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Design of Human Motion Signal Gathering System Based on USB 2.0

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Abstract: *In order to design a human motion signal acquisition system, through the virtual hardware platform, the firmware and the driver program of the data acquisition system are designed, so it can run in computers with Windows 7 and Lab Windows/CVI platform. At the same time, the 12-bit A/D conversion chip with high sampling rate and high precision is used for A/D conversion circuit design. In addition, the multi-channel technology is used to realize A/D conversion of multiplexing signal, which improves the measurement accuracy of the system. The results showed that this research implemented the advantages of USB 2.0 interface, improved the data serial transmission speed and met the high data throughput requirements. To sum up, the system achieves the design of human motion signal acquisition system with high efficiency, convenience, low cost and high-performance price ratio.*

Keywords: *Human motion signal, USB 2.0, A/D conversion.*

Introduction

With the rapid development of digital technology, human motion signal detection instruments have also made new progress [12]. At present, data acquisition interface and computer system of human motion medical signals transfer, generally follow the approach of plug-in the card, but the installation of which is quite troublesome and vulnerable to the interference in the case of the environment. Due to the constraints in slot number, address and interrupt resources, it cannot connect many devices, making it unfit to meet the development trend of medical instrument digitally, modularly, small in volume and Plug & Play [9]. In addition, the Rs-232 serial interface has a slow transmission rate and cannot meet the transmission requirements of the human motion signal. The emergence of USB interface technology solves all these problems, especially the USB 2.0 protocol enables USB to achieve 480 Mbps speed. This rate can be applied to some medical signals, such as the real-time transmission of medical image signals [2]. In recent years, virtual instruments have attracted much attention in the field of industrial control instruments at home and abroad, and customer groups are increasing. However, it has few applications in medical field, especially in domestic literature [8]. As for USB technology, although the USB 2.0 protocol was established in 1999, its application in medical devices is not enough. It only focuses on real-time transmission of small signals. In fact, physiological parameters of human body need a variety of biomedical detection signals to reflect [14]. In this paper, the concept of virtual instrument is combined with USB technology to detect and deal with the human motion signal acquisition system.

The principle of human motion signal gathering

The image sequence containing human motion is extracted and processed to get the motion information of the human body. The human body's motion data are collected and analyzed by using sensors [13]. There are four kinds of human motion capture methods: mechanical, electromagnetic, optical and inertial. The following describes in detail the principle of human motion signal acquisition of these types of capture methods.

Mechanical capture methods rely on mechanical devices to track and measure the body's motion trajectory. A typical mechanical system consists of multiple joints and rigid links. An angle sensor is installed in the rotatable joint to measure the change of the joint rotation angle [15]. When the device is moving, based on the angle change measured by the angle sensor and the length of the connecting rod, the position of the end of the rod member and the trajectory of the movement can be obtained. In fact, the trajectory of any point on the device can be found. Rigid links can also be replaced with telescopic rods of variable length. Displacement sensors are used to measure changes in their length. An application of mechanical motion capture is to connect the moving object to be captured with a mechanical structure. The motion of the object drives the mechanical device and is recorded by the sensor in real time. X-Ist's Full Body Tracker is a representative mechanical motion capture product. The advantage of this method is its low cost and high precision. It can measure in real time, and it also allows multiple characters to perform at the same time. However, the disadvantages are also obvious. The operation is very inconvenient and the mechanical structure hinders and limits the performance of the performers.

Motion capture consists of an emission source, a receiving sensor, and a data processing unit. While the performer is performing in the electromagnetic field, the receiving sensor transmits the received signal to the processing unit through the cable. Based on these signals, the spatial position and direction of each sensor can be solved [5]. There are many advantages to this approach. First, it records six-dimensional information. Therefore, it can not only get the spatial position, but also get the direction information, which is very valuable for some special applications. Second, it is fast and has good real-time performance. When the human body moves, the character models in the animation system can react at the same time, which facilitates rehearsal, adjustment, and modification. The calibration of the device is relatively simple, the technology is mature, and the cost is relatively low. The disadvantage is that it has strict environmental requirements. There must be no metal objects near the performance venue, otherwise it will cause electromagnetic field distortion and affect the accuracy. The allowable range of performance of the system is smaller than that of the optical type. In particular, the limitation of cable activity for performers is relatively large, and it is not applicable to more intense sports and performances.

