Embedded Systems

Cristian Rotariu

Dept. of of Biomedical Sciences
"Grigore T Popa" University of Medicine and Pharmacy of Iasi, Romania
cristian.rotariu@bioinginerie.ro

May 2016

Introduction

An embedded system is a dedicated computer system designed for one or two specific functions.

This system is embedded as a part of a complete device system that may include hardware, such as electrical and mechanical components.

Because an embedded system is engineered to perform certain tasks only, design engineers may optimize size, cost, power consumption, reliability and performance.

Introduction

Embedded systems are managed by single or multiple processing cores in the form of:

- microcontrollers
- digital signal processors (DSP)
- field-programmable gate arrays (FPGA),
- application-specific integrated circuits (ASIC)
- gate arrays.

These processing components are integrated with components dedicated to handling electric and/or mechanical interfacing.

Examples of Embedded Systems

1. Embedded System for remote monitoring of atrial fibrillation

2. Embedded System for remote monitoring of SpO2 and HR

ES for Remote Monitoring of AF

Atrial fibrillation (AF) is the most common chronic cardiac arrhythmia;

AF affects about 0.4% to 1.0% of the entire population;

AF increases the mortality rate;

The irregularity of the heart beat intervals can be used for the detection of AF episodes.

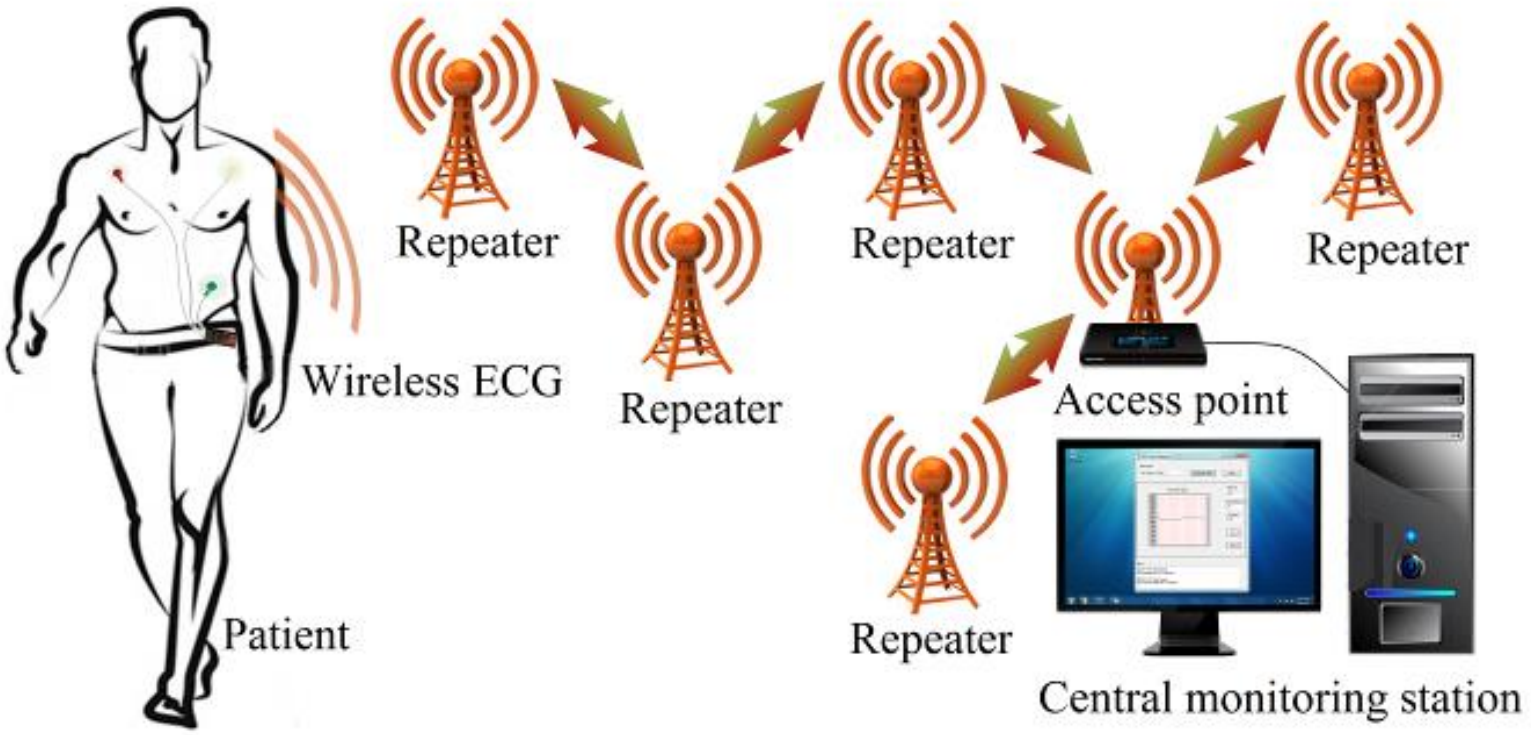
ES for Remote Monitoring of AF

The homecare monitoring of patients represents an alternative to medical supervision within hospitals;

Patient monitoring requires the use of sensors attached by wires to the medical devices, which limits the patient's activity;

ES is based on wireless devices for patient monitoring in a limited area.

