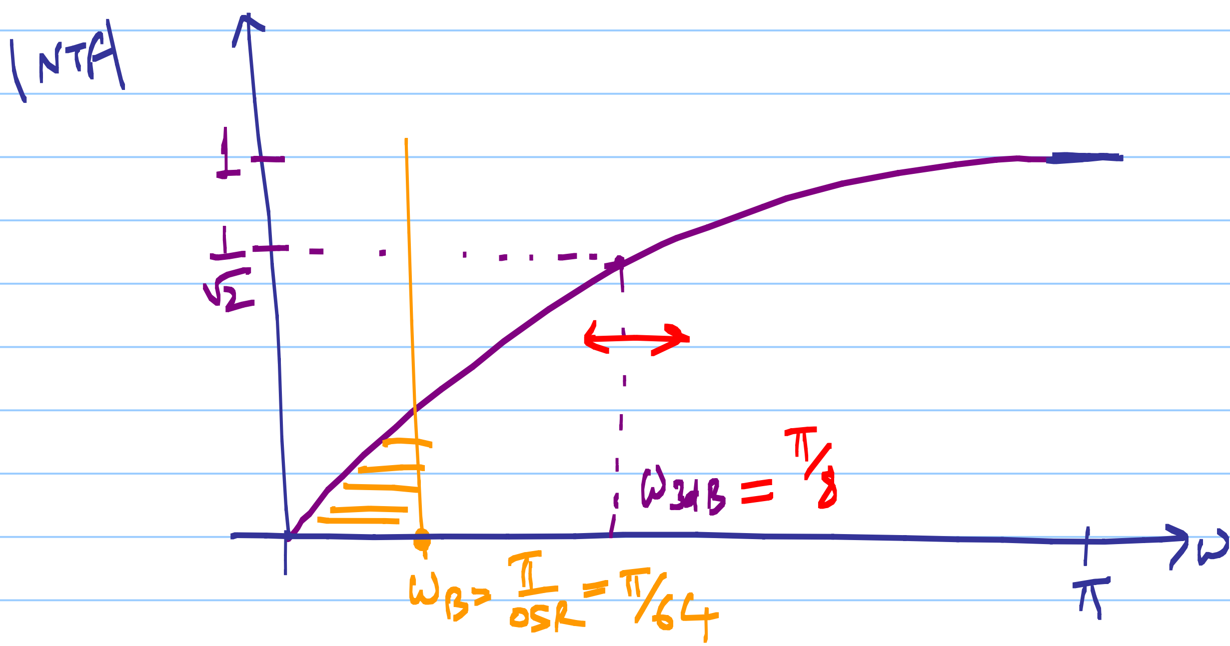
ECE 615 – Lecture 11

Start with:

order (L) = 3, OSR = 64, $n = 16$ (# of levels in quantizer), SQNR ≥ 115 dB

Butterworth high-pass NTF ω_{3dB}



Initial guess

$\omega_{3dB} = \frac{\pi}{8}$ (slightly larger than the $\omega_B = \frac{\pi}{64}$)

MATLAB sets $|H(e^{j\pi})| = 1$ "SystematicNTFDesign.m"

① get $H(z)$ from MATLAB

[b, a] = butter(3, 1/8, 'high')

