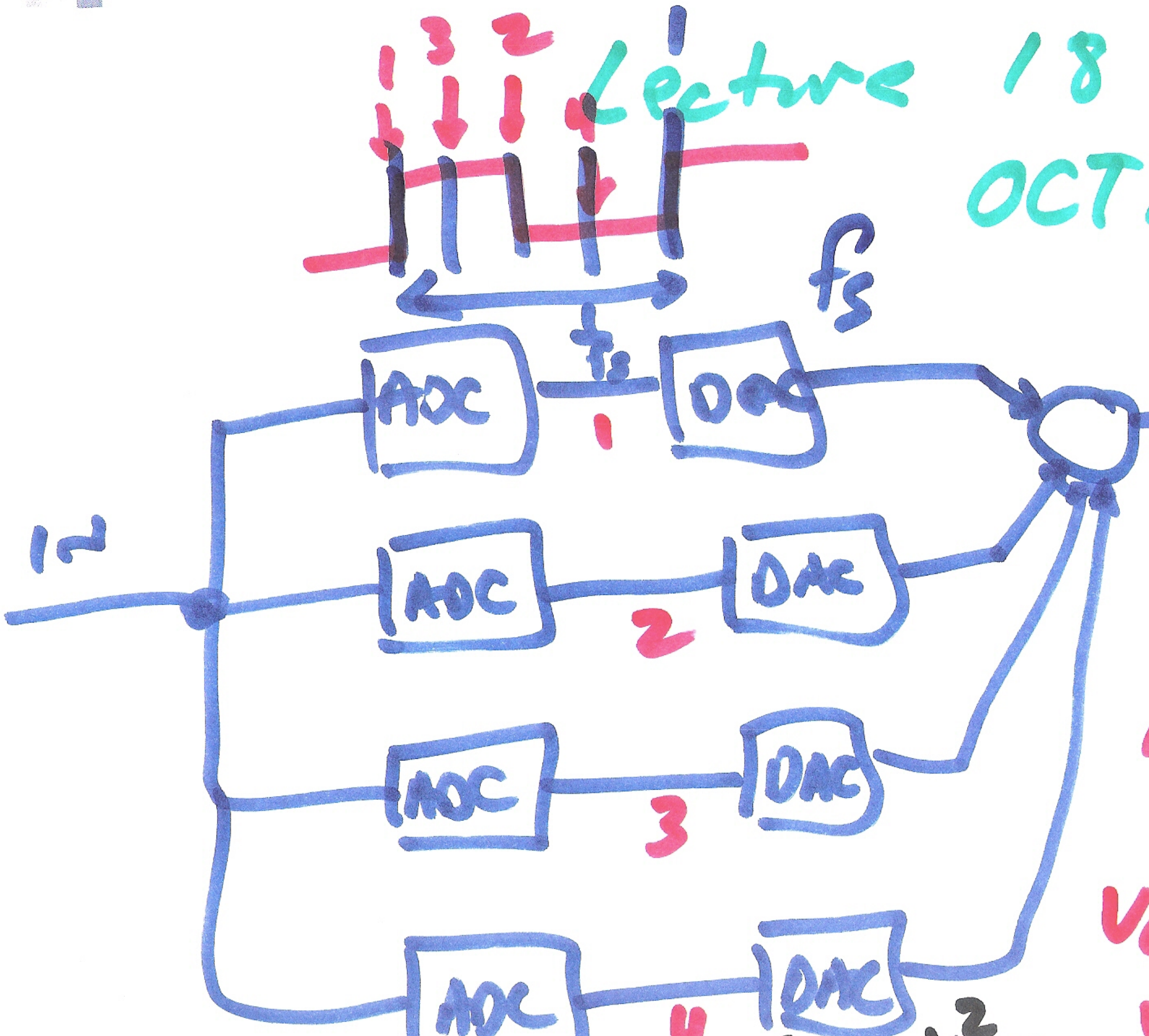
ECE 615 CMOS Mixed-Signal

Lecture 18

OCT. 25, 2010



$$V_T^2 = \frac{V_{Qe,rms1}^2 + V_{Qe,rms2}^2 + V_{Qe,rms3}^2 + V_{Qe,rms4}^2}{4}$$

