

# **Real Time Systems Laboratory Development Using the TI OMAP Platform**

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## **Abstract**

The laboratory curriculum developed for a semester long senior-level elective course in Real Time Systems is presented. The projects were developed on the OMAP 5912 starter kit (OSK5912) module supplied by Texas Instruments (TI). Some of the applications covered are: implementing a finite impulse response (FIR) filter and testing with audio, modifying the filter for different band pass characteristics, testing a media codec and implementing an embedded web server. TI expects to disseminate the instructional resources developed and tested in this course to other universities and industry partners.

## **Introduction**

This paper presents the laboratory curriculum developed for a senior-level elective course in Real Time Systems. The labs developed for this semester long course are aimed at providing a challenging experience to electrical and computer engineering students and exposing them to state-of-the-art tools from industry. The projects were developed on the OMAP 5912 starter kit module supplied by Texas Instruments (TI). The open multimedia architecture platform (OMAP) technology from TI consists mainly of dual-core processor chips<sup>1</sup>. The OMAP 5912 chip has an ARM processor and a C55 digital signal processor (DSP) in the same package, a functional block diagram<sup>2</sup> of which is shown in Figure 1. The Linux kernel runs on the ARM processor and the DSP-BIOS kernel runs on the TI C55 DSP in tandem. The real time software development tools for this system are the Code Composer Studio integrated development environment (IDE) and the MontaVista Linux environment. The platform is thus ideally suited to expose students to real time systems. The projects developed cover the following topics sequentially: introduction to the environment, real time operating systems, software development and application debugging<sup>3</sup>. Some of the applications covered are: implementing a finite impulse response (FIR) filter and testing with audio, modifying the filter for different band pass characteristics, testing a media

codec and implementing an embedded web server. TI expects to disseminate the instructional resources developed and tested in this course to other universities and industry partners.

