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USB Interface with FPGA for Data Acquisition System Using in X-Ray Applications

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Abstract :
The image processing system with acquisition, transmission and display was designed based on the new type CMOS image sensor and USB2.0 controller. Using the OmniVision OV9715 CMOS image sensor as photoelectric imaging device, glueless connecting was achieved between the USB2.0 controller CY7C68013A and the sensor by general programmable interface (GPIF). The simple high efficiency and low-cost hardware which be adapt for high speed image capture was designed and the software system was also compiled based on the multi-thread technology. This project attempts to develop a novel solution to the image acquisition system catering to the X-ray applications. The salient features of this project is to attempt to build an acquisition system that are reconfigurable, and can adapt to any kind of CMOS sensor.

Key words*: CMOS image sensor，USB，CY7C68013A，GPIF*

1. Introduction

Digital X-ray (DXR), magnetic resonance imaging (MRI), and other medical devices require small, high-performance, low-power data-acquisition systems to meet the demands of doctors, patients, and manufacturers in a competitive marketplace. This project will be showcasing a high-precision, low-power signal chain that solves the challenges of multichannel applications - such as digital X-ray that multiplex large and small signal measurements from multiple channels With medical imaging holding the key to many diagnoses, it is imperative that the acquisition systems used to acquire medical images are robust. They key requirements to medical imaging lies in good signal to noise ratio, good contrast among others. There are various imaging modalities in the spectrum. Among them Radiography, Fluoroscopy, CT, MRI, Ultrasound have held the key. This project aims at developing a data acquisition system for X-ray applications like Radiography, Fluoroscopy and in future CT.

Most existing systems are built around analog subsystems implemented either with discrete circuit, or with application specific integrated circuits (ASICs) to reduce power consumption, space, noise and cost. This technology good results and dedicated systems, but offers little flexibility and size of modern field programmable gate arrays (FPGAs) allow a large part of the analog electronics to be replaced by digital logic, enabling a new paradigm where more optimal statistical approaches to the gamma event detection are possible.

To sum up, it has been very important and necessary to integrate all the advantages of CMOS image sensor and USB interface into the image acquisition system and complete over all process within 2-3sec. we use the Omni Vision OV9715 CMOS image sensor and Cypress FX2LP high-speed USB2.0 CY7C68013A as the main chips to achieve our design. This project attempts to develop a novel solution to the image acquisition system catering to the X-ray applications. The salient features of this project is to attempt to build an acquisition system that are reconfigurable, and can adapt to any kind of CMOS sensor.

2. Block Diagram

USB controller communicate with user interface for high speed data transfer system, data stored in EEPROM because USB is does not have any memory system. Its parallel interface system have high speed data transfer using FPGA device interface. Configure memory system is interface and controlled by USB. FPGA technology is reprogrammable device, USB device by transmitting an SOF(Start of Frame) packet every millisecond each one millisecond frame is divided into eight microsecond micro frame. USB transfer type is control transfer used for scanner control x-ray machine. Since the current imaging trend moves towards higher frame rates, FPGA is the ideal choice, because of its capability of parallel processing at high-speed, whereas a microcontroller does sequential processing. Figure 1 shows the block diagram of USB controller Interface

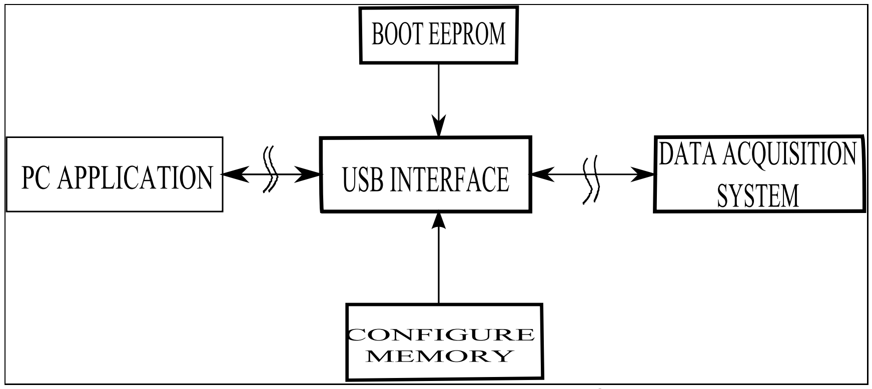

Figure 1: block diagram USB interface

EEPROM boot USB startups circuit: EEPROM is used to boot the USB device, we only need to write the VID and PID of USB device to the EEPROM chip and connect EEPROM chip to the I2C bus of the USB chip. SRAM is chosed because of it higher read/write time and no refresh cycles. For any acquisition system, the memory holds the key. For any imaging system, the sensor holds the key. The selection of the sensor is the most critical aspect of the system. all are interfaceed in USB controller through FPGA davice. CMOS sensor is image capatured and its produce analog output and its converted to digital using ADC. This project attempts to develop a novel solution to the image acquisition system catering to the X-ray applications. The parallel data transmission standards utilize X-ray machine using FPGA for data acquisition system using USB controller. It's very high speed interface the overall performance is completed within 2-3 second.

