4. Elemental 2-ports and Operational Amplifier

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Part 4: Elemental 2-port …

1. **Controlled sources**
2. **Nodal Analysis revisited**
3. **Analysis of networks with controlled sources**
4. **2-port Elements**
5. **Important 2-port elements**
   - 5.1. controlled sources
   - 5.2. ideal transformer
   - 5.3. operational amplifier

5. Important 2-port Elements: Operational Amplifier

multi-transistor 2-port amplifier with high voltage gain

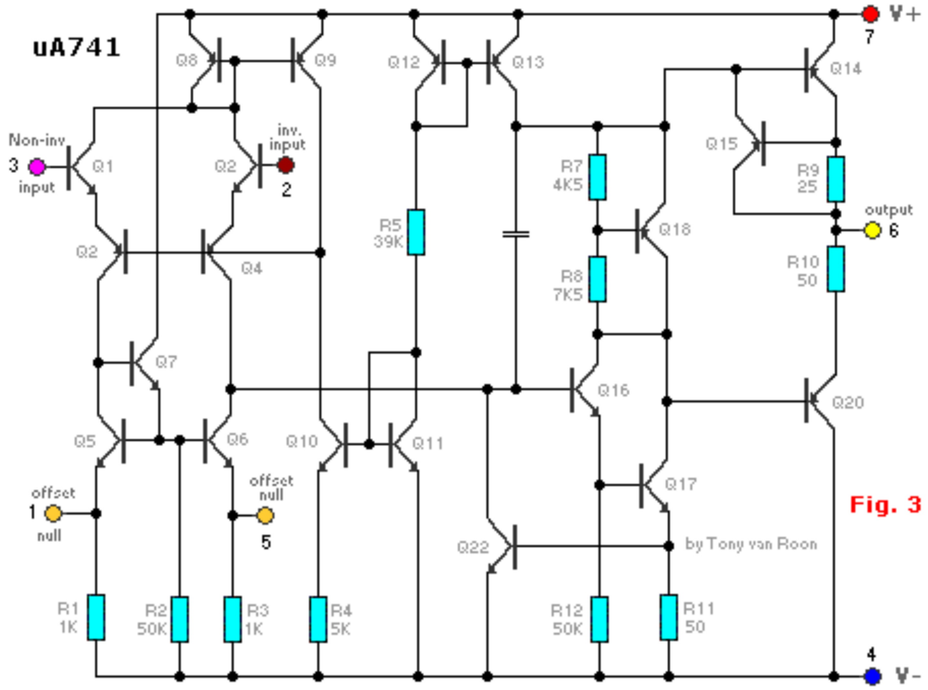
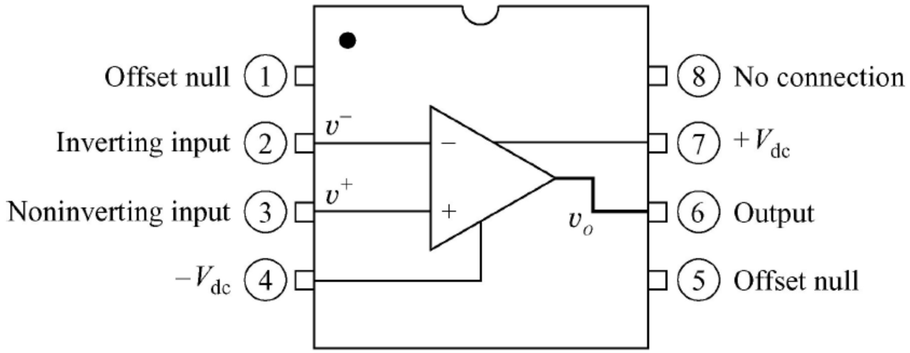
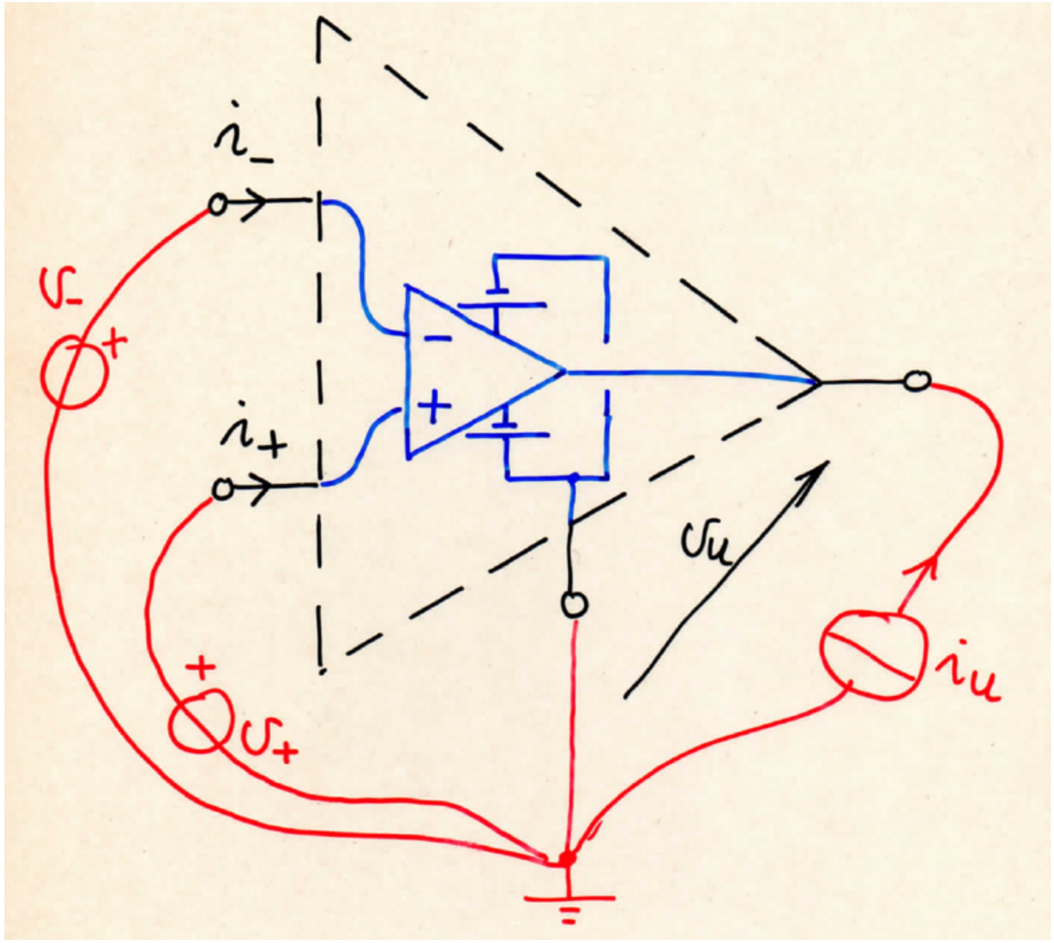


