A Method to Measure the Signal Amplitude Probability Density Function Avoiding the Influence of Differential Non-Linearity of ADC

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Abstract-This paper presents a new method to measure the discrete probability density function (p.d.f.) of an ergodic random path avoiding the influence of differentioal non-linearity of applied ADC. This method is useful to measure the precise p.d.f. by using the successive approximation type ADC or the flash type ADC. The most important field to apply is the radiation pulse height analysis.

1.Introduction

The differential non-linearity (DNL) of ADC is the channel width irregularity on the quantizing. The DNL is coused by the irregularity of registances in the ADC circuit. And, the small irregularity of the registances in ADC circuit generates remarkably large error of measured discrete probability density function (p.d.f.). The Wilkinson-type ADC which is a kind of integral or pulse counting type has the best differential linearity in comparison with other type of ADCs; Successive approximation type or Flash type. The aim of this research is to propose a new method to escape from the DNL of used ADC (Successive approximation type or Flash type).

2.Methodology

The proposed ADC circuit is shown in **Fig.1**. The used ADC is Successive approximation type or Flash type. The unique point of this circuit is that a small DC voltage V is added to the input analog sample holded voltage to obtain the voltage shifted cumulative probability distribution function (c.p.d.f.). For one sampling point, the sample hold timing and two (primary and secondary) A/D conversion timings are shown in **Fig.2**. The primary A/D conversion is normal. But the secondary A/D conversion is done for the voltage of the sample holded value +V. The primary normal A/D converted datas, which are not shifted, are used for the construction of normal c.p.d.f.. And the secondary one's, which are uniformly shifted, are used for the construction of uniformly shifted c.p.d.f.. Therefore, we obtain a couple of c.p.d.f.;one is normal and the other is uniformly shifted. The important point is that these two c.p.d.f. have voltage shifted c.p.d.f. and "the same DNL error". Finally, by computing the subtruction of these two c.p.d.f., we are able to obtain the correct probability density sunction avoiding the influence of DNL. This measureing procedure is shown by the flow chart in **Fig.3**.

3.Principle of avoidance

Including the channel irregularity and the small constant voltage which is used for the shift of c.p.d.f., the measuring discrete p.d.f. is formulated as follows,

$$p_N^* = \text{Prob.}[\, V_N < v_i \leqq V_{N+1} \,]$$

$$= \text{Prob.}[\, N\delta V + \varepsilon_N < v_i \leqq (N+1)\delta V + \varepsilon_{N+1} \,]$$

$$= \int_{V_N}^{V_{N+1}} p(v)dv = P(V_{N+1}) - P(V_N)$$

$$= P((N+1)\delta V + \varepsilon_{N+1}) - P(N\delta V + \varepsilon_N)$$

$$= P((N+1)\delta V + \varepsilon_{N+1}) - P((N+1)\delta V - \delta V + \varepsilon_{N+1} - (\varepsilon_{N+1} - \varepsilon_N))$$

$$= P((N+1)\delta V + \varepsilon_{N+1}) - P((N+1)\delta V + \varepsilon_{N+1} - \delta V - (\varepsilon_{N+1} - \varepsilon_N))$$

$$= P((N+1)\delta V + \varepsilon_{N+1}) - P((N+1)\delta V + \varepsilon_{N+1} - (\delta V + (\varepsilon_{N+1} - \varepsilon_N)))$$

where,

v_i : Sampled train of an analog ergodic sample path.

V_N : Ideal quantizing level of ADC.

δV : Ideal minimum quantizing voltage width.

ε_N : Real quantizing voltage errror of ADC.

$p(v)$: Probability density function to be measured.

$P(V_{N+1})$: Probability distribution function of this sample path.

In this equation, $(\varepsilon_{N+1}-\varepsilon_N)$ generates the remarkable large error of measured discrete p.d.f.. Then, for the avoidance or escape from DNL error which is generated by $(\varepsilon_{N+1}-\varepsilon_N)$, a constant DC small voltage $V \fallingdotseq \delta V + (\varepsilon_{N+1}-\varepsilon_N)$ is prepared and used to make the uniformly shifted c.p.d.f..

Using this V ,we get the two c.p.d.f.(normal and shifted), and the subtraction is computed between these two c.p.d.f.. Then we get the correct p.d.f. avoiding the influence of differential non-linearity of ADC.

4.Conclusions

A new method to measure the p.d.f. avoiding the influence of DNL error of used ADC. This problem is not so important in the field of usual signal processing, for example a voice signal power or correlation or machine vibrating signal analysis. But on the measurement of complex p.d.f. (not simple Gaussian distribution) ,for example the isotope radiation pulse hight analysis, this is extremely important. On this proposed method, the DNL errors do not appear on measured discrete p.d.f.. It just shift the each horizontal display position of discrete p.d.f. dot position. It is extremely small, and is not sensed by human eyes. The integrating type ADC has the most high differntial linearity. So, it is used for the measurement of correct p.d.f.. But it is slow for the A/D conversion. Another feasible point of this method is that the parallel or flash type ADC is suitable to use on this method. This means that very fast and correct measurement of p.d.f. ,by using this method and the parallel or flash type ADC, is possible.

