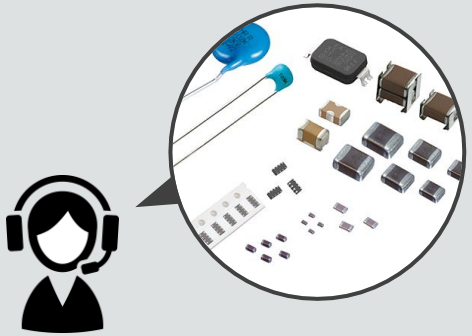
【Introduction】Basics of Ceramic Capacitors

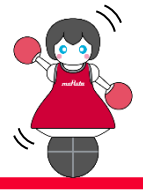
Introduction to MLCC components in circuits/role and function

As of 2024



Murata Manufacturing Co., Ltd.

Overview of Murata



As of 2024

Corporate Profile

Murata is an electronic components manufacturer producing a wide range of cutting-edge technologies and components. We are committed to creating a prosperous society in line with the “Innovator in Electronics” slogan.

Our Strengths

- Research and development in advanced materials
- Extensive product lineup
- Global production and sales networks

Key facts

- Established : 1944
- Net sales : 1,640,158 million yen
- Group companies : 84 (30 domestic, 54 overseas)
- Employees : 73,165 (33,908 domestic, 39,257 overseas)

* Sales figures for fiscal year ended March 2023.
* Employees as of March 31, 2024
* Group companies as of March 31, 2024
* “Group companies” excludes Murata

Product Lineup

Capacitors

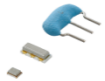
Inductors

Noise suppression components, EMI suppression filters, ESD protection devices

Resistors

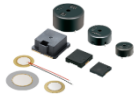
Thermistors/ temperature sensors

Sensors



Timing devices (MEMS oscillators, crystal units, ceramic resonators)

Quartz products

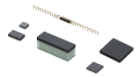


Sound generators/ buzzers

Power products

Batteries

Micro mechatronics



RFID

High-frequency substrates

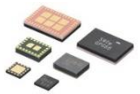
Baluns

Couplers

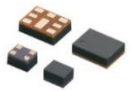
Filters

Phase shifters

RF switches



Front end modules



Acoustic wave devices

Connectors

Antennas

Communication modules

Ionizer modules Ozonizer modules

AIRSual
spatial visualization solution

Pifaa
sensor data platform

Wireless sensing solutions

Workplace safety monitoring systems

m-FLIP

id-Bridge RFID solution

JIGlet
site efficiency tool

Traffic counter systems

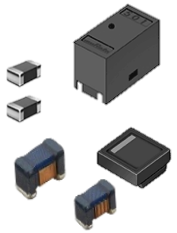
Fatigue stress meters

Medical devices

Global share of key products

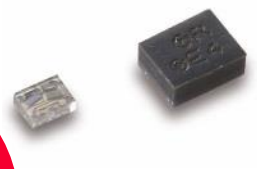
40%

Chip multilayer ceramic capacitors



40%

EMI suppression filters (EMIFIL®)



50%

Surface wave filters

40%

Multilayer LC filters (including filters, baluns and couplers)

40%

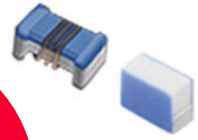
Silver oxide micro batteries

95%

Shock sensors

95%

Ceramic resonators



60%

High-frequency inductors

* Global shares are Murata estimates; subject to market and application type

How key Murata products are used

Product name	Required quantity					
	Smartphone 	Laptop 	Tablet computer 	Motor vehicle 	Digital TV 	Smartwatch 
Chip multilayer ceramic capacitors	1,200	800	600	5,000 - 8,000	600	350
EMI suppression filter (EMIFIL®)	60	60	90	270 - 400	50	30
Surface wave filters	10 - 70	0 - 30	10 - 70	0 - 30		0 - 30
Shock sensors		1 - 3		4		
Ceramic resonators				15		
Chip inductors	300	30 - 50	200	400 - 500	30	30 - 50
Multilayer LC filters (including filters, baluns and couplers)	2 - 20	2 - 4	2 - 20	2 - 8	2	3 - 6

* Figures are Murata estimates, and represent the quantity required per unit rather than the number of Murata products used

Main Business Areas

Wellness

Toward a new prosperity in the era of 100-year lives

By utilizing our knowledge in the field of electronics and our proprietary technologies, we seek to provide value for the development of medical care, disease prevention, and health and wellbeing.

Environment

Market commitment to the transition to a sustainable society

We work actively on environmental measures and aim to create innovation that links businesses with solutions to social challenges.

Mobility

The automobile industry is entering a once-in-a-century period of major change

In addition to contributing to the evolution of automobiles (In-Car), we aim to seize business opportunities in the area of expanding mobility (Out-Car).

Communication

Everything is connected and optimized by communication

We continue to provide value by accurately identifying the diversifying applications and changing customer structure and by taking an unassailable lead in technological innovation.

Social and Community Contributions/Environmental Considerations

We hold science classes and incursions at elementary schools, talking about the work of engineers who support manufacturing and emphasizing the enjoyment aspect of their work. In this way, we support the development of human resources for the future.

Systems that combine solar panels, storage batteries and control software, as well as mega solar panels

Basics of Ceramic Capacitors

Introduction to MLCC components in circuits/role and function

As of 2024

Murata Co., Ltd.
Ceramic Capacitor Business Unit
Sales Division, Product Technology Department, Product Technology Section 1

Agenda

1. What is a capacitor?
2. Function of the capacitor
3. Types of capacitors and what is MLCC
4. Key characteristics of ceramic capacitors
5. Ceramic Capacitors from Murata

Agenda

1. What is a capacitor?

2. Function of the capacitor

3. Types of capacitors and what is MLCC

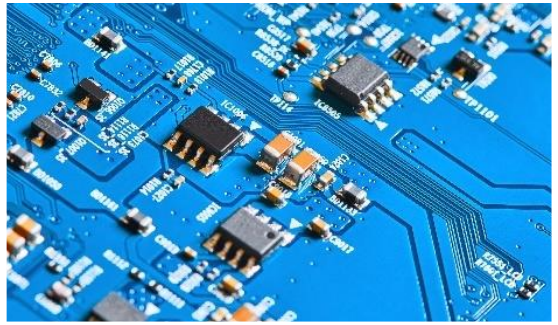
4. Key characteristics of ceramic capacitors

5. Ceramic Capacitors from Murata

Common Applications of Capacitors

Capacitors are used in a wide range of settings in modern society.
They are an essential component of electronic equipment and electronic circuits.









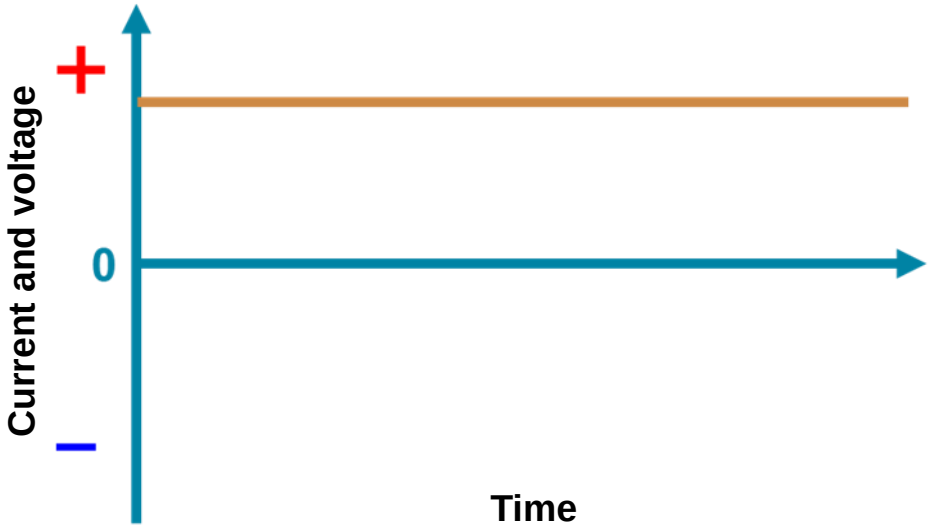




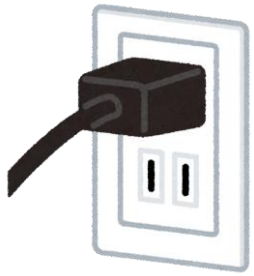
What is a capacitor?

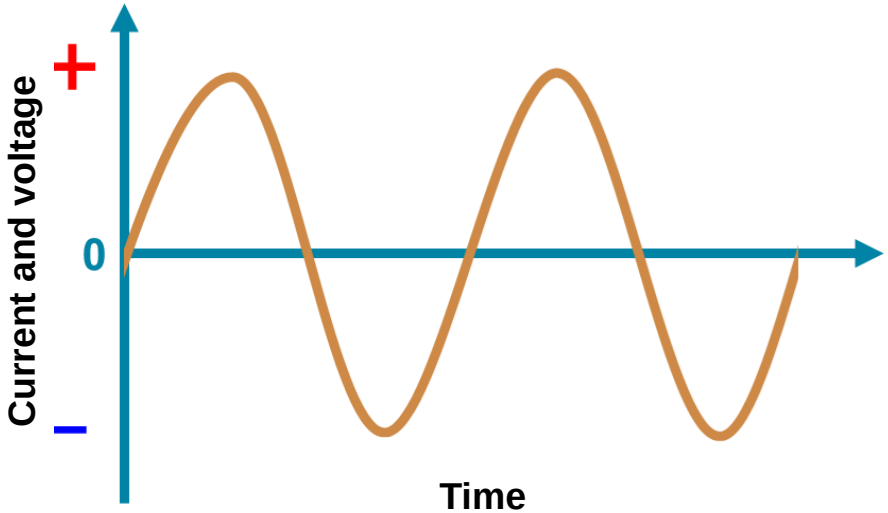
(1) Able to store/release electricity

(2) Blocks direct current (DC)



(3) Conducts alternating current (AC)





What is a capacitor?

