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Session 5
Passive Components

Electronic Components and Circuits

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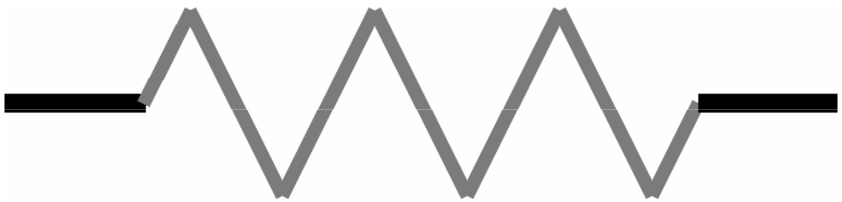
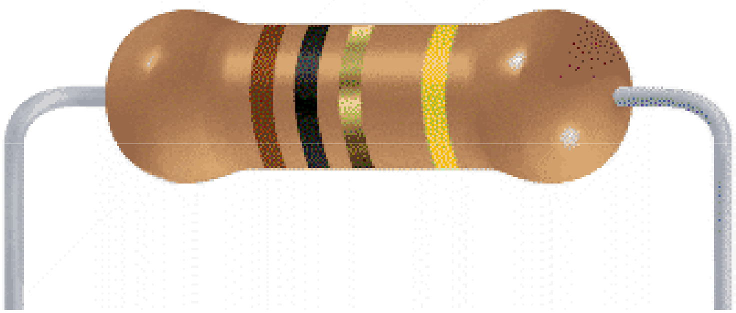
Passive Components

OBJECTIVES

- Review the basic definitions and the electrical parameters associated with resistors, capacitors and inductors.
- Understand the selection of components and their limitations.
- Understand the magnetic coupling and their use in transformers. Knowing the relationship of current, voltage and power in an ideal transformer and the impedance matching.

Resistor: Overview





- Opposition to the flowing of Q
- Ohmic value (Ω…kΩ…MΩ) [V/mA]
- In circuits, Ohm's Law $V=I \cdot R$
- Resistance: heat dissipation (P_D), it heats (Tº)
- Manufacturing: Types, series, tolerance, etc.

Characteristic parameters

- **Resistivity** (*conductivity*)

$$R = \rho \frac{l}{S}[\Omega] \qquad \rho = \frac{E}{J}[\Omega \cdot cm] \qquad \sigma = \frac{1}{\rho}$$

Example: Graphite 20 μΩ·m = 2mΩ·cm

- **Temperature coefficient** (mean)

$$\alpha = \frac{1}{R(T_0)} \cdot \frac{\Delta R}{\Delta T}[ppm/^{\circ}C] \qquad R(T) = R(T_0) \cdot [1 + \alpha \cdot (T - T_0)]$$

- **Operating limits** (*maximum voltage*)

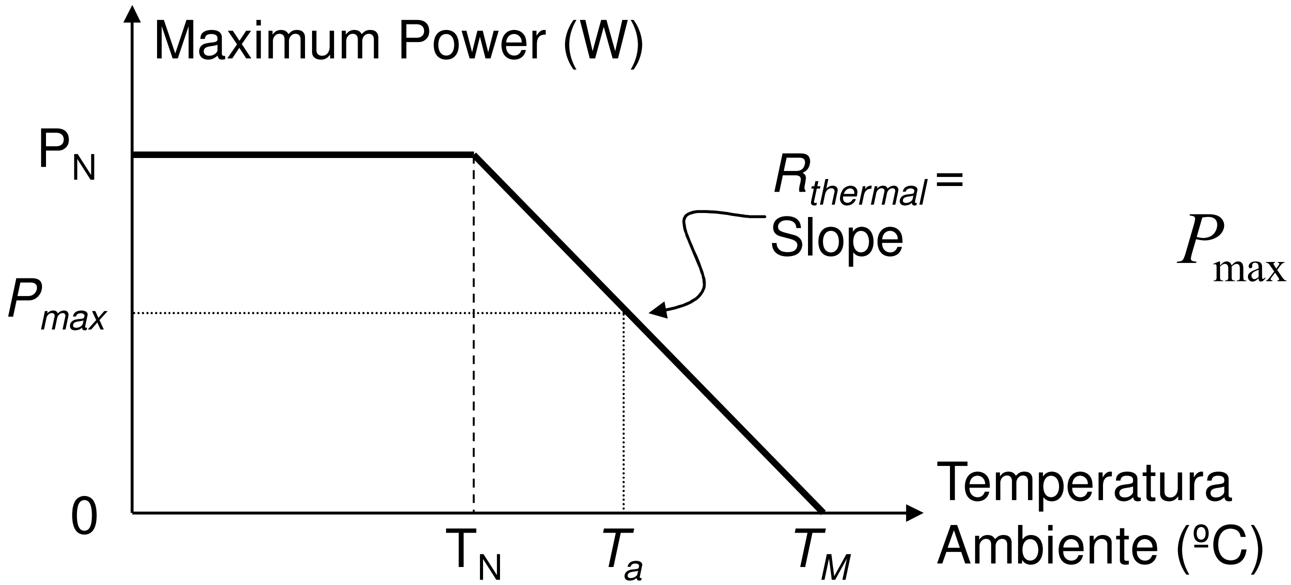
Power ($P=V^2/R$) or Dielectric breakdown voltage

