OP AMP AND TRANSFER FUNCTIONS MACROMODELS

Systems containing a significant number of Op Amps can take a lot of time of simulation when Op Amps are described at the transistor level. For instance a 5^{th} order filter might involve 7 Op Amps and if each Op Amps contains say 12 to 15 transistors, the SPICE analysis of a circuit containing 60 to 75 Transistors can be too long and tricky in particular for time domain simulations. Therefore the use of a macromodel representing the Op Amp behavior reduces the simulation time and the complexity of the analysis.

The simplicity of the analysis of Op Amps containing macromodels is because macromodels can be implemented using SPICE primitive components. Some examples of macromodels are discussed next.

http://www.analog.com/static/imported-files/application_notes/48136144500269408631801016AN138.pdf

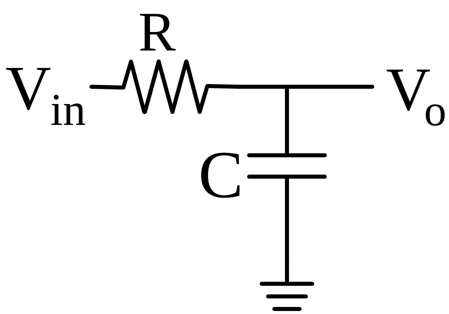
http://www.national.com/analog/amplifiers/spice_models

