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Today's Outline

1. **Fundamentals**

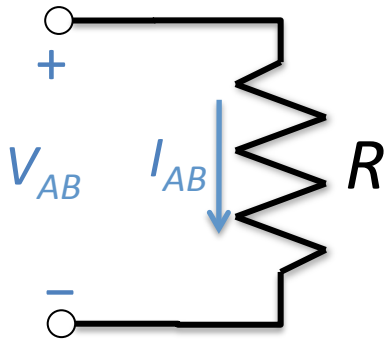
- I-V Diagrams
- Independent Sources
- Ideal Voltmeters and Ammeters
- Dependent Sources
- Transducers

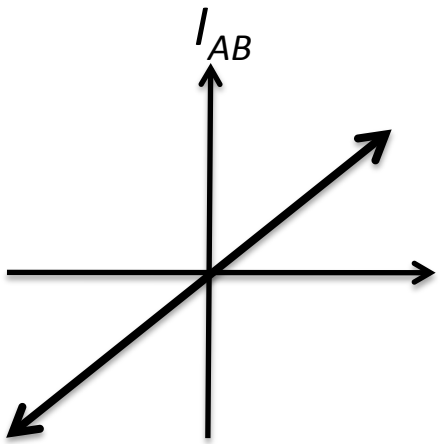
I-V Diagrams

I-V diagram: diagram of terminal current versus terminal voltage of a circuit element, often used to specify the behaviour of a circuit element.

You have seen the I-V diagram of a resistor before.

Question: What is the value of *R* ?

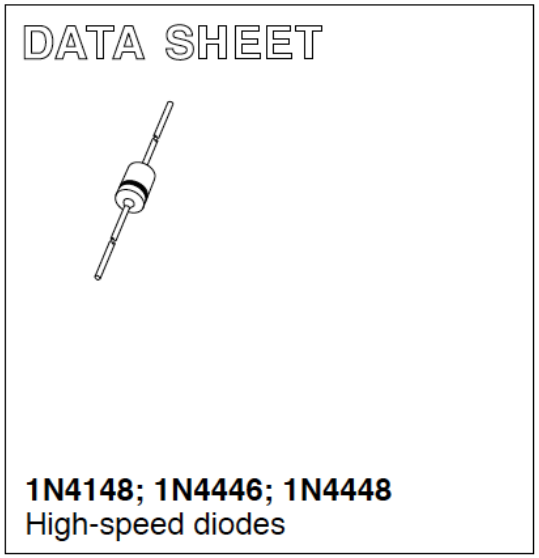




$$I_{AB} = 0.3183 \text{ A/V} \times V_{AB}$$

I-V Diagrams

Example: Even if you don't know what a "diode" is or what it does, you can use the I-V diagram from the manufacturer to predict diode behaviour in a circuit.


DATA SHEET

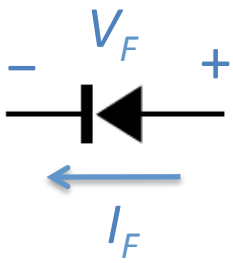
1N4148; 1N4446; 1N4448
High-speed diodes

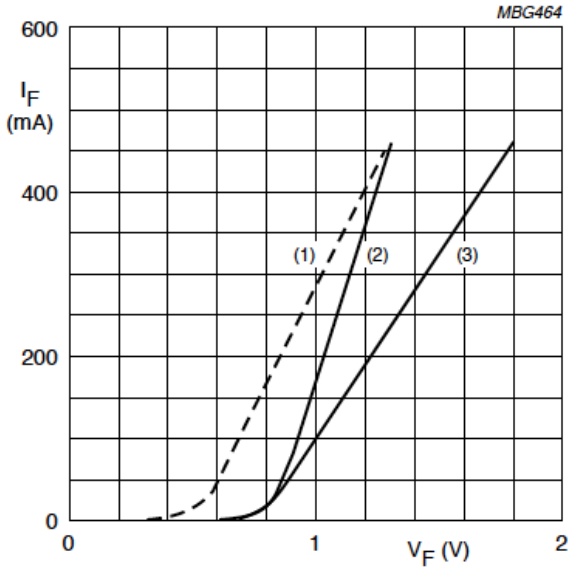
Product specification
Supersedes data of April 1992
File under Discrete Semiconductors, SC01

1996 Apr 15

Philips Semiconductors

PHILIPS





(1) T_j = 175 °C; typical values.
(2) T_j = 25 °C; typical values.
(3) T_j = 25 °C; maximum values.

Question: What should V_F be in order to pass a current I_F = 300mA?

Fine print: Diodes are not on the ECSE-200 final exam.

