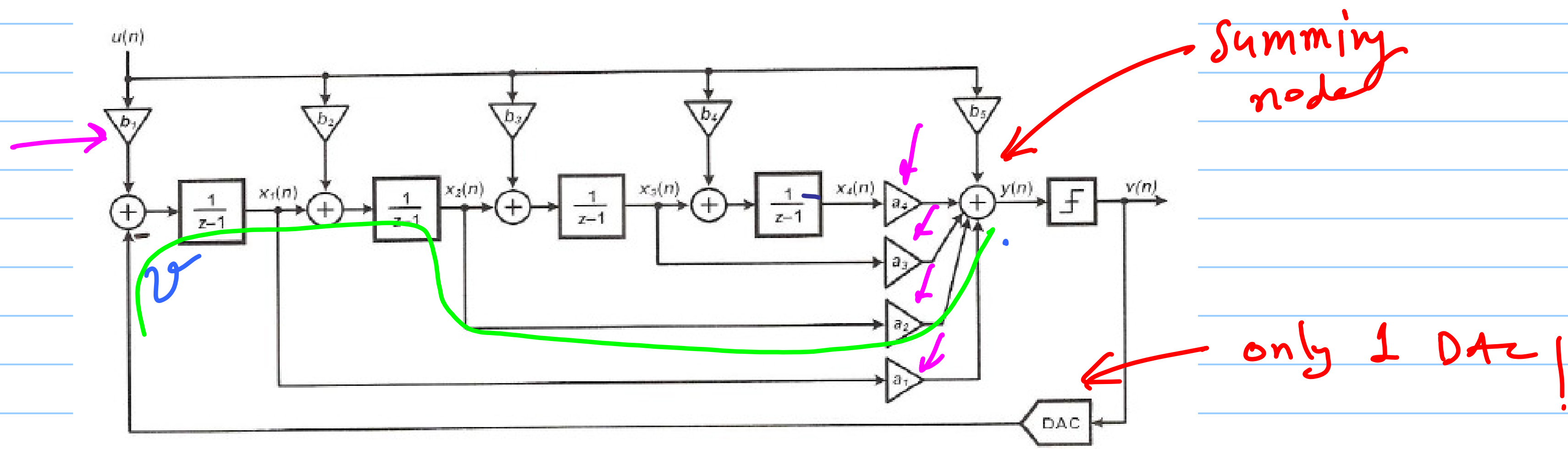
ECE 615 - Lecture 19

Note Title 3/15/2016

Feedforward loop-filter:



* CIFF → cascade of integrators with feedforward summation

$$I(z) = \frac{1}{z-1} = \frac{z^{-1}}{1-z^{-1}} \leftarrow \text{delaying integrator}$$

$$L_1(z) = -a_1 I(z) - a_2 I^2(z) - \cdots - a_N I^N(z)$$

L_1 is same as in the case of CIFB

$$L_0(z) = \frac{\gamma_1 + \gamma_2 (z-1) + \cdots + \gamma_N (z-1)^{N-1} + \gamma_{N+1} (z-1)^N}{(z-1)^N}$$

Same NTF

↳ But different STF than FB

$$\left.\begin{aligned}
\gamma_{N+1} &= b_{N+1} \\
\gamma_N &= b_1 a_1 + b_2 a_2 + b_3 a_3 + \cdots \\
\gamma_{N-1} &= b_1 a_2 + b_2 a_3 + b_3 a_4 \cdots \\
&\vdots \\
\gamma_1 &= b_1 a_N
\end{aligned}\right\}$$

complicated topology

⇐ This generic case is not usually employed

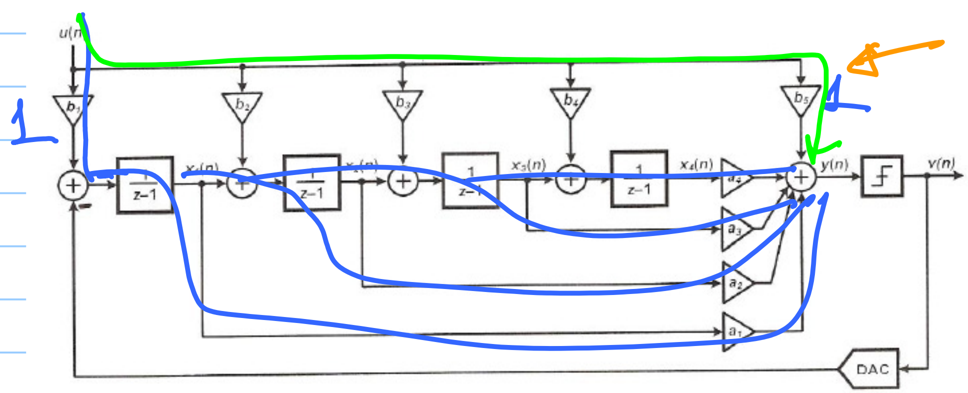
Now consider the case when $b_2 = b_3 \cdots = b_N = 0$

