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Lightning Acquisition and Processing On Sensor Node Using NI cRIO

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Abstract
In this paper, we propose a digital design implementation for continuous real time data acquisition in case of a lightning event. The proposed system is capable of acquiring the lightning data at the rate of 1 MS/s on the FPGA. The system is also capable of providing very accurate timestamps in microsecond's resolution. The data logging is carried out continuously on the PC using the TDMS file format with each and every sample being timestamped. The entire acquisition design is being implemented using NI cRIO hardware. The components of this assembly consist of the cRIO-9030 chassis , which contains a Kintex-7 FPGA , NI 9223 which is a sixteen bit ADC module, along with the NI 9467 which is a GPS module with the receiver antenna, it is used for accurate timestamping. The analog front end has been already developed, it comprises of an anti aliasing filter ,Low Noise Amplifiers and level shifters which can provide the signal with necessary gain to be processed by the digital section. The output of the analog front end is then fed to the NI 9223 four channel ADC module for sampling at 1MS/s. The samples along with their respective timestamps would be processed for identifying probable lightning data chunks on a preliminary basis which would then be transmitted over an Ethernet interface to the Central Processing system using Network Streams. The proposed digital design implementation for the entire acquisition system on the FPGA is briefly discussed in this paper.
Keywords: *ADC, Amplitude Thresholding, Cloud To Ground Lightning, DMA FIFO, Rise Time Detection, Sferic Detection, Time Of Arrival.*

I. INTRODUCTION

Lightning has a negative impact on the human safety. There has to be certain measures which helps detect and monitor lightning and its parameters[8]. There are various lightning acquisition techniques which are already being discussed[1][2]. This paper lays emphasis on the development of the Digital Processing section at the Sensor Node. The Sensor Node at present is equipped with a Cross Magnetic Loop Antenna[5][6] which detects the magnetic field component and an analog front end for noise removal and signal conditioning[7] . We, hereby propose a Digital Architecture which is capable of acquiring the lightning data at the rate of 1 MS/sec as well as carry out certain preliminary stages of real time processing like determination of 'Time Of Arrival' through GPS timestamping[1]. The signal acquisition capability involves interfacing of GPS module(NI 9467) with the entire data acquisition model which is carried out on the Kintex-7 FPGA. The processing section comprising of 'Amplitude Thresholding' and 'Rise Time Detection' and is implemented on the Crio-9030 controller. This entire assembly comprising of preliminary processing stage aims to create probable lightning data chunks and send them to the Central Processing System using an Ethernet interface which would later on be used to determine certain useful parameters of the lightning signal such as the Peak Lightning Current amplitude[4] .The entire architecture involving Real Time Processing of the Lightning Signal at present can be basically used to detect and process the Cloud to Ground Lightning and is briefly discussed in this paper.

II. SENSOR NODE DATA ACQUISITION

The sensor node data acquisition can be briefly split into two parts

1. Data acquisition at 1 MS/sec and GPS timestamping on the FPGA.
2. Amplitude thresholding and Rise Time detection to determine probable lightning data chunks on the cRIO.

2.1 Data Acquisition At 1 MS/sec And GPS Timestamping On The FPGA

The process of data acquisition is carried out on the Kintex-7 FPGA . The process of data Acquisition is composed of two distinct parts ADC sampling using sixteen bit ADC NI 9223 module and the important lightning parameter 'Time of Arrival' at a particular sensor node is determined using the NI 9467 GPS module. The design for the data acquisition is shown below

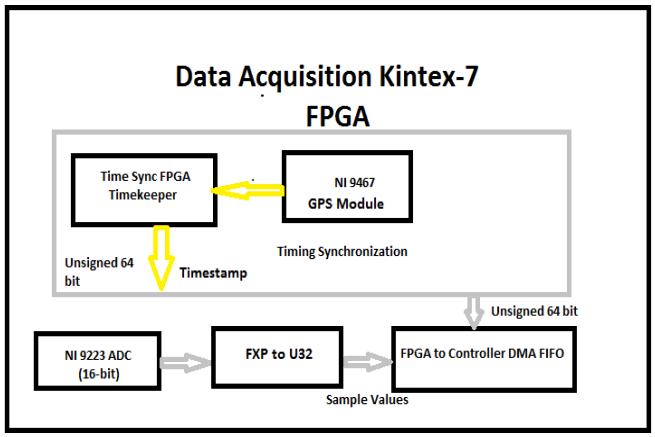

Figure 1: Data Acquisition and Timestamping on the FPGA

The above block diagram shows the design architecture on the FPGA VI. The data acquisition loop comprises of two parts

1: The 'NI Time Sync: FPGA Timekeeper VI' which is used to synchronize the absolute time on the FPGA target

2: The Data Acquisition loop which includes a loop timer set to 1 microseconds. The acquisition loop basically converts the Fixed point values obtained from the NI 9223 ADC module to unsigned 32 bits and then it packs the unsigned 64 bit timestamps obtained from the 'NI Time Sync: FPGA Timekeeper VI' along with the data values onto a 'FPGA to Controller DMA FIFO' these values are now transported to the Real Time target(cRIO-9030)

2.2 Real Time Processing On cRio

The data is recovered on the cRIO . There are different processes like Data Recovery, Amplitude Thresholding, Rise Time Detection and the Communication .These processes are carried out on different priorities on the Real Time target. The process of reading data from the FIFO buffer is of the highest priority while the process of communicating data from the cRIO to the PC is of the lowest priority after processing all the relevant data.

