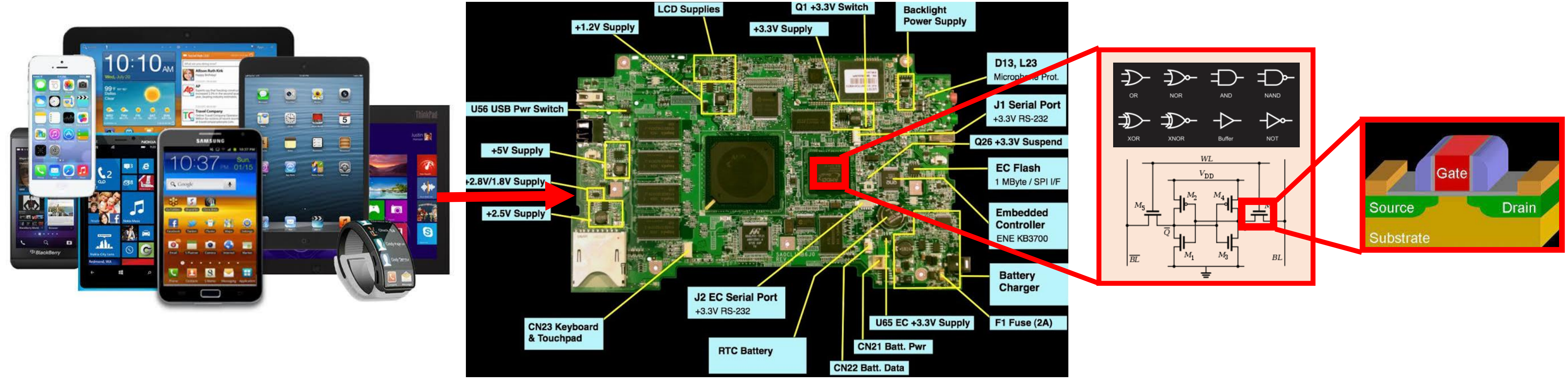

ESC201: INTRODUCTION TO ELECTRONICS

MODULE 5: AMPLIFIERS

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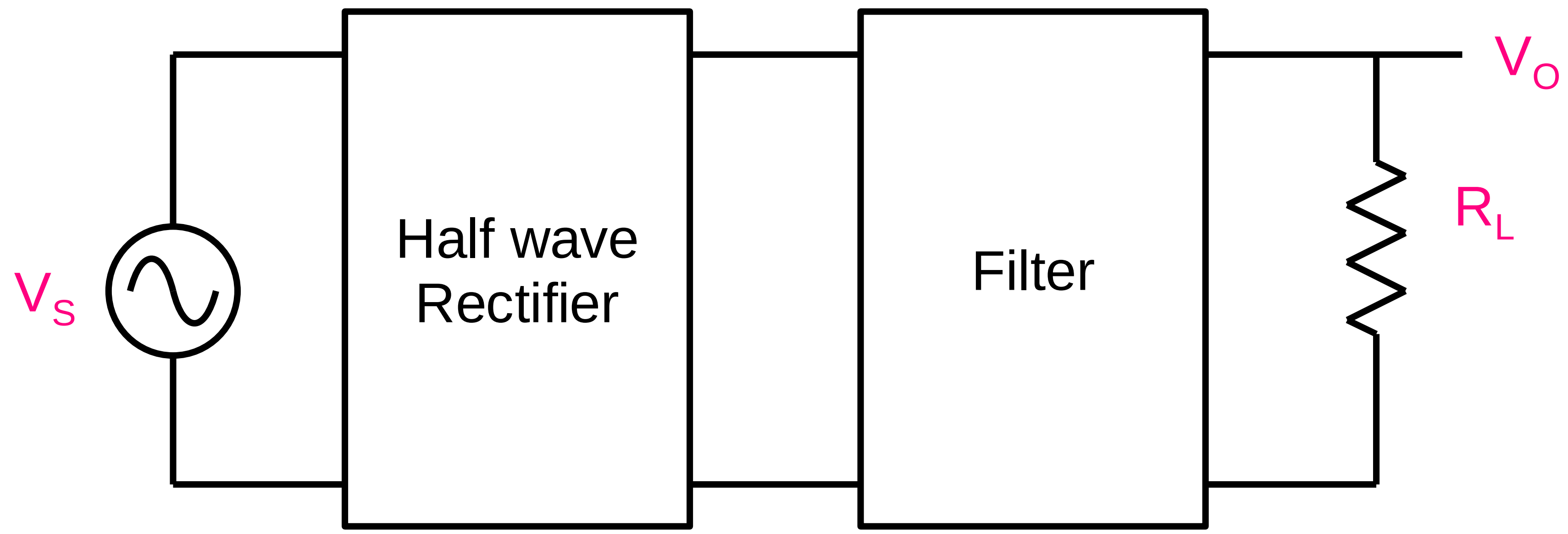
Department of Electrical Engineering,
IIT Kanpur

