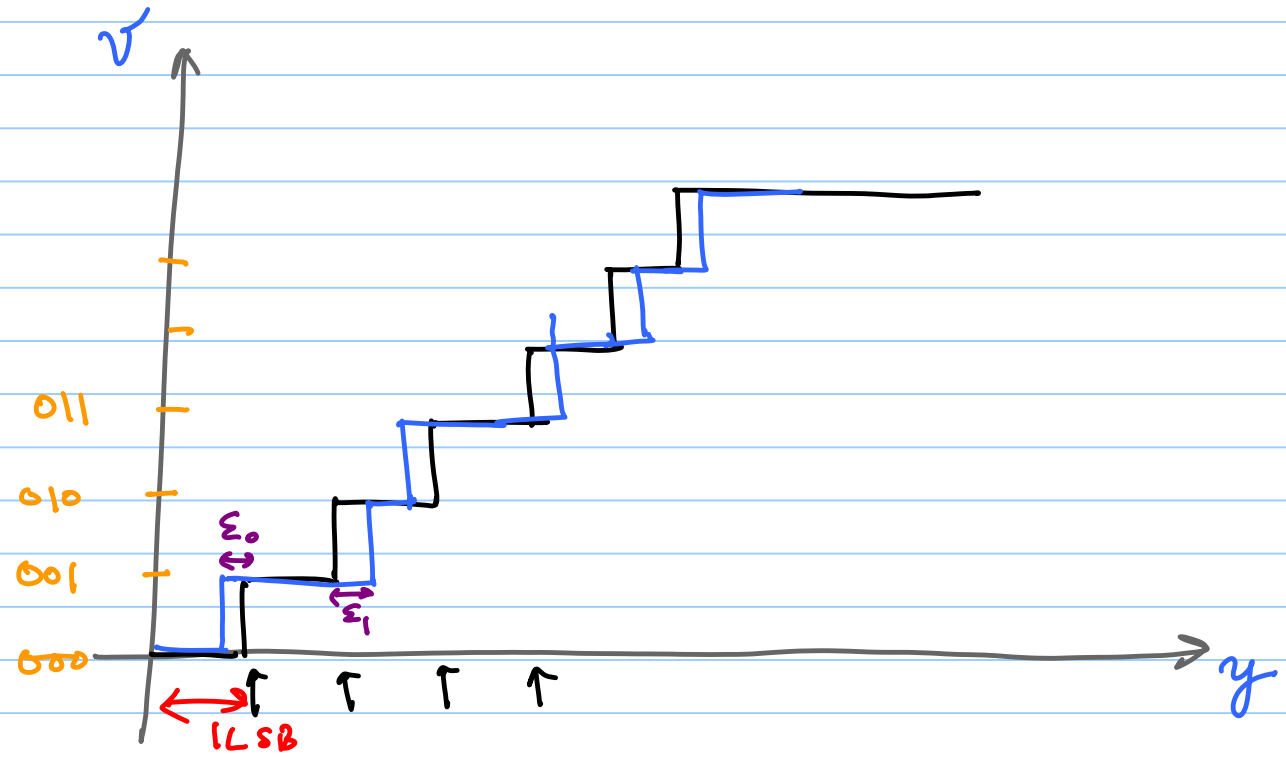
ECE 517 – Lecture 11

Note Title 2/21/2017



HW 2 is posted

Static characteristics

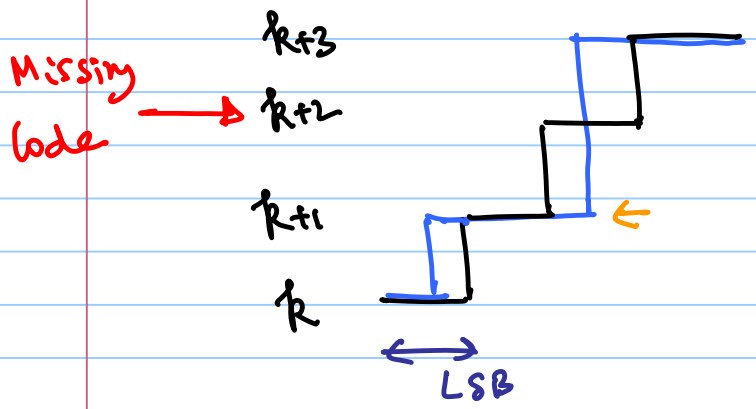
DNL

INL

$$DNL(k) \triangleq \frac{\text{Width of code '}k\text{'} - 1\,LSB}{1\,LSB}$$

(k^{th} code)

