A NEW DIGITAL SIGNAL PROCESSING (DSP) EVALUATION BOARD FOR REAL TIME APPLICATION

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A project report submitted in partial fulfillment of the requirements
for the award of the degree of
Master of Engineering (Electrical - Computer and Microelectronic System)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

May 2010

Specially dedicated to my beloved parents, brother, girl friend, supervisor, lectures, fellow friends and those who have guided and inspired me throughout my journey of education.

ACKNOWLEDGEMENT

This project will not able to complete without the help and guidance from others. Thus, I would like to take this opportunity to acknowledge the people below.

First and most importantly, I would like to express my gratitude to my project supervisor Dr. Muhammad Nasir Ibrahim. He guided me along the journey and always gives constructive suggestions and opinions. With his help, I do not lose in term of the project scope and objectives. I would say, throughout the whole year of working under him, I really gain a lot of knowledge not only in the technical area but also prepare myself to be a better person.

On top of that, I would like to thank my manager and Intel Penang Design Centre for supporting and sponsoring me to sign up this part time course. Thanks to my manager for being so thoughtful and always allows me to take examination leave to complete my project.

On a personal level, my deepest thank go to my parents, girl friend Patricia Ng Mee Ling and peers for their mental support throughout my academic years.

ABSTRACT

This project has a final goal of designing a new digital signal processing (DSP) evaluation board for real time application. DSP encompasses the digital representation of signals and the digital hardware to analyze, modify, extract information from digital signals. An evaluation board is a general purpose board with an embedded processor and generally with a way to download and execute user's program on it. Real time application places stringent demands on hardware and software design to complete predefined tasks within a certain time frame. This project consists of both hardware and software developments. The evaluation board accepts audible sounds (less than 10kHz) as its inputs and performs real time frequency and time domain transformation, frequency filtering and shifting operation. The results are designed to be outputted through computer screen and speaker. In this project, schematic is designed using Cadence Orcad v16.2 Capture, layout is designed using Cadence Orcad v16.2 PCB designer, programmer is developed under Microchip MPLAB IDE v8.46, DSP programs are developed by using Microchip C30 combo lite edition v3.23 tool suite and computer reception programs are developed by using Microsoft Visual C# 2008 express edition. This project was scheduled for two semester in which the activities of project requirements determination, embedded cores selection, modules planning, schematic design, component footprint checkup and layout design were done in first semester whereas activities to fabricate PCB board, solder components, set up programmer, develop software programs, validate output were carried out in semester 2. Experiment results prove that the project objectives have been fulfilled and problem statements have been solved.

ABSTRAK

Projek ini mempunyai tujuan akhir mencipta papan penilaian pemprosesan isyarat digital (DSP) baru untuk aplikasi “real time”. Pemprosesan isyarat digital meliputi perwakilan digital dari isyarat dan peranti keras digital untuk menganalisis, mengubah, mengekstrak maklumat dari isyarat digital. Sebuah papan penilaian adalah sebuah papan tujuan umum dengan prosesor tertanam dan umumnya dengan cara untuk memuat dan menjalankan program pengguna di atasnya. "Real time" aplikasi mengenakan tuntutan ketat pada peranti keras dan perancangan perisian untuk menyelesaikan tugasan yang telah ditetapkan dalam jangka waktu tertentu. Projek ini terdiri daripada perkembangan hardware dan software. Papan penilaian ini menerima suara terdengar kurang dari 10kHz sebagai masukkan dan melakukan "real time" transformasi domain masa dan frekuensi, frekuensi penapisan dan frekuensi pergeseran. Keputusan direka untuk dipapar melalui skrin komputer dan speaker. Dalam projek ini, litar direka dengan Cadence Orcad v16.2 Capture, tata letak direka dengan Cadence Orcad v16.2 PCB desainer, pengaturcara dibangunkan dengan Microchip MPLAB IDE v8.46, Program DSP direka dengan Microchip C30 combo lite v3.23 dan program penerimaan data direka dengan Microsoft Visual C # 2008. Projek ini dijadualkan selama dua semester di mana projek penentuan keperluan, seleksi core, modul perancangan, rekaan skematik, pemeriksaan bahagian tapak dan rekaan tata letak dilakukan pada semester 1 sementara kegiatan untuk membuat papan PCB, solder komponen, menyiapkan programmer, mengembangkan program perisian, memvalidasi output dilakukan pada semester 2. Keputusan eksperimen membuktikan bahawa tujuan projek telah dipenuhi dan pernyataan masalah telah diatasi.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
ADC	-	Analog to Digital Converter
AI	-	Artificial Intelligence
DAC	-	Digital to Analog Converter
DC	-	Direct Current
DCE	-	Data Circuit-terminating Equipment
DRC	-	Design Rule Check
DSC	-	Digital Signal Controller
DSP	-	Digital Signal Processing
DTE	-	Data Terminal Equipment
FFT	-	Fast Fourier Transform
I/O	-	Input Output
IC	-	Integrated Circuit
ICSP	-	In Circuit Serial Programming
IDE	-	Integrated Development Environment
IFFT	-	Inverse Fast Fourier Transform
IIR	-	Infinite Impulse Response
LCD	-	Liquid Crystal Display
LED	-	Light Emitting Diode
MCU	-	Micro Controller Unit
MIPS	-	Million Instructions Per Second
Op-Amp	-	Operational Amplifier
PLL	-	Phase Locked Loop
RS232	-	Recommended Standard 232
SMC	-	Surface Mount Component
SMT	-	Surface Mount Technology

