

A Review: Compensation of Mismatches in Time Interleaved Analog to Digital Converters

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Abstract

The execution of today's correspondence frameworks is exceedingly subject to the utilized Analog-to-Digital converters (ADCs), and with a specific end goal to give more flexibility and exactness to the developing correspondence innovations, superior-ADCs are needed. In this respect, the time-interleaved operation of an exhibit of ADCs (TI-ADC) might be a sensible result. A TI-ADC can build its throughput by utilizing M channel ADCs or sub converters in parallel and examining the data motion in a period-interleaved way. In any case, the execution of a TI-ADC gravely suffers from the bungles around the channel ADCs. In this paper we survey the advancement in the configuration of low-intricacy advanced remedy structures and calculations for time-interleaved ADCs in the course of the most recent five years. We devise a discrete-time model, state the outline issue, and finally infer the calculations and structures. Specifically, we examine proficient calculations to outline time-differing remedy filters and additionally iterative structures using polynomial based filters. Thusly, the remuneration structure may be utilized to repay time-differing recurrence reaction befuddles in time-interleaved ADCs, and in addition to remake uniform examples from nonuniformly tested indicators. We examine the recompense structure, research its execution, and exhibit requisition zones of the structure through various illustrations. At long last, we give a standpoint to future examination questions.

Index Terms—Analog-to-digital converter, compensation, frequency response mismatches, reconstruction, time-inter- leaved, time-varying filter.

I. INTRODUCTION

Beginning in 1980 with the first paper from Black [1], we have now three many years of exploration on time-interleaved simple-to-computerized converters (ADCs). In the most recent decade, the enthusiasm toward time-interleaved ADCs significantly expanded. New correspondence norms [2] oblige high-transmission capacity converters with mid to high determination and the potential outcomes of advanced post redress got more attainable [3], [4]. One of the greatest tests in time-interleaved ADCs is sign contortions handled by jumbles around the channel ADCs [5], [6]. These bungles commonly rely on upon methodology, voltage, temperature varieties, and maturing impacts. Thus, actually for showy simple plans, adjustment strategies are obliged to acquire the focused on powerful execution measures for mid to high determination time-interleaved ADCs [7]. In view of the expanding hole between simple and computerized circuits [8], and the points of interest of advanced circuits regarding exactness and long-term steadiness, computerized post handling calculations and structures are utilized for the alignment of time-interleaved ADCs. The simple-to-computerized converter (ADC) is a discriminating part in up to date advanced correspondence beneficiaries, empowering

financially savvy-and all-advanced execution of complex base-band sign preparing calculations.

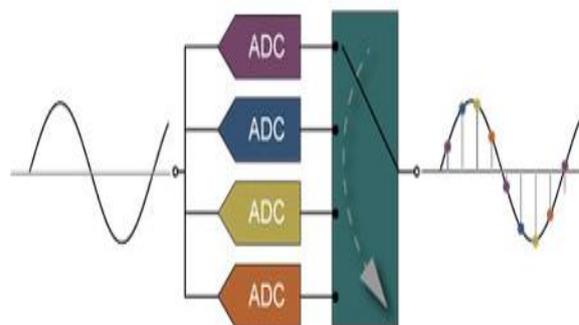


Figure.1 Generalized block diagram of time interleaved ADC system

Notwithstanding, as correspondence data transmissions build, the accessibility of ADCs with sufficient pace and determination turns into a worry: Gigahertz transmission capacities are needed for rising ultra wideband [8] and millimeter wave [9] provisions, while 8-12 bits of determination are needed for giving enough dynamic reach when working in multipath situations with extensive groups of stars. The engineering of decision at GHz velocities is "one shot" flash ADC, yet it gets unmanageable past 5 bits determination, because of

exponentially (in number of bits) expanding force utilization and fittings unpredictability [10]. An alluring elective [10] is a period-interleaved (TI) building design, where high rate and high determination might be accomplished by utilizing a few low rates, high determination, sub-ADCs in parallel. A perfect TI-ADC framed by time-interleaving four sub-ADCs. On the other hand, a natural issue with the TI-ADC structural planning is bungle between the sub-ADCs, which to first request could be thought to be increase; timing and voltage-balance confound [11]. Left uncompensated, such befuddle prompts blunder floors when TI-ADCs are utilized in correspondence beneficiaries. In this paper, we explore versatile (as the amount of sub-ADCs and the jumble levels expansion) confound remuneration procedures for uprooting confuse-affected failure floors because of TI-ADCs utilized in OFDM gathering.

