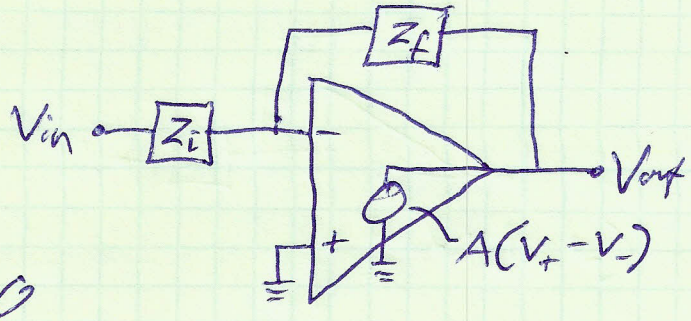
# Question #1




a) $\frac{V_- - V_{out}}{Z_f} + \frac{V_- - V_{in}}{Z_i} = 0$

$V_{out} = A(V_+ - V_-) = -AV_- \longrightarrow V_- = -V_{out}/A$

$$\frac{-V_{out}/A - V_{out}}{Z_f} + \frac{-V_{out}/A - V_{in}}{Z_i} = 0$$

$$V_{out}\left(Z_f + Z_i + AZ_i\right) = -AZ_f V_{in}$$

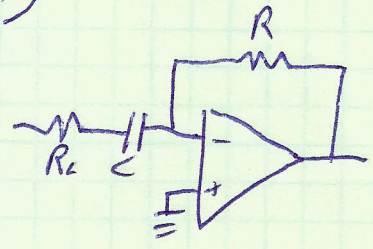
$$\frac{V_{out}}{V_{in}} = \frac{-Z_f}{Z_i} \cdot \frac{AZ_i}{Z_f + Z_i + AZ_i} = \frac{-Z_f}{Z_i} \cdot \frac{A\frac{Z_i}{Z_f+Z_i}}{1 + A\frac{Z_i}{Z_f+Z_i}} = \frac{-Z_f}{Z_i} \cdot \frac{AB}{1+AB}$$

b) $B = \frac{1/sC}{R + 1/sC} = \frac{1}{1+sCR}$, $A = G/s$

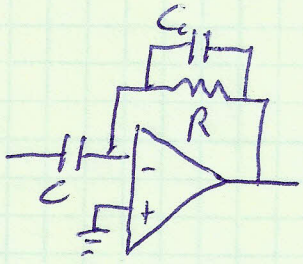
$$H = -sCR \cdot \frac{\frac{G}{s} \cdot \frac{1}{1+sCR}}{1 + \frac{G}{s} \cdot \frac{1}{1+sCR}} = -sCR \cdot \frac{1}{\frac{s}{G}(1+sCR)+1}$$

$$= \frac{-sCR}{1 + \frac{s}{G} + \frac{s^2CR}{G}} \rightarrow \text{second order response}$$

c)



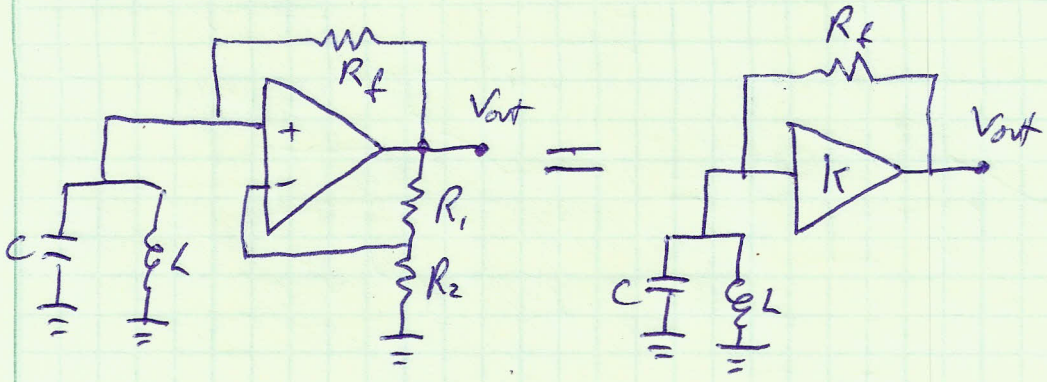

Compensation resistor




Compensation capacitor

Both of these can be used to add a zero to the transfer function.

