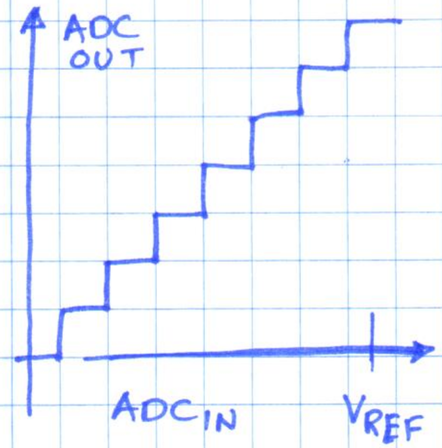
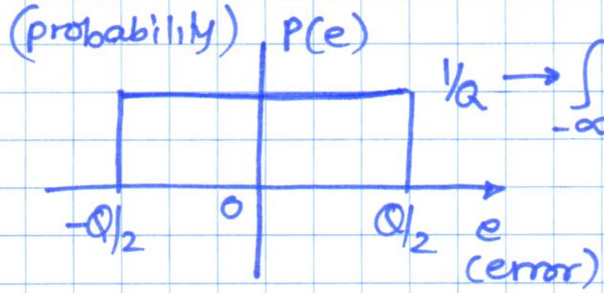
SNR - QUANTIZATION NOISE DERIVATION.



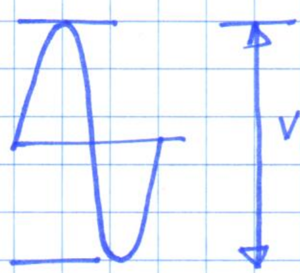
$\Rightarrow$



$$\tfrac{1}{Q} \longrightarrow \int_{-\infty}^{\infty} P(e)\,de = 1$$

$$\sigma^2 = \text{Quantization Noise power} = \int_{-Q/2}^{Q/2} e^2 . P(e)\,de$$

$$= \frac{1}{Q}\int_{-Q/2}^{Q/2} e^2\,de = \frac{1}{Q}\left[\frac{e^3}{3}\right]_{-Q/2}^{Q/2} = \frac{Q^2}{12} = \overline{V_{n_{rms}}}^{\,2}$$



$V_{REF} = 2^N Q.$

$$V_{sig_{rms}} = \frac{2^N Q}{\sqrt{2}\cdot 2}$$

$$SNR = 20\log\left(\frac{V_{sig\,rms}}{v_{n\,rms}}\right)$$

$$= 20\log\left(\frac{2^N Q}{2\sqrt{2}} \times \frac{\sqrt{12}}{Q}\right)$$

$$SNR = 20\log 2^N + 20\log\left(\sqrt{\tfrac{3}{2}}\right) = 6.02N + 1.76$$

Filter Approximations

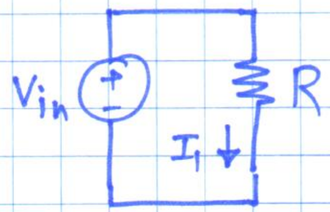
	Butterw	Chebyshev	Elliptic Cauer	Bessel
Passband	***	****	****	**
Stopband Atten	***	****	*****	**
Group Delay	***	**	*	*****

Filter Design Process

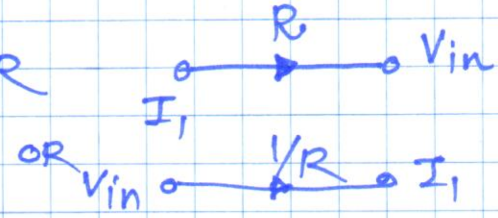
1. Choose Filter Approx based on desired filter Characteristics
2. For Normalized fstopband, use filter curves to determine order of filter.
3. Use filter tables to find out compoment values.