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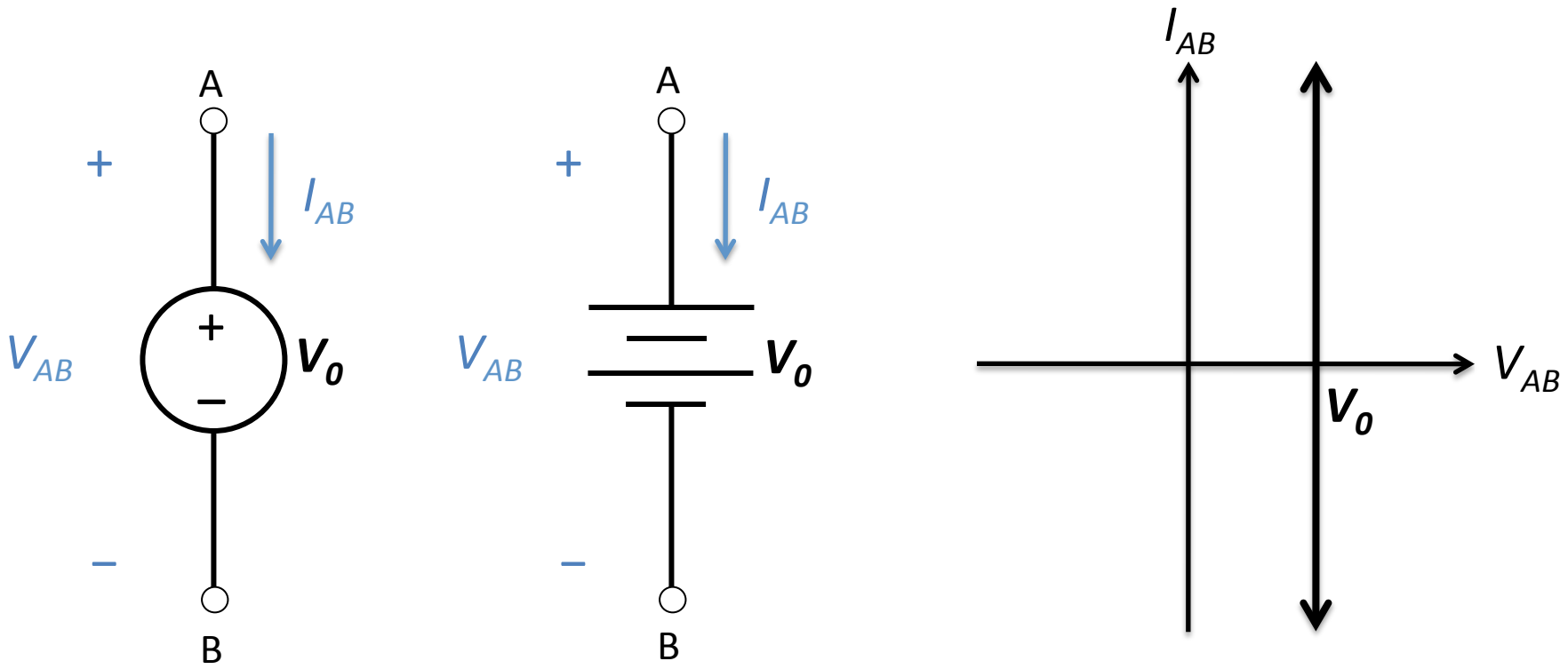
Independent Voltage Source

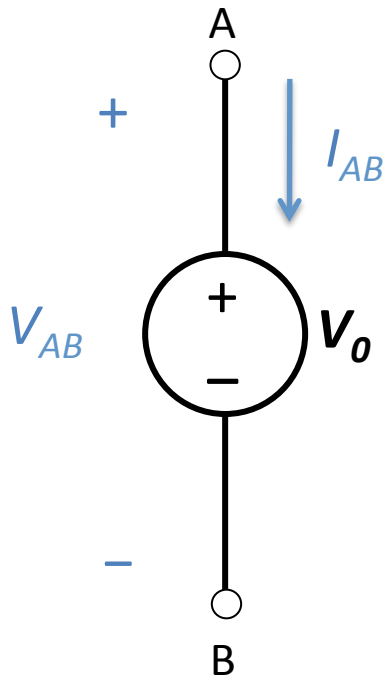
Independent voltage source: a two terminal circuit element that maintains a constant voltage across its terminals, *regardless of the current flowing through it.*

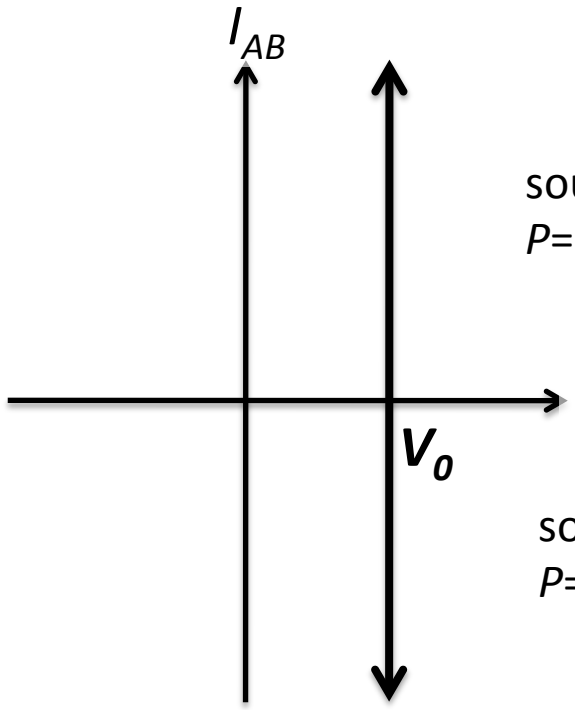


reminder: this source, and the sources that follow, are *mathematical models* that are useful for appoximating real physical elements.

