# Embedded-Based Touch Screen Driver Design and Implementation

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*Abstract*—**With the development of the Internet, embedded systems have become one of the hottest industries at present, and the embedded market still shows a huge demand. People have put forward higher requirements for embedded products, such as stable, intuitive, convenient and easy to operate. Touch screen undoubtedly provides people with great convenience, so in embedded systems, touch screen design with good performance, stable operation and high precision has positive and extensive significance. At the same time, in the embedded field, the Linux operating system's open source code licensing model, easy to customize, easy to cut and port features, making Linux the most popular and most popular operating system in the embedded development platform and application platform. Embedded systems are superior in terms of high specialisation and real-time, with a wide range of application-centric and computer technology-based applications. As today's electronic devices continue to be intelligent, the traditional keyboard, mouse and other human-computer interaction has been unable to meet the needs of people, people want more convenient human-computer interaction tools. The touch screen through the finger touch can achieve the operation of positioning, greatly simplifies the input method of electronic equipment, truly zero distance operation, so the touch screen has been more and more widely used. This paper is based on the Samsung S3C2410 embedded, design and implementation of the touch screen program, to achieve the control and operation of the touch screen, with touch screen sensitivity, positioning touch screen position and other characteristics, to improve the use of touch screen efficiency and user experience. Finally, the feasibility and effectiveness of the design program is verified through experiments.**

***Keywords—Embedded, S3C2410, Touch Screen, Linux, Human-Computer Interaction***

## I. Introduction

With the development of electronic information technology and the popularity of digital devices, various products based on embedded systems are being used more and more widely and are becoming more and more powerful. Driven by the huge market demand, people also have higher and higher requirements for the human-machine interface of various electronic products[1]. Touch screens are gradually replacing keyboards and mice as the main input devices used by people.

Due to the embedded system with good performance, low power consumption, high reliability and industry-oriented application of outstanding features, touch screen in China's application range is very broad, is now widely used in consumer electronics, information appliances, network communications, industrial control and other fields. Today, touch screen as a new input device everywhere, mobile phones, PDAs, ATMs and some public enquiry systems may use touch screen. As an important medium for human-computer interaction, touch screens are coming into our lives at a faster pace.

Embedded system of low-end products mainly to single and the core of the machine, in a relatively simple development environment, to achieve embedded system software and hardware application development, embedded system of high-end products mainly in the computer professional field, the use of software engineering design and development methods, relying on the hardware environment of embedded computer systems, embedded real-time operating system support and mature development platform, to complete the embedded system Application development, the emergence of embedded systems, greatly improving the efficiency of embedded system development, changing the previous embedded system development can only be done from scratch for specific applications of repetitive, tedious situation[2].

## II. Design Principle

### A. Embedded Design Introduction

Embedded systems consist of hardware and software and are devices that can operate independently. The software content consists only of the software runtime environment and its operating system[3]. The hardware content includes various aspects including signal processors, memory, communication modules, etc. Embedded systems are application-centred, dedicated computer systems based on modern computer technology and capable of flexible tailoring of hardware and software modules according to user requirements, functionality, cost, volume, power consumption, environment, etc.

The embedded design process consists of the following main steps:

1) Requirements analysis and planning: Determine the functional and performance requirements of the embedded system, develop the overall architecture of the system and hardware-software interface specifications.

2) System design and framework building: According to the requirement analysis and planning, determine the hardware and software design scheme of the system, and build the framework and modules of the system.

3) Hardware design: according to the hardware design plan of the system, carry out circuit schematic design, PCB layout and board making, etc.

4) Software design: according to the system software design plan, carry out software design, programming and debugging work, including embedded software, drivers, applications, etc.

5) Hardware and software integration testing: integrate hardware and software together for testing, including functional testing, performance testing, stability testing, etc.

6) System debugging and optimization: debug and optimize the system, including hardware debugging, software debugging, system performance optimization, etc.

7) System verification and validation: verify that the system meets the requirements and specifications, and confirm the stability, reliability and security of the system[4].

