FPGA-BASED LIGHTNING SENSOR

A thesis submitted in partial fulfilment of the

Requirements for the degree of

Bachelor of Electronics Engineering (Wireless Communication) (Hons.)

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APPROVAL

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This thesis is dediceted to my beloved mom, Loh Phaik See;

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my sister, Seah Boon Yun;

and

my fellow BBNET friends.

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ABSTRACT

Lightning has been a mysterious natural phenomenon since ancient time. People used to fear and worship the lightning and took it as the wrath of God. Although the phenomenon of lightning has been revealed as the transmission of electrical discharges, there are still many unknown areas inside the occasion of lightning itself such as the positron, the contents of the emission in lightning flashes and so on. Thus, the studies or researches about lightning are still a hot topic and being carried out until nowadays. Many equipment involved during these researches but they are very expensive and turn out to be a costly budget to the whole research or studies for example, PicoScope. This PicoScope is a PC software developed by Pica Technology Inc. which a lot of functionalities such as oscilloscope and digitizer. However, the market pricing for a standard PicoScope package nowadays is around RM 8,000. A master kit of PicoScope can even reach more that RM10,000 per unit. Thus, this project is carried out to make a low-cost digitizer by implementing the module (syntax) onto the FPGA board so that it will be running as a digitizer. Why is this digitizer so important? As we know, the signals from this real world, including lighting signals are in the analog form which cannot be understand by the electronics components which communicate in digital form. Therefore, implementing the FPGA board as the ADC is of great use and help in converting the real-world signals and further processing to extract vital information from the lightning signals.

Keywords: Field Programmable Gate Array (FPGA), Analog to Digital Convertor(ADC), XILINX Spartan 3AN, Verilog HDL.

ABSTRAK

Kilat telah merupakan salah satu fenomena semula jadi yang misteri sejak zaman purba lagi. Orang purba takut akan kilat dan menganggap kilat sebagai murka Allah. Walaupun fenomena kilat telah dikemukakan sebagai penghantaran pelepasan elektrik selepas abab ke- 18, namum di situ masih terdapat banyak kawasan yang tidak diketahui dalam kriteria kilatnya seperti positron, kandungan pelepasan dalam kilat dan sebagainya. Oleh itu, kajian dan penyelidikan tentang kilat masih merupakan satu topik hangat dan giat dijalankan sehingga masa kini. Banyak peralatan yang terlibat dalam kajian ini tetapi peralatan ini adalah sangat mahal dan secara tidak langsung telah membebankan bajet penyelidikan secara keseluruhannya. Sebagai contoh, PicoScope. PicoScope ini adalah perisian PC yang diperkenalkan oleh Pica Technology Inc. yang boleh digunakan dalam pelbagai fungsi seperti osiloskop dan digitizer. Namun begitu, harga pasaran untuk satu PicoScope yang standard pada masa kini adalah sekitar RM 8,000 dan boleh mencecah RM10,000 sekiranya terdapat kelebihan yang lain lagi. Oleh itu, projek ini dijalankan untuk membuat digitizer kos rendah dengan memperisikan modul (syntax) pada FPGA supaya ia akan berfungsi seperti digitizer. Apakah kepentingan digitizer? Sebagaimana yang kita tahu, isyarat dari dunia ini adalah dalam bentuk analog yang tidak boleh difaham oleh komponen elektronik yang berkomunikasi dalam bentuk digital. Oleh itu, FPGA akan digunakan sebagai ADC untuk membantu dalam penukaran isyarat dunia nyata kepada isyarat digital dan selanjutnya untuk mendapatkan maklumat penting daripada isyarat kilat yang ditangkapkan.

Kata Kunci: Field Programmable Gate Array (FPGA), Analog to Digital Convertor (ADC), XILINX Spartan 3AN, Verilog HDL.

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CHAPTER 1

INTRODUCTION

1.1 Background

Lightning has been a field of studies since the civilization of the Europe science. The phenomenon of the lightning is feared by people during ancient and assumed as the wrath of the God until it is being revealed as the propagation of the electrons inside the cloud. Somehow or rather, the lightning is still consisting of many unknown phenomena such as its fundamental mechanism, emission of the lightning flash (gamma ray and positron) and so on. Despite the records based on the raw eyes observations about the lightning in the ancient scriptures, we cannot really or fully understand what are the mechanisms of lightning flash and there are a lot of scientists still carry on the research on it until nowadays.

At the second half of the 18th century, the first scientific study about lightning was conducted by Benjamin Franklin who had proven the nature of lightning which consists of electrical charges or so-called electrons through experiments [1]. Lightning is defined as the electrical discharges in air (dielectric break down) which will emit electromagnetic (EM) field along the channel of ionized air (leader). Typically, lightning can be considered as a type of electric current made by the thundercloud. Modern studies of lightning are done by capturing the EM field emitted from the lightning flashes in which the analog signals are converted into digital data and being analyzed later.

