Application and research of Bluetooth technology in the development of the portable device for the evaluation of myodynamia

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***Abstract*—The portable device for the evaluation of muscle strength based on Bluetooth technology is developed in this research, which consists of muscle strength sensor, MSP430F149 microcontroller system, Bluetooth communication module and PC. The muscle strength of the limbs and other different parts of trunk in human body can be measured and evaluated within 0~500N. Bluetooth communication module can realize data transmission from muscle strength sensor to PC within 10m. This device has the merit of low power, simple architecture, easy to operate, etc., which can provide quantitative analysis in the rehabilitation of muscle function in clinic.**

Keywords: Bluetooth technology ; Wireless transmission ; MSP430 microprocessor; Evaluation of muscle strength

I. INTRODUCTION

The inspection of myodynamia is the basic checking method of the musculoskeletal system and nervous system's lesions. Especially, it's very important to evaluate the weakness of muscle caused by peripheral neuropathy. It has a great significance in neurology, neurosurgery, orthopedics, sports medicine and rehabilitation departments. Clinically, the most commonly internationally recognized evaluation method is so called MMT (Manual Muscle Test). Although MMT is easy to operate, its classification is relatively rough, and often accompanies with errors of subjective evaluations from operators. Furthermore, force measurement devices are relatively simple to operate, such as dynamometer or pinch strength meter, which can only measure hands' myodynamia, and it also has greater measurement error. Some good equipment for measurement and training of myodynamia, such as Power Track II, Computer Interfaced Manual Muscle, Tracker Freedom Wireless Muscle Testing [1-3], etc., are too expensive and complicated in operation to be extended and applied in clinical field.

With the development of communication technology, the short-range wireless communicating technologies represented by Bluetooth technique are constantly penetrated in the healthcare industry, which makes the development of medical device more and more intelligent, miniaturized and networked. As for traditional medical devices, each hardware device is primarily connected by the communicated cable, which is applicable in some occasions, but its complex connection makes much limitation to many applications of medical devices, especially for patients with cerebrovascular disease, who urgently want to have the rehabilitation equipment with the function of both diagnosis and treatments because of their poor muscle function, balanced function and difficulties in movement. Besides, the equipment can send collected data wirelessly to a computer with central control for data processing and quantitative analysis, which provides a scientific basis for the therapeutic program that set up clinically. As Bluetooth technique has features of micro-power, anti-interference abilities, flexible networking, etc. [4], it is an ideal choice to achieve terminal therapy of rehabilitation and the central control system.

II. OVERALL STRUCTURE OF DESIGN

The portable device for the evaluation of myodynamia based on wireless Bluetooth technique is developed in this study. The device is mainly consisted by the muscle strength sensor, MSP430F149 microcontroller system, Bluetooth communication module and PC, which can achieve testing and evaluating of different parts of the limbs and trunk in human body's strength in the range of 0 ~ 500N. And, the Bluetooth communication module can achieve data transmission between dynamometer and PC in the range of 10 m. The device is characterized with low power consumption, simple structure, easy to operate, powerful functions, etc., which can make quantitative analysis for muscle rehabilitating function of the clinical assessment.

The device for the evaluation of myodynamia is designed to reach the requirements of high accuracy, low cost, low power, small size and easy operation. For the above requirements, the device mainly consists of muscle strength sensors, MSP430F149 microcontroller systems, Bluetooth communication modules, PC and other components. After conditioning and amplification, signals that obtained by the sensor are collected in the microcontroller and communicate with PC via the Bluetooth module, the overall structure is shown in Figure 1.

