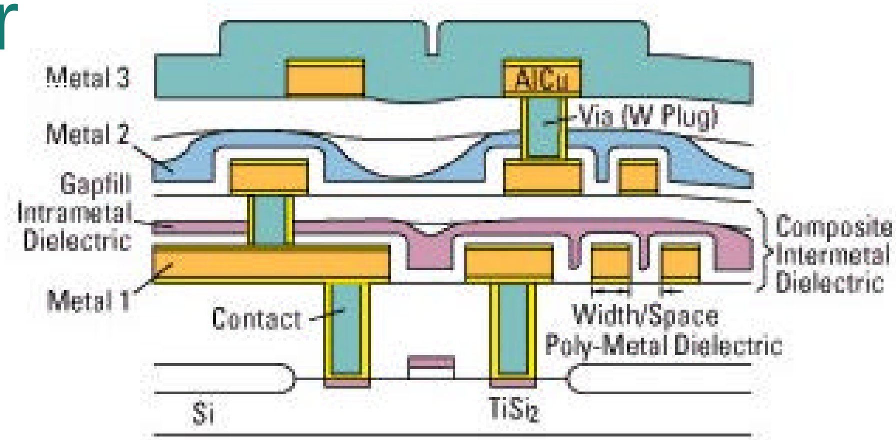
Week 2, Lectures 3-5, February 22-26, 2001

EECS 105 Microelectronics Devices and Circuits, Spring 2001

Andrew R. Neureuther

Topics: Practice Loop and Node Eqns., Two-Ports, Silicon Physics – Carriers, Process Flow and Layout, Sheet Resistance, Squares



Reading for week: (review of EE 40), HS 8.2.2, 9.1, 2.1-2.4, 2.5.4-2.6, 4.1.1, 4.5.7,6.2, 7.1.1,7.7,

Version 1/21/01

Outline: Week 2 Lectures 3-5

L3: More Basic Circuits (HS 8.2.2, 9.1)

Loop and Node Equations, Two-Ports

L4: Silicon Physics (HS 2.1-2.4, 2.5.4, 4.1.1, 5.4.7, 6.2, 7.1.1,7.1)

Carriers, Process Flow and Layout

L5: IC Resistors (HS 2.6)

Sheet resistance and Number of Squares

Lecture 3, February 22, 2001

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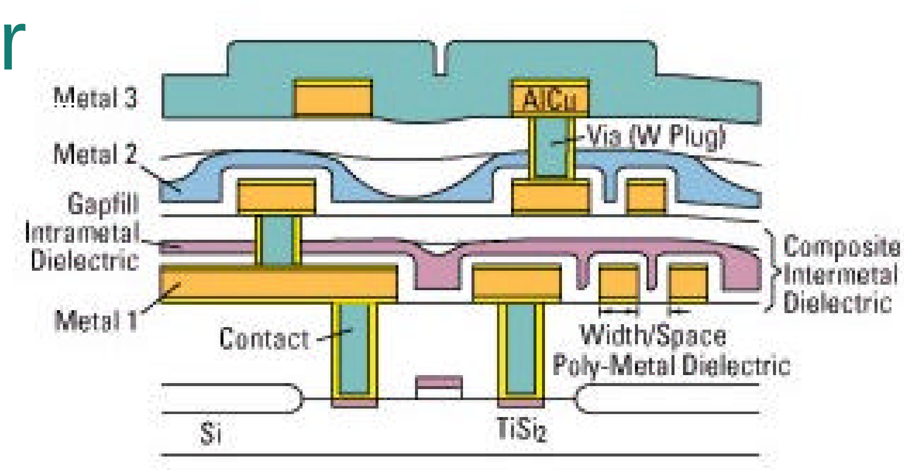


