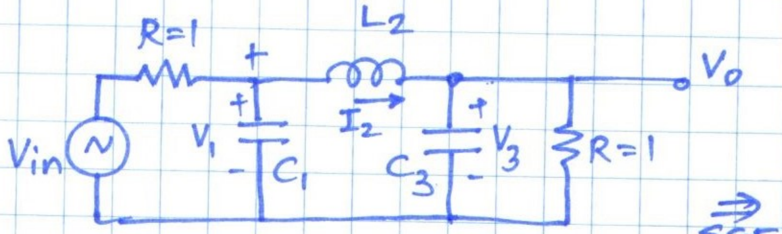
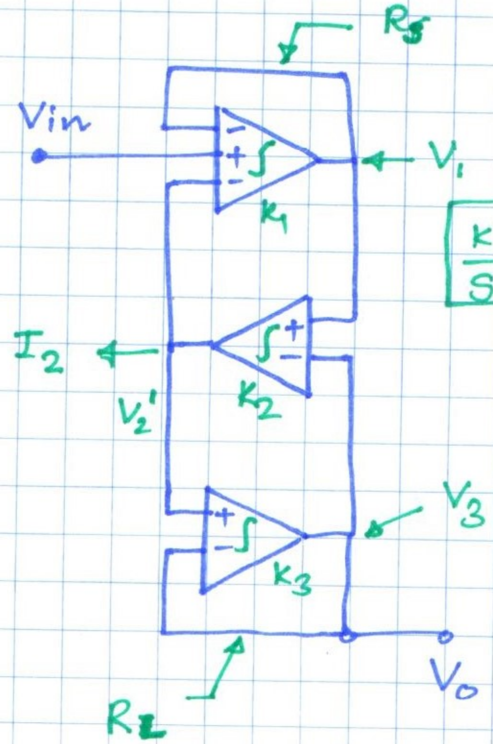
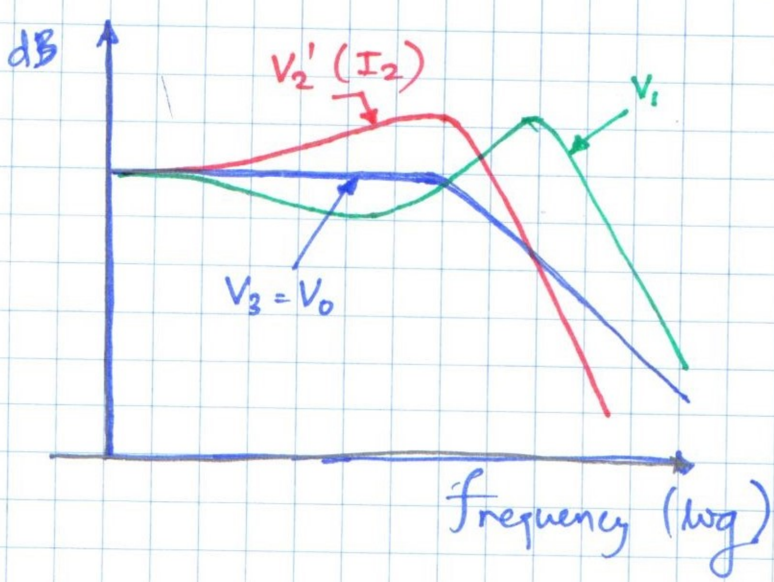


⇒ SGF



$$\boxed{\frac{k_1}{s} = \frac{1/C_1}{s}}$$



Observing voltages internally, V_1 & V_2' are about 3.2 dB higher than V_o. (Based on SPICE simulations)

→ Optimal voltage swing @ each integrator output — Depends on V_{DD}.

→ Since V_1 & V_2' are 3.2 dB higher [specific to our current example] max o/p voltage swing is reduced by 3.2 dB

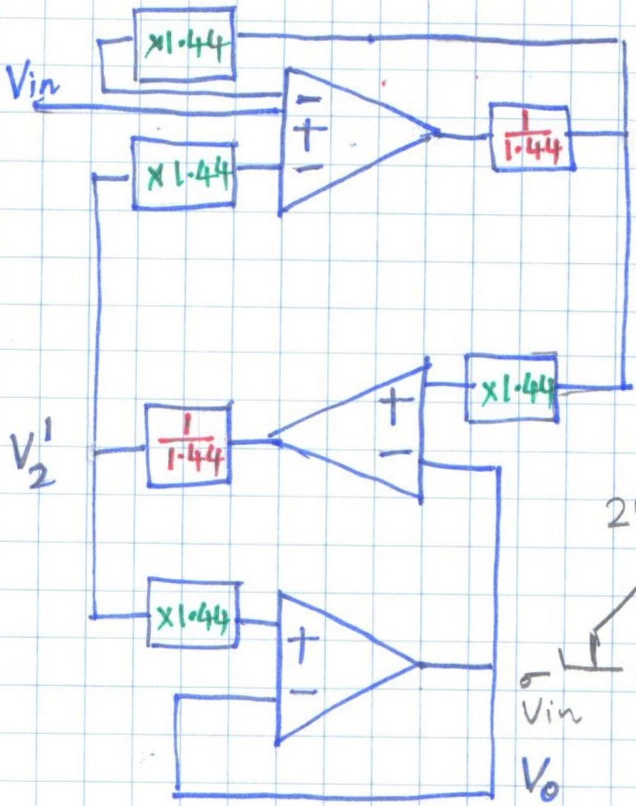
→ Else Distortion will result.

