# 1-6 Independent source

- Using the concepts of current and voltage, it is now possible to be more specific in defining a *circuit element*.
- Let us agree that we will use the expression *circuit element* to refer to the mathematical model.
- For simplicity, we initially consider circuits with idealized components represented by simple models.
- All the simple circuit elements that we will consider can be classified according to the relationship of the current through the element to the voltage across the element.
- For example, if the voltage across the element is linearly proportional to the current through it, we will call the element a resistor. Other types of simple circuit elements have terminal voltages which are proportional to the *derivative* of the current with respect to time (an inductor), or to the *integral* of the current with respect to time (a capacitor).

- There are also elements in which the voltage is completely independent of the current, or the current is completely independent of the voltage; these are termed *independent sources*.
- Furthermore, we will need to define special kinds of sources for which either the source voltage or current depends upon a current or voltage elsewhere in the circuit; such sources are referred to as *dependent sources*.
- Dependent sources are used a great deal in electronics to model both dc and ac behavior of transistors, especially in amplifier circuits.

# 1. Independent voltage source

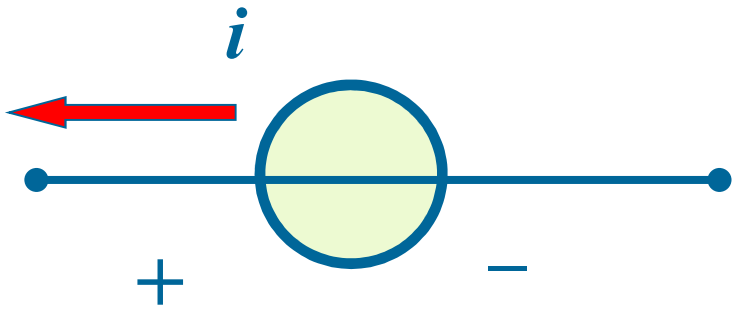
## • Definition

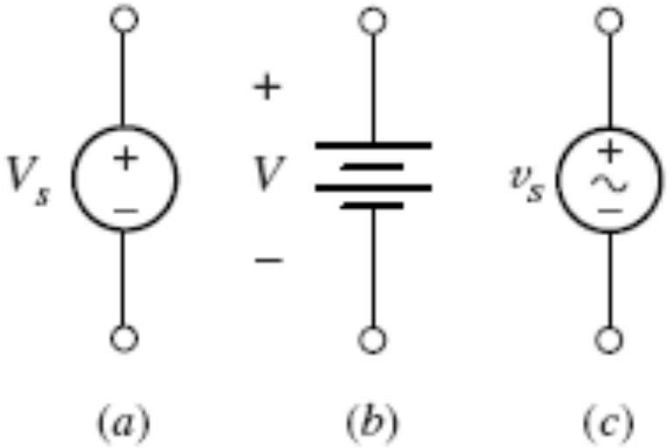
*An independent voltage source is characterized by a terminal voltage which is completely independent of the current through it.*

Thus, if we are given an independent voltage source and are notified that the terminal voltage is 12V, then we always assume this voltage, regardless of the current flowing.

The independent voltage source is an *ideal* source and does not represent exactly any real physical device, because the ideal source could theoretically deliver an infinite amount of energy from its terminals. This idealized voltage source does, however, furnish a reasonable approximation to several practical voltage sources.

# ● Symbols for independent voltage sources



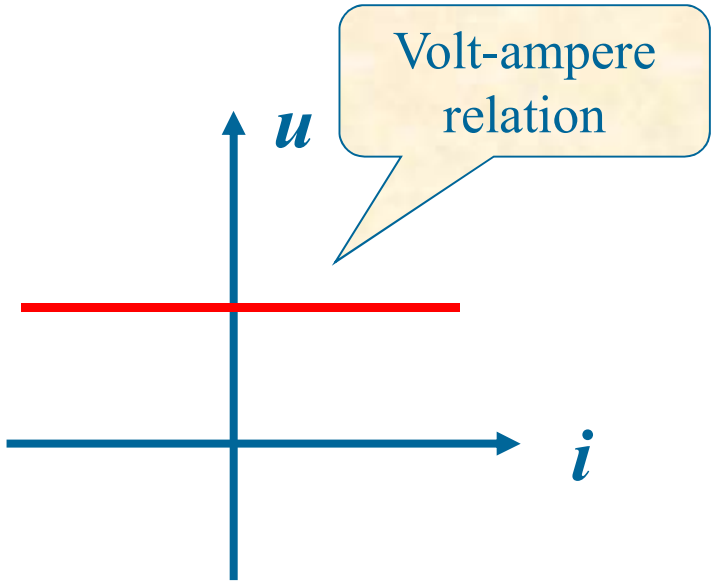


(*a*) DC voltage source symbol;
(*b*) battery symbol;
(*c*) ac voltage source symbol.

