Design of Wearable System for Hand Function Monitoring

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Abstract. Quantitative detection of the status of the injured site of the patient contributes to the assessment of the rehabilitation effect. This paper designs a wearable device based on embedded system, which can get the pressure, temperature and attitude information of the finger parts and send these messages to terminal via Bluetooth communication technology successfully. Experiments show that the system can obtain the finger strength, flexibility, temperature and other information correctly, which can provide objective data for the evaluation of hand function rehabilitation.

Introduction

Hand is the most vulnerable and injured limb in daily life. Stroke is one of the main causes of hand function failure, and hand function is mainly accomplished by flexible and coordinated movements of wrist and fingers. Therefore, it is vital to recover the hand muscle strength, the range of motion of the joint , the coordination and flexibility of the fingers as soon as possible for the patients with hand injury or hemiplegia. During rehabilitation, the muscle strength, posture and other information of the fingers can accurately reflect the rehabilitation state of the fingers, and can be used to evaluate hand function.

Many universities have launched relevant research work, and Hou Wensheng of Bioengineering College of Chongqing University has made some achievements in this field.

The innovation of this paper is to design a wearable finger state detection device, when the device works, sensor is fixed on the fingers to detect the movement posture, pressure and temperature information that contribute to rehabilitation assessment.

Architecture of system

Hand dysfunction in patients with upper limb disability is often characterized by flexion contracture, difficulty in extension of the inter phalangeal and meta carpophalangeal joints, loss of grip, lateral pinch, opposition to the palms and fingers, and other fine motor functions. Based on the above characteristics, this system designed a pressure acquisition circuit and joint angle motion detection circuit, which can accurately detect the clinical features of the patient's gripping, side pinching and range of angular motion of the joint.

The detailed system diagram of the system is shown in Fig.1. As shown, The system is

composed of power circuit, analog front-end and signal conditioning circuit, display circuit and Bluetooth wireless communication circuit.
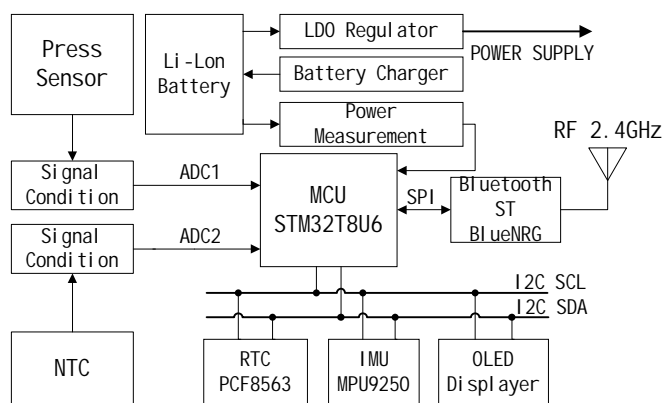

Fig.1 Block diagram of system

Hardware design

1. Temperature and pressure measure module

Appropriate sensors should be choose to achieve skin temperature and pressure measurements. Here high sensitivity Flexiforce pressure sensors and NTC thermistors are chosen as pressure and temperature probes respectively. The varying physical quantity is converted into a voltage signal by a suitable signal conditioning circuit. Because the two sensors are both resistive sensors, the same configuration for signal conditioning circuit can be used, as shown in Fig.2, The sensor adopts constant current source excitation, here REF200 dual 100uA constant current source is used, R1 is precision reference resistor, then Low power instrumentation amplifier AD8236 is used to amplify the differential voltage(magnification of 20 times). The stm32 microcontroller samples the amplified signal via internal 12 bit ADC. Finally, the temperature and pressure data of the skin can be obtained by inquiring the characteristic table of the sensor, and the temperature and pressure measurements can be completed.
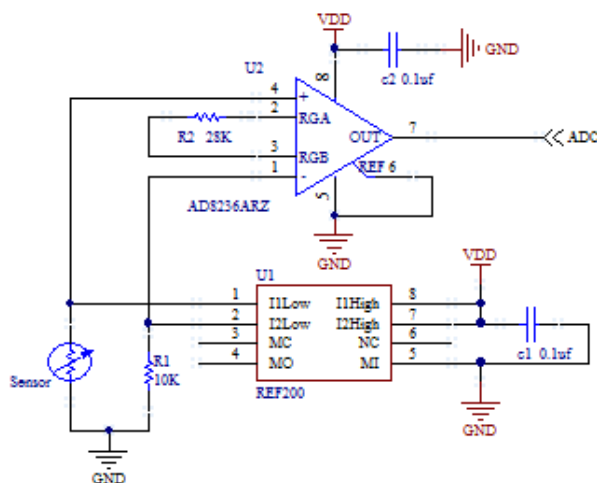