*B. Touch Screen Principle*

Depending on the type of sensor, touchscreens are broadly classified into four types: infrared, resistive, surface acoustic wave and capacitive touchscreens. Touch screen systems generally consist of two parts: the touch detection device and the touch screen controller. The touch screen is essentially a sensor, which consists of a touch detection component and a touch screen controller. Touch detection components installed in front of the display screen, used to detect the user's touch position, accepted and sent to the touch screen controller; touch screen controller's main role is to receive touch information from the touch point detection device, and it will be converted into contact coordinates to the CPU, while the CPU can receive the command sent and implemented[5].

Infrared touch screen in front of the display is installed in a circuit board frame, the circuit board in the screen on all sides of the line of infrared emitter and infrared receiver tube, one by one to form a horizontal and vertical cross infrared matrix. When the user touches the screen, the finger will block the horizontal and vertical infrared rays passing through the location, and thus can determine the location of the touch point in the screen. Any touching object can change the infra-red light on the contacts to achieve touch screen operation.

The outermost layer of resistive touchscreens is generally used as a soft screen, with the inner contacts connected up and down by pressing. The inner layer is equipped with the physical material metal oxide, the N-type oxide semiconductor - IndiumTinOxides (ITO), also known as Indium Oxide, light transmission rate of 80%, the upper and lower layers, separated by the middle.ITO is the main material used in resistive touch screens and capacitive touch screens, their working surface is the ITO coating, press the outer layer with your fingertips or any object, so that the surface film is concave and deformed, so that the two layers of ITO touch each other to conduct electricity and thus locate the coordinates of the press point to achieve control.

Surface acoustic wave touch screen is not affected by temperature, humidity and other environmental factors, high resolution, scratch resistance, long life, high light transmission and clarity, no colour distortion and drift, no need for calibration after installation, excellent scratch resistance, can withstand all kinds of rough touch, the most suitable for public places to use. However, dust, water and dirt can seriously affect its performance and require frequent maintenance to keep the screen surface clean.

Capacitive touch screen, this touch screen is the use of the human body's current induction to work, the glass surface is attached to a transparent layer of special metal conductive material, when a conductive object touches, it will change the capacitance of the contact, so that the location of the touch can be detected. However, there is no response when touched with a gloved hand or holding a non-conductive object, which is due to the addition of a more insulating medium.

*C. Technology related to resistive touch screens*

The main part of the resistive touch screen is a resistive film screen with a very compatible display surface, which is a multi-layer composite film, from a layer of glass or plexiglass as the base, the surface is coated with a transparent conductive layer called ITO, covered with a layer of external hardening treatment, smooth and scratch-resistant plastic layer, its inner surface is also coated with a conductive layer (ITO or nickel gold). Between the two conductive layers there are many small transparent isolation points to separate them from the insulation. Resistive touch screen of the two layers of ITO working surface must be complete, in each working surface of the two edges of each coated with a silver glue, one end with 5V voltage, one end with 0V, can be in the working surface of a direction to form a uniform continuous parallel voltage distribution[6].

When a definite voltage is applied to the X-direction electrode pair and no voltage is applied to the Y-direction electrode pair, the voltage value at the electrocution in the X-parallel voltage field can be reflected at the Y+ (or Y-) electrode, and the X-coordinate value of the electrocution can be found by measuring the voltage magnitude of the Y+ electrode to ground and converting it by A/D. Similarly, when a voltage is applied to the Y electrode and no voltage is applied to the X electrode, the Y coordinate of the electrocution can be found by measuring the voltage at the X+ electrode and converting it by A/D.

When the finger or pen touches the screen, the two conductive layers, which are normally insulated from each other, make contact at the touch point, as one of the conductive layers (top layer) is connected to a uniform voltage field of 5V in the X-axis direction, making the voltage of the detection layer (bottom layer) change from zero to non-zero, the controller detects this connection, carries out A/D conversion and compares the voltage value obtained with 5V to obtain the X-axis coordinates of the touch point ( The origin is at the end close to the contact point).

