IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
ISSN: 2278-2834, ISBN: 2278-8735, PP: 32-36
www.iosrjournals.org

Image Processing Based on Embedded Linux

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ABSTRACT :*The continuous improvement in developmentof Linux for the Embedded system makes it secure, table and reliable. Embedded Linux plays an important role in the embedded field. Linux has been widely used in embedded system due to its small size kernel, stable performance, versatility and low prize. This paper describes the transplantation of the Linux operating system as well as implementation of CMOS device driver based on the mini2440 development board. The transplantation of Embedded Linux includes the development of cross compile environment, the compilation of bootloader, porting of Linux kernel and the construction of root file system. The SCCB bus, camera interface and V4L2 structure are included in development of CMOS camera device driver for the mini 2440 board*

Keywords -*S3C2440 processor; bootloader; Linux 2.6.32; CMOS camera driver; V4L2; SCCB*

I. INTRODUCTION

Embedded Linux is designed in accordance with the requirements of embedded operating system. This is a small system with a very small kernel, generally only a few hundred KB, and the storage space needed is also very small even adding up other necessary modules and applications. So it is very suitable for transplanting to embedded system and at the same time it has the system feature of multi-tasking and multiprocess[2].

The camera uses mainly CCD (Charge-Coupled Device) and CMOS (Complementary Metal Oxide Semiconductor) image sensors. The signal captured by theCCD requires additional circuitry to convert the analog lightdata into a readable digital signal. In a CMOS sensor, each pixel has neighbouring transistors which locally perform theanalog to digital conversion. The advantages of CMOS sensorover CCD are lower complexity on the sensor leading to fasterimage capture and reduced power consumption. A CMOS sensor is used for multi-megapixel cameras due to its fasterreadout.The system uses the CMOS camera to capture videounder the embedded Linux system platform which based onS3C2440 micro controls chip. Transport the data to thedevelopment board and display the captured video by usingLCD display.

II. HARDWARE DESIGN

The core of system is the high performance 16/32RISC (Reduced Instruction Set Computer) S3C2440embedded microprocessor based on ARM920T kernel. Thecamera which is used in this system is Omni Vision's OV9650CMOS camera. The block diagram of image acquisitionsystem is shown in Fig.1.

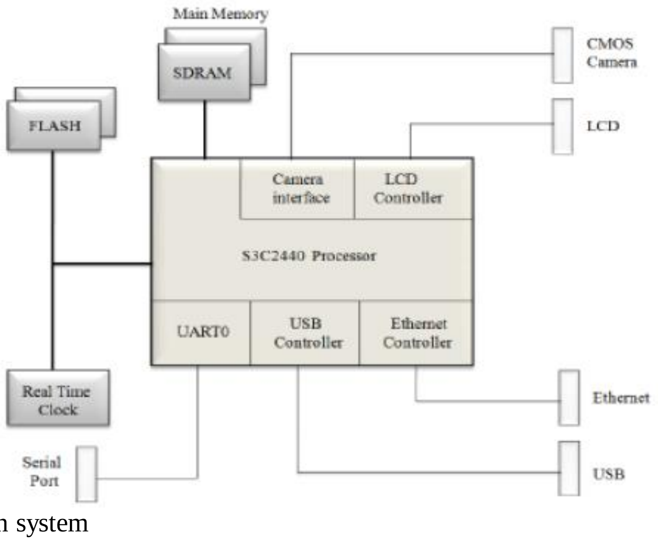


Fig. 1 :- Image Acquisition system

The S3C2440 provides versatility ofplatform design by supporting 300,400 and 533MHz corespeed. 64MB This processor has USB, SDRAM and LCDcontroller, camera interface. The advantage of S3C2440 processor is high performance and low power consumption.The OV9650 is a low voltage CMOS camera sensor having 1.3million pixel image capture capacity. It provides fullframe,subsampledor windowed 8bit/10bitimages in a widerange of formats, controlled through the Serial CameraControl Bus (SCCB)[3]. The OV9650 is connected to theS3C2440 through the camera interface. The S3C2440processor has no support to the SCCB. The SIO_C and SIO_Dpins of OV9650 connected to the IICSCL and IICSDA pins ofS3C2440 processor for clock as well as data signal. Theconnection between processor and image sensor is shown inFig.2.

