



The Fundamental Technical Knowledge of Passive Components

— for Windows version —

Chapter I : Capacitor

Chapter II : Inductor

**Chapter III : Electro-Magnetic
Compatibility (EMC)**

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TOP


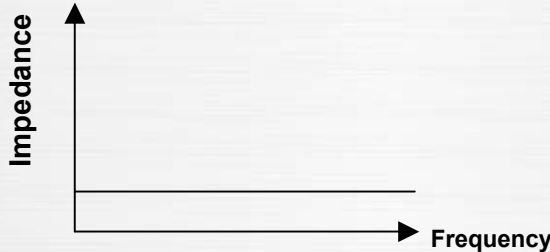
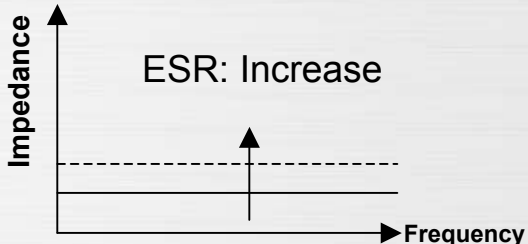

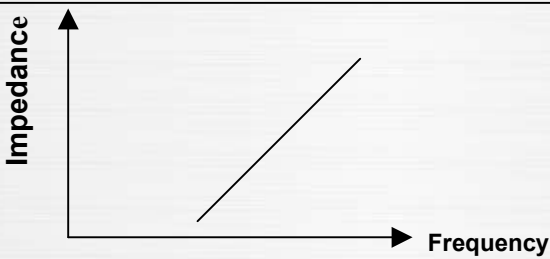
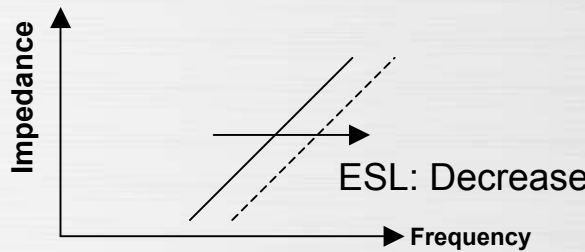

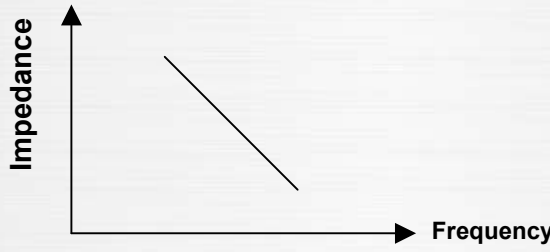
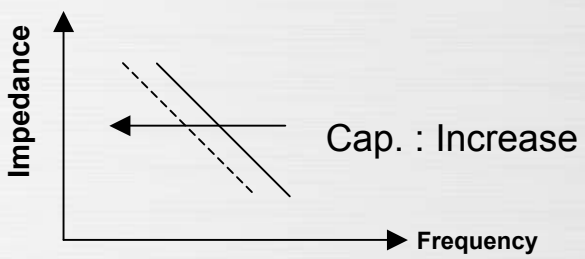


- Chapter 1 -

Capacitor

Impedance Characteristics of Capacitor

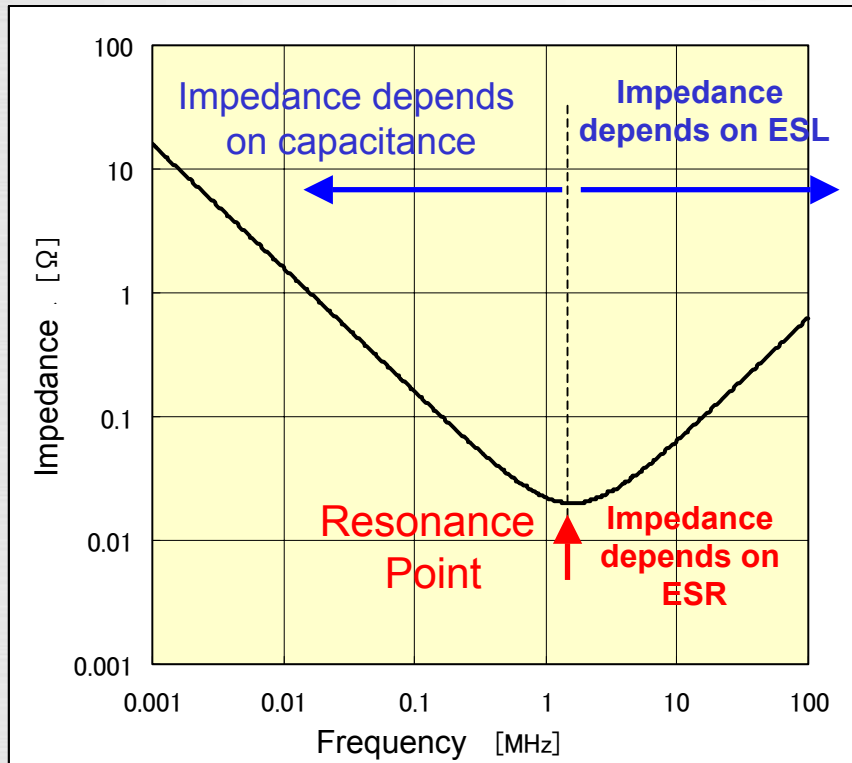
Impedance equivalent circuit with capacitor is the same as the RLC series model.

Elements in Capacitor	Changes in Frequency	Changes in Element
ESR 	 ESR is constant	 ESR: Increase
ESL 	 ESL increases	 ESL: Decrease
Capacitance 	 Capacitance decreases	 Cap. : Increase

What happens to the impedance level when connected in series?