FUNDAMENTAL ON MACROMODELING USING ONLY PRIMITIVE SPICE COMPONENTS

1. Low Pass First Order

$$H_{LP_1} = \frac{k}{1 + s/\omega_p}$$

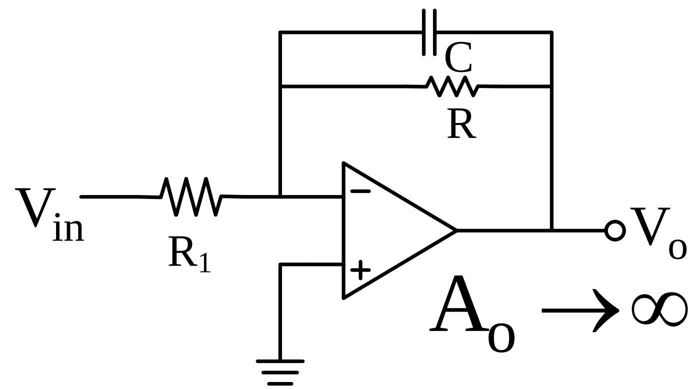
Option 1



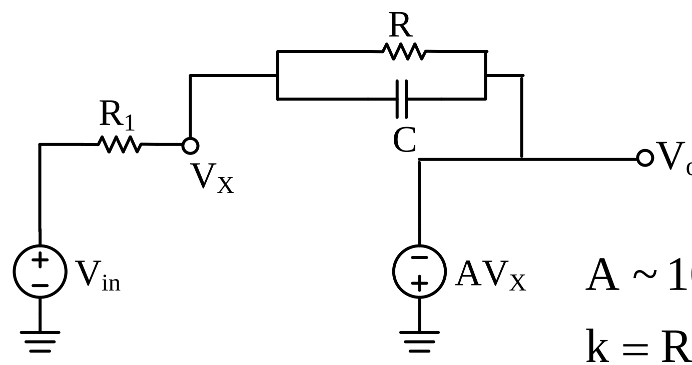
$$\omega_p = \frac{1}{RC}$$

$$k = 1$$

Option 2



$$A_o \rightarrow \infty$$

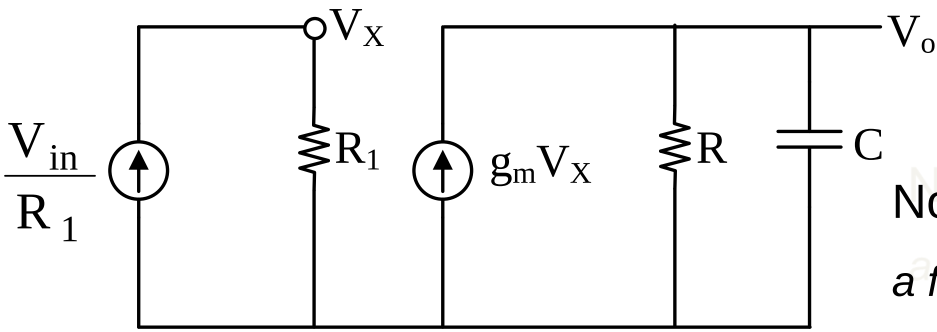


$$A \sim 10^9$$

$$k = R/R_1$$

$$\omega_p = \frac{1}{RC}$$

Option 3



Note.- *If you need to isolate the output use a final VCVS with a gain of one*

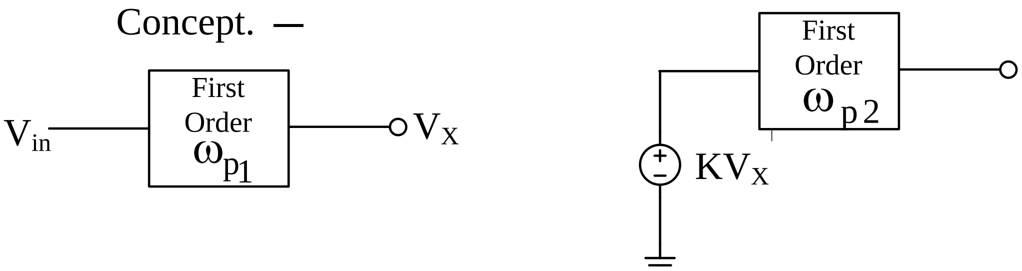
$$k = g_m R \quad ; \quad \omega_p = \frac{1}{RC}$$

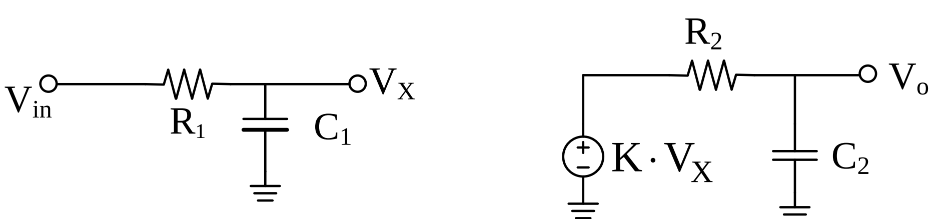
2. Higher Order Low Pass

$$H_{LP_2} = \frac{K}{\left(1 + s/\omega_{p_1}\right)\left(1 + s/\omega_{p_2}\right)}$$

Le us consider a second-order case:

Concept. –





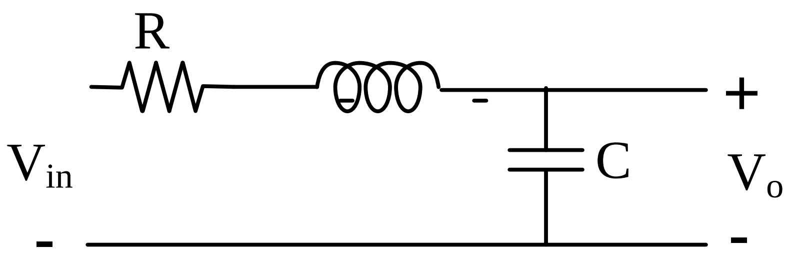
$$\omega_{p_1} = 1/R_1C_1$$

$$\omega_{p_2} = 1/R_2C_2$$

$$K = K$$

Second-Order LP (two complex poles)

