ECE 615 CMOS Mixed-Signal CKT

BOISE STATE UNIVERSITY

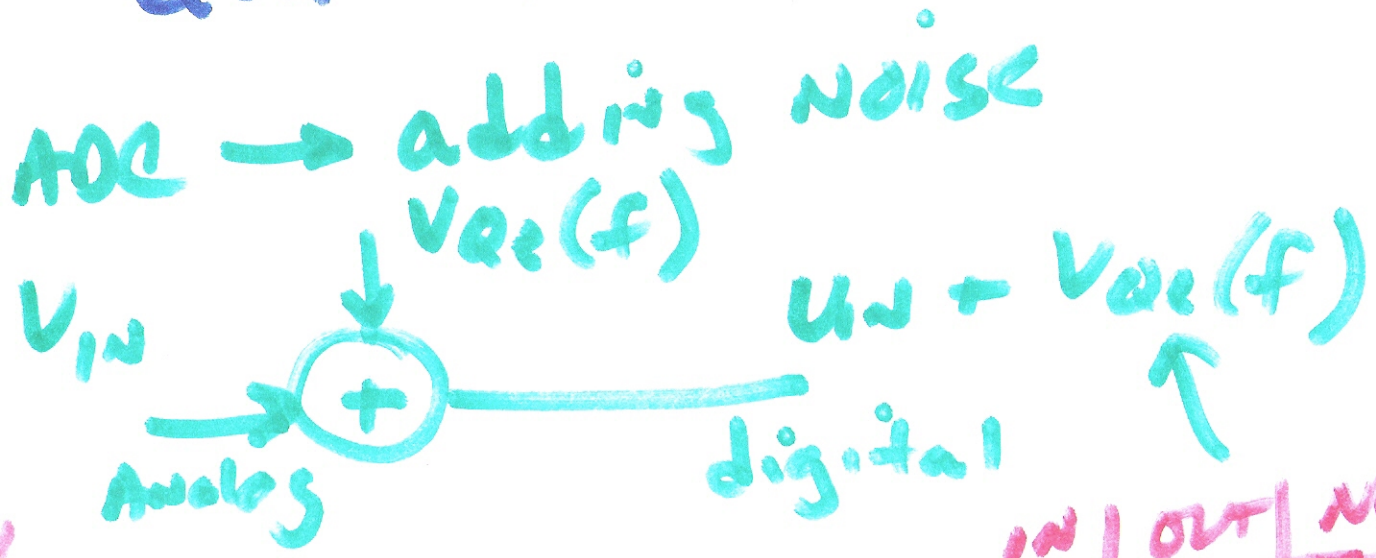
Lecture 16

RL - Record

Design

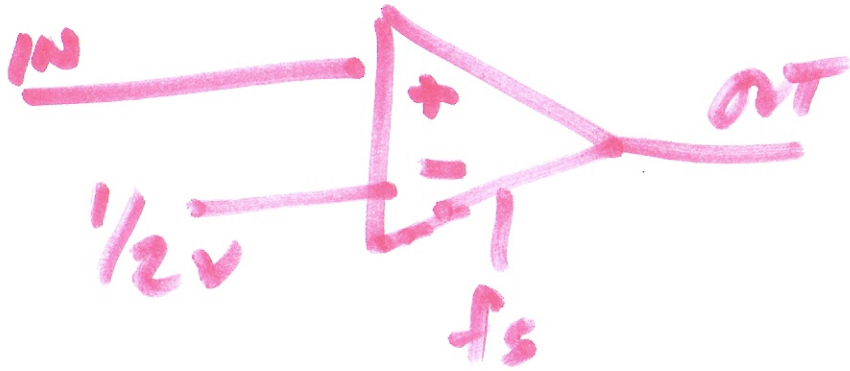
Quantization Noise

ADC → adding noise



$V_{DD} = 1$

