General License Class

1

General License Class

Chapter 4
Components & Circuits
(Part 1)

2

Power and Decibels

Electrical Review

- Current.
  - Electric current is the flow of electrons through a material.
  - The unit of measurement is the Ampere.
    - 1 Ampere = 1 coulomb/second.
      - 1 coulomb ≈ 6.24 billion billion (6.24×10^{18}) electrons.
    - Abbreviated to ”Amp” or “A”.
  - Use the symbol “I” in formulas.

3

Power and Decibels

Electrical Review

- Voltage
  - Voltage is the electrical force that causes electrons to flow.
    - a.k.a. – Electromotive force (EMF) or potential.
    - The unit of measurement is the volt.
      - Abbreviated to “V”.
    - Use the symbol “E” in formulas.

4

Power and Decibels

Electrical Review

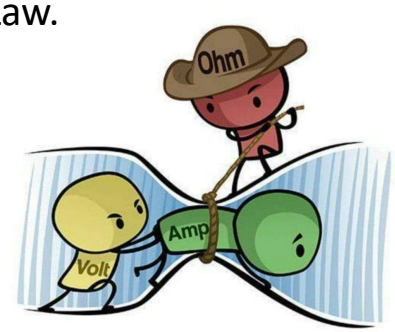
- Resistance
  - Resistance is the opposition to the movement of electrons.
    - The unit of measurement is the Ohm (Ω).
    - Use the symbol “R” in formulas.

5

Power and Decibels

Electrical Review

- Voltage, current, & resistance are all related by Ohm’s Law.



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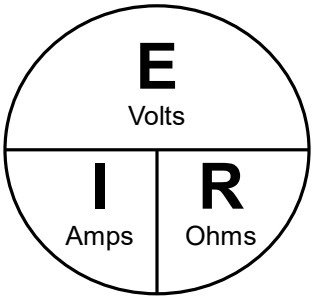
Power and Decibels

Ohm's Law



E = I x R **I = E / R** **R = E / I**

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Power and Decibels

Electrical Review

- Power
  - Power is the rate at which energy is transferred to another form (e.g. – heat or mechanical energy).
    - The unit of measurement is the watt.
      - Abbreviated to "W".
    - Use the symbol "P" in formulas.

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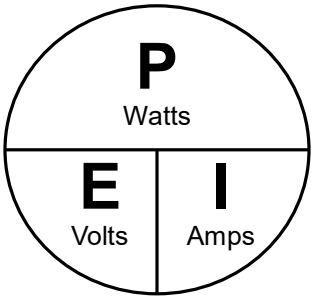
Power and Decibels

Power Formula



P = E x I **E = P / I** **I = P / E**

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Power and Decibels

More Power Equations

- Combining Ohm's Law (E = I x R) with the power equation (P = E x I) gives us 2 more ways to calculate power:
  - $P = E^2 / R$
  - $P = I^2 \times R$

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Power and Decibels

AC and DC Waveforms

- Direct Current (DC)
  - Current that always flows in the same direction.
- DC Voltage
  - Voltage that always has the same polarity.

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Power and Decibels

AC and DC Waveforms

- Alternating Current (AC)
  - Current that reverses direction of current flow.
- AC Voltage
  - Voltage that changes polarity.

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Power and Decibels

AC and DC Waveforms

- Frequency
  - Rate at which voltage changes polarity or current changes direction.
  - The unit of measurement is the Hertz (Hz).
    - 1 Hz = 1 cycle per second.

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Power and Decibels

AC and DC Waveforms

- Wavelength
  - Radio waves travel at the speed of light.
    - 186,000 miles/second
    - 300,000,000 meters/second
      - 300 x 10^6 meters/second

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Power and Decibels

AC and DC Waveforms

- Wavelength.
  - The distance a radio wave travels during the time it takes to complete one cycle.
    - The unit of measurement is usually the meter (m).
    - As the frequency increases, the wavelenth decreases & vice-versa.

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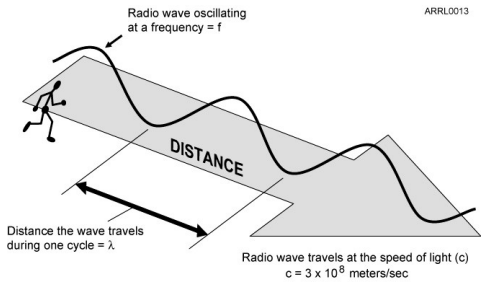
Power and Decibels

AC and DC Waveforms

- Wavelength.



λ= c/f = 300 / f in MHz

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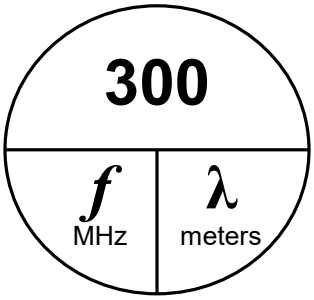
Power and Decibels

Wavelength



$300 = f \times \lambda$ $f = 300 / \lambda$ $\lambda = 300 / f$

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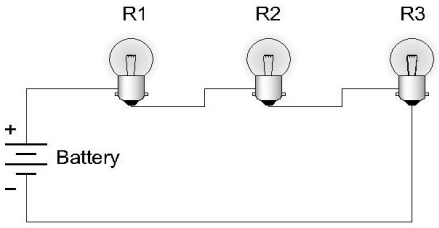
Power and Decibels

Series and Parallel Circuits

- Series Circuit.
  - Only one path for current to flow.
  - Current through each device is the same.



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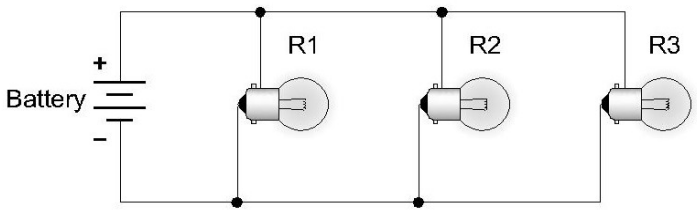
Power and Decibels

Series and Parallel Circuits

- Parallel Circuit.
  - Multiple paths for current to flow.
  - Voltage across each device is the same.



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Power and Decibels

Decibels

- A measure of the ratio between 2 values on a logarithmic scale.
  - Power Ratio:
    - $dB = 10 \log_{10} (P_1/P_2)$
  - Voltage Ratio:
    - $dB = 20 \log_{10} (V_1/V_2)$

20

Power and Decibels

dB	Power Ratio	Voltage Ratio
0	1.000	1.000
-1	**0.794**	**0.89**
-2	0.631	0.79
-3	**0.501**	**0.707**
-4	0.398	0.631
-5	0.316	0.562
-6	0.250	0.501
-7	0.200	0.447
-8	0.159	0.398
-9	0.126	0.355
-10	0.100	0.316

dB	Power Ratio	Voltage Ratio
0	1.000	1.000
1	**1.259**	**1.122**
2	1.585	1.259
3	**1.995**	**1.414**
4	2.512	1.585
5	3.162	1.778
6	4.000	1.995
7	5.012	2.239
8	6.310	2.512
9	7.943	2.818
10	10.00	3.16

21

G5B01 -- What dB change represents a factor of two increase or decrease in power?

A. Approximately 2 dB
B. Approximately 3 dB
C. Approximately 6 dB
D. Approximately 9 dB

22

G5B03 -- How many watts of electrical power are consumed if 400 VDC is supplied to an 800 ohm load?

A. 0.5 watts
B. 200 watts
C. 400 watts
D. 3200 watts

23

G5B04 -- How many watts of electrical power are consumed by a 12 VDC light bulb that draws 0.2 amperes?

A. 2.4 watts
B. 24 watts
C. 6 watts
D. 60 watts

24

G5B05 -- How many watts are consumed when a current of 7.0 milliamperes flows through a 1,250-ohm resistance?

A. Approximately 61 milliwatts
B. Approximately 61 watts
C. Approximately 11 milliwatts
D. Approximately 11 watts

25

G5B10 -- What percentage of power loss is equivalent to a loss of 1 dB?

