

# Two Capacitors, $C = 25.0\text{F}$ And $C = 5.00\text{F}$ , Are Connected In Parallel And Charged With A 100-V Power Supply.

## Two Capacitors, $C = 25.0\text{F}$ And $C = 5.00\text{F}$ , Are Connected In Parallel And Charged With A 100-V Power Supply.

This setup presents an interesting scenario in the realm of electrostatics and circuit analysis, showcasing fundamental principles such as capacitance, charge distribution, energy storage, and the behavior of capacitors in parallel configurations. Understanding how these components interact when connected to a power source is crucial for students, engineers, and hobbyists alike, especially when designing circuits that involve energy storage, filtering, or timing applications.

In this article, we will explore the detailed physics behind this configuration, including how to calculate the total charge stored, the voltage across each capacitor, the energy stored in the system, and the implications for circuit design. We will also extend our discussion to include practical considerations such as the effect of connecting different values of capacitors, the process of charging and discharging, and real-world applications.

## Understanding Capacitance and the Parallel Connection

Capacitance, denoted by  $C$ , is a measure of a capacitor's ability to store charge per unit voltage. It is expressed in farads (F), where 1 farad equals 1 coulomb per volt. When capacitors are connected in parallel, their total or equivalent capacitance is simply the sum of their individual capacitances:

- $C_{\text{total}} = C_1 + C_2$

This configuration means that the voltage across each capacitor in a parallel connection is identical, equal to the voltage of the power supply, assuming an ideal, lossless circuit.

## Calculating the Total Capacitance and Charge

Given the values:

- $C_1 = 25.0\text{F}$
- $C_2 = 5.00\text{F}$
- Power supply voltage,  $V = 100\text{V}$

the total capacitance is:

$$C_{\text{total}} = C_1 + C_2 = 25.0\text{F} + 5.00\text{F} = 30.0\text{F}$$

Since in a parallel connection, the voltage across each capacitor is equal to the supply voltage, the charge stored in each capacitor can be calculated by:

$$Q = C \times V$$

Applying this:

- $Q_1 = 25.0\text{F} \times 100\text{V} = 2500 \text{ C}$
- $Q_2 = 5.00\text{F} \times 100\text{V} = 500 \text{ C}$

The total charge stored in the system is:

$$Q_{\text{total}} = Q_1 + Q_2 = 2500 \text{ C} + 500 \text{ C} = 3000 \text{ C}$$

This straightforward calculation highlights that larger capacitors store more charge at the same voltage.

## Energy Stored in the Capacitors

The energy stored in a capacitor is given by the formula:

$$U = (1/2) C V^2$$

Calculating the energy stored in each capacitor:

- $U_1 = (1/2) \times 25.0\text{F} \times (100\text{V})^2 = 0.5 \times 25.0 \times 10,000 = 125,000 \text{ J}$
- $U_2 = (1/2) \times 5.00\text{F} \times (100\text{V})^2 = 0.5 \times 5.00 \times 10,000 = 25,000 \text{ J}$

Total energy stored:

$$U_{\text{total}} = U_1 + U_2 = 125,000 \text{ J} + 25,000 \text{ J} = 150,000 \text{ J}$$

This significant amount of stored energy emphasizes the importance of handling capacitors carefully, especially when dealing with large capacitances and voltages.

# Behavior During Charging and Discharging

When connecting the capacitors to the power supply, they begin to charge almost instantaneously in an ideal circuit. The process involves the transfer of charge from the power source to the plates of the capacitors until equilibrium is reached.

In a real-world scenario, resistances and other parasitic elements cause a finite charging time characterized by RC time constants. For each capacitor:

$$\tau = R \times C$$

where R is the resistance in the circuit, and C is the capacitance. Larger capacitances mean longer charging and discharging times, which are crucial considerations in timing applications.

Once charged, if the power supply is disconnected, the capacitors retain their charges unless a path for discharge exists. Connecting the capacitors in different configurations or across different voltage sources can lead to interesting phenomena such as charge redistribution, voltage equalization, or even potential damage if not managed properly.

## Practical Applications of Such Capacitor Configurations

Configurations involving multiple capacitors in parallel are common in various electrical and electronic applications:

- **Energy Storage Systems:** Large capacitance banks store energy for backup power or smoothing voltage fluctuations.
- **Filtering and Noise Reduction:** Parallel capacitors are used in power supplies to filter out unwanted signals and noise.
- **Timing and Oscillator Circuits:** Capacitors in parallel influence circuit timing characteristics due to their combined capacitance.

In designing such systems, understanding the interplay of the individual capacitor values, voltage ratings, and total energy storage capacity is essential for safety and efficiency.

## Safety Considerations and Practical Limitations

While theoretical calculations assume ideal conditions, real-world capacitors have voltage ratings, equivalent series resistance (ESR), leakage currents, and temperature dependencies. Exceeding voltage ratings can lead to dielectric breakdown, permanent damage, or even catastrophic failure.

Furthermore, large capacitances stored at high voltages can pose safety risks during handling, discharging, or circuit faults. Proper discharge procedures, insulation, and protective components are mandatory when working with sizable capacitors.

