General License Class

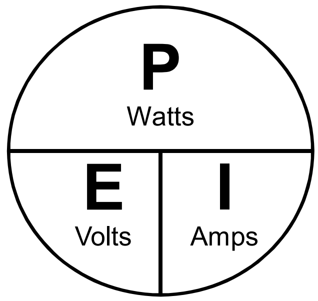
Chapter 4
Components & Circuits
(Part 1)

Electrical Review

- Current, Voltage, & Power
  - Current (I)
    - Movement of electrons past a given point.
    - Unit of Measurement = Ampere (A)
      - 1 Ampere = 6.241×10^{18} electrons/second
  - Voltage (E)
    - Electromotive Force
    - Unit of Measurement = Volt (V)
  - Power (P)
    - Rate of at which energy is transferred, used, or transformed.
    - Unit of Measurement = Watt (W)

Electrical Review

Power Formula



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

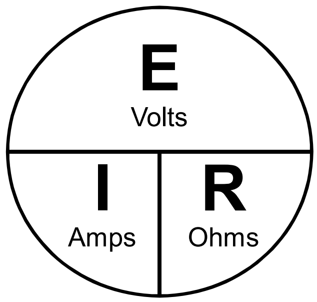
Electrical Review

- Resistance & Ohm's Law
  - Resistance (R)
    - Opposition to movement of electrons.
    - Unit of Measurement = Ohm (Ω).
  - Voltage, current, & resistance are all related by Ohm's Law.

Voltage = Current x Resistance

Electrical Review

Ohm’s Law



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

Electrical Review

- 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:
    - $P = E^2 / R$
    - $P = I^2 \times R$

Electrical Review

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

Electrical Review

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

Electrical Review

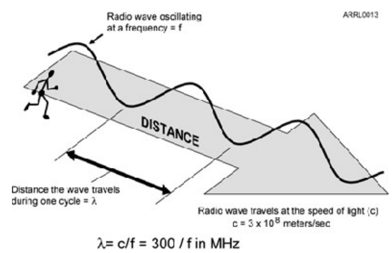
- AC and DC Waveforms
  - Frequency
    - Rate at which voltage changes polarity or current changes direction.
    - Unit of Measurement = Hertz (Hz).
      - 1 Hz = 1 cycle per second.

Electrical Review

- AC and DC Waveforms
  - Wavelength
    - Radio waves travel at the speed of light.
      - 186,000 miles/second
      - 300,000,000 meters/second
        - 300×10^6 meters/second

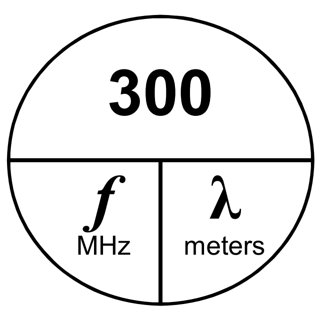
Electrical Review

- AC and DC Waveforms
  - Wavelength
    - The distance a radio wave travels during the time it takes to complete one cycle.