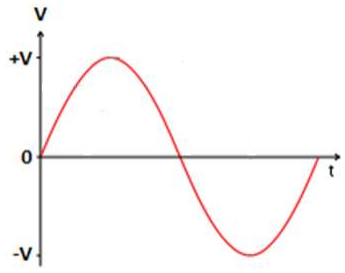
A. 10.9 percent
B. 12.2 percent
C. 20.6 percent
D. 25.9 percent

26

AC Power

RMS: Definition and Measurement

- If a DC voltmeter is used to measure an AC voltage, it will display the average voltage, which is zero volts.



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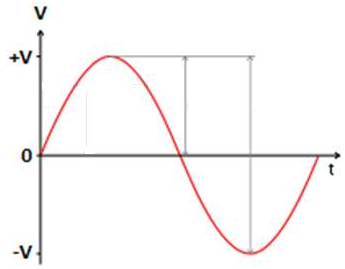
AC Power

RMS: Definition and Measurement

- With an oscilloscope, it is easy to read the peak-to-peak voltage or the peak (maximum) voltage.



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AC Power

RMS: Definition and Measurement

- A current will heat up a resistor.
- The amount of DC current that causes the same amount of heating as the AC current is called the root-mean-square (RMS) value of the AC current.
  - The AC current dissipates the same average power as the DC current.

29

AC Power

RMS: Definition and Measurement

- To calculate the RMS value:
  - Calculate the square of the current.
  - Calculate the average of the squared current.
  - Calculate the square root of the average.

30

AC Power

RMS: Definition and Measurement

- For sine waves, the RMS value is the peak value multiplied by 0.707.
  - $I_{RMS} = 0.707 \times I_P$
  - $V_{RMS} = 0.707 \times V_P$
  - **These formulas work for sine waves only!**

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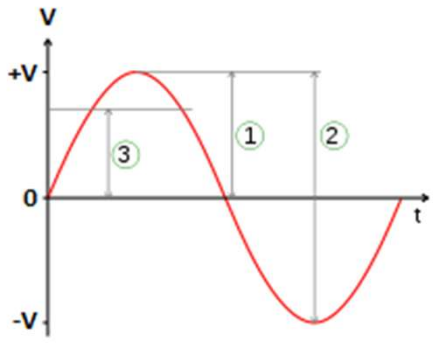
AC Power

RMS: Definition and Measurement



1 = Peak
2 = Peak-to-Peak
3 = Root-Mean-Square (RMS)

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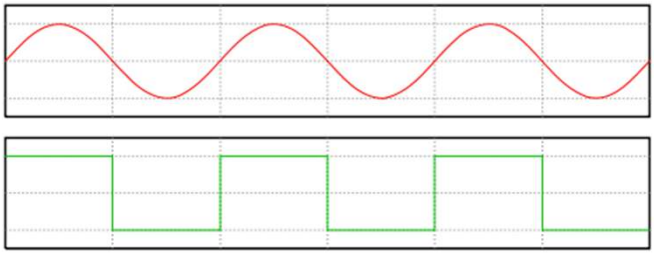
AC Power

RMS: Definition and Measurement

To Calculate	Sine Wave	Square Wave
RMS	0.707 x Peak	Peak
Peak	1.414 x RMS	Peak



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AC Power

RMS: Definition and Measurement

- When selecting components, always keep in mind the peak value of any AC voltages or currents.
  - Can you use a capacitor rated at 150V maximum as a filter on a 120-volt circuit?
    - **No!** -- 120 V_{RMS} = 170 V_{Peak} and the maximum voltage rating of the capacitor would be exceeded.

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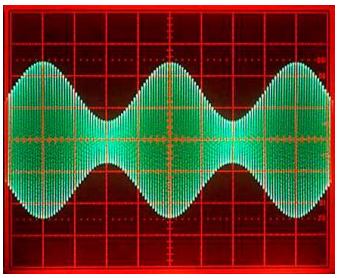
AC Power

PEP: Definition and Measurement

- PEP = Peak Envelope Power
  - Average power over one complete cycle at the peak of the RF envelope.



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AC Power

PEP: Definition and Measurement

- Peak Envelope Power (PEP).
  - Measure V_P or V_{P-P} using an oscilloscope.
    - $V_{P-P} = 2 \times V_P$
  - Calculate V_{RMS} from V_P
    - $V_{RMS} = 0.707 \times V_P$
  - Calculate PEP from V_{RMS} and load impedance.
    - $PEP = V_{RMS}^2 / R_{Load}$
- PEP is equal to the average power if no modulation or if FM-modulated.

36

G5B06 -- What is the PEP produced by 200 volts peak-to-peak across a 50-ohm dummy load?

A. 1.4 watts
B. 100 watts
C. 353.5 watts
D. 400 watts

37

G5B07 -- What value of an AC signal produces the same power dissipation in a resistor as a DC voltage of the same value?

A. The peak-to-peak value
B. The peak value
C. The RMS value
D. The reciprocal of the RMS value

38

G5B08 -- What is the peak-to-peak voltage of a sine wave with an RMS voltage of 120.0 volts?

A. 84.8 volts
B. 169.7 volts
C. 240.0 volts
D. 339.4 volts

39

G5B09 -- What is the RMS voltage of a sine wave with a value of 17 volts peak?

A. 8.5 volts
B. 12 volts
C. 24 volts
D. 34 volts

40

G5B11 -- What is the ratio of PEP to average power for an unmodulated carrier?

A. .707
B. 1.00
C. 1.414
D. 2.00

41

G5B12 -- What is the RMS voltage across a 50-ohm dummy load dissipating 1200 watts?

A. 173 volts
B. 245 volts
C. 346 volts
D. 692 volts

42

G5B13 -- What is the output PEP of an unmodulated carrier if the average power is 1060 watts?

A. 530 watts
B. 1060 watts
C. 1500 watts
D. 2120 watts

43

G5B14 -- What is the output PEP of 500 volts peak-to-peak across a 50-ohm load?

A. 8.75 watts
B. 625 watts
C. 2500 watts
D. 5000 watts

44

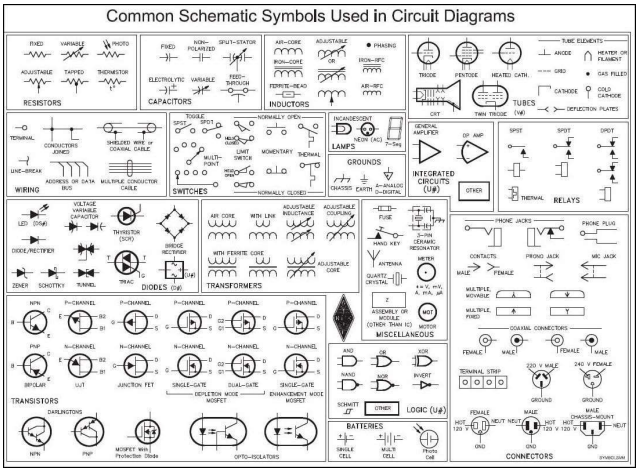
Basic Components

Schematic Diagrams & Symbols

- Standardized symbols represent each type of component.
- Symbols are combined to form a schematic diagram.
- Schematic diagrams represent how components are interconnected in a circuit.
  - Not actual physical arrangement.

45

Basic Components



46

G7A09 -- Which symbol in Figure G7-1 represents a field effect transistor?