$$H_{LP_3} = \frac{K_o}{s^2 + \frac{\omega_o}{Q}s + \omega_o^2}$$



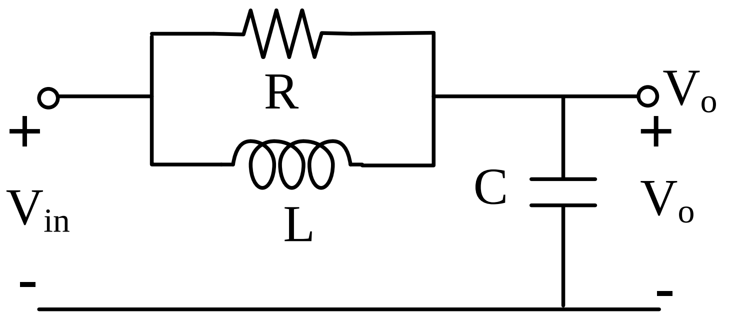
$K_o = 1/LC \quad ; \quad H_{LP_3}(0) = 1$

$\omega_o^2 = 1/LC$

$\frac{\omega_o}{Q} = \frac{R}{L}$

Resonator (one zero, two complex poles)

$$H_R = \frac{k(1 + s/\omega_z)}{s^2 + \frac{\omega_o}{Q}s + \omega_o^2}$$



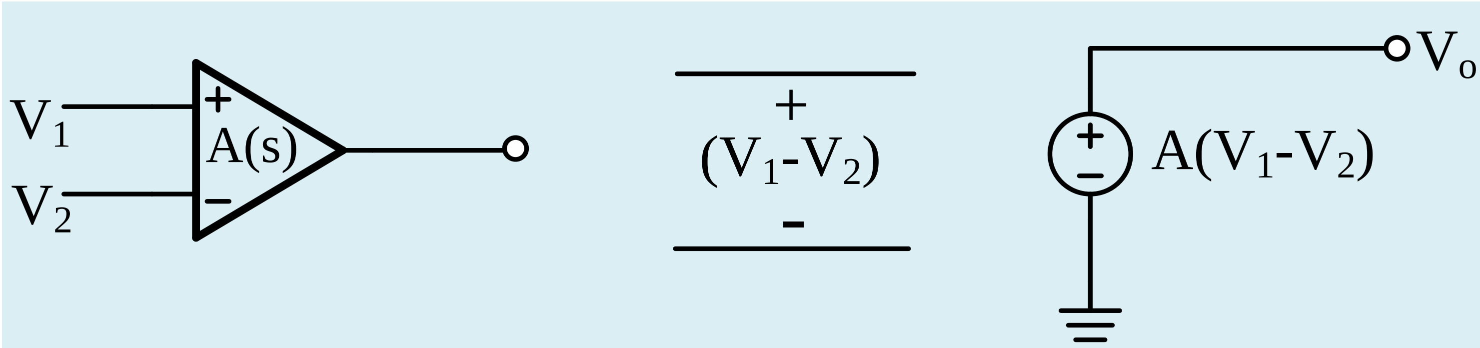
$k = 1/LC$

$\omega_z = R/L$

$\omega_o^2 = 1/LC$