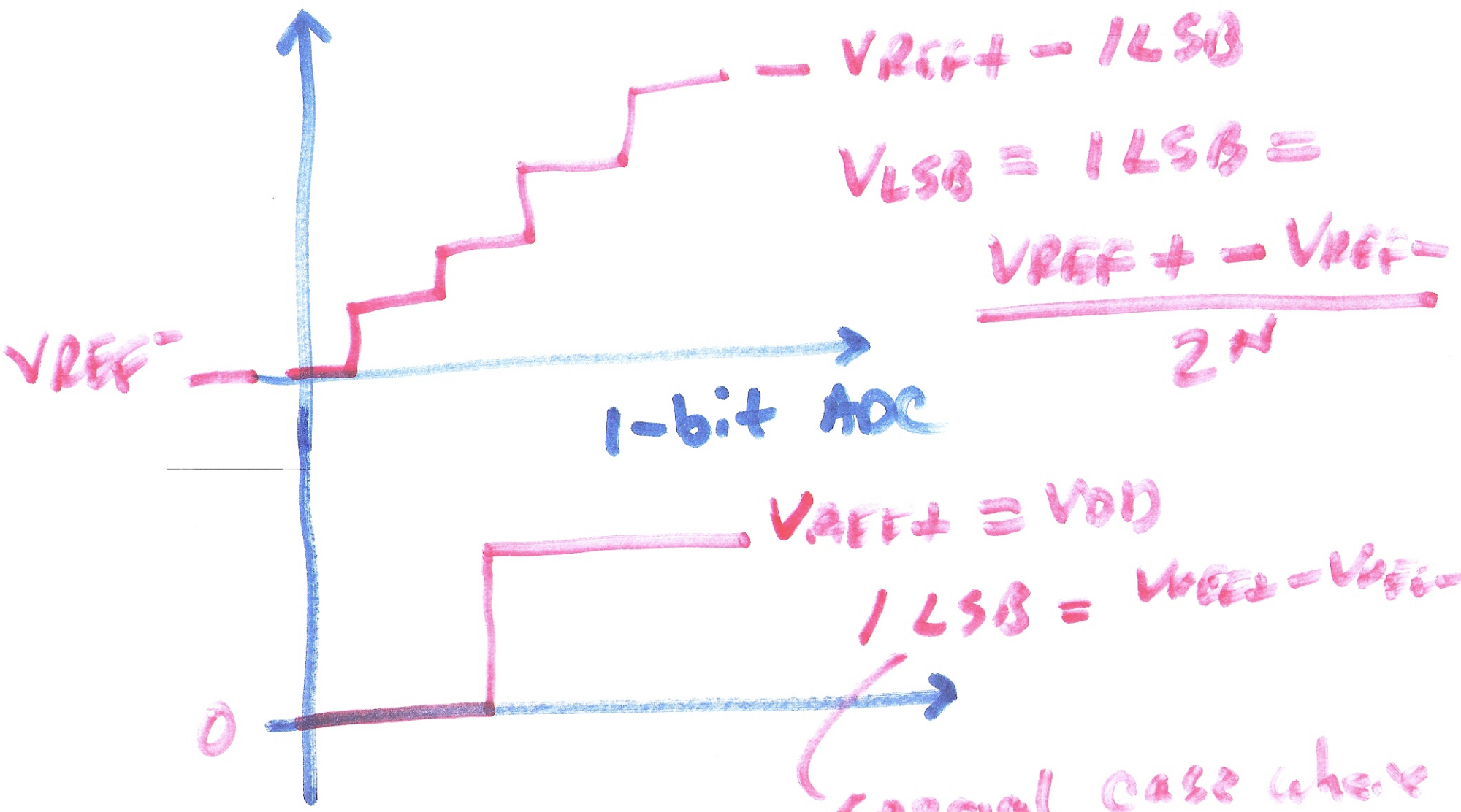
$V_{REF} = \frac{1}{2}V$



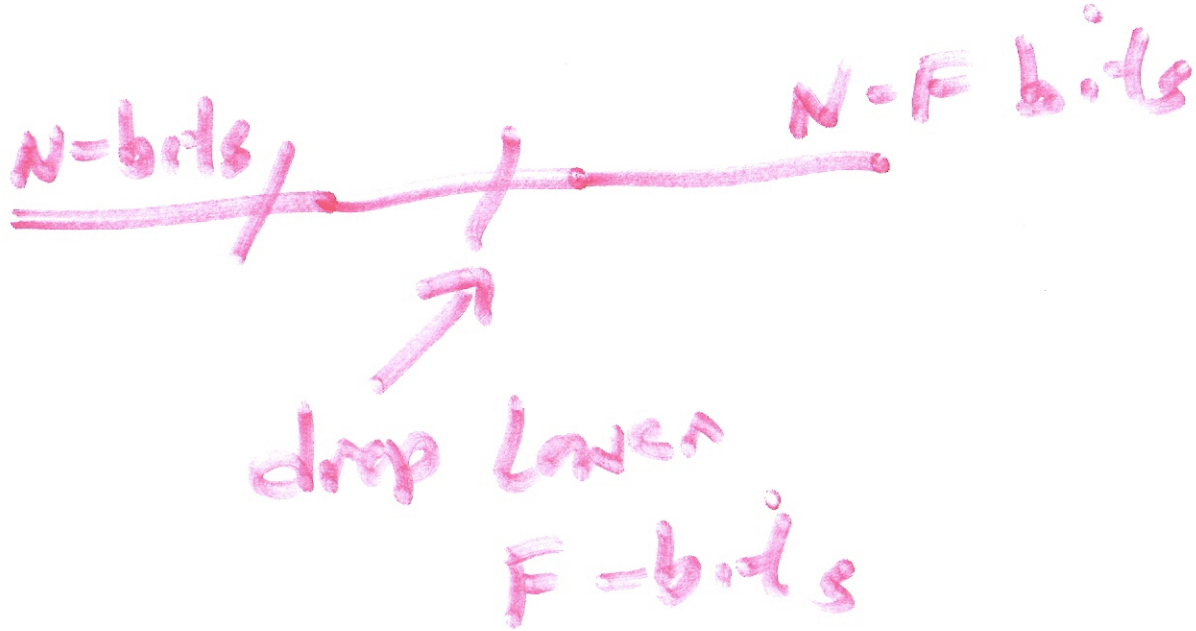
IN	OUT	NOISE
.5	1V	.2
.6	1V	.4
.3	0	-.3

1)

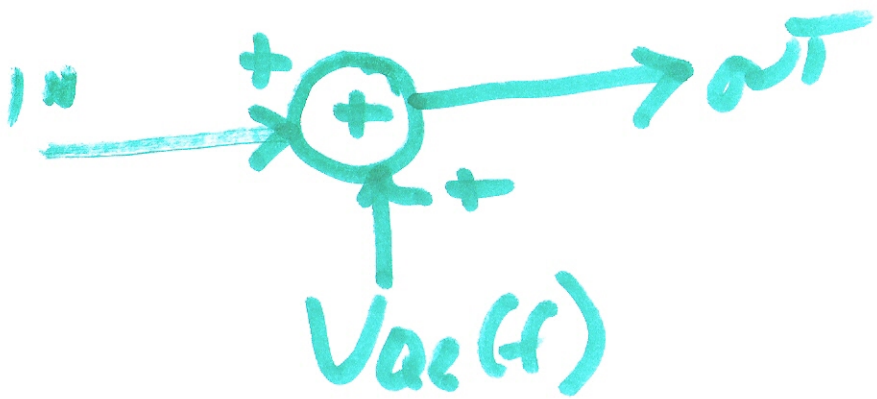
ADC transfer Curve



Digital Quantization Error



