

## Research on Image Sensor System Acquisition Based on ARM

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**Abstract:** This article designed and had completed a digital image gathering system by the means of the ARMS3C44B0X processor and CMOS image sensing component. Considering the superiority of the ARM technology and the CMOS image sensing technology, the system combined the image gathering with the imagery processing recognition function in a module and had the advantages of rich function, strong handling ability, nimble connection and convenient expansion. The characteristic system was that it constructed the image gathering hardware platform on the base of S3C44B0X, studied and transplanted the Bootloader vectoring procedure and the uClinux operating system and can realize the real-time and multi-duty processing, thus enhanced the manageable capacity of the system largely. *Copyright © 2013 IFSA.*

**Keywords:** ARM technology, CMOS sensor, Image gathering.

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### 1. Introduction

With the characteristics of slow speed, simple function, big volume and great power consumption, the traditional CCD image gathering system cannot satisfy the need of machine vision application, in particular in some new application domain as the need of the embedded vision and the intelligent monitoring aspect.

CMOS is a new type of solid image sensor developed in recent years. With the same CMOS process, it can integrate the pixel array, drive circuit and signal processing circuit on the same chip. When using a CMOS image sensor acquisition system, it only needs to design an appropriate interface circuit [1] without using the traditional image of A/D acquisition.

This paper studies a solution to design and implement an embedded image monitoring system

that uses CMOS image sensor with low price. This small-sized monitor device can be implemented in one circuit board and has the function of image gathering, image recognition, image storage and image display. The above device can not only be the independent image monitoring instrument, but also be used as an intelligent component in some other application system.

### 2. CMOS Image Sensor

#### 2.1. The Structure and Basic Operational Principles of CMOS Image Sensor

The structure of CMOS image sensor is shown in Fig. 1. It includes Photosensitive pixels array, line logic gate, column gate logic, timing and control circuits and analog signal processor (ASP) [2].

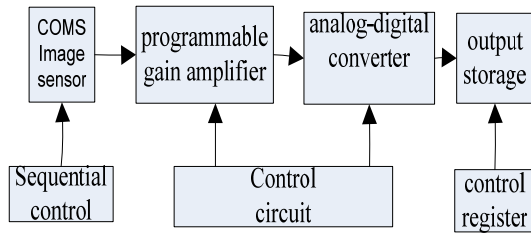


Fig. 1. The structure of CMOS image sensor.

## 2.2. CMOS Image Sensor – ETZIX130D

ETZIX130D is a monochrome digital CMOS image sensor, whose effective pixel array is 160×120. For each pixel unit has higher light sensitivity, so it can effectively convert the light energy into a voltage signal. The installed 8 ADC can convert analog voltage signal into digital signal [3]. The circuit with relative frequency multiplication sampling can significantly inhibit the fixed pattern noise. The whole chip with a small amount of control signals can directly output the original image data who's each pixel is eight on the chip pins. Therefore, ETZIX130D is in common use.

## 3. Hardware and Software Design of the System

The basic structure of data image constitutes of ARM microprocessor, peripheral circuit, CMOS image sensor circuit and so on. ARM microprocessor adopts S3C44B0X as CUP, which belongs to ARM7 microprocessor kernel without MMU.

The structure of hardware system is shown in Fig. 2.

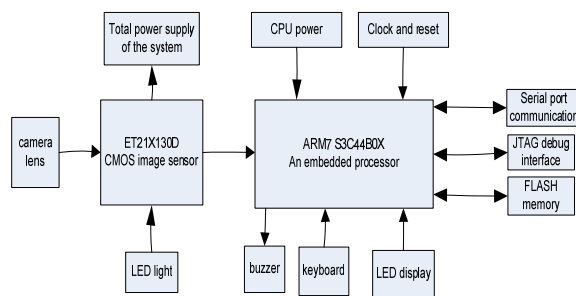


Fig 2. The structure of hardware system.

### 3.1. Design of ARM System Peripheral Circuit

#### 3.1.1. Power Circuit

The embedded processor of S3C44B0X needs two sets of power supply. The power supply of I/O is 3.3 V and power supply of kernel is 2.5 V. Fig. 3 is the switching circuit of 2.5 V.

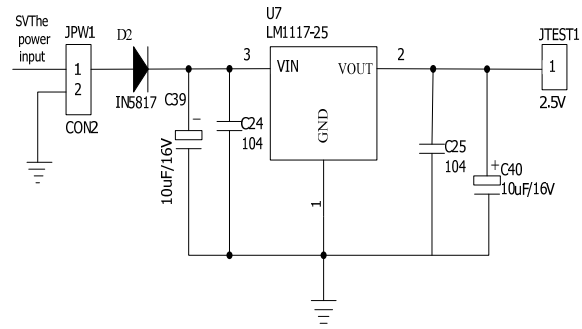


Fig. 3. The switching circuit of 2.5 V.