Independent Voltage Source

The current flowing through an independent voltage source is determined by the circuit to which the source is connected. This can lead to power delivery or power absorption by the source.



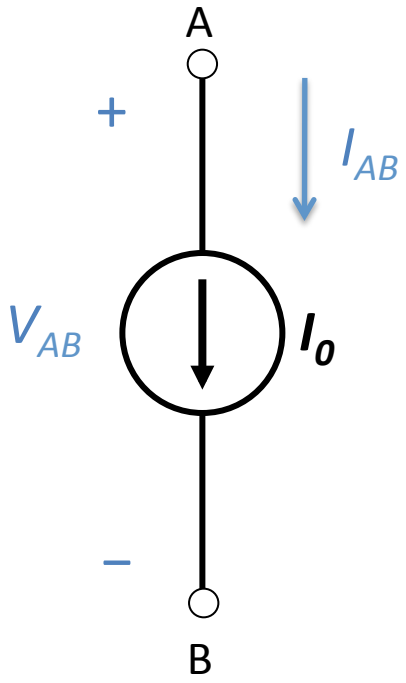


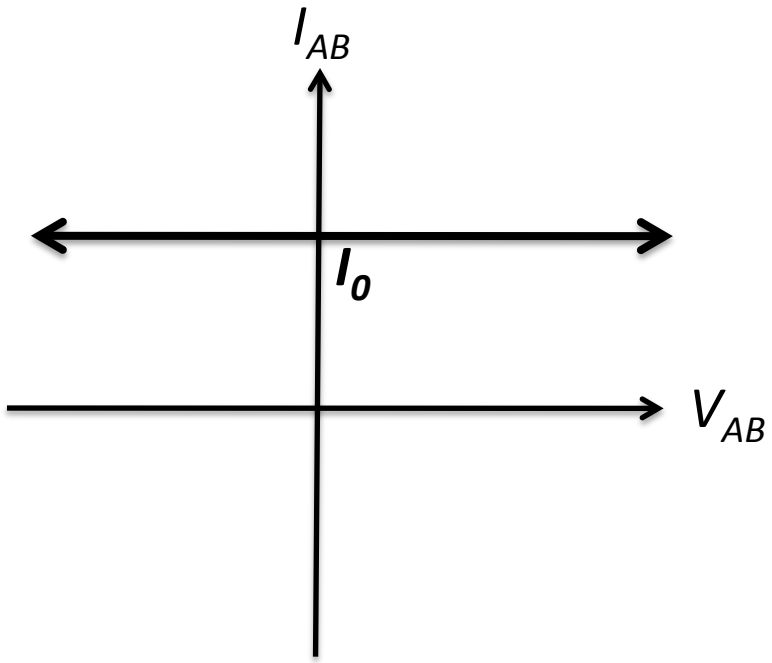
source absorbs power
$P=I_{AB}V_{AB}>0$

source delivers power
$P=I_{AB}V_{AB}<0$

Independent Current Source

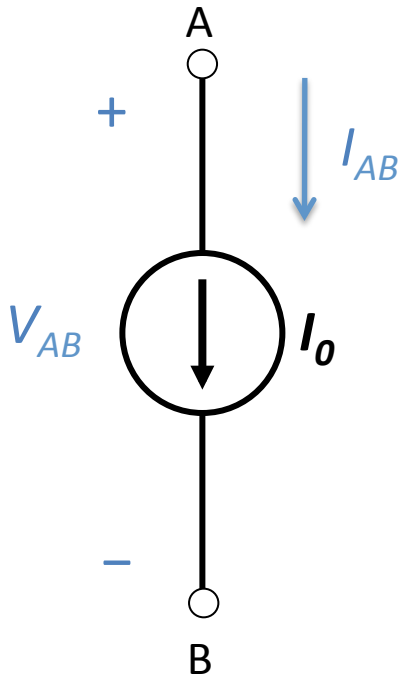
Independent current source: a two terminal circuit element that maintains a constant current through its terminals, *regardless of the voltage across it*