A. Symbol 2
B. Symbol 5
C. Symbol 1
D. Symbol 4

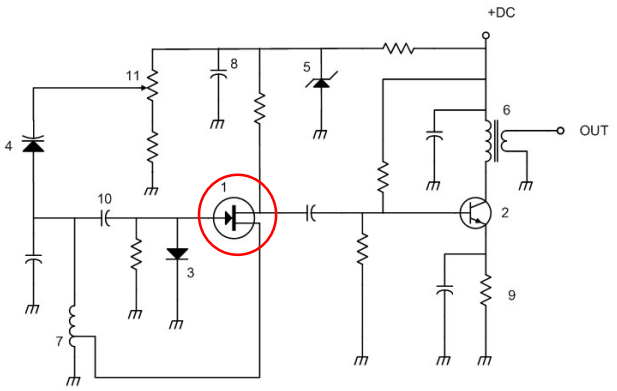


Figure G7-1

47

G7A10 -- Which symbol in Figure G7-1 represents a Zener diode?

A. Symbol 4
B. Symbol 1
C. Symbol 11
D. Symbol 5

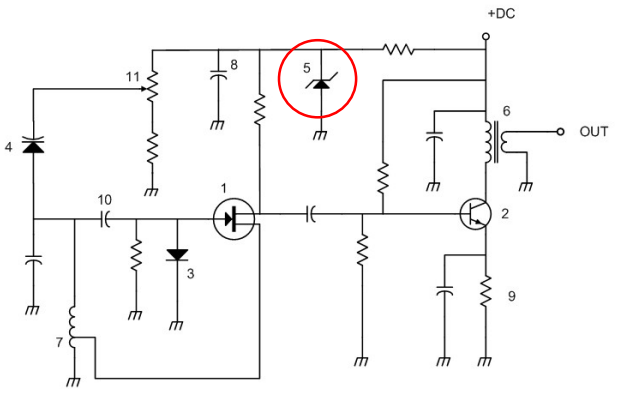


Figure G7-1

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G7A11 -- Which symbol in Figure G7-1 represents an NPN junction transistor?

A. Symbol 1
B. Symbol 2
C. Symbol 7
D. Symbol 11

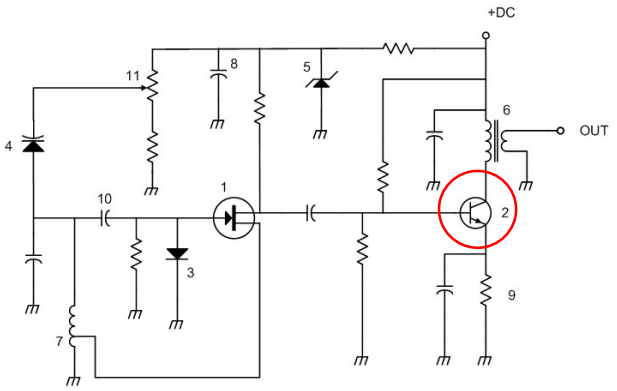

Figure G7-1

49

G7A12 -- Which symbol in Figure G7-1 represents a solid core transformer?

A. Symbol 4
B. Symbol 7
C. Symbol 6
D. Symbol 1

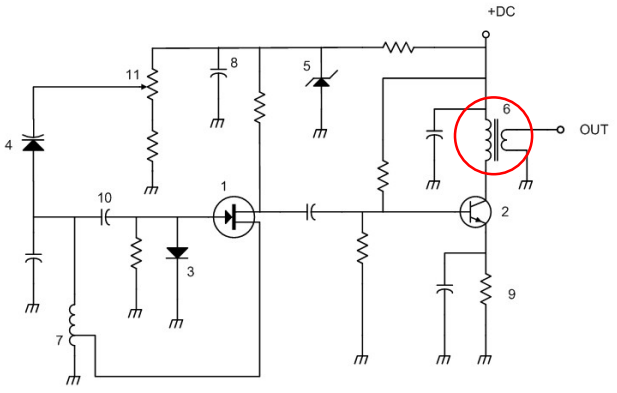

Figure G7-1

50

G7A13 -- Which symbol in Figure G7-1 represents a tapped inductor?

A. Symbol 7
B. Symbol 11
C. Symbol 6
D. Symbol 1

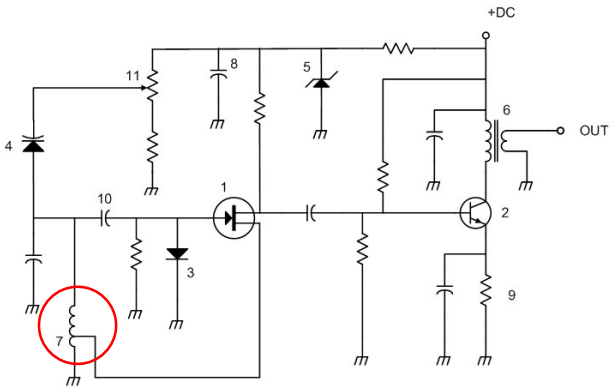

Figure G7-1

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Basic Components

Metric Units

- Most of the time we will be using metric units.
- Need to be familiar with several of the metric prefixes & how to convert between them.

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Basic Components

International System of Units (SI)—Metric Units

Prefix	*Symbol*	*Multiplication Factor*
Tera	T	$10^{12} = 1{,}000{,}000{,}000{,}000$
Giga	G	$10^{9} = 1{,}000{,}000{,}000$
Mega	M	$10^{6} = 1{,}000{,}000$
Kilo	k	$10^{3} = 1000$
Hecto	h	$10^{2} = 100$
Deca	da	$10^{1} = 10$
Deci	d	$10^{-1} = 0.1$
Centi	c	$10^{-2} = 0.01$
Milli	m	$10^{-3} = 0.001$
Micro	μ	$10^{-6} = 0.000001$
Nano	n	$10^{-9} = 0.000000001$
Pico	p	$10^{-12} = 0.000000000001$

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Basic Components

Metric Units.

- Some examples:

pico / 1000 → nano	nano x 1000 → pico
nano / 1000 → micro	micro x 1000 → nano
micro / 1000 → milli	milli x 1000 → micro
kilo / 1000 → mega	mega x 1000 → kilo
mega / 1000 → giga	giga x 1000 → mega

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Basic Components

Definitions:

- **Nominal Value**
  - Intended value of the component.
- **Tolerance**
  - Amount value of the component may vary from the nominal value.

55

Basic Components

Definitions:

- **Temperature Coefficient**
  - Amount & direction of component value changes with changes in temperature.
- **Power/Voltage/Current Rating**
  - Maximum power/voltage/current the component will withstand before damage occurs.

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Basic Components

Resistors & Resistance

- Resistance
  - Opposition to the flow of electrons.
  - Converts electrical energy to heat.
  - Unit of measurement = Ohm (Ω).
  - Symbol used in equations = R.
  - Components designed to provide resistance are called “resistors”.

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Basic Components

Resistors & Resistance

- Resistors
  - Resistances range from <1 Ω to >10 MΩ
  - Tolerances of 0.1% to 20%.
  - Temperature coefficients can be positive or negative depending on material.
    - Positive = Value increases as temperature increases.
    - Negative = Value decreases as temperature increases.

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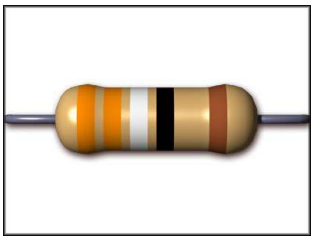
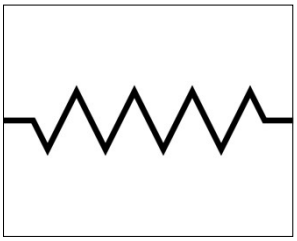
Basic Components

Resistors & Resistance

- Resistances range from <1 Ω to >20 MΩ
- Values often indicated by colored bands on body.