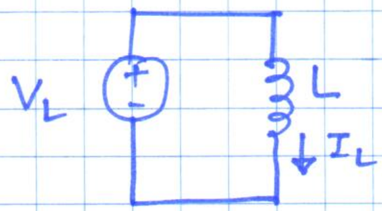
Signal flow Graph Technique SFG

Basics

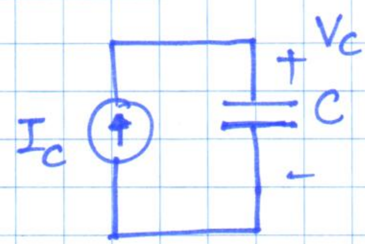


$V_{in} = I_1 R$

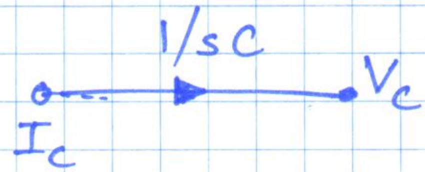


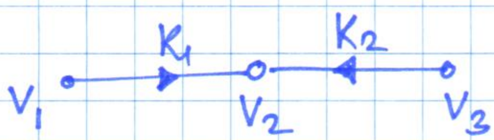


$I_L = \frac{V_L}{sL}$

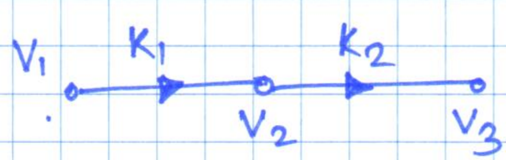


$V_c = \frac{1}{sC} I_c$

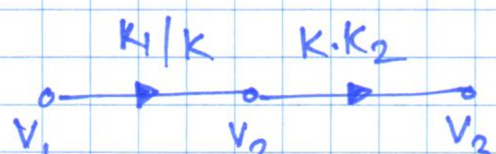




$\Rightarrow \quad V_2 = K_1 V_1 + K_2 V_3$



$\Rightarrow \quad V_3 = K_1 K_2 V_1$

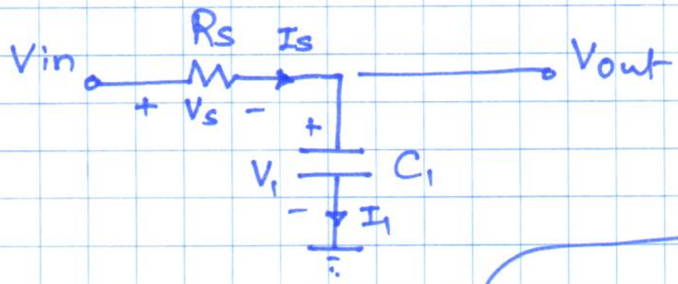


$\Rightarrow \quad V_3 = \frac{K_1}{K} \cdot K K_2 V_1$

$= K_1 K_2 V_1$ equivalent

Signal Flow Graph Technique simulates voltage-current relationship in passive network.

Example : One pole RC Lowpass filter



Equations for this ckt

$V_s = (V_{in} - V_1)$

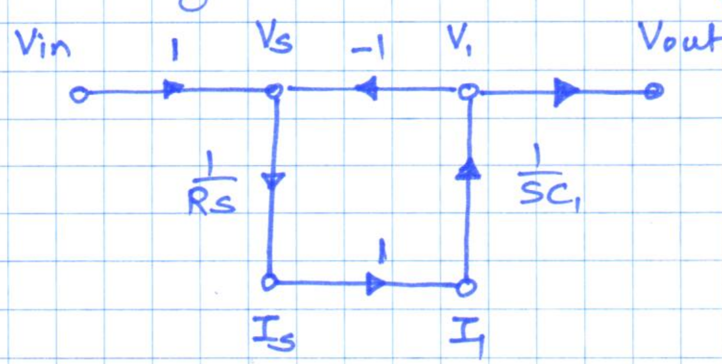
$V_{out} = V_1$

$V_1 = \frac{1}{sC_1} I_1$ (Integrator)

