ECE/ENGRD 2100

Introduction to Circuits for ECE

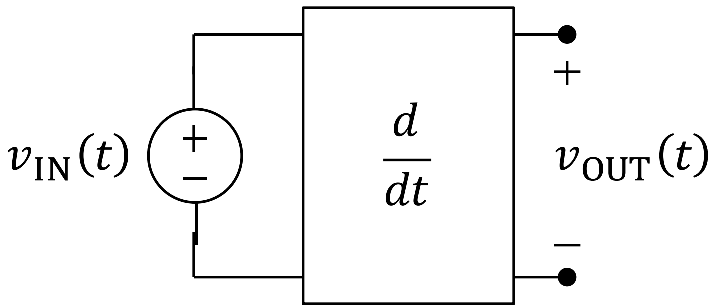
Lecture 33

Additional Dynamic Op-Amp Circuits

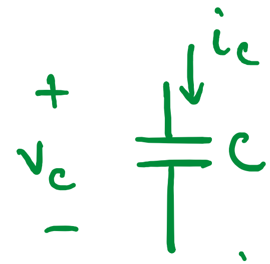
Announcements

- 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

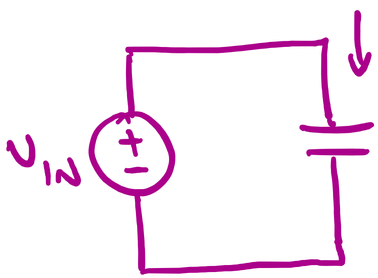
Differentiation – First Attempt



$= \frac{dv_{IN}}{dt}$



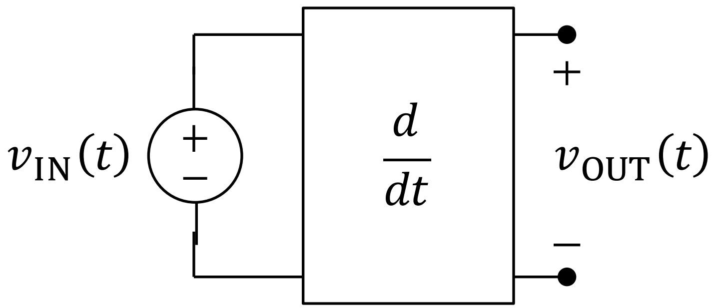
$i_c = C\frac{dv_c}{dt}$



$i_c = C\frac{dv_{IN}}{dt}$

Need to convert i_c into a voltage

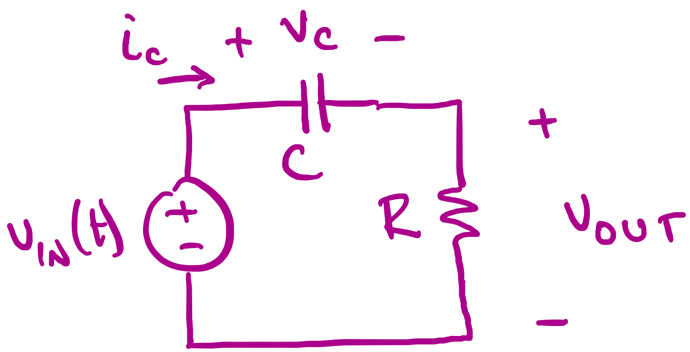
Differentiation – Second Attempt



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

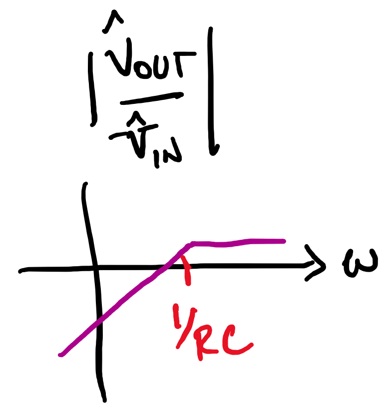
$$v_c = v_{IN} - v_{OUT}$$

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



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

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

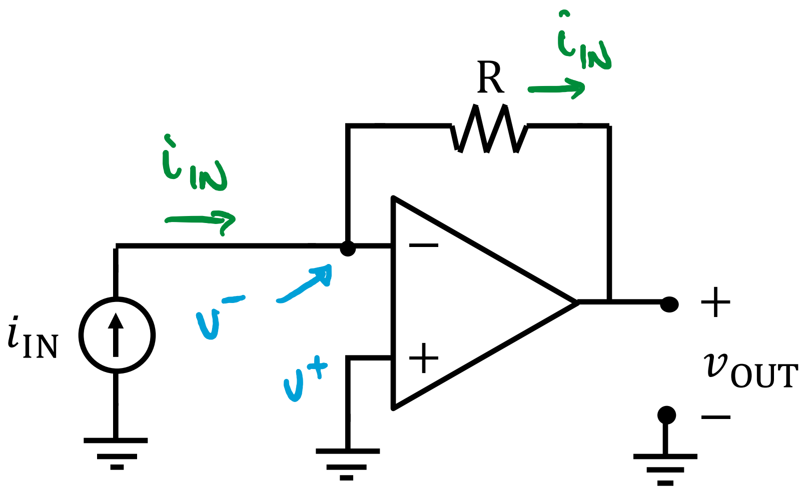


$$\left|RC\frac{dv_c}{dt}\right| \ll |v_c| \qquad \left(RC\frac{dv_c}{dt} = v_{OUT}\right)$$