$Xi = Lx*Vi / V$ (i.e. the principle of voltage division), and similarly the coordinates of the Y-axis

There are two types of resistive touchscreens: four-wire and five-wire. Four-wire touch screen X working surface and Y working surface were added to the two conductive layer, a total of four lead lines: X +, X -, Y +, Y - were connected to the touch screen X electrode pairs and Y electrode pairs, as shown in Figure 1 resistive touch screen working principle diagram. Five-wire touch screen when the four-wire touch screen improvement type. Five-wire touch screen X and Y working surface are added to the conductive layer of the glass base layer, the work of the voltage voltage, that is, so that the two directions of the voltage field time to work on the same working surface, while the outer conductive layer is only used as a conductor and voltage measurement electrodes.

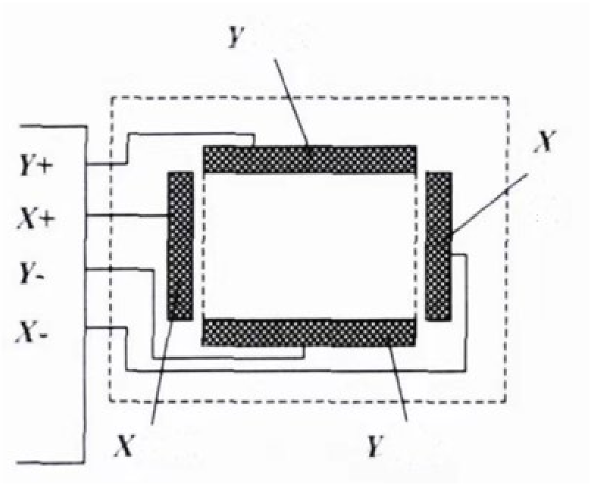


Fig.1 Resistive touch screen working principle diagram

*D. Touch screen controls*

1) Initialize the touch screen controller chip. You need to configure the operating mode, communication interface, sampling rate and other parameters of the touch screen controller chip.

2) Collect the touch screen coordinate data. It is necessary to read the coordinate data of the touch screen by the touch screen controller chip and process it to get the coordinates of the touch points.

3) Perform touch screen calibration. As the sensitivity and accuracy of different touch screens are different, touch screen calibration is required to ensure the accuracy of the touch point position.

4) Implement touch screen control functions. According to the coordinates of the touch point data, you can achieve touch screen control functions, such as drawing, selection, sliding, etc.

In short, to achieve touch screen control, you need to choose the right touch screen control chip, use the right communication interface, touch screen calibration, and to achieve touch screen control functions. This system uses the S3C2410 processor's own touch screen controller to control the touch screen, and the main reference for the development of this part is the S3C2410 processor's chip manual. This part of the control is mainly to set the sampling mode of the touch screen, the mode provided by the processor.

(a) Normal conversion mode

(b) Manual x/y position change mode

(c) Automatic x/y position conversion mode

We are using the third conversion mode here. It is important to note that a mode change is required during the completion of an xy coordinate sample, i.e. wait for an interrupt before tapping the touch screen, when a touch action generates a touch screen interrupt, set the x/y coordinate acquisition driver to automatic x/y position conversion mode, and then switch back to wait for an interrupt mode after the acquisition is complete, ready for the next touch sample.

## III. Overall design

1) Hardware design: Selecting a suitable embedded processor and touch screen module and connecting them together.

2) Software design: design and write embedded programs, including drivers and applications. The driver is used to collect touch screen input data and control touch screen output data, and the application is used to implement touch screen operation and user interface. 3.

3) Collecting touch screen input data: Collecting touch screen input data through the driver, including information such as coordinates of touch points and pressure.

4) Processing touch screen input data: the driver processes the captured touch screen input data, including coordinate conversion, pressure judgement and other operations.

5) Control touch screen output data: control the output data of the touch screen through the driver, including display content, text size, colour and other information.