1)
$$V_{Qe,rms}^2 = \frac{V_{LSB}^2}{12}$$

K = 4 = # paths

$$V_{T,rms}^2 = 4\cdot V_{Qe,rms}^2$$

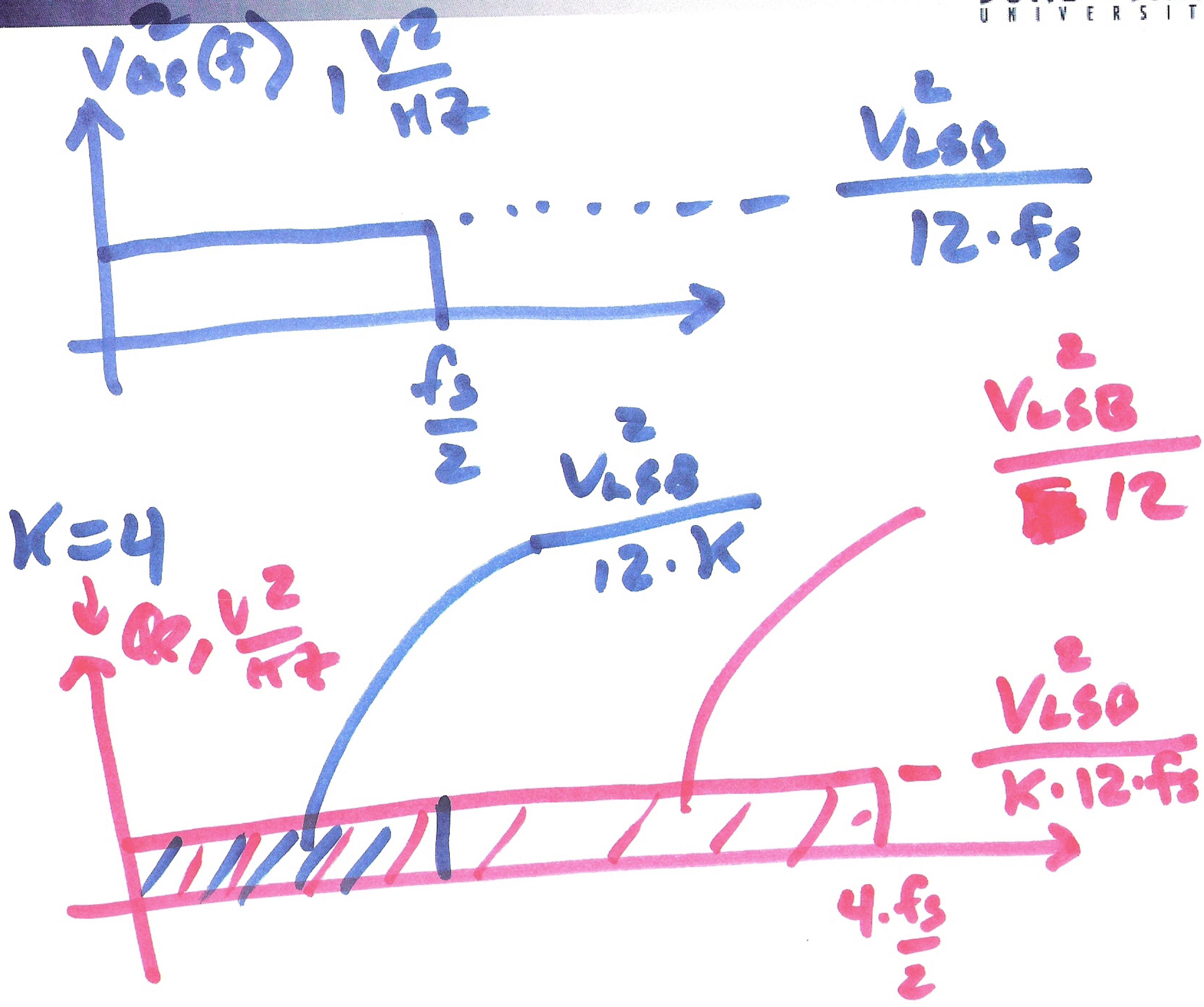
$$= 4\cdot \frac{V_{LSB}^2}{12} = \frac{V_{LSB}^2}{3}$$

$$= \frac{V_{Qe,rms}^2}{4} = \frac{V_{Qe,rms}^2}{K}$$

effective rms changing

$$V_{Qe,rms} = \frac{1}{\sqrt{K}}\cdot\frac{V_{LSB}}{\sqrt{12}}$$

2)



$V_{QE}^2(f)$, $\frac{V^2}{Hz}$
$\frac{V_{LSB}^2}{12 \cdot f_s}$
$\frac{f_s}{2}$
$\frac{V_{LSB}^2}{12 \cdot K}$
$K = 4$
$\frac{V_{LSB}^2}{12}$
$\frac{V_{LSB}^2}{K \cdot 12 \cdot f_s}$
$\frac{V^2}{Hz}$
$4 \cdot \frac{f_s}{2}$

3)

How does SNR change with K?

$$SNR = 20 \cdot \log \frac{V_P/\sqrt{2}}{V_{Q,rms}}$$

$$= 20 \cdot \log \frac{V_{DD}/(2 \cdot \sqrt{2})}{V_{LSB}/\sqrt{12K}}$$

$$= \underbrace{20 \log \frac{V_{DD}/(2\sqrt{2})}{\frac{V_{LSB}}{\sqrt{12}}}}_{6.02N + 1.76} + \underbrace{20 \log \sqrt{K}}_{10 \log K}$$

