ECE 615 - Lecture 15

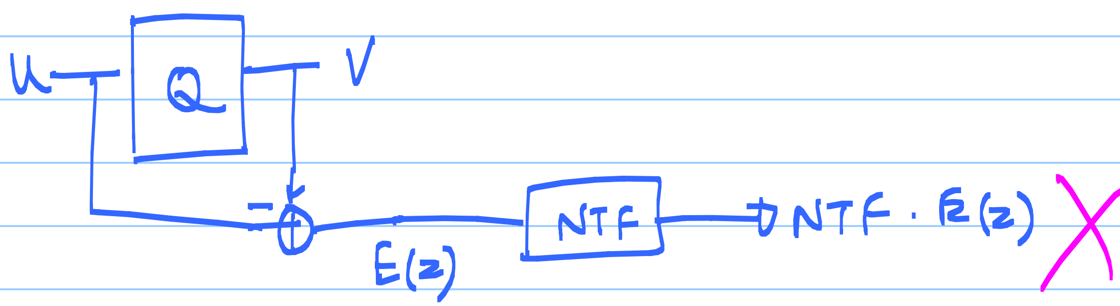
Note Title

10/24/2013

L-0 Cascade

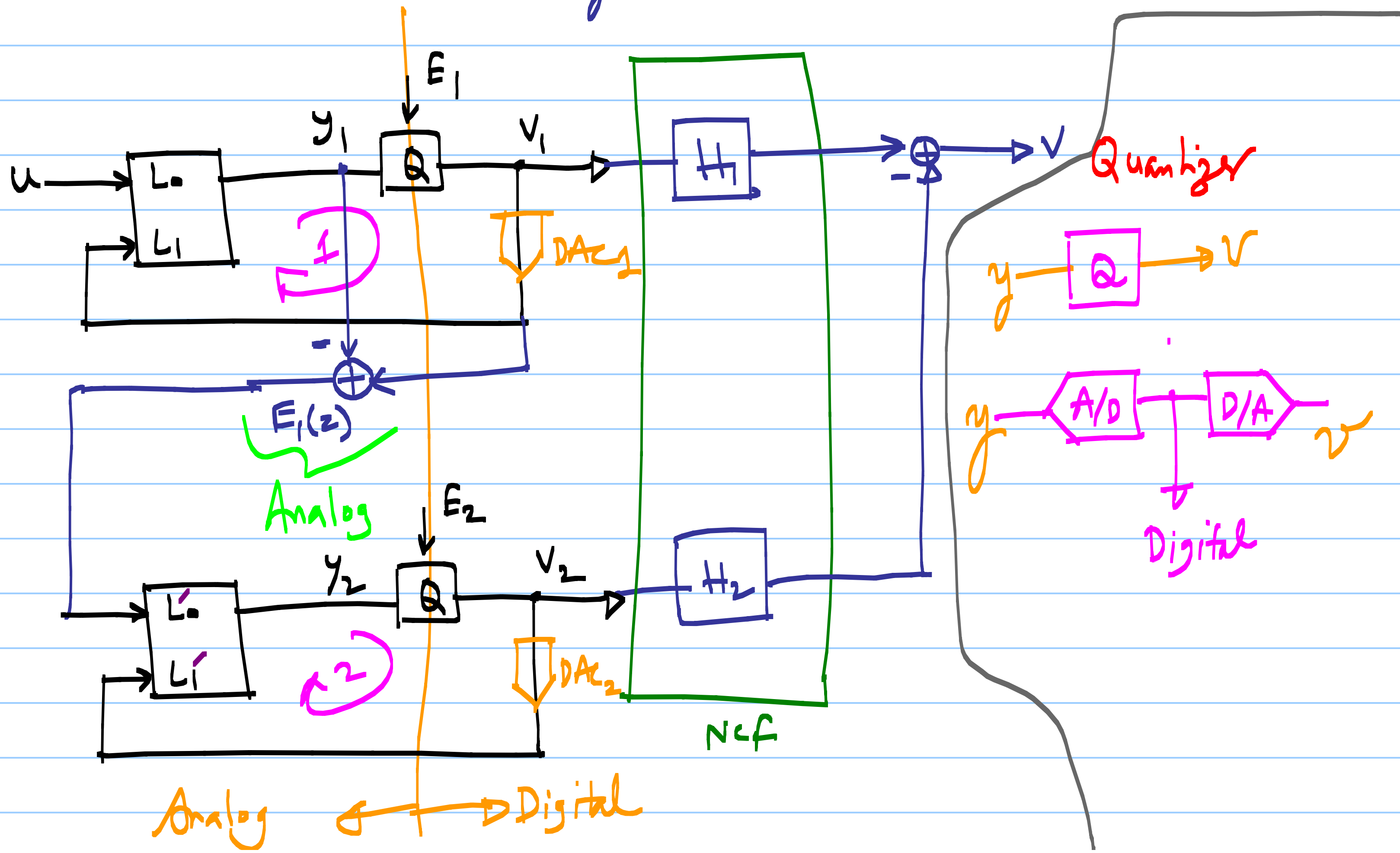
$$V(z) = STF_1 \cdot U + \overbrace{NTF_1}^{\text{digital filter}} \cdot E_2$$