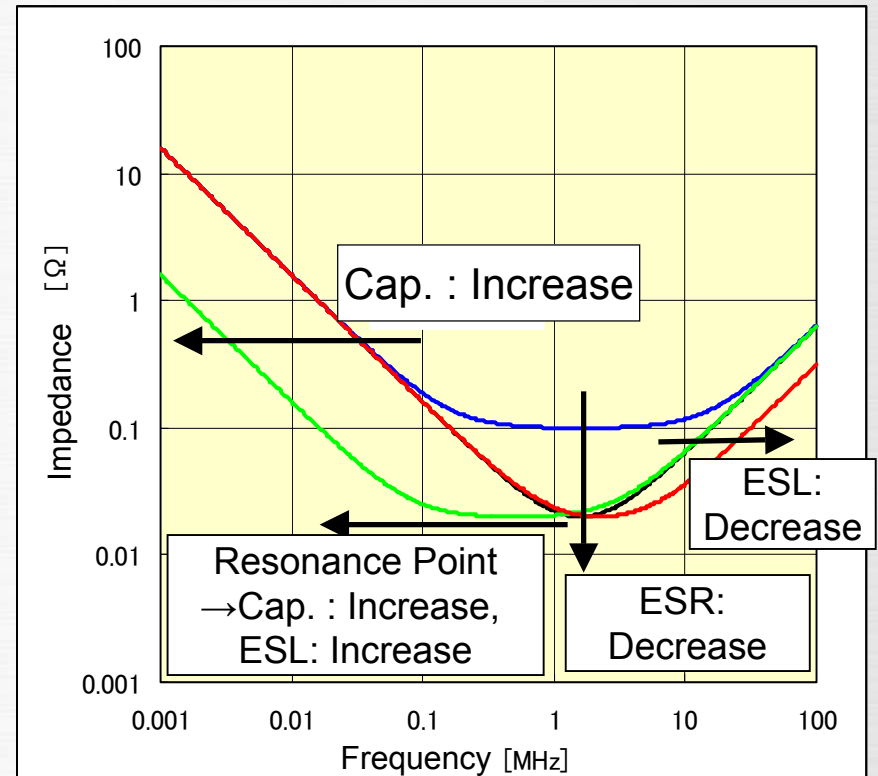
Impedance Characteristics of Capacitor

Impedance for series connection



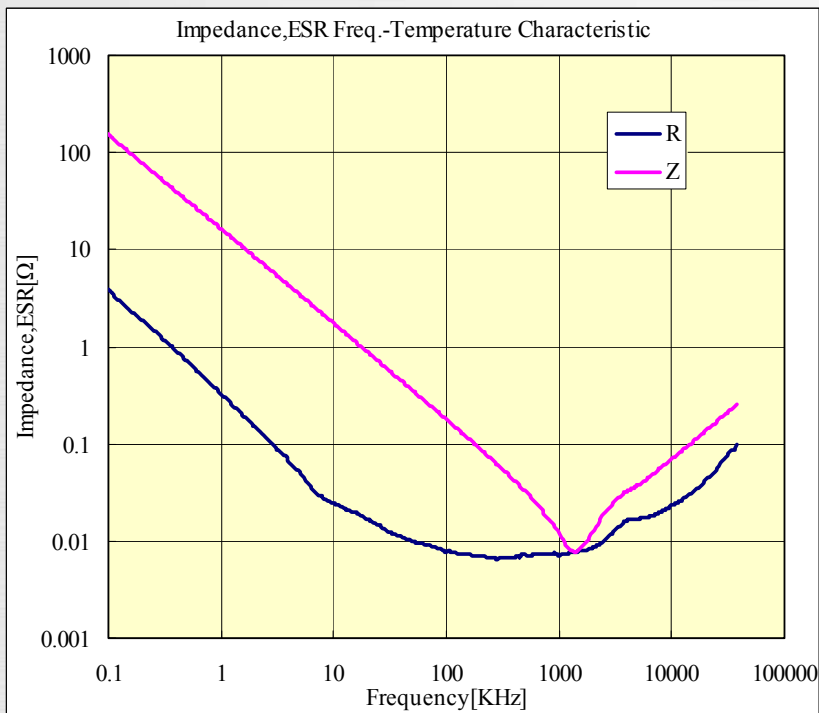
- At resonance point, no impedance for Capacitor & ESL (Impedance for ESR only)
- The frequency at resonance point depends on Capacitor & ESL

Impedance with different elements



Impedance characteristics vary depended on each element.

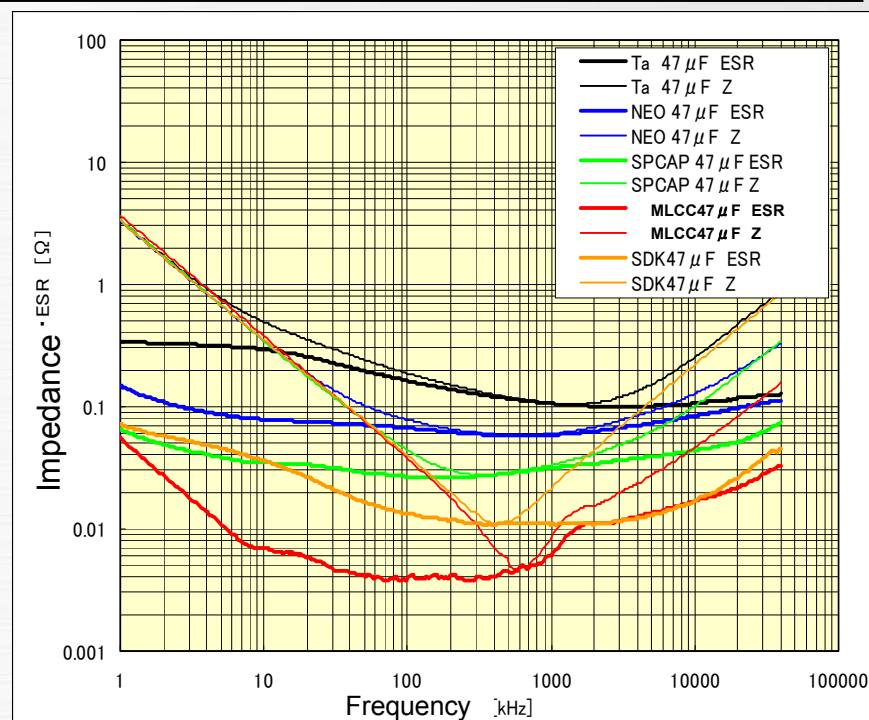
ESR varies depended on frequency



RLC Series Model → ESR independent from frequency

ESR actually varies.

Frequency characteristics for different type of capacitors



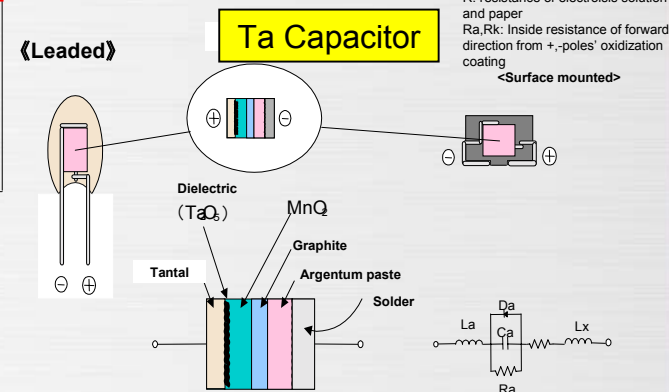
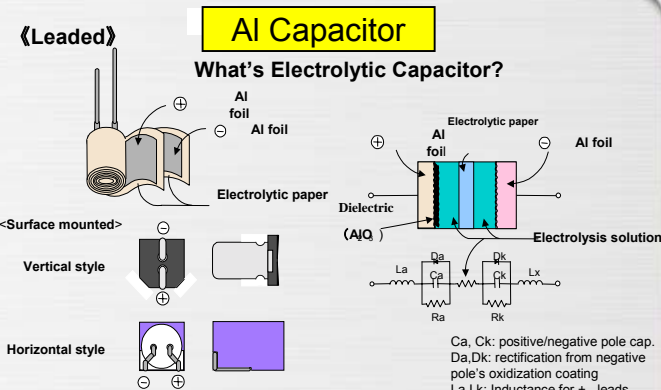
RLC varies depended on capacitor's material, structure and case size

Frequency characteristic varies depended on the type of capacitor, especially on ESR.

Reliabilities of Multi-Layered Ceramic Capacitor

1. Operational condition comparison chart for Circuit

	Polarity	De-rating	Ripple CU. Limitation	Heat Resistance	Solvent Resistance	Loading Test
MLCC	No	◎	◎	◎	◎	◎
Ta Cap.	Yes	×	△	×	△	×
Al Cap.	Yes	×	×	△	×	△
Application Problems	*Layout *Polarity exam When mounting *Reverse voltage Consideration	*Operational limitation for rated voltage (70~50%level)	*Have margin capacity for ripple current *Less reliable associated from self heating	*Limitation for reflow molding and degrading advancement	*Liquid solution flooding except block structure MLCC	*Al capacitor: decreasing in capacitance from electrolysis loss *Ta capacitor: diffusion of Ag, short circuit from degrading of insulating layer