Critical Resistance Pmax·R=(Vbreakdown)^2

Operating Limits

Dissipated power (*produces heat, T rises*)

- Rated power *¼W, ½W, etc.*
- Curve with temperature (*Thermal resistance*)

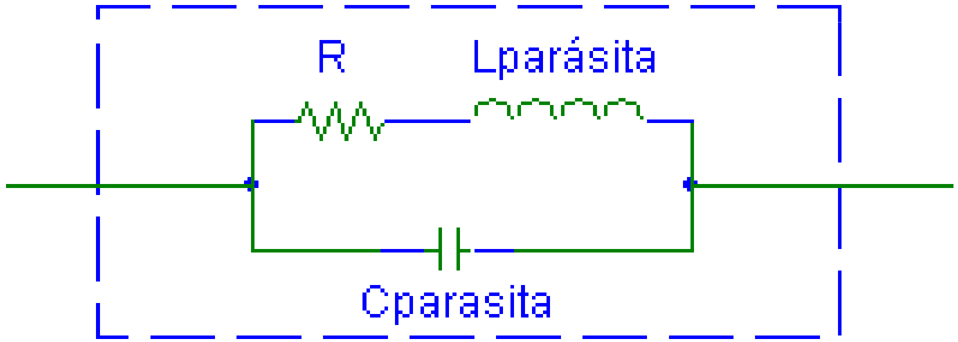


$$P_{\max} = \frac{T_M - T_a}{R_{thermal}}$$

- Maximum voltage $P=V^2/R$

Limitations

- Frequency Response



- Noise
  - *Thermal noise* (thermal agitation, 1/f)
  - Beware of Voltage *high DC, high R, etc.*

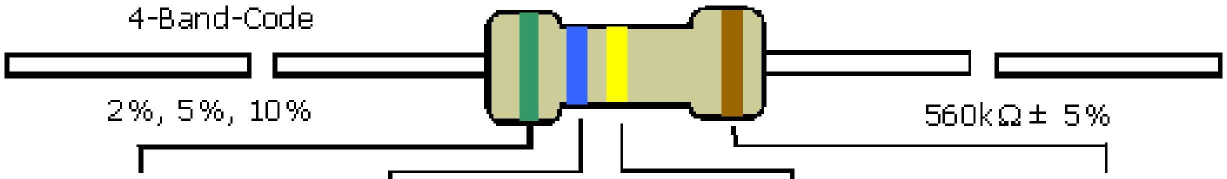
Standard values of resistors

1% Standard Values Decade multiples are available from 10.0 Ω through 1.00 MΩ (also 1.10 MΩ, 1.20 MΩ, 1.30 MΩ, 1.50 MΩ, 1.60 MΩ, 1.80 MΩ, 2.00 MΩ and 2.20 MΩ)											
10.0	10.2	10.5	10.7	11.0	11.3	11.5	11.8	12.1	12.4	12.7	13.0
13.3	13.7	14.0	14.3	14.7	15.0	15.4	15.8	16.2	16.5	16.9	17.4
17.8	18.2	18.7	19.1	19.6	20.0	20.5	21.0	21.5	22.1	22.6	23.2
23.7	24.3	24.9	25.5	26.1	26.7	27.4	28.0	28.7	29.4	30.1	30.9
31.6	32.4	33.2	34.0	34.8	35.7	36.5	37.4	38.3	39.2	40.2	41.2
42.2	43.2	44.2	45.3	46.4	47.5	48.7	49.9	51.1	52.3	53.6	54.9
56.2	57.6	59.0	60.4	61.9	63.4	64.9	66.5	68.1	69.8	71.5	73.2
75.0	76.8	78.7	80.6	82.5	84.5	86.6	88.7	90.9	93.1	95.3	97.6

