BJT's Fundamental relations for DC and AC analyses
ECE352 - Spring 2007.

DC analysis

$$I_E = I_B + I_C$$

$$I_C = \alpha I_E = \beta I_B$$

$$I_E = (\beta+1) I_B$$

$$\beta = \frac{\alpha}{1-\alpha} \; ; \quad \alpha = \frac{\beta}{\beta+1}$$

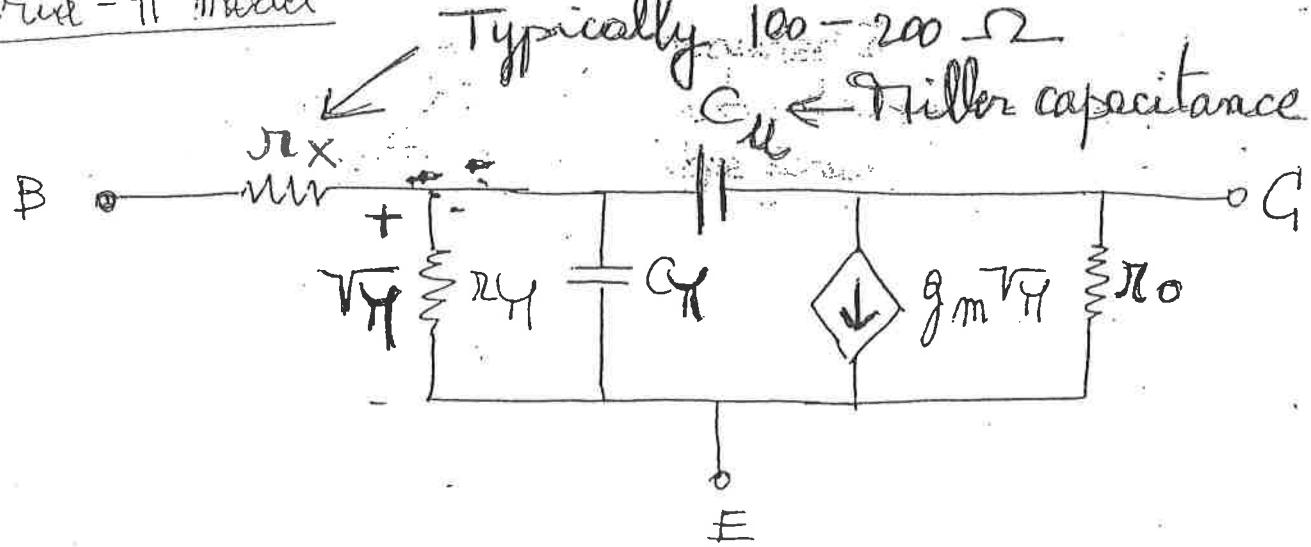
AC analysis

$V_T \simeq 26\,meV$

$V_A \sim [50-100V]$ ← Early voltage

$r_\pi = \frac{V_T}{I_B}$	$r_e = \frac{V_T}{I_E}$
$r_\pi = (\beta+1) r_e$	
$g_m = I_C / V_T$	
$r_\pi g_m = \beta$; $r_e g_m = \alpha$	
$r_o = V_A / I_C$	

