

ECE/ENGRD 2100

Introduction to Circuits for ECE

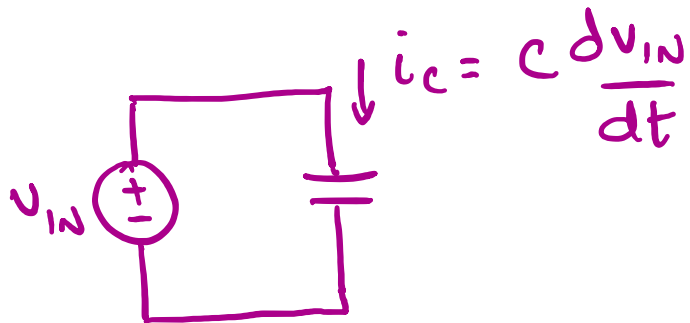
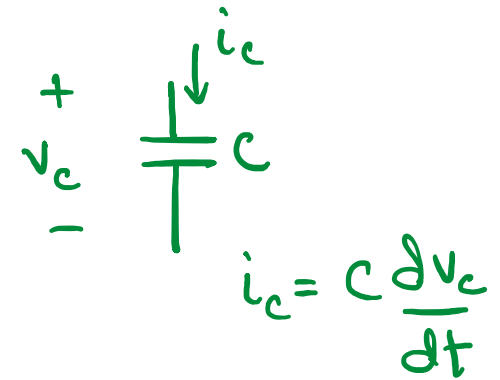
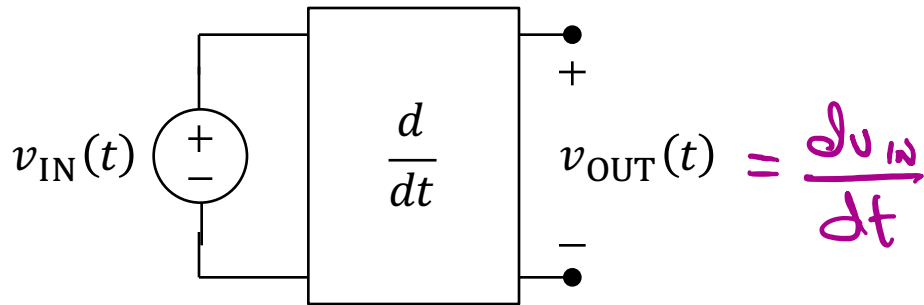
Lecture 33

Additional Dynamic Op-Amp Circuits

Announcements

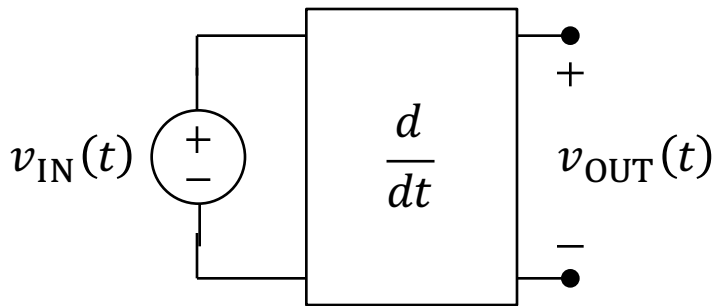
- Recommended Reading:
 - Textbook Chapter 7.7 and Chapter 8.5
- Upcoming due dates:
 - Lab report 5 due by 11:59 pm on Friday April 19, 2019
 - Homework 5 due by 11:59 pm on Friday April 26, 2019
 - Prelab 6 due by 11:59 pm on Friday April 26, 2019

