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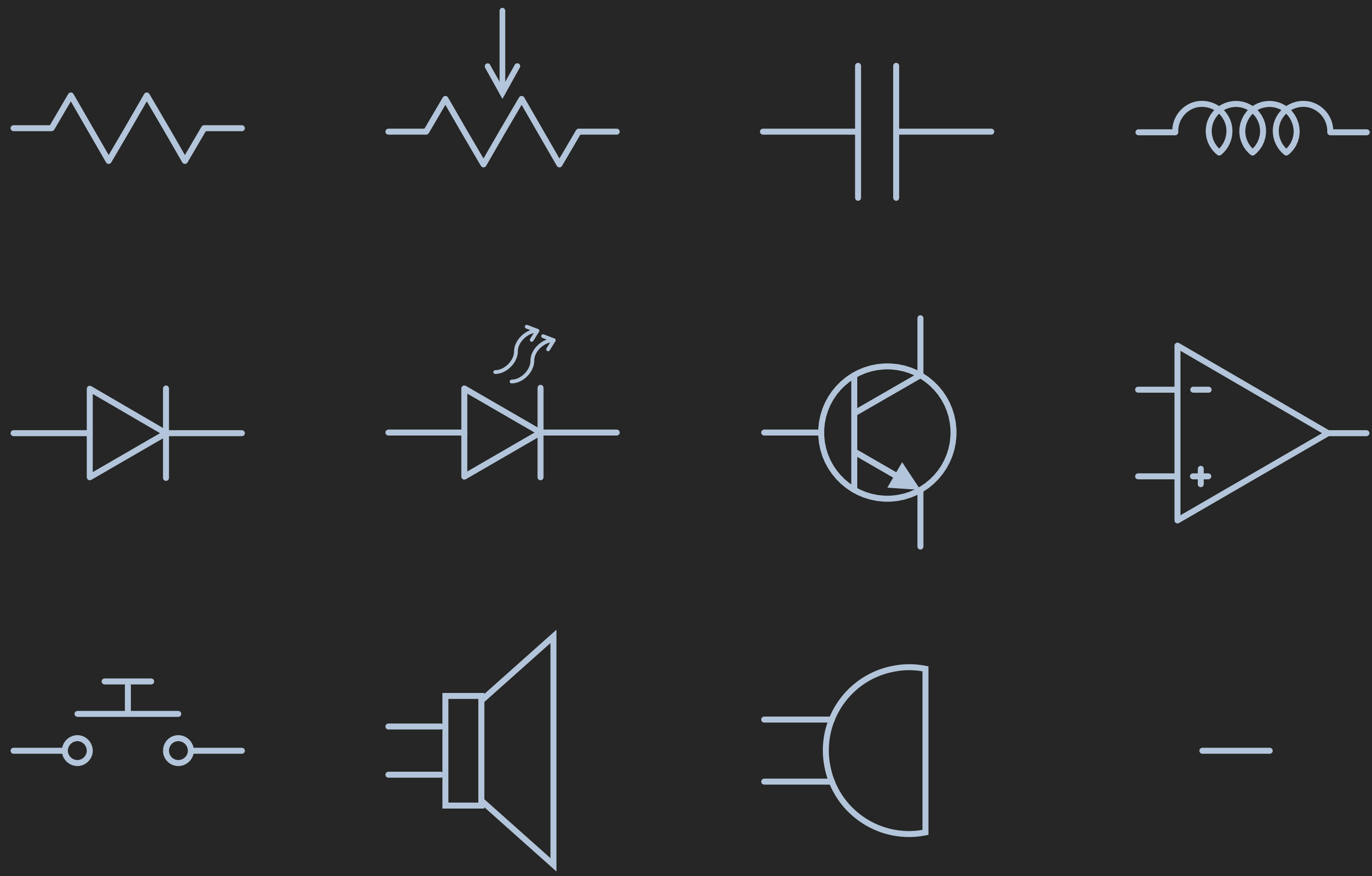
0-1 Pre-class