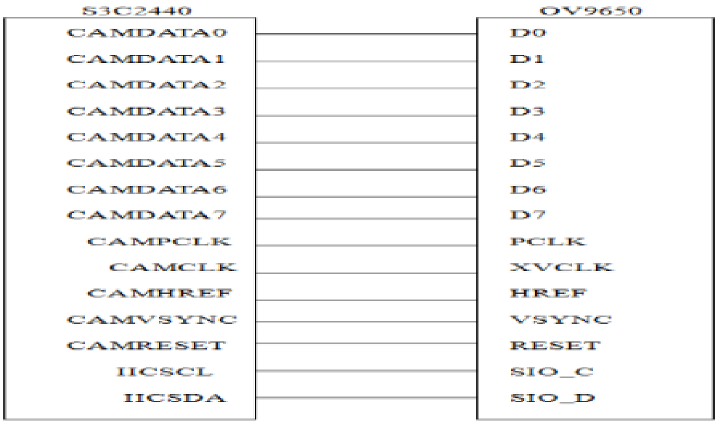


Fig.2. The interconnection of S3C2440 and OV9650

III. TRANSPLANTATION OF LINUX

The detailed description of the different stepsinvolved in transplantation of Linux has been presented in thesubsequent sections.

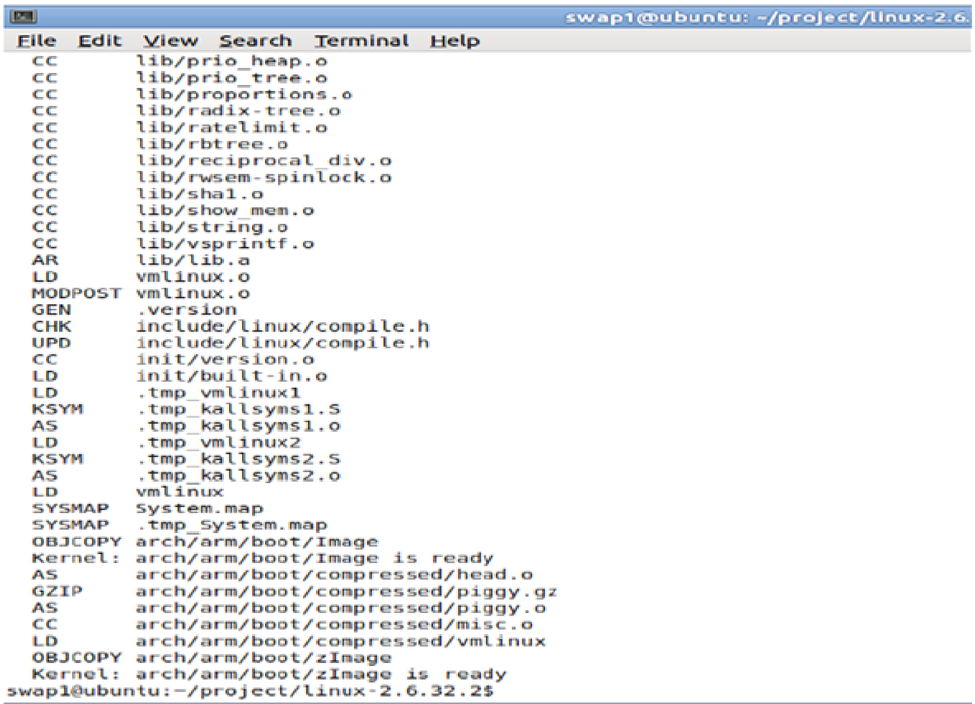
A. Porting of Bootloader :-

Bootloader is a small program runningbefore operating system kernel. Its main role is to initializehardware equipment, establishing the memory space map andbring the environment of the system's hardware and softwareto an appropriate state. The bootloader used in this paper isUniversal bootloader whose acronym is U-boot. U-boot ishighly customizable to provide both a rich feature set and asmall binary footprint.The Uboot1.3.2 downloaded to thetarget board's RAM through the serial port connection, andthen bootloader was written to FLASH on the target machineclass solidstatestorage device. Ubootis mostly used to loadand boot a kernel image, but it also allows to change thekernel image and root file system stored in FLASH.