The data from cRIO would be dispatched to the host PC in small chunks using Ethernet interface. This would mean an ideal deterministic data transmission since the data would be streamed to the host PC using Network Streams, which is a lossless buffered data transmission technique and the usage of Ethernet simply signifies that data transmission is supported at higher data rates. The data which is continuously logged on the PC can be later used for several analysis techniques like computation of several lightning parameters such as the Lightning Peak Current [5] and other useful lightning parameters.

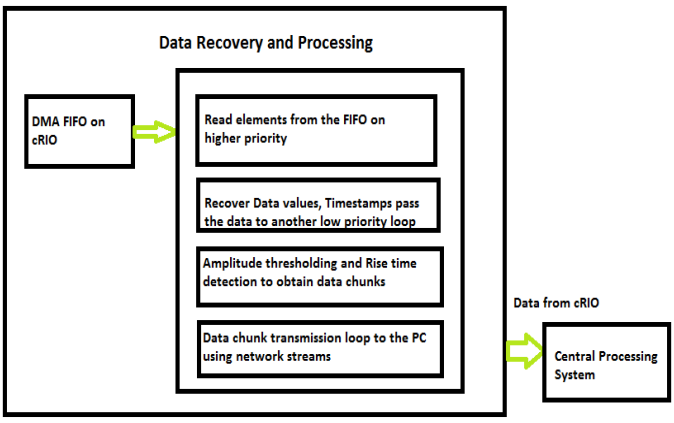

Figure 2: Processing on cRIO

2.3 Algorithm

The flow chart depicts the System Design Architecture

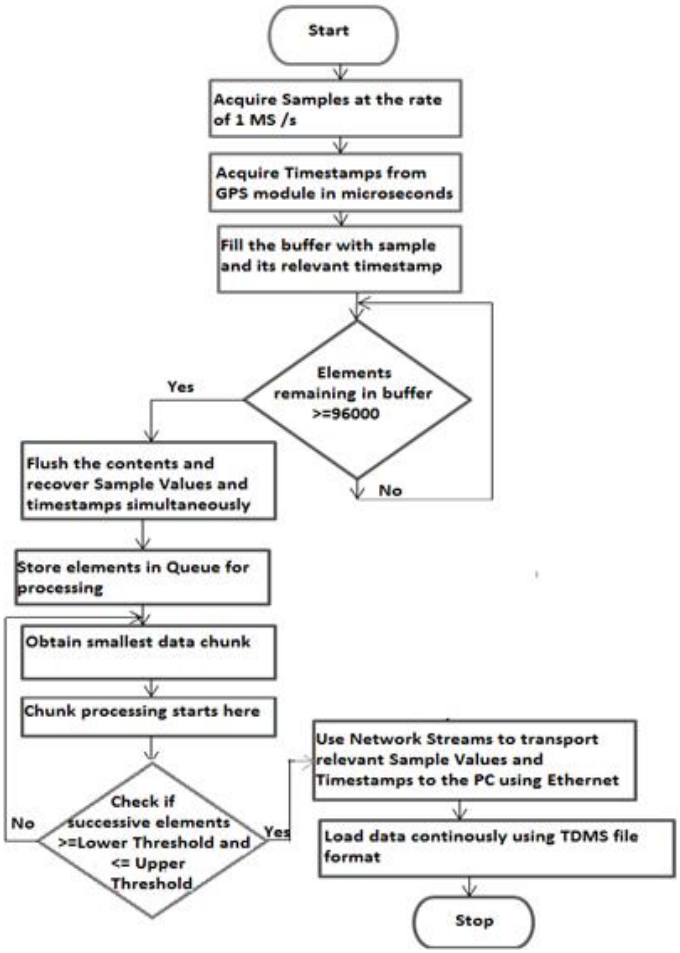

Fig3 :Algorithm For System Design

III.CONCLUSION

Lightning information can play significant role in proper working of Air traffic , Power utility staff, Weather monitoring, Forest managers. In our current design the entire acquisition system is designed to obtain real time lightning data, specifically used to detect the Cloud to Ground Lightning with a high sampling rate of 1 MS/s . The data is also pre-processed to determine the possible train of pulses corresponding to a lightning signal and eliminate those which cannot be a part of lightning signal. The current design can be applied to a single sensor node. However, the same design once developed can be replicated to 5-6 sensor nodes . The information from all these sensor nodes can together be analysed on the Central Processing Server, after further Sferic detection algorithms are applied to the acquired signal to accurately determine the location of lightning, again further processing steps such as grouping of the several strokes corresponding to a single flash, determination of the peak Lightning Current amplitude, determination of lightning peaks and further classification of Lightning can be easily carried out on the Central Processing Server.

IV.FUTURE SCOPE

This design can be efficiently used to acquire the Cloud to Ground lightning strokes effectively, for detecting the Cloud to Cloud flash and the Intracloud Lightning the sampling frequency should be increased to atleast 5 MS/s. The current ADC module can provide a sampling rate of 1 MS/s. Hence, suitable hardware needs to be chosen and also the current analog front end works at 1-30 KHz . This needs to be further scaled up to detect lightning signal at frequencies of atleast 1 MHz. The current paper also does not detail the entire Sferic Processing algorithms and includes only the preliminary processing check based on Amplitude thresholding as well as Rise time detection to determine a valid pulse train. Hence, further Sferic processing algorithms need to be applied on the currently pre-processed real time data which could accurately determine and detect the valid lightning data chunk and it can be further processed on the Central Processing System to Classify the lightning and determine other useful lightning parameters.

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