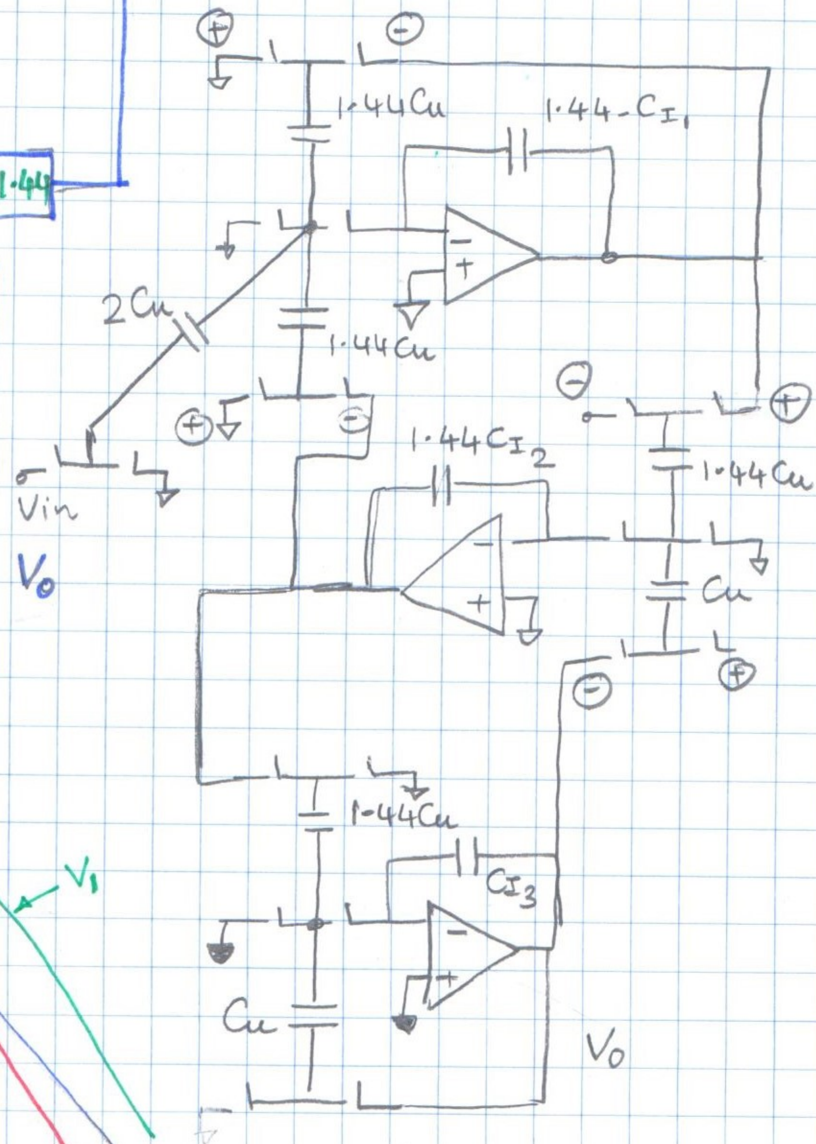
→ Need to do voltage swing equalization at each integrator o/p. {same peak amplitude for each stage

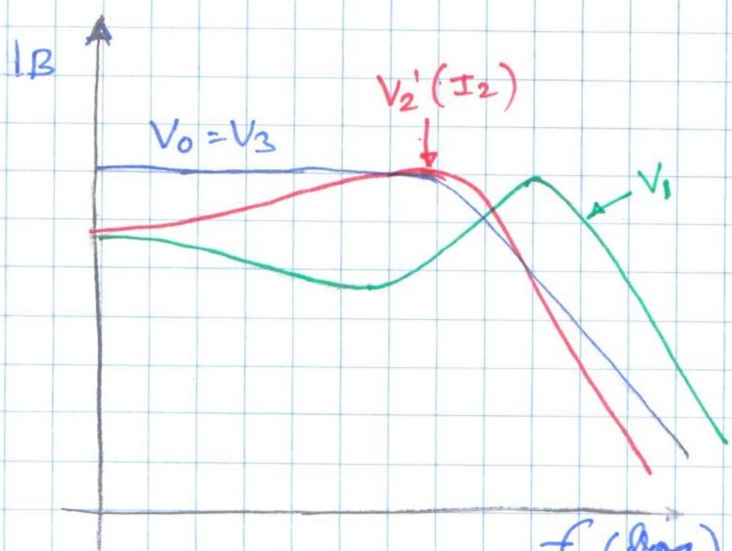
→ Also called Dynamic Range Scaling.