B. Porting of Linux kernel :-

The Linux kernel 2.6.32.2 is used in this paper. Thecompilation of kernel has following steps,

- Download the Linux 2.6.32.2 tar.bz2 source package fromofficial Linux website;
- Uncompress the source code of Linux kernel;
- Build cross-compiler environment on Linux host: Thecross-compilation is: the use of certain types of machinesrunning on the compiler to compile a source program andgenerate object code run on another machine. Download andinstall arm-linux-gcc compiler, toolchain;
- Modify the Makefile of kernel: Select the architecture asARM and give the path of arm-linux-gcc from the system;
- Configure the kernel: make menuconfig , with a convenientmenu-driven, user-interface, allows the user to choose thefeatures of the Linux kernel that will be compiled[2].
- Compilation of kernel: After configured with the makecommand to the kernel, Compile the kernel using thefollowing command,
  #make uImage: -Builda Uboot kernel image. After thecompilation, three kernel image files "Image", "zImage" and"uImage" will be generated in arch/arm/boot directory.Image is the normal size of image file, but zImage is thecompressed kernel imagefile. The Uboot image is composedof zimage and the Ubootloaderheader file. Linux kernelimage file zImage, which is to be transplanted to the targetboard. The generated zImage is shown in Fig.3.



```
swap1@ubuntu: ~/project/linux-2.6.
File  Edit  View  Search  Terminal  Help
  CC      lib/prio_heap.o
  CC      lib/prio_tree.o
  CC      lib/proportions.o
  CC      lib/radix-tree.o
  CC      lib/ratelimit.o
  CC      lib/rbtree.o
  CC      lib/reciprocal_div.o
  CC      lib/rwsem-spinlock.o
  CC      lib/sha1.o
  CC      lib/show_mem.o
  CC      lib/string.o
  CC      lib/vsprintf.o
  AR      lib/lib.a
  LD      vmlinux.o
  MODPOST vmlinux.o
  GEN     .version
  CHK     include/linux/compile.h
  UPD     include/linux/compile.h
  CC      init/version.o
  LD      init/built-in.o
  LD      .tmp_vmlinux1
  KSYM    .tmp_kallsyms1.S
  AS      .tmp_kallsyms1.o
  LD      .tmp_vmlinux2
  KSYM    .tmp_kallsyms2.S
  AS      .tmp_kallsyms2.o
  LD      vmlinux
  SYSMAP  System.map
  SYSMAP  .tmp_System.map
  OBJCOPY arch/arm/boot/Image
  Kernel: arch/arm/boot/Image is ready
  AS      arch/arm/boot/compressed/head.o
  GZIP    arch/arm/boot/compressed/piggy.gz
  AS      arch/arm/boot/compressed/piggy.o
  CC      arch/arm/boot/compressed/misc.o
  LD      arch/arm/boot/compressed/vmlinux
  OBJCOPY arch/arm/boot/zImage
  Kernel: arch/arm/boot/zImage is ready
swap1@ubuntu:~/project/linux-2.6.32.2$
```

Fig.3. The generated z-Imge after compilation

The generated zImage can be transferred to theboard by TFTP (Trivial File Transfer Protocol) protocol. Thetftpboot command makes Ubootto download the kernelimage from TFTP server. The kernel image is downloaded tothe RAM and then placed into the target system's respectedmemory address. Finally, Uboot's "bootm" command is usedto start operating system images. The first argument to"bootm" is the memory address (in RAM, ROM or flashmemory) where the image is stored, followed by optionalarguments that depend on the Operating System. The modelof crosscompilerenvironment is shown in Fig.4.