SNR

4)

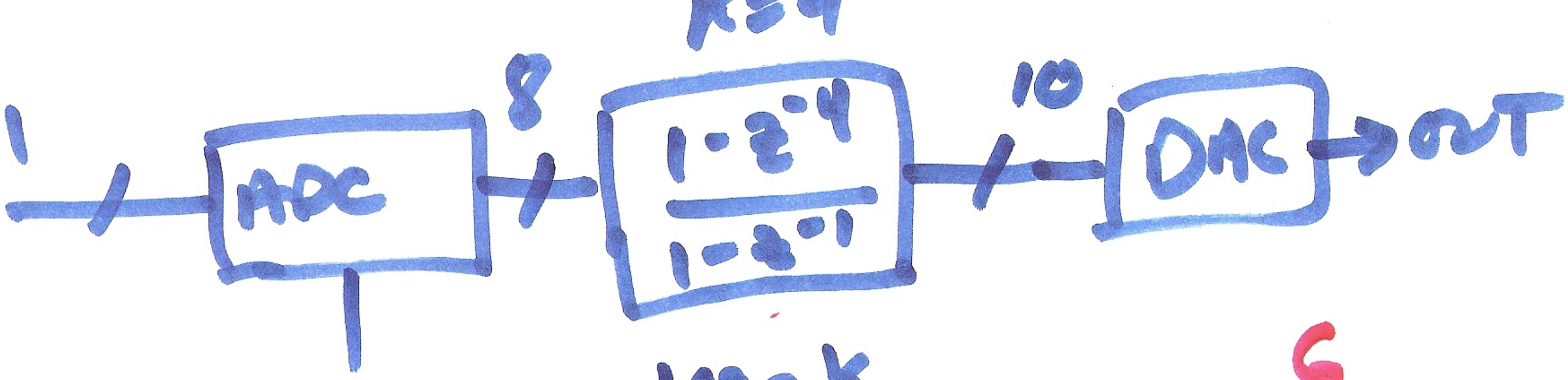
every doubling in K gives 3dB ↑ in SNR

1) Simple oversampling
every doubling in K
we get **3dB** increase
in SNR OR **0.5 bits ↑ res.**

First-order noise-shaping
9dB inc. with doubling K
1.5 bits

Second-order noise-shaping
2.5 bits
15dB

5)



$\log_2 K$

$1+z^{-1}+z^{-2}+z^{-3}$

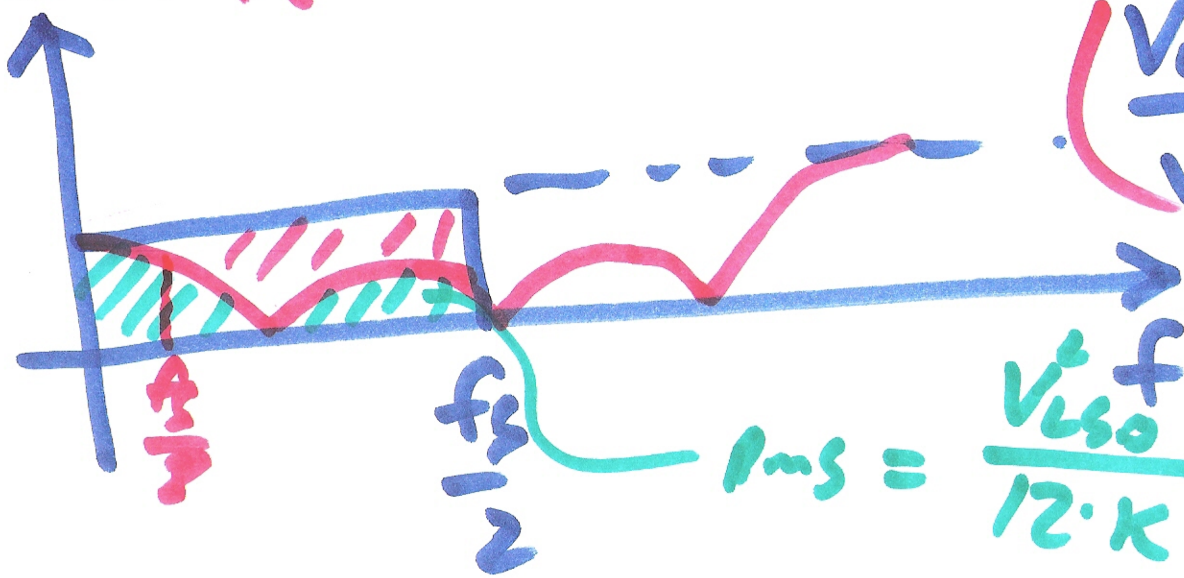
$\frac{6}{8}$

$$2\int_0^{f_s/2} \frac{V_{LSB}^2}{12\cdot f_s}\cdot df$$

$$\frac{V_{LSB}^2}{6 f_s} f \Big|_0^{\frac{f_s}{2}}$$

$$= \frac{V_{LSB}^2}{12}$$

Q_e, $V/\sqrt{Hz}$



$$\left(\frac{V_{LSB}}{\sqrt{12\cdot f_s}}\right)^2$$

$$rms = \frac{V_{LSB}^2}{12\cdot K}$$

b)

