The Application Design of Solar Radio Spectrometer Based on FPGA

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Abstract. The Solar radio spectrometer is the key instrument to observe solar radio. By programing the computer software, we control the AD signal acquisition card which is based on FPGA to get a mass of data. The data are transferred by using PCI-E port. This program has realized the function of timing data collection, finding data in specific time and controlling acquisition meter in real time. It can also map the solar radio power intensity graph. By doing the experiment, we verify the reliability of solar radio spectrum instrument, in the meanwhile, the instrument simplifies the operation in observing the sun.

1.Introduction

The solar radio dynamic spectrometer instrument originated from radio astronomy. It is a kind of radio telescope to do sun continuous observation. It works with wide range of frequency and can get the dynamic data of the outbreak of sun. When the sun break out with huge energy output, the radio frequency usually distribution between MHz and GHz. The radio power characteristic is rich in this range of frequency, so the collect frequency of the instrument is mainly between 0M and 250MHz. The spectrometer is make up with wide band antenna system, wide band receiving system and display system. Because of its characters, the performance is shown in frequency and time resolution ratio.

At present, time resolution of instrument in the same kind is generally higher than 10ms, and frequency resolution ratio cannot reach more than 60 KHz at the same time. In this design, we program a software to do the data processing in high speed by FPGA and control the data collection. This spectrometer can collect the data with the time resolution ratio of 10 milliseconds and the frequency resolution ratio of 32 KHz. The data can be get together by the software. And the software can also change the parameter and model of data collection. When it loads the mass of data, it can carry on data analysis and get the strength of the solar radio signal so that we can observe the sun's outbreak.

2.THE TOTAL DESIGN OF SOLAR RADIO DYMANATIC SPECTROMETER

The total design of solar radio dynamic spectrometer mainly contain 3 part: data collection, data saving and data processing. In the data collection part, the signals come from array antenna, then we get 2 road solar

radio signals. After that signals are magnified by bandpass filter for low noise amplifier and sent to the high speed collection card. The A/D converter turn the analogue signal into digital signals and transmit it to FPGA. The high speed data stream is collected by FIFO multi model. When the FPGA get data, it can be packed with reality signal data and time data together to finish the collection. The data packages are sent to computer by PCI-E port and load in memory of the virtual hard disk. The data load in the directory which is named by time so that we can find data easily. We also analyzethe data with FFT arithmetic in specified time and get frequency radio figure. We can see the solar radio signal in this figure.

3.THE SOFTWARE AND HARDWARE OF SOLAR RADIO SPECTROMETER

3.1 The Hardware Design of Solar Radio Spectrometer. The sampling frequency is the most important parameter. During the data collection, the sampling frequency must be in the range limited by Nyquist theorem so that we can get all the original data. Because the spectrometer's output signal frequency we made should be between 0M and 250MHz, the acquisition ratio should be 500MHzsps at least.

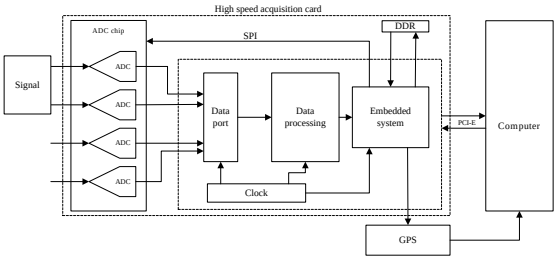

Fig.1 The total flow chart of system

In this design, we set QT1135 designed by Queentest as the high speed acquisition card. This card not only has direct-coupled amplifier but also supports wide frequency input.The speed of data transmission by PCI Express 2.0 x8 port can be 2.8GB/s. It is fast enough for transmission. The FPGA of QT1135 is Xilinx Virtex-6 FPGA which has high arithmetic speed and can be programming inside by user. The acquisition card has four collection channels and support 500Msps transmission rate. Transmission rate in direct current can reach 250MHz and fit for the solar radio collection.
When observing the solar radio, the input signals could be sent to high speed acquisition card from antenna array. After that, we can do a series of work to get data and save it in computer. Because of the mass of data input and avoiding the weak of low speed,we use high speed virtual hard disk to save and protect data.

3.2 The Software Design of Solar Radio Spectrometer. The QT1135 high speed acquisition card support programing in C. Main control program is made up with three part: PCI-E control part, API port program and main control interface.

3.2.1 PCI-E Control and API Port Program. The duty of PCI-E is to control data transmission port. There are a lot of control function inside the card and can be easily used. After compiled these files, they will become PCI-E call file. And in the process of the main program compiling, we can use these files to control PCI-E data transmission part. In the process of sampling, we need get continuous data, so the integrity of data is necessary. The fifo multi model can figure out this program.