& $b_1 = b_{N+1} = 1$

$\Rightarrow$ $L_0(z)$ simplifies to

$$L_0(z) = (a_1 I + a_2 I^2 + \cdots + a_N I^N) + 1$$

$$= 1 - (-a_1 I - a_2 I^2 \cdots - a_N I^N) = 1 - L_1(z) \longrightarrow (1)$$



implementation can be challenging

$$
\begin{cases}
L_0(z) = 1 - L_1(z) & \text{when } b_{N+1} = 1 \\
L_0(z) = -L_1(z) & \text{when } b_{N+1} = 0
\end{cases}
\Rightarrow
$$

Two simple cases supported by the Toolbox

for $b_{N+1} = 1 \Rightarrow$ full input feedforward case

$$
STF(z) = \frac{L_0(z)}{1 - L_1(z)} \Rightarrow \frac{1 - L_1(z)}{1 - L_1(z)} \Rightarrow 1
$$

for $b_{N+1} = 0 \Rightarrow$ only one input is coupled

$$
STF(z) = \frac{-L_1(z)}{1 - L_1(z)} = 1 - NTF(z)
$$

we will come back to this.

when $b_1 = b_{n+1} = 1$

$STF = \underline{\underline{1}}$ → distortion free!

$$\Rightarrow \quad \underbrace{U(z) - V(z)}_{\text{input to the loop filter}} = U(z) - \left[U(z) + NTF(z) \cdot E(z)\right]$$

$$= -NTF(z) \cdot E(z)$$

input to the loop filter

↳ integrator swings are small

↳ simplifies circuit design

↳ compare with low-distortion CIFB case

↳ FF implementation is easier

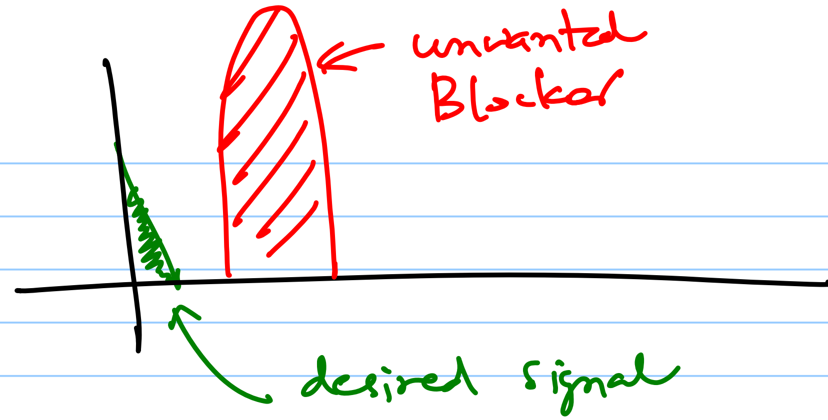
when $b_2 = b_3 \cdots = b_{N+1} = 0 \Rightarrow$ only $b_1 \neq 0$