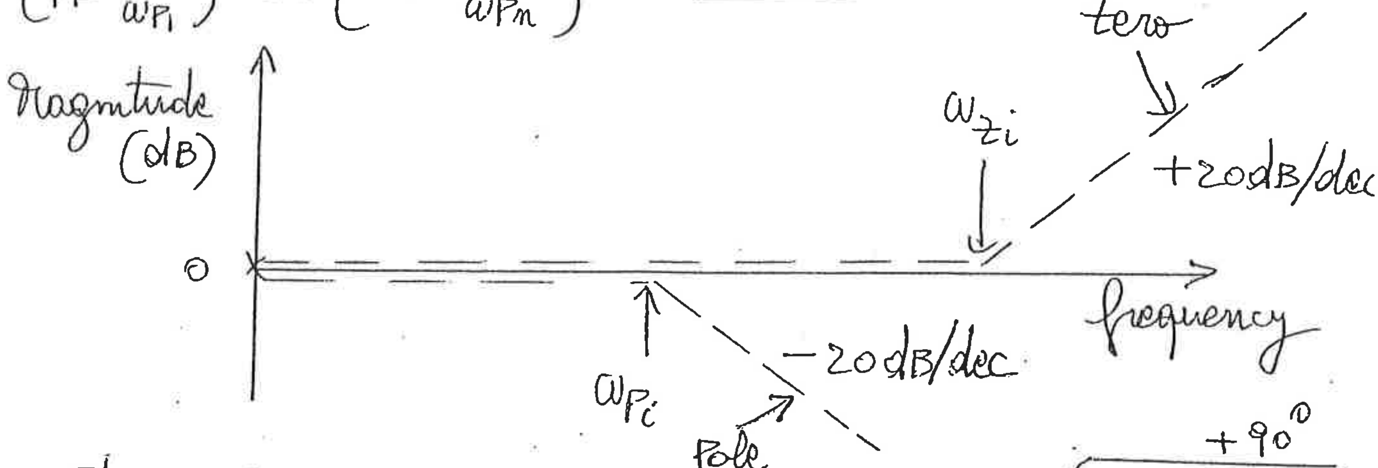
Hybrid-π model

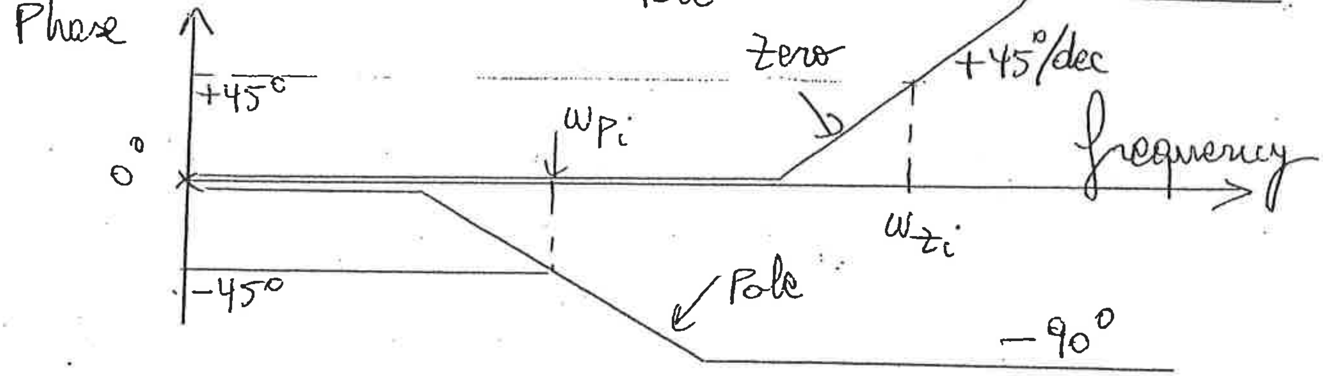


Summary Sheet

$$(s) = \frac{\left(1+\frac{s}{\omega_{z1}}\right) \cdots \left(1+\frac{s}{\omega_{zn}}\right)}{\left(1+\frac{s}{\omega_{P1}}\right) \cdots \left(1+\frac{s}{\omega_{Pn}}\right)}$$

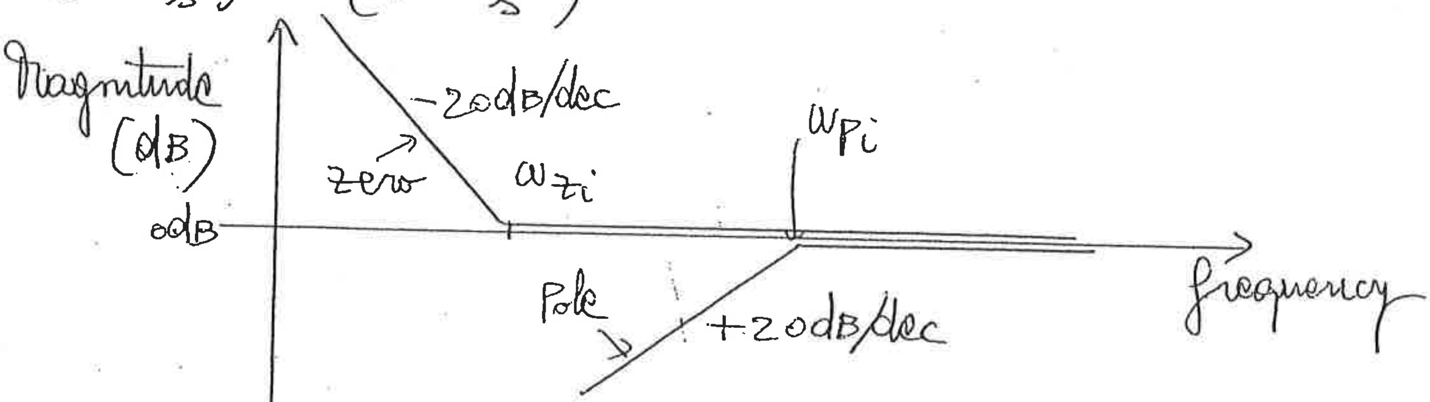
n poles
n zeros

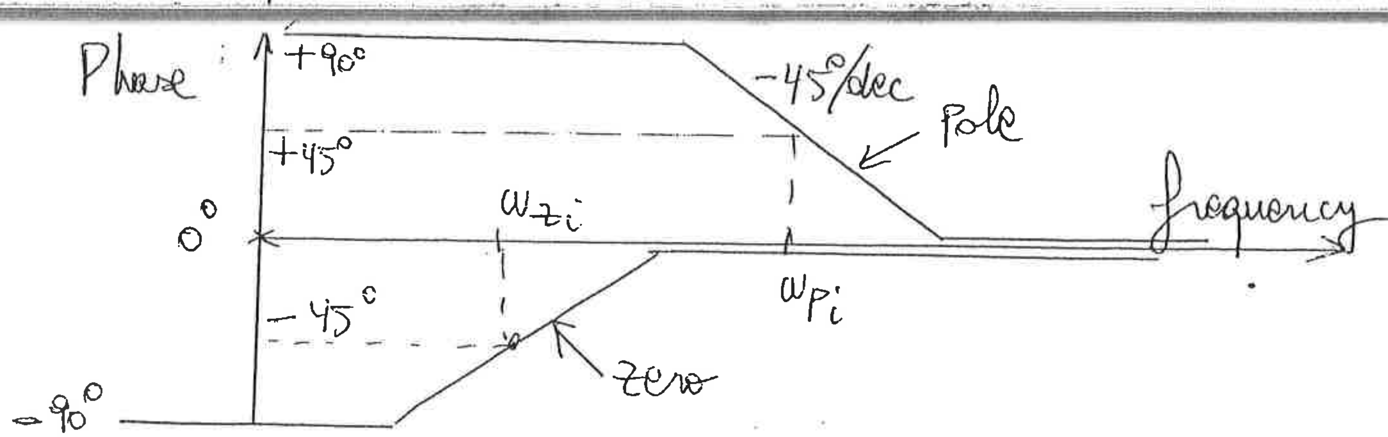




$$F_L(s) = \frac{\left(1+\frac{\omega_{z1}}{s}\right) \cdots \left(1+\frac{\omega_{zn}}{s}\right)}{\left(1+\frac{\omega_{P1}}{s}\right) \cdots \left(1+\frac{\omega_{Pn}}{s}\right)}$$

n poles & n zeros.