N > F



3)

Bennetts Criteria

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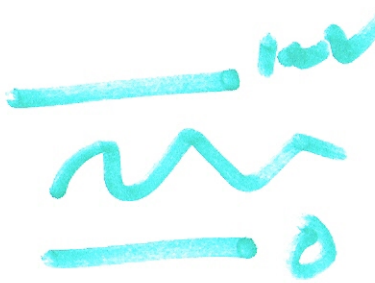
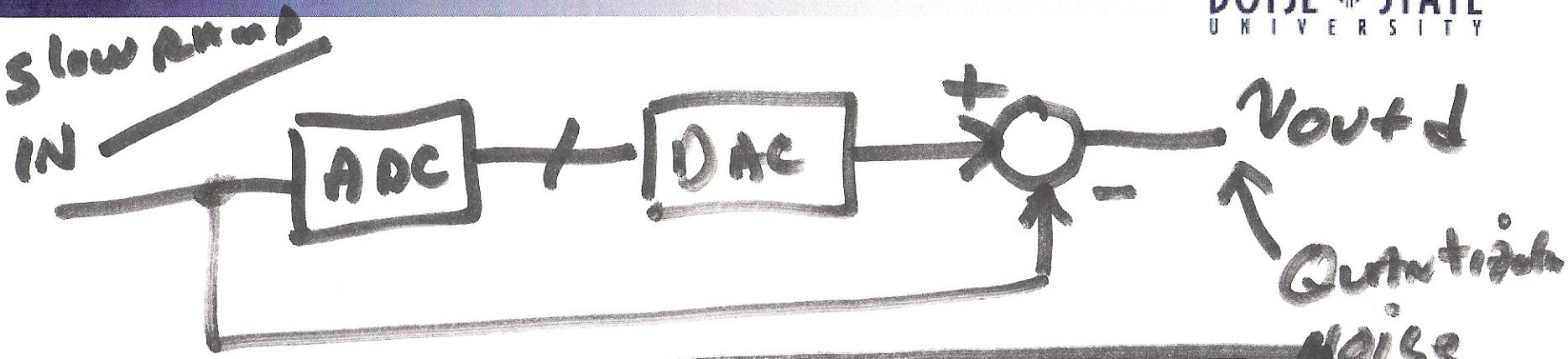
1) input to ADC falls between V_{REF+} and V_{REF-}