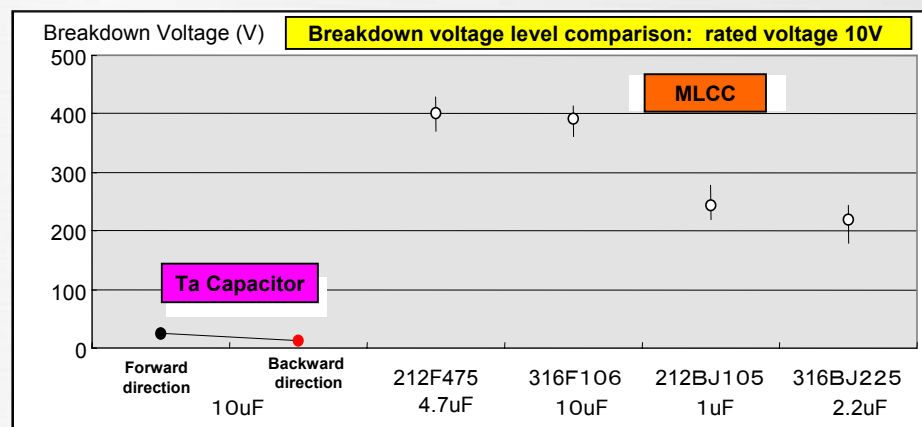


Ceramic Capacitor

Dielectric:
Barium Titanate

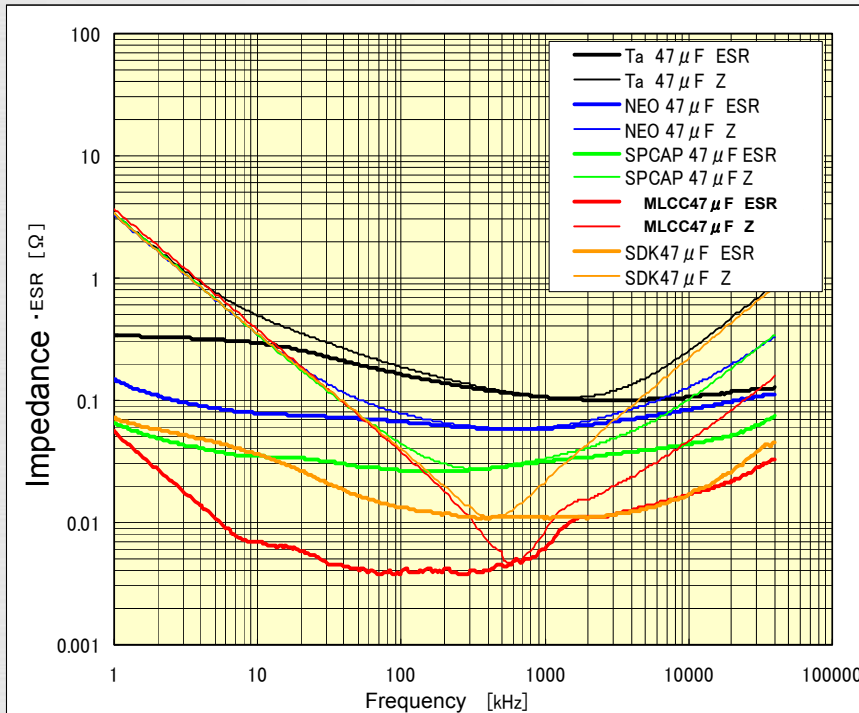


Electrode: Ni



Characteristics Comparison for the Different Type of Capacitors

Frequency Characteristics



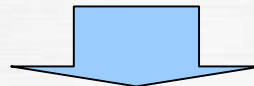
ESR varies greatly depended on each type of capacitors.

Al>Ta>Functional Ta>Functional Al>ML

The lower ESR becomes, the lower the impedance for high frequency gets.

Al>Ta>Functional Ta>Functional Al>ML

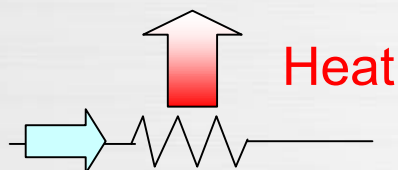
MLCC has superior frequency characteristics.



The most competitive merit

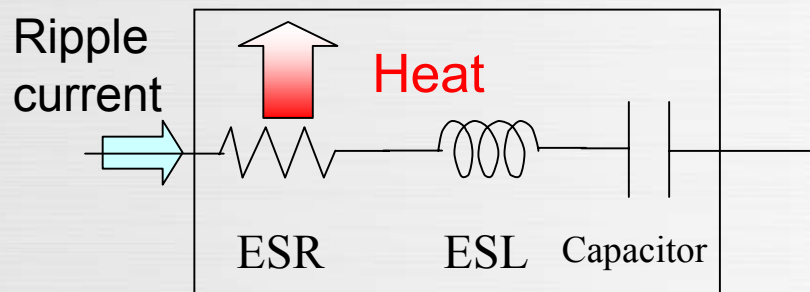
Characteristics Comparison for the Different Type of Capacitors

Ripple Current Characteristics



Electrical energy is converted to heat when current goes through resistance.

Capacitor

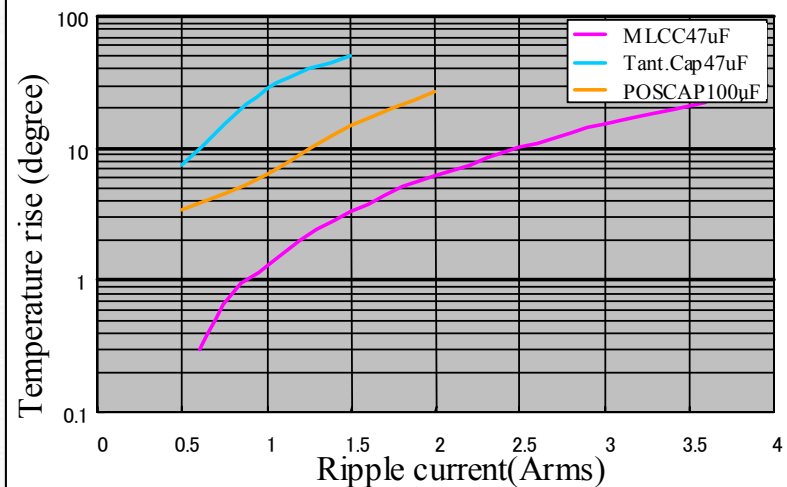


Electrical energy is converted to **heat** when **ripple current** (AC) goes through capacitor. (DC does not go through it)

Heat shortens capacitor's durability.

Ripple current characteristics for the different type of capacitors

Temperature rise characteristic due to ripple current



Given the same amount of calorific power, **ripple current** goes through **MLCC** the most because of its **low ESR**.

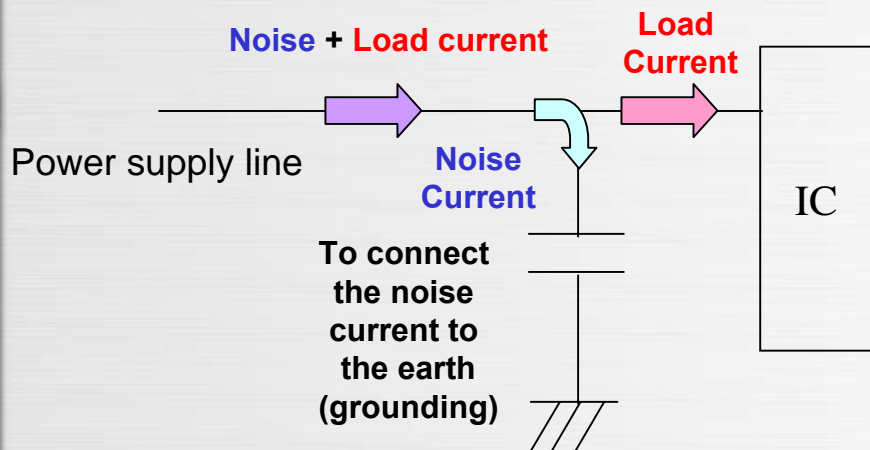
Operational recommendation of **heat release value** for MLCC is **within 10°C**.
There is no limitation of allowed ripple current for MLCC.

Operational recommendation of **heat release value** for **electrolytic capacitor** is **within 5°C**.
Allowed ripple current is regulated by makers.

The Basic Knowledge of Circuits

The Functions of Bypass (decoupling) Capacitor

The Role of Bypass Capacitor



The principle of operation for Bypass Capacitor

DC does not go through the capacitor
(Impedance: ∞)

➡ **DC is supplied directly to IC**

AC (noise) does go through the capacitor

➡ **AC (noise) is grounded**



Noise Suppression → Stabilize IC operation

Necessary Characteristics for Bypass Capacitor

It has low impedance.

(low prevention of an electric current)



It electrifies an electric current well.



It efficiently grounds the noise current.



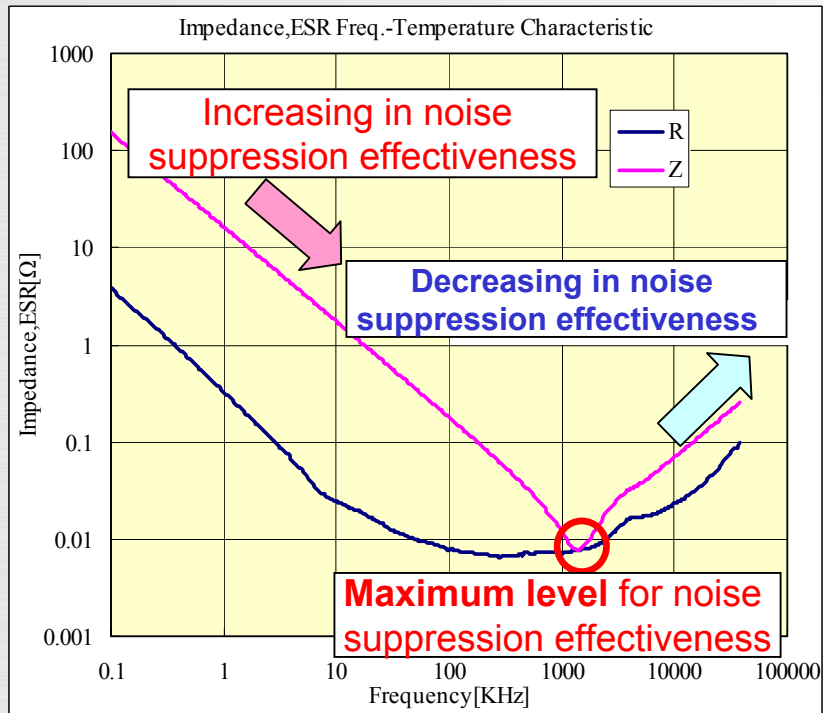
It effectively decreases the noise current.