II. SYSTEM MODEL

A time-interleaved ADC works at a higher inspecting rate by using a cluster of numerous ADCs with easier testing rates. The band constrained simple info sign $x(t)$ is handled by the sub-ADCs in a period-interleaved way to transform the advanced yield $y[n]$. As indicated in Figure.2, the change rate in every individual ADC is decreased to f_s/M where the period of the clock for the m th channel ADC is given by $\phi = m2\pi/M$, while the general inspecting rate is kept at f_s , where M is the amount of ADCs that are utilized within parallel.

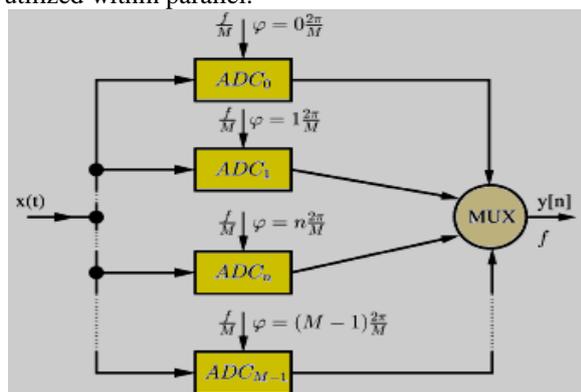


Figure 2(a) Time interleaved ADC with M channels

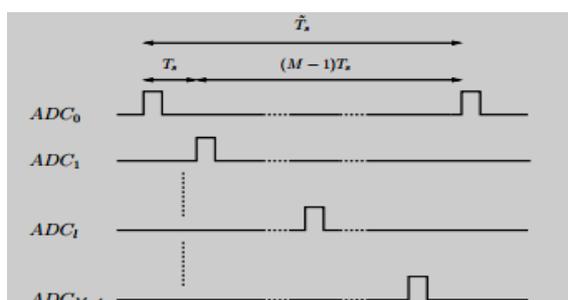


Figure 2. (b) Timing diagram of a time-interleaved ADC with M channels

The yields are then multiplexed together to structure a sign inspected M times quicker than the yield from every ADC. Regarding the timing of a TI-ADC, a specimen is taken by an alternate sub-ADC at each one time step and a computerized yield is processed.

TI-ADC modeling with Mismatches

In a signal processing system, an ADC changes over a simple indicator into an advanced indicator, i.e., an arrangement of limited-exactness or quantized examples. This assignment is proficient by the framework indicated in Figure 2.1.

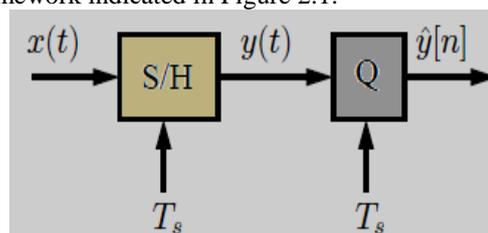


Figure 2.1. Analog to digital conversion model

The A/D transformation is begun and finished each T_s second under the control of a clock. In any case, this change is not prompt and in light of this reason the information esteem should essentially be held consistent throughout the time that the converter performs a transformation. This task is accomplished by a sample-and-hold (S/H) circuit that stores the input sample value at the sampling instant and holds it for the next sampling time. The output of the S/H is later quantized by a quantizer to produce the digital output $\hat{y}[n]$.

The model shown in Figure 2.1 can be replaced by a linear model of an ADC as shown in Figure 2.2. The model assumes that the S/H can be represented by a filter $H(j\Omega)$ followed by the multiplication with an impulse-train $\sum_{n=-\infty}^{+\infty} \delta(t - nT_s)$ where $\delta(t)$ the Dirac delta distribution is. Although this is not fully true in practice, it was shown in [64, 66], that even a model which considers the transient effects of a S/H can be transformed with some modifications of the frequency responses into the model shown in Figure 2.2.

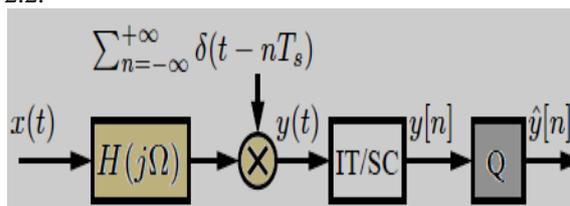


Figure 2.2. Linear model of an ADC

The multiplication with the impulse-train produces the analog output $y(t)$ which is passed on to an impulse-train to sequence converter (IT/SC) to produce the output sequence $y[n]$. Later the sequence

$y[n]$ is passed through a quantizer to produce the quantized samples $\hat{y}[n]$.