→ Applicable to continuous-time filters also.

- Need to attenuate V_1 & V_2' by 3.2 dB $\left(\frac{1}{1.44}\right)$ WITHOUT changing overall xfer function.
- How ?



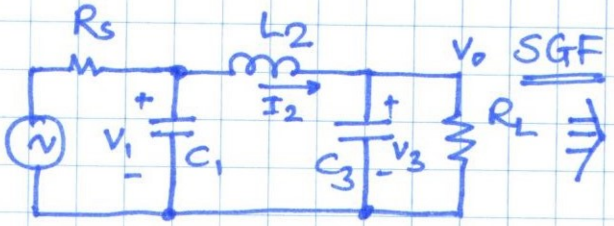


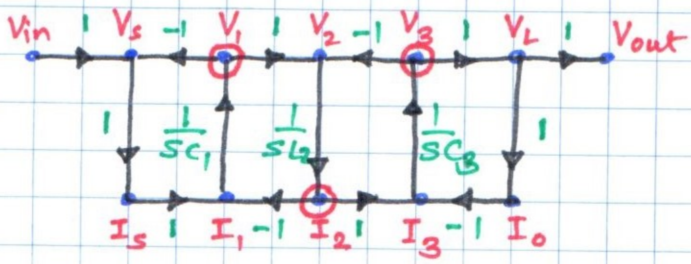


→ peak swings of all integrators equalized.

Another way to explain Voltage Swing Equalization

Start with RLC filter Refer: L-20 page 6





→ Simulate RLC circuit using SPICE → Determine peak gain for each variable representing INTEGRATOR OUTPUT.

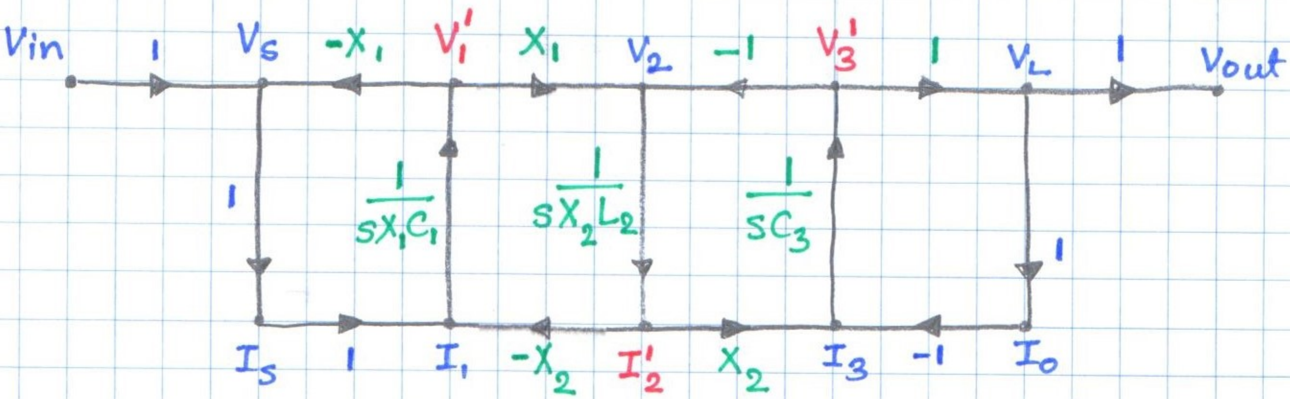
For example: In this case V_1, I_2 & V_3 → (Same as V_0)

$$\frac{V_1}{V_{out}} = X_1 \quad ; \quad \frac{I_2}{V_{out}} = X_2 \quad ; \quad \frac{V_3}{V_{out}} = 1$$

X_1 & X_2 > 1 → Need to scale Integrator 1,2 So that peak gain for all integrator o/ps is same.

(Represent Peak values)

Modified SGF implementation



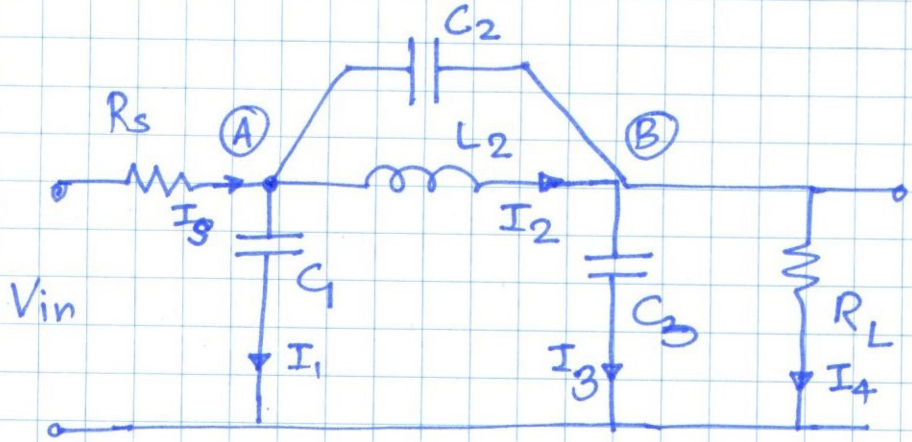
$$V_1' = \frac{V_1}{X_1} \quad ; \quad I_2' = \frac{I_2}{X_2}$$

Now all integrator O/ps will have same peak values (may be at different frequencies)

→ Optimum dynamic range.