Topics:
Practice Circuit Analysis,
Two-Ports

Reading: (review of EE 40), HS 8.2.2, 9.1

Version 1/21/01

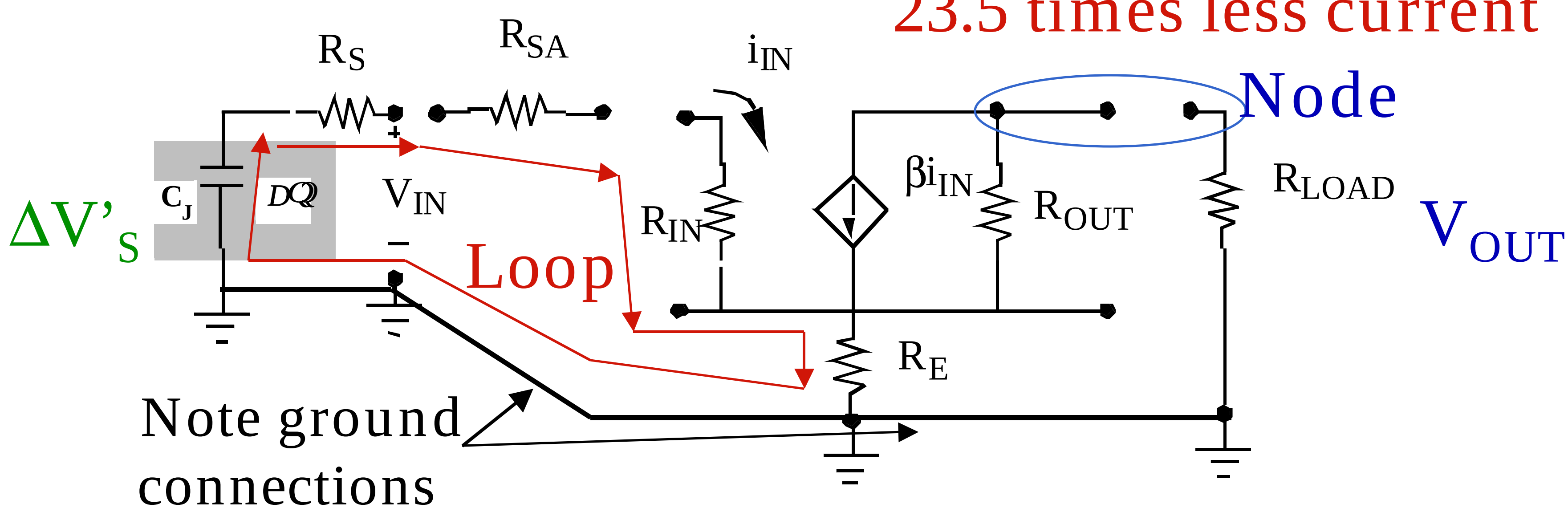
W2 M L3 : More Basic Circuits

- Practice circuit analysis
  - » R_{IN} with R_E
  - » Gain or Rout with R_E
- Standard Two-ports
- Difficulty of two-ports with output coupled back to input