Power supply: block diagram

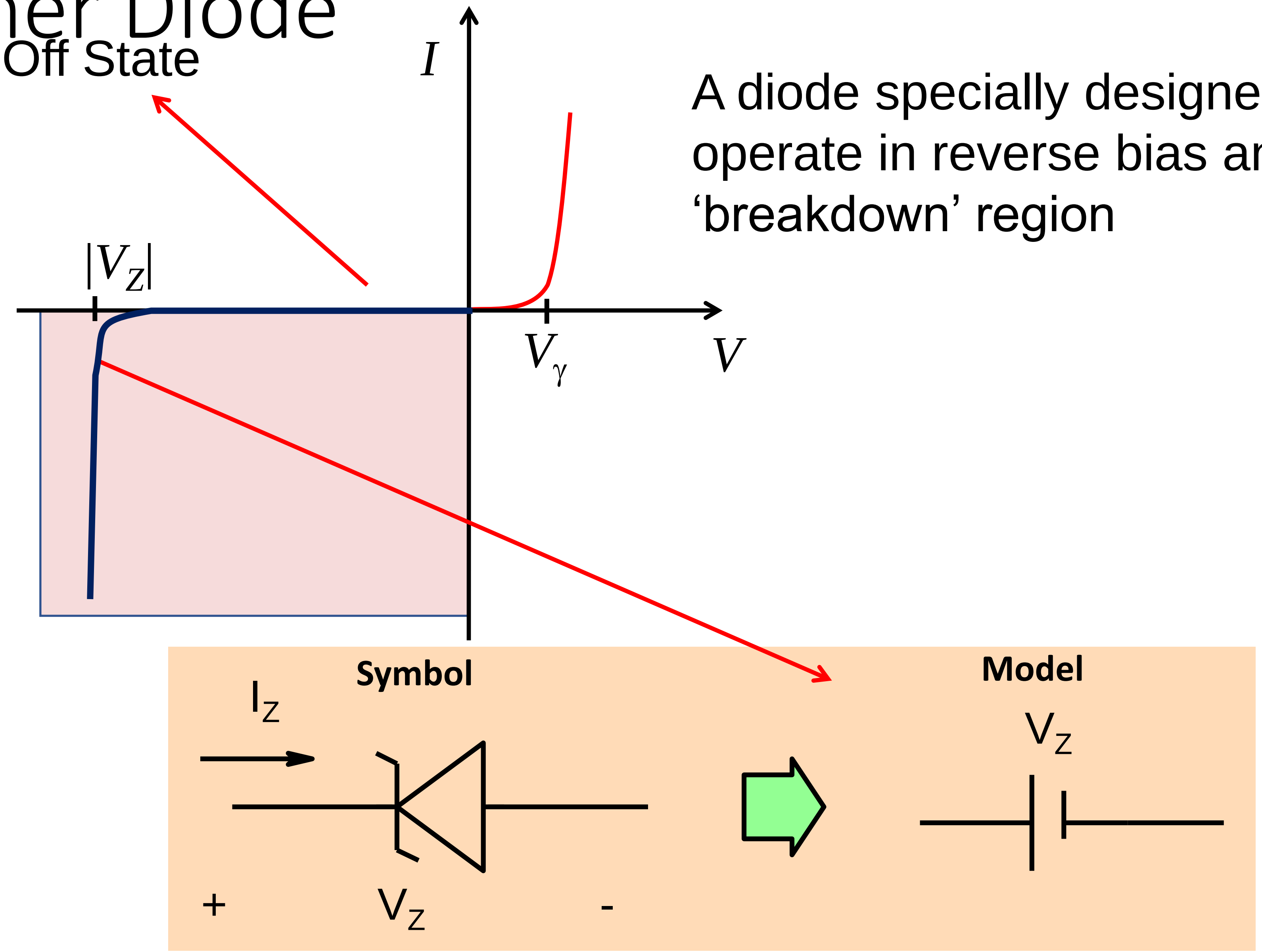


Comparison

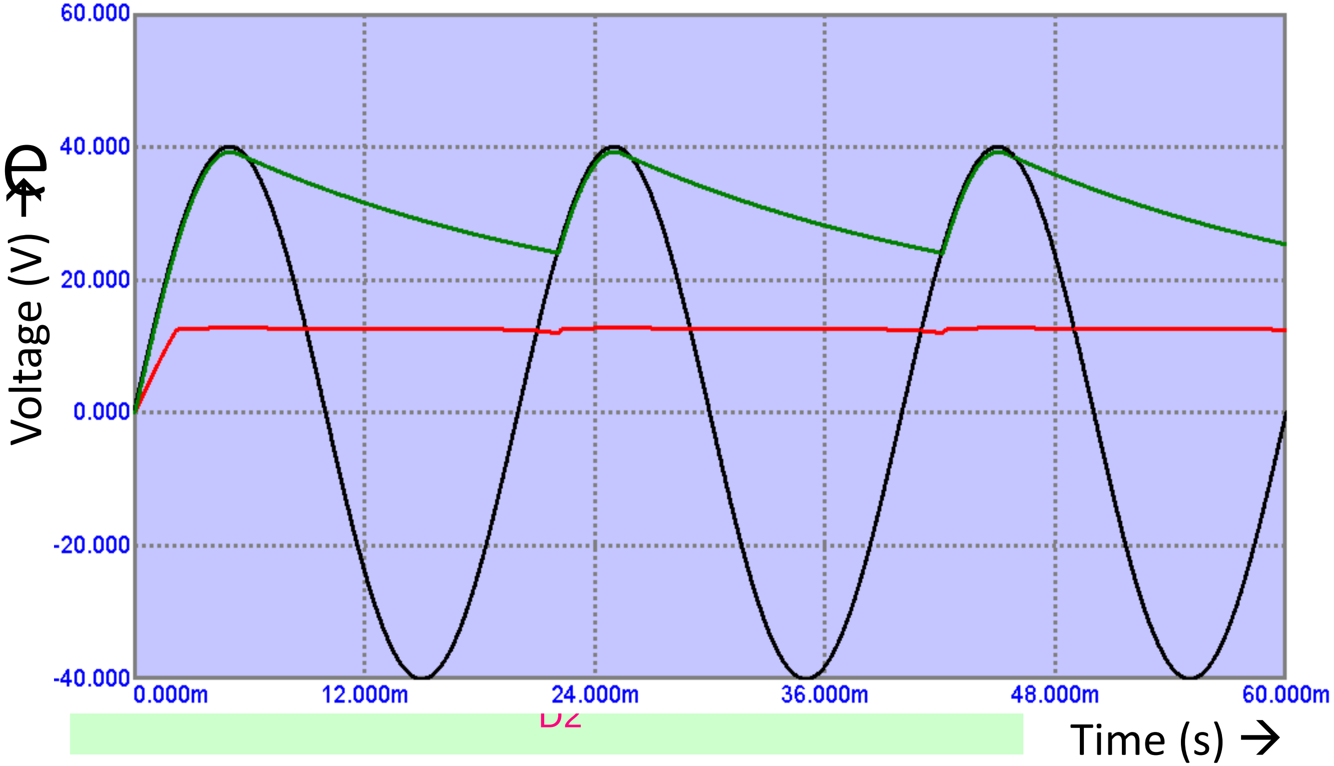
	Half Wave Rectifier	Full Wave Rectifier	Bridge Rectifier
Number of diodes	1	2	4
Ripple Voltage V_r	$V_r \cong \dfrac{V_M}{fR_L C}$	$V_r \cong \dfrac{V_M}{2fR_L C}$	$V_r \cong \dfrac{V_M}{2fR_L C}$
Peak Diode Current i_{DMAX}	$\omega C \times \sqrt{2V_r V_M} + \dfrac{V_M}{R_L}$	$\omega C \times \sqrt{2V_r V_M} + \dfrac{V_M}{R_L}$	$\omega C \times \sqrt{2V_r V_M} + \dfrac{V_M}{R_L}$
Peak Inverse Voltage *PIV*	V_M	$2V_M - V_\gamma$	$V_M - V_\gamma$

Zener Diode

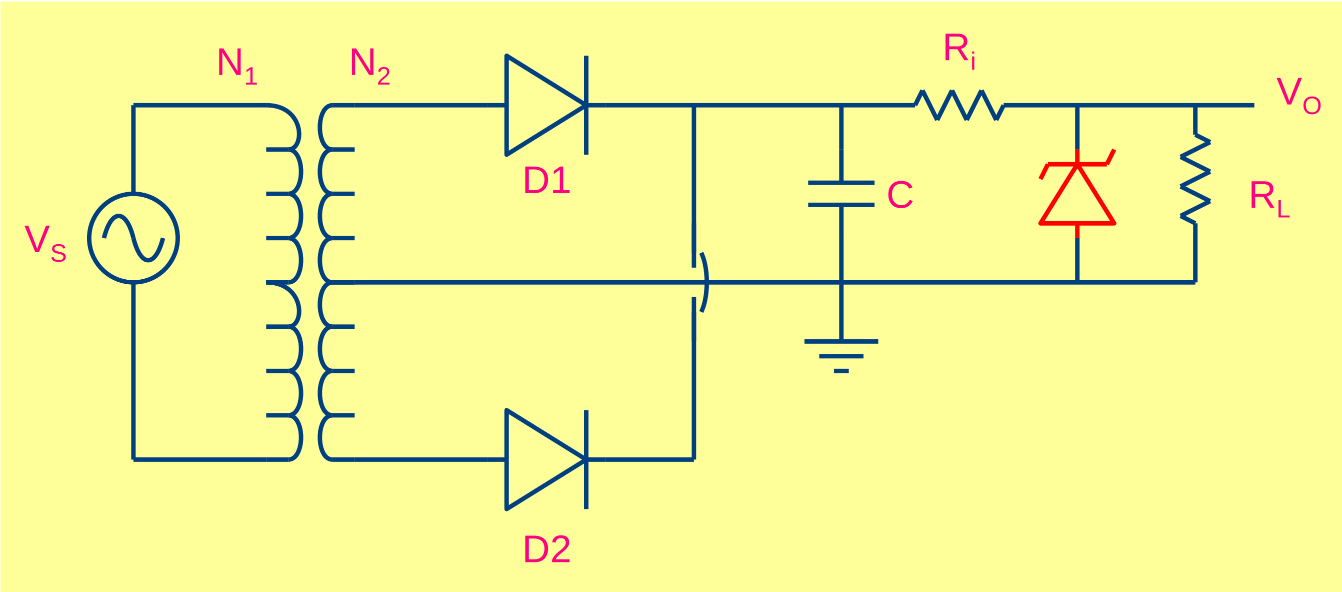
A diode specially designed to operate in reverse bias and in 'breakdown' region