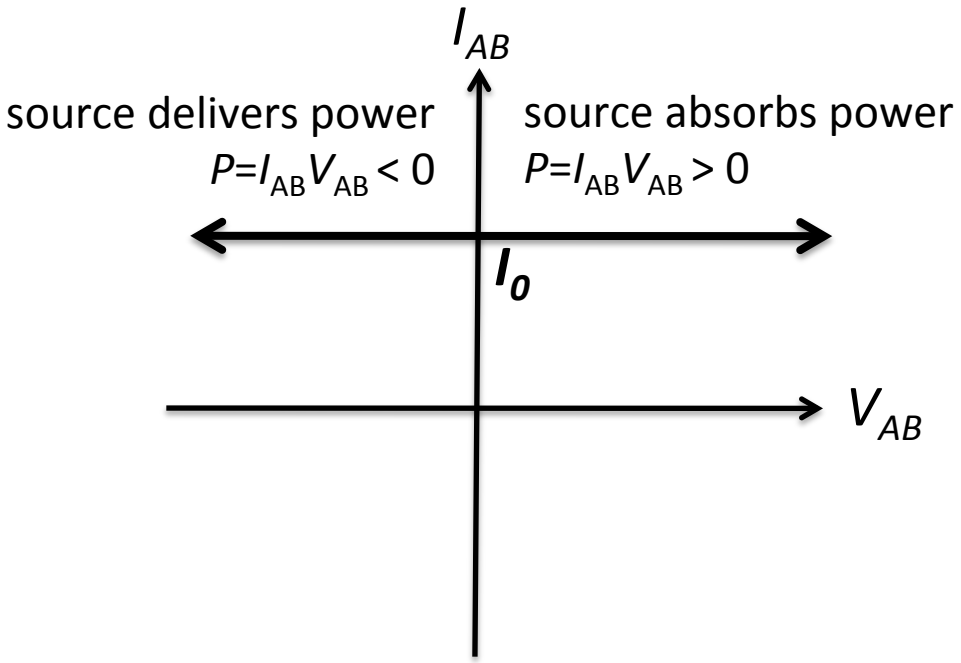




Independent Current Source

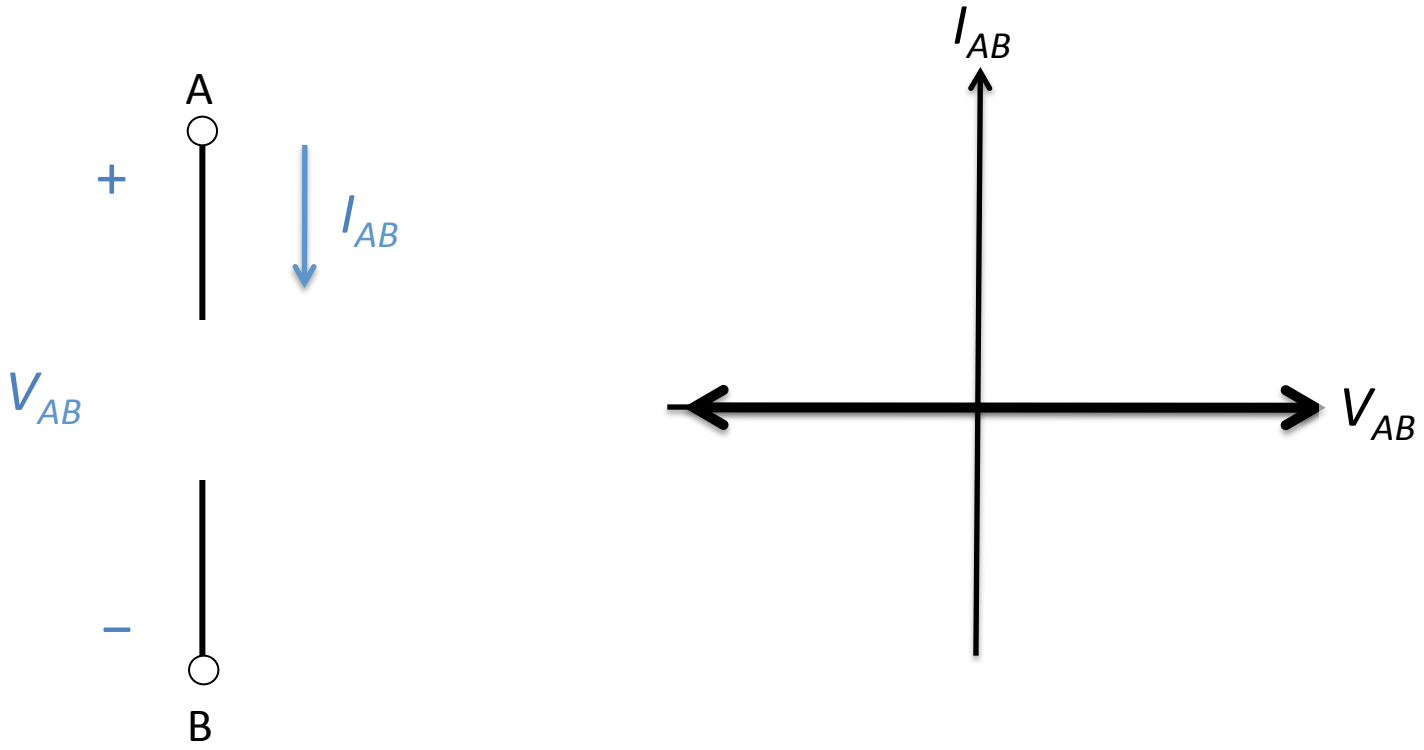
The voltage across an independent current source is determined by the circuit to which the source is connected. This can lead to power delivery or absorption by the source.





