The University of Texas at Arlington

Talking Points - 2
A.C. Power

CSE@UTA

CSE 3323 – Electronics for Computer Engineers

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A.C. for Power

CSE@UTA

- “The war of currents”, i.e., Tesla (A.C.) vs. Eddison (D.C.)
  - Who won? Why? (transformer) Was the victory forever?
- Transformers (The Hungarian "ZBD" Team (Károly Zipernowsky, Ottó Bláthy, Miksa Déri)) make A.C. power more efficient to transport as high voltages can be used in the long haul. (Assuming that there is a lot of resistive loss over these lines.)
- A.C. power is a sinusoidal voltage compared to a line that is assumed to be and kept to be (ground) on a zero potential.
- D.C. silent killer (chemically changing blood); A.C. violent killer (interferes with signals in our body – e.g., our heart); it can also burn

A.C. power

- U(t)=A*sin(ωt) , where $\omega=2\pi f$ so we can use radians in the sine
- A is the peak value or amplitude
- What is peak-to-peak?
- What is the frequency?
  - Common: 50Hz (EU), 60Hz (USA)
  - Relationship to moving images; clocks
- But then how much energy does it provide?
  - Energy is proportional to the square of the voltage
  - Effective value (root mean square – RMS)
  - $A/\sqrt{2}$
  - Thus for 120V (USA) A~=170V ; V_{pp}~=340V
  - For 230V (EU) A~=325V Vpp~=650V
  - Does this depend on the frequency?
  - Which frequency is better?

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A.C. Power

- Why is higher voltage better?
  - For same power less current needs to flow
  - Thus wire diameters can be less
  - Insulation has to be better
- Single phase circuits
- Power delivery is generally different in the US and EU. US has more small transformers dedicated to small neighborhoods, sometimes houses.

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Transformers

- Two inductors coupled by a magnetic field (same core)
- Only for A.C. as induction requires change
  - Transformers on D.C. will burn as their resistance is usually low. No D.C. on transformers!!
- The relationship of the number of windings on the supply (primary) side and the secondary side determine the conversion rate.
- There are losses in a real transformer.

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Ideal Transformer

- symbol
- An ideal transformer has zero resistance on both primary and secondary side.
  - This does not mean short circuit as the impedance is not zero!
  - $V_p/V_s=N_p/N_s=a$ (identity) and since power must remain the same, $V_p*I_p=V_s*I_s$ and thus $V_p/V_s=I_s/I_p$.
  - What does this mean (not loading transformer)?
  - The load on the secondary side transforms with the square of the identity to the primary side.
  - (works with V_{eff},V_p,V_{pp})

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Real transformer

- Full of losses
  - Size matters! (How much power it can handle)
- Some due to the actual resistance of the copper windings (copper loss)
- Internal resistances mean that they do not load nicely.
- Some due to the loss in the magnetic transformation (iron loss)
- Higher frequencies can help – smaller transformers possible
- http://en.wikipedia.org/wiki/Transformer

Resistive Loads

- Everything we learned with D.C. applies to A.C. as the current is in phase with the voltage on resistive loads.
  - $V=V_p*\sin(wt+\phi)$ $I=I_p*\sin(wt+\phi)$ and ϕ is the same.
  - Thus we can just calculate with the effective values.
- However, not all loads are resistive (most loads are not)

Out of Phase

- The voltage can become out of phase with the current due to “delays” (actually, due to energy stored in the system).
- Thus we need to talk about instantaneous voltage and current and their product the instantaneous power.
- In general:
  - the current can be delayed compared to the voltage – inductive load
  - the voltage can be delayed compared to the current – capacitive load.

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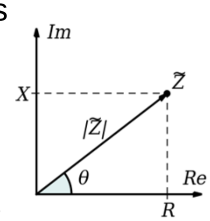
Electrical Impedance

- Electrical impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied.
- When the voltage changes (e.g., A.C.) components can store energy in an electric (capacitive) or magnetic (inductive) field. Thus the opposition changes with the voltage…
- Symbol is Z. It can be represented by a magnitude and a phase shift.
  - In complex algebra a single complex number
    - Magnitude is the voltage amplitude/current amplitude
    - Phase is the phase shift



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Capacitors - basics

- Two conducting areas divided by an insulating dielectric.
  - the capacitance (measured in Farad) is determined by the areas and their closeness
  - Dielectric should be strong (no spark ionization – kills capacitor)
- Capacitors store energy in this electric field.
  - **They want to maintain potential.** They are charged by current.
  - Kind of work like weak rechargeable batteries.
  - Can be used to buffer potential for short times.
- Common capacitor values.
- Optimal resistance is infinite.
- Impedance (resistance against A.C.) depends on frequency. The higher the frequency the less the impedance. The higher the capacity, the less the impedance. ($Z=1/(j\omega C)$) (only imaginary component!)

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Capacitor types

- Many different materials.
- http://en.wikipedia.org/wiki/Types_of_capacitor
- Polarized capacitors are usually smaller (compared to their values)
  - They are polarized! (may explode)
  - Used to buffer – get close to D.C.
  - Noisy
  - Not really for signals
- Non-polarized capacitors:
  - Mostly for signals (for filtering)

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Use of capacitors

- Primary use for us: to create stabile D.C. out of A.C.
  - A.C. is not good for powering digital (or even analog) circuits.
  - A.C. is for delivery; D.C. is for powering
- Secondary use: to filter analog signals
  - Remove frequency components (later)
  - Border case of this is removing all high frequencies -> letting only D.C. through (see above)
  - Removing D.C. – letting only A.C. through

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Inductors- basics

- Wound wire (usually copper) usually around a core ("iron")
  - Measured in Henry
- Store energy in a magnetic field.
  - **Want to maintain current.** (resist current changes)
- Optimal resistance is zero.
- Impedance depends on frequency. The higher the frequency the more the impedance. The higher the inductivity, the more the impedance. (Z=jwL)) (only imaginary component!)

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Use of Inductors

- Not much (for us). They are large and hard to design.
- Shunting against spikes (against A.C.)
- Rarely for filtering.
- Sometimes for LC band-pass and thus for oscillators.

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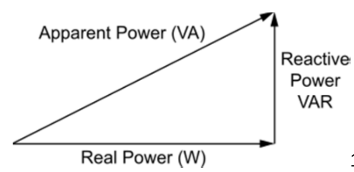
Power

- Peak-to-peak voltage, current? No
- Effective voltage, current? No
  - Well, yes. This is the “apparent power” but it is not measured in W but in VA
- Effective voltage and current and the cos of the phase
  - Measured in W (real power)
- Reactive power comes from energy storage (L,C)
- You would not want to pay based on VA!
- Energy meters have to multiply instantaneous (as phase changes…)
- Audio speakers?
  - (http://en.wikipedia.org/wiki/Audio_power)



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Two Phase (US)

- Really single phase
- Most U.S., households receive this.
- The two phases are 180 degrees to each other
  - From each other’s perspective they “double” the voltage.

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Three phase (EU)

- Three phase means an equal phase distribution – 120 degrees between phases.
  - (two phase in EU is 120 degrees apart – not double!)
- Used to [power industrial and high power loads.

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