Capacitors Cheat Sheet

A quick reference guide to capacitors, covering types, characteristics, applications, and common formulas. This cheat sheet is designed for engineers, students, and hobbyists working with electronics.

Capacitor Basics

Capacitance

Definition: Capacitance (C) is the ability of a component to store an electrical charge.

Unit: Farad (F)

Formula: `C = Q / V`

Where:

- `C` is the capacitance in Farads
- `Q` is the charge in Coulombs
- `V` is the voltage in Volts

Typical Values: Ranging from picofarads (pF) to millifarads (mF).

Energy Stored: The energy (E) stored in a capacitor is given by `E = 0.5 * C * V^2`

Capacitor Construction

Basic Structure:	Two conductive plates separated by a dielectric material.
Dielectric:	The dielectric material affects capacitance and voltage rating. Common materials include ceramic, plastic film, and electrolytic solutions.
Lead Types:	Axial (leads on either end) and radial (leads on the same end).

Key Parameters

Voltage Rating:	Maximum voltage that can be safely applied to the capacitor.
Tolerance:	The allowable deviation from the specified capacitance value (e.g., ±10%).
Temperature Coefficient:	Change in capacitance per degree Celsius (°C).
ESR (Equivalent Series Resistance):	Represents the internal resistance of the capacitor, affecting its performance in AC circuits.

Capacitor Types

Ceramic Capacitors

Characteristics: Non-polarized, small size, low cost, good for high-frequency applications.

Applications: Decoupling, bypass, and filtering.

Types: Multilayer Ceramic Capacitors (MLCCs) are common.

Electrolytic Capacitors

Characteristics:	Polarized, high capacitance values, suitable for low-frequency applications.
Types:	Aluminum electrolytic and tantalum electrolytic.
Applications:	Power supply filtering, energy storage.
Polarity:	Must be connected with correct polarity to avoid damage.

Film Capacitors

Characteristics: Non-polarized, good stability, low ESR, various dielectric materials (e.g., polyester, polypropylene).

Applications: Audio circuits, precision timing, high-frequency circuits.

Types: Polyester film, polypropylene film, etc.

Other Capacitor Types

Supercapacitors (Ultracapacitors):	Very high capacitance, used for energy storage in applications like electric vehicles and backup power systems.
Variable Capacitors:	Adjustable capacitance, used in tuning circuits.

Capacitor Circuits

Series and Parallel Combinations

Series Capacitors:	Total capacitance is less than the smallest individual capacitance. `1/C_total = 1/C_1 + 1/C_2 + ... + 1/C_n`
Parallel Capacitors:	Total capacitance is the sum of individual capacitances. `C_total = C_1 + C_2 + ... + C_n`

RC Circuits

Charging: The voltage across the capacitor increases exponentially when charging through a resistor.

Discharging: The voltage across the capacitor decreases exponentially when discharging through a resistor.

Time Constant (τ): `τ = R * C` (in seconds), where R is the resistance in ohms and C is the capacitance in farads. Represents the time it takes for the capacitor to charge or discharge to approximately 63.2% of its final value.

Capacitive Reactance

Definition:	Opposition to AC current flow, similar to resistance but frequency-dependent.
Formula:	`X_C = 1 / (2 * π * f * C)` Where: • `X_C` is the capacitive reactance in ohms • `f` is the frequency in Hertz • `C` is the capacitance in Farads
Frequency Dependence:	Capacitive reactance decreases as frequency increases.

Applications

Filtering: Blocking DC signals while allowing AC signals to pass (or vice versa).

Coupling: Passing AC signals from one circuit to another while blocking DC bias.

Decoupling/Bypass: Providing a local energy source for ICs, reducing noise on power supply lines.

Timing Circuits: Using RC time constants for creating delays and setting frequencies in oscillators.

Practical Considerations

Reading Capacitor Values

Direct Marking:	Some capacitors have the capacitance value directly printed on them (e.g., 100nF, 4.7µF).
Code Systems:	Others use a code system (e.g., 104 = 10 x 10^4 pF = 100nF). Last digit is multiplier (power of 10) in pF.
Tolerance Codes:	Letters indicate tolerance (e.g., K = ±10%, M = ±20%).

Selecting the Right Capacitor

Considerations: Capacitance value, voltage rating, tolerance, temperature coefficient, ESR, size, and cost.

Application Specific: Choose capacitor type based on the specific application requirements (e.g., ceramic for high frequency, electrolytic for high capacitance).

Troubleshooting

Testing:	Use a multimeter with capacitance measurement or an LCR meter to test capacitor values.
Common Failures:	Short circuits, open circuits, decreased capacitance, increased ESR.
Visual Inspection:	Check for bulging, leakage, or physical damage, especially in electrolytic capacitors.

Safety Precautions

Discharge: Always discharge capacitors before handling, especially high-voltage capacitors, to avoid electric shock.

Polarity: Ensure correct polarity when using polarized capacitors.

Voltage Rating: Never exceed the rated voltage of a capacitor.