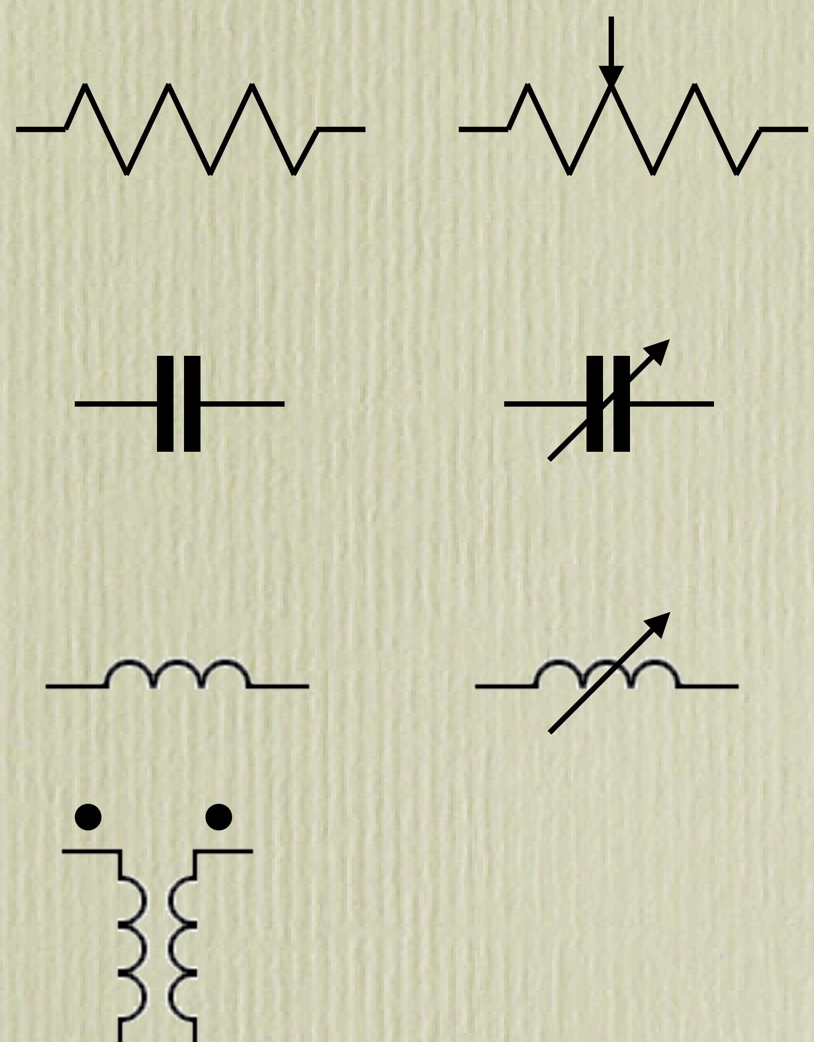
Basic Passive Components

<u>Fixed</u> <u>Variable</u>



- Resistor (Ohms) R
- Capacitor (Farads) C
- Inductor (Henries) L
- Transformer T

Things to know!

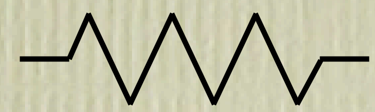
- Voltage is designated by V (Volts) (or sometimes E)
- Current is designated by I (Amps)
- Power is designated by P (Watts)

- Your powers of 10: Pico, nano, micro, milli, kilo, mega, giga
- High school algebra for series and parallel circuits
- Very basic knowledge of complex numbers for X_C and X_L

Powers of Ten - Steps of 1000

Giga (G)	10^9	1,000,000,000
Mega (M)	10^6	1,000,000
kilo (k)	10^3	1,000
	10^0	1
milli (m)	10^-3	0.001
micro (μ)	10^-6	0.0000001
nano (n)	10^-9	0.000000001
pico (p)	10^-12	0.000000000001

Resistor

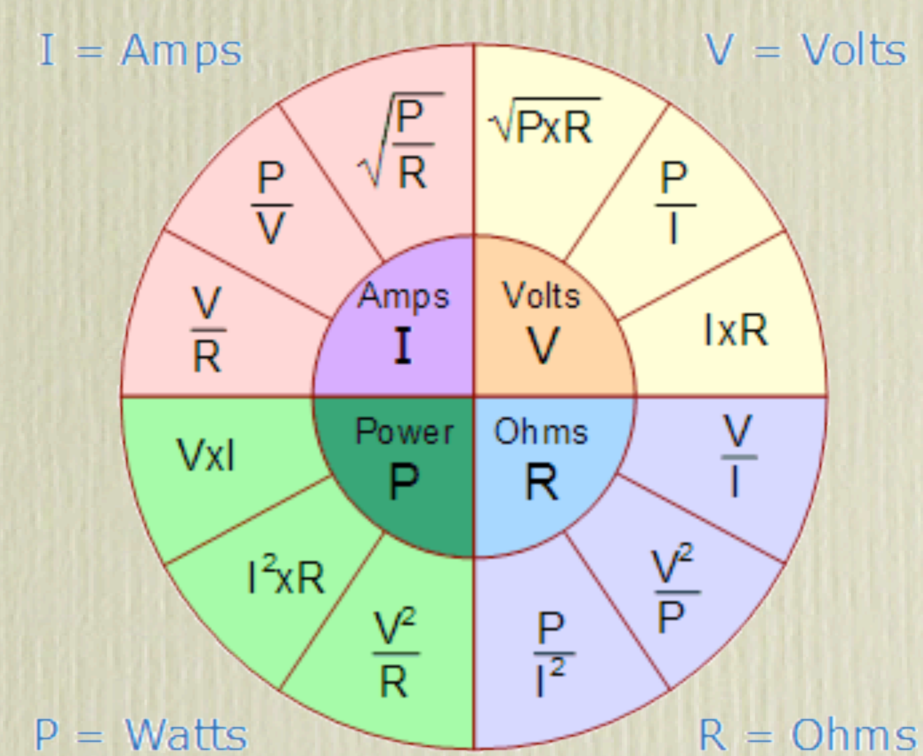


Characteristics:

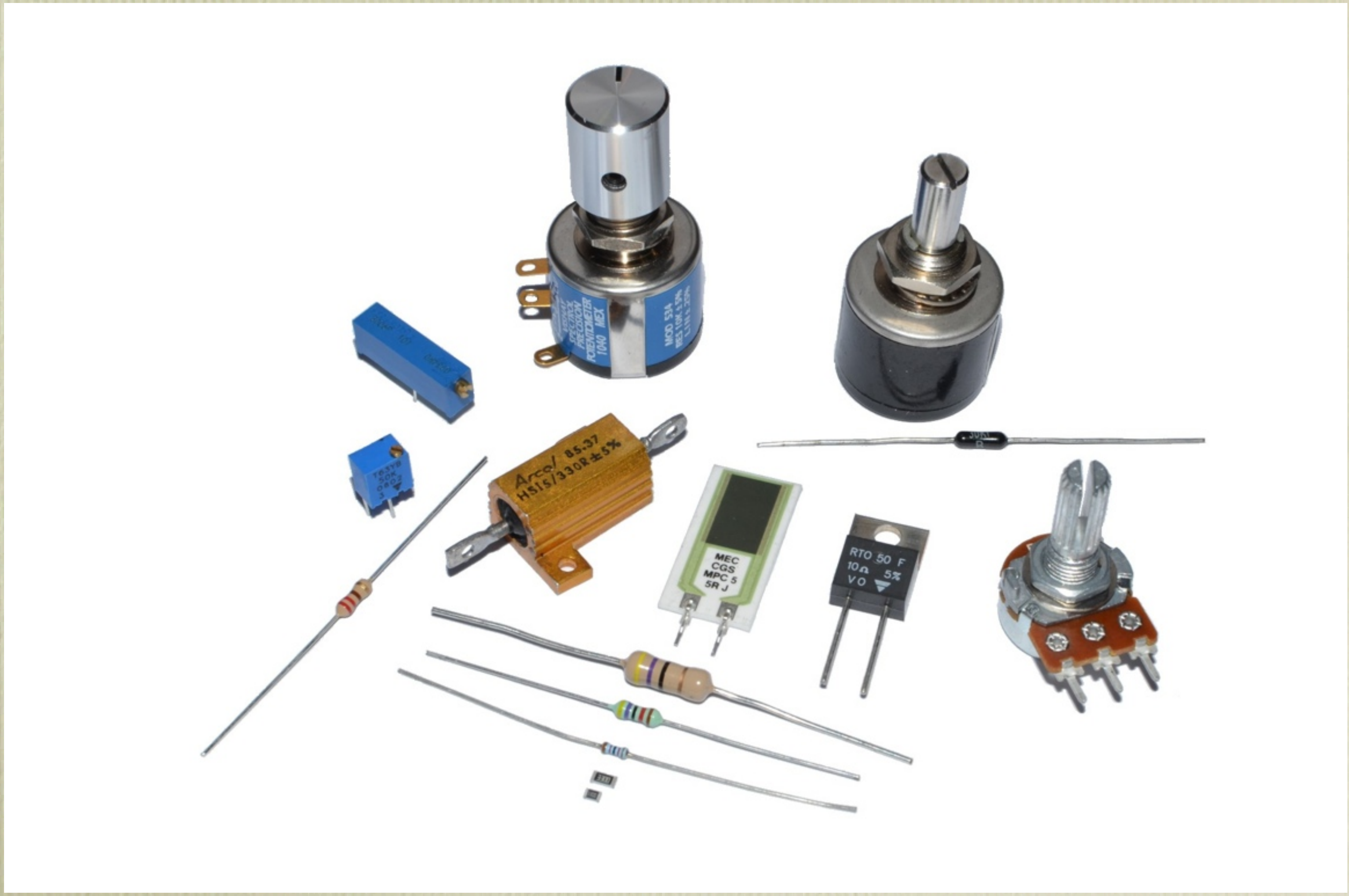
- Resists the flow of current
  In theory, equal resistance to AC or DC (No reactance)
- Doesn't store energy
  Power is dissipated as heat
- Voltage and current are in phase
- Non-polarized
- Metal Film, Wirewound, Carbon
- Variable: Rheostat (2 pins), Potentiometer (3 pins)
- Large range of values – mΩ to GΩ
- Large range of power – mW to KW

Formulas:

- V = I * R (Ohm's Law)
  Voltage = Current * Resistance
- P = V * I or P = I^2 * R
  Power = Voltage * Current



Resistor



Test Questions

T5D06: What is the resistance of a circuit that draws 4 amperes from a 12-volt source?

A) 3 ohms

B) 16 ohms

C) 48 ohms

D) 8 Ohms

- R = V / I --> R = 12 / 4 = 3 Ohms (A)

T5D07: What is the current flow in a circuit with an applied voltage of 120 volts and a resistance of 80 ohms?

A) 9600 amperes

B) 200 amperes

C) 0.667 amperes

D) 1.5 amperes

- I = V / R --> I = 120 / 80 = 1.5 Amperes (D)

T5D10: What is the voltage across a 2-ohm resistor if a current of 0.5 amperes flows through it?