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

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

Current-to-Voltage Conversion using Op-Amp

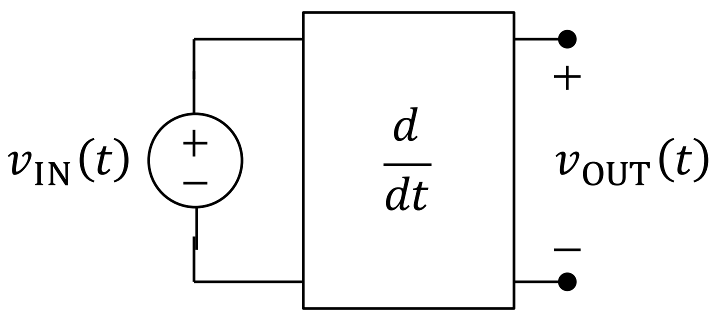


$v^- \approx v^+ = 0$

$v_{OUT} = 0 - Ri_{IN}$

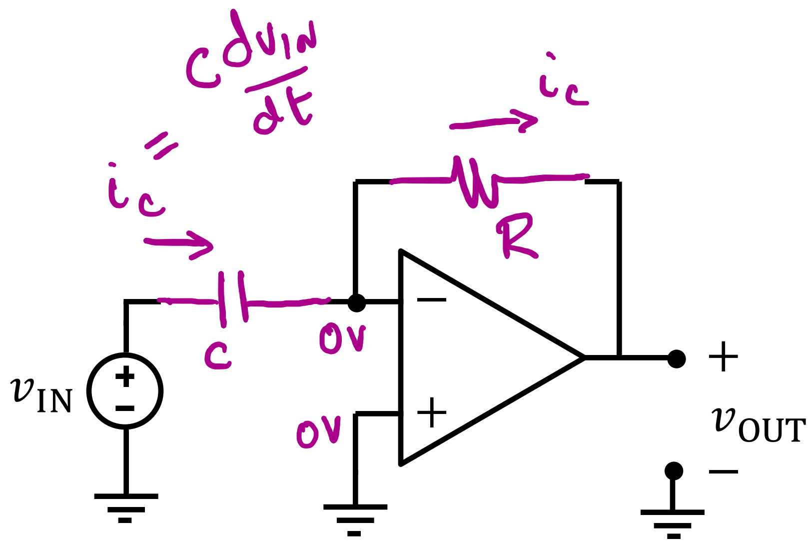
$v_{OUT} = -Ri_{IN}$

Better Differentiation

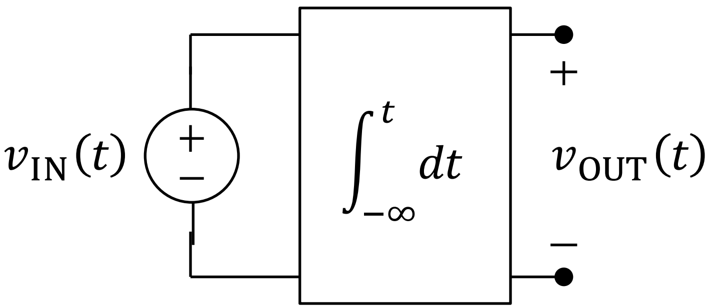


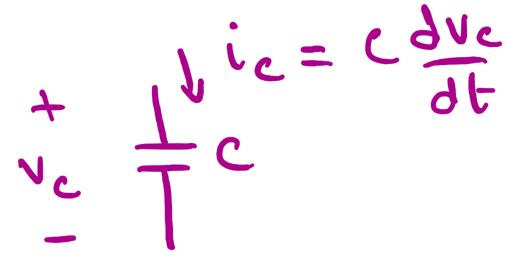
$v_{OUT} = -Ri_c$

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

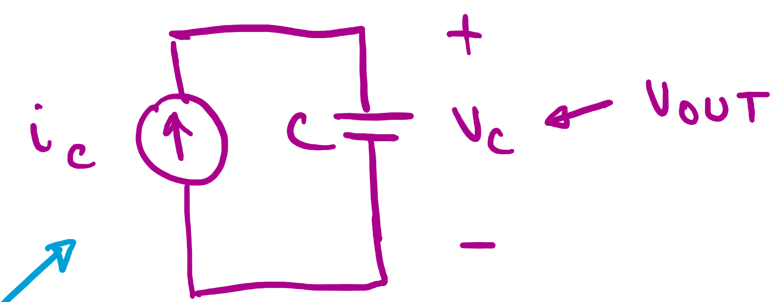