Battery versus capacitor

- High volume of charge
- Slow charge and discharge rate

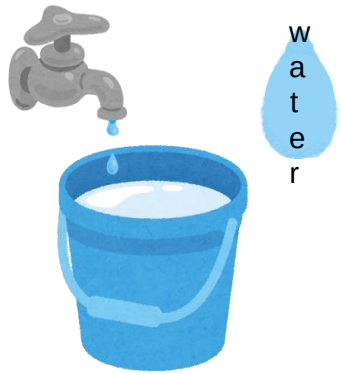
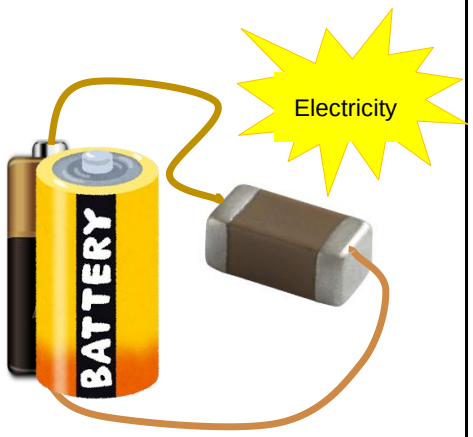
⇒ Source of power

Capacitor

- Very limited volume of charge
- Rapid charge and discharge rate

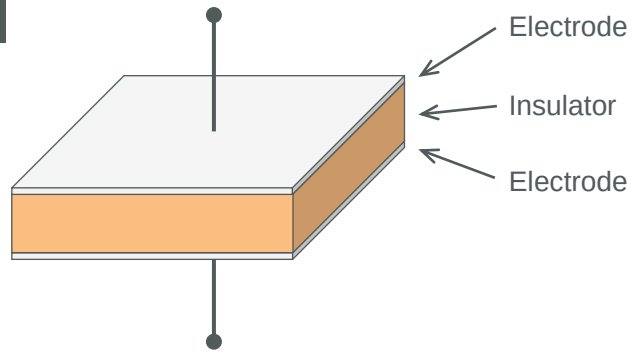
⇒ Backup for times of insufficient power

What is a capacitor?

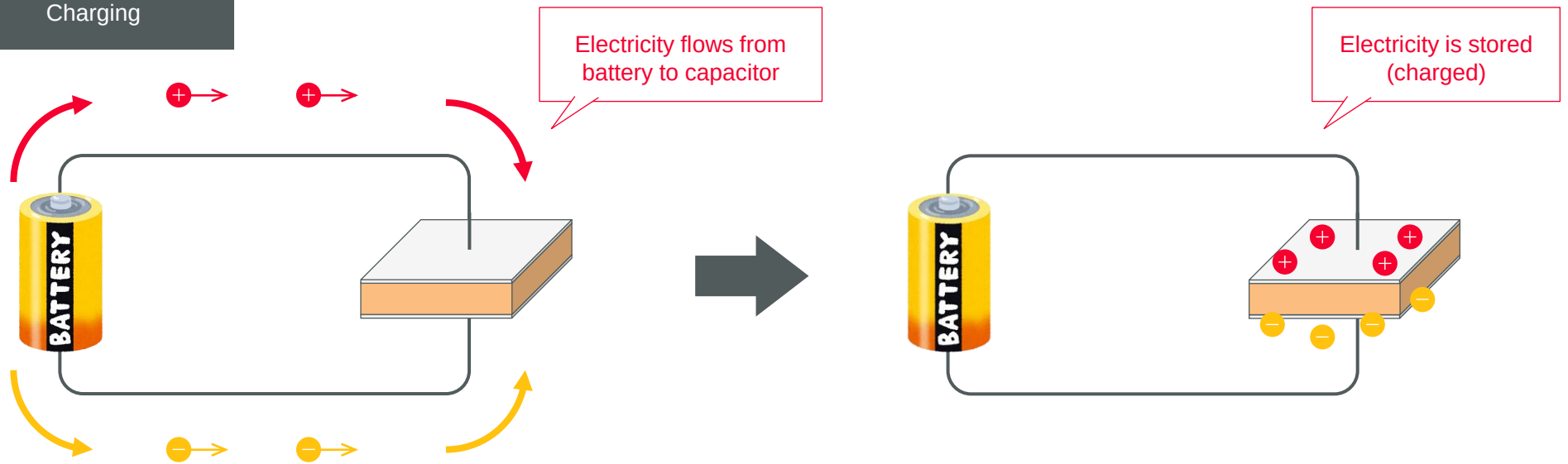
	Stored items	Stored Capacity	Unit of measurement
Bucket		The capacity of the bucket can be stored.	Liter (L)
Capacitor		The **capacitance** of the capacitors can be stored.	Farad **(F)** 例：μF (Microfarad) pF (Picofarad)

What is a capacitor?

Capacitor structure

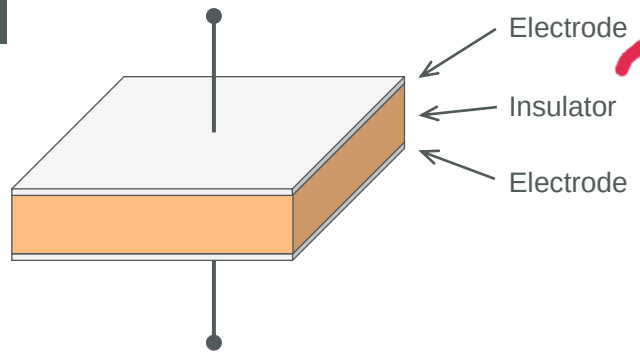


Charging



What is a capacitor?

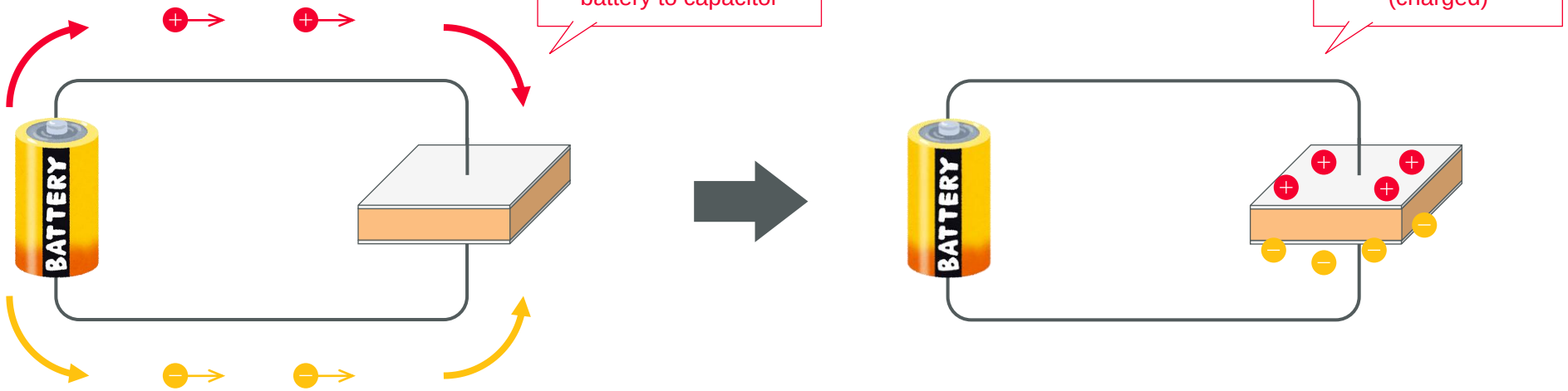
Capacitor structure



Dielectric boosts capacitance!

Dielectric: Any material with high dielectric constant (ability to store electricity)

Charging



Key Points to Remember

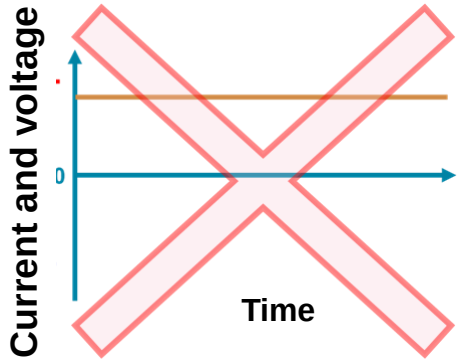
(1) What is a capacitor?

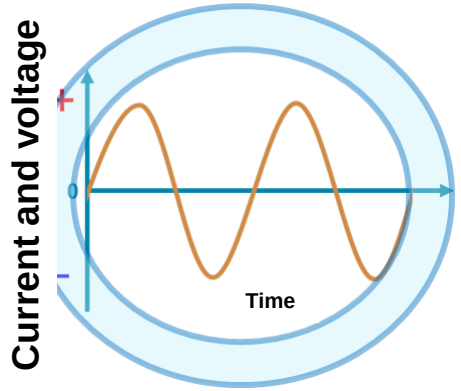
- Characteristics

  (1) Able to store/release electricity

  (2) Blocks direct current (DC)

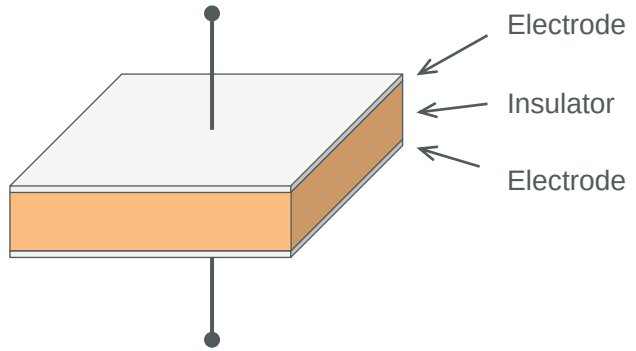
  (3) Conducts alternating current (AC)





- Capacitor structure and dielectric

  Boost capacitance by using a dielectric instead of an insulator



Agenda

1. What is a capacitor?

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3. Types of capacitors and what is MLCC

4. Key characteristics of ceramic capacitors

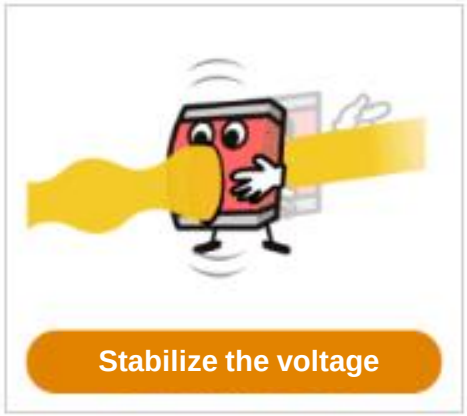
5. Ceramic Capacitors from Murata

Role of The Capacitor in an Electrical Circuit

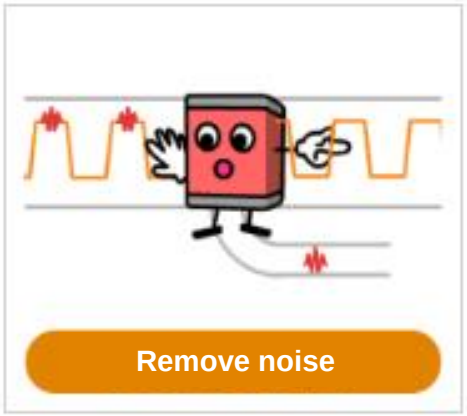
(1) Stores/releases electricity → stabilizes power levels

(2) Blocks DC → extracts signal

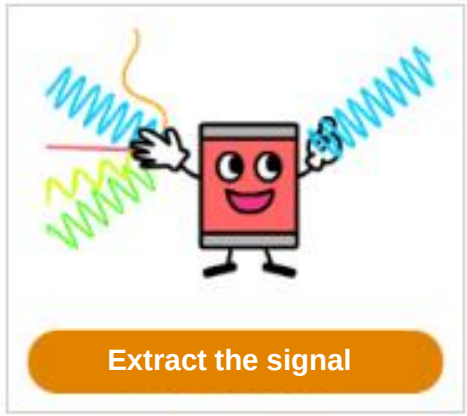
(3) Conducts AC → eliminates noise



It absorbs voltage changes through charging and discharging.



