EEE 241
ANALOG ELECTRONICS 1
Lecture 1 – 2 port network

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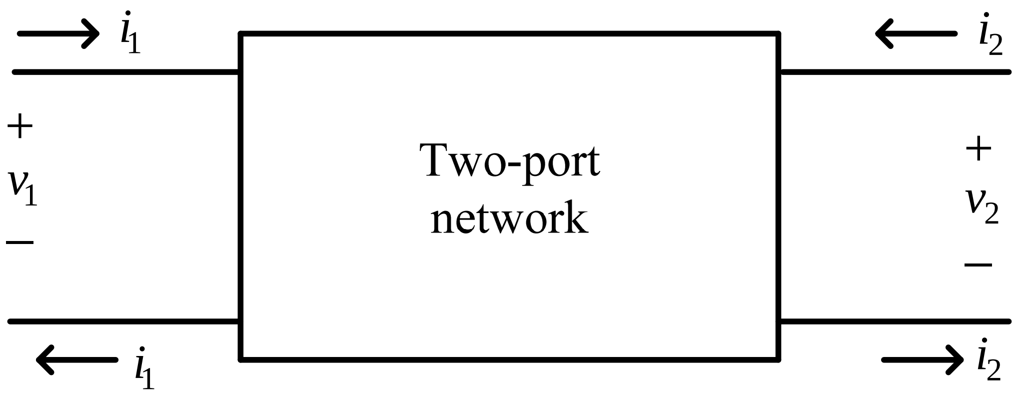
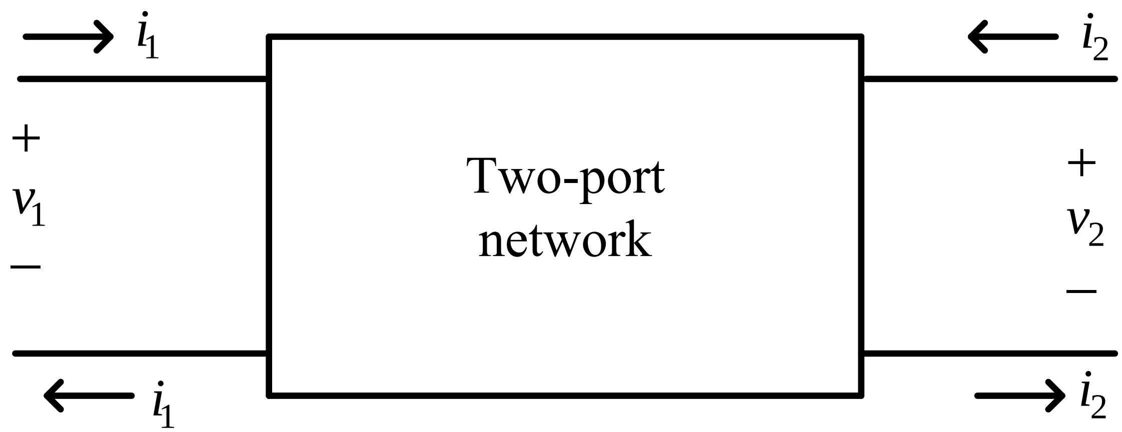
3.2 Two-Port Modeling of Amplifiers

The most basic parameter of an amplifier is its gain. Since amplifier may be connected to a wide variety of sources and loads, predicting the dependence of the gain on the source and load resistance is important.

To simplify the amplifier analysis for varying source or load resistance, amplifiers are often modeled as two-port equivalent networks.