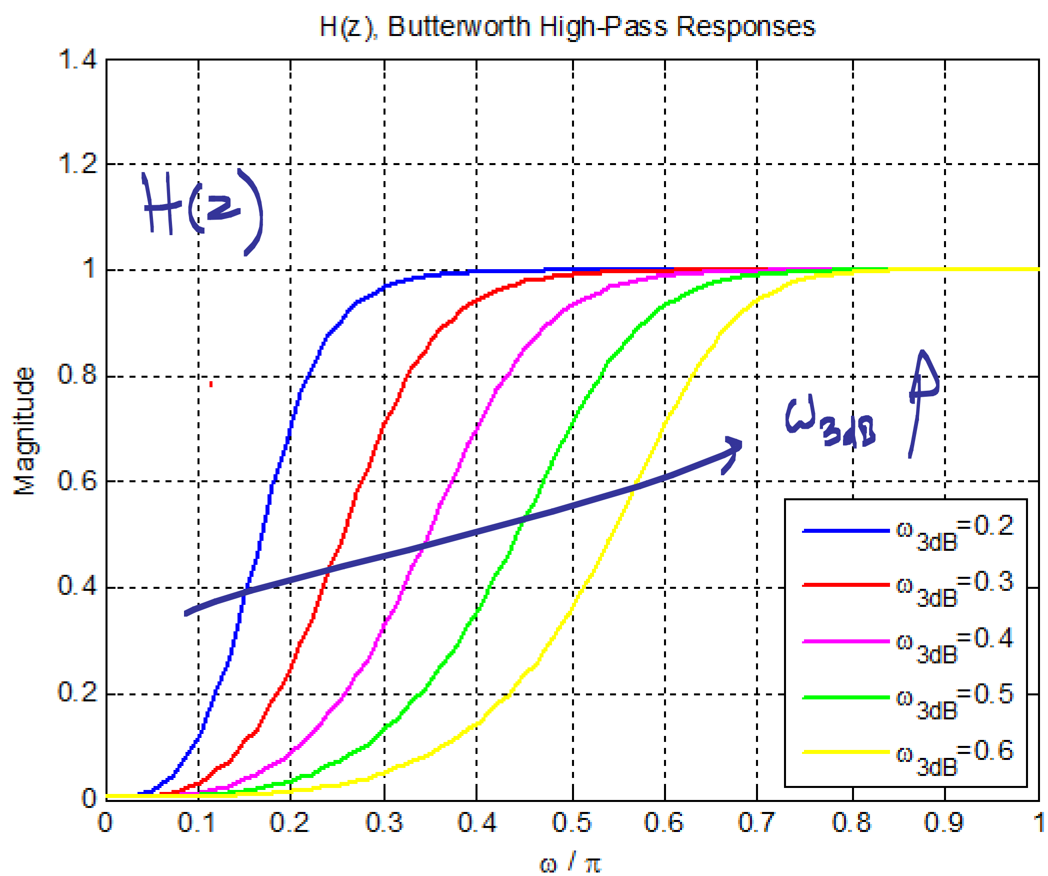
Butterworth HPF polynomial ⇒ $H(z) = \frac{0.6735 - 2.02 z^{-1} + 2.02 z^{-2} - 0.673 z^{-3}}{1 - 2.219 z^{-1} + 1.715 z^{-2} - 0.454 z^{-3}}$ (b_0 = 0.6735)