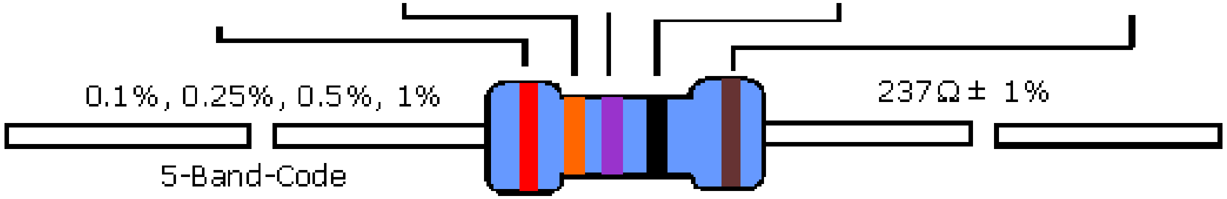
5% Standard Values											
10	11	12	13	15	16	18	20	22	24	27	30
33	36	39	43	47	51	56	62	68	75	82	91

10% Standard Values											
10	12	15	18	22	27	33	39	47	56	68	82

Resistor color code

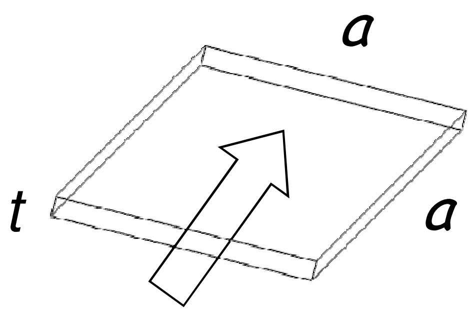


COLOR	1st BAND	2nd BAND	3rd BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	±0.5% (D)
Blue	6	6	6	1MΩ	±0.25% (C)
Violet	7	7	7	10MΩ	±0.10% (B)
Grey	8	8	8		±0.05%
White	9	9	9		
Gold				0.1	± 5% (J)
Silver				0.01	± 10% (K)



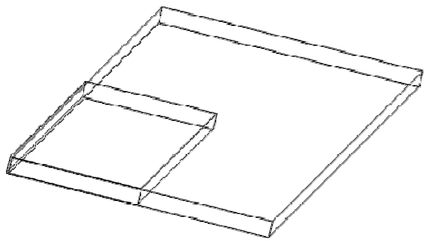
Resistive thin films

- Sheet resistance (ohms per square Ω/□)



$$R_{Square} = \rho \frac{a}{a \cdot t} = \frac{\rho}{t} = \rho_S [\Omega / square]$$

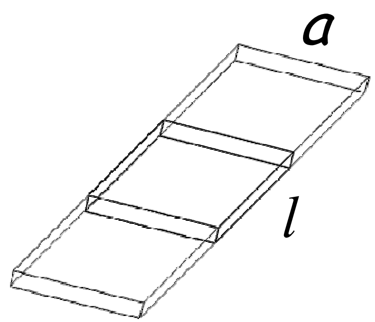
- Power density (W/cm²)



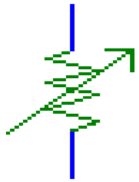
$$P_{Dmáx} = DP_{Dmáx} \cdot a^2$$

- Aspect ratio

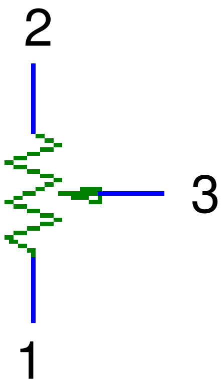
$$R = \rho_S \frac{l}{a} \qquad FF = \frac{l}{a}$$



Variable Resistors



$R = \alpha R_n$



$R_{12} = R_N$

$R_{13} = \alpha R_N$

$R_{23} = (1-\alpha) R_N$

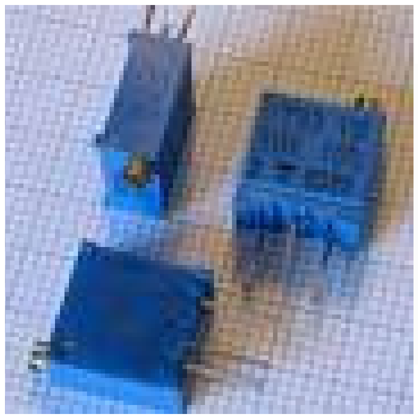
α Between 0 y 1

Electrical Parameters

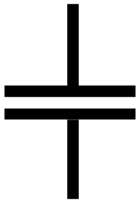
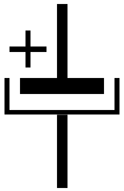
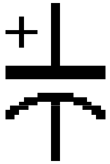
- Total R
- Minimum R
- Terminal R (full range)
- R cursor (any position)
- Maximum current of the cursor
- Dissipation Factor P_m/α
- Adjustability, resolution, etc.