$I_s = I_1$

$I_s = \frac{V_s}{R_s}$

Modeling in SFG Technique



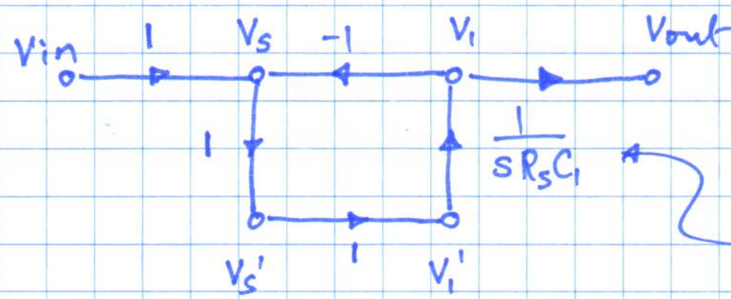
* More $\frac{1}{R_s}$ around loop

* scaling resistance R

$V_s' = R I_s$

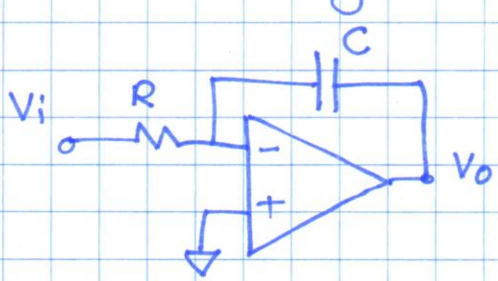
$V_1' = R I_1$

Choosing $R = 1$ (convenience)

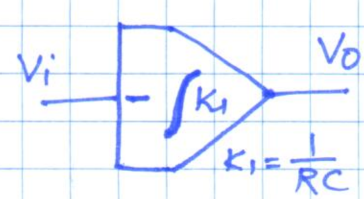


Integrator

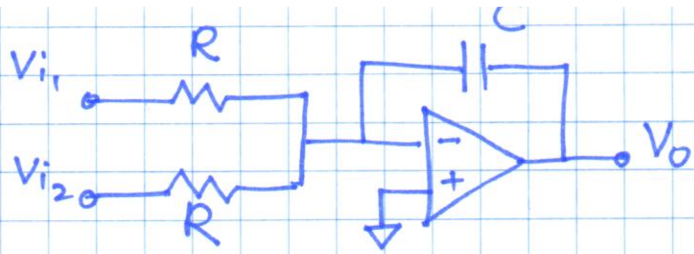
Implementing Integrator

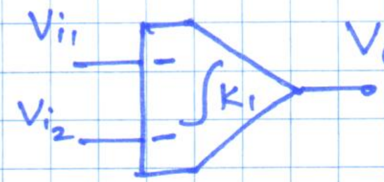


$\frac{V_i}{R} = \frac{-V_o}{1/sC} \Rightarrow V_o = -\frac{V_i}{sRC}$

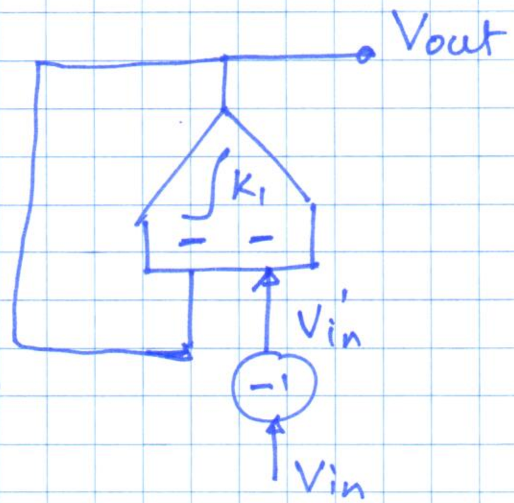


Note: i/p & o/p both voltages.