#### 3.1.2. Crystal Oscillator and Reset Circuit

Crystal oscillator circuit provides working clock for CPU and other circuits. According to the highest working frequency of S3C44B0X and the working mode of PLL circuit, it chooses 10 MHz crystal oscillator. After the frequency multiplication of PLL circuit in S3C44B0X, 10 MHz crystal oscillator's frequency can reach to 66 MHz [4]. The following figure is the system clock crystal oscillator circuit and the clock oscillator circuit of RTC.

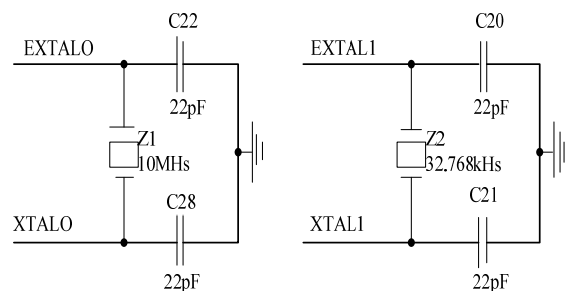


Fig 4. System clock crystal oscillator circuit.

#### 3.1.3. Serial Interface Circuit

RS-485 standard is an interface standard and a universal serial bus [5], which uses serial binary data to exchange data between data terminal equipment and data communication equipment.

The highest data transmission rate of RS-485 is 10 Mbps. The interface of RS-485 composes balance drive and differential receiver, which is a good resistance to noise. The maximum transmission distance of RS-485 interface is 4000 feet, but actually is 3000 meters, which has more standing ability. Serial port communication 485 interface circuit is shown in Fig. 5.

#### 3.1.4. JTAG Interface Circuit

JTAG is an international standard test protocol, which is mainly used in chip internal test and system simulation and debugging. JTAG technology is an

embedded debugging technique, which has a special test circuit TAP in chip and by using special JTAG test tools to test internal contact [6]. Through JTAG interface, it has an access to all parts in chip. Therefore, it becomes a kind of concise and efficient method in developing embedded system. JTAG interface circuit is shown in Fig. 6.

### 3.2. Module Design of CMOS Image Sensor

ET21X130D image sensor chip is an important part of this system. Fig. 7 is the schematic diagram of ET21X130D.

The working voltage of chip is 3.3 V, in which the output signal VSYNC, HSYNG and PXCLK connect with S3C44B0X and ExINT0-ExINT2 respectively. It reads the data according to output of temporal logic. SDATA is a bi-directional serial data interface. The serial interface clock of SCLK connects with  $I^2C$  brought by ARM processor.

The main advantages of  $I^2C$  is its simplicity and effectiveness. There are three signal types of  $I^2C$  in transmitting data. They are starting signal, ending signal and responding signal. Fig. 8 is the schematic diagram of  $I^2C$ .

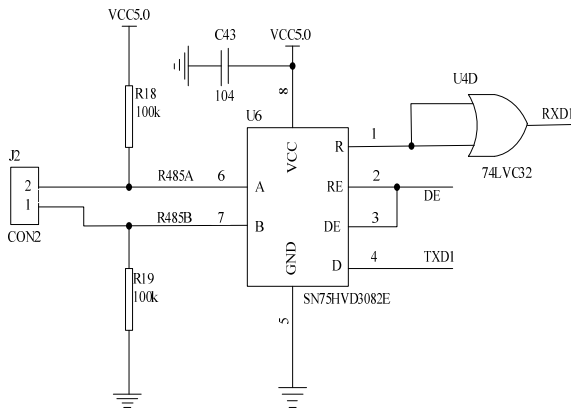


Fig. 5. Serial port communication 485 interface circuit.

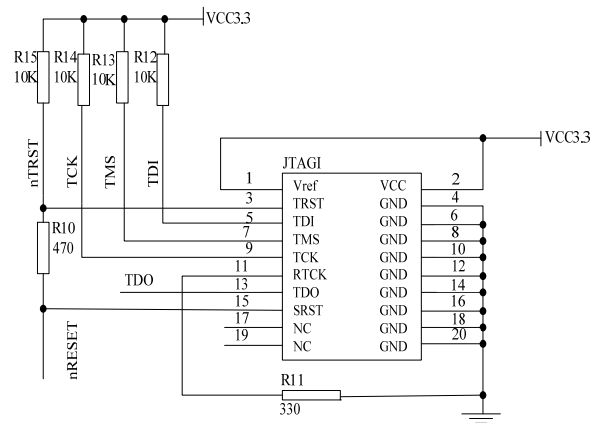


Fig. 6. JTAG interface circuit.