High Input Impedance Circuit

$R_E = 30\ k\Omega \quad R_{IN\ EQ} = R_{IN} + (\beta+1)R_E = 3.06\ M\Omega$

23.5 times less current

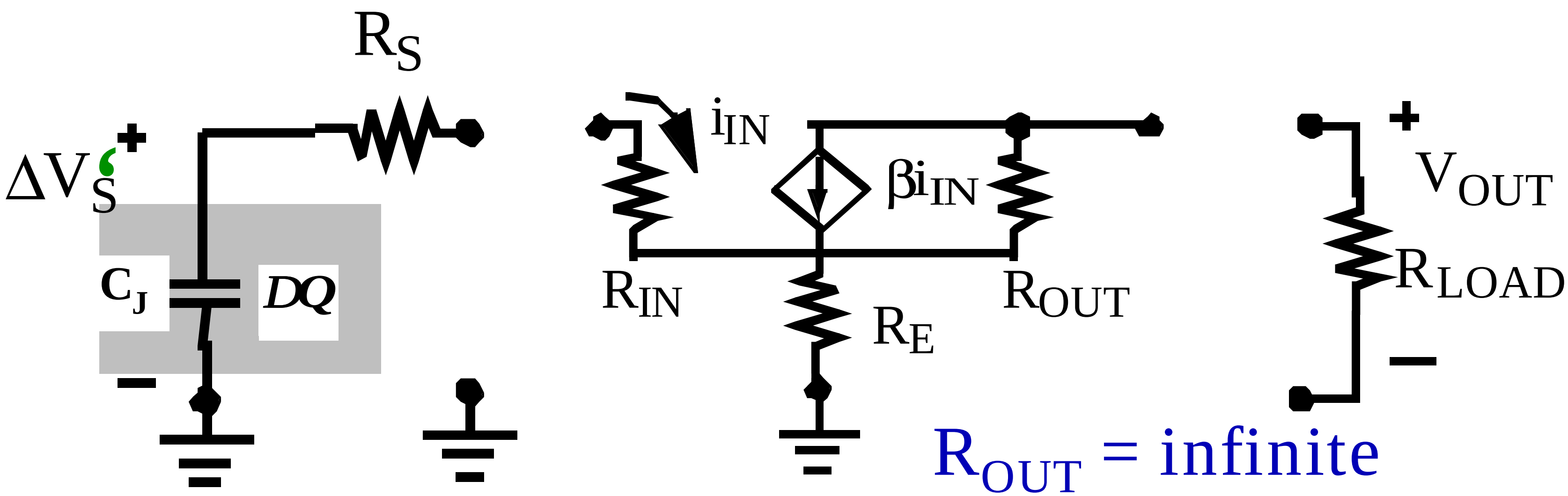


$$V_{OUT} = [\Delta V'_S/(R_S+R_{SA}+R_{IN\ EQ})](-\beta)R_{LOAD} = 5\ mV$$

$\Sigma V_i = 0 \Rightarrow i_{IN}$

23.5 times smaller gain

High Input Impedance Circuit



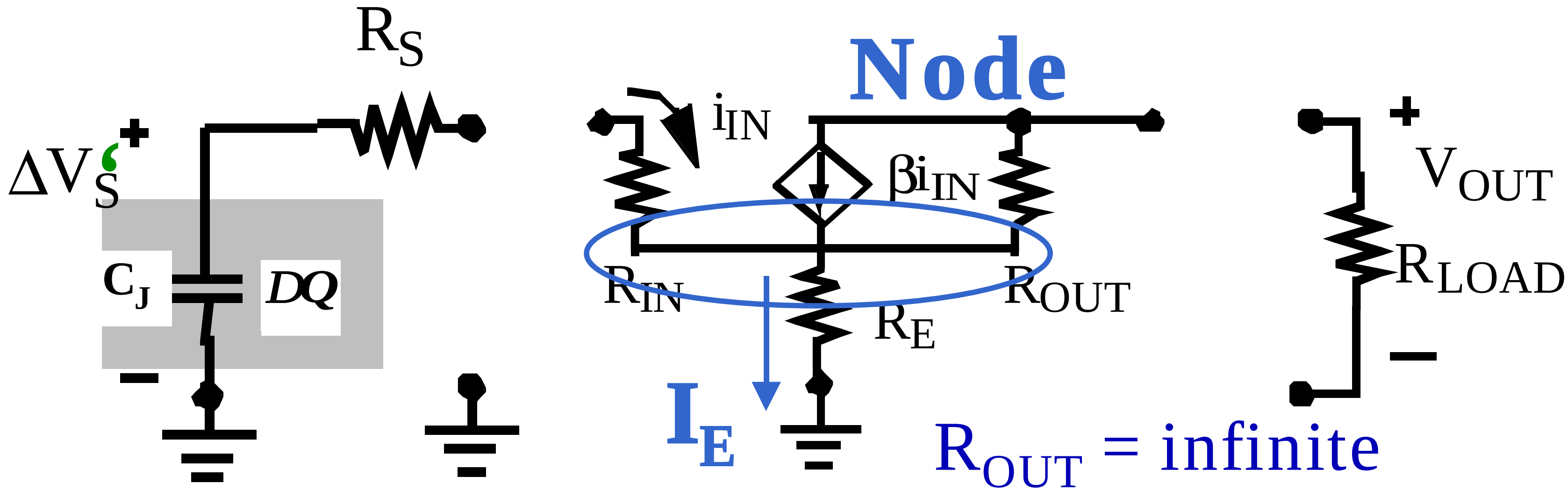
R_{OUT} = infinite

Result:

$$V_{OUT} = [\Delta V'_S/(R_S+R_{SA}+R_{IN\ EQ})](-\beta)R_{LOAD}$$

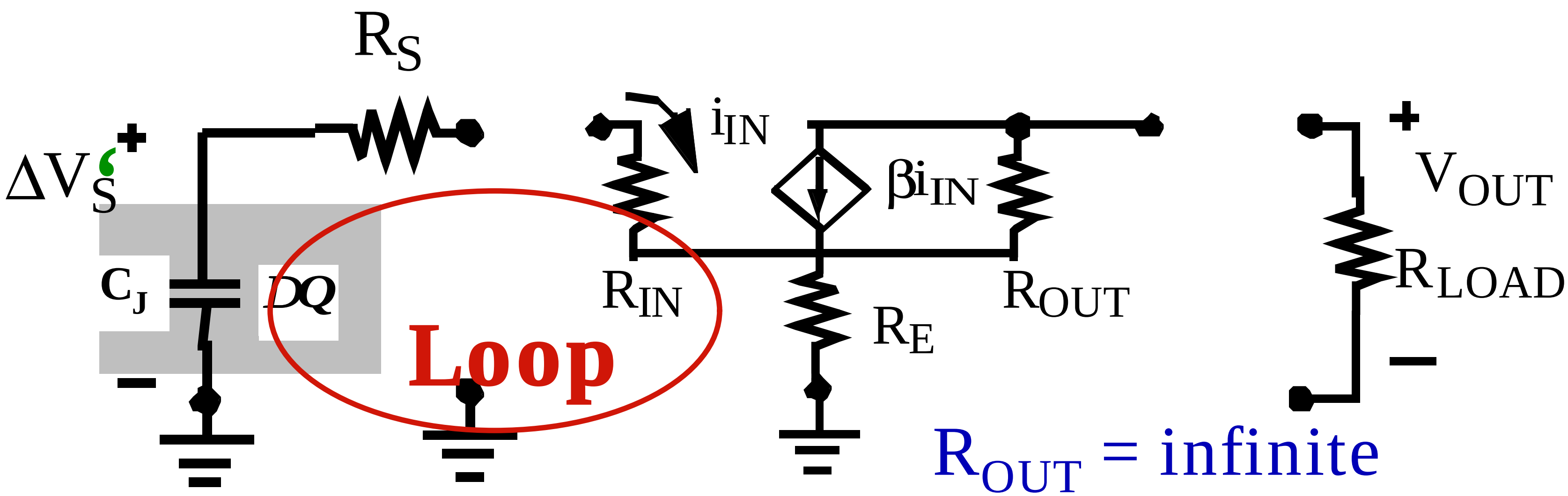
How is the circuit analysis done?