References

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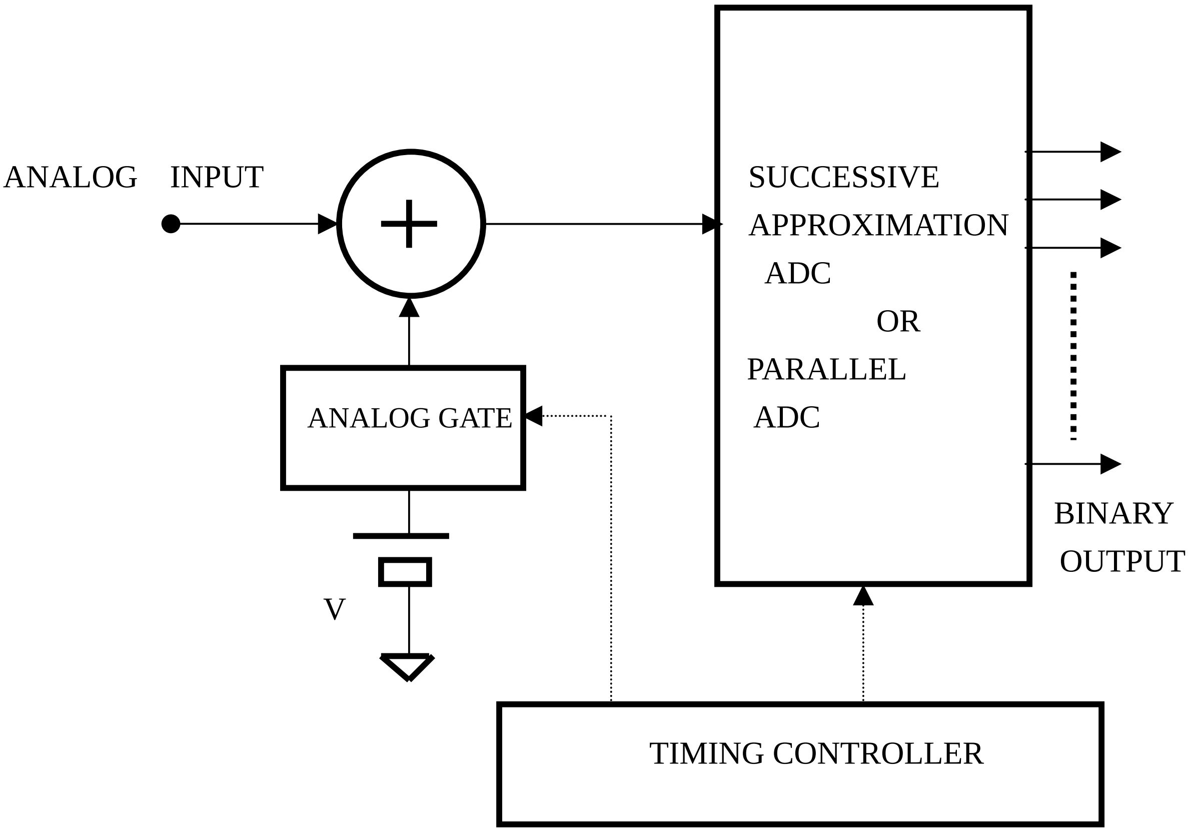

Fig.1. Block diagram of proposed A/D converter circuit.