A) 1.0 volt

B) 0.25 volts

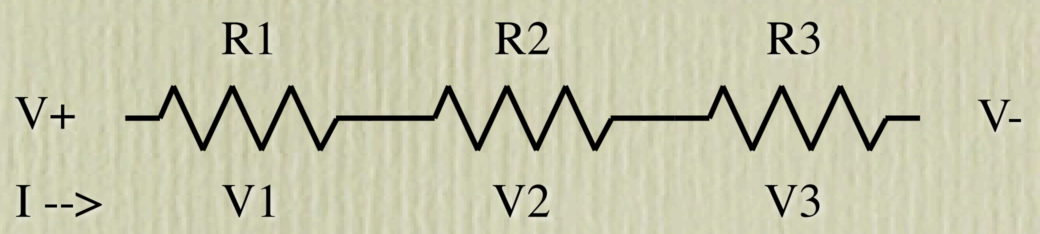
C) 2.5 volts

D) 1.5 volts

- V = I * R --> V = 0.5 * 2 = 1.0 Volt (A)

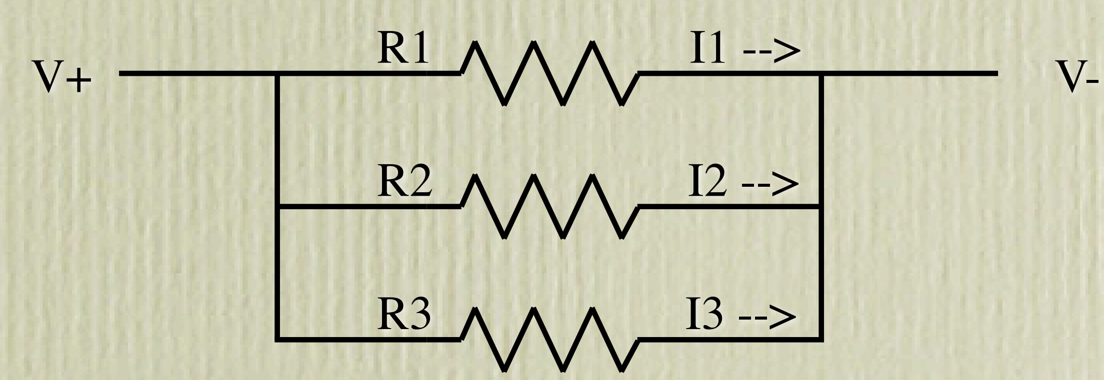
Series / Parallel Resistors

Series:



- Rt = R1 + R2 + …
- Always LARGER than the largest value
- Current is the same through all resistors
- Voltage across each resistor is dependent on the individual resistor values

Parallel:



- Rt = 1 / (1/R1 + 1/R2 + …)
- Always SMALLER than the smallest value
- For two resistors, Rt = (R1 * R2) / (R1 + R2)
- Voltage is the same across all resistors
- Current through each resistor is dependent on the individual resistor values

Test Questions

G5C05: If three equal value resistors in series produce 450 ohms, what is the value of each resistor?

~~A) 1500 ohms~~

B) 90 ohms

C) 150 ohms

D) 175 ohms

- R = Rt/3 = 450 / 3 = 150 Ohms (C)

G5C15: What is the total resistance of a 10 ohm, a 20 ohm, and a 50 ohm resistor connected in parallel?

A) 5.9 ohms

B) 0.17 ohms

~~C) 10000 ohms~~

~~D) 80 ohms~~

- Rt1 = (R1*R2) / (R1+R2) --> Rt1 = (10*20) / (10+20) = 200 / 30 = 6.667 Ohms
  Rt = (Rt1*R3) / (Rt1+R3) = (6.667*50) / (6.667+50) = 333.333 / 56.667 = 5.88 Ohms (A)

  \- OR -

- Rt = 1 / (1/R1 + 1/R2 + 1/R3) = 1 / (0.1 + 0.05 + 0.02) = 1 / 0.17 = 5.88 Ohms (A)

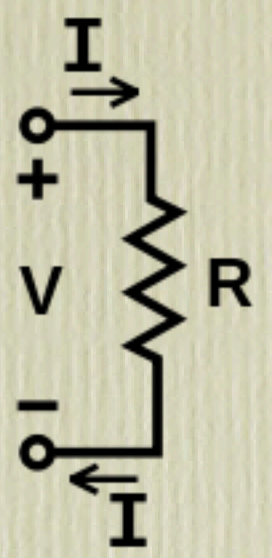
  \- OR - Use currents, Assume 50V to make the math easy

- [I(50Ω) = 1A] + [I(20Ω) = 2.5A] + [I(10Ω) = 5A] --> It = 8.5A
  Rt = V/I = 50 / 8.5 = 5.88 Ohms (A)

Uses

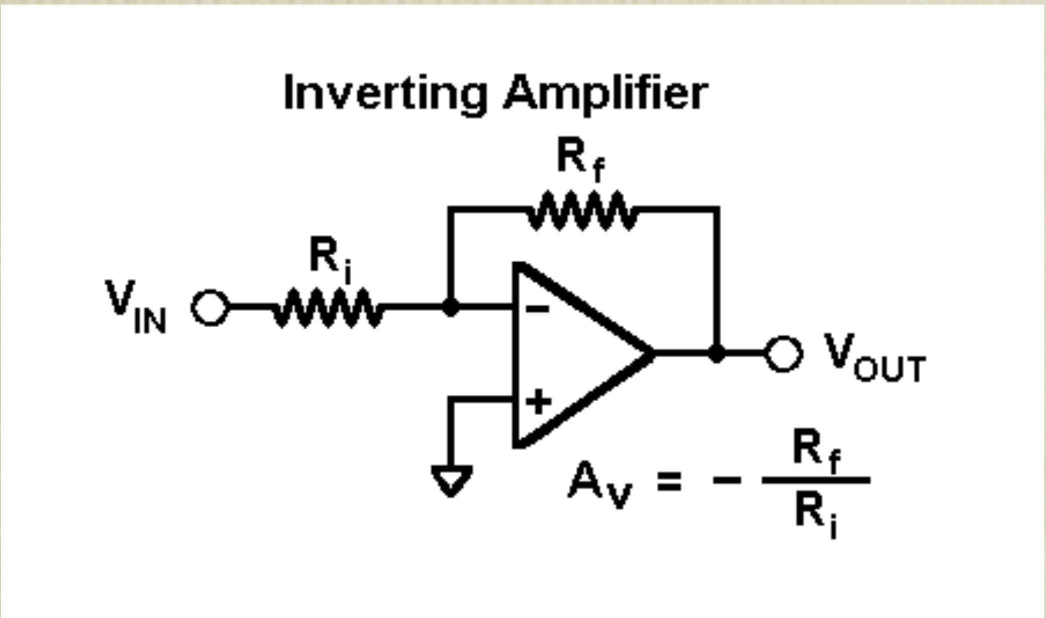
- Convert Current to Voltage

  V = I * R



- Gain Setting

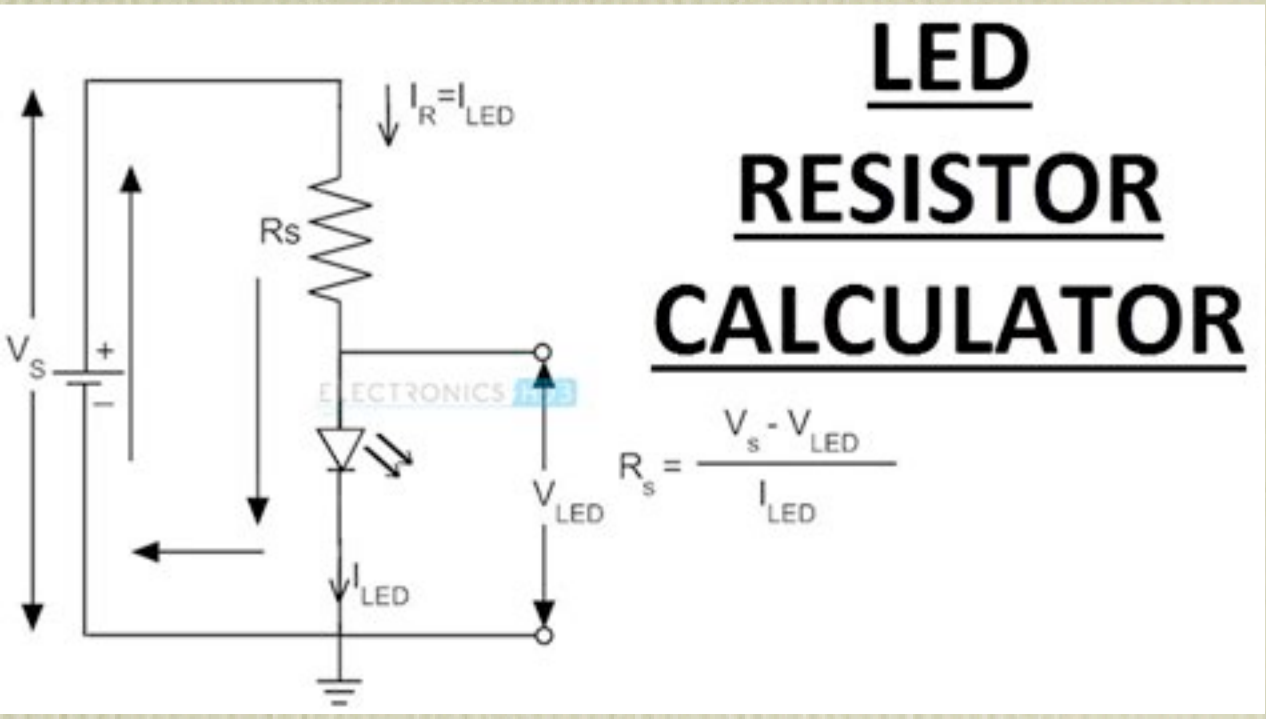
  Ratio of resistance values determines amplifier gain



