USB Input-based PCM Decommutation by Software

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Abstract—This paper describes the current status of telemetry PCM data decommutation and presents a new concept of "input first and then decommutation". This is a new method with which PCM data are input into a computer via the universal serial bus (USB) first and then decommutation of the telemetry PCM data is performed by software. It also explains the hardware and driver design of the PCM-USB conversion interface, the frame and sub-frame synchronization strategies and the implementation of decommutation by software.

Key Words—Decommutation by software, universal serial bus (USB), PCM, telemetry data processing

1 Introduction

The PCM (Pulse Code Modulation) data in compliance with the telemetry standard IRIG-106 have a wide application in aviation, space and other telemetry areas. Telemetry PCM data processing has been extensively used in the flight test of aircrafts and will find more applications in the flight test of advanced aircrafts. For example, on the US F-22 aircraft, a typical representative of advanced aircrafts, two 5Mbps PCM data streams are used, one transmitting all data and the other transmitting compressed and digitized video images. Telemetry PCM data processing has become an important approach for ensuring flight test safety, reducing flight test cost and implementing integrated flight test of modern aircraft. As a critical technique for telemetry PCM data processing, decommutation has been the focus of research efforts all the time. With the rapid development of electronics, and also with the rapid development of telemetry data processing in flight test and computer technology, PCM decommutation is changing from the traditional hardware decommutation toward hardware and software integrated decommutation and full software decommutation.

This paper presents the hardware and software of a new method of PCM decommutation by software based on USB-input.

2 Current Status of PCM Decommutation and A New Concept of Decommutation by Software

Decommutation refers to the technique of separating the information in a data stream created by merging and restoring the information prior to the merging. It is the decommutation of multiplexing. Traditionally, PCM decommutation is implemented by hardware based on electronic circuits. The representative product is a decommutator. It has evolved from the heavier 19" box-structure in the early phase into the highly-integrated card-structure with FPGA technology at present. The decommutator applied in field test has developed into the current PCMCIA card-structure. An universal standard bus is used between a decommutator and a computer transmission interface, from VME bus and ISA bus to the current commonly used Compact PCI bus. In terms of decommutation rate which indicates the main performance, it has also developed from several kilo words per second in the early phase to 20Mbps currently. The traditional decommutation is implemented by hardware with relative drivers, resulting in technical complexity and higher cost.

With the rapid development of computer technology, decommutation by software has been developed and applied in the world in resent years. It is focused on two modes. One mode is still base on the current decommutation by hardware of "decommutation first and then input". The functions, such as serial-to-parallel conversion, frame synchronization check, word synchronization, sub-frame synchronization check, sub-frame synchronization strategy and data extraction during decommutation are performed by CPLD hardware logic and DSP processor software. The data after decommutation are transmitted to a computer via a high-speed parallel bus. In the other mode, decommutation of the PCM data recorded in a bit stream onboard or on the ground is performed fully by software during the re-production after flight test. For the PCM data recorded in a frame structure, all the decommutation functions are performed by software, with the exception of frame synchronization.

By summarizing and analyzing the research achievements in the world, a new concept of "input first and then decommutation" is presented, in which telemetry PCM data are input into a general computer via a computer universal serial bus (USB) first and then PCM data decommutation is performed by the software in the computer. Sponsored by the "Aviation Fund", it is successful in the early phase. Both bit stream and frame stream modes are available in the prototype and tests show that the decommutation rate can be up to 10Mbps in both modes. The PCM decommutation by software based on USB input can replace the traditional and expensive decommutation by hardware and the DSP-based decommutation partially by software of "decommutation first and then input" at present. In addition, as the more complex parallel bus input is replaced with USB input, the features of USB, such as warm plug-in/out and plug & play will greatly facilitate the field test application of PCM data.

3 Design of PCM-USB Conversion Interface

The main function of a PCM-USB conversion interface is to input the serial PCM data stream into a general computer, which is the first step for implementing the concept of "input first and then decommutation". The design of the PCM-USB conversion interface includes a hardware interface and a software driver.

3.1 Functions of PCM-USB Conversion Interface

The PCM-USB conversion interface receives PCM data (NRZ+CLK) and transmits them reliably into a Windows-based PC through an USB interface in a frame mode or bit mode.

The major functions of the PCM-USB conversion interface in the frame transmission mode include:

a. Set up the PCM-USB conversion interface through the USB interface, including the synch pattern and bit rate;
b. Check the synch pattern of PCM data and perform the frame synchronization of PCM data;
c. Provide frame synchronization indication;
d. Transmit data into the computer in frames via the USB (2.0) interface.

The major functions of the PCM-USB conversion interface in the bit transmission mode include:

a. Check the bit rate of PCM data stream automatically;
b. Transmit the bit stream data received into the computer in optimum data blocks via the USB (2.0) interface.

3.2 Hardware Design of PCM-USB Conversion Interface

The hardware interface for PCM to USB conversion consists of a PCM receiver, a USB controller and CPLD programmable chips, as shown in Figure 1. Figure 2 shows the prototype of the PCM-USB conversion interface.