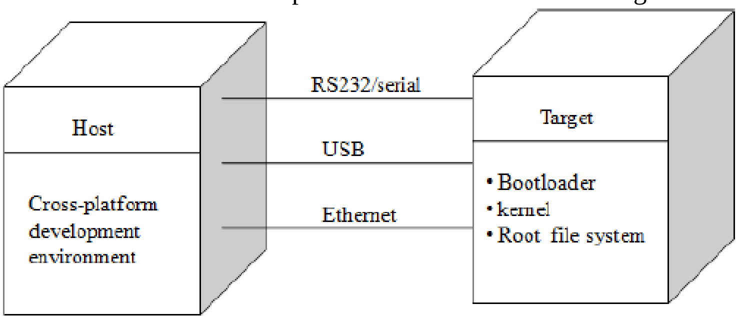


Fig.4. The cross-compiler environment model

IV. SYSTEM SOFTWARE DESIGN

The S3C2440 processor communicates withOV9650 camera through camera interface. The camerainterface is having two scalars. One is preview scalar whichgenerates smaller image like PIP(Picture In Picture) and codec scalar is dedicated to generate codec useful image like planetype YCbCr 4:2:0 or 4:2:2 which followed by two DMApaths. The preview path is used to store the RGB image datainto memory for PIP. The codec path stores the YCbCr 4:2:0or 4:2:2 image data into memory for codec as MPEG-4[6].The CMOS camera driver design is similar tothe character driver. The camera driver mainly consists of twoparts. First is the initialization of OV9650 registers and secondis the main program which captures the image through camerainterface of S3C2440 processor.

A. Design of SCCB driver :Themaster device is S3C2440 processor andslave device is 0V9650 CMOS camera. When bus is idle, themaster will drive the SIO_D signal high. The transmission willstart when the SIO_C is high and SIO_D is low. The master willinitiate read and write operation, only after occurrence of thestart condition. The completion of write operation occursonly when the master asserts the stop condition. Similarly themaster asserts stop condition to complete the readoperation. The transmission will stop only when the masterwill hold SIO_D high and maintain the SIO_C signal at high.There are three types of transmission cycles depending uponwrite and read phase.

(1). Three phase write transmission cycle- The three phasewrite transmission cycle is a full write cycle. In this the masterwill write one byte of data to a specific slave. The master willidentify the specific slave by its ID address and the specificregister location by its sub-address. The 8 bit write data usedto overwrite the content of specific address by the master. Theninth bit of three phases are don't care bits.

(2). Two phase write transmission cycle- In order to read datafrom specific slave the master must know its sub-address. Theuse of two phase write transmission cycle is to identify thesub-address of particular slave. The master reads the data fromspecific slave for the two phase read transmission cycle.

(3). Two phase read transmission cycle- The sub-address ofspecific slave can't be identify the two phase read transmission cycle. So there is a need of three or two phasewrite transmission cycle to identify the sub-address. Then themaster can read the data for two phase read transmissioncycle. The two phase read transmission cycle contains readdata of 8 bits and a ninth, NA bit.

In order to write 8 bit data to the internalregisters of OV9650 camera, initially SIO_C signal must below. The MSB bit of the 8 bit data checked for high or lowcondition. The result of last bit can be put in the SIO_D signal.The data then left shifted by one bit, which circulates 8 timesuntil the process completes.The 8 bit data can be read by S3C2440processor from the internal registers of OV9650 CMOScamera. To read data, set SIO_D pin as input. Pull downSIO_C to low and set data contents as zero. Set the SIO_Csignal to high and left shift the data by 1 bit. Then the dataORed with the state of SIO_D signal. Once again set theSIO_C signal to low which circulate 8 times until the processcompletes. The flow of reading 8 bit data is shown in Fig.5.

