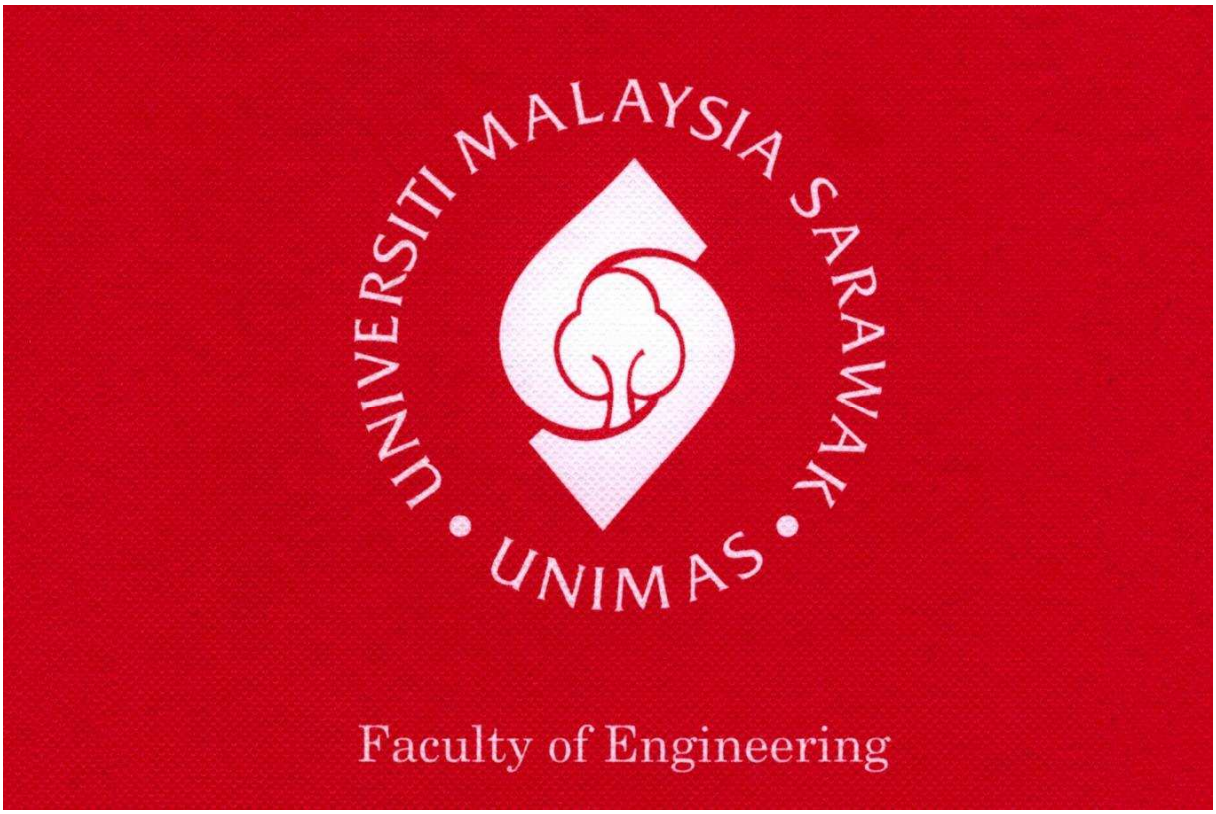


# DESIGN OF DIGITAL SIGNAL PROCESSOR

**TEO SIAW HUI**

Bachelor of Engineering with Honours
(Electronics and Computer Engineering)
2009

# UNIVERSITI MALAYSIA SARAWAK

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Project Supervisor

# DESIGN OF DIGITAL SIGNAL PROCESSOR

**TEO SIAW HUI**

Thesis is submitted to
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# ABSTRAK