ES for Remote Monitoring of AF

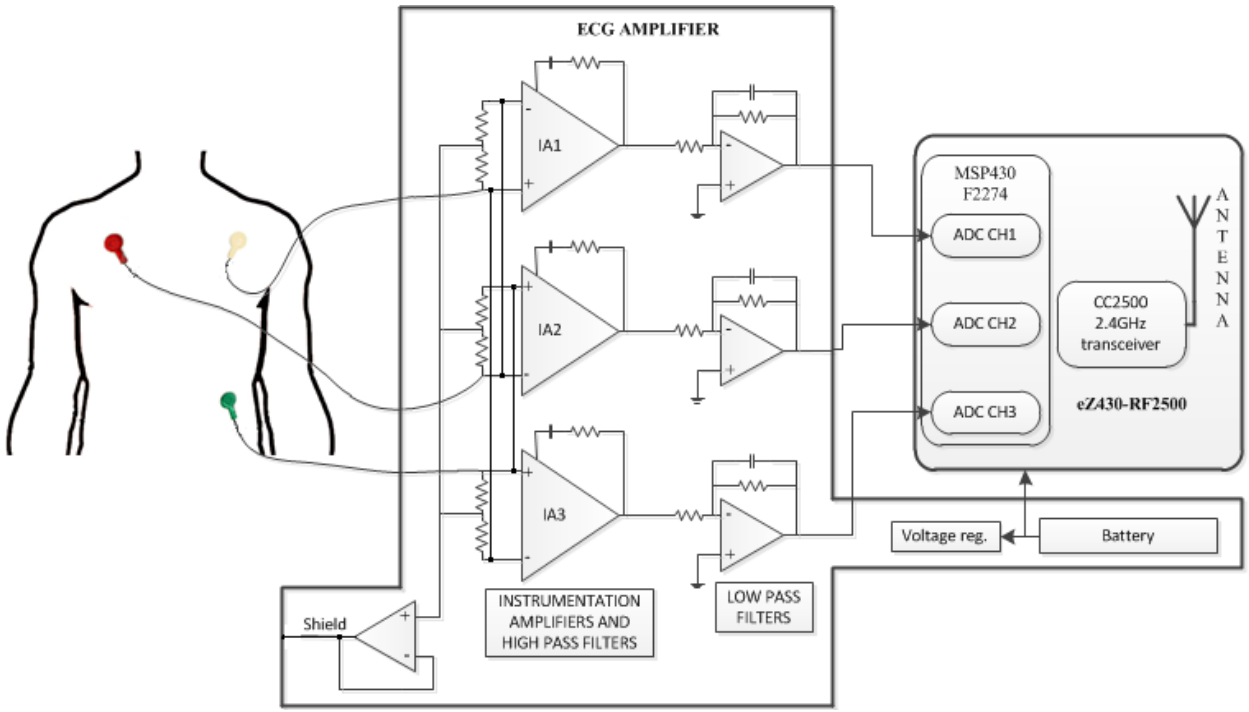


Overall architecture of the system

ES for Remote Monitoring of AF

Wireless ECG device (ES) contains:

- a custom developed ECG amplifier;
- an eZ430RF2500 wireless module.



ECG amplifier connected to wireless module

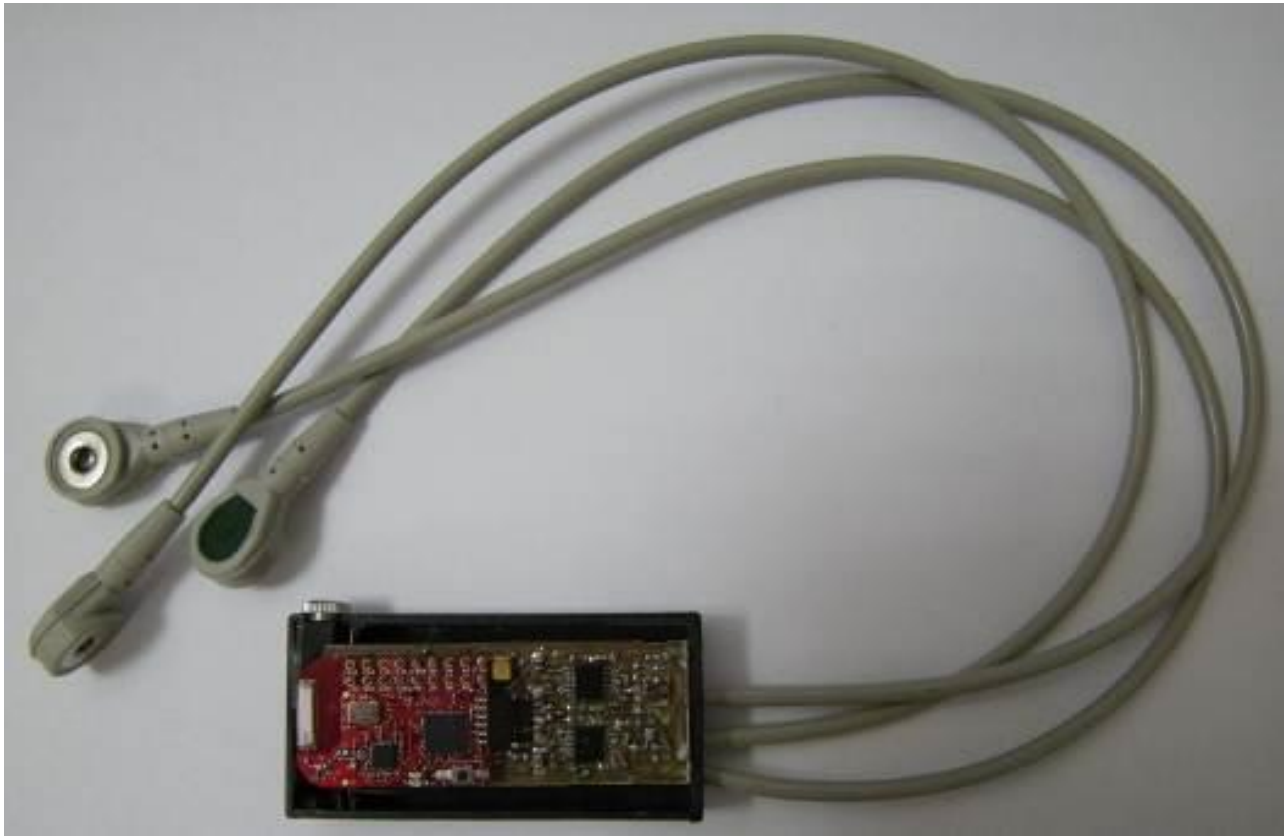
ES for Remote Monitoring of AF

We used the SimpliciTi protocol to transfer data from wireless ECG device to central monitoring station;