The input interface provides the matching and optical-electric isolation of PCM single-ended and differential inputs. USB2.0 microprocessor is able to receive and buffer the data from two 32Kbyte FIFOs, and set, read and write the status registers.

EZ□USB FX2□Cy7c68013□USB2.0 of Cypress Semiconductor has been chosen as the USB2.0 controller. It integrates a USB2.0 transceiver, a SIE (serial interface engine), an enhanced 8051 micro-controller and a programmable peripheral interface. FX2, a unique structure, allows the data transmission rate to be up to 56Mbytes/s which is the maximum bandwidth allowed by USB2.0. In the FX2, the smart SIE is able to process many USB1.1 and USB2.0 protocols by hardware, thus reducing the time for development and ensuring USB compatibility.

ISP 4512V system programmable chips of Lattice

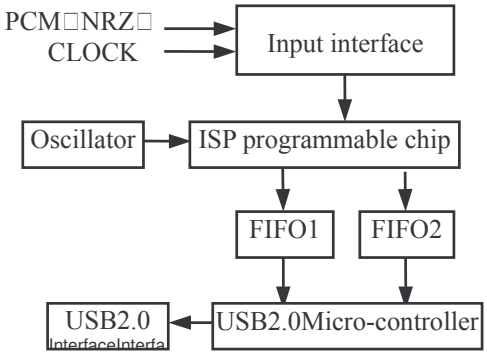

Figure 1 Structure of PCM-USB Conversion Interface

Company are used as CPLD programmable chips. ISP components are easy for field replacement, thus reducing the cost for development and the time for system debugging. Its processing logic has two modes for selection. One is the bit stream mode and the other is the frame stream mode with frame synchronization.

Technical specifications of PCM-USB conversion interface:

a. PCM data format in compliance with IRIG-106 telemetry standard
b. Input code: NRZ+CLK
c. Input rate: Less than 10Mbps, continuously variable;
d. Input level: TTL or RS422

Figure 2 Prototype of PCM-USB Conversion Interface

3.3 Driver Design of PCM-USB Conversion Interface

The driver is responsible for access to the bottom hardware. In accordance with the features of PCM signals and the requirements of USB interface, this driver includes three parts: USB interface driver, PCM-to-USB driver and application driver.

The USB interface driver is developed by Cypress for USB access and control. By invoking the corresponding data access function of this device, according to the requirement of WIN32 driver model and obtains the hardware information of this device, thus performing the control of and access to this device. PCM-to-USB driver performs the conversion from PCM to USB according to the requirements of PCM processing, and constitutes a PCM stream according to the application requirement. The application driver starts the USB interface driver and the PCM-to-USB driver. It also identifies the features of application to obtain the correct device information and perform the conversion from PCM to USB data in frame mode.

A VC++ platform is used for developing the driver in combination with the access mechanism of DDK (Developing or Debugging in Kernel).

4 Implementation of Decommutation by Software

4.1 Data Flow of Decommutation by Software

The data flow of decommutation by software is shown in

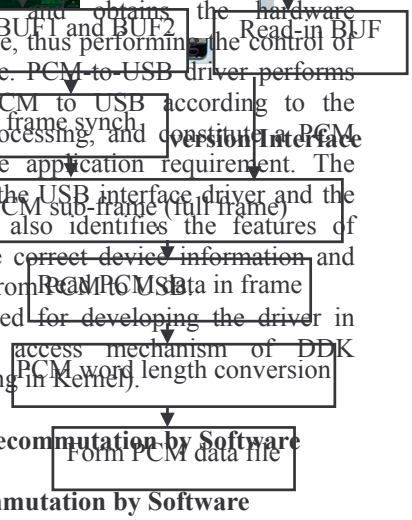

Figure 3 Data Flow of Decommutation by Software

Figure 3. The data objects of PCM decommutation by software include bit stream format data and PCM frame format data input from the PCM-USB conversion interface into the PC buffer. For the bit stream format data, decommutation is performed fully by software. The data flow is as follows: First find out the synch pattern in the bit stream format data buffer and then perform frame synchronization according to the frame synchronization strategy. Afterwards, perform sub-frame synchronization according to the sub-frame synchronization strategy so that continuous PCM frame data can be obtained. Then, restore the raw bits of multiple parameters. Also sort out and convert PCM words and finally form a PCM data file. This is the end of decommutation task. After this, users can perform analysis and processing, such as PCM data extraction, parameter selection and EU conversion.

For frame format data, it is not necessary to perform frame synchronization by software as it is accomplished by hardware in the PCM-USB conversion interface. So, it can proceed directly to the sub-frame synchronization flow according to the sub-frame synchronization strategy. The remaining processing is the same as that of bit stream format data.

As the ID for frame synchronization, the synch pattern is originated from the definitions of PCM format information. It is a string of continuous and unique binary codes specified in IRIG-106 telemetry standard and the criterion for identifying frame synchronization.