Integration – First Attempt



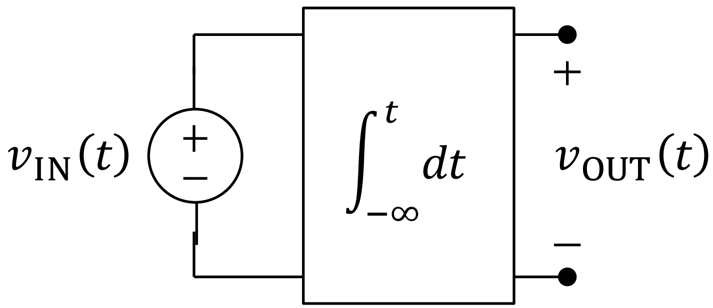


$$v_c = \frac{1}{C}\int_{-\infty}^{t} i_c \, dt$$



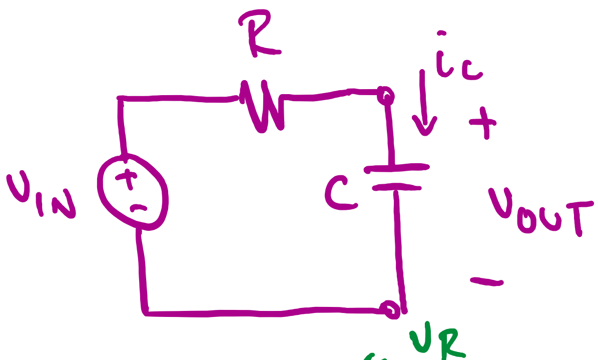
Need to convert v_{IN} into i_c

Integration – Second Attempt



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

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



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

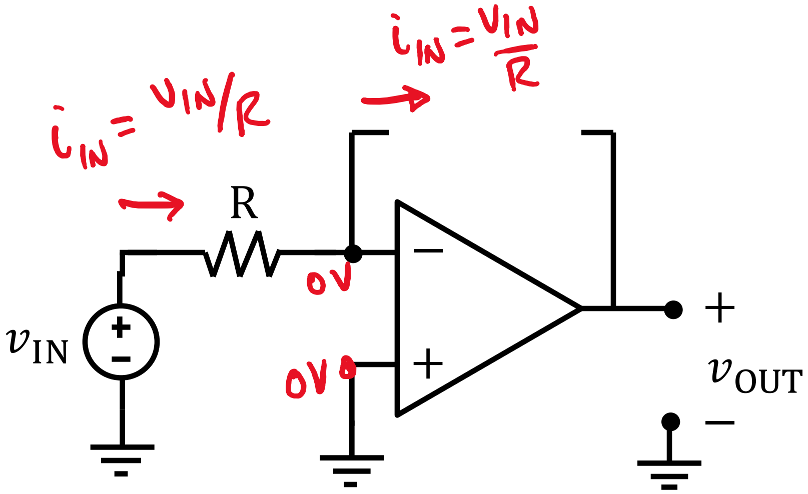
$$v_{OUT} \approx \frac{1}{RC}\int_{-\infty}^{t} v_{IN}\, dt$$