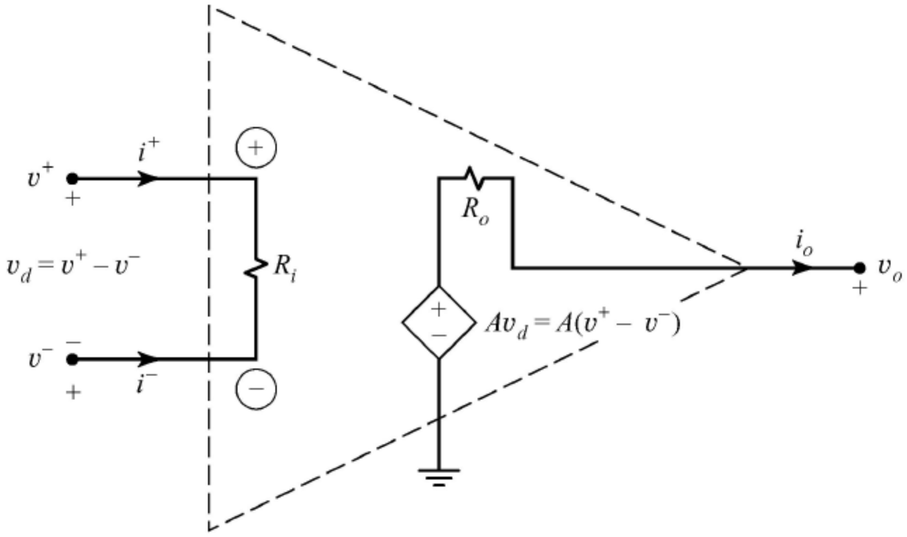
Fig. 3



5. Important 2-port Elements: Operational Amplifier

static models





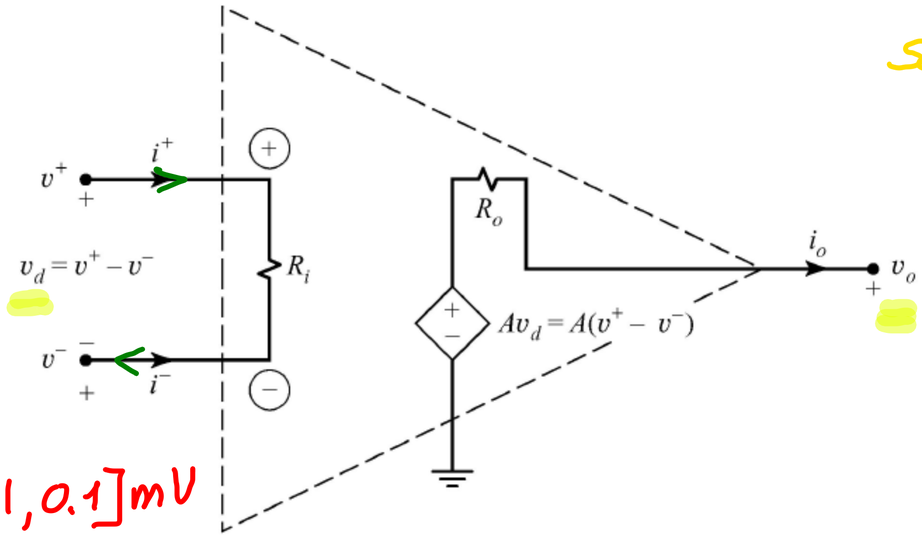
$$R_i \approx 10\,k\Omega$$

$$R_o \approx 10\,\Omega$$

$$A \approx 10^5$$

5. Important 2-port Elements: Operational Amplifier

static models



$v_d \in [-0.1, 0.1]\,mV$

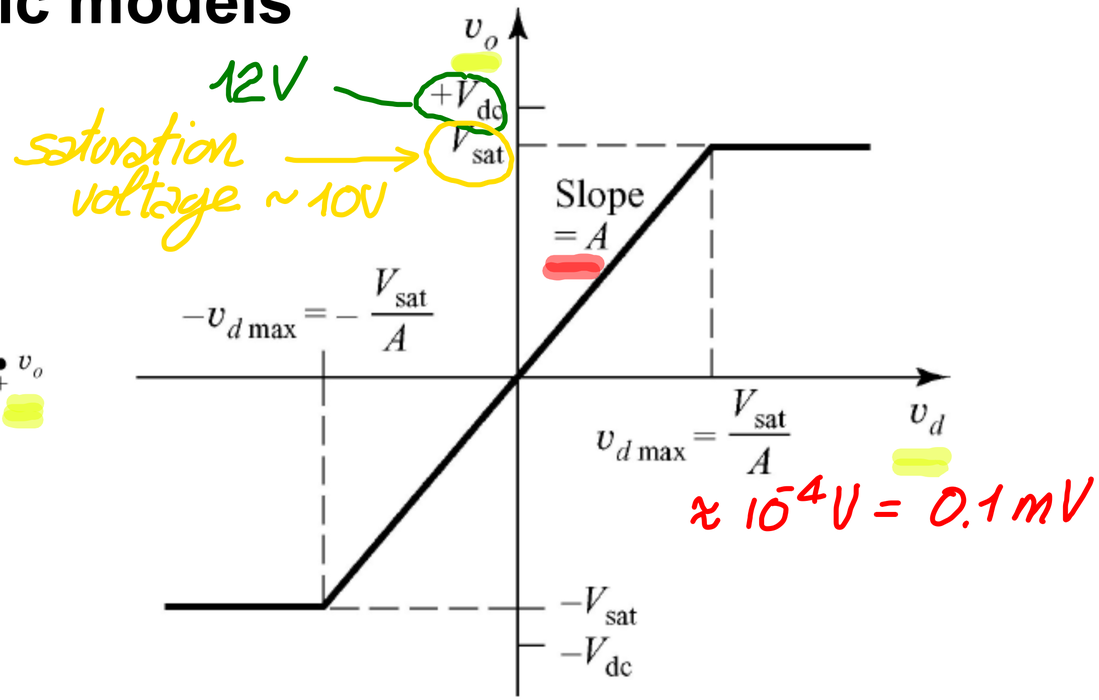
$i^+ = -i^- =$

$[-10, 10]\,nA$

$$R_i \approx 10\,k\Omega$$

$$R_o \approx 10\,\Omega$$

$$A \approx 10^5$$



in linear region: v_d negligible → i^+ and i^- negligible

5. The Ideal Operational Amplifier

$$v_d = 0$$

$$i_+ = i_- = 0$$

v_o independent of v_d

CHAPTER 4

The Operational Amplifier (Op Amp)

