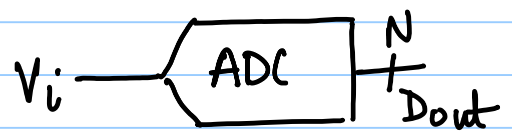
Note Title

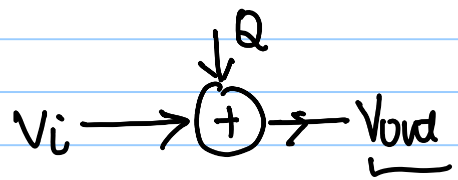
Lecture # 46

Errors in A/D Converters

1. Quantization Error



$\rightarrow V_{out} = \frac{V_{ref}}{2^N}\left[2^{N-1} B_N + \dots + 2^1 B_2 + 2^0 B_1\right]$



$= \frac{V_{ref}}{2^N}\left[2^{N-1} D_{OUT}[N] + 2^{N-2} D_{out}[N-1] \dots + 2^0 D_{OUT}[1]\right]$

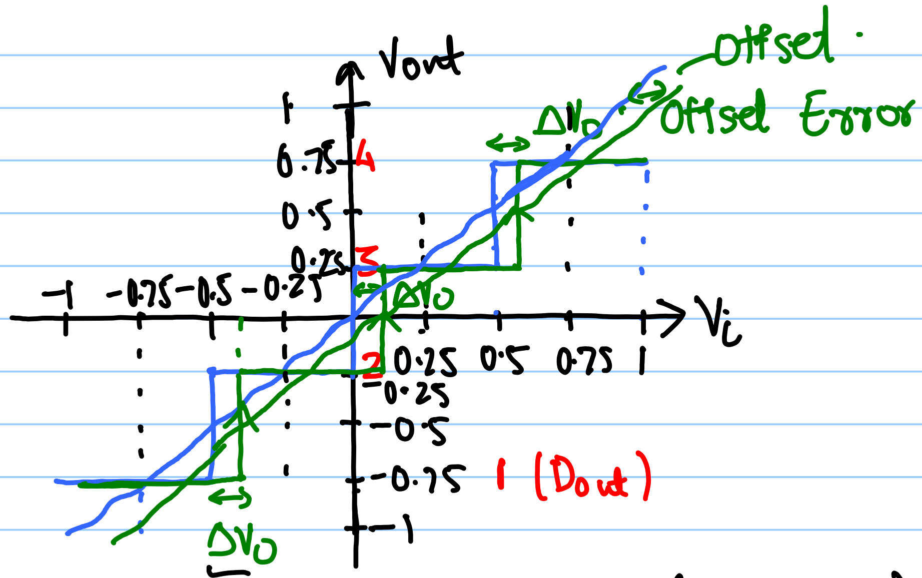
$V_{out} = V_i + Q$

$$SNR[dB] = 10 \log_{10}\left(\frac{\text{Signal Power}}{\text{Noise Power}}\right)$$

$$= 6.02N + 1.76 \quad dB$$

For every increase in bit for ADC o/p $\Rightarrow$ Increase SNR by 6 dB.

2. Offset Error



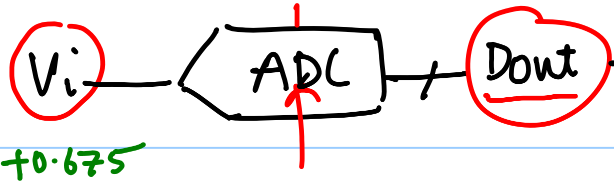
$V_{out} = 1\, V_i + Q - 0.75$ (blue curve)

$V_{out} = (V_i - \Delta V_o) + Q - 0.75$ (green curve)