Uses

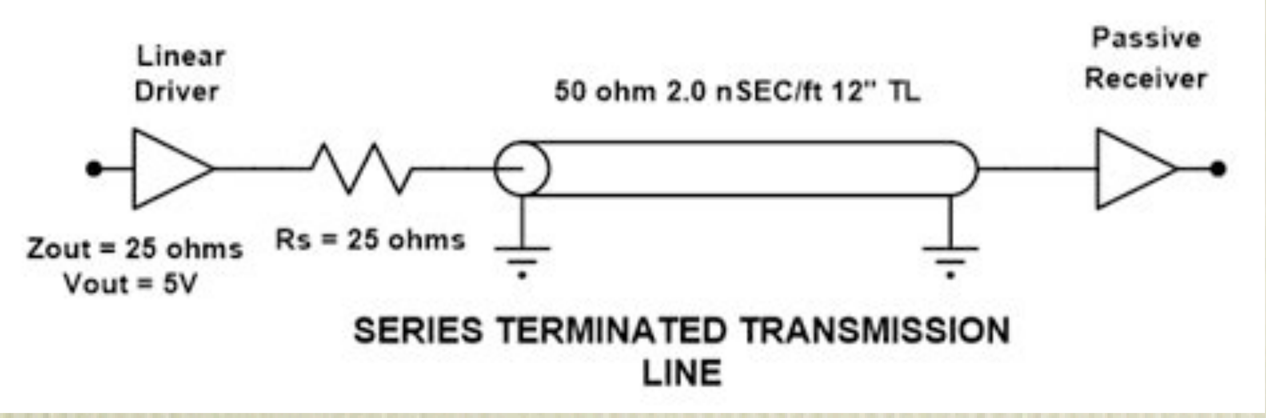
- Limit circuit current

  Drop excess voltage to prevent LED burn out

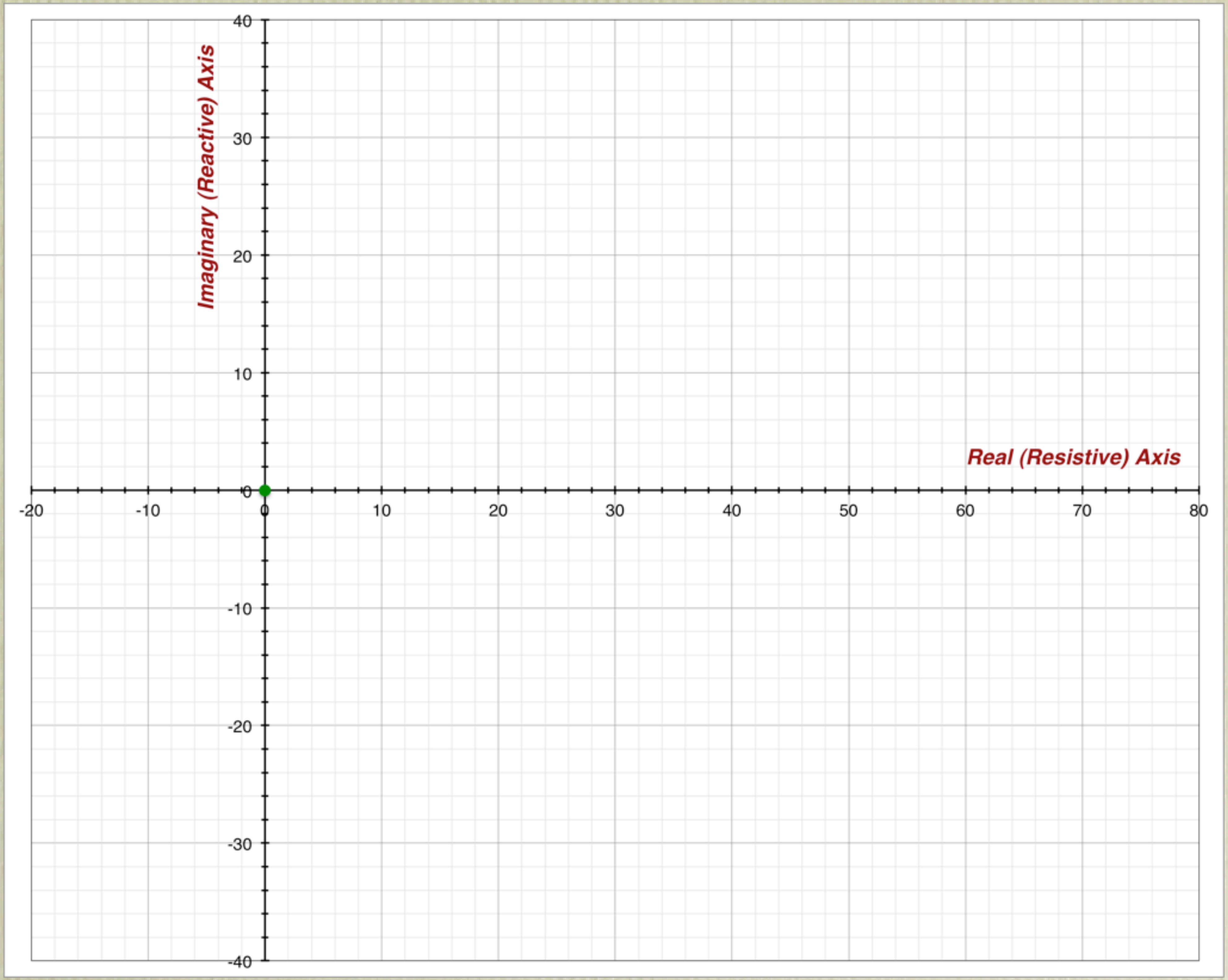


- Match impedance

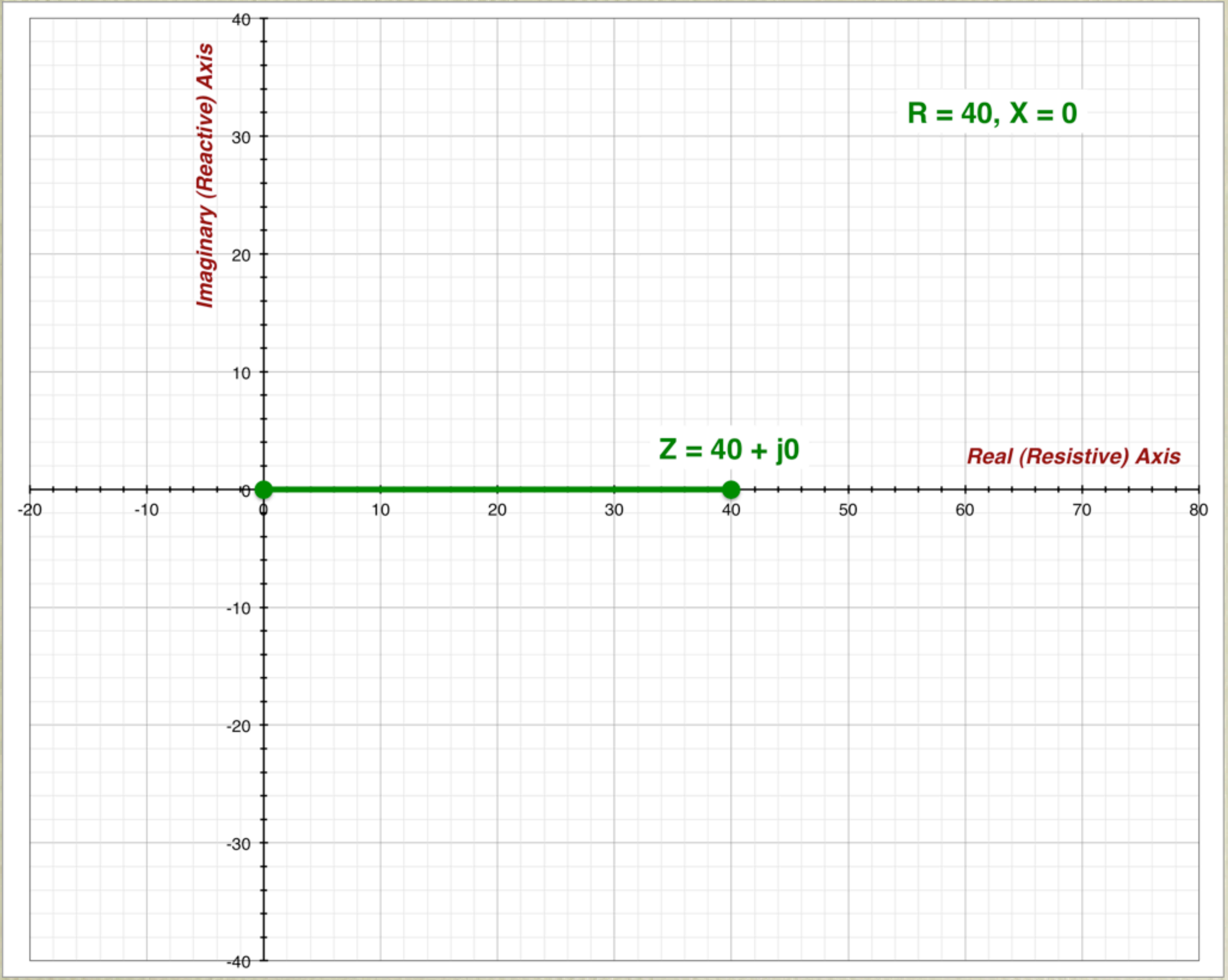
  Very inefficient at high power, but used a lot on high speed PCB traces



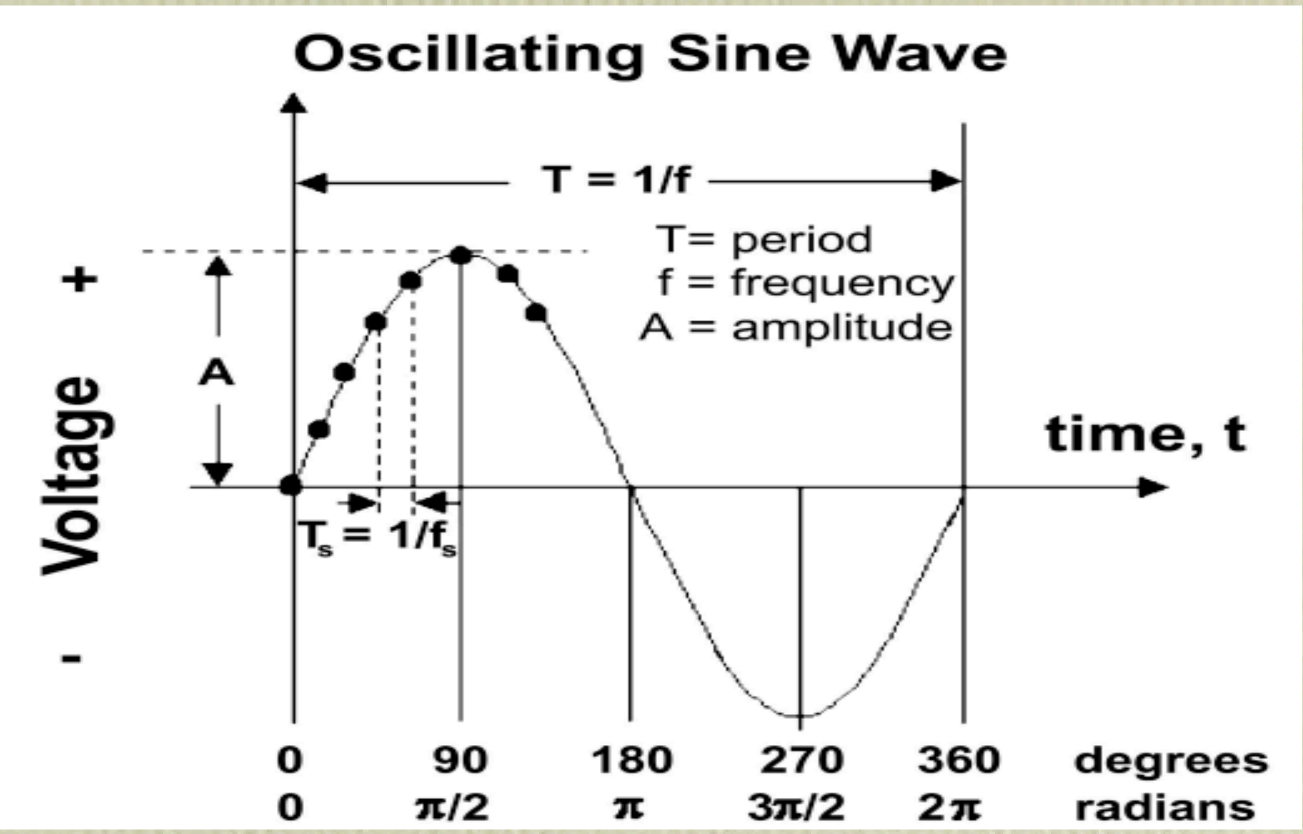
Impedance Plots

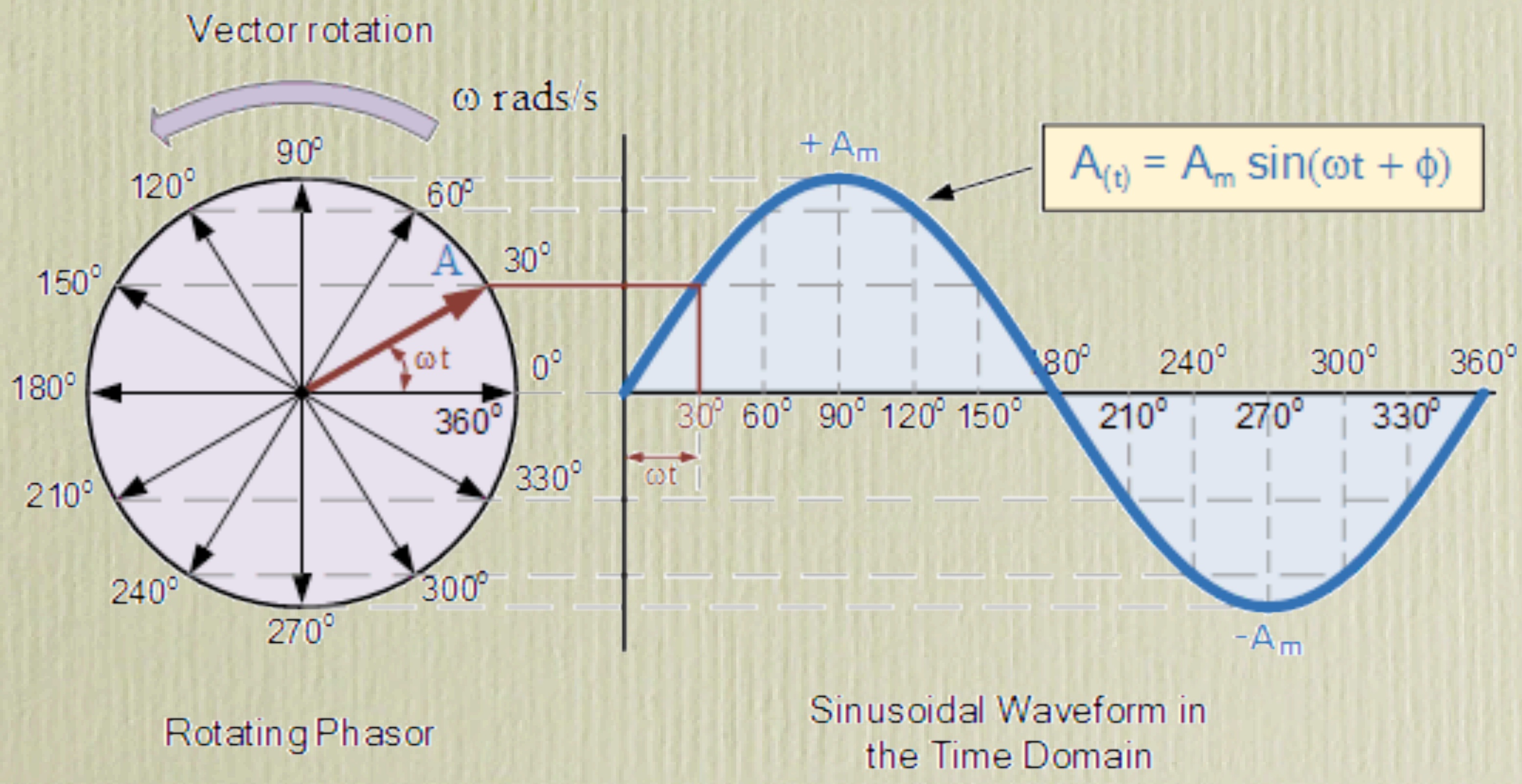


Impedance Plot



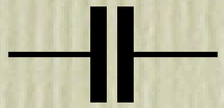
Sine waves and phase angles





Capacitor

Characteristics:



- Resists a CHANGE in voltage
- Stores energy in an electric field
  Ideally any input energy is returned to the source
- Non-polarized: Air, Ceramic, Film, Mica
- Polarized: Electrolytic (Aluminum, Tantalum)
- Variable: Generally air (2 pins)
- Usually from pF to μF
- Passes AC, Blocks DC
- Current through the capacitor leads the voltage by 90° -- ELI the ICE man
- Capacitive reactance has a negative phase angle (-jX)

Formulas:

- $X_C = 1 / (2\pi fC)$; Reactance decreases with increase in frequency or capacitance
- $I = C\ dv/dt$
  Current = Capacitance * Change in voltage with respect to time

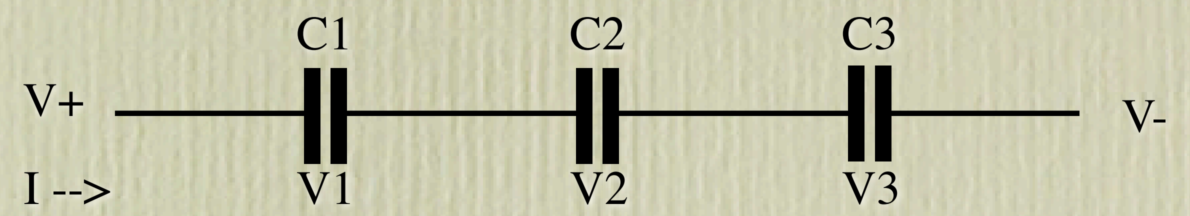
Capacitor


nichicon
4700μF 35V
CAPACITOR
189-505-5
193-10 8216
103K
500V
224K
100V
151


SPRAGUE
POWERLYTIC
50VDC
+95°C
U.S.A.
MADE IN
400V
560μF

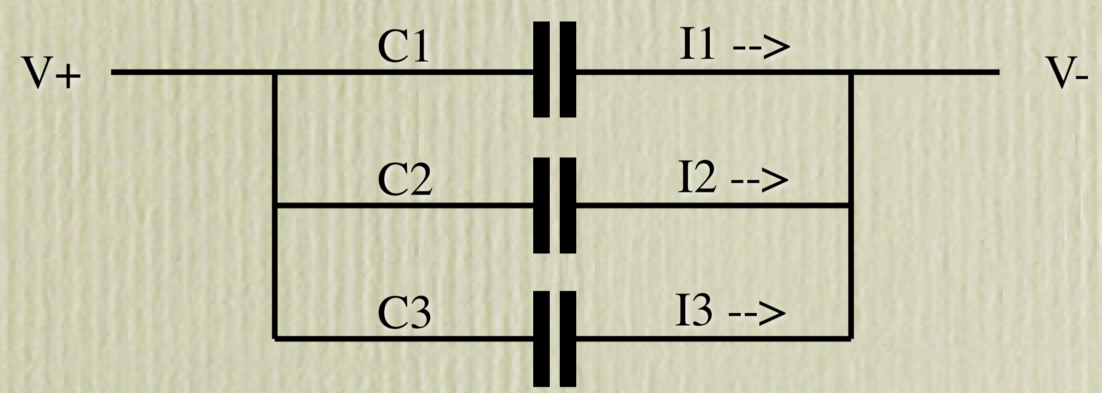
Series / Parallel Capacitors

Series:



- Ct = 1 / (1/C1 + 1/C2 + …)
- For two capacitors, Ct = (C1 * C2) / (C1 + C2)
- Always SMALLER than the smallest value
- AC Current is the same through all capacitors
- Voltage across each capacitor is dependent on the individual capacitor values

Parallel:

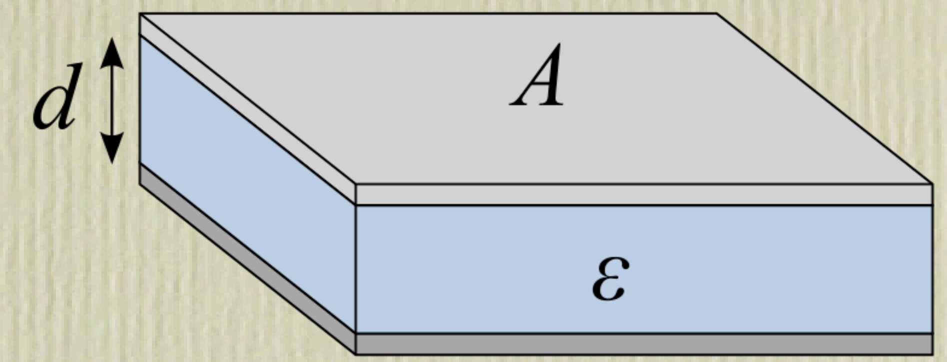


- Ct = C1 + C2 + ...
- Always LARGER than the largest value
- Voltage is the same across all capacitors
- AC Current through each capacitor is dependent on the individual capacitor values

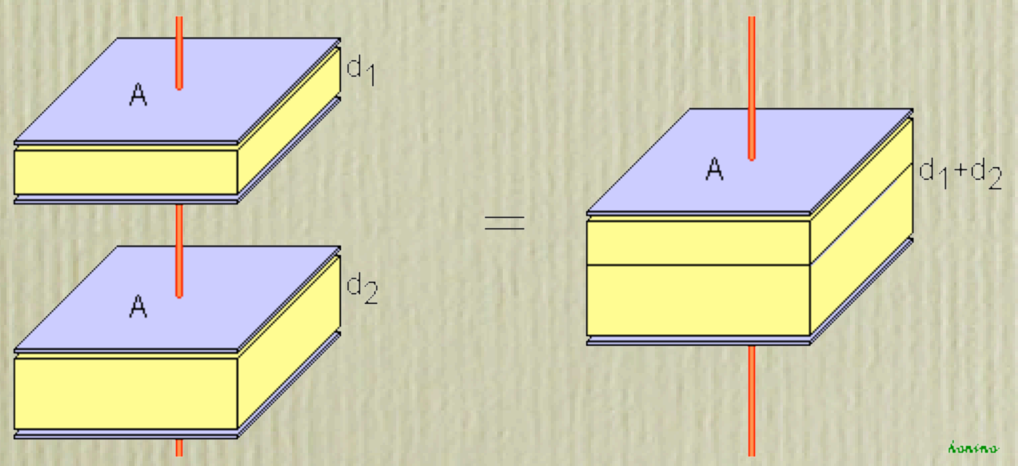
Capacitor construction

Capacitance: C ∝ εA/d

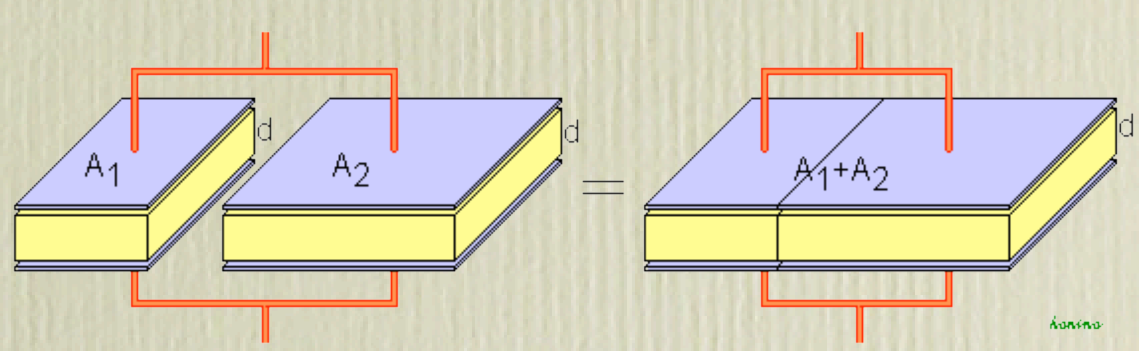
ε: Permittivity (Dielectric constant)
A: Area of the electrodes
d: Distance between the electrodes



Series



Parallel



Test Questions

G5C09: What is the capacitance of three 100 μF capacitors connected in series?

A) 0.30 μF

B) 0.33 μF

C) 33.3 μF

~~D) 300 μF~~

- C = Ct/3 = 100μF / 3 = 33.3μF (C)

G5C08: What is the equivalent capacitance of two 5.0 nF capacitors and one 750 pF capacitor connected in parallel?

A) 576.9 nF

~~B) 1733 pF~~

~~C) 3583 pF~~

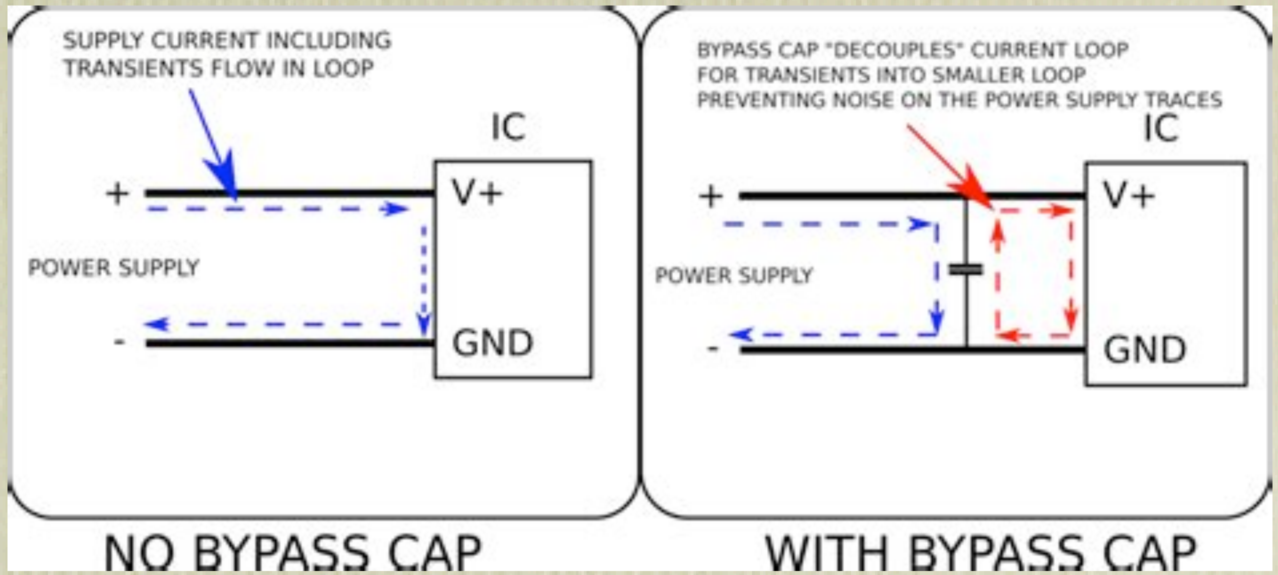
D) 10.750 nF

- Ct = C1 + C2 + C3 = 5.0 + 5.0 + 0.75 = 10.75nF (D)