6) Implement touch screen operation: Implement touch screen operation through the application, including click, double click, slide and other operations[7].

7) User interface design: design the user interface through the application to display the touch screen output data on the screen so that the user can intuitively understand the status and operation of the touch screen.

It is important to note that different touchscreens may require different drivers and capture methods, so the implementation of touchscreen control needs to be adapted and optimised for the specific hardware and software environment. At the same time, it is important to ensure the security and stability of the touch screen to avoid problems such as faults and data leakage. The touch screen control of this system uses the touch screen controller that comes with the S3C2410 processor, which controls the sampling mode of the set touch screen and the automatic X/Y position conversion mode of the processor. Before clicking on the touch screen is waiting for the terminal mode, when there is a touch action to generate touch screen interrupt, in the X / Y coordinate acquisition driver set to automatic X / Y position conversion mode, after the completion of the acquisition and then switch back to the waiting interrupt mode, ready for the next touch sampling. And recognise the touch mode: click, double click, press, lift, move.

## IV. Hardware design

Based on the specific application requirements, choose the right embedded processor and touchscreen module and make the hardware connections. At the same time, you need to know the model, size, resolution and interface type of the touch screen. Experimental equipment and tools: ARM embedded development platform, JTAG emulator for ARM920T, PC Pentium100 or above.

To use the touch screen in an embedded system consisting of the S3C2410, the configuration process is as follows:

1) Connect the touchscreen pins to the S3C2410 via an external transistor.

2) Select separate X/Y position transition mode or automatic sequential X/Y position transition mode to obtain the X/Y position.

3) Set the touch screen interface to wait for an interrupt mode.

4) If an interrupt occurs, the corresponding conversion process will be activated, i.e. separate X/Y position

conversion mode or automatic sequential X/Y position conversion mode.

5) Return to wait for interrupt mode after obtaining the correct value for the X/Y position.

Connecting the touchscreen module to the S3C2410. Normally, the touchscreen module has four wires: X+, X-, Y+ and Y-. They need to be connected to the corresponding pins of the S3C2410, e.g. X+ to pin AD0.0, X- to pin AD0.1, Y+ to pin AD0.2 and Y- to pin AD0.3.

The X and Y values obtained from the touch screen controller are only A/D conversions of the voltage value of the current touch point and are not of practical value. The size of this value is not only related to the resolution of the touch screen, but also to the fit of the touch screen to the LCD. Moreover, the LCD resolution and touch screen resolution is generally different, the coordinates are not the same, so if you want to get the touch screen position reflecting the LCD coordinates, but also need to be converted in the program. Conversion formula is as follows[8].

x=(x-TchScr_Xmin)*LCDWIDTH/(TchScr_Xmax-TchScr_Xmin)

y=(y-TchScr_Ymin)*LCDHEIGHT/(TchScr_Ymax-TchScr_Ymin)

where TchScr_Xmax, TchScr_Xmin, TchScr_Ymax and TchScr_Ymin are the ranges of the x and y axes of the voltage values returned by the touch screen, and LCDWIDTH and LCDHEIGHT are the width and height of the LCD screen.

## V. Software design

Experimental equipment and tools: PC operating system Win2000 or WinXP. ARM ADS1.2 integrated development environment, emulator driver, super terminal communication program

1) Driver design: write the touch screen driver. The main task of the touch screen driver is to collect the touch screen input data and control the touch screen output data. On the S3C2410, the ADC module can be used to capture touch screen input data and the LCD module to control the touch screen output data. It needs to be adjusted and optimised according to the specific touch screen model and hardware environment.

2) Application design: write the touch screen application. The main task of the touch screen application is to implement the touch screen operation and user interface. On the S3C2410, the Linux operating system and the QT GUI library can be used to implement the application. It needs to be designed and developed according to specific application scenarios and user requirements.

3) Debugging and testing: Debugging and testing of touch screen drivers and applications. Tools such as debuggers and emulators can be used for testing, or the program can be burned into the actual hardware for testing. Attention needs to be paid to the stability and security of the touch screen to avoid problems such as faults and data leakage.