UART	-	Universal Asynchronous Receiver Trasmitter
USB	-	Universal Serial Bus
VCO	-	Voltage Controlled Oscillator
VCP	-	Virtual COM Port
ZIF	-	Zero Insertion Force

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CHAPTER 1

INTRODUCTION

1.1 Title & brief introduction

The title of this project is “A New DSP Evaluation Board For Real Time Application”. Digital signal processing encompasses the digital representation of signals and the digital hardware to analyze, modify, extract information from digital signals. There are certain advantages in term of flexibility, reproducibility, reliability and complexity we can acquire in using digital techniques for processing rather than traditional analog devices.

Real time application is an application which places stringent demands on hardware and software design to complete predefined tasks within a certain time frame. Hence, a limitation of digital signal processing system for real time application is that the bandwidth of the system is limited by sampling rate. The processing speed determines the rate at which the analog signal can be sampled. In other words, a real time digital signal processing system demands that the signal processing time must be less than the sampling period in order to complete the current processing task before the new sample comes in. This real time constraint limits the highest frequency signal that can be processed by a digital signal processing system.

A common characteristic found in many emerging deeply embedded markets is a need to process some form of real time analog data, regardless a communications stream or multimedia information, while at the same time maintaining real time control of external events. The mixture of the two varies as widely as the diversity of the real time systems.

Embedded processors like microcontrollers are designed primarily in handling control oriented applications that are interrupt-driven and excited by external events. The external event is detected either via digital input/output, interrupt pins, or analog to digital convertor inputs. The source of the signals to these pins comes from switches, analog and digital sensors, or status signals from other systems. Each input represents a piece of information on the status of some outside event. Outputs are sent to actuators, relays, motors, or other drivers that control events. In between input excitations and output responses, there sits the microcontroller, which analyzes the inputs and the present state of the system, determining what and when the correct decisions need to be done. Table 1.1 below shows how microcontroller is specially designed to perform control oriented applications.

Embedded Processor	System Requirement	Processor feature	Benefit
Microcontroller	I/O control	I/O ports with bit-level control	Efficient control of external devices
			Direct interface to actuators, switches, etc
	Peripheral communications	Serial Ports: SPI, I²C, UART, CAN	Hardware support for expansion & external device networking and communications

Precision control of motors and actuators	Sophisticated timers and PWM peripherals	Low software overhead
Quickly resolve complex software program control flow	Conditional jumps Bit test instructions Interrupt priority control	Efficiently implement control oriented algorithms
Fast response to external events	External interrupts with multiple priority levels	Program control Immediately redirected on event occurrence with minimal overhead
Conversion of sensor data	Analog-to-digital (A/D) converters	Hardware support for external sensors

Table 1.1: Summary of a microcontroller's features

Digital Signal Processors (DSP), on the other hand, are embedded processors which found in systems that require the precision processing of digitized analog signals. The ultimate goal of a digital signal processor is to perform as many arithmetic operations as possible in the smallest number of cycles. Traditional DSPs use complex, compound instructions that allow the programmer to perform multiple operations in a single instruction and increase the amount of useful processing done. DSP cores are designed to be number crunchers. They must perform two tasks very well: first, a DSP core must perform multiple math functions, including multiplication, extremely quickly; and second, a DSP needs to continuously feed the data path to the number crunching computational units so that they can continue to crunch away. All this makes the programming model of a DSP look all so different when compared to a microcontroller. Table 1.2 below shows how a DSP is specially designed to perform number crunching digital signal processing applications.

Embedded Processor	System Requirement	Processor feature	Benefit
Digital Signal Processor	Software filters	Multiply/Accumulate unit	Digital filtering in few cycles
		Zero-overhead loops	
	Interface to codec	High-speed serial ports	Hardware support for translation of analog signals
	High data throughput from serial ports	Peripheral DMA	Less wasted cycles fetching data from serial ports
	Fast data access	Harvard architectures and variants	Fast execution of signal processing algorithms

Table 1.2: Summary of a digital signal processor's features

The two divergent paths of microcontroller and DSP may cross occasionally each other with each processor performing both tasks (controlling tasks and digital signal processing tasks) due to the explosive growth in personal computing, telecommunications, internet technologies, telephony, and portable applications.

An evaluation board is a general purpose board with an embedded processor and generally with a way to download user's program and execute user's program as well on it. This is very useful as a quick development aid for a user. An evaluation board can be bought as an off–the-shelf product or can be self developed in accordance to user's project requirements. Self tailored evaluation board integrates a bare embedded processor with different types of modules based on user's requirements. Once the evaluation board is ready, a user can develop a large variety of programs for different design applications.

