

# Design and Simulation of Determining the Unknown Sampling Frequency Testing Procedures in Analog-Digital-Conversions

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**Abstract—** *In this study, the researcher investigates one of the testing procedures on acquiring the unknown sampling frequency which is relevant in (ADC) Analog-to-Digital Conversion on Digital Signal Processing. With the help of the Simulink tool in MATLAB, the researcher could be able to conclude after numerous simulations run attempts. The simulation result shows that to avoid aliasing phenomenon, the sampling frequency must be at least twice its maximum frequency.*

**Indexed Terms—***Sampling Frequency, Simulink, Aliasing, A/D converter*

## I. INTRODUCTION

Digital Signal Processing primarily contracts with signals such as speech, music, video, image and etc. Moreover, these occurs naturally in terms of analog continuous-time signals. Analog-to-Digital Conversion (ADC) simply deals on converting analog signal into a discrete digital time signal. It has three major steps: Sampling, Quantization and Coding. Time sampling is the first fundamental step where the continuous-time signal is sampled uniformly at an interval of time in seconds [1]. In various ADC circuits, the sampling frequency may not be readily given, and it takes numerous procedures in order to find the proper sampling frequency to get the maximum frequency of the input signal.

With this, the researcher conducted a testing procedure in order to develop a certain sampling frequency using Simulink tool in MATLAB in accordance with the sampling theorem. MATLAB and Simulink has become more popular and powerful because of the numerous applications with simulation packages in Digital Signal Processing, since the modeling and

simulation result display and validation can be solved easily with this tools [2].

A study conducted by Kesava et al. (2012) have designed a low power sigma delta ADC which consumes only 1.96mW only because of their efficient circuit designs techniques. Moreover, they have proposed the second order sigma modulator and third order Cascaded Integrated Comb filter, and they have used MATLAB for simulation and applied the Sampling Theorem which states that the Nyquist frequency or the sampling frequency must be equal or twice the maximum frequency of the input signal [3].

Also, Sashank Pujari et al. (2014) designed and implemented an FIR Filters using On-board ADC-DAC & FPGA. Different types of digital FIR filters are implemented on external signal by using VERILOG HDL language over FPGA. Further model based design approach using MATLAB and Simulink is taken into account for optimized designing and resource computation. This project gave a basic detailed study and implementations of Signal Processing on FPGA, and so also different types of filtering method are being experienced. In their testing procedures specifically on Low Pass Filtering, Band Pass Filtering and Band Stop Filtering, they have obeyed the Sampling theorem and used a sampling frequency which is greater than twice its maximum frequency. Furthermore, the expected signal can be established in any high end FPGA and different IIR filter can be designed using the above said methods [4].

JRIDI Masher et al. have shown a complete model of analog to digital converter and we have oriented our study on the jitter model. Digital simulations made on MATLAB validated the mathematics formulas already quoted in literature. The same model was injected around a time interleaved ADC structure. A

comparison was made between the jitter and the timing skew. This has showed differences in the indices of peaks in the output spectrum but it also showed similitude in the value of jitter and timing skew. This is true only under some initialization conditions. In terms of the testing procedure, they have used also the Simulink tool in MATLAB. One of the approaches they have used is based on a qualitative validation, and proposed a quantitative validation of the jitter model is based in spectral parameters evaluation with a fixed jitter. They have made the magnitude input signal changed until the full scale. The input signal frequency is near to the half of sampling frequency [5].

Another study conducted by J. Snehalatha, which introduces the principle of sigma-delta ADC modulator with high accuracy and the applied oversampling technique, noise shaping technique and multi-bit quantizer technique. and it makes the behavior level verification for this scheme by Simulink tool in MATLAB. The simulation result Shows that multi-bit quantizer modulator can get very high SNR. With this, one of the testing procedure thy have made is the oversampling in which the sampling of the analog signal whose frequency is much higher than Nyquist sampling frequency. To avoid the aliasing phenomenon, so the over sampling frequency must be much higher Nyquist sampling frequency. The over sampling frequency (usually between 8 to 512) is defined as the ratio of sampling frequency and Nyquist frequency [6].

Thiago Bezerra et al. (2014) proposed the Sigma-Delta A/D converters as a practical application for A/D conversion at high rates because of its simplicity and robustness to imperfections in the circuit, also because the traditional converters are more difficult to implement in VLSI technology. These difficulties with conventional conversion methods need precise analog components in their filters and conversion circuits, and are more vulnerable to noise and interference. This paper aims to analyze the architecture, function and application of Analog-Digital converters (A/D) Sigma-Delta to overcome these difficulties, showing some simulations using the Simulink software and Multisim. In their testing procedure, they have stated that amplitude quantization and sampling in time are the important parts of digital modulators. Regular sampling at rates greater than twice the bandwidth of

the signal does not introduce distortion, but the quantization introduces. The primary objective in the design of modulators is to limit this distortion. They are acquired also the sampling theorem so as result of the oversampling, the noise entry reduces. Therefore, each sampling frequency double reduces the input noise by 3dB, increasing the resolution in only half a bit [7].

