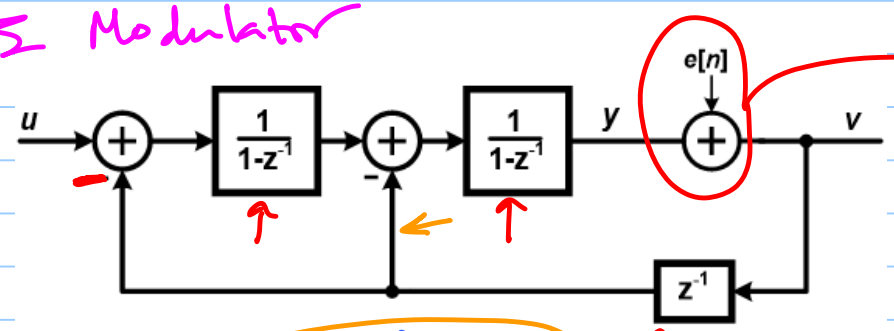
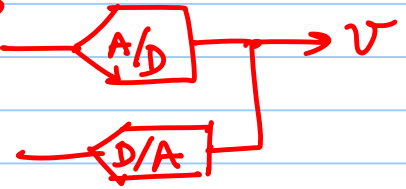
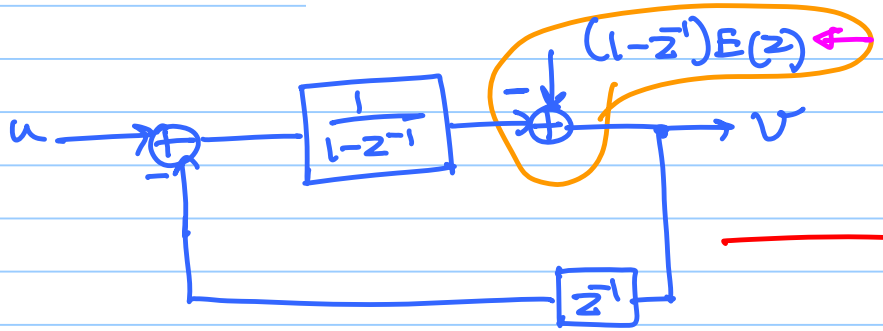
ECE 517 – Lecture 27

Note Title 4/25/2017

2nd order ΔΣ Modulator







$$NTF(z) = (1-z^{-1})^2$$

Second order noise shaping

↳ double differentiation of quantization error

$$V(z) = \underbrace{z^{-1}}_{STF(z)} U(z) + \underbrace{(1-z^{-1})^2}_{NTF(z)} E(z)$$

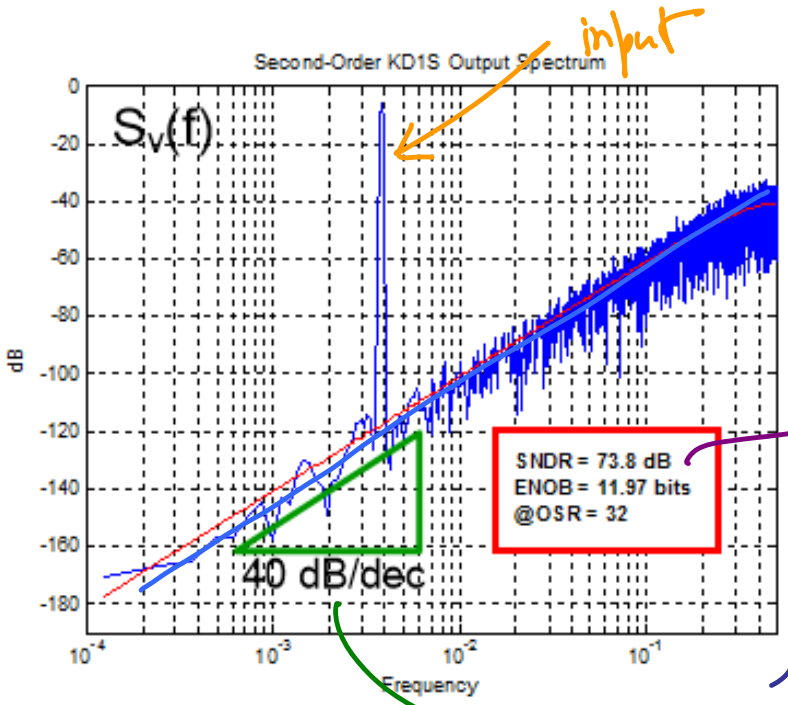
In band noise $\Rightarrow$ $\underbrace{\frac{\Delta^2}{12} \cdot \frac{\pi^4}{5} \cdot OSR^{-5}}$