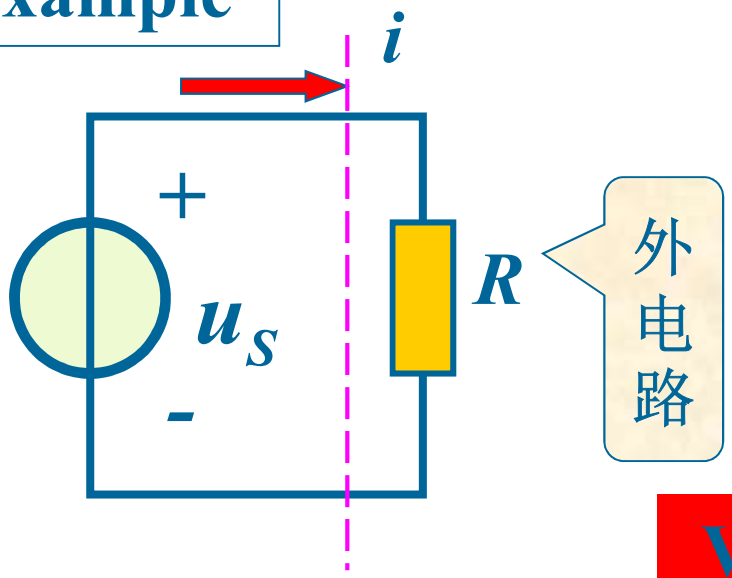
## ● Voltage-Current relationship for ideal voltage source

(1) The voltage is independent of peripheral circuit and the current passing through voltage source.

(2) The current passing through voltage source was decided by voltage source and peripheral circuit




**Example**




外电路

$$i = \frac{u_S}{R}$$

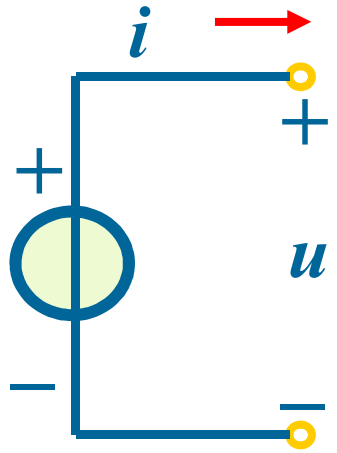
$$i = 0 \quad (R = \infty)$$

$$i = \infty \quad (R = 0)$$

**Voltage source cannot short circuit**

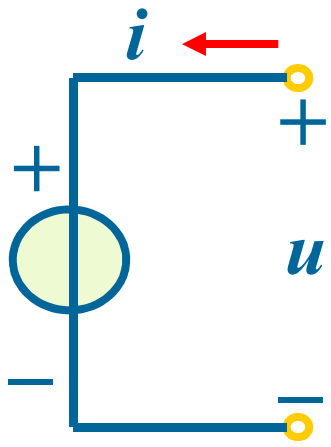
## ● Power

（1） *u*、*i* : *Non*associate reference direction ;




$P = u_S i$ → Deliver power

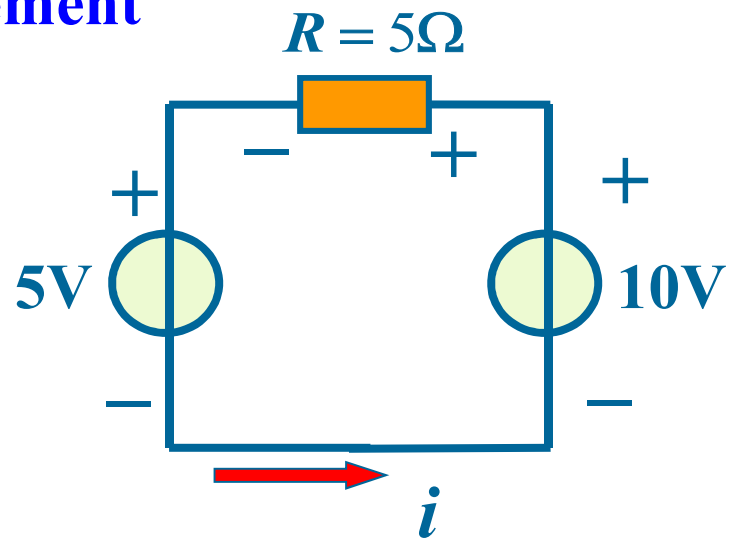
（2） *u*、*i* : Associate reference direction ;




