IMPLEMENTATION OF THE BLUETOOTH WIRELESS COMMUNICATION USING THE FINITE STATE MACHINE

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Abstract

In this paper is described software implementation of the Bluetooth wireless communication using finite state machine. This implementation is a part of project which is focused on long term vital sign monitoring. Bluetooth technology is highly usable in assistive technology and Ambient and assisted living. Bluetooth is used for wireless transfer of measured signals and preprocessed data from sensors to control PC and other devices. The state machine which is used for controlling Bluetooth wireless module provides very robust software implementation for real-time applications in embedded devices with microprocessors.

Keywords

Bluetooth, finite state machine, embedded device, serial communication

Introduction

The assistive technology and Ambient and assisted living (AAL) have very high importance to improve quality of life. These technologies are usually focused on seniors. The long-term vital signs monitoring and telemedicine is one part of AAL technologies [1].

The Bluetooth standard has very wide options of applications. Many devices of daily use using Bluetooth wireless connection and therefore this standard is suitable for the Smart Homes applications.

The conventional Home Appliance can be networked and controlled via Bluetooth connection [2, 3]. The next application is used Bluetooth transmission for various types of signals from sensors, for example biosignals, in Smart Home. This data could be used for data fusion to detect risk situations [4, 5].

Moreover very important part of Smart Homes is vital sign monitoring systems. These systems are used for measuring biosignals like ECG, PPG, physical activity and so on. Also next functionality of these systems is detection and evaluation life threatening situations [6, 7].

The signal and data transmission is one very important part of vital sign monitoring systems. The Bluetooth technology is suitable to implement wireless transmission. These systems should have very low power consumption and computing demands [8].

The real-time signal processing and data transmission (processed in seconds) are also desired.

The right software implementation of controlling the communication between data transmission module and microprocessor is required in the type of application.

Whereas the controlling of many Bluetooth modules is done by UART interface, the finite state machine is our solution to control it.

On the other hand case program statement could be used this implementation but it isn't enough clear program code.

This article describes one of possibilities to very easy and robust implementation of the finite state machine to real-time system.

Hardware description

Described software implementation is done on the STM32F100RB that is microprocessor (microcontroller) from STMicroelectronics with ARM Cortex-M3 core. It is a 32-bit microprocessor that can be used for highly deterministic real-time applications and its product family contains many various types as low cost, high configurability and big performance. The easy to buy and low cost STM32 VL Discovery development kit is used and contains described processor. On the STM32 VL Discovery development kit are available almost all pin of microprocessor [9].

The photography of the development kit is displayed in the Figure 1.

The Bluetooth Wirefree KC-21 Serial module is used for wireless data transfer with a PC. It looks like a transparent asynchronous serial port (UART) from microprocessor site. It is used a standard Serial Port

Profile (SPP) that emulates RS-232 interface transferred over Bluetooth.

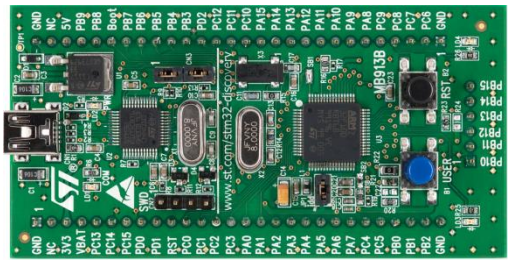

Fig.1: STM32VLDiscovery development kit with the ARM CORTEX M3 microprocessor [9].

The module UART interface supports baud rates from 1200 kbps to 3 Mbps, 3 wire (GND, TX, RX) or 5 wire (moreover CTS, RTS) interface and maximum wireless range is 10 meters. The photography of the Bluetooth module with KcSerial Wirefree chipset is displayed in the Figure 2.

The whole hardware was placed and connected using the non-solder contact field. These components were selected because the software implementation will be used for next extension of the modular development telemonitoring system [10] and board with Bluetooth module is designed as part of this modular system.

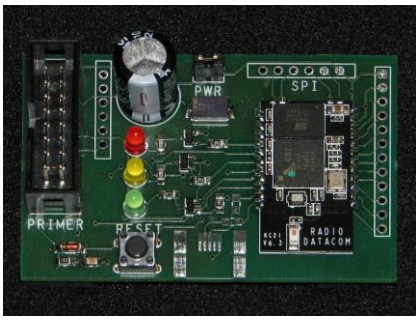

Fig.2: Wireless communication Bluetooth module with the Wirefree KC-21 Serial chipset.