The optical capture method sticks some active or passive reflective markers on key parts of the performer. In the capture process, multiple high-frequency cameras are used to detect and track the marking points. Through the computer, the 3D human body motion data are obtained. At present, the most common optical motion capture is based on the principle of computer vision. In theory, for a point in space, as long as it can be seen by two cameras at the same time, according to the images and camera parameters captured by the two cameras at the same time, the position of the point in space at this moment can be determined. When the camera shoots continuously at a sufficiently high rate, the motion trajectory of the point can be obtained from the image sequence. Inertial capture mainly relies on Earth's gravity and magnetic fields. Inertial sensors, Inertial Measurement Unit (IMU) are used to capture the performance of the performers' acceleration, azimuth, and inclination. It is not disturbed by the environment and is not affected by the obstructions. Capture accuracy and sampling speed are high, reaching 1000 times per second or higher. The inertial sensor is worn on the performer's head. Alternatively, a data dress composed of 17 sensors is worn by the performer. It is connected to the host through USB cable, Bluetooth, 2.4 Gzh DSSS wireless, etc., which can track head and body movements and display the full action in real time [1].

Circuit design of hardware

The design of hardware circuit mainly includes the following parts: multiplexing circuit design, A/D conversion circuit design, USB interface circuit design, power circuit design, EEPROM circuit and firmware loading design. Since it is in the embryonic stage of the system, the design does not need to be too complex and the principle for now is flexible usage [4].

Design of multiplexed circuit

The purpose of multiplexed circuit is to control the path of the 8road signal by a single chip. When a multi-channel switch switches from one channel to another, there will be a transient phenomenon, which causes the output to generate a short spike voltage. If multi-channel switch output signal is collected at this time, the error will occur [6]. The measures to solve this problem require software delay. If a later multichannel extension is made, only one latch 74LS237 is needed, and the locker address is locked. This design uses the PA.0 in the CY7C68013-128pin chip port A as the enabling end of the 8 selected l multiplexed chip cD405l, Pc.0, l, and 2 channels are selection pins. When the system is initialized, the energy end is 0 and the channel is 0. This module also uses a 74LS373 latch to lock the gated signal of the memory channel, which is used to submit to the host to make it know the channel number of the data.

Design of A/D conversion circuit

AD574A is a 12-bit successive approximation A/D conversion chip. The clock signal does not need to be externally supplied, and there are two different working states: one is the conversion process; the other is the data read out process [16]. All work controls here are done by control signals CS, CE, R/C, 12/8 and A0. Here AD574A uses a unipolar input connection, and the input signal range is selected from 0 to 10V. The three-state gate 8D latch 74LS373 locks the single chip signal to control CS, R/C and A0 bits, and CE is the chip allowing signal to be directly controlled by the single chip microcomputer. AD585 is a sample holder that can keep the signal of the multiplexed switch CD405l output, and wait for the output of a converted data on the AD574A to be output to the AD574A. The control of the A/D conversion is achieved through the 7, 6, 2, 1, and 0 pins of the PE port. When firmware is initialized, the state of A/D is set to transform. When the multiplexer sends data, A/D can be transformed. After A/D conversion, STA's status bit triggers the channel selection of multiplex switches.

Design of USB port circuit

As shown in Fig. 1, the USB interface chip CY7C68013-128pin is powered by 3.3 V. XTALIN and XTALOUT connect passive 24MHz crystal oscillator. Through the phase locked loop (PLL) and frequency doubling and division, all kinds of clock (12 MHz, 24 MHz and 48 MHz) needed inside the chip are generated [10]. The clock output is the CLKOUT pin. DPLUS and DMINUS are USB differential data transmission lines. RESET# is a reset line, which is connected to a reset circuit. When the chip is in the hang state, the chip can be reworked through the key S6 or by setting the register bit WU2EN = l. EA is external program memory and on-chip program memory to select input control bits, l means external program memory selection, and 0 refers to select on-chip program memory mode, here it stands as 1 [11].