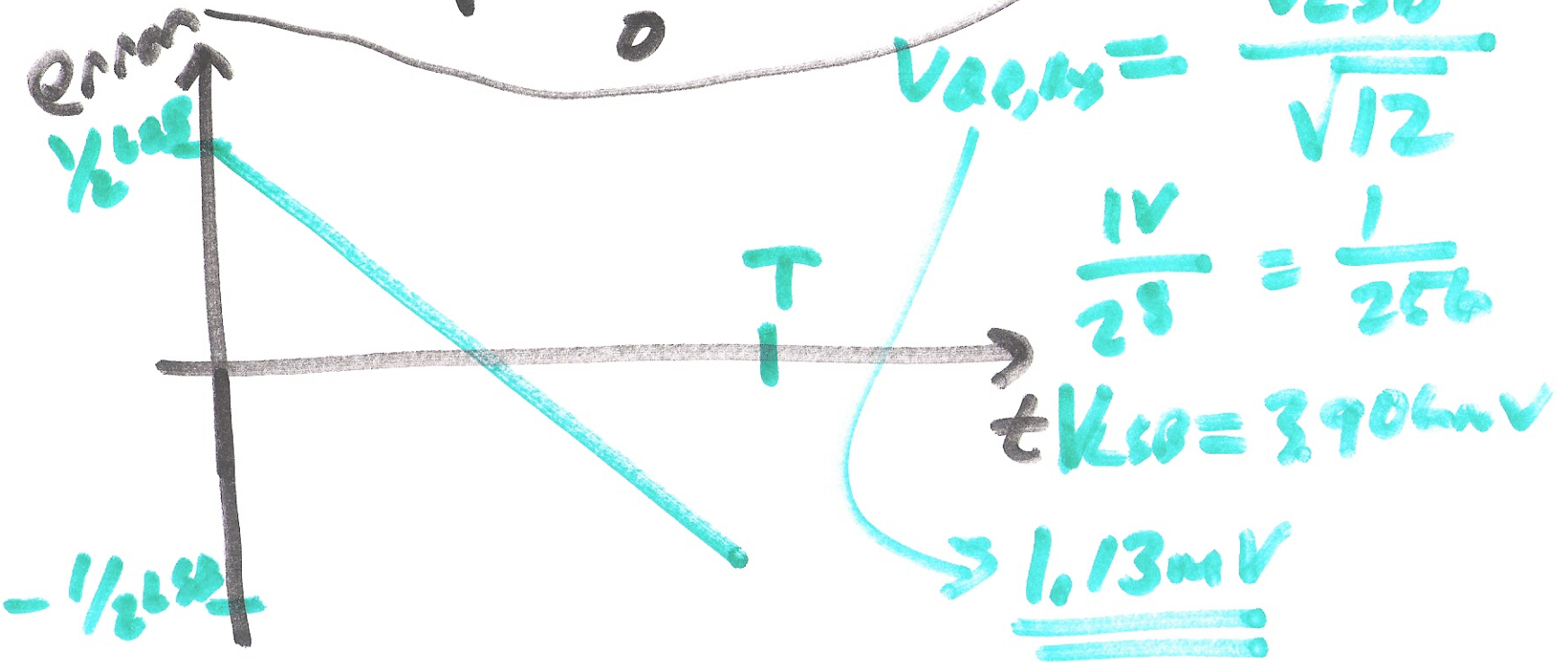
2) input signal >> 1 LSB



3) input signal is busy



$$V_{QE,Rms} = \sqrt{\frac{1}{T}\int_0^T \left(\tfrac{1}{2}LSB - \frac{LSB}{T}\cdot t\right)^2 \cdot dt}$$