Fig.2 Signal condition circuit of analog front-end

2. Joint angular motion detect module

An angular motion measurement circuit based on gyroscope is designed to complete parameters test of joint angular motion. The 9 axis MEMS gyroscope MPU9250 is selected here. The joint flexibility can be evaluated by analyzing the amplitude and frequency of joint angular motion. The specific circuit, shown in Fig.3, STM32 microcontroller communicates with the gyroscope through the I2C bus to complete the initialization of the chip (range and sampling rate setting) and the
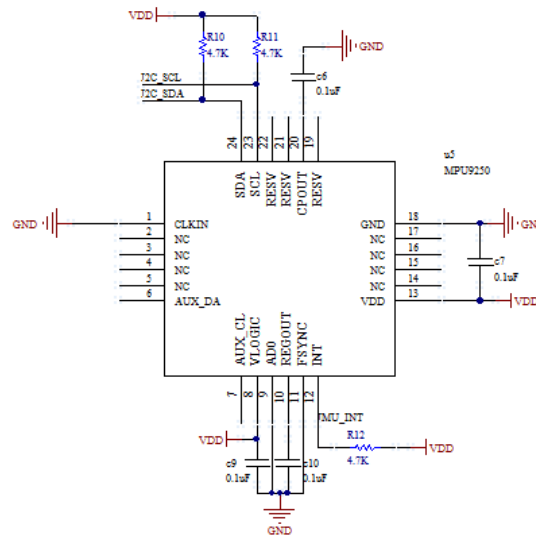
reading of the measurement results.

Fig.3 Circuit of angle motion detection

3. Bluetooth module

The BlueNRG is a very low power Bluetooth low energy (BLE) single-mode system-onchip, compliant with Bluetooth specification. The BlueNRG extends the features of award-winning BlueNRG network processor, enabling the usage of the embedded Cortex M0 for running the user application code. The BlueNRG can be conFigd for supporting Single Chip or Network processor applications. Here we conFig it as a network coprocessor. In this case a dedicated firmware is provided for supporting the interface with an external application, as Fig.4 shows.
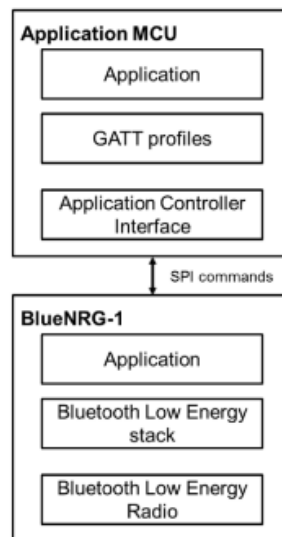

Fig.4   Network processor RF software layers of   BlueNRG

Software design

The system uses the C programming language, the system goes to the hardware initialization process which is responsible for register settings including MCU system clock, I2C bus, ADC and gyroscope hardware resource after powering up. Then the Bluetooth protocol stack initialization task is implemented ,which including GAP, GATT , Service and characteristics adding. So far, the initialization of the system has been completed, the main task routine will been perform. On the one hand , updating the temperature and skin pressure information periodically. On the other hand,

waiting for terminal command and executing the angular motion parameters routine. The whole flowchart is shown as Fig.5.
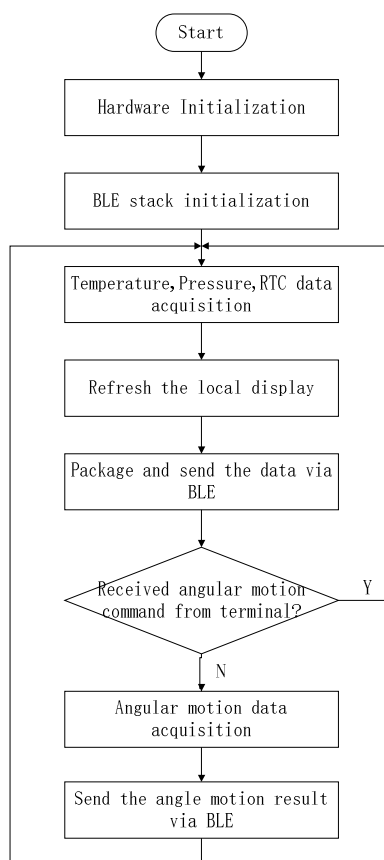

