Design of a Modular type Hardware Platform for Convergence Home Network Service

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Abstract
To make a smart space, we need to integrate scattered hardware (Set-top box, Modem etc.) with a platform, according to each service independently. In this paper, we present a modular type Home Service platform prototype of power efficient and high performance to meet the requirement for the 3 modular type services (Internet Protocol Television, Fixed Mobile Convergence and Health Care). This platform is called modular type platform because it has flexibility to support each service, depend on the selected hardware module. Our Platform is equipped with ARM Cortex-A8 processor (AM3894) and different types of interfacing facilities. This platform has PCI-Express, SATA, SPI, McASP, SD/SDIO, GPMC, GPIO, I2C, HDMI, USB, UART, EMAC interfaces. Android (Gingerbread) is used as an operating system for the platform. Though the presented platform is designed for 3-services, it can be expanded and applied to another services.

Keywords: Modular type Platform, AM3894 Processor, Peripheral Interface, Smart Home, PCIe.

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I. INTRODUCTION
Ubiquitous Computing allows users to access varieties of services at any time and any place. Presently, a house has several separated distribution and communication infrastructures. In most cases these infrastructures are isolated islands and interconnected only on rare occasions. These infrastructures provide four major services, Home security Services, Health Care Services, Remote Control and Maintenance of Appliances, and Entertainment Services [1]. Internet Protocol Television (IPTV), Health Care and Fixed Mobile Convergence (FMC) are most popular of them. Online entertainment is now possible at home by means of a plethora of ubiquitous services that can be provided based on wireless technologies such as, for instance, the common Wi-Fi IEEE802.11g network technology [2]. High quality television broadcasts are transmitted over satellite, cable or broadband Internet connections. IPTV is a relatively new and emerging alternative service that transmits TV signals over broadband Internet. In IPTV service, operators install a network switch at the customer’s broadband connection, and install Ethernet cables from the switch to television sets [3]. The percentage of Elderly populations of industrialized nations, who are affected by disabilities and chronic diseases, are increasing. In recent years novel care models based on home networking have been proposed [4]. Through those systems, care centers and hospitals are capable of continuous collecting the biomedical signals of cared people and the cared people also can enjoy the on-line services of clinic appointments, medical consultant, remote alarming, etc. FMC provide consistent and seamless handover services to users regardless of access and core transport layer. The FMC infrastructure consists of wired and wireless network infra. Therefore a mobile
device needs the function of connection method on the FMC infrastructure. A mobile controlled handover algorithm is used for keeping channel continuity in the wired and wireless mixture network environment that consists of WLAN, CDMA and wired network [5]. FMC services are provided by several TelCo’s.

People are enjoying above facilities as a discrete service. We have to install Set Top Box (STB) for IPTV, Application Programming Interface (API) for Healthcare and modem for FMC services. Those services are networked by PC based Home server and interfaced with wired and wireless infrastructure. We are facing problems like device wiring and configuration, Communication between heterogeneous networks and appliances, and Coordination between services. Modular type platform fulfills various functions thorough combination of distinct buildings blocks (Modules) [6][7]. Building a modular type Service platform for those services with expansion facilities could be reduced the complexity and performance cost ratio. Our aim is to develop a low power modular type Integrated platform with AM3894 ARM cortex-A8 processor having different types of interfacing facilities with an open source Real time operating system. We call it Home Service Platform. It likes a digital device Hub for Home Network as shown in Fig. 1. This Platform can support modular type open home network Framework and provide user selectable services.

![Diagram]

**Fig. 1. System Overview.**

Embedded system widely used low-cost, power-efficient and high performance ARM based embedded processors. An ARM based embedded processor is a highly integrated System-on-Chip (SOC) including an ARM core with a variety of different system peripherals [8]. These peripherals enable the embedded system to communicate and interactive with the circumstance in the real world [9]. ARM has continued to evolution of new features and enhancement to the processors and system block. AM3894 is an architecture version 7, profile-A processor which is designed for high performance open application platforms. This processor requires the highest processing power, virtual memory system support with memory management unit (MMU) and optionally enhanced Java support and secure program execution environment.