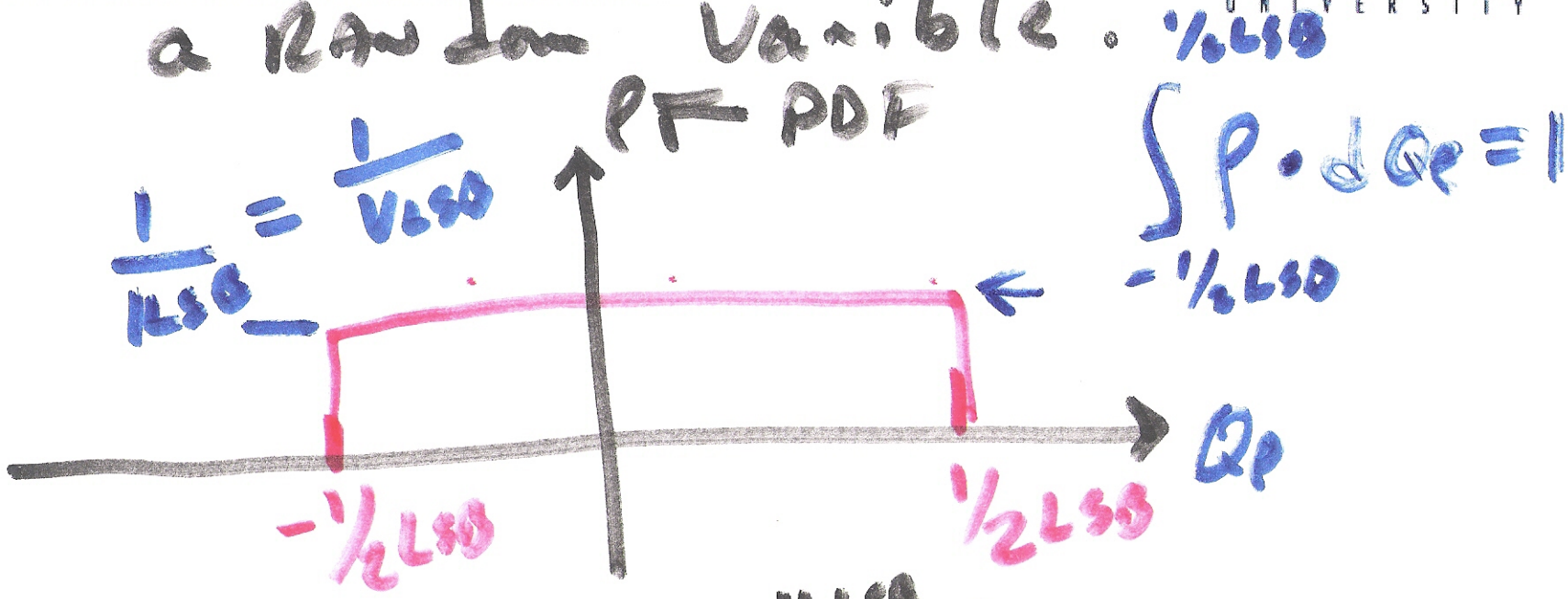
$$V_{QE,Rms} = \frac{V_{LSB}}{\sqrt{12}}$$

$$\frac{1V}{2^8} = \frac{1}{256}$$

$V_{LSB} = 3.906mV$

$\rightarrow$ 1.13mV

Treat Quantization Error as a Random Variable.



$$\text{Standard deviation} = \sigma = V_{Qe,rms} = \left[\int_{-\frac{1}{2}LSB}^{\frac{1}{2}LSB} p(Q_e)^2 \cdot dQ_e\right]^2$$

$$\text{VARIANCE} = \sigma^2 = V_{Qe,rms}^2 = \text{Power in noise} = \frac{V_{LSB}^2}{12}$$