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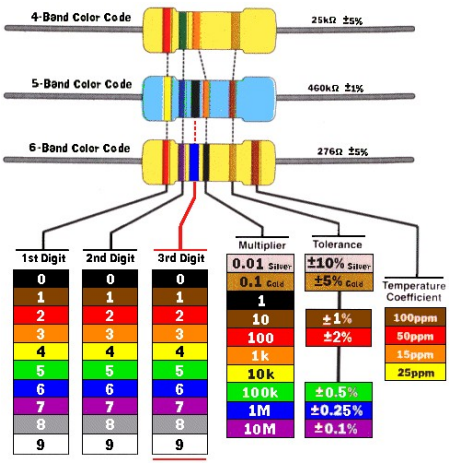
Basic Components



Color	Value
Silver	0.01
Gold	0.1
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

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Basic Components

Resistors & Resistance

- Resistor types
  - Carbon composition.
    - Axial wire leads.
    - <1 Ω to 22 MΩ.
    - 1/8 to 2 Watts.
    - Tolerance 5%, 10%, & 20%
    - Poor temperature stability
    - Along with wirewound, the oldest technology.
      - Not commonly used after 1970.

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Basic Components

Resistors & Resistance

- Resistor types
  - Carbon film.
    - Axial wire leads or SMT.
    - 1 Ω to 10 MΩ.
    - 1/8 to 5 Watts.
    - Wide operating temperature range.

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Basic Components

Resistors & Resistance

- Resistor types
  - Metal Film.
    - Axial wire leads or SMT.
    - <1 Ω to >10 MΩ.
    - 1/8 to 2 Watts.
    - Tolerance 0.1%, 1%, & 2%.
    - Good temperature stability.
    - Low noise.
    - Most commonly used today.

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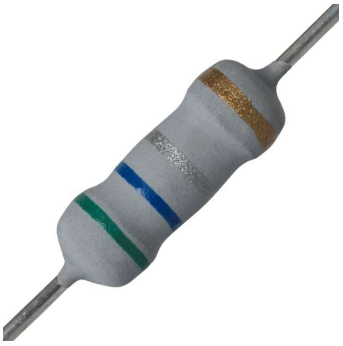
Basic Components

Resistors & Resistance

- Resistor types
  - Metal-oxide film.
    - Axial wire leads or SMT.
    - Similar to metal film.
    - Higher operating temperatures.
    - Higher temperature stability.
    - Low stray inductance.
      - Good for RF circuits.



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Basic Components

Resistors & Resistance

- Resistor types
  - Wirewound.
    - High power.
      - Up to 200 Watts or more.
    - High inductance – not good for RF circuits.
    - May have metal case for attaching to a heat sink.
    - May be tapped to adjust value.

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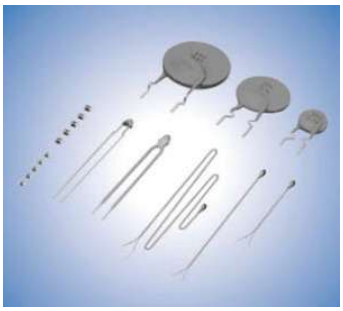
Basic Components

Resistors & Resistance

- Resistor types
  - Thermistor.
    - Special type of resistor with precisely known temperature coefficient.
      - Both positive (PTC) & negative (NTC) temperature coefficients are available.
    - Used for temperature sensing.



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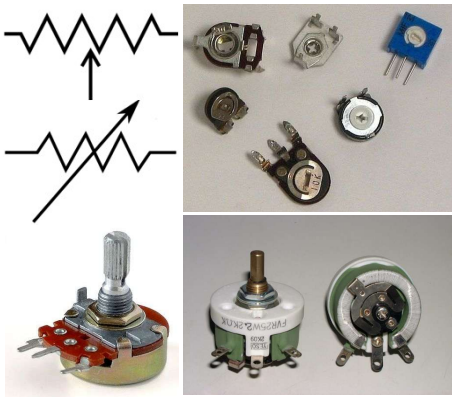
Basic Components

Resistors & Resistance

- Resistor types
  - Variable Resistors.
    - Potentiometers.
    - Rheostats
    - Materials
      - Graphite.
      - Cermet.
      - Wirewound.
    - Taper.
      - Linear.
      - Semi-Log.



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Basic Components

Resistors & Resistance

- Parasitic inductance.
  - Parasitic inductance changes characteristics of resistor at high frequencies.
  - Use low-inductance resistors in RF circuits.
    - Carbon composition.
    - Carbon film.
    - Metal film.
    - Metal-oxide film. (Best)
  - Avoid high-inductance resistors in RF circuits.
    - Wirewound.

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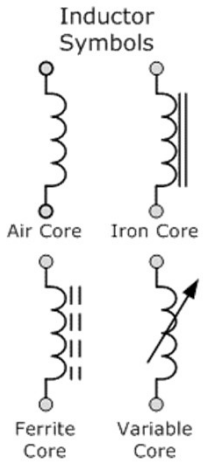
Basic Components

Inductors & Inductance

- Inductance.
  - Ability to store energy in a magnetic field.
  - Opposes a change in current flow.
  - Unit of Measurement = Henry (H)
  - Symbol used in equations = L.
  - Components are called "inductors" or "coils".

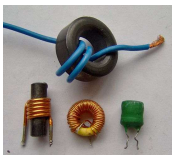


69

Basic Components

Inductors & Inductance

- Inductors.
  - Inductances range from <1 µH to >1 H.
    - H = henries
    - mH = millihenries (10^{-3} henries)
    - µH = microhenries (10^{-6} henries)


70

Basic Components

Inductors & Inductance

- Inductors.
  - Some inductors are wound on a non-magnetic form.
    - a.k.a. – Air-wound.
    - Air-wound indictors are used for low-inductance, high-frequency applications.

71

Basic Components

Inductors & Inductance

- Inductors.
  - Some inductors are wound around a core made of magnetic material.
    - Allows higher values of inductance to be achieved.
    - Most of the magnetic field is contained within the core.

72

Basic Components

Inductors & Inductance

- Inductors.
  - Different core materials.
    - Laminated iron.
      - Used in high-inductance, low-frequency applications such as power supply filter chokes.
    - Powdered iron and ferrite.
      - Used in medium-inductance applications.

73

Basic Components

Inductors & Inductance

- Inductors.
  - Different core materials.
    - For inductors with a ferrite core, the composition or “mix” of the material used can be varied to optimize performance at different frequencies.

74

Basic Components

Inductors & Inductance

- Inductors.
  - Different shapes.
    - Solenoidal.
      - Coils is wound in a cylindrical shape.
      - More turns → higher inductance.
      - Larger diameter → higher inductance.
      - Longer length → lower inductance.
      - Any type of core material may be used.

75

Basic Components

Inductors & Inductance

- Inductors.
  - Different shapes.
    - Toroidal.
      - Wound on ferrite core.
      - Large values of inductance are possible.
      - The magnetic properties of the core material may be optimized for a specific range of frequencies.
      - Most of the magnetic field is contained within the core.

76

Basic Components

Inductors & Inductance

- Inductors.
  - Mutual inductance.
    - If the magnetic field from one inductor extends to another inductor, then the current flowing in the 1st inductor will effect the current flowing in the 2nd inductor. This is called mutual inductance or transformer action.

77

Basic Components

Inductors & Inductance

- Inductors.
  - Mutual inductance.
    - Usually undesirable.
    - Minimizing mutual inductance.
      - Shield with magnetic material.
      - Place solenoidal coils at right angles to one another.
      - Use toroidal cores.

78

Basic Components

Inductors & Inductance

- Inductors.
  - At high frequencies, inter-turn capacitance can become significant.
    - Inductor can become self-resonant.

79

G6B01 -- What determines the performance of a ferrite core at different frequencies?

A. Its conductivity
B. Its thickness
C. The composition, or “mix,” of materials used
D. The ratio of outer diameter to inner diameter

80

G6B05 -- What is an advantage of using a ferrite core toroidal inductor?

A. Large values of inductance may be obtained
B. The magnetic properties of the core may be optimized for a specific range of frequencies
C. Most of the magnetic field is contained in the core
D. All of these choices are correct

81

Basic Components

Capacitors & Capacitance

- Capacitance
  - Ability to store energy in an electric field.
  - Opposes a change in voltage.
  - Unit of Measurement = Farad (F).
  - Symbol used in equations = C.
  - Components designed to provide capacitance are called “capacitors” or “condensers”.