3. Software Design

In this section, we will show the firmware design software

3.1. Firmware

Except for setting up communication and triggering the GPIF it does not do anything. It does no data processing at all. All data received from the image sensor is put into the MCUs FIFOs and then passed on to the USB without CPU intervention. However, there are a few points in firmware that is worth mentioning. The framework is helpful to the research worker to realize the most parts of the USB protocol. According to peripheral device and requirement, we just need to write different functions to finish our design. To be aimed at the high-speed data and the USB 2.0 protocol, there are several aspects in our firmware software design:

3.1.1. Initial The USB Port and Fifo Register

Set the 8051 CPU clock to 48MHz. Set the endpoint2 IN, bulk, size 512, 4x buffered. Set NAKALL bit to NAK all transfers from host. Reset EP2 FIFO and clear NAKALL bit to resume normal operation. Set EP2FIFOCFG register auto in mode, disable PKTEND zero length send, word ops.

3.1.2. Setup The GPIF Interface Engine

Except the initial code in the function GpifInit(), the function code void TD_Poll(void) must be written in the firmware program. It is the kernel code to ensure the GPIF engine operates smoothly. In the TD_Poll (void) function, we define the condition of when the GPIF engine start and how many times it operate.

4. Hardware Desing

4.1. CMOS Image Sensor

The CMOS sensors that are integrated in The Imaging Source USB cameras offer resolutions from 744x480 to 2048x1536 pixels. The main advantage of the CMOS sensors is their low price and minimal power consumption. The 744x480 sensor uses a global shutter, while all other sensors are based on a rolling shutter.

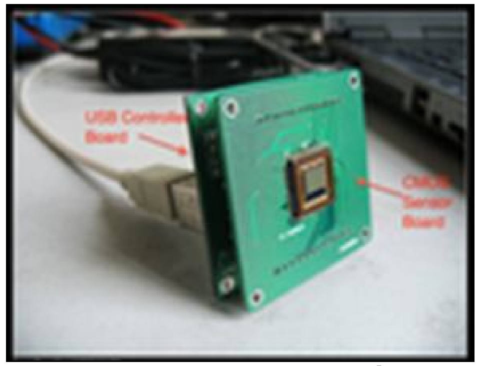

Fig 2: CMOS Sensor Board

4.2. USB2.0 Controller

Cypress Semiconductor Corporation's EZ-USB FX2LP™ (CY7C68013A) is a low-power version of the EZ-USB FX2LP (CY7C68013), which is a highly integrated, low-power USB 2.0 microcontroller. By integrating the USB 2.0 transceiver, serial interface engine (SIE), enhanced 8051 microcontroller, and programmable peripheral interface in a single chip, CY7C68013A has created a very cost-effective solution that provides superior time-to-market advantages with low power to enable bus powered applications. The ingenious architecture of CY7C68013A results in data transfer rates of over 53 Mbytes per second in theory, the maximum-allowable USB 2.0 bandwidth, while still using a low-cost 8051 microcontroller in a small package. Because it incorporates the USB 2.0 transceiver, the CY7C68013A is more economical, providing a smaller footprint solution than USB 2.0 SIE or external transceiver implementations. The Smart SIE handles most of the USB 1.1 and 2.0 protocols in hardware, freeing the embedded microcontroller for application-specific functions and decreasing development time to ensure USB compatibility. The General Programmable Interface (GPIF) and Master/Slave Endpoint FIFO (8- or 16-bit data bus) provides an easy and glueless interface to popular interfaces such as ATA, UTOPIA, EPP, PCMCIA, and most DSP processors.

4.3. Principle of USB Image Acquisition System

There are three parts of the USB image acquisition system.

4.3.1. Acquisition Part

The light from outside scenery is converged to CMOS pixel array through lens. Each compact active pixel element has high photo-sensitivity and converts photon energy to analog voltage signal. The sensor OV9715 has on-chip Analog to Digital Converter and comparators to digitize the pixel output. The output rate of CMOS image sensor is relatively high. It is required that USB controler's rate match the sensor's. There are several signals to be considered in system design: 8 bit image data, PCLK , VSYNC , HREF, and I2C bus etc.