Types

- Rotatory
- Multiturn



Capacitor: Overview

- Stores energy in the form of charge
- Capacitance Value (pF…nF…μF) [Cul/V]
- In circuits $Q=C\cdot V$ $I=C\cdot dV/dt$
- Shunt associación (C_1+C_2), series ($1/C_1+1/C_2$)
- Continuous current: $Ic = 0$
- Alternating sinusoidal: $Ic = C\omega V_p\cos(\omega t) \Rightarrow Zc$

Characteristic Parameters

- Capacitance (plane-parallel plates, *etc.)*

  ε (f, V, T, etc.)

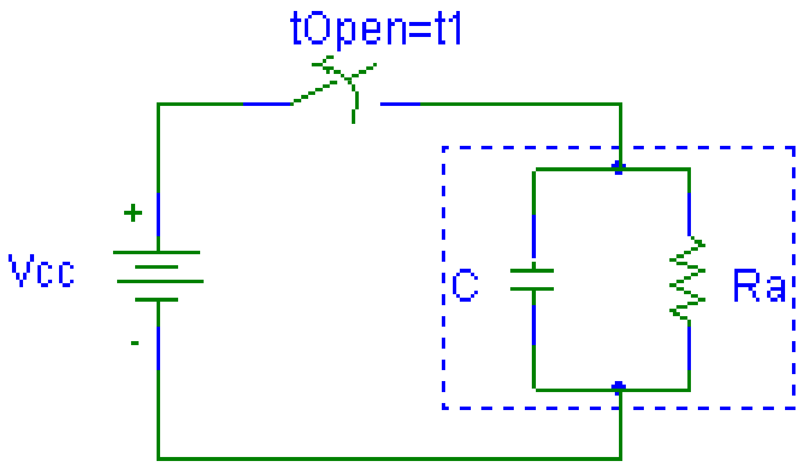
  Dielectric constant

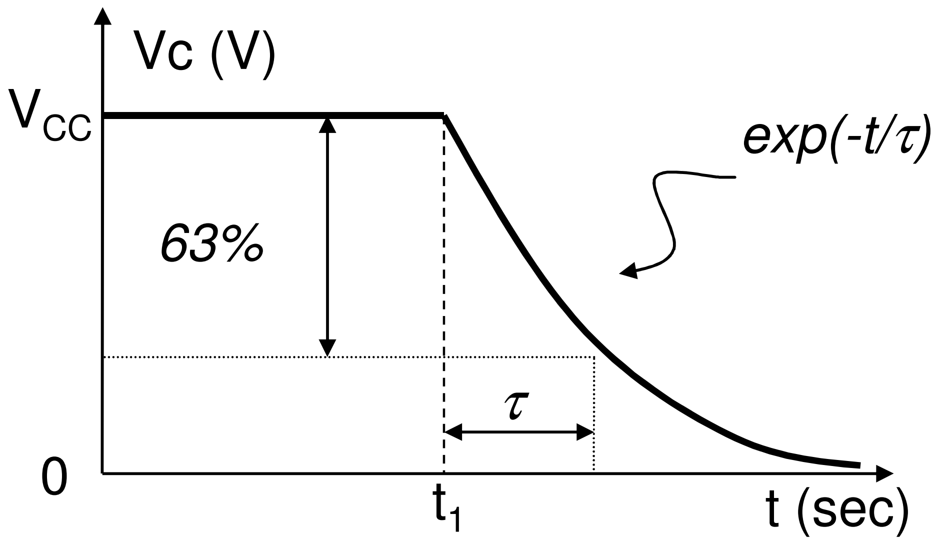
  $$C = \frac{Q}{V} \qquad C = \varepsilon_o \varepsilon_r \frac{S}{d}$$

- DC Fundamentals
  - Leakage Current (Isolation resistance [MΩ])
  - Self-discharge time constant: $\tau = R_A \cdot C$ [sec]
- Power dissipation
  - Continuous (*within R_A*)
  - Alternating
    - Angle of losses: δ (idea of the resistive part)
    - Dissipation Factor D=tgδ (<<1)

DC Parameters

- Self-discharge

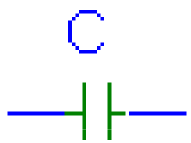




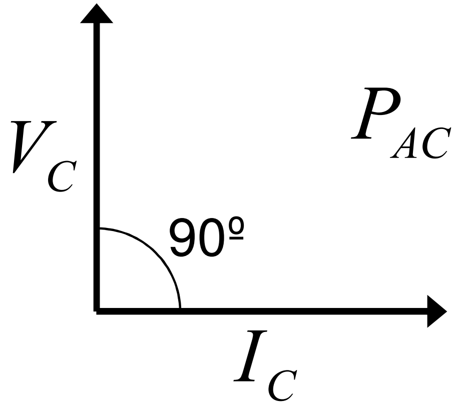
- Dielectric Strength of the material
  - E max [V/m] ⇒ V max (Breakdown voltage)