This Home Service Platform present version designed to support three types of services, Internet Protocol Television (IPTV) service, Health Care Service and Multiple Fixed Mobile Convergence (FMC) service. We designed different interface ports for interfacing daughter board of those services. We have used Gigabit Media Independent Interface (GMII, 2ports) for IPTV and WAN; General Purpose Memory Controller (GPMC) for 2 port 10/100 Mbps Ethernet; High-Definition Multimedia Interface (HDMI) for HDTV; Multi Channel Audio Serial Prot (McASP) for Audio; Peripheral Component Interconnect Express (PCIe, 3 ports) for Healthcare and FMC Module; Universal Asynchronous Receiver/Transmitter (UART) for Bluetooth, IrDA receiver and RS485 interface; SD/SDIO for WiFi chip.

The rest of the paper is organized as follows. In section 2, we discuss the details of our developed Home Network Service Platform. Section 3 shows the experimental results followed by an overall conclusion in section 4.

**II. THE DESIGN OF HOME PLATFORM**

**A. Overview**

AM3894 ARM Cortex-A8 processor is used in the developed service platform. This Processor is a High-performance highly integrated ARM core processor with outstanding performance and peripheral integrations ideally suitable for Communication and Network Processing Applications including Radio, Gateways, switches, and network attached storage. This is also fruitful for single board computer and distributed system as well as human machine...
interfaces and operator panel. This MPU is compatible with a wide range of operating systems, including Linux, Microsoft Windows Embedded Compact7 and Android. This is an application processor that is designed to handle complex applications [10]. This processor is a member of ARM cortex family of general-purpose microprocessors. This processor is targeted at multi-tasking applications where full memory management, high performance, low die size, and low power are all important. The ARM subsystem is the master controller of ARM Cortex-A8. Fig. 2 shows the block diagram of AM3894 Subsystem. The ARM Cortex-A8 is responsible for configuration of the various subsystem, peripheral, and external memories. This processor supports the ARM debug architecture and includes logic to assist in both hardware and software debug.

The ARM Cortex-A8 processor has a Harvard architecture and provides a complete high-performance subsystem, including ARM Cortex-A8 integer core, Superscalar ARMv7 instruction set, Thumb-2 instruction set, Jazelle RCT acceleration, CP14 debug coprocessor, CP15 system control coprocessor, NEON 64/128 bit hybrid SIMD engine for multimedia, Enhanced MMU, Separate level-1 instruction and data caches, Integrated level-2 cache, 128-bit interconnect to system memories and peripherals, Embedded trace module (ETM). The rich peripheral set provides the ability to control external peripheral devices and communicate with the external processors.

**B. Peripheral Interface**

The developed Service platform has different peripheral interface ports to control external peripheral devices and communicate with external processors as shown in Fig. 3.

