ECE 615 → Lecture 14

Note Title 10/22/2013

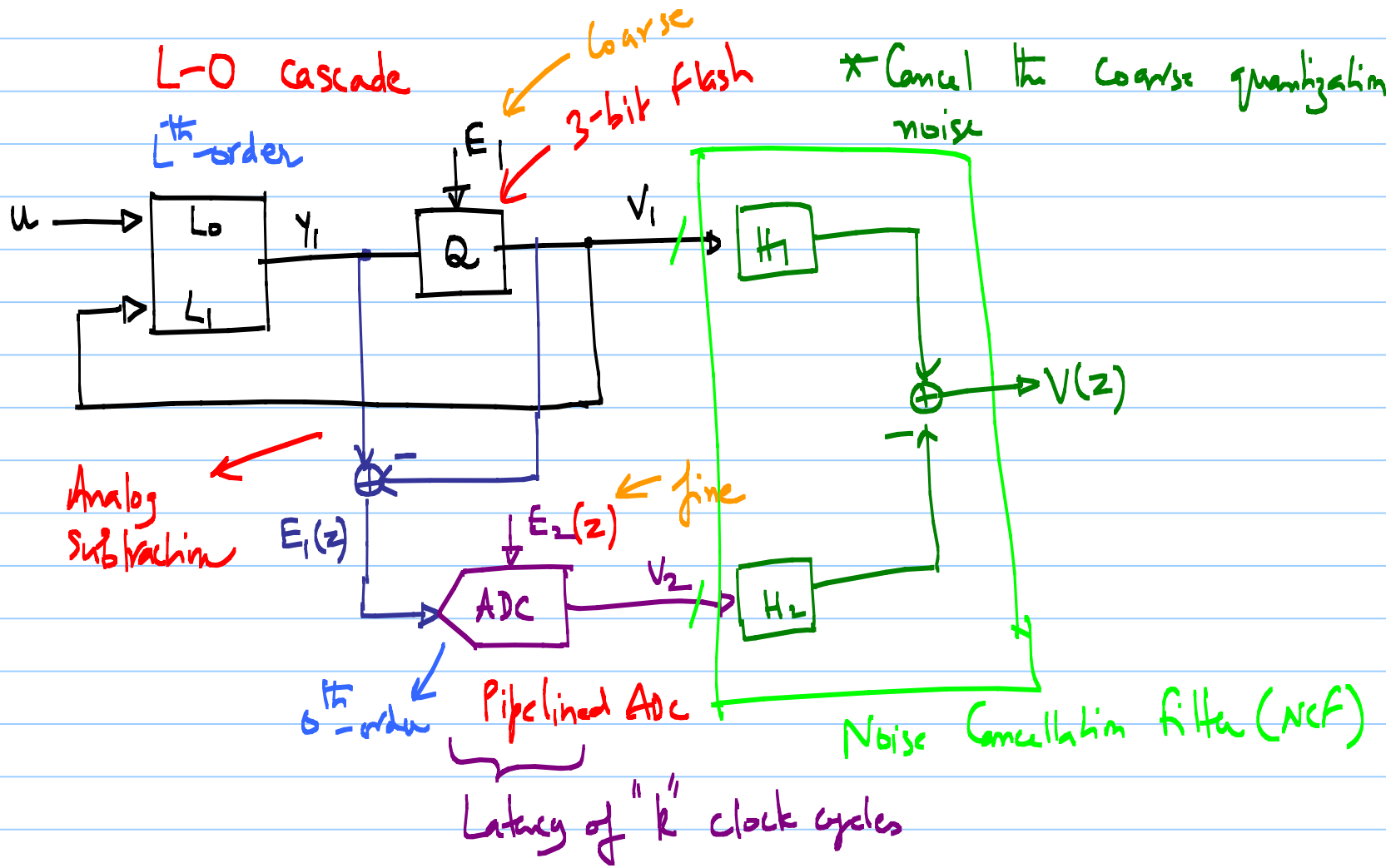
* Single-loop Modulator

order ≤ 5

Low-OSR $\Rightarrow$ large order modulators

Complexity of 5^{th}-order modulator

Multi Stage Modulators (Cascaded ΔΣ Modulators)



* "Combine" V_1 & V_2 to obtain overall output V.