82

Components and Units

Capacitors & Capacitance

- Capacitors.
  - Two conductive surfaces separated by an insulator.

83

Basic Components

Capacitors & Capacitance

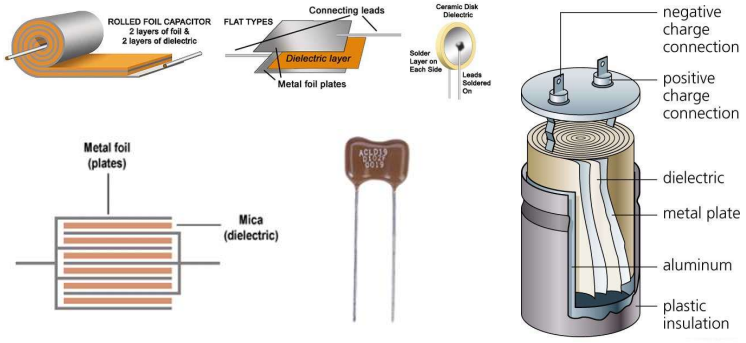
- Capacitors.
  - The larger the conductive surfaces, the higher the capacitance.
  - The closer the conductive surfaces are together, the higher the capacitance.
  - The higher the dielectric constant of the insulator, the higher the capacitance.

84

Basic Components

Capacitors & Capacitance

- Capacitors.

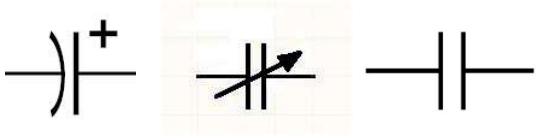


85

Basic Components

Capacitors & Capacitance

- Capacitors.
  - Capacitances range from <1 pF to >1 F.
    - F = Farads
    - µF = microfarads (10^{-6} farads)
    - pF = picofarads (10^{-12} farads)



86

Basic Components

Capacitors & Capacitance

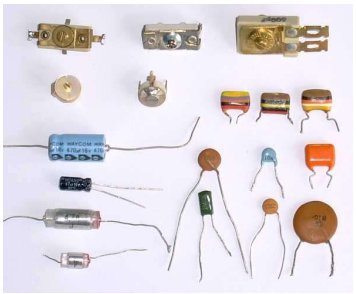
- Types of Capacitors.
  - Air / Vacuum.
  - Mica / Silver Mica.
  - Ceramic.
  - Plastic Film (Polystyrene or Mylar).
  - Paper.
  - Oil-filled.
  - Electrolytic / Tantalum.

87

Basic Components

Capacitors & Capacitance

- Capacitors.

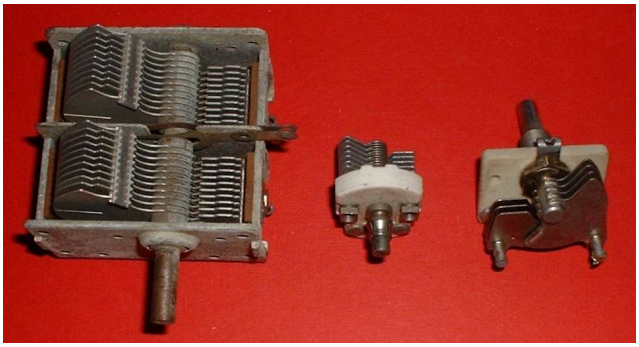


88

Basic Components

Capacitors & Capacitance

- Variable Capacitors.



89

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Air / Vacuum.
    - High voltage applications.
    - Low Capacitance.
    - Transmitter circuits.

90

Basic Components

Capacitors & Capacitance

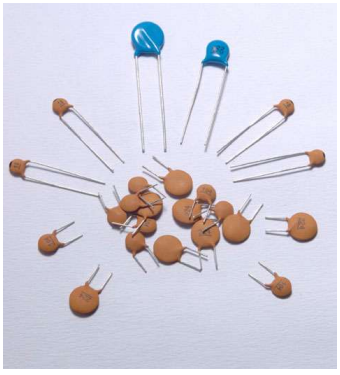
- Types of Capacitors.
  - Mica / Silver Mica.
    - High stability.
    - Low loss.
    - RF circuits.

91

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Ceramic.
    - Inexpensive.
    - Wide range of capacitances available.
    - Low to high voltage ratings available.
    - RF bypassing & filtering.

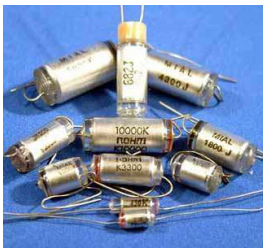


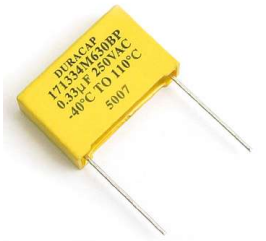
92

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Plastic Film
    - Polystyrene or Mylar.
    - AF & lower frequencies.
    - Susceptible to damage from high temperatures.



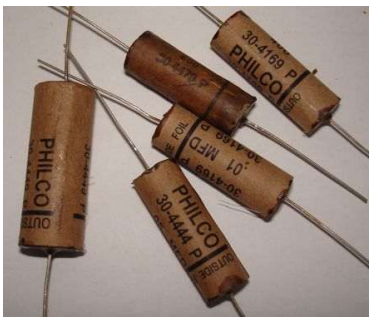


93

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Paper.
    - Not commonly used today.
    - Found in older equipment.



94

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Oil-filled.
    - High voltage.
    - AC Power circuits.
    - Oil can contain PCB's.

95

Basic Components

Capacitors & Capacitance

- Types of Capacitors.
  - Electrolytic / Tantalum.
    - Polarized.
    - High capacitance in physically small size.
    - Power supply filters.
    - Low-impedance AF coupling.

96

Basic Components

Capacitors & Capacitance

- Capacitors.
  - At high frequencies, inductance of leads can become significant.
    - Effective capacitance can be reduced.
    - Capacitor can become self-resonant.

97

G6A04 -- Which of the following is characteristic of an electrolytic capacitor?

A. Tight tolerance
B. Much less leakage than any other type
C. High capacitance for a given volume
D. Inexpensive RF capacitor

98

G6A08 -- Which of the following is characteristic of low voltage ceramic capacitors

A. Tight tolerance
B. High stability
C. High capacitance for given volume
D. Comparatively low cost

99

Basic Components

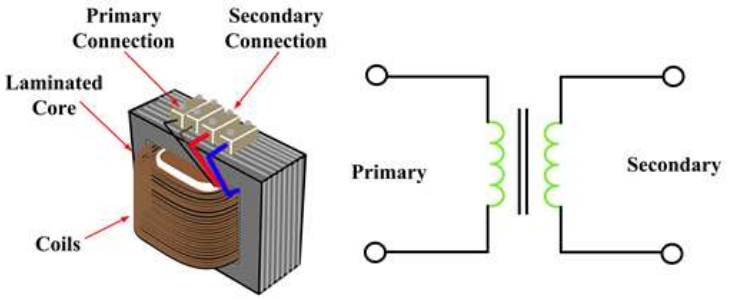
Transformers

- Usually mutual inductance between two inductors is a bad thing.
- One exception to this is the transformer.
  - Two or more inductors wound on a common core to maximize mutual inductance.
    - The inductors are called “windings”.

100

Basic Components

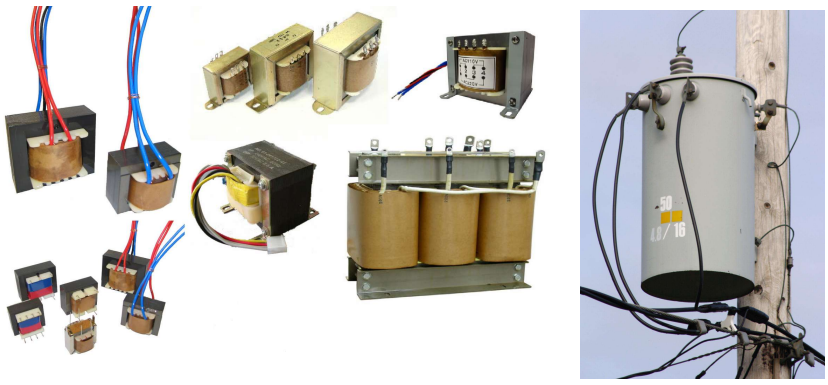
Transformers



101

Basic Components

Transformers



102

Basic Components

Transformers

- Primary winding.
  - The winding that is connected to a signal source.
    - In special applications, there may be more than one primary.

