Third Prize

Wireless Multifunction Digital Storage Center

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Design Introduction

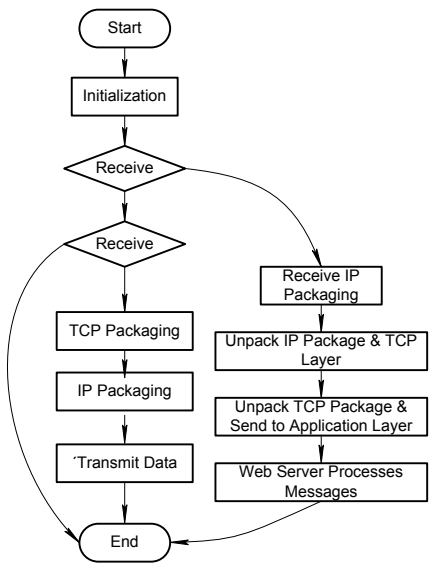
With the ever increasing use of data-transmission networks, data is increasing in geometric progression, and the traditional storage network architecture cannot cope. To deal with the massive amounts of data, data storage architecture is evolving to centralize data and features expandability, adaptability and reliability. This evolution now serves large enterprises and system management enterprises (SMEs). Interestingly, studies now show that many customers set aside a significant amount of their IT budget to handle storage. A wireless multifunctional digital storage center can efficiently provide mass data storage.

A wireless multifunctional digital storage center has centralized data and features a separate OS for data management and network performance enhancement. This cost-effective design meets the requirements of SME data transmission and storage. The system provides wireless network access applicable to wireless office environment and enables network access through an RJ-45 network interface. This setup makes it convenient for users accessing the WAN and LAN ports to set task allocation for the device. The shared document database on user management ensures the safety of stored data; the operation and management tasks controlled by web interface, LCD, and keypad make it easy to use the device. For experienced users who are familiar with Linux commands, the device provides a Java command-line mode for remote control.

Our design is based on an Altera® FPGA and the Nios® II processor, as well as Altera development tools. We applied system-on-a-programmable-chip (SOPC) design principles and used the Microtronix tool to migrate the uCLinux OS and integrated wireless data transmission storage, user management, FTP server, web server, Windows document share directory service, remote upload/download, and remote control functions. The uCLinux OS handles dispatching and management tasks of the system and ensures expandability of the product design. For enhanced performance, users can upload software to update the device in the software layer.

Our design is based on embedded SOPC technology that integrates Ethernet, compact flash card, SRAM, and PIO interfaces with the system to facilitate the functional modules integration with the whole system. The design uses a TCP/IP connection to connect to the Internet directly to perform data storage/transmission and system control based on the user's requirement, simplifies data upload/download, and facilitates document management. See Figure 1.

Figure 1. System Flow Chart



Function Description

The system contains the following parts:

- *Multi-User Storage Management System*—The operation rights of managers and common users are kept separate, and are validated with passwords. This mechanism has enhanced device data security and improved resource utilization.

- *Management & Control Base on Web Interface*—To establish a web service function, the uCLinux OS can read the device state information any time. At the same time, users can control the storage center with a web browser using the common gateway interface (CGI) protocol. Common users can only access functions such as examining system status and remote download, whereas managers can perform additional functions, such as user addition/deletion, open/close of Samba and FTP services, FTP and Samba directory setting, restart of system, and disconnection of FTP.

- *FTP Function*—This function establishes FTP service on uCLinux OS, which is the same principle as a Web server function.

- *Windows Shared Directory*—This function helps the user to migrate Samba software onto the uCLinuxoperating system and realizes file sharing using the SMB communication protocol. It also helps the user view the shared directory of the product on the network.

- *Local LCD and Keypad Control*—By interfacing the LCD and keyboard, users can read and control the local device status using the PIO signal lines of development panel. Our system can automatically receive the DHCP IP address distribution, and the IP address can be set manually by

the user if no DHCP server is configured. You can also read the IP address that has established the FTP connection in real time, as well as the download task name and status.

- *Wireless Network Access*—The product can be used in a wireless office environment with a access point (AP) supplied by Huawei Corporation.

- *Java Telnet Application (JTA)*—This application should not be confused with the Java Transaction application programming interface (API). This application is a client tool that integrates telnet and ssh, and gives advanced users a command-line mode for the device based on the Linux OS. Furthermore, mobile devices that support Java can carry out access and control, thereby improving the expandability of the device.