Uses

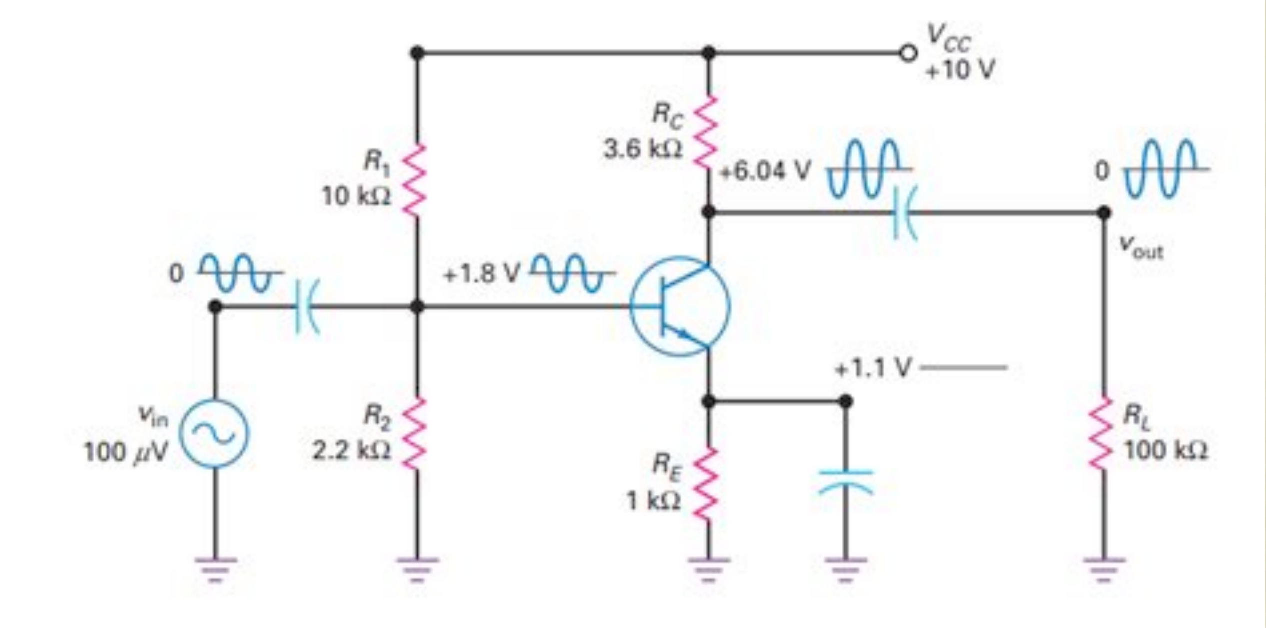
- Decoupling / Bypass

  Keep high frequency noise from affecting power supply lines



- Coupling

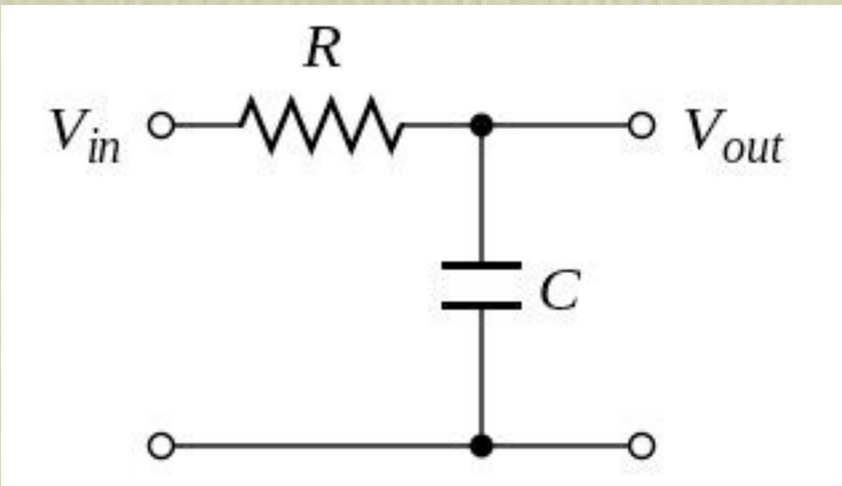
  Pass AC signals between circuits with different DC voltages



Uses

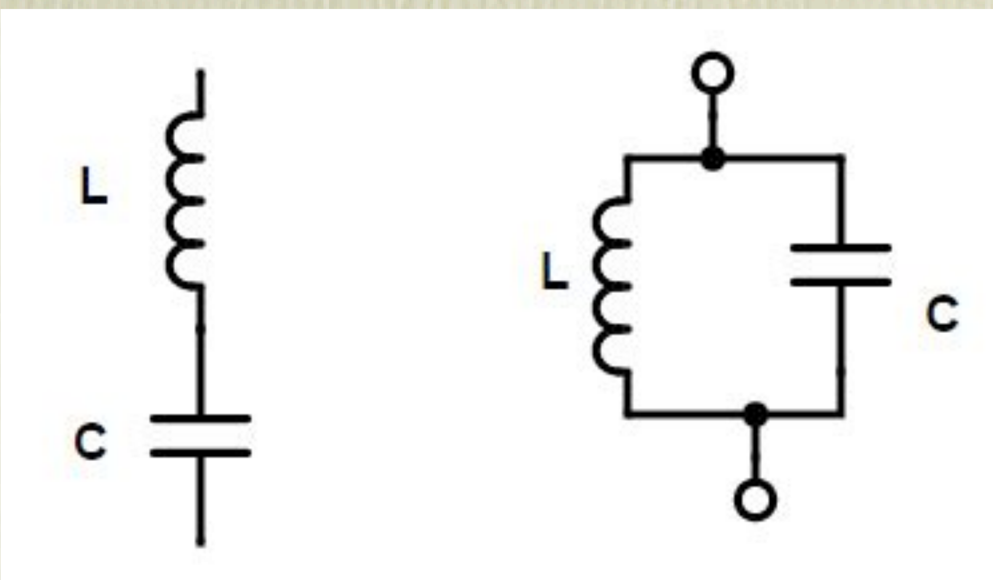
- Filtering

  Simple (first order) low pass and high pass RC filters

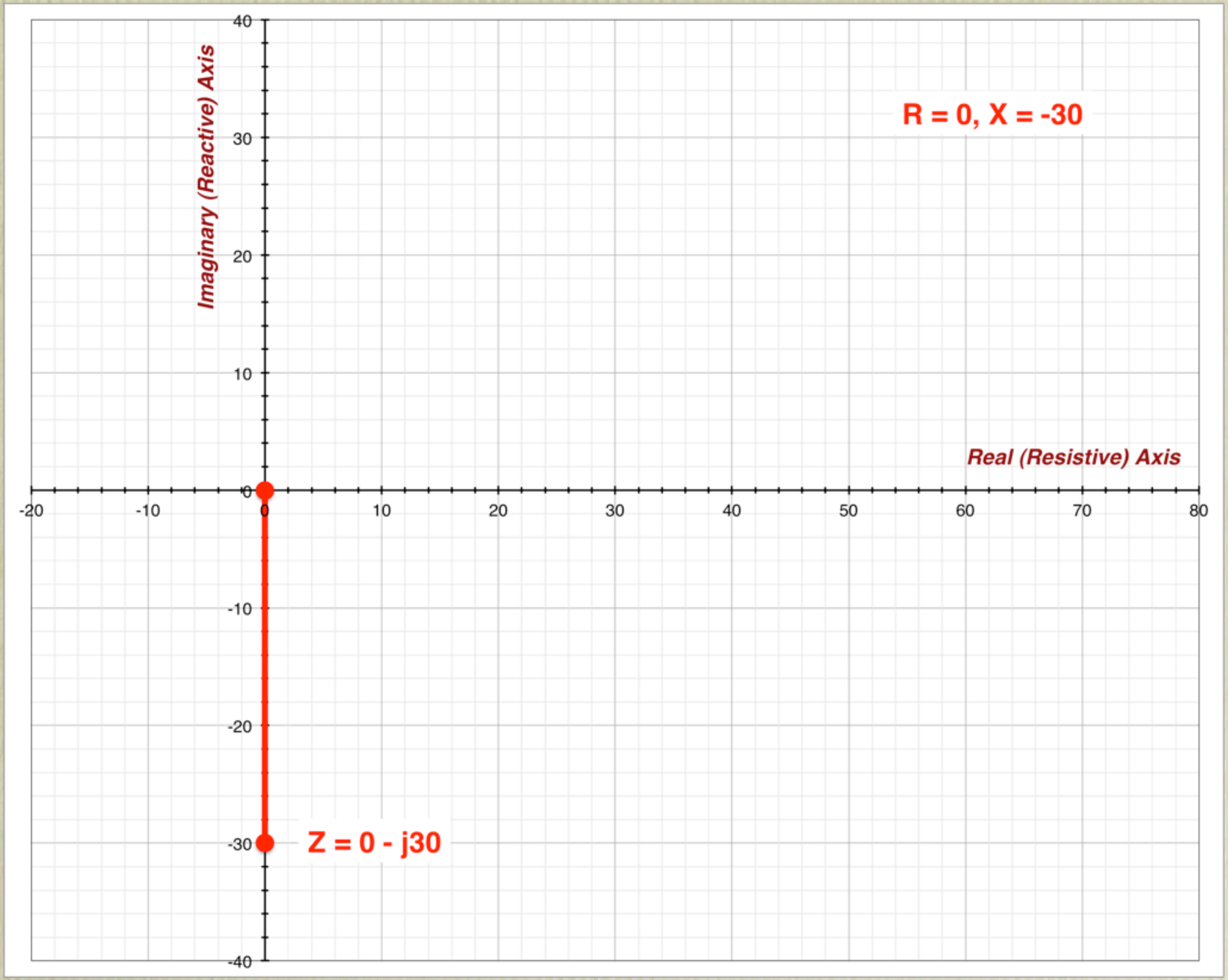


- Tuned Circuits

  Frequency selectivity when used with an inductor



Impedance Plot



Inductor

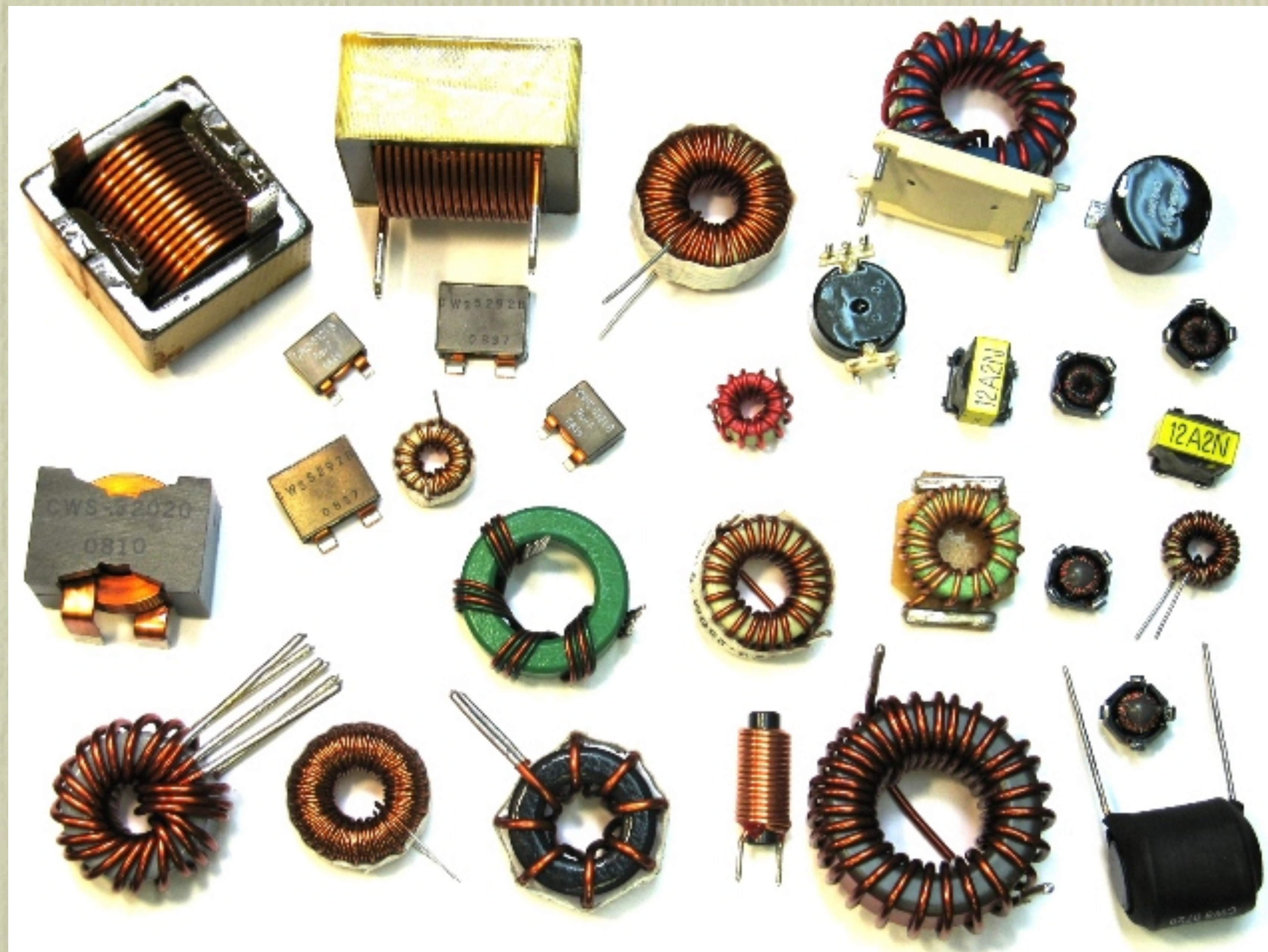
Characteristics:

- Resists a CHANGE in current
- Stores energy in a magnetic field
  Ideally any input energy is returned to the source
- Non-polarized
- Cores: Air, Iron, Ferrite (Permeability μ)
- Variable: Tapped (Roller inductor), Moveable core
- Usually from nH to H
- Passes DC, Impedes AC
- Voltage across the inductor leads the current by 90° -- ELI the ICE man
- Inductive reactance has a positive phase angle (+jX)

Formulas:

- $X_L = 2\pi fL$; Reactance increases with an increase in frequency or inductance
- $L = N^2 * AL$; Inductance depends on number of turns and Inductance Index
- $V = L\ di/dt$
  Voltage = Inductance * Change in current with respect to time

Inductor



Test Questions

E5D09: What happens to reactive power in an AC circuit that has both ideal inductors and ideal capacitors?