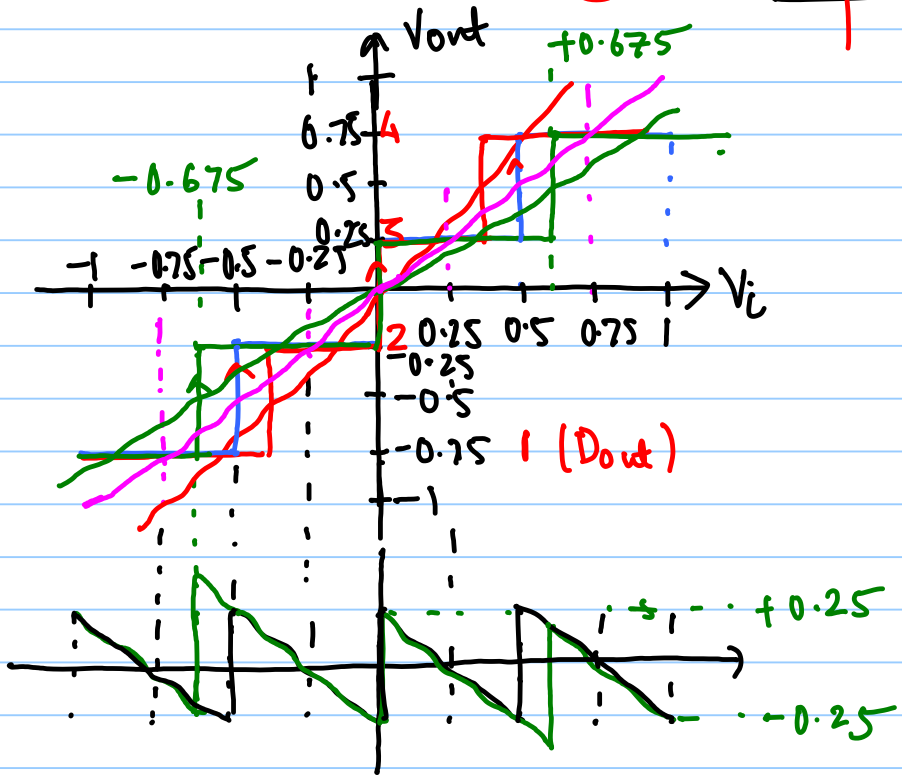
↓

$(-0.5 + \Delta V_o)$

3. Gain Error



$\rightarrow V_{out} = \frac{V_{ref}}{2^N}\left[2^{N-1} D_{out}[N] + \ldots\right]$



$V_{out} = 1 \cdot V_i + Q$

$V_{out} = k \cdot V_i + Q$

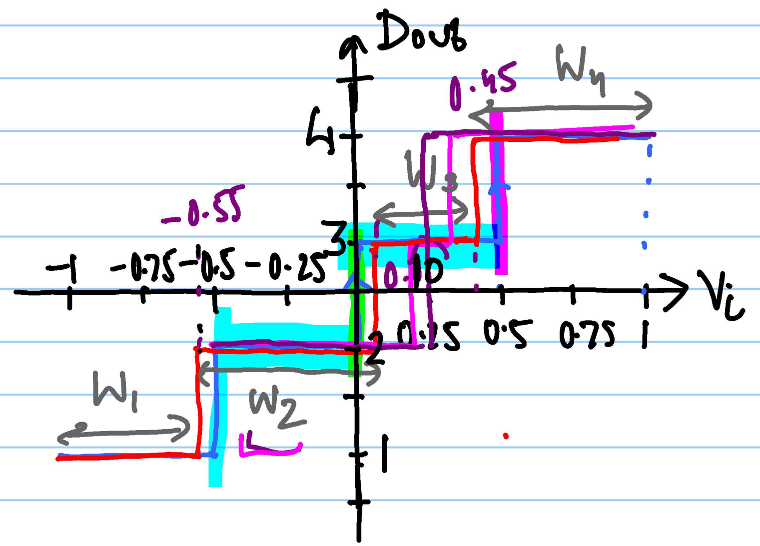
$k < 1$

$-0.25 = -0.675 + Q$

$Q = +0.325$

After removing gain error and offset error, you characterize ADC with Differential Non-linearity (DNL)