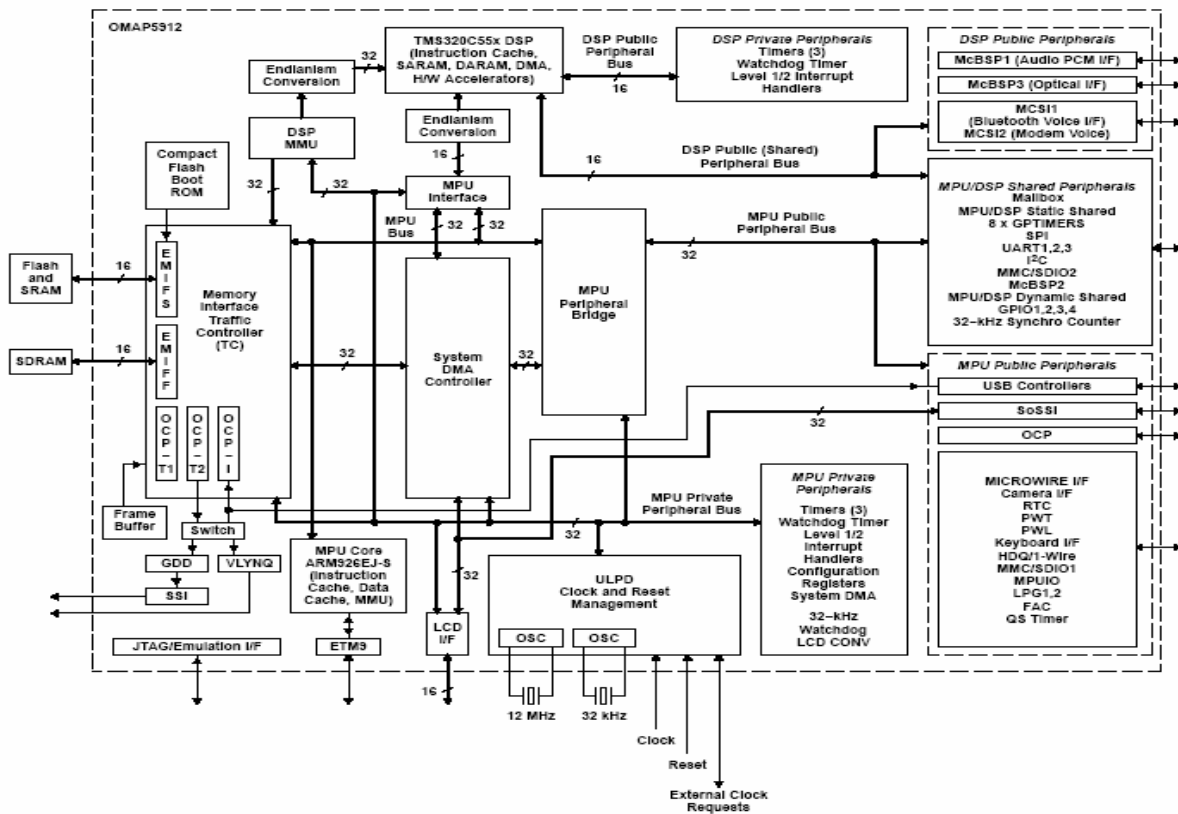


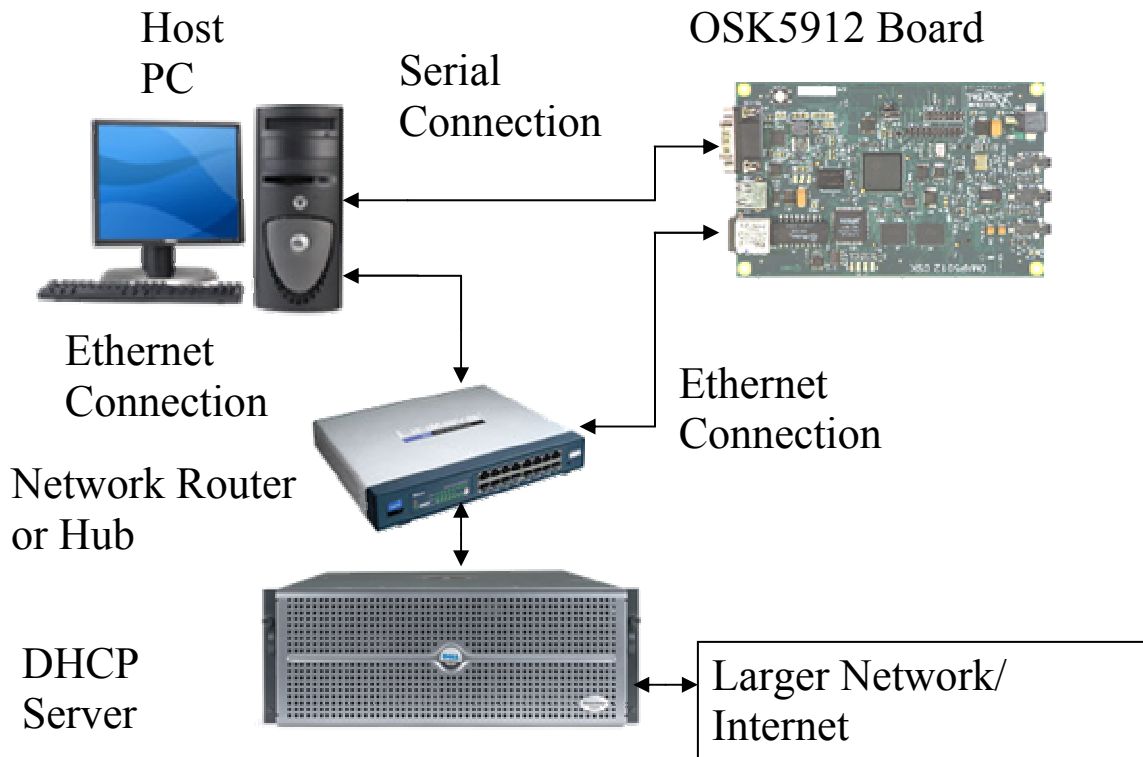
Figure 1. OMAP 5912 Dual Core Chip Architecture

The labs developed for the OMAP 5912 architecture assume that the students or persons learning with the labs may not have previous Linux experience. They are required to have at least one course in structured programming, and a course or prior experience with the operation of microprocessors.