Write a Node Equation for I_E



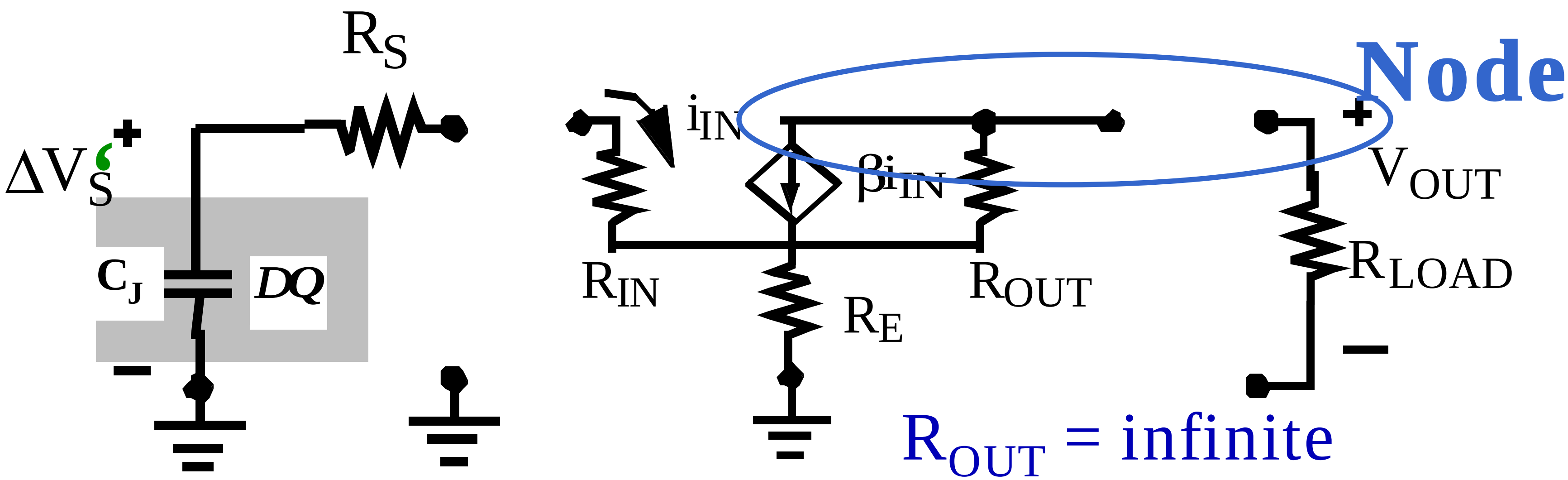
R_{OUT} = infinite

Write a Loop Equation for I_{IN}



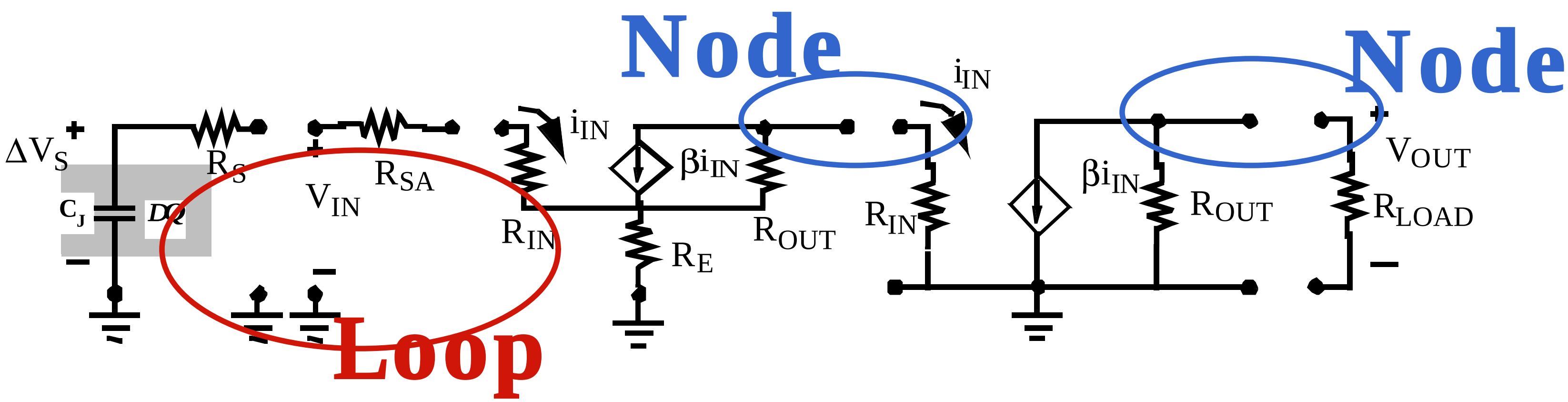
R_{OUT} = infinite

Find $V_{OUT} / \Delta V'_s$



$$V_{OUT} / \Delta V'_S = [1/(R_S + R_{SA} + R_{IN\ EQ})](-\beta)R_{LOAD}$$

Analysis of Multistages



Background on Two-Ports

- Designed for cascading components
  - » Hi-Fi components
  - » IC stages of amplifier circuit
- Based on Matrix Multiplication

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

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

Impedance
(transresistance)

$I_1 = Y_{11}V_1 + Y_{12}V_2$

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

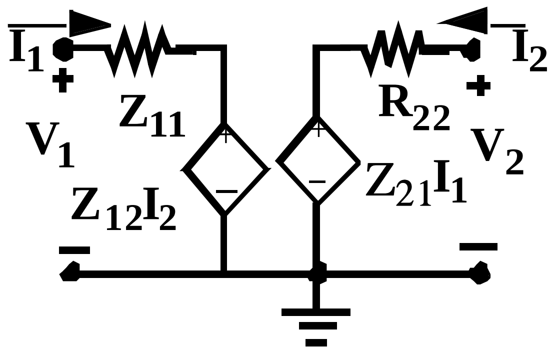
Admittance
(transconductance)