Attention needs to be paid: A/D chip chosen is a high-precision 12-bit conversion chip, and the data designed for a channel is collected by the last four bits of port B and port D [7]. The first four bits of port D, set the first place to a low level, that is, 0, second bit third bit and fourth bit, collect the switch number of multiple switches. Its format is:

0 * * * * * * * * * * * * (12-bit A/D conversion data).

In this way, at the time of data acquisition, the Slave FIF0 endpoint reads both the converted data and the switch number. Finally, they are packaged together into two bytes of data to transmit to the host. The host user program can decode packets, or it can decode in DLL, separating data and switch numbers in the data package, and the detailed design is detailed later.

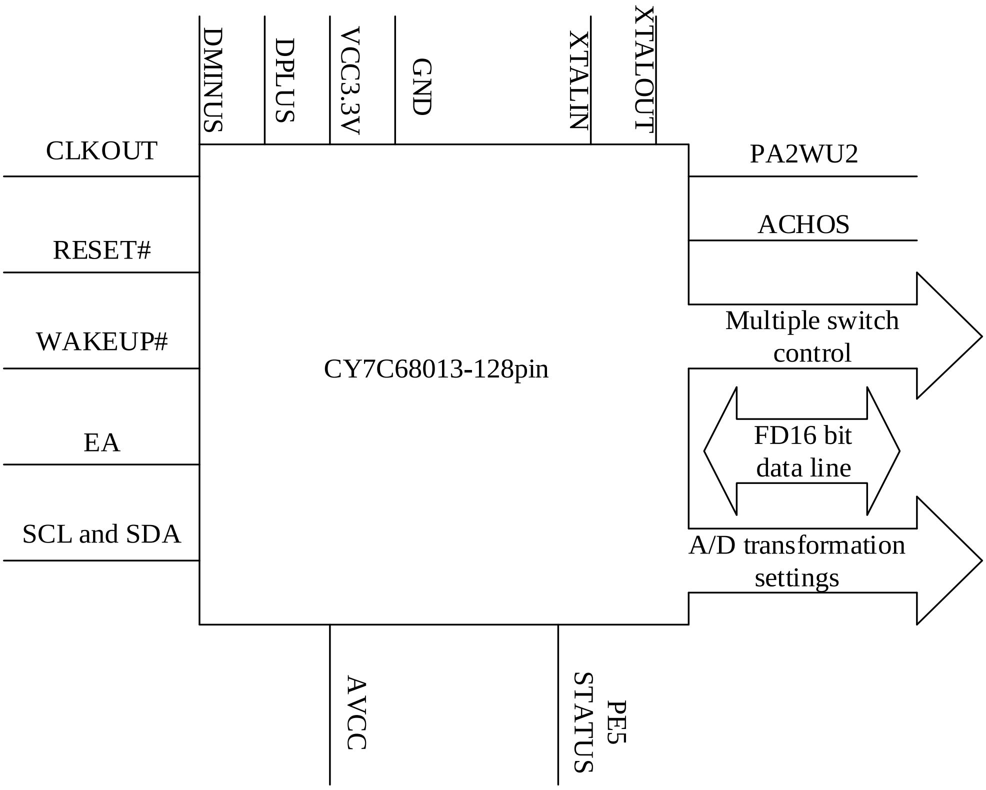

Fig. 1 CY7C68013-128pin and joint with exterior

Power circuit design

After the above modules are designed, the power supply will be considered. For convenience, using the self-power supply mode, the power supply is obtained from the USB interface from the upper computer [3]. From the host computer system 5 V voltage can be obtained, 500 mA current is maximum, the maximum power is 2.5 W, the voltage of the whole system needs to be: 3.3 V, 15 V, -15 V, respectively. It is necessary to start DC-DC transform: change 5 V into 3.3 V and 15 V, then change 15 V through the negative power conversion circuit into -15 V. The schematic diagram of the power management module is shown in Fig. 2.