↳ specifying the DNL defines the entire static characteristics



$DNL(k) = -0.3$

$DNL(k+1) = +0.6$

$DNL(k+2) = -1$? ← Missing code

$DNL(k+3) = +0.7$

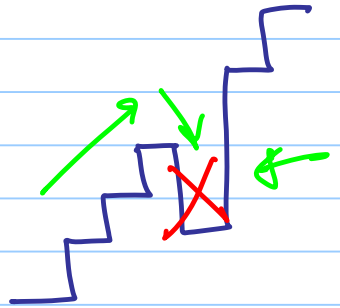
$|DNL| \leq 0.5\ LSB$, is sufficient to ensure no missing codes

↳ sufficient by necessary

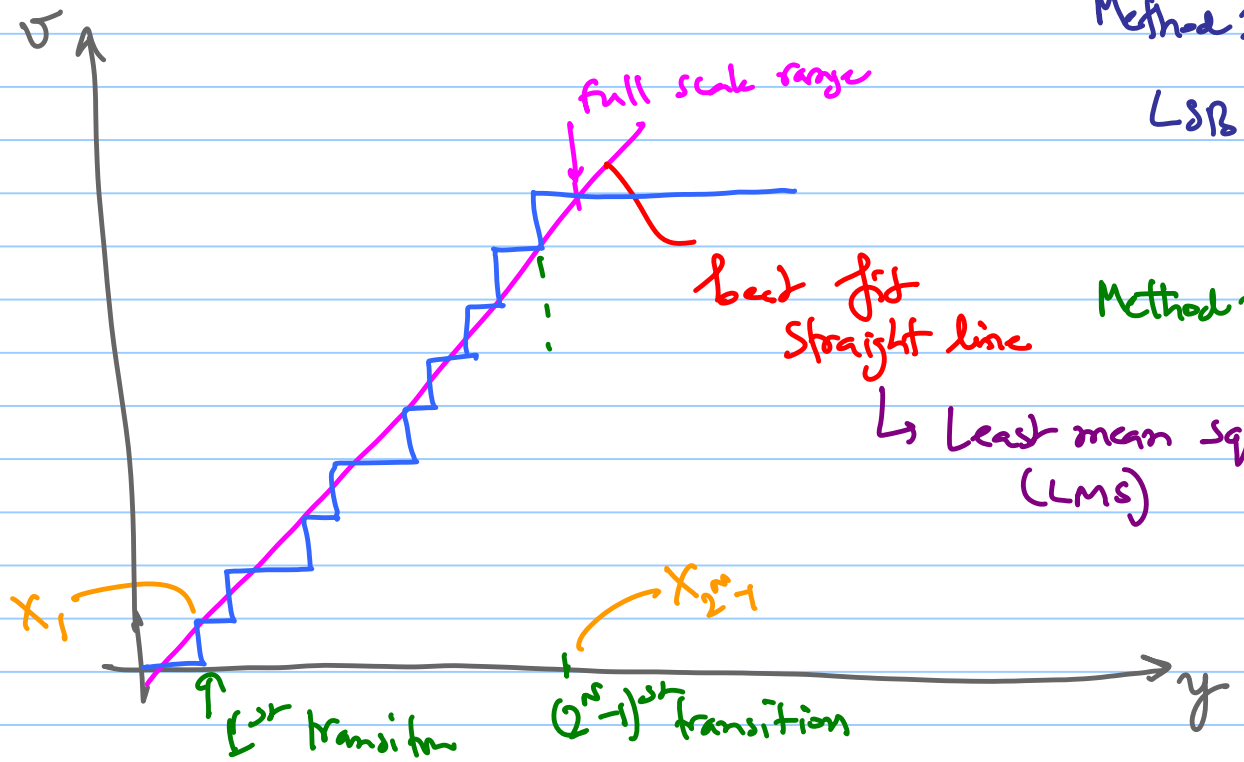
* However, there can be situations where $DNL_k > 1\ LSB$, yet no missing codes.