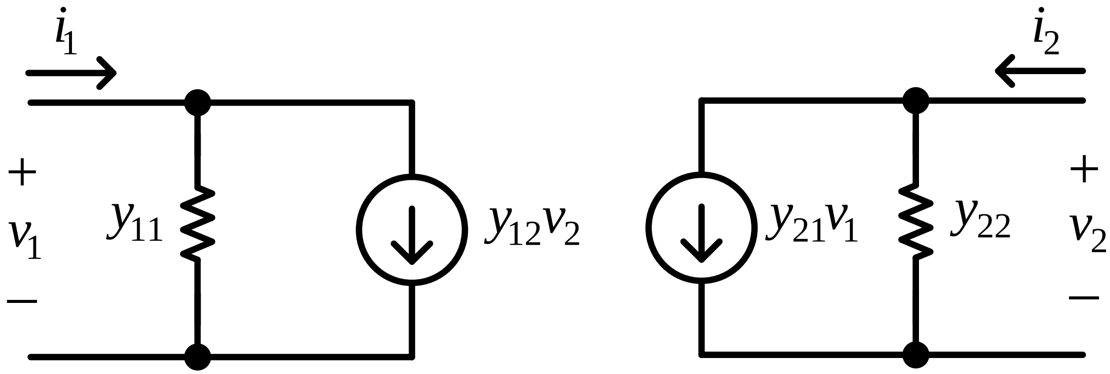
4 terminals and 4 port variables (a voltage and a current at each port). A pair of terminals is a port if the current that flows into one terminal is equal to the current that flows out of the other terminal.



The model of an amplifier : one port represents the amplifier input characteristics and the other represents the output.

$$i_1 = y_{11}v_1 + y_{12}v_2$$
$$i_2 = y_{21}v_1 + y_{22}v_2$$

Admittance-parameter two-port circuit



$$i_1 = y_{11}v_1 + y_{12}v_2$$
$$i_2 = y_{21}v_1 + y_{22}v_2$$

$y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2=0}$ = Input admittance with output short circuit

$y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0}$ = Reverse transconductance with input short circuit

$y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0}$ = Forward transconductance with output short circuit

$y_{22} = \left.\frac{i_2}{v_2}\right|_{v_1=0}$ = Output admittance with input short circuit

$$y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0}$$ = Reverse transconductance with input short circuit

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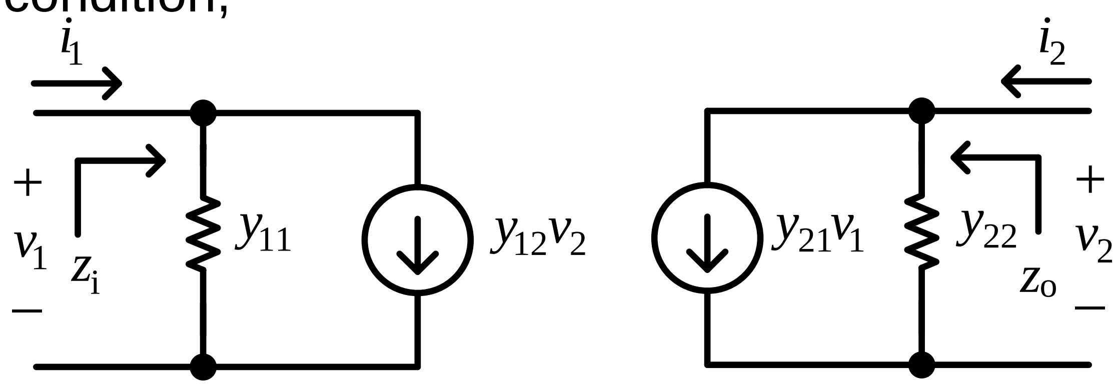
y_{12} represents feedback in the amplifier when signal propagates back from the output to the input as well as forward from the input to the output. When y_{12} is present, the amplifier is said to be bilateral.

In many cases, especially at low frequency this feedback is negligible and y_{12} is assumed 0. The amplifier is then said to be unilateral and characterize by the other 3 parameters. Since the model now includes one transconductance (i.e. y_{21} when y_{12} =0, y_{12} is usually referred to simply as the short circuit transconductance and under this condition,

$$y_{21} = G_M$$

Input impedance $z_i = \frac{1}{y_{11}}$

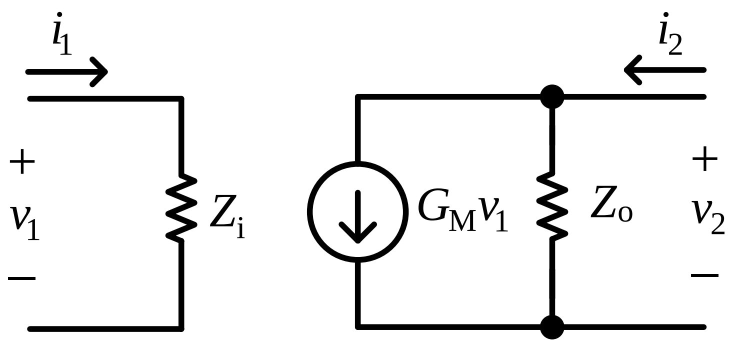
Output impedance $z_o = \frac{1}{y_{22}}$