Performance Parameters

CPU: Nios II/f Core
JTAG DEBUG LEVEL: LEVEL 1
Small LCD refresh time: 0.1 μs
Small LCD response time: 1000 ns
LCD Size: 128[x]64 lattice
Time interval for reading information on LCD system: 5 seconds (on a time-sharing basis)
Average memory utilization: 75%
Capacity of CF card: 16 MByte (extendable)
Size of uCLinuxoperating system: 2012 KByte (kernel)
File system size: 3,612 KByte
Nios II kernel frequency: 50 MHz
Nios II kernel Mps: 23 MIPS (Dhrystones 1.1)
Number of consumed logic unit: 6,409 / 10,570 (60 %)
Pin utilization: 229 / 427 (53 %)

Design Architecture

Figures 2 and 3 show the design architecture.

Figure 2. Design Architecture

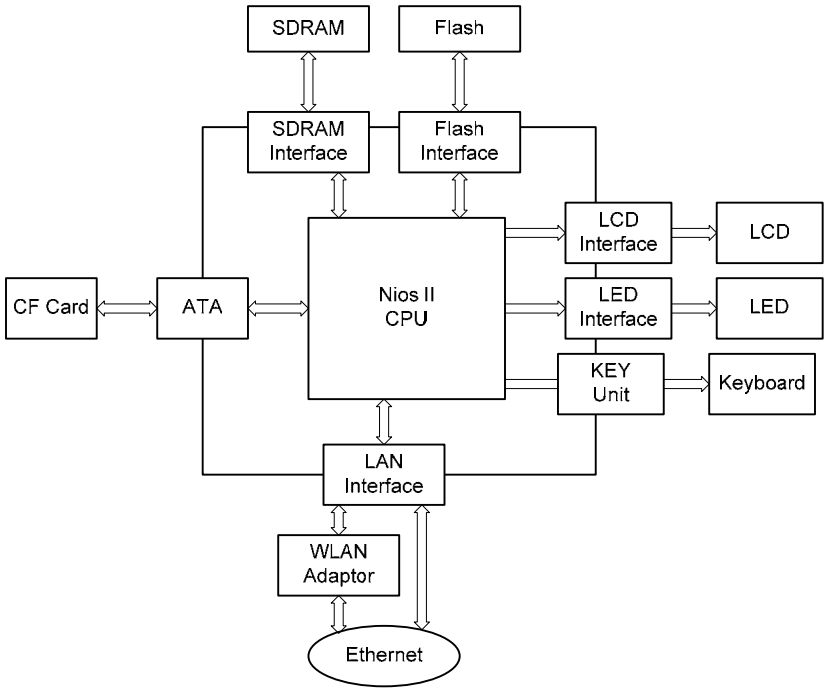
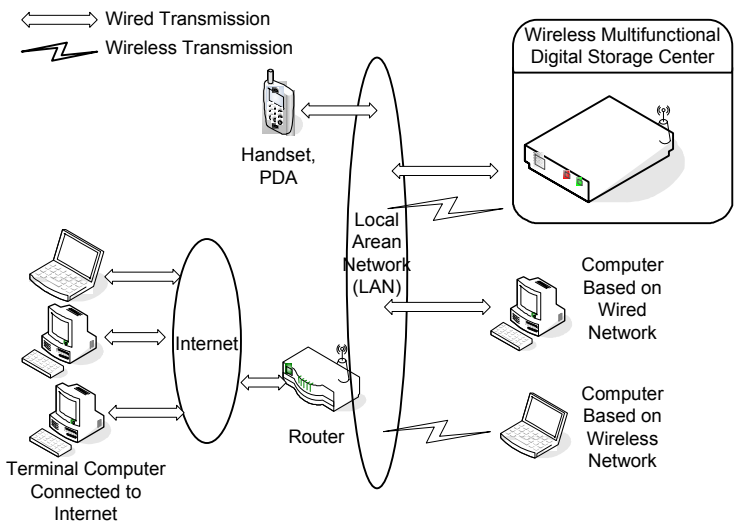


Figure 3. System Operation



Design Methodology

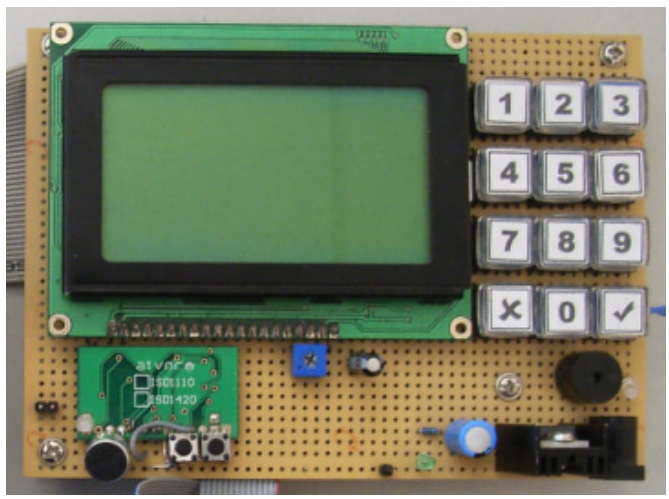
Altera's SOPC Builder improves the working efficiency of the design. Using SOPC Builder, we easily integrated the flash memory, Ethernet, compact flash card, and SDRAM modules together with the IP kernel provided by Altera. In doing so, we avoided having to design peripheral circuitry, which greatly reduced the design time and cost.