Need to ensure $|DNL(k)| \leq 0.5\ LSB$

Quantizer characteristics must be monotonic



+ How do we define LSB



Method 1:

$$LSB = \frac{X_{2^N-1} - X_1}{2^N - 1}$$

Method 2:

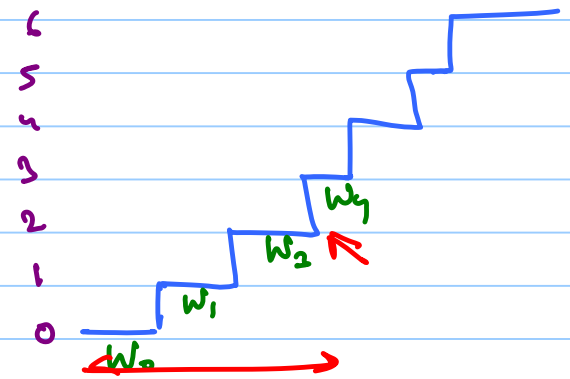
↳ Least mean squares algorithm (LMS)

* Numerically fit a straight line (LMS)
  - Remove the offset & gain error from the staircase
    - best fit straight line
      - from the slope, compute ideal LSB
        - Compute DNL (k)

* INL (Integral Non Linearity) ← another common metric

INL (k) = deviation in LSB of the code transition wrt to the ideal transition.

↳ don't care about the individual code widths, but the cumulative effect on the code transition



Ideal transition for the k^{th} code $\Rightarrow k \cdot LSB$

Real transition = $\sum_{i=0}^{k-1} W_i$

$$INL(k) = \frac{\sum_{i=0}^{k-1} W_i - k \cdot LSB}{1\ LSB}$$

$LSB \triangleq 1$

(-1) $$INL(k) = \sum_{i=0}^{k-1} W_i - k$$

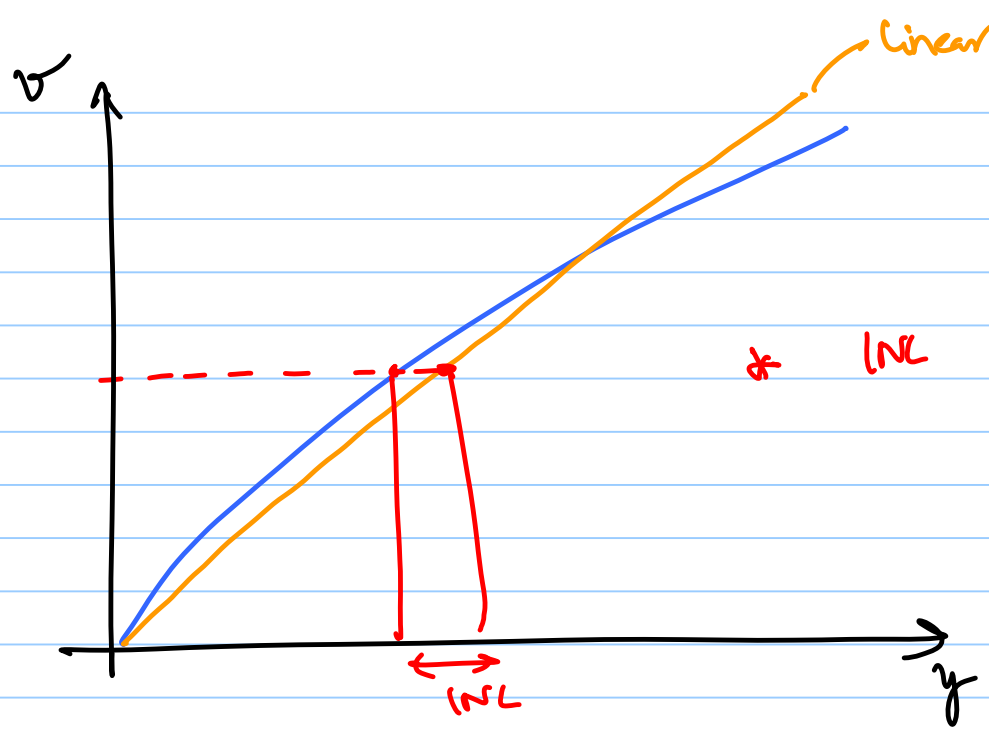
(+) $$INL(k+1) = \sum_{i=0}^{k} W_i - k - 1$$

