Summary for Analogue Electronics

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Chapter 1

Basics of Circuits

1.1 The direction of current and voltage

In complex problems, we can not always know the direction of currents or voltage. The usual solution is to assume a direction, and use it to solve problems. If the solution of current or voltage, is positive, then the position is just what we assumed, and vice versa.

1.2 How to determine whether a component is consuming or providing energy

For resistors, resistors are always consuming energy.

For power sources, if the direction of current is from the positive electrode to the negative electrode, then the power source is consuming energy, and vice versa.

1.3 Eletcronic Components

1.3.1 Resistors

$$U = -IR$$

1.3.2 Power Sources

(Controlled) Voltage Source

$$P = UI$$

The resistance of an ideal voltage source is : 0

Note that an ideal voltage source must not be short-circuited.

(Controlled) Current Source

The current through a current source is only decided by the source itself.

The resistance of an ideal current source is : ∞

Note that an ideal current source must not be open-circuited.

1.4 Kirchhoff's Laws

- branch
- node
- loop
- mesh

1.5 Kirchhoff's Current Law

For each node in the circuit, as the node can not accumulate charges, the sum of current is zero.

$$\sum I = 0$$

1.5.1 Kirchhoff's Voltage Law

For each loop in circuit, the sum of the voltage in of all branches is zero.

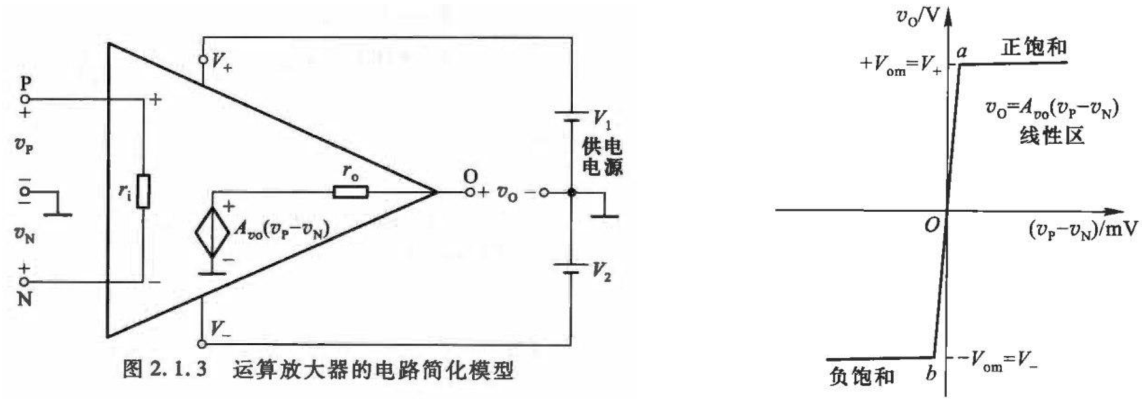
$$\sum U = 0$$

Chapter 2

Operational Amplifier

2.1 Operational Amplifier

The abstracted model of a operational amplifier is like this figure below:



(a) the model of an operational amplifier

(b) How the output voltage varies

Figure 2.1

We define r_i as the input impedance, r_o as the output impedance. v_p as the non-inverting input, v_n the inverting input.

Usually, we have $v_p \approx v_n$, $r_i \approx \infty$, $r_o \approx 0$.

Note that the output voltage of a operational amplifier has limits, called **Bandwidth**. When the input voltage exceeds the limits, it outputs the maximum or minimum value.

2.2 Ideal Operational Amplifier

For ideal operational amplifier:

- $v_p = v_n$, $i_i = 0$, $r_i = \infty$
- $r_o = 0$, $v_o = A_{vo}\left(v_p - v_n\right)$
- $bandwidth = \infty$

Here is a model which shows all the feature of an ideal operational comparator:

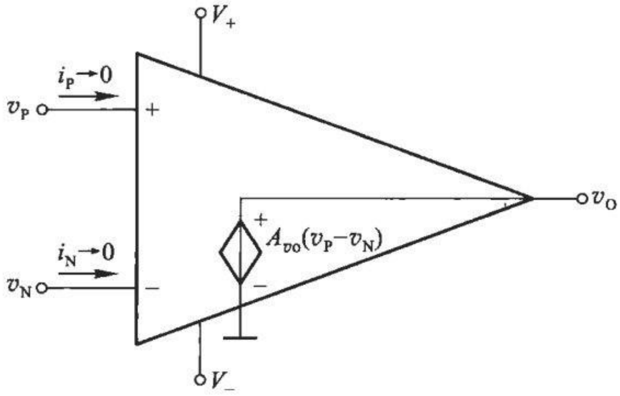


Figure 2.2: An ideal operational amplifier

2.3 Closed-looped Amplifier

Usually operational amplifiers are used with vegetative feedback to ensure its stability. We apply a portion of output voltage to input, reducing the gain of a circuit.