## II. METHODS

### A. Testing Procedures

The following are the testing procedures of the case study, to wit:

1. The researcher developed a ADC circuit Simulink model as shown Figure 1 which mainly composed of Sampler, Quantizer and Coder. The output frequency of the model will be simulated and it will be displayed in the Spectrum Analyzer.
2. The case study was conducted its testing procedures using trial-and-error method in the Simulink. The input frequency was varied from frequency ranging from 1kHz up to 6kHz until such time that the input frequency and output frequency have discrepancy.
3. After the conduct of run simulations, the input frequency, output maximum frequency were tabulated for each case to determine the result with aliasing and with no aliasing. The output of this case will be compared and determine the appropriate sampling frequency for a certain ACD circuit.
4. Moreover, the evaluation of the case study will be evaluated in accordance with the Sampling Theorem or the Nyquist Theorem in Digital Signal Processing.

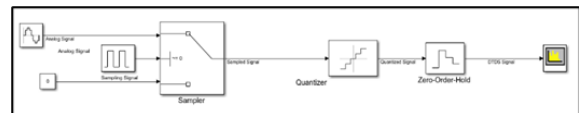


Fig. 1 Simulink Model of an ADC Circuit

## II. RESULTS AND DISCUSSION

This section revealed the results of the simulations using the Simulink model.

Table 1 shows the tabulation results of the simulation using Spectrum Analyzer in the Simulink. It was clearly reflected in this table that the input frequency

and the output frequency start to have a huge discrepancy when the input frequency is at 4.995kHz.

Table 1 Tabulation of the Simulation output using Spectrum Analyzer

Input Frequency	Output Frequency
1000	1003
2000	1999
3000	3001
4000	3997
4500	4499
4600	4603
4900	4902
4910	4909
4920	4922
4930	4928
4940	4941
4950	4948
4960	4961
4980	4980
4990	4987
4993	4993
4994	4993
4995	2044
4998	4902
5000	4902
6000	3997

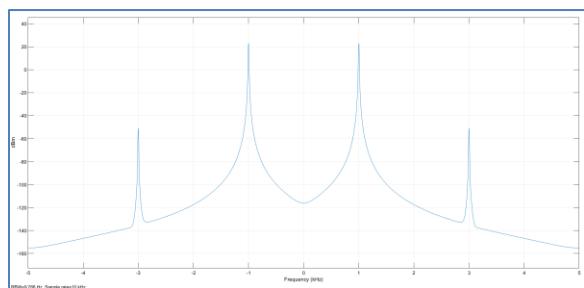


Figure 2 The input frequency used is 1kHz.

The Figure 2 above shows that the input frequency used is 1kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal also to 1kHz.

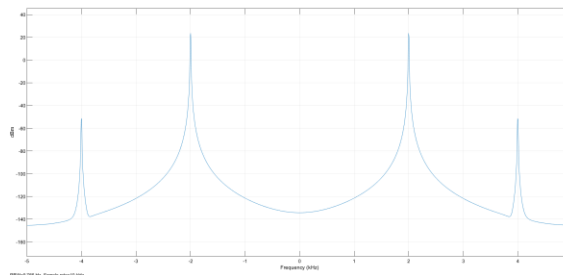


Figure 3 The input frequency used is 2kHz.

The Figure 3 above shows that the input frequency used is 2kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal also to 2kHz.

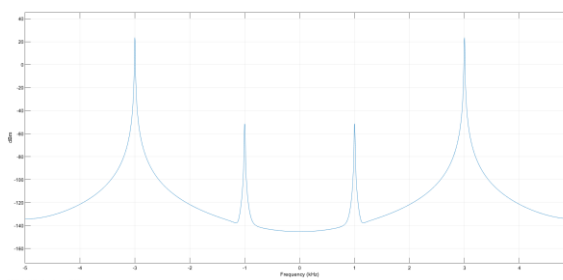


Figure 4 The input frequency used is 3kHz

The Figure 4 above shows that the input frequency used is 3kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal also to 3kHz.