Extra SQNR of $50 \log_{10}(OSR)$

↳ 2-5 bits per doubling in OSR

↳ 1.5 bit for 1st order

0.5bit for oversampling



input

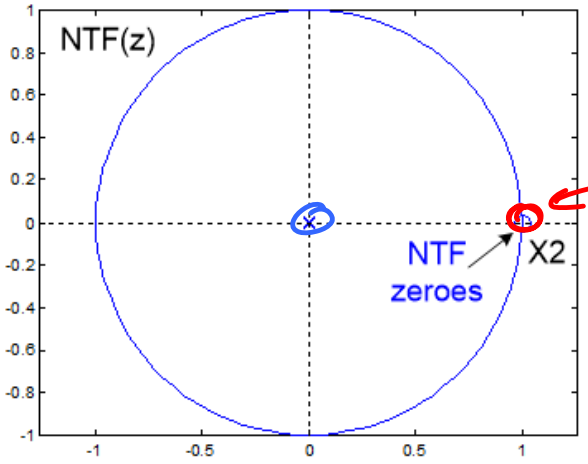
dB

LNTA

SQNR = 74 dB
↳ 12 bits ENOB
@ OSR = 32

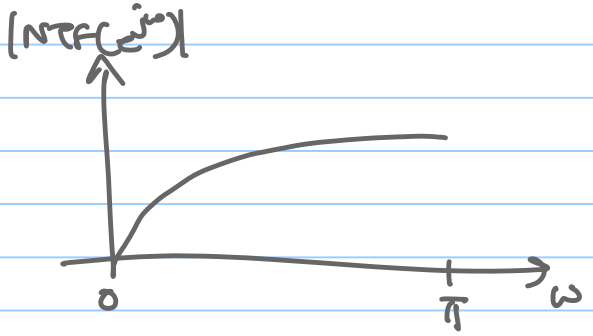
log(f)

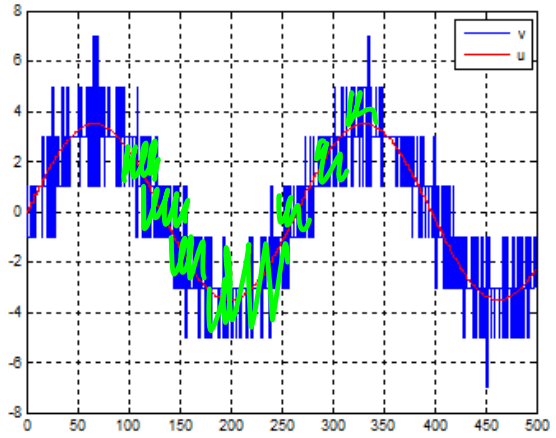
40 dB/dec slope for 2nd order noise shaping