$$INL(k+1) - INL(k) = \underbrace{W_k - 1}_{DNL(k)}$$

$$DNL(k) = INL(k+1) - INL(k)$$

$$INL(k) = \sum_{i=0}^{k-1} DNL(i)$$

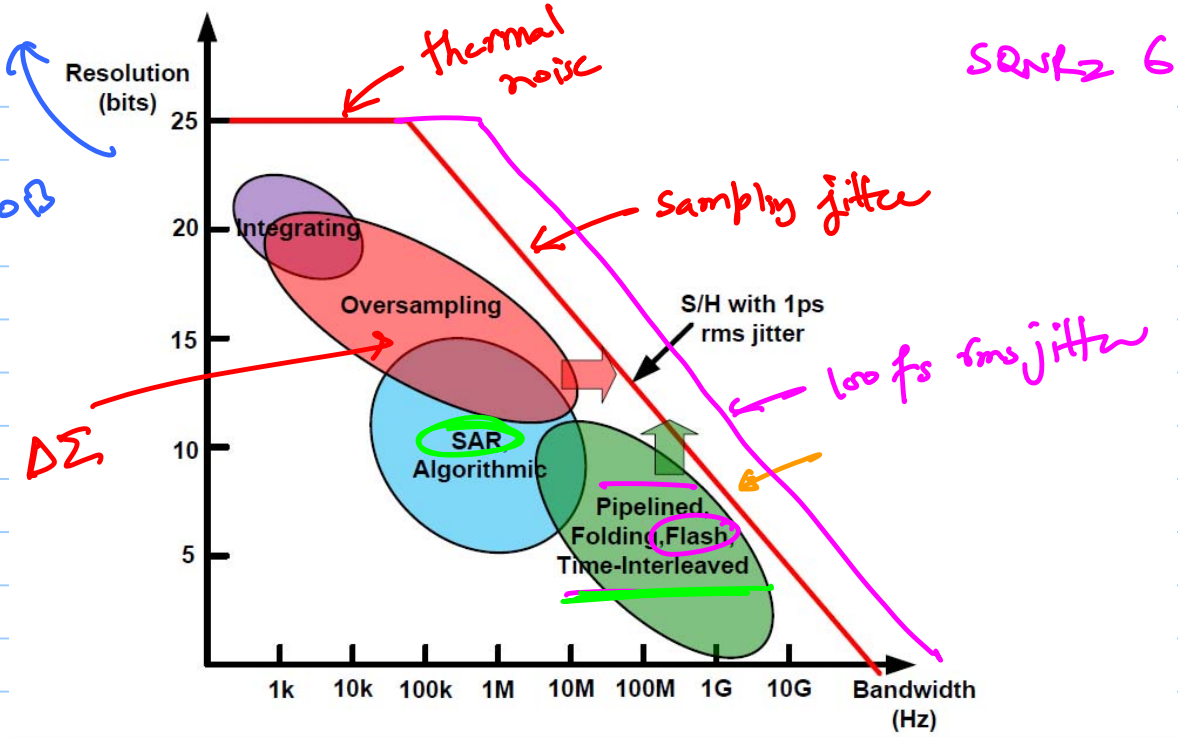
* INL is the running sum of the DNL



* INL tells us the overall trend of the ADC

Communication ⇒ INL needs to be small

Video ⇒ DNL needs to be small



ENOB

thermal noise

sampling jitter

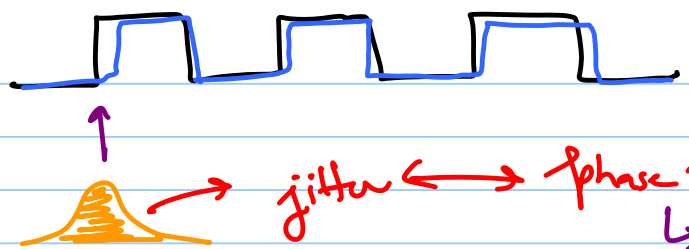
100 fs rms jitter

ΔΣ

SQNR = 6.02 N − 1.76

↑ ENOB

Conversion BW



jitter ⟷ phase noise

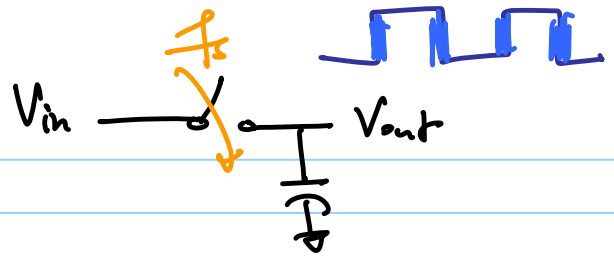
↳ oscillator

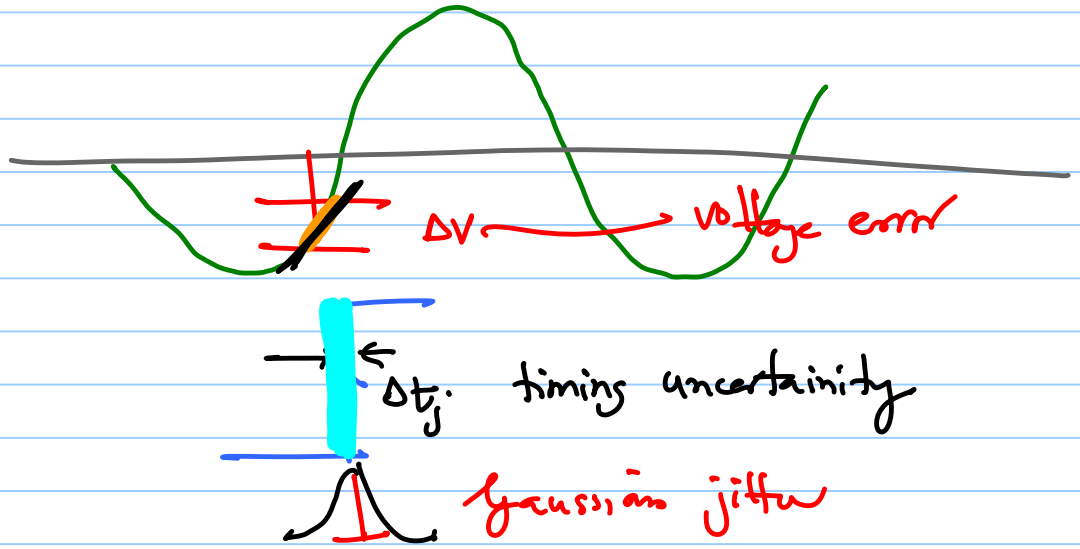
↳ PLL

$\sigma_j \Rightarrow$ rms value of the clock source jitter

$\sigma_j =$ 100 fs rms

Sampling jitter





$$V_{in} = A \sin(2\pi f_{in} t)$$

Voltage error, $\Delta V = \left(\left. \frac{dV_{in}}{dt} \right|_{t = nT_s} \right) \cdot \Delta t_j$

(Δt_j: random variable; $\left. \frac{dV_{in}}{dt} \right|_{t = nT_s}$: slope)

$$V_{in} = A \sin(2\pi f_{in} t)$$

$$\frac{dV_{in}}{dt} = 2\pi f_{in} A \cos(2\pi f_{in} t)$$

$$\therefore E\left[\left(\frac{dV_{in}}{dt}\right)^2\right] = (2\pi f_{in} A)^2 \cdot \frac{1}{2}$$

$$\sigma_{\Delta V}^2 = E[\Delta V^2] = E\left[\left(\frac{dV_{in}}{dt}\right)^2 \cdot \Delta t_j^2\right]$$

$$= E\left[\left(\frac{dV_{in}}{dt}\right)^2\right] \cdot E[\Delta t_j^2]$$

$$= \frac{1}{2} \cdot (2\pi f_{in} A)^2 \cdot \sigma_j^2$$

$$\sigma_{\Delta V}^2 = \frac{1}{2}\left(2\pi f_{in} A\right)^2 \cdot \sigma_j^2$$

