# CDL Presents
# Basic Electronics

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# Joe's Background



- Licensed since 1961
  - Extra Class - WA2SFF
- Electrical Engineer
- Co-author of three books on Wireless Communications

# Outline



- Week 1
  - DC circuits
  - Basic formulas
  - AC circuits
  - Basic Parts
- Week 2:
  - Diodes
  - Transistors
- Week 3:
  - Analog Integrated Circuits
- Week 4:
  - Digital Integrated Circuits

# Week 1

Basic Circuits and Formulas



June 2025

# DC circuits

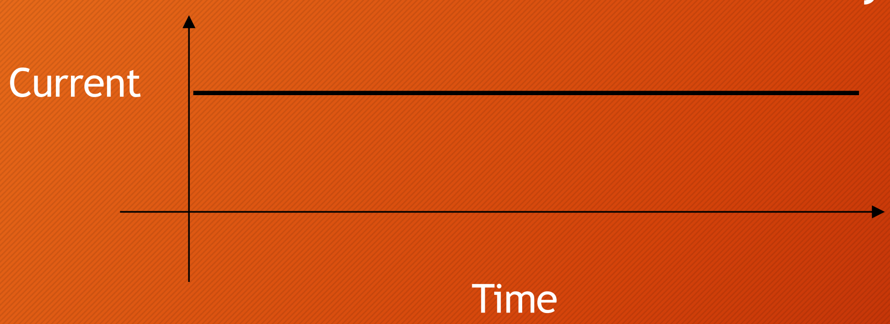


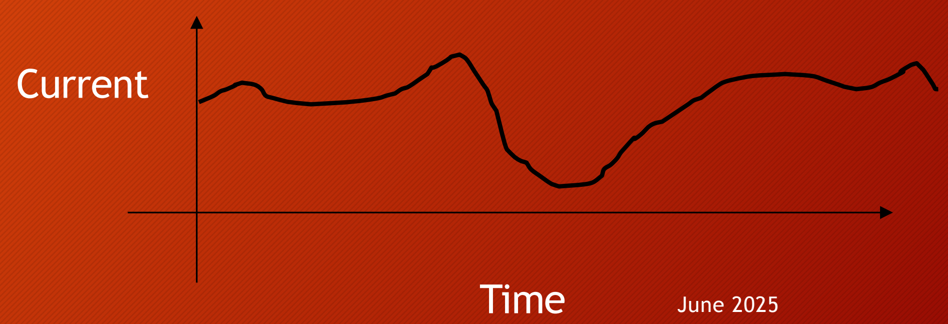
- Voltage
- Resistors
- Current
- Power
- Ohms Law
- Series and Parallel circuits

# Direct Current (DC)



- DC means that the current flows in the same direction at all times
- The current can vary with time but is always the same direction
- Current flows from a negative terminal to a positive terminal
- The current flow is electrons moving through a wire or other device that conducts electricity