$P = u_S i$ → Absorb power

## *Example*

**Calculate the power of circuit element**




**Solution**

$$u_R = (10-5) = 5V$$

$$i = {u_R}/{R} = {5}/{5} = 1A$$

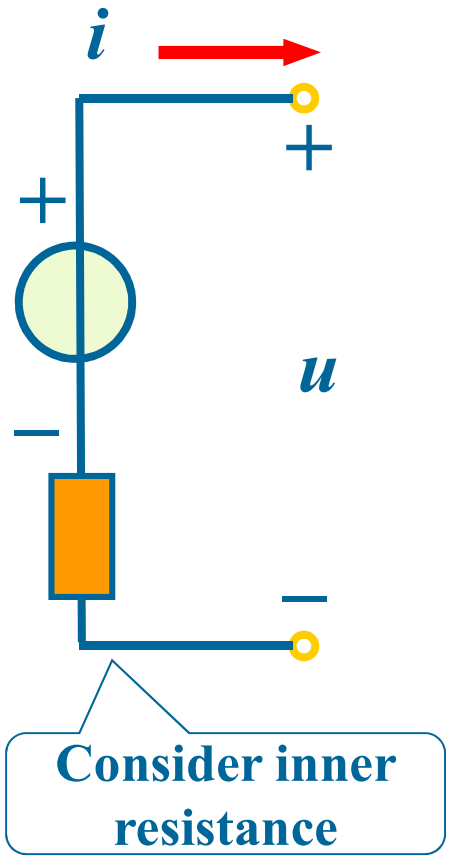
$P_{10V} = u_S i = 10 \times 1 = 10W$ **Deliver power**

$P_{5V} = u_S i = 5 \times 1 = 5W$ **Absorb power**

$P_R = Ri^2 = 5 \times 1 = 5W$ **Absorb power**

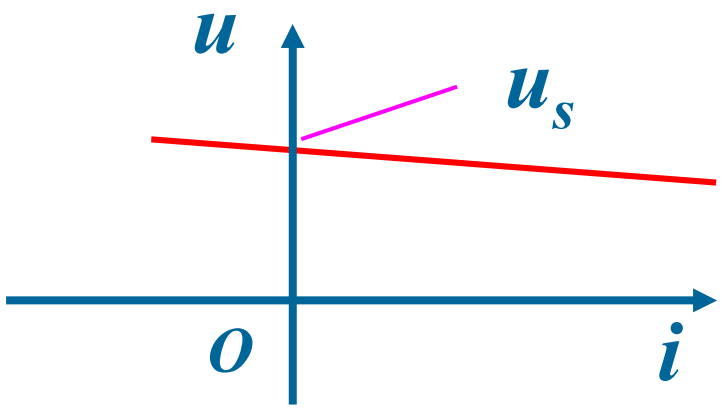
**satisfy： *P*（deliver）＝*P*（absorb）**

## ● Practical voltage source




**Volt-ampere relationship**

$$u = u_S - R_S i$$




$R_S \to 0$ (Good )

实际电压源也不允许短路。因其内阻小，若短路，电流很大，可能烧毁电源。

## 2. Independent current source

- **Ideal current source**

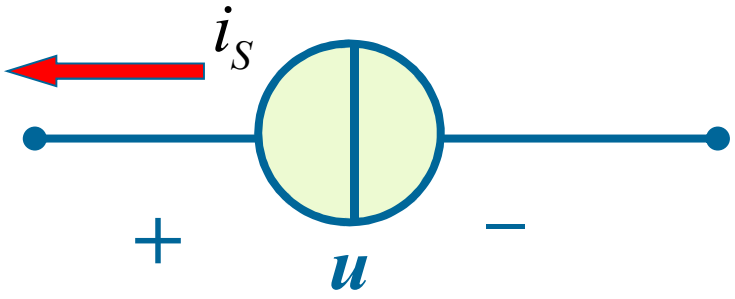
The current through the element is completely independent of the voltage across it.

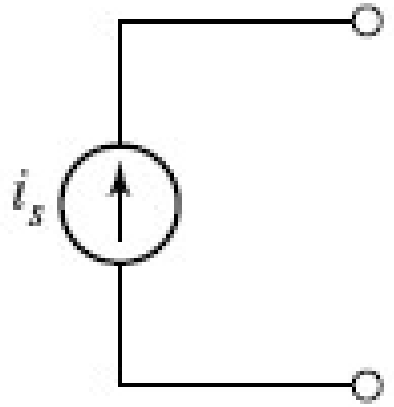
Like the independent voltage source, the independent current source is at best a reasonable approximation for a physical element.