A pathway for electricity to divert unnecessary noise off the main route.

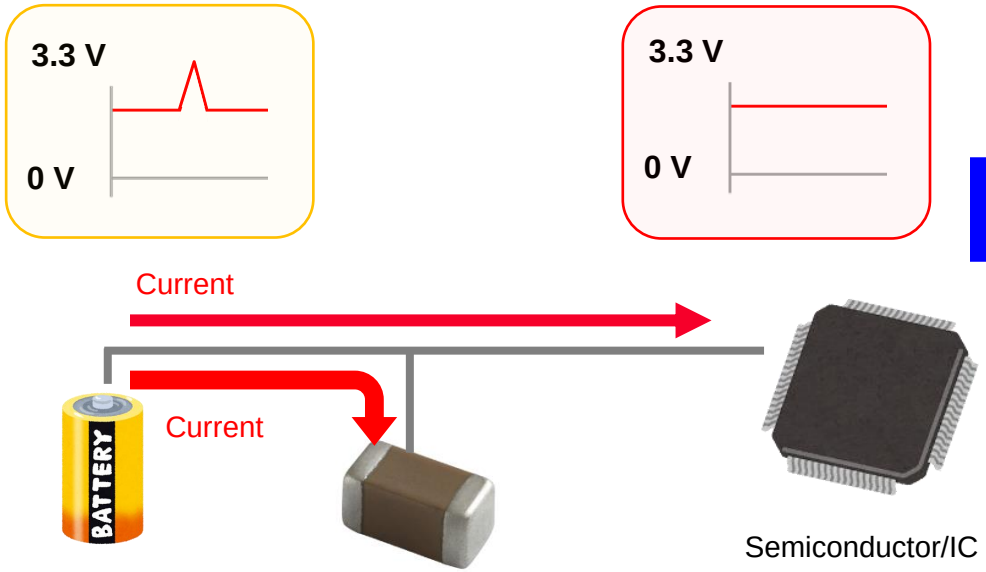


It blocks direct current and separates signals by frequency.

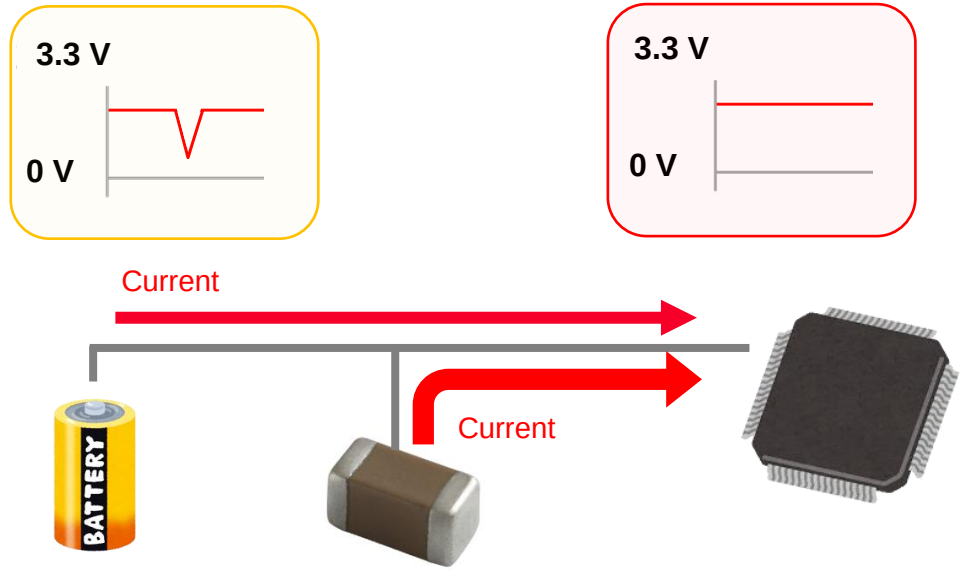
Role of The Capacitor in an Electrical Circuit

(1) Store/release electricity → stabilize power levels

1. **Stores electricity** when there is a large amount of electricity in the circuit

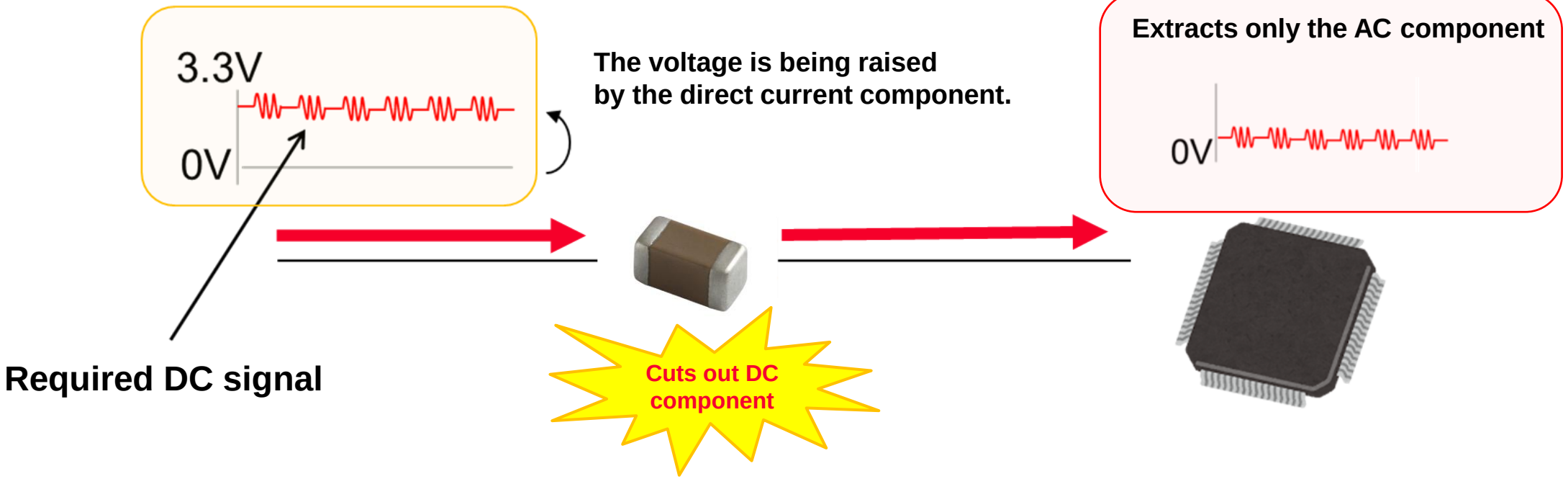


2. **Releases electricity** when there is insufficient available in the circuit



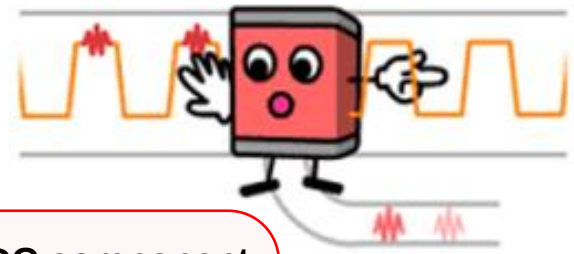
Role of The Capacitor in an Electrical Circuit

