

A Portable Device for a Modular System of Patient ECG Monitoring

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Abstract

The aim of this paper is to discuss the main characteristics of a low cost and consumption portable device, which is part of a system for ambulatory monitoring of patients with heart diseases. The solution is based on the microcontrollers MSP430F5419A and CC2540 (Bluetooth), both from Texas Instruments and the modem SIM908 from Simcom, which includes GSM/GPRS and GPS modules. This device is an attractive solution to use in systems where low cost is a critical issue. Three prototypes of the device were developed and tested. A total of 9 standardized ECG signals with different shapes, suggested by IEC 60601-2-25: 2011 for testing purpose were applied to the system. The developed device allows acquiring and transmitting the ECG signal in a safety way. According to the connectivity options it could be integrated in different systems for patient monitoring.

1. Introduction

Monitoring systems of electrocardiographic signals (ECG) are of vital importance in medical practice. In hospitals and health care centers is very common to find devices that record vital signs, which are displayed in the interface of the device or in a personal computer.

When there is a central for patient monitoring is desirable to get the information of all monitoring devices at the same place. It facilitates monitoring the current state and progress of patients from the central.

Nowadays, the versatility of these systems has increased because they can connect to an intranet or Internet using different ways of communication and enabling its application in non-clinical environments where they are very useful [1].

The benefits offered by communications networks and interconnection of data at present, have allowed the development of health services and medical care using computing and telecommunications platforms [2].

This allows the exchange of data, associated with a patient, between hospitals or between patient and physician reducing the limitations of time, distance and access to remote places. The systems for ambulatory

monitoring of patient with cardiac diseases are very useful in patients having difficult symptoms to diagnose as: syncope, palpitations, breathing troubles, pain in the chest and dizziness. All of those symptoms may suggest cardiac arrhythmia [3].

They are also used in patients under the control of various drug therapies that may require medical monitoring to adjust their dose. In these situations, depending on the symptoms and the patient's history is important to acquire the ECG signal to perform necessary analyzes by medical personnel to take the correct decisions about the treatment of the patient.

That is why a lot of companies all around the world have developed different portable devices for recording ECG signal no matter the location of the patient. This kind of device provides the ability to transmit the acquire ECG using the telephone systems to a central monitoring system.

The goal of this paper is to present and discuss the main characteristics of a portable device for a modular system of patient monitoring. The solution is based on the microcontrollers MSP430F5419A [4] and CC2540 [5] (Bluetooth), both from Texas Instruments and the modem SIM908 [6] from Simcom, which includes GSM/GPRS and GPS modules. This device is an attractive solution to use in systems where low cost is a critical issue. Also it allows to acquire and transmit the ECG signal in a safety way. According to the connectivity options of the device, it could be integrated as a part of different systems for ambulatory patient monitoring [7].

2. Materials and methods

The proposed solution is a portable device which its main characteristics are low cost and consumption. It is intended as a part of a system for ambulatory patients monitoring with heart diseases. This device is based on MSP430F5419A and CC2540 (Bluetooth), both from Texas Instruments and the modem SIM908 from Simcom, which includes GSM/GPRS and GPS modules.

The developed device includes a TFT display of 256k colors and a resolution of 320 240 pixels. This display show all indications of the device like: four levels of coverage, four levels of the battery status, current time, Bluetooth status and the connection status. It also allows

visualization of the current ECG signal which is being acquiring in real time. The solution has a matricial keyboard which permit to interact with it and enter information like letters and numbers.

The portable device is powered by a Li-Ion battery of 3.7V, 1020mA, BL-5C. This battery gives autonomy of 48 hours acquiring continuously.

As part of its components, it has an 8MB memory flash, W25Q64FV [8], with SPI interface. This amount of memory is good enough to store 10 different studies with duration of 10 minutes from same patient. This memory is intended to store the acquired ECG signal before to try to transmit it. If there is any problem establishing a connection, the device can try to connect again after a period of 10 minutes and in that way there is no loss of the acquired ECG signal. Figure 1 shows the portable device without its case, which allows seeing all of its internal components. In Figure 1, we can see the display.

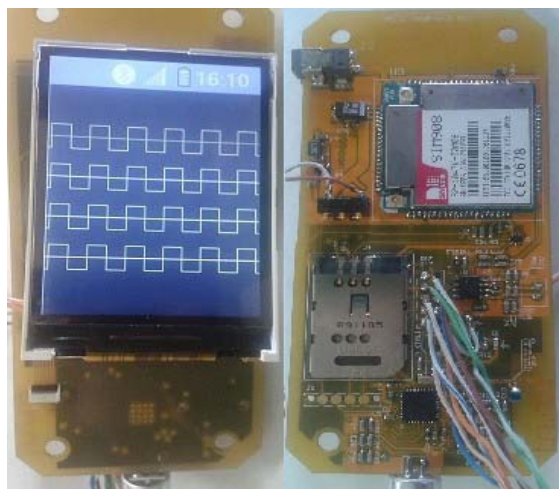


Figure 1. Developed device for patient monitoring with small size dimensions (105mm x 50 mm).