A) It is dissipated as heat in the circuit

B) It is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated

C) It is dissipated as kinetic energy in the circuit

D) It is dissipated in the formation of inductive and capacitive fields

Test Questions

E6D05: What is one reason for using ferrite cores rather than powdered iron in an inductor? **(C)**

A) Ferrite toroids generally have lower initial permeability
B) Ferrite toroids generally have better temperature stability
C) Ferrite toroids generally require fewer turns to produce a given inductance value
D) Ferrite toroids are easier to use with surface mount technology

E6D06: What core material property determines the inductance of an inductor? **(D)**

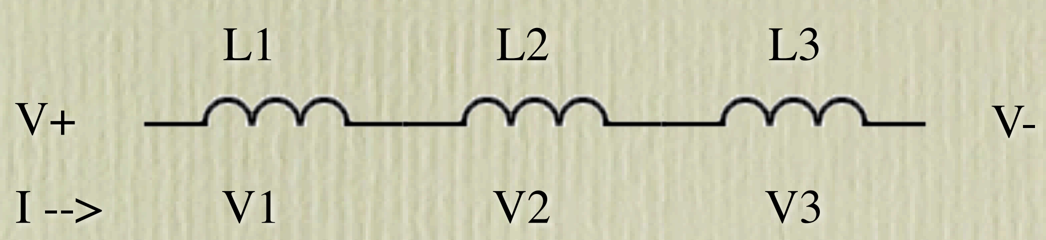
A) Thermal impedance
B) Resistance
C) Reactivity
D) Permeability

E6D08: What is one reason for using powdered-iron cores rather than ferrite cores in an inductor? (B)

A) Powdered-iron cores generally have greater initial permeability
B) Powdered-iron cores generally maintain their characteristics at higher currents
C) Powdered-iron cores generally require fewer turns to produce a given inductance
D) Powdered-iron cores use smaller diameter wire for the same inductance

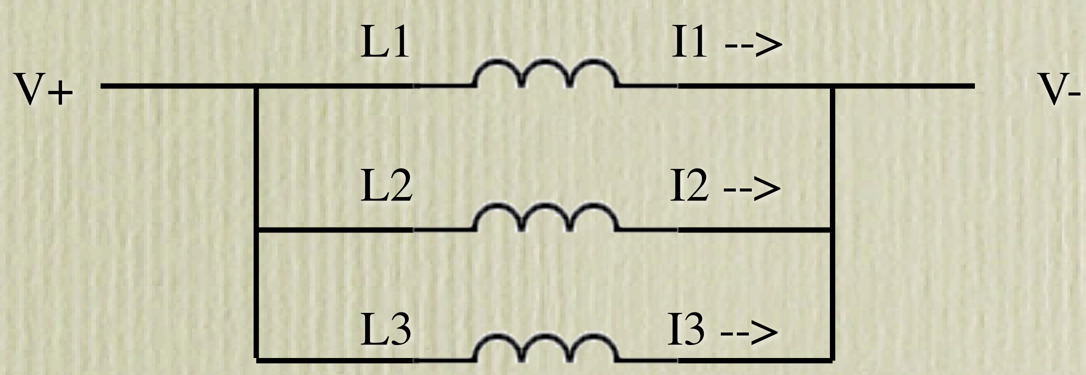
Series / Parallel Inductors

Series:



- Lt = L1 + L2 + …
- Always LARGER than the largest value
- Current is the same through all inductors
- Voltage across each inductor is dependent on the individual inductor values

Parallel:



- Lt = 1 / (1/L1 + 1/L2 + …)
- Always SMALLER than the smallest value
- For two inductors, Lt = (L1 * L2) / (L1 + L2)
- Voltage is the same across all inductors
- Current through each inductor is dependent on the individual inductor values

Test Questions

G5C10: What is the inductance of three 10 mH inductors connected in parallel?

~~A) 0.30 H~~

~~B) 3.3 H~~

C) 3.3 mH

~~D) 30 mH~~

- $Lt1 = (L1*L2) / (L1+L2) \rightarrow Lt1 = (10*10) / (10+10) = 100 / 20 = 5\ mH$

  $Lt = (Lt1*L3) / (Lt1+L3) = (10*5) / (10+5) = 50 / 15 = 3.33\ mH$ (C)

  \- OR -

- $Lt = 1 / (1/L1 + 1/L2 + 1/L3) = 1 / (100 + 100 + 100) = 1 / 300 = 3.33\ mH$ (C)

  \- OR -

- $Lt = 10 / 3 = 3.33\ mH$ (C)

G5C11: What is the inductance of a 20 mH inductor connected in series with a 50 mH inductor?

~~A) 0.07 mH~~

~~B) 14.3 mH~~

C) 70 mH

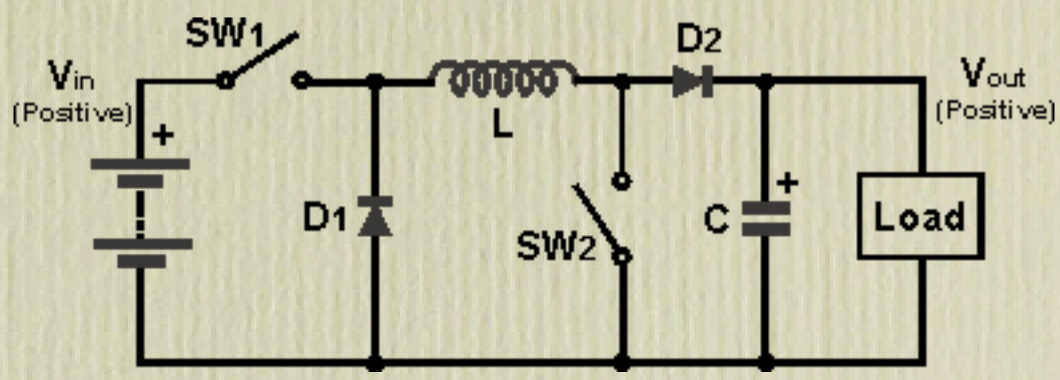
D) 1000 mH

- $Lt = L1 + L2 = 20 + 50 = 70\ mH$ (C)