The ES was configured as ED, the wireless module connected to central monitoring station as AP, and several others are configured as RE;

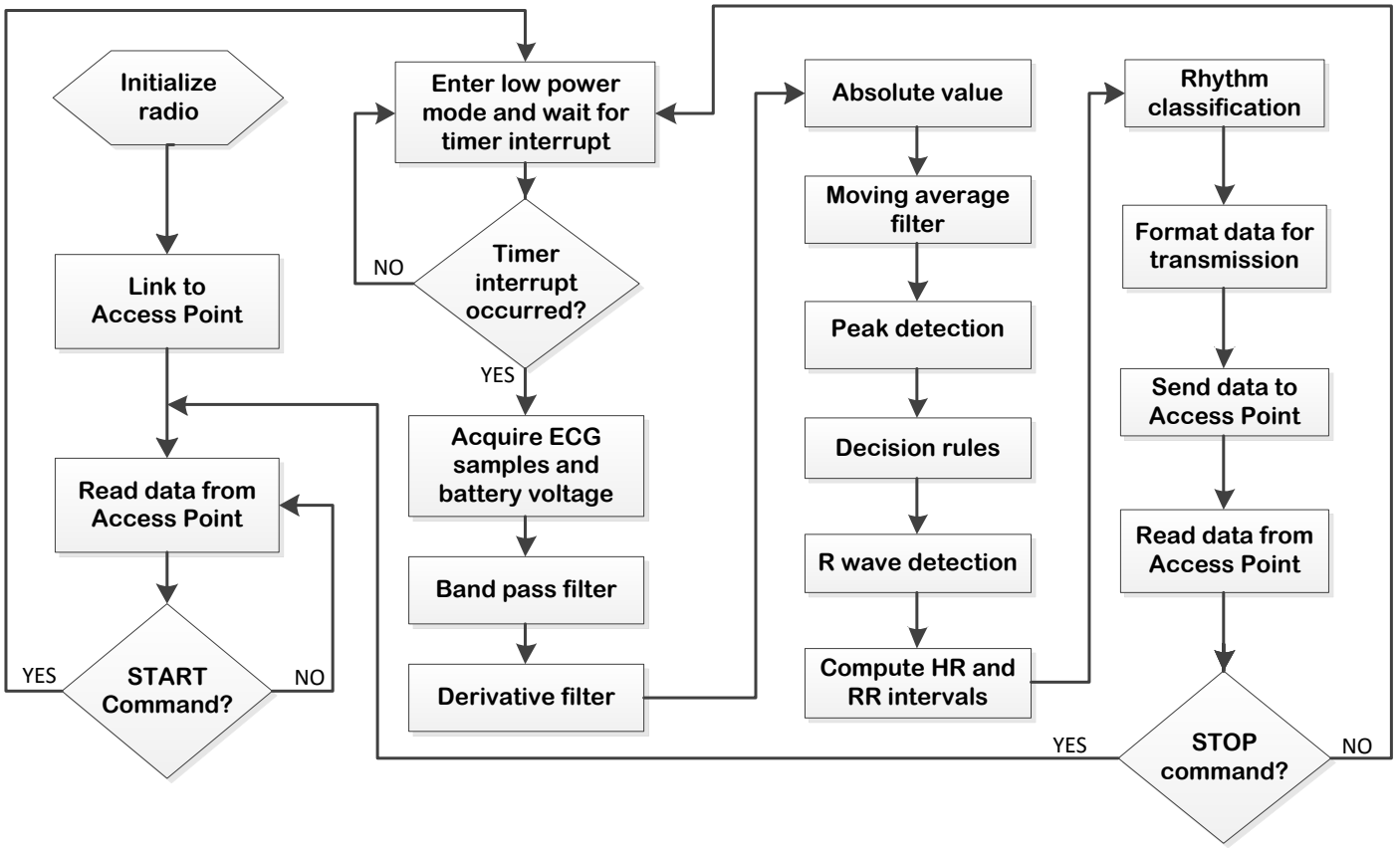
Data transmission rate between the ED and AP through RE depends on patient's HR, and usually range from 0.5Hz (for HR = 30bpm) to 3Hz (for HR = 180bpm).