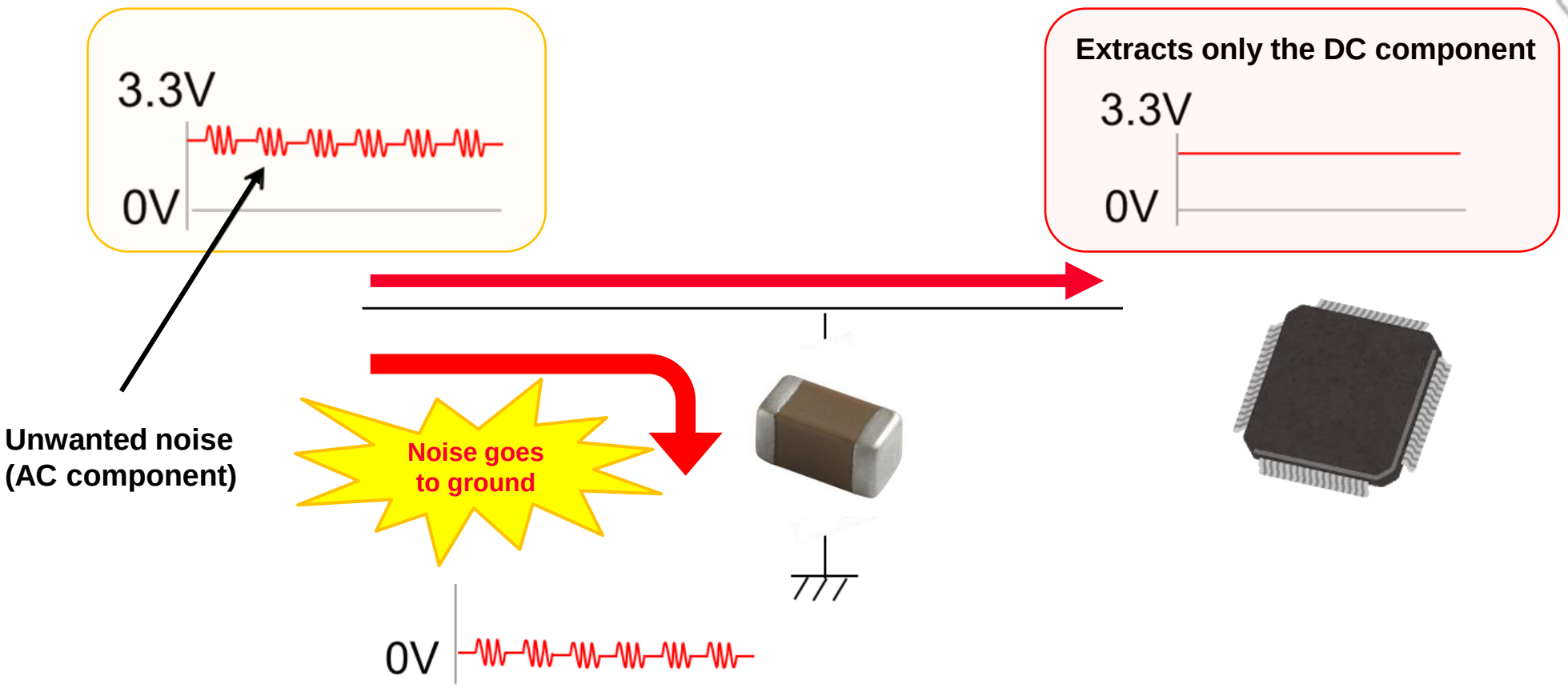
(2) Blocks DC → extracts signal



Role of The Capacitor in an Electrical Circuit

(3) Conducts AC → eliminates noise





Key Points to Remember

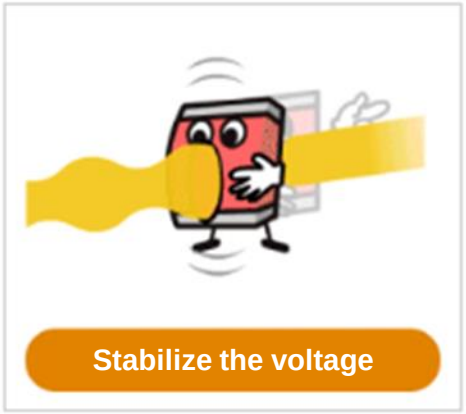
(2) Function of the capacitor

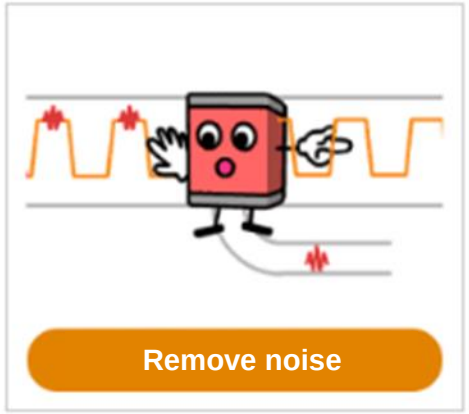
- Role of The Capacitor in an Electrical Circuit

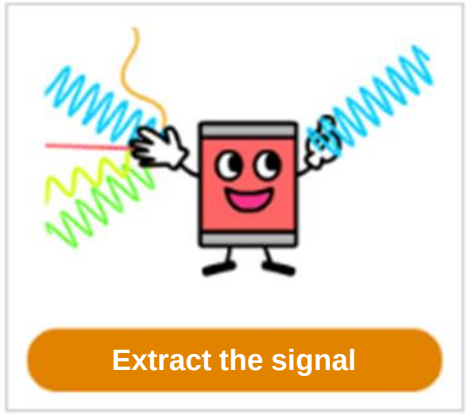
  (1) Stores/releases electricity → stabilizes power levels

  (2) Blocks DC → extracts signal

  (3) Conducts AC → eliminates noise



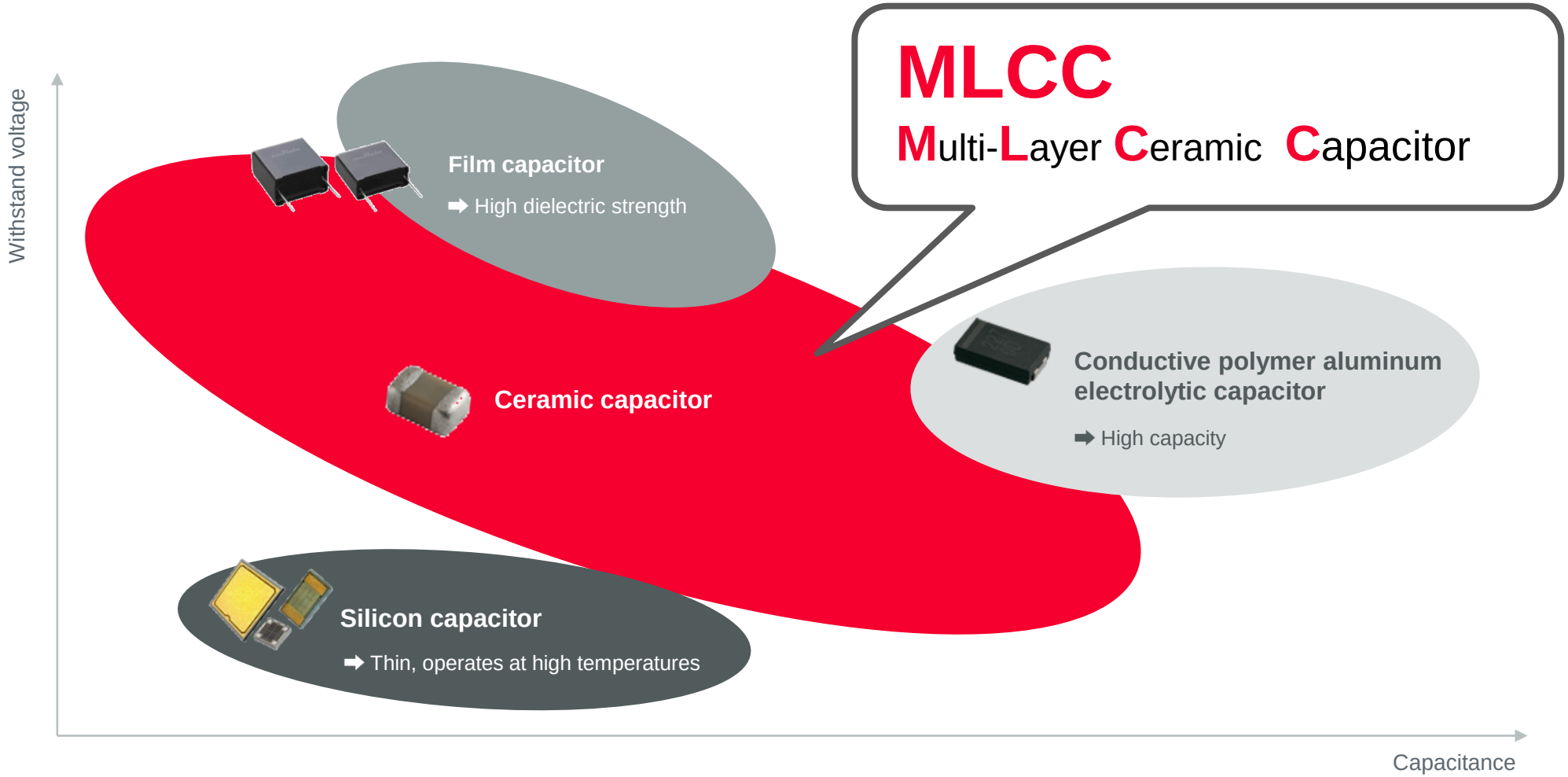




Agenda

1. What is a capacitor?
2. Function of the capacitor
3. **Types of capacitors and what is MLCC**
4. Key characteristics of ceramic capacitors
5. Ceramic Capacitors from Murata

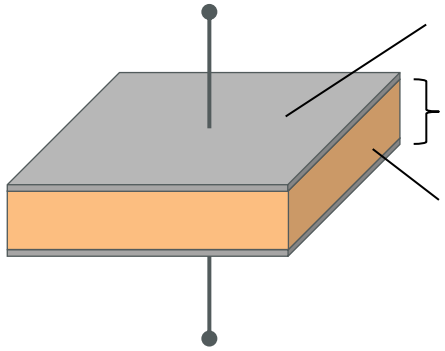
Types of Capacitors



Capacitor structure

Capacitance formula

$$C = \varepsilon \times \frac{S}{d}$$



S = electrode area

d = dielectric thickness

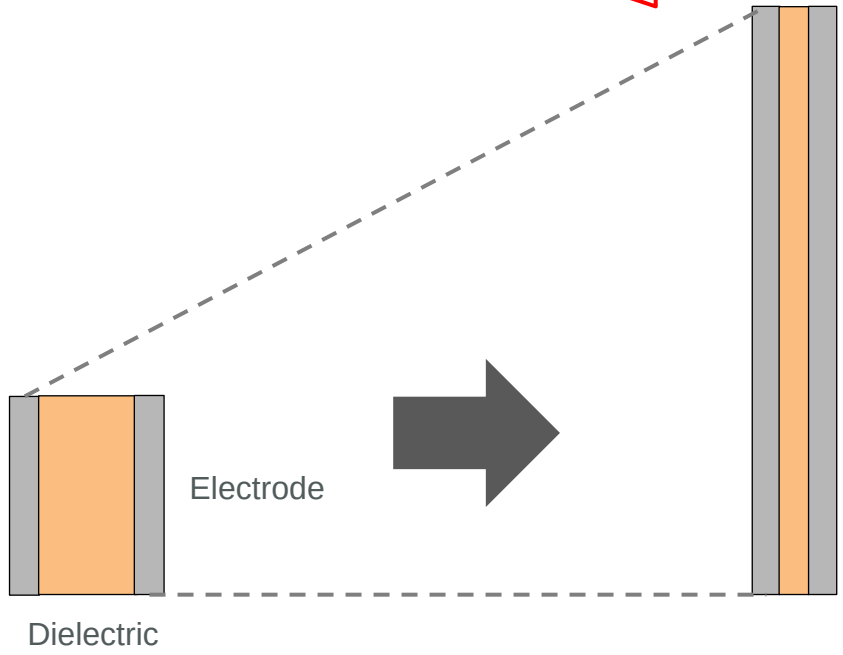
ε = dielectric constant of dielectric

How to increase the capacitance of a capacitor

- **Increase the dielectric constant** of the dielectric
- **Increase** the electrode **area**
- Make the dielectric **thinner**

Simply making the electrodes bigger...