ρ = PDF

$$V_{Qe,Rms}^2 = \int_{-\frac{1}{2}LSB}^{+\frac{1}{2}LSB} \rho(Qe)^2 \cdot dQe$$

$$1\,LSB = V_{LSB}$$

$$= \frac{1}{1\,LSB}\,\frac{1}{3}x^3 \Big|_{-\frac{1}{2}LSB}^{+\frac{1}{2}LSB}$$

$$= \frac{1}{3\,LSB}\left[\left(\frac{1}{2}LSB\right)^3 - \left(-\frac{1}{2}LSB\right)^3\right]$$

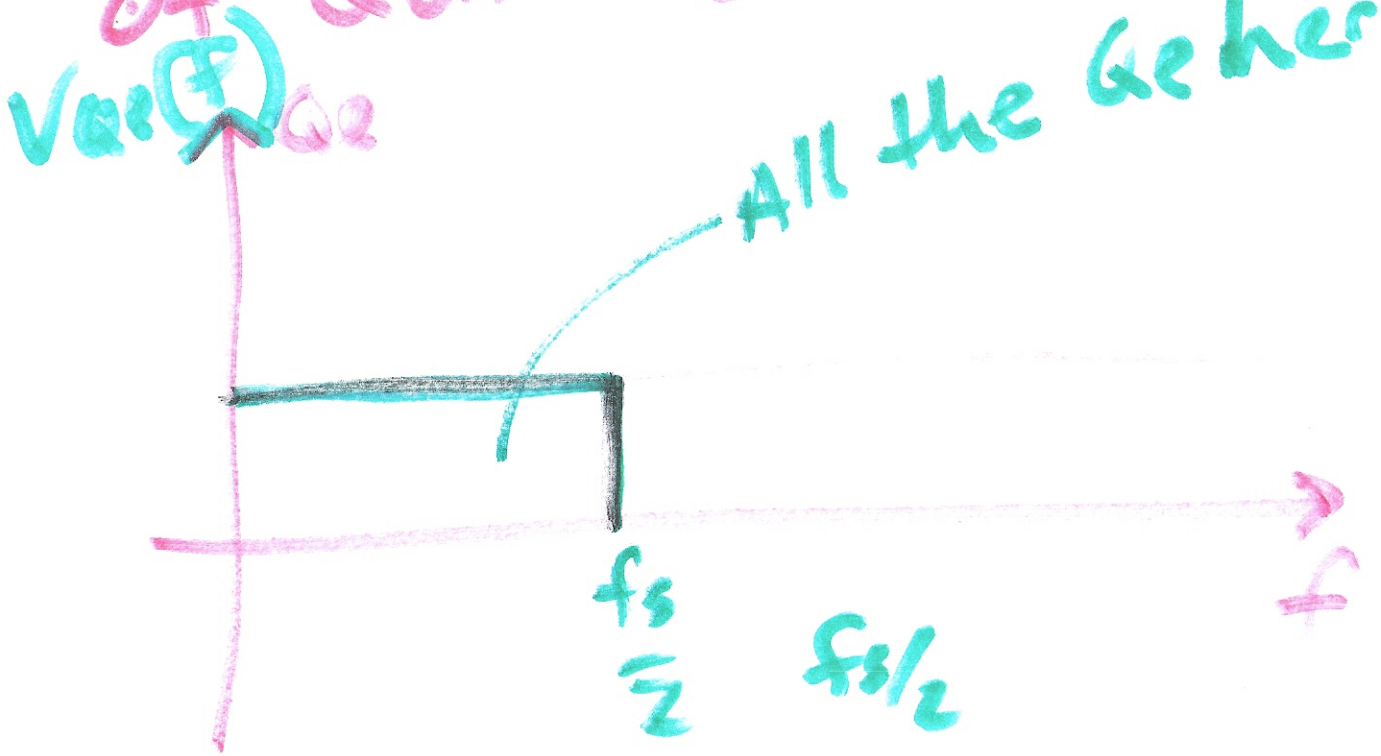
$$= \frac{1}{3\,LSB}\left(\frac{V_{LSB}^3}{8} + \frac{V_{LSB}^3}{8}\right)$$

$$= \frac{1}{3}\cdot\frac{2V_{LSB}^3}{8} = \frac{V_{LSB}^2}{12}$$

$$\boxed{V_{Qe,Rms} = \frac{V_{LSB}}{\sqrt{12}}}$$

7)