Electrical Review

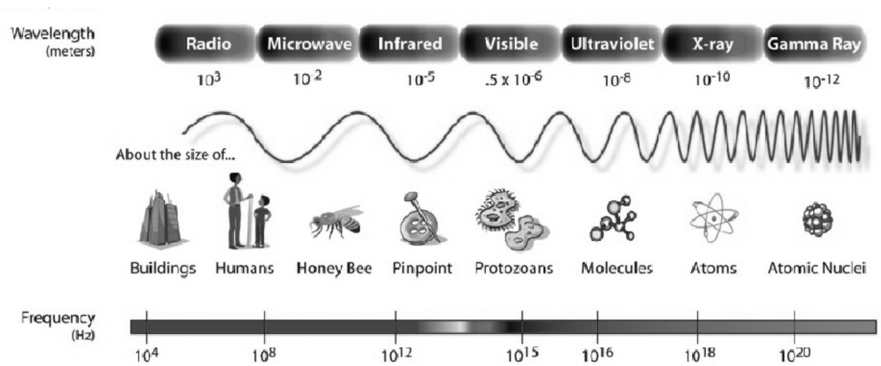
Wavelength



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

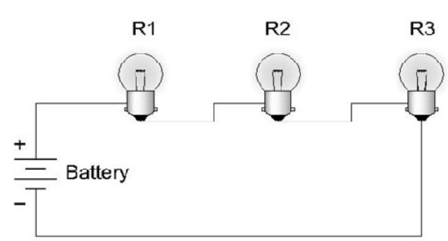
Electrical Review

- AC and DC Waveforms
  - Electromagnetic Spectrum



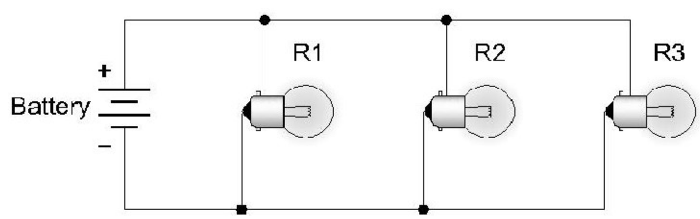
Electrical Review

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



Electrical Review

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



Electrical Review

- Decibels
  - Measures a ratio.
    - Logarithmic scale.
    - Power Ratio:
      - $dB = 10 \log_{10} (P_1/P_2)$
    - Voltage Ratio:
      - $dB = 20 \log_{10} (V_1/V_2)$

Electrical Review

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

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

A. Approximately 2 dB
B. Approximately 3 dB
C. Approximately 6 dB
D. Approximately 12 dB

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

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

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

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

G5B05 -- How many watts are dissipated when a current of 7.0 milliamperes flows through 1.25 kilohms?

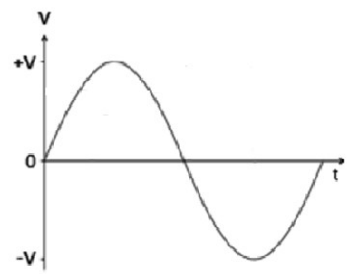
A. Approximately 61 milliwatts
B. Approximately 61 watts
C. Approximately 11 milliwatts
D. Approximately 11 watts

G5B10 -- What percentage of power loss would result from a transmission line loss of 1 dB?

A. 10.9%
B. 12.2%
C. 20.5%
D. 25.9%

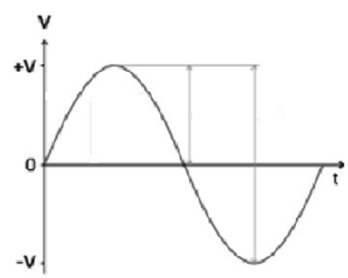
AC Power

- RMS: Definition and Measurement
  - A DC voltmeter will read the average voltage, which is zero.



AC Power

- RMS: Definition and Measurement
  - With an oscilloscope, it is easy to read the peak-to-peak voltage or the peak (maximum) voltage.

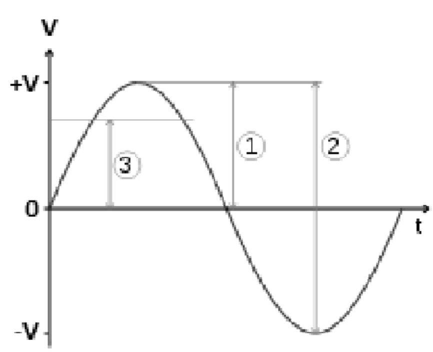


AC Power

- 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 does is the root-mean-square (RMS) value of the AC current.
    - $I_{RMS} = 0.707 \times I_P$
    - $V_{RMS} = 0.707 \times V_P$
    - **Sine waves ONLY!**

AC Power

- RMS: Definition and Measurement

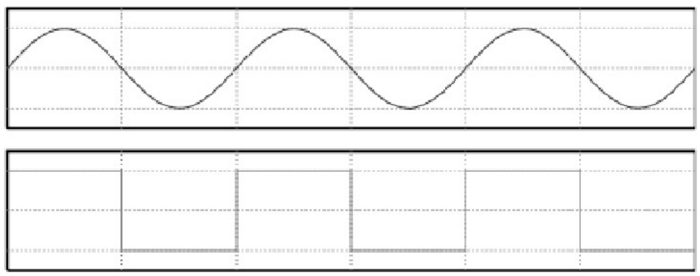


1 = Peak
2 = Peak-to-Peak
3 = Root-Mean-Square (RMS)

AC Power

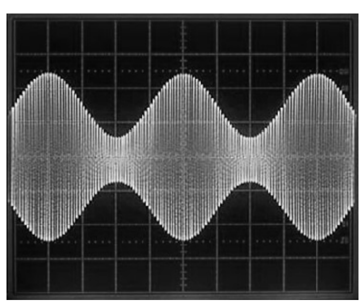
- RMS: Definition and Measurement

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



AC Power

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



AC Power

- PEP: Definition and Measurement
  - PEP = Peak Envelope Power
    - 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 imdepance.
      - $PEP = V_{RMS}^2 / R_{load}$
  - PEP is equal to the average power if no modulation or if FM-modulated.