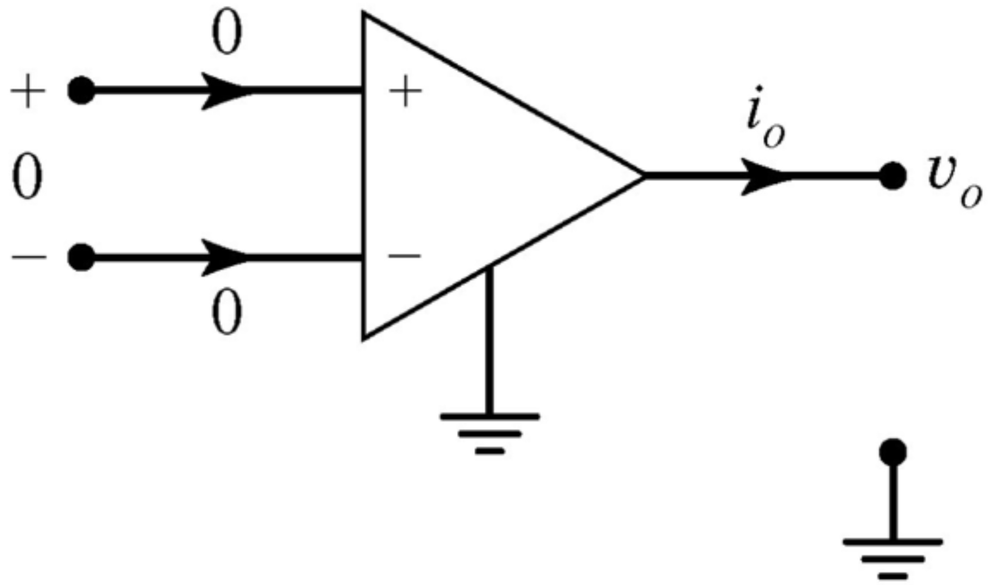


Figure 4.4

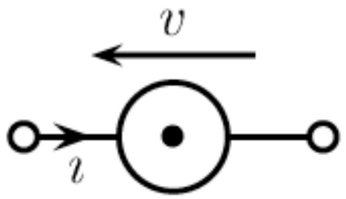
The ideal op amp and its virtual short-circuit properties.

Fundamentals of Electric Circuit Analysis, by Clayton Paul

5. The Ideal Operational Amplifier

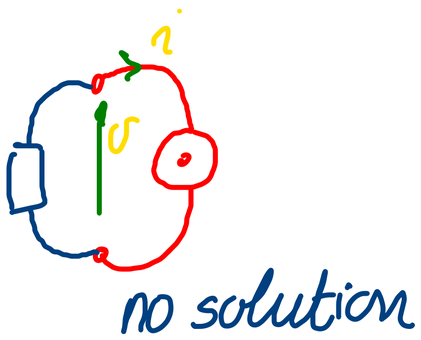
Nullator, Norator and Nullor ...

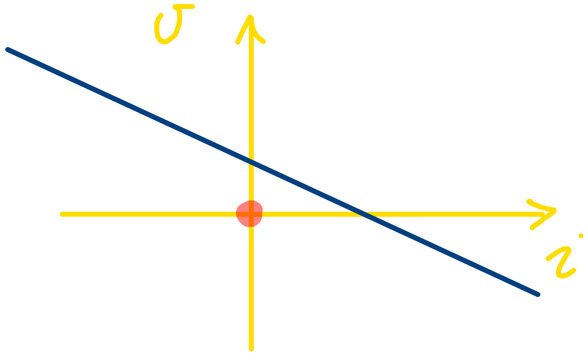
Nullator



$$\begin{cases} v = 0 \\ i = 0 \end{cases}$$

Resistive, linear, t-invariant, **over-constrained**

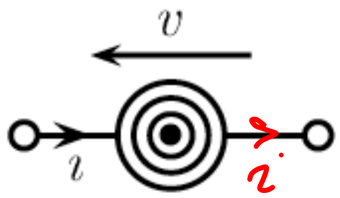




5. The Ideal Operational Amplifier

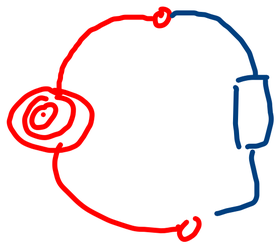
Nullator, Norator and Nullor ...