Zene



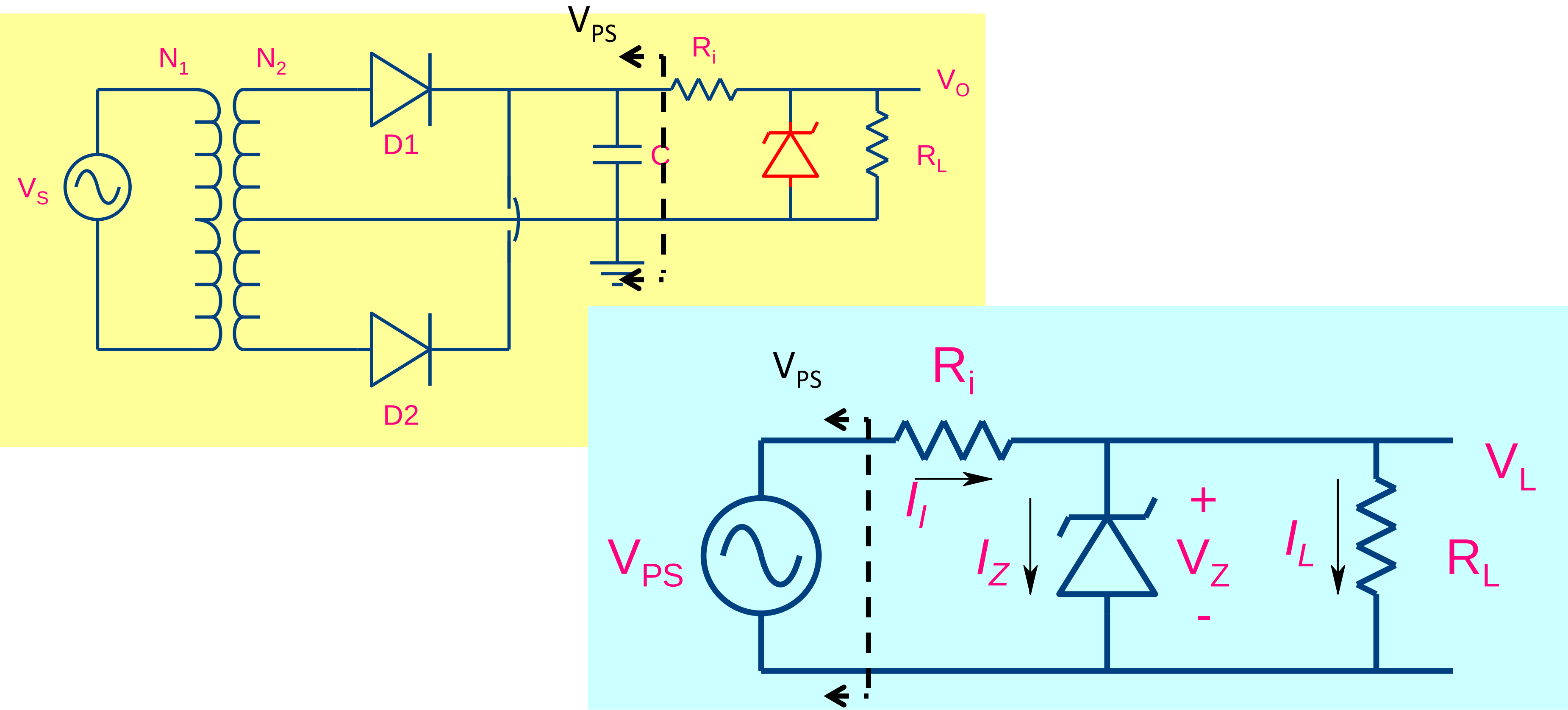
ithout Zener



Regulated supply

Zener diode regulates supply

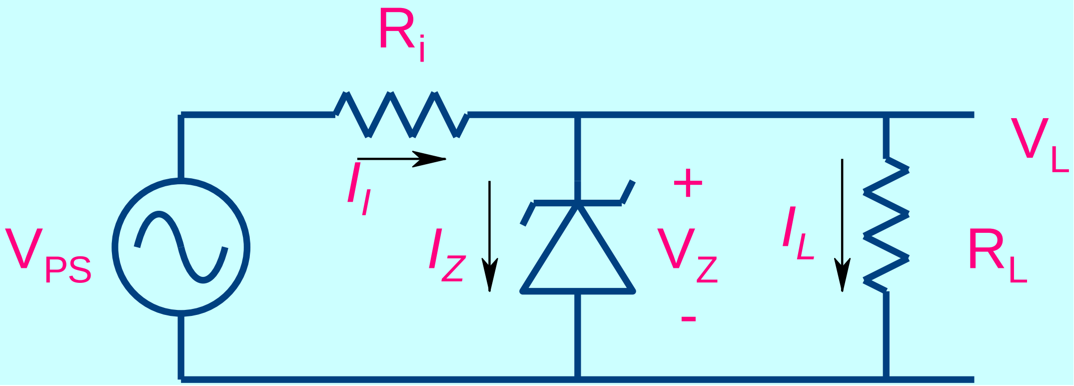
Example Design a voltage reference circuit



Design Problem: Determine R_i and Zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V. I_{Zmax}/I_{Zmin}=10.

Example (continued)

Design Equations



$$P_{Z\max} = V_Z I_{Z\max}$$

$$I_i = \frac{V_{PS} - V_Z}{R_i} = I_Z + I_L$$

$$I_Z = \frac{V_{PS} - V_Z}{R_i} - I_L$$

$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min}$$

$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max}$$

$$\frac{I_{Z\max}}{I_{Z\min}} \cong 10$$

$$R_i = \frac{V_{PS\min} - 0.1V_{PS\max} - 0.9V_Z}{I_{L\max} - 0.1I_{L\min}}$$

Example (continued)

Design Problem: Determine R_i and zener diode specifications such that output voltage is +12V, load current can vary between 0 to 0.1A. The input voltage may vary between 18 to 15.5V.

$$R_i = \frac{V_{PS\min} - 0.1V_{PS\max} - 0.9V_Z}{I_{L\max} - 0.1I_{L\min}} = 29\Omega$$

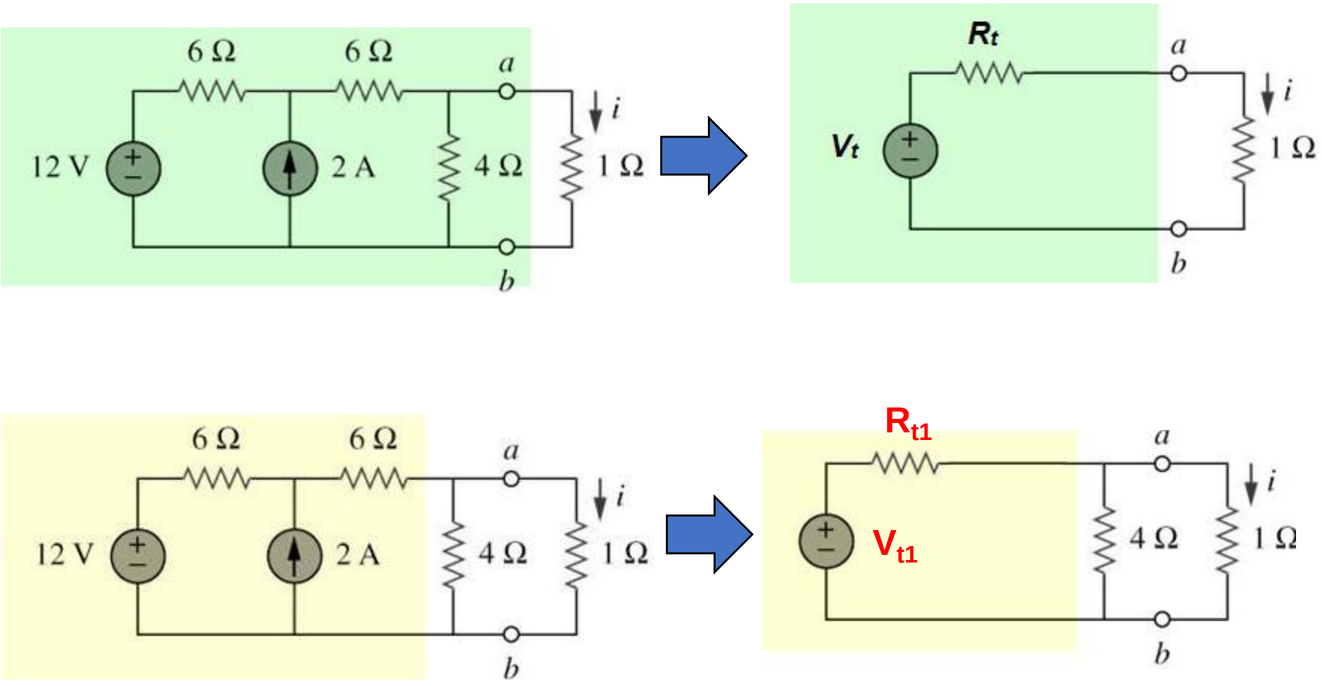
$$I_{Z\max} = \frac{V_{PS\max} - V_Z}{R_i} - I_{L\min} = 0.207A$$