# Question #2

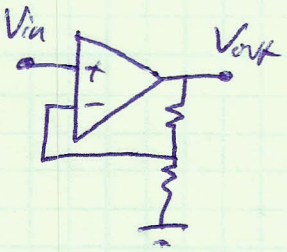



a) $V_{out} = A(V_+ - V_-)$ as $A \to \infty$

$V_{out} = A\left(V_{in} - \frac{R_2}{R_1+R_2} V_{out}\right)$

$V_{out}\left(1 + A\frac{R_2}{R_1+R_2}\right) = A V_{in}$

$K = \frac{V_{out}}{V_{in}} = \frac{A}{1 + A\frac{R_2}{R_1+R_2}}$ as $A \to \infty$ $\quad K = \frac{R_1+R_2}{R_2}$

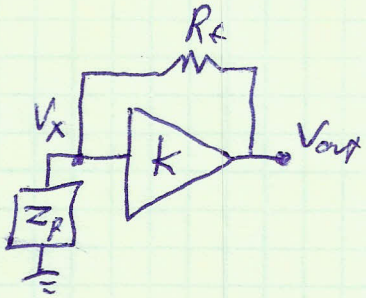



b) $A = K$

$B = -V_x / V_{out}$

$\frac{V_x}{Z_p} + \frac{V_x - V_{out}}{R_f} = 0$

$V_x\left(\frac{1}{Z_p} + \frac{1}{R_f}\right) = \frac{V_{out}}{R_f}$




$B = -\frac{V_x}{V_{out}} = \frac{-1}{R_f\left(\frac{1}{Z_p} + \frac{1}{R_f}\right)} = \frac{-Z_p}{Z_p + R}$

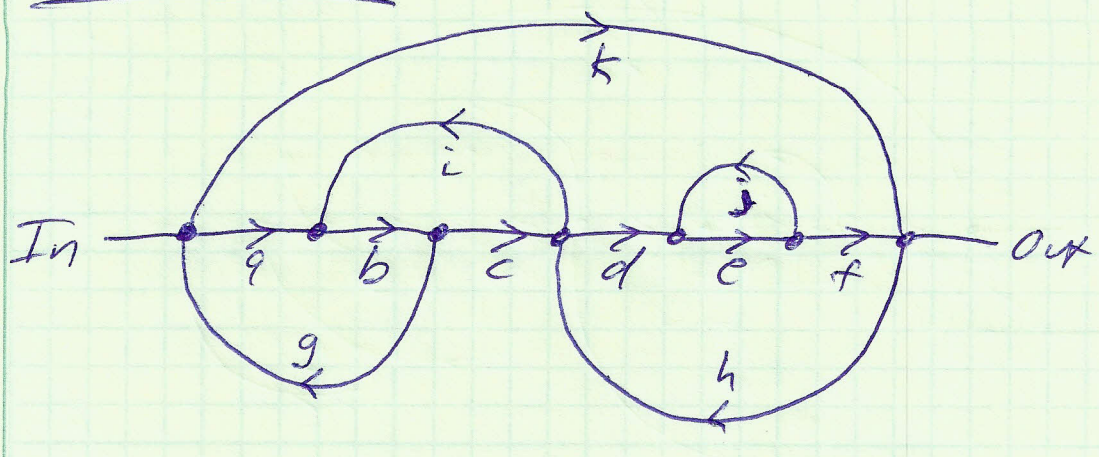
$Z_p = \frac{1}{sC + 1/sL} = \frac{sL}{1+s^2LC}$

$AB = \frac{-KsL/(1+s^2LC)}{sL/(1+s^2LC) + R_f} = \frac{-KsL/R}{1 + sL/R + s^2LC}$

c) at $\omega = \omega_o = \frac{1}{\sqrt{LC}}$, $AB = \frac{-j\omega_o KL/R}{1 + j\omega_o L/R - 1} = -K$

oscillator: $AB = -1$, $K = 1$, $R_1 = 0$ and $R_2 = \infty$ or any value

# Question #3




a) $\Delta = 1 - abg - bci - defh - ej - khibg + abgej + bciej + abgdefh + khibgej$

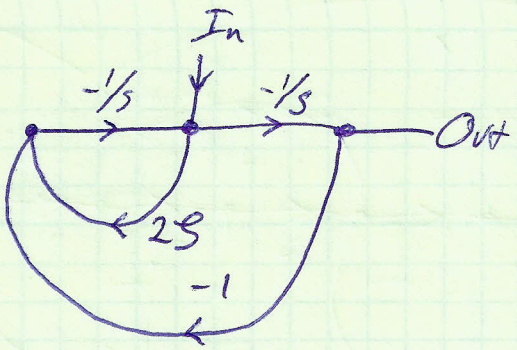
b) two forward paths: $k$ and $abcdef$

c) $H = \dfrac{abcdef + k(1 - bci - ej + bciej)}{\Delta}$

$$H = \frac{abcdef + k(1 - bci - ej + bciej)}{1 - abg - bci - defh - ej - khibg + abgej + bciej + abgdefh + khibgej}$$

# Question #4

a)




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

$$H = \frac{-1/s}{1 + 2\zeta/s + 1/s^2} = \frac{-s}{1 + 2\zeta s + s^2} \rightarrow \text{band-pass response}$$

c)