NTF(z) = H(z) ?? Not directly

Realizability Condition: $NTF(z=\infty) = 1 \Rightarrow z^{-1} = 0$

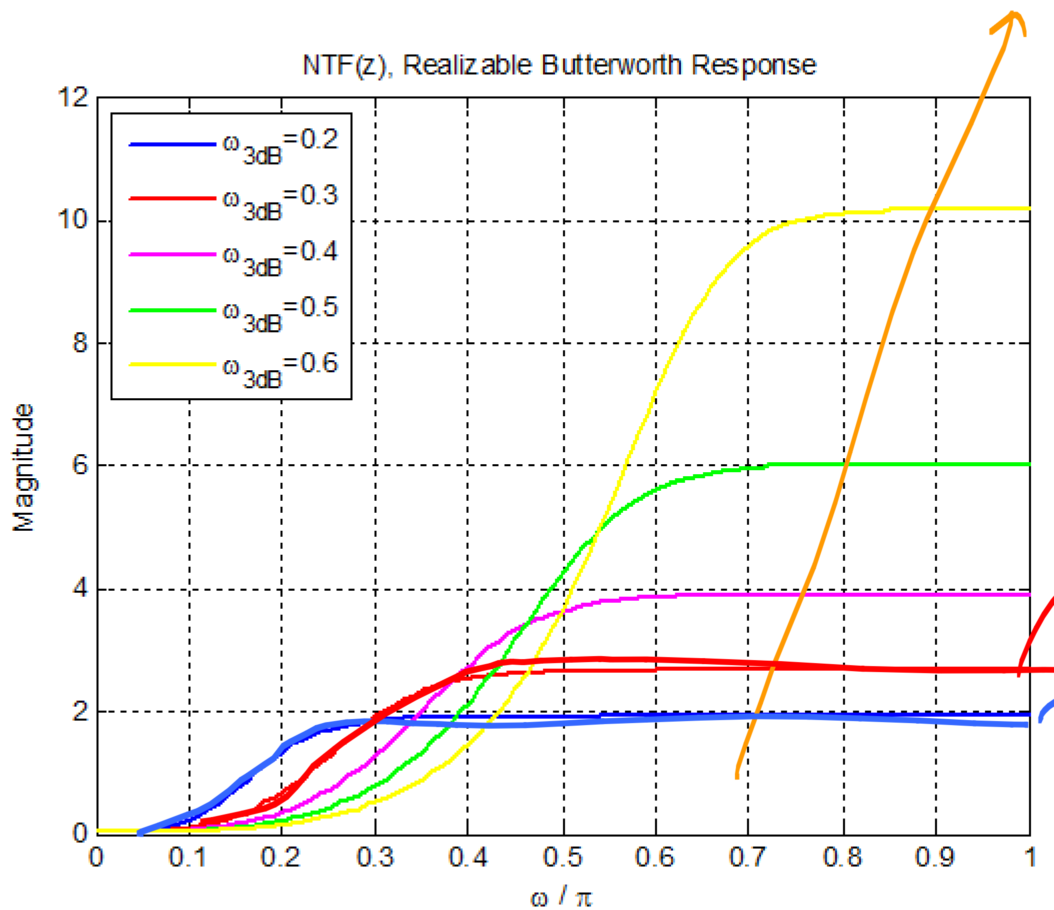
$$H(z^{-1}=0) = \underline{0.6735} = b_0$$

$$NTF(z) = \frac{H(z)}{b_0}$$



H(z), Butterworth High-Pass Responses
Magnitude
ω / π
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0.1
0.3
0.5
0.7
0.9
ω_{3dB}=0.2
ω_{3dB}=0.3
ω_{3dB}=0.4
ω_{3dB}=0.5
ω_{3dB}=0.6
H(z)
ω_{3dB}

$NTF(z) = \frac{H(z)}{b_0}$



$\omega_{3dB} \uparrow$

SQNR = 130 dB
MSA = 0.6 FS
OBG = 2.7

SQNR = 100 dB
$\omega_{3dB} \uparrow$
OBG = 2

for initial $\omega_{3dB} = \frac{\pi}{8}$ $\Rightarrow$ $NTF(z) = \frac{H(z)}{b_0}$

② Find the loop filter $NTF(z) = \frac{1}{1+L(z)}$

transfer function $L(z)$

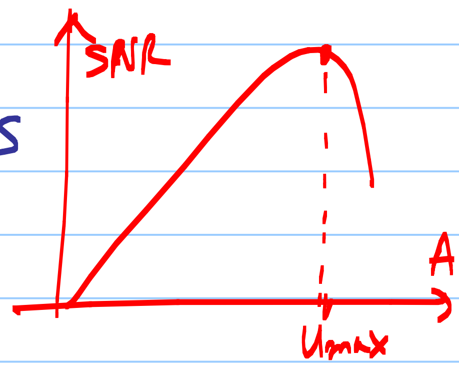
③ Behavioral simulation using $L(z)$ as loop filter