$$I_{Z\min} = \frac{V_{PS\min} - V_Z}{R_i} - I_{L\max} = 0.0207$$

$$P_{Z\max} = V_Z I_{Z\max} = 2.48W$$

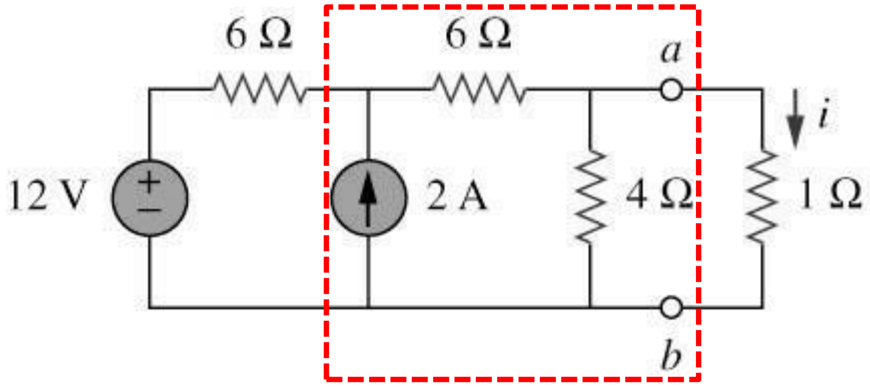
Abstractions

An abstract representation is a simplified representation that has appropriate level of detail for the problem being addressed.



Abstraction is a technique for coping with complexity

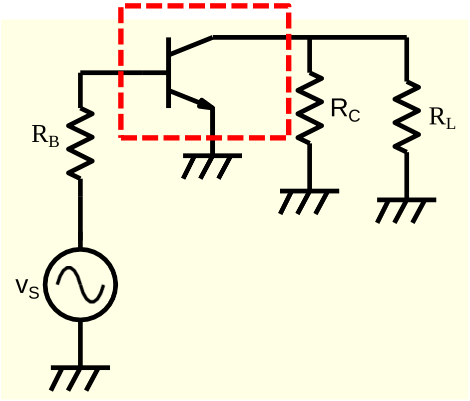
Limitation of Single Port Network



How do we build a simplified representation of only this portion of the circuit?

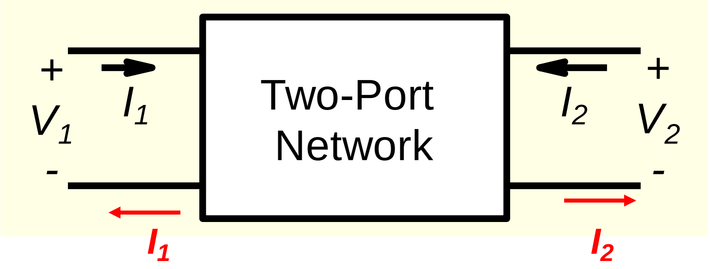
Thevenin’s or Norton’s Theorem are not Sufficient

Analysis of Elements Occurring In Circuits



How do we analyze circuits containing new components?

Two-Port Networks



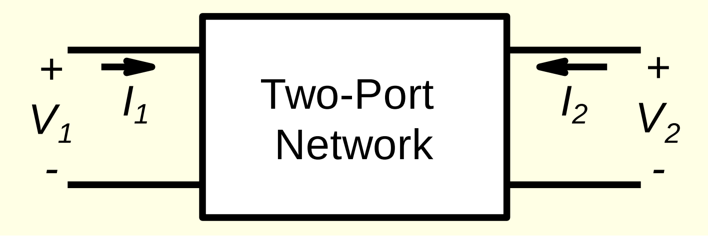
- Port: A pair of terminals through which a signal can enter/leave the network
- Constraints on analysis:
  1. Linear elements only (R,L,C, dependent sources,..)
  2. No independent sources or stored energy inside the network

No matter how complicated is the circuit inside the two-port network, it can be represented by only four elements !

Popular Forms of Two Port Network

- Z (Impedance) Parameters
- Y (Admittance) Parameters
- H (Hybrid) Parameters
- G (Inverse Hybrid) Parameters

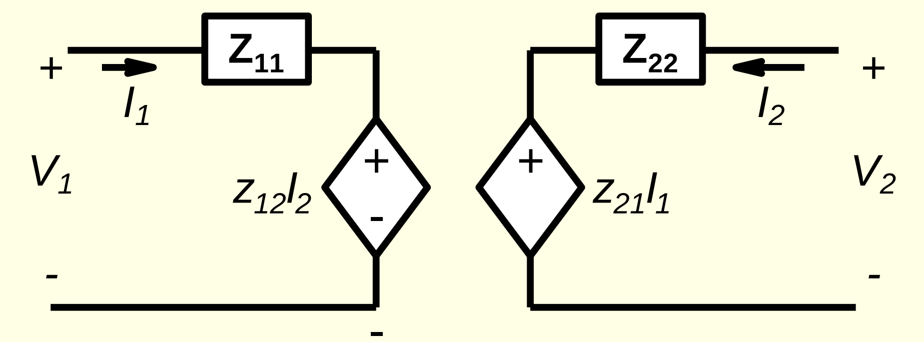
Z or Impedance Parameters



$$V_1 = z_{11}I_1 + z_{12}I_2$$

$$V_2 = z_{21}I_1 + z_{22}I_2$$

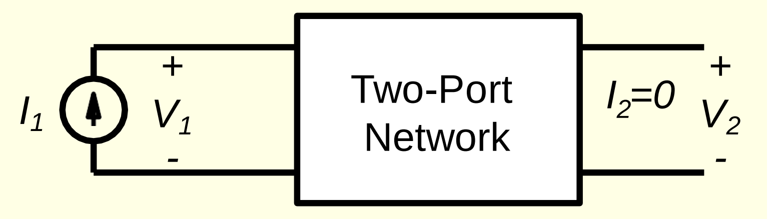
$$\begin{pmatrix} V_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{pmatrix} \begin{pmatrix} I_1 \\ I_2 \end{pmatrix}$$