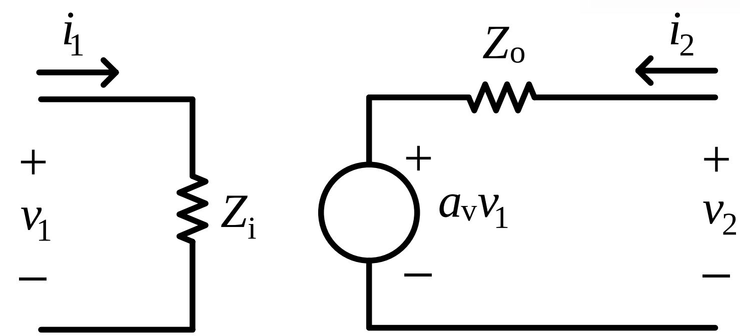
Another parameter is the open circuit voltage gain, a_v.

Unilateral z-port circuit :

a) Norton output model



b) Thevenin output model



$$v_2 = -G_M v_1 Z_o$$

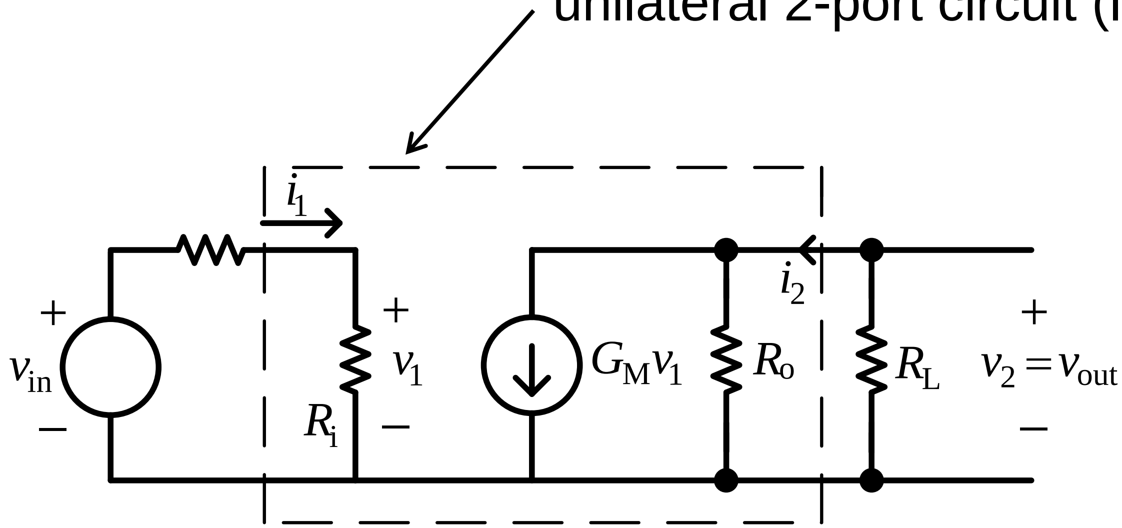
Open circuit voltage gain,

$$a_v = \left.\frac{v_2}{v_1}\right|_{i_2=0} = -G_M Z_o$$

At low frequencies, the input and output impedance are usually dominated by resistance. Hence, characterization of amplifier low frequency behavior can be determined from R_i , R_o, G_M, and a_v .

General overall amplifier circuit

unilateral 2-port circuit (low frequency)



(Do example on pg. 174)

Symbol convention

Condition	Examples
Bias or DC quantities are represented by uppercase symbols with uppercase subscripts.	I_B and V_{BE}
Small-signal quantities are represented by lowercase symbols with lowercase subscripts.	i_b and v_{be}
Elements in small-signal circuit are represented by lowercase symbols with lowercase subscripts.	g_m and c_{gs}
Total quantities, i.e. sum of bias and signal, are represented by uppercase symbols and lowercase subsripts.	I_b and V_{be}