Uses

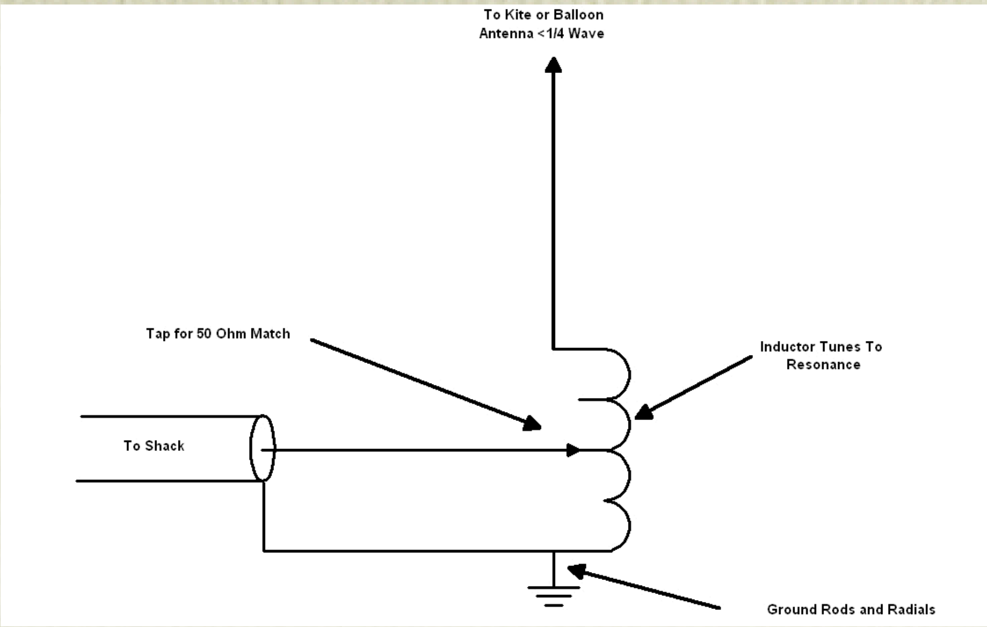
- Switching Power Supplies

  Energy is stored in the inductor’s magnetic field



- Loading Coil

  Tunes out the capacitive reactance of the antenna



Uses

- Common Mode Choke

  Lots of info from K9YC and GM3SEK

X

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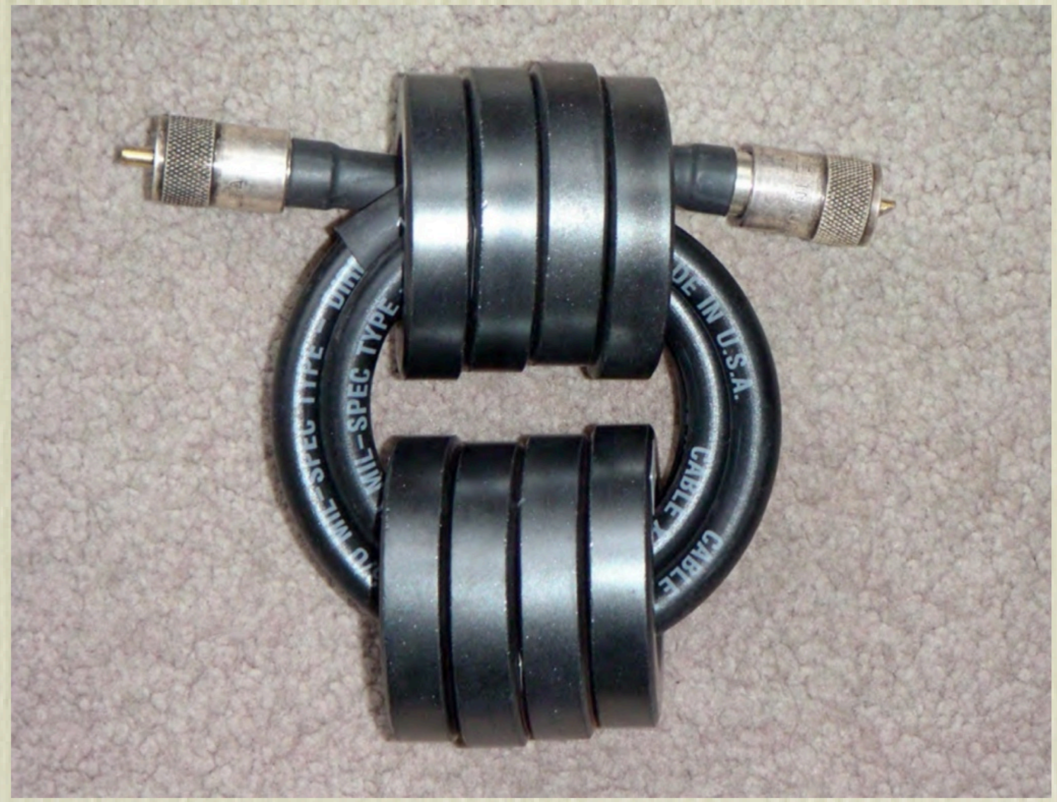
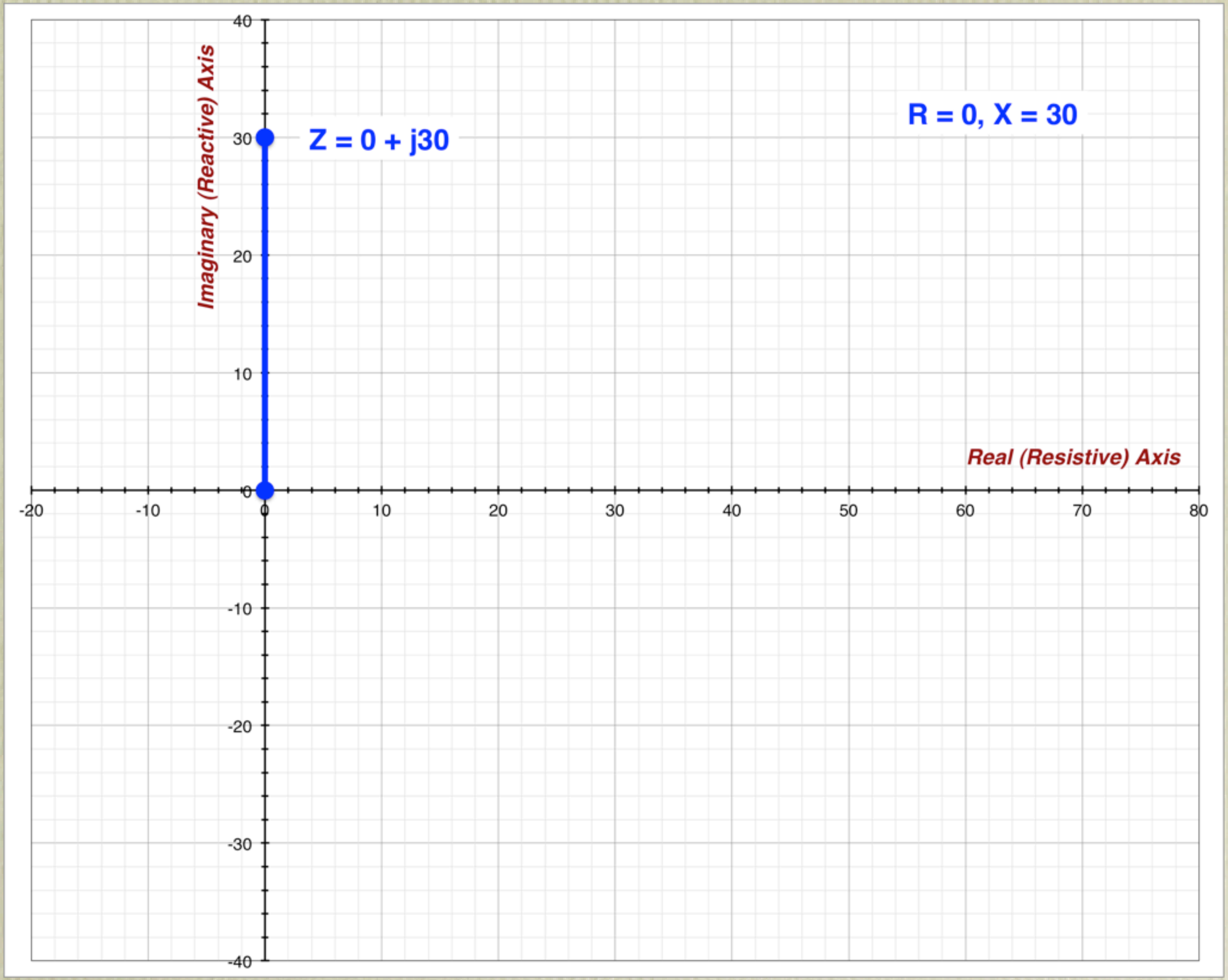


Impedance Plot



Transformer

Characteristics:

- Consists of two (or more) coupled inductors - One primary, one or more secondaries
- Only responds to a differential AC input voltage
- Non-polarized (sort of) ...
- Typical Cores: Iron, Ferrite

Uses:

- Transforming impedance or voltage / current
- Changing a balanced line to an unbalanced line (balun)
- Common mode noise rejection
- Isolation

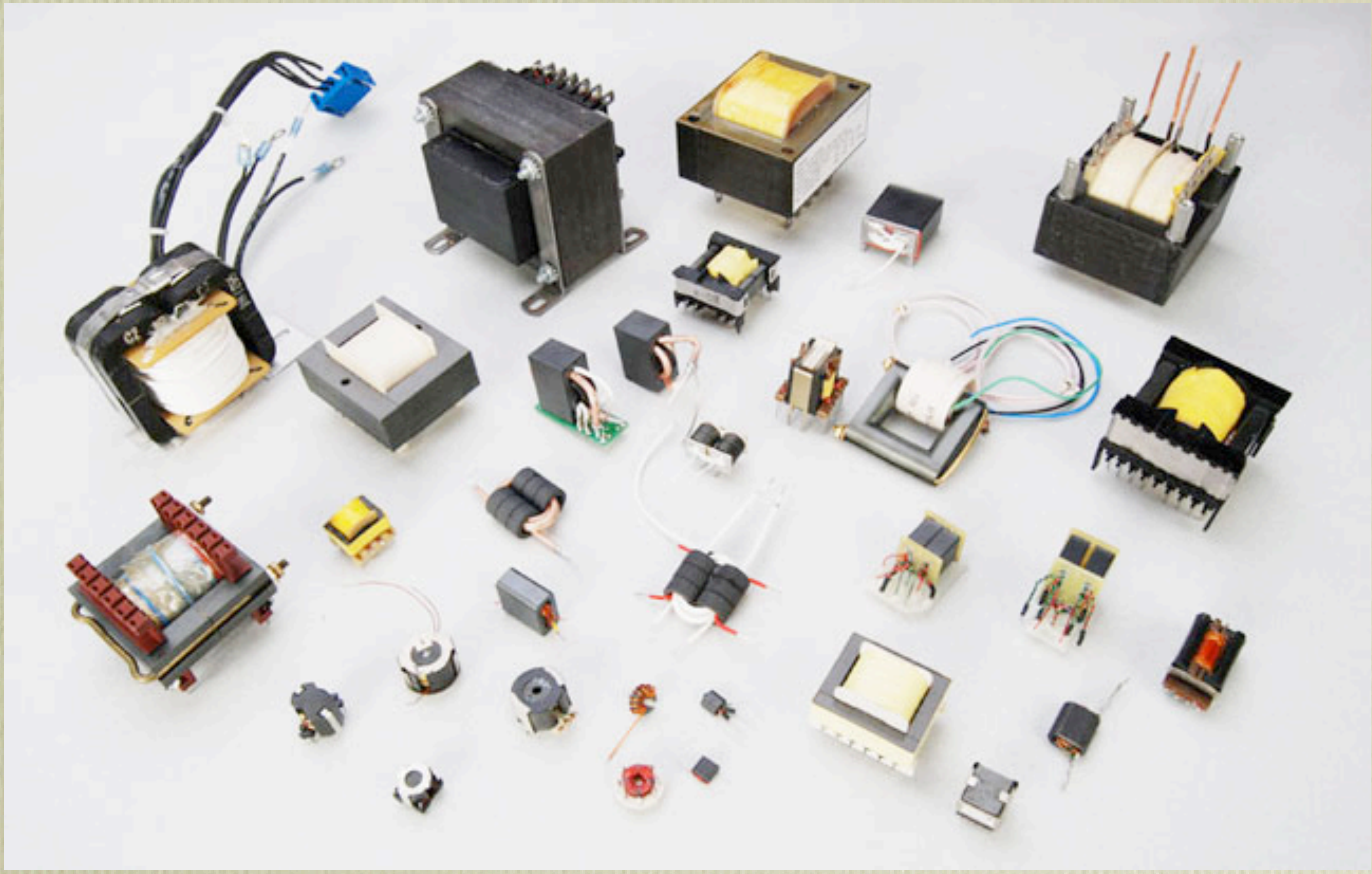
Formulas:

If N1 = Number of turns on the primary, N2 = Number of turns on the secondary

- Voltage ratio = N2 / N1 ---> VOut = VIn * (N2 / N1)
- Current ratio = N1 / N2 ---> IOut = IIn * (N1 / N2); Power must remain constant!

- Impedance ratio = V / I = (N2 / N1) / (N1 / N2) = $(N2 / N1)^2$
  --> Z2 = Z1 * $(N2 / N1)^2$

Transformer



Test Questions

G5C06: What is the RMS voltage across a 500-turn secondary winding in a transformer if the 2250-turn primary is connected to 120 VAC?

~~A) 2370 volts~~

~~B) 540 volts~~

C) 26.7 volts

D) 5.9 volts

- VOut = VIn * (N2/N1) = 120 * (500/2250) = 26.7 Volts (C)

G5C07: What is the turns ratio of a transformer used to match an audio amplifier having 600 ohm output impedance to a speaker having 4 ohm impedance?

A) 12.2 to 1

B) 24.4 to 1

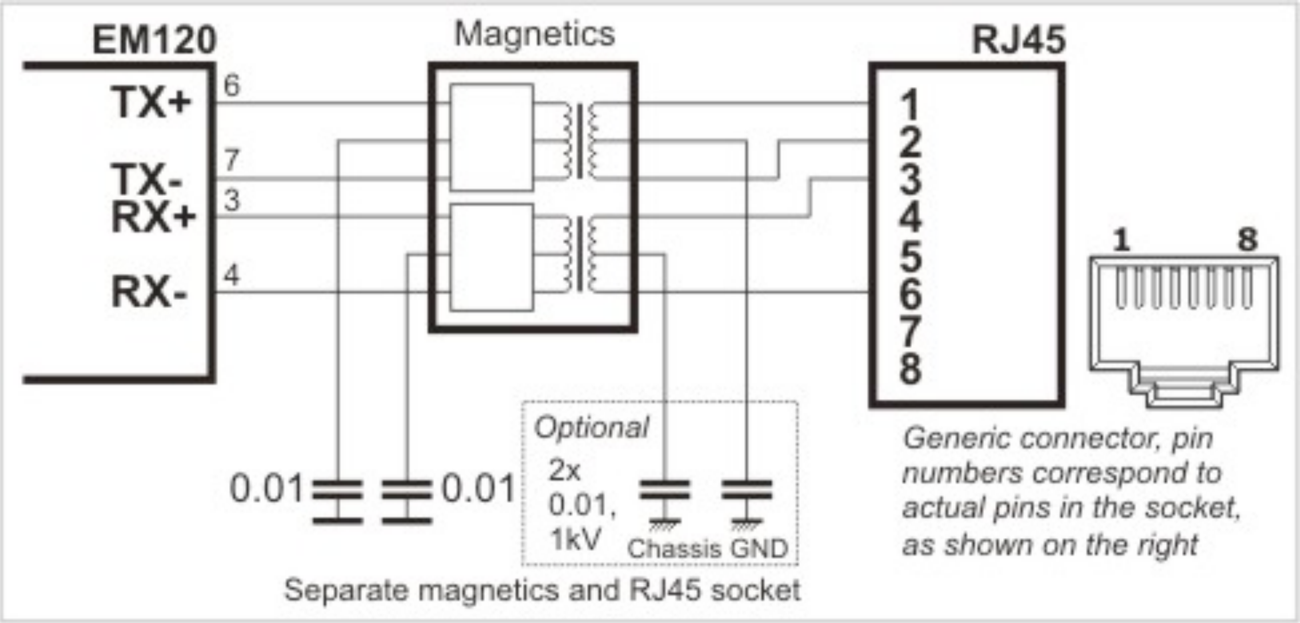
C) 150 to 1

D) 300 to 1

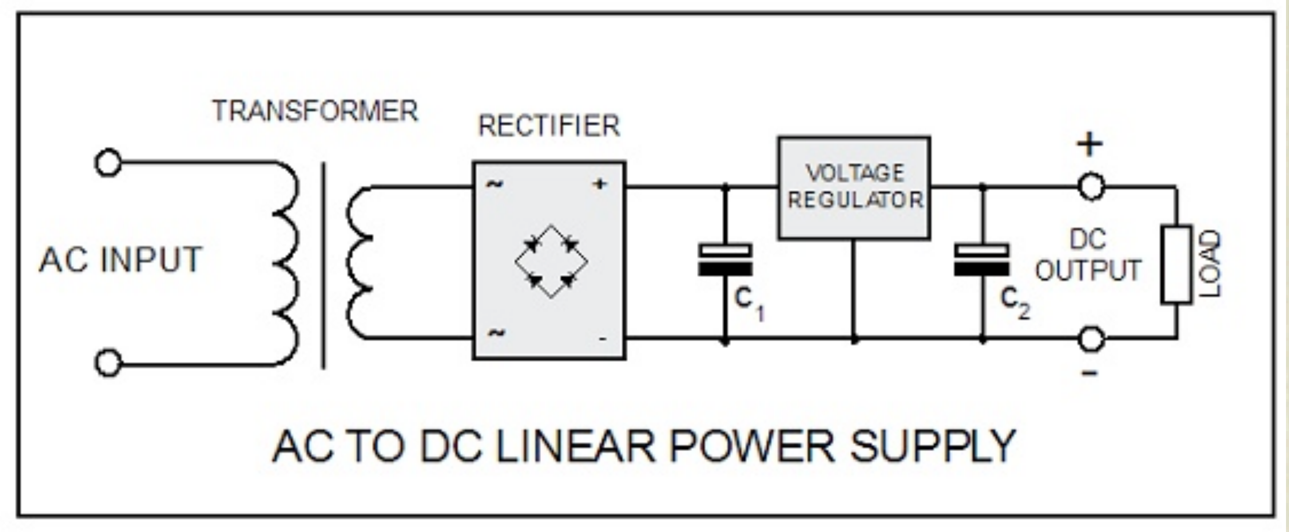
- Z2 = Z1 * $(N2/N1)^2$; By convention Z2 is the highest impedance for turns ratio (N2/N1) = Sqrt(Z2/Z1) = Sqrt(600/4) = Sqrt(150) = 12.25 (A)