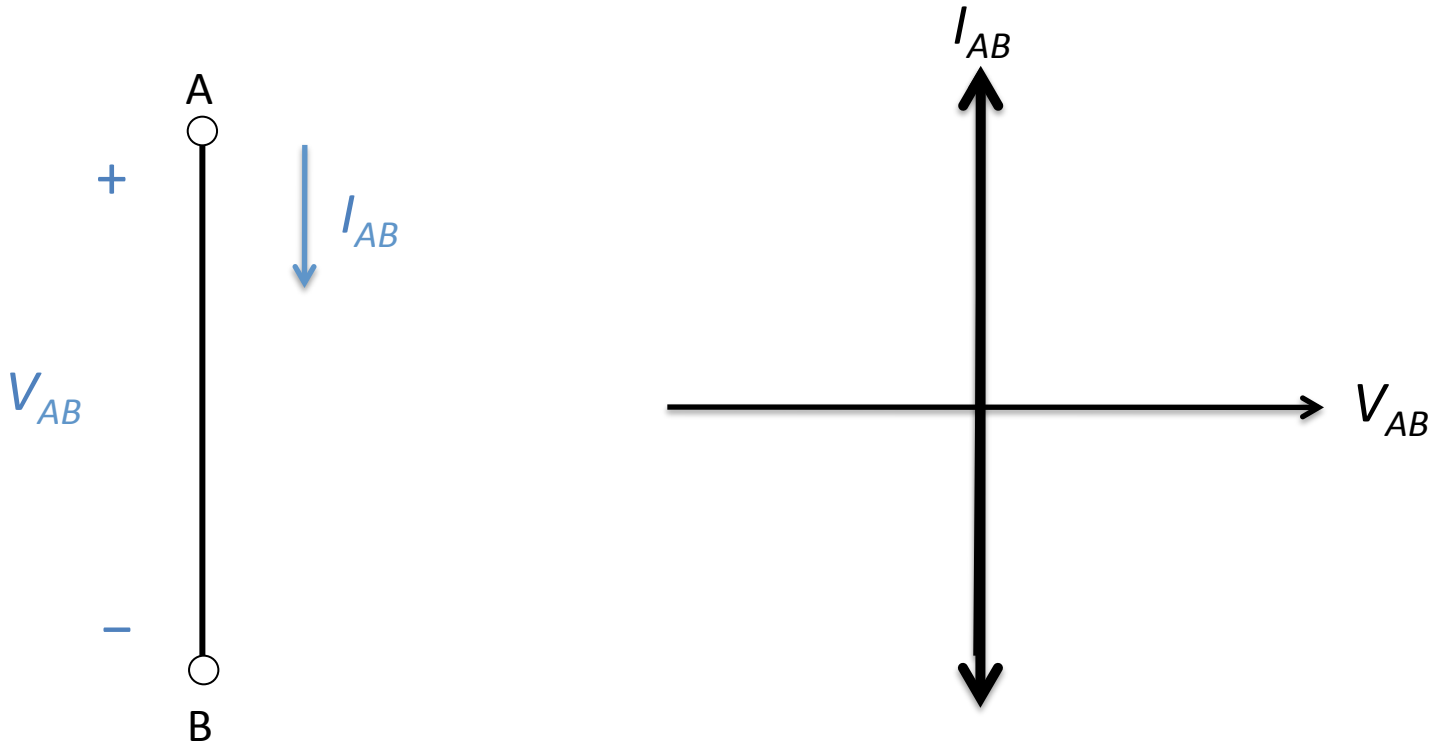
Open Circuit

The current through an open circuit is 0A irrespective of the voltage applied across the terminals. Equivalent to a 0A current source, or a resistor with G = 0 (or R ≈ ∞).



Short Circuit

The voltage across a short circuit is 0V irrespective of the current applied through the terminals. Equivalent to a 0V voltage source, or a resistor with R = 0 (or G ≈ ∞).

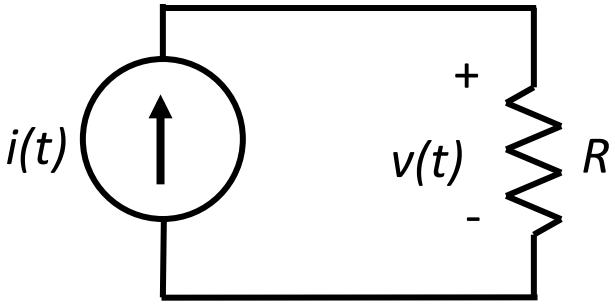


Ideal Voltmeter

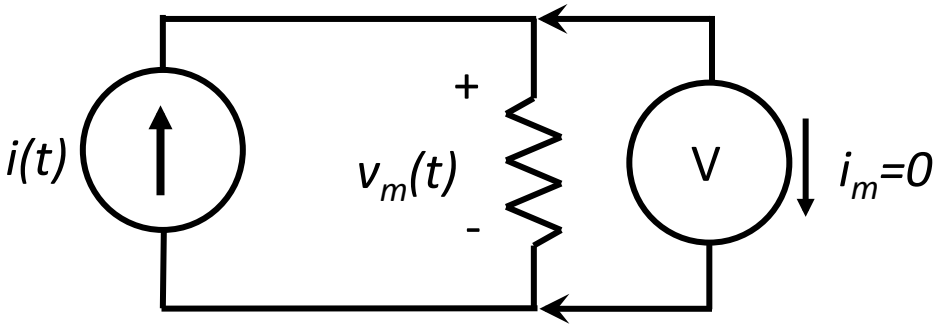
Ideal voltmeter: an element that measures the voltage across its terminals with zero power absorbed, meaning the voltmeter draws a current $i_m = 0$, and is therefore equivalent to an **open-circuit**