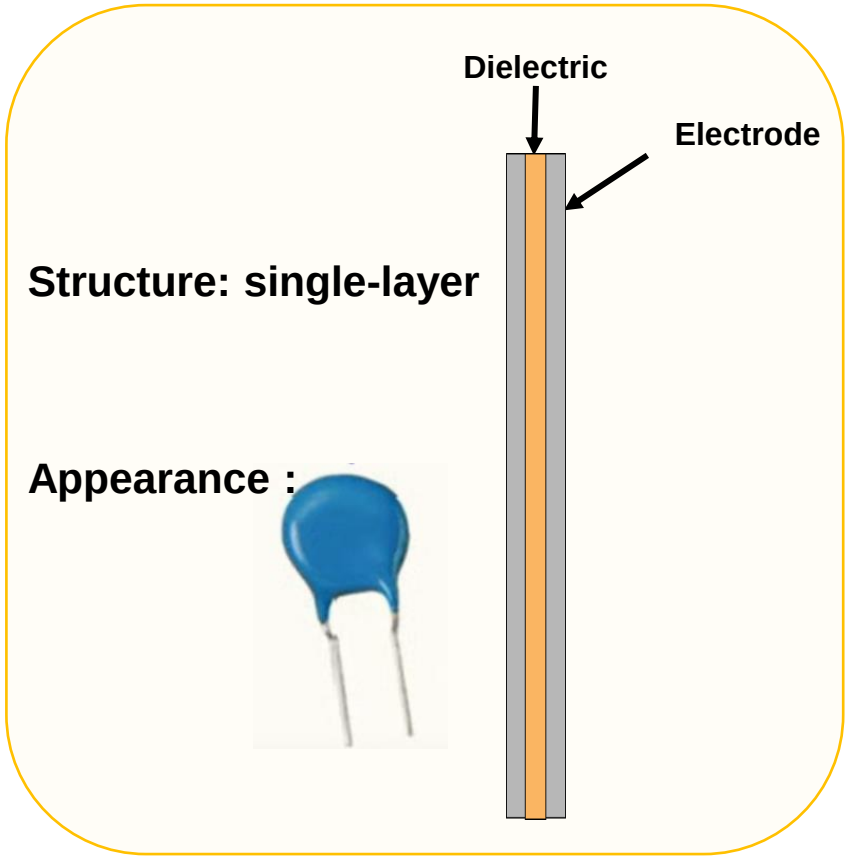
Larger components required

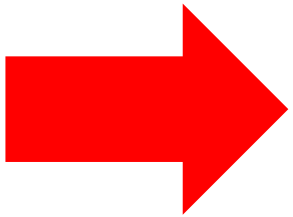


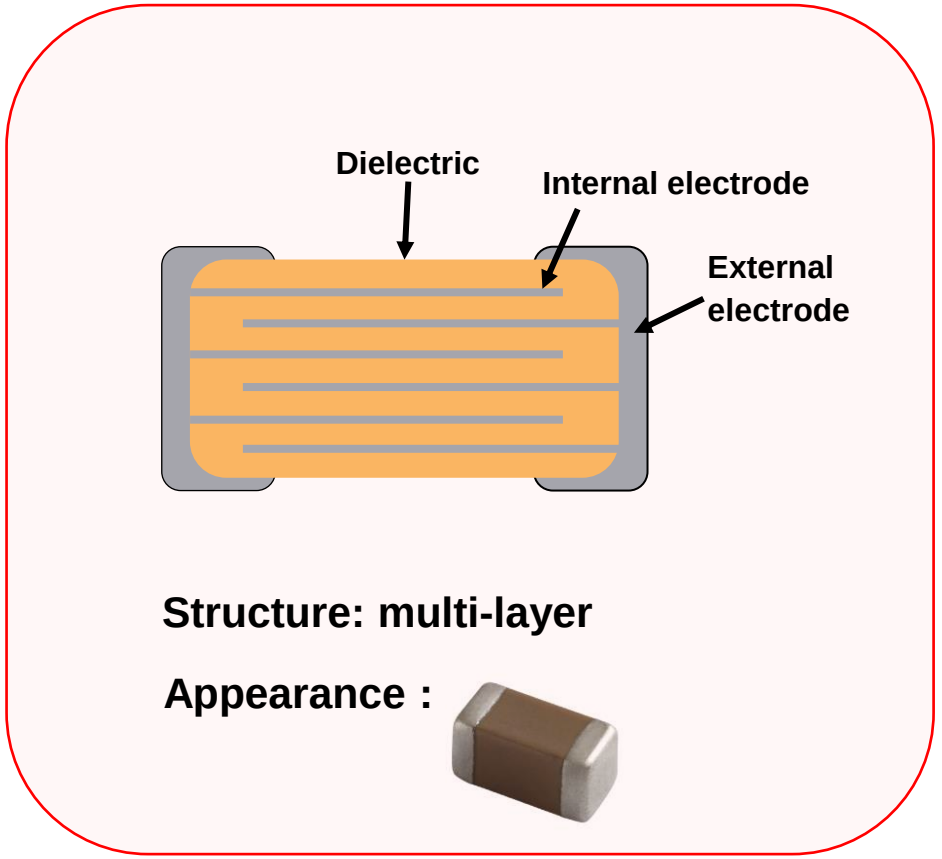
Capacitor structure

Single-layer dielectrics are larger (left)

→ Layer dielectric with electrodes (right)

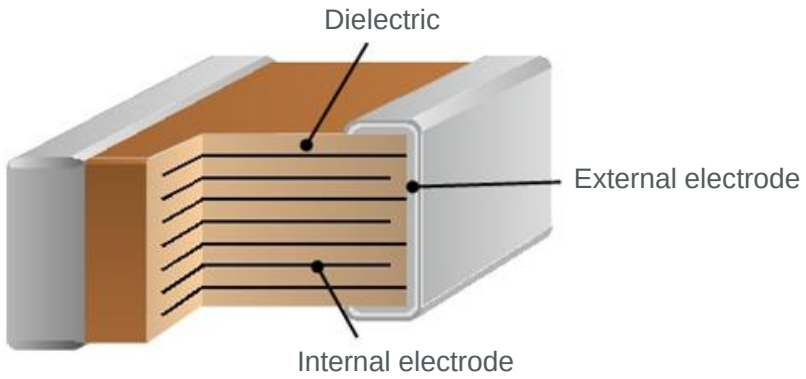




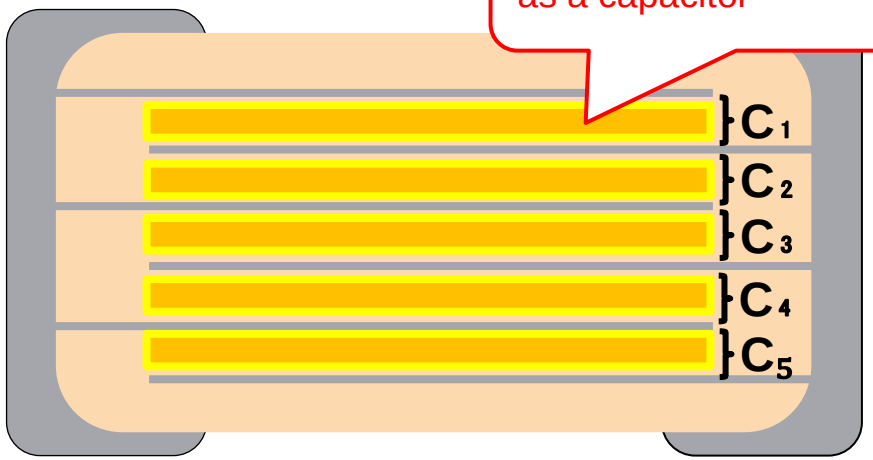


MLCC structure

- **Structure**

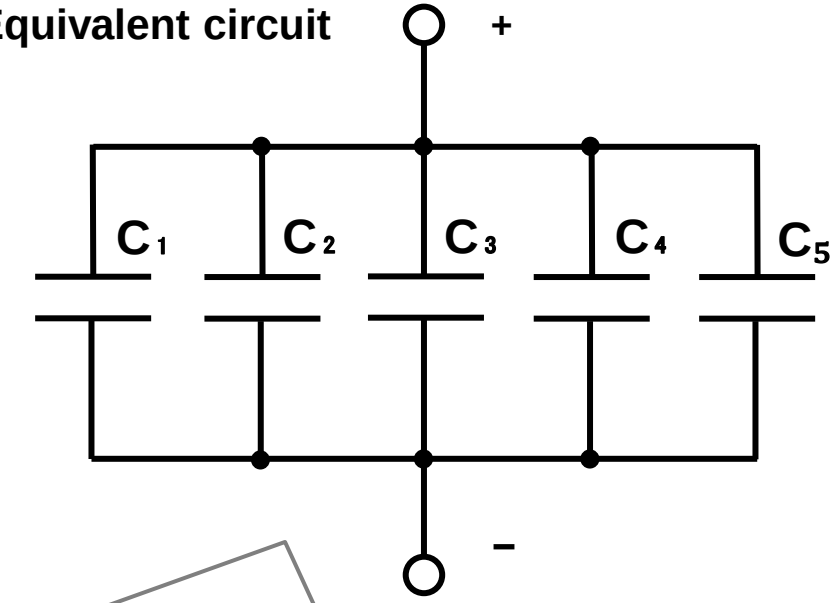


- **Cross-section**



Each electrode sandwich acts as a capacitor

- **Equivalent circuit**



$$C = C_1 + C_2 + C_3 + C_4 + C_5$$

⇒ The more layers, the larger the capacitance.

