TRC3000 Automation Project

Electronics: Analog AC Circuits

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Alternating Current Supply

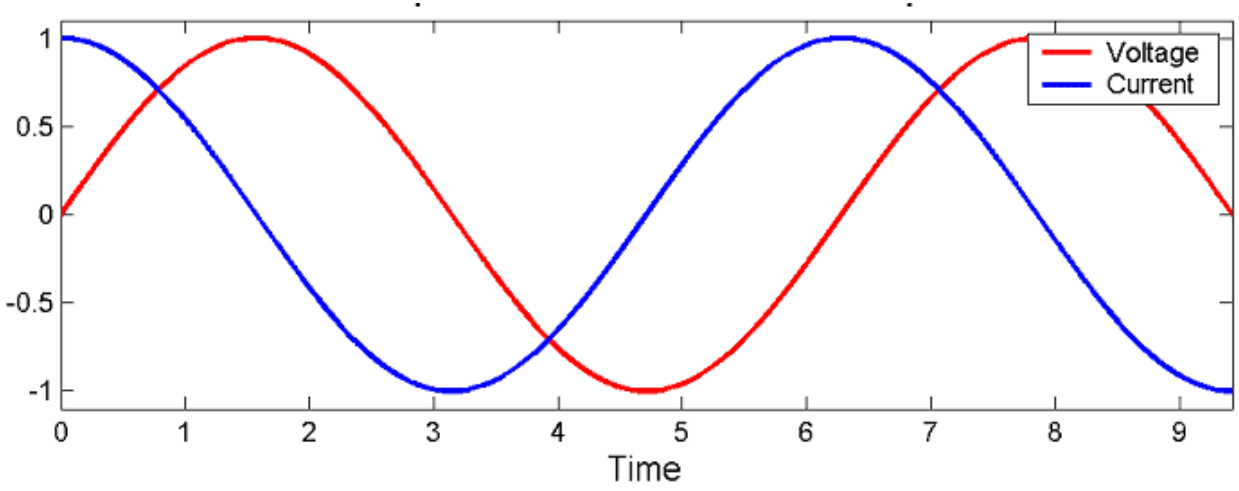
- The form of electrical energy that is typically used for consumer appliances.
- AC supply is
  - Used in applications where DC supply is unfeasible
  - Able to be generated using rotating machinery
  - Able to be used to drive rotating machinery

Alternating Current and Voltage

- When linear circuit excited by AC signal, current & voltage in every element are AC signals of the same frequency
- The voltage and current may be out of phase with each other

$$V(t) = V_m \sin(\omega t + \phi)$$

V_m – amplitude, ω – angular frequency, ϕ – phase angle



$$f = \frac{1}{T} = \frac{\omega}{2\pi}$$ f – frequency, T - period

$$\phi = \omega \Delta t$$ Δt – time shift

$$V(t) = V_{dc} + V_m \sin(\omega t + \phi)$$

V_{dc} – DC offset

Impedances in AC Circuits

$$V = ZI$$

Z – is called impedance (complex number)

Resistor $Z_R = R$

Inductor $Z_L = Lj\omega = \omega L\langle 90^o \rangle$

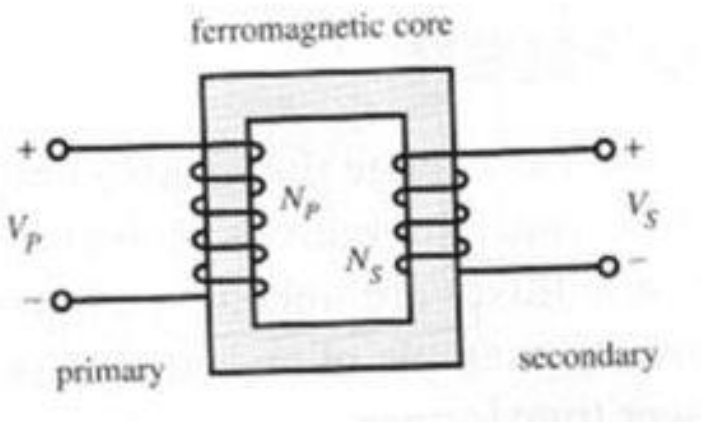
Capacitor $Z_C = \frac{-j}{\omega C} = \frac{1}{\omega C}\langle -90^o \rangle$

