Reconfigurable FFT Architecture with Spectrum Analysis for 3G/4G Technologies

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Abstract: In general to analyze the spectrum of the signals, Fast Fourier Transform (FFT) was widely used. The FFT converts the signal from time domain to frequency domain. After converting it to frequency domain the spectral analysis operation can be carried out. By spectral analysis it notifies about the spectral leakage problem. If that problem takes place by proper calibration it can be nullified. For that in this paper, a 64 Point FFT architecture was proposed to done the spectral analysis. The spectrum analysis was performed along with the digital calibration control. The 64 Point FFT was designed in Verilog HDL language by using Modelsim software.

Key words: Fast Fourier Transform • Spectral analysis • Digital calibration

INTRODUCTION

Due to spectral leakage problem, the efficient Fast Fourier Transform analysis was needed. By increasing the number of FFT points, the spectral leakage problem can be avoided. Not only the FFT, the resolution of ADC and efficient calibration technique also needed. There are three methods to get an optimized spectral analysis, first to calculate the signal characteristics and to find out the parameters for match the spectrum with the signals and then the signal were reanalyzed with respect to the parameters [1]. This method was comes under calibration. For accurate and reliable prediction of spectrum, spectral predictors were used. It uses extra FFT technique to calculate the various number of input predictor variables. The main drawback of this method was the computational complexity, due to this complexity it increases number of operations and it gradually increases the area [2]. So that to overcome this smaller predictor variables can be used. For spectrum analysis DFT technique was used along with the calibration technique. To done the calibration more than one number of ADC and DAC were used. This leads to the increase in amount of power and area [3]. For that using the FFT increases the computation speed of the spectrum analysis. To carry out the spectrum analysis for higher range of frequencies, the FFT points must be increased. In this 1024 point FFT was used to reduce the computational complexity but it was inadequate for high frequency [4]. The Charge Reuse Analog Fast Fourier Transform (CRAFT) engine was used for spectrum analysis in analog domain. The chargereuse technique reduces the amount of power consumption. A 16 point FFT was use to one the analysis, while reusing the charge on the capacitor was reused [5] during FFT operation. Due to analog, the hardware cost was high and also it occupies more area. The 16 point FFT architecture was used to done the spectral analysis based on on-chip built in testing method. If this analysis made in digital, it gradually decreases the amount of power and cost [6]. Due to smaller FFT point analysis for high frequency were limited. In the proposed method 64 point FFT was used to analysis the spectrum with calibration technique for tuning purpose.

Fast Fourier Transform: The Fast Fourier Transform was mainly used to analysis the spectrum of the signal. The FFT was the efficient algorithm to implement the discrete fourier transform because the computation speed was high in the FFT. There were two types of FFT algorithms. One was Decimation in Time (DIT) and the one was Decimation in Frequency (DIF). In this paper, the proposed FFT architecture was based on radix-2 decimation in frequency (DIF) algorithm.
Fig. 1: 64-point Fast Fourier Transform Architecture for spectral analysis

Fig. 2: FFT Architecture

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X(k) = \sum_{n=0}^{N-1} X[n]W^{nk}
\]

where K belongs from 0 to N-1.

To get an accurate FFT output mainly the number of FFT points must be increased. By increasing number of FFT points the samples were increased, due to that the accuracy of the output was increased. The FFT was mainly used in voice communication. In voice communication, two users were interacted during that time the users voice signal was transmitted from one end to another end. During the transmission of speech signal the unwanted noise signal was also added with that. The noise signal was nothing but the signal which are all other than the users voice signal. Due to addition of noise it may cause the misunderstanding between the users. To remove the unwanted noise signals, FFT algorithm was widely used. It removes the noise signal by converting from the signal from time domain to frequency domain. Due to that, the user can easily interact without any disturbance. FFT was used not only for voice communication and also for all kind of analog signals. For any kind of analog signal, FFT will do the spectrum analysis. The main problem in the FFT analysis was the spectral leakage, the spectral leakage will occur when the sampling frequency can’t meet the nyquist criterion.