AC Power dissipation

- Ideal

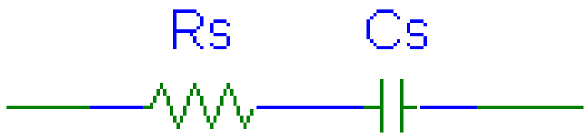


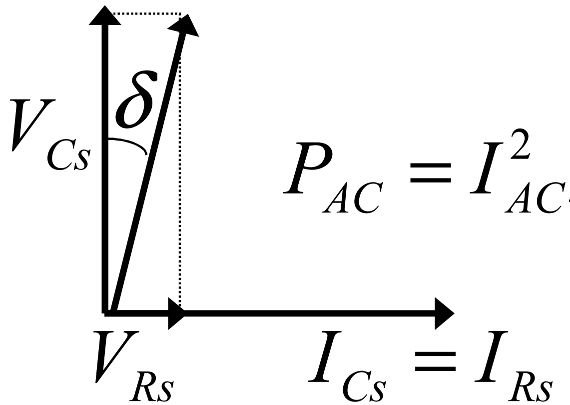
$$v_C = V_0 \sin(\omega t)$$
$$i_C = C\omega V_0 \cos(\omega t)$$



$$P_{AC} = 0$$

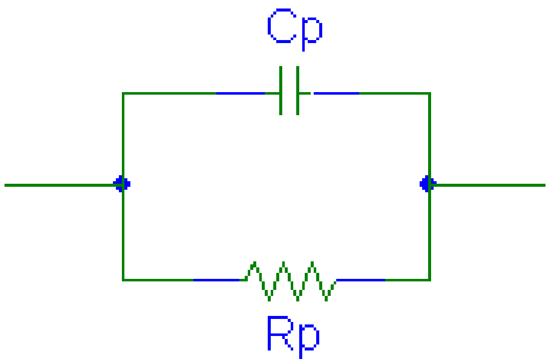
- Series





$$P_{AC} = I^2_{AC-RMS} R_S = \frac{I^2_{AC-RMS}}{\omega C_S} tg\delta$$

- Shunt



$$P_{AC} = \frac{V^2_{AC-RMS}}{R_P} = V^2_{AC-RMS} \cdot \omega C_P tg\delta$$

Inductor: General

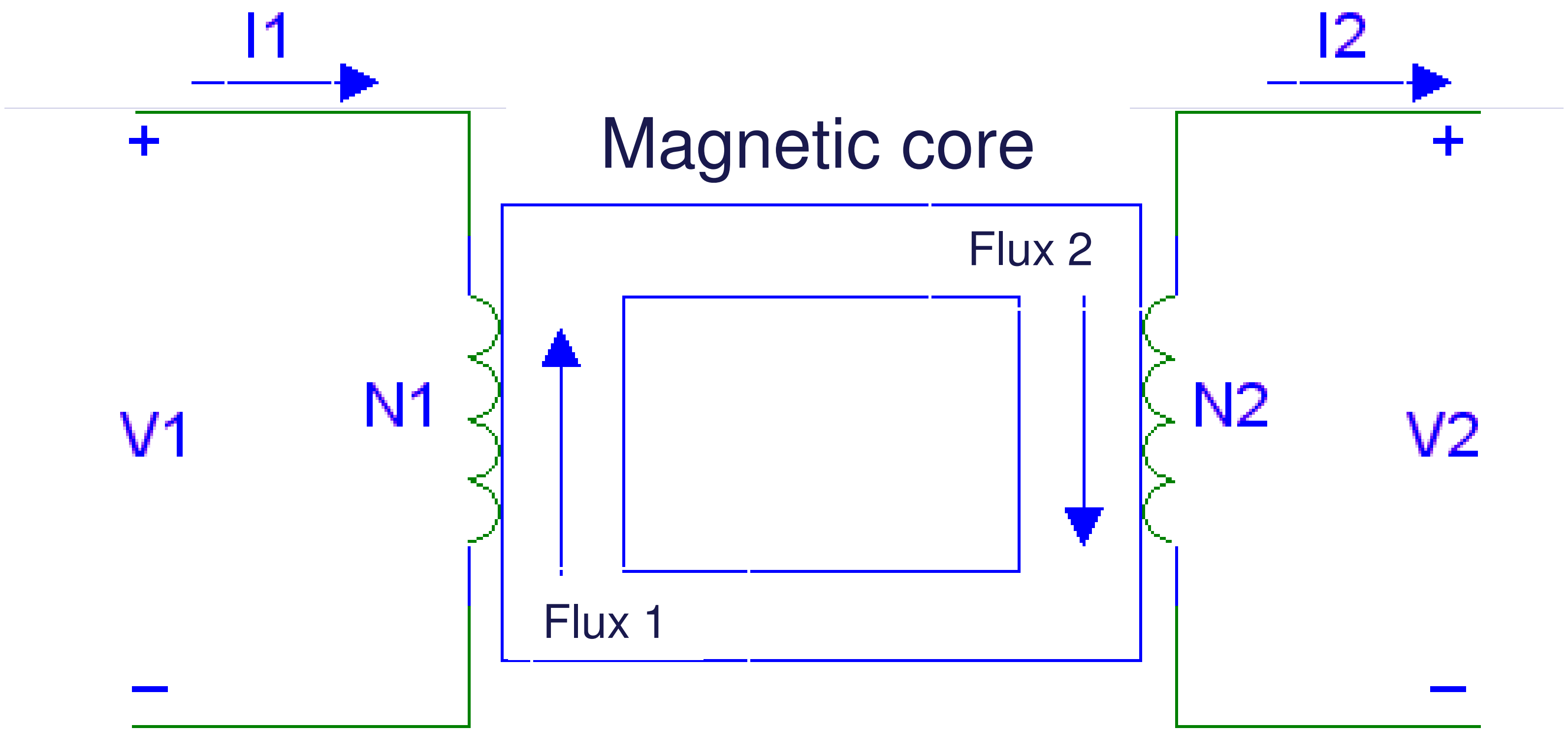
Basic Definitions and Electrical Parameters