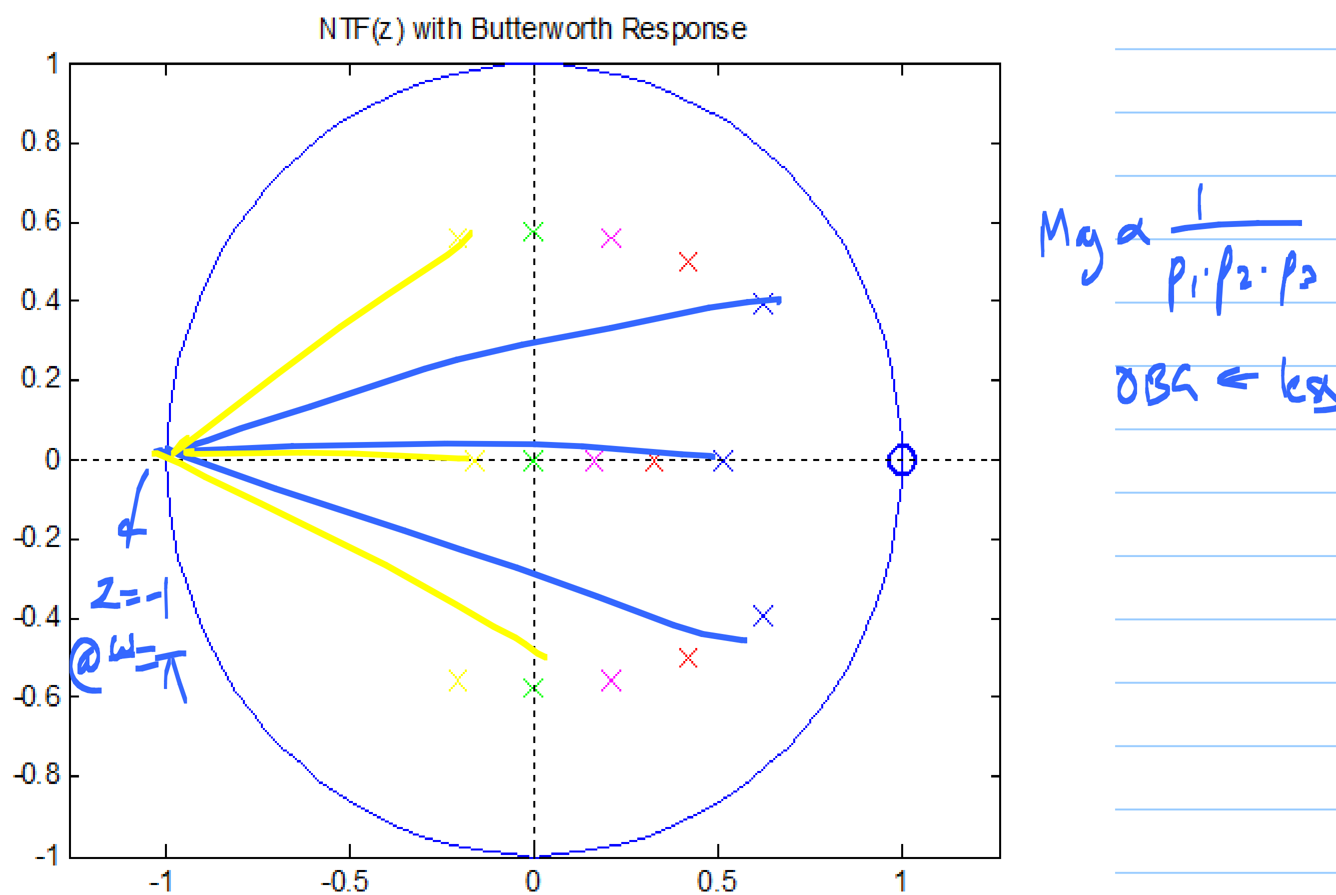
Sine input : $\omega_{in} \leq \omega_{3dB}$