103

Basic Components

Transformers

- Secondary winding(s).
  - The winding or windings that are connected to a load.
    - It is not unusual to have more than one secondary.

104

Basic Components

Transformers

- Transformers transfer AC power from the primary to each secondary.
- Transformers work equally well in both directions.
  - Which winding is the “primary” and which is the “secondary” depends on how the transformer is connected in the circuit.

105

Basic Components

Transformers

- Turns ratio.
  - The primary & secondary windings can have different numbers of turns (and usually do).
    - Turns Ratio = N_P:N_S.

106

Basic Components

Transformers

- Turns ratio.
  - The ratio of the voltage applied to the primary to the voltage appearing at the secondary is equal to the turns ratio.
    - Turns Ratio = E_P:E_S.
  - Consequently:
    - $E_S = E_P \times (N_S/N_P)$ and $E_P = E_S \times (N_P/N_S)$

107

Basic Components

Transformers

- Turns ratio.
  - Power input = power output (ignoring losses).
    - If $120V_{AC}$ is applied to the primary of a transformer with a turns ratio of 10:1, then the secondary voltage will be $12V_{AC}$.
    - If a 1A current is flowing in the primary, then the current flowing in the secondary will be 10A.
      - $120V_{AC} \times 1A =$ **120W** $= 12V_{AC} \times 10A$

108

G5C01 -- What causes a voltage to appear across the secondary winding of a transformer when an AC voltage source is connected across its primary winding?

A. Capacitive coupling
B. Displacement current coupling
C. Mutual inductance
D. Mutual capacitance

109

G5C02 -- What is the output voltage if an input signal is applied to the secondary winding of a 4:1 voltage step-down transformer instead of the primary winding?

A. The input voltage is multiplied by 4
B. The input voltage is divided by 4
C. Additional resistance must be added in series with the primary to prevent overload
D. Additional resistance must be added in parallel with the secondary to prevent overload

110

G5C05 -- Why is the primary winding wire of a voltage step-up transformer usually a larger size than that of the secondary winding?

A. To improve the coupling between the primary and secondary

B. To accommodate the higher current of the primary

C. To prevent parasitic oscillations due to resistive losses in the primary

D. To ensure that the volume of the primary winding is equal to the volume of the secondary winding

111

G5C06 -- What is the voltage output of a transformer with a 500-turn primary and a 1500-turn secondary when 120 VAC is applied to the primary?

A. 360 volts

B. 120 volts

C. 40 volts

D. 25.5 volts

112

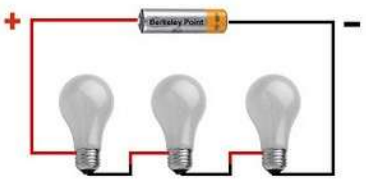
Break

113

Basic Components

Components in Series & Parallel Circuits

- Series Circuits.
  - FACT:
    - Electrons cannot be created or destroyed.
  - CONCLUSION:
    - In a series circuit the current through each component is equal.

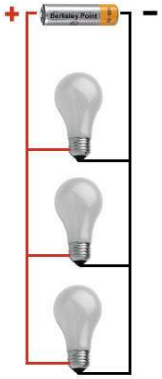


114

Basic Components

Components in Series & Parallel Circuits

- Parallel Circuits.
  - FACT:
    - There is no voltage drop across a junction (or node).
  - CONCLUSION:
    - In a parallel circuit the voltage across each component is equal.

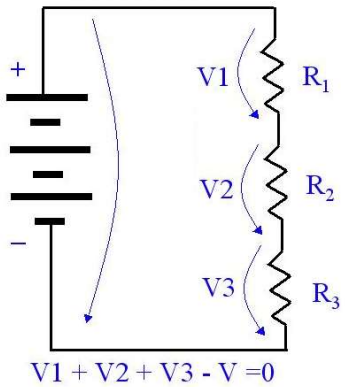


115

Basic Components

Components in Series & Parallel Circuits

- Kirchoff's Voltage Law.
  - The sum of the voltages around a loop must be zero.

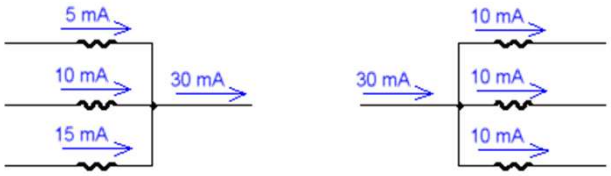


116

Basic Components

Components in Series & Parallel Circuits

- Kirchoff's Current Law.
  - The sum of all currents entering a node is equal to the sum of all currents leaving the node.



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Basic Components

Components in Series & Parallel Circuits

- Components of the same type that are connected in series or parallel can be replaced by a single component using one of the following 2 formulas:
  - $X_T = X_1 + X_2 + X_3 + \ldots . + X_n$
    - X_T is **always** greater than the highest value component.
  - $X_T = 1 / (1/X_1 + 1/X_2 + 1/X_3 + \ldots . + 1/X_n)$
    - If only 2 components: $X_T = (X_1 \times X_2) / (X_1 + X_2)$
    - If all components are the same: $X_T = X /$ (nr of components)
    - X_T is **always** less than the lowest value component.

118

Basic Components

Components in Series & Parallel Circuits

- Resistors.
  - Series: $R_T = R_1 + R_2 + R_3 + \ldots + R_n$
  - Parallel: $R_T = 1 / (1/R_1 + 1/R_2 + 1/R_3 + \ldots + 1/R_n)$
    - If only 2 resistors: $R_T = (R_1 \times R_2) / (R_1 + R_2)$
    - If all resistors are same value: $R_T = R /$ (nr of resistors)
    - Total resistance is **always** less than lowest value resistor.

119

Basic Components

Components in Series & Parallel Circuits

- Inductors.
  - Series: $L_T = L_1 + L_2 + L_3 + \ldots + L_n$
  - Parallel: $L_T = 1 / (1/L_1 + 1/L_2 + 1/L_3 + \ldots + 1/L_n)$
    - If only 2 inductors: $L_T = (L_1 \times L_2) / (L_1 + L_2)$
    - If all inductors are same value: $L_T = L /$ (nr of inductors)
    - Total inductance is **always** less than lowest value inductor.

120

Basic Components

Components in Series & Parallel Circuits

- Capacitors.
  - Series: $C_T = 1 / (1/C_1 + 1/C_2 + 1/C_3 + \ldots + 1/C_n)$
    - If only 2 capacitors: $C_T = (C_1 \times C_2) / (C_1 + C_2)$
    - If all capacitors are same value: $C_T = C /$ (nr of capacitors)
    - Total capacitance is **always** less than lowest value capacitor.
  - Parallel: $C_T = C_1 + C_2 + C_3 + \ldots + C_n$

121

Basic Components

Components in Series & Parallel Circuits

- In Summary:
  - Voltages add in a series circuit.
  - Currents add in a parallel circuit.

Component Type	Adding in Series	Adding in Parallel
Resistor	Increases Total Value	Decreases Total Value
Inductor	Increases Total Value	Decreases Total Value
Capacitor	Decreases Total Value	Increases Total Value

122

G5B02 -- How does the total current relate to the individual currents in a circuit of parallel resistors?

A. It equals the average of the branch currents
B. It decreases as more parallel branches are added to the circuit
C. It equals the sum of the currents through each branch
D. It is the sum of the reciprocal of each individual voltage drop

123

G5C03 -- What is the total resistance of a 10-, a 20-, and a 50-ohm resistor connected in parallel?