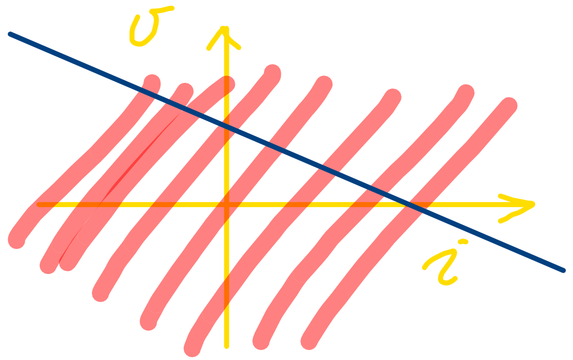
Norator



no constraints on v and i

under-constrained

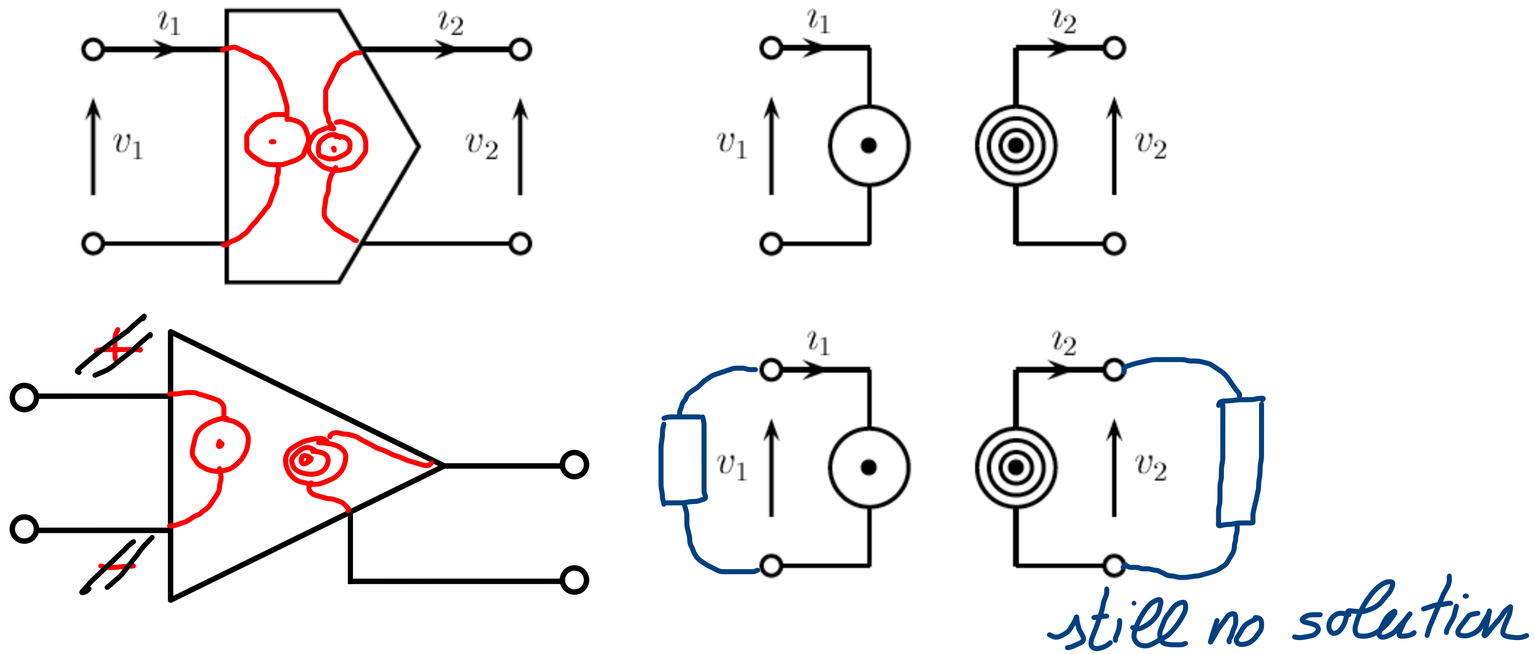




5. The Ideal Operational Amplifier

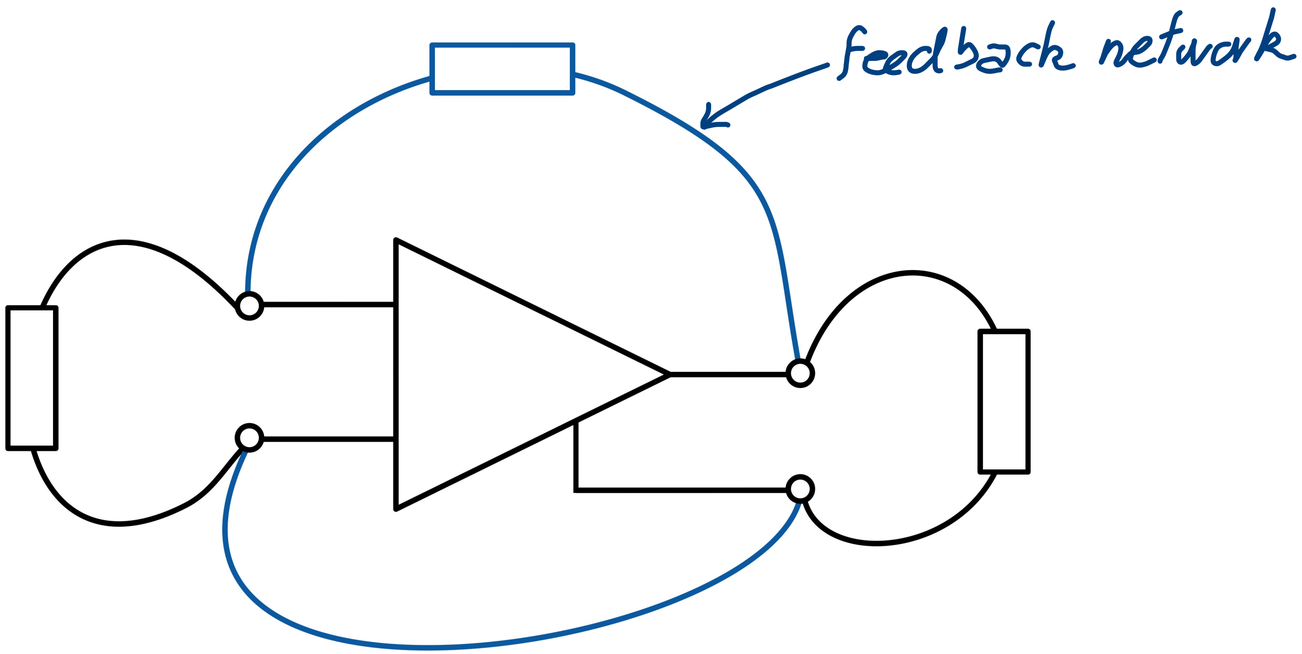
Nullor or Ideal Operational Amplifier (OA)