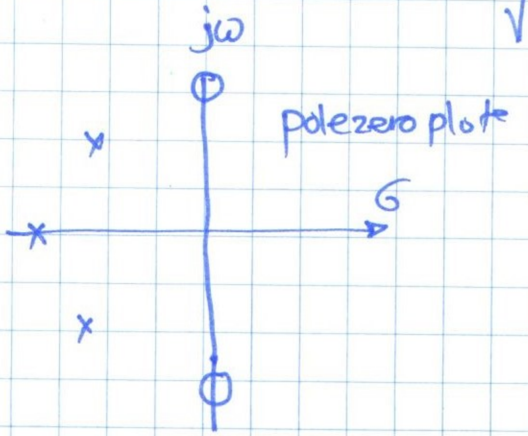
" Implementing finite transmission zeros

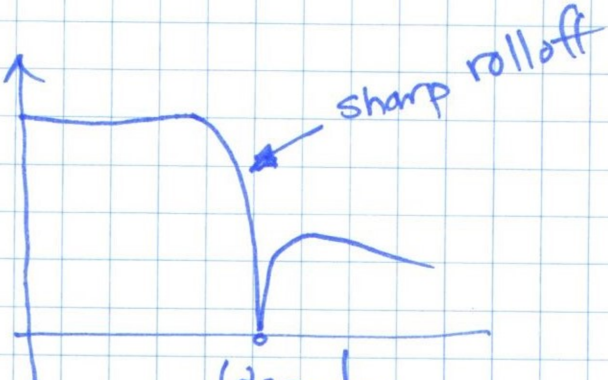
Ref: Allstot "MOS SC Ladder Filters" JSSC - Dec 1978.



Tx zero @ resonance of $L_2 C_2$

$$\omega_{zero} = \frac{1}{\sqrt{L_2 C_2}}$$





$$\omega_z = \frac{1}{\sqrt{L_2 C_2}}$$

KCL @ A $\qquad I_g = sC_1 V_1 + sC_2(V_1 - V_3) + I_2$

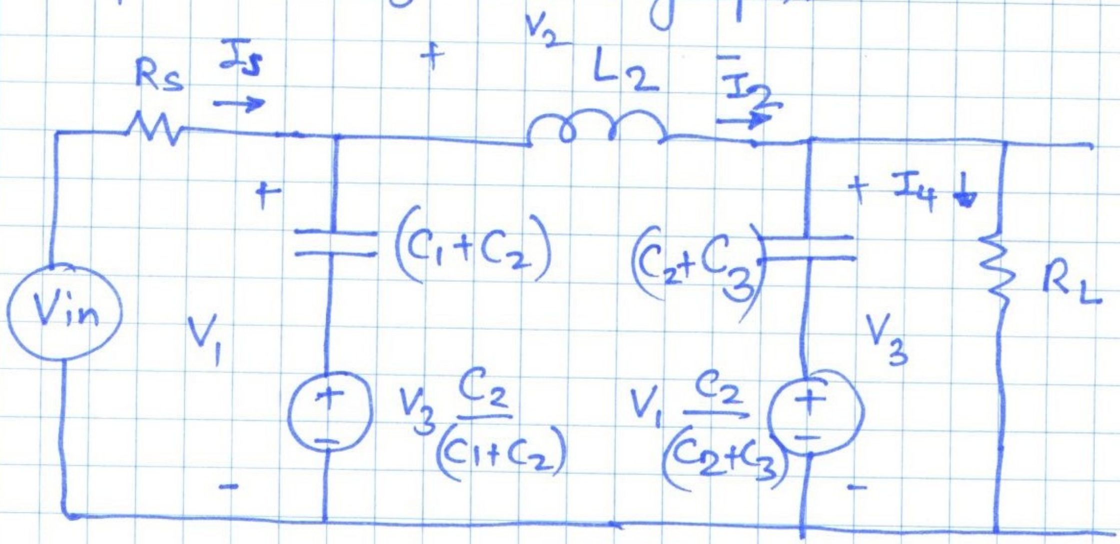
$$V_1 = \underbrace{\frac{I_g - I_2}{s(C_1 + C_2)}}_{\text{Integration}} + \underbrace{V_3 \frac{C_2}{(C_1 + C_2)}}_{\text{Addition.}}$$