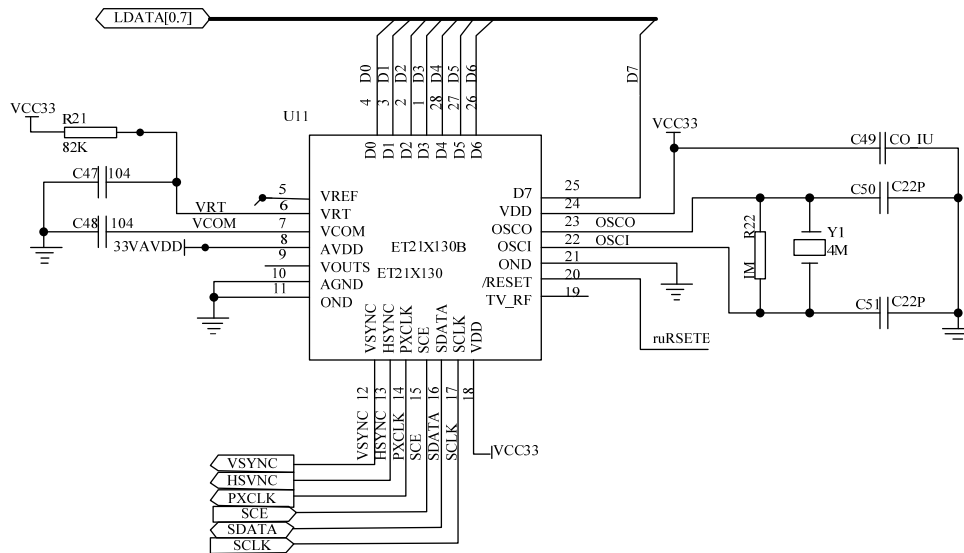


Fig 7. Schematic diagram of ET21X130D.

### 3.3. The Circuit Board Wiring of System Hardware

In order to get stable operational system, it needs to consider Signal integrity and crosstalk between different signals caused by high-speed signal.

For the interference caused by power line and ground wire, it needs to make changes in the

following three aspects when arranging circuit board wire. 1) Add decoupled capacitance between the power supply and ground wire; 2) Try to widen the power cord, ground wire width; 3) Use magnetic beads to isolate analog and digital power supply.

It also should pay attention to the following points when printing circuit board wiring. 1) Try to reduce the discontinuity of printed wiring; 2) routing should

near the ground loop and drive should be close to the connector; 3) small difference between the same address line and data line; 4) concatenate impedance 33 resistance in the power supply for the important signal; 5) try to keep away from the high speed digital devices and high speed digital signal keeps away from the analog part and ensure that they do not pass through the analog ground plane.

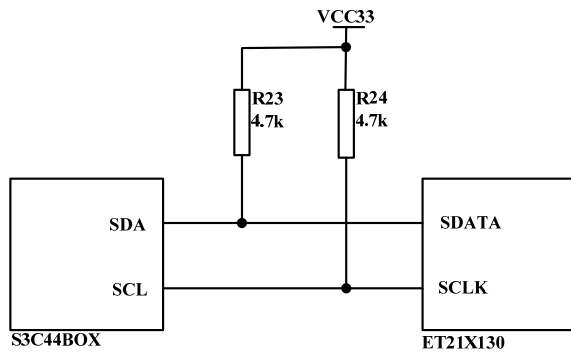


Fig. 8. Interface Circuit of  $I^2C$ .

#### 4. Software Design

uCLinux is a variation of Linux, which is an operating system with open source and developed specially for no MMU micro controller. The main difference between Linux lies in memory management mechanism and process scheduling management mechanism [7]. At the same time, in order to satisfy embedded application, it adopts romfs file system, and simplifies C programming language glibe on Linux. The overall diagram of system software is shown in Fig. 9.