$$\frac{1-z^{-K}}{1-z^{-1}} \rightarrow \cancel{K} \cdot \frac{\sin \pi K \cdot \frac{f}{f_s}}{\pi \cdot \cancel{K} \cdot \frac{f}{f_s}}$$

$$V^2_{Qe,RMS,TOT} = 2\int_0^{f_s/2} \frac{V_{LSB}^2}{12 f_s} \cdot \frac{\sin^2 \pi K \cdot \frac{f}{f_s}}{\left(\pi \cdot \frac{f}{f_s}\right)^2} \, df$$

$$= 2\int_0^{f_s/2} V_{Qe}^2(f) \cdot |H(f)|^2 \cdot df$$

7)

Let $X = 2 \cdot \frac{V_{LSB}^2}{12 f_s} \cdot \frac{f_s^2}{\pi^2}$

$$V_{Qe,rms}^2 = 2X \int_0^{f_s/2} \frac{\sin^2 \pi K \cdot \frac{f}{f_s}}{f^2} \cdot df$$

$$\sin^2 x = \frac{1 - \cos 2x}{2}$$

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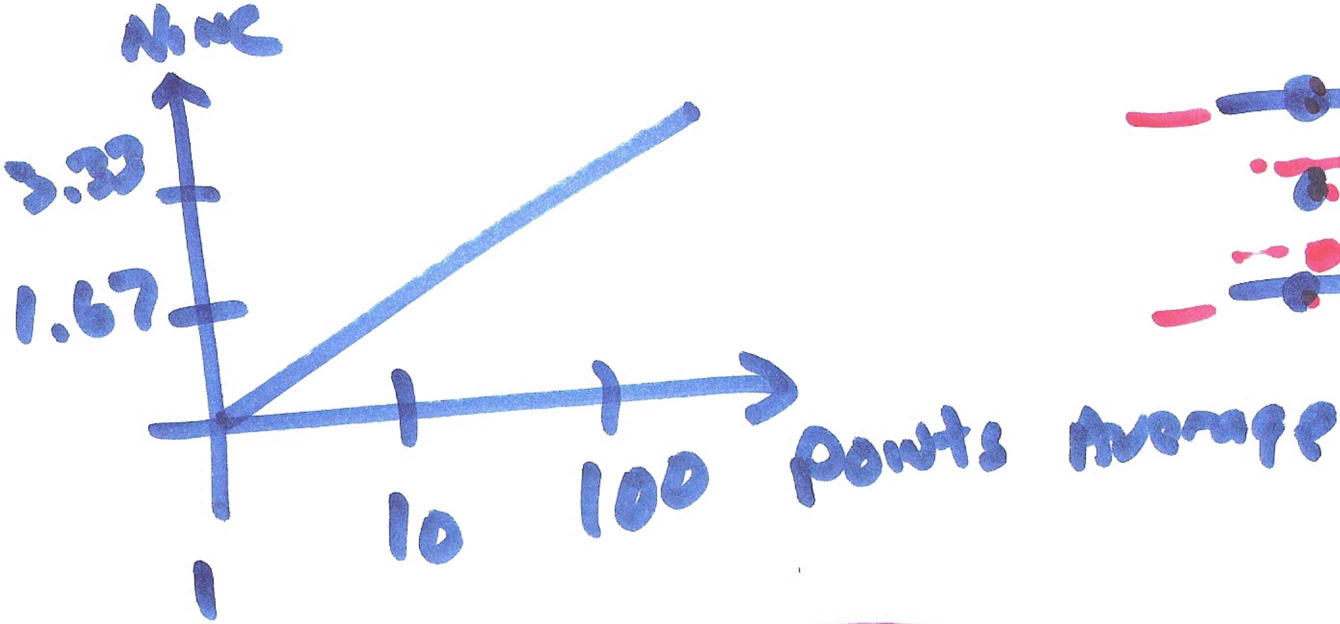
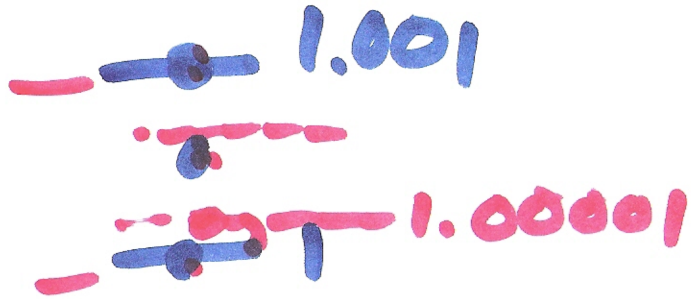
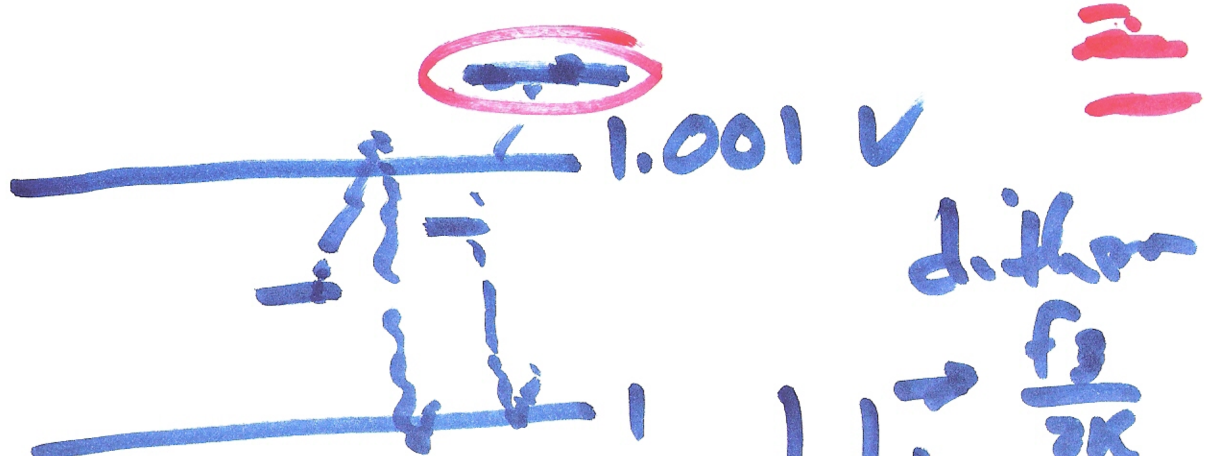
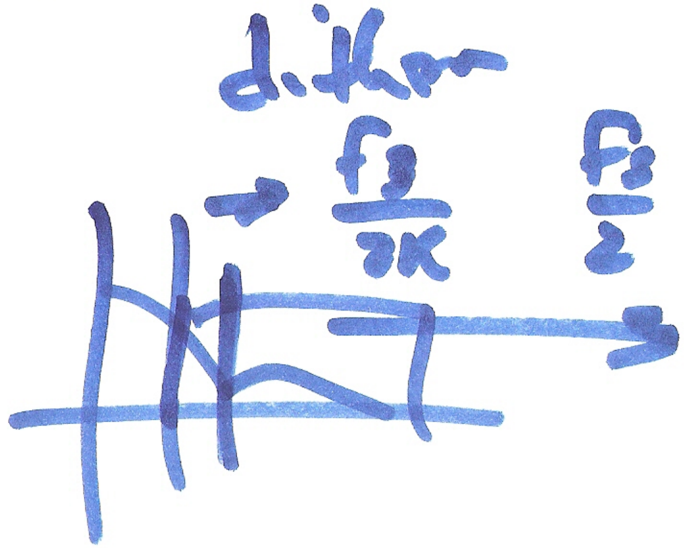
8)





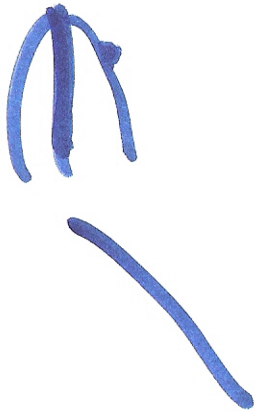




9)

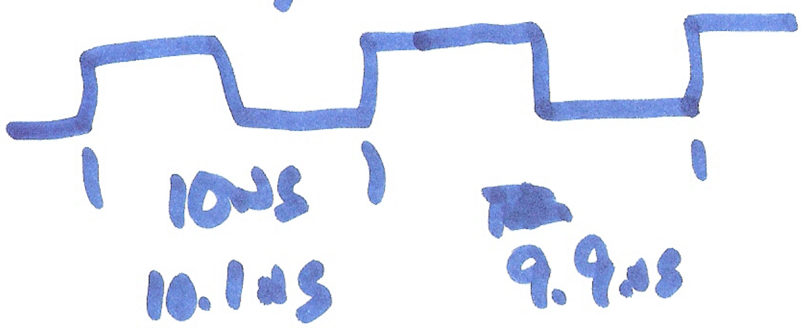
Jitter & K

$$P_{AVG,jitter} = \left[\sigma \cdot \frac{V_p}{\sqrt{2}} \cdot 2\pi f_{in}\right]^2$$



$$P_{QE,AVG} = \frac{1}{K} \cdot \frac{V_{LSB}^2}{12}$$

$$P_{AVG,jitter} = \frac{1}{K}\left[\sigma \cdot \frac{V_p}{\sqrt{12}} \cdot 2\pi f_{in}\right]^2$$