Z Parameter Determination

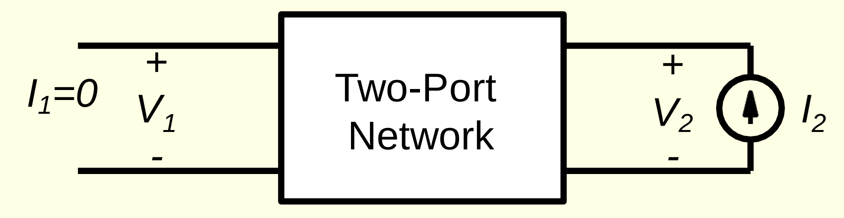
$$V_1 = z_{11}I_1 + z_{12}I_2$$

$$V_2 = z_{21}I_1 + z_{22}I_2$$



$$z_{11} = \left.\frac{V_1}{I_1}\right|_{I_2=0}$$

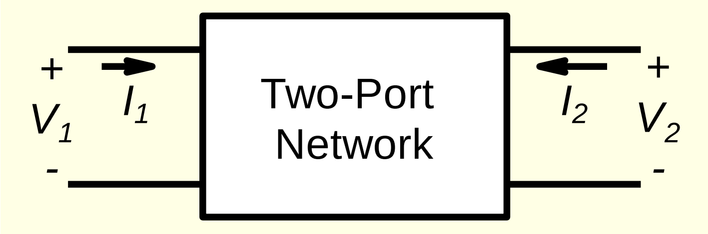
$$z_{21} = \left.\frac{V_2}{I_1}\right|_{I_2=0}$$



$$z_{22} = \left.\frac{V_2}{I_2}\right|_{I_1=0}$$

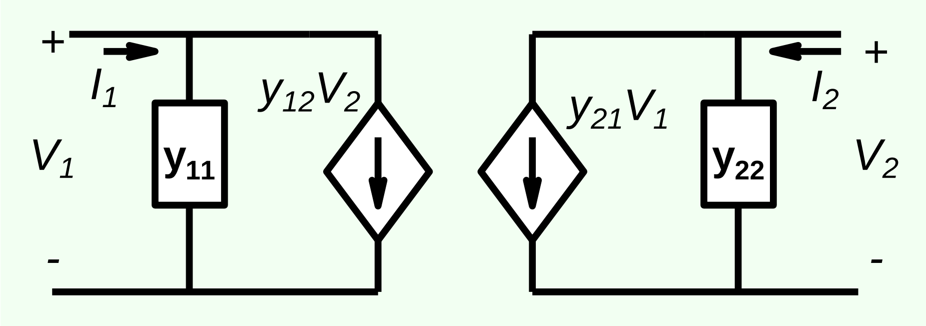
$$z_{12} = \left.\frac{V_1}{I_2}\right|_{I_1=0}$$

Y or Admittance Parameters

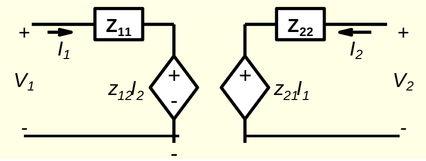


$$I_1 = y_{11}V_1 + y_{12}V_2 \qquad I_2 = y_{21}V_1 + y_{22}V_2$$

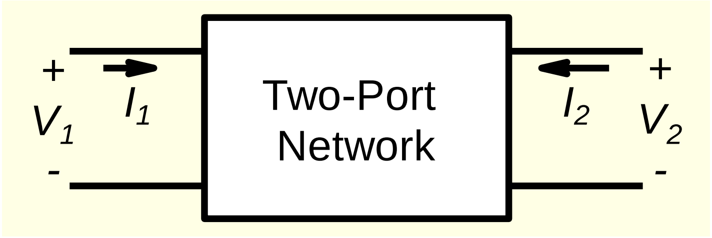
$$\begin{pmatrix} I_1 \\ I_2 \end{pmatrix} = \begin{pmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{pmatrix} \begin{pmatrix} V_1 \\ V_2 \end{pmatrix}$$



For comparison

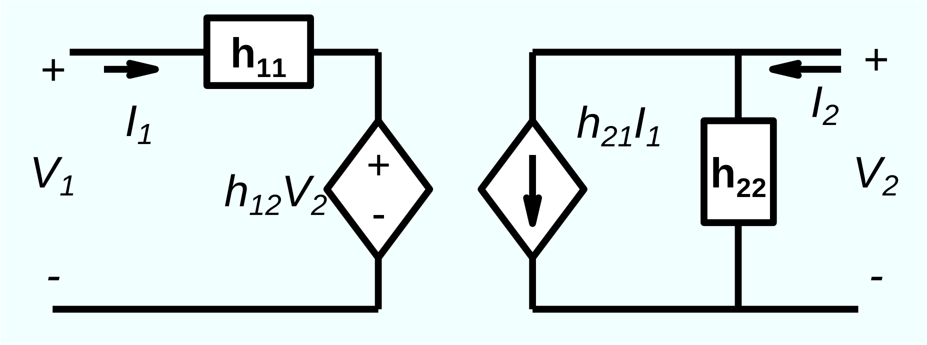


H or Hybrid Parameters

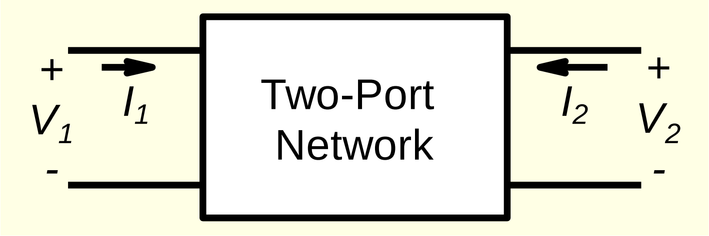


$$V_1 = h_{11} I_1 + h_{12} V_2 \qquad I_2 = h_{21} I_1 + h_{22} V_2$$

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



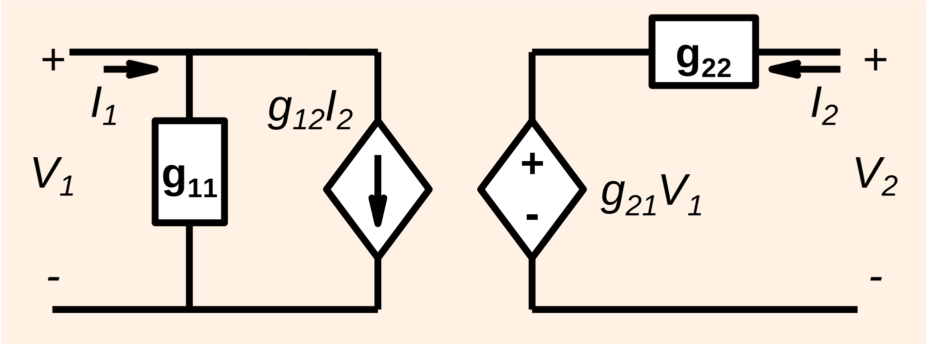
G or Inverse Hybrid Parameters



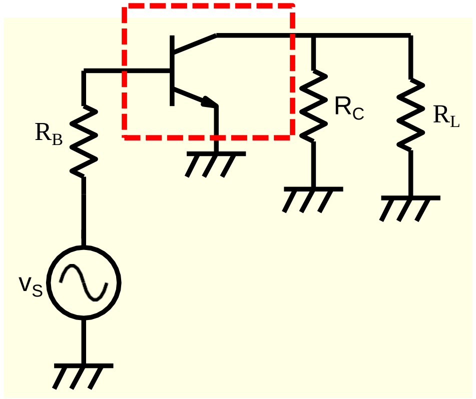
$$I_1 = g_{11}V_1 + g_{12}I_2$$

$$V_2 = g_{21}V_1 + g_{22}I_2$$

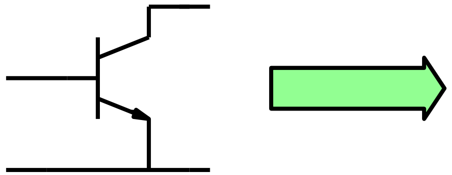
$$\begin{pmatrix} I_1 \\ V_2 \end{pmatrix} = \begin{pmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{pmatrix} \begin{pmatrix} V_1 \\ I_2 \end{pmatrix}$$

