Real time patient monitoring system

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***Abstract*—In the following document is described the development of a wireless temperature and heart rate tracking system ,with alarm, controlled by two microcontrollers ATmega328P (Arduino UNO). Systems for monitorization that are in use nowadays works in offline mode but this system is designed in a matter of way that a person can be monitored in real time and remote. The entire ensemble is formed of two sensors which measures body temperature respectively heart rate of a patient, one button and one buzzer, entirely controlled by microcontrollers, with real time operating system running on them. Both values are printed on an liquid-crystal display which have the role of HMI. This device could be made available at a decent cost with appreciable effect.**

I. Introduction

Nowadays, technology provides us a lot of new methods to communicate or exchange information. So, the use of wireless technology is suitable to control and monitoring from afar. RPM (Remote patient monitoring) is a technology that can help us to monitor a patient when he or she is not present in the hospital. With RPM, this project purpose is to saves time of both patient and doctor, increasing the efficiency of health services. Two major signs that are very often measured by medics after the arrival of a person for consultation are heart rate and body temperature. Heart rate is referring to number of times that a heart contracts and relaxes in a unit of time (per minute). For a human adult, a normal resting heart rate is approximate 72 beats per minute (bpm). Like heart rate, normal body temperature also varies from person to person and changes throughout the day. For example in the early morning body temperature is lowest and highest in the early evening. The normal body temperature is around 37°C / 98.6 °F. The range of temperature for human body is 97 to 100 degrees Fahrenheit or 36.1 to 37.8 degrees Celsius. These two collected data are send to a remote terminal where the information will be displayed on an user interface. Medical personal will be able to have a minimum idea about him/her health status. This device would be very useful during an emergency time or for saving time of both patient and medic. [1]

II. BRIEF DESCRIPTION

This remote patient monitoring system include two important parts: data sending and data receiving modules. The transmission module consists of one button, to trigger manual the alarm if the patient is in danger, temperature and heart beat sensors to senses the changes in the respective person physiological parameters. The collected data are processed by the microcontroller. After that, these information are being transmitted to the second main component, the receiving module. The hardware component responsible for transmission, via wireless, and also for receiving is the nRF24L01 module, so we find this component in both system components. The receiving component is composed of another microcontroller, an LCD 16x2 to display the monitored data from the patient and a buzzer, used for the alarm case. The I2C communication protocol is used to interface the Arduino board with the LCD.

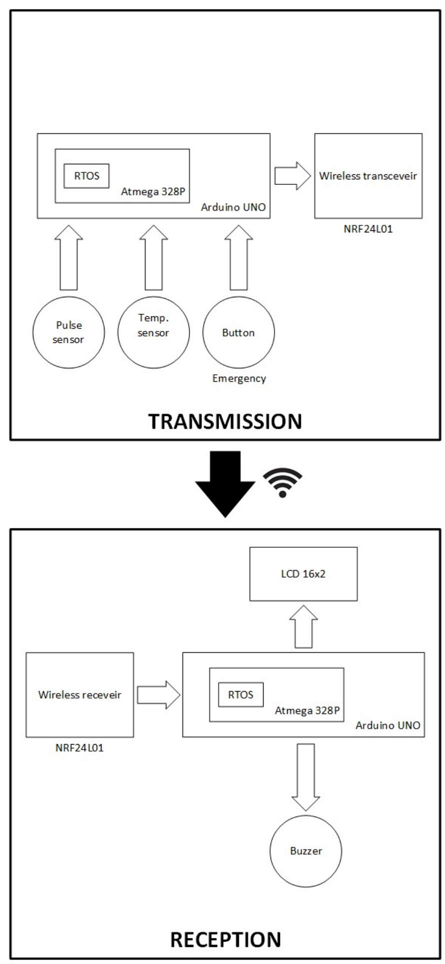

Fig. 1. System architecture

III. Hardware architecture

In this section, will be presented the used components and the outline hardware architecture. Like in the previous section, will be present the electronic components and physical connections, first time for the transmission subsystem, then for the receiving one.