Integral Non-Linearity (INL)



Ideally. $W_1 = W_2 = W_3 = W_4 = \frac{V_{ref}}{2^N} = \frac{(V_{refh} - V_{refl})}{2^N}$

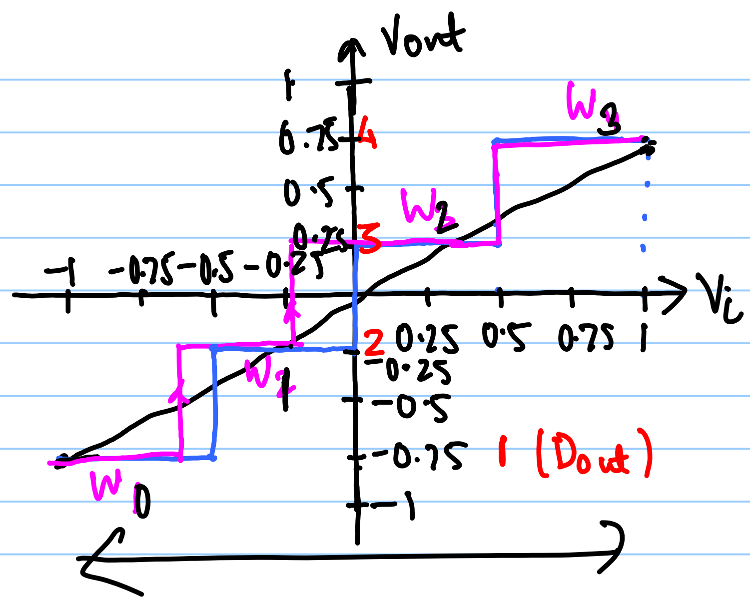
$$DNL(K) = \frac{W_K - 1LSB}{1LSB}$$

$$DNL(1) = \frac{(-0.55-(-1)) - 0.5}{0.5} = \frac{0.45-0.5}{0.5} = -\frac{1}{10}$$

$$DNL(2) = \frac{(0.1-(-0.55)) - 0.5}{0.5} = \frac{0.15}{0.5} = +\frac{3}{10}$$

For 10-bit ADC, calculate DNL[K], $k = 1, 2, \ldots, 1024$

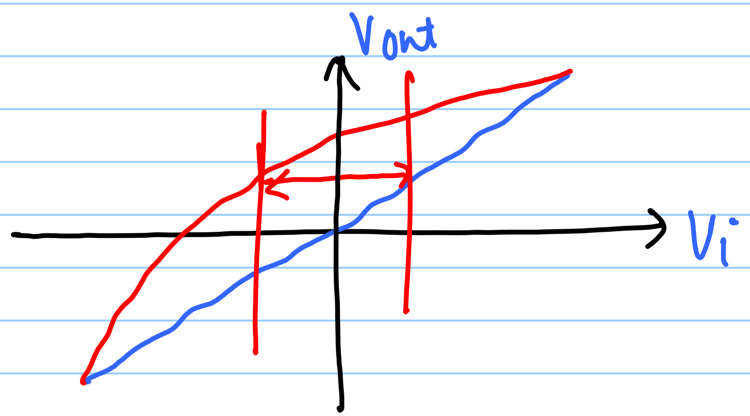
$|DNL| < 0.5$ to ensure that there is no missing code in the o/p.



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

$$= (W_0 - 1LSB) + (W_1 - 1LSB) + (W_2 - 1LSB) + \cdots + (W_{k-1} - 1LSB)$$

$$INL(4) = \underbrace{(W_0 + W_1 + W_2 + W_3)}_{4\,LSB} - 4 \cdot LSB = 0$$



$$INL(2) = (W_0 + W_1) - 2 \cdot LSB$$

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

$$= \sum \frac{(W_i - 1LSB)}{1LSB}$$

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