AAF

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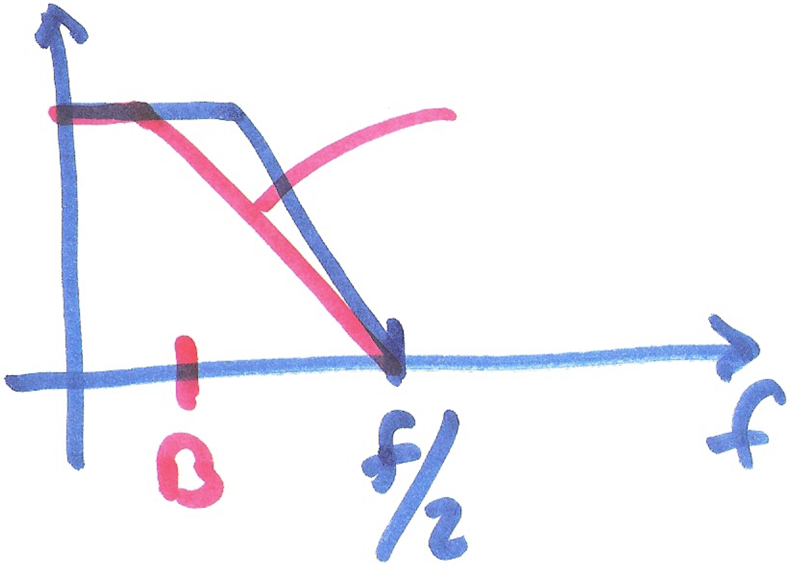
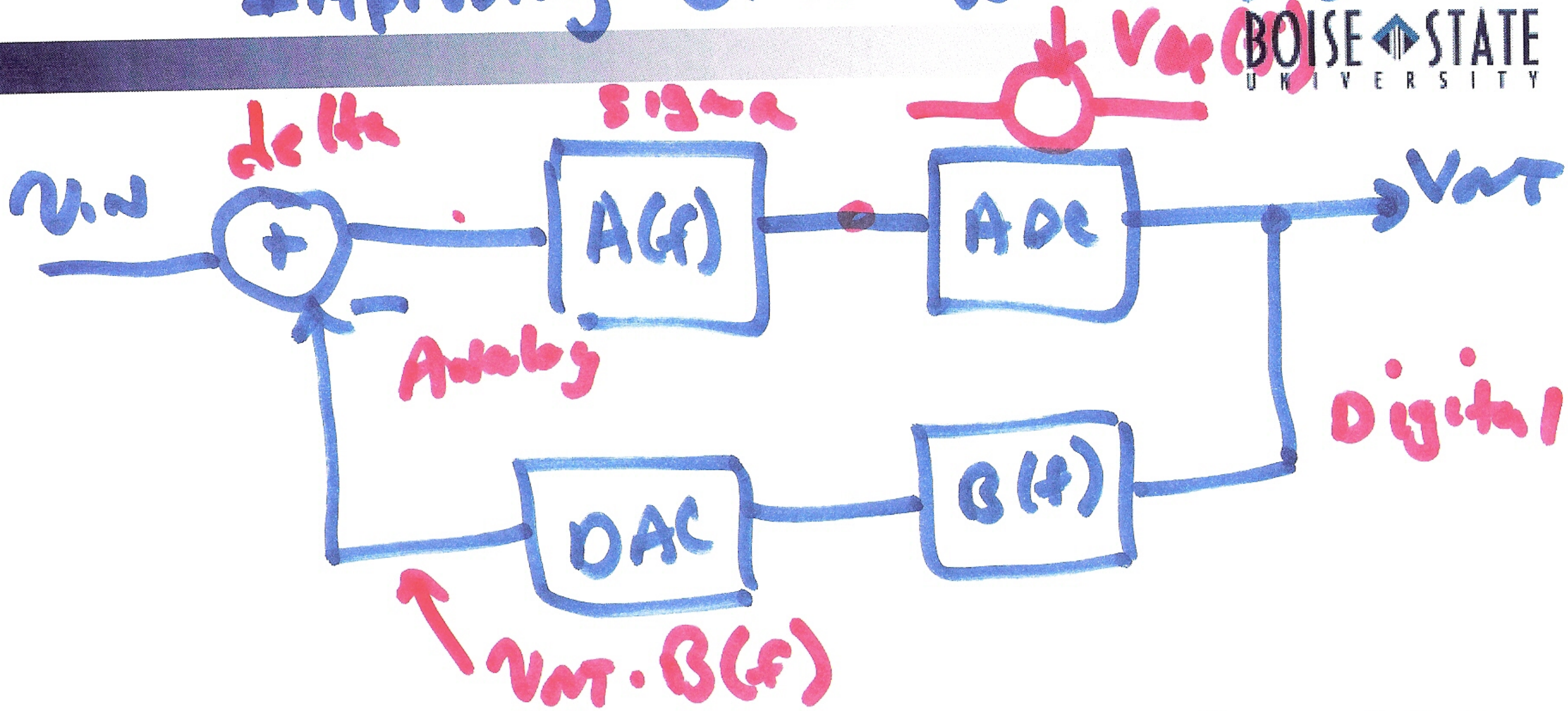