Amplitudes $0 \leq A \leq FS$

Compute peak SQNR

→ MSA

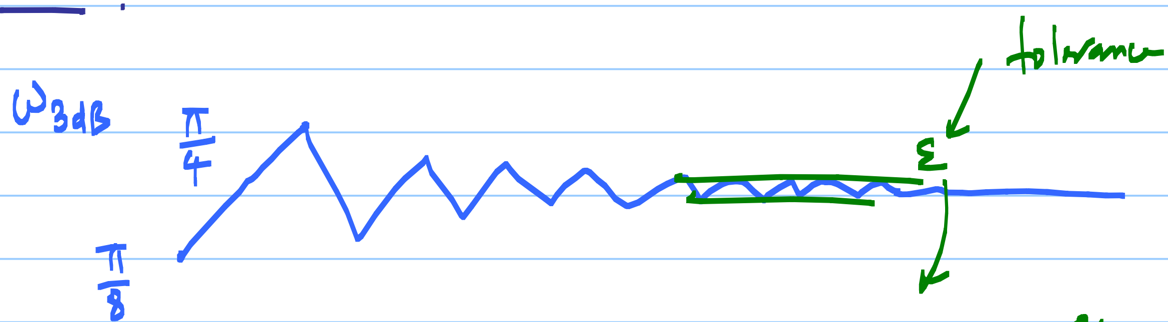




NTF(z) with Butterworth Response
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1
-0.5
0
0.5
1
z=-1
@ω=π
Mag ∝ 1/p₁·p₂·p₃

$\omega_{3dB} \leftarrow$ find

Convergence

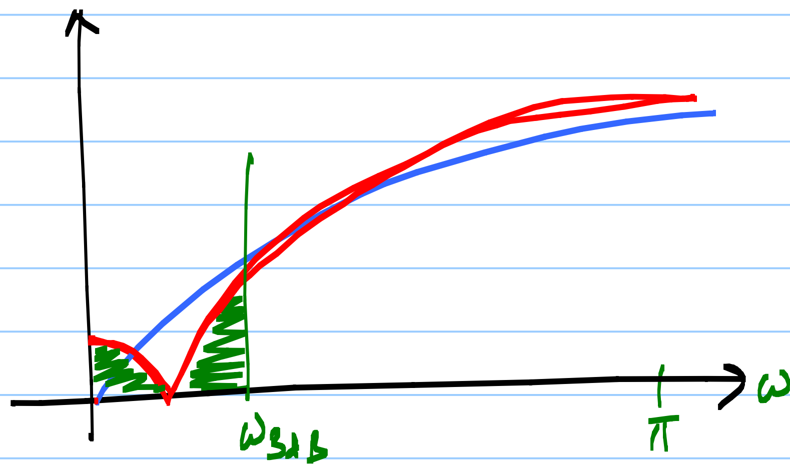


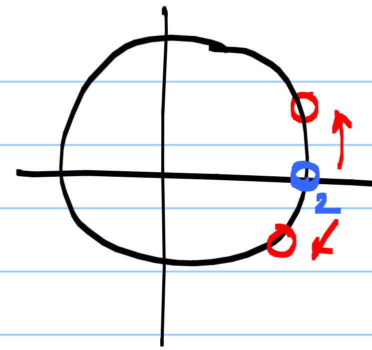
$\epsilon = 0.1\%$

while ($\epsilon > 0.1\%$) do {

}

NTF zero - optimization





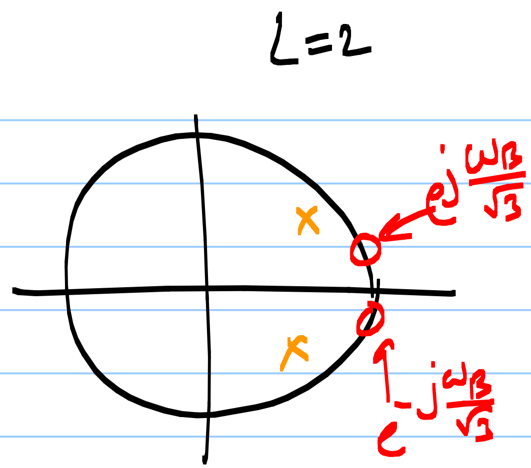
opt = 1 ⇒ NTF has optimized values for complex NTF zeros.