Discrete-Time System Model

In this section, we develop the discrete-time representation $Y(e^{j\omega})$ for the output $Y(j\Omega)$. However, we first exploit a useful relation between the analog frequency Ω and the discrete frequency ω . In the time-domain we can represent the process of sampling through the modulation of a continuous-time signal with a periodic impulse-train $\sum_{n=-\infty}^{+\infty} \delta(t - nT_s)$. The sampled signal can be expressed as

$$x_s(t) = \sum_{n=-\infty}^{+\infty} x(t)\delta(t - nT_s) \quad (2.1)$$

The CTFT of (2.1) is

$$X_s(j\Omega) = \sum_{n=-\infty}^{+\infty} x(nT_s)e^{-j\Omega T_s n} \quad (2.2)$$

Since a sequence of samples $x[n]$ is obtained from a continuous-time signal $x(t)$ through sampling with period T_s using the relation

$$x[n] = x(nT_s) \quad -\infty < n < \infty \quad (2.3)$$

The discrete-time Fourier transform (DTFT) of the sequence $x[n]$ is given by

$$X(e^{-j\omega}) = \sum_{n=-\infty}^{+\infty} x[n]e^{-j\omega n} \quad (2.4)$$

If we compare (2.4) and (2.2), then it follows that

$$X_s(j\Omega) = X(e^{j\omega})|_{\omega=\Omega T_s} = X(e^{j\Omega T_s}) \quad (2.5)$$

By developing the term $\delta(t - nT_s)$ into a Fourier series, we get another representation for the CTFT of (2.1) which is

$$X_s(j\Omega) = X(e^{j\Omega T_s}) = \frac{1}{T_s} \sum_{n=-\infty}^{+\infty} X(j(\Omega - n\Omega_s)) \quad (2.6)$$

The equivalent DTFT representation of (2.6) while using (2.5) can be written as

$$X(e^{j\omega}) = \frac{1}{T_s} \sum_{n=-\infty}^{+\infty} X\left(j\left(\frac{\omega}{T_s} - n\frac{2\pi}{T_s}\right)\right) \quad (2.7)$$

To get $Y(e^{j\omega})$, we can express the summation index q as

$$q = k + nM, -\infty < n < \infty, 0 \leq k \leq M - 1 \quad (2.8)$$

Rearranging above equation gives the DTFT representation of $Y(e^{j\omega})$ as

$$Y(e^{j\omega}) = \sum_{k=0}^{M-1} \frac{1}{T_s} \sum_{n=-\infty}^{+\infty} \bar{H}_k\left(j\left(\frac{\omega - k\frac{2\pi}{M}}{T_s} - n\frac{2\pi}{T_s}\right)\right) X(e^{j\omega - k\frac{2\pi}{M}}) \quad (2.9)$$

If we assume that the input signal $x(t)$ is bandlimited, i.e., its CTFT $X(j\Omega)$ satisfies

$$X(j\Omega) = 0, |\Omega| \geq B, \quad BT_s \leq \pi \quad (2.10)$$

where B is the signal bandwidth then using (2.7) we can finally (2.9) in discrete time as

$$Y(e^{j\omega}) = \sum_{k=0}^{M-1} \bar{H}_k\left(e^{j\left(\omega - k\frac{2\pi}{M}\right)}\right) X(e^{j\left(\omega - k\frac{2\pi}{M}\right)}) \quad (2.11)$$

where

$$\bar{H}_k(e^{j\omega}) = \frac{1}{M} \sum_{m=0}^{M-1} H_m(e^{j\omega}) e^{-jk\frac{2\pi}{M}m} \quad (2.12)$$

and the discrete-time channel frequency responses $H_m(e^{j\omega})$ are the 2π -periodic extension of the analog channel frequency responses $\widehat{H}_m(j\Omega)$, i.e.,

$$H_m(e^{j\omega}) = \widehat{H}_m\left(j\frac{\omega}{T_s}\right) \text{ for } -\pi \leq \omega < \pi \quad (2.13)$$