Software description

The communication between Bluetooth module and microprocessor is realized by the principle of a finite state machine which is reliable and easy to implement than much complicated programs.

The finite state machine is a mathematical model of computation used to design both computer programs and sequential logic circuits. It is conceived as an abstract machine that can be in one of a finite number of states. The machine is in only one state at a time. It can change from one state to another when initiated by a triggering event or condition. This is called a transition [11].

State machine implementation

In this project was used the very easy and platform independent software implementation of the finite state machine in the C programming language.

There is one structure in one FSM that contains FSM variables and data for communication between states, for example current state, next state, UART baudrate and so on. Local variables of the states are declared in state functions. Every function represents one state. There are standard C functions and variable like current state is declared as type pointer to function.

The every state has also defined three events: Entry, Do and Exit. These events are executed when the state function is called. Event Entry and Exit are called once when entering and exiting from the state. Event Do is called repeatedly when the program still remains in the same state. The transitions between states are done by changing function pointers in global FSM structure.

Implementation more FSMs in one program is possible to simulate parallel behavior of the system. Different FSMs run time periods can be set different FSMs priorities.

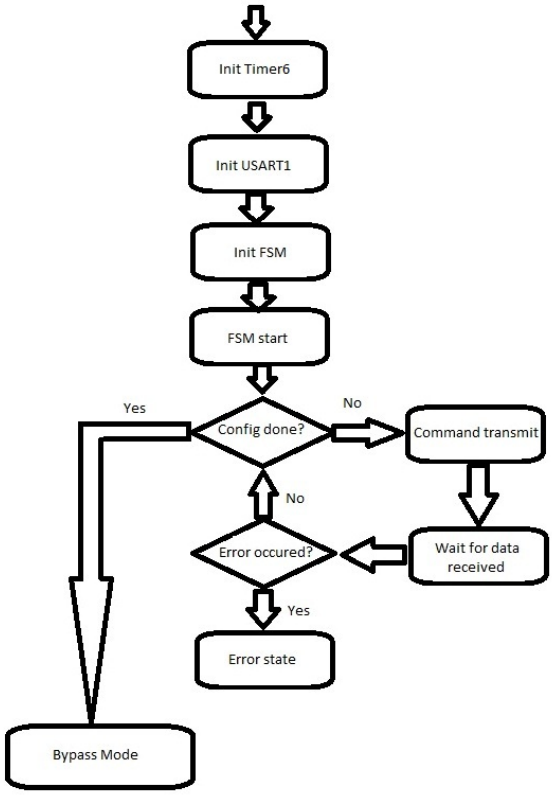

Fig.3: Microprocessor program state diagram

Main program implementation

After the start of microprocessor, one of basic timers and UART peripheral are initialized. The timers are used for detection of the missed responses from Bluetooth module. The UART baud rate is set to 115200 kbps. This is default baud rate value of the

Bluetooth module. There is used a firmware both in version 2.4 and 3.0 for the module, so microprocessor has to be able to recognize used firmware.

After initialization of microprocessor, Bluetooth module is in the Command mode where all received configuration commands are executed. The state machine starts and switches between "transmit", "receive" and "switching" states until all of the configuration commands are transmitted. When it is done, the Bluetooth module is switched into Bypass Mode and the user data are transmitted between PC and microprocessor over Bluetooth [12].

If any error is occurred during configuration, state machine jumps into error state and whole configuration procedure has to be repeated.

In the Figure 3 is displayed the state diagram of the program.

Conclusion

The software implementation of the Bluetooth wireless communication on ARM microprocessor has been designed and realized.

The control communication between microprocessor and Bluetooth modules was done by using simple and reliable state machine algorithm. The robust and simple algorithm is suitable for other implementation in real-time embedded systems.

This program will be implemented in the control unit of the modular telemonitoring development system which is using the ST ARM family microprocessor.

The whole system with wireless Bluetooth data transfer will be used for research in long-term real-time monitoring of vital signs in Smart Home.

Moreover, simplicity of the finite state machine algorithm and data structure provides the easy way to use it to communication between microprocessor and other external devices like Bluetooth, Wi-Fi and GSM modules.

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