To get the coordinates of the touch point: TchScr_GetScrXY(x, y), get the coordinates multiple times and then take the average.

Then determine the key mode by getting the lift time: press, click, double-click, lift, move in five modes. The loop determines whether the key is lifted in a for loop with i<40, if it is lifted within the specified time it is a click or a double click, and further determines whether it is pressed again in a for loop with i<60, if it is pressed again, a short press after the stand-alone is not considered a double click, and no press again within the specified time is considered a click[9].

## VI. Experimental results and analysis

Power on the lab instrument, enter HyperTerminal in the windows environment, press any key other than "Enter" in the current directory to go online, enter vivi in HyperTerminal. type load flash ucos x, press "Enter "Then open the "Transfer" menu at the top of the HyperTerminal and select Send file, click on the Browse button to find and access the compiled image folder and open the file. Then select Xmodem in the protocol field of the send file dialog and finally select send. After sending, the image file is downloaded to flash. Type the bootucos command and enter to run the ucos program. The result: press a point on the touch screen and the coordinates of the corresponding point are displayed on the HyperTerminal[10].

Touch Point Coordinate Accuracy Test: Test the accuracy of the touch point coordinates by clicking on different locations on the touch screen, recording the touch point coordinates and comparing them to the actual coordinates. Press the four corners of the touch screen and record the coordinates as the following table1 Coordinate values corresponding to press points

TABLE I Coordinate values corresponding to press points

| Directin | Top left | Lower left corner | Top right corner | Bottom riight corner | Middle of the screen | Difference between maximum and minimum values |
|---|---|---|---|---|---|---|
| X direction | 98 | 165 | 436 | 268 | 345 | 338 |
| Y direction | 655 | 435 | 862 | 534 | 397 | 465 |

Running result: Press a point on the touch screen and the coordinate value of its corresponding point is displayed on the HyperTerminal.

Touch screen sensitivity test: Test the sensitivity of the touch screen by light touch or heavy press on the touch screen, etc. Stability test: Test the stability and reliability of the program by running the touch screen driver for a long time. Performance test: You can test the performance of the program by testing the response time, CPU occupancy, memory occupancy and other indicators of the touch screen driver. The test results meet the requirements.

## VII. Conclusion

The design and implementation of an embedded based touch screen driver is a complex system design project. The design of this system requires consideration of numerous factors. The design is based on embedded, the design of the hardware circuit and the selection of the embedded operating system, including the construction of the embedded Linux system platform, and finally the completion of the touch screen driver writing under the linux operating system. Careful reading of the s3c2410 chip manual, in-depth study of the design principles of embedded systems, for the working characteristics of the touch screen, in-depth study of its theoretical basis and working principles, a detailed understanding of its operating mode, register characteristics, while completing the development.

The output of the LCD display and touch screen with, reflects the advantages of close cooperation between LCD and touch screen, the code logic is clear, easy to understand, and after complex transformation can be used in more practical life.

In summary, the design and implementation of the embedded touch screen driver needs to consider the following aspects: first, the need to select the appropriate touch screen control chip, and according to the project requirements to select the appropriate communication interface, sampling rate, accuracy and other parameters. Secondly, a suitable calibration algorithm needs to be designed to improve the accuracy and stability of the touch screen. Once again, suitable data acquisition and processing procedures need to be designed, including reading the coordinate data from the control chip, performing calibration, and processing the touch point coordinate data. At the same time, a suitable interface needs to be designed to ensure program compatibility and ease of use. Finally, optimisation and debugging is required to improve the stability, reliability and performance of the program. In summary, the design and implementation of an embedded touchscreen driver is a comprehensive project, and the design process also needs to take full account of the actual application scenarios and requirements in order to achieve an efficient, high-performance and highly reliable touchscreen driver system. A number of factors need to be considered for optimisation and improvement to improve system performance and stability. At the same time, attention needs to be paid to user experience and interface design in order to improve the user experience.

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