(3) Types of capacitors and MLCC

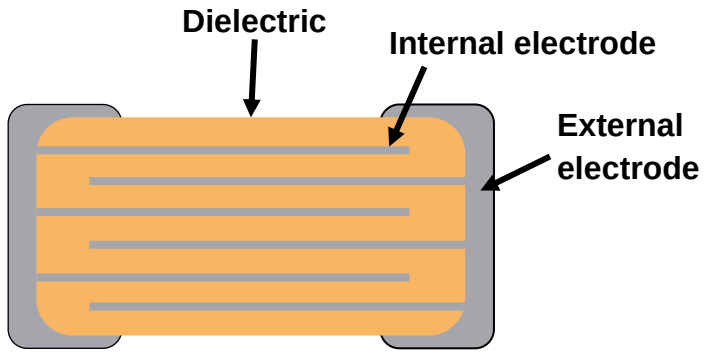
- What is an MLCC?

  MLCC stands for Multi-Layer Ceramic Capacitor.

- MLCC structure

  Dielectric and electrodes are stacked

  ⇒ The greater the number of stacked layers, the higher the capacitance.



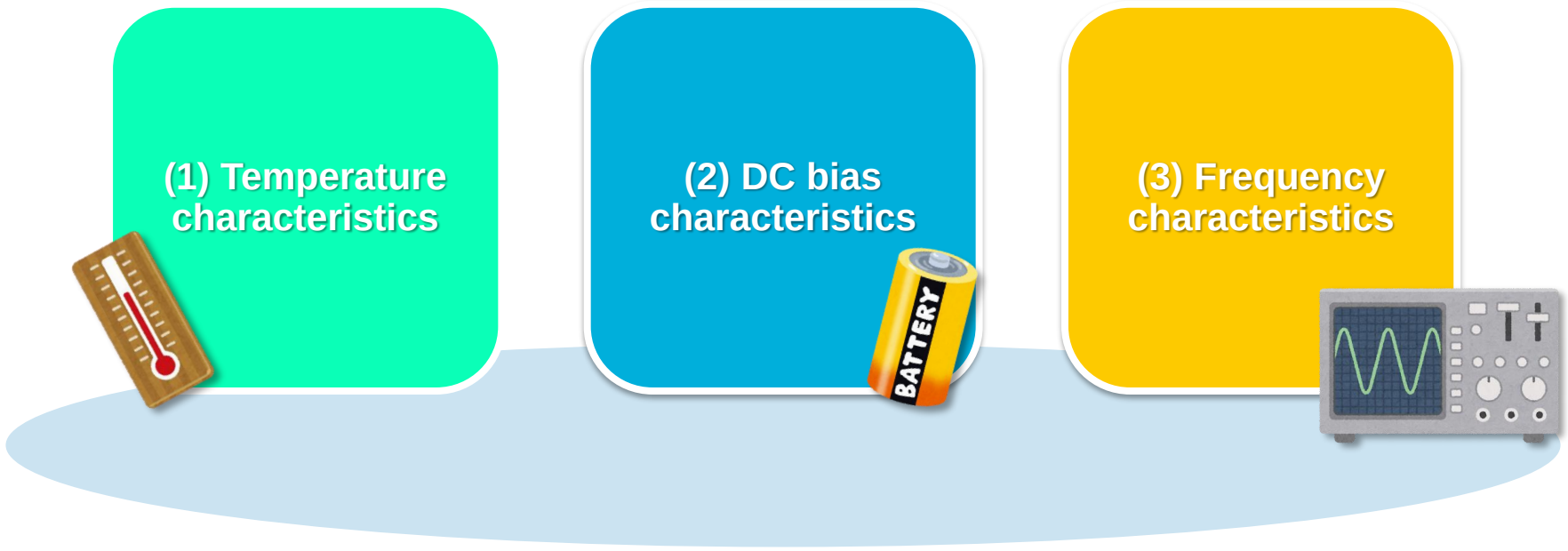
Agenda

1. What is a capacitor?
2. Function of the capacitor
3. Types of capacitors and what is MLCC
4. **Key characteristics of ceramic capacitors**
5. Ceramic Capacitors from Murata

Classification of Ceramic Capacitors

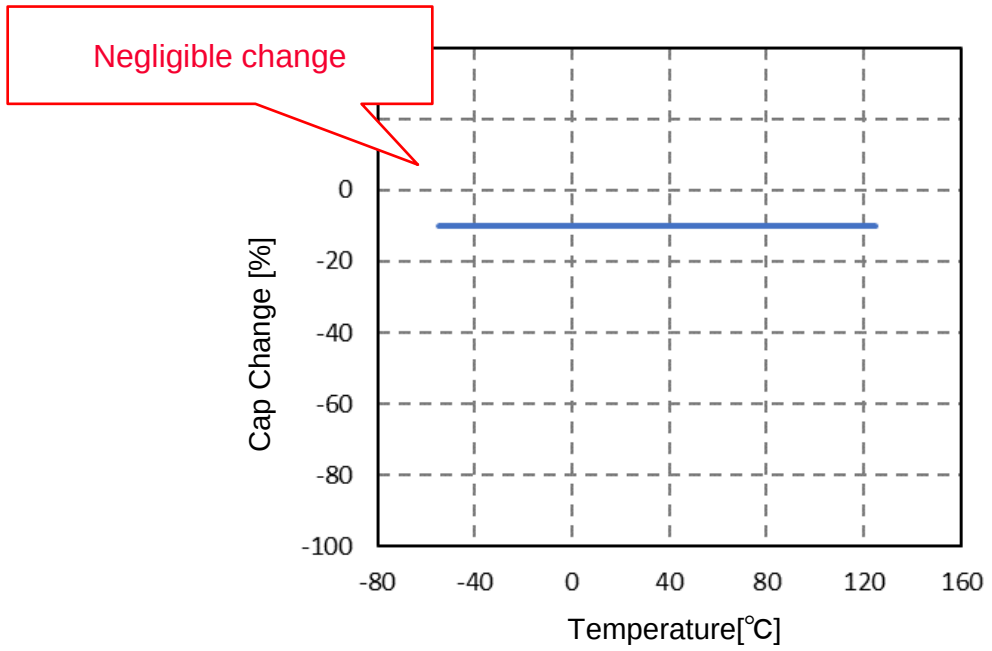
	Temperature compensation type (Class 1)	High dielectric constant type (Class 2)
Material	Paraelectric material	Ferroelectric material
Effect of temperature on capacitance	Change in capacitance is linear and moderate in nature	Change in capacitance is greater than Class 1
Effect of applied voltage on capacitance	Negligible effect	Noticeable effect
Capacitance	Relatively small	Relatively large
Typical applications	Oscillation, tuning (filter), coupling, matching	Bypass circuits, smoothing, coupling and decoupling

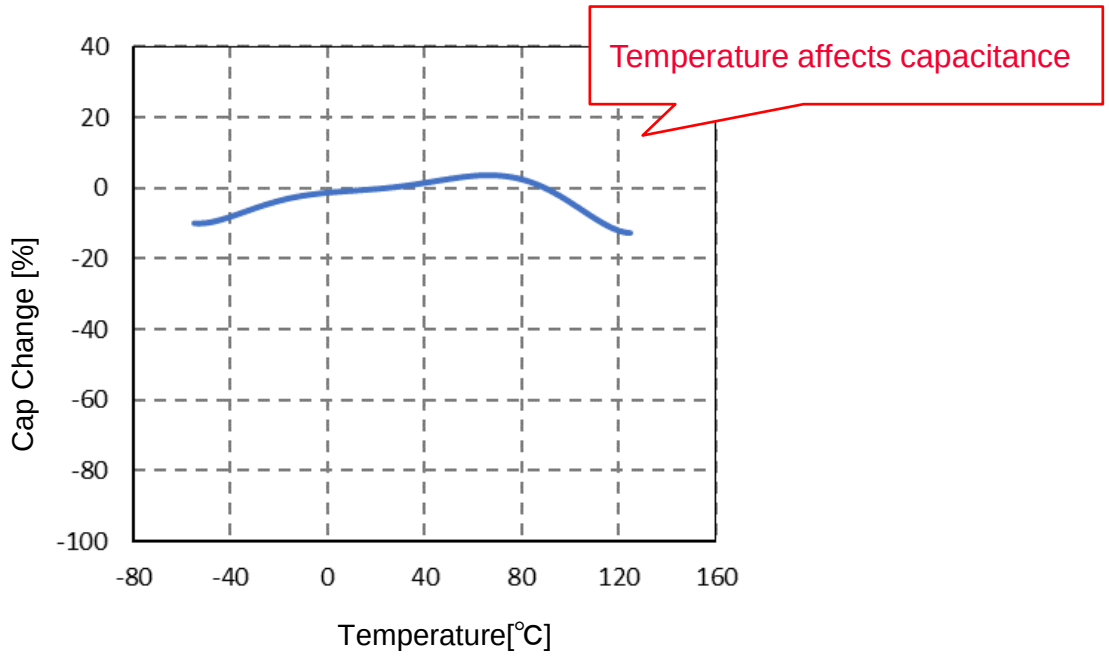
Key Characteristics of Ceramic Capacitors



(1) Temperature Characteristics

Temperature compensation type (Class 1)	High dielectric constant type (Class 2)
• Change in capacitance temperature is linear and moderate in nature	• Temperature has greater impact compared to Class 1 capacitors