Impedance	Low	↔	High
Noise effect of decreasing	More effective	↔	Less effective

The Functions of Bypass (decoupling) Capacitor

Selection Criteria for Capacitor

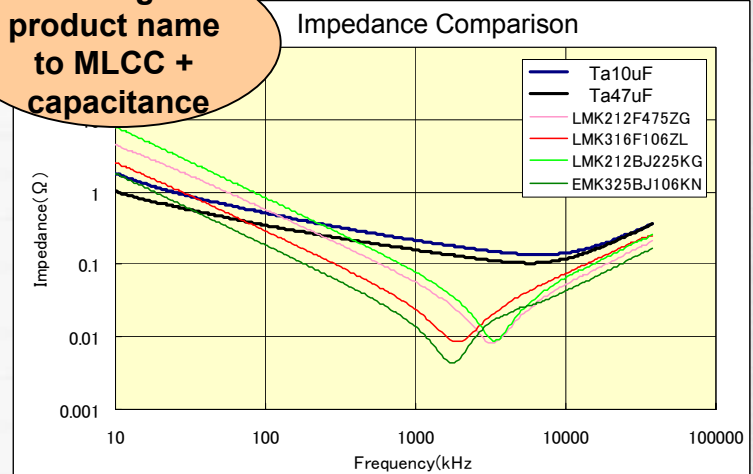


Several kinds of Noise Frequencies

Select a Capacitor based on noise frequency needs to be eliminated

Replacement of Ta capacitor by Bypass Capacitor

Change product name to MLCC + capacitance



When the frequency is over 10kHz, the impedance of MLCC is lower than that of Ta capacitor.

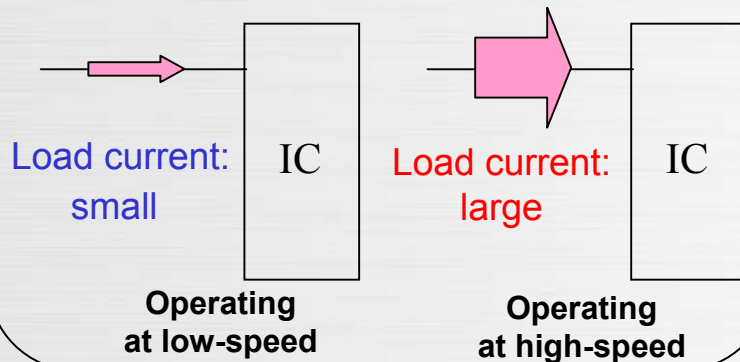
Effectiveness of reduction in high frequency noise for MLCC is more superior than that of Ta capacitor.

It enables to replace Ta capacitor with a smaller value of MLCC.

The Functions of Backup Capacitor

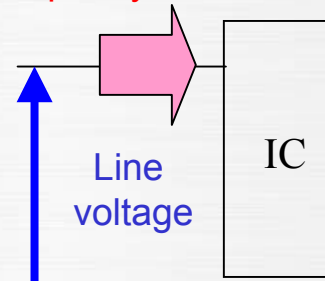
Load current to IC

Load current doesn't stay constant.

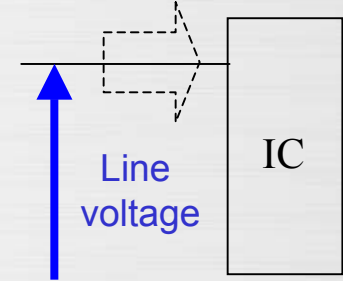


Power line for high-speed load changing

Large load current is quickly needed.

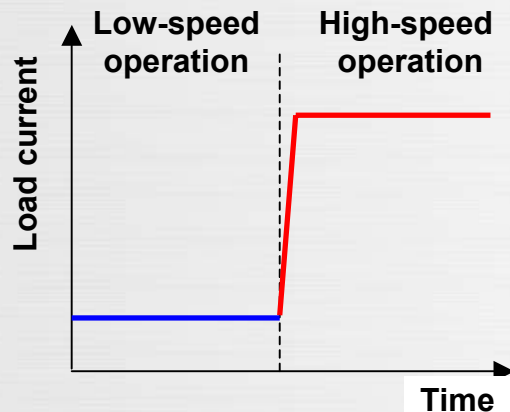


The current can't flow to IC quickly enough.

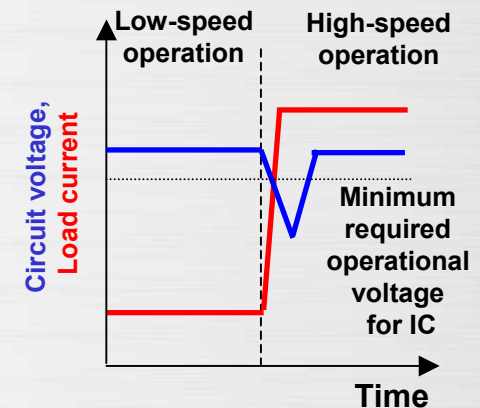
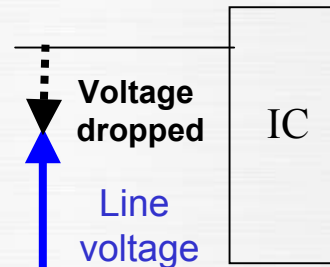


High-speed load change

When IC's operational speed changes rapidly, large load current is quickly needed.



Line voltage can't be maintained, therefore voltage is dropped.

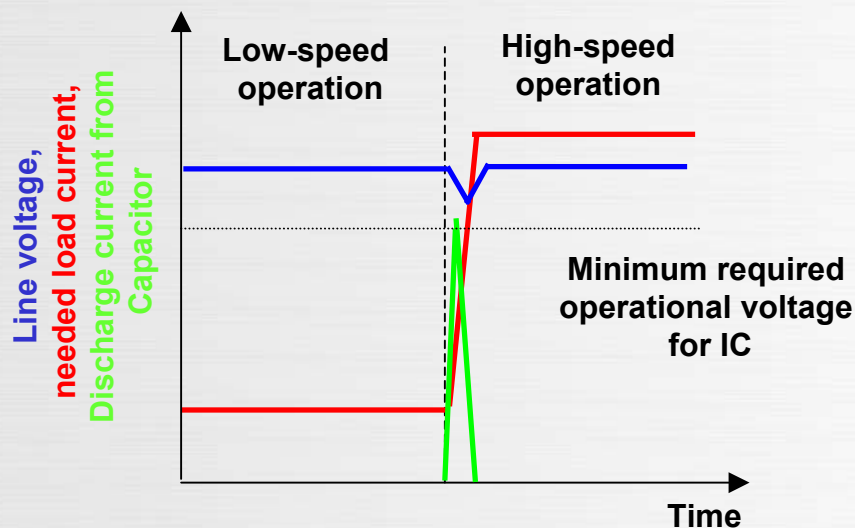
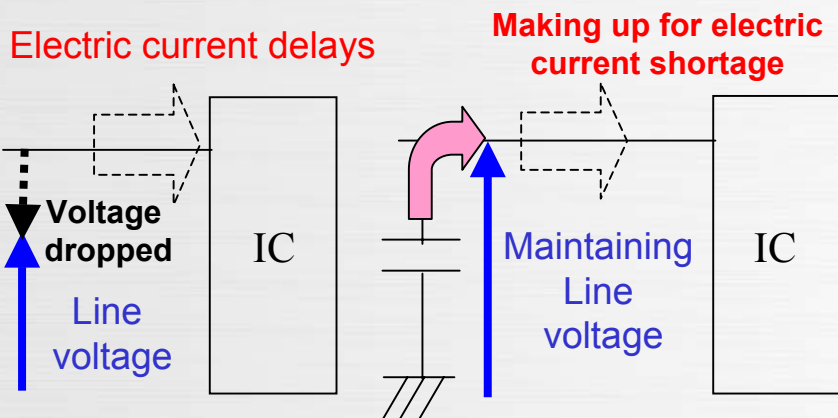


Line voltage decreases below the required operational voltage for IC.