## Laboratory Environment

The OSK5912 comes complete with the OMAP 5912 starter kit module, serial cable, Ethernet cable, power supply, MontaVista Linux Preview kit 3.1 and the OSK5912 CD-ROM. All that is necessary in addition to the OSK5912 is a network ready PC host running a compatible Linux installation. As of this writing, Red Hat Linux 7.3 or 9.0 are the recommended Linux versions for the development environment<sup>4</sup>. Other Linux versions may also be viable for the OSK5912 development environment. Figure 2 shows a typical network setup that includes the Linux host machine and the OSK5912 client. Initial setup of the board includes configuration of the board to mount its root file system from a network file system (NFS) mountable partition located on the host machine's hard drive over the Ethernet connection. The board is configured to acquire a network IP address on boot up from the Dynamic Host Configuration Protocol (DHCP) server. The serial RS-232 connection between the board and the host PC is used for allowing the host to

directly issue commands to the board via a serial communications terminal program (i.e. minicom, cu, or C-Kermit). Included with the OSK5912 is MontaVista Linux preview kit 3.1 which includes utilities to build Linux kernels for the ARM core of the OMAP 5912 processor as well as cross compilers so that software can be compiled that will run on the ARM core.

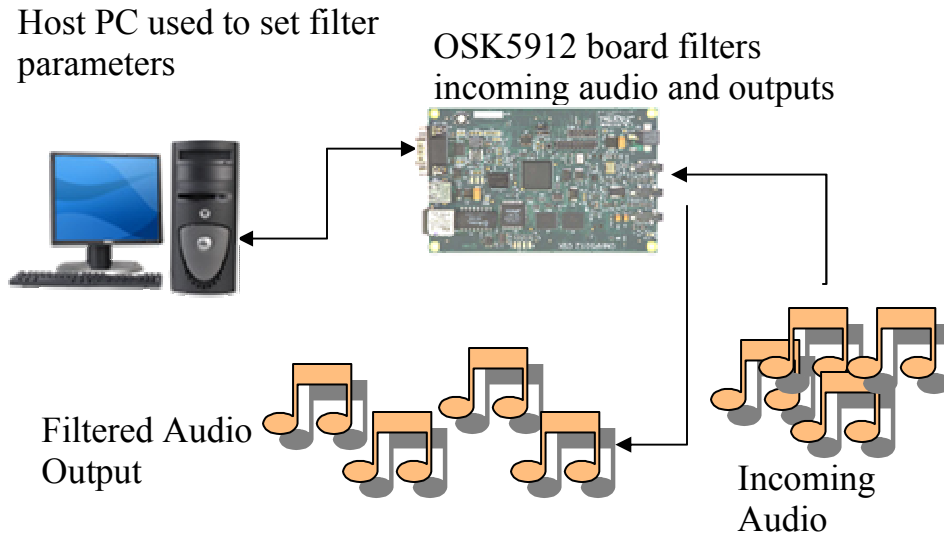


**Figure 2.** Laboratory Network Environment Setup

### Laboratory Curriculum

The laboratory curriculum is intended to demonstrate several of the concepts necessary for real time application development with the OMAP 5912 processor. This is achieved by incorporating relevant embedded systems applications into the labs including web servers and codecs. This section lists the laboratory exercises developed and describes them briefly.