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



Multi Stage Noise Shaping (MASH)

* All the stages are a $\Delta\Sigma$ modulator



1^{st} stage : $V_1(z) = STF_1 \cdot U + NTF_1 \cdot E_1$

$$V_2(z) = STF_2 \cdot E_1 + NTF_2 \cdot E_2$$

final output :

Cancel out

$E_1 \leftarrow$ Coarse Q-Noise

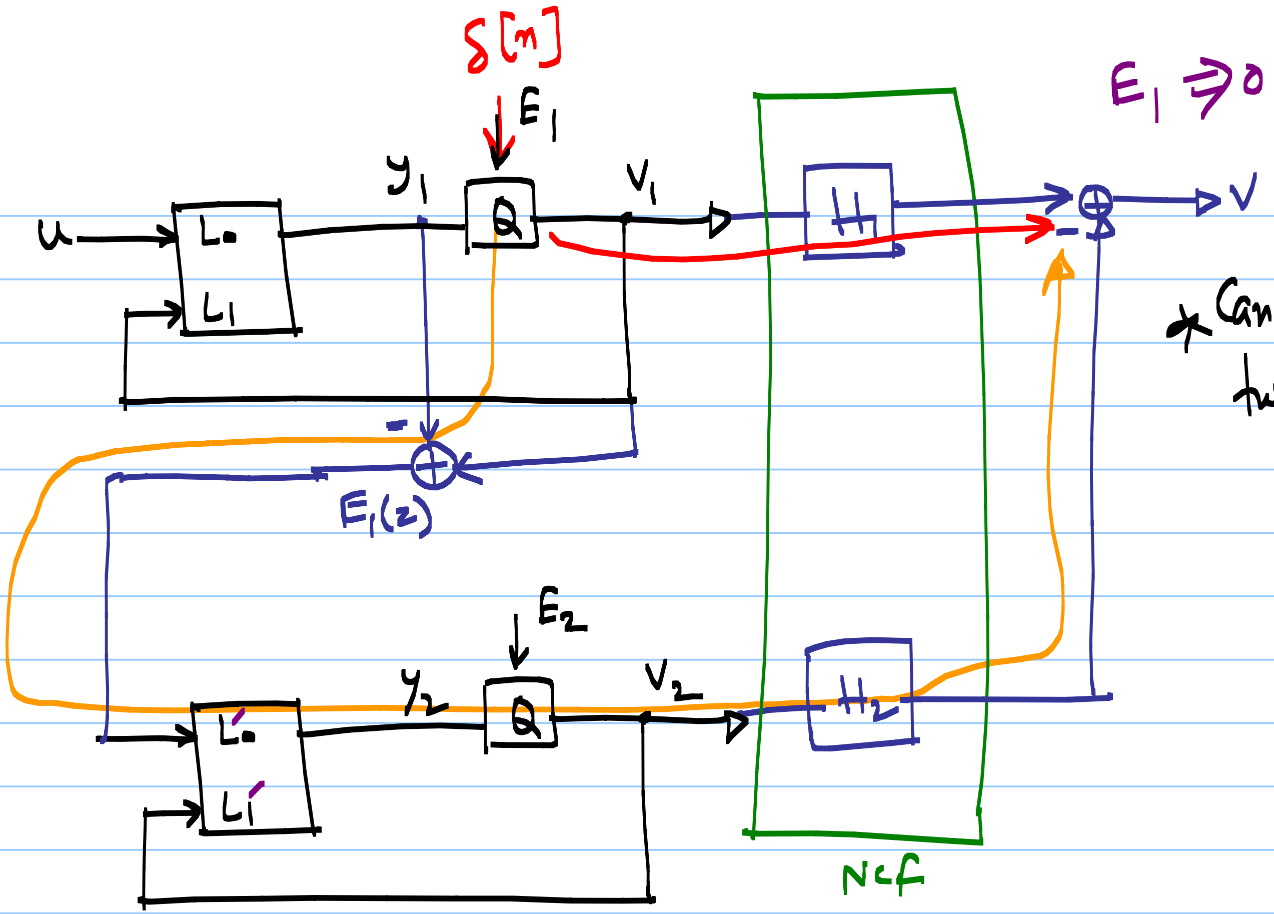
$E_2 \leftarrow$ fine Q-noise

$$V(z) = \overset{\text{Dig}}{H_1} \cdot V_1 - \overset{\text{Dig}}{H_2} \cdot V_2$$