Circuit Analysis

元件



Content

Symbols

Laws & Methods

Components

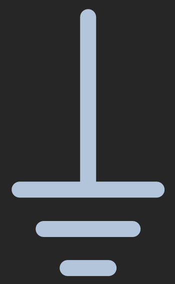
Branch

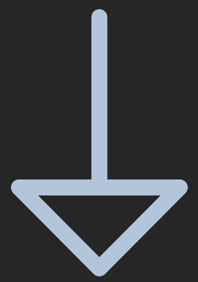
- A single element.

Node

- Point of connection between multiple branches.

Ground (GND)





- A selected voltage reference node ($V_{GND} = 0$).
- A common return path for electric current.
- A direct physical connection to the Earth.

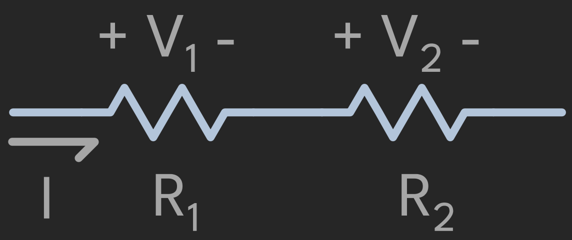
Resistor

▶ Ohm's Law

$$R \triangleq \frac{V}{I}$$

R : *Resistance* (Ω)
V : *Voltage* (V)
I : *Current* (A)

Connected in Series



$$I = \frac{V_1}{R_1} = \frac{V_2}{R_2}$$

$$V_1 + V_2 = IR_{eq}$$

$$R_{eq} = \frac{V_1}{\mathrm{I}} + \frac{V_2}{\mathrm{I}} = R_1 + R_2$$

Connected in Parallel

$$V = I_1R_1 = I_2R_2$$

$$I_1 + I_2 = \frac{V}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \frac{I_1}{V} + \frac{I_2}{V}$$

$$= \frac{1}{R_1} + \frac{1}{R_2}$$

Connected in Series

- n resistors connected in series.
- Same current.

$$I = \frac{V_n}{R_n}$$

$$\sum V_n = IR_{eq}$$

$$R_{eq} = \sum R_n$$

Connected in Parallel

- n resistors connected in parallel.
- Same voltage.