# Definitions

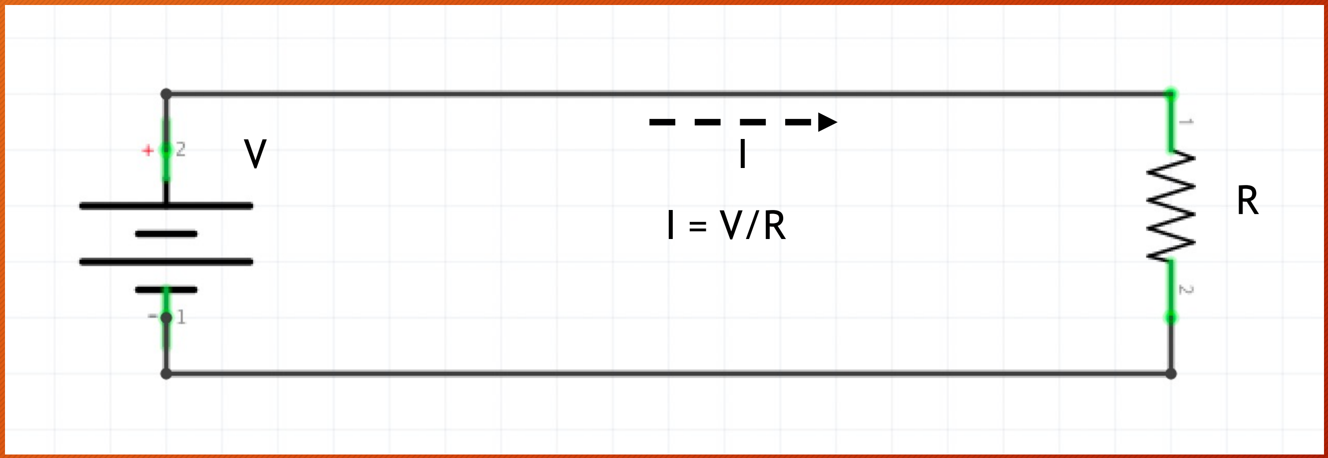


- The Voltage (V - Volts) is a measure of the strength of an electrical signal
- The Amperage/Current (I, i - Amps) is a measure of the flow of the electrical signal
- A Resistor (R - Ohms) regulates the current for a specified Voltage
- Power (P – Watts) is the heating effect of current flowing through a resistor
- Ohms Law: V = I x R, or I = V/R, or R = V/I
- P = I x I x R = ($I^2$ x R)

# Simple DC Circuit



Battery




Resistor

# Resistor Types



- Most electronic resistors are made with carbon with sizes of:
  - 1/8 watt
  - 1/4 Watt
  - 1/2 Watt
  - 1 Watt
  - 2 Watts
- Old radio circuits used carbon resistors
- Newer resistors are metal film and often cause problems in radio circuits
- Try to find "old" carbon resistors when working with old radios
- Larger resistors are often made with wire
- Resistors can be a fixed or variable (adjustable) resistance

# Resistors Come in Many Different Forms



# Resistor Color Code

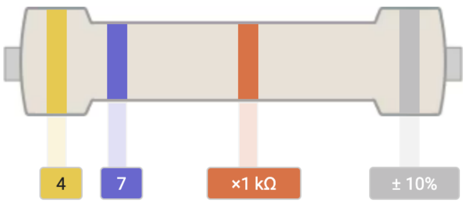


- Value:
- 0 Black
- 1 Brown
- 2 Red
- 3 Orange
- 4 Yellow
- 5 Green
- 6 Blue
- 7 Violet
- 8 Grey
- 9 White