G5B06 -- What is the output PEP from a transmitter if an oscilloscope measures 200 volts peak-to-peak across a 50-ohm dummy load connected to the transmitter output?

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

G5B07 -- Which value of an AC signal results in the same power dissipation 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

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

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

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

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

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

G5B13 -- What is the output PEP of an unmodulated carrier if an average reading wattmeter connected to the transmitter output indicates 1060 watts?

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

G5B14 -- What is the output PEP from a transmitter if an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output?

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

Basic Components

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

Basic Components

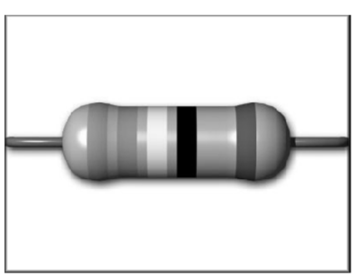
- Resistors & Resistance
  - Resistance
    - Opposition to the flow of electrons.
    - Converts electrical energy to heat.
    - Unit of measurement = Ohm (Ω).
    - Symbol used in equations = R.
    - Components designed to provide resistance are called “resistors”.

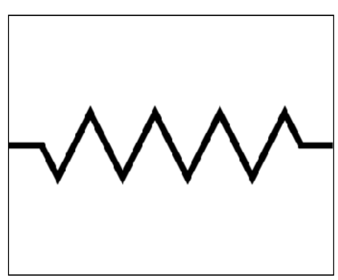
Basic Components

- Resistors & Resistance
  - Resistors
    - Resistances range from <1 Ω to >10 MΩ
      - Ω = ohms
      - kΩ = kilohms (10^3 ohms)
      - MΩ = megohms (10^6 ohms)
    - 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.

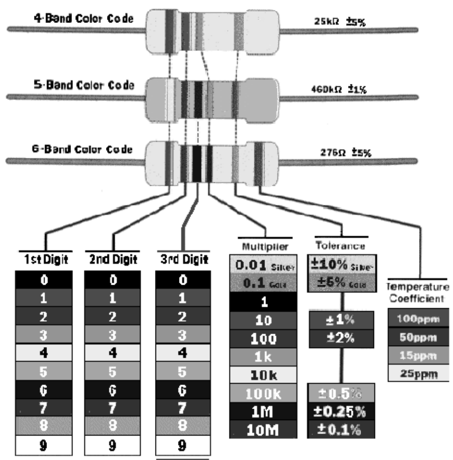
Basic Components

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





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
* Tolerance & multiplier only	

Basic Components

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

Basic Components

- Resistors & Resistance
  - Resistor types
    - Carbon film.
      - 1 Ω to 10 MΩ.
      - 1/8 to 5 Watts.
      - Wide operating temperature range.

Basic Components

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

Basic Components

- Resistors & Resistance
  - Resistor types
    - Metal-oxide film.
      - Similar to metal film.
      - Higher operating temperatures.
      - Higher temperature stability.
      - Low stray inductance.
        - Good for RF circuits.

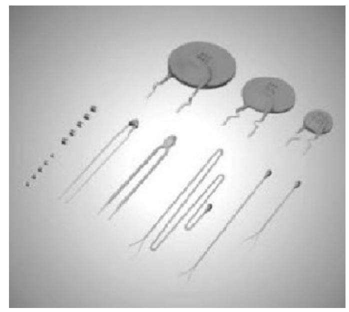
Basic Components

- 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.



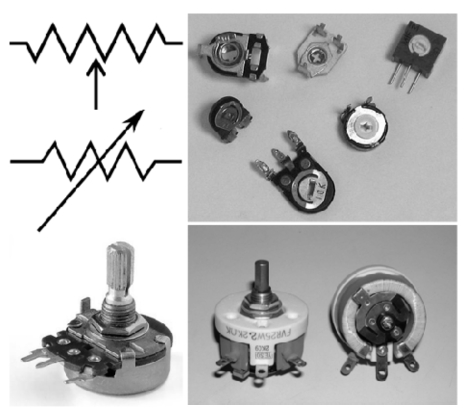
Basic Components

- 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.



Basic Components

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

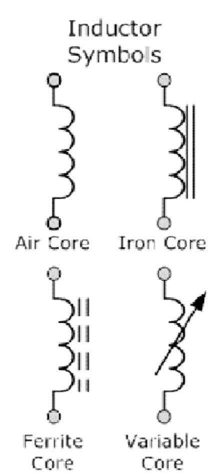


Basic Components

- 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.