Transformer

- A transformer is a device that changes the amplitudes of voltage & current in an AC current
- It consists of primary & secondary windings whose magnetic fluxes are linked by a ferromagnetic core
- Step-up transformer ($N_s > N_p$)
- Step-down transformer ($N_s < N_p$)
- Isolation transformer ($N_s = N_p$)

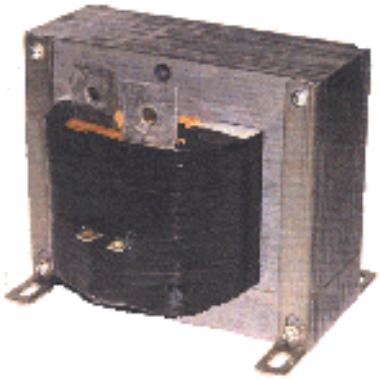
$$\frac{V_p}{N_p} = \frac{V_s}{N_s}$$

$$V_p I_p = V_s I_s$$



Industrial transformers

High voltage transformer in a power distribution station that steps down power to homes

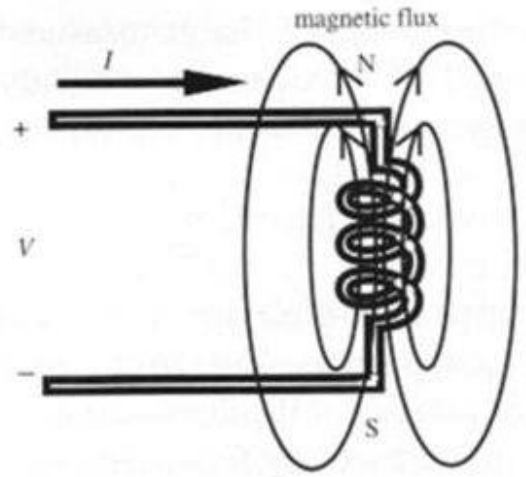


Low voltage transformer used in domestic appliances and equipment

Isolation Transformer

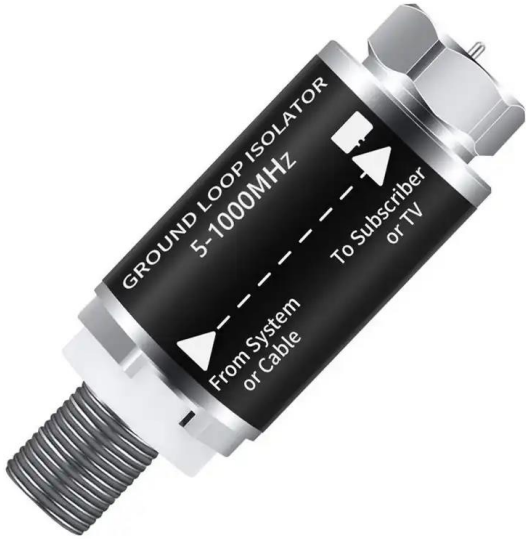
The operation of a transformer is similar to an inductor.

$$V(t) = L\frac{dI}{dt}$$



Isolating transformers block transmission of DC signals from one circuit to the other, but allow AC signals to pass. This is useful in eliminating ground loops.

Ground loop refers to current connecting two points that are supposed to be at the same potential, but are actually at different potentials. Ground loops can be detrimental to the intended operation of electrical systems.



Electrical Isolation

Case Study

The electrical isolation offered by transformers can help to protect circuits somewhat.

The processor circuit (left image) was destroyed while a USB charger was used.

Since transformers are typically heavy, the unscrupulous manufacturer of the USB charger placed a nut to feign presence of a transformer.