$$= H_1 (STF_1 \cdot U + NTF_1 \cdot E_1) - H_2 (STF_2 \cdot E_1 + NTF_2 \cdot E_2)$$

$$= (H_1 \cdot STF_1 \cdot U - H_2 \cdot NTF_2 \cdot E_2) + \underbrace{H_1 \cdot NTF_1 \cdot E_1 - H_2 \cdot STF_2 \cdot E_1}_{=0}$$

$$\boxed{H_1 \cdot NTF_1 = H_2 \cdot STF_2}$$



* Cancel out the two paths

The simplest choice for H_1 & H_2

$$H_1 \cdot NTF_1 = H_2 \cdot STF_2$$

easy to realize

$$\rightarrow H_1 = STF_{2,d}$$

$$\leftarrow H_2 = NTF_{1,d}$$

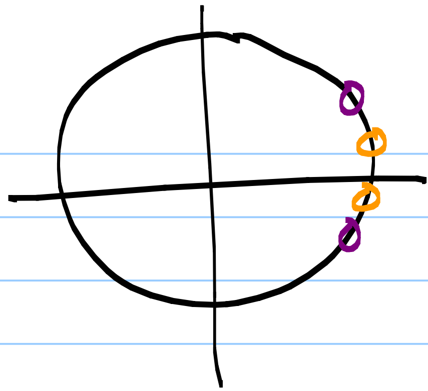
digital filters

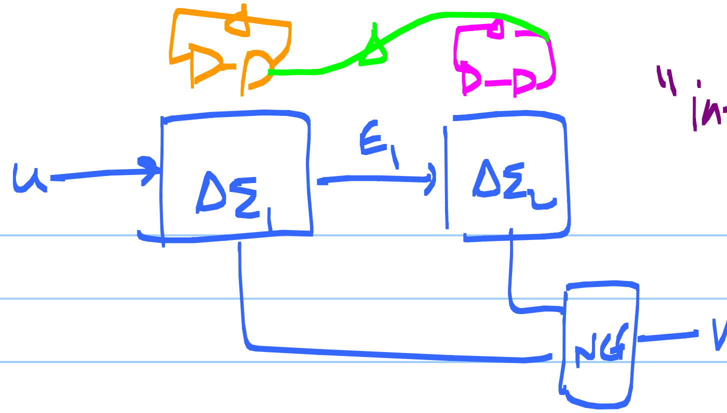
$$STF_2(z) = z^{-k} \text{ or } \underline{\underline{1}}$$

overall output:

$$V = H_1 \cdot V_1 - H_2 \cdot V_2 = \underbrace{STF_1 \cdot STF_2}\cdot U - \boxed{NTF_1 \cdot NTF_2} \cdot E_2$$

$$NTF = NTF_1 \cdot NTF_2$$





"interstage resonation"

$$NTF = \prod_i NTF_i$$

$$STF = \prod_i STF_i$$

Ex:

2-2 MASH (SOSO)

2-1
2-2
2-2-1
2-1-1

$\cancel{1\text{-}1}$ or $\cancel{1\text{-}2}$

tonal Q-noise
"lots of spurs in the spectrum"

$STF_1 = STF_2 = z^{-2}$

$NTF_1 = NTF_2 = (1-z^{-1})^2$

$V(z) = z^{-4}U(z) - (1-z^{-1})^4 \cdot E_2(z)$

* 4^{th}-order noise shaping
Stability is governed by 2^{nd}-order
* loop

* E_1 input to the second modulator needs to be scaled to fit it within the stable range (MSA)

Ex. for 2nd-order single-bit first-stage ΔΣ output

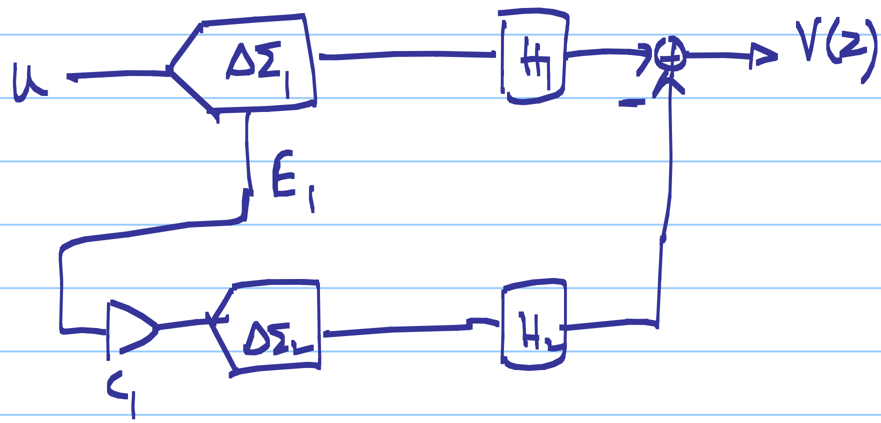
$\Rightarrow \quad c_{12} = 1/4$

↳ If multibit quantization is used in the first stage, c_{12} can be greater than 1