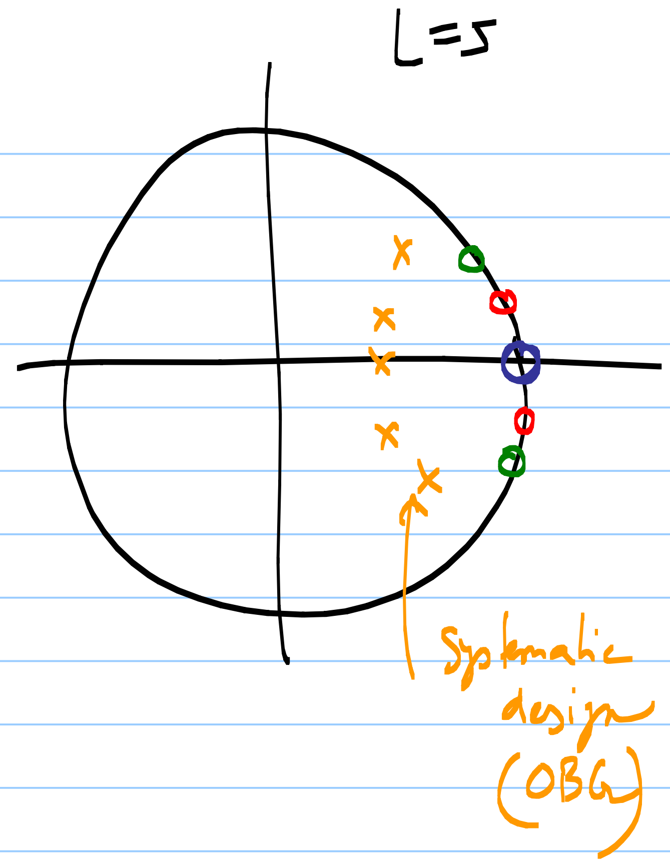
$$\text{IBN}(\alpha) \Rightarrow \frac{\partial I(\alpha)}{\partial \alpha} = 0$$

$z_i = e^{j\alpha_i}$

L	NTF zero locations normalized to ω_B (α)	SQNR increase wrt all NTF zeros at DC
1	0	0 dB
2	$\pm \frac{1}{\sqrt{3}}$	3.5 dB
3	$0, \pm\sqrt{\frac{3}{5}}$	8 dB
4	$\pm\sqrt{\frac{3}{7} \pm \sqrt{\left(\frac{3}{7}\right)^2 - \frac{3}{35}}}$	13 dB
5	$0, \pm\sqrt{\frac{5}{9} \pm \sqrt{\left(\frac{5}{9}\right)^2 - \frac{5}{21}}}$	18 dB

ds_optzero(order, 1)