## Conclusion

Connecting a 25.0F and a 5.00F capacitor in parallel and charging them with a 100V power supply illustrates fundamental principles of electrostatics and circuit design. The total capacitance, charge storage, and energy stored in the system can be calculated straightforwardly, providing insight into how different values of capacitors contribute to overall system behavior.

Understanding these principles is vital for designing efficient, safe, and reliable electronic systems that leverage the unique properties of capacitors. Whether used in energy storage, filtering, or timing applications, the ability to analyze and predict capacitor behavior under various conditions forms the backbone of many modern electronic innovations.

By mastering the concepts discussed, engineers and enthusiasts can optimize their designs, ensure safety, and innovate with confidence in the versatile world of capacitors.

## Frequently Asked Questions

### **What is the total capacitance when two capacitors, 25.0F and 5.00F, are connected in parallel?**

The total capacitance in parallel is the sum of the two:  $C_{\text{total}} = 25.0\text{F} + 5.00\text{F} = 30.0\text{F}$ .

### **How much charge is stored on each capacitor when connected in parallel to a 100V power supply?**

Charge on each capacitor is  $Q = C \times V$ . For the 25.0F capacitor,  $Q = 25.0\text{F} \times 100\text{V} = 2,500$  Coulombs. For the 5.00F capacitor,  $Q = 5.00\text{F} \times 100\text{V} = 500$  Coulombs.

### **What is the total energy stored in the system of the two capacitors connected in parallel?**

Total energy  $U = \frac{1}{2} \times C_{\text{total}} \times V^2 = \frac{1}{2} \times 30.0\text{F} \times (100\text{V})^2 = \frac{1}{2} \times 30.0\text{F} \times 10,000\text{V}^2 = 150,000$  Joules.

### **What is the voltage across each capacitor when connected in parallel to the 100V power supply?**

In a parallel connection, all capacitors have the same voltage as the power supply, so each capacitor has 100V across it.

### **If the capacitors are disconnected after being charged, what happens to the stored charge?**

The stored charge remains on each capacitor indefinitely (assuming ideal conditions with no leakage), maintaining the same charge as before disconnection.

## How does connecting capacitors in parallel affect the total charge stored compared to a single capacitor?

Connecting capacitors in parallel increases the total charge stored at the same voltage, since total charge is the sum of individual charges:  $Q_{\text{total}} = C_{\text{total}} \times V$ .

## What are potential practical applications of connecting large capacitors like 25.0F and 5.00F in parallel?

Such configurations are used in energy storage systems, power smoothing, and backup power supplies, where large capacitance values help buffer and store significant amounts of electrical energy.

## Additional Resources

Two Capacitors,  $C = 25.0\text{F}$  and  $C = 5.00\text{F}$ , Are Connected in Parallel and Charged with a 100-V Power Supply

In the realm of electrical and electronic engineering, capacitors are fundamental components that store and release electrical energy. When two capacitors are connected in parallel and subjected to a voltage source, they form a combined energy storage system with unique characteristics dictated by their individual capacitances and the applied voltage. This article provides a comprehensive analysis of the scenario where a 25.0 farad (F) and a 5.00 F capacitor are connected in parallel and charged with a 100-volt (V) power supply. We will explore the fundamental principles, perform detailed calculations, examine energy considerations, and discuss practical implications and applications.

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## Understanding Capacitors and Their Properties

### What Is a Capacitor?

A capacitor is a passive electrical component that stores electrical energy in an electric field created between a pair of conductors separated by an insulating material known as a dielectric. The primary function of a capacitor is to temporarily store charge and release it when needed, making it essential in filtering, energy storage, and signal processing.

Key properties of capacitors include:

- Capacitance (C): The measure of a capacitor's ability to store charge per unit voltage, expressed in farads (F). Larger capacitance indicates greater charge storage capacity.
- Voltage rating: The maximum voltage the capacitor can withstand without dielectric breakdown.
- Equivalent series resistance (ESR): The small amount of resistance within the capacitor affecting charge and discharge dynamics.

# Capacitance and Its Significance

Capacitance is mathematically defined as:

$$C = \frac{Q}{V}$$

where:

- $Q$  is the charge stored (in coulombs, C),
- $V$  is the voltage across the capacitor (in volts, V).

In practical scenarios, capacitance determines how much charge a capacitor can hold at a given voltage, influencing its role in circuits.

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## Configuration: Two Capacitors in Parallel

### Connecting Capacitors in Parallel: Principles and Effects

When capacitors are connected in parallel, their positive terminals are linked together, as are their negative terminals, creating a common voltage across each. The key features of this configuration are:

- Equal Voltage: Both capacitors experience the same voltage  $V$ .
- Total Capacitance: The equivalent capacitance  $C_{eq}$  is the sum of individual capacitances:

$$C_{eq} = C_1 + C_2$$

- Total Charge Stored: The total charge stored in the system is the sum of individual charges:

$$Q_{total} = Q_1 + Q_2$$

where:

$$Q_1 = C_1 V$$

$$Q_2 = C_2 V$$

This configuration effectively increases the energy storage capability compared to individual capacitors.