In theory it can deliver infinite power from its terminals because it produces the same finite current for any voltage across it, no matter how large that voltage may be.

It is, however, a good approximation for many practical sources, particularly in electronic circuits.

## ● Circuit symbol for the independent current source




The symbol for an independent current source is shown in Fig.

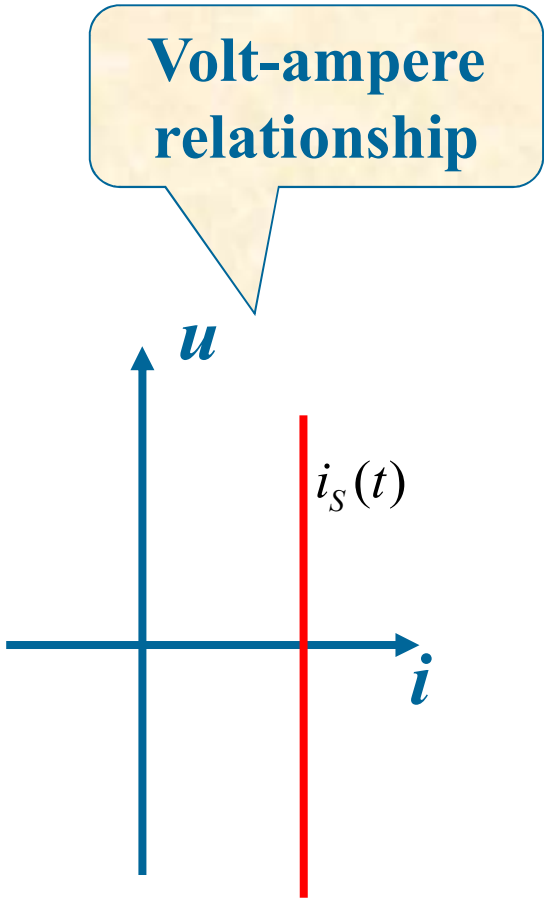
If $i_s$ is constant, we call the source an independent dc current source. An ac current source is often drawn with a tilde through the arrow, similar to the ac voltage source.

## • Voltage-Current relationship for ideal current source

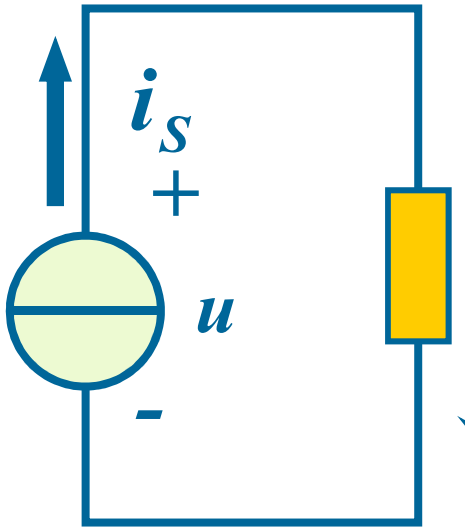
The current through the element is completely independent of the voltage across it.

Although most students seem happy enough with an independent voltage source providing a fixed voltage but essentially any current, *it is a common mistake* to view an independent current source as having zero voltage across its terminals while providing a fixed current.

In fact, we do not know a priori what the voltage across a current source will be—it depends entirely on the circuit to which it is connected.



*Example*




$$u = Ri_S$$

$$u = 0 \quad (R = 0)$$

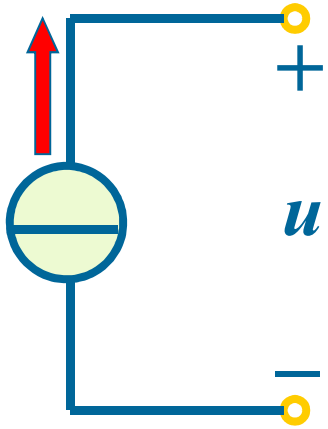
$$u = \infty \quad (R = \infty)$$

**Exterior circuit**

**Current source cannot open !**

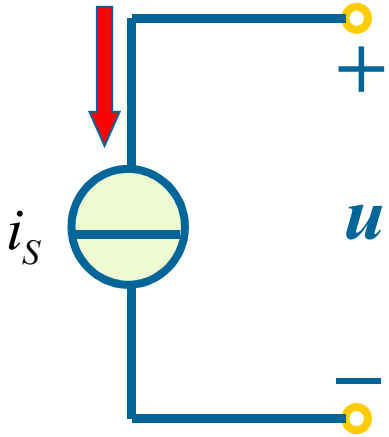
- **Power** → $P = ui_S$

（1） $u$、$i$ : *Non*associate reference direction ;