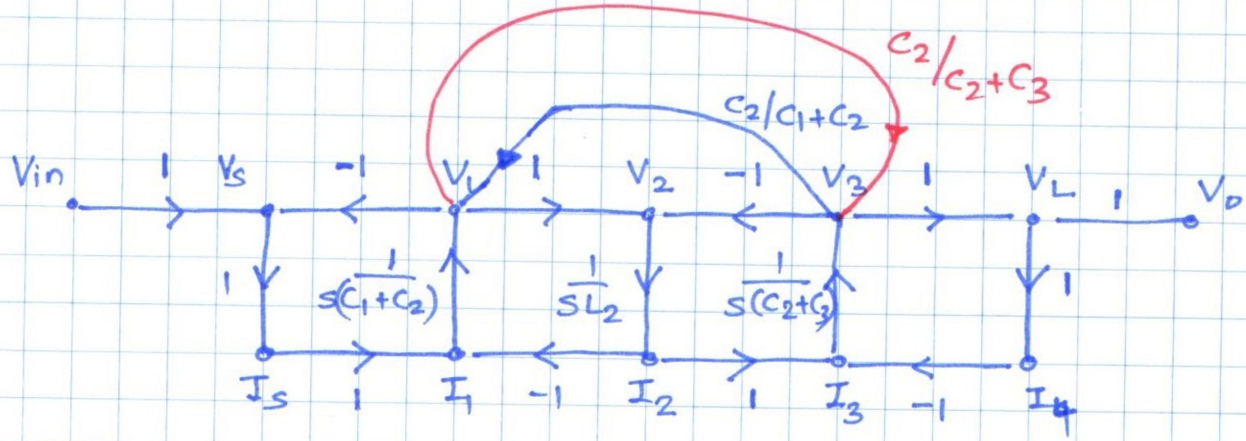
KCL @ B

$$I_2 = I_4 + sC_3 V_3 + sC_2(V_3 - V_1)$$

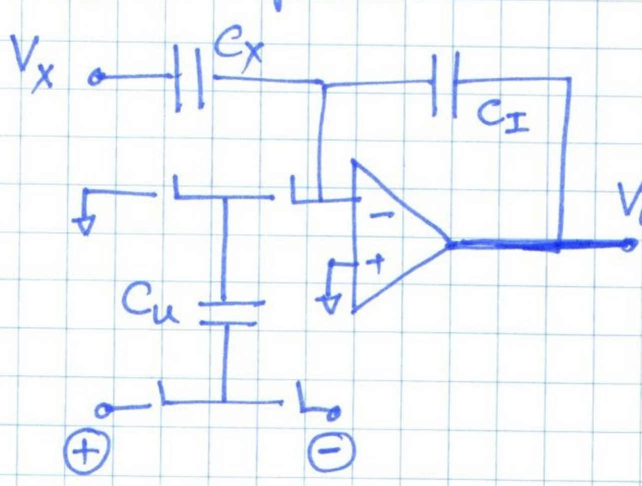
$$V_3 = \frac{I_2 - I_4}{s(C_2 + C_3)} + V_1 \frac{C_2}{C_2 + C_3}$$

Update signal flow graph.





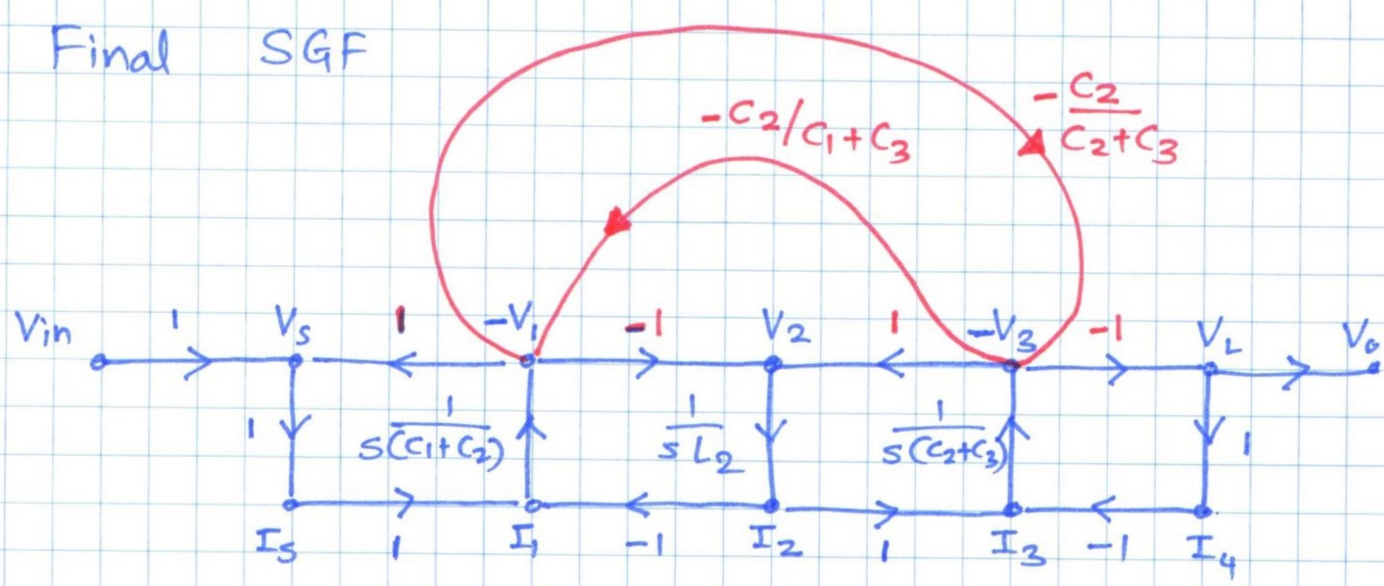
How to implement scaled addition in SC?