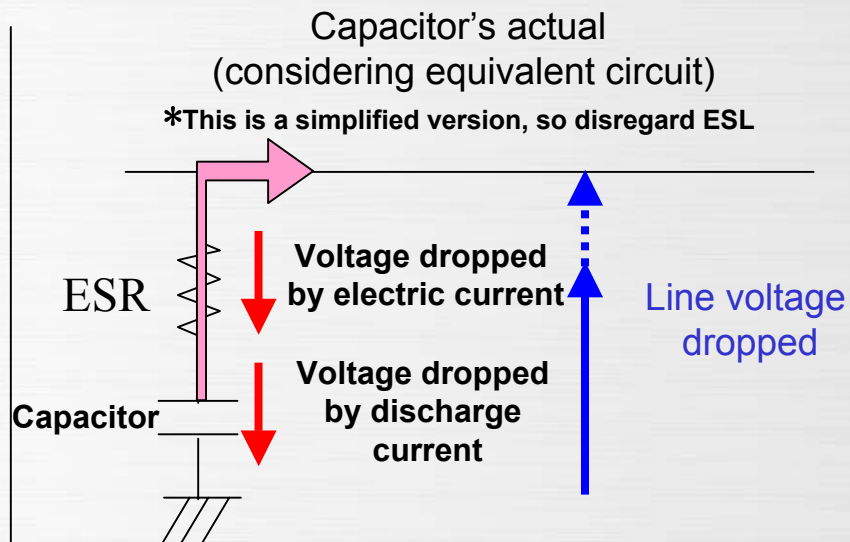
The IC stops its operation.

The Functions of Backup Capacitor

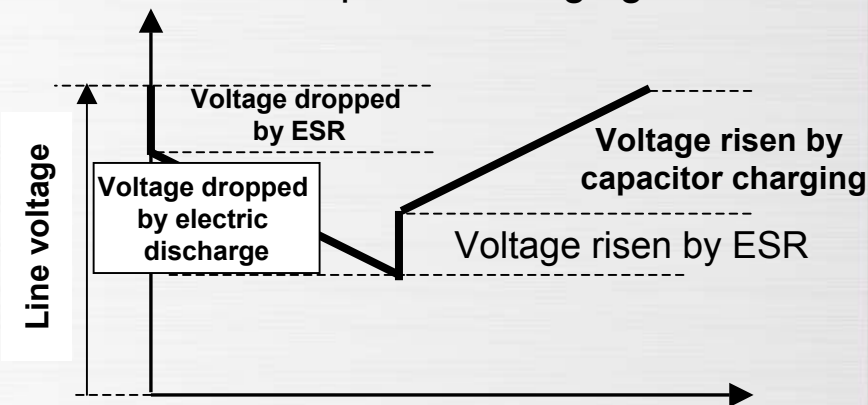
The Role of Backup Capacitor



Keeping the minimum required operational voltage for IC → Maintaining stable operation



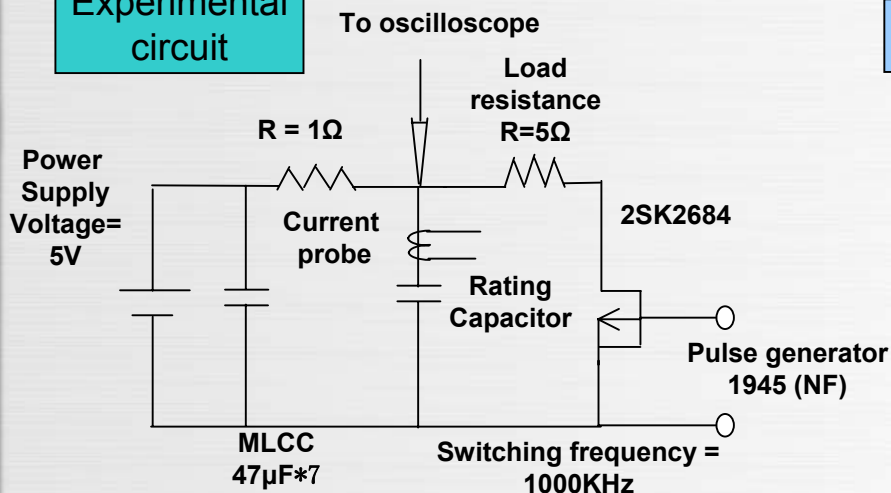
Voltage fluctuation occurs when capacitor charging



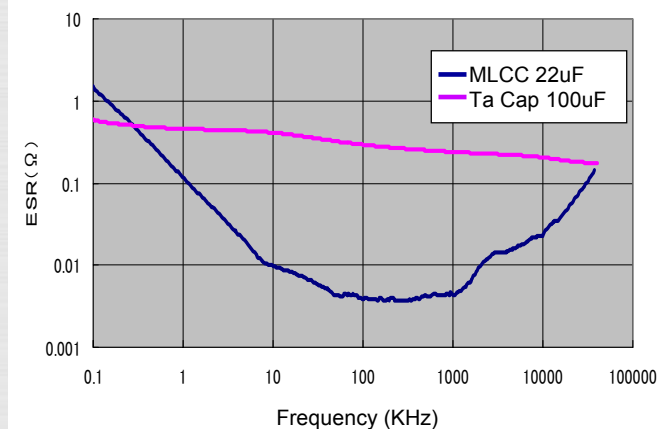
Capacitor and ESR decide the amount of voltage dropped

The Functions of Backup Capacitor

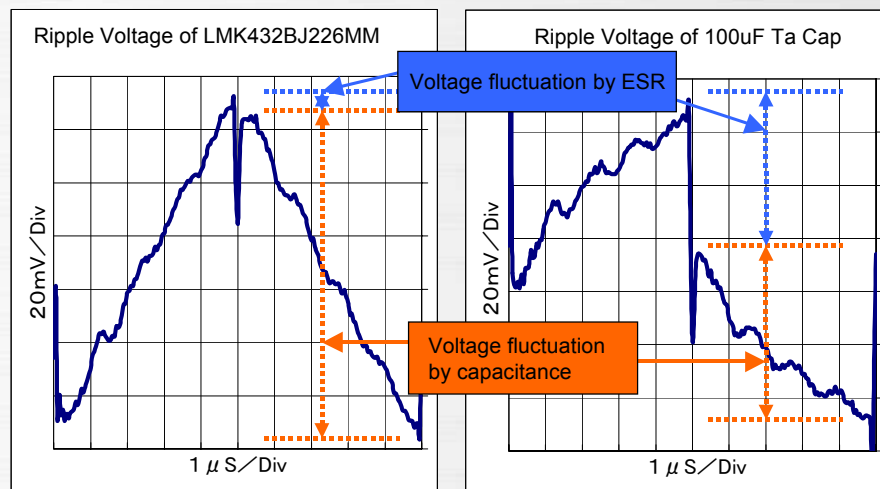
Experimental circuit



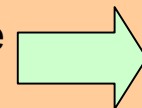
ESR comparison



Experimental result for Capacitance and ESR



High Value
Low ESR



The fluctuation band of
line becomes narrower.

Merits of MLCC

It enables to replace Ta capacitor with a smaller value of MLCC.

The effectiveness of MLCC's voltage fluctuation depressing effect is greater than that of Ta capacitor.

Application Examples for Backup Capacitor

10uF

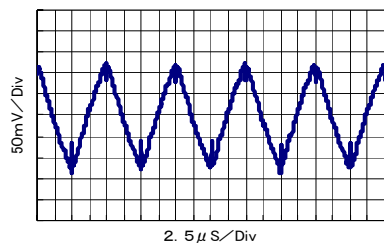
22uF

47uF

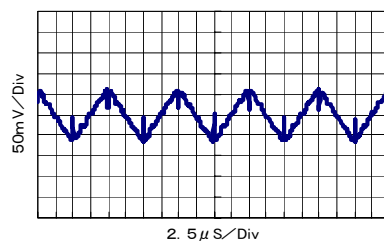
100uF

MLCC

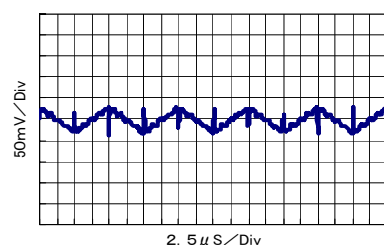
JMK316BJ106ML(10uF)



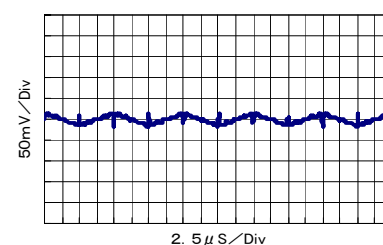
JMK325BJ226MM(22uF)



JMK432BJ476MM(47uF)

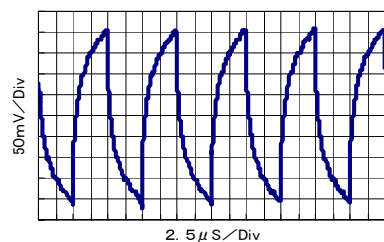


JMK550BJ107MM(100uF)