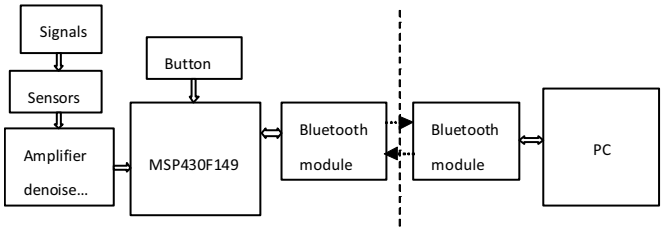

Figure1. Overall structure

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Using the ultra-low power MSP430F149 microcontroller as the core control unit is mainly to control each module's power supply, convert signal of myodynamia to the digital signal and communicate with the Bluetooth module and so on. Task for PC is to complete human-computer interaction function through the Bluetooth module communicating with the MSP430F149 microcontroller. When the device is working, the Bluetooth module of PC will search Bluetooth device, and then establish a connection with Bluetooth module of microcontroller. PC sets appropriate serial port communication parameters, such as COM port, baud rate and other parameters. After setting parameters, PC sends the instruction of shaking hands, beginning or stopping to microcontroller for changing the working status. The system for myodynamia evaluation on PC will process and analyze the data that received.

III. THE HARDWARE DESIGN OF BLUETOOTH COMMUNICATION INTERFACE

Bluetooth data transmission system is actually a Bluetooth wireless modulator. The data sent by the myodynamia dynamometer is processed by the MSP430F149 before transmitting to the Bluetooth module through the UART port. The Bluetooth module converts the data into a special Bluetooth type of signal called RF and transmits wirelessly to PC. Throughout the system, MSP430F149 is the main unit that communicates with the Bluetooth module to complete establishment and management of the Bluetooth link, users' security management, packing and split of the data. The main job of Bluetooth module is to complete each level's functions under the HCI level defined in Bluetooth protocol.

A. MSP430 microcontroller module

MSP430F149 microcontroller is a kind of 16Bit Flash-based processors with much on-chip peripheral, ultra-low power produced by Texas Instruments in United States, low supply voltage, 1.8V ~ 3.6V, 12-bit A/D with internal reference, two serial communication interface (USART), function as asynchronous UART or synchronous SPI interface, dozens of parallel input and output ports with direction configuration and interrupt function. Flexible clock source can make the device reach the lowest power consumption (five types of low-power mode, the minimum standby current is 0.1μA). The oscillator (DCO) controlled by the digital oscillator can make the device wake up quickly from low power mode, and be activated to the working mode in less than 6μs. Taking advantage of the JTAG interface or inner-chip's BOOT ROM in the microcontroller, it can download the program and complete program debugging with the help of a PC and a compact JTAG controller, which is suitable for the functional requirements of the device for the evaluation of myodynamia[5 ~ 7].

In the evaluation of myodynamia, 1-pin and 63-pin of the chip are respectively the positive side and negative side of digital power. 64-pin and 62 pin are respectively the positive side and negative side of analog power. 8 pin and 9 pin are accessed in 6MHz oscillator using as A / D converter and UART communication clock. Except for No. 54,55,56,57 pins being used as four-wire JTAG of functional simulation and Flash download that can not be configured by users, other pins can be configured at will as a general-user pin.

B. BC4EXTA Bluetooth module

BC4EXTA Bluetooth module is a single chip integrated with RF transceiver, the control and management of the baseband, and the main controlling interface protocol of Bluetooth (HCI), which is produced by CSR Co. Its core voltage is 1.8V, input and output port voltage is 3.3V. Hardware and firmware of the module is conformed to Bluetooth specification V2.0. It is built with 8M external Flash memory inside. The maximum transmit power is 5dbm (CLASS2) .It has a USB port ,the UART port, PCM CODEC audio interface, SPI serial peripheral interface and 14 programmable I/O ports. The main chip of Bluetooth reduces the number of external components to the minimum.

C. Hardware implementation

The device for the evaluation of myodynamia uses a small force sensor. The sensor's output is 0 ~ 2.5V, which represents the range of pressure within 0 ~ 50kg .The signals of myodynamia are transmitted into electrical signals by the sensor. After being amplified and denoised, the electrical signals are sent to the microcontroller to convert the analog signal into digital signal. The A/D convertor of MSP430F149 microcontroller uses single-channel single conversion mode, and its internal referential voltage is 2.5V. The ADC is triggered by the time interruption of timer A. Before interruption, ADC completes its conversion, and then the microcontroller reads and packages the data according to the correspondent protocol, and sent to PC by the Bluetooth module.