3. Firmware

The main microcontroller of the device is MSP430F5419A, which has an external 12 MHz clock. Its firmware was developed using the real time operating system FreeRTOS [9] because is designed to be small and simple and provides methods for multiple threads or tasks, mutexes, semaphores and software timers which converts it in a powerful option for embedded devices. The MSP430F5419A handles using developed libraries the TFT, the keyboard, the 8MB memory flash and communicates with the modem SIM908. The communication with the modem is done using a MSP430F5419A serial port by means of AT commands. These commands allow configuring all things related to the modem like: level of coverage, configure the volume

of the microphone and earphone. It also allows transmitting and receiving information.

The microcontroller CC2540 receives ECG signal in real time by means of Bluetooth interface integrated on it. This device also has a low consumption. Its firmware was developed using a Bluetooth API stack provided by Texas Instruments and written in C. This API stack has a robust and modular design which facilitates the firmware development. Its main function is receiving ECG signal and transmitting it to the MSP430F5519A via serial port interface. The CC250 wrap the ECG signal in package of 25 bytes according to a defined protocol and once the package is full, transmit them with no delay.

This protocol starts each data frame with the hexadecimal value 55H. It provides a synchronization method with the MSP430F5519A. The frame also includes the digitalized and conditioned ECG signal, lead connection status and information about any pacemaker present.

Figure 2 shows a block diagram of a modular system for patient monitoring, which includes the developed device presented in this paper.

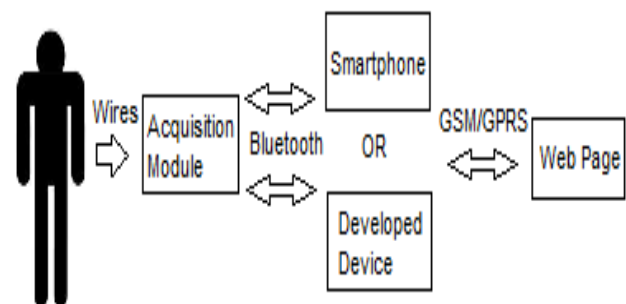


Figure 2. Modular system for patient monitoring.

One of the most important characteristic of this system for patient monitoring is its modularity. It provides independence in each part that it is composed by. There are a lot of smartphones that provide Bluetooth, GSM/GPRS and GPS modules and an application can be developed to acquire and transmit ECG signal. The portable device presented in this paper is an attractive solution to use in systems where low cost is a critical issue. It was intended to be an alternative solution to smartphones so all its components stands out to have low cost and consumption.

Once ECG signal is received by the MSP430F54919, the device try to establish a data connection to any of the predefined phone numbers or establish a communication through GSM/GPRS module.

Over the established connection, the device sends the acquired ECG signal and the GPS coordinates of the patient to a web page, where this information will be analyzed by specialized medical staff. With the goal to permit a closer link between patients and their doctors,

the developed device let the patient receive any kind of feedback information from the doctors by means of a sms or voice call indicating him the best behavior he has to follow.

4. Results

Three prototypes of the presented device in this paper were developed and tested.

A total of 9 standardized ECG signals with different shapes, suggested by IEC 60601-2-25:2011 [10] for testing purpose were applied to the system. The ECG used signals are summarized in Table 1:

Table 1. Print standard ECG signals used for testing.

Name	Testing intervals (min)
CAL20002	3 and 5
CAL20110	5 and 10
CAL20160	3, 5 and 10
CAL20210	3, 5 and 10
CAL20260	3 and 5
ANE20001	3, 5 and 10
ANE20002	3, 5 and 10
CAL05000	5 and 10
CAL50000	5 and 10

The main characteristics of the used signal are:

- The CAL20002 is a RS-wave signal with amplitude $\pm 2\text{mV}$ and 120 bmp.
- The CAL20110 and CAL20160 are R-wave signals with amplitude $\pm 2\text{mV}$, 60 bmp, with ST depression and ST elevation.
- The CAL20210 and CAL20260 are Q-wave signals with the same characteristics of the CAL20110 and CAL20160 signals.
- The ANE 20001 and ANE 20002 are normal ECG signals with amplitude $\pm 2\text{mV}$, 40 and 120 bpm.
- The CAL05000 and CAL50000 are RS-wave signals with frequency of 60 bmp, 0,5 and 5 mV.

All ECG signals were transmitted with different testing intervals according to the Table 1.

These signals were received and transmitted using a protocol which includes a cyclic redundancy code used for error checking.

The entire transmitted ECG signal were received and analyzed in computer connected to internet, which runs the web page application system. There was not any loss

in the received signal.

5. Conclusions

A portable device for patient monitoring has been designed, built and tested by the authors. It provides a low cost solution of communication device which could be used in ambulatory monitoring system where the cost is tight.

The developed device allows receiving and transmitting the ECG signal in a reliable way. The solution offers important options of connectivity like GSM/GPRS and GPS.

Because of the performance, low cost and technical characteristics of the developed device, it could be used as part of this ECG monitoring system.

Also it could be integrated in other physiological monitoring system where the low cost is mandatory.

The proposed developed device has been built and tested with satisfactory results.

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