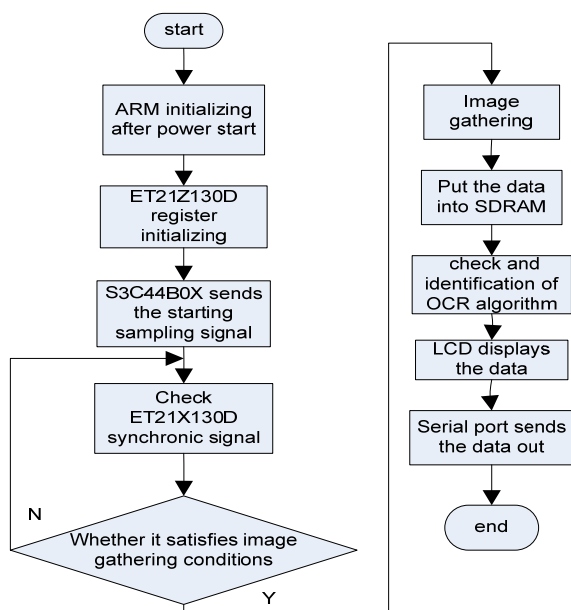


Fig. 9. The overall diagram of system software.

When gathering image data, embedded system sets the value of ET21X130D and configures the proper image gathering mode through  $I^2C$ . When an image is completely stored in the FLASH, S3C44B0X begins to read the image data and identify OCR algorithm, then display the results and last send the data through serial port.

#### 4.1. Software Architecture of Embedded Linux System

Embedded Linux system can be divided into four levels from the view of software. 1) Boot loader; 2) Linux kernel; 3) File system; 4) User application program.

#### 4.2. Design of Boot Loader

Boot loader is a small program performed before the operating system. Through this small program, we can initialize the hardware equipment and establish memory space mapping table so as to establish proper system software and hardware environment and prepare for the operating system kernel. Eventually, boot loader loads operational system kernel into RAM and transmits system control to it. When the system is power up, CPU first executes boot loader program.

#### 4.3. Transplantation of uCLinux

There are four steps to transplant uCLinux to ARM. Firstly, it should be well prepared, including source code and establish cross compiling environment. Secondly, configure and compile the kernel and make some changes to source code if necessary. Thirdly, make Cramfs to mount root file system. Lastly, add application programs into root file system.

##### 4.3.1. Progress of uCLinux

Progress is a run program and an entity that provides execution environment for itself, including an address space and at least one control point. Progress performs a single instruction sequences in this address space. The address space of the progress includes the collection of access and reference memory unit. The control point controls and tracks process instruction sequence through a hardware register of program counter. uCLinux without MMU needs the protection of data when processing multiple processes.

Multi-process implementation mechanism of uCLinux is related to its memory management. Due to the development of Normmu, uCLinux has to use a memory management mode called Flat, which needs

to distribute memory space for application when starting a new application, and quickly load application to memory. uCLinux without memory mapping mechanism of MMU has to process Reloc when in the stage of file loading, so as to enable the program to directly use physical memory.

#### 4.3.2. Device Driver of Linux

A device driver completes the following functions. First, initialize the equipment. Second, transfer data between the kernel and device. Third, make equipment go into work. Fourth, process equipment's fault.

There are two types of device driver of Linux. One is character and the other is block type. There are two types of choices for the use of device driver. The first type is load device driver as loadable module into kernel. The second type is to compile device driver as kernel code into the kernel.

#### 4.3.3. Operational Mode of uCLinux Kernel

There are two operational ways to choose for uCLinux kernel. One is FLASH operational mode and the other is kernel loading mode. In this paper, kernel loading mode is adopted. First, it puts compressed files of the kernel on FLASH, then reads the compressed file and decompresses when the system starts. Last it executes. Although this mode is a little complex, the operational speed is very fast.

#### 4.3.4. Adding Application Programs to uCLinu

First it loads the mirror image file of Linux to the target board. Second, it can find application program in file system after target board compresses Linux image. If it wants to add user application program into mirror image file of Linux, it can add the compressed application program into remfs after making remfs, that is, add it to category of bin. Last, repeat the above compilation process.

#### 4.3.5. Configuration and Compilation of uCLinux Kernel

Open terminal under Linux environment, and then type in the order: cd/home/sun/uClinux-dist and Make menuconfig. Next chooses Vendor/Product Selection, and presses Enter to the Product selection interface, last chooses 44B0ARM processor.

Now back to the main interface, after choosing Kernel/Library/Defaults selection, presses Enter. It can be compiled when the configuration completes.

After the successful compilation, there are three files under category of uClinux-dist/image: image.

ram; image.rom and romfs.img, Namely, the binary file that can be used. Image.rom is compressed kernel image, whose starting process is compressed in memory. Although it needs a lot of space when it is compressed, it can still operate in SDRAM.