$$V_1(z) = STF_1 \cdot U + NTF_1 \cdot E_1 \longrightarrow (1)$$

$$V_2(z) = z^{-k}\left(E_1(z) + E_2(z)\right) \longrightarrow (2)$$

Design choice

$H_1(z) = z^{-k}$ & $H_2(z) = NTF_1(z)$

$$V(z) = H_1(z) \cdot V_1(z) - H_2(z) \cdot V_2(z)$$

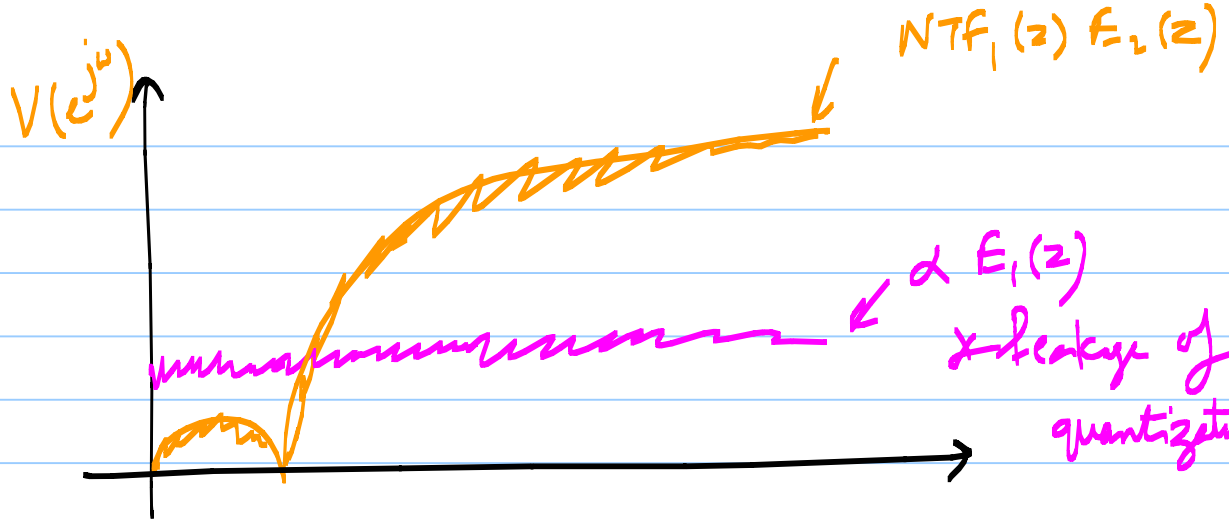
$$= z^{-k}\left[STF_1 \cdot U + \underbrace{NTF_1}_{\text{Analog}} \cdot E_1\right] - \underbrace{NTF_1}_{\text{Digital}} \left[E_1 + E_2\right] \cdot z^{-k}$$

$$= z^{-k}\left[STF_1 \cdot U - NTF_1 \cdot E_2\right]$$

In general:

$NTF_1(z) \cdot NTF_2(z) E_2(z)$

for L_1-L_2 cascade

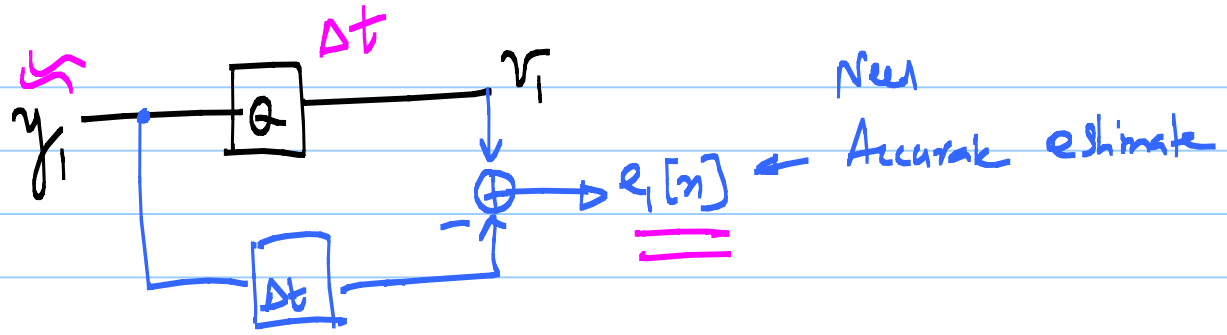


* Imperfect cancellation of the coarse quantization noise

Digital s/c Analog

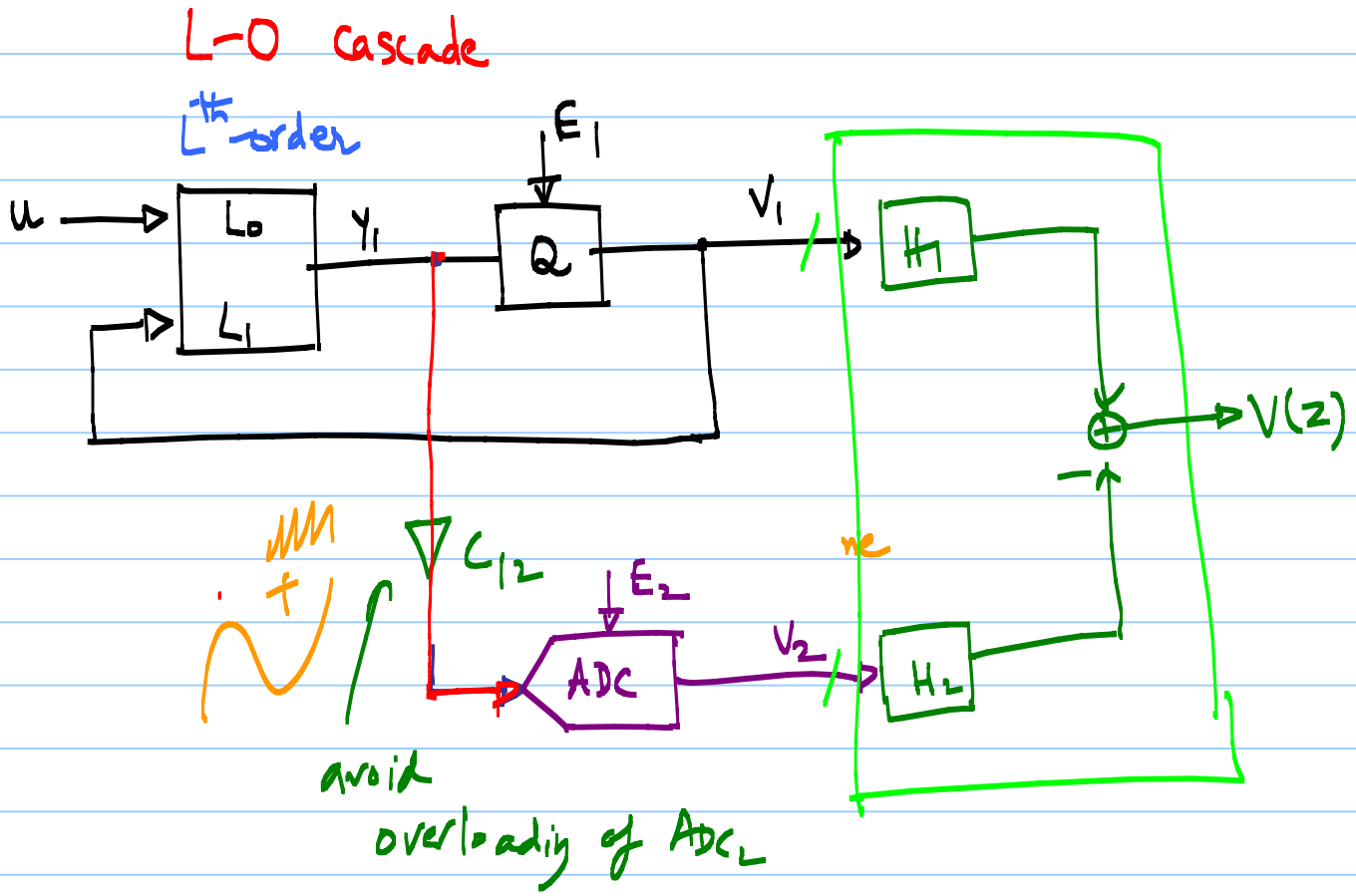
$H_2(z) = NTF_1(z)$

↑ Adaptability ⇐ Calibration b/w Digital and Analog TFs



New
Accurate estimate

* To avoid the analog subtracting, use y_1 as the input to the second-stage


L-O cascade
L^th order
u
L0
L1
y1
E1
Q
V1
H1
V(z)
C12
E2
ADC
V2
H2
ne
avoid
overloading of ADC2

$$Y_1(z) = V_1(z) - E_1(z) = STF_1 \cdot U + (NTF_1 - 1)E_1 \longrightarrow (1)$$

Digital NCFs $\Rightarrow$ $H_1(z) = z^{-k}$

$$H_2(z) = \frac{NTF_1(z)}{NTF_1(z) - 1}$$ to ensure noise cancellation

$$V(z) = z^{-k}\left[STF_1 \cdot U + NTF_1 \cdot E_1\right] - \frac{NTF_1}{NTF_1 - 1} \cdot z^{-k}\left\{STF_1 \cdot U + (NTF_1 - 1)E_1 + E_2\right\}$$

$=$

$$V(z) = \frac{z^{-k}\,STF_1(z)}{1 - NTF_1(z)} \cdot U(z) + \left(\frac{z^{-k}\,NTF_1(z)}{1 - NTF_1(z)} \right) \cdot E_2(z)$$