Our product design is based on the uCLinuxoperating system that handles Samba (network sharing software of Linux and NT system), ftpd (software supporting FTP service), httpd (the simplest web server software), Boa (web sever software that can support authentication and CGI), uncgi (analysis software of webpage form), and wget (download software based on HTTP and FTP protocols running on Linux's operating system).

We created the user management and system setting functions using CGI forms, shell scripts, standard expressions, and the file system.

We can control the LCD by a set of keyboard commands. Users can read the main menus of the data analysis module and all subfunction menus using up/down keys. The keypad and LCD provide the interaction between the user and designed module. See Figure 4.

Figure 4. LCD & Digital Keyboard



The LCD control program and the keypad was compiled with the Nios II integrated development environment (IDE) and uCLinuxdevelopment plug-in provided by Microtroni. We used the multithreading technique in the uCLinuxoperating system to implement keystroke processing operations, display screen refresh, and read different system state operations under different rates. In doing so, we took full advantage of the dispatching function of the operating system and omitted the more complicated information exchange among function modules to save CPU resources.

With a view to enhance functional features of the system at a later date, we have not fully addressed features such as the security of CGI and shell script programs, the remote control of handset WAB, the handling of independent memory space for multi-user operation, as well as personal ID authentication of the IC card. Moreover, concerns on the stability of migrated software will require a validation process that will take a long time to process.

Design Features

With an SOPC design methodology, our design integrates SDRAM, Ethernet, compact flash, and flash control interface modules. This methodology helped us to simplify circuit design and reduce costs. Compared to the available memory devices in the market, our product offers a variety of advantages such as wireless network access, hierarchical user-management mode, reliable security, and multi-control mode.

- *Wireless Network Access*—Adapting the device for wireless AP mode, users can easily access an office network or wireless network, and conveniently move from one network to another.

- uCLinux*Operating System*—Because of the open source nature of uCLinuxoperating system, you can easily adopt many software modules into the design. In doing so, you can add the relevant software modules to expand the device functions and update system software.

- *Easy & Maneuverable Control Mode*—We can easily manage data and users by deploying the web browser interface without the need for storage drives. You can do this even with the PDA and smart phones that can access network to carry out remote setting of the device. The local LCD and keypad can monitor the device in real time, directly manage the system using with control panel on storage center even when the Internet is unavailable.

- *Hierarchical User Management & Virtualized Storage*—By adopting a hierarchical user-management system, in which the administrator and normal users are provided with separate rights and different control capabilities for the system, you can enhance system security. The process works as follows: users log into the storage center via a password authentication system, which is adopted by different levels of administrators to prevent unauthorized access.

- *Remote Download Based on FTP & HTTP*—The user can access the LAN or WAN where the device is located, and can download data remotely and store into the device.

- *JTA (Java Telnet Application)*—Any mobile equipment supporting Java can be used to control the equipment, which makes for easy expansion of storage applications.

Conclusion

In this design competition, we gained considerable knowledge of the Nios II processor and Altera's development tools, and realized the benefits brought by the SOPC design concept and understood the development features of Nios II processor.

The building block system of SOPC design enables flexible custom peripherals to suit different needs; Altera has provided drivers for most of the peripherals, which reduces the difficulty of hardware design, shortens development cycles, increases reliability of design, and helps those unfamiliar with IP core development to integrate system modules. Furthermore, we have access to many resources via the network, which greatly expanded our scope and depth of development, reflected the flexible and comprehensive features of embedded development, and significantly reduced development cost.

With the Nios II embedded processor and uCLinuxoperating system, many Linux resources can be adapted into applications, which eliminates repeat development of application software, thereby simplifying software development and reducing cost.

In the development process, however, we also found some disadvantages of the Nios II processor application and SOPC development. For instance, the development board lacks expandability; we hope

that in the future the development board will allow the user to control more pins, and that it will integrate more interfaces.

Thanks to Altera and Cytech for providing this competition as a learning opportunity for us.