Bluetooth module uses three UART signal line, as two of them are TXD and RXD, and also uses RTS (flow control signal). CTS port is connected with a 47KΩ resistor to ground, and PIO7 port is used to check the status of Bluetooth connection. MSP430F149 uses UART0 (the serial ports) to be connected with Bluetooth module. Because there is no flow control signal line in UART0, it uses P3.6 as RTS; the specific connection is shown in Figure 2.

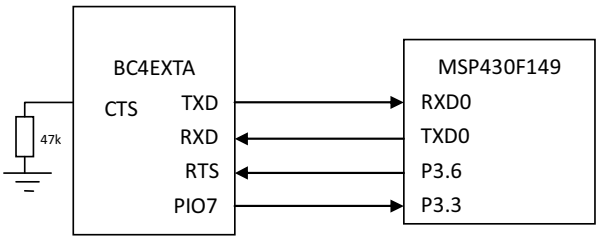


Figure 2.Connection between MCU and Bluetooth module

IV. SOFTWARE DESIGN

The IAR Embedded Workbench Evaluation for MSP430 is applied for integrated development environment to

establish project files of MSP430F149. Collection of signals, processing conversion, sending or receiving control signals, transmitting data are developed in C programming language [8]. The PC software is mainly to send or receive data via the serial ports. Data is sent or received to the portable device for the evaluation of myodynamia through the serial ports. This part of the software is using Microsoft Visual Studio 2010.

The functions of MSP430 microcontroller's software is responsible for system's initialization, and carrying out the instructions given by PC. These instructions include: a. online responding test; b. start data collection; c. stop data collection. The main tasks for Bluetooth data transmission and communication software are to complete initialization of the Bluetooth chip, edit the managing commands of Bluetooth link, establish the link, remove the link and interpret the data. These parts of the functions are realized in the microcontroller of MSP430F149. Therefore, the processing of MSP430's software is to distinguish the instructions given by PC in the main program; and configure the system flag and the internal register, or to call the appropriate subroutine.

Controls of Microcontroller on Bluetooth module is completed with the basic instructions, including the reset of Bluetooth devices, the reading Bluetooth devices, the address initialization, inquire, connecting the link, sending data, receiving data and disconnecting etc. [9]. Data transmission process is as follows: PC-side Bluetooth device scans and pairs the other Bluetooth devices, and the device for the evaluation of myodynamia receives the instructions from PC and changes its status, which realizing the correspondence between PC and Bluetooth module. The work process of Bluetooth to the microcontroller is shown in Figure 3. Figure 4, Figure 5, which respectively shows the main program processing chart of the MSP430 microcontroller and the subroutine processing chart associated with UART.