intrinsic 2-port composed of one nullator and one norator



5. Circuits with Ideal OA

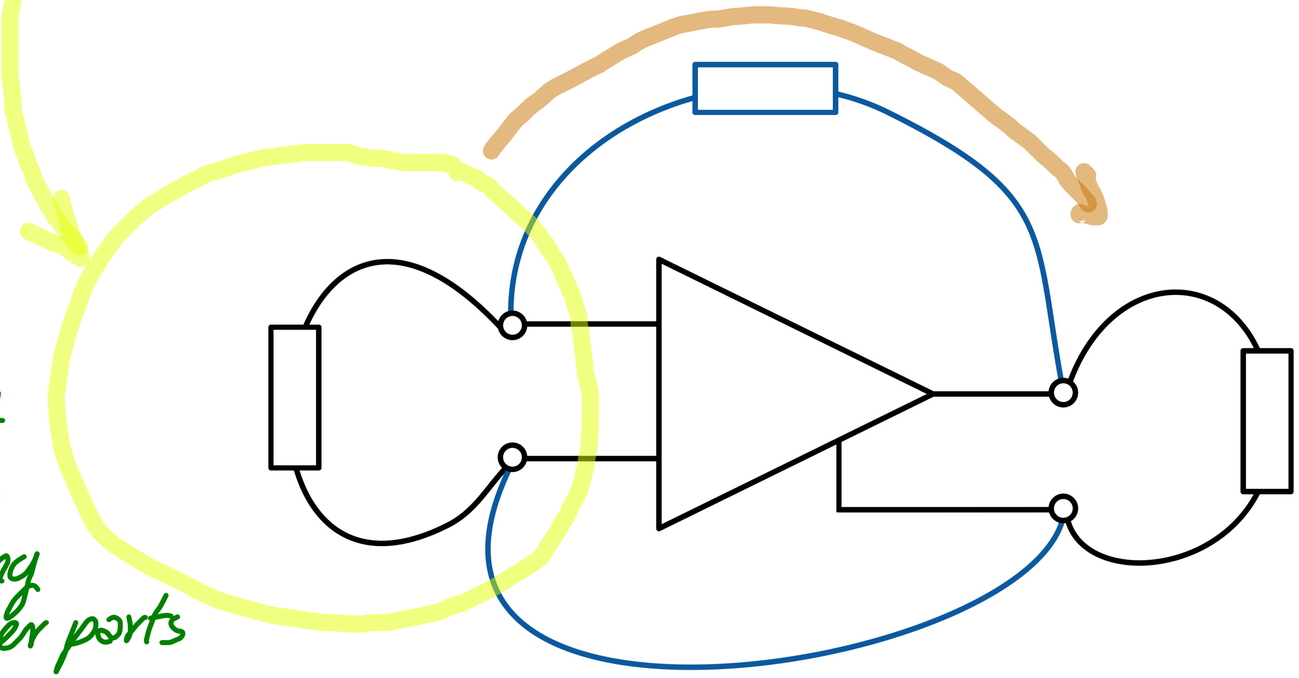
Nullor circuits are based on **Feedback Networks** coupling the input and output ports



5. Circuits with Ideal OA

Analysis:

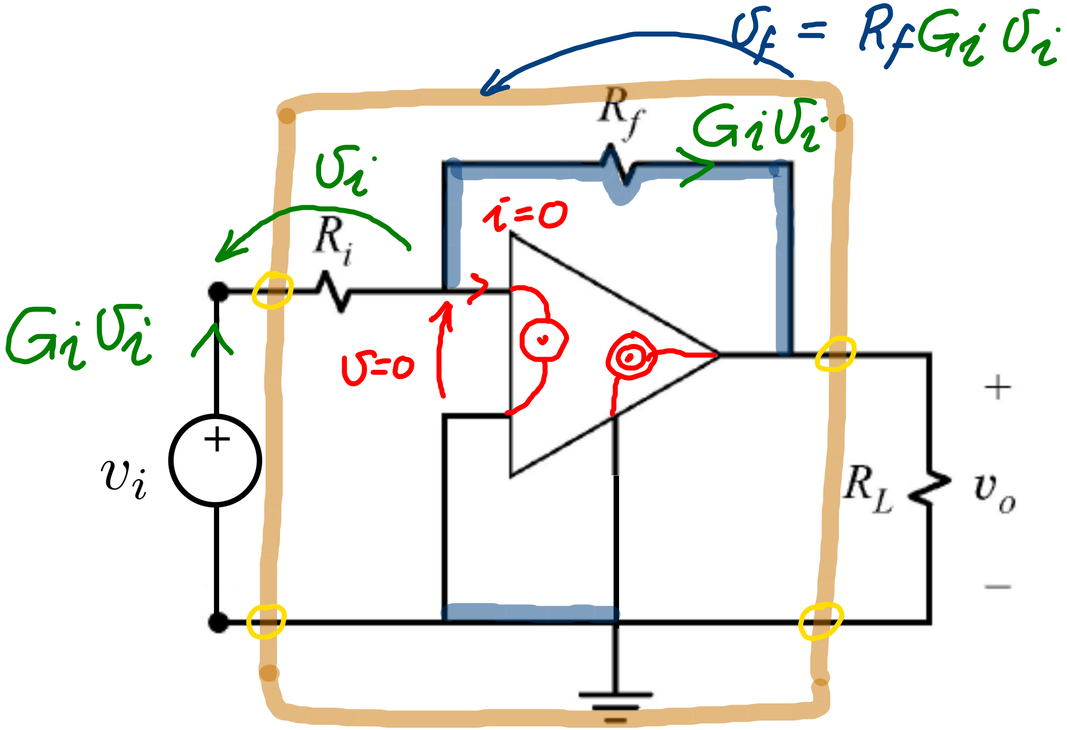
- by VE and CE involving input port (see Book)
- by Nodal Equations



possible to solve the input port wo involving the other ports

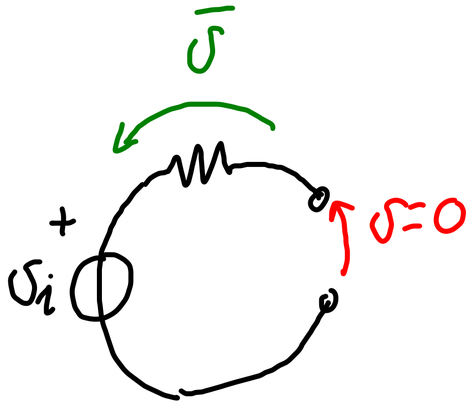
5. Circuits with Ideal OA

The Inverting OA circuit



$$v = v_f + v_o$$

$$v_o = -\frac{R_f}{R_i} v_i$$



5. Circuits with Ideal OA

Problem: compute v_o

CHAPTER 4

The Operational Amplifier
(Op Amp)