at DC

$$NTF(z) = (1-z^{-1})^2$$

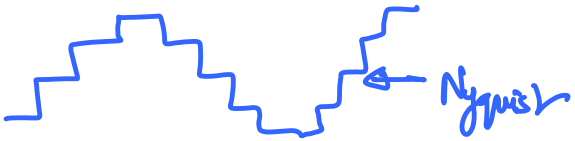




$$NTF(z) = (1-z^{-1})^2$$

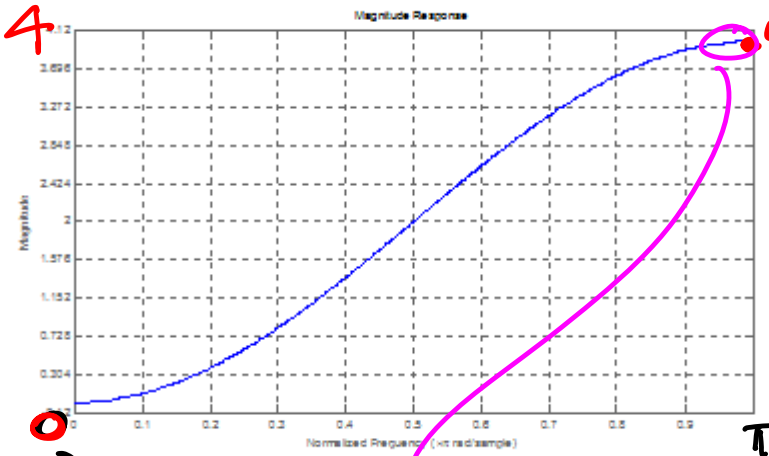
$$|NTF(e^{j\omega})| = \left(2\sin\left(\frac{\omega}{2}\right)\right)^2$$

$$= 4\sin^2(\omega/2)$$



$|NTF(e^{j\omega})|$

4

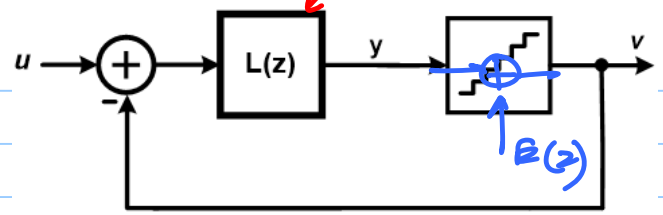


NTF gain at π is 4

0

π ω

Out of band gain (OBG)

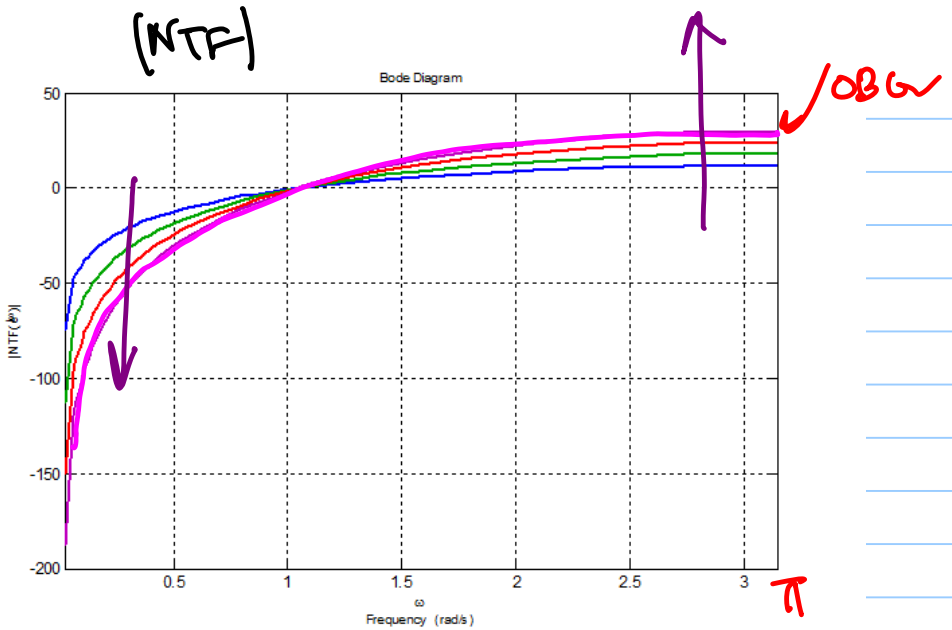


$$V(z) = \underbrace{\frac{L(z)}{1+L(z)}}_{\text{STF}} U(z) + \underbrace{\frac{1}{1+L(z)}}_{\text{NTF}} E(z)$$

$$\Rightarrow \underbrace{NTF(z)}_{\text{Synthesize an NTF to meet desired ADC specifications.}} = \frac{1}{1+L(z)}$$

$$(U(z) - V(z))L(z) + E(z) = V(z)$$

$$\Rightarrow V(z) = \underbrace{\frac{L}{1+L}}_{\text{STF}} U(z) + \underbrace{\frac{1}{1+L}}_{\text{NTF}} E(z)$$