$P = ui_S$ → 发出功率，起电源作用

（2） $u$、$i$ : Associate reference direction ;

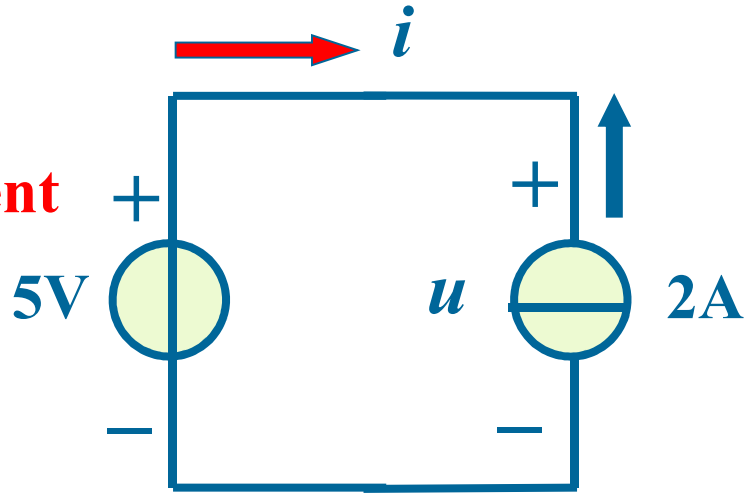



$P = ui_S$ → 吸收功率，充当负载

or: $P = -i_S u$ → 发出负功

*Example*

**Calculate the power of circuit element**




**Solution**

$$i = -i_S = -2A$$

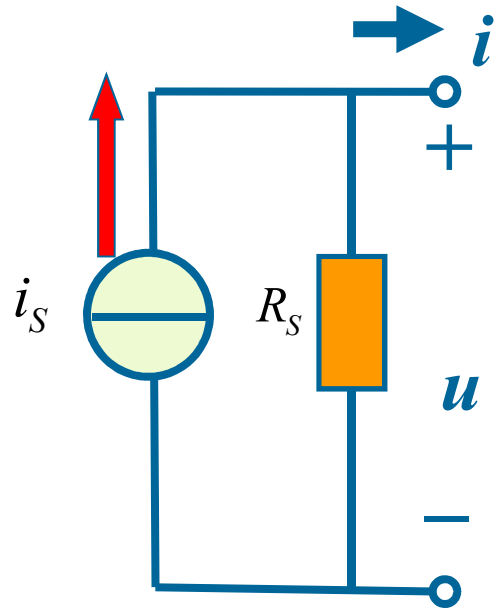
$$u = 5V$$

$$P_{2A} = i_S u = 2 \times 5 = 10W$$ 发出

$$P_{5V} = u_S i = 5 \times (-2) = -10W$$ 发出

满足：*P*（发）＝*P*（吸）

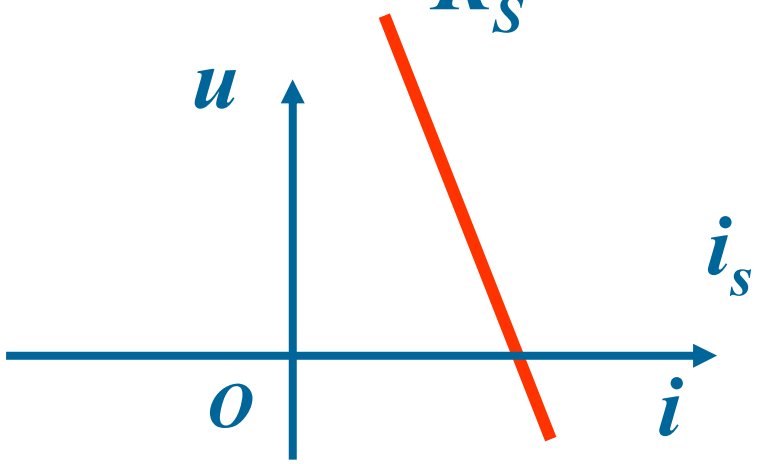
## Practical current source




Consider inner resistance

**Volt-ampere relationship**

$$i = i_S - \frac{u}{R_S}$$




$R_S \to \infty$ (Good)

实际电流源也不允许开路。因其内阻大，若开路，电压很高，可能烧毁电源

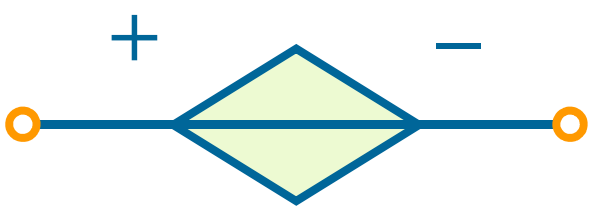
# 1-7 Controlled source or Dependent source