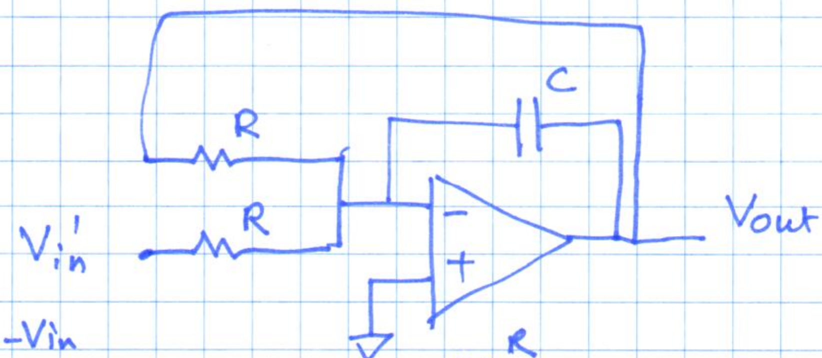


Pushing this in SFG

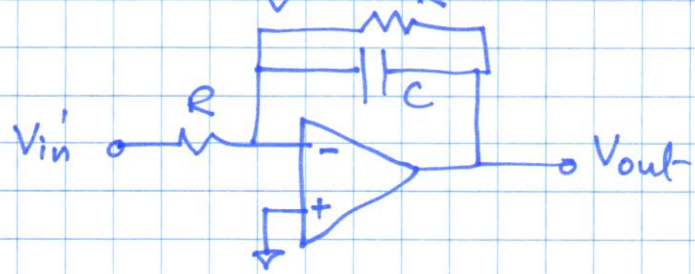


$$\boxed{K_1 = \frac{1}{R_s C_1}}$$

✱



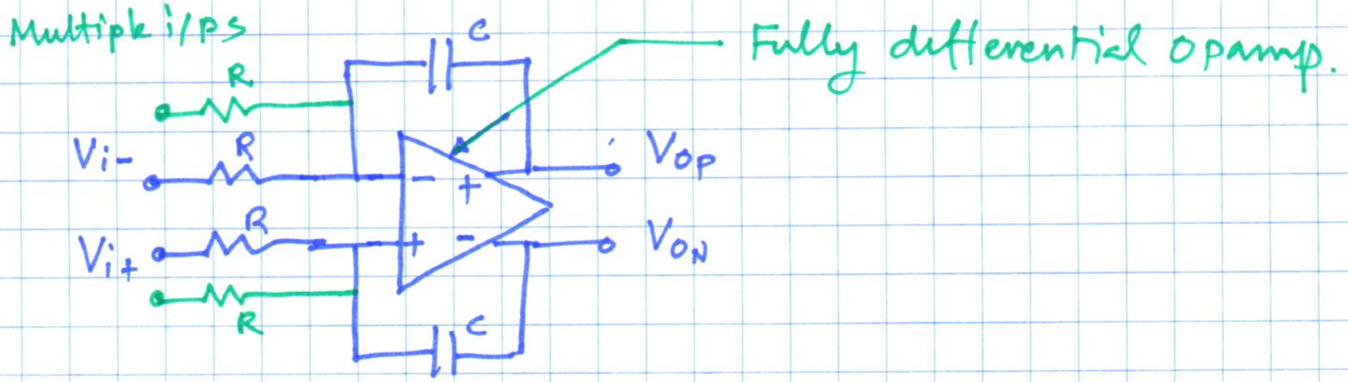
$= -V_{in}$



$$\frac{V_{out}}{V_{in}'} = \frac{-1}{1+RCs}$$

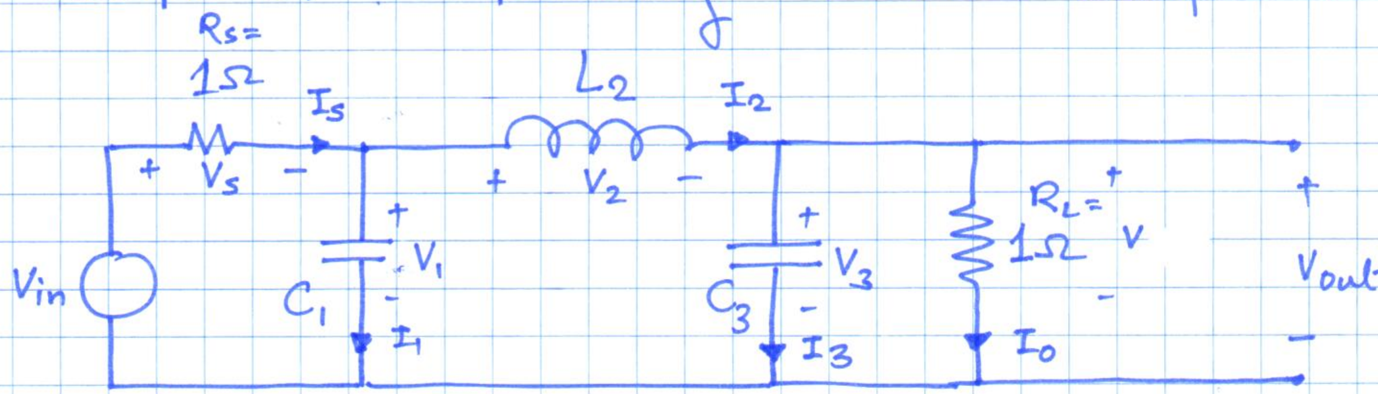
NOTES

- ✱ Active RC (or OPAMP RC) integrator has inverting i/p only.
- ✱ Other integrators we will study have both +/− i/p.
- ✱ Active RC integrator can be used in fully differential configuration with both + & −ve i/p.
  — will study fully differential circuits later.