lower in band noise ↓

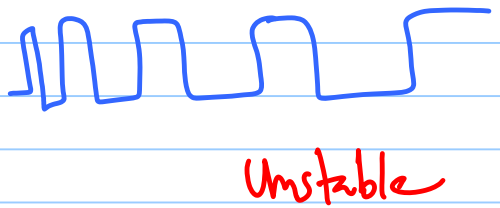
⇒ OBG ↑

↑ OBG ↑ ⇒ more 'wiggly' in the quantization noise

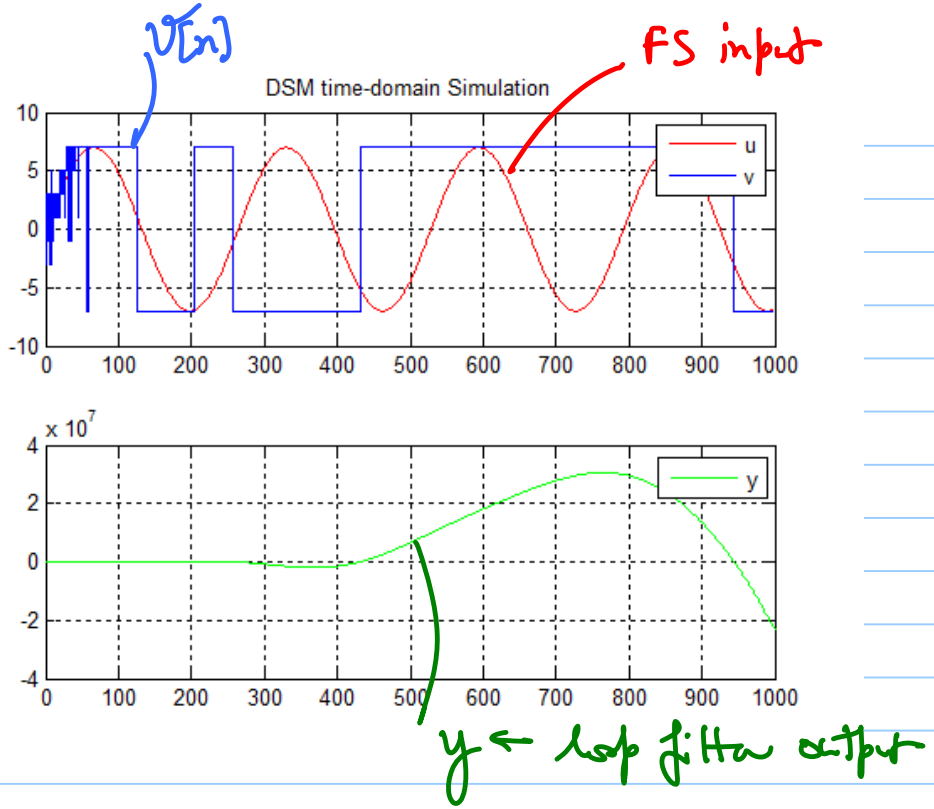
Third-order modulator