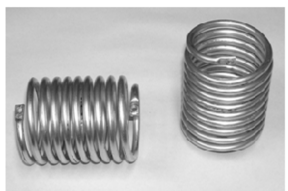
Basic Components

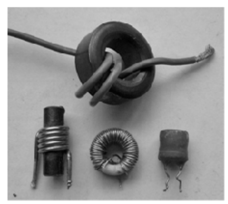
- Inductors & Inductance
  - Inductance.
    - Ability to store energy in a magnetic field.
    - Opposes a change in current flow.
    - Unit of Measurement = Henry (H)
    - Symbol used in equations = L.
    - Components designed to provide inductance are called "inductors" or "coils".



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)





Basic Components

- Inductors & Inductance
  - Inductors.
    - Different shapes.
      - Solenoidal
      - Toroidal.

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 or ferrite.
        - Used in medium-inductance applications.
      - Air.
        - Used in low-inductance, high-frequency applications such as transmitting coils.

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

Basic Components

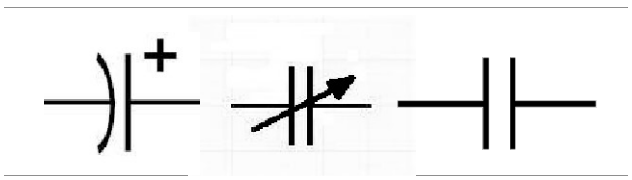
- Inductors & Inductance
  - Inductors.
    - At high frequencies, inter-turn capacitance can become significant.
      - Inductor can become self-resonant.

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”.

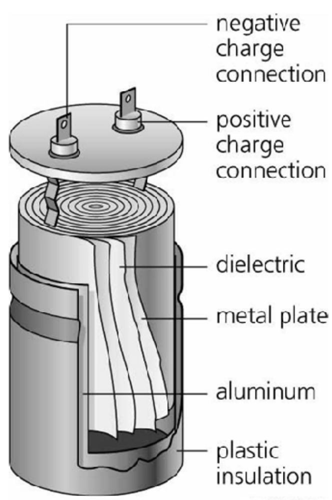
Basic Components

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



Basic Components

- Capacitors & Capacitance
  - Capacitors.
    - Two conducting plates separated by an insulator.
      - The larger the plates, the higher the capacitance.
      - The closer the plates, the higher the capacitance.
      - The higher the dielectric constant of the insulator, the higher the capacitance.

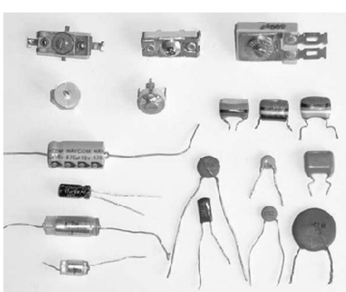


Basic Components

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

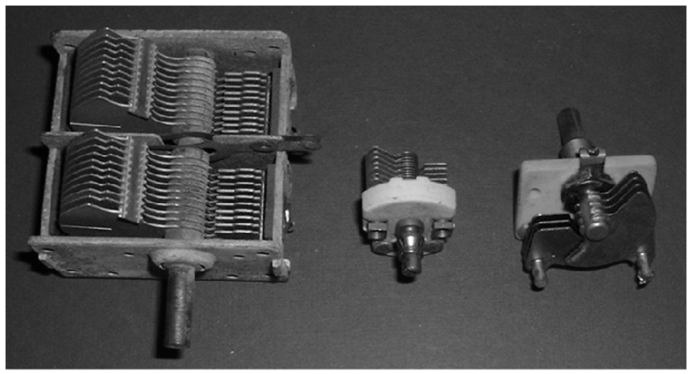
Basic Components

- Capacitors & Capacitance
  - Capacitors.



Basic Components

- Capacitors & Capacitance
  - Variable Capacitors.



Basic Components

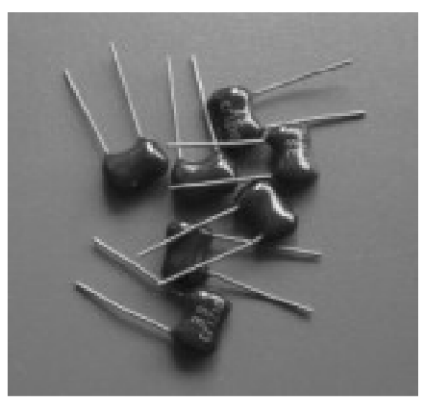
- Capacitors & Capacitance
  - Types of Capacitors.
    - Air / Vacuum.
    - Mica / Silver Mica.
    - Ceramic.
    - Plastic Film (Polystyrene or Mylar).
    - Paper.
    - Oil-filled.
    - Electrolytic / Tantalum.