If $V_{LSB_1} < MSA_2 \Rightarrow c_{12} > 1$

$\Rightarrow$ $c_{12} \Rightarrow$ changes in the NCF logic

Coupling of stages:



$H_1 = STF_{2,d}$

$H_2 = \frac{1}{c_1} \cdot NTF_{1,d}$

$$V(z) = STF_1 \cdot STF_{2,d} \cdot U(z) + \frac{1}{c_1} \cdot NTF_{1,d} \cdot NTF_2 \cdot E_2(z)$$

$$NTF_{cascade} = \frac{(1-z^{-1})^{N_{cascade}}}{\prod_{i}^{M} c_i}, \quad N_{cascade} = \sum_{i=1}^{M} N_i$$

$M \Rightarrow$ stages

$$IBN = \frac{IBN_0}{\prod_i c_i^2}$$

if $c_i < 1$

$\Rightarrow IBN > IBN_0$

for $\prod_i c_i^2 < 1 \Rightarrow$ MASH performance is below ideal

* Noise leakage $\quad H_1 \cdot NTF_1 \neq H_2 \cdot NTF_2$

E_1 leaks into $V(z)$

* Use low-distortion topology in the first-stage.

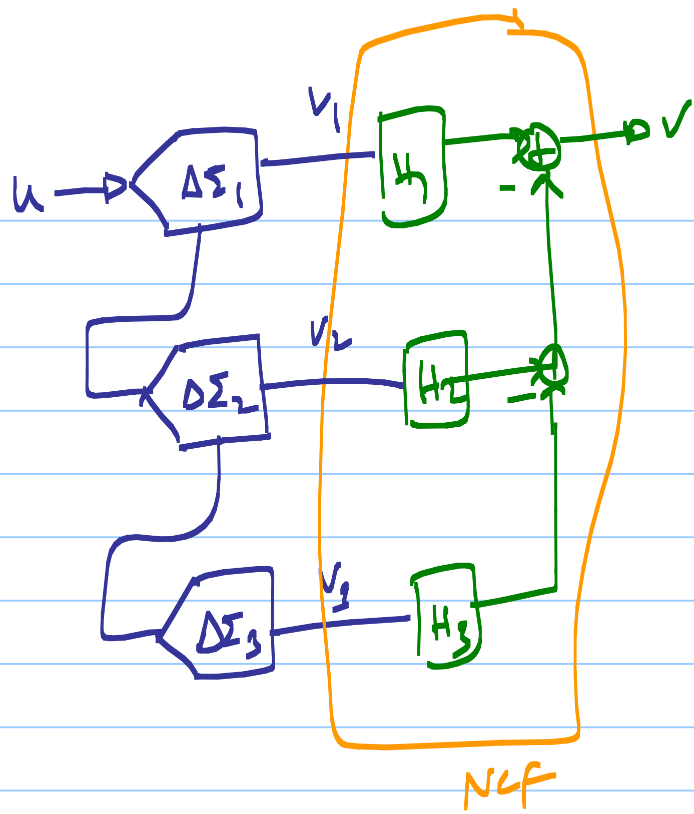
* In a MASH

$$E_2 = Q(E_1)$$

more noise-like

$\Rightarrow$ less correlated with $U(z)$

↳ requires lower dithering



2-1-1

2-2-1

2-2-2 ⇒ 6th-order NTF

* Single-loop ΔΣ modulator, issues with S/C implementation:

↳ imperfect matching of capacitors ⇒ changes $NTF(z)$ ← $I(z)$

↳ A_v: finite of opamps

$$I(z) = \frac{z^{-1}}{1-z^{-1}} \Rightarrow A_v = \infty$$

$A_v \Leftarrow$ finite

$$\frac{z^{-1}}{1-az^{-1}}$$

↳ incomplete settling and slewing of opamps

* All these change NTF & STF of the modulator

$|NTF| \simeq \frac{1}{|L_1|} \ll 1$; for single-loop $\Delta\Sigma$ not a big issue

as long as $\boxed{A_v \geq \frac{OSR}{\pi}}$

"Use SIMSIDES to simulate this"

"Look at the notes for analysis for MASH ADC"