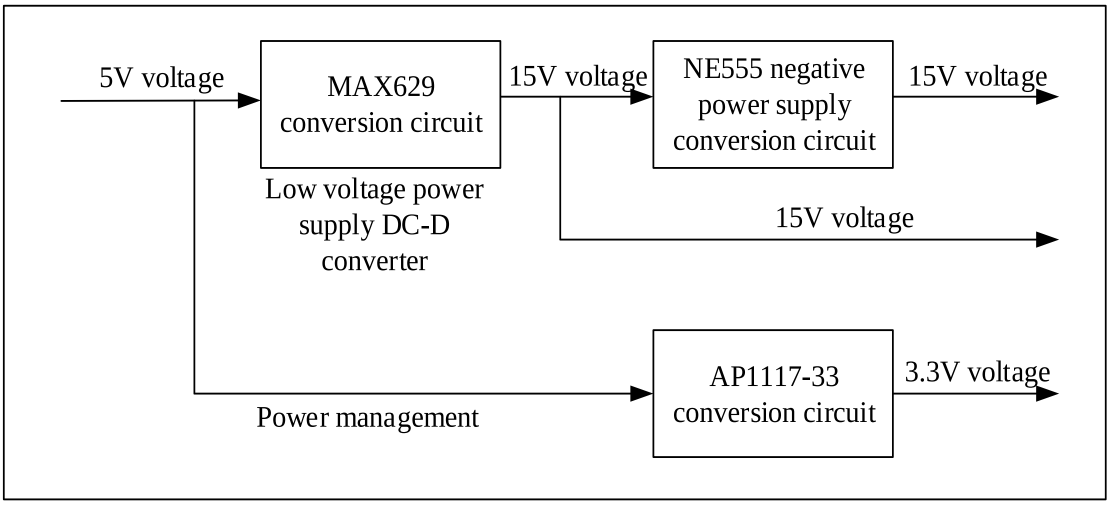

Fig. 2 Power management model principle graph

Firmware design introduction

CYPRESS company's FX2 chip

CYPRESS has introduced EZ-USB, EZ-USB FX and EZ-USB FX2 successively. EZ-USB series data transmission have to go through MCU, the USB transmission speed is restricted to MCU storage outside data and MCU filling endpoint FIFO speed; FX series supports DMA transmission, USB transmission speed is still restricted to the endpoint FIFO and external FIFO data exchange rate; while the FX2 completely conforms to the USB2.0 standard, the USB endpoint FIFO and FIFO peripheral that connects closely with each other is made into one, and thus completely overcome four major bottlenecks of USB transmission. CY7C68013 is a typical FX2 chip. The EZ-USB data transmission structure is shown in Figs. 3-5.

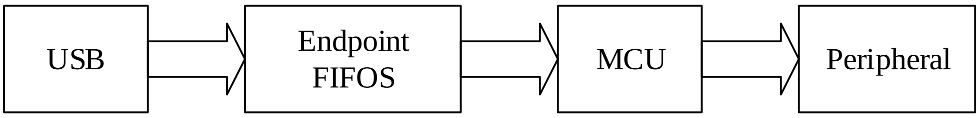

Fig. 3 EZ-USB data transfer structure

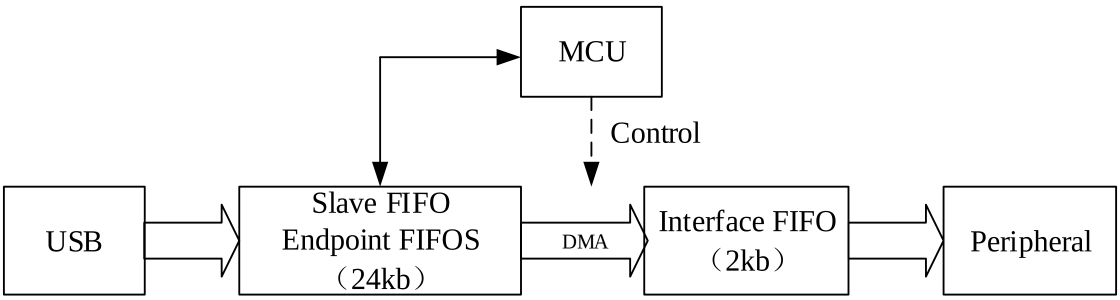

Fig. 4 EZ-USB FX data transfer structure

Software and hardware platform for firmware design

This design uses the EZ-USB FX2 series of development boards and keil51 to write the original firmware. Keil51 is a software platform that can be programmed using C language.