Different types of peripherals are used for serial interfaces, Program/Data Storage, DMA, System control and Connectivity. HD Video Processing Subsystem (HDVIPSS), which provides output of simultaneous HD and SD analog video and dual HD video inputs. The connectivity peripheral set includes, two Gigabit Ethernet MACs (10/100/1000 Mbps) with GMII and MII interface, two USB ports with integrated 2.0 PHY, PCIe port x2 lanes GEN2 compliant interface, which allows the device to act as a PCIe root complex or device endpoint. The Serial peripheral set includes, one 6-channel McASP audio serial port (with DIT mode), two dual-channel McASP audio serial ports (with DIT mode), one McBSP multichannel buffered serial port, three UARTs with IrDA and CIR support, SPI serial interface, two I2C master/slave interfaces. The program/Data storage peripheral set includes, SD/SDIO serial interface, dual DDR2 SDRAM interface, flexible 8/16-bit asynchronous memory interface, and two SATA interfaces for external storage on two disk drives, or more with the use of a port multiplier. The System control peripheral set includes, seven 32-bit General purpose timers, Real-Time Clock, system watchdog timer. Block diagram of the developed modular type Platform is shown in Fig. 4.
AM3894 has multiple on-chip memories associated with its processors and various subsystems. To simplify software development, a unified memory map is used where possible to maintain a consistent view of device resources across all bus masters. The Cortex-A8 includes a memory management unit (MMU) to translate virtual addresses to physical addresses which are then decoded within the Host ARM Subsystem. The subsystem includes its own ROM and RAM, as well as configuration registers for its interrupt controller and secure state machine. These addresses are hard-coded within the subsystem. In addition, the upper 2GB of address space is routed to a special port (Master 0) intended for low-latency access to DDR memory. All other physical addresses are routed to the L3 port (Master 1) where they are decoded by the device infrastructure. The general device level-3 (L3) high-performance interconnect is based on a Network-on-Chip (NoC) interconnect infrastructure. The NoC uses an internal packet-based protocol for forward (read command, write command with data payload) and backward (read response with data payload, write response) transactions. Re-mapping is also possible through an internal or external Memory management unit (MMU). The L4 standard Peripheral bus accesses standard peripherals and IP configuration registers.

AM3894 supports one PCI Express (PCIe) 2.0 port with integrated PHY, so we used a 8-lane 8-port PCI Express Switching device (PEX 8609) for the three PCIe ports of the developed platform. This device offers PCIe switching capability for communication platforms, servers, storage systems and embedded systems. It provides a versatile and powerful 4 channels DMA engine built into the device. We used WLAN & Bluetooth & FM combo module IC AW-NH387 based on IEEE 802.11b/g/n. It is interfaced by using SD/SDIO with Cortex-A8 processor. On board connectors allow ease of interfacing to the daughter boards. Health care module uses PCIe, Multiple FMC Service Module uses PCIe, WiFi, Ethernet and IPTV modules uses GMII for connecting with the host processor. Different types of services interface with the module are shown in Fig. 5.
A +12 V, 6A external power supply is used for the Home Service Platform. Fig. 6 shows the block diagram of Power system used in Home Platform.

Different Modules in AM3894 are configured by separate power supply module for the stability of the system. A Triple Buck Power Management IC TPS65232 is used to divide the 12 +V into three different voltages (5V, 3.3V, 1.0V). Synchronous buck Dc to Dc controller TPS40041 is used for the Power Monitor section. Step down converter with dual low dropout regulators TPS65001 provides three voltages of 1.8V Digital, 1.8V Analog and 0.9V. PLL, SATA and PCIe block uses 1.5 V which is supplied by linear regulator TPS74701. Sink/Source DDR terminator regulator TPS51200 is used for DDR block. 1.0V supplied by TPS65232 is used for VDDA_HDMI, VDDT_SATA and CVDCC block. Two Step down converters (TPS54620) are used for PCIE and DDR memory. 5V power is supplied to IPTV by a step down regulator MP1593.

C. Software

The operating system is one of the most important parts in the whole system. It is in charge of managing all available resource and distributing them among different tasks in order. According to different resource distribution strategies, there are two kinds of the operating system, Real-Time and Time-Sharing Operating system [11]. Android is an open source platform that includes an operating system, middleware and applications such as client, contact manager, Google Maps, a web browser, a calendar and so on for the development of consumer, telecom, automotive, medical and home applications devices. Android is an application framework on top of the Linux, which facilitates its rapid development in many domains. Three layer model is followed for the software of the developed service platform. U-boot 2010.03 and Linux Kernel 2.6.35 is used in Hardware driver layer. Real Time Open source Android 2.3 (Gingerbread) is used in Operating System and Java is used in Application Layer. This platform supports different types of wired (TFTP, ARP, RARP, IPv4 and NFS) and wireless (WiFi, Bluetooth) Network protocol.