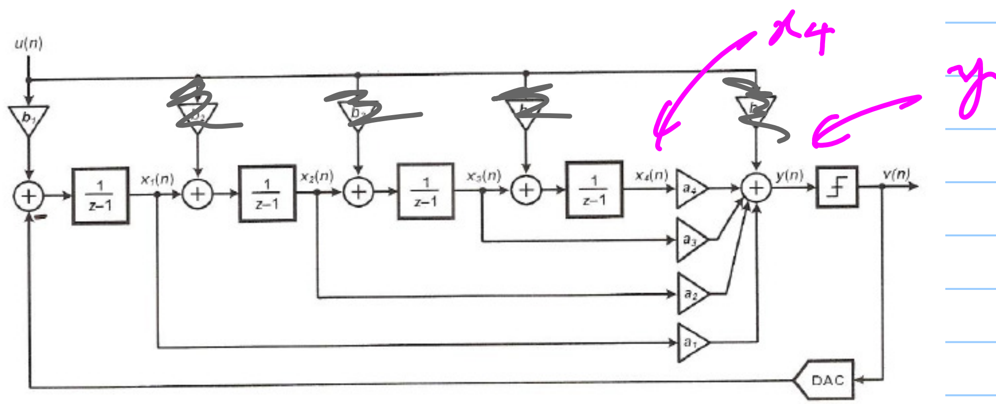
$$STF(z) = 1 - NTF(z)$$

↳ results in high-frequency peaking in the STF

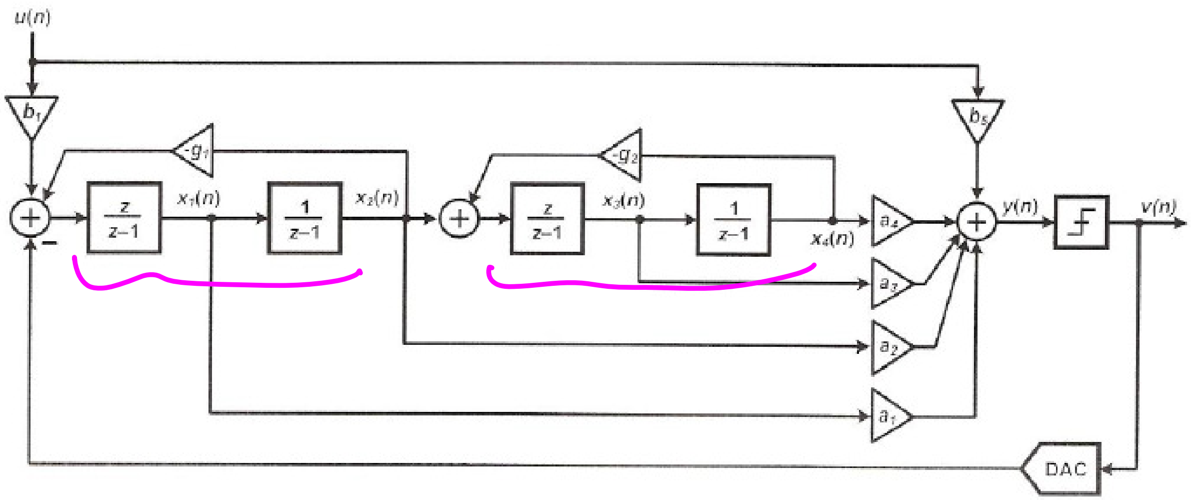
$\Leftrightarrow$ Quantizer overloading

RF Rx scenario

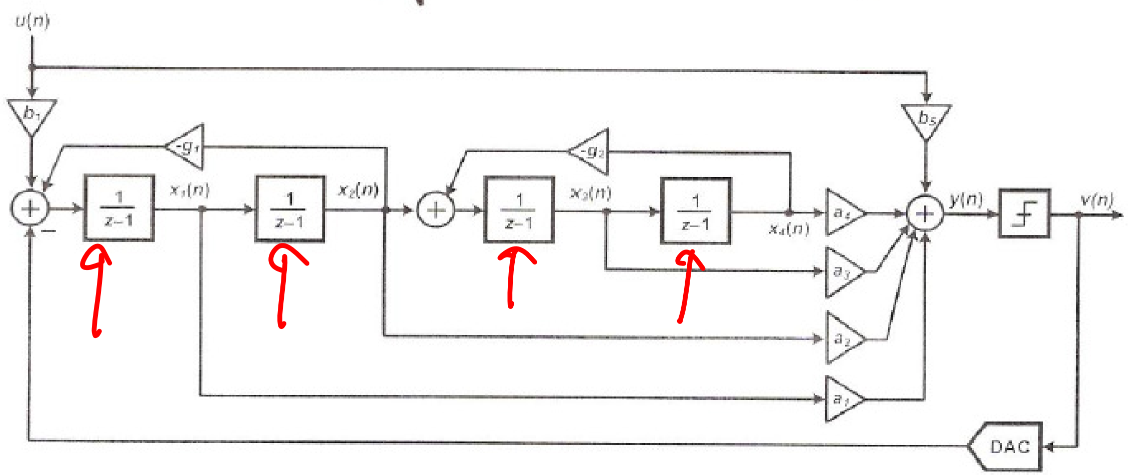


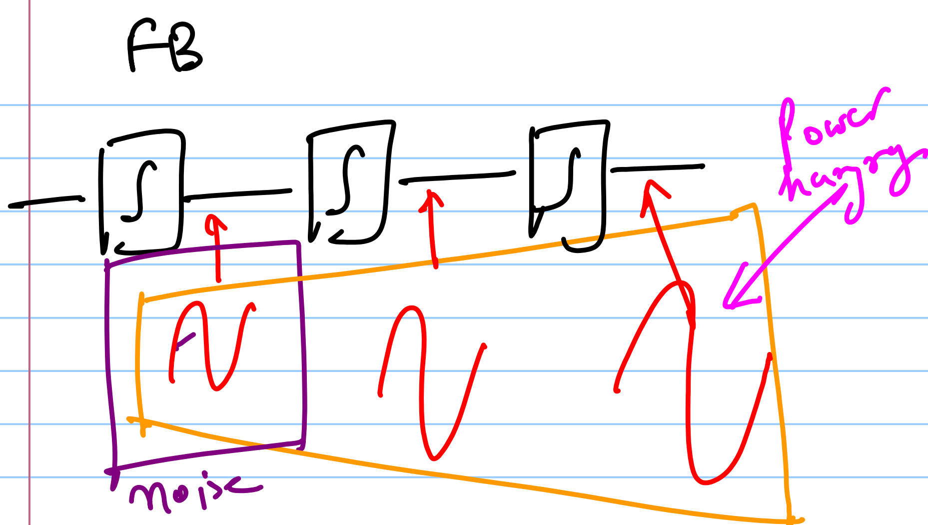


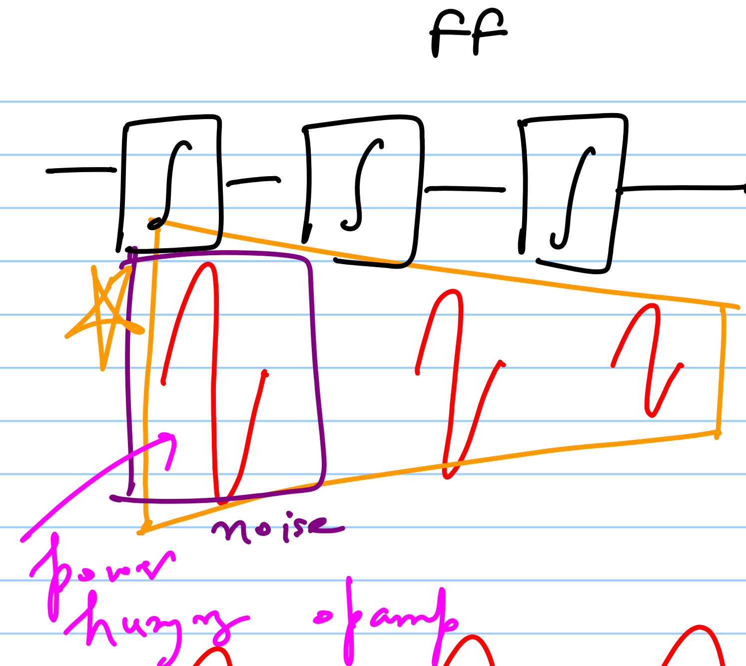
CRFF



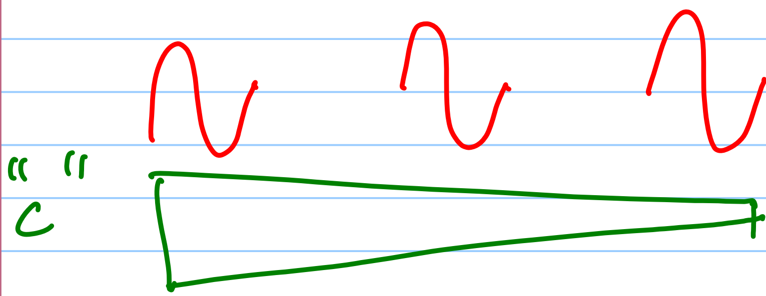
CIFF

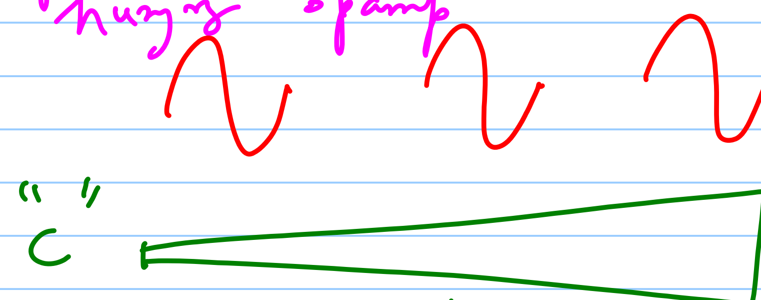






Dynamic Range scaling.





$c<1$ to shrink integrator state

Comparison:

	Feedforward	Feedback
①	FF has relaxed dynamic range requirements	integrators contain significant amount of signal + quantization noise
②	STF peaking	STF is low-pass
③	only 1 DAC reqd.	many feedback DACs
④	Need summation block	—
⑤	Timing can be tricky for $b_{N+1}=1$	—

⑥ first integrator is fastest ✓

⑦ first opamp is power hungry due to noise

"golden opamp"

⑧ Small capacitor area

Last integrator is fastest (has more signal content) X

first opamp is power hungry due to noise

Large cap areas to accomodate scaling of large integrator swings (c < t)

↳ DRS results in large C's

↳ larger Layout

↳ more power

* If dTF/AAF is not an issue, FF architecture is generally preferred.

Dynamic Range Scaling!