A. 5.9 ohms
B. 0.17 ohms
C. 17 ohms
D. 80 ohms

124

G5C04 -- What is the approximate total resistance of a 100- and a 200-ohm resistor in parallel?

A. 300 ohms
B. 150 ohms
C. 75 ohms
D. 67 ohms

125

G5C08 -- What is the equivalent capacitance of two 5.0-nanofarad capacitors and one 750-picofarad capacitor connected in parallel?

A. 576.9 nanofarads
B. 1,733 picofarads
C. 3,583 picofarads
D. 10.750 nanofarads

126

G5C09 -- What is the capacitance of three 100-microfarad capacitors connected in series?

A. 0.33 microfarads
B. 3.0 microfarads
C. 33.3 microfarads
D. 300 microfarads

127

G5C10 -- What is the inductance of three 10-millihenry inductors connected in parallel?

A. 0.30 henries
B. 3.3 henries
C. 3.3 millihenries
D. 30 millihenries

128

G5C11 -- What is the inductance of a circuit with a 20-millihenry inductor connected in series with a 50-millihenry inductor?

A. 7 millihenries
B. 14.3 millihenries
C. 70 millihenries
D. 1,000 millihenries

129

G5C12 -- What is the capacitance of a 20-microfarad capacitor connected in series with a 50-microfarad capacitor?

A. 0.07 microfarads
B. 14.3 microfarads
C. 70 microfarads
D. 1,000 microfarads

130

G5C13 -- Which of the following components should be added to a capacitor to increase the capacitance?

A. An inductor in series
B. An inductor in parallel
C. A capacitor in parallel
D. A capacitor in series

131

G5C14 -- Which of the following components should be added to an inductor to increase the inductance?

A. A capacitor in series
B. A capacitor in parallel
C. An inductor in parallel
D. An inductor in series

132

Reactance, Impedance, and Resonance

Reactance

- All resistors do is convert electrical energy into heat.
  - They don't care whether current is DC or AC.

133

Reactance, Impedance, and Resonance

Reactance

- Inductors & capacitors store energy.
  - They react differently to AC than to DC voltages/currents.
  - The response to an AC voltage or current is called *reactance*.
    - Unit of measurement = Ohm (Ω)
    - Symbol used in equations = X_L or X_C

134

Reactance, Impedance, and Resonance

Reactance

- Capacitive reactance.
  - $X_C = 1 / (2\pi fC)$
  - In a DC circuit (f = 0), $X_C = \infty$.
    - Capacitor looks like an open circuit.
      - After initial charging current, the current flow drops to zero.
  - At extremely high frequencies (f = ∞), $X_C = 0$.
    - Capacitor looks like a short circuit.

135

Reactance, Impedance, and Resonance

Reactance

- Capacitive Reactance
  - Reactance decreases with increasing frequency.
  - Capacitors oppose changes in voltage.
  - Capacitor looks like open circuit at 0 Hz (DC).
  - Capacitor looks like short circuit at very high frequencies.
  - A capacitor blocks DC current, resists low-frequency AC current, & passes high-frequency AC current.

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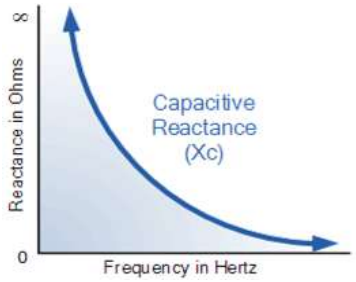
Reactance, Impedance, and Resonance

Reactance

- Capacitive Reactance



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Reactance, Impedance, and Resonance

Reactance

- Capacitive Reactance
  - When energy is first applied to a capacitor, the voltage is zero, & the current jumps to a large value.
  - As the capacitor charges up, the voltage climbs to the steady state value and the current drops to zero.

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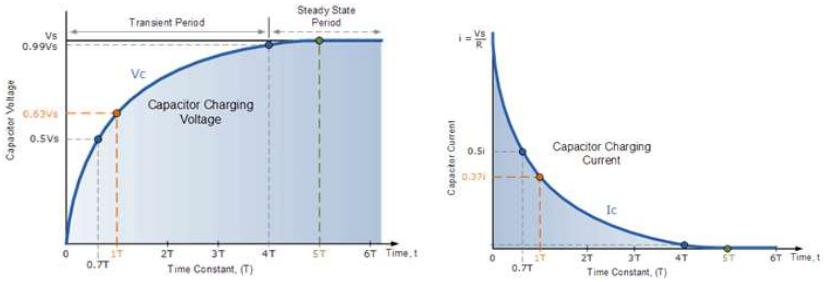
Reactance, Impedance, and Resonance

Reactance



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Reactance, Impedance, and Resonance

Reactance

- Inductive Reactance
  - $X_L = 2\pi fL$
  - In a DC circuit (f = 0), $X_L = 0$.
    - Inductor looks like a short circuit.
  - At extremely high frequencies (f = ∞), $X_L = \infty$.
    - Inductor looks like an open circuit.

140

Reactance, Impedance, and Resonance

Reactance

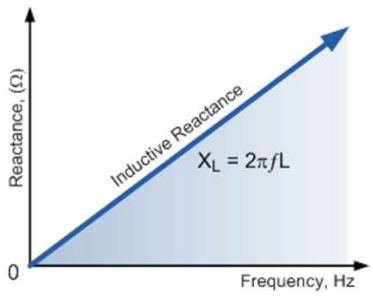
- Inductive Reactance
  - Reactance increases with increasing frequency.
  - Inductors oppose changes in current.
  - An inductor passes DC current, resists low-frequency AC current, & blocks high-frequency AC current.

141

Reactance, Impedance, and Resonance

Reactance

- Inductive Reactance



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Reactance, Impedance, and Resonance

Reactance

- Inductive Reactance
  - When energy is first applied to an inductor, the current is zero, & the voltage jumps to a large value.
  - As the inductor charges up, the current climbs to the steady state value and the voltage drops to zero.

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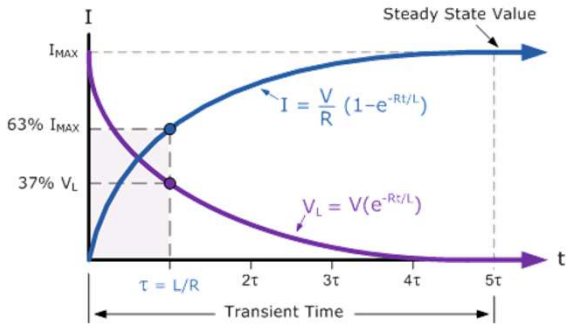
Reactance, Impedance, and Resonance

Reactance

- Inductive Reactance



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Reactance, Impedance, and Resonance

Reactance

- Parasitic inductance and capacitance.
  - Real-world components are never “pure” resistance, inductance, or capacitance.
    - They always exhibit all 3 properties.
      - Unwanted inductances or capacitances are called “parasitic”.

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Reactance, Impedance, and Resonance

Reactance

- Parasitic inductance and capacitance.
  - Parasitic inductance.
    - The leads & wires used to connect components act like inductors at high frequencies.
      - Wire-wound resistors exhibit very high inductance and should never be used in RF or other high-frequency circuits.
      - Parasitic inductance in capacitors due to internal construction or lead length can result in self-resonance at high frequencies.

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Reactance, Impedance, and Resonance

Reactance

- Parasitic inductance and capacitance.
  - Parasitic capacitance.
    - The construction of physical components results in parasitic capacitances.
      - Between turns in an inductor.
      - Between points where leads are connected to the component.

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G5A02 -- What is reactance?

A. Opposition to the flow of direct current caused by resistance

B. Opposition to the flow of alternating current caused by capacitance or inductance

C. Reinforcement of the flow of direct current caused by resistance

D. Reinforcement of the flow of alternating current caused by capacitance or inductance

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G5A03 -- Which of the following is opposition to the flow of alternating current in an inductor?