" v_R

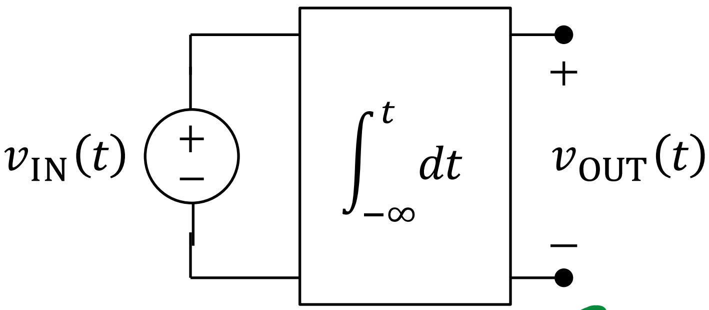
$$|v_{OUT}| \ll \left| RC\frac{dv_{OUT}}{dt} \right|$$

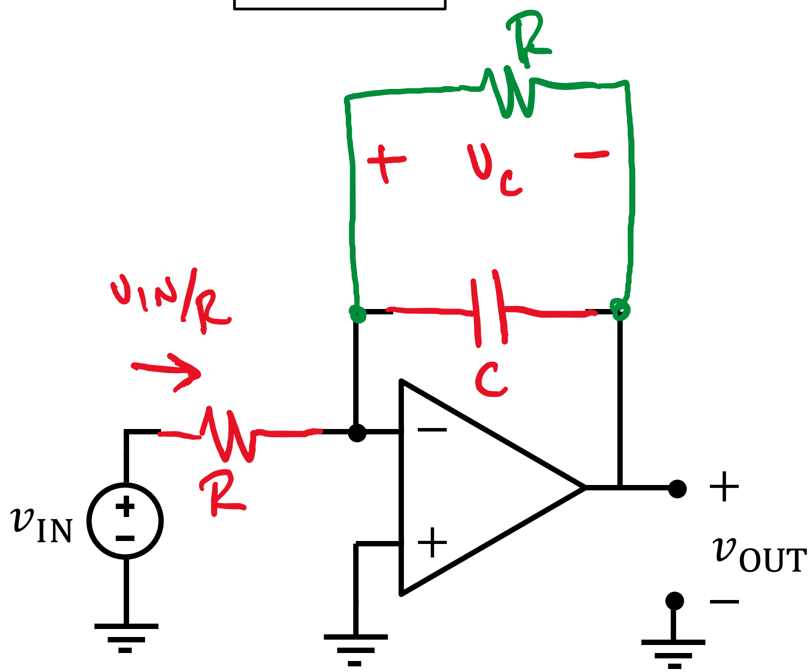
$$\Rightarrow \left|\hat{V}_{OUT} e^{j\omega t}\right| \ll \left|RCj\omega \hat{V}_{OUT} e^{j\omega t}\right| \Rightarrow 1 \ll \omega RC \Rightarrow \omega \gg \frac{1}{RC}$$