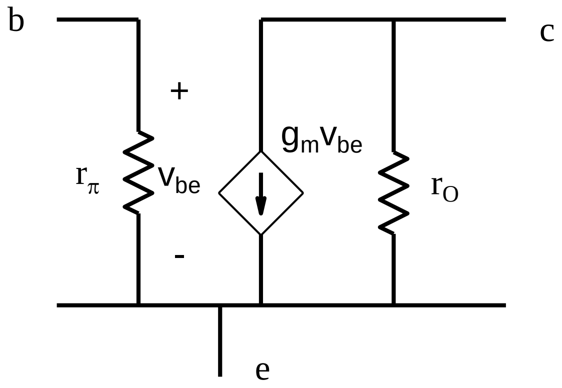


Representation of Complex Elements Within Circuits



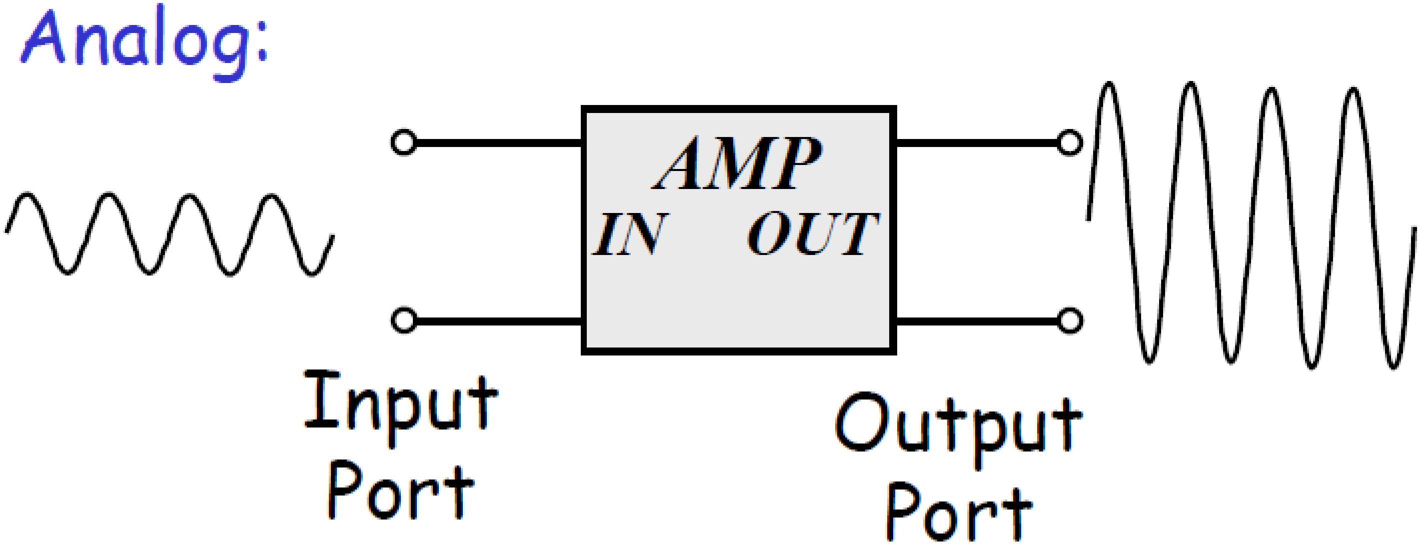
Two port network allows transistor representation in terms of familiar elements.





Why amplify?

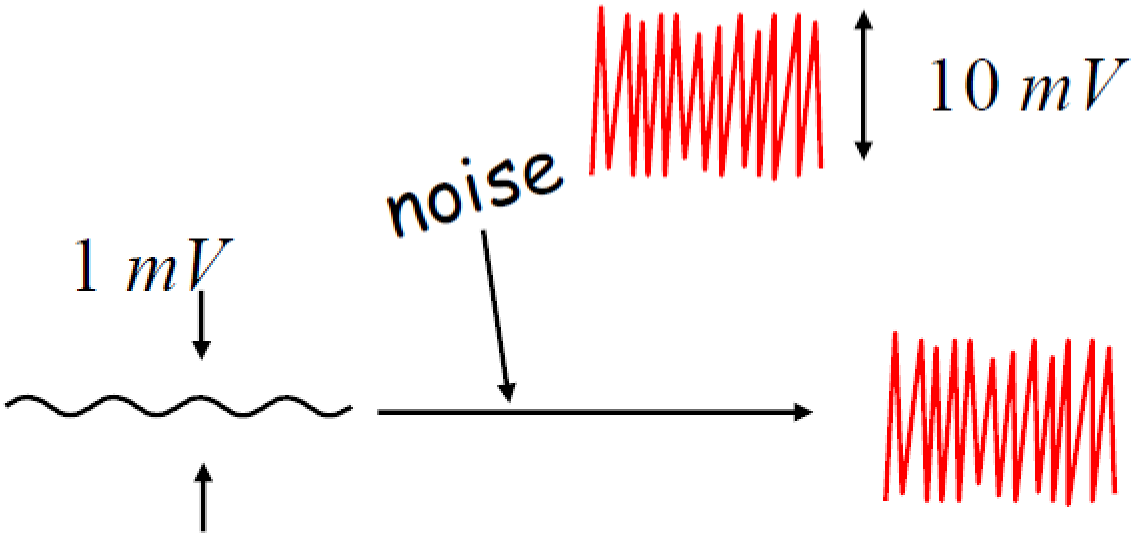
- Key to analog and digital processing



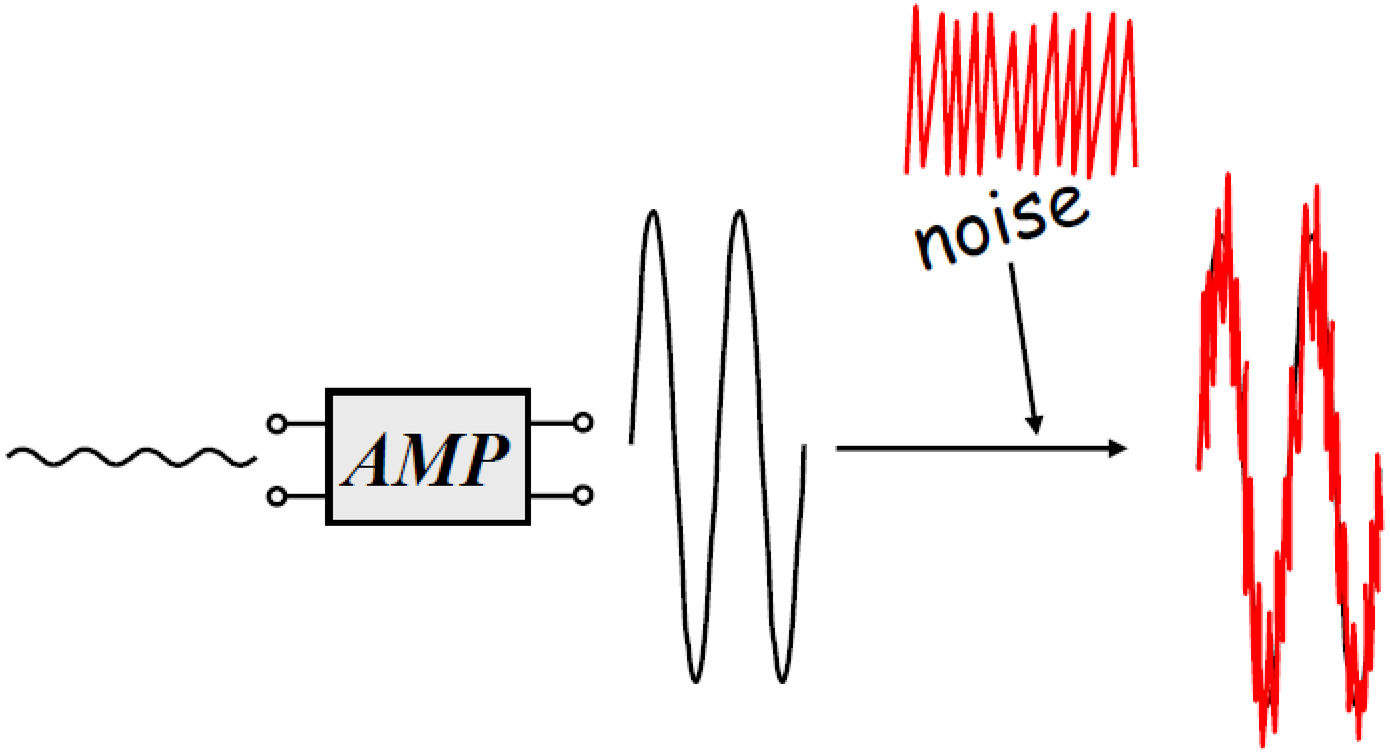
Active Device: supplies power

Noise tolerance

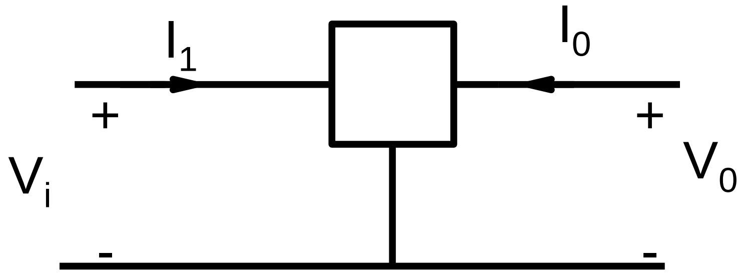
- Amplification is the key to noise tolerance during communication