ES for Remote Monitoring of AF



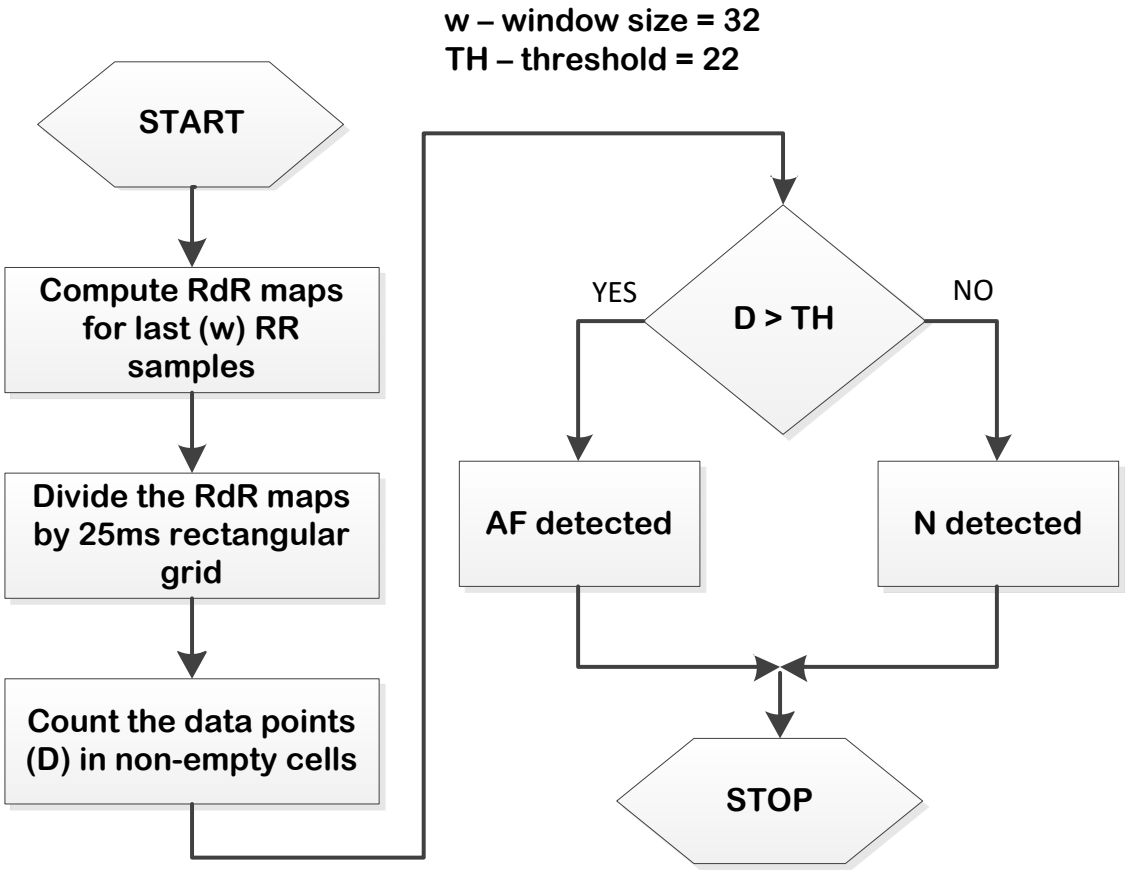
Wireless Embedded System

ES for Remote Monitoring of AF



Flowchart of firmware running on the MSP430F2274

ES for Remote Monitoring of AF

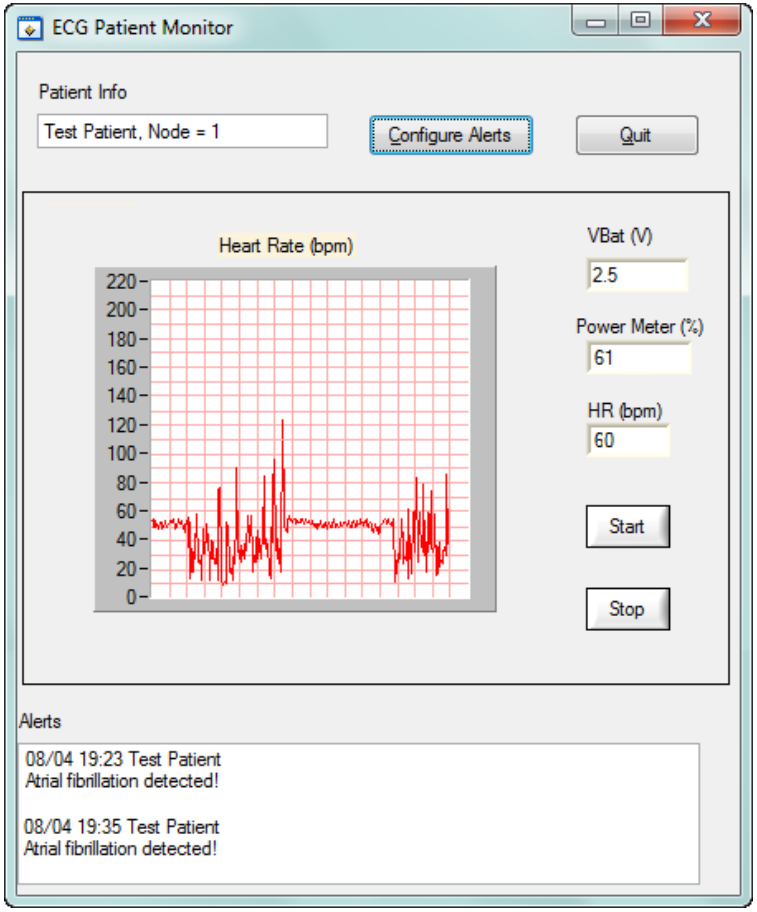


AF detection and rhythm classification

ES for Remote Monitoring of AF

On the GUI are displayed:

- temporal waveform of HR signal;
- the status of each wireless ECG device;
- AF alerts.



Graphic User Interface

ES for Remote Monitoring of AF

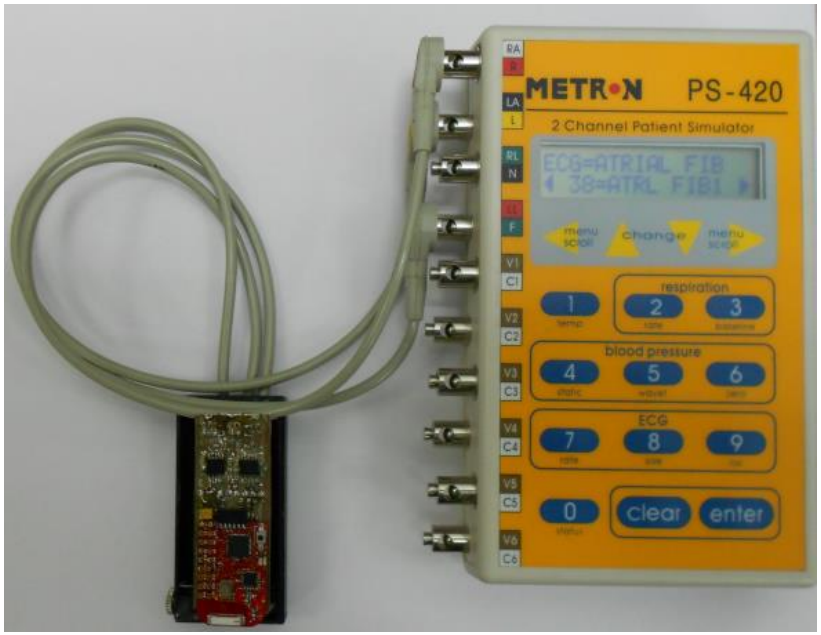
Using a patient simulator we test the accuracy of HR detection method;