$5V - 0V - 2V - v_o = 0$

$v_o = 3V$

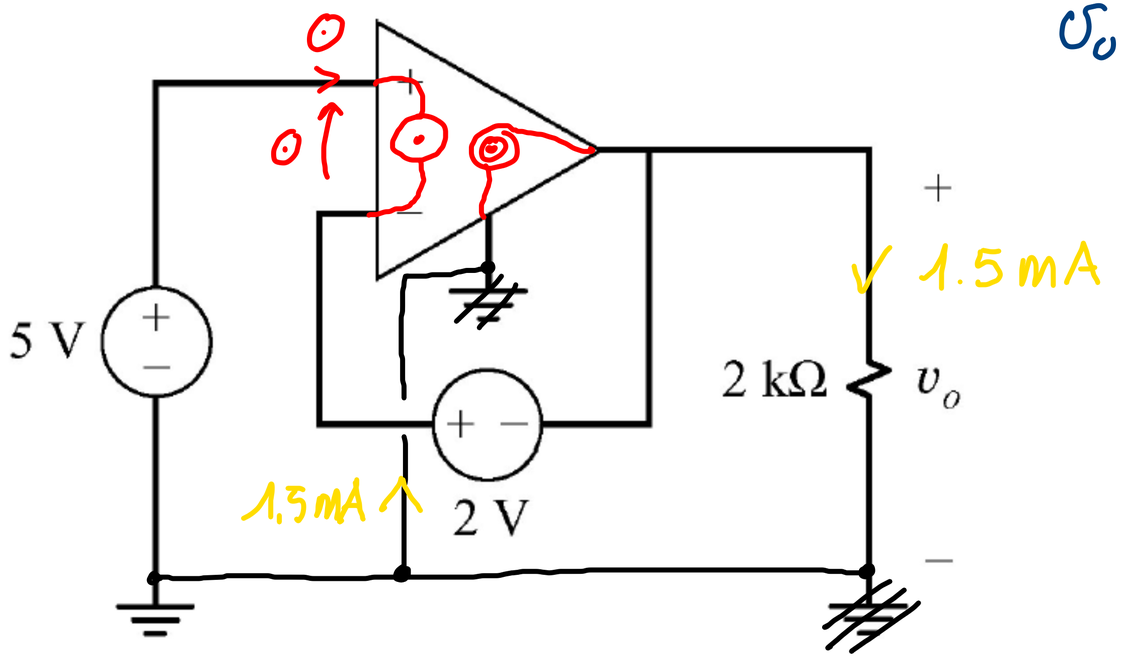
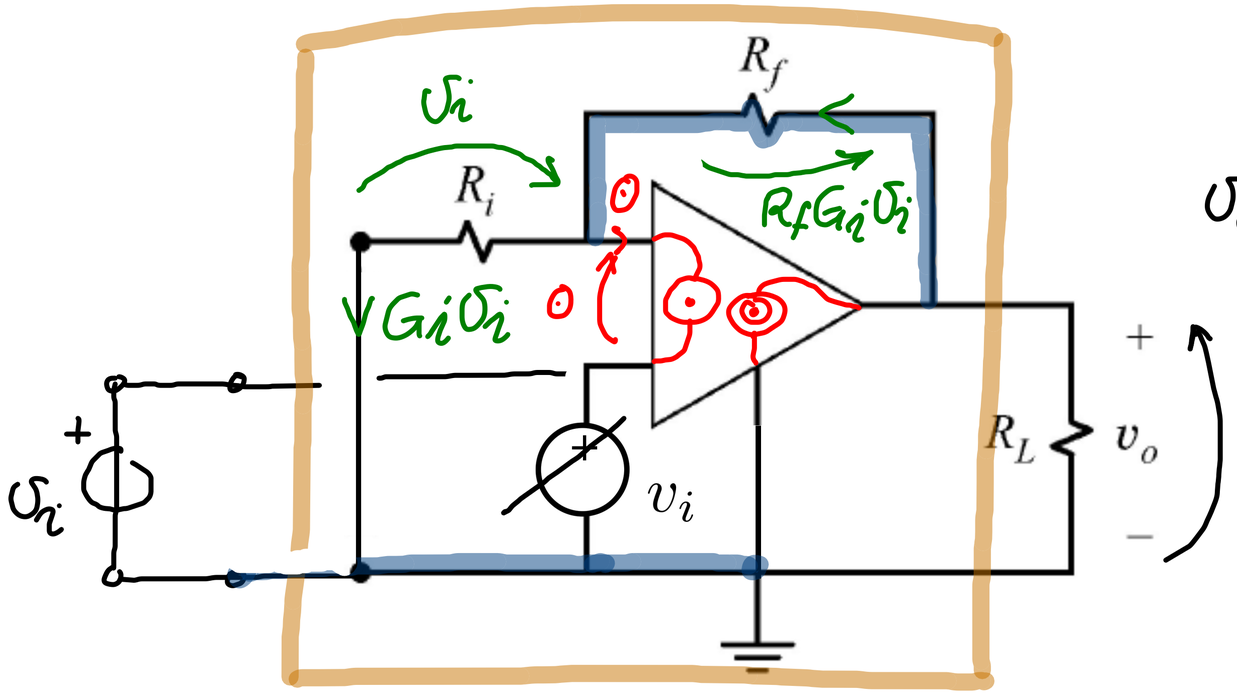


Figure P4.2-7

Fundamentals of Electric Circuit Analysis, by Clayton Paul

5. Circuits with Ideal OA

The Non Inverting OA circuit

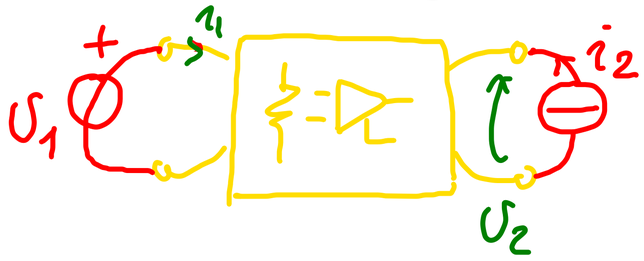


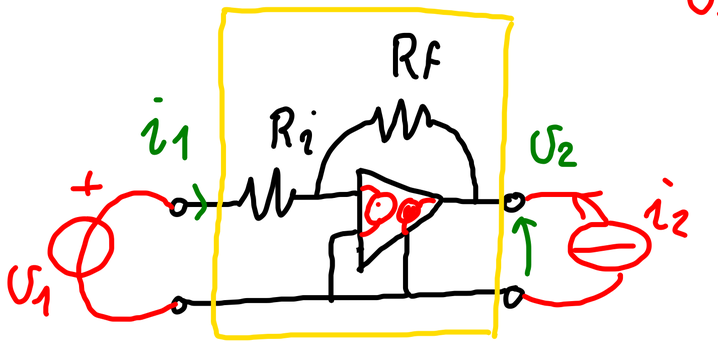
$$v_o = R_f G_i v_i + v_i$$

$$= \left(\frac{R_f}{R_i} + 1 \right) v_i$$

5. Circuits with Ideal OA

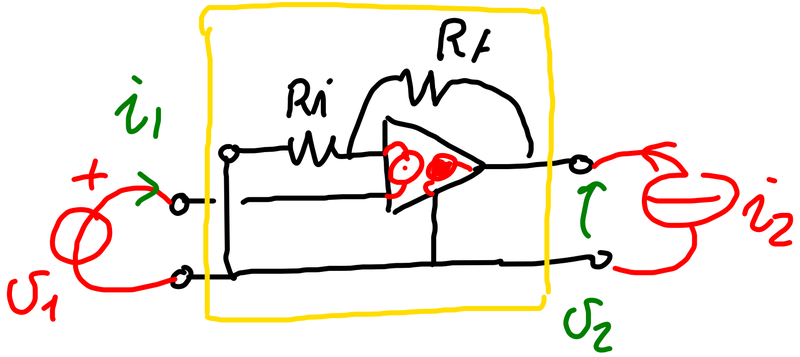
Hybrid characteristics and eq. circuits for the inverting and non-inverting OA circuits





$$\begin{cases} i_1 = G_i\, v_1 \\ v_2 = -\dfrac{R_f}{R_i}\, v_1 \end{cases}$$

$$\begin{bmatrix} i_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} G_i & 0 \\ -\dfrac{R_f}{R_i} & 0 \end{bmatrix} \begin{bmatrix} v_1 \\ i_2 \end{bmatrix}$$



$$\begin{cases} i_1 = 0 \\ v_2 = \left(\dfrac{R_f}{R_i} + 1\right) v_1 \end{cases}$$