$$V = I_n R_n$$

$$\sum I_n = \frac{V}{R_{eq}}$$

$$\frac{1}{R_{eq}} = \sum \frac{1}{R_n}$$

Connected in Series

$$+$$

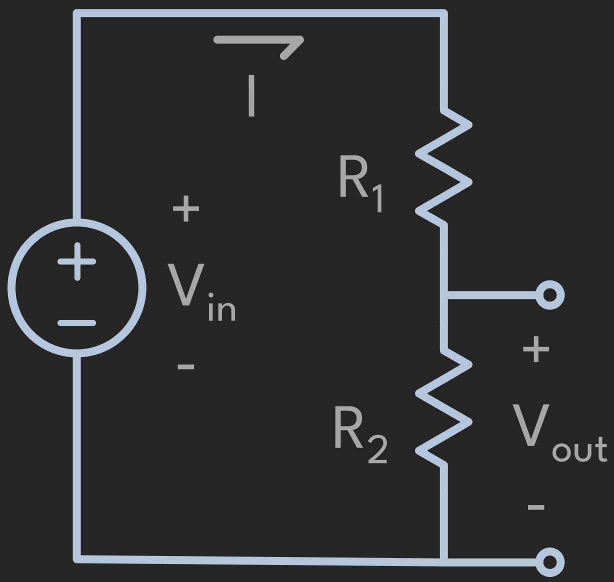
$$R_{eq} = R_1 + R_2 + \cdots + R_n$$

Connected in Parallel

$$||$$

$$R_{eq} = R_1 \,||\, R_2 \,||\, \ldots \,||\, R_n$$

Voltage Divider



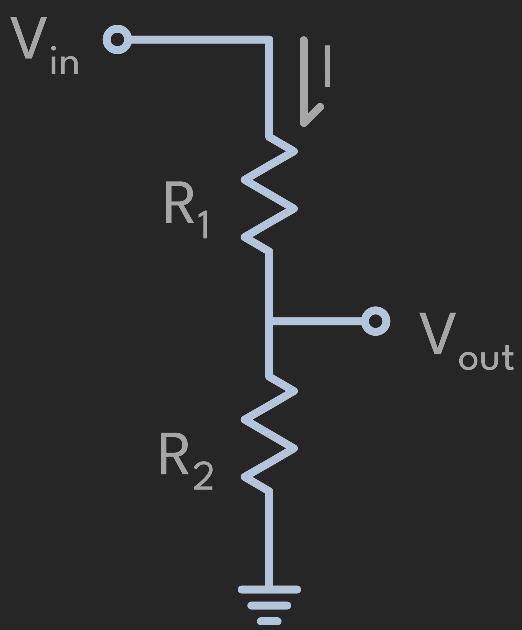
- Two resistors connected in series form a voltage divider.

$$V_{in} = I(R_1 + R_2)$$

$$V_{out} = IR_2$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{R_2}{R_1 + R_2}$$

Voltage Divider



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$$V_{in} = I(R_1 + R_2)$$

$$V_{out} = IR_2$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{R_2}{R_1 + R_2}$$

Potentiometer

- Can be used as a **variable resistor**.
- A three-terminal resistor with a sliding or rotating contact forms an adjustable voltage divider.

$$R = \frac{\rho L}{A}$$

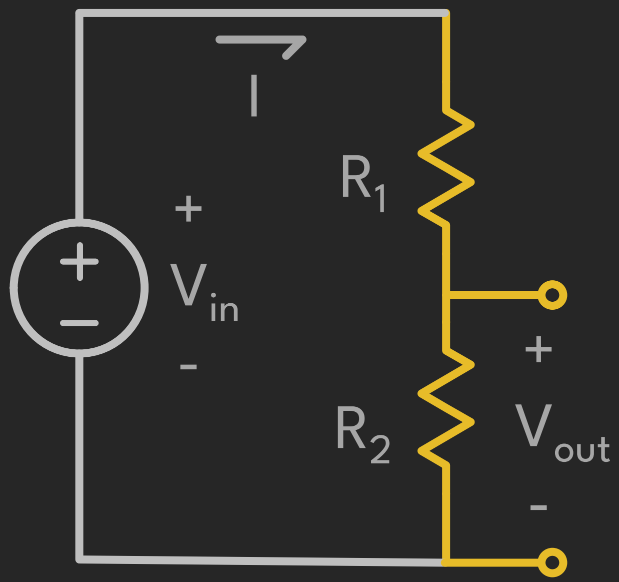
R : $Resistance$ (Ω)

ρ : $Resisivity$ (Ωm)

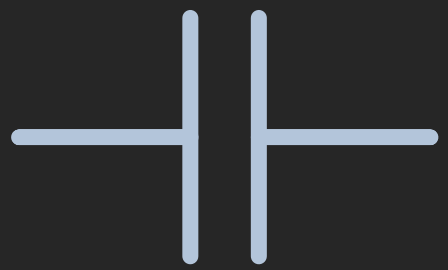
L : $Length$ (m)

A : $Cross\ section\ Area$ (A)

Potentiometer



Capacitor

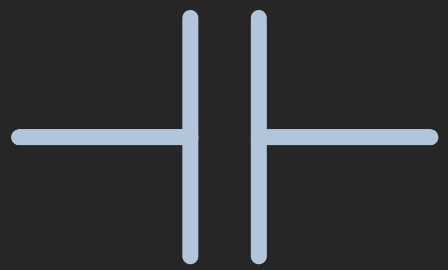


- Definition of **capacitance**

$$C \triangleq \frac{Q}{V}$$

C : $Capacitance$ (F)
Q : $Charge$ (C)
V : $Voltage$ (V)