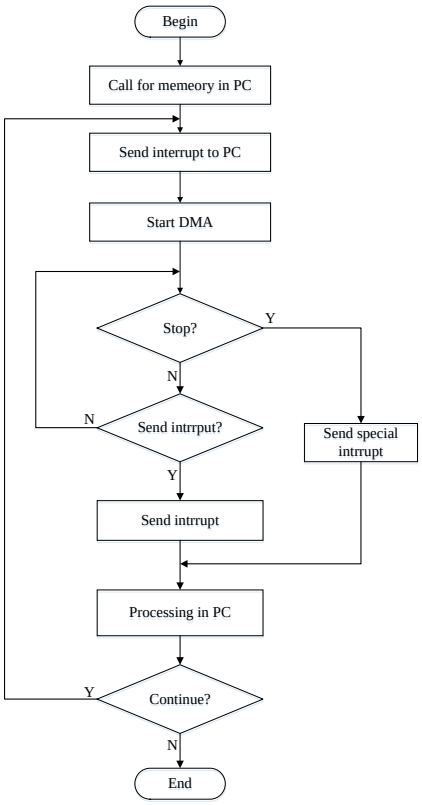

Fig. 2 The flow chart of PCI-E uploading

Fifo multi is a kind of model which can get data from part to part. It will load continuous data in FPGA firstly. When the DDR3 memory in cardis full, data will move to computer. The weakness of this job just be the speed of moving data from FPGA to computer and the data will not lose if the computer use high speed hard disk. The Fifo multi model is defined in PCI-E control program and the main program use it directly.

The card complete DMA move by PCI-E port. The specific operation process is as follows:

(1) Computer program opensup and lock a contiguous physical address memory to prevent being used;
(2) When the memory in FPGA is full, send an interrupt to computer;
(3) The computer check the interrupt and begins DMA;
(4) FPGA gets the order of starting the DMA and transfers data to computer by PCI-E port. The data package will be write to the size we set. After that, FPGA will send an interrupt to computer and finish transmission;
(5) When computer gets the finish interrupt, it will move the physics address data to the memory and the step change to step (2).

PCI-Euploading diagram is shown in “Fig. 2”.

3.2.2 User API. The user API is used to control ADC in card. Moreover, it defines some card functions to finish the work of data move. The main program must use the API functions to compile together so that complete the work of controlling card. The API projects contain FFT algorithm and it could process the data from A/D converter directly. There are also many card parameter set functions. Before the main program control the acquisition card, it should use these functions to set board parameter.

The main API functions are shown in the table 1:

TABLE 1 MAIN API FUNCTION

API function	State
QTOpenBoard	Open the board
QTResetBoard	Reset the board
QTCloseBoard	Close the board
QTRegisterWrite	Write registers
QTRegisterRead	Read registers
QTStart	Start DMA
QTWaitDMA	Wait DMA to stop
QTDMADone	Finish the DMA

The data transfer into binary style by A/D converter and load in memory for reading. The binary style is very easy to read in the later processing. The package of data contain timestamp and it is the offset from the start of the collection time. We can know the precise time of data by read the timestamp. It will make easily to find the rule of sun's outbreak.

The timestamp include 32 bit, there is different meaning for different bit. The former seven bits stand for the number of A/D, the extension is for the highest bit of last byte. It will be expanded to 2 bytes and enough to stand for the number of byte. For example, if the number of A/D is 14, then the first byte will be 0xFF and the second will be 0x3F. The sum of power is defined by the bits from 8to 15 which stand for the wholepower during the collection time. The number of 10 milliseconds is defined from 16 bit to 25 bit, it can show us the past number of time from the beginning of collection. The unit is 10 milliseconds. Similarly, the bits from 24 to 34 are also stand for time. But the unit becomesminute.

3.2.3 The Main Data Collection Program. The main data collection program is a MFC program. The duty is to set parameter, send work orders, control data collection time and set data save directory. Before the start of main program, we should build API project and PCI-E project. After that, the main program can use these function to control card. The interface of main program is shown as follow:

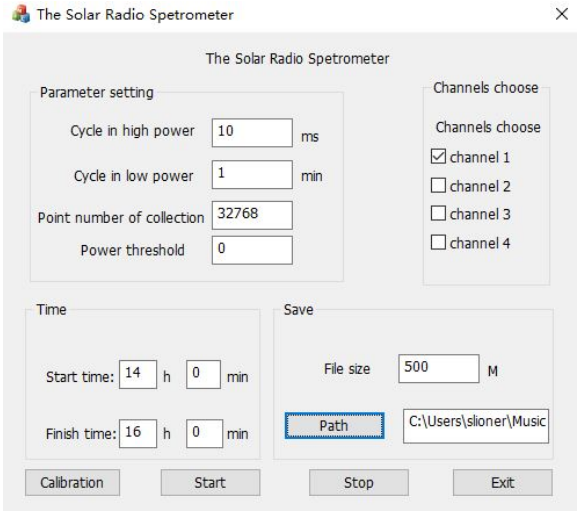

Fig. 3 The main program

The main program include five parts, there are parameters setting part, channels choose part, collection time part, file save part and control button. Because of the indiscipline of sun's outbreak, we set power threshold to control the size of data. When the power is more than the power threshold, the fast collection begin and get a lot of data. While, if the sun is in peace, the main program will not collect a lot. Moreover, the parameter setting part can also control sampling number, the more sampling number is set, the higher sampling rate it