Basic Components

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

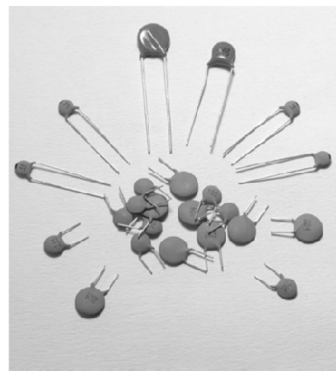
Basic Components

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

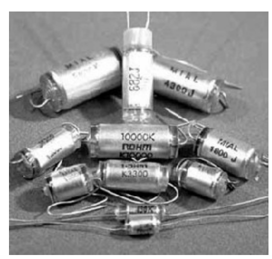


Basic Components

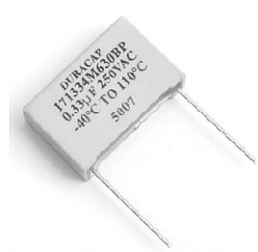
- Capacitors & Capacitance
  - Types of Capacitors.
    - Ceramic.
      - Inexpensive.
      - Wide range of capacitances available.
      - Low to high voltage ratings available.
      - RF bypassing & filtering.



Basic Components

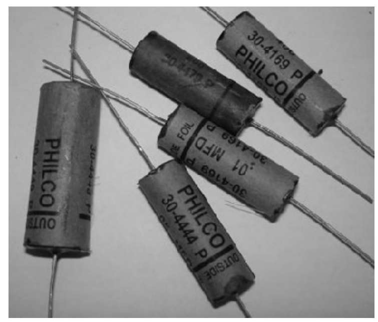


- Capacitors & Capacitance
  - Types of Capacitors.
    - Plastic Film
      - Polystyrene or Mylar.
      - AF & lower frequencies.
      - Susceptible to damage from high temperatures.



Basic Components

- Capacitors & Capacitance
  - Types of Capacitors.
    - Paper.
      - Obsolete.
      - Found in antique equipment.



Basic Components

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

Basic Components

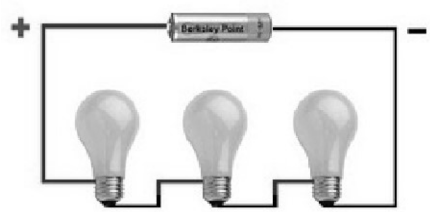
- Capacitors & Capacitance
  - Types of Capacitors.
    - Electrolytic / Tantalum.
      - Polarized.
      - High capacitance in physically small size.
      - Power supply filters.
      - Low-impedance AF coupling.

Basic Components

- Components in Series & Parallel Circuits
  - Kirchoff's Voltage Law: The sum of the voltages around a loop must be zero.
  - Kirchoff's Current Law: The sum of all currents entering a node is equal to the sum of all currents leaving the node.

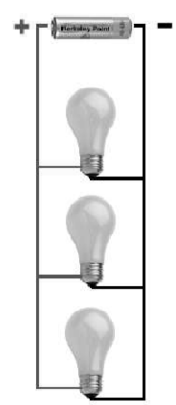
Basic Components

- 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.



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.



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 **always** less than lowest value resistor.

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 **always** less than lowest value inductor.

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 **always** less than lowest value capacitor.
    - Parallel: $C_T = C_1 + C_2 + C_3 + \ldots + C_n$

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

Basic Components

- Transformers
  - Two or more inductors wound on a common core to maximize mutual inductance.
    - Inductors are called “windings”.
    - A winding connected to a signal source is called a “primary”.
      - In special applications, there may be more than one primary.
    - A winding connected to a load is called a “secondary”.
      - It is common to have more than one secondary.

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.

Basic Components

- Transformers
  - Turns ratio.
    - The primary & secondary windings can have different numbers of turns (and usually do).
      - Turns Ratio = N_P:N_S.
    - 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:
      - $E_S = E_P \times (N_P/N_S)$ and $E_P = E_S \times (N_S/N_P)$

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.
      - $120V_{AC}$ x 1A = **120W** = $12V_{AC}$ x 10A

G5B02 -- How does the total current relate to the individual currents in each branch of a purely resistive parallel circuit?

A. It equals the average of each branch current
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

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

G5C02 -- What happens if you reverse the primary and secondary windings of a 4:1 voltage step down transformer?

A. The secondary voltage becomes 4 times the primary voltage
B. The transformer no longer functions as it is a unidirectional device
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

G5C03 -- Which of the following components should be added to an existing resistor to increase the resistance?