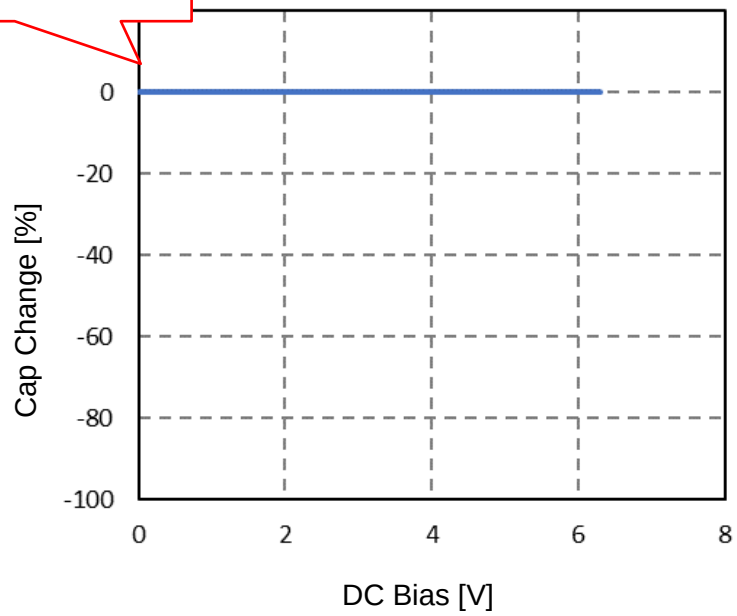




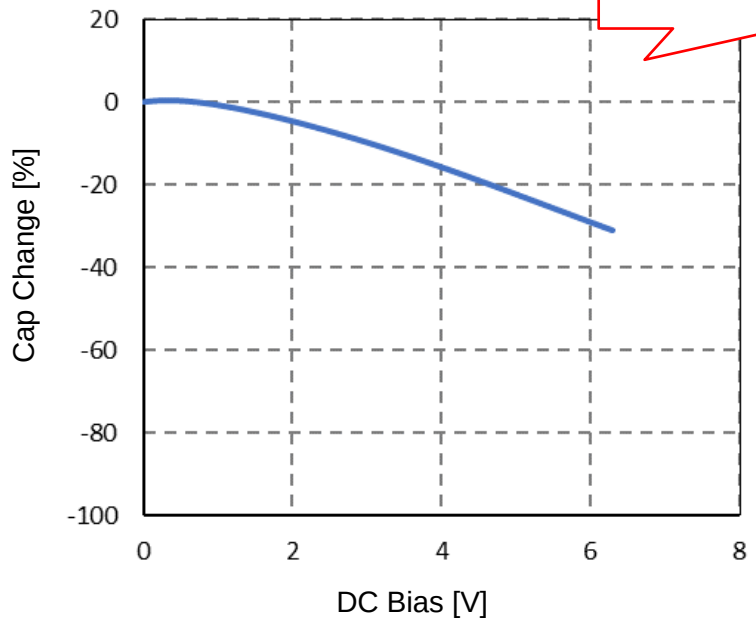
(2) DC Bias Characteristics

Temperature compensation type (Class 1)	High dielectric constant type (Class 2)
• Temperature has negligible effect on capacitance	• Temperature has considerable effect on capacitance

Negligible change

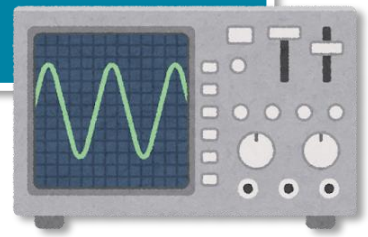


Voltage affects capacitance



(3) Frequency Characteristics

Frequency characteristics of capacitors
⇒ Performance in terms of eliminating noise from power line and suppressing voltage fluctuation
Critical parameter in circuit design

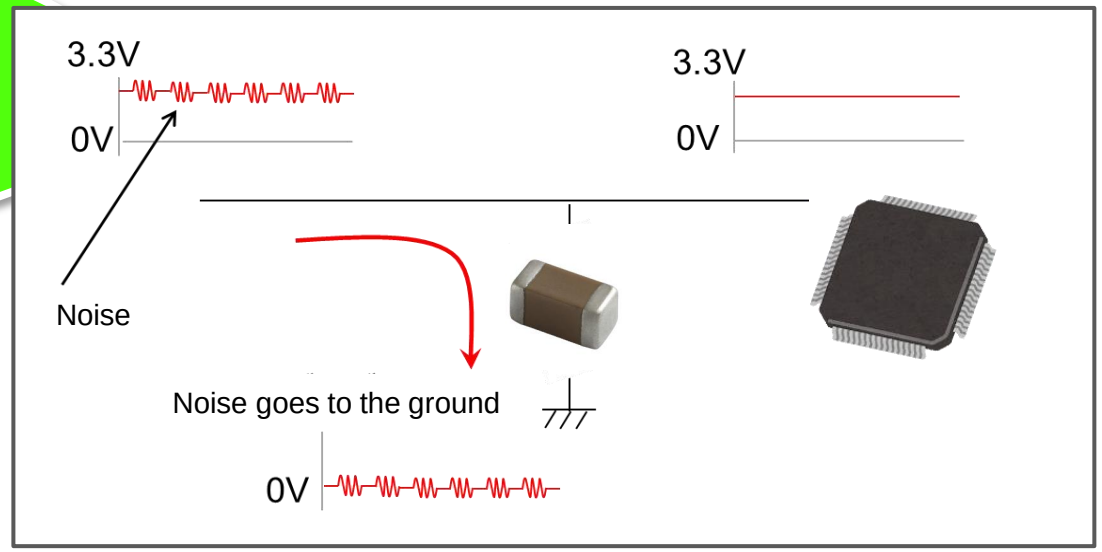


Impedance |Z|

Resistance to alternating current

Equivalent Series Inductance (ESL)
Parasitic inductance of electrodes and lead wires

Equivalent Series Resistance (ESR)
Resistance from dielectric and electrodes



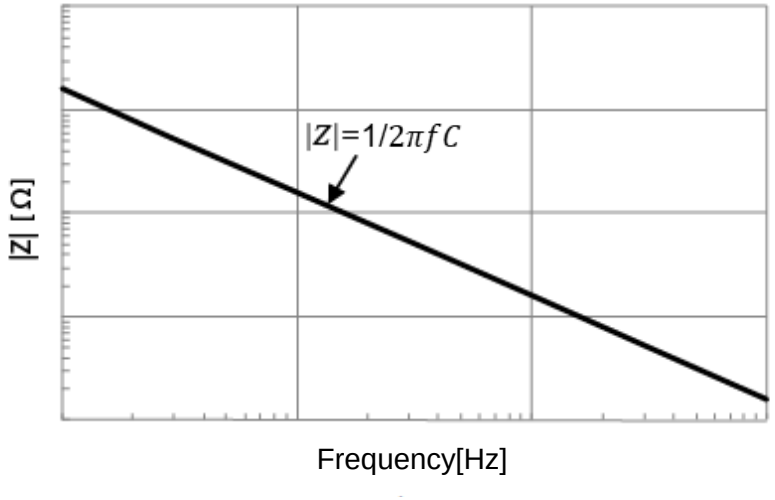
(3) Frequency Characteristics of Ideal Capacitor

The impedance Z of an ideal capacitor is expressed by the following equation.

$$Z = \frac{1}{2\pi f C}$$

f = frequency
C = capacitance of capacitor

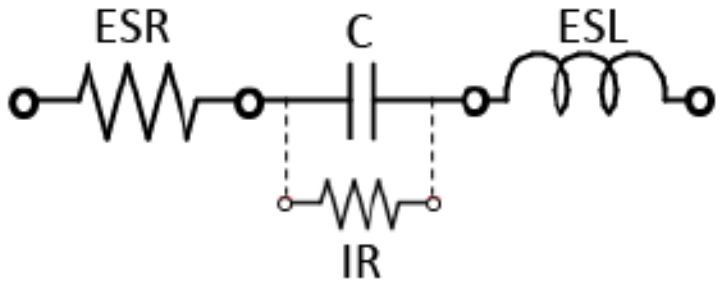
Impedance |Z| decreases in inverse proportion to frequency as shown below.



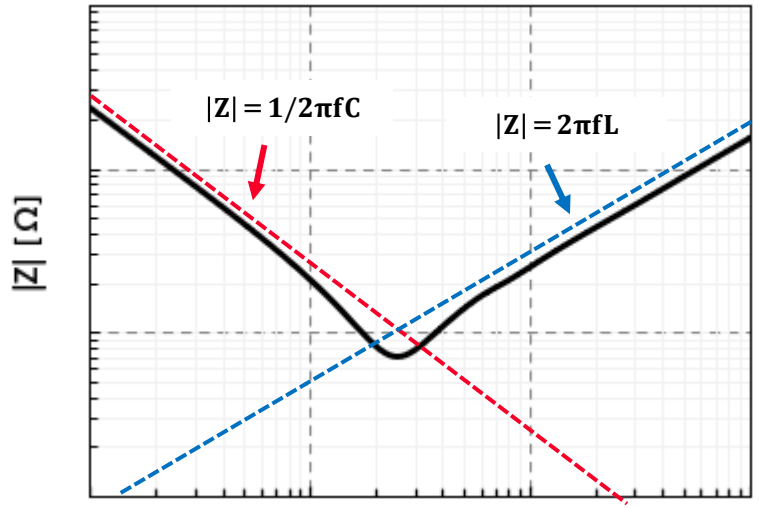
Frequency characteristics of ideal capacitors

(3) Frequency Characteristics of Real-life Capacitors

Real-life capacitors are subject to both ESR and ESL,
and the impact is particularly noticeable at high frequencies.



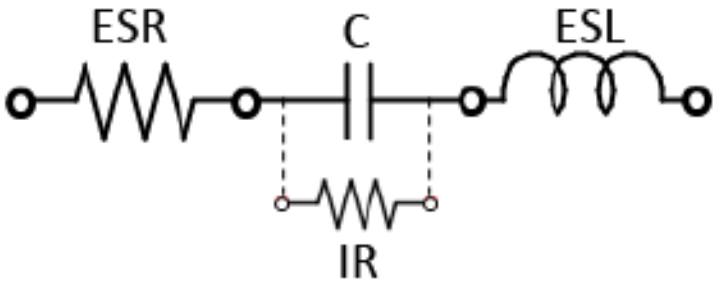
Equivalent circuit for real-life capacitor



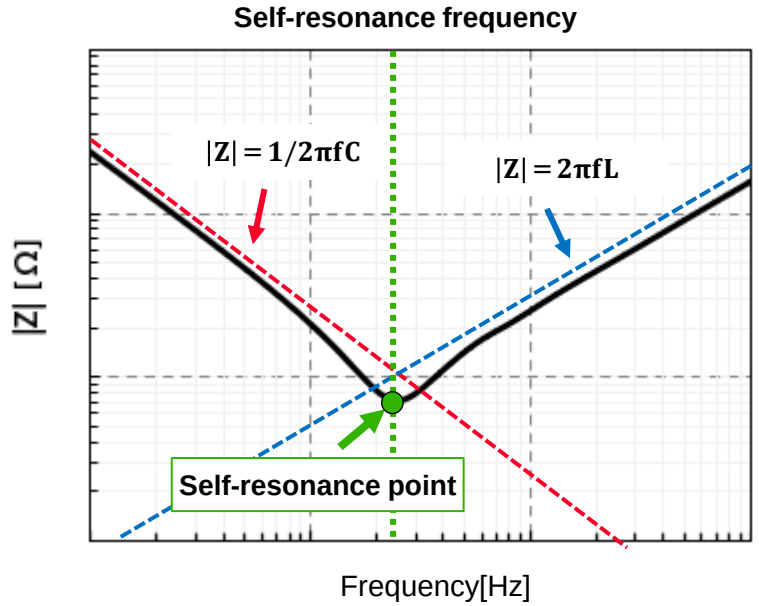
(3) Frequency Characteristics of Real-life Capacitors

Real-life capacitors are subject to both ESR and ESL,
and the impact is particularly noticeable at high frequencies.