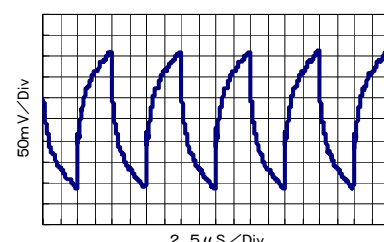


Ta Cap

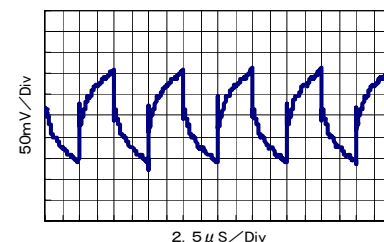
Ta Cap 10uF



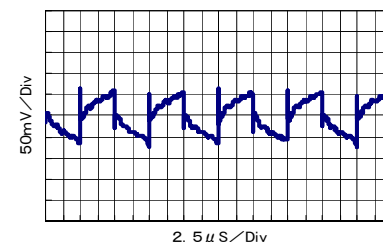
Ta Cap 22uF



Ta Cap 47uF

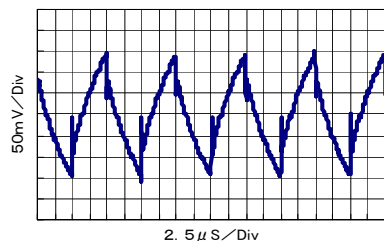


Ta Cap 100uF

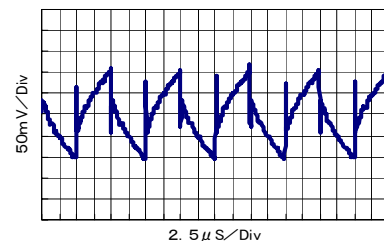


OS-CON

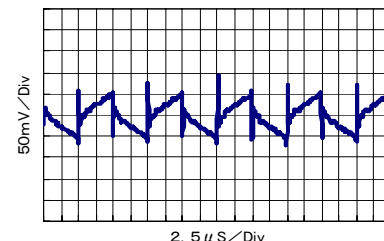
OS-CON 10uF



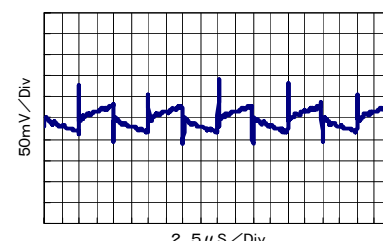
OS-CON 22uF



OS-CON 47uF



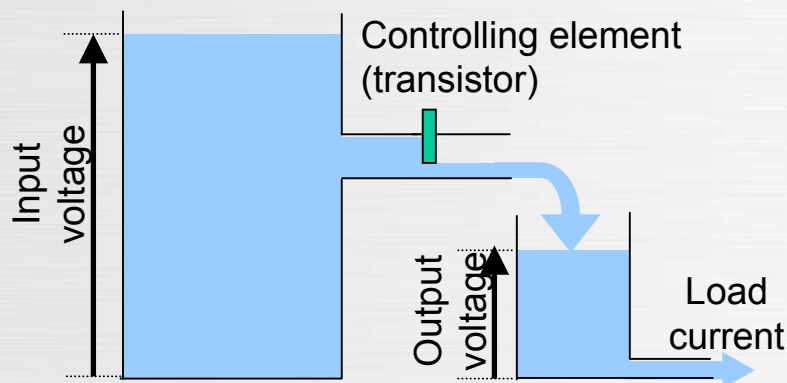
OS-CON 100uF



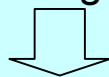
The Basic Knowledge of Power Supply Circuit

Series Regulator (3 Terminal Regulator)

Circuit operation (water gate model)

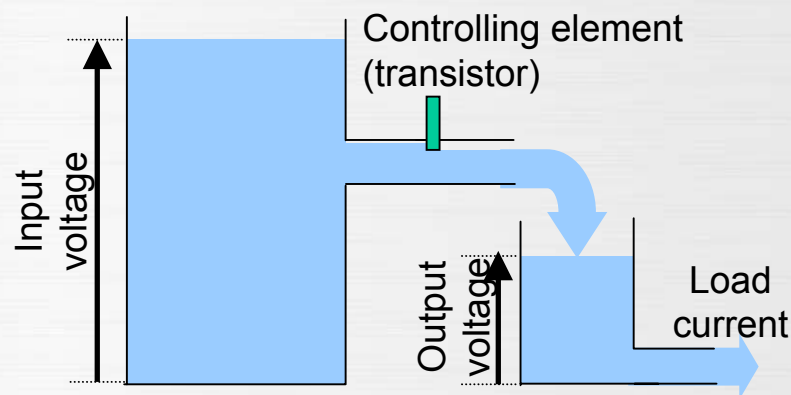


Producing output voltage by lowering certain amount of input voltage



Step-down power supply

Load current fluctuation



Controlling water gate to keep the water level constant

Controlling load current with transistor

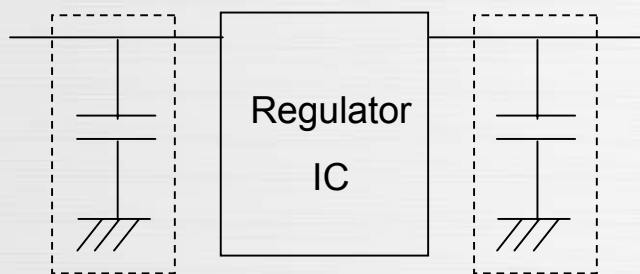


Output voltage stays constant.

Series Regulator (3 Terminal Regulator)

Circuit structure

Input voltage > Output voltage

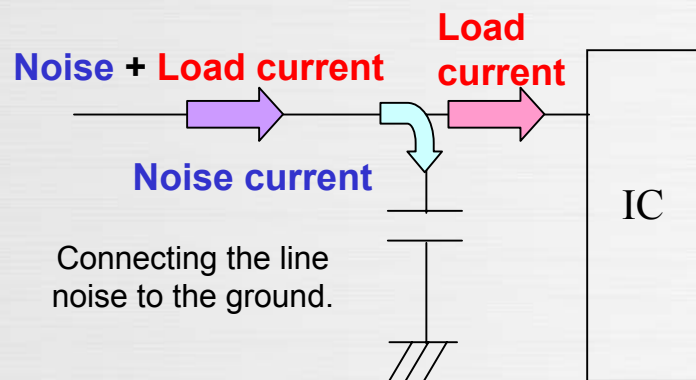


Input Capacitor

Output Capacitor

Consisting of IC, input and output capacitors.

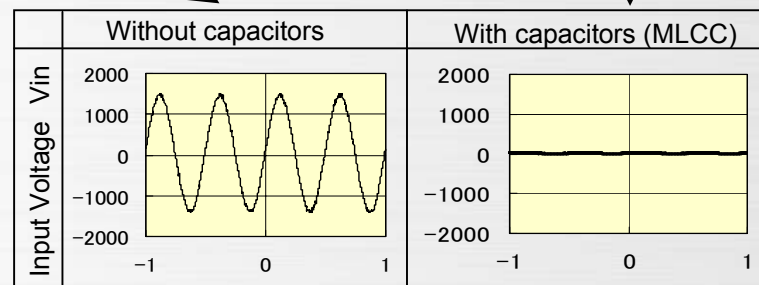
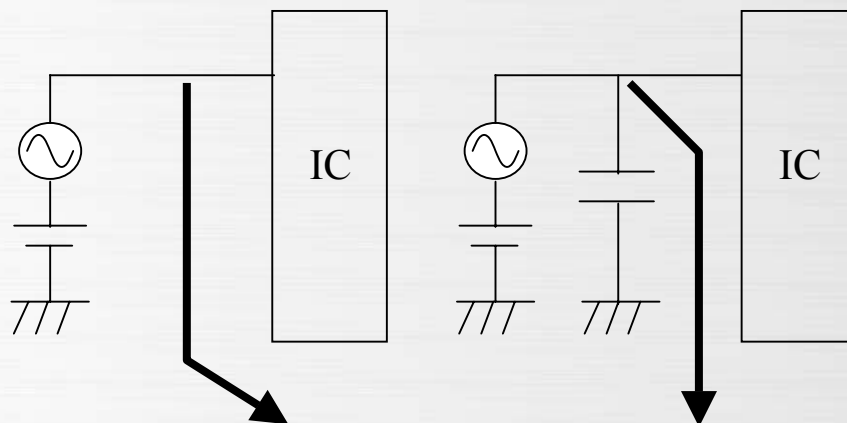
Function of input capacitor