Power in Electrical Circuits

- All circuit elements dissipate, store, or deliver power through interaction of charge and electromagnetic fields
- Power is the rate of work done
- P is positive
  - Current flows in direction of increasing current
  - Element is generating or releasing energy
- P is negative
  - Current flows in the direction of decreasing current
  - Element is dissipating or storing energy

Shinkansen Japan

Melbourne tram

Instantaneous and Average Power

Instantaneous power

$$P = VI = I^2R = V^2 / R$$

Average power of AC signal with resistors

$$P_{avg} = V_{rms} I_{rms} = RI_{rms}^2 = V_{rms}^2 / R$$

Average power of AC signal with resistors, inductors, & capacitors

$$P_{avg} = I_{rms} V_{rms} \cos\theta = I_{rms}^2 |Z| \cos\theta = (V_{rms}^2 / |Z|) \cos\theta$$

$$V_{rms} = \frac{V}{\sqrt{2}}; I_{rms} = \frac{I}{\sqrt{2}}$$

Power factor – cos θ

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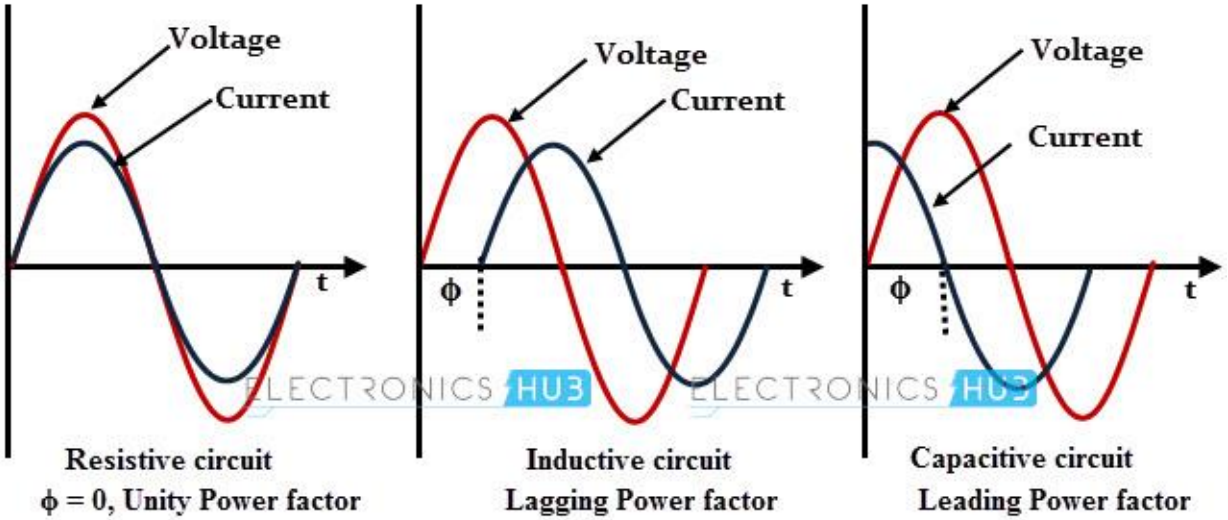
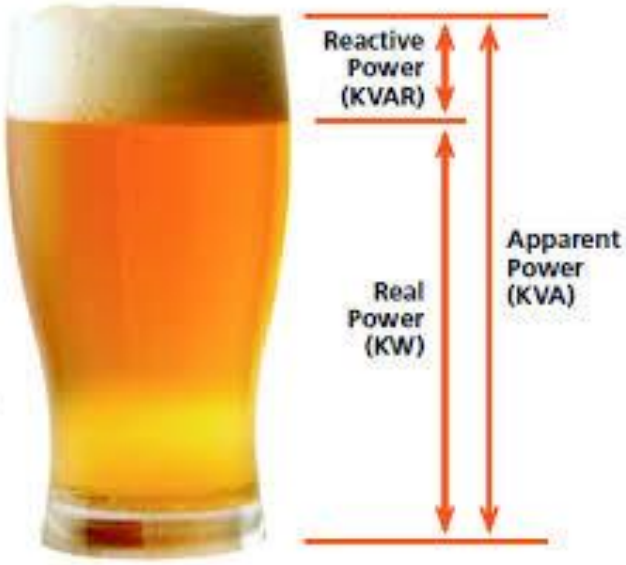
Power factor





Only real power (kW) used is chargeable. The reactive power (kVAR) does no work. The apparent power (kVA) is what is delivered.

In analogy to beer, the froth represents the reactive power.