The frequency characteristics for |Z| describe a V-shaped curve as shown on the right.



Equivalent circuit for real-life capacitor

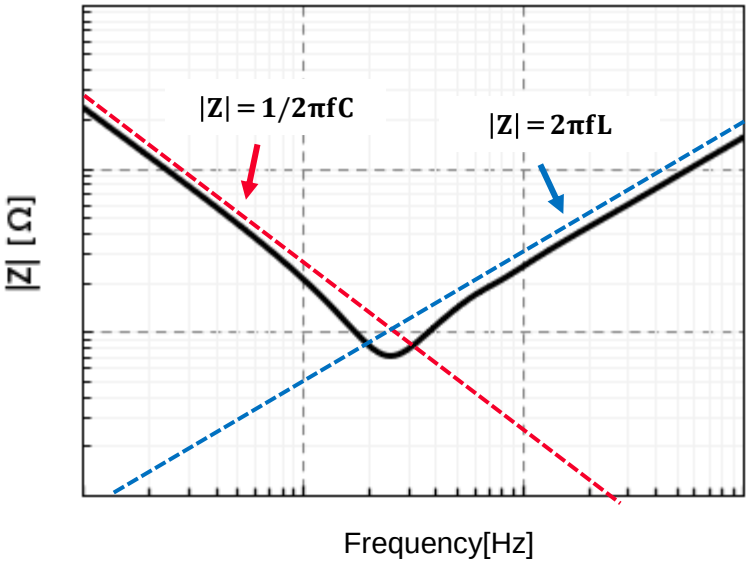


(4) Key characteristics of ceramic capacitors

- Temperature compensation type vs. high dielectric constant type

  High dielectric constant capacitors have greater variation in capacitance associated with temperature and applied voltage than temperature compensation capacitors.

- Frequency characteristics
  - Impedance, the degree to which alternating current flow is hindered, describes a V-shaped curve as shown on the right.
  - Noise can be removed more efficiently by using a capacitor with low impedance.



Agenda

1. What is a capacitor?
2. Function of the capacitor
3. Types of capacitors and what is MLCC
4. Key characteristics of ceramic capacitors
5. **Ceramic Capacitors from Murata**

Extensive Product Lineup

Small, thin, high capacity

Ultra-compact products
(0201M/0.1 uF, 0402M/1 uF)

High capacity products
(up to 330 uF)

Low ESL products
(up to 27 uF)

Conductive polymer aluminum electrolytic capacitor
(up to 560 uF, 2.5–25 V)

Low-loss products
(25–500 V, 1–10 GHz)

Film capacitor

Wire bonding
(0808 M, up to 0.47 uF)

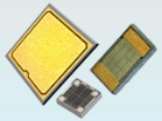
Extra-reliable

Vehicle-mounted components
(ISO9001, AEC-Q200, IATF16949)

Crack-resistant products
(ISO9001, AEC-Q200, IATF16949)

Medical supplies

Resin-coated products
(ISO9001, AEC-Q200, IATF16949)
(up to 1 kV, up to 47 uF)



Silicon capacitor

Anti-noise products
(1608 M, up to 47 uF)

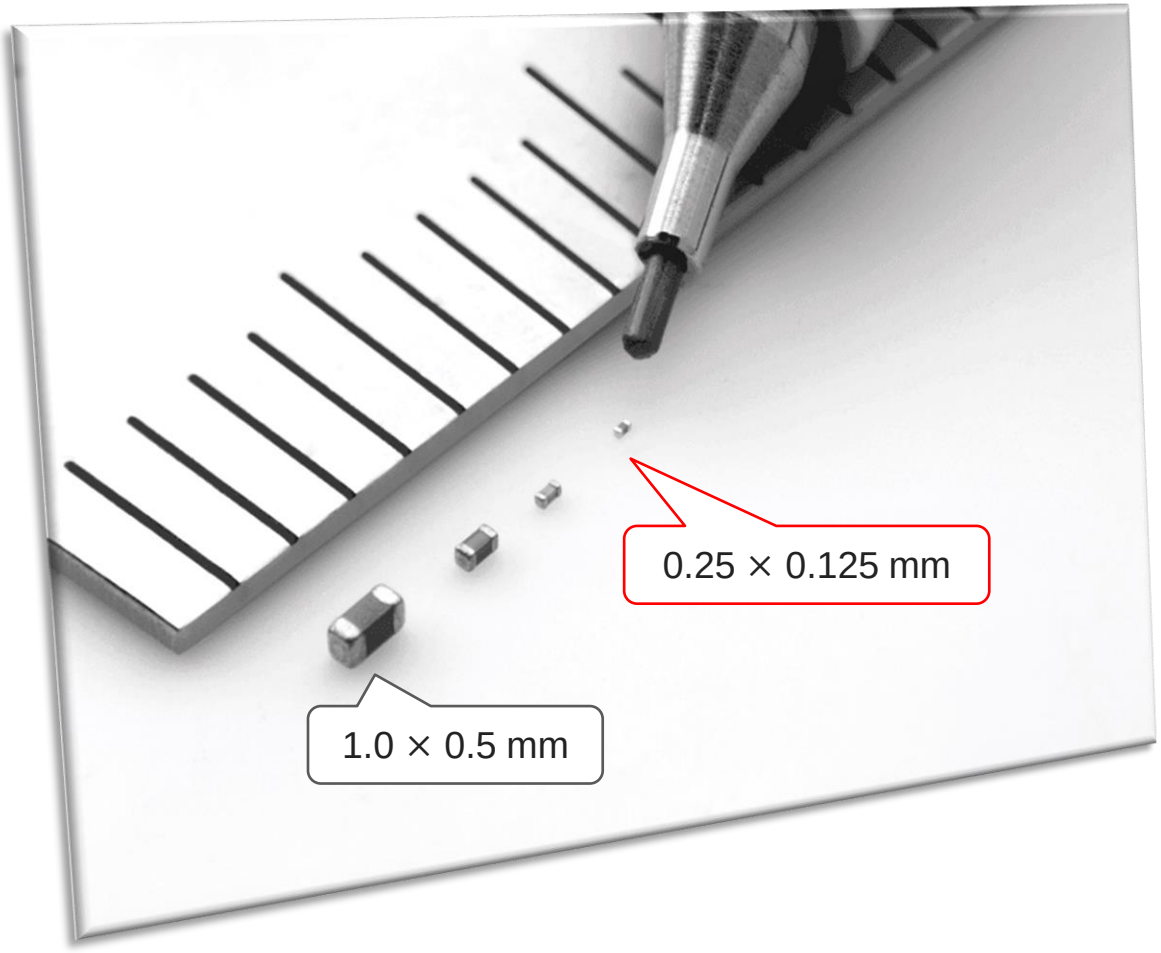
High dielectric strength products
(up to 3.15 kV)

Capacitors with metal terminals
(ISO9001, AEC-Q200, IATF16949)
(16 V-1 kV, up to 100 uF)

Safety rated products

Application-specific

State-of-the-Art Ultra-Compact MLCC



Part Numbering System

Murata MLCC part number

GR	M	03	3	R6	0J	225	M	E01	D
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

(1) and (2) : series (recommended applications)
(3) : dimensions (L x W)
(4) : dimensions (T)
(5) : temperature characteristics
(6) : rated voltage
(7) : capacitance
(8) : capacitance tolerance value
(9) : individual product specifications
(10): package specification code

(such as "180 mm reel" or "330 mm reel")

See also:

Ceramic Capacitors FAQ

Would you tell me how to read the part numbers?

Would you tell me how to read the part numbers? | Capacitors FAQ | Murata Manufacturing Co., Ltd.

Web Services & Support

https://www.murata.com/products/capacitor

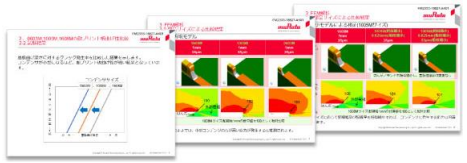
Search capacitors
Product search

- Search by part number or specifications
- Download documents and materials

Search products

Learn more about capacitors
FAQ

- Answers to a range of questions and queries such as key considerations in board design for downsizing MLCC

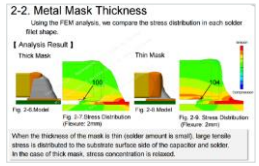


View FAQ

Latest news and updates from Murata
my Murata

- Request free samples
- Bulletin board for posting, answering and viewing questions
- Member-only information

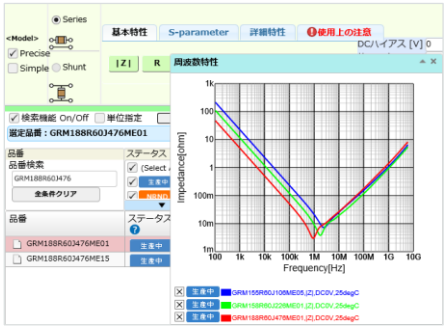
News about products in development



View my Murata

Design support
SimSurfing

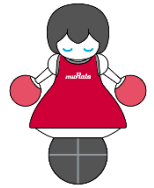
- Search capacitors by effective capacitance (e.g., "at least 5 uF at 1 Vdc and 50°C")
- Download Netlists and S-parameters
- Compare the electrical characteristics of multiple products

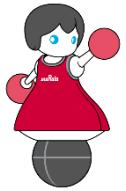


View SimSurfing

Murata as a innovative, reliable and trusted supplier of capacitors

Thank you for taking the time to attend this webinar. We look forward to working with you in the future.





A survey will be displayed at the end of the video.
Complete the survey to get exclusive access to our Q&A booklet !