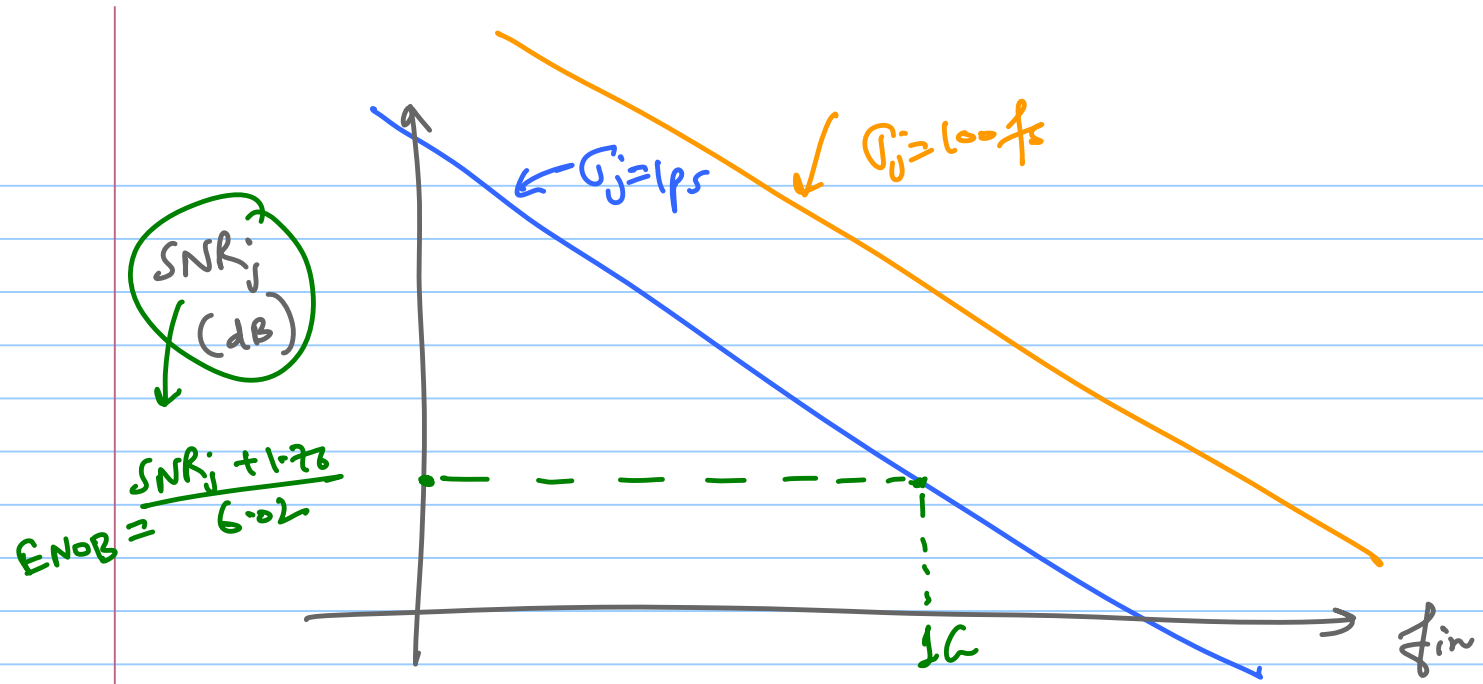
$\sigma_{\Delta V}^2$: noise due to sampling jitter

jitter limited SNR

$$SNR_j = 10\log_{10}\left(\frac{P_S}{P_N}\right) = 10\log_{10}\left(\frac{A^2/2}{(2\pi f_{in} A)^2 \cdot \frac{1}{2} \cdot \sigma_j^2}\right)$$

$$= 20\log_{10}\left[\frac{1}{2\pi f_{in}\sigma_j}\right]$$

$$\boxed{SNR_j = -20\log_{10}\left(2\pi f_{in}\sigma_j\right)}$$


SNR_j (dB)
ENOB = (SNR_j + 1.76) / 6.02
σ_j = 1ps
σ_j = 100fs
fc
f_in

Flash ADC

N bit ⇒ $2^N - 1$ Comparators