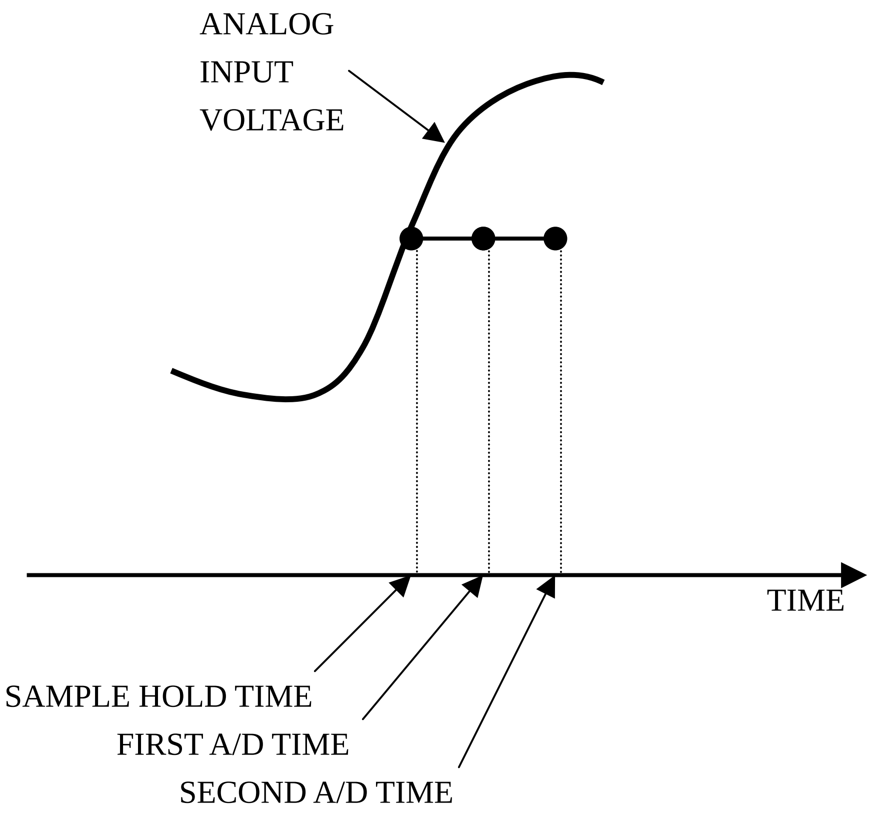

Fig.2. Timing chart of sample hold and double A/D conversion.

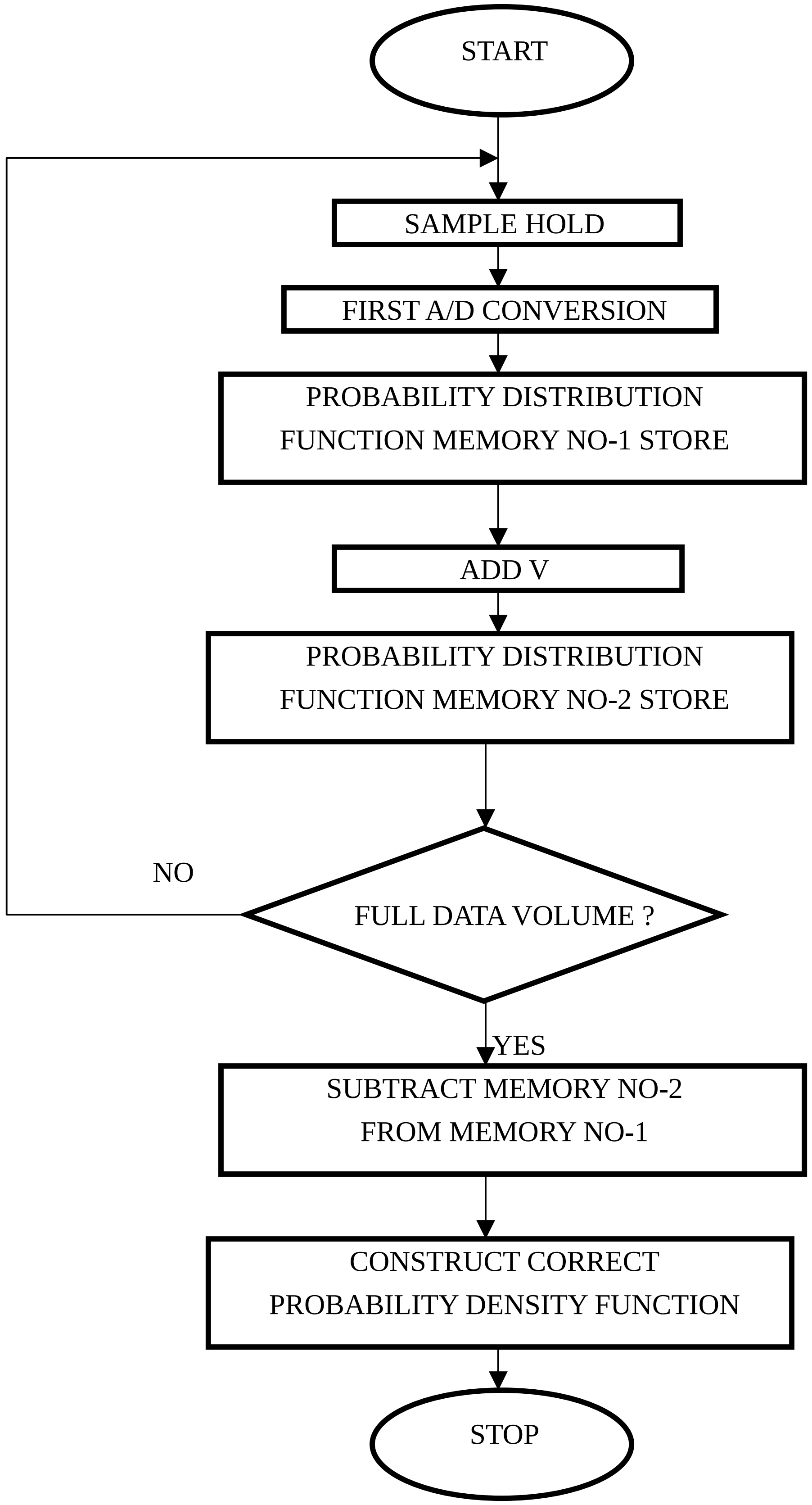

Fig.3. Flow chart of proposed procedure.