– voltmeter is placed in parallel with branch voltage, *v(t)* to be measured

– the measured voltage $v_m(t) = v(t)$ because the ideal voltmeter is equivalent to an open circuit in parallel, leaving all circuit currents unchanged



circuit



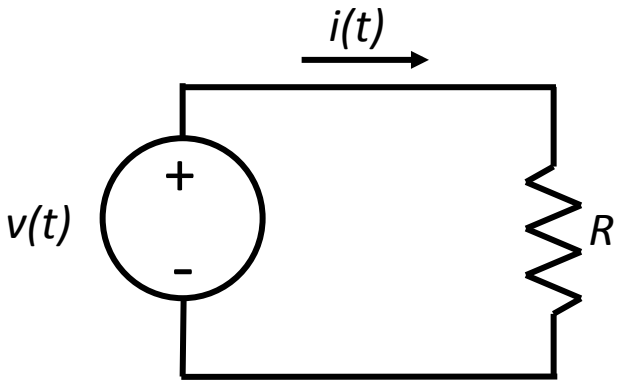
circuit with ideal voltmeter

Ideal Ammeter

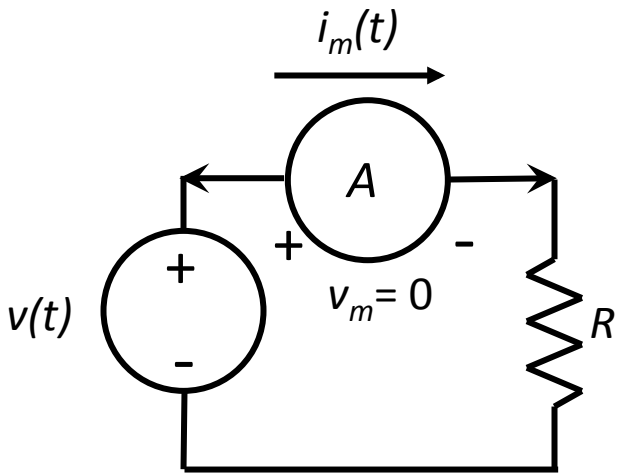
Ideal ammeter: an element that measures the current flowing through its terminals with zero power absorbed, meaning the ammeter produces a voltage drop $v_m = 0$, and is thus equivalent to a **short-circuit**

– ammeter is placed in series with branch current, *i(t)* to be measured

– the measured current $i_m(t) = i(t)$ because the ideal ammeter is equivalent to a short circuit in series, leaving all circuit voltages unchanged



circuit

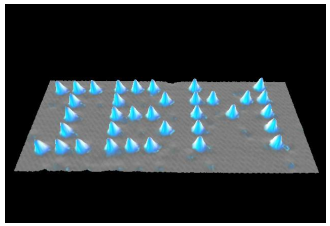


circuit with ideal ammeter

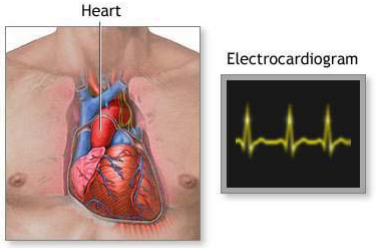
Dependent Sources

Dependent sources are the ideal circuit elements that allow us to model **amplifiers,** circuits that amplify a voltage or current. Amplifiers are found in practically all electronics, some examples of applications:

telecommunications



science



health diagnostics

consumer electronics

industrial control and monitoring

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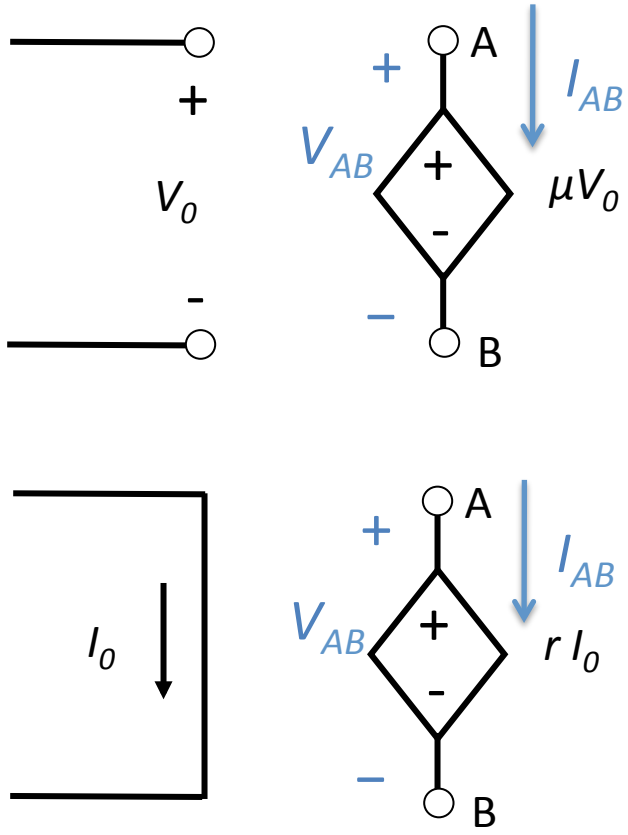
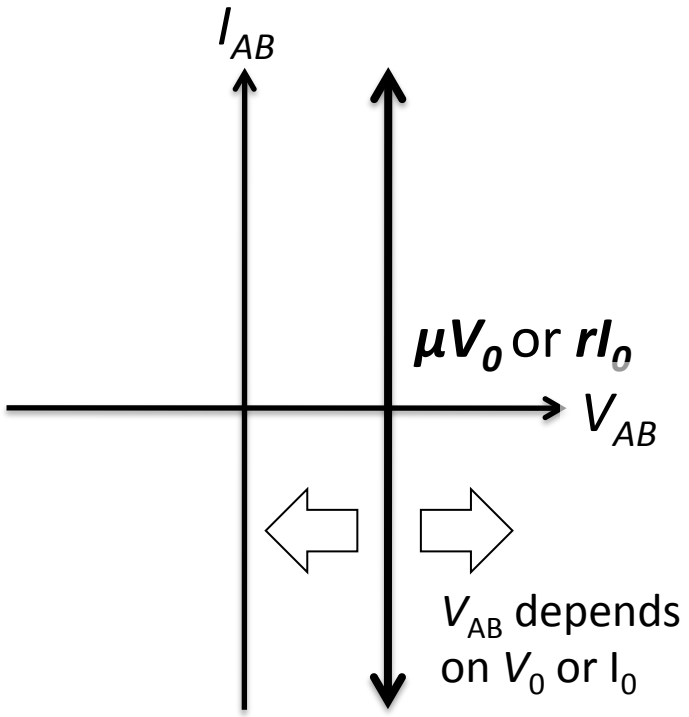
Dependent Voltage Source

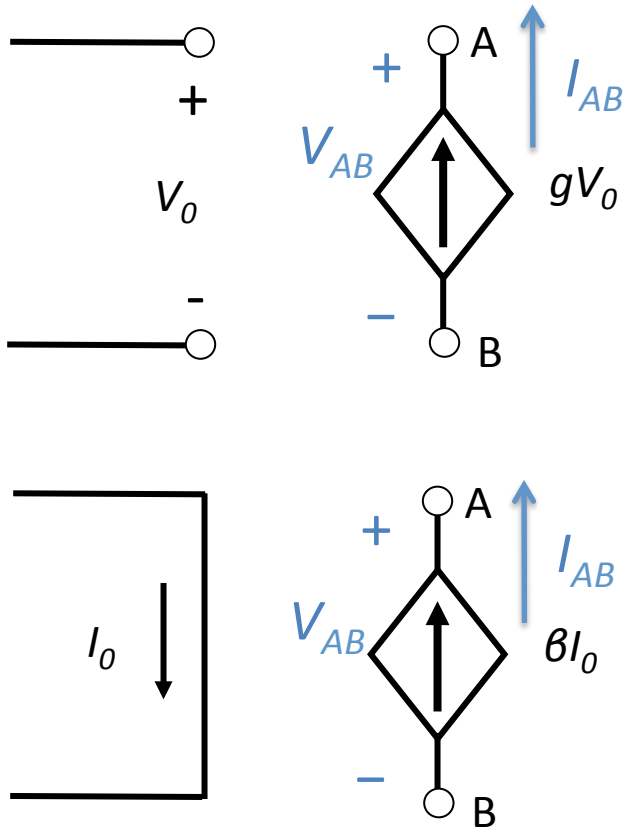
Dependent voltage source: a two terminal circuit element that maintains a voltage across its terminals *regardless of the current flowing through it,* the terminal voltage depends on a voltage or current elsewhere in the circuit