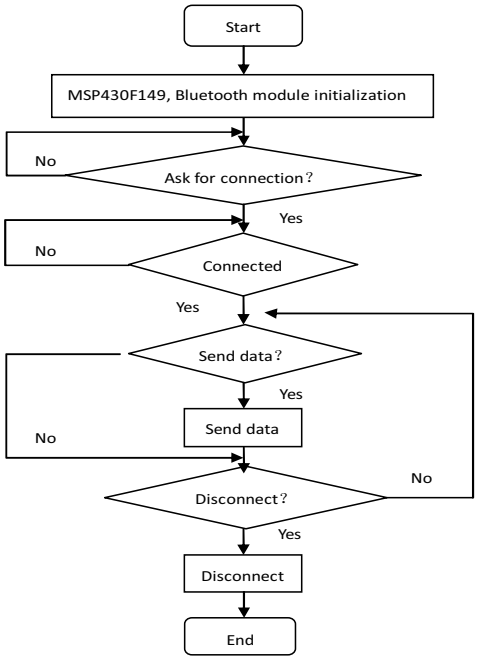
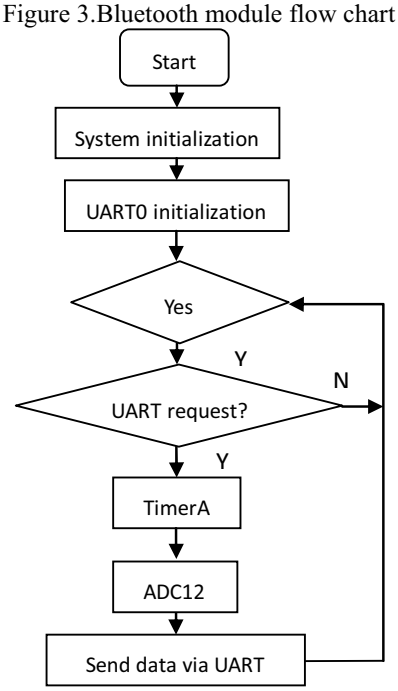
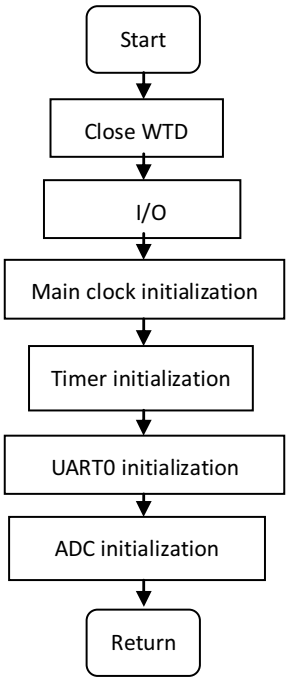


Figure 3.Bluetooth module flow chart



（a）



(b)

Figure 4.Main program flow chart
(a) Main program flow chart; (b) Initialization module

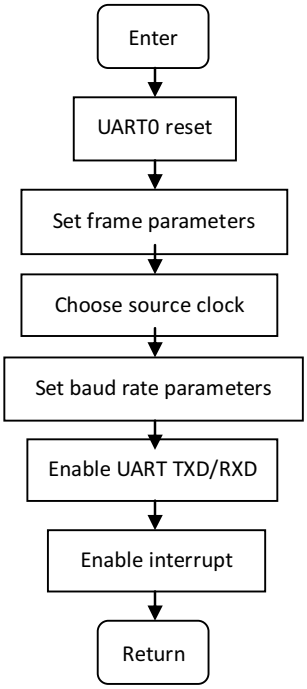


Figure 5.UART setting

Figure 6 shows the measurement result of the device. The Bluetooth module of both microcontroller and PC should be paired firstly before measurement. The sample rate of AD is 20Hz and the baud rate is 115200 bps. The data is filtered and smoothed through the smoothing algorithm of PC. As it shows in the Figure 6, the design meets the requirement.

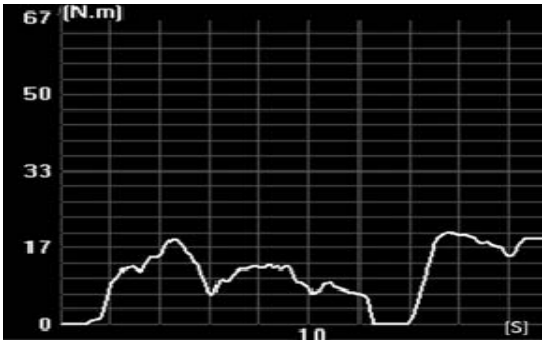


Figure 6.The chart of data collection

V. CONCLUSIONS

The portable device for the evaluation of myodynamia discussed in this paper uses the ultra-low power, high-performance microcontroller (MSP430F149) and Bluetooth communication module, which fully exerts the significant advantages of microcontroller's (MSP430) with peripheral rich resources, low powered consumption and convenient software development environment etc.. Bluetooth wireless technology breaks away from the limitations of power lines and signal lines. It has great signification for the patients who suffer from low myodynamia and disabled in moving function. Currently, studies show that Bluetooth technology used in the medical device are still on the starting phase, but it will have broad application prospects with the development and improvement of network technology.

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