MULTIFUNCTION SYSTEM BASED ON A STATE-OF-THE-ART MICROCONTROLLER

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Abstract: This paper presents the hardware and software design of a new point of sale terminal. It is a multifunction system with a wide range of functionalities: state-of-the-art user interface, a host of communication possibilities (RS232, Ethernet, GSM, RTB MODEM) etc. The core of the whole development is the IMX21 microcontroller which allows the system design to be simplified. The Linux operating system is used due to the complexity of the hardware systems and the fact that it has to be reconfigured for different functionalities. The peripheral drivers have therefore been programmed. The result is a totally portable, low-consumption system capable of performing many functions.

1 INTRODUCTION

This paper describes the hardware and software design of a new portable terminal, the main purpose of which is to serve as a Point of Sale Terminal (POS), implemented with the state-of-the-art technologies currently available. Devices of this type are used on an increasingly massive scale every day (e-Payment) in shops, the service sector, etc. One of the most important functions of a POS is that of connecting up to a financial institution and reading the various types of payment cards (magnetic, contactless, etc.), obtaining in each case an approval code after remote consultation with the financial institution and printing the corresponding receipt. This function calls for a series of security standards to be met, to cut down the chances of fraud and mistakes (Dhem & Feyt, 2001). The options for establishing this long-distance communication are a conventional telephone line (IDSN), the mobile telephony network (GSM) or the Ethernet protocol, calling for specific modems to be designed for each type of communication.

But these terminals can also be set up for other functions, such as issuing car park tickets, issuing fines, receiving orders in a restaurant, etc., and in general, tasks involving the issuing of a paper ticket and, in certain cases, connection with a central control unit.

This device needs to be portable and user friendly. The user interface has to have a keyboard (normally reduced in size), a printer and a display monitor (if possible in colour); if a touch screen is used the information can be input from the screen, thus making it even easier to use. It is also useful for certain applications to have a multimedia sound generation capacity, one use of which might then be the giving of guidance in how to use the device. Other worthwhile functions are those of communicating with other electronic equipment through USB, RS232, JTAG, for such tasks as transferring information, reconfiguration, etc.

As regards the developers that might be used for programming new system functions, the POS control software needs to be easily programmable, cutting down the design costs without forfeiting any of the design reliability commitments. To this end a Linux operating system has been implemented as the control core of the hardware system and the developer is furnished with a series of drivers to harness the hardware resources to the full. This allows the POS to be configured for new applications, such as a variation of the information shown on the display or the information furnished by the printer, use of a given MODEM type, storage

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of certain types of events, use of different types of cards, etc.

In light of all the above the general specifications of the system developed are the following:

- 32-bit architecture with sufficient memory for different complex applications and for storing data.
- Flash memory, RAM and MMC and SD CARD.
- User interface: keyboard, touch screen (TFT) and thermal printer.
- Means of payment: readers for magnetic cards, SAM and contactless cards (MIFARE).
- Communications: RS232, Ethernet, USB-OTG, RTB Modem and GSM Modem.
- Low consumption, fed by rechargeable batteries.
- Laptop, implying an integrated architecture giving a compact and robust footprint, necessary due to the terminal use conditions.

The main software specifications are an open operating system with free 32-bit Linux code and the development of the necessary APIs for controlling all peripherals and programming particular applications without needing to have an in-depth knowledge of the hardware controlled.

The system is used for making money transfers and as such has to meet the additional security requisites to suit this circumstance: a) Security, the terminal cannot be allowed to degrade the security level of the cards themselves. b) If the terminal is opened or dismantled, the sensitive information has to be erased before allowing access. c) Its protection systems include multiple-tamper-detectors to protect customers' PINs, magnetic stripe data, application programme and transaction data.

This paper has been broken down into the following sections: after this introduction section two below gives an account of the hardware block diagram, with a comment on all the modules making up the design; section 3 deals with the software architecture; section 4 comments on the results and winds up the article with the main conclusions.