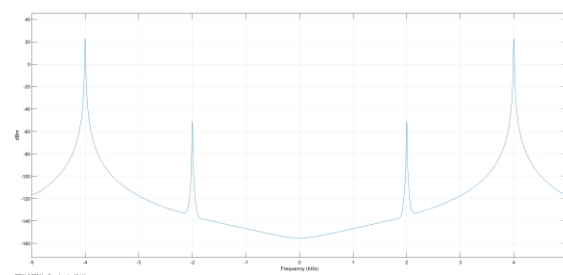


Figure 5 The input frequency used is 4kHz

The Figure 5 above shows that the input frequency used is 4kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal also to 4kHz.

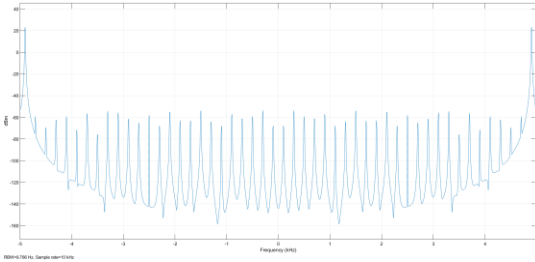


Figure 6 The input frequency used is 5kHz

The Figure 6 above shows that the input frequency used is 5kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal to 4.902kHz. In this case, there is a great almost 100Hz discrepancy.

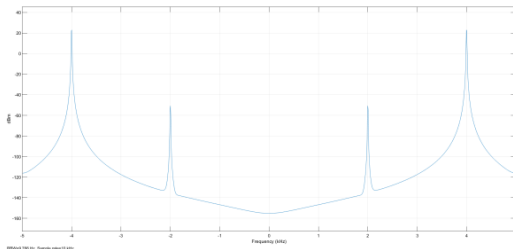


Figure 7 The input frequency used is 6kHz

The Figure 7 above shows that the input frequency used is 6kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal to 3.997kHz. In this case, there is a great almost 2kHz discrepancy.

Since the discrepancy occurs between the input frequency 4kHz and 5kHz, the researcher tried to varied the input frequency from 4kHz to 5kHz as shown in Figure 8 and 9.

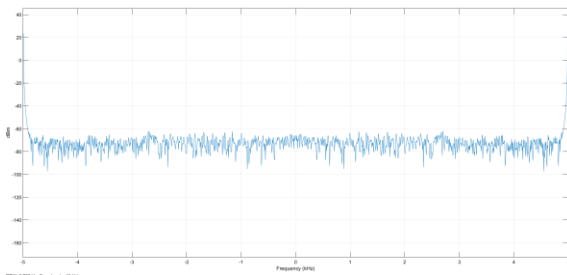


Figure 8 The input frequency used is 4.994kHz

The Figure 8 shows that the input frequency used is 4.994kHz and it resulted to an approximately equal to 4.994kHz output frequency. It was found that, it is the

last point which input and output frequency have no discrepancy.

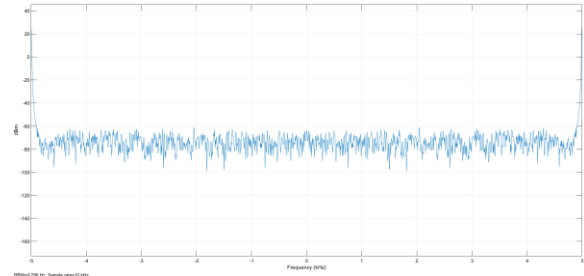


Figure 9 The input frequency used is 4.995kHz

The Figure 9 above shows that the input frequency used is 4.995kHz and the maximum output frequency result using the Spectrum Analyzer is approximately equal to 2.044kHz. In this case, there is a great almost 3kHz discrepancy.

In summary, when the input frequency used from 1kHz up to 4.994kHz, there is no discrepancy detected as shown in the Table 1 and reflected in Figure 2, 3, 4, 5 and 8. On the other hand, when the input frequency used from 4.995kHz up to 6kHz, there is a huge discrepancy detected as shown in Table 1 and reflected in Figure 6, 7 and 9.

Applying the Sampling Theorem which states that the sampling frequency is equal to twice of the maximum output frequency, then the sampling frequency for this Simulink model or for this system is 2 times 4.994kHz, which is equal to 9.988kHz.

## CONCLUSION

Taking everything into account, obeying the sampling theorem which states that the sampling frequency is at least twice the maximum frequency, is the best tool to get the appropriate unknown sampling frequency. Also, as long as there is no huge discrepancy between the input frequency and output frequency, then the aliasing is absent. Otherwise, if there is a huge discrepancy, then the aliasing is present. To avoid the aliasing phenomenon, the Sampling Theorem must be acquired.

In this case study, Simulink tool in MATLAB have made this into a stress-free procedure. With this, the

researcher concluded that the sampling frequency is equal to 9.988kHz.

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