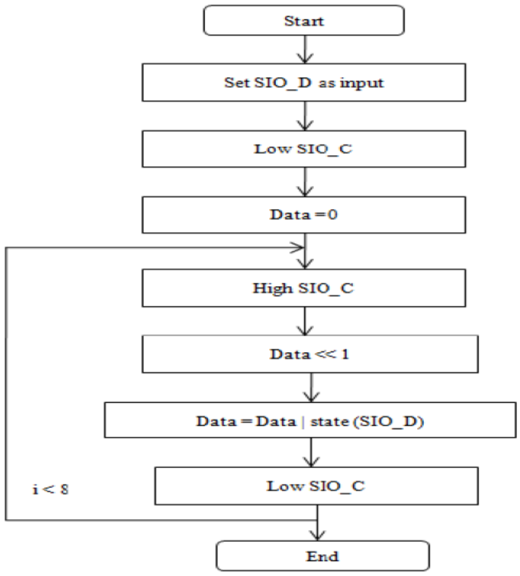


Fig.5. The flow of reading 8 bit data

B. Implementation of V4L2 driver :-The camera driver is implemented under the Linux with the V4L2 (Video4Linux2) structure. The image can be captured through V4L2 driving interface. Video4Linux is a video capture application programming interface for Linux. Using the V4L2 structure, the video device is packaged as a file that can be read and written directly. The camera device driver workflow is as follows,

- Open the video device;
- Read the device information
- Allocate the frame buffer for the device;
- Capture the image through V4L2 interface.
- Close the video device

When an application calls the camera, the systemuses sub device number to find the particular device. Thecamera initialization function contains the registration of I2Cdevice, registration of device driver structure, registration ofV4L device, initialization of camera virtual memory,initialization of camera clock and sccb_init. The camerainterface file operations member in the struct of camif deviceis to operate the basic functions such as camif_open(),camif_read(), camif_ioctl2(), camif_poll(), andcamif_release()[5]. Some of the functions are explained asfollows,

1) camif_open()
a. Changing the relevant registers of S3C2440 internal cameramodule. Allocate the memory for the file handle and checkwhether the device is a master open or a slave open.
b. Open the interrupt for P mode and C mode by calling theinterrupt functions.
c. The two interrupt handling programs C mode and P modeuse the value of pdev ->cmdcode to achieve correlativeresponse, such as switching between P mode and C mode,windowing, zooming and updating format, through changingthe relevant registers of S3C2440 internal camera module

2) camif_read()
a. Close the P mode interrupt and C mode interrupt by callingrespective disable interrupt functions.
b. Call the start_capture fuction to start the capturing ofimages.
c. Use the copy_to_user function to transmit the data to theuser space from driver buffer.
d. Call the stop_capture function to open the interrupt andreturn back from the interrupt handling program.

3) camif_release()
a. Close camera interface
b. Stop capture and camif clock
c. Release P mode and C mode interrupts
d. free frame buffer memory.

The camif_cleanup() function is used for removal of camerainterface module from the kernel. This function containsdeallocation of frame buffer memory, sccb cleanup functionand unregister the device.With the V4L2 framework the program can easily call theapplication programming interface and control the camera,when application calls the CMOS video device.

C. Driver Implementation :-There are two methods for loading the cameradriver. One is direct method in which driver is directlycompiled to the kernel and the other is module method inwhich driver is dynamically loaded into the kernel as amodule. The driver includes three main programs: sccb.c,s3c2440camif.c, and s3c2440_ov9650.c. The sccb.c is usedfor transmission of data. The s3c2440_ov9650.c is used forequipment initialization and communication between user andkernel. The camera initialization can be done by module_init()function. It includes checking and selection of imageacquisition format. The module_exit function is used torelease the interrupt and memory. The driver gets uninstalledat the end of application.The programs are compiled using the Makefile.

The Makefile contains the list of programs which are neededto be compiled. And also the Makefile includes the kernel pathwhich is essential for the compilation of driver. The “make”command is used to build the kernel object file. The generatedfile is transferred to the development board. The object file isthen loaded on the development board which completes theCMOS camera driver installation process.

V. CONCLUSION
An image acquisition system is developedusing the mini2440 development board. The process of transplantation includes steps such as compilation ofbootloader followed by reduction and compilation of kernel aswell as construction of root file system has been implemented.

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