Because C language is more portable and readable than assembly language, it can speed up development.

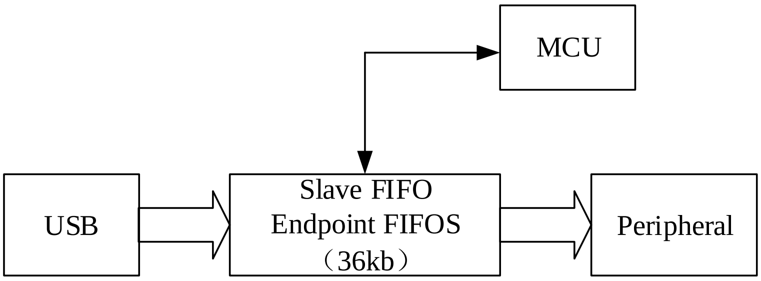

Fig. 5 EZ-USB FX2 data transfer structure

Endpoint and Slave FIFO design

Cyperss provides a complete framework program for its USB chips. Users can only develop a firmware program to meet their needs based on a slight modification of the framework program. FX2 is 0, 1, 2, 4, 6, 8 points; the 0 endpoints can be configured to control the size of the transmission buffer of 64 bytes; endpoint lIN and 1OUT have 64-byte buffer, which can be set to interrupt or bulk transfer; 2, 4, 6, 8 end points have a total of 8 512-byte buffer that can be set to interrupt, batch or isochronous transfer. The system set the endpoint 1OUT to mass, which is used for the communication between the machine and USB MCU, to transmit control data. Then USB MCU wrote the control data to the multiplex switch control terminal and A/D conversion control terminal through 1/O operation. The endpoint is configured as a bulk lIN endpoint of 512. The data after A/D transformation is written to the USB Slave FIFO of the endpoint 8 by I/0 writing. Then USB sends the data to the host and all the end point descriptors are in the file dscr.A51 file. The batch endpoint used is as shown in Table 1.

Table 1. Bulk endpoint use

Bulk endpoint use	**Size**	**Endpoint use**
Endpoint 1OUT	64	Receive the data packet of the controller data acquisition module, set the sampling rate
Endpoint 8IN	512	Return data collected

When 8051 receives data packet from the host, it must be able to identify each USB packet and start related operations, so it must define a custom communication protocol. The provisions of the study include that each data transmission is even byte, start from protocol code and followed by a single byte operand. The OUT endpoint 1 is used to receive packets that control the data acquisition module. The protocol code and its meaning for the OUT endpoint 1 are shown in Table 2.

Table 2. EPlOUT communication protocol

Protocol code	**Code implication**
0x00	Setting the system sampling rate (50 Hz, 200 Hz, 500 Hzl) with the subsequent data
0x01	Starting data acquisition, initial data collection, and data become invalid later
0x02	End data collection and these data become invalid thereafter

The MCU of the USB needs to take the endpoint data to receive the control signals transmitted by the host to the MCU. Through the following code, the endpoint 1OUT can be directly mapped to an array variable of MCU:

Extern XDATA volatile BYTE EPlOUTBUFat_0xE780 [64]; / / lOUT endpoint

By making the above mapping, the process of reading the data from the endpoint 1OUT by the USB's MCU is only a read operation for the EPlOUTBUF array variable [64].

USB batch OUT transmission process: the host produces OUT Token to USB SIE, followed by a packet. If USBSIE receives the data correctly, it responds in ACK. At this time, the BUSY bit in the CS register of the OUT endpoint is 'O', and USB SIE generates an interrupt notification 8051 to read the data from the endpoint BUFFER. 8051 read the value of the byte count register EPlOUTBC and read the number of bytes of the corresponding length from the endpoint BUFFER. After 8051 read the data, write any data to the EPlOUTBC, notify the USBSIE reading operation to complete, and BUFFER can receive the next OUT transmission. When the value is written in EPlOUTBC, the USB SIE places the BUSY bit in the EPlOUTBC, and notifies 805l that this endpoint BUFFER cannot be used.