A. Conductance
B. Reluctance
C. Admittance
D. Reactance

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G5A04 -- Which of the following is opposition to the flow of alternating current in a capacitor?

A. Conductance
B. Reluctance
C. Reactance
D. Admittance

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G5A05 -- How does an inductor react to AC?

A. As the frequency of the applied AC increases, the reactance decreases
B. As the amplitude of the applied AC increases, the reactance increases
C. As the amplitude of the applied AC increases, the reactance decreases
D. As the frequency of the applied AC increases, the reactance increases

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G5A06 -- How does a capacitor react to AC?

A. As the frequency of the applied AC increases, the reactance decreases
B. As the frequency of the applied AC increases, the reactance increases
C. As the amplitude of the applied AC increases, the reactance increases
D. As the amplitude of the applied AC increases, the reactance decreases

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G5A09 -- What unit is used to measure reactance?

A. Farad
B. Ohm
C. Ampere
D. Siemens

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G6A06 -- Why should wire-wound resistors not be used in RF circuits?

A. The resistor's tolerance value would not be adequate
B. The resistor's inductance could make circuit performance unpredictable
C. The resistor could overheat
D. The resistor's internal capacitance would detune the circuit

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Reactance, Impedance, and Resonance

Impedance and resonance

- The opposition to AC current flow caused by resistance, capacitive reactance, inductive reactance, or any combination thereof is called *impedance*.
  - Unit of measurement = Ohm (Ω)
  - Symbol used in equations = Z.

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Reactance, Impedance, and Resonance

Impedance and resonance

- The inverse of impedance is called admittance.
  - Unit of measurement = Siemens (S)
  - Symbol used in equations = Y.
  - Y = 1/Z

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Reactance, Impedance, and Resonance

Resonance

- A condition when the frequency of the applied signal matches the “natural” frequency of a circuit.

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Reactance, Impedance, and Resonance

Resonance

- At the resonant frequency, the inductive & capacitive reactances are equal and cancel each other out, leaving a purely resistive impedance.

$X_L = X_C \rightarrow 2\pi fL = 1 / (2\pi fC) \rightarrow f_R = 1 / \sqrt{2\pi LC}$

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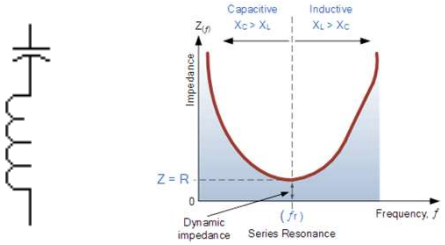
Reactance, Impedance, and Resonance

Resonance

- In a series L-C circuit, the impedance is very low at resonance.



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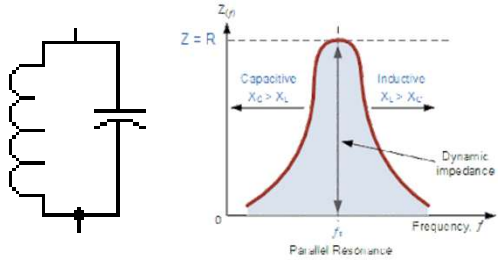
Reactance, Impedance, and Resonance

Resonance

- In a parallel L-C circuit, the impedance is very high at resonance.



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Reactance, Impedance, and Resonance

Resonance

- Resonant circuits are used in:
  - Filters.
  - Tuned stages in receivers & transmitters.
  - Antennas & Traps.

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Reactance, Impedance, and Resonance

Resonance

- Parasitic inductances & capacitances can cause a component to become “self-resonant” & lead to unwanted behavior.
  - Above the self-resonant frequency:
    - An inductor acts like a capacitor.
    - A capacitor act like an inductor.

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Reactance, Impedance, and Resonance

Impedance Transformation

- In a DC circuit, resistance is calculated using Ohm's Law:

  $R = E / I$

- Similarly, in an AC circuit, impedance is also calculated using Ohm's Law:

  $Z = E / I$

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Reactance, Impedance, and Resonance

Impedance Transformation

- Since a transformer changes the voltage & current levels in an AC circuit, it also changes the impedance.
  - Impedance is calculated from the turns ratio (N_P/N_S) using the following formulas:
    - $Z_P = Z_S \times (N_P/N_S)^2$
    - $Z_S = Z_P \times (N_S/N_P)^2$

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Reactance, Impedance, and Resonance

Impedance Transformation

- The turns ratio required for a specific impedance transformation is calculated using the following formula:

$$\text{Turns Ratio } (N_P/N_S) = \sqrt{Z_P/Z_S}$$

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Reactance, Impedance, and Resonance

Impedance Matching

- All power sources have an internal impedance which limits the amount of power that can be delivered.
- Maximum power is delivered only when the load impedance matches the source impedance.
  - $Z_S = Z_L$

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Reactance, Impedance, and Resonance

Impedance Matching

- Most modern amateur transmitting equipment is designed to have a source impedance of 50 Ohms.
- Therefore, the load impedance should be 50 Ohms for maximum power transfer to the load.
- This is not usually the case!

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Reactance, Impedance, and Resonance

Impedance Matching

- Antenna impedance varies from one frequency to another.
- A matching network is needed to transform the antenna system impedance to a 50Ω resistive load.

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Reactance, Impedance, and Resonance

Impedance Matching

- Types of matching networks:
  - L-C circuits.
    - Most common type.
  - Lengths of transmission line.
  - Transformers.
    - Cannot eliminate reactance.

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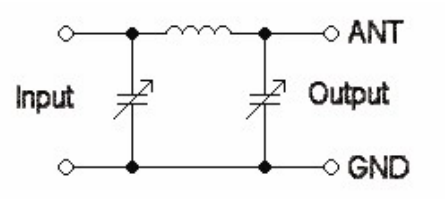
Reactance, Impedance, and Resonance

Impedance Matching

- Pi-Network.
  - Often used in transmitter output stages to provide 50Ω source impedance.



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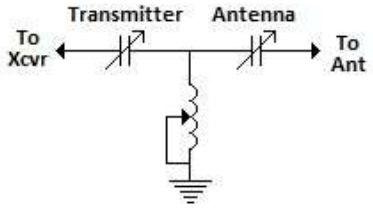
Reactance, Impedance, and Resonance

Impedance Matching

- T-Network.
  - Most common circuit for antenna tuners or "Transmatches".



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G5A01 -- What happens when inductive and capacitive reactance are equal in a series LC circuit?

A. Resonance causes impedance to be very high
B. Impedance is equal to the geometric mean of the inductance and capacitance
C. Resonance causes impedance to be very low
D. Impedance is equal to the arithmetic mean of the inductance and capacitance

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G5A07 -- What is the term for the inverse of impedance?

A. Conductance
B. Susceptance
C. Reluctance
D. Admittance

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G5A08 -- What is impedance?

A. The ratio of current to voltage
B. The product of current and voltage
C. The ratio of voltage to current
D. The product of current and reactance

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G5A10 -- Which of the following devices can be used for impedance matching at radio frequencies?

A. A transformer
B. A Pi-network
C. A length of transmission line
D. All these choices are correct

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G5A11 -- What letter is used to represent reactance?

A. Z
B. X
C. B
D. Y

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G5A12 -- What occurs in an LC circuit at resonance?

A. Current and voltage are equal
B. Resistance is cancelled
C. The circuit radiates all its energy in the form of radio waves
➡ D. Inductive reactance and capacitive reactance cancel

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G5C07 -- What transformer turns ratio matches an antenna's 600-ohm feed point impedance to a 50-ohm coaxial cable?

➡ A. 3.5 to 1
B. 12 to 1
C. 24 to 1
D. 144 to 1

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G6A11 -- What happens when an inductor is operated above its self-resonant frequency?

A. Its reactance increases
B. Harmonics are generated
C. It becomes capacitive
D. Catastrophic failure is likely

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Questions?

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General License Class

Next Week

Chapter 4

Components & Circuits

(Part 2)

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