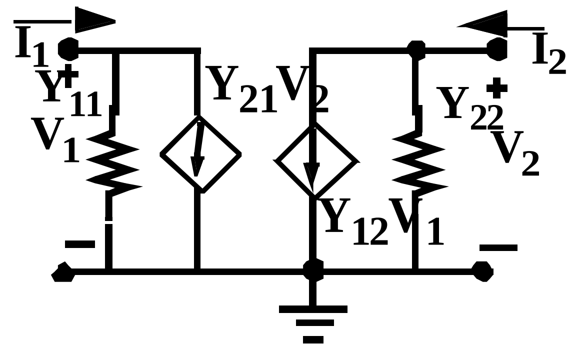
$V_1 = H_{11}I_1 + H_{12}V_2$

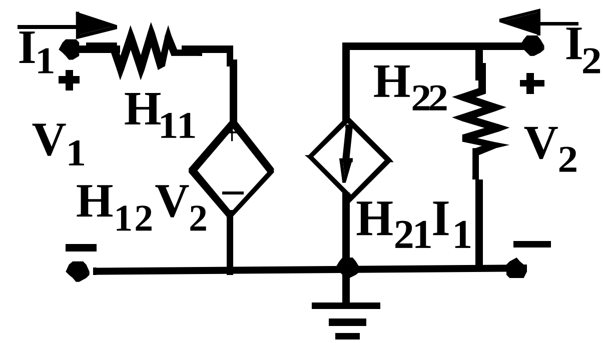
$I_2 = H_{21}I_1 + H_{22}V_2$

Hybrid_1
(current 1-2)

Two-Port Equivalent Circuits







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

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

Two Thevenin

(transresistance)

$I_1 = Y_{11}V_1 + Y_{12}V_2$

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

Two Norton

(transconductance)

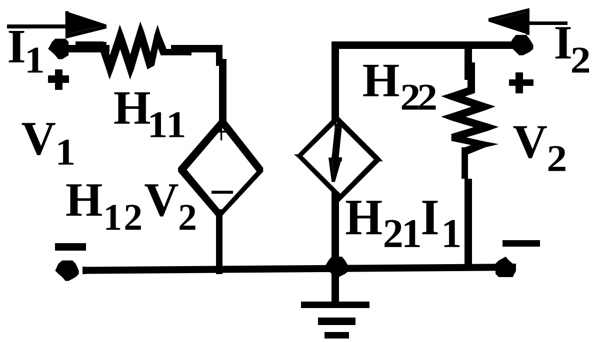
$V_1 = H_{11}I_1 + H_{12}V_2$

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

Thevenin input
Norton output

(current 1-2)

Finding the Two-Port Parameters



$V_1 = H_{11}I_1 + H_{12}V_2$

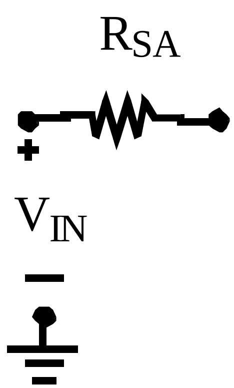
$I_2 = H_{21}I_1 + H_{22}V_2$

H_{11} is found by taking V_1 over I_1 when V_2 is zero.

H_{12} is found by taking V_1 over V_2 when I_1 is zero.

Note: The conditions to determine each matrix element arise from the terminal variables multiplying the right hand side.

Hybrid Two-Port for a Resistor



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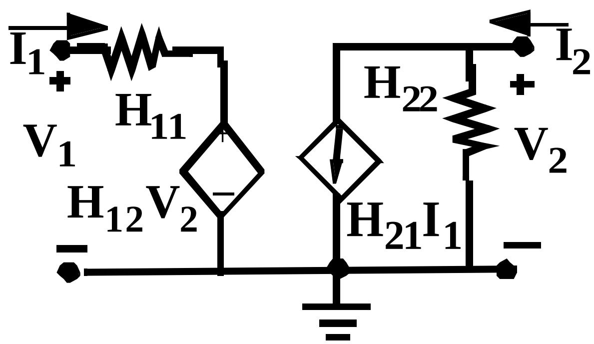


$$V_1 = H_{11}I_1 + H_{12}V_2$$

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

$V_2 = 0$:

$V_1 = H_{11}I_1 = R_{SA}I_1$

$H_{11} = R_{SA}$

$I_2 = H_{21}I_1 = -1I_1$

$H_{21} = -1$

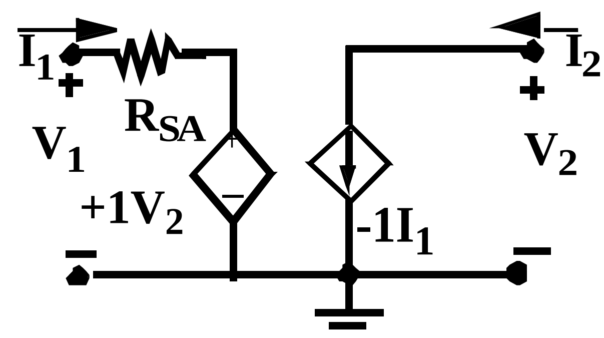
$I_1 = 0$:

$V_1 = H_{12}V_2 = +1V_2$

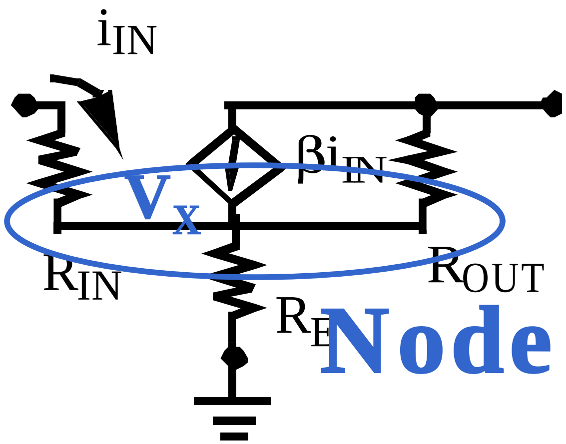
$H_{12} = +1$

$I_2 = H_{22}V_2 = 0V_2$

$H_{22} = 0$



Find H_{11} with R_E and R_{OUT}



$V_1 = H_{11} I_1 + H_{12} V_2$

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

$V_X = (\beta + 1)\, i_{IN} / (1/R_S + 1/R_{OUT})$

$V_{IN} = i_{IN} R_{IN} + V_X$

$H_{11} = (V_{IN} / i_{IN})\,|_{V2=0} =$

$R_{IN} + (\beta + 1)(R_S R_{OUT}) / (R_S + R_{OUT})$

$V_2 = 0$:

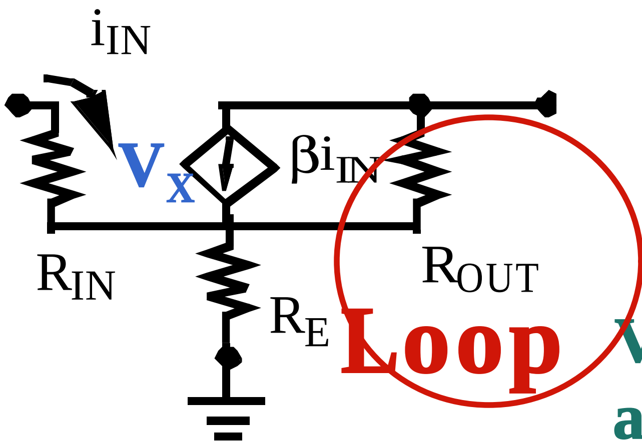
R_{OUT} in || with R_E

Node Eq. For V_X

$i_{IN} - V_X/R_S - V_X/R_{OUT} + \beta i_{IN} = 0$

Note: R_{IN} depends on R_{OUT} when the output feeds back to the input.

Find H_{12} with R_E and R_{OUT}



$V_1 = H_{11}I_1 + H_{12}V_2$

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

$I_1 = 0$:

$i_{IN} = 0$

$V_1 = V_X$

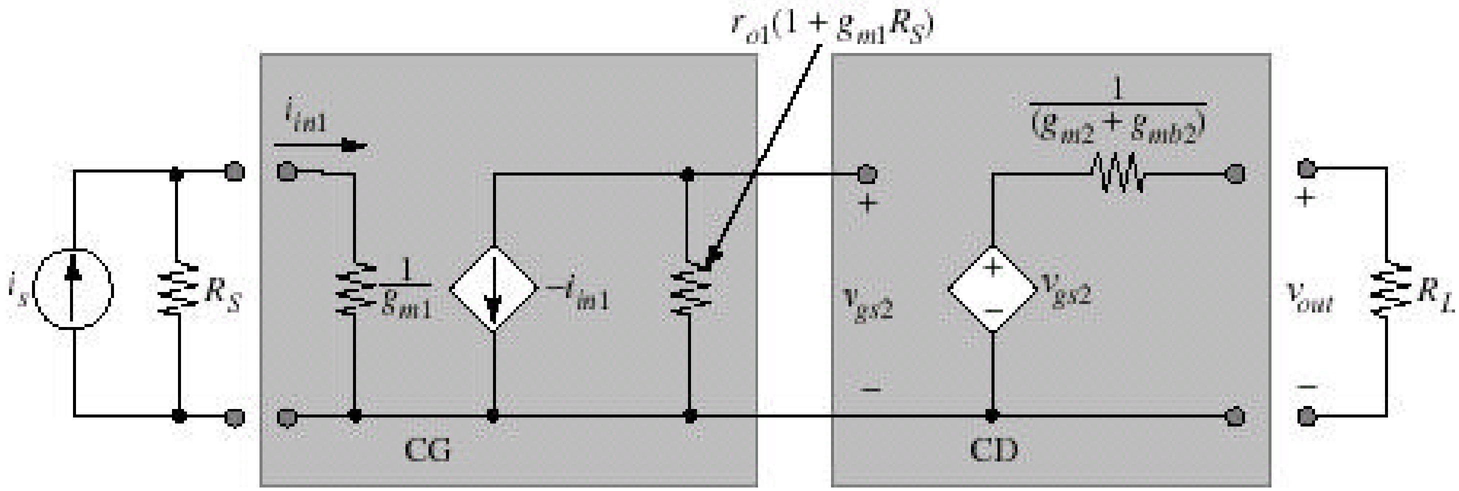
Voltage V_2 is divided across R_{OUT} and R_E

$V_1 = V_2 R_E/(R_E + R_{OUT})$

$H_{12} = (V_1/V_2)|_{I1=0} = R_E/(R_E + R_{OUT})$

Note: The voltage source in the input port is not zero when RE is not zero.

Multistage Amplifiers



This example from the reading in Chapter 8 this week.

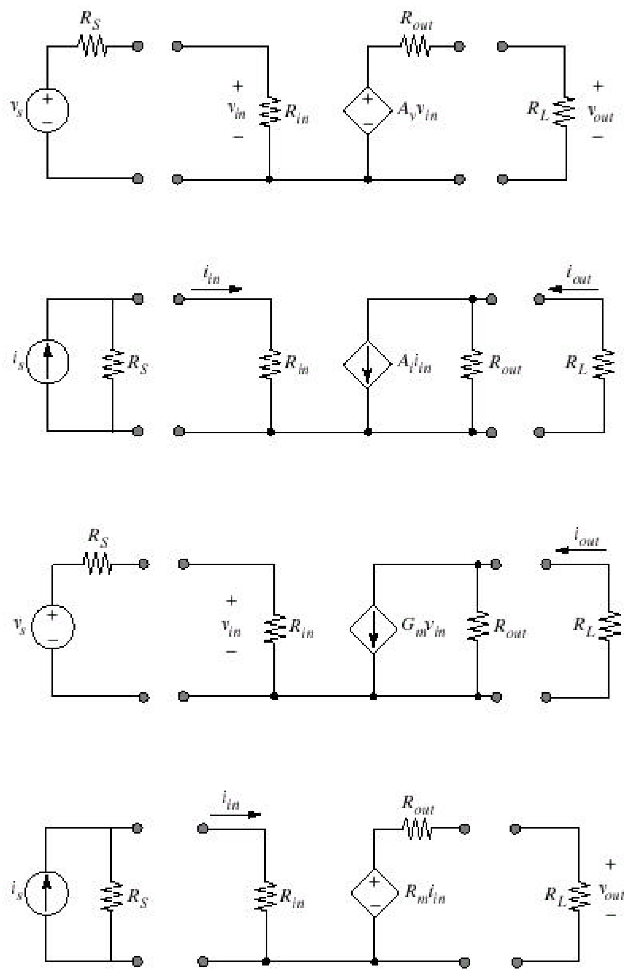
Classification of Two-Port Amplifiers

Voltage Amplifier

Current Amplifier

Transconductance Amplifier

Transresistance Amplifier



Voltage

Current

Transconductance

Transresistance

Figure 8.2