Uses

- Ethernet
  - Eliminate ground loops
  - Reject common mode noise

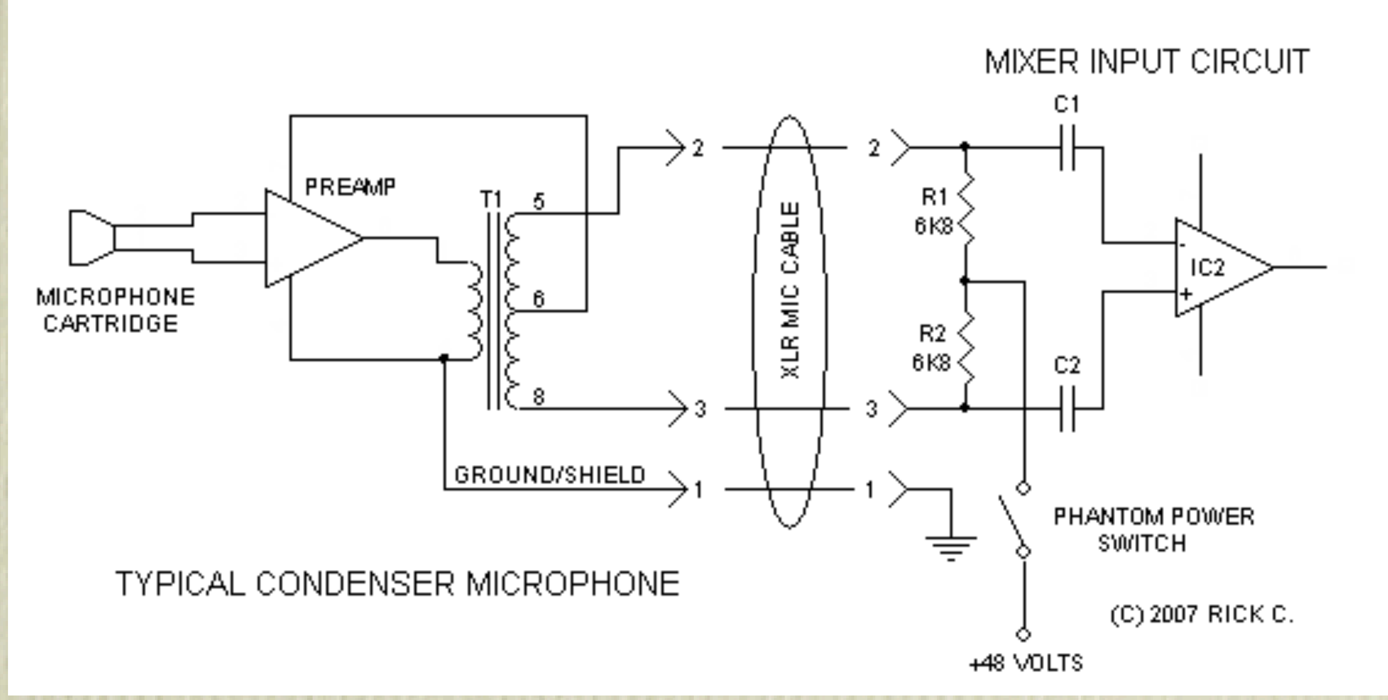


- Linear Power Supplies
  - Convert line voltage to desired output voltage and current

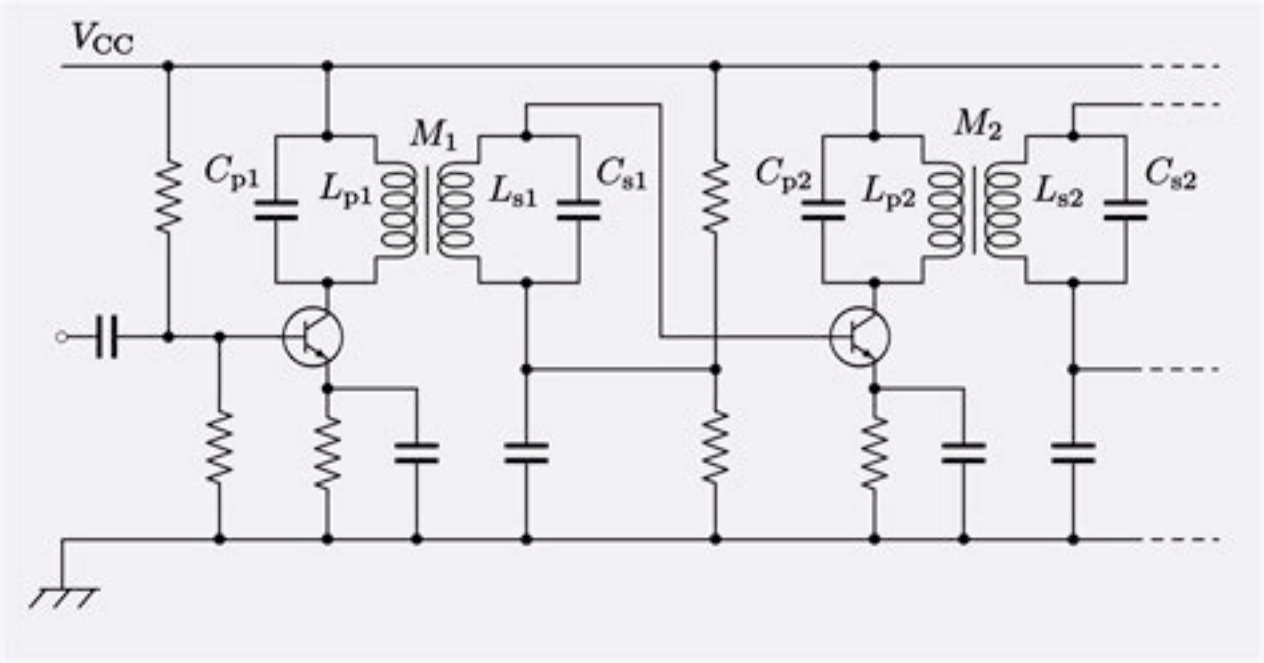


Uses

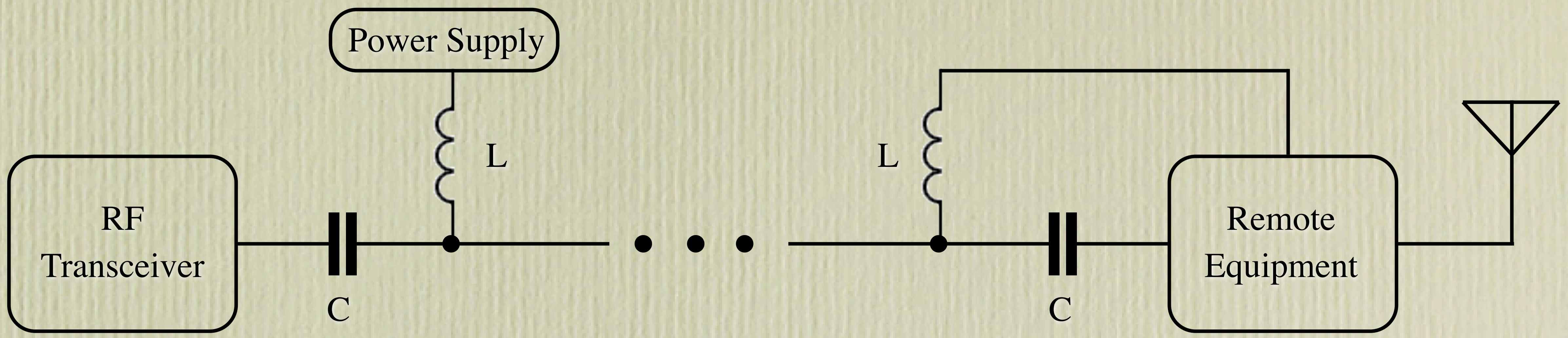
- Professional Audio
  - Receive phantom power
  - Match impedances



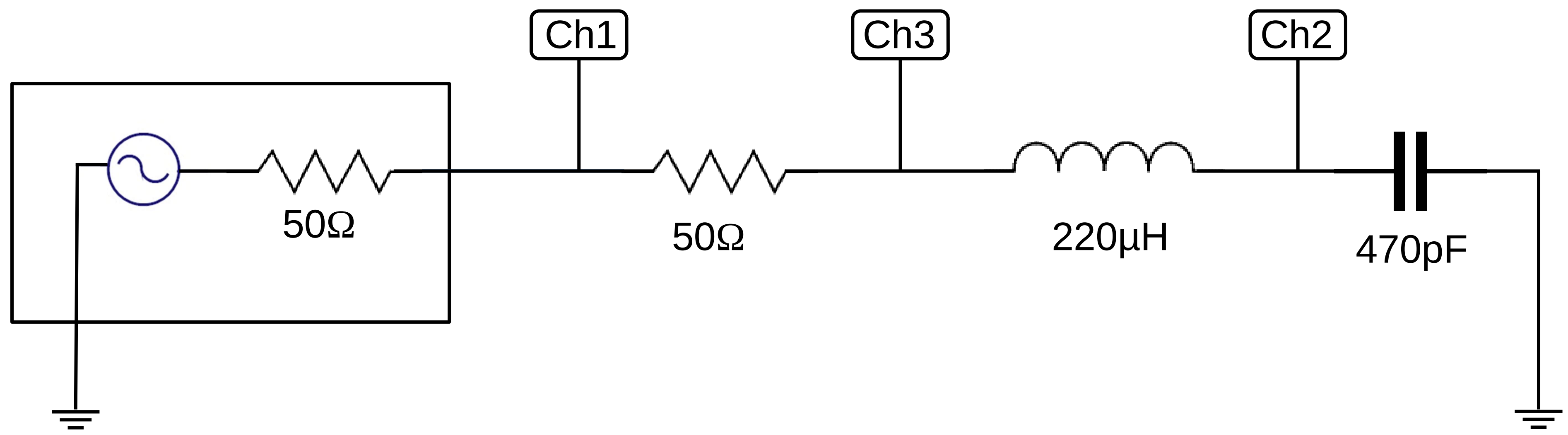
- RF Coupling
  - Control voltage, impedance and frequency response between stages



Bias Tee



RLC Demo



$$X_C = \frac{1}{2\pi fC} \qquad X_L = 2\pi fL \qquad \text{Resonant if } X_C = X_L \quad \Rightarrow \quad fr = \frac{1}{2\pi\sqrt{LC}}$$

$$fr = \frac{1}{2\pi\sqrt{220 \, x \, 10^{-6} \, x \, 470 \, x \, 10^{-12}}} = 494.95 \, kHz$$

$$X_L = 2\pi fL = 2\pi \;\; x \;\; 494950 \;\; x \;\; 220 \, x \, 10^{-6} = 684 \, \Omega$$

$$\text{Measure } V_r, \;\; I_r = \frac{V_r}{R} = \frac{0.895}{50} = 0.0179 \, A$$

$$V_L = I_r \, x \, X_L = 0.0179 \, A \;\; x \;\; 684 \, \Omega = 12.25 \, V$$