In this paper, 64 point FFT architecture was proposed to take up the spectral analysis as shown in Fig. 1. First of all, the input analog signal and noise were generated by using MATLAB. Before the signal was going to given as input signal to the FFT block, it must be converted in to binary data, because the 64 point FFT was designed in Verilog HDL. The converted binary data was given as the input to the radix-2 64 point FFT as shown in Fig 2.

The input digital signals were converted from time domain to frequency domain. The output of the FFT was given as the input to the digital calibration control. In the calibration control, the output of the FFT was tuned. In this the step size of the spectrum was increased. This makes the incoming signal as exactly as original signal. The output of the digital calibration control was given as input to the Digital to Analog Conversion operation. In this Digital to Analog Conversion operation, the digital signal can be converted in to an analog signal with the features of Modelsim Software, without any noise and spectral leakage. This process can be used at the receiver end to get an signal without noise. From the Fig. 2, the twiddle table contains the coefficients for the sine wave and cosine wave. The coefficients were given as input to the butterfly block, in the butterfly block, the operations such as addition and subtraction of the coefficients takes place based on the number of FFT. The dual port RAM stores the execution results of the FFT logic. In the FFT logic block, the spectrum analysis operation takes place to remove the unwanted noise signal.

RESULTS AND DISCUSSION

The 64 point FFT architecture was designed by using Verilog HDL and simulated in Modelsim software. The digital calibration control operation was also designed using Verilog HDL. The calibration method calibrates the output of the 64 point FFT architecture output. For any number of FFT outputs the method of calibration of the FFT output was similar. Using Modelsim software, only the simulation operation can be done. The synthesis operation cannot be done using this software. The simulated result were shown in Fig. 3. In that output, the input analog signal along with noise...
and distortion was given as input in the form of digital signal to the 64 point FFT architecture. At the output of the FFT, the distortion less noise free signal was showed.

The output signal of the FFT needs to be calibrated. For that, it was given as input to the digital calibration. At the calibrated output waveform, the signal was tuned as like as the original input signal. From the Fig. 4, it shows the input analog signal with unwanted noise signal. The presence of the unwanted noise signal in the input waveform was showed as the glitches present in the signal. That glitches made the unwanted interruption.

In the Fig. 5, it shows the distortion signal which was also added with the input noisy analog signal. The distortion signal have unwanted glitches in the form of binary data.

In the Fig. 6, the output waveform signal of the 64 point FFT was showed. This FFT output waveform was distortion less noise free signal. This signal was analyzed by FFT after converting the signal from time domain to frequency domain. This FFT output didn’t had spectral leakage problem.
In the Fig. 7, the calibrated final FFT output waveform was showed. In this, by using digital calibration control method tuning operation was done. The calibrated signal was looks exactly as the original input signal. The digitally calibrated output was the final output waveform. In tuning, the signal strength was gradually increased. The digital calibration method was important to complete the overall process, without calibration technique the output cannot be fulfilled. The original output signal was retrieve at the output of the calibration control. The calibration operation plays an important role in the analysis operation. The calibration operation gave the fulfilled output of the overall operation.

CONCLUSION

An 64 point FFT based spectrum analysis approach was designed and verified. The demand for analyzing the spectrum of the signal was always high with respective to the growth of the technology. When the technology grows many different kinds and different format signals can be formed. For all kinds of signals, testing must be an important thing for troubleshooting the signals during the presence of noise or any other errors. The proposed 64 point FFT can be used to troubleshoot any kind of analog signals. In future, a reconfigurable FFT architecture was going to propose to carry out spectral analysis for the 3rd generation and 4th generation technologies. The reconfigurable FFT architecture may contain multiple number of Fast Fourier Transform engine. Based on the frequency of the incoming signal, the desired FFT engine can be selected. Further this reconfigurable FFT architecture can be implement in real time using Field Programmable Gate Array (FPGA). Due to this reconfigurable FFT architecture, it may reduce the amount of power and the hardware cost. This system is going to be designed based on System On Chip (SOC) approach. Nowadays, all kind of electronic systems were designed and manufactured based on system on chip approach.

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