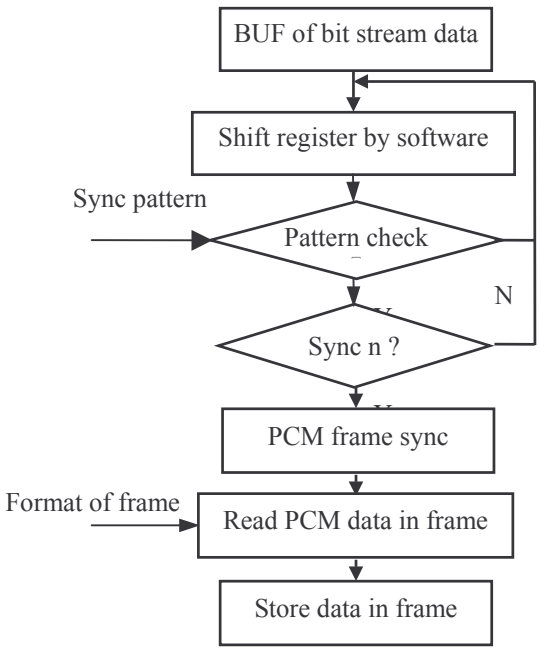

Figure 4 Frame Strategy and Implementation by Software

4.2 Frame Synchronization Strategy and Its implementation by Software

Frame synchronization is one of the critical techniques of PCM decommutation by software. Frame synchronization strategy aims at minimizing the "missing synchronization" and "false synchronization" in data transmission so as to lower the bit error rate and increase the reliability and validity of data check. Figure 4 shows the frame synchronization strategy and its implementation by software.

A basic and reliable frame synchronization strategy as proven by practice is as follows: Find out a synch pattern in consistency with the PCM format definitions in the bit stream data buffer and then find out several (normally 3) synch patterns consecutively according to the PCM word length and frame length of PCM format definitions. This case is regarded as frame synchronization.

In the implementation by software, two input data buffers are created and formed as ping-pang buffers to increase the rate and efficiency of data read. From the data read out and with software shift register and software comparator, find out a synch pattern in consistency with the PCM format definitions in the bit stream data buffer and then find out several (normally 3) synch patterns consecutively according to the PCM word length and frame length of PCM format definitions. This case is regarded as frame synchronization. It is possible to determine the position of a frame in the data buffers. After the data of a complete frame are read out from one or two buffers, it proceeds to the sub-frame processing flow.

4.3 Sub-frame (Full-frame) Synchronization Strategy and Its implementation by Software

Sub-frame synchronization is another critical technique of PCM decommutation by software. Sub-frame synchronization strategy aims at further tolerance check of the data reliability on the basis of frame synchronization. A common and reliable sub-frame synchronization strategy as proven by practice is as follows: Check the data of several consecutive sub-frames (normally 3). If their ID words in the same position are the same or the corresponding ID words of adjacent sub-frames are consecutive, it is judged as sub-frame synchronization. Otherwise, there is no sub-frames synchronization. Figure 5 shows the sub-frame synchronization strategy and its implementation by software.

In the implementation by software, read out the corresponding ID words in the data of three consecutive sub-frames in the PCM frame format data buffers after frame synchronization according to the position of ID words defined in the PCM grid file. Judge if they are the same in the same position or the corresponding ID words of adjacent sub-frames are consecutive. If true, it is sub-frame synchronization. If not, continue to read out ID words for check. After sub-frame synchronization, PCM word length is converted into 16-bit computer word length and a new PCM data file is formed so that the software for data processing can extract data, as required

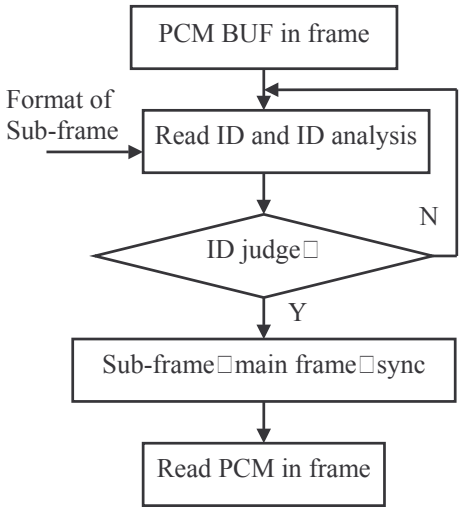

Figure 5 Sub-frame Strategy and Implementation by Software

for further analysis and processing.

ID words are frame counting words. In the PCM grid file, They are defined as consecutive counting with the increment of 1. The max. value of an ID word data is the length of a sub-frame minus 1. ID words are the criteria for judging sub-frame synchronization.

5 Conclusions

The new concept of "input via USB first and then decommutation by software" is an innovation of PCM data decommutation by software. It is convinced that the products to be introduced in the near future will progressively replace the traditional and expensive decommutation by hardware and reduce the cost of decommutation devices significantly. It will be extensively applied in the telemetry PCM data processing and field PCM test in aviation, space, weapon, ship and other test areas and will gain remarkable economic and social efficiencies.

References

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