Differentiation – First Attempt



Need to convert i_c into a voltage

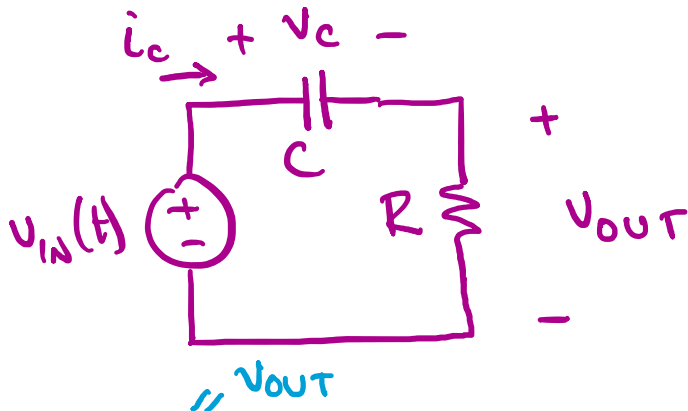
Differentiation – Second Attempt



$$i_c = C \frac{dv_c}{dt} \Rightarrow v_{OUT} = RC \frac{dv_c}{dt}$$

$$v_c = v_{IN} - v_{OUT}$$

$$v_{OUT} = RC \frac{d(v_{IN} - v_{OUT})}{dt}$$



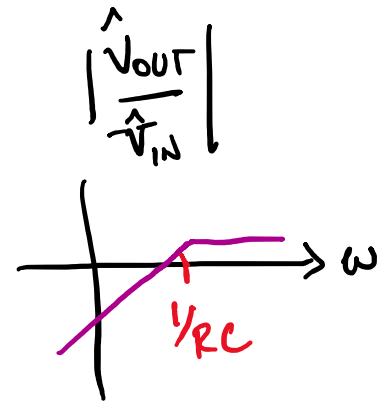
$$|v_{OUT}| \ll |v_c|$$

$$\Rightarrow v_{OUT} \approx RC \frac{dv_{IN}}{dt}$$

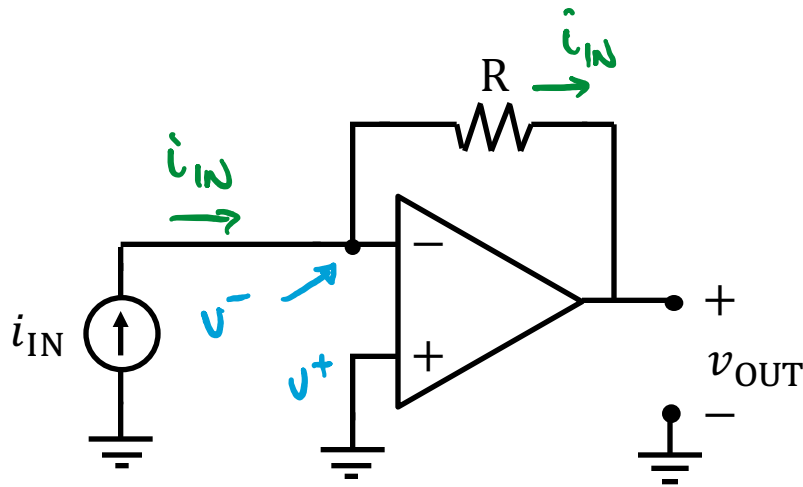
$$|RC \frac{dv_c}{dt}| \ll |v_c|$$

$$v_c \rightarrow \hat{V}_c e^{j\omega t} \Rightarrow |RC j\omega \hat{V}_c e^{j\omega t}| \ll |\hat{V}_c e^{j\omega t}|$$