- Tolerance
- 1 % Brown
- 5 % Gold
- 10 % Silver
- 20 % nothing

There are various ditties for remembering the color code

Find your favorite using a search engine




**Resistor value:**

**47k Ohms 10%**

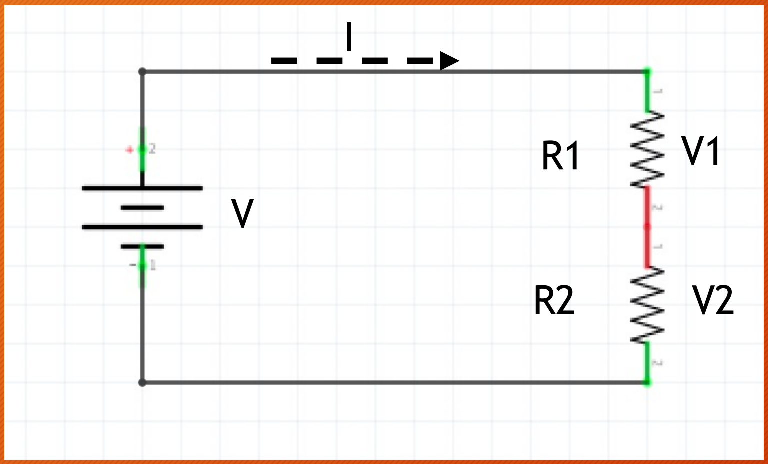


https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code

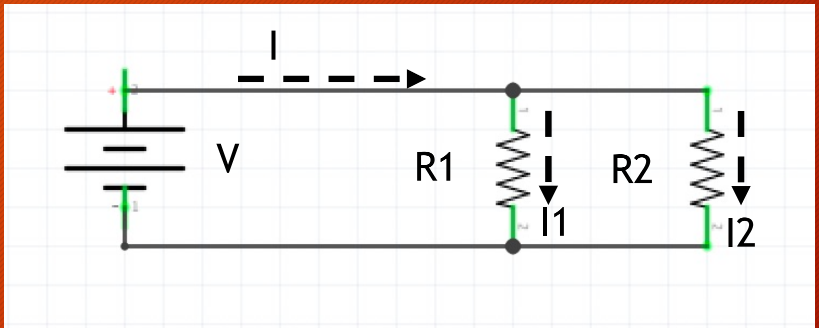
# Series and Parallel Circuits



Series Circuit




Parallel Circuit




I = V/(R1+R2)  V1=$\frac{VXR1}{R1+R2}$  V2=$\frac{VXR2}{R1+R2}$

Equivalent Resistance =R1+R2

$I1 = \frac{V}{R1}$  $I2 = \frac{V}{R2}$  $I = I1 + I2$

Equivalent Resistance =$\frac{R1XR2}{R1+R2}$

# How do we measure Voltage and Current?



- We measure with a:
  - Volt Ohm Meter (VOM), or
  - Multimeter
- It measures
  - Volts
  - Amps
  - Ohms
  - Sometime other things



# AC circuits



- Frequency
- Capacitors
- Inductors
- Power Factor
- Resonance
- Q

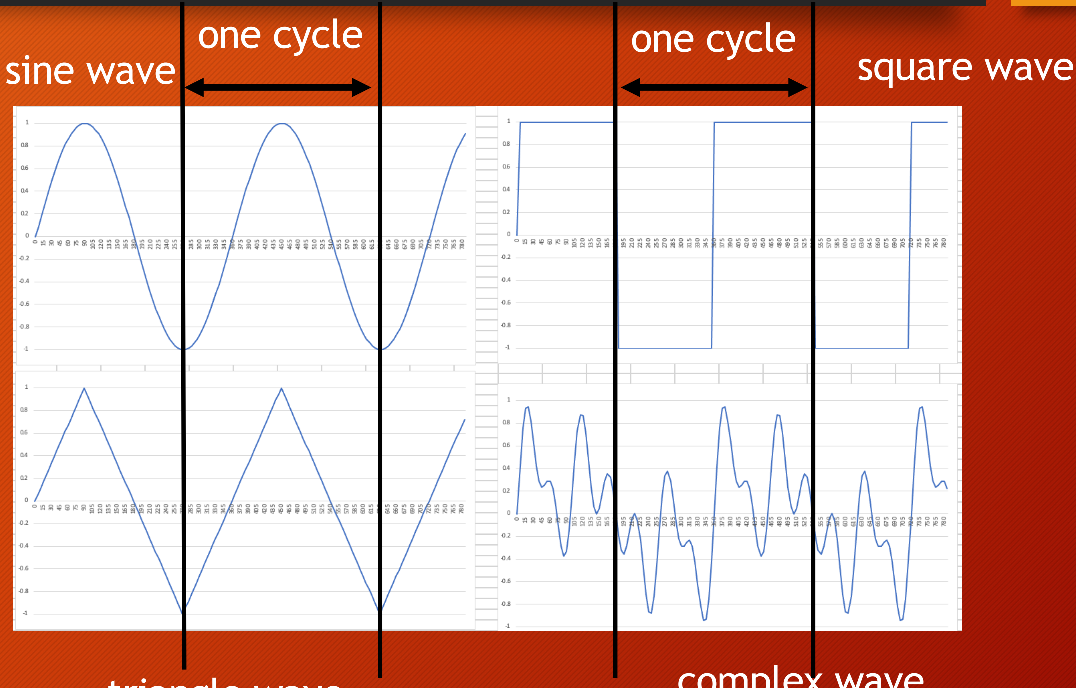
# Alternating Current (AC)



