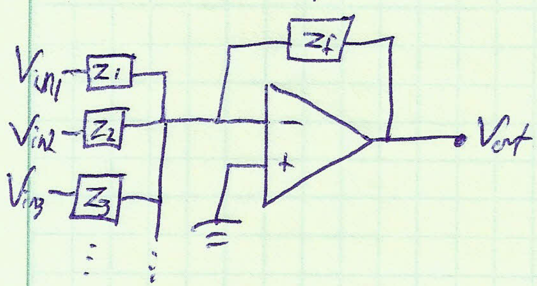
Lab #6 Review

Dual Integrator Realization of Filters

Available components:



$$\frac{V_- - V_{out}}{Z_f} + \frac{V_- - V_{in1}}{Z_{in1}} + \frac{V_- - V_{in2}}{Z_{in2}} + \dots = 0$$

$$V_- = V_+ = 0$$

$$V_{out} = -Z_f\left(\frac{V_{in1}}{Z_{in1}} + \frac{V_{in2}}{Z_{in2}} + \dots\right)$$

If all Zs are resistors, $V_{out} = -R_f\left(\frac{V_{in1}}{R_{in1}} + \frac{V_{in2}}{R_{in2}} + \dots\right)$

this performs sum function (with $\ominus$ sign)

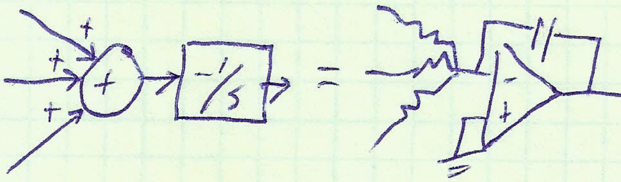
If Z_f is a capacitor, $V_{out} = \frac{-1}{sC}\left(\frac{V_{in1}}{R_{in1}} + \frac{V_{in2}}{R_{in2}} + \dots\right)$

This performs integration, and sum (with $\ominus$ sign)

Thus we can use fewer op-amps by combining integration and sum
Sometimes we still need inverters though.

note negative sign

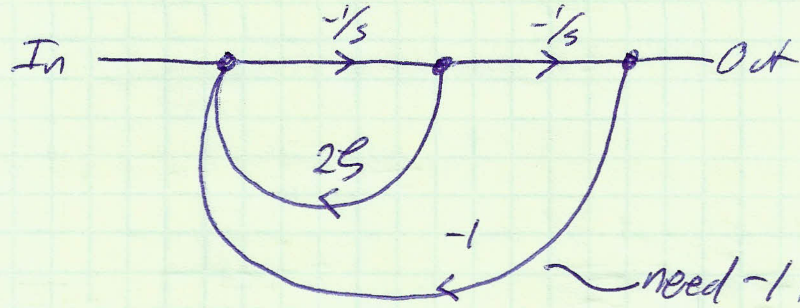
note negative signs



note only one negative sign

inverter

Low-Pass Filter:



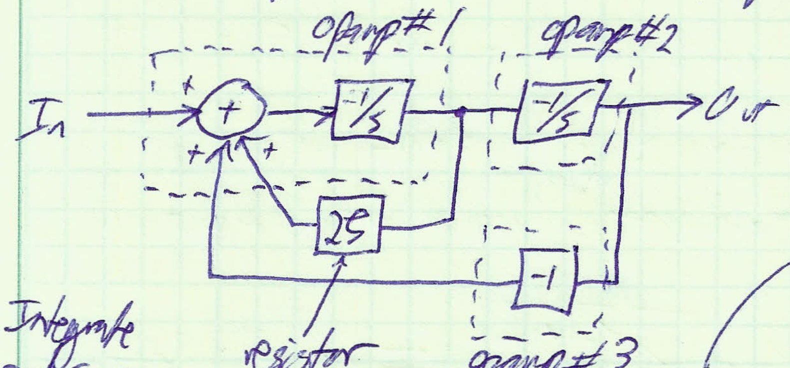
need -1 to make sign come out right

$$\Delta = 1 - \sum_i L_i + \sum_{ij} L_i L_j - \ldots$$

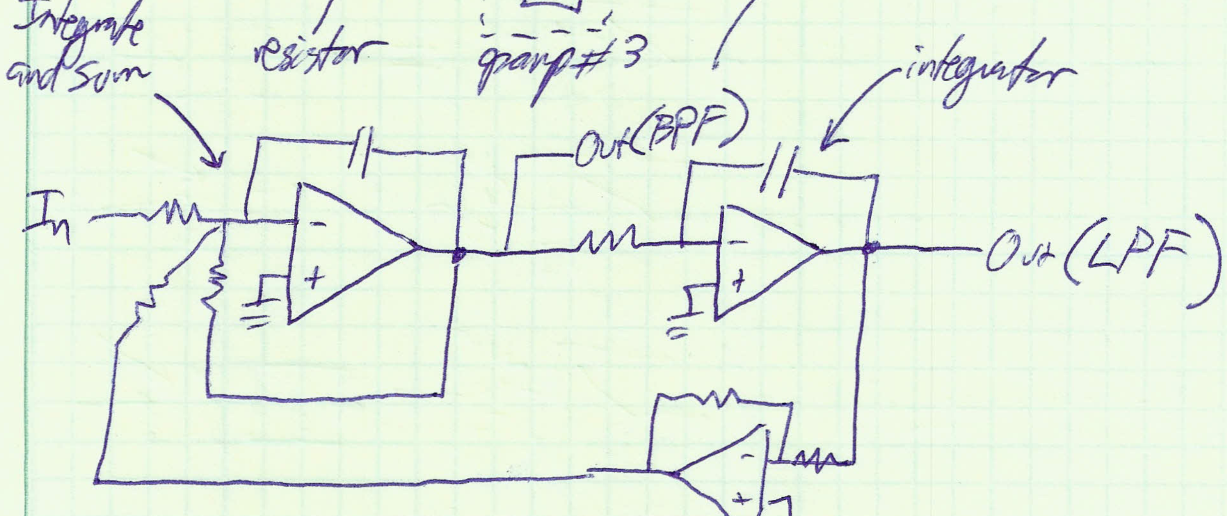
$$\Delta = 1 + 2\zeta/s + 1/s^2$$

$$H = \frac{\sum P_i \Delta_i}{\Delta} = \frac{1/s^2}{1 + 2\zeta/s + 1/s^2} = \frac{1}{1 + 2\zeta s + s^2} : LPF$$

what about ω_0? we will have Rs and Cs that determine this. we are only concerned here with topology and functional form.



$$H(BPF) = \frac{s}{1 + 2\zeta s + s^2}$$

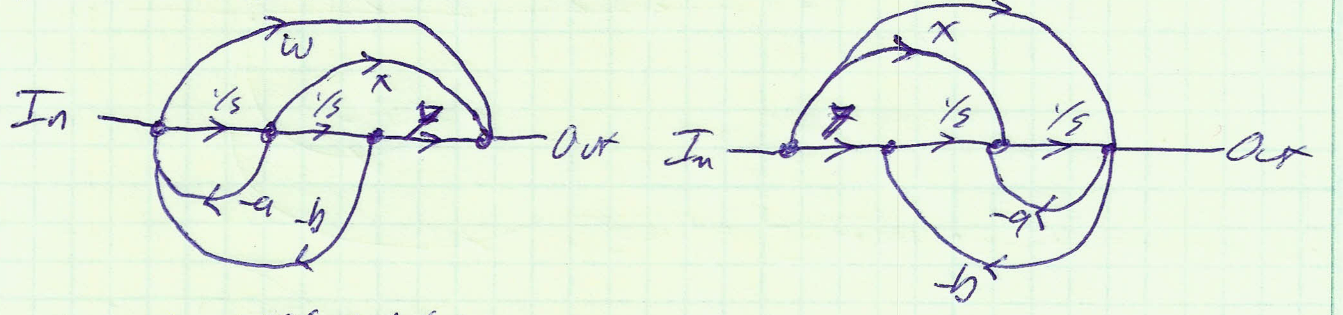


inverter

$Out(BPF) = s \cdot Out(LPF)$

High-Pass, Band-Reject, and All-Pass:

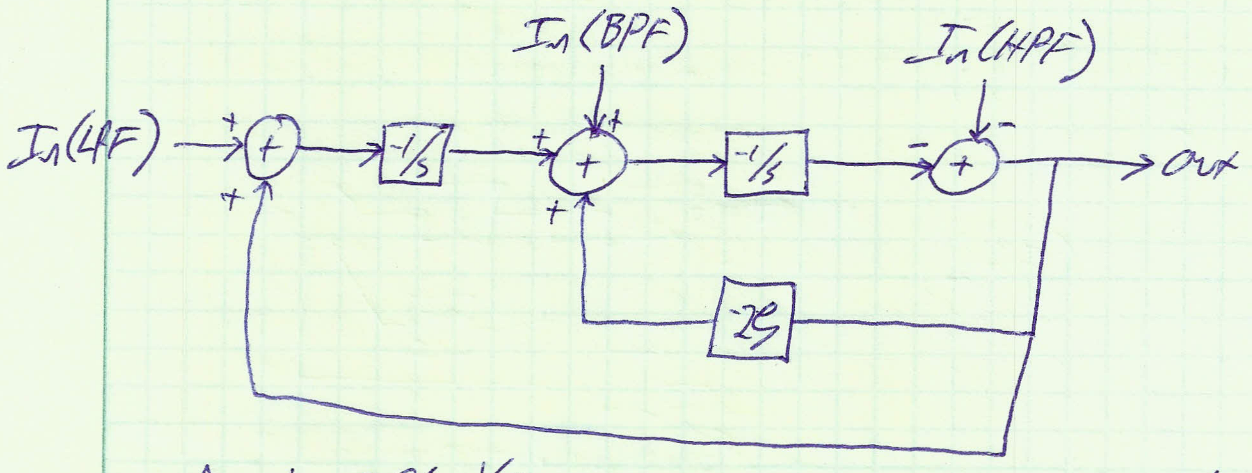
Recall the dual forms



$$H = \frac{w + x/s + y/s^2}{1 + a/s + b/s^2} = \frac{ws^2 + xs + y}{s^2 + as + b}$$

based on flow reversal theorem. Check both cases to see.

Consider this circuit:



$\Delta = 1 + 2\zeta/s + 1/s^2$

$P_{LPF} = -1/s^2$, $P_{BPF} = 1/s$, $P_{HPF} = -1$

$$H = \frac{-1 - s^2}{1 + 2\zeta s + s^2}$$

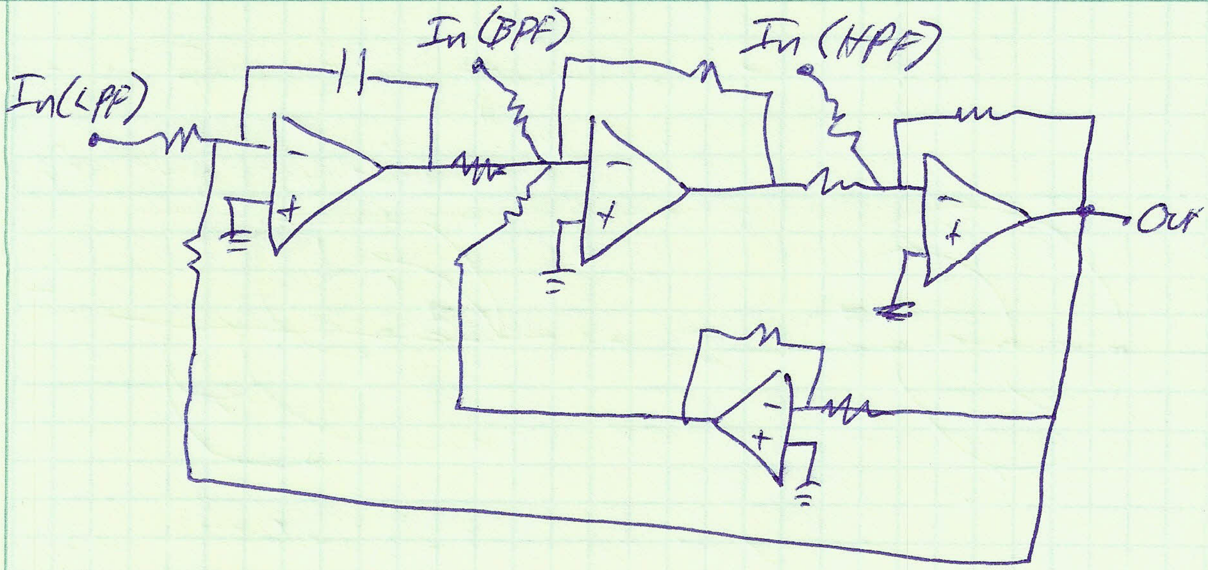
note: 1 − BPF

For HPF, connect only to In (HPF)

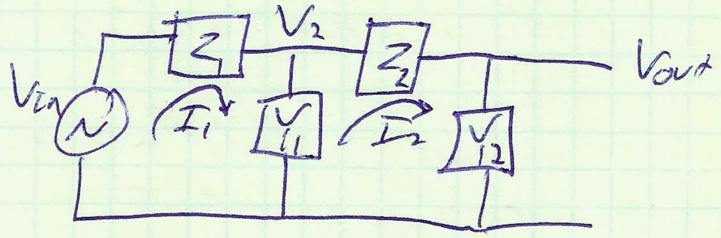
For BRF, connect input to both In (LPF) and In (HPF)

For APF, connect to all three inputs, because BP is negative

2nd order approximation is $e^{-s\tau} \simeq \dfrac{1 - \frac{s\tau}{2} + \frac{s^2\tau^2}{12}}{1 + \frac{s\tau}{2} + \frac{s^2\tau}{12}}$



Signal Flow Graph of Ladder Network



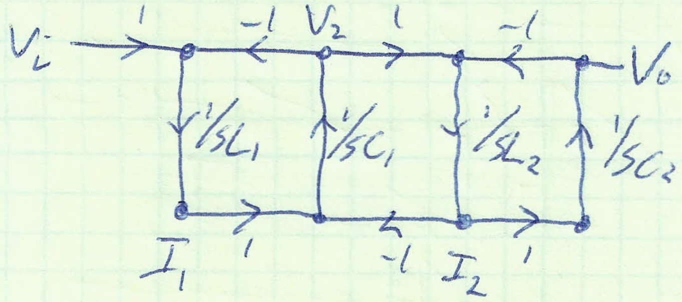
$I_2 = V_{out} Y_2$, $V_2 = V_{out} + I_2 Z_2 = V_{out}(Y_2 Z_2 + 1)$

$I_1 = V_2 Y_1 + I_2$, $V_{in} = V_2 + I_1 Z_1 = V_2(1 + Y_1 Z_1) + V_{out} Y_2 Z_1$

$$V_{in} = V_{out}\left[(1 + Y_2 Z_2)(1 + Y_1 Z_1) + Y_2 Z_1\right]$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{1 + Y_2 Z_2 + Y_1 Z_1 + Y_2 Z_1 + Y_1 Z_1 Y_2 Z_2}$$

$$H(s) = \frac{1}{1 + s^2(C_2 L_2 + C_1 L_1 + C_2 L_1) + s^4(C_1 L_1 C_2 L_2)}$$



3 loops

$$\Delta = 1 - L_1 - L_2 - L_3 + L_1 L_3$$

1 forward path

$$P = \frac{1}{s^4 L_1 C_1 L_2 C_2}$$

$$H = \frac{1/s^4 L_1 C_1 L_2 C_2}{1 + 1/s^2 L_1 C_1 + 1/s^2 L_2 C_1 + 1/s^2 L_2 C_2 + 1/s^4 L_1 C_1 L_2 C_2}$$

$$= \frac{1}{s^4 L_1 C_1 L_2 C_2 + s^2 (L_2 C_2 + L_1 C_2 + L_1 C_1) + 1}$$

Same as circuit result

Make V_2 and I_2 negative