The highest heart rate measured by the system is above 280bpm;

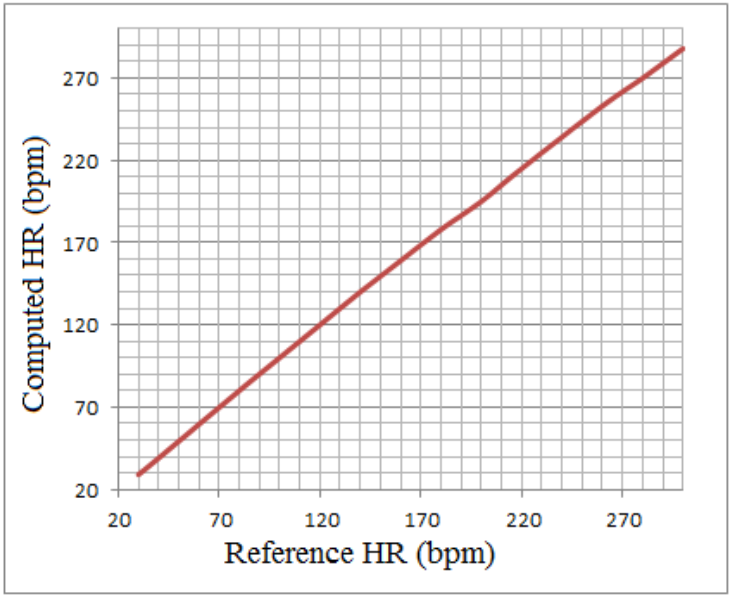
The simulated HR was then forwarded through the to the central monitoring station and the GUI displays the data correctly.

Finally, we tested the AF detection algorithm on MIT/BIH atrial fibrillation database (SE = 90.3% and SP = 91.2%).

ES for Remote Monitoring of AF



ES connected to the PS



Results for different simulated HR

ES for Remote Monitoring of SpO2 and HR

Reliable long term monitoring of patients is useful for a number of medical conditions: heart diseases, sleep-related breathing disorder, patients with chronic diseases;

Oxygen saturation is an important vital parameter, used for detection of hypoxemia;

Heart rate is physiological parameter commonly used by wireless patient monitoring systems.

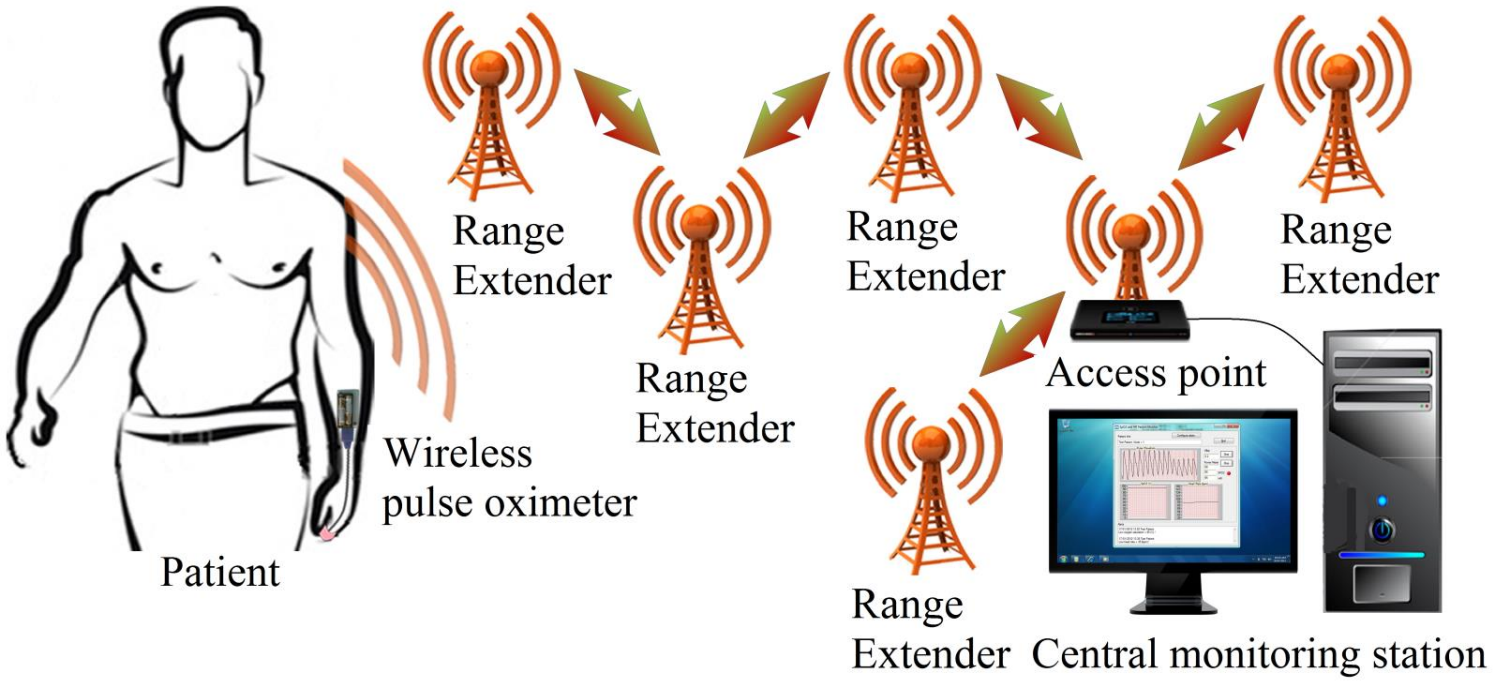
ES for Remote Monitoring of SpO2 and HR

The advances of the IC technology, wireless networks, and medical sensors have opened the way to miniature, low power, and intelligent monitoring pulse oximeters, suitable for many wireless medical applications;

Monitoring patient's SpO2 and HR within hospital or his home requires the use of sensors attached by wires to the medical devices, which limits the patient's activity;

The SpO2 and HR are continuously measured using commercially available pulse oximeters and the results are transmitted to a central monitoring station.