- In AC, the current flow can reverse direction with time
- Typical AC from your Electric Outlet is in the shape of a sine wave
- AC is measured by frequency (f): how many times per second it reverses direction:
  - originally measured in cycles per second (CPS), now measured in Hertz (Hz)
- In the US, power is delivered at 60 Hz
- In other parts of the world power is delivered at 50 Hz
- With AC we use the word Impedance (Z) to current flow instead of resistance

# We use an Oscilloscope to look at AC signals





# Capacitor

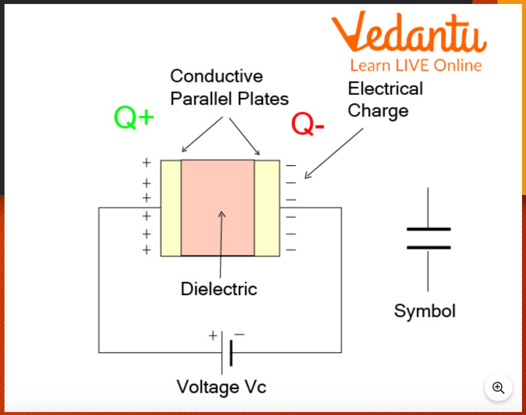


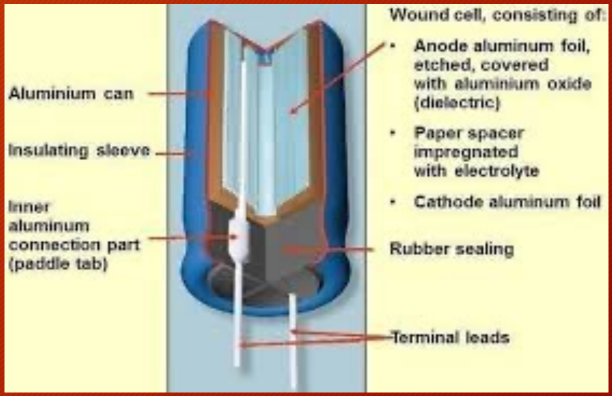
- A capacitor (C) passes AC signals  and blocks DC signals
- How well a capacitor passes AC signals depends on its value and the frequency of the signal
- A capacitor's values is measured in Farads
- Values range from:
  - micro-micro (pico) Farads (radio circuits) to
  - micro Farads (for audio and power circuits)
  - More recently capacitors with values in the Farad Range are used for very High Power Audio Amplifiers in vehicles
- A perfect capacitor does not heat up
- A capacitor has Capacitive Reactance ($X_C$) to AC signals
- $X_C = 1/(2\pi f C)$
- The Impedance $Z_C = -j X_C$, where $j = \sqrt{-1}$
- We will discuss this further in a later slide

# How Capacitors Work



- Capacitors are made with two metal plates separated by air or other insulating (non-conductive of electricity) material
- The plates of the capacitor store charges (positive and negative), thus storing electricity
- The plates can be flat or wound around each other
- When insulating material is used, a measure of the material is called the dielectric constant
- The higher the dielectric constant, the larger the value of the capacitor
- The dielectric constant of a vacuum is 1.0
- The dielectric constant of air is (approximately) 1.0




https://www.easybom.com/blog/a/what-is-an-electrolytic-capacitor

# Types of Capacitors



- Electrolytic Capacitors are used for audio and power applications
  - The are marked with their capacitance and voltage
  - e.g., 150 uF (micro-Farads), 50 volts
  - They have a polarity: plus and minus
  - The minus lead will have a long strip next to it or a minus sign
- Ceramic Capacitors are used in radio circuits and for bypass capacitors in digital circuits
  - They are marked with their value as a number
  - e.g., 102 is 1000 uuF (Micro-Micro-Farads, or pico Farads)
  - Sometimes just 50 meaning 50 uuF (or 60 pF)
  - They have no polarity
  - Sometimes the only way to determine the value is with a capacitance meter
- Mica or Silver Mica Capacitors were found in 30s-60s Vacuum Tube radios/TVs