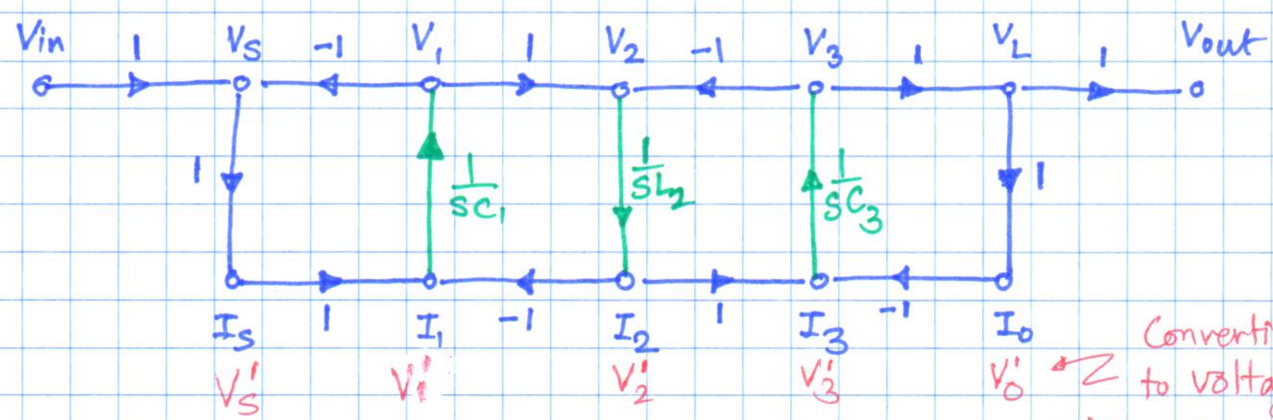
Fully differential Active RC integrator

Example 2. Implementing Third Order Chebyshev filter

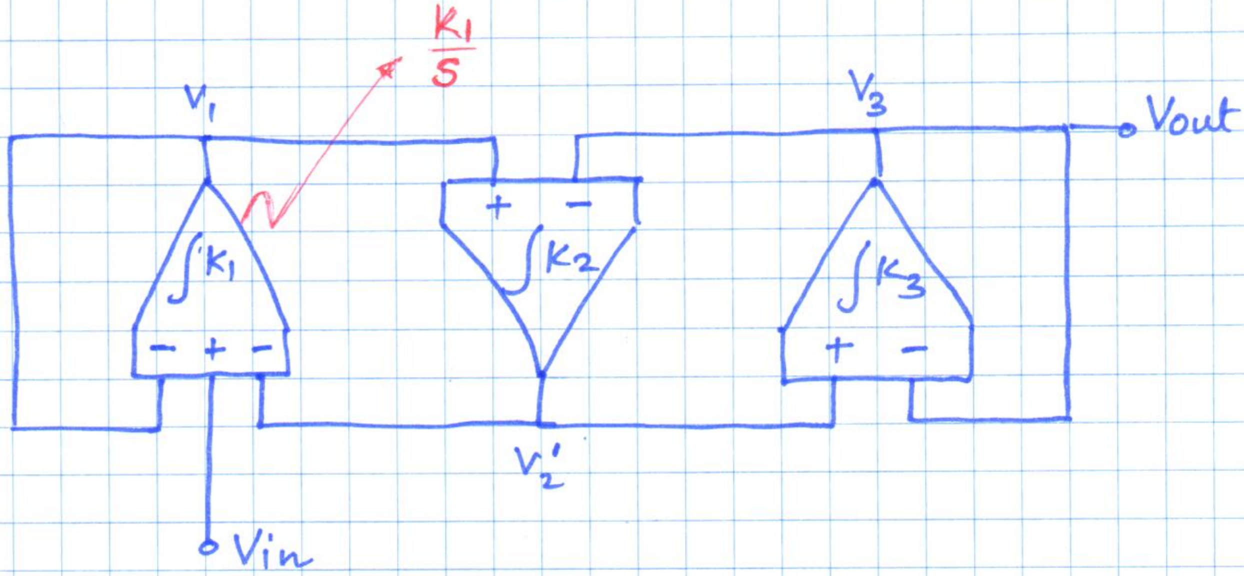


SFG. Steps

1. Lable all branch currents & voltages.
2. Draw voltage as "node" on top & current as "node" on bottom.
3. Represent Integrator relationships first
4. Complete SFG with Rest of KVL & KCL equations.