$$\Rightarrow RC\omega \ll 1 \Rightarrow \omega \ll 1/RC$$



Current-to-Voltage Conversion using Op-Amp

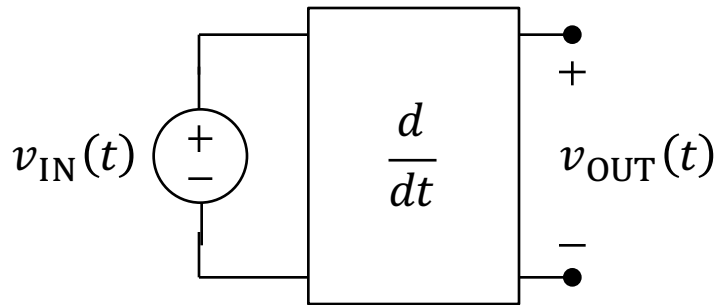


$$v^- \approx v^+ = 0$$

$$v_{OUT} = 0 - R i_{IN}$$

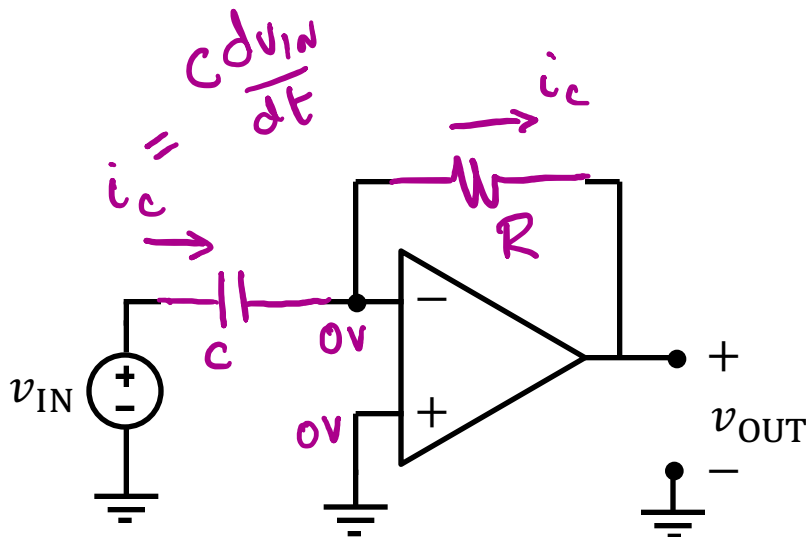
$$v_{OUT} = -R i_{IN}$$

Better Differentiation

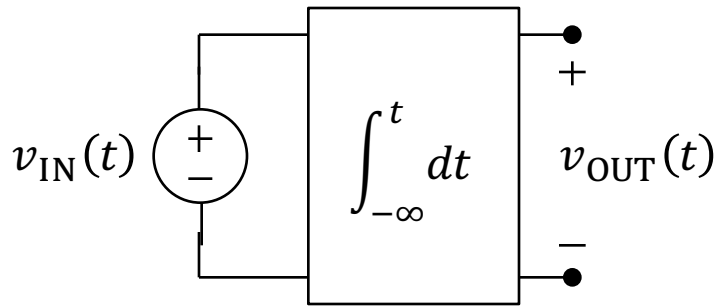


$$v_{OUT} = -Ri_c$$

$$v_{OUT} = -RC \frac{dv_{IN}}{dt}$$



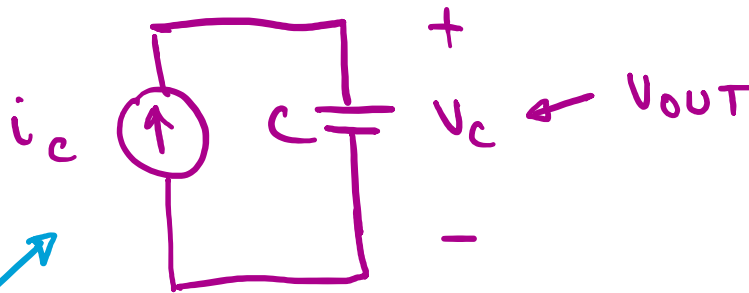
Integration – First Attempt



$$i_c = C \frac{dv_c}{dt}$$

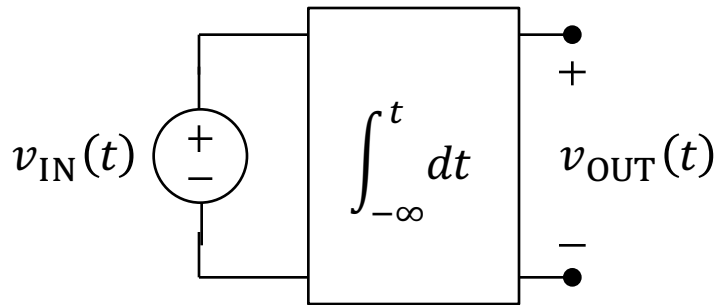
A hand-drawn circuit diagram of a capacitor. It consists of two parallel vertical lines representing the capacitor plates. The top plate is labeled with a plus sign (+) and the bottom plate with a minus sign (-). The voltage across the capacitor is labeled v_c . A downward-pointing arrow next to the capacitor is labeled i_c , representing the current flowing into the top plate.