Fig.5 Flowchart of software

Experiment results

Fig.6 to Fig.8 are actual experiment results of the system function, the sampling rate of the device is 100Hz. Fig.6 is the temperature curves of hand skin. Fig.7 shows the skin pressure curve of the finger during the side pinch motion. Fig.8 shows the joint angular motion curve. It is proved by the graphs that the system accurately reproduces all the signs and parameters during the test process.
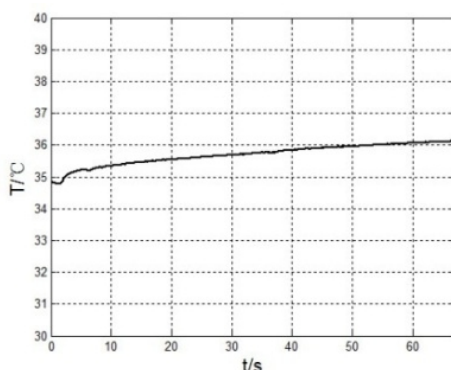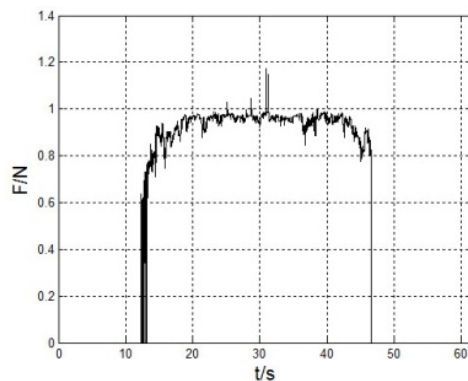

Fig.6   Temperature test
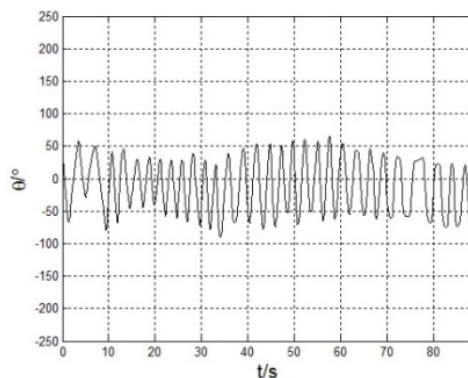
Fig.7   Skin pressure test

Fig.8   Joint angular motion test

Conclusion

This paper proposes a wearable system to monitor the rehabilitation of the hand function.First we select appropriate analog and digital sensors , and deign the signal condition circuits. Then the the sign information such as temperature, pressure and angle motion are extracted and transmitted to the terminal via Bluetooth under the control of the microcontroller. Experiments show that the system is stable and reliable and can obtain the key information successfully for evaluating the hand function.

References

[1] Zheng YL, Ding XR, Poon CCY. Unobtrusive sensing and wearable devices for health informatics[J]. Biomedical Engineering, IEEE Transactions, 2014, 61(5):1538-1554.

[2]YAN Nini ,ZHANG Hui , DENG Yongmei. Research progress and development trend of wearable medical monitoring clothing[J], Journal of Textile Research, 2015, 36(6):162-167.

[3] ZHANG Zhengbo，YU Mengsun，ZHAO Xianliang．Collaborative wearable multi-parameter monitoring system design[J]．Journal of Aerospace Medicine and Medical Engineering, 2008, 21(2): 66-69.

[4] Hung, Kevin, CC. Lee, and Sheung-On Choy. Ubiquitous Health Monitoring: Integration of Wearable Sensors, Novel Sensing Techniques, and Body Sensor Networks[J].Mobile Health. Springer International Publishing, 2015,5:319-342.

[5] Shi Xin , Zhang Tao. Design of a wearable fall detection device[J], Chinese Journal of Scientific Instrument,2012,33(3):575-579.