1.2 Problem Statement

Even though there are a lot of equipment that will help us a lot during capturing the lightning flash signals, there are still some improvement can be made such as combining all the equipment into one system which can carry out all the functions of those equipment respectively at the same time. As for the FPGA based lightning sensor, it is proposed to be able to run the doings of ADC, PC, oscilloscopes, and temporary storages of data collected. The details working flows are shown in *Figure 1.2.1: Process Flow of The Signal Processing of Lightning Flash (without FPGA)* and *Figure 1.2.2: Signal Processing Flow of Lightning Signals (with FPGA).*

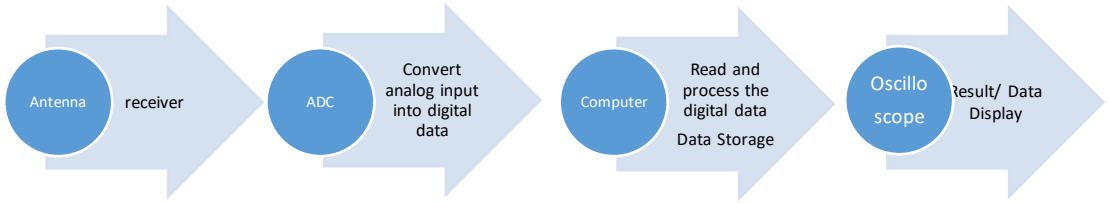

Figure 1.2.1: Process Flow of The Signal Processing of Lightning Flash (without FPGA)

Figure 1.2.2: Signal Processing Flow of Lightning Signals (with FPGA)

This project is mainly to compromise with the existence of the equipment involved, in other word, we are constructing a FPGA based lightning sensor that can run all the properties of the equipment so that we do not need too many of the equipment during carry out the lightning studies.

1.3 Objectives

This project aims to design and develop a digitizer with FPGA-based system which can digitize the analog signal from the antenna (receiver) into digital signal with the sample rate up to 100MS/s and 12-bits vertical resolution. In the other words, we will have a Spartan 3AN FPGA platform which is able to detect the lightning signals with maximum frequency of 50MHz in a finest display sector of 4054 divisions/ boundaries.

1.4 Scope of Work

The project mainly consists of four parts, understanding the working principle of ADC and Picoscope, constructing the flow of Verilog modules (ADC, LCD, SDRAM controller), implementing the coding onto the FPGA Board and then conducting the experiments.

The first scope, understanding the working principle of ADC and Picoscope is to identify the functionalities of a Picoscope in reading the input data and how does it display on the monitor. Besides, the working of ADC should be understood so that it will help a lot in programming the FPGA as a virtual ADC via Verilog code and clearly know about the specification of the components, devices capable of.

Next, we will research about the coding for ADC and LCD modules, then editing the coding to make sure the FPGA board system can digitize the input signals with the desired sample rate and resolution. When the simulation shows a stratified result, we will start to generate the Bits. File for the modules so that it can be implemented onto the FPGA board and starts collecting the actual results from the real-world signals in real time.

1.5 Thesis Structure

This thesis consists of five chapters which are Introduction (Chapter 1), Literature Review (Chapter 2), Methodology (Chapter 3), Results & Analysis (Chapter 4) and Conclusion & Suggestions (Chapter 5).

The first chapter states a brief introduction about the history of lightning and the evolution of human knowledge in the understanding about lightning, the problem statement about the difficulty faced and expected to be overcome by conducting this project, thus lead us to the objectives or goals expected to be achieved at the end of this project. Besides, there are also some information about the scope of works in this project and the last part is about the thesis structure which shows us the brief structure flow of each chapters respectively.

The second chapter states about the information or knowledge about the lightning such as definition of lightning, how does the lightning occur, what is the structure of a thundercloud, types of lightning flashes, the electromagnetic field emitted by the lightning based on the understanding from the various literature reviews and researches, and how does it related to this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Lightning

2.1.1 Formation of Thundercloud

What is lightning? As stated in Chapter 1 – 1.1 Background, it is the natural result of dielectric break down or electrostatic discharge caused by imbalances within or between thundercloud(s), or between the storm cloud and the ground [1]. So, how does the lightning occur? The hot surface of the ground or earth will start to heat up the air, causing the warm air rise. The warm air will cool down when it reaches a certain level in the atmosphere and the water vapour forms cloud(s). there will be ice forming on the top of the cloud when it is getting bigger and bigger as the air continuously rises and turns out to be a thundercloud. The collision of water and ice particles inside the thundercloud causes the imbalance of electrostatic charge/ potential difference between the surface of the earth and the lower part of the thundercloud [1].