Pemprosesan digital signal (DSP) bergantung kepada perwakilan dari signal dengan urutan nombor dan signal pemprosesannya. Prosesor digital signal yang ringkas dapat dibentuk dengan pelbagai blok seperti unit aritmetik logik (ALU), pendarab-acumulator (MAC), dan penganjak lipatan. Oleh sebab itu, projek ini telah dilaksanakan untuk menggabungkan pelbagai blok yang telah dicipta untuk memproses jalur data kepada Bus Sesiri Universal(USB) dengan manfaatnya kurang logik atau kecil daerah di dalam memori. DSP arkitektur yang dicipta telah diterjemahkan ke dalam kod sumber VHDL. Seperti yang dirancangkan, jalur penting untuk setiap blok telah dikurangkan sebanyak mungkin untuk meminimakan kadar penundaan. Pemprosesan digital signal sering memproses data menggunakan aritmetik titik tetap, walaupun terdapat beberapa aplikasi yang tersedia untuk menggunakan aritmetik titik apung yang lebih berkesan, ia tergantung kepada rekacipta tertentu. Fungsi logik menawarkan penyelesaian untuk kiraaan intensif yang ditemukan dalam pemprosesan digital signal. Oleh kerana itu, logic di dalam perisian dapat memberikan peningkatan prestasi pada sistem DSP yang mengurangkan kos sistem. Jadi, alat penghantaran data USB untuk kemudahan pindah data dapat dihasilkan dengan harga yang lebih murah tetapi prestasinya kekal tinggi.

## ABSTRACT

Digital signal processing (DSP) is concerned with the representation of the signals by a sequence of numbers and the processing of these signals. A simple digital signal processor could be constructed from blocks like arithmetic logic unit (ALU), multiply-accumulator (MAC), multiplier and shifter. Thus, this project is carried out to combine those blocks and design the processing datapath for Universal Serial Bus with less logic utilization or small area. The architecture of DSP is constructed and translates into VHDL source code. In designing, critical path for each block are reduced as much as possible to minimum the delay. Digital signal processing often process data using fixed-point arithmetic, although some applications are available to use floating point arithmetic which is more powerful depending on the design. Logic function offers a solution for the computationally-intensive found in digital signal processing. Therefore, programmable logic can provide increased DSP system performance at reduced system cost. So, a cheaper price but higher performance USB interface devices could be created for the convenient of data transfer.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

The invention of microprocessor has been innovating and impacting the world for the past few decades. From analogue signal processing, Integrated Circuit design has evolved to digital form to support the increasing of great numbers of transistors in a single IC. Applications of electronic devices are deal with various types of signals and multiple sets of data stream, these included mathematical manipulations of digitally represented signals. So, Digital Signal Processing (DSP) is a method introduced to do the signal processing. However, DSP would not operate without DSP Processor. DSP Processor is a microprocessor designed to perform digital signal processing. A Digital Signal Processor is a super-fast chip computer that has been optimized for the detection; processing and generation of the real world signals such as voice, video, music, etc in real time. Most DSP Processor share some common basic features designed to support high-performance and repetitive. Because of DSPs generally provide more parallelism than General

Purpose Processors (GPPs), it have some advantages compare to GPPs like cycle and memory use efficiency, and compiler friendliness to the user.

Therefore, for the better use of DSPs due to the efficiency purposes, DSPs memory architecture shall not be neglected and make it the first priority in the design for the faster processing speed. However with the targeting high speed processor, the crucial design parts would be an efficient data path which is needed to optimise the processor's performance and minimise the time consumed for critical path.

## 1.2 Project Overview

DSP systems are designed to sample incoming analog signals at fixed time intervals; so it must be fast enough to accurately describe the incoming signal, with enough resolution to keep the noise level as low as possible. In addition to doing this, it must convert the signal into a long list of numbers that represent the amplitude (e.g., voltage) of the signal at these points. The accuracy of this approximation determines the system's performance and the sampling rate determines the dynamic range that can be handling by the micro-controller.

A micro-controller requires an additional component such as data converters like the analog to digital (A/D) and digital to analog (D/A) converters to be able to interface to analog signals. A/D and D/A converters are electronic circuits that convert analog signals to digital signals or vice versa. Commonly, their

representative sampling frequency range from 5.5125 kHz to 48 kHz and a 16-bit resolution or higher are used.

As digital signal processing becomes ubiquitous in both personal computers and embedded applications, designers must decide how best to implement signal-processing functions in their systems and understand the key characteristics of the DSP processor design. However, there are limited possibilities, therefore in most cases designers have the choice to implement DSP on dedicated DSP chips or general-purpose microprocessors depend on the implementation purpose.