$$V_{out} = \underbrace{-\left(\frac{C_X}{C_I}\right)}_{\uparrow \text{ inverting sign.}} V_X + \text{integrator parts.}$$

→ Modify SGF − Replace V_1 by $(-V_1)$
& Replace V_3 by $(-V_3)$

Final SGF

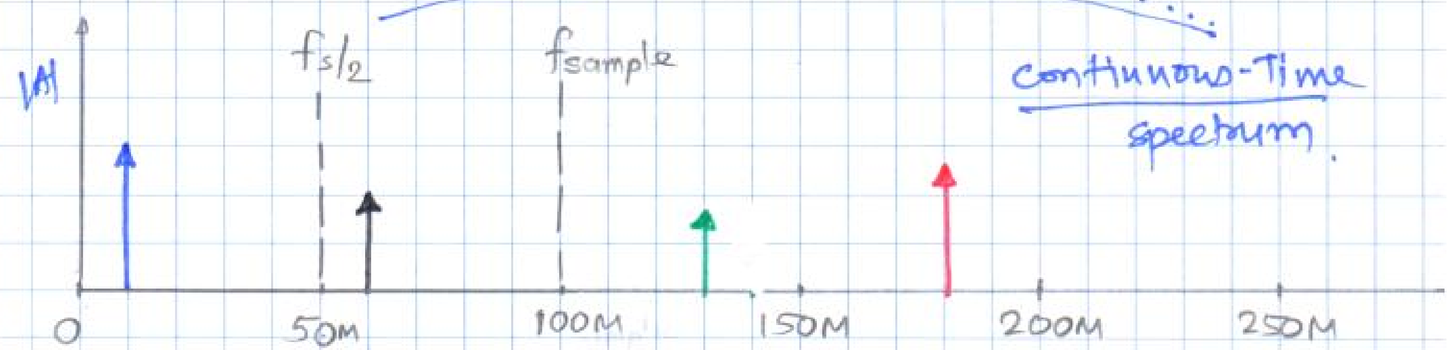


Now this can be implemented using SC integrators & scaled addition units.

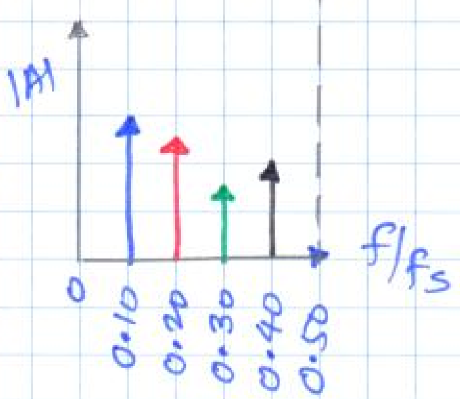
→ HOME EXERCISE.

→ Identical Technique can be applied to Continuous-Time filters for implementing zeros (Eg. Elliptic filters)

ANTIALIASING FILTER



continuous-Time spectrum.



Signals higher than $\frac{f_s}{2}$ fold back into the desired band

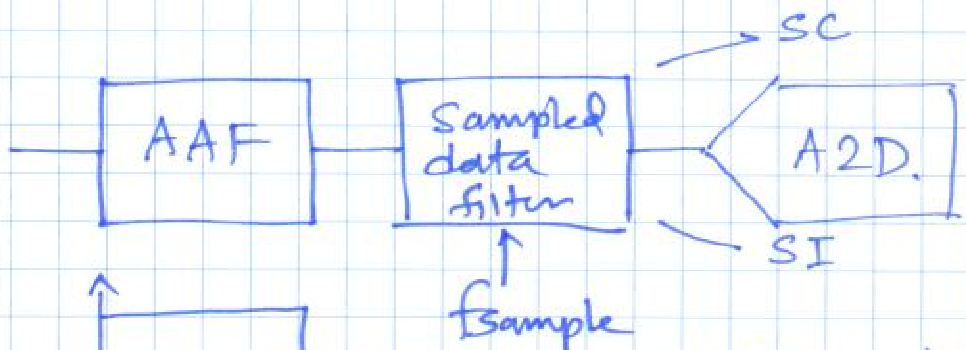
— Aliasing.