# Examples of Capacitors



Electrolytic

Ceramic


Air Variable Capacitors

Electrolytic

Ceramic

Electrolytic

# Inductor

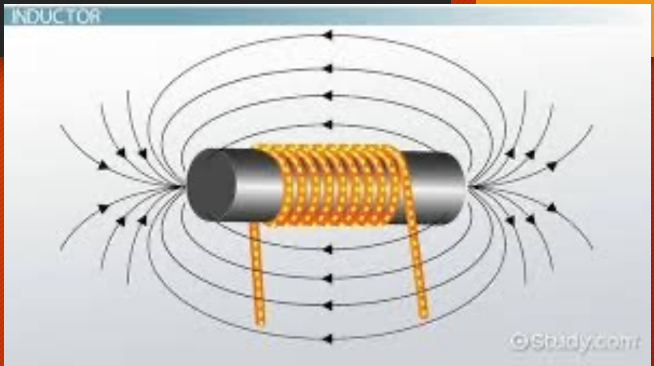


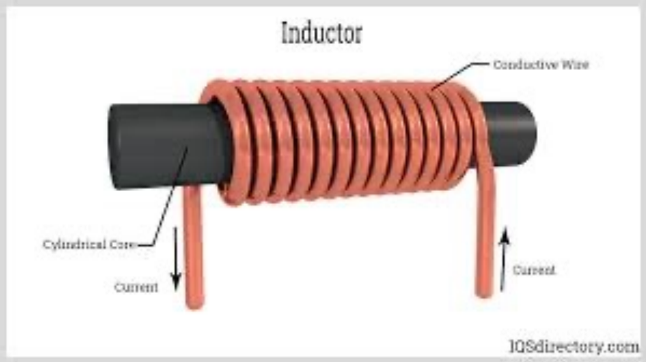
- An inductor (L) passes both AC and DC signals
- How well an inductor passes AC signals depends on its value and the frequency of the signal
- An inductor's value is measured in Henrys
- Values are from microHenrys (RF circuits) to Henrys (Power Circuits)
- A perfect inductor does not heat up
- An Inductor has Inductive ($X_L$) Reactance to AC Signals
- $X_L = 2 \pi f L$
- The Impedance $Z_L = +j X_C$ , where $j = \sqrt{-1}$
- We will discuss this further in a later slide

# How Inductors Work



- Inductors store energy in the magnetic field created by passing electricity through wires
- Wires wound around magnetic material increase the inductance of the Inductor
- When magnetic material is used, a measure of the material is called the permeability
- The higher the permeability, the larger the value of the Inductor
- The permeability of air is 1.0