2 HARDWARE ARCHITECTURE

Figure 1 shows the block diagram of the implemented hardware system. This block diagram gives a good idea of the device's functionality; it should also be taken into account that the system is totally reconfigurable at hardware level: for example

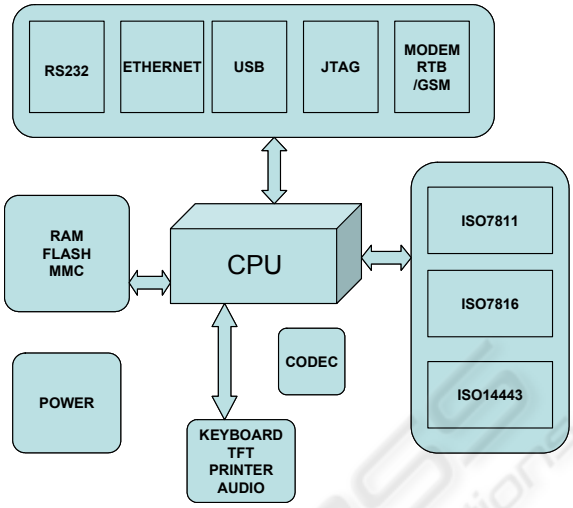

Figure 1: Hardware block diagram.

the GSM modem could be implemented in a commercial model instead of the RTB modem, obviously accompanied by the suitable software.

The system has been designed around a state-of-the-art microcontroller with a sufficiently wide range of resources for the design to be optimised. Freescale's iMX21 (Freescale Semiconductor, 2004) microcontroller is the central unit of the POS. This is a device especially designed for multimedia applications, with sufficient resources for implementing the design: ARM9 core, JTAG connection, timers, equipad, SLCD controller, SDRAMC, MMC, multimedia accelerator, a complete memory access interface, bootstrap, etc. This microprocessor's wealth of internal resources has enabled the hardware development of this system to be greatly simplified.

The following sections comment on the main characteristics of each one of the blocks of figure 1.

CPU + Memory + Power: power feed control: As already pointed out, the core of the system is the IMX21. Its capacities have been optimised in the interests of achieving the best possible design. This circuit is fed with 3.2 volts, which is the working voltage of most of the circuits. The module for the control of the circuit power-feed is based on C.I.: TPS 65012.

The system has been equipped with 32 Mb of FLASH memory and 64 Mb of SDRAM (133 MHz), sufficient for running the Linux Kernel and implementing the applications for which the system has been designed. The FLASH memory is implemented with the low-consumption integrated circuit S29GL128M, at 3.0 V_{DC}. The SDRAM is

implemented with the integrated circuit K4M513233A.

MMC/SDCARD: The multimedia cards allow the storage and conveyance of mass data using a widely used standard. For this reason an SD card reader/writer has been implemented.

Means of payment

The following means of payment have been incorporated into the POS:

- **Magnetic stripe cards**, (ISO 7811): These are the oldest type of card and have the lowest storage capacity but they are used on a mass scale due to their low cost. A system has been set up for reading the tracks recorded on the magnetic stripes of these cards.
- **Contact smart card,** (ISO 7816): The connection is made when the reader contacts a small gold-plated area on the front of the card. The integrated circuit TDA8007BHL is used for reading the cards, according to standard ISO 7816, allowing the control of up to 3 SAM. It is a dual card interface for dual smart card readers.
- **Contactless cards, (**ISO 14443). Contactless or proximity smart cards communicate at RF (radio frequency). The point-of-sale terminal can communicate with contactless cards by means of the MIFARE protocol. Philips Mifare is the standard for contactless and dual interface smart card and reader technology operating at 13.56Mhz, in accordance with ISO 14443, allowing a transfer rate of 106 Kbs/s up to a distance of 10 cms. The advantages of contactless cards are their ease of use, immunity to dirt, grease, etc; they are also less vandalism prone since the reader needs no slots.