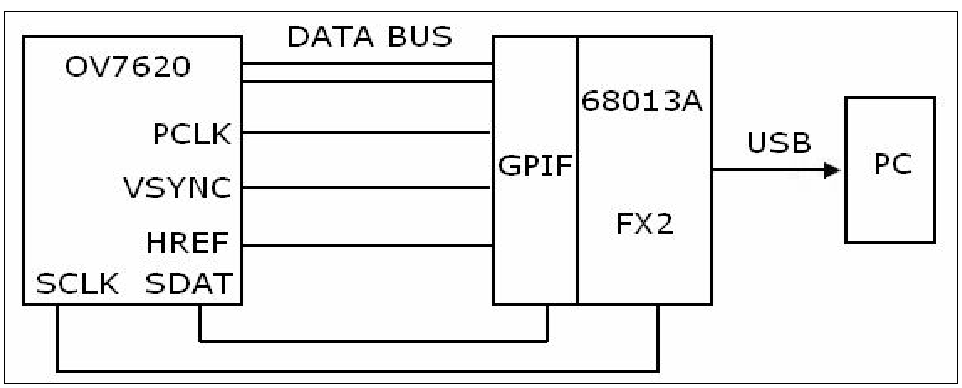

Fig 3: USB Acquisition System Block Diagram

4.3.2. Transmission Part

To achieve the maximum sustained throughput in USB 2.0 High Speed designs, the physical interconnect should never be the primary bottleneck in the system. CY7C68013A 's GPIF (General Programmable InterFace) provides a highly configurable and flexible glueless peripheral interface that allows the highest possible bandwidth to be achieved over the physical layer.

4.3.3. Display Part

The development environment of software is Borland C++ Builder 6.0 under Windows. The application software capture the image data from the USB cable and display on the screen.

5. Result

The USB interface device consider BULKLOOP.C interface program transfer data through usb interface using Cypress device and its transfer data within 2-3sec

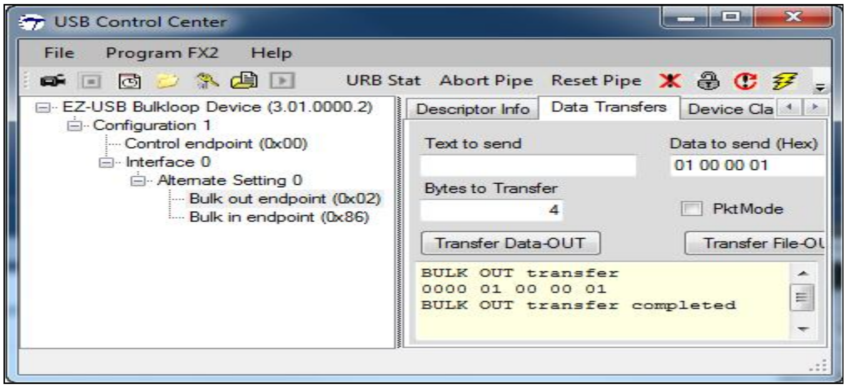

Fig 4: USB Control Center Transfers Data

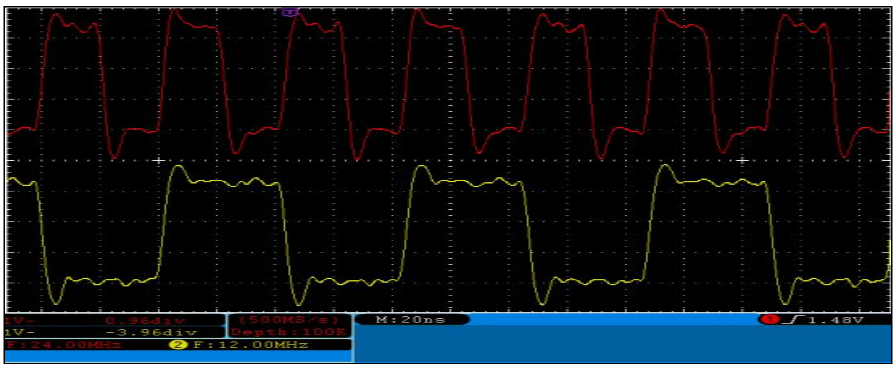

Fig 5: GPIF 48-MHz Clock Divided by 2 and 4

6. Conclusion

This USB image acquisition system adopt the new type CMOS image sensor OV9751 and USB 2.0 high-speed controller CY7C68013A to realize the design which has created a very cost-effective, simple high efficiency and low-cost solution compare with the traditional method. It can be applied to a great many fields such as video camera, automatic device, robot, mobile communication, safeguard, All X-ray machine and pattern recognize conveniently and flexibly. The parallel data transmission standards utilize X-ray machine using FPGA for data acquisition system using USB controller. Over all performance is completed within 2-3 second.

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