Same as the function of Bypass Capacitor

Effects of input capacitor

Add alternate current to input voltage purposely to measure input current amount with or without input capacitor

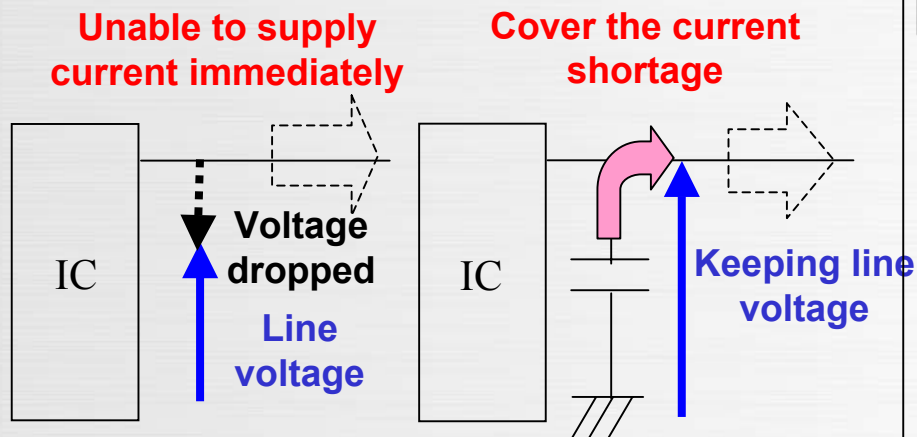


Vertical: mV Horizontal: u sec

Input voltage is stabilized as input capacitor is connected.

Series Regulator (3 Terminal Regulator)

Function of output capacitor

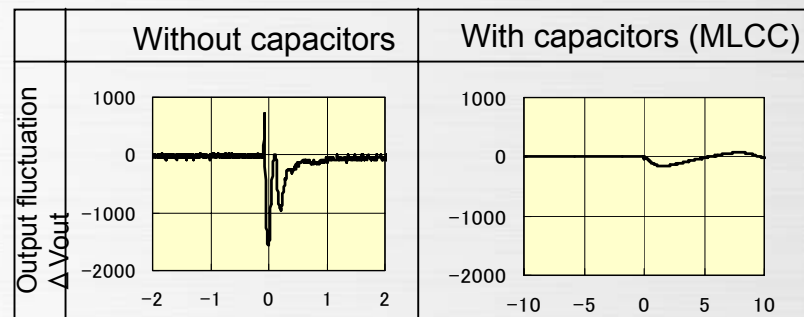
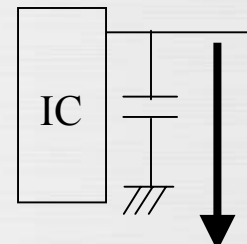
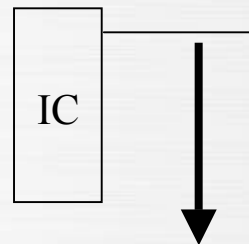
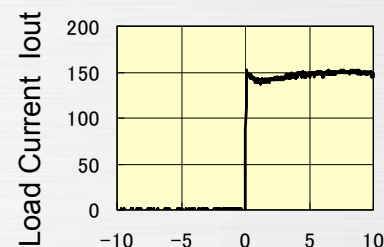


Supply current to control voltage fluctuation for rapid load change

Same as the function of Backup Capacitor

Effects of output capacitor

Measuring the voltage fluctuation when load change is occurred with/without output capacitor.

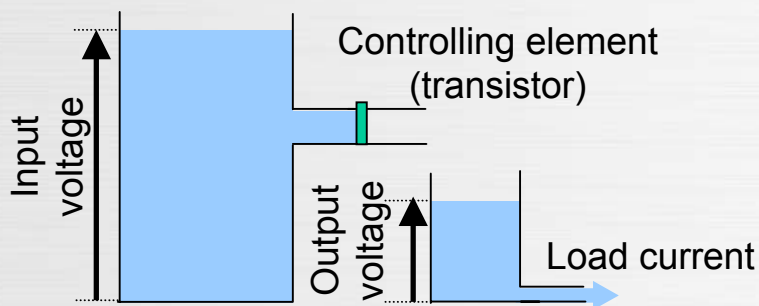
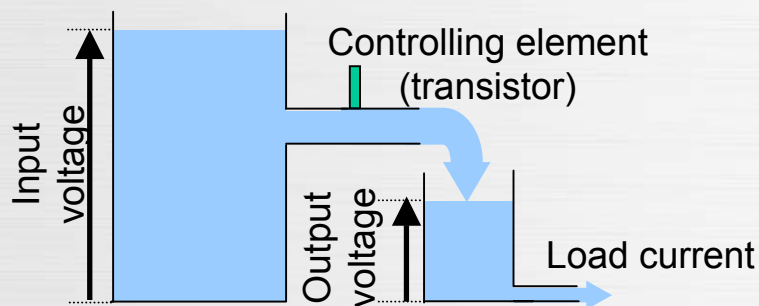


Output voltage is stabilized as output capacitor is connected.

Step-Down Converter

Circuit operation (water gate model)

Producing output voltage by lowering input voltage with transistor



Transistor for switching power supply has only ON or OFF signal.

Switching operation

Controlling output voltage by switching

Turn-on cycle → Constant

Time to be ON → Changes



PWM method

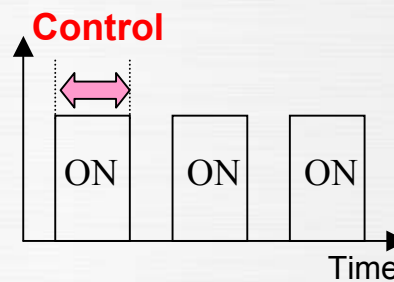
Turn-on cycle → Constant

Time to be ON → Constant

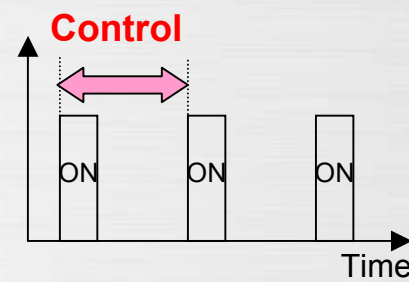


PFM method

Turn-on cycle of the switch → Switching frequency



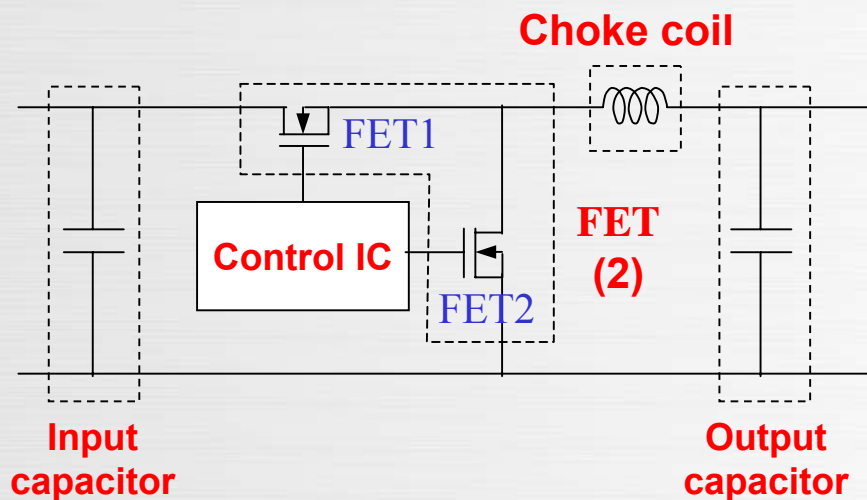
PWM



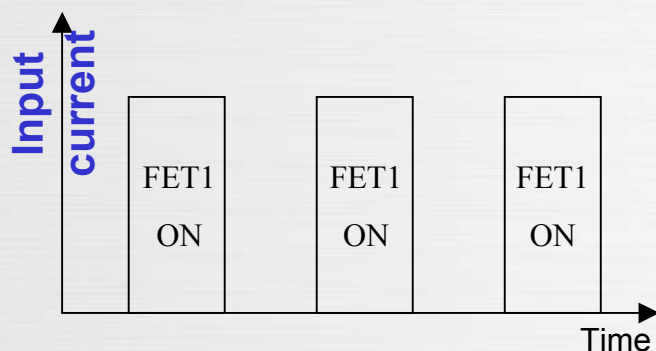
PFM

Step-Down Converter

Circuit structure

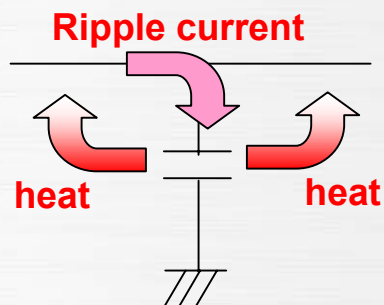


Input side current



Large amount of alternating current (ripple current) flows.