In order to get an expression for the error signal due to the frequency response mismatches, we decompose (2.11) as

$$Y(e^{j\omega}) = \bar{X}(e^{j\omega}) + E(e^{j\omega}) \quad (2.14)$$

with

$$\bar{X}(e^{j\omega}) = \bar{H}_0(e^{j\omega})X(e^{j\omega}) \quad (2.15)$$

is the DTFT of the input signal $X(e^{j\omega})$ multiplied by the average channel frequency responses $\bar{H}_0(e^{j\omega})$ given by

$$\bar{H}_0(e^{j\omega}) = \frac{1}{M} \sum_{m=0}^{M-1} H_m(e^{j\omega}) \quad (2.16)$$

and

$$E(e^{j\omega}) = \sum_{k=1}^{M-1} \bar{Q}_k(e^{j\left(\omega - k\frac{2\pi}{M}\right)}) \quad (2.17)$$

is the DTFT of the error signal $E(e^{j\omega})$ due to the normalized frequency response mismatch

$$\bar{Q}_k(e^{j\omega}) = \frac{\bar{H}_k(e^{j\omega})}{\bar{H}_0(e^{j\omega})} \quad (2.18)$$

Now taking the inverse DTFT of (2.14) we get

$$y[n] = \bar{x}[n] + e[n] \quad (2.19)$$

where

$$\bar{x}[n] = \bar{h}_0[n] * x[n] \quad (2.20)$$

and

$$e[n] = \sum_{k=1}^{M-1} \bar{q}_k[n] * \bar{x}[n] e^{jk\frac{2\pi}{M}n} \quad (2.21)$$

The discrete-time system model of an M -channel TI-ADC represented by (2.19)-(2.21) is shown in Figure 2.3. The ideally sampled signal $x[n] = x(nT)$ is filtered by the impulse response $\bar{h}_0[n]$ resulting in the desired signal $\bar{x}[n]$. The signal $\bar{x}[n]$ represents the output of an ideal TI-ADC without any frequency response mismatches. Furthermore, we see the error signal $e[n]$, which is the outcome of the signal $\bar{x}[n]$

being first filtered by the discrete-time filters $\bar{q}_k[n]$ and then modulated by $e^{jk\frac{2\pi}{M}n}$, $k = 1, 2, \dots, M - 1$.

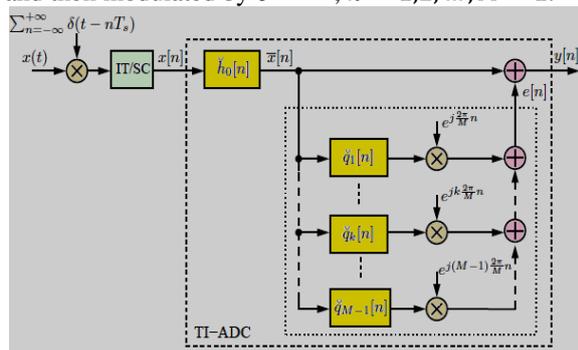


Figure 2.3. Discrete time system model of M-channel TI-ADC

The filters $\bar{q}_k[n]$ represent the frequency response mismatches in a TI-ADC leading to the error signal $e[n]$. At the output of our system model, the error signal $e[n]$ is added to the desired signal $\bar{x}[n]$ resulting in the distorted TI-ADC output $y[n]$. For the system model discussion we can conclude that we have to remove the error signal $e[n]$ from the TI-ADC output signal $y[n]$ to mitigate the distortions caused by the frequency response mismatches.

III. LITERATURE REVIEW

“Digital Automatic Calibration Method for a Time-Interleaved ADCs System used in Time-Domain EMI Measurement Receiver”[12], The sampling rate of state of the art analog to digital converters (ADCs) limits the base-band frequency range of real-time time domain electromagnetic interference (TD-EMI) measurement systems to 1 GHz. In this paper, a time interleaved sampling architecture is introduced to overcome this limitation and to extend the baseband of the time-domain EMI receiver. Using three parallel time-interleaved ADC converters a TD-EMI measurement system with 3 GHz base bandwidth has been realized. The misalignment effects are studied and an automatic calibration routine is introduced. The 40 dB spurious free dynamic range required by the CISPR standards is achieved

“Adaptive calibration of gain and offset errors for time-interleaved ADCs”. Time-interleaved (TI) Analog- to-Digital Converters (ADC) are effective for fast-information procurement. On the other hand, bumbles around distinctive directs in a TIADC framework because of assembling procedure varieties cause mutilation in the examined indicator and debase the SNR and SFDR essentially. The counterbalance and addition confuses are the two vital mistake hotspots for the TIADC framework. In this paper, a system focused around Least Mean Square (LMS) versatile calculation is proposed for synchronous recompense of the increase and balance

jumbles. The proposed strategy is likewise versatile to the moderate progressions of the crisscrosses brought on by temperature variety and maturing impact. Numerical reenactments are led to accept the versatile calculation.