$$v_c = \frac{1}{C} \int_{-\infty}^t i_c dt$$



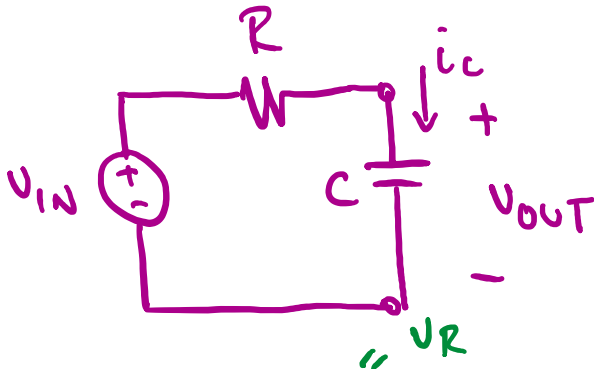
Need to convert v_{IN} into i_c

Integration – Second Attempt



$$i_c = \frac{v_{IN} - v_{OUT}}{R}$$

$$v_{OUT} = \frac{1}{C} \int_{-\infty}^t i_c dt = \frac{1}{RC} \int_{-\infty}^t (v_{IN} - v_{OUT}) dt$$



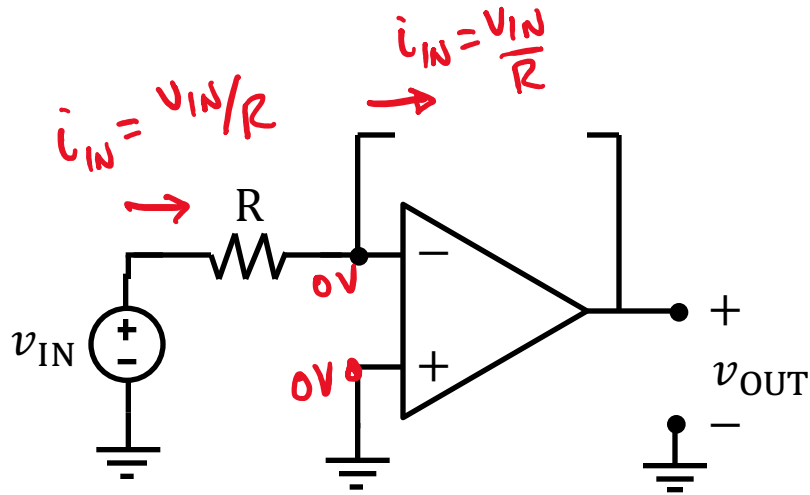
$$\text{if } |v_{OUT}| \ll |v_R|$$

$$v_{OUT} \approx \frac{1}{RC} \int_{-\infty}^t v_{IN} dt$$

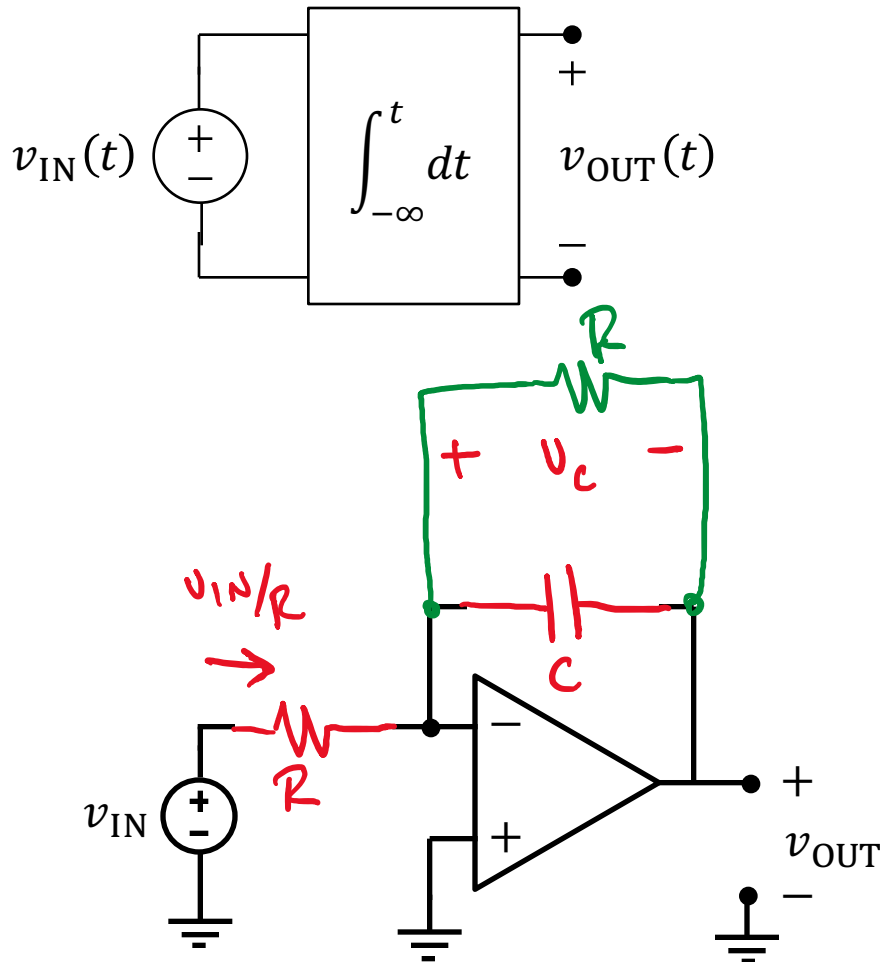
$$|v_{OUT}| \ll \left| RC \frac{dv_{OUT}}{dt} \right|$$