If the endpoint is not ready to receive the data (the BUSY bit in EPlOUTCS is '0'), the USB SIE discards the data and responds in NAK. The host continues to generate OUT Token until the USB SIE receives the data and generates an ACK response. LOUT transmission produces an interruption to 805l. 8051, the work in this process is mainly to respond to interrupts, read the data first, then write any value to the byte counter of the corresponding endpoint, then interpret its meaning according to the pre-defined protocol code, and perform the corresponding operation. The flow chart of the control data transmission of the endpoint 1OUT is shown in Fig. 6.

Data collection firmware design

Fig. 7 is a block diagram of the system firmware. After powering system, initialize the global variable, which includes: suspended state of Sleep USB chip, Rwuen remote wake-up function and Selfpwr power supply mode, and the number of the current Configuration. In another file endpoint configuration information describing configuration information is contained, and buffer configuration has already at the endpoints of the program; then initializes the function call TD_Init (), the user program here according to the situation to configure the sign equipment function of I/O port, then define global variables; then re enumeration: if the sign with the configured status is received, call TD_POLL () function to start round robin equipment.

This design in the TD_Init (), the port A.0 is set to control the switch chip to enable state control, three corresponding pins C as multiway switch; port B and D as the data input port; E control A/D conversion, the initial state is to start the transition state. Since the Slave FIF0 state is set, the setting of endpoint 8 is the automatic transmission of the data without the need for a lot of MCU intervention. If there is no flag that has been configured, the software will simulate the device's disconnection and re-access until the receiving data is set at intervals of 1 second.

Results and analysis

DLL connecting LabWindows/CVI design

In Windows, the application and implementation of WDM communication process is: application *CreatFile* function used to open the device, and then communicate with *DeviceIOControl* and WDM, including the read data and write data WDM from the two WDM, *ReadFile* can also be used to read from the WDM or use *WriteFile* to write data to the WDM. When the application exits, the device is closed with *CloseHandle*. The five Win32API functions correspond to the driving IRP are as shown in Table 3.