Operation of input capacitor



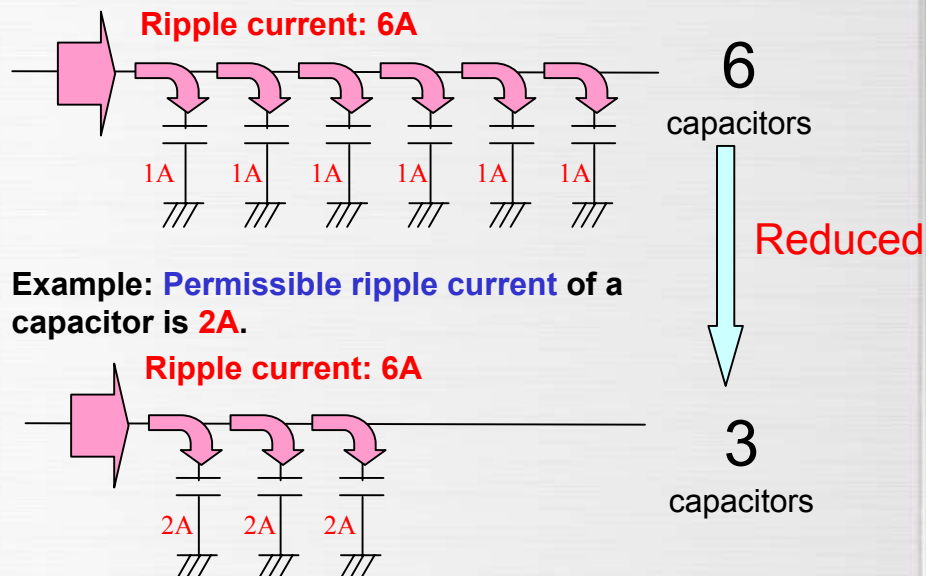
Ripple current flows into input capacitor.

Heat generated by ESR

Necessary characteristics of input capacitor

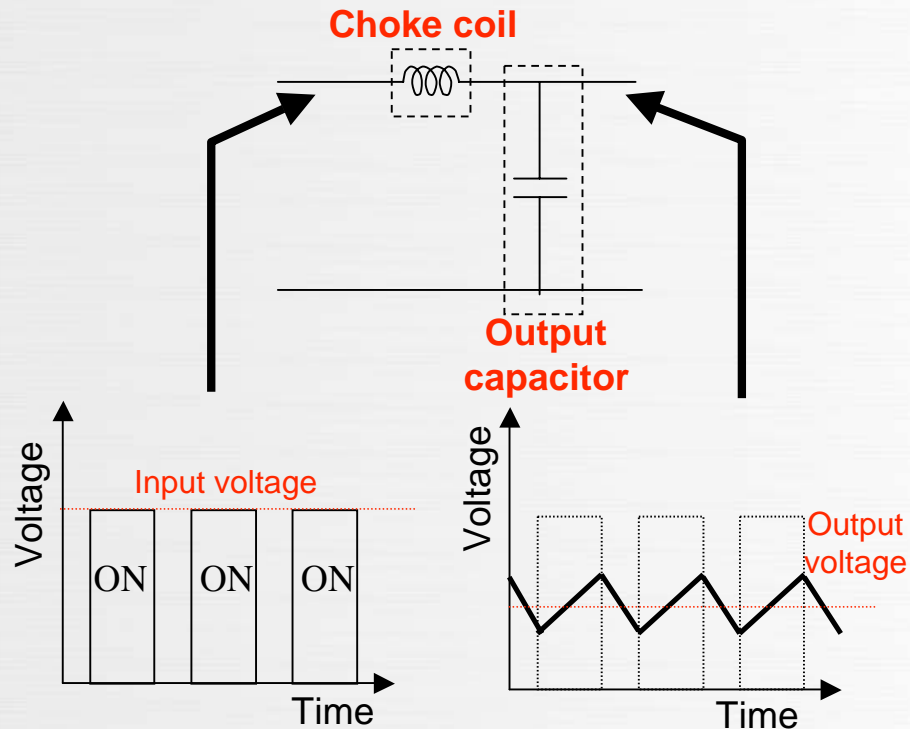
High tolerance for ripple current

Example: Permissible ripple current of a capacitor is 1A.



Step-Down Converter

Output side operation



Input voltage is controlled by an on-off switching.

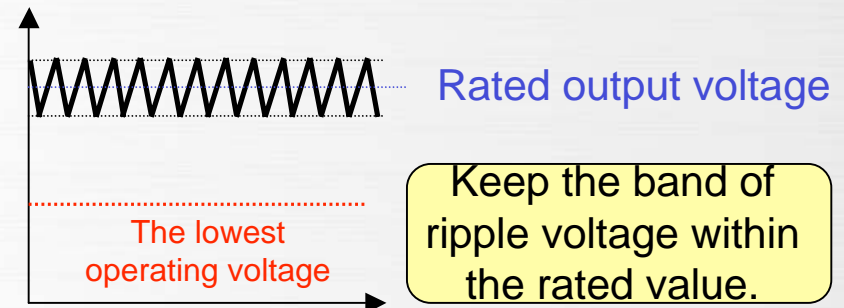
It is smoothed with a choke coil and an output capacitor.

Ripple voltage is included.

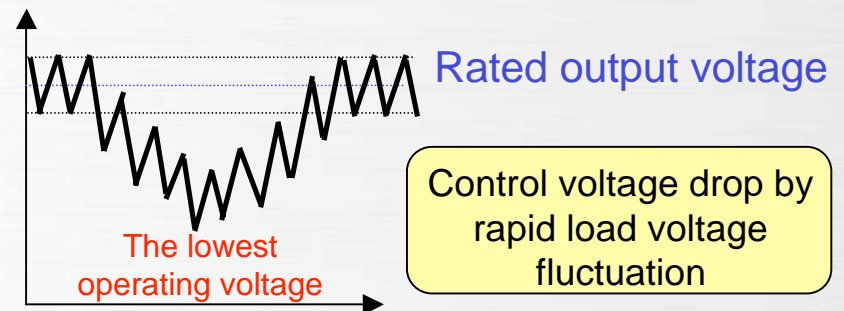
Points of output voltage to remember

Keeping higher voltage than **the lowest operating voltage** of load IC.

Ripple voltage



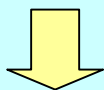
Rapid load voltage fluctuation



Step-Down Converter

Factor for determining voltage drop by rapid load voltage fluctuation

Operation at rapid load change



Same as Backup Capacitor

Necessary characteristics for capacitor when rapid load fluctuation occurred

High capacitance

→ Supply capacitor of high electronic charge

Low ESR

→ Reducing voltage drop when supplying electronic charge

High Value MLCC



Suitable

Factor for determining ripple voltage

Repeating an on-off switching signal



Charge and discharge are repeated with output capacitor.

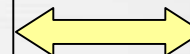
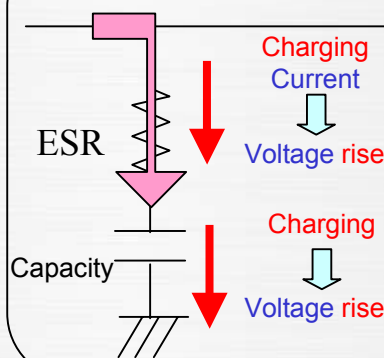


Voltage is fluctuated by current flowing in and out.

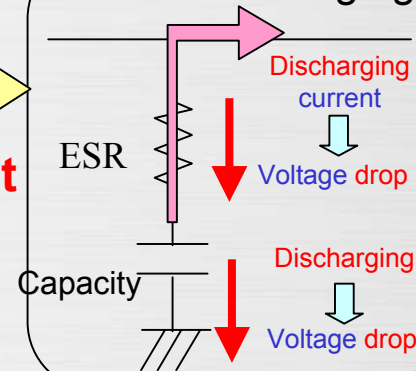


Ripple voltage

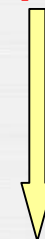
When charging



When discharging



Repeat