Voltage-to-Current Conversion using Op-Amp



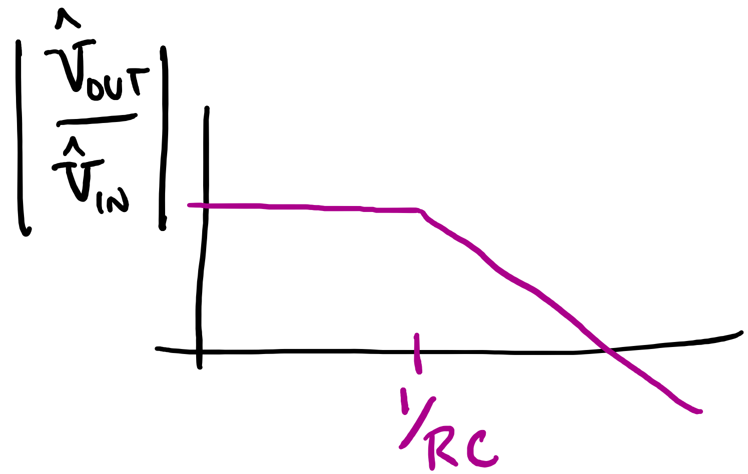
Better Integration



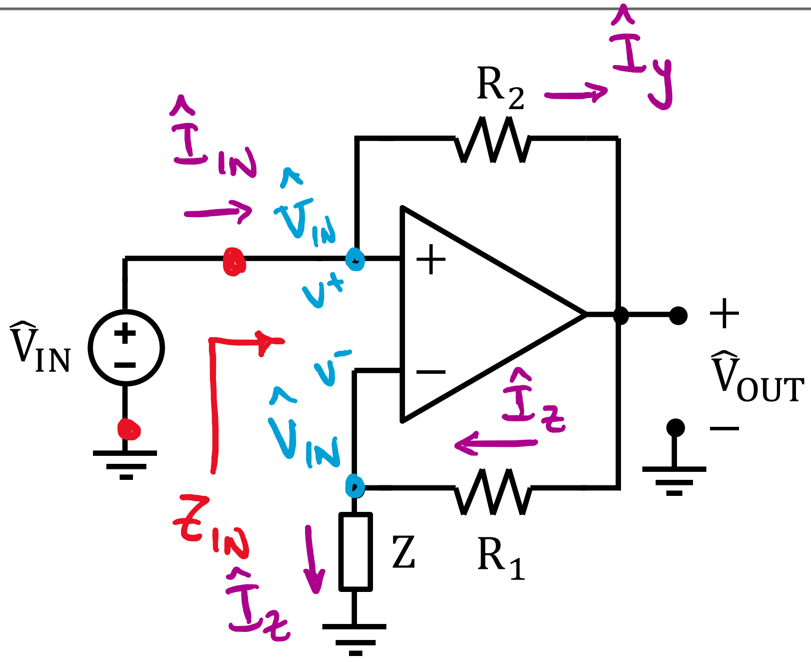


$$v_{OUT} = -v_C = -\frac{1}{C}\int_{-\infty}^{t} \frac{v_{IN}}{R}\, dt$$

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



Negative Impedance Converter (NIC)



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

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

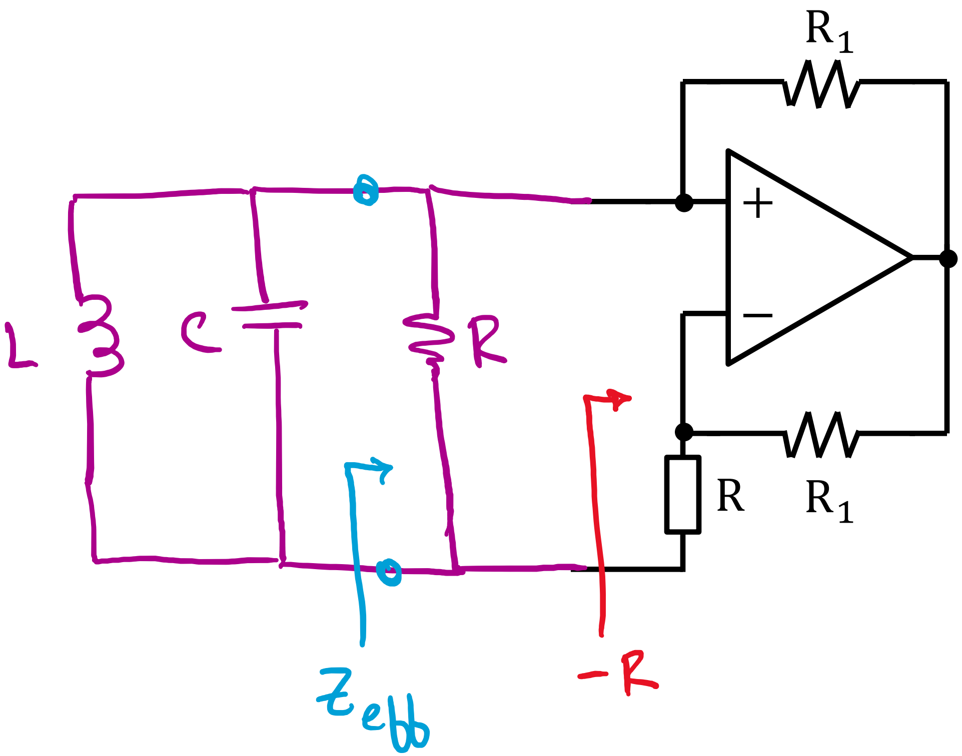
$$\hat{I}_{IN} = \hat{I}_y = \frac{\hat{V}_{IN} - \hat{V}_{OUT}}{R_2} = -\frac{(\hat{V}_{OUT} - \hat{V}_{IN})}{R_1}\frac{R_1}{R_2}$$