## 1. Definition

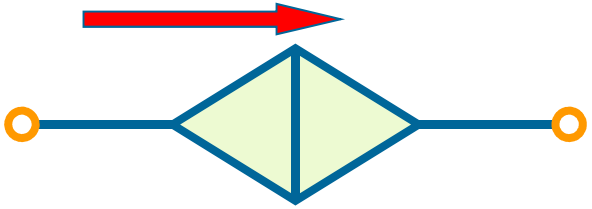
- The value of independent source quantity is not affected in any way by activities in the remainder of the circuit.
- The *dependent,* or *controlled,* source, in which the source quantity is determined by a voltage or current existing at some other location in the system being analyzed.
- Sources such as these appear in the equivalent electrical models for many electronic devices, such as transistors, operational amplifiers, and integrated circuits.

## ● Circuit symbol for the dependent source

To distinguish between dependent and independent sources, we introduce the diamond symbols shown in Fig.




*Controlled* voltage source



*Controlled* current source

## 2. Classify

Since the control of the dependent source is achieved by a voltage or current of some other element in the circuit, and the source can be voltage or current, it follows that there are four possible type of dependent source, namely:

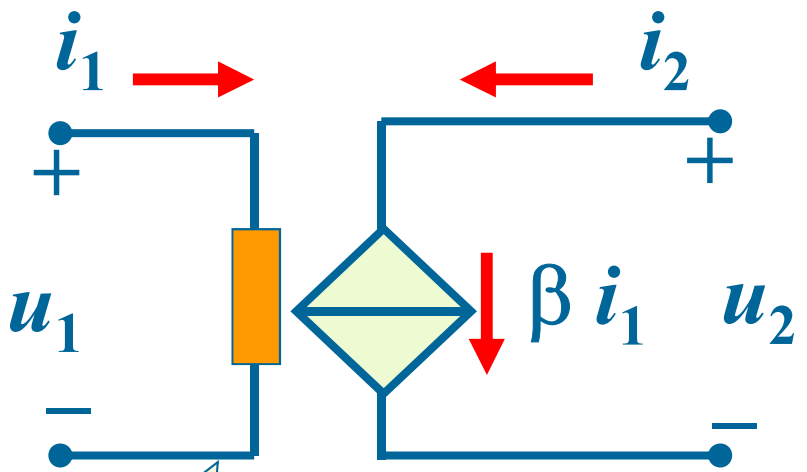
**(1) Current-controlled current source（ CCCS ）**