oversampl.-i
Relaxed AAF
requirements

B goes down :(

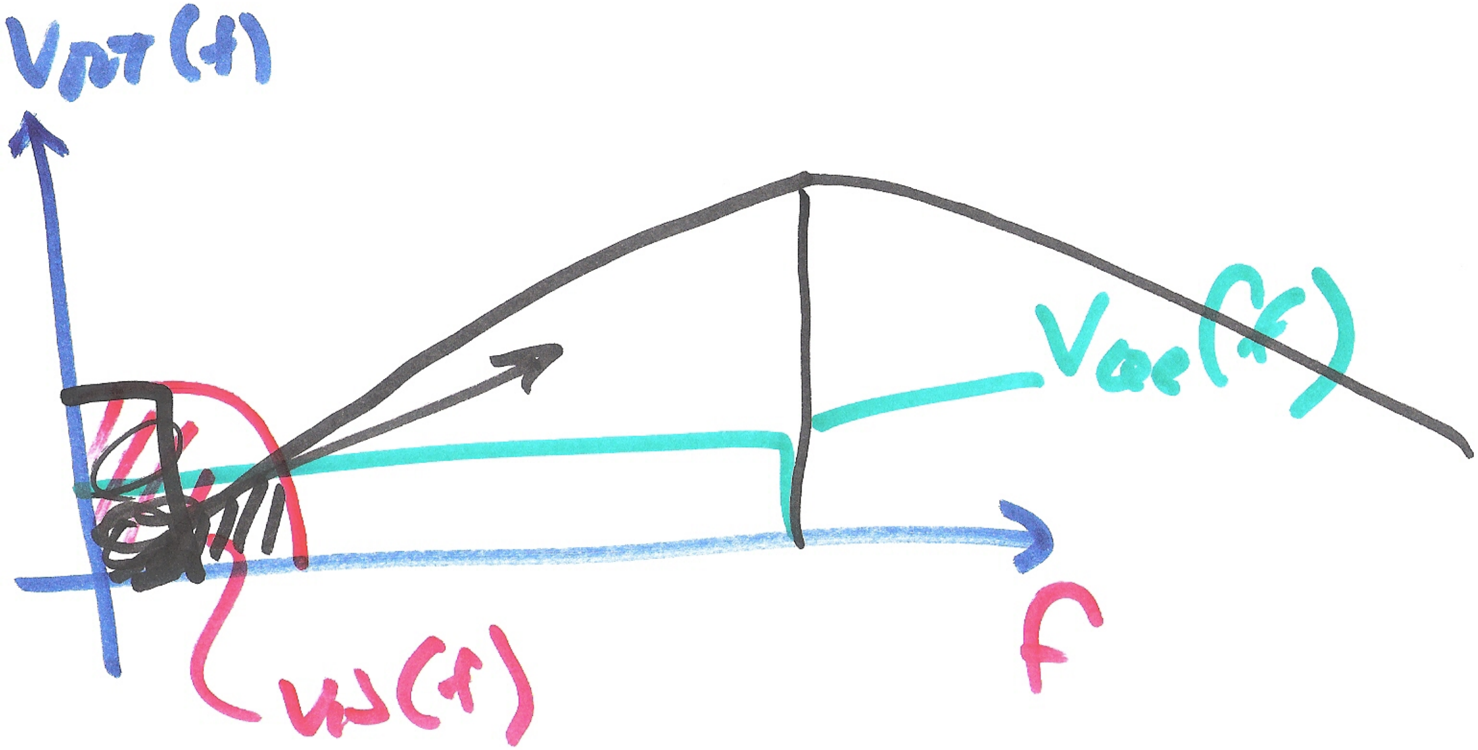
Improving SNR with f.b.