Basic Types of Feedback Amplifiers

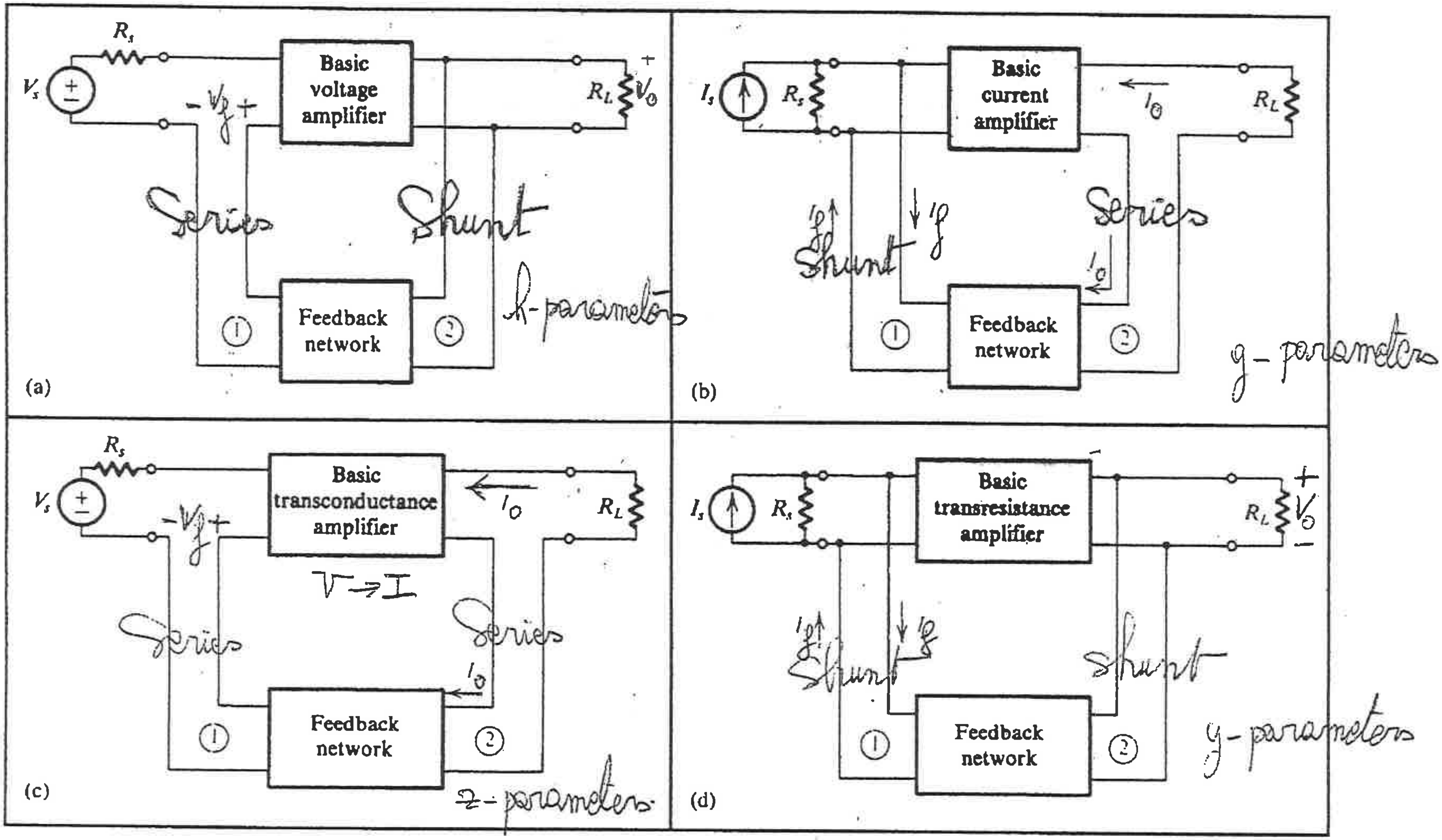
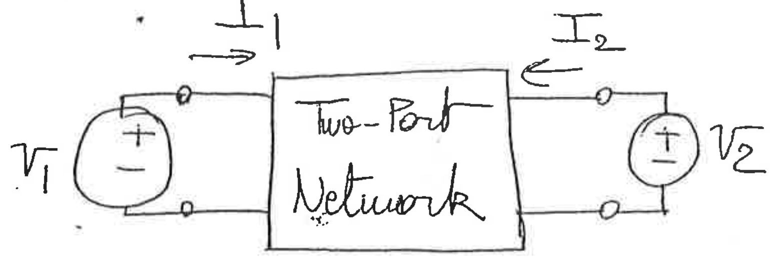
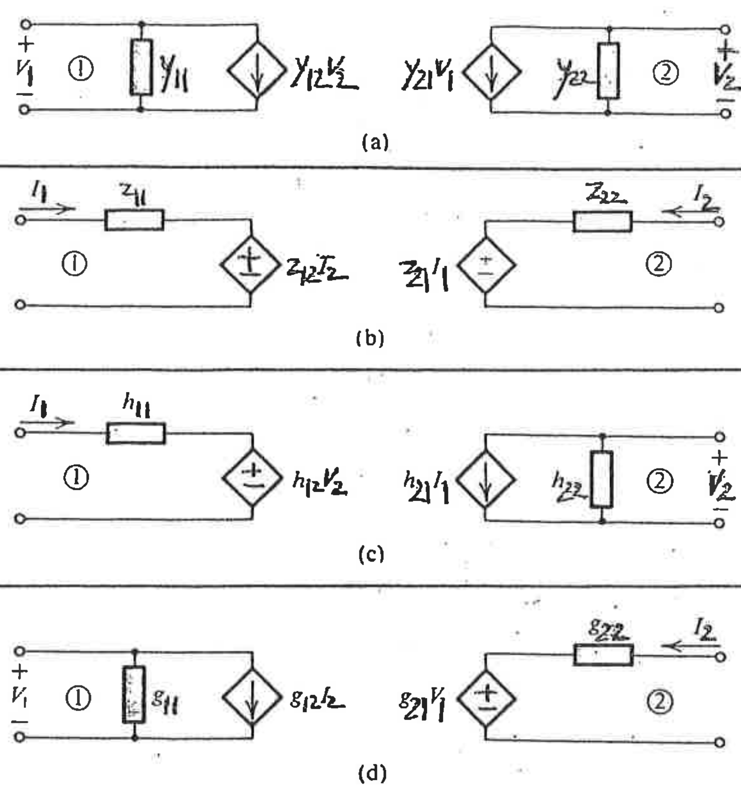