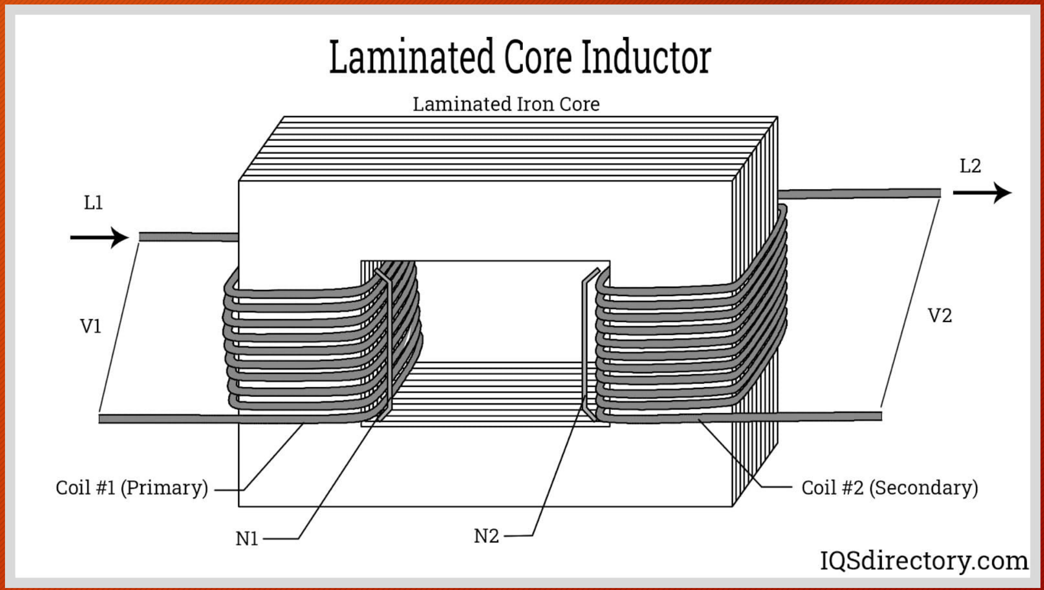


# Transformers



- A transformer is made when two, or more, sets of windings are used on the same magnetic material
- Transformers are used to change the value of an AC signal up or down



# Inductor Coding



- Many inductors have no coding of their size
- Some small inductors look like small resistors and use the same color code description
- You may need to use an Inductance Meter to measure them

# Inductor Examples



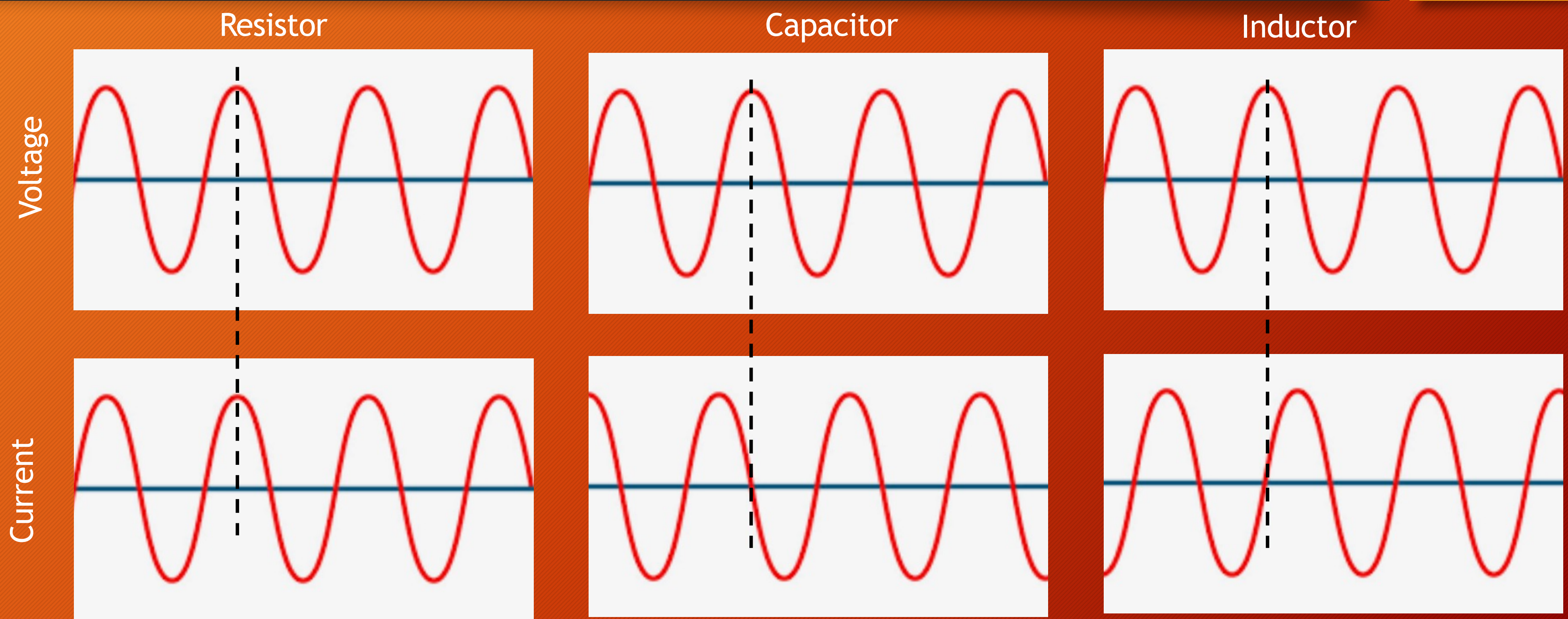
# Resistors, Capacitors and Inductors in AC Circuits