- Inductance. Magnetic permittivity and geometry.

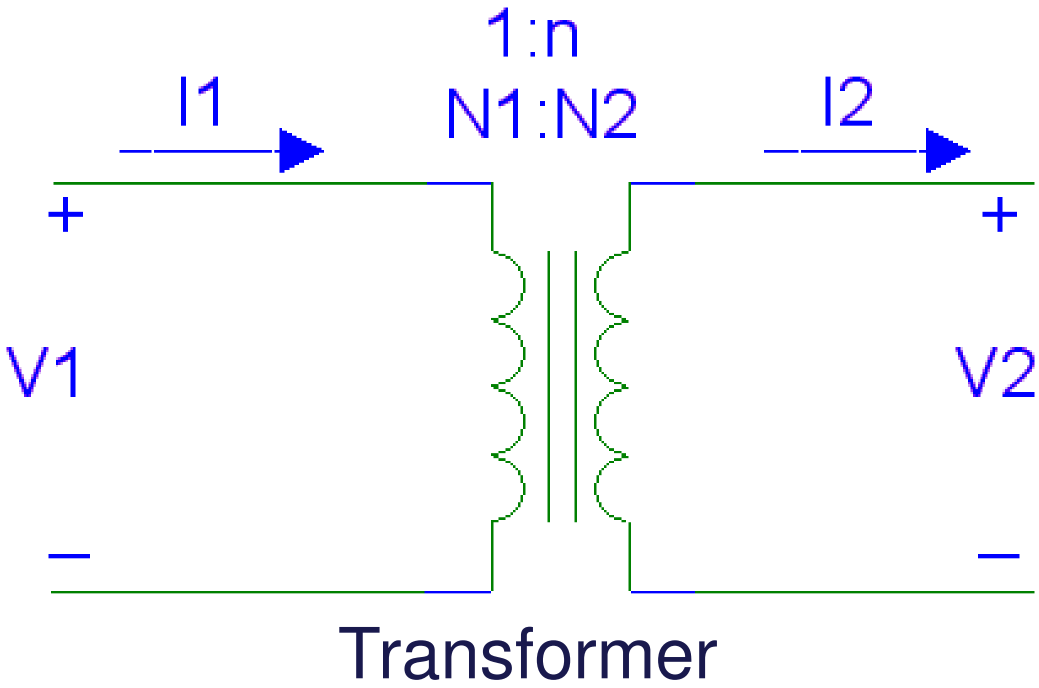
$$\phi(t) = L \cdot i(t) \qquad L = \mu_o \cdot \mu_r \frac{N^2 S}{l}$$

- Nominal Value and Tolerance
- Temperature Coefficient
- Current Range. Core Saturation
- Inductor resistance (DC)
- Types (depending on the type of cores)

Magnetic coupling



Ideal transformer and properties (exampe: transformer up voltage)