Noise tolerance



Simple voltage amplifier

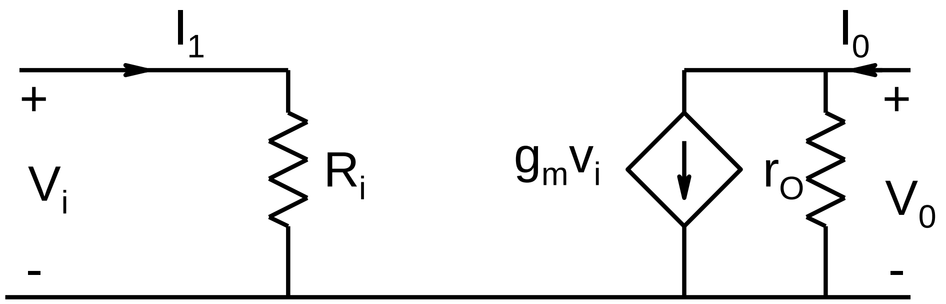


$V_o = G\,V_i$

Gain

$G > 1$

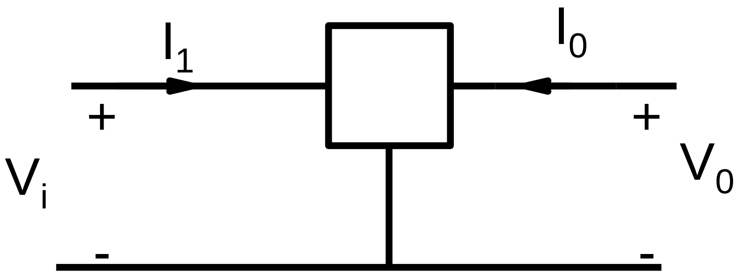
- Equivalent representation

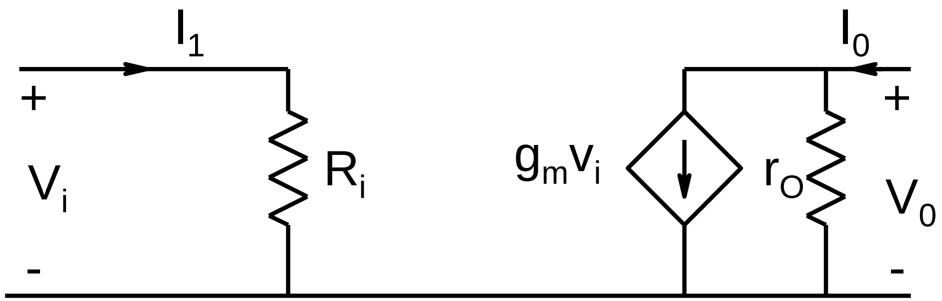


Note: V_i depends on I_1 but does not depend on I_o

V_o depends on I_1 and I_o

Voltage amplifier parameters





$$I_o = g_m V_i + g_o V_o$$

$$R_i = \frac{V_i}{I_i}$$

Input resistance

Large

$$g_m = \left.\frac{I_o}{V_i}\right|_{V_o=0}$$

Trans-conductance

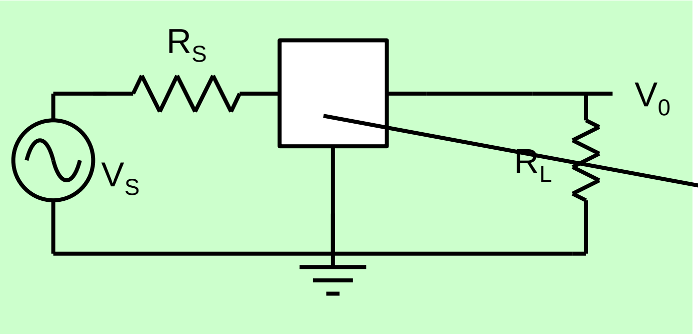
Large

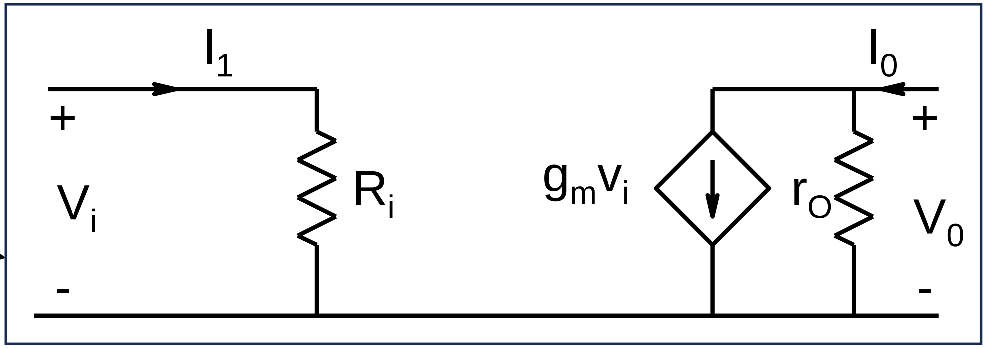
$$g_o = \frac{1}{r_o} = \left.\frac{I_o}{V_o}\right|_{V_i=0}$$