- Resistors, Capacitors and Inductors act differently in an AC Circuit
- A simple example shows what happens when the AC signal is at only one frequency and is thus a sine wave function
- The voltage and current in a resistor are in phase
  - i.e., they rise and fall in step with each other
- The current in a capacitor is 90 degrees out of phase with the voltage
- The current in an inductor is 90 degrees out of phase with the voltage in the opposite direction to that of a capacitor
- We represent the 90 degree phase shift by using complex numbers, j,
  - where $j = \sqrt{-1}$
  - In electric and electronic circuits, j is used instead of the math i to avoid confusing it with current, I
- See examples on the next page

# Resistor, Capacitor and Inductor in AC Circuit





# AC Series and Parallel Circuits



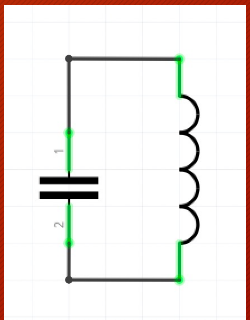
- The formulas for series and parallel circuits still apply for AC signals
- But we have to use complex math to calculate the Impedance of the circuit
- where $j = \sqrt{-1}$
- and j times j = -1

# Resonance



- A capacitor and inductor can be arranged in a Parallel circuit
- The parallel circuit is called a "Tuned Circuit"
- If you plot the impedance of the combined circuit with frequency, it peaks at a particular frequency called the resonant frequency
- The resonant frequency, $f_R$, is when the capacitive impedance equals the inductive impedance
- $f_R = {}^{1}/_{(2\pi\sqrt{LC})}$
- All inductors and capacitors have resistance
- A measure of the tuned circuit is the Q
- Q is the ratio of the impedance at resonance to the resistance of the inductor
- The higher the Q the better the tuned circuit works to filter out signals

C



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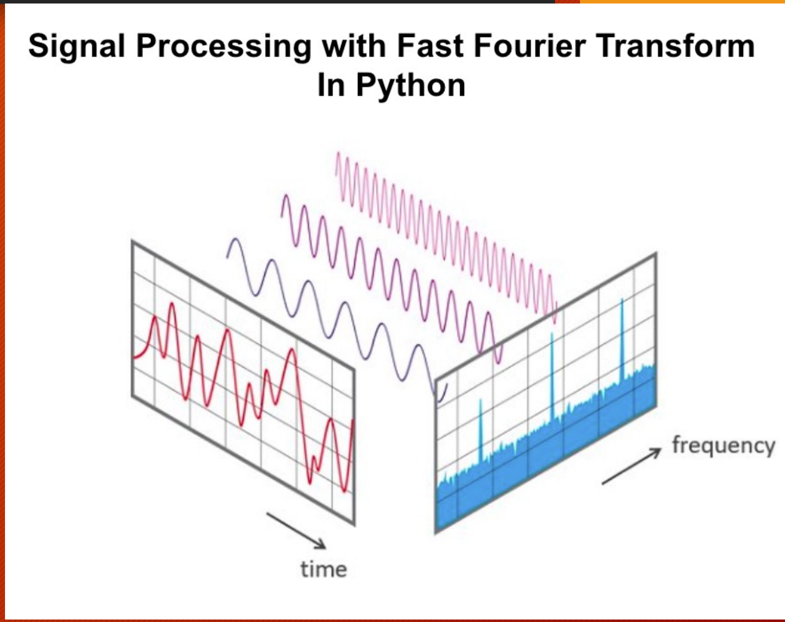
# What if the AC signal is not a sine wave