Capacitor



- A capacitor can remove the DC part of a signal.

$$\mathrm{Q} = C\mathrm{V}$$

$$\Rightarrow i(t) = \frac{dQ}{dt} = C\frac{dv(t)}{dt}$$

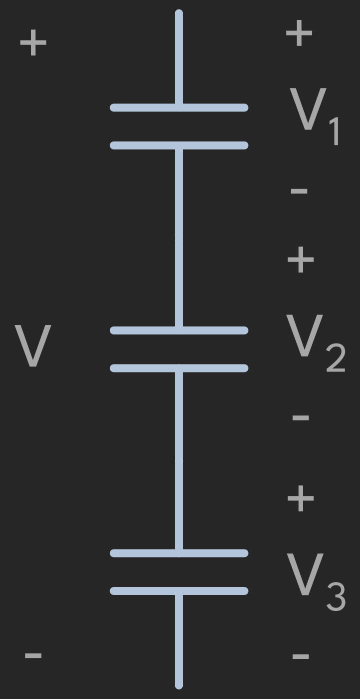
Connected in Series

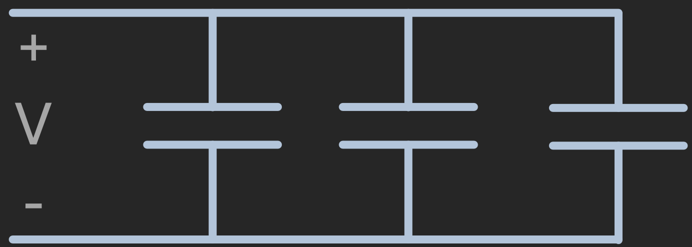
- n capacitors connected in series.

$$V = \sum V_n$$

$$\frac{Q}{C_{eq}} = \sum \frac{Q}{C_n}$$

$$\frac{1}{C_{eq}} = \sum \frac{1}{C_n}$$





Connected in Parallel

- n capacitors connected in parallel.

$$Q_n = C_n V$$

$$\sum Q_n = C_{eq} V$$

$$C_{eq} = \sum C_n$$

Connected in Series

- n capacitors connected in series.

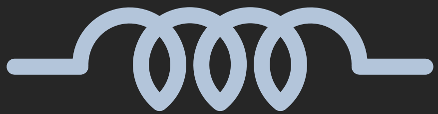
$$\frac{1}{C_{eq}} = \sum \frac{1}{C_n}$$

Connected in Parallel

- n capacitors connected in parallel.

$$C_{eq} = \sum C_n$$

Inductor



- i-v equation

$$v(t) = L\frac{di(t)}{dt}$$

$L : Inductance$ (H)

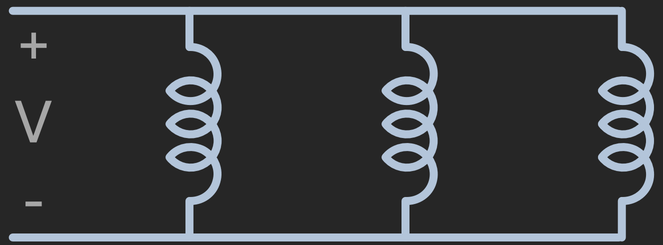
Connected in Series

- n inductors connected in series.

$$v(t) = \sum v_n(t)$$

$$L_{eq}\frac{di(t)}{dt} = \sum L_n \frac{di(t)}{dt}$$

$$L_{eq} = \sum L_n$$



Connected in Parallel

- n inductors connected in parallel.

$$v(t) = L_{eq}\frac{di(t)}{dt} = L_n\frac{di_n(t)}{dt}$$

$$\frac{di(t)}{dt} = \sum \frac{di_n(t)}{dt}$$

$$\frac{v(t)}{L_{eq}} = \sum \frac{v(t)}{L_n}$$

$$\frac{1}{L_{eq}} = \sum \frac{1}{L_n}$$

Connected in Series

- n inductors connected in series.