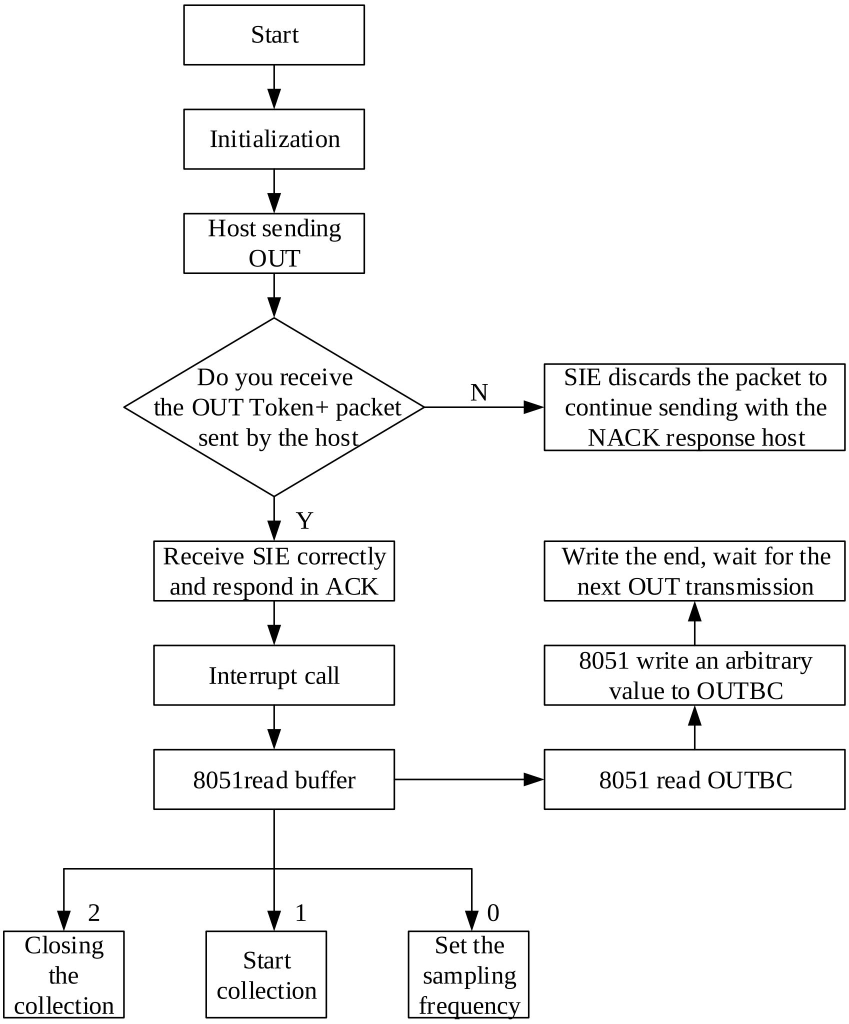

Fig. 6 Data controlled by end OUT transfer graph

Table 3. Read function

Win32API	**DRIVER_FUNCTl0N_xxxIRP_MJxxx**
CreateFile	CREATE
ReadFile	READ
WriteFile	WRITE
DeviceIOControl	DEVICE_CONTROL
CloseHandle	CLOSE_CLEANUP

CreateFile opens the device through the device name. The name has been registered in the driver, and so is the device handle. With the device handle, one can start read and write the device.

The *ReadFile* read device, the EZUSB driver does not define the IRP_MJ_READ, so it cannot be called to read the device.