Fig. 8.4 The four basic feedback topologies: (a) voltage-sampling series-mixing (series–shunt) topology; (b) current-sampling shunt-mixing (shunt–series) topology; (c) current-sampling series-mixing (series–series) topology; (d) voltage-sampling shunt-mixing (shunt–shunt) topology.

Equivalent Two-port Network for feedback circuits.





$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

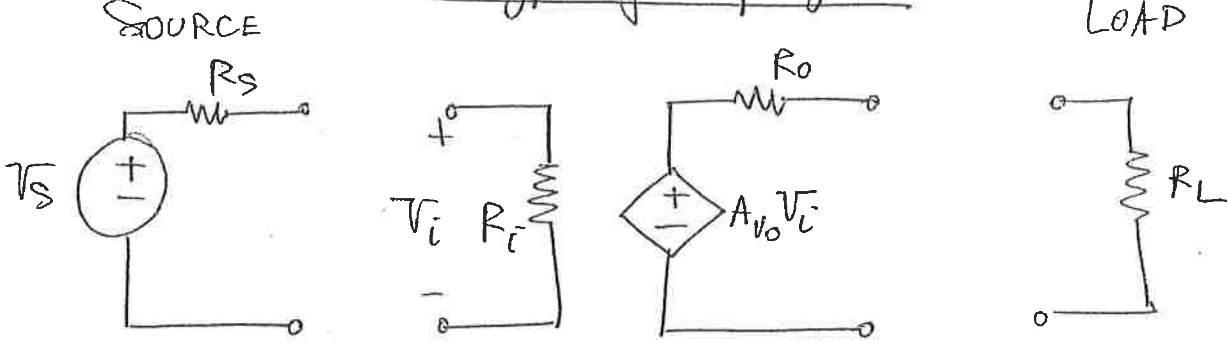
$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

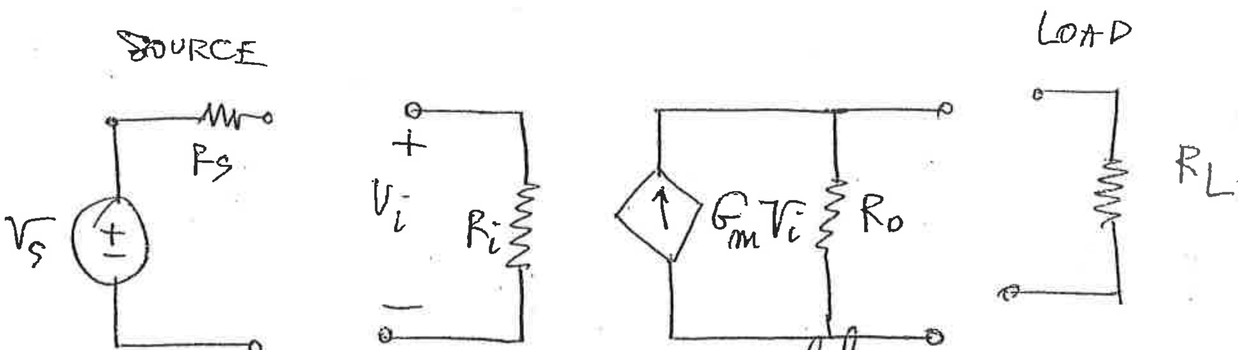
$$\begin{bmatrix} I_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ I_2 \end{bmatrix}$$

FIGURE B.6 Equivalent circuits for two-port networks in terms of (a) y, (b) z, (c) h, and (d) g parameters.