A. A resistor in parallel
B. A resistor in series
C. A capacitor in series
D. A capacitor in parallel

G5C04 -- What is the total resistance of three 100-ohm resistors in parallel?

A. .30 ohms
B. .33 ohms
C. 33.3 ohms
D. 300 ohms

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

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

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

A. 576.9 picofarads
B. 1733 picofarads
C. 3583 picofarads
D. 10750 picofarads

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

A. .30 microfarads
B. .33 microfarads
C. 33.3 microfarads
D. 300 microfarads

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

A. .30 Henrys
B. 3.3 Henrys
C. 3.3 millihenrys
D. 30 millihenrys

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

A. .07 millihenrys
B. 14.3 millihenrys
C. 70 millihenrys
D. 1000 millihenrys

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

A. .07 microfarads
B. 14.3 microfarads
C. 70 microfarads
D. 1000 microfarads

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

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

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

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

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

A. 5.9 ohms
B. 0.17 ohms
C. 10000 ohms
D. 80 ohms

G5C16 -- Why is the conductor of the primary winding of many voltage step up transformers larger in diameter than the conductor 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 insure that the volume of the primary winding is equal to the volume of the secondary winding

G5C17 -- What is the value in nanofarads (nF) of a 22,000 pF capacitor?

A. 0.22 nF
B. 2.2 nF
C. 22 nF
D. 220 nF

G5C18 -- What is the value in microfarads of a 4700 nanofarad (nF) capacitor?

A. 47 µF
B. 0.47 µF
C. 47,000 µF
D. 4.7 µF

G6A13 -- Why is the polarity of applied voltages important for polarized capacitors?

A. Incorrect polarity can cause the capacitor to short-circuit
B. Reverse voltages can destroy the dielectric layer of an electrolytic capacitor
C. The capacitor could overheat and explode
D. All of these choices are correct

G6A14 -- Which of the following is an advantage of ceramic capacitors as compared to other types of capacitors?

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

G6A15 -- Which of the following is an advantage of an electrolytic capacitor?

A. Tight tolerance
B. Non-polarized
C. High capacitance for given volume
D. Inexpensive RF capacitor

G6A16 -- What will happen to the resistance if the temperature of a resistor is increased?

A. It will change depending on the resistor’s reactance coefficient
B. It will stay the same
C. It will change depending on the resistor's temperature coefficient
D. It will become time dependent

G6A17 -- Which of the following is a reason not to use wire-wound resistors in an RF circuit?

A. The resistor's tolerance value would not be adequate for such a circuit
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

G6A18 -- 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

G6A19 -- How should the winding axes of two solenoid inductors be oriented to minimize their mutual inductance?