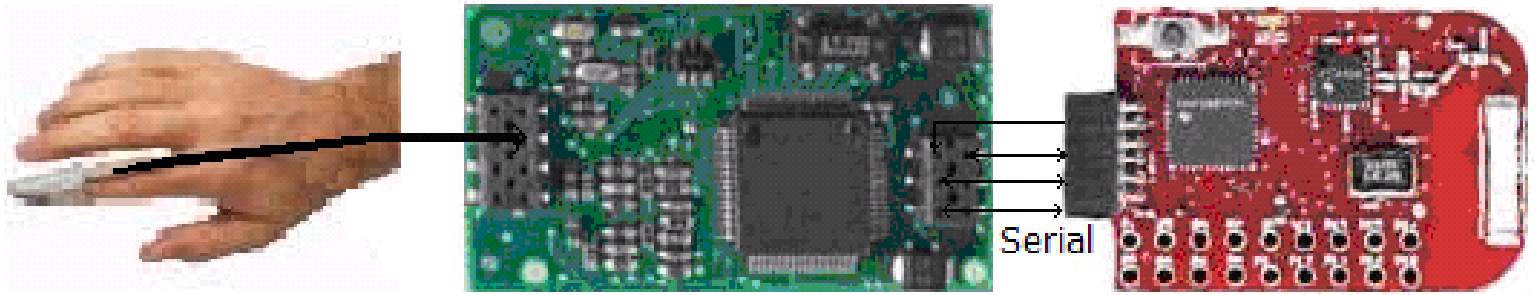
ES for Remote Monitoring of SpO2 and HR



Overall architecture of the system

ES for Remote Monitoring of SpO2 and HR

Each wireless pulse oximeter (ES) contains a commercially available Micro Power Oximeter Board from Smiths Medical connected to an eZ430RF2500 module from Texas Instruments using serial interface;



Micro Power Oximeter Board connected to eZ430RF2500

ES for Remote Monitoring of SpO2 and HR

The pulse oximeter used to collect the SpO2 and HR has the following specifications:

measurement range of 0–99% SpO2 with ±2% accuracy for 70–99% SpO2;

pulse rate measurement range of 30–254bpm with ±2bpm or ±2% accuracy.

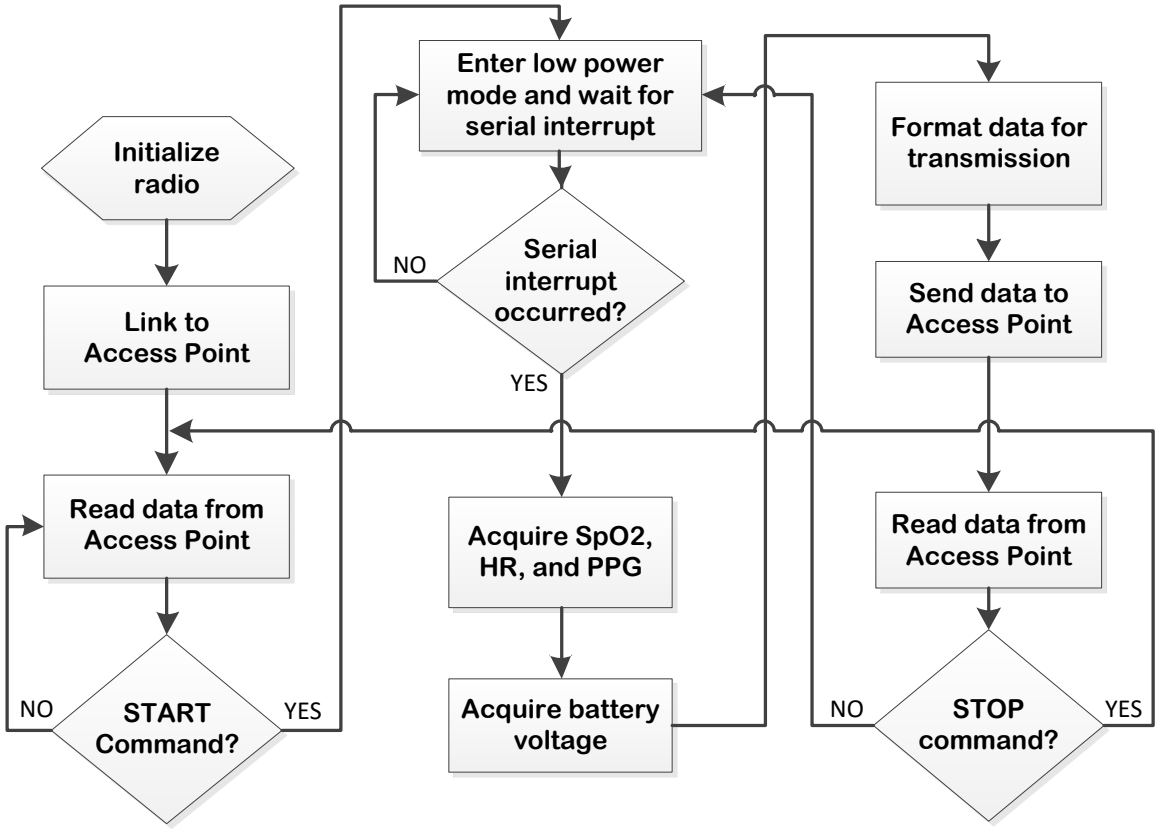
ES for Remote Monitoring of SpO2 and HR

We used the SimpliciTi protocol from Texas Instruments to transfer data from wireless pulse oximeter to central monitoring station;

The ES was configured as End Device, the eZ430RF2500 connected to central monitoring station as Access Point, and several others are configured as Range Extenders;

Data transmission rate between the ED and AP through RE was set at one transmission per second.