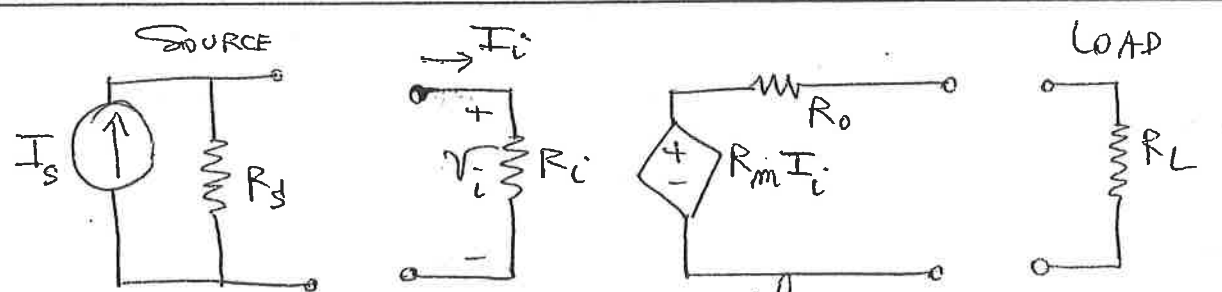
4 Types of amplifiers



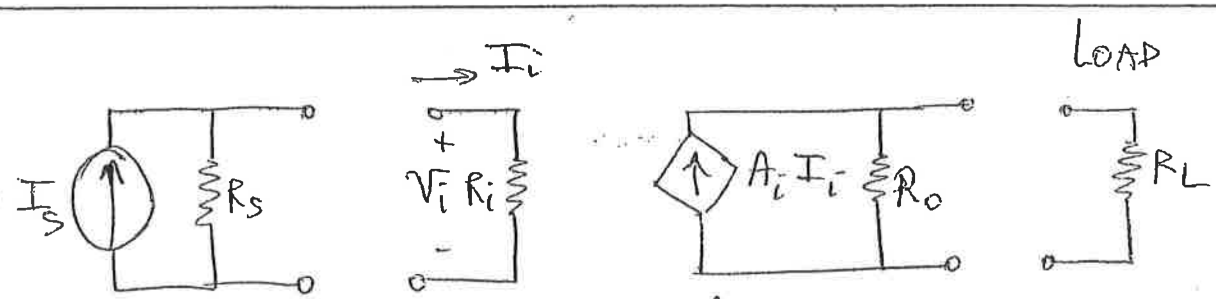
Basic voltage amplifier



Basic Transconductance amplifier



Basic Transresistance amplifier



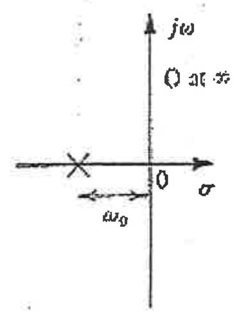
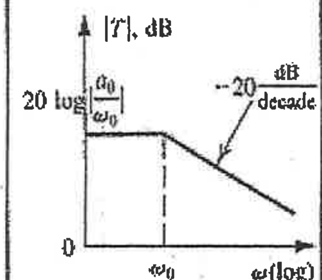
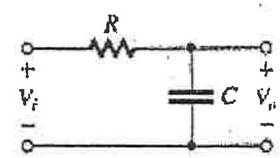
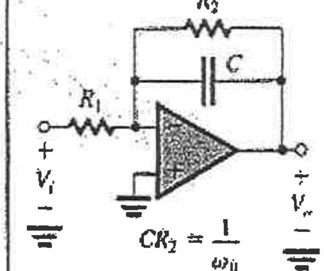
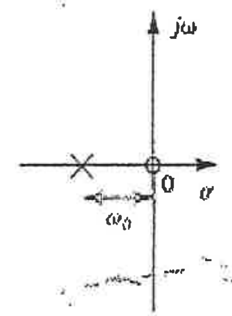
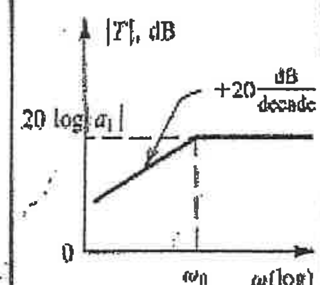
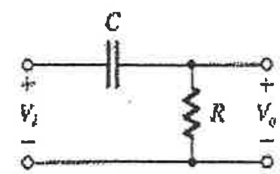
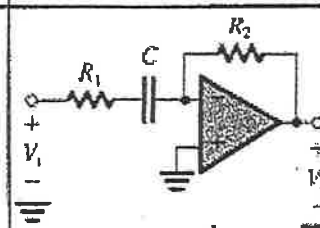
Basic current amplifier

First Order Filter Functions

* **First order filter functions are of the form**

$$T(s)=\frac{a_1 s+a_o}{s+\omega_0}=\frac{a_1\left(s+\frac{a_o}{a_1}\right)}{s+\omega_0}$$