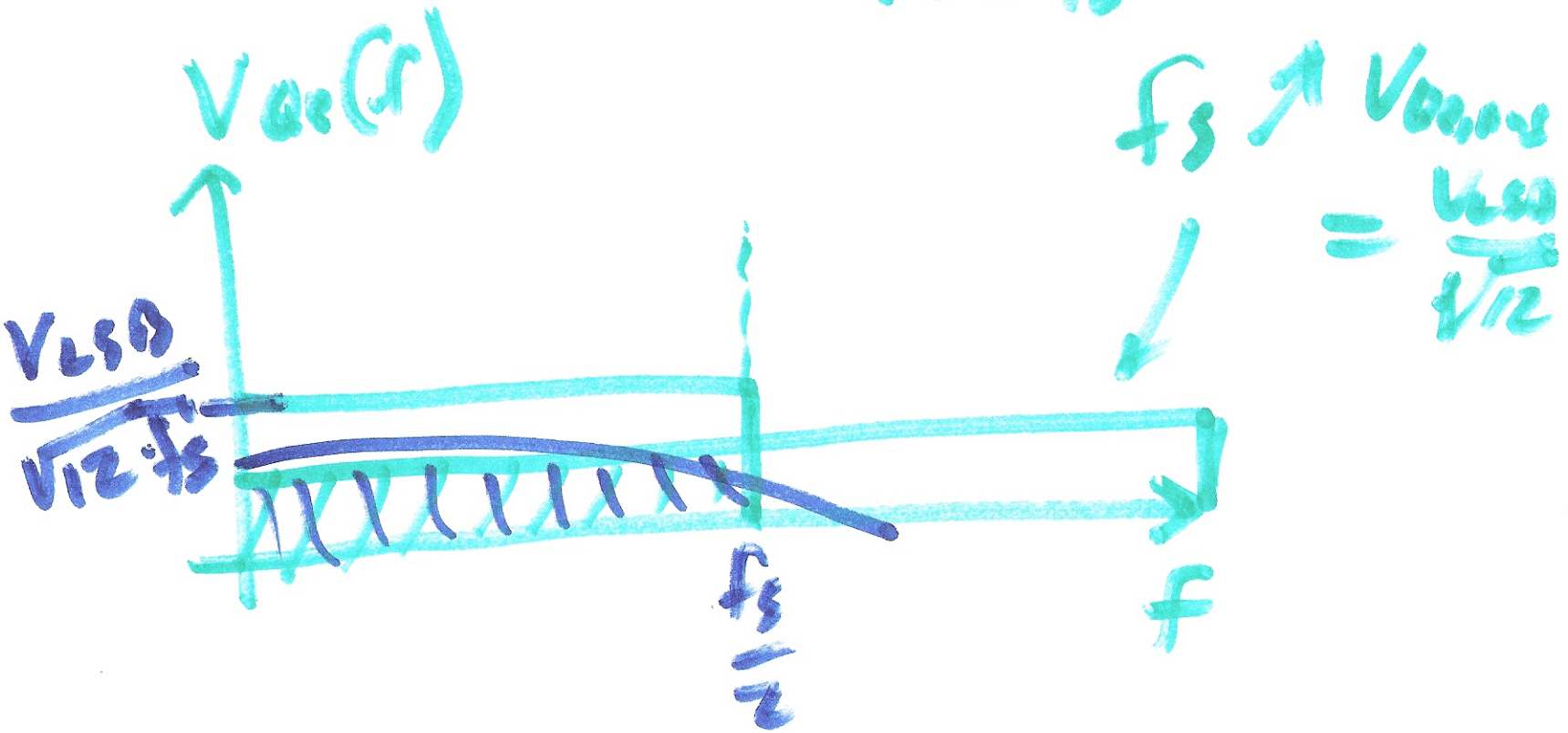
Spectral Characteristics of Quantization Noise



$$\frac{V_{LSB}^2}{12} = 2\int_0^{f_s/2} V_{qe}^2(f)\cdot df$$

8)

$$V_{Qe}(f) = \frac{V_{LSB}}{\sqrt{12 \cdot f_s}}$$



$-74\,dB \rightarrow .2\,mV$

$$Rms = \sqrt{32 \cdot (.2\,mV)^2} = 1.13\,mV$$

LTSpice

$-73dB = 224\,\mu V$

$$Rms = \sqrt{25 \cdot (224\,\mu)^2} = 1.12\,mV$$