will be.
QT1135 has 4 input channels, they can be open in the channels choose part. The start and finish sampling time should be set in collection time part. Data file size will be set in file save part, the directory is also set in this part. When the program works, files will be load in directory named by time, we can find data by these directory easily. The main program uses multithreading program to make data saving speed improved.
There are calibration, begin, stop and exit button in this program. Before data collection, we should click calibration button to correct the IO delay of channels. Then, we can click begin button to start sampling. The stop button can finish sampling.

3.2.4 The Sampling and Storage Method. Data acquisition is the core of this paper. The key work is get data from PCI-E DMA to user memory and save it in binary file. The whole data collection and storage will be carried out in a "while" cycle. Before "while" cycle, the program use "UCHAR *pBuf = new UCHAR[buflen]" to call for a data memory. When the card is on, the program use "memcpy" function to copy data from DMA memory. The storage file will be named by time. If the stop button is clicked, the program finishes.

It should be noted that we should call for the user memory whose size is more than DMA memory. If it is less thanDMA memory, the program will return fault code. The user memory will be free after program stop.
The sampling and storage flow chart is shown in figure 4：

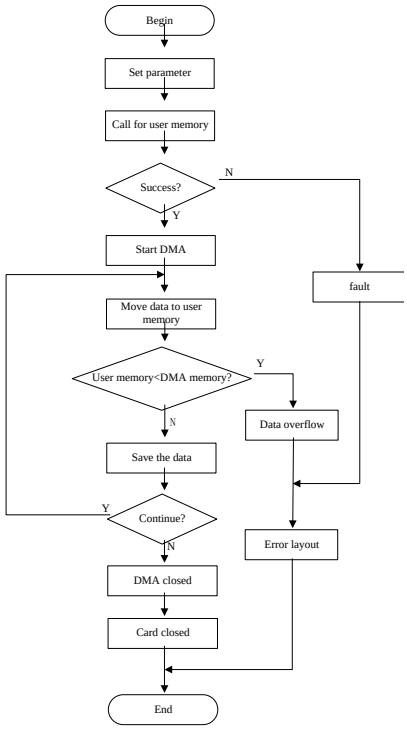

Fig. 4 The flow chart of saving data

3.2.5 DataProcessing Program. Data processing program can make the frequency intensity map. The data will be computed with FFT algorithm. A map will be shown in a cycle of analysis. As is shown in "Fig. 5", the strength is shown by the color. Color boxes shown the strength of each color. You can get your need color freely. The ordinate in left side stand for frequency. It can show the strength of frequency from 0 to 250MHz. The abscissa stand for time.

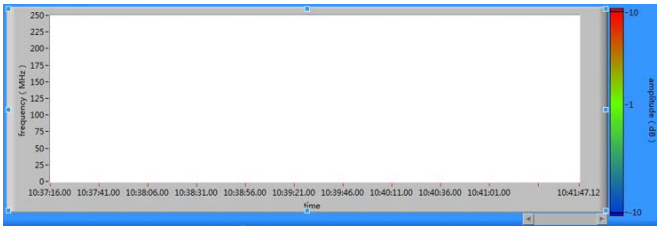

Fig. 5 Data processing program

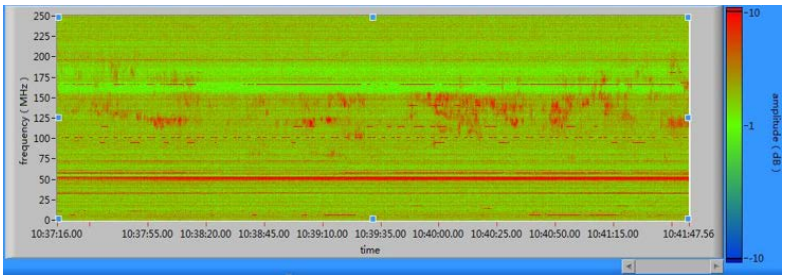

Fig.6 The result of data processing

4.DATA ANALYSIS

"Fig. 6" is a map which show the strength of signals in June 20, 2016. The time resolution is 250 milliseconds. The map one is the result of real data. The power of signals was high from 10:37 to 10:42. It stands for the outbreak of sun. The main frequency is between 0MHz and 250MHz. The map two remove the background color and we can find outbreak easier.

5.CONCLUSION

By using MFC and LabVIEW, we designed a kind of autonomous control solar radio spectrometer. It can collect data with 10 milliseconds resolution ratio and 32 KHz frequency resolution ratio tested by experiments. The software make it easy to do acquisition and save data file accurately. It will become the main tool to do the solar observation and make great sense.

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