Communications

One of the design priorities was to ensure that the system had a great capacity of communicating with other devices in different formats. The system has therefore been fitted with 2 RS232, USB ports, and JTAG.

The system as designed allows for communication through 2 different mobile telephony modems; firstly, through a GSM modem and secondly through the conventional telephone line (RTB Model). The system also offers the possibility of communicating via a GSM modem, by exchanging the appropriate commands with a conventional modem. Other option is to use the conventional telephonic line; this module has been designed on the basis of integrated circuit IPS3333.

The Ethernet protocol is widely used for transferring information between computers and other devices; its popularity is largely to due to internet, facilitating access to a wide range of information points. The integrated circuit CS8900A has been used for implementation of Ethernet communications; this circuit includes one on-chip RAM, 10Base-T transmit-and-receive filters, and a direct ISA-Bus interface. The CS8900A´s analog front end incorporates a Manchester encoder/decoder, clock recovery circuit, 10BASE-T transceiver, and complete Attachment Unit Interface (Figure 2).

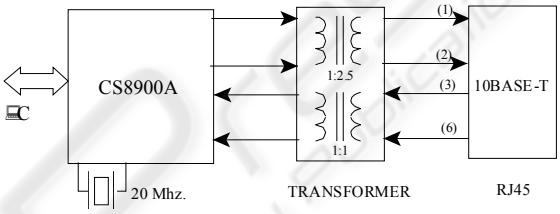

Figure 2: Ethernet communications.

Keyboard + printer + display

The user interface is implemented by means of a keyboard of 5x4 keys, a thermal printer and a state-of-the-art TFT, making it possible for state-of-the-art graphics to be displayed. A colour touch screen has been implemented, using the integrated circuit ADS7843 for obtaining the point selected by the user. The print is a roll paper, usefulness in this type of devices

CODEC

The system has been designed with a codec (WM8731) with audio amplifier and loudspeaker outlet to endow it multimedia possibilities, including the generation of sounds and reproduction of MP3 files.

3 SOFTWARE ARCHITECTURE

The Linux operating system is used for managing the resources of the designed system, for the following reasons:

- It is a scalable operating system that can be run in a great variety of hardware devices. This also means that it can be customised to meet the needs of each case or application.

- It is an open, well documented operating system with a network of experienced developers.
- The manufacturer itself provides drivers in this operating system.

The operating system is divided into the following layers:

- System boot.
- Kernel, version 2.4.20 for ARM processors.
- Root file system, based on JFFS2.

The Kernel is mainly responsible for the following functions:

- The scheduling of tasks
- The on-demand granting of non volatile memory pages and volatile zones pages
- The inter-task communication
- The access control to non volatile memory
- The context switching

The dedicated operating system offers the appropriate services for managing the system hardware resources: display, printer, smart power supply, etc.

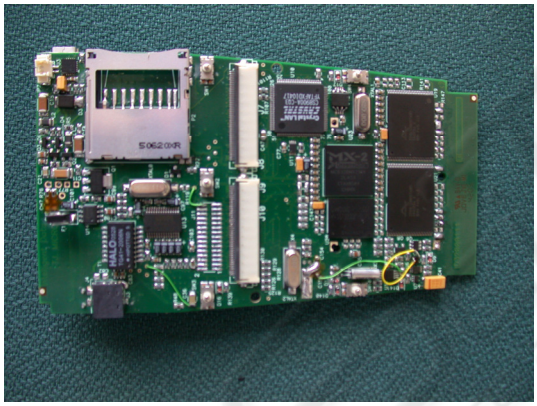

Figure 3: Real system.

Figure 4: Real system.

4 RESULTS

Once the system had been implemented both at hardware level (Figures 3 and 4) and at software level, the relevant checks were carried out to make sure the design specifications had been met. By way of example, the consumption of the circuit on stand-by is 50 microamperes; when running with the colour display it is 300 milliamperes).

In short, the system as developed can be used as an indispensable item in many services of e-Payment, e-Commerce, e-Health (Hall et al., 2003)(Song et al., 2002), etc.

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