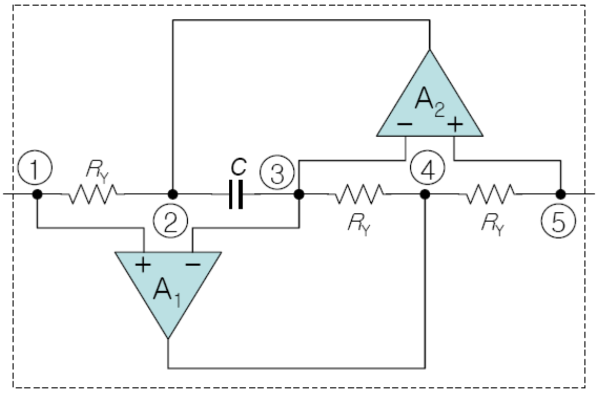
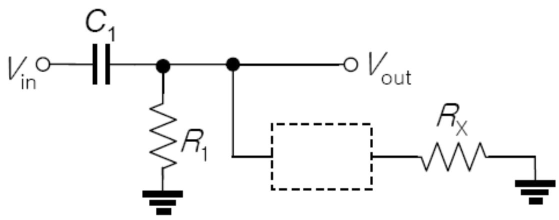
| **Quiz 10** | Subject | Professor | Student ID# | Student Name | Score |
|---|---|---|---|---|---|
| Date: 2009.11.18 | Microelectronics 2 | Jong-Ho Lee | | | |

1. Following figure depicts main part of general impedance converter (GIC). Assume all op amps are ideal. Answer for the following questions.




(a) Using the circuit in the dashed box above, now we implement following circuit. The dashed box and a resistor $R_x$ connected in series represent so-called simulated inductor. The box in this problem has the same circuit shown above. Prove that node 4 in the box can also serve as an output. The node 4 exhibits lower output impedance than does node 1 ($V_{out}$). Briefly describe the reason. (5)




**Answer)**

Since $V_{out} = V_1 = V_3 = V_5$, the current flowing through $R_X$ is equal to $V_{out} / R_X$, yielding

$$V_4 = \frac{V_{out}}{R_X} R_Y + V_{out} = V_{out}\left(1 + \frac{R_Y}{R_X}\right)$$

Thus, $V_4$ is simply an amplified version of Vout.

A output impedance at the output node is

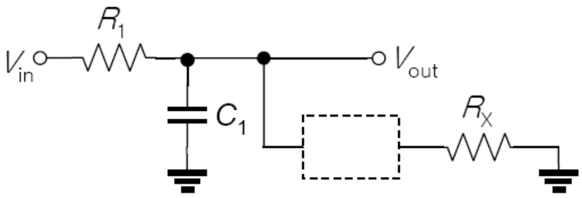
$$Z_{out} = \frac{1}{C_1 s} \parallel R_1 \parallel R_X R_Y C s$$

On the other hand, a output impedance at node 4 is very small because a output impedance of an ideal op amp is very small. ($Z_{out,opamp} \approx 0$)

$$Z_{out,node4} = R_Y \parallel R_Y \parallel Z_{out,opamp} \approx 0 \quad (Z_{in,opamp} = \infty)$$

Therefore, the node 4 exhibits lower output impedance than does node 1(Vout).

(b) Using the circuit in the dashed box above, now we implement following circuit. What is type of the filter shown below? Select one among LP, BP, HP, and BR filters and describe the reason qualitatively. (3)



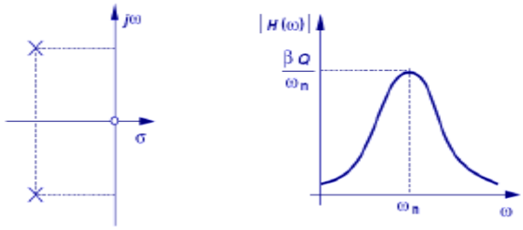

**Answer)**

$$H(s) = \frac{V_{out}}{V_{in}} = \frac{\frac{1}{C_1 s} \parallel R_X R_Y C s}{R_1 + \left(\frac{1}{C_1 s} \parallel R_X R_Y C s\right)} = \frac{\frac{R_X R_Y C s}{1 + R_1 R_Y C C_1 s^2}}{R_1 + \frac{R_X R_Y C s}{1 + R_1 R_Y C C_1 s^2}}$$

$$= \frac{R_X R_Y C s}{R_1 R_Y C C_1 s^2 + R_X R_Y C s + R_1}$$

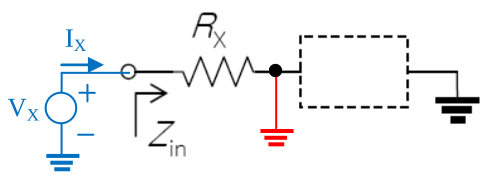
The magnitude approaches **zero** for both **s→0** and **s→∞**, reaching a maximum in between. It can be proved that the peak occurs at $w = w_n$ and has a value of $\beta Q / w_n$.

$$\left(w_n = \frac{1}{\sqrt{R_Y C C_1}}, \quad Q = \frac{R_1}{R_X}\sqrt{\frac{C_1}{R_Y C}}\right)$$




Therefore, the type of the filter is a band-pass filter shown above.

(c) Using the circuit in the dashed box above, now we implement following circuit. Calculate the $Z_{in}$. (2)




**Answer)**

Since $V_1 = V_3 = V_5 = 0$ ($V_5$ is grounded),

$$Z_{in} = \frac{V_X}{I_X} = R_X$$

Use front side only