2.3.1 Non-inverting Operational Amplifier

If we connect the inverting input, to the ground, and use the non-inverting input, we get an non-inverting operational amplifier.

The gain of the amplifier is:

$$A_{vo} = \frac{R_2 + R_1}{R_1}$$

The picture below is a non-inverting amplifier.

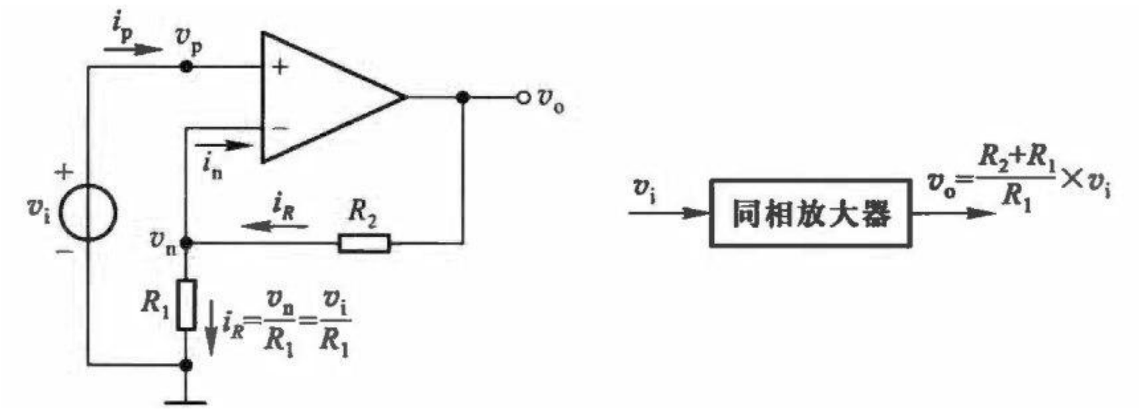


Figure 2.3: An non-inverting amplifier

Note that when $R_2 \ll R_1$, $A_{vo} = 1$, $v_i = v_o$.

2.3.2 Inverting Operational Amplifier

If we connect the non-inverting input, to the ground, and use the inverting input, we get an inverting operational amplifier.

The gain of this type of amplifier is:

$$A_{vo} = -\frac{R_2}{R_1}$$

The picture below shows as inverting operational amplifier:

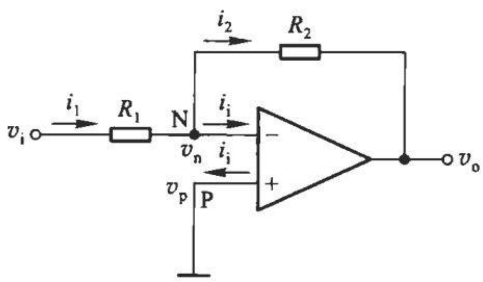


Figure 2.4: An inverting amplifier

2.4 Applications of operational amplifiers

2.4.1 Subtraction Circuit

An subtraction circuit can calculate the difference of inverting input and non-inverting input.

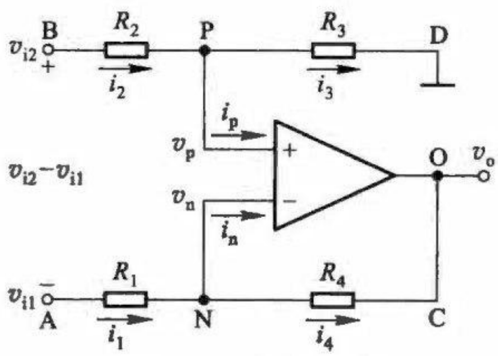


Figure 2.5: A subtraction circuit

Since we have

$$i_p = i_n = 0$$
$$v_p = v_n$$

According to Kirchhoff's Circuit Law:

$$i_2 = i_3$$
$$i_1 = i_4$$

So that

$$\frac{v_{i2} - v_p}{R_2} = \frac{v_p}{R_3}$$
$$\frac{v_{i1} - v_n}{R_1} = \frac{v_n - v_o}{R_4}$$

Then we have

$$v_{i2}R_3 - v_pR_3 = v_pR_2$$
$$v_n = v_p = \frac{R_3}{R_2+R_3}v_{i2}$$

$$R_4v_{i1} - R_4v_n = R_1v_n - R_1v_o$$
$$R_1v_o = -R_4v_{i1} + (R_1+R_4)\,v_n$$

Finally, we get

$$\begin{aligned} v_o &= -\frac{R_4}{R_1}v_{i1} + \frac{R_1+R_4}{R_1}\frac{R_3}{R_2+R_3}v_{i2} \\ &= \left(1+\frac{R_4}{R_1}\right)\frac{R_3/R_2}{1+R_3/R_2}v_{i2} - \frac{R_4}{R_1}v_{i1} \end{aligned}$$

When we set

$$R_3/R_2 = 0$$
$$R_4/R_1 = 0$$

We have

$$v_o = v_{i2} - v_{i1}$$

2.4.2 Sum Circuit

An sum circuit adds the inverting input and the non-inverting input.