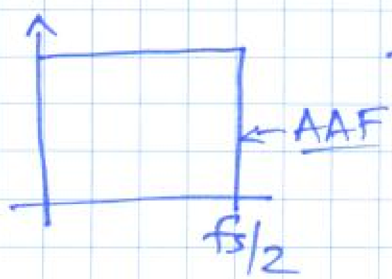
— Corrupt desired signal forever.

- <u>Nyquist Sampling Thm</u> : Signal should be bandlimited to $f_s/2$.

→ Need to filter out everything above $f_s/2$

→ AAF



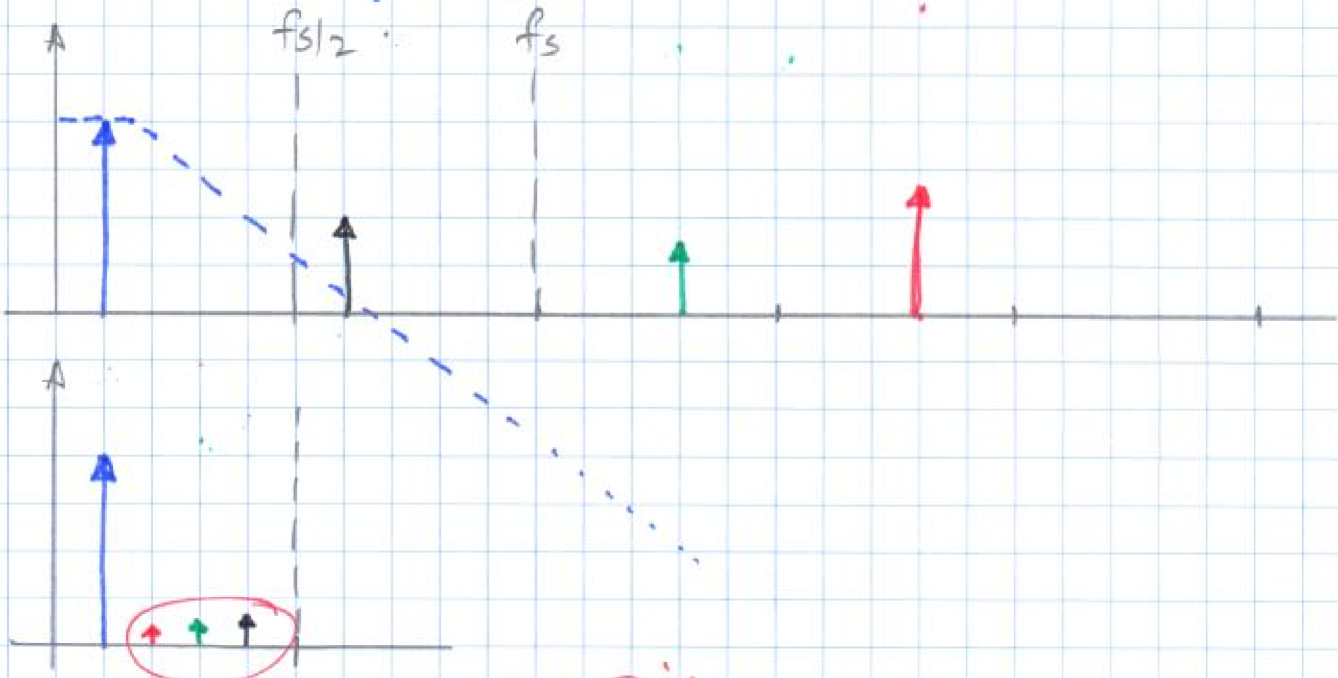


← Done with continuous time filters.

Brickwall filters very difficult in cont-time.

→ Increase sampling rate - Oversample

→ Ease requirement on AAF.