$\frac{\omega_o}{Q} = 1/RC$

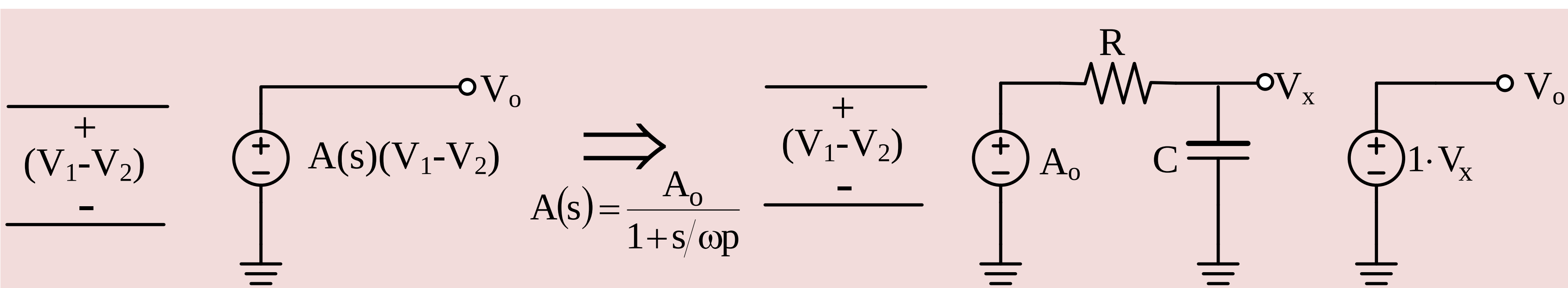
Op Amps (VCVS) Modeling



Op Amp Symbol

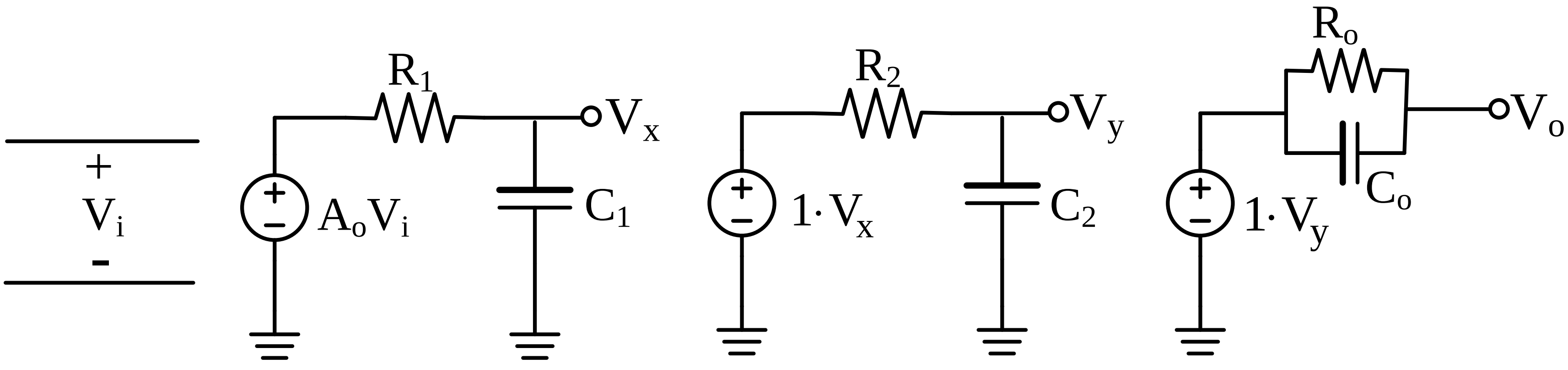
1. Quasi-Ideal Model, $A >> 10^3$

2. For finite DC Gain, Make $A = A_o$
3. Frequency Dependent Gain (one dominant pole)



4. Frequency dependent gain with two poles:

$$A(s) = \frac{A_o}{(1 + s/\omega_{p1})(1 + s/\omega_{p2})} \quad \text{and} \quad Z_o = C_o \,//\, R_o$$