902

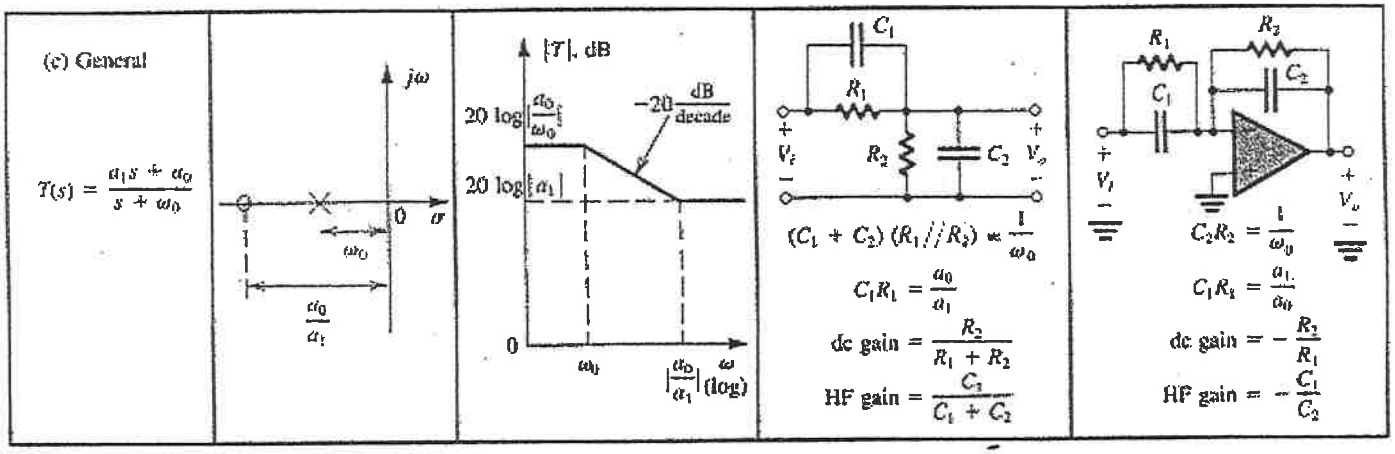
	Filter Type and $T(s)$	s-Plane Singularities	Bode Plot for $\lvert T \rvert$	Passive Realization	Op Amp-RC Realization
Low Pass	(a) Low-Pass (LP) $T(s)=\frac{a_0}{s+\omega_0}$			 $CR=\frac{1}{\omega_0}$ dc gain = 1	 $CR_2=\frac{1}{\omega_0}$ dc gain $=-\frac{R_2}{R_1}$
High Pass	(b) High-Pass (HP) $T(s)=\frac{a_1 s}{s+\omega_0}$			 $CR=\frac{1}{\omega_0}$ High-frequency gain = 1	 $CR_1=\frac{1}{\omega_0}$ High-frequency gain $=-\frac{R_2}{R_1}$

First Order Filter Functions

* **First order filter functions are of the form**

$$T(s) = \frac{a_1 s + a_o}{s + \omega_0} = \frac{a_1\left(s + \frac{a_o}{a_1}\right)}{s + \omega_0}$$

General



All Pass

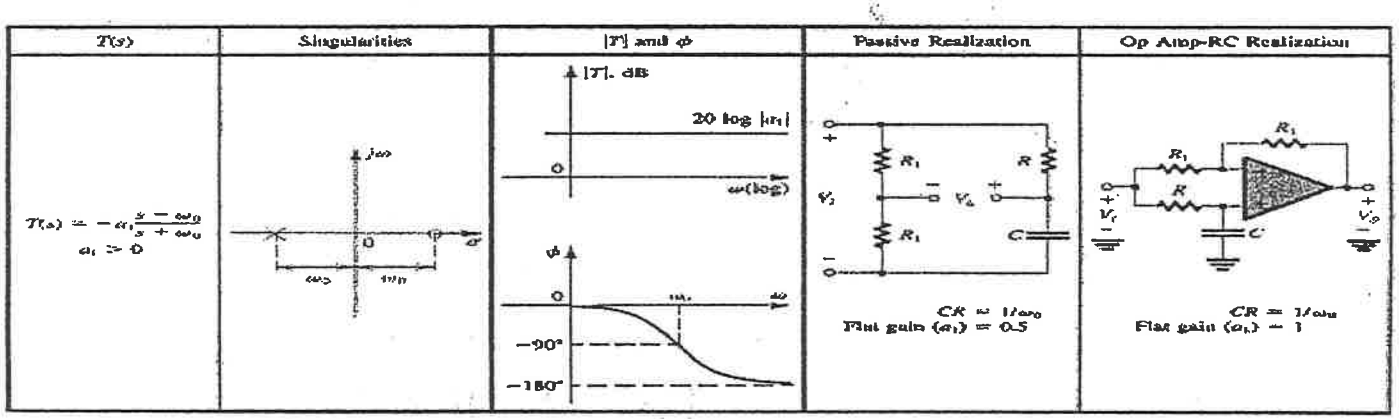


Fig. 11.14 First-order all-pass filter.