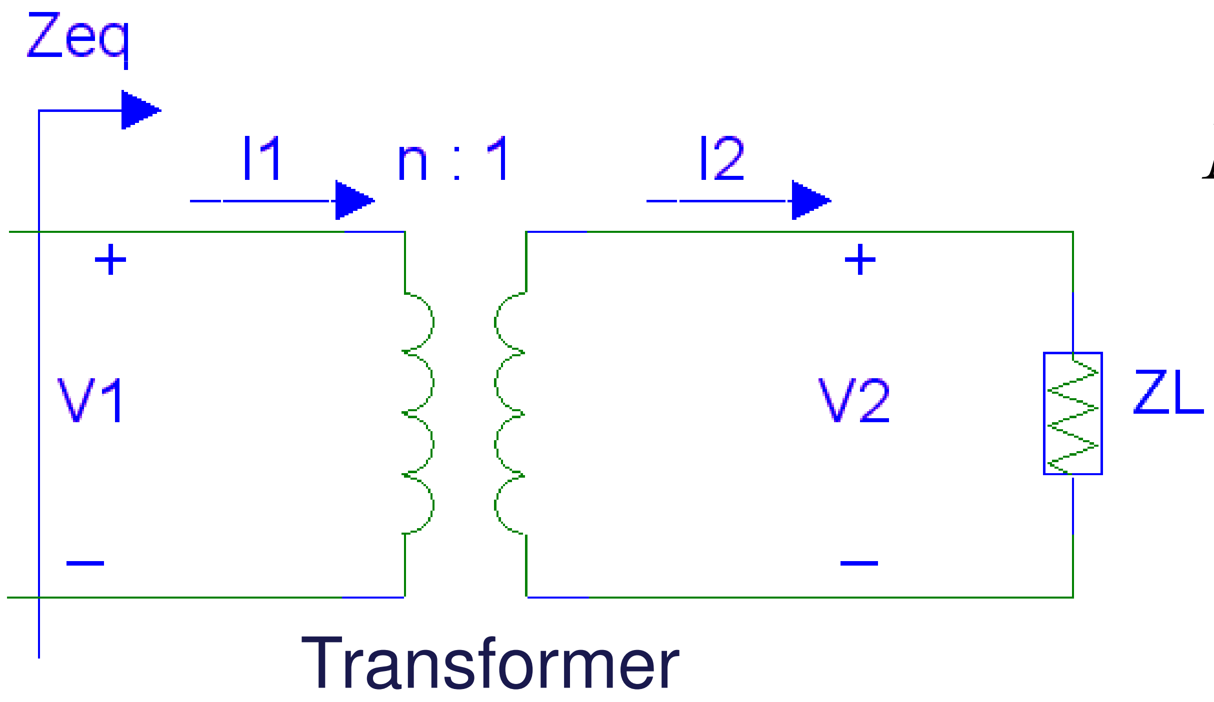
$$N_2 > N_1 \Rightarrow V_2 > V_1$$

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = n$$

$$\frac{I_2}{I_1} = \frac{N_1}{N_2} = \frac{1}{n}$$

$$P_2 = P_1$$

Impedance matching
(Example: Transformer down voltage)