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

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

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

Ideal Oscillator using NIC



$$Z_{eff} = R \| (-R) = \frac{R(-R)}{R-R} = \infty$$

Gyrator using NIC

$$Z_1 = (R+Z) \| (-R)$$

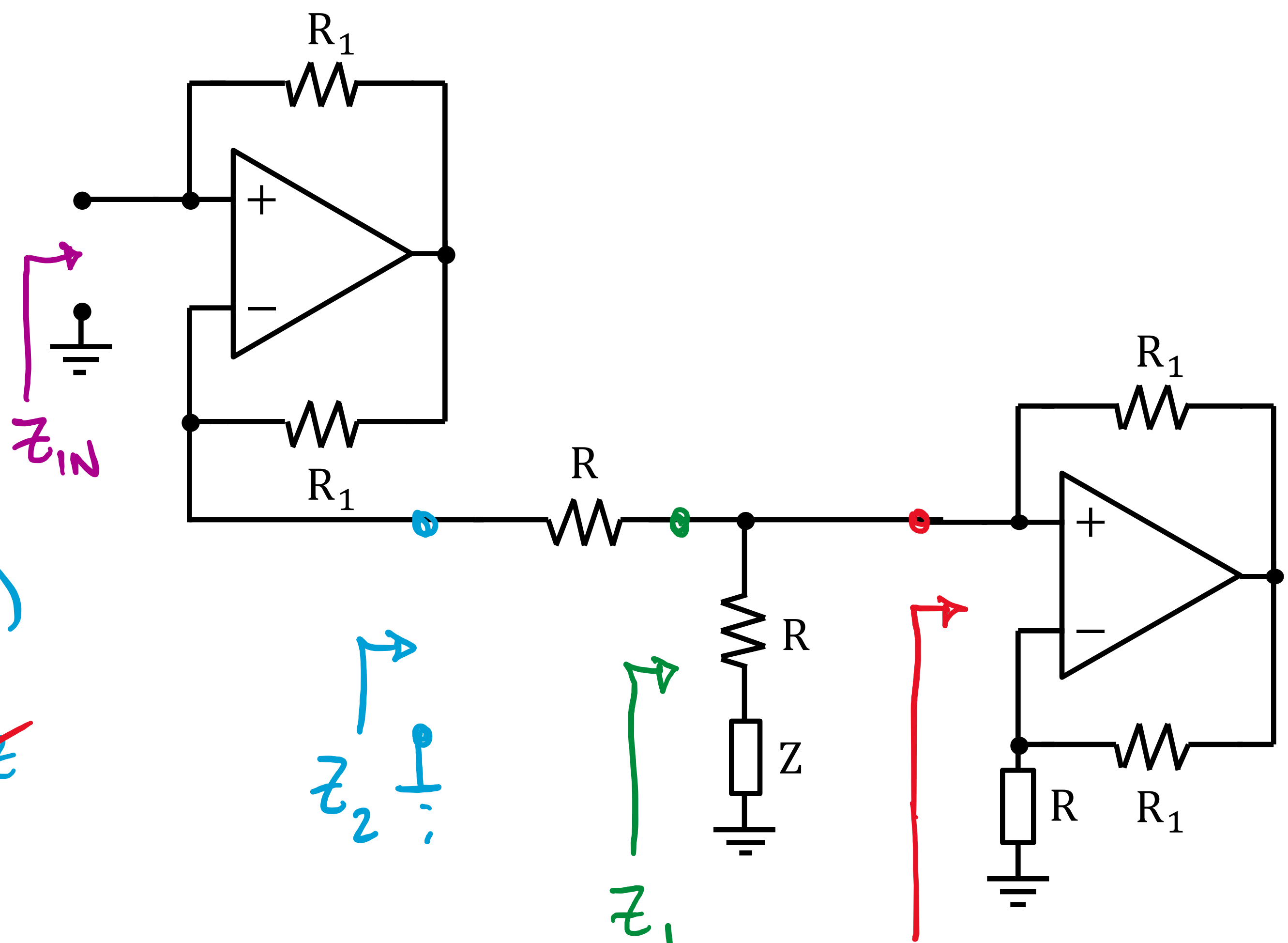
$$= \frac{-R(R+Z)}{\cancel{R}+Z-\cancel{R}}$$