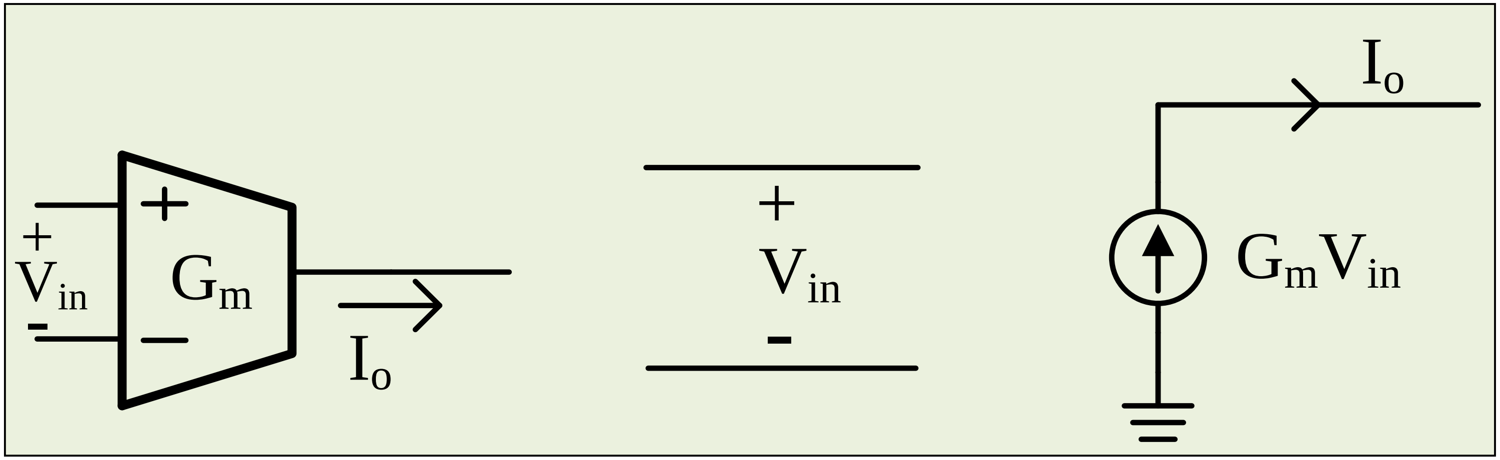


$$\omega_{p_1} = \frac{1}{R_1 C_1} \quad , \quad \omega_{p_2} = \frac{1}{R_2 C_2}$$

A_o is the open loop DC gain.

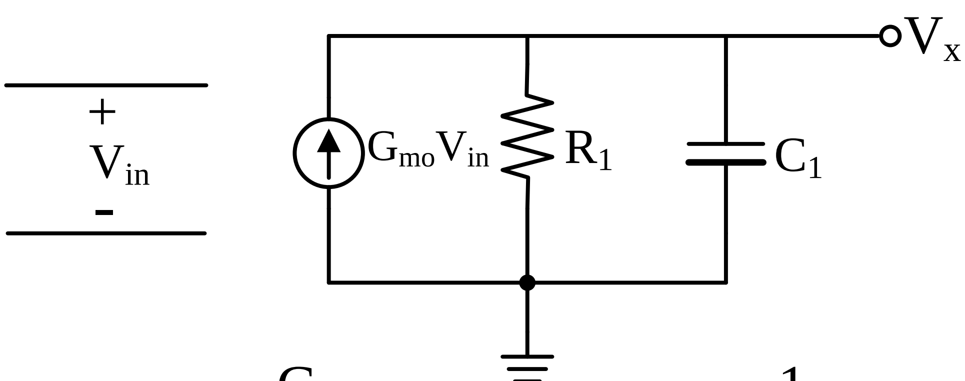
The output impedance consists of $R_o//C_o$.

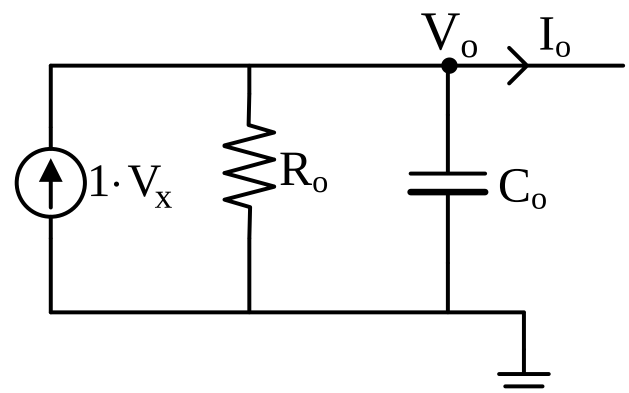
Transconductance Amplifier (VCIS) Modeling



Ideal Transconductance Amplifier

Frequency dependent G_m and fine output impedance





$$G_m(s) = \frac{G_{mo}}{1 + s/\omega_p} \quad ; \quad \omega_p = \frac{1}{R_1 C_1}$$

Z_o consists of a large output resistor (R_o) and a small output capacitance (C_o).