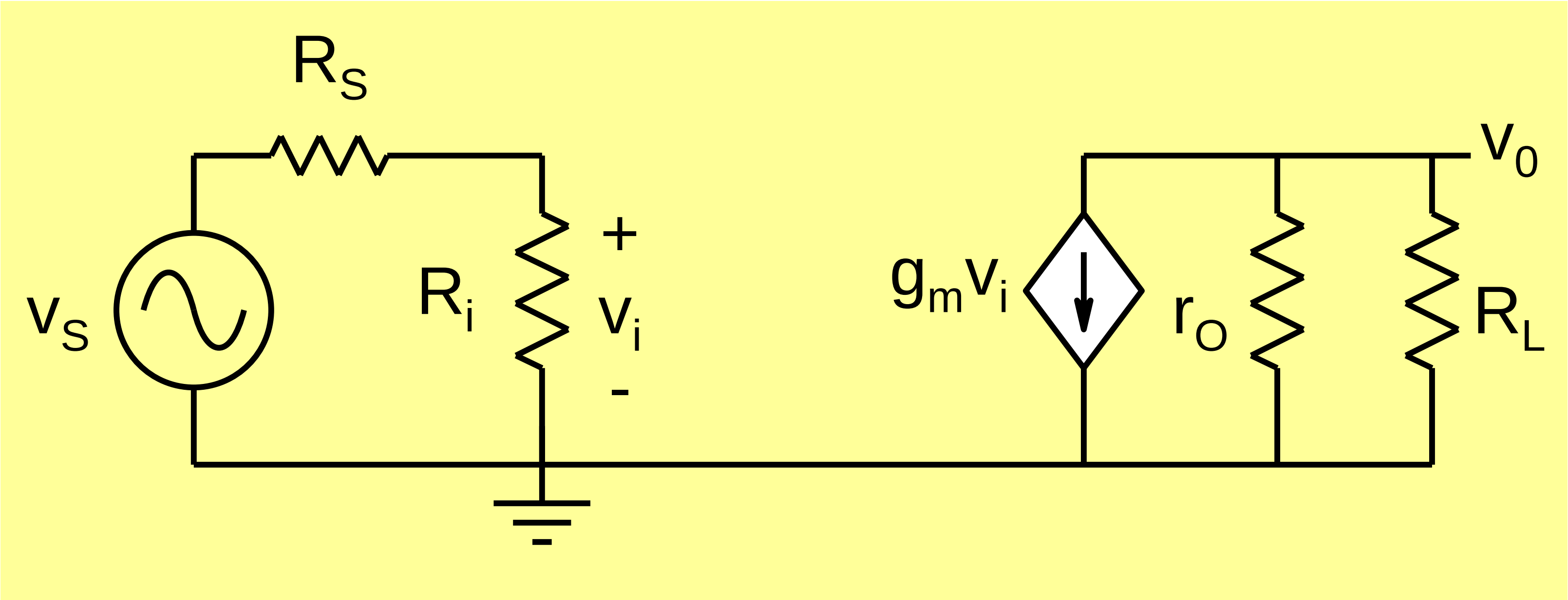
Output conductance

Small

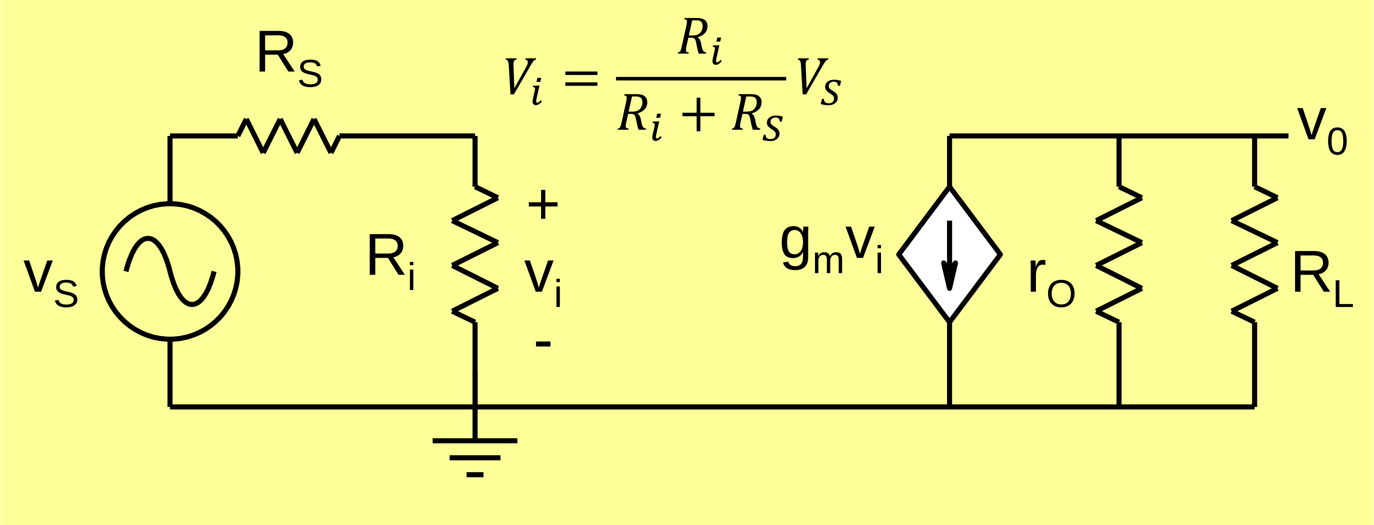
Amplifier circuits







Voltage gain



$$V_o = -g_m V_i \times r_o \| R_L$$

$$A_V = \frac{V_o}{V_s} = -g_m r_o \times \frac{R_L}{r_o + R_L} \times \frac{R_i}{R_i + R_S}$$

Necessary Condition for Voltage Amplification

$$|A_V| \le g_m \times r_o$$

$$g_m \times r_o > 1$$

R_i	Large
g_m	Large
r_o	Large

High voltage gain

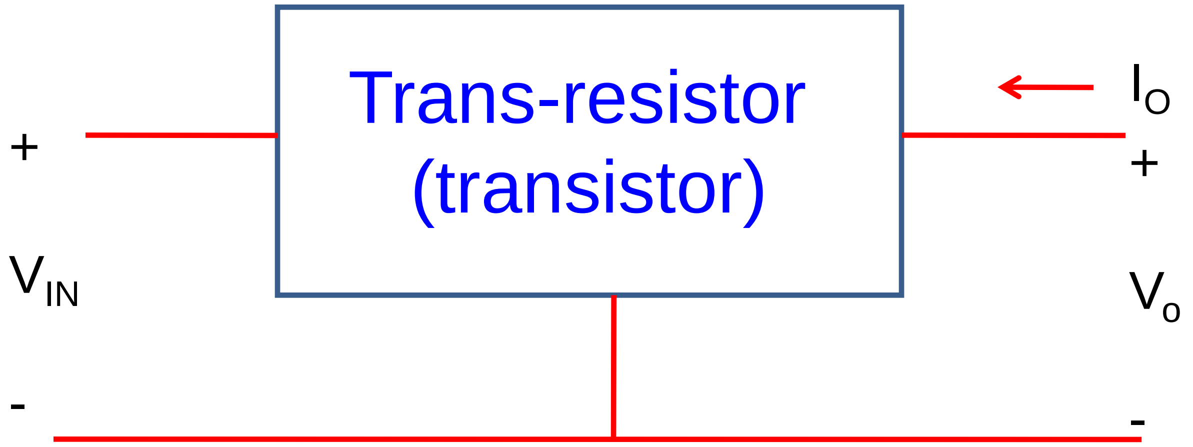
$$g_m \, r_o >> \; 1$$

$$g_m \;\; >> \; \frac{1}{r_o} = g_o$$

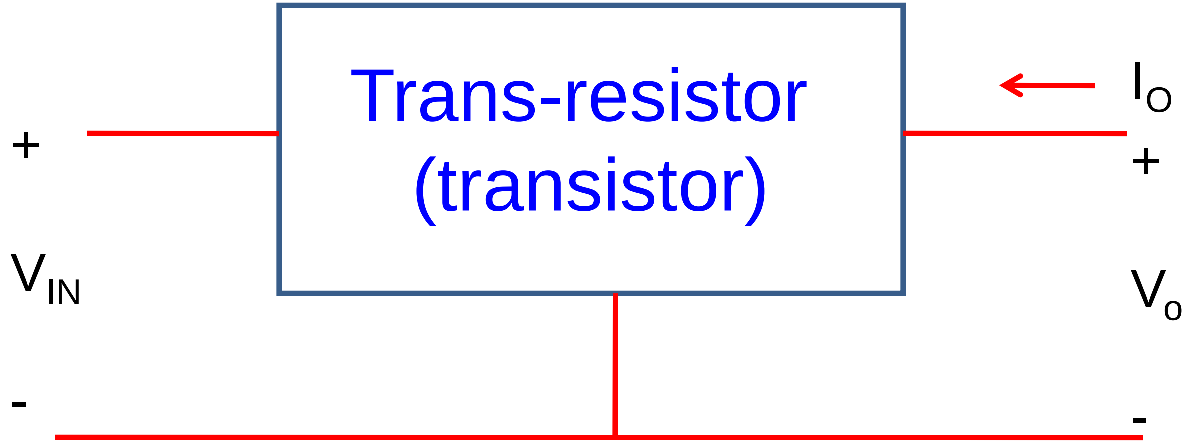
Trans-conductance >> Output Conductance

Trans-resistance << Output resistance

i.e. current I_O is much more sensitive to V_{IN} than V_O



High voltage gain



i.e. current I_O is much more sensitive to V_{IN} than V_O

- Can be used for voltage amplification
- Can be used as a switch
- Implement logic
- …