- Complex AC waves can be represented as a sum of sine waves of different frequencies
- This is expressed mathematically by the Fourier Transform
- For analyzing signals with software the Fast Fourier Transform (FFT) is used and it is often a library function in programming languages
- We use a Spectrum Analyzer to see the frequency representation of a signal



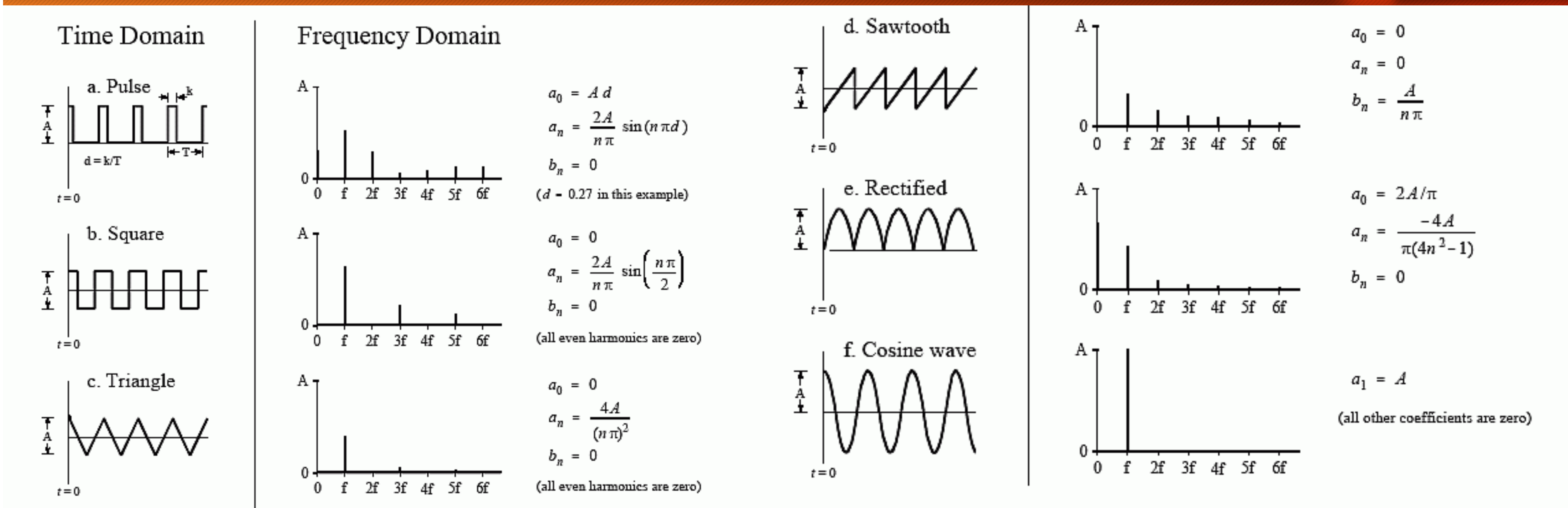

https://quantscience.io/newsletter/b/signal-processing-with-fast-fourier-transform

# Spectrum Analyzer



# Examples of Time and Frequency Domain






https://www.dspguide.com/ch13/4.htm

# One Final Important Point!



- In Electronic Circuits, by tradition:
  - Red wires are the positive connections to battery or power supply
  - Black wires are the negative and often the ground connections to the battery and power supply and to the metal chassis of the circuit

- In AC Power in houses and businesses the tradition is different
  - Black is the "Hot" wire (120 volts or 240 volts)
  - White is the neutral/return wire and is not a ground wire
  - The copper wire is the ground wire

Do not confuse the black of the power wire with the black wire of an electronic circuit.
Bad things can happen!!!!

# Questions

# References




- Radio Amateur's Handbook, ARRL, Newington CT
  - https://www.amazon.com/ARRL-Handbook-Radio-Communications-101st/dp/1625952074
- https://www.elenco.com/wp-content/uploads/2017/10/ECK-10_REV-O-2.pdf
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