L=2
e^{j ωB/√3}
e^{-j ωB/√3}

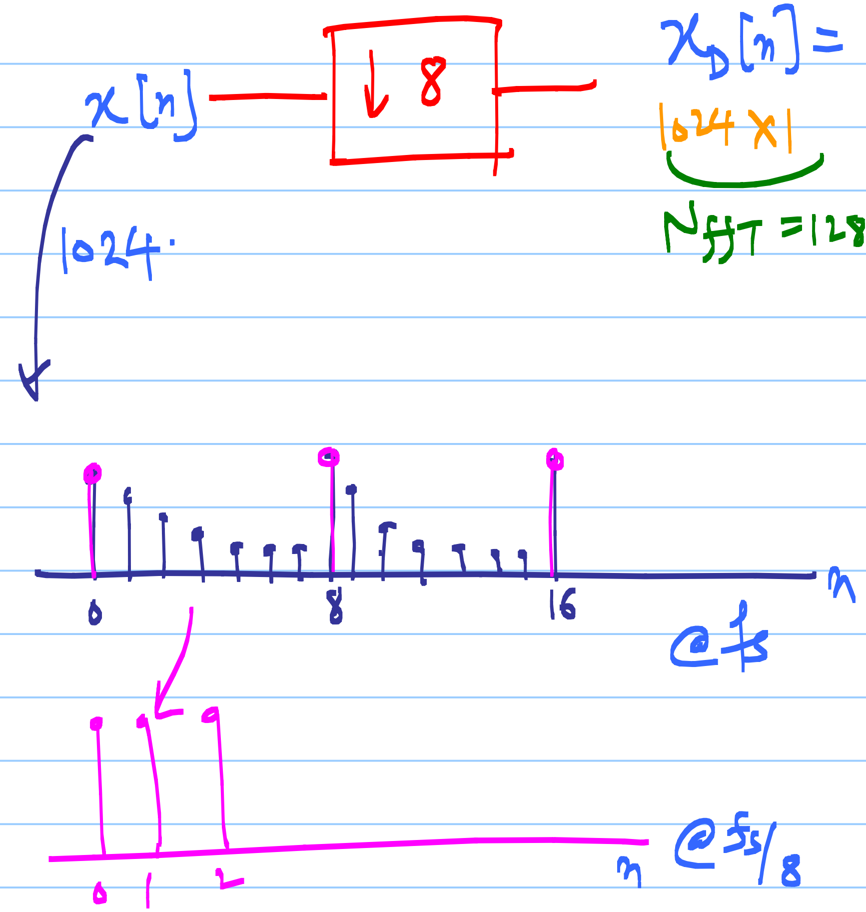

L=5
Systematic
design
(OBG)