The first lab is an introduction to the OSK5912 kit and to the Linux operating system. The initial part of this lab includes exercises to utilize Linux commands in a terminal environment with several examples. While learning the Linux environment, students establish the NFS mountable partition that will be used in later labs for application development. In the latter part of this lab, students use a pre-packaged application program that is already included with the board. This program demonstrates the utility of the dual core architecture by using a FIR filter to alter an input audio stream. The altered stream is then fed to the output audio port of the board. The physical setup is shown in Figure 3. The students can change the filter parameters in real-time and observe the resulting change in performance.



**Figure 3.** Audio Filter Laboratory

Lab 2 exposes the student to the process of customizing and building a Linux kernel<sup>5</sup> to be run on the ARM processor in the OMAP chip. The students use a configuration utility to select drivers that should be included in the kernel. The Linux make utility is then used to build the bootable kernel that will be stored in the board's flash memory. The Uboot 1.1.1 boot-loader commands are used to configure the board in order to load a file system from the hard drive of the host machine. This boot-loader program already exists in the OSK flash memory. The students compile and run a simple "Hello World!" program on the OSK5912 board to verify that the system is working correctly.

Lab 3 introduces students to adapting software application programs available from the open source community and compiling them to run on the OMAP platform. The application program used in this lab is the **madplay** MP3 audio player. The appropriate libraries for the MP3 player are installed in the board's file system and the application program source is cross-compiled on the host machine for the OMAP platform. After program installation, the students verify **madplay** operation by playing MP3 songs and listening via headphones or speakers connected to the board's audio output port.

Lab 4 is an introduction to image processing using the OMAP platform. The students compile and install software application programs to the target board. These programs facilitate several functions including conversion between the JPEG format and other graphics formats, image editing and image analysis. In addition, Portable Pixel Map (PPM) images tools are installed that allow PPM images<sup>6</sup> to be processed by the OMAP processor. The students utilize images to test these programs and the results may be viewed on the host machine using any image viewing software available on the Internet.

Lab 5 introduces students to designing an embedded web server. The intent is for the board to act as an Apache web server and host web pages that are stored on the board's file system. The first exercise is to set up the server to display an image using a static HTML page. Later exercises use

Common Gateway Interface (CGI) scripts that allow dynamic web serving. For example, information about the current status of the OSK5912 board and operation history may be served.

## Conclusions

The laboratory curriculum developed will be piloted for the ENGR 4350 Real Time Systems course in 2005. In addition to the labs described in the paper, other labs are currently being developed to highlight applications of the OMAP architecture. Lab 6 is an audio demonstration lab that incorporates the ARM side MP3 player of Lab 3 and a FIR filter implemented on the DSP side of the OMAP processor. The audio output of the MP3 player is streamed to the DSP and filtered before being sent to the audio output port. Lab 7 will incorporate video processing and display on a liquid crystal display (LCD). Further labs that will incorporate topics such as media processing primitives used extensively in graphics, audio and image libraries and video codecs<sup>7</sup> are being planned for an advanced course in real time systems.

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## Biography

MARK HUMPHRIES received his Bachelor of Science in Electrical Engineering in 2004 from the University of Texas at Tyler, where he is currently pursuing his Master's degree. He is currently developing real-time systems labs for the OMAP platform and working on ratification of JPEG and MPEG standards. His interests include real-time imaging, open source software and spatial geometry optimization algorithms for multi-faceted cubes.

MUKUL SHIRVAIKAR received the Ph.D. degree in Electrical and Computer Engineering from the University of Tennessee in 1993. He is currently an Associate Professor of Electrical Engineering at the University of Texas at Tyler. He has also held positions at Texas Instruments and the University of West Florida. His research interests include real-time imaging, embedded systems and pattern recognition.

LEONARDO ESTEVEZ received the Ph.D. degree in Electrical and Computer Engineering from Texas A & M University in 1997. He is currently the OMAP Software Architecture and Requirements Manager at Texas Instruments. He has many national engineering awards including SHPE in 2001 and the HENAAC "Most Promising Engineer" award in 2002. He is an Associate Editor for the Journal of Real Time Imaging.