$$N_2 < N_1 \Rightarrow V_2 < V_1$$

$$V_2 = \frac{V_1}{n}$$

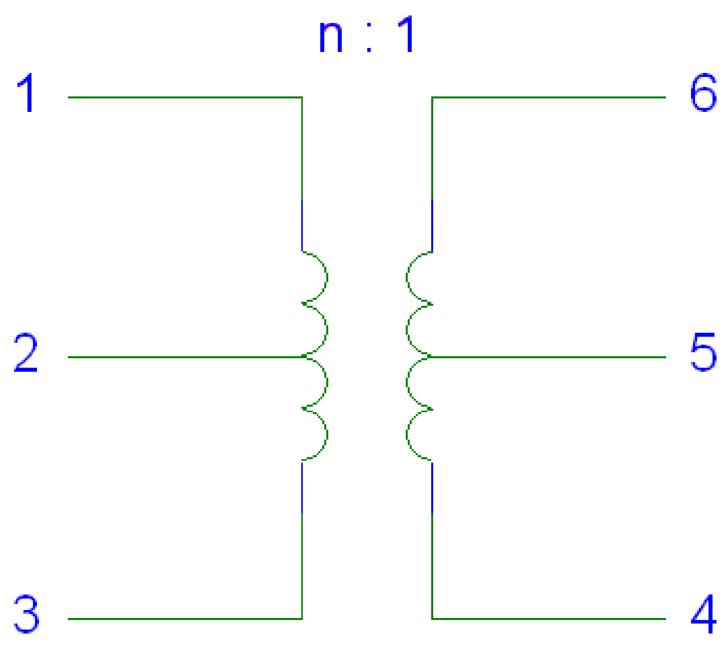
$$I_2 = n \cdot I_1$$

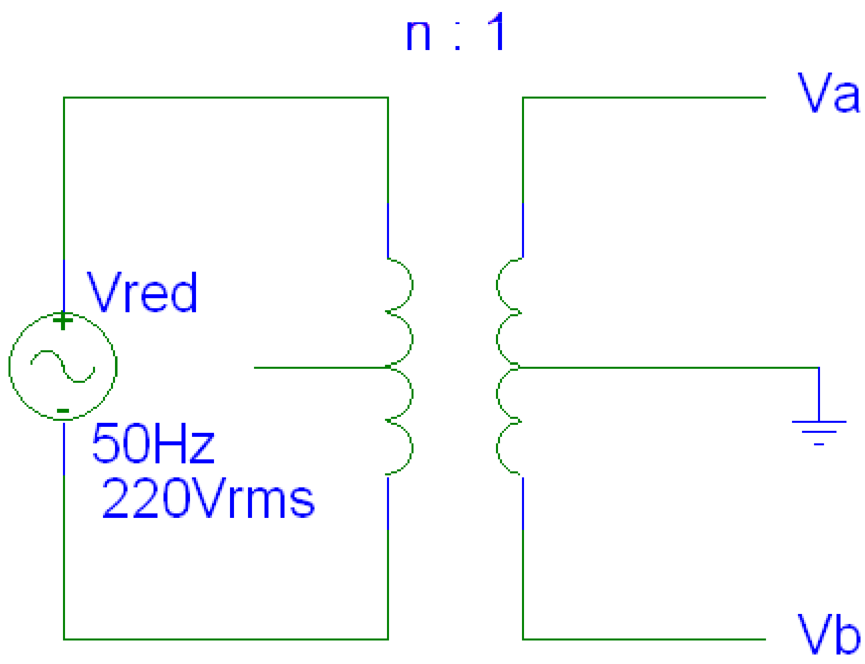
$$P_2 = P_1$$

Impedance matching

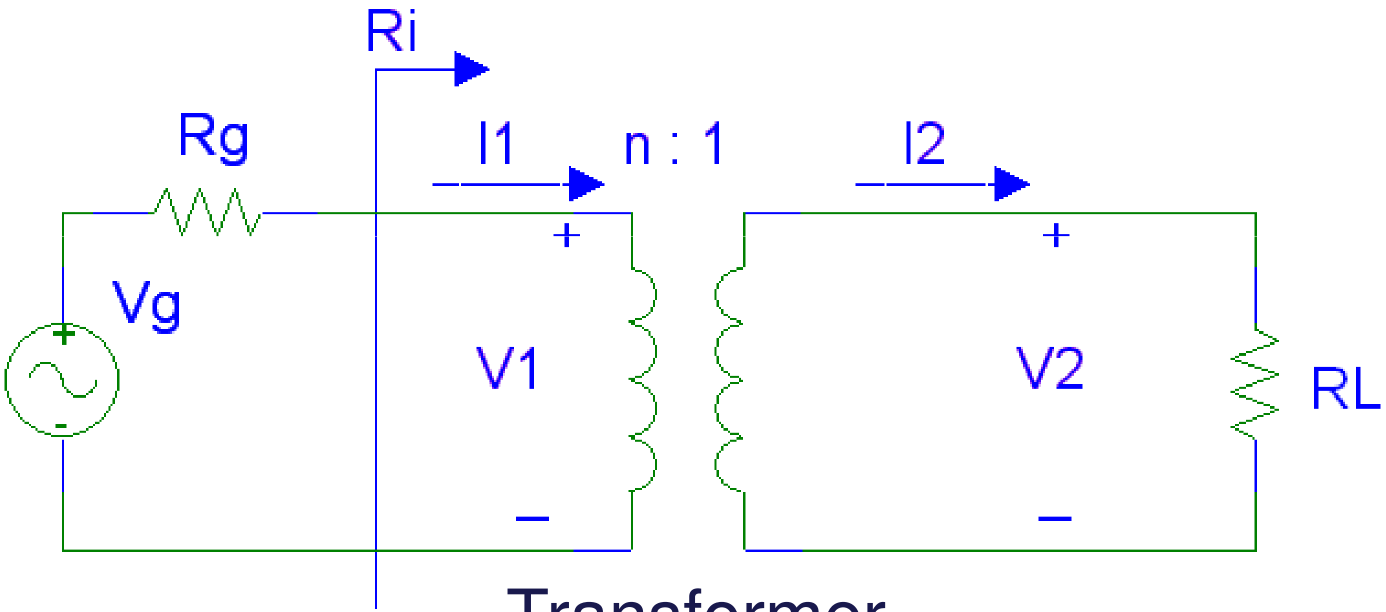
$$Z_{eq} = Z_L \cdot n^2$$

Intermediate tap transformer





Example



Transformer

Substitute values:

- Vg = 5 Vrms
- Rg = 1 KΩ
- RL = 10 Ω
- n = 10

1. Currents of primary and secondary (I_1 e I_2)
2. Voltages at the terminals of primary and secondary (V_1 y V_2)
3. Power supplied by the generator and power dissipated in the resistances Rg y RL.
4. Impedance value from the primary input Ri.