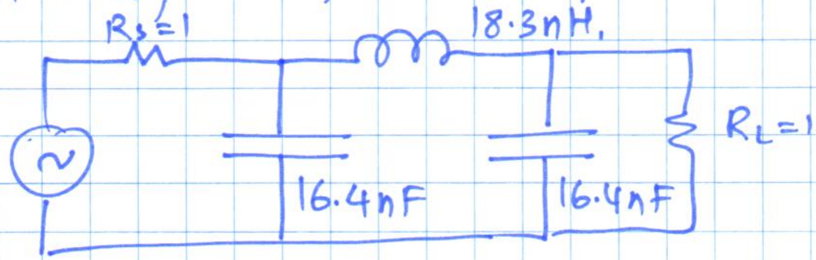


Converting to voltages with scaling R=1



$K_1 = \frac{1}{C_1}$ $\quad K_2 = \frac{1}{L_2}$ $\quad K_3 = \frac{1}{C_3}$

For Chebyshev filter example



Implementing each integrator with fully diff. active RC integrator.

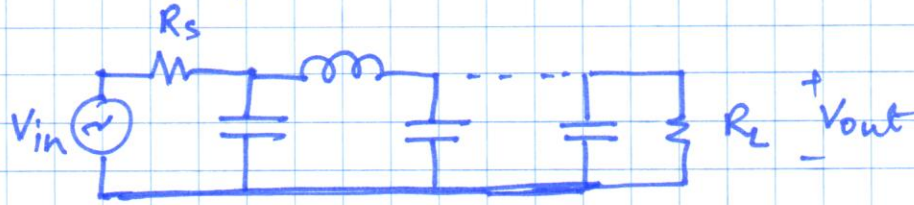
$K_3 = K_1 = \frac{1}{16.4n} = \frac{1}{R_1 C_1} \Rightarrow$ Choosing $C_1 = 1pF$, $R_1 = 16.4 K\Omega$

$K_2 = \frac{1}{18.3n} = \frac{1}{R_2 C_2} \Rightarrow$ Choosing $C_2 = 1pF$, $R_2 = 18.3 K\Omega$

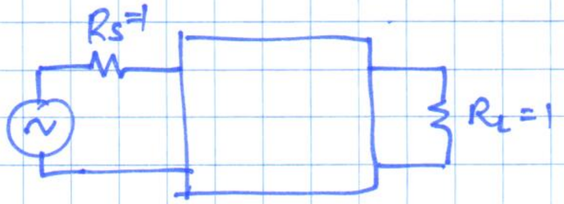
Values compact realizable on chip.

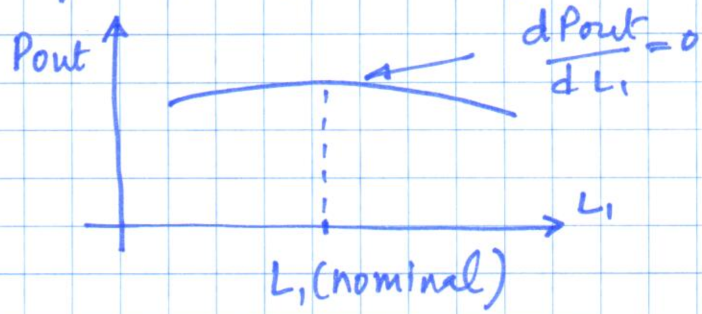
Few comments on filter implementation.

1. Doubly-Terminated Ladder filter



Low sensitivity due to component variation.





→ Component variation insensitivity in passband.

2. Attenuation of $\underline{\underline{6\,dB}}$ due to double-termination

→ Can be corrected by adding gain @ i/p.

<u>Next Lecture:</u>

→ Various ways of implementing Integrators.

→ Trade-offs.