$$L_{eq} = \sum L_n$$

Connected in Parallel

- n inductors connected in parallel.

$$\frac{1}{L_{eq}} = \sum \frac{1}{L_n}$$

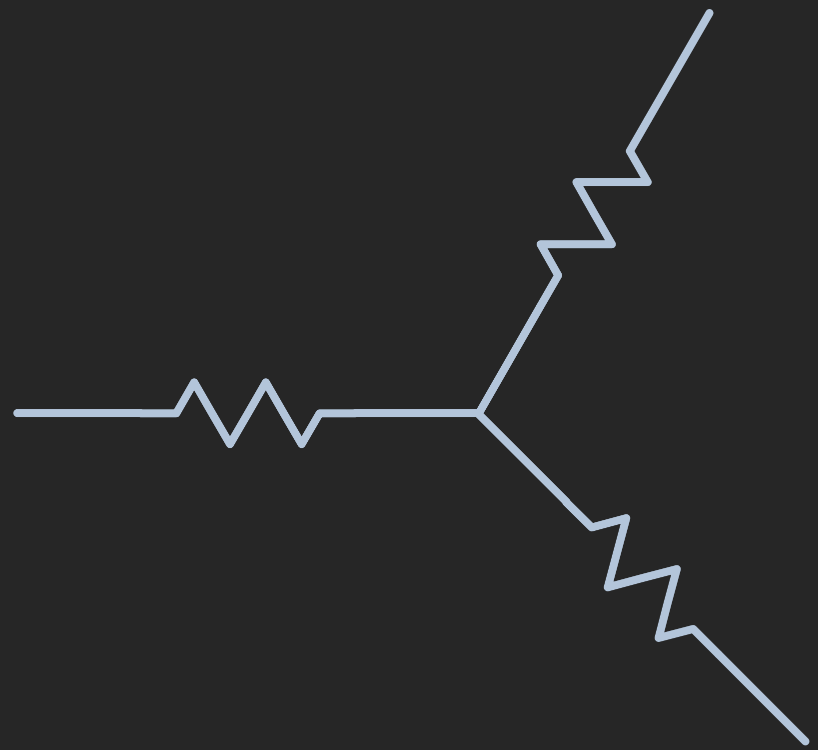
Laws & Methods

Kirchhoff's Current Law (KCL)

- The sum of current that flow in a node is equal to the sum of current that flow out of itself.
- See also KVL...

$$\sum I_{in} = \sum I_{out}$$

Kirchhoff's Current Law (KCL)



Resistance (R)

- Real numbers.
- Electrical energy is dissipated in the form of heat. ($P=I^2R$)

(X) Reactance

- Imaginary numbers.
- Opposition presented to AC by inductance or capacitance.