$\left(\frac{R_f}{R_i} + 1\right)$

5. Circuits with Ideal OA

Example: compute v_o as function of v_i

CHAPTER 4

The Operational Amplifier (Op Amp)

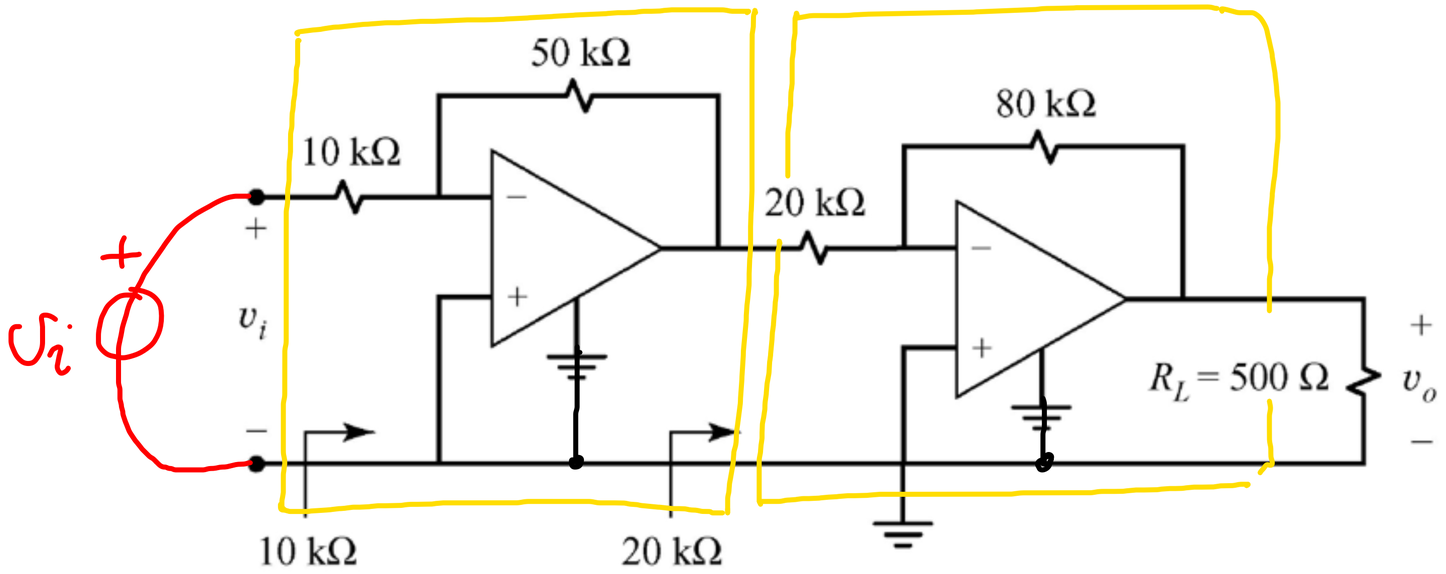
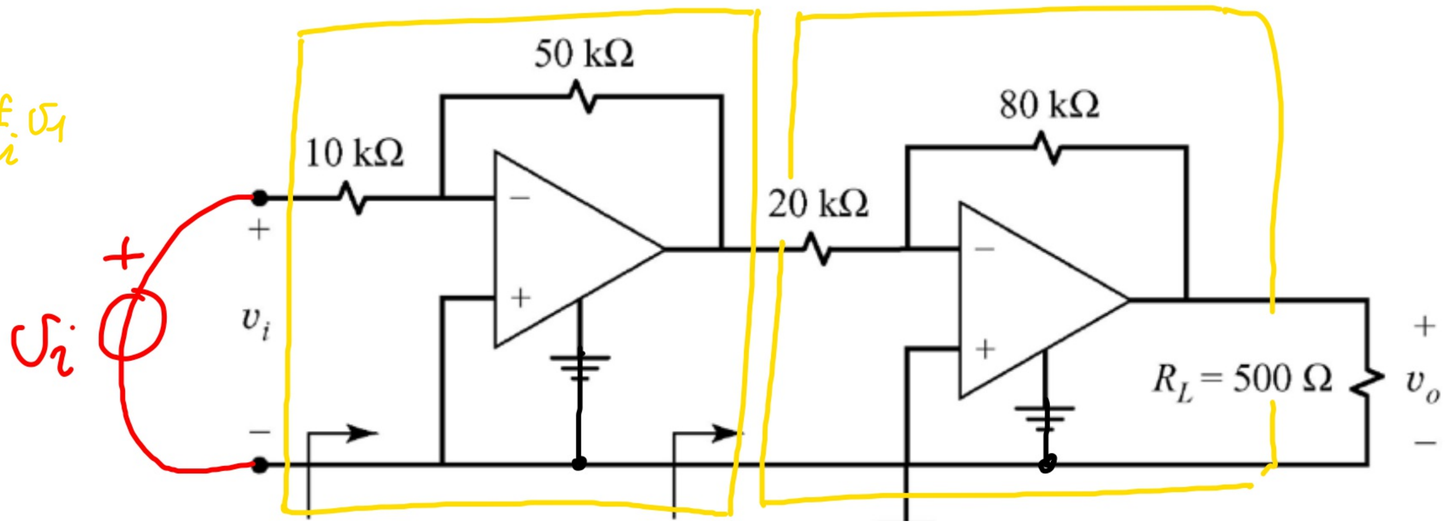
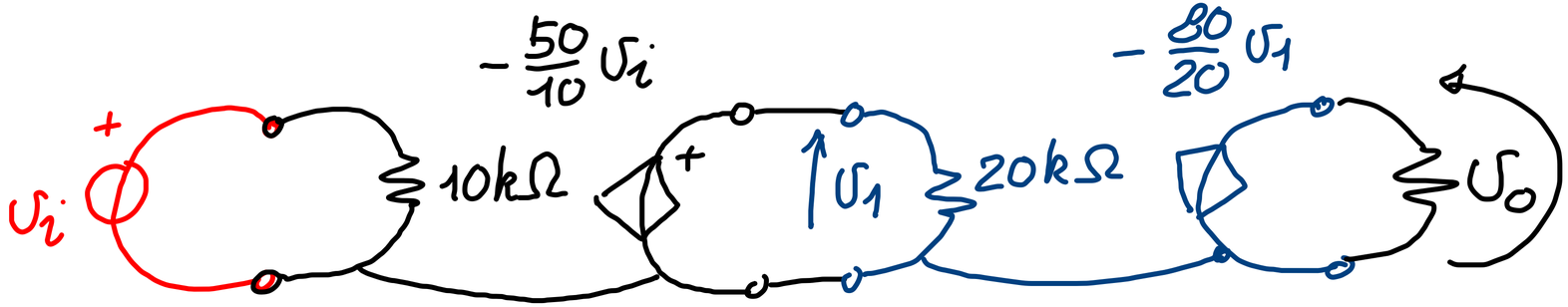