$$(v_{in} - v_{out}\cdot B)A + V_{qe}(f) = v_{out}$$

$$A v_{in} + V_{qe} = v_{out}(1 + BA)$$

$$v_{out} = v_{in}\cdot \frac{A}{1+BA} + \frac{V_{qe}}{1+BA}$$



Vout(f)
Vaae(f)
Vin(f)
f

$$V_{OUT} = V_{IN} \cdot \frac{A}{1+A} + V_{QE} \cdot \frac{1}{1+A}$$

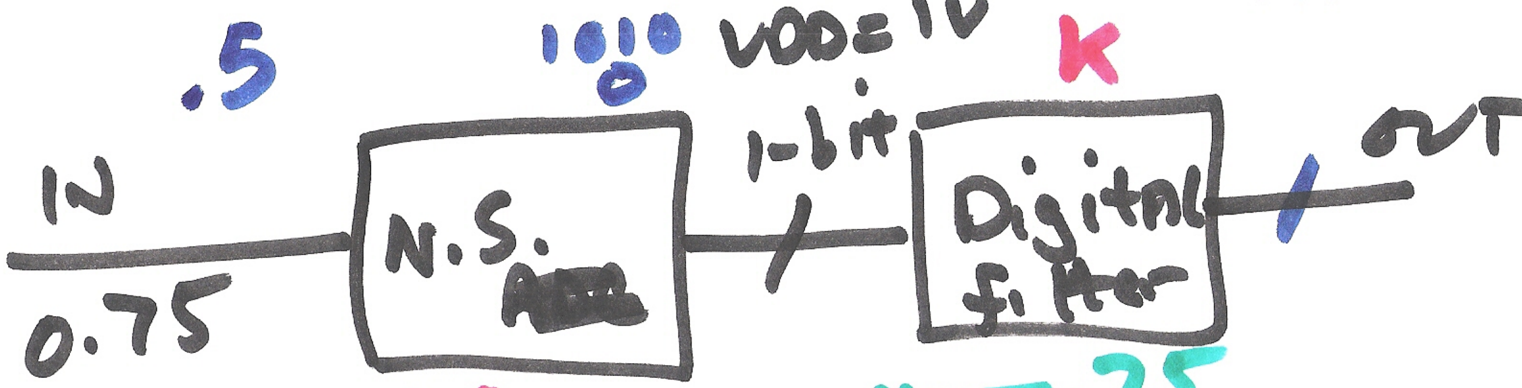
$B = 1$

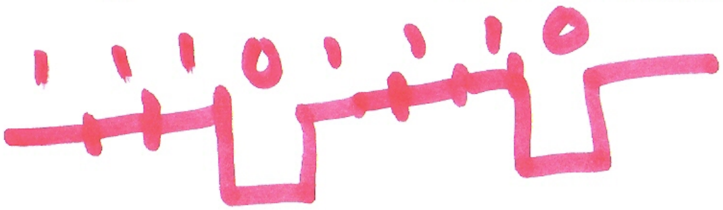
$$A = \frac{z^{-1}}{1-z^{-1}}$$

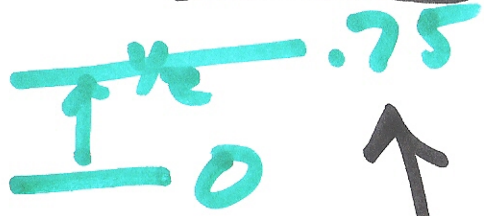
$$= V_{IN} \cdot \frac{\dfrac{z^{-1}}{1-z^{-1}}}{\dfrac{z^{-1}}{1-z^{-1}} + 1 - z^{-1}} + \frac{V_{QE} \cdot z}{1 - z^{-1} + \dfrac{z^{-1}}{1-z^{-1}}}$$

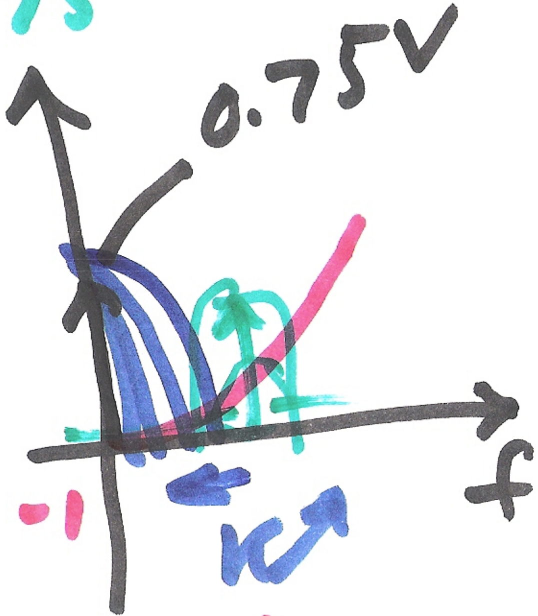
13) $$\boxed{V_{OUT} = V_{IN} \cdot z^{-1} + V_{QE}^{(1)}\left(1 - z^{-1}\right)}$$

Simple Example









1 → +1 01

0 → −1 11

+1 +1 +1 −1 +1 +1 +1 −1

K = 4

$V_{REF} \cdot (1 - z^{-1})$

Modulation noise

14) Understand! $\frac{1}{2}$