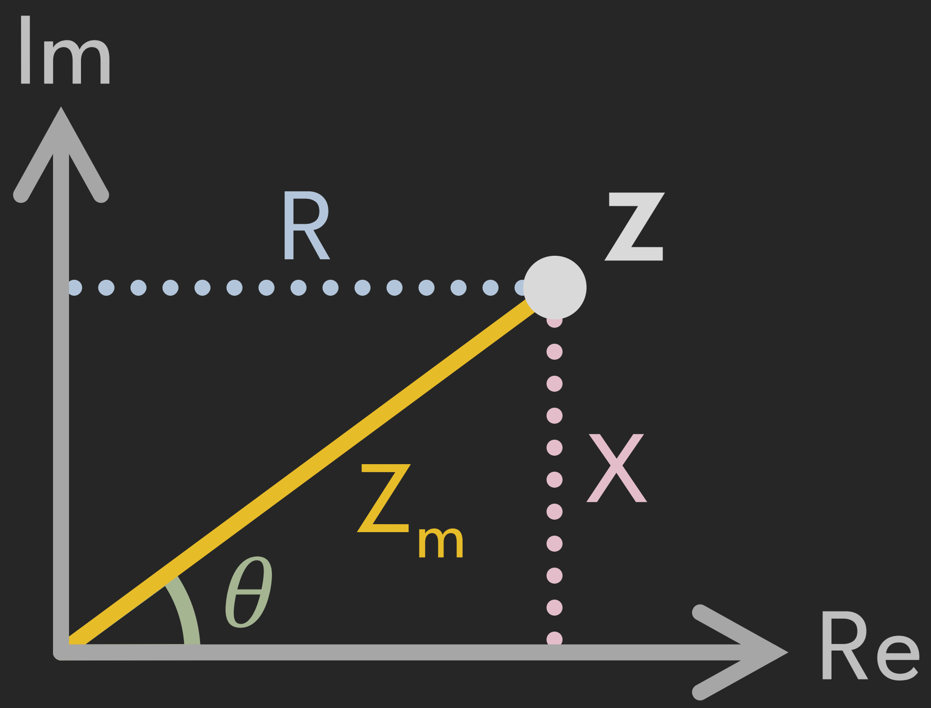
Impedance (Z)

- Complex numbers
- $j = \sqrt{-1}$
- Cartesian form:

$$\boldsymbol{Z} = R + jX$$

- Polar form:

$$\boldsymbol{Z} = Z_m \angle \theta$$



Impedance (Z)

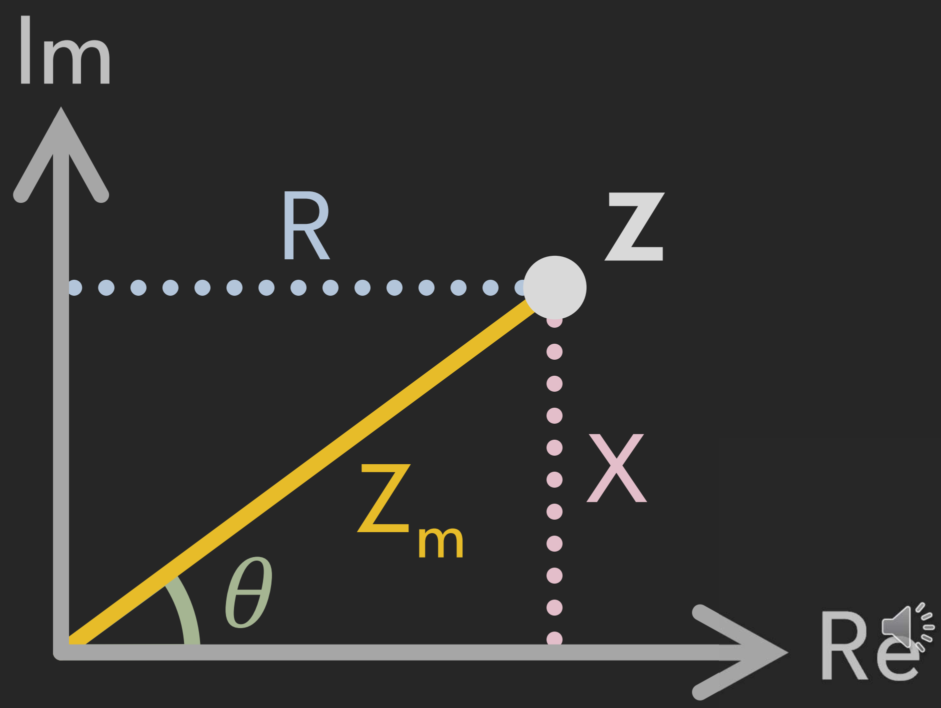
$$\mathbf{Z} = R + jX$$

$$R = Re\{\mathbf{Z}\} = Z_m \cos\theta$$

$$X = Im\{\mathbf{Z}\} = Z_m \sin\theta$$

$$Z_m = |\mathbf{Z}| = \sqrt{R^2 + X^2}$$

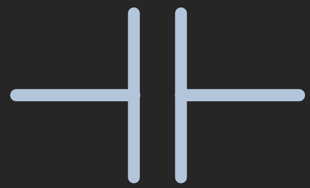
$$\theta = \tan^{-1}\frac{X}{R}$$



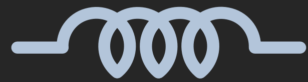
Impedance (Z)