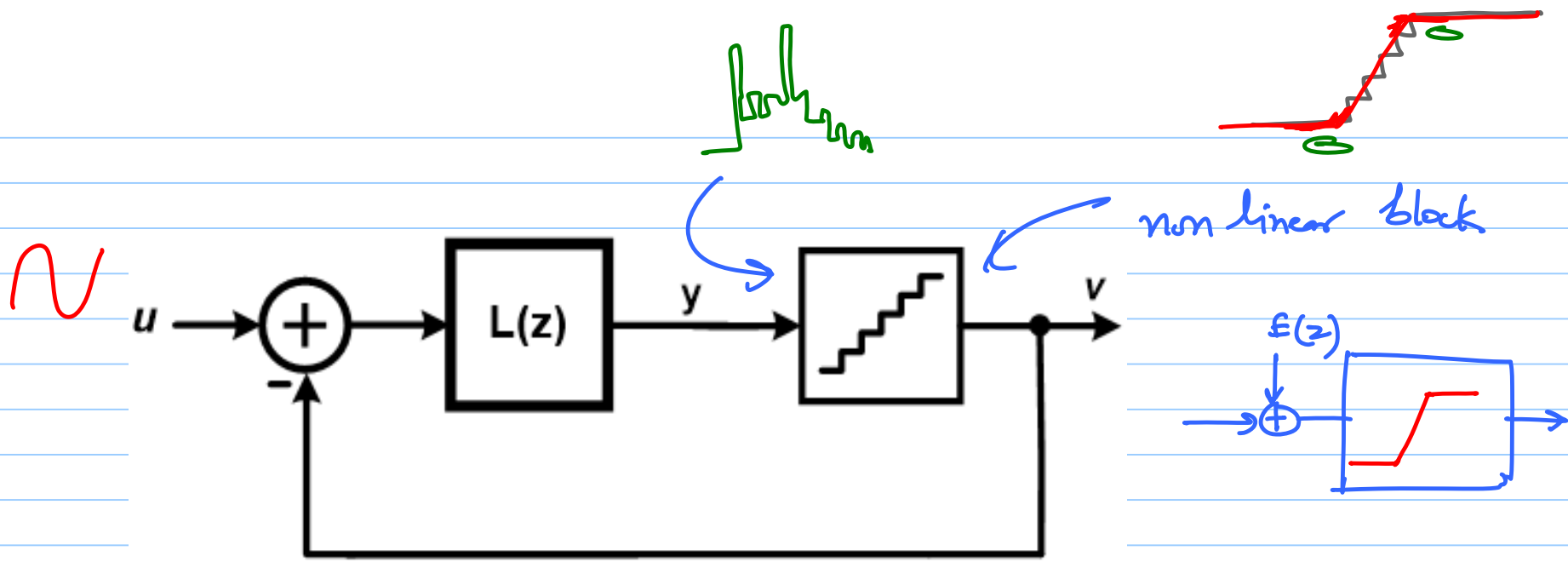
$NTF(z) = (1-z^{-1})^3$

↳ OBG = 8



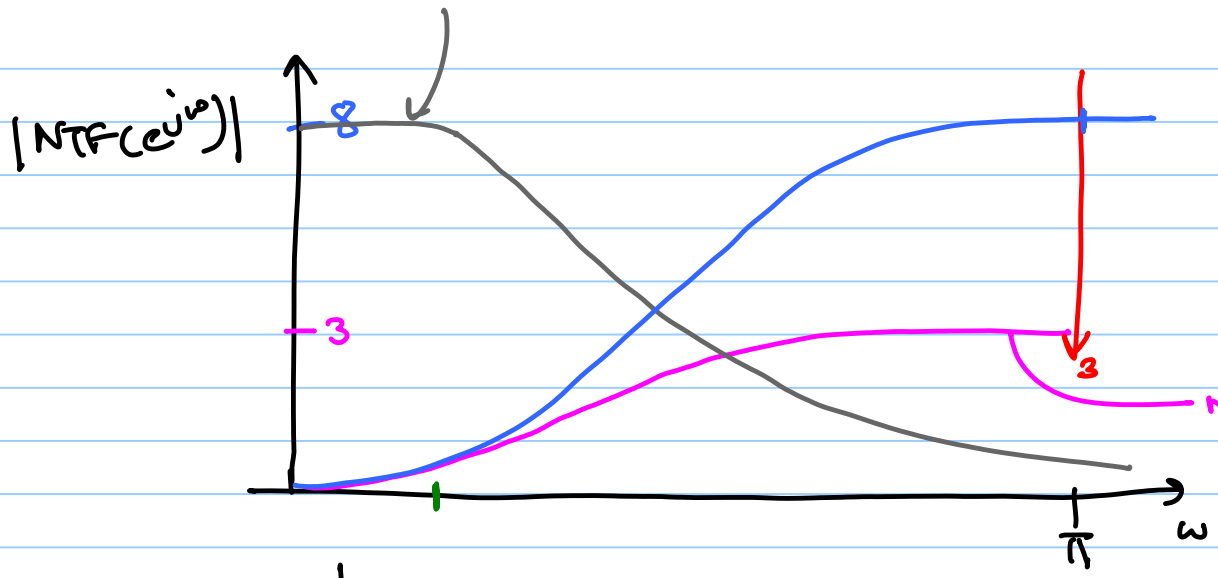
Unstable





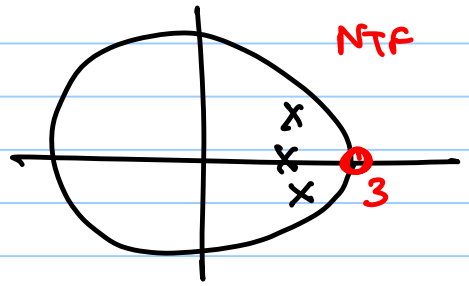
* OBG ⇒ has a bearing on the modulator stability