A. Transmission subsystem

ELECTRONIC COMPONENTS

- Arduino UNO R3
- Temperature sensor LM35
- Heart rate sensor
- Button
- nRF24L01 Module

B. Receiving subsystem

ELECTRONIC COMPONENTS

- Arduino UNO R3
- LCD 16x2
- Buzzer
- nRF24L01 Module

The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller. This chip is the brain of the entire ensemble. It's main responsabilities in this project is to host the RTOS, convert the analog inputs via ADC, read the digital inputs, send data to the receiver. [2]

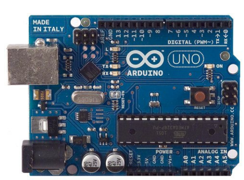

Fig. 2. Arduino UNO

LM35 is a precession integrated circuit temperature sensor, whose output voltage varies, based on the temperature around it. It is a small and cheap IC which can be used to measure temperature anywhere between -55°C to 150°C. It can easily be interfaced with any microcontroller that has ADC function or any development platform like Arduino. In this project this sensor is used to monitor the patient body temperature. [3]

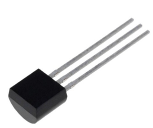

Fig. 3. Temperature sensor LM35

Pulse Sensor is a plug-and-play heart-rate sensor for Arduino and Arduino compatibles. Pulse sensor adds amplification and noise cancellation circuitry to the hardware. It's noticeably faster and easier to get reliable pulse readings. Like LM35 this sensor can easily interfaced with any microcontroller that has ADC function. Pulse sensor works with between 3V and 5V. The pulse detection module shows a cavity for measurements, and is composed of one LED and one photoresistor (LDR). Patient's finger is placed between LED and LDR, and the heart pulses are detected. After that, the analog voltages are processed with an operational amplifier. Result is displayed on the LCD. [4]

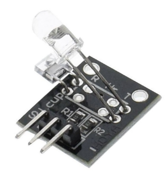

Fig. 4. Pulse sensor KY-039

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, also his role in this system, timers. [5]

Fig. 5. Buzzer

An LCD (Liquid Crystal Display) screen is an electronic display module and has a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. [6]

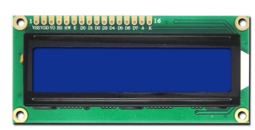

Fig. 6. LCD 16x2

nRF24L01 is a single chip radio transceiver for the world wide 2.4 - 2.5 GHz ISM band. The transceiver consists of a fully integrated frequency synthesizer, a power amplifier, a crystal oscillator, a demodulator, modulator and Enhanced ShockBurst protocol engine. Output power, frequency channels, and protocol setup are easily programmable through a SPI interface. Current consumption is very low, only 9.0mA at an output power of -6dBm and 12.3mA in RX mode. [7]

Fig. 7. Wireless module nRF24L01

C. Electrical diagram

The hardware design was build in Proteus Design Suite.

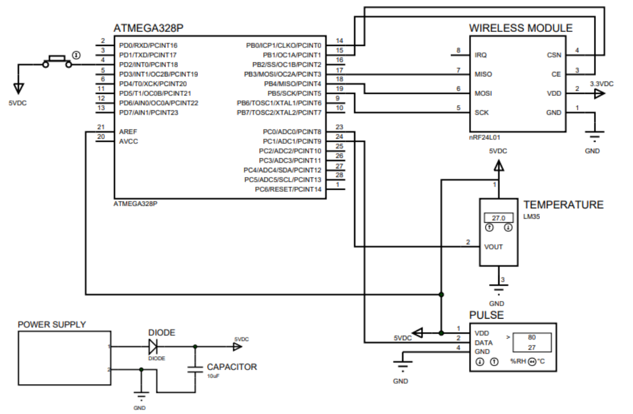

Fig. 8. Transmission subsystem schematic

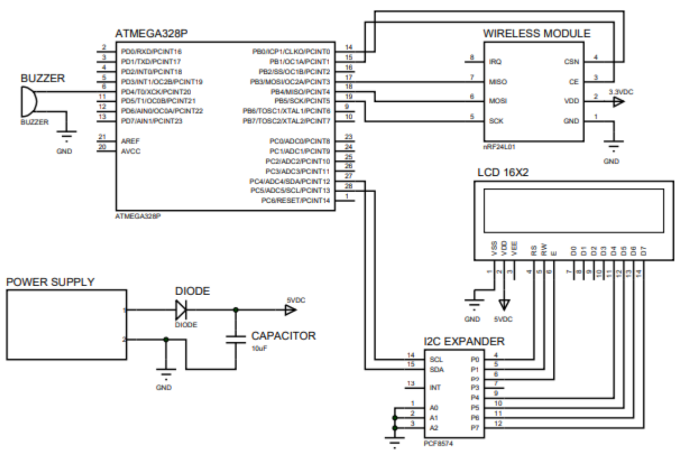

Fig. 9. Receiving subsystem schematic

IV. Software Architecture

The entire control algorithm is described via the organizational charts from Fig. 10 and Fig. 11. For both transmission and reception, in this project, is used the finite-state machine model.

A. Organizational chart

First diagram, Fig. 10, is composed by one initial state for initialization, continued by four other states, representative for each task used in code.

The second one, for reception, is composed also from one initial state, followed this time by two states and one decision block which lead to another state or return to first one.