ES for Remote Monitoring of SpO2 and HR

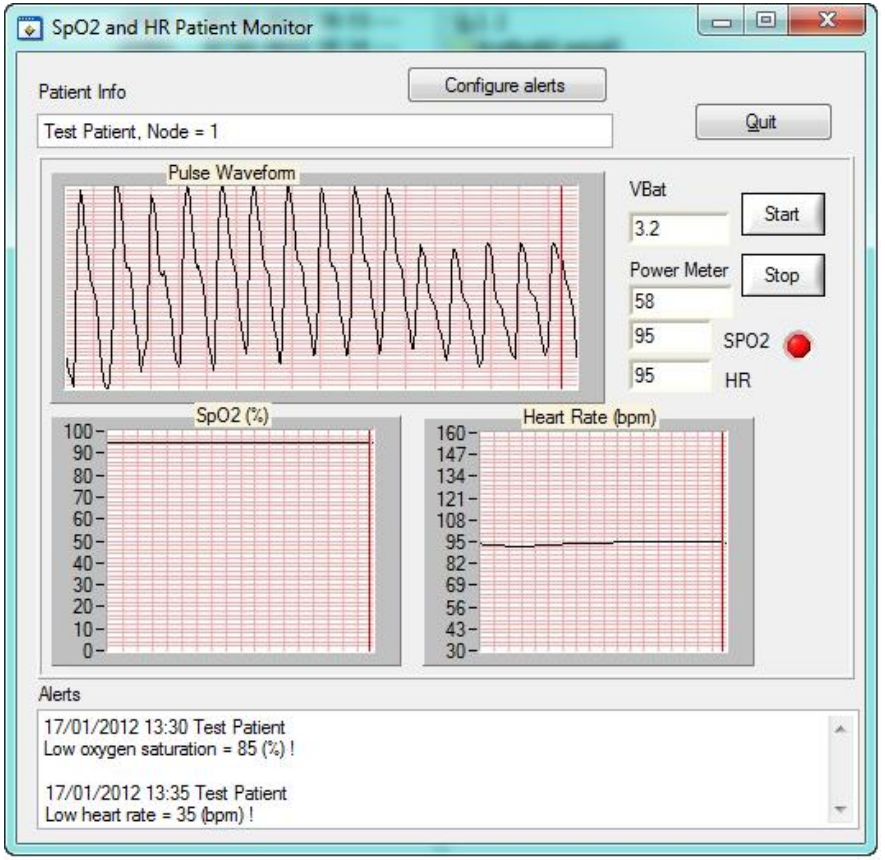


Flowchart of firmware running on the MSP430F2274

ES for Remote Monitoring of SpO2 and HR

A user-friendly Graphical User Interface has been developed;

Temporal waveform of SpO2, HR, PPG, and the status of ES;



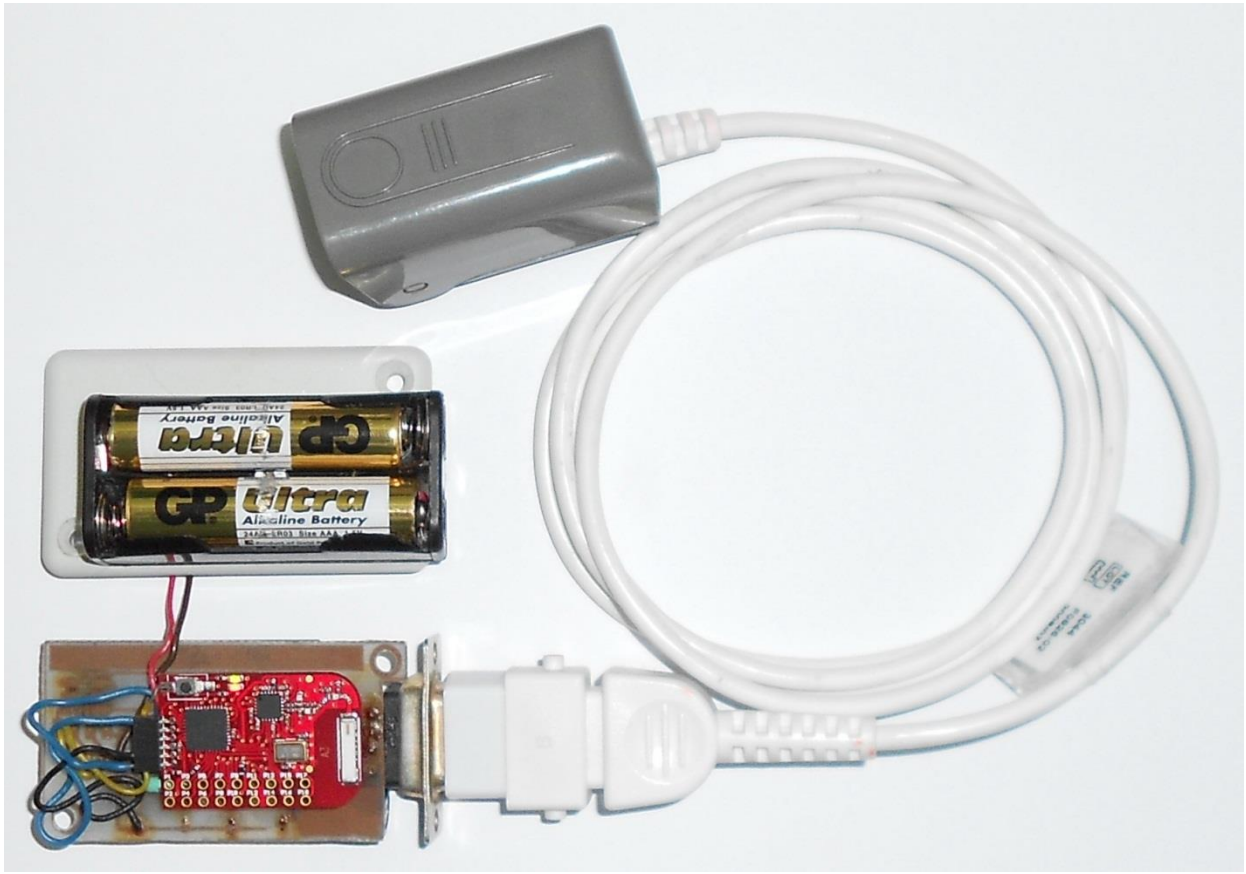
Graphic User Interface

ES for Remote Monitoring of SpO2 and HR

The physiological conditions that cause alerts are:

- low SpO2 if SpO2<93%,
- bradycardia if HR<40bpm,
- tachycardia if HR>150bpm,
- HR arrhythmia if ΔHR/HR over last 5 min.>20%,
- HR variability if max HR variability>10% /the last 4 readings,
- low battery voltage if VBAT<1.9V, low value for RSSI if measured RSSI<30%.