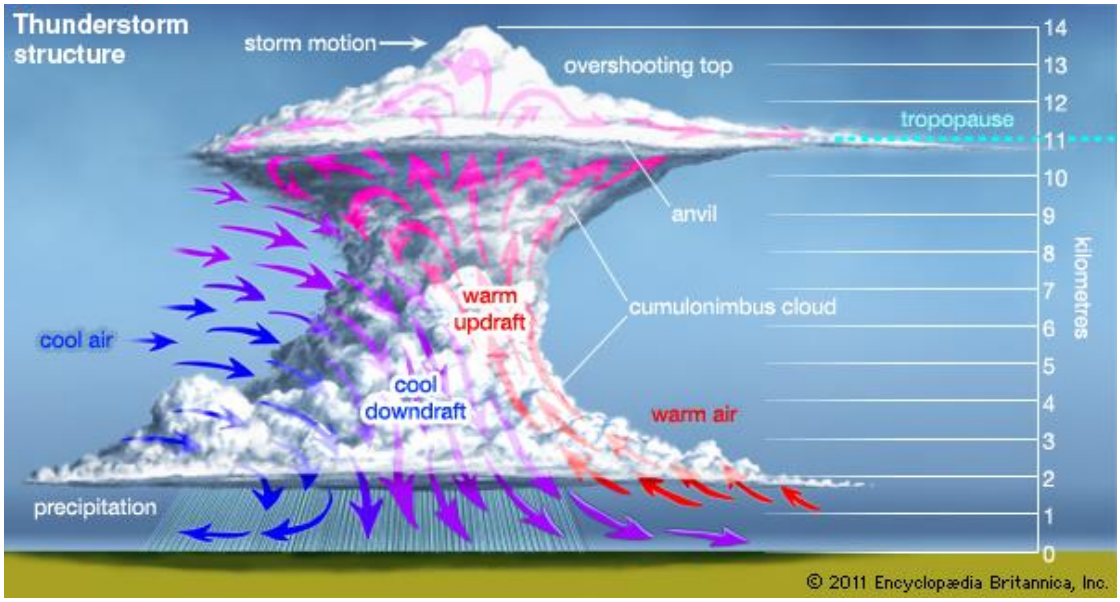

Figure 2.1.1: Formation of the Thundercloud [29]

2.1.2 Thundercloud Structure

Before continuing explain about lighting, we need to understand what is thundercloud, what is its structure and how does it lead to an electrical discharge occurrence. A cloud vertical distance is basically from 500m up to 2km above the ground and the vertical diameter of the cloud itself can reach up to 19km. One of the conditions to form a thundercloud is the vertical diameter of the cloud must be at least 10km [2].

Thundercloud is a triple charge structure (tripole) as shown in Figure 2.1.2: Thundercloud Structure. The top of the thundercloud is positively charged (>30C) while the middle part is negatively charged (< -30C). The lowest part is known as pocket positive charge region, which accumulates with small amount of positive electrons (+5C) only compared to the number of charge of top and middle part of the thundercloud [1].

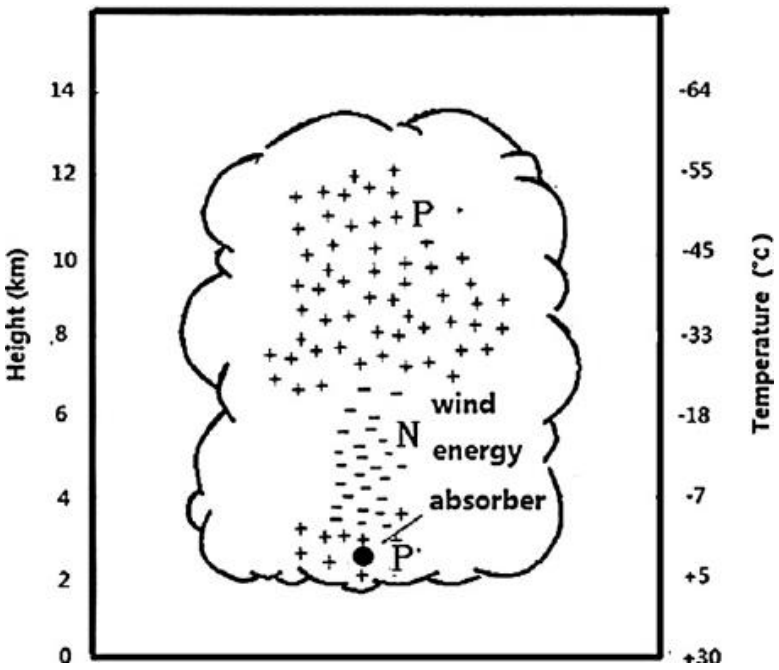

Figure 2.1.2: Thundercloud Structure

Thus, when the lower part of the thundercloud exceeds -30C, the objects on the earth such as trees, buildings, and earth surface itself will become positively charged, causing a great potential difference or imbalance that nature seeks remedy by passing current between two points and this phenomenon is known as corona. Corona discharge is due to the partial breakdown in the air at the points of high voltage conductor with the highest electrical stress [1]. As for a thundercloud, the electrons inside will try to move to the other opposite region (objects and earth surface) and the attachment process formed with the 'leader' or leader channel which is lightning [3].

2.1.3 Lightning Flashes and Thunder

Lightning causes the light in the form of plasma (flash) and sound in the form of thunder. Sometimes, lightning may be witnessed without hearing any sound of thunder due to the lightning itself occurs at a distance that is so far for the sound to be able to reach as far as the light of the flash. Typically, lightning is an extremely hot flash which can heat the air surrounding up to temperature five times hotter that the surface of the