#### 4.4. Programming of Digital Image Gathering

The implementation of software module in embedded operational system lies in the control of hardware equipment and the completion of image gathering, identifying, displaying and transmitting. It includes  $I^2C$ , image gathering, image display and transmitting program.

For the part of image gathering, after executing it first configures CMOS sensor and the value of register through  $I^2C$ . Register has its default at first. Then it test whether VSYNC and HSYNC synchronic signal are triggered from low level to high level. After the test, if begins to test PXCLK clock signal. One clock signal only reads one data, which is called the pixel value. It reads the pixel value one after another. The flow chart of image gathering is shown in Fig. 10.

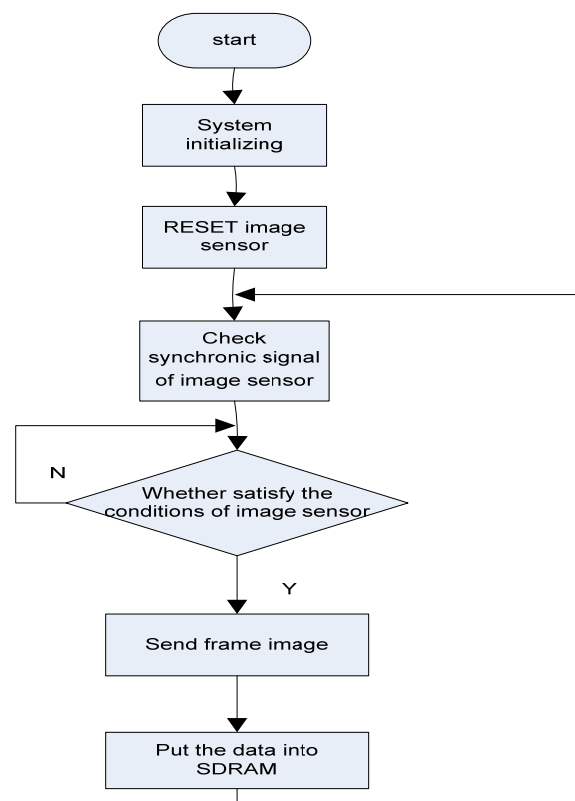


Fig. 10. The flow chart of image gathering.

#### 4.5. Programming of LCD Display

S3C44B0X processor has installed LCD controller, whose function is to display drive signal

so as to drive LCD. The most important step to configure LCD controller is the appointment of frame buffer. The content displayed is read from frame buffer, then displays on the screen. The size of the frame buffer is determined by distinguish ability and display colors of the screen. Frame buffer is the main point of drive development process.

LCD controller in S3C44BOX includes REGBANK, LCDDMA, VIDPRCS and TIMEGEN. There are 18 programmable register in LCD controller, through which it can configure the size of display module, display mode and the width of the interface data. Fig. 11 is the flow chart of LCD display programme.

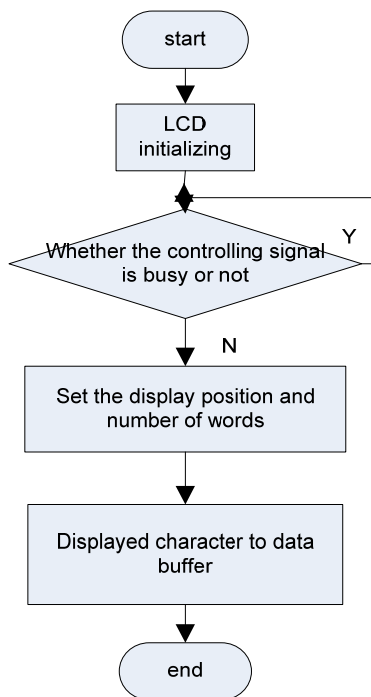


Fig. 11. The flow chart of LCD display programme.

## 5. Conclusions

Based on ARM embedded micro processor, the real-time operating system of uCLinux is adopted in

this paper. First, it introduces the principle and basic knowledge of this system and puts forward the overall design scheme. This paper mainly discusses the detailed design of hardware and the functions of software on image gathering system.

The hardware system adopts S3C44BOX ARM7 embedded processor as the core and uses CMOS image sensor to gather the original image. Based on this, it extends power circuit, FLASH Memory interface circuit, SDRAM interface circuit, communication interface circuit and so on. This paper designs Boot Loader for S3C44BOX processor, realizing the transplanting of embedded real-time operating system. Meanwhile, the software design process is also discussed in this paper, which achieves the combination of image gathering module, display module and transmission module.

This system is a study of the digitization and integration of digital image gathering. Also it is a practice of CMOS image sensor, which has an important role in the application and promotion of CMOS image sensor.

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