1.2 Objectives

Our ultimate goal is to produce a new digital signal processing evaluation board for real time application. We wish to seek best solution among market available architectures to perform digital signal processing task and controlling task for real time application.

With ultimate objective as mentioned above in mind, we eagerly wish to analyze digital signal processing algorithms and transform these theorized algorithms into real time application by developing high level language or machine language programs. Accomplished program will be downloaded into microprocessor for application purposes.

On top of application program development, we aim to resolve rigid hardware design problem which is inherent in off-the-shelf evaluation board. To achieve this, we customize our own evaluation board for this project.

On the other hand, we wish to expose ourselves towards knowledge of embedded processor core selection, module selection, module planning, module testing, module integration, printed circuit board design, communication channel between personal computer and embedded microprocessor and other related knowledge fields.

Cost reduction is anticipated can be achieved as well through self developed evaluation board compared to a purchase of an off-the-shelf evaluation board.

In a nutshell, we hope to figure out the process flow of designing an evaluation board which seems to be a black box for most of the users in addition to develop digital signal processing algorithm by using appropriate embedded microprocessor. This project provides us a precious opportunity to achieve all the objectives as discussed earlier.

1.3 Scope of project & project background

This project is an effort continuation from a student who has designed an evaluation board by using TMS320 digital signal processor core 2 semesters ago. The student, who comes from the faculty of biomedical engineering, Universiti Teknologi Malaysia, is not having his prototype completely functioning due to certain specific reasons.

Due to time frame and hardware equipment constraints, the project has been scoped down to concentrate on the digital signal processing of human voice which falls below the frequency of 10 kHz.

The personal computer terminal which connects to the evaluation board is expected to display the real time output result in textual or graphical format from the digital signal processing tasks that have been performed by embedded processor. For instance, the computer terminal should be able to display the human voice signal in frequency domain at monitor screen.

This project is targeted to have its embedded microprocessor performing some basic digital signal processing functions such as frequency domain manipulations, time domain manipulations and filtering operations. Amount of

additional digital signal processing operations to be included in this project strongly depends on available project's bandwidth.

Fundamental modules and control modules which will be integrated into evaluation board are LCD module, LED module, power module, direct port access module and key press/keypad/switch module

Communication module which establishes connection between personal computer and evaluation board will preferably be Universal Serial Bus (USB) via Universal asynchronous receiver/transmitter (UART) output from embedded microprocessor core. Recommended Standard 232 (RS232) communication will be included as well as a secondary connection link if time frame permits since most of the early generation computers still support this type of connection.

Since this project focuses on human voice signal processing, some related modules will be included in order to favor this digital signal processing task. These modules are codec module and analog to digital converter input module.

1.4 Problem statement

Certain embedded microprocessors have been designed for their supervisory & control ability while others have been crafted for their data throughput & computational power. Explosive growth in electronic field places a strong request for an embedded system to own both excellent supervisory ability and high computational ability. Every embedded microprocessor available in market more or less faces some challenges for certain extent to possess those two abilities.

An evaluation board can be bought as an off–the-shelf product or can be self developed. Generally, an evaluation board is used by users who intend to exploit the full potential of the embedded microprocessor. The board is designed to demonstrate the capability the embedded microprocessor and to provide a hardware tool for developing and evaluating applications for the embedded microprocessor. Off the shelf evaluation board often includes tool suite which allows the user to develop and simulate routines, download the software to on-chip memory, run it and debug it using a debugger.

From an initial view, it seems like off-the-shelf evaluation board provide a complete and satisfactory solutions towards application system development. But, on the contrary, taking a closer look will discover that off-the-shelf evaluation board only provides flexibility in term of program design and does not favor flexibility of hardware design. Flexible program design enables a user to develop various types of applications but rigid hardware design may results in performance mismatch, system incompatibility, project failure, cost ineffectiveness and other undesired consequences.

It is true for certain extent that we can choose among off-the-shelf evaluation boards which best suit our hardware demands, but it is very hard to find one board which completely fulfills every desired specification. Discrepancy always exists between an anticipated and ready made evaluation board. For example, a user who chooses an off-the-shelf evaluation board with his or her intended core operating speed, supply voltage and memory size may not find the board providing useful USB connection as a communication channel with personal computer. Same theory applies when a user successfully finds a board with intended communication channel but the board is accompanied with disappointing core performance at the same instant.

Besides core performance and communication methods, there are some hardware factors which a user may also greatly wish to have the freedom to customize such as the various types of evaluation board's integrated modules like LCD, codec, motor and the others. The size of the evaluation board sometimes is listed into user's consideration as well when buying an off-the-shelf product. Undoubtedly, the cost of an evaluation board plays an important role as well. Even if we are optimistic enough to assume that we finally manage to buy a product which match all of our requirements, it is still not guaranteed that we can get it in low price.

All the factors as mentioned above have forced the users to achieve certain tradeoff towards design specifications when they decide to utilize an off-the-shelf evaluation board for their project development. Design tradeoff unavoidably leads to performance mismatch, system incompatibility, project imperfection, cost ineffectiveness and other undesired consequences.