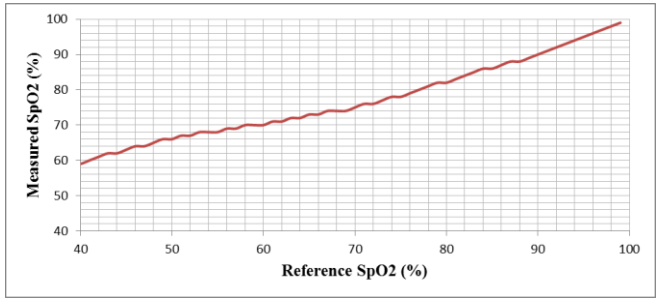
ES for Remote Monitoring of SpO2 and HR

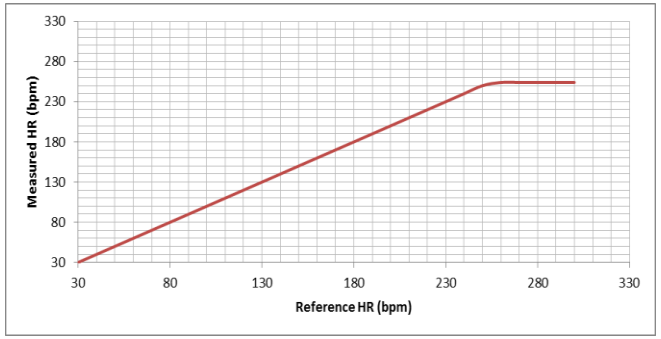


Wireless Embedded System

ES for Remote Monitoring of SpO2 and HR

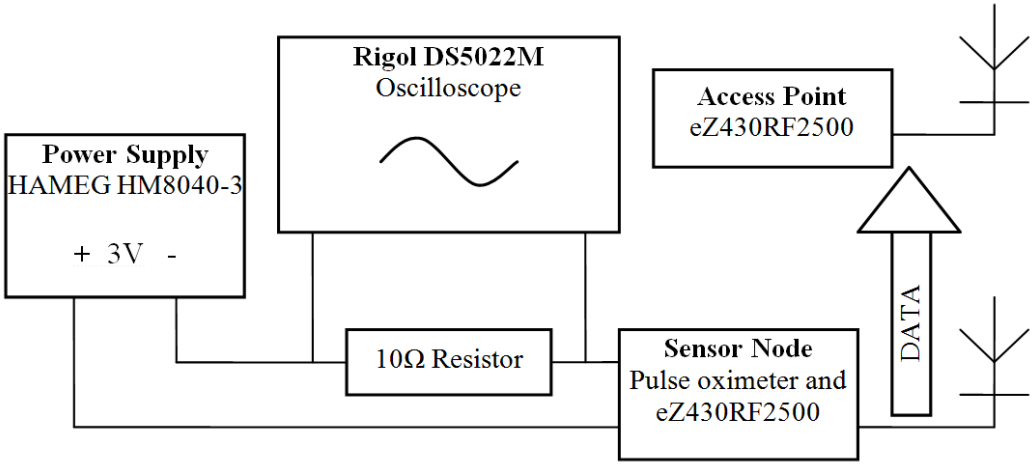
ES test hardware





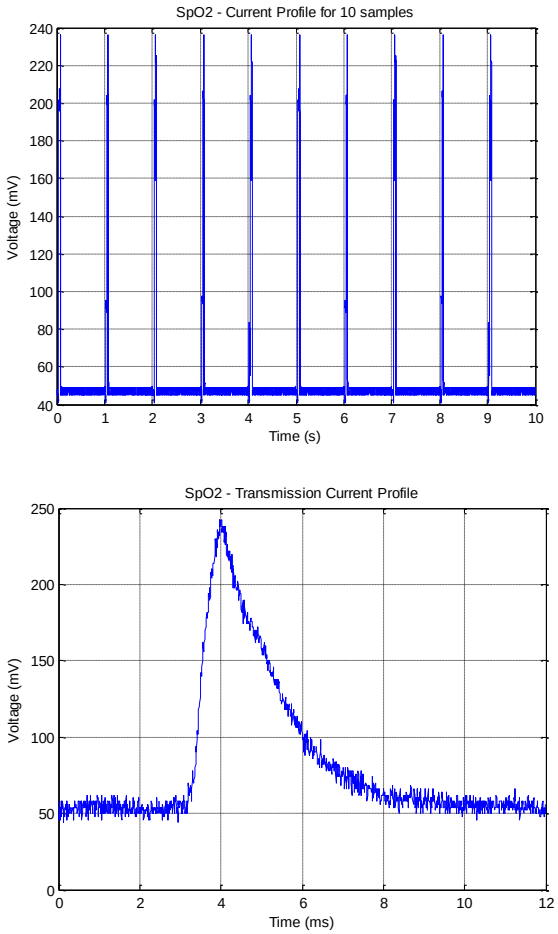
Test results

ES for Remote Monitoring of SpO2 and HR



ES test hardware

To calculate the average current consumption for the ES, the voltage curve has been acquired and Matlab computed the average current, obtaining a value of 6.1mA



Test results

Conclusions

The described ES allow patients to be monitored:

- from a remote location;
- preventive or after major medical events;
- within their home, as an alternative to medical supervision in hospitals.

References

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