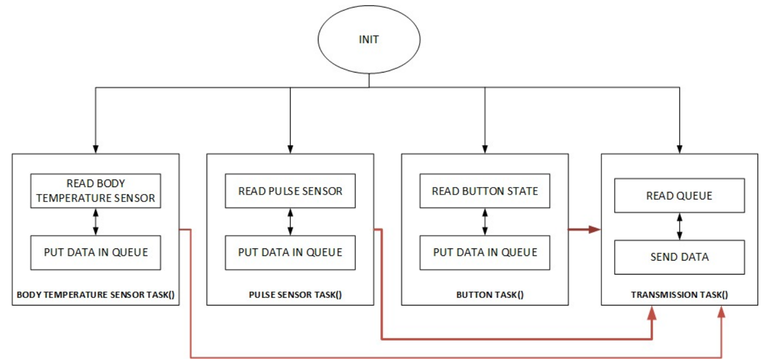

Fig. 10. Organizational chart for transmission

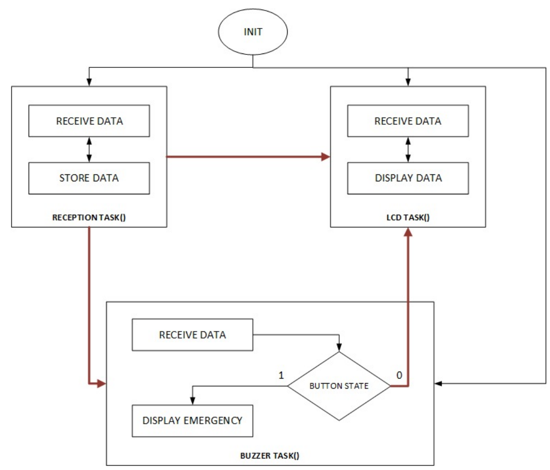

Fig. 11. Organizational chart for reception

B. Real-Time Operating System

Like the a lot of devices related to medical field, this project is a time critic and time dependent one. According to this, an RTOS is very suitable for this application. For the used microcontroller in this project the most fitting OS is FreeRTOS because of it is very compatible with AVR architecture. Few characteristics of this library are:

- FreeRTOS is designed to be small and simple.
- The code is readable, easy to port, and maintainable, written mostly in C.
- Provides methods for multiple threads or tasks, mutexes, semaphores and software timers.
- Thread priorities are supported. [8]

V. Results

After the experiments were made, the notable results are:

A. Transmission

Good points:

- The connection between nRF24L01 modules is very prompt.
- The received data is accurate.
- nRF24L01 is using the medical field radio bands (ISM)

Bad points:

- The module is using too many pins of the microcontroller.
- The distance of transmission is pretty reduced if obstacles like walls are encountered. In an ideal case the maxim range is approximately 100 meters.

B. Temperature Measurement

Good points:

- Pretty accurate sensor, after the conversion of data(-0.5/+0.5°C).
- Only one wire for data.
- Temperature changes detection time is very short.

Bad points:

- Can not be found for this application.

C. Heartbeat Measurement

Good points:

- Fast detection.
- We use only one wire for data.

Bad points:

- Very sensitive at external interventions.
- Hard to develop software for it without research about heart functionality.

Fig. 12. Temperature and heart rate

D. Alarm

Good points:

- The relation between the button and the buzzer works as expected.

Bad points:

- Transmission causes very short delay.

Fig. 13. Alarm

VI. Conclusion

Patient health parameters, temperature and heartbeat, are monitored wirelessly using nRF24L01 with success. Emergency alarm is very useful and works very precisely. The data measured was displayed successfully using the LCD. The RTOS is very helpful in this system because, task scheduling gives the illusion of executing a number of tasks simultaneously, so the dates are processed, transmitted and received very fast. The wireless communication offers mobility to the equipment and because of that the costs are reduced.

VII. Future Applications and Developments

- Data sending to Cloud, so the information can be analyzed from anywhere.
- The collected information can be sent to smartphones using a GSM module.
- More parameters (like EKG) can improve the functionality of the device.

VIII. Figures and Tables

A. Tables

TABLE I
Abbreviation Table

Abbreviation	Word
LCD	Liquid crystal display
RPM	Remote patient monitoring
bpm	Beats per minute
C	Celsius
F	Fahrenheit
I2C	I-squared-C
V	Volts
A	Ampere
RTOS	Real time operation system
ADC	Analog-digital converter
GHz	Gigahertz
ISM Band	Industrial, Scientific and Medical Band
dBm	Decibel-milliwatts
PC	Personal computer
EKG	Electrocardiography
LDR	Light-dependent resistor

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