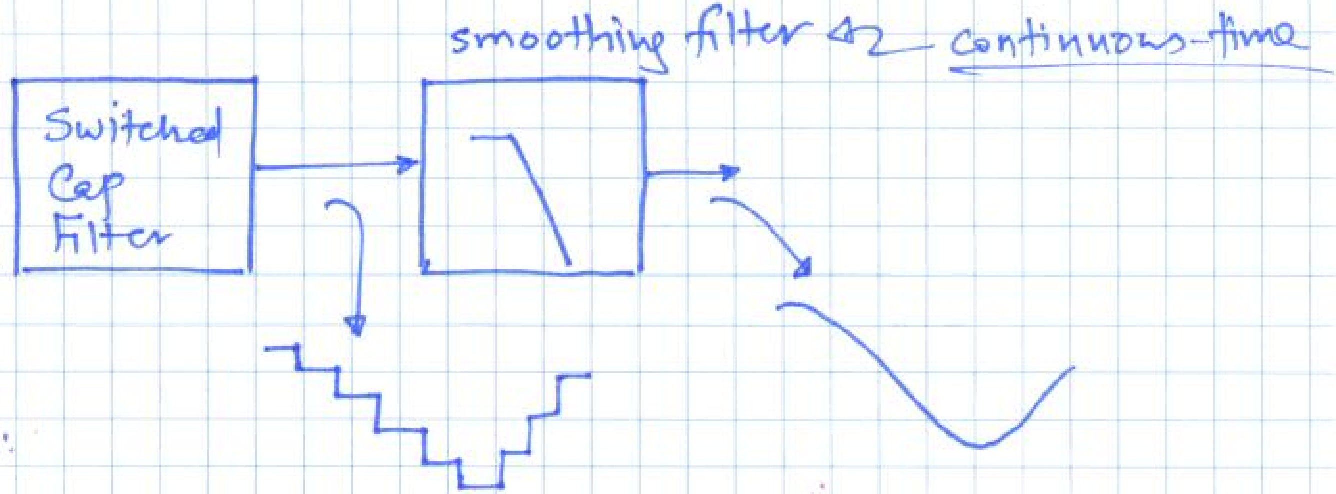
Filtered by AAF @ i/p

General AAF design guidelines

→ low order design - of course continuous-time filter

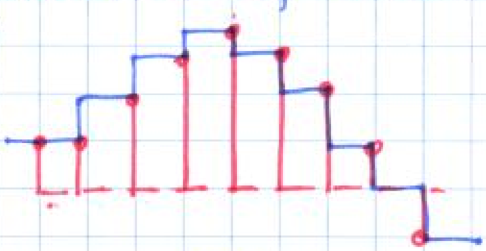
→ Make sure AAF attenuates undesired signals sufficiently with largest PVT variation

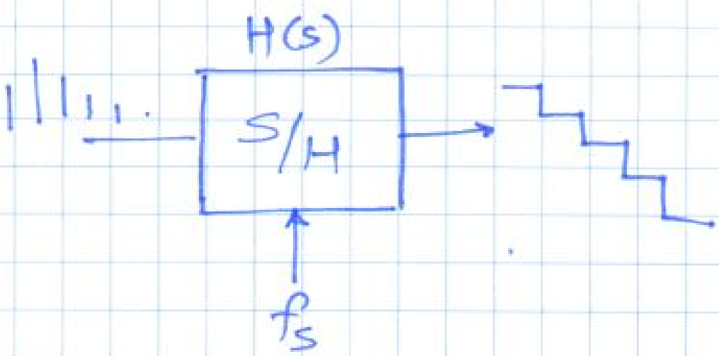
→ No frequency tuning.



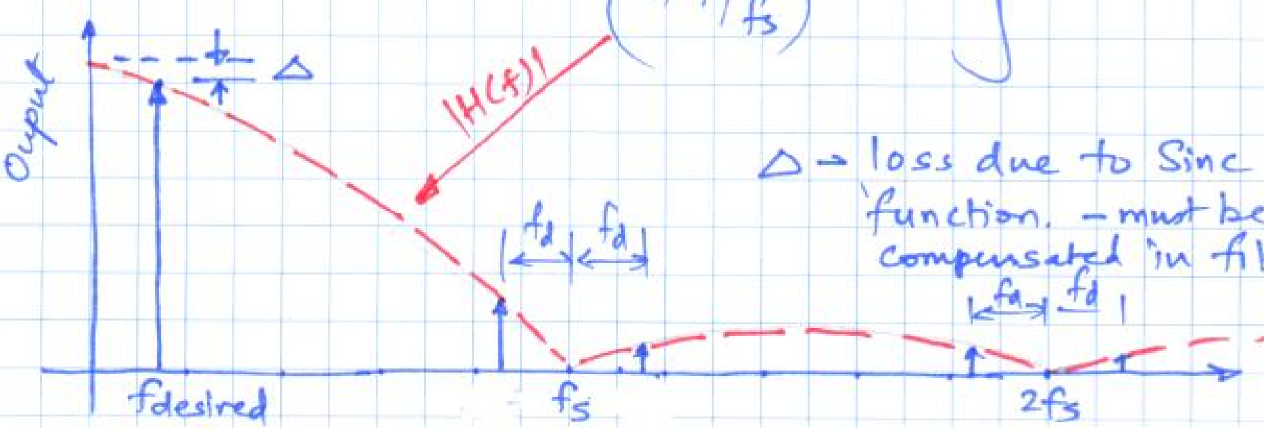
Smoothing filter – Removes clock & high frequency artifacts.

Switched cap filter o/p. — Sampled & held o/p





$$|H(f)| = \frac{\sin(\pi f/f_s)}{(\pi f/f_s)} \quad \Bigg\} \text{ Sinc function}$$



Δ → loss due to Sinc function. – must be compensated in filter design