A. In line
B. Parallel to each other
C. At right angles to each other
D. Interleaved

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

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

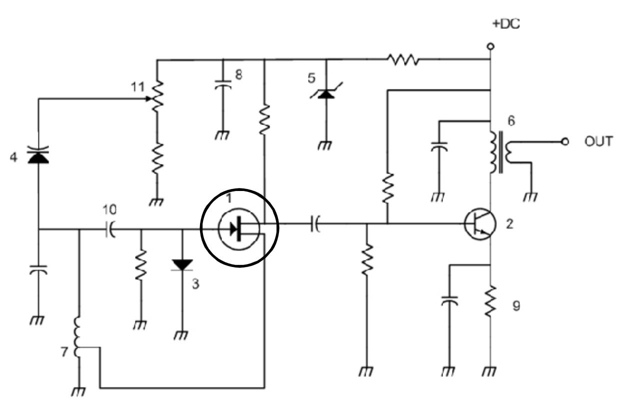


Figure G7-1

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

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

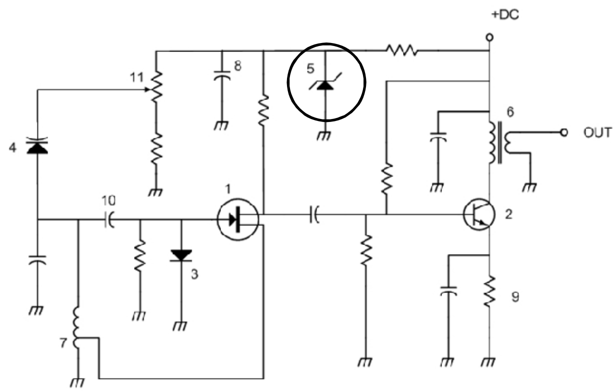


Figure G7-1

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

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

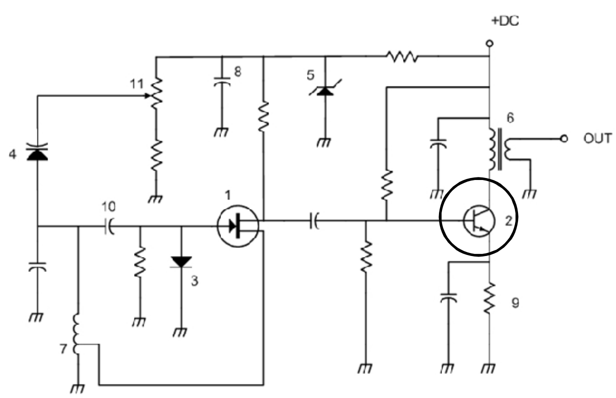


Figure G7-1

G7A12 -- Which symbol in Figure G7-1 represents a multiple-winding transformer?

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

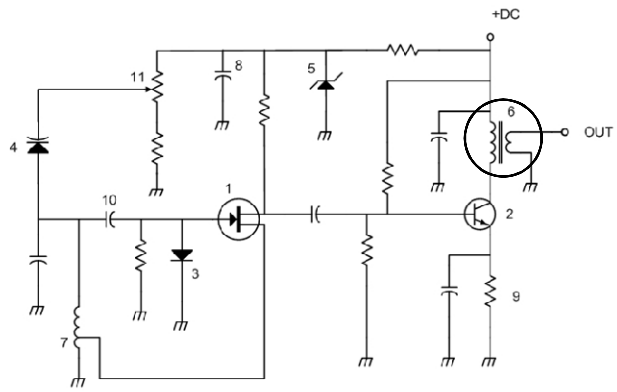


Figure G7-1

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

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

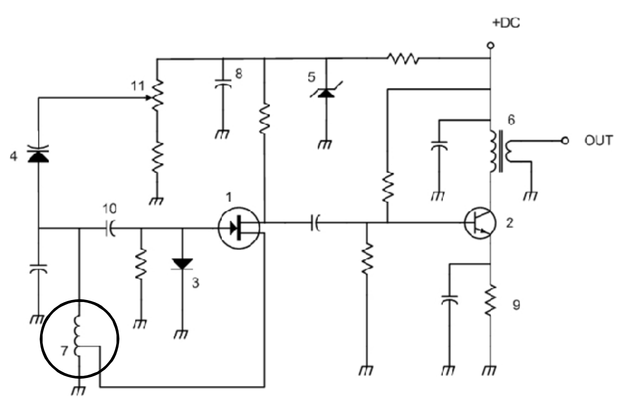


Figure G7-1

Break

Reactance & Impedance

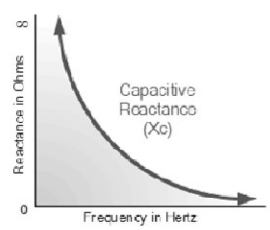
- Reactance
  - All resistors do is convert electrical energy into heat.
    - They don't care whether current is DC or AC.
  - Inductors & capacitors store energy.
    - React differently to AC than to DC voltages/currents.
    - Response to an AC voltage or current is called "reactance".
      - Unit of measurement = Ohm (Ω)
      - Symbol used in equations = X_L or X_C

Reactance & Impedance

- 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 ($f = \infty$), $X_C = 0$.
      - Capacitor looks like a short circuit.

Reactance & Impedance

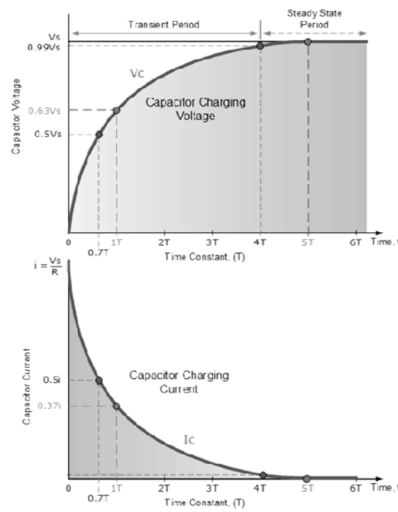
- Reactance
  - Capacitive Reactance



    - XC = 1 / (2πfC)
    - Reactance decreases with increasing frequency.
    - Capacitors oppose change 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.

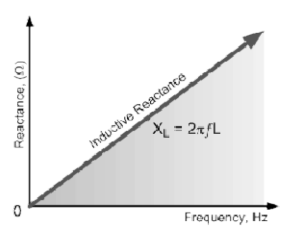
Reactance & Impedance

- 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.