$\omega: frequncy$

$$\boldsymbol{Z}_{\mathrm{R}} = R$$



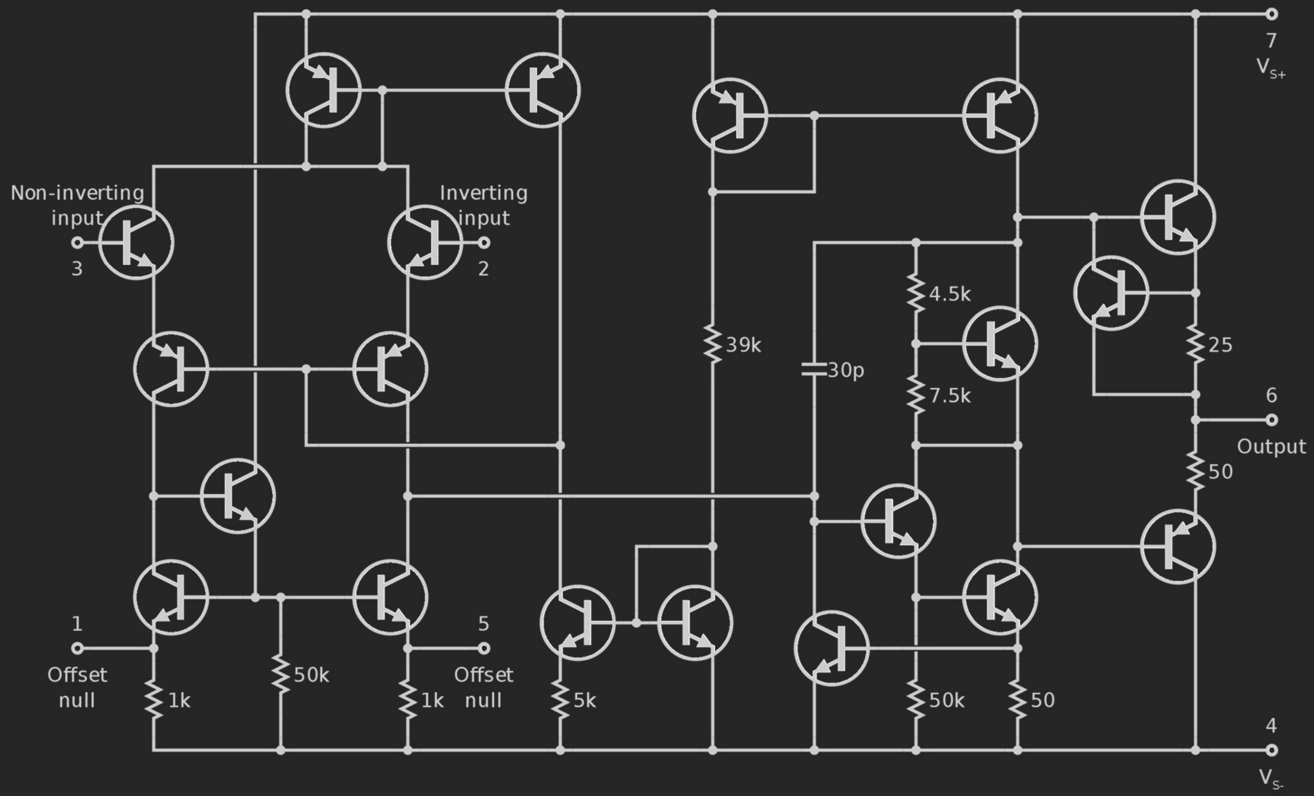
$$\boldsymbol{Z}_{C} = \frac{1}{j\omega C}$$