“A Flexible and Scalable Structure to Compensate Frequency Response Mismatches in Time-Interleaved ADCs”. In this paper, creator introduced an adaptable and versatile structure to repay recurrence reaction confounds in time-interleaved simple-to-computerized converters (TI-ADCs). The adaptability of the structure takes into account planning remuneration channels free of the amount of channels that can accomplish any sought indicator-to-clamor proportion because of the versatility of the structure. Thusly, the payment structure may be utilized to repay time-shifting recurrence reaction befuddles in TI-ADCs, and to recreate uniform specimens from nonuniformly tested indicators. We dissect the recompense structure, examine its execution, and exhibit provision zones of the structure through various cases.

“A Polynomial-Based Time-Varying Filter Structure for the Compensation of Frequency-Response Mismatch Errors in Time-Interleaved ADCs”. This paper presented a structure for the recompense of recurrence- reaction confuses slips in M-channel time-interleaved simple-to-computerized converters (ADCs). It makes utilization of various settled advanced channels, approximating differentiators of distinctive requests, and a couple of variable multipliers that compare to parameters in polynomial models of the channel recurrence reactions. At whatever point the channel recurrence reactions change, which happens every now and then in a reasonable time- interleaved ADC, it suffices to adjust the qualities of these variable multipliers. Thusly, unmanageable on-line channel outline is evaded. The paper incorporates a few configuration illustrations that outline the properties and abilities of the proposed structure.

“A Least-Squares Filter Design Technique for the Compensation of Frequency Response Mismatch Errors in Time-Interleaved A/D Converters”. This paper presented a minimum-squares channel plan system for the payment of recurrence reaction crisscross lapses in M-channel time-interleaved simple-to-advanced converters. The general recompense framework is outlined by deciding M channel motivation reactions systematically through M separate grid reversals. The proposed strategy offers an elective to minimum-squares methods that focus all channels at the same time. A few configuration samples are incorporated for outline.

“Generalized Blind Mismatch Correction for a Two- Channel Time-Interleaved ADC: Analytic Approach”. Time-interleaved analog-to-digital converters (TIADC) oblige crisscross adjustment to

accomplish high sign-to-clamor proportions. In this paper, we display another visually impaired strategy for M=2 TIADC's with taking after properties: (1) rectification of general jumbles and also static increase and timing mistake, (2) extraordinary multi-parameter ID under practical presumptions, and (3) explanatory blunder measure and slope. The proposed system conquers the restriction of conventional addition-timing confuse model. Time recurrence conversion is killed by logical methodology, upgrading productivity.

"Adaptive Blind Calibration of Timing Offset and Gain Mismatch for Two-Channel Time-Interleaved ADCs". In this paper, creator portrayed a visually impaired alignment technique for addition and timing crisscrosses in two-channel time-interleaved low-pass simple-to-computerized converters (ADC). The system obliges that the info indicator ought to be somewhat oversampled. This guarantees that there exists a recurrence band around the zero recurrence where the Fourier changes of the ADC sub channels are moniker free. Low pass sifting the ADC sub channels to this without moniker band lessens the visually impaired adjustment issue to a traditional addition and time delay estimation issue for an obscure indicator in clamor. A versatile sifting structure with three altered FIR channels and two versatile addition and postponement parameters is utilized to attain the alignment. A joining examination is exhibited for the visually impaired alignment method. Numerical reproductions for a band restricted repetitive sound and for inputs holding a few sinusoidal parts show the adequacy of the proposed system.

The advanced alignment of befuddles in a TI-ADC has pulled in light of a legitimate concern for some specialists throughout the most recent decade. The primary center has been on the adjustment of addition and timing confuses. As of late, the center has moved towards the alignment of recurrence reaction confuses, as this can prompt further change in the general execution of TI-ADCs.

IV. CONCLUSION

Digital rectification of recurrence-ward jumble failure is vital for high-determination and fast-TI-ADCs. In this paper, we have created a framework model of a two-channel TI-ADC and four channels TI-ADC with recurrence reaction confuses and introduced a visually impaired adjustment structure to adjust these bumbles in a two channel TI-ADC. The recurrence reaction confuses are spoken to by polynomial. This paper additionally incorporates the audit of distinctive sorts of adjustment technique which is fit for adjusting diverse recurrence reaction bumbles including increase, timing, and transfer speed confounds by utilizing multitone and WGN info signs. Taking into account the polynomial spoke to

framework. The identification of mismatches helps in the removal of spurious images from the TI-ADC output spectrum and thus increases the signal-to-noise ratio (SNR).

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