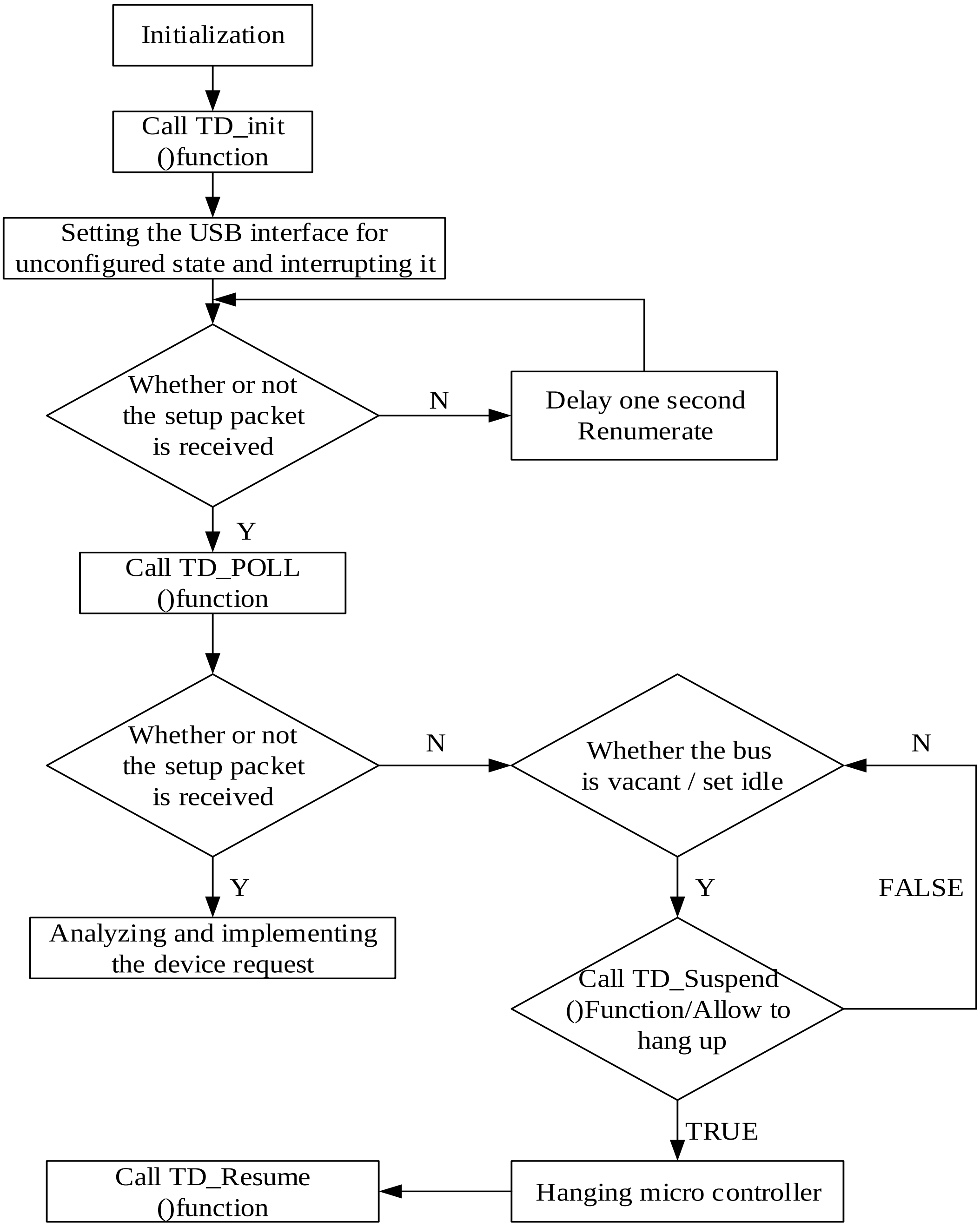

Fig. 7 Block diagram of solid firmware

WriteFile writes device, this function EZUSB driver is not defined.

CloseHandle closes the device through the device handle. There is a *CloseHandle* once per *CreateFile*.

DeviceIOControl read and write device control so that it can complete other requests by this function.

Firmware circuit test

The design of the hardware circuit is based on the EZUSB FX2 development board, and the development board is integrated with EEPROM, CY7C68013-128pin chip and extended pin of CY7C68013-128pin chip. A circuit board is used as a user board, and then a multiplex and AD conversion hardware circuit is built, and the extended pin on the development board corresponding to the pin of the CY7C68013-128pin chip in the data acquisition system design is connected. Set up a test platform.

Interface design

In order to test the availability of this system, a simple application is written under Labwindows/CVI to test the overall performance of the system. The "start collection" command button on the edit operation panel (Command Button) is implemented by the callback function plotcallback (). After collecting, the software finds the data acquisition device Ezusb-0, and acquires data with the default sampling frequency 450 Hz, and reads the corresponding array with switch numbers of 0 and 1. By using the function PlotY, the corresponding values in the array are displayed on the Graph of the chanel-0 and chanel-1. After changing the sampling frequency, the data is recollected.

Performance analysis

This system uses the Delta of Bus Hound software to detect the conversion time. This software can be used to analyze the captured I/O and device drivers. The results are shown in Table 4.

Table 4. EPlOUT communication protocol

Item	Transferred data (bit)	Transfer time (ms)	Transfer rate (Mbit/s)
1	64	49	1.276
2	512	302	1.656
3	1024	621	1.634

Analysis

A: the system set three sampling rates for human motion signals in firmware design. When sampling at the highest sampling rate, the actual sampling rate of each channel is 450×8 Hz, which is the main reason leading to low speed. Because the system is designed to delay the A/D conversion part when designing the firmware, the change of this part of the programming way can improve the sampling rate.

B: the system software is also a determinant in addition to the system hardware, mainly the restriction of the A/D conversion. Since the system use is also packaged channel number and data mode for data transmission, data packets need to decompress before they can get the correct data in the client, the whole time of such a system will be affected, but as is for biomedical signal data transmission, the amount of data, real-time performance is not strong enough, so this system can meet the requirements basically.

Conclusion

This system is a kind of human motion signal data acquisition system based on USB 2.0. It basically realized from the initial acquisition of human motion signal to the final data processing and display of the entire process. With a prototype of data acquisition system, it can collect multi-channel human motion detection signal, to achieve diversity on human physiological parameters. Data acquisition interface is developed on the basis of USB bus, making it convenient, fast, supporting plug and play, easy for expansion and low in cost. It has high reliability, no loss of data, strong anti-interference, and easy data transmission and processing. Therefore, it has good application prospects. The above technology features show that the USB 2.0 based human motion signal acquisition system has the correct technical route, reasonable implementation of the scheme, advanced design of hardware and software, and the research results have certain innovative and practical value.

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