$\frac{NTF_1}{1 - NTF_1}$ $\Rightarrow$ in the signal band $|NTF_1| \ll 1$

$\Rightarrow$ NTF_1 in the signal band

$$H_2(z) = \frac{NTF_1(z)}{NTF_1(z) - 1}$$

$$= \frac{1 - 2z^{-1} + z^{-2}}{\cancel{1} - 2z^{-1} + z^{-2} \cancel{- 1}}$$

IIR

more complexity in NCF

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

$$H_{2,\text{original}} = 1 - 2z^{-1} + z^{-2}$$

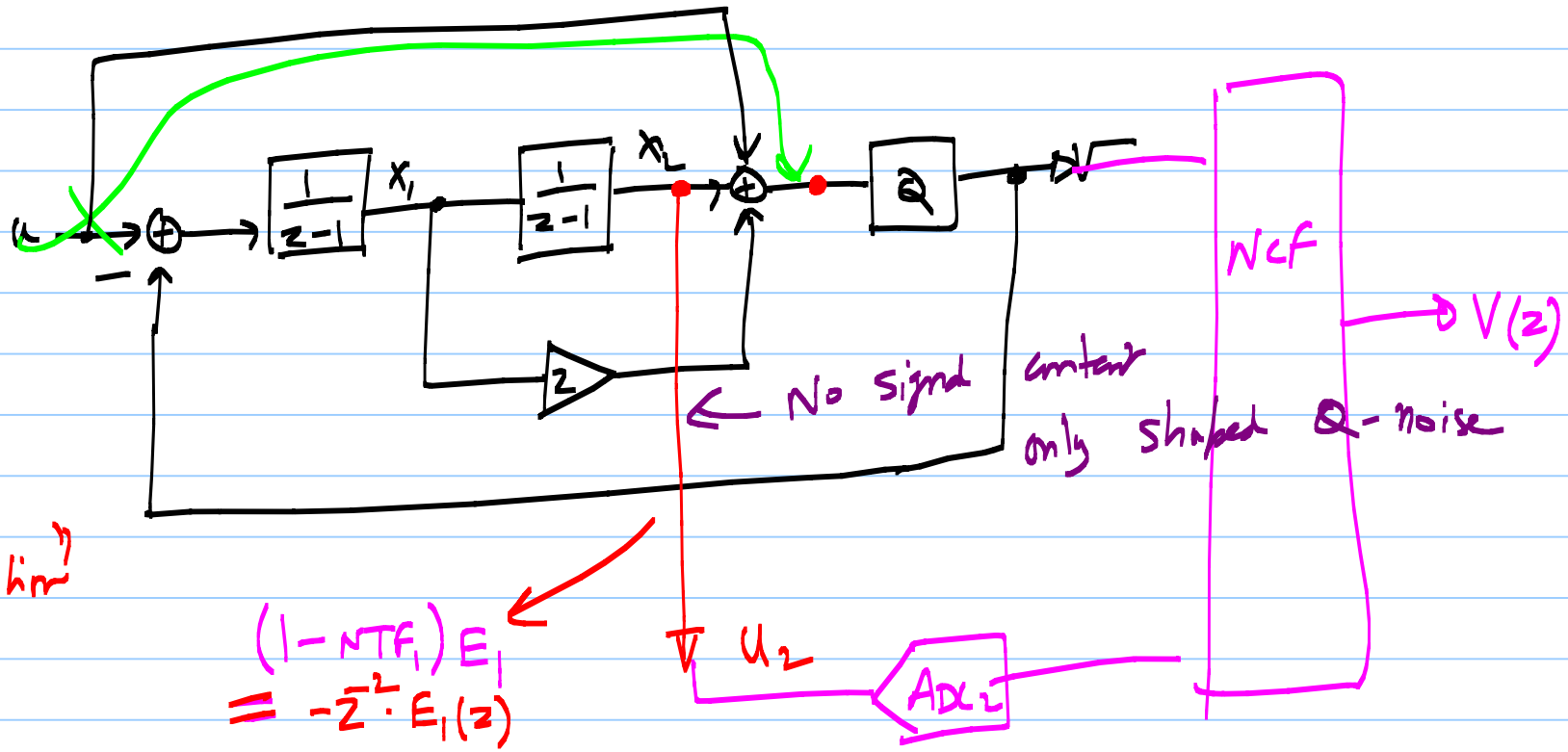
FIR filter

* If the first-stage is a low-distortion modulator (STF = 1)

$X_N(z) = -(1 - NTF(z))\,E(z)$

$X_2(z)$

2nd-order CIFF



Multi Stage Noise Shaping (MASH)

2-1 MASH $\Rightarrow$ 3rd-order noise-shaping

2-2-1 MASH $\Rightarrow$ 5th-order "