Passive Second Order Filter Functions

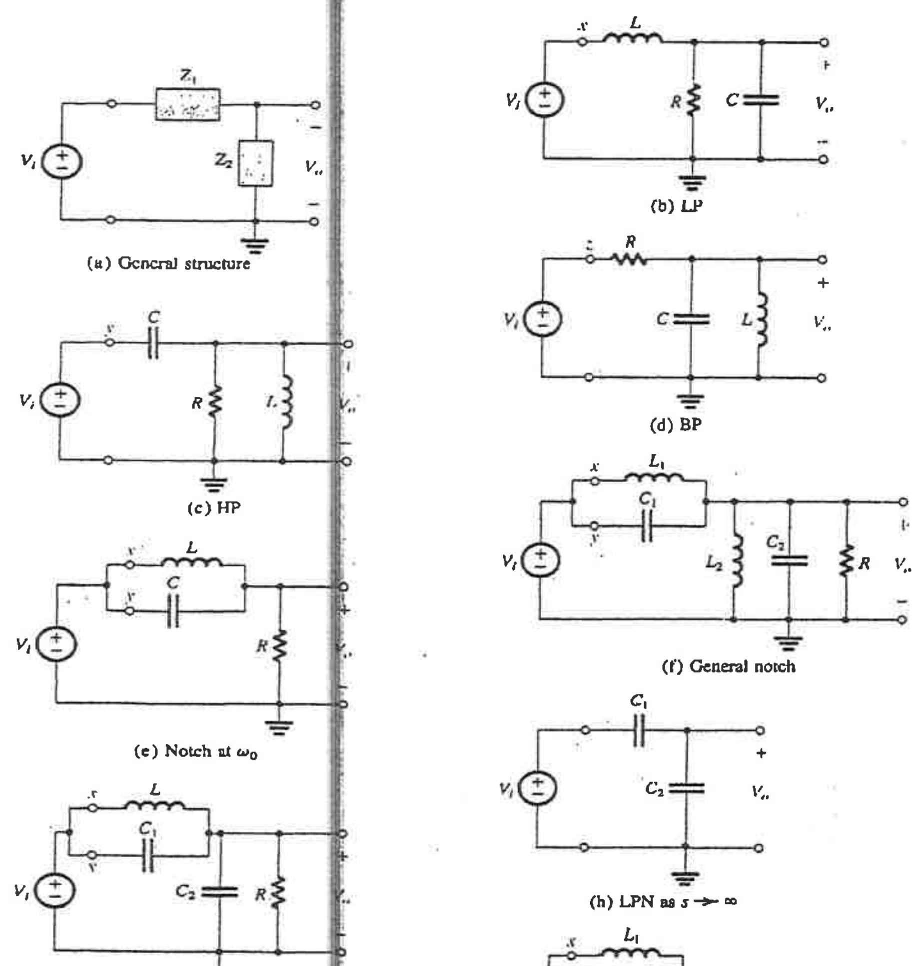


Fig. 11.18 Realization of various second-order filter functions using the LCR resonator of Fig. 11.17(b): (a) general structure, (b) LP, (c) HP, (d) BP, (e) notch at ω_0, (f) general notch, (g) LPN ($\omega_n \geq \omega_0$), (h) LPN as $s \to \infty$, (i) HPN ($\omega_n < \omega_0$).

912

* Second order filter functions can be implemented with simple RLC circuits
* General form is that of a voltage divider with a transfer function given by

$$T(s) = \frac{V_o(s)}{V_i(s)} = \frac{a_2 s^2 + a_1 s + a_o}{s^2 + \frac{\omega_0}{Q}s + \omega_0^2}$$

* Seven types of second order filters
  - High pass
  - Low pass
  - Bandpass
  - Notch at
  - General notch
  - Low pass notch (2 types)
  - High pass notch

Second-Order Filter Functions

$$T(s) = \frac{a_2 s^2 + a_1 s + a_o}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