Figure 4.8
Example 4.1.

Fundamentals of Electric Circuit Analysis, by Clayton Paul

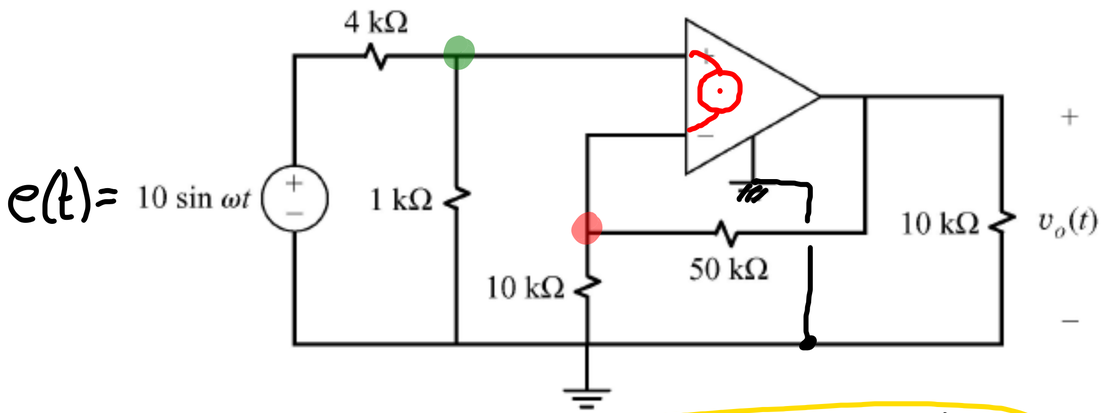


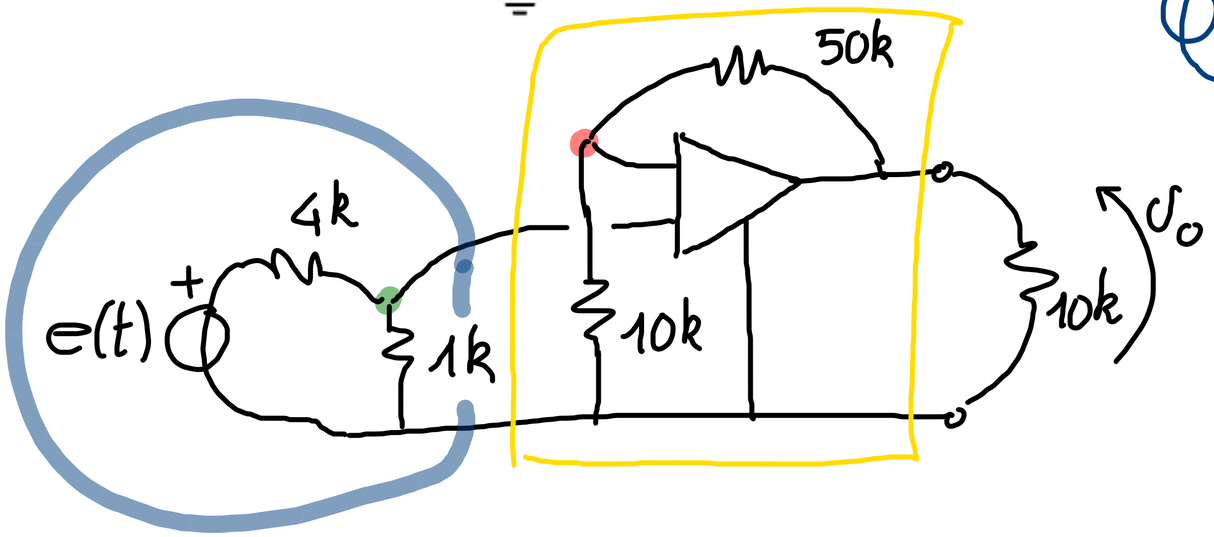


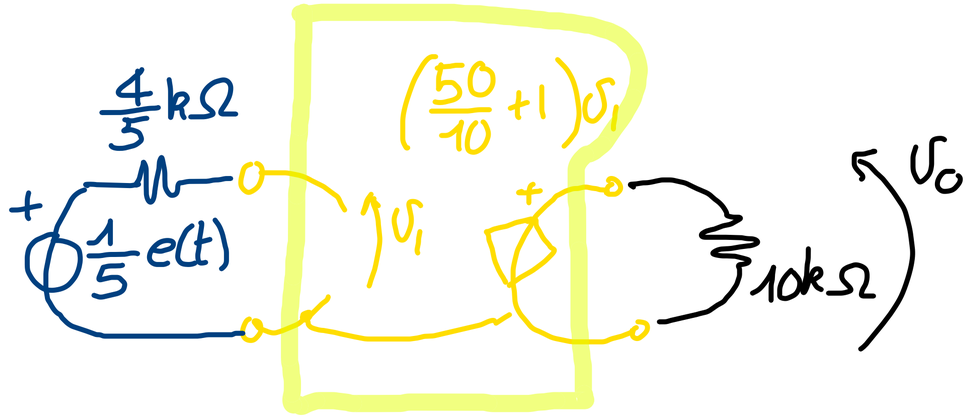
$$v_o = -4v_1 = -4(-5v_i) = 20v_i$$

5. Circuits with Ideal OA

Example: compute v_o







$$v_o = 6 v_1 = 6 \frac{1}{5} e(t)$$