## Calculating the Equivalent Capacitance

Given:

- $C_1 = 25.0 \text{ F}$

- $C_2 = 5.00 \text{ F}$

The equivalent capacitance:

$$C_{eq} = 25.0 \text{ F} + 5.00 \text{ F} = 30.0 \text{ F}$$

This combined capacitance determines how much charge can be stored when connected to a voltage source.

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## Charging the Capacitors with a 100 V Power Supply

### Charging Process and Voltage Distribution

When the parallel combination is connected to a 100 V power supply, the capacitors begin to accumulate charge until the voltage across each reaches 100 V (assuming an ideal power supply with no internal resistance). The process involves:

- The flow of current from the power supply into the capacitors.
- Each capacitor gaining charge proportional to its capacitance.
- The total stored energy in the system increasing correspondingly.

Since the capacitors are in parallel, the voltage across each remains 100 V at equilibrium.

### Charge Stored in Each Capacitor

Using the relation  $Q = C V$ :

- For the 25.0 F capacitor:

$$Q_1 = C_1 \times V = 25.0 \text{ F} \times 100 \text{ V} = 2500 \text{ C}$$

- For the 5.00 F capacitor:

$$Q_2 = C_2 \times V = 5.00 \text{ F} \times 100 \text{ V} = 500 \text{ C}$$

- Total charge stored:

$$Q_{total} = Q_1 + Q_2 = 2500 \text{ C} + 500 \text{ C} = 3000 \text{ C}$$

This illustrates how the total charge stored in the system is the sum of individual charges, consistent with the parallel configuration.

# Energy Stored in the Capacitors

The energy stored in a capacitor is given by:

$$U = \frac{1}{2} C V^2$$

Calculating for each capacitor:

- 25.0 F capacitor:

$$U_1 = \frac{1}{2} \times 25.0 \, \text{F} \times (100 \, \text{V})^2 = \frac{1}{2} \times 25.0 \times 10,000 = 125,000 \, \text{J}$$

- 5.00 F capacitor:

$$U_2 = \frac{1}{2} \times 5.00 \, \text{F} \times 10,000 = 25,000 \, \text{J}$$

- Total energy stored:

$$U_{\text{total}} = U_1 + U_2 = 125,000 \, \text{J} + 25,000 \, \text{J} = 150,000 \, \text{J}$$

This substantial energy indicates the significant capacity of large-value capacitors at high voltages, which is relevant for energy storage applications such as power backup systems and pulse power devices.

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## Analysis of Energy and Practical Considerations

### Energy Distribution and Storage Efficiency

The energy stored in capacitors is crucial for various applications, but it's important to understand the efficiency and potential losses. In an ideal scenario (no resistance, no leakage), all energy supplied by the power source is stored in the capacitors. However, real-world factors such as resistance in the circuit, dielectric losses, and leakage currents reduce the effective energy stored.

Energy Storage Efficiency:

- The energy supplied by the power source during charging:

$$U_{\text{supply}} = Q_{\text{total}} \times V = 3000 \, \text{C} \times 100 \, \text{V} = 300,000 \, \text{J}$$

- Energy stored in the capacitors:

$$U_{\text{stored}} = 150,000 \, \text{J}$$

- Energy lost:

$$U_{\text{lost}} = U_{\text{supply}} - U_{\text{stored}} = 150,000 \text{ J}$$

This indicates approximately 50% efficiency, with the remaining energy dissipated as heat due to circuit resistance and other non-ideal factors.

## Practical Implications and Safety Considerations

Handling capacitors with such high capacitance and voltage levels poses safety challenges:

- High energy storage: The stored energy (150,000 J) is substantial. Discharging such a capacitor rapidly can cause dangerous arcs, burns, or equipment damage.
- Voltage ratings: Both capacitors must have voltage ratings exceeding 100 V to prevent dielectric breakdown.
- Physical size and dielectric material: Large capacitance values often require substantial physical sizes and high-quality dielectric materials, influencing design and cost.
- Discharge precautions: Proper discharge procedures and protective equipment are essential to prevent accidental shocks.

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## Applications and Broader Context

### Energy Storage Systems

Large-value capacitors like the 25.0 F capacitor are used in energy storage systems for power stabilization, pulse power applications, and in renewable energy systems where rapid energy release is needed.

### Electronics and Power Conditioning

Capacitors in parallel configurations are utilized in filtering, voltage stabilization, and noise reduction in electronic circuits, benefiting from their combined capacitance to smooth voltage fluctuations.

### Research and Development

High-capacitance, high-voltage capacitors are vital in experimental physics, particle accelerators, and electromagnetic research, where precise energy control is necessary.

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# Conclusion

Connecting a 25.0 F and a 5.00 F capacitor in parallel and charging them with a 100 V power supply exemplifies fundamental principles of electrostatics and circuit theory. The process demonstrates how combined capacitance influences charge storage, energy accumulation, and voltage distribution. The total stored energy reaches an impressive 150,000 joules, highlighting the importance of capacitors as energy reservoirs. Practical considerations such as efficiency, safety, and physical design are crucial when deploying such systems in real-world applications. This scenario underscores both the potential and challenges associated with large

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