Notch

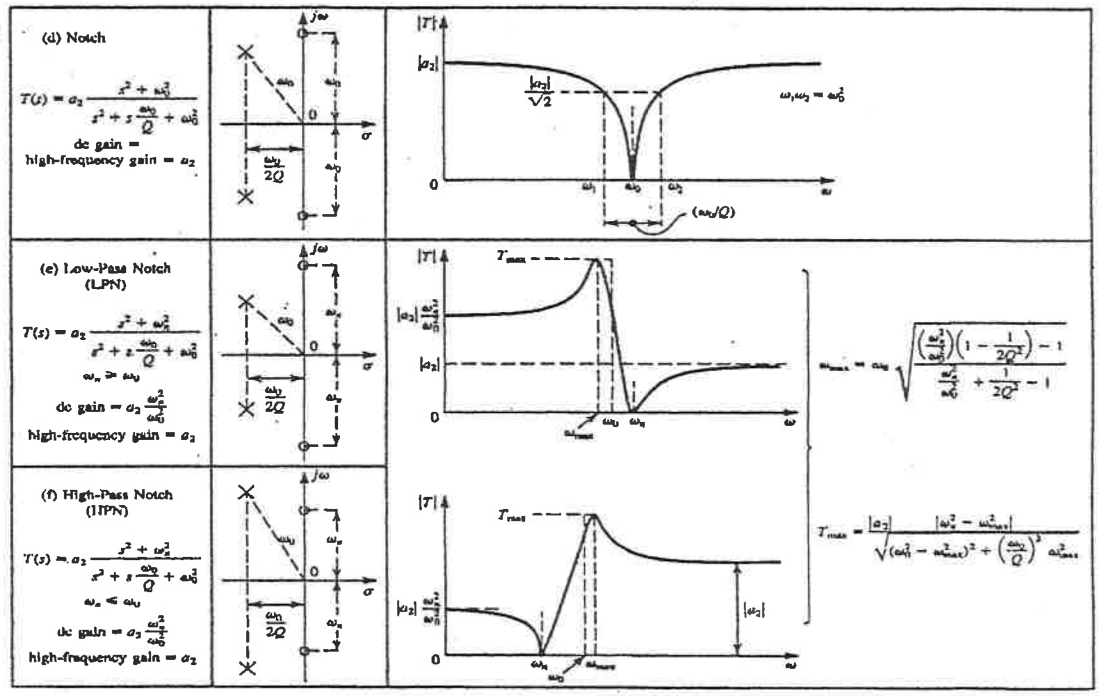
a_1=0

Low Pass Notch

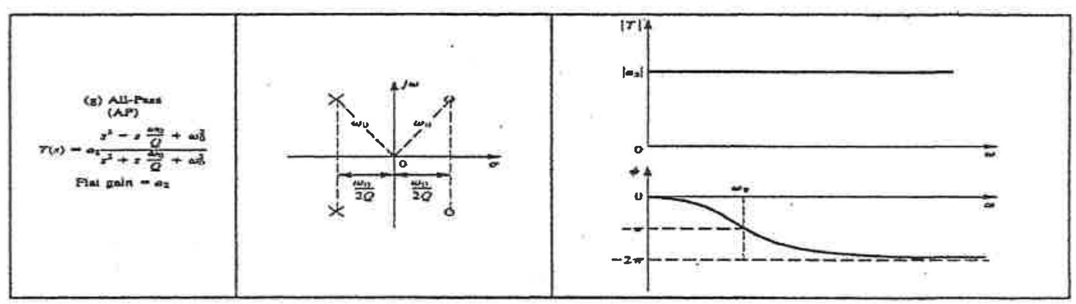
a_1=0

High Pass Notch

a_1=0



All-Pass



Second-Order Filter Functions

$$T(s) = \frac{a_2 s^2 + a_1 s + a_o}{s^2 + \frac{\omega_0}{Q} s + \omega_0^2}$$

Low Pass

$a_1=0$, $a_2=0$

High Pass

$a_0=0$, $a_1=0$

Bandpass

$a_0=0$, $a_2=0$

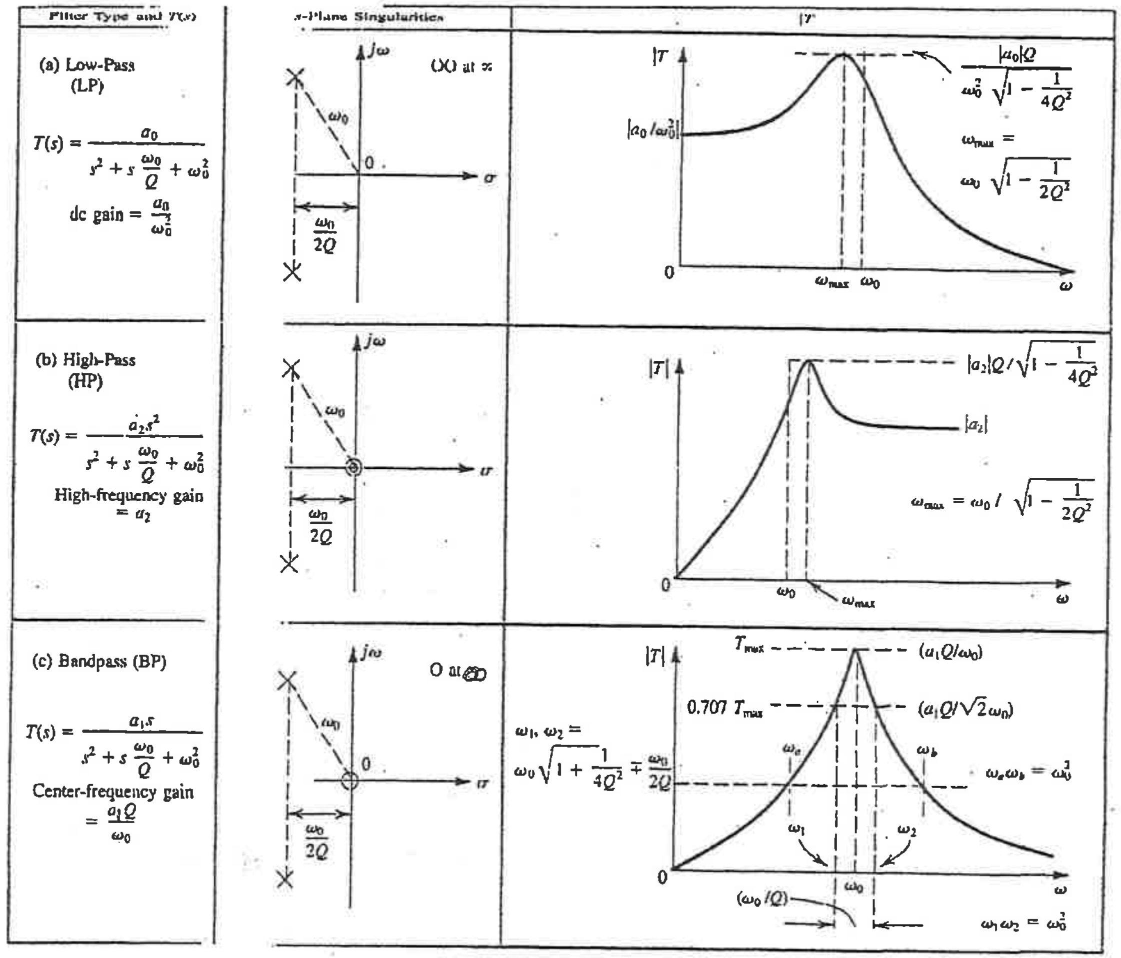


Fig. 11.16 Second-order filtering functions.