In MATLAB

$x_D[n] = x[1:8:N]$

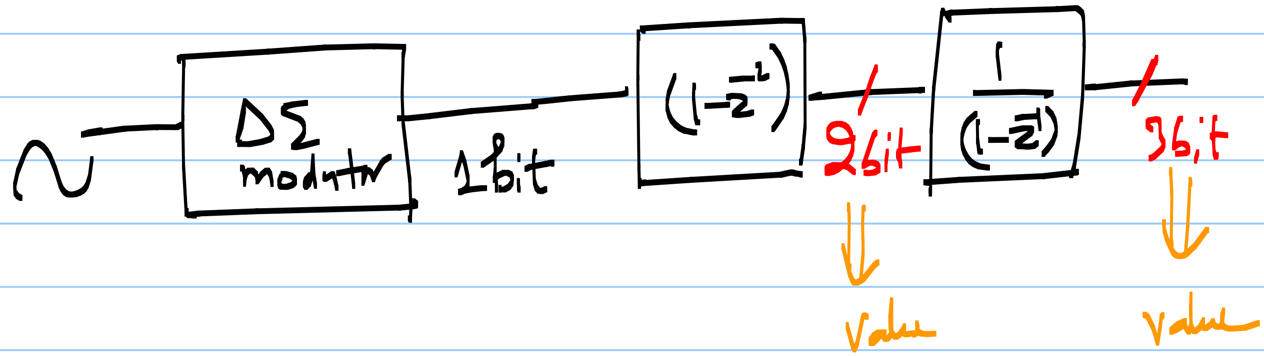
1024×1 $\quad$ 128×1

$N_{fft} = 128$ $\quad$ $N_{fft} = 128$



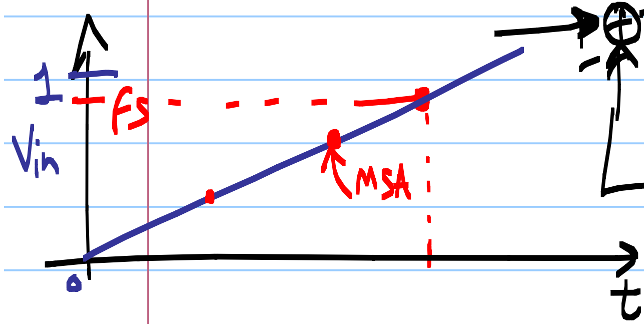
Sinc

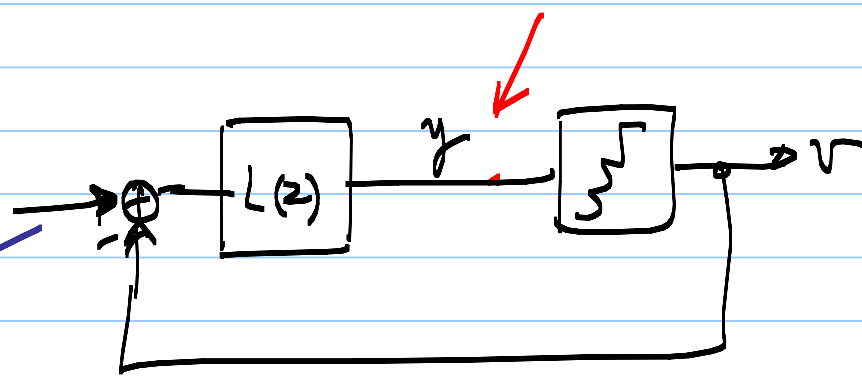
CIC



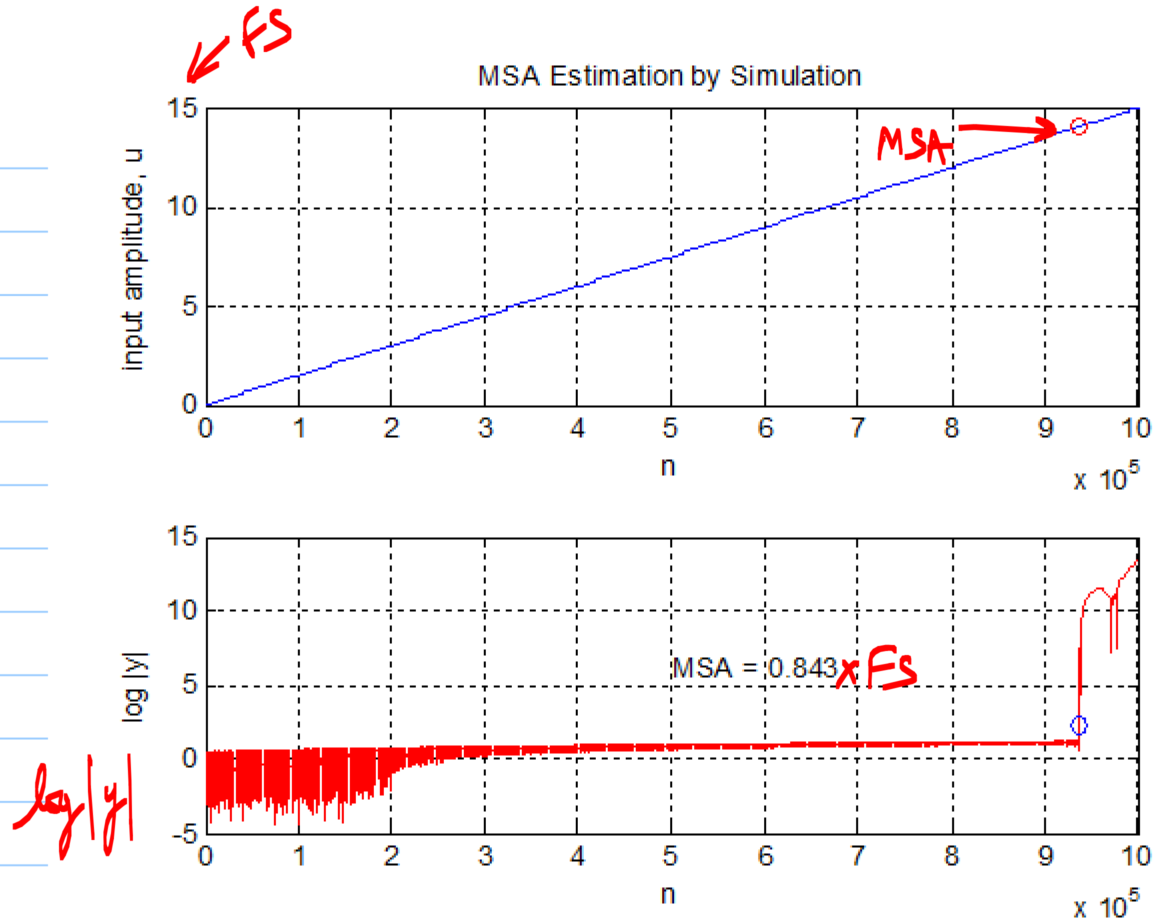
Estimating MSA ← Risbo Method

Slow ramp





observe y



File: MSA_Risbo_Method.m