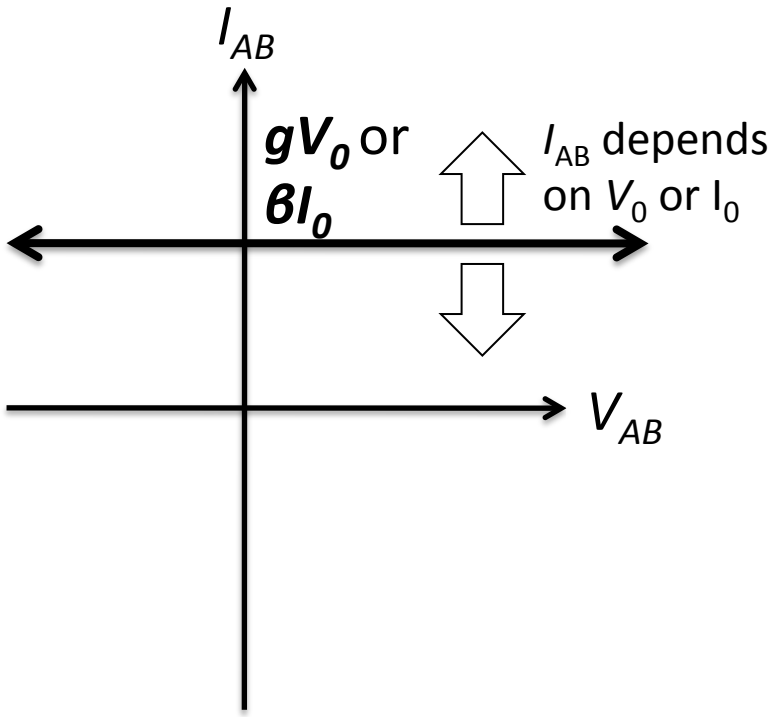




Dependent Current Source

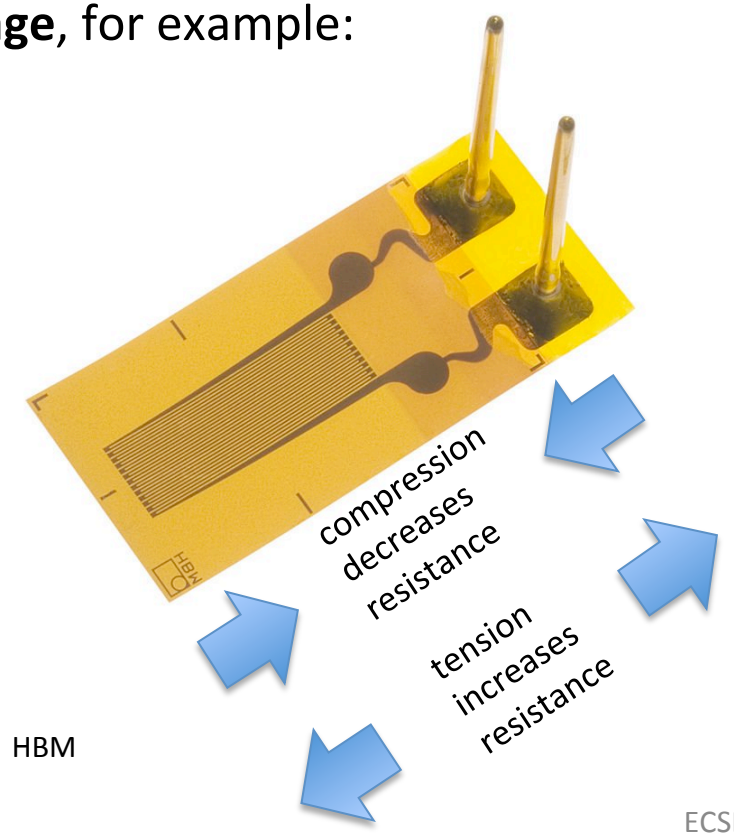
Dependent current source: a two terminal circuit element that maintains a current through its terminals *regardless of the voltage across it,* the terminal current depends on a voltage or current elsewhere in the circuit





Transducers

Transducer: a circuit element that converts physical quantities (e.g. position, strain, pressure, liquid level, sound, acceleration, temperature, pH, magnetic field, visible light intensity, X-ray intensity) into electrical quantities (e.g. current, voltage, resistance). Consider a resistive **strain guage**, for example:

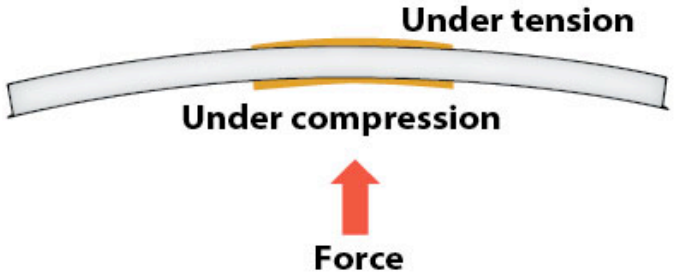


HBM

The physics of resistance and material deformation determines the resistance change:

$$R = \rho\frac{L}{A} \quad \rightarrow \quad \Delta R = \rho \cdot \Delta\left(\frac{L}{A}\right)$$

Strain gauges can be used to measure beam deflection.



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Section 1 Summary

Algebraic variables: consist of a definition and a signed value, usually more than one way to describe the same physical situation

Current: the rate of charge flow along a reference direction, a magnitude and sign are always specified

Voltage: the energy per unit charge that is gained by a particle passing from a reference "–" terminal to a "+" terminal

Power: the time rate of change in energy absorbed or delivered, determined entirely by the product of current and voltage at an element's terminals. Instantaneous power is the product of instantaneous current and voltage.

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Section 1 Summary

Passive element: an element that cannot deliver a net positive energy to a circuit

Active element: an element that can deliver a net positive energy

Linear element: an element with a linear (function or operator) relationship between terminal current and terminal voltage

Independent voltage source: element with a fixed voltage across its terminals

Independent current source: element with a fixed current through its terminals

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Section 1 Summary

Ideal Resistor: an element whose terminal current and voltage satisfy Ohm's Law

Dependent voltage source: an element with a voltage across its terminals determined by another circuit variable

Dependent current source: an element with a current through its terminals determined by another circuit variable

Transducer: an element converting between physical quantities and electrical quantities