$$\Rightarrow \left| \hat{V}_{OUT} e^{j\omega t} \right| \ll \left| RC j\omega \hat{V}_{OUT} e^{j\omega t} \right| \Rightarrow 1 \ll \omega RC \Rightarrow \omega \gg \frac{1}{RC}$$

Voltage-to-Current Conversion using Op-Amp

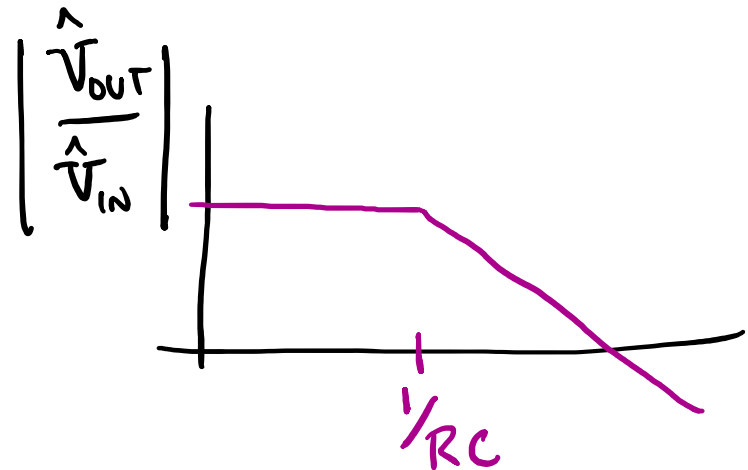


Better Integration

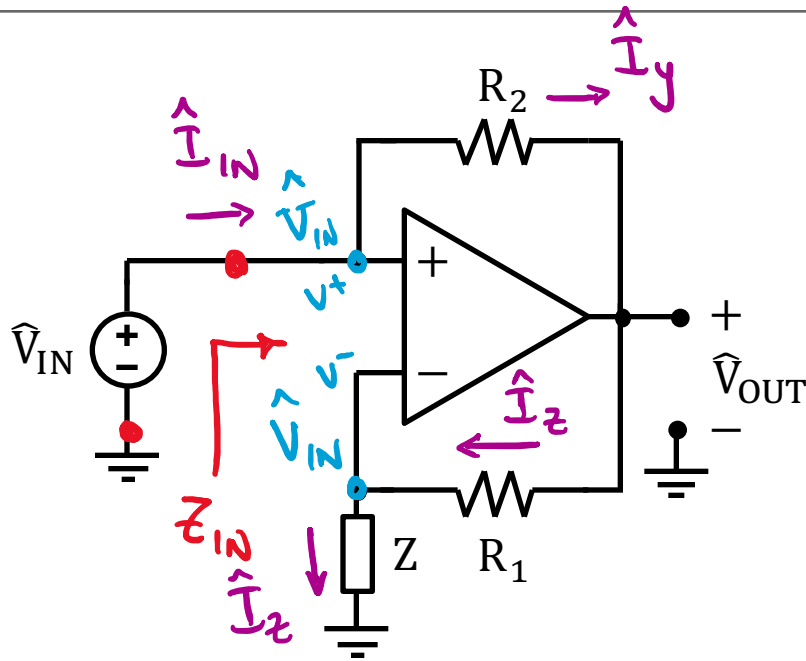


$$v_{OUT} = -v_C = -\frac{1}{C} \int_{-\infty}^t \frac{v_{IN}}{R} dt$$

$$v_{OUT} = -\frac{1}{RC} \int_{-\infty}^t v_{IN} dt$$



Negative Impedance Converter (NIC)