## 1.3 Project Objectives

Today, there is a wide range of products incorporating DSPs. So, digital signal processing has now become a core study of Electronic Engineering Department of University Malaysia Sarawak, especially for the real-time signal processing. With the ready of both hardware and software tools in the faculty, this project is providing a clear objectives and conveniences to undergraduate. The major objectives of this project are to:

- To study and analysis digital signal processor architecture.
- To understand the characteristics of DSP processor design.
- To design a simple Digital Signal Processor based on the characteristic of DSP with VHDL.

## 1.4 Project Scope

Indeed digital signal processing is a very wide field of study. For implementation of DSP design, there are a lot of architectures need to be considered and study. Applications of development tools are also to be determined. For this digital signal processor project, the scope would cover more on the study of Altera Quartus II even though Matlab softwares might be used for designing and simulink purposes. Besides, VHDL code would be studies and used for the writing of the designing language. Once the design has done, the written language would be implemented on the FPGA for the final outcome.

## 1.5 Project Outlines

Chapter 1 is basically the introduction to the whole project about, starting from the project overview of digital signal processing to it application. With the clear objectives guided, it is significantly contributes to the development of the project progress. DSP designation and its development tools are briefly introduced as well, and the project scope is determined. Overall, this chapter is divided into 5 parts which are the project background, project objectives, project scope and project outlines.

Chapter 2 is the most important and crucial chapter for the whole project which is literature review. This chapter is divided into 3 main parts. First part

discussed about typical microprocessor architecture and its application, while the second part discussed about digital signal processing architecture and its functional blocks briefly. The third part mentioned about development tools, software and hardware used, and a little bit regarding the designing methods and algorithm used.

Chapter 3 introduces the methodology of the design in digital signal processor by using hardware tools. It illuminates all the methods and techniques that used to carry out this project. All progress steps will be clearly shown and explain through this chapter.

Chapter 4 discusses all results that obtained from the software and hardware throughout this project. Top level of each block of data path is obtained as binary input applied. Synthesis and waveform generated from every single block of data path is also observed. Designing through two methods which are block diagram and VHDL code are also discusses. The responses obtained are compared and analyses are made based on the results.

Chapter 5 concludes the whole project implementation. The whole processes are analyzed whether it meets the project objectives or not. Problems that encountered during the whole process is stated and discussed in this chapter, as well as some constructive recommendations for future improvement and enhancement.

# CHAPTER 2

# LITERATURE REVIEW

Basically, the analyse of digital signal processor and study of the key characteristic of DSP processor designation, could be split into three majors areas which are microprocessor architectures, digital signal processor architectures and instruction set used for both microprocessors and DSPs. DSPs design could be non-real-time signal processing or real-time signal processing [5]. Real-time signal processing is a processing system that must keep pace with some external event while non-real-time processing has no such timing constraint, both has pro and con depending where it apply. To understand it, some architectures of DSP and instruction sets can be referred and implement it on DSP development tools for analysis purposes. In this simple DSP processor design, non-real-time processing design will be first considered as timing constraint problems can be neglected in the application. Differentiation between architecture of microprocessors and DSP processors will also be review and referred for the new DSP processor architecture design.

## 2.1 Introduction to the Architecture of Microprocessor

A microprocessor is a digital electronic component with multiple transistors on a single semiconductor integrated circuit (IC). Typically, microprocessors serve as a central processing unit (CPU) in a computer system. But before this, electronic CPUs were typically made from bulky discrete switching devices that containing the equivalent of only a few transistors. By the integration of a few very large-scale integrated circuit packages, which containing millions of discrete transistors onto one circuit, the cost of processor power was greatly reduced and made the possible of microcomputer.

The evolution of microprocessors has been known to follow Moore's Law when it comes to steadily increasing performance over the years. This law suggests that the complexity of an integrated circuit, with respect to minimum component cost, doubles up every 18 months. This dictum has generally proven true since the early 1970s. From their humble beginnings as the drivers for calculators, the continued increase in power has led to the dominance of microprocessors over every other form of computer; every system from the largest mainframes to the smallest handheld computers now uses a microprocessor at its core.

### 2.1.1 Von Neumann Architecture

Figure 2.1 shows the seemingly simple design of traditional microprocessor, which is commonly known as a Von Neumann Architecture,