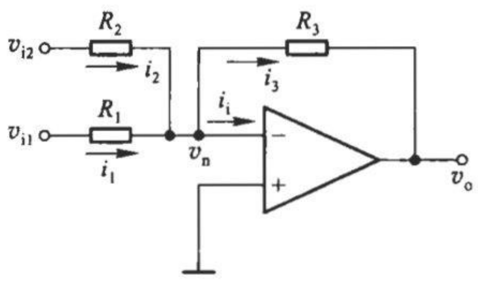


Figure 2.6: Sum Circuit

Similarly, we have

$$\frac{v_{i1}-v_n}{R_1} + \frac{v_{i2}-v_n}{R_2} = \frac{v_n - v_o}{R_3}$$

Since

$$v_n = v_p = 0$$

We may get

$$\frac{v_{i1}}{R_1} + \frac{v_{i2}}{R_2} = \frac{-v_o}{R_3}$$

When we set

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$$v_o = -\left(v_{i1} + v_{i2}\right)$$

2.4.3 Integrating Circuit

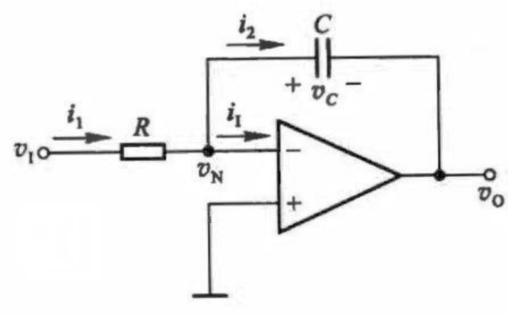

Figure 2.7: integrating circuit

$$-v_o = \frac{1}{C}\int \frac{v_1}{R}\mathrm{d}t$$

We define

$$\tau = RC$$

Then

$$-v_o = \frac{1}{\tau}\int v_1 \mathrm{d}t$$

2.4.4 Differential Circuit

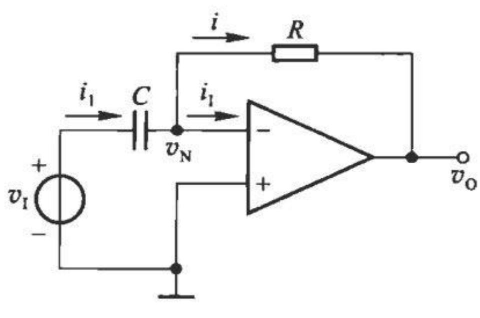

Figure 2.8: differential circuit

$$-v_o = RC\frac{\mathrm{d}v_i}{\mathrm{d}t}$$

Chapter 3

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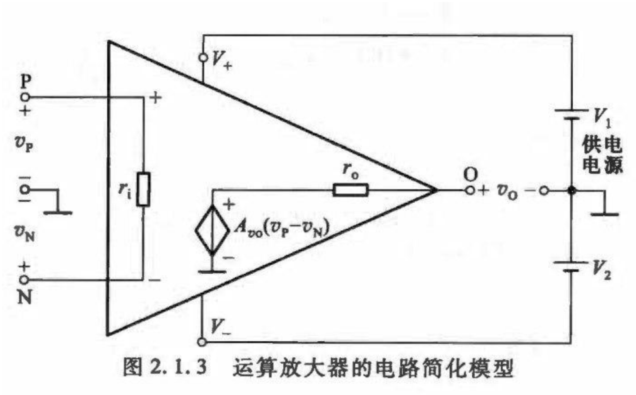

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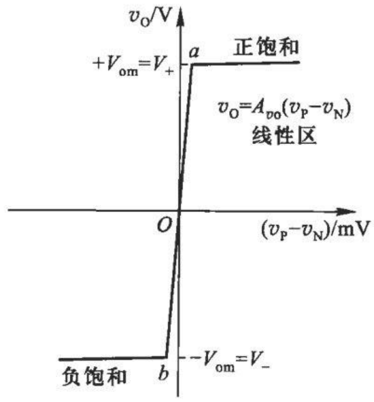