$$Z_1 = \frac{-R(R+Z)}{Z}$$

$$Z_2 = R - \frac{R(R+Z)}{Z}$$

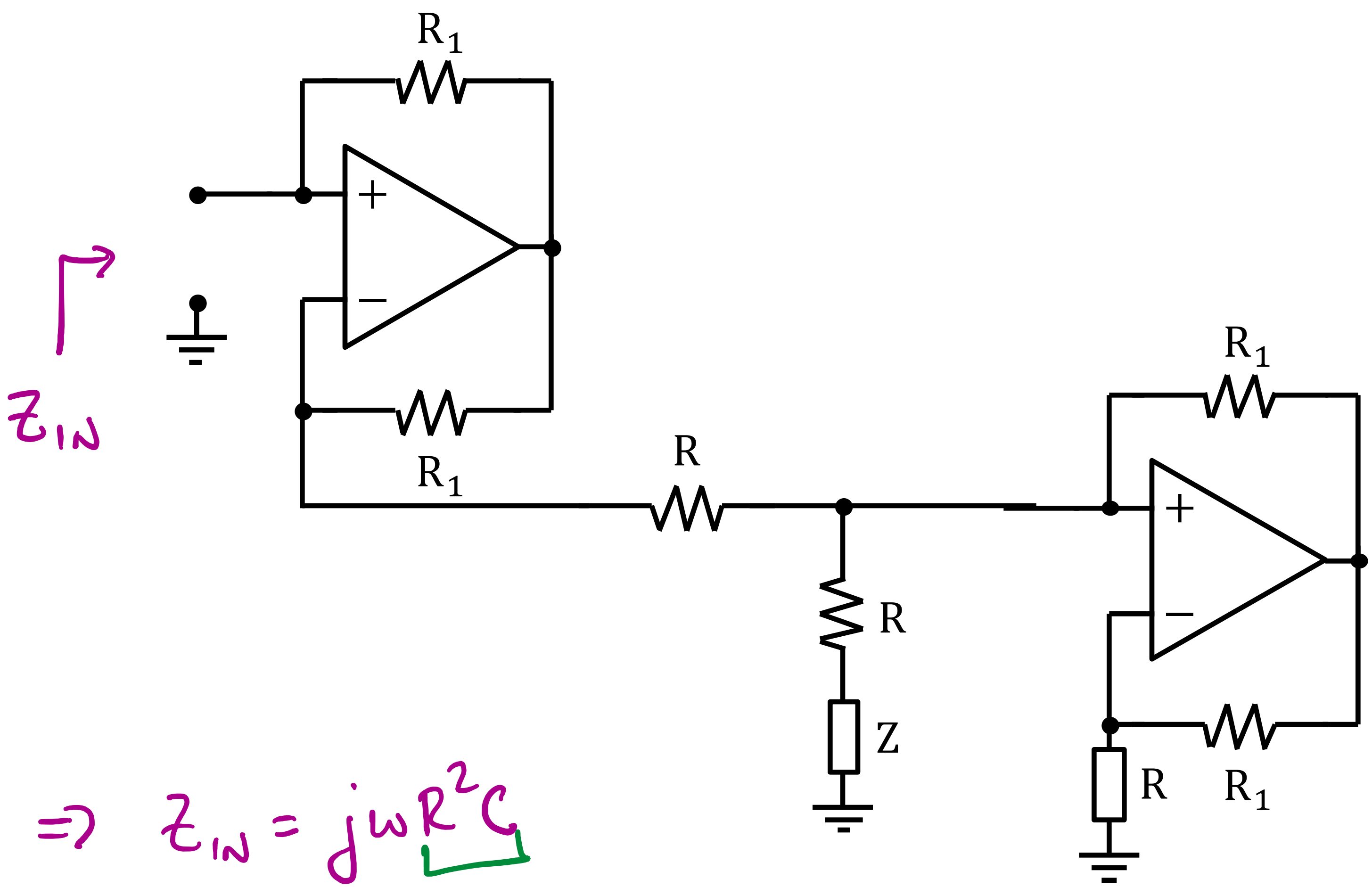
$$Z_2 = \frac{\cancel{RZ} - R^2 - \cancel{RZ}}{Z}$$

$$Z_2 = -\frac{R^2}{Z}$$



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

Gyrator using NIC (Cont.)



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

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