III. EXPERIMENTAL RESULT

We use OrCAD software tools for circuit designing as per specifications. Then the PCB is designed through Artwork and gerber process. Our developed Home Platform PCB is 12 layers. 3 different Layers are used for Ground connection, 2 Layers for power and all others are used for component connections. After fabricating the PCB, components are mounted by SMT (Surface mount Technology). Fig. 7 and Fig. 8, shows Gerber layout of PCB for layer C-MASK and INNER- 4.
Modular type Hardware Platform

Fig. 7. Gerber Layout of C-MASK layer.

Fig. 8. Gerber Layout of INNER-4 layer.

U-boot, Linux Kernel, File system, Device driver and Android OS software are downloaded to the module from the host PC. We have tested all interfacing ports separately. We used a 400MHz, 2.5GS/s 4ch Oscilloscope to check the function of output pins of different ports. The photograph of Front Panel, Back Panel and Different service Module interface with Home Service Platform is shown in Fig. 9, Fig. 10 and Fig. 11.

Fig. 9. Front Panel of Modular Type Home Network Service Platform.

Fig. 10. Back Panel of Modular Type Home Network Service Platform.

Fig. 11. Different service Modules interface with Home Network Service Platform.

HDMI can carry both uncompressed high-definition (HD) video and uncompressed multi-channel audio in all HD formats including 720p, 1080i and even upcoming 1080p. An all-digital, uncompressed signal translates into the highest quality video and audio, seen and heard, direct from the
source. HDMI connectors carry four differential pairs that make up the transition minimized differential signaling (TMDS) data and clock channels. These channels are used to carry video, audio and auxiliary data across the three TMDS data channels. The video pixel clock is transmitted on the TMDS clock channel and is used by the receiver as a frequency reference for data recovery on the three TMDS data channels. Video data is carried as a series of 24-bit pixels on the three TMDS data channels. To eliminate the routing glitch for the differential signal pair, a single-chip HDMI transmitter port protection and interface device TPD12S521 is used between the AM3894 processor and HDMI connector pin. The Oscilloscope captured waveform of TMDS_CLK, TMDS_D0+, TMDS_D1- and TMDS_D2- pins are shown in Fig. 12. The output waveform has an obvious distorting in rising edge due to the self inductance, capacitance to ground, mutual inductance and mutual capacitance between the lines. We observed that it has a symmetric character with HDMI pin definition.

![Oscilloscope captured waveform of HDMI port.](image1)

The RS-232 is the UART port of this platform. MAX3232 transceiver is used between AM3894 processor and RS-232 DB9M port which provides true performance. We set the Baud rate to 19200 and send a command (printenv) from the host PC to the module. In response to this command the values of environment variables of the module are displayed in the host PC. Fig. 13 shows the Oscilloscope captured waveform of TX, RX pins of RS-232 port.

![Oscilloscope captured waveform of RS-232 port.](image2)

For the PCIe interfacing ports, we used a device PEX 8609 which switches three PCIe ports. This device supports a large number of port configurations. This device has 1-lane upstream port and 7 downstream ports. We use 1-lane upstream port for interfacing with AM3894 and 3 downstream ports for different service modules. 36 pin PCI Express Right Angle Connectors are used with the three downstream ports of PEX 8609 switch. PEX8609 has four channel flexible DMA engine. The data rate per channel of this engine is up to 4.0GB/s and it can transfer data from any port to any port including the same port. Fig. 14 shows the Oscilloscope captured waveform of PEX_REF_CLK_P and PEX_REF_CLK_N Clock pin of a downstream port of PEX8609.

![Oscilloscope captured waveform Clock signal of PCIe Switch.](image3)

This Home Platform module has dual USB 2.0ports with Integrated PHYs. Each port uses one differential data pair (USB_DP and USB_DM), one voltage bus (VBUS), and one USB DRVVBUS signal. Oscilloscope captured waveform of differential data pair of a USB port is shown in Fig. 15.

![Oscilloscope captured waveform of differential data pair of a USB port.](image4)

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