**(2) Voltage-controlled current source（ VCCS ）**

**(3) Voltage-controlled voltage source（ VCVS ）**

**(4) Current-controlled voltage source（ CCVS ）**

## (1) Current-controlled current source ( CCCS )




Four terminal element

Output: controlled part

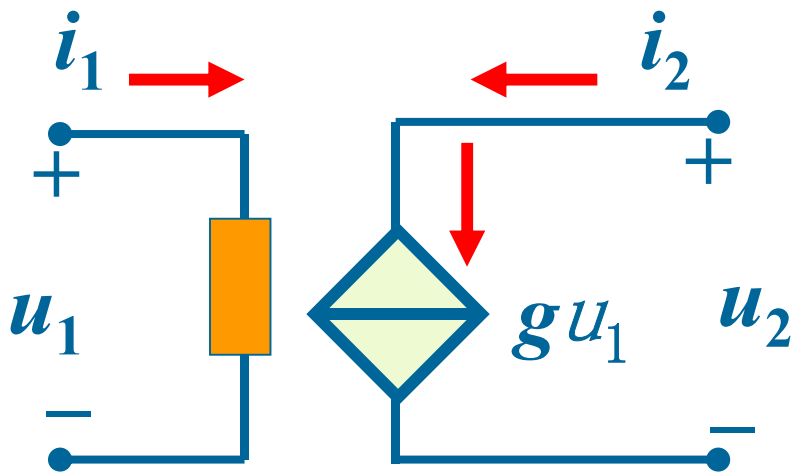
Input: control part

$$i_2 = \beta\, i_1$$

$\beta$: is a dimensionless scaling constant

Current amplification

## (2) Voltage-controlled current source ( VCCS )

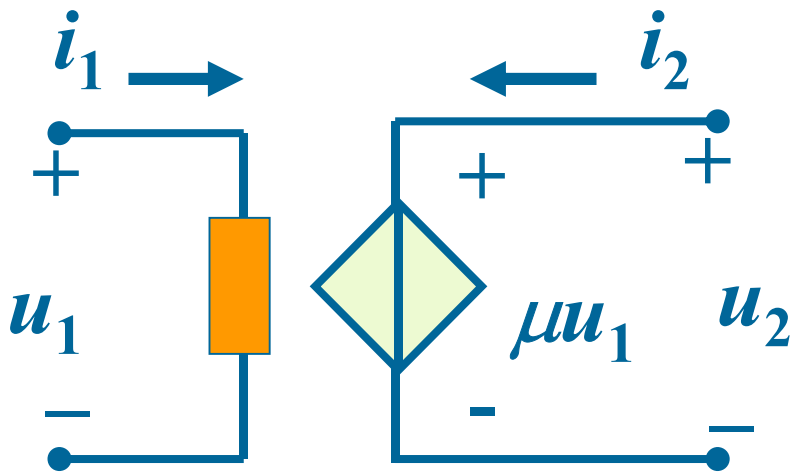



$$i_2 = g u_1$$

$g$ is a scaling factor with units of A/V

$g$: transfer conductance

## (3) Voltage-controlled voltage source ( VCVS )

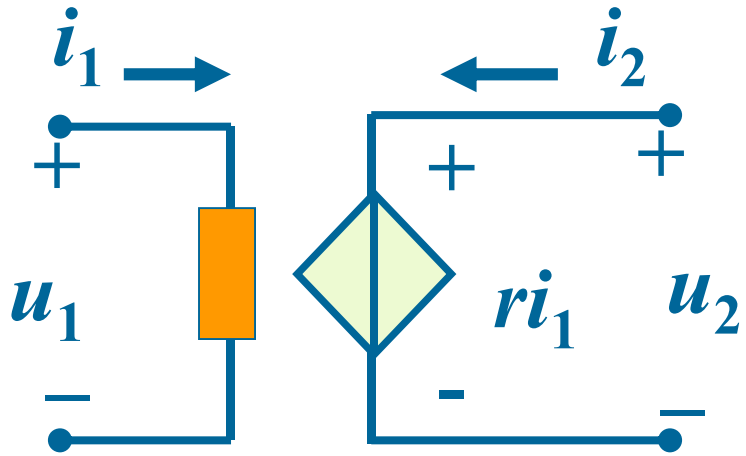



$$u_2 = \mu\, u_1$$

$\mu$ is a dimensionless scaling constant

$\mu$: voltage amplification

## (4) Current-controlled voltage source ( CCVS )

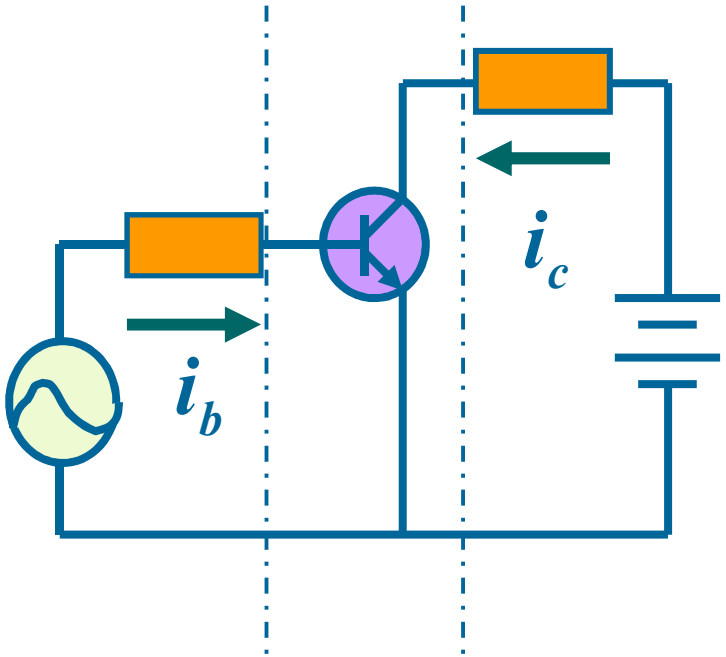



$$u_2 = ri_1$$

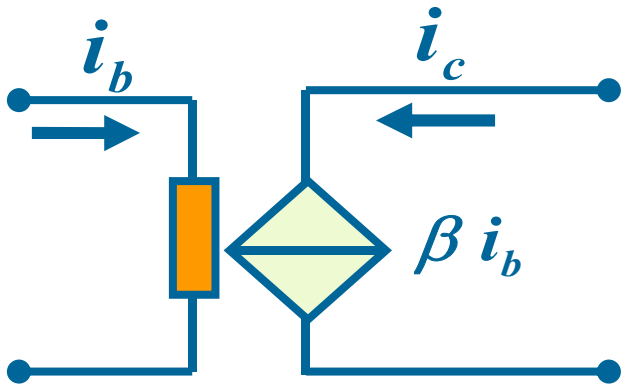
*r* is a scaling factor with units of V/A

