter Controller: This unit refines the necessary data, such as ID data, control data of ACK, NAK, EOT, etc., and optionally electrocardiograph data, into the serial form, and then transfers such serial data to SAW Transmitter.

Electrocardiograph Interface: This unit is to read the data of the electrocardiograph optionally connected to the terminal, and then to transfer them to Transmitter Controller.

III. IMPLEMENTATION RESULTS

ASIC Module has been implemented with the use of 120 pins by employing ROHM 0.6um three-metal-layer CMOS process. The main features are shown in Table 1, where it should be noticed that the power dissipation has been lowered to 0.98mW at 3V by means of the sophisticated drive and protocol mechanism. Fig. 4 shows the final layout patterns.

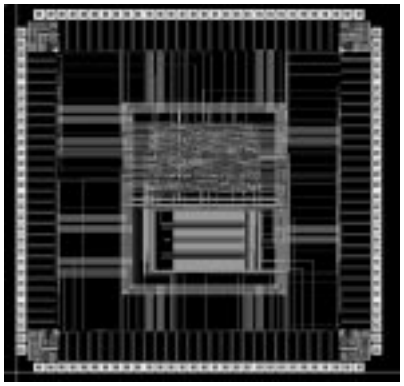

Fig. 4 Final layout Patterns.

IV. APPLICATIONS TO MEDICAL CARES

This wireless data system can be applied to the monitoring in a variety of medical cares, mainly because a data terminal can be constructed in the form of an IC-card, and moreover, due to a precisely refined set of protocols for the intermitten drive, the power consumption of the data terminal can be lowered to 300 μW in the idling mode and 9 mW in the data receiving mode.

We have attempted to apply this wireless data system to monitoring facilities of medical cares. By taking advantage of the ability of medium-speed and short-range wireless data transmission, we have exploited this data system for the 24-hour monitoring of portable electrocardiographs. With the recent advance of medical electronics, such a small electrocardiograph as 118 mm (H) x 64 mm (W) x 23 mm (D) with 150 g has been realized.

This electrocardiograph has a functionality to detect irregular pulses of the heat of the holder, as well as to memorize the waveform for 32 sec in advance of the occurrence of such irregularity. Thus once it detect any irregularity, it transfers the memorized waveform to Electrocardiograph Interface, which in turn transmits it to a base station in accordance with the protocol.

V. CONCLUDING REMARKS

This paper has devised a wireless data system composed of base stations and an IC-card type of terminals. The terminal is distinctive in that a sophisticated ASIC module is incorporated with the adopted SAW based Transmitter/Receiver so as to control the data communications as well as to lower the power consumption. The total power dissipation of this system has been lowered to such an extent that it can be practically used for monitoring portable electrocardiographs.

VI. REFERENCES

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