Reactance & Impedance

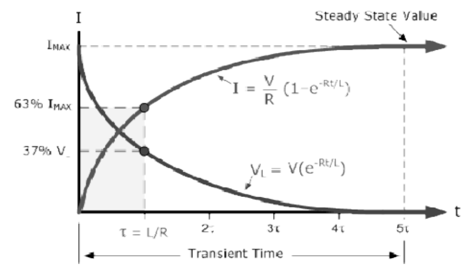
- Reactance
  - Inductive Reactance
    - $X_L = 2\pi fL$



- Reactance increases with increasing frequency.
- Inductors oppose change in current.
- Inductor looks like a short circuit at 0 Hz (DC).
- Inductor looks like an open circuit at very high frequencies.
- An inductor passes DC current, resists low-frequency AC current, & blocks high-frequency AC current.

Reactance & Impedance

- 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.



Reactance & Impedance

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

Reactance & Impedance

- Resonance
  - Condition when frequency of applied signal matches “natural” frequency of circuit.
  - At the resonant frequency, the inductive & capacitive reactances are equal and cancel each other out, leaving a purely resistive impedance.

$$X_L = X_C \rightarrow 2\pi f L = 1 / (2\pi f C) \rightarrow f = 1 / \sqrt{2\pi LC}$$

Reactance & Impedance

- Resonance
  - Resonant circuits are used in:
    - Filters.
    - Tuned stages in receivers & transmitters.
    - Antennas & Traps.
  - Parasitic inductances & capacitances can cause a component to become “self-resonant” & lead to unwanted behavior.

Reactance & Impedance

- 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:
  - $Z = E / I$

Reactance & Impedance

- 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:
      - $Z_P = Z_S \times (N_P/N_S)^2$
      - $Z_S = Z_P \times (N_S/N_P)^2$
  - The required turns ratio is calculated using the following formula:
      - Turns Ratio (N_S/N_P) = $\sqrt{Z_P/Z_S}$

Reactance & Impedance

- 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.
    - $Z_S = Z_L$

Reactance & Impedance

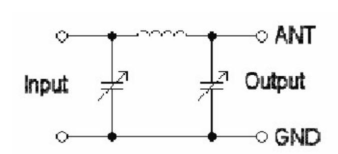
- Impedance Matching
  - Most modern amateur transmitting equipment is designed to have a source impedance of 50 Ohms.
    - $Z_S = 50\ \Omega$
  - Therefore, load impedance should be 50 Ohms for maximum power transfer to the load.
    - $Z_L = 50\ \Omega$
  - This is not usually the case!

Reactance & Impedance

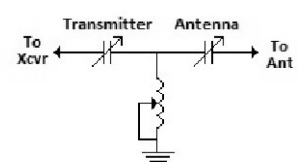
- Impedance Matching
  - Antenna impedance varies from one frequency to another.
  - A matching network is needed to transform the antenna system impedance to a 50Ω resistive load.
    - L-C circuits.
      - Most common type.
    - Lengths of transmission line.
    - Transformers.
      - Cannot eliminate reactance.

Reactance & Impedance

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



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



G5A01 -- What is impedance?

A. The electric charge stored by a capacitor
B. The inverse of resistance
C. The opposition to the flow of current in an AC circuit
D. The force of repulsion between two similar electric fields

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. A property of ideal resistors in AC circuits
D. A large spark produced at switch contacts when an inductor is de-energized

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

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

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

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

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

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

G5A07 -- What happens when the impedance of an electrical load is equal to the output impedance of a power source, assuming both impedances are resistive?

A. The source delivers minimum power to the load
B. The electrical load is shorted
C. No current can flow through the circuit
D. The source can deliver maximum power to the load

G5A08 -- Why is impedance matching important?

A. So the source can deliver maximum power to the load
B. So the load will draw minimum power from the source
C. To ensure that there is less resistance than reactance in the circuit
D. To ensure that the resistance and reactance in the circuit are equal

G5A09 -- What unit is used to measure reactance?

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

G5A10 -- What unit is used to measure impedance?

A. Volt
B. Ohm
C. Ampere
D. Watt

G5A11 -- Which of the following describes one method of impedance matching between two AC circuits?

A. Insert an LC network between the two circuits
B. Reduce the power output of the first circuit
C. Increase the power output of the first circuit
D. Insert a circulator between the two circuits

G5A12 -- What is one reason to use an impedance matching transformer?

A. To minimize transmitter power output
B. To maximize the transfer of power
C. To reduce power supply ripple
D. To minimize radiation resistance

G5A13 -- 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 of these choices are correct

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

Questions?

Next Week

Chapter 4

Components & Circuits

(Part 2)