$NTF(z) = (1-z^{-1})^3$



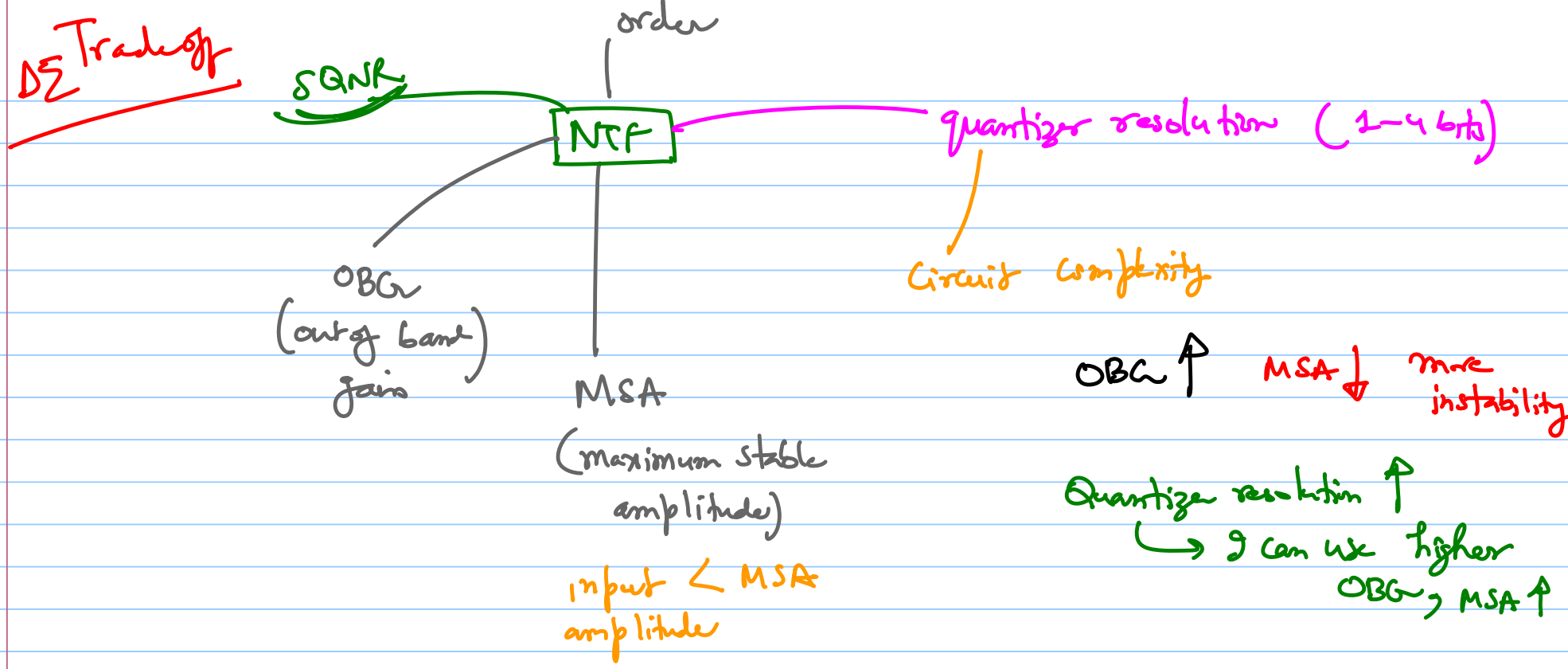
↳ OBG = 3

NTF with OBG = 3



* introduced poles to reduce OBG

$$NTF(z) = \frac{(1-z^{-1})^3}{D(z)}$$


DE Tradeoff
SQNR
order
NTF
quantizer resolution (1–4 bits)
OBG
(out of band gain)
MSA
(maximum stable amplitude)
Circuit complexity
OBG ↑ MSA ↓ more instability
Quantizer resolution ↑
→ I can use higher OBG, MSA ↑
input < MSA amplitude