Chapter 2
Time-Interleaved ADCs

The time-interleaved ADC is an architecture that cycles through a set of \( N \) sub-ADCs, such that the aggregate throughput is \( N \) times the sample rate of the individual sub-ADCs [5]. Therefore, such an architecture enables the sample rate to be pushed further than that achievable with single channel ADCs. This chapter discusses the operation of time-interleaved ADCs and analyzes how the sub-ADCs interact. It also analyzes the drawbacks of the architecture and presents closed-form equations relating performance degradation to mismatch.

2.1 Modeling the Time-Interleaved ADC

This section discusses the operation of the time-interleaved ADC. The model presented serves as a foundation that allows the inclusion of time-varying errors due to differences between the sub-ADCs, as discussed in Sect. 2.2.

The time-interleaved ADC, as shown in Fig. 2.1a, has an input \( x(t) \) and an output \( y[n] \). The sampling period of the time-interleaved ADC and the \( N \) sub-ADCs are \( T_s \) and \( \hat{T}_s = N \cdot T_s \), respectively. The \( i \) th sub-ADC, where \( i = 0, ..., N - 1 \), is strobed with clock \( \phi_i(t) \), which ideally has sampling edges at

\[
t_i[n] = n\hat{T}_s + iT_s = (nN + i) \cdot T_s
\]  

(2.1)

Thus, the sampling edges of two consecutive clocks are offset by \( T_s \), as in Fig. 2.1b, and the input signal is uniformly sampled. The output of the \( i \) th sub-ADC is \( \hat{y}_i[n] \), where

\[
\hat{y}_i[n] = x\left(t_i[n]\right) = x\left(nN + i \cdot T_s\right)
\]  

(2.2)

The sub-ADC outputs $\hat{y}_i[n]$ are multiplexed to create $y[n]$, such that

$$y[n] = \hat{y}_i \left[ \frac{n - i}{N} \right] \text{ where } i = n \mod N$$ (2.3)

Setting $y_i[n]$ as the sub-ADC output $\hat{y}_i[n]$ upsampled by $N$ results in

$$y_i[n] = \begin{cases} \hat{y}_i \left[ \frac{n - i}{N} \right] & \text{if } \frac{n - i}{N} \text{ is an integer} \\ 0 & \text{else} \end{cases}$$ (2.4)

This is simplified by defining

$$\delta_i[n] = \sum_{k=-\infty}^{\infty} \delta[n - kN - i]$$ (2.5)