*r* : transfer risistance

## *Example*



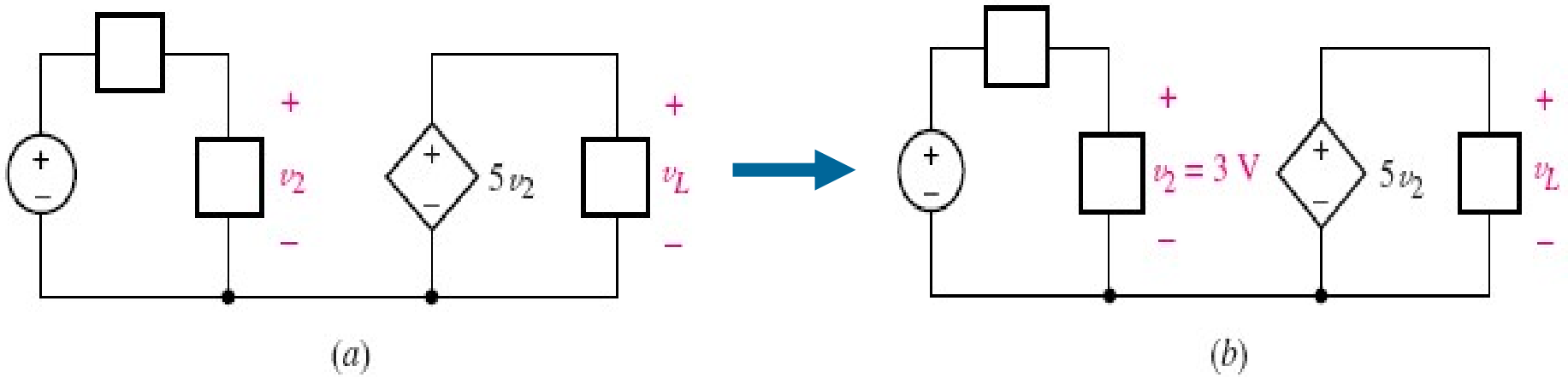

model




$$i_c = \beta\, i_b$$

## *Example*

***In the circuit of Fig. a, if $v_2$ is known to be 3V, find $v_L$.***




**Solution**

$$v_2 = 3V$$

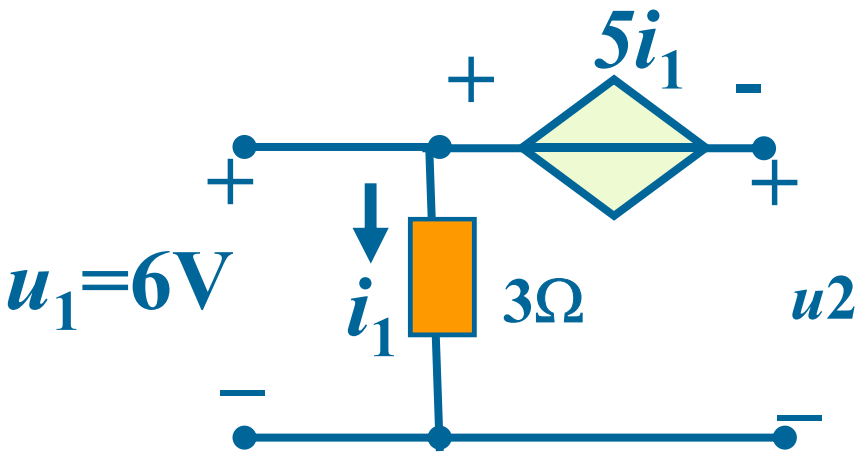
$$v_L = 5v_2 = 5 \times 3 = 15V$$

## 3. Compare controlled source and independent source

(1) 独立源电压(或电流)由电源本身决定，与电路中其它电压、电流无关，而受控源电压(或电流)由控制量决定。

(2) 独立源在电路中起“激励”作用，在电路中产生电压、电流，而受控源只是反映输出端与输入端的受控关系，在电路中不能作为“激励”。

***Example*** ***Find：voltage $u_2$。***




**Solution**

$$i_1 = \frac{6}{3} = 2A$$

$$u_2 = -5i_1 + 6$$

$$= -10 + 6 = -4V$$