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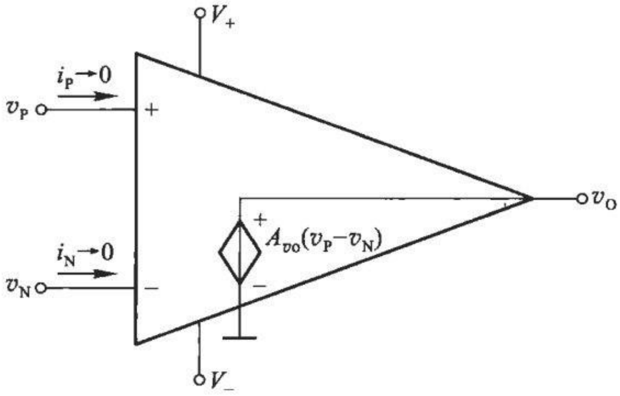

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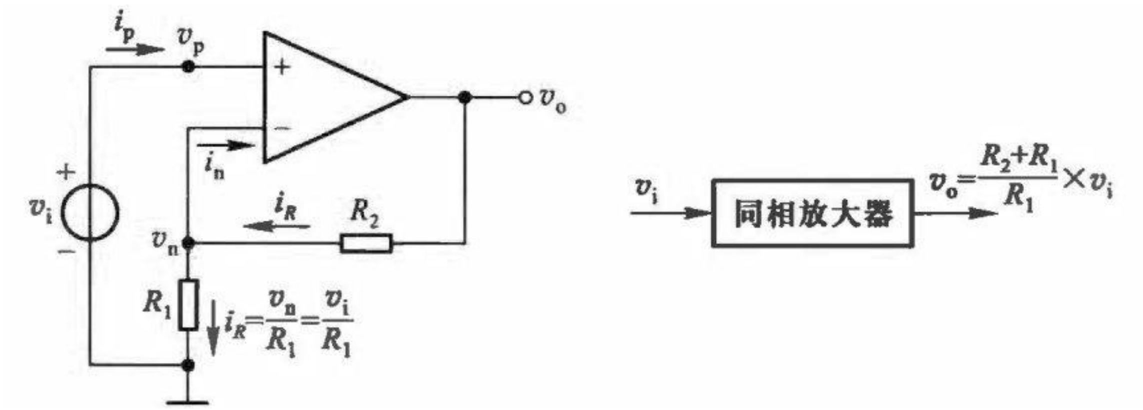

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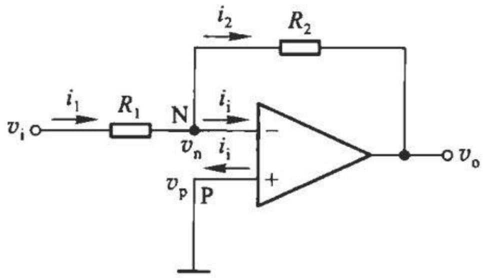

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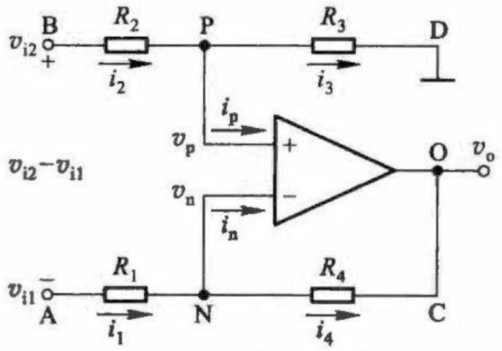

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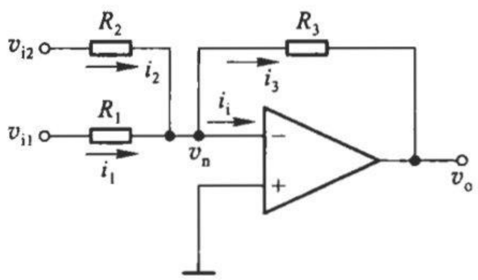

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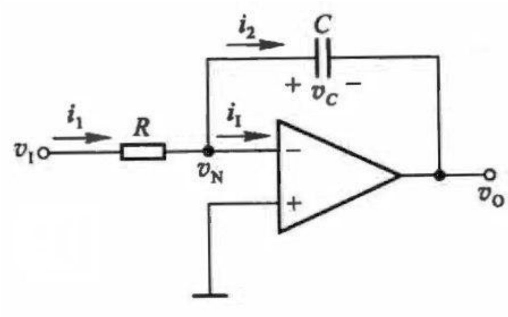

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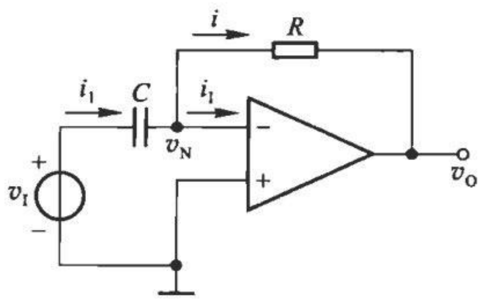

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