$$\boldsymbol{Z}_{L} = j\omega L$$

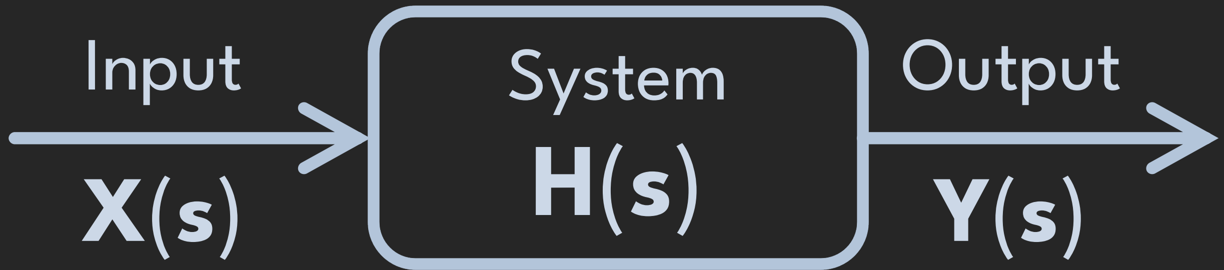
$$\boldsymbol{V = IZ}$$

Transfer Function



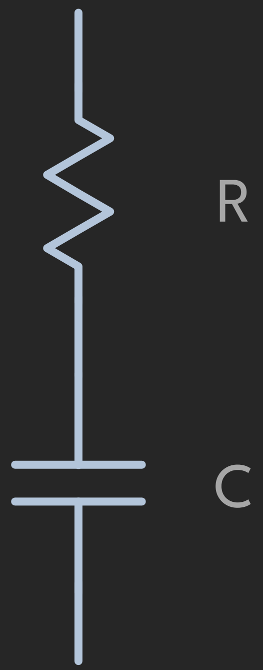
Transfer Function

- A math function that describes the relationship between the input and the output of a system.
- $H(s) \triangleq \frac{Y(s)}{X(s)}$
- Mostly, we discuss about V_{out}/V_{in}.



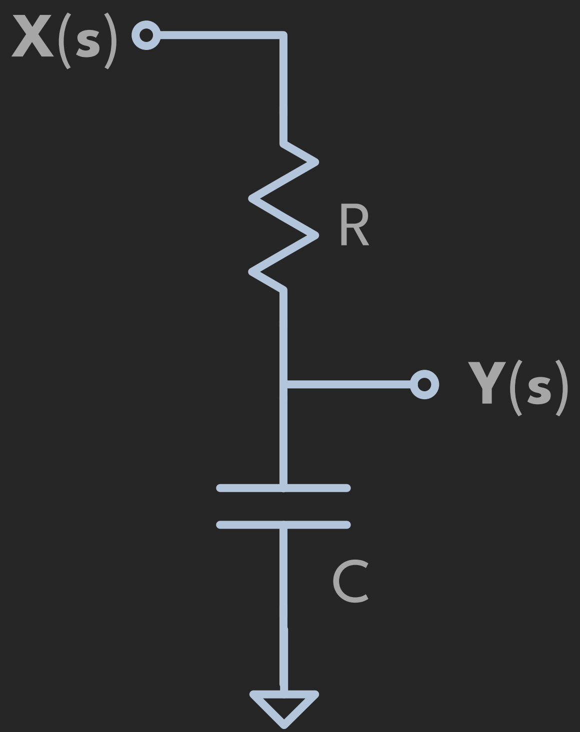
EXAMPLE

- Calculate the equivalent impedance.



EXAMPLE

- Derive the transfer function **Y**(**s**)/**X**(**s**) as a function of ω.



Thank You