$$\hat{I}_z = \frac{\hat{V}_{IN}}{Z} \quad \leftarrow$$

$$\hat{I}_z = \frac{\hat{V}_{OUT} - \hat{V}_{IN}}{R_1}$$

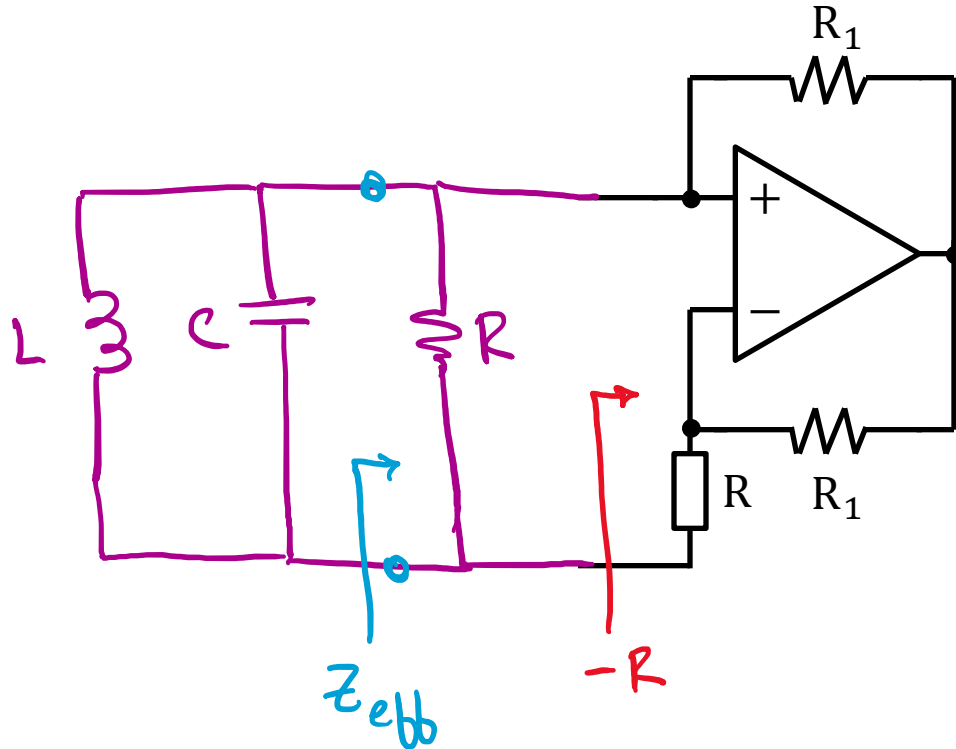
$$\hat{I}_{IN} = \hat{I}_Y = \frac{\hat{V}_{IN} - \hat{V}_{OUT}}{R_2} = -\frac{(\hat{V}_{OUT} - \hat{V}_{IN})R_1}{R_1 R_2}$$

$$\hat{I}_{IN} = -\hat{I}_z \frac{R_1}{R_2} = -\frac{R_1}{R_2} \frac{\hat{V}_{IN}}{Z}$$

$$Z_{IN} \equiv \frac{\hat{V}_{IN}}{\hat{I}_{IN}} = -\frac{R_2}{R_1} Z$$

$$\text{if } R_1 = R_2 \text{ \& } Z = R \Rightarrow \boxed{Z_{IN} = -R}$$

Ideal Oscillator using NIC



$$Z_{ebb} = R \parallel (-R) = \frac{R(-R)}{R-R} = \infty$$

Gyrator using NIC

$$z_1 = (R+z) \parallel (-R)$$

$$= \frac{-R(R+z)}{R+z-R}$$

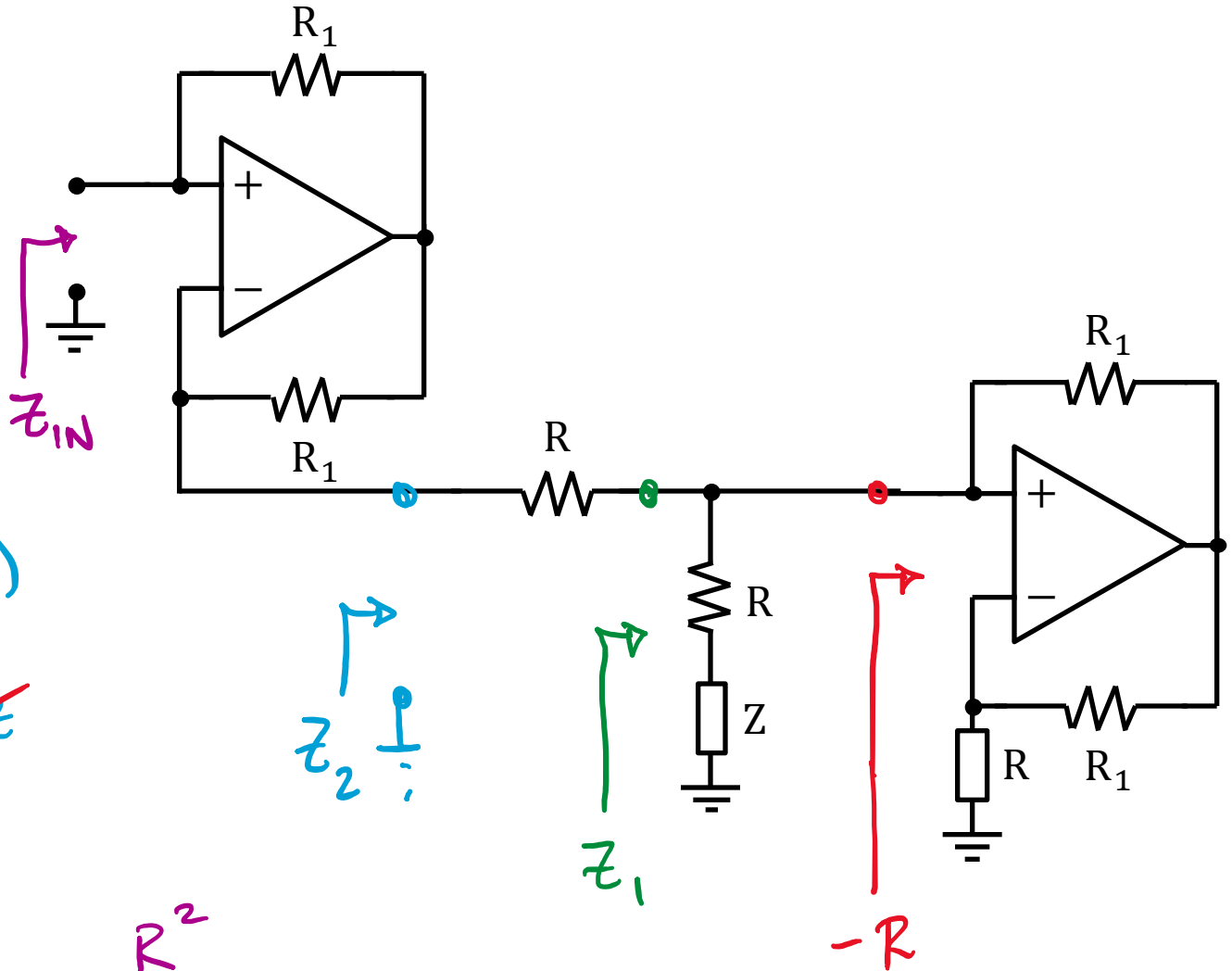
$$z_1 = \frac{-R(R+z)}{z}$$

$$z_2 = R - \frac{R(R+z)}{z}$$

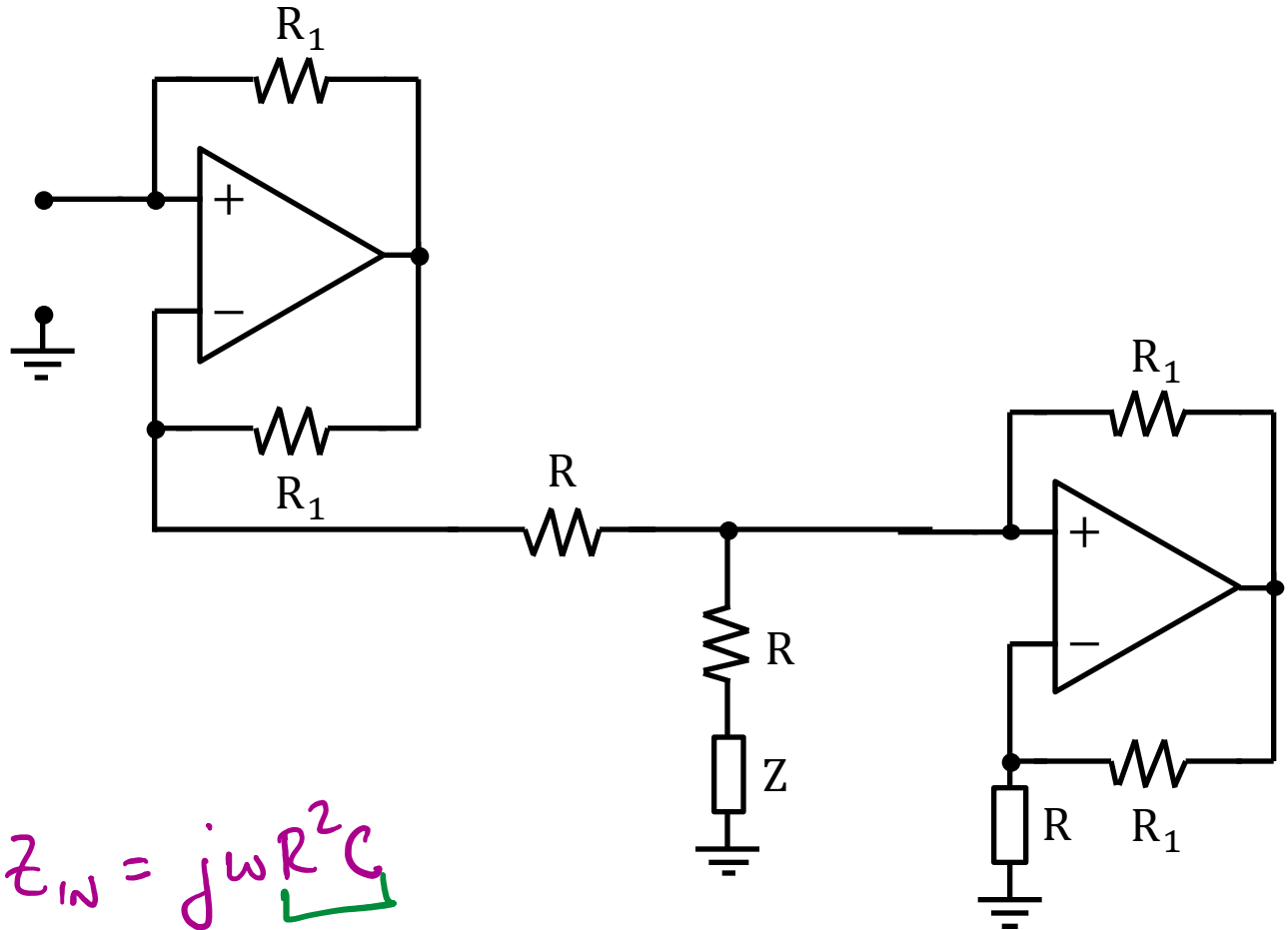
$$z_2 = \frac{Rz - R^2 - Rz}{z}$$

$$z_2 = -\frac{R^2}{z}$$

$$z_{IN} = \frac{R^2}{z}$$



Gyrator using NIC (Cont.)



Z_{IN}

$$Z_{IN} = \frac{R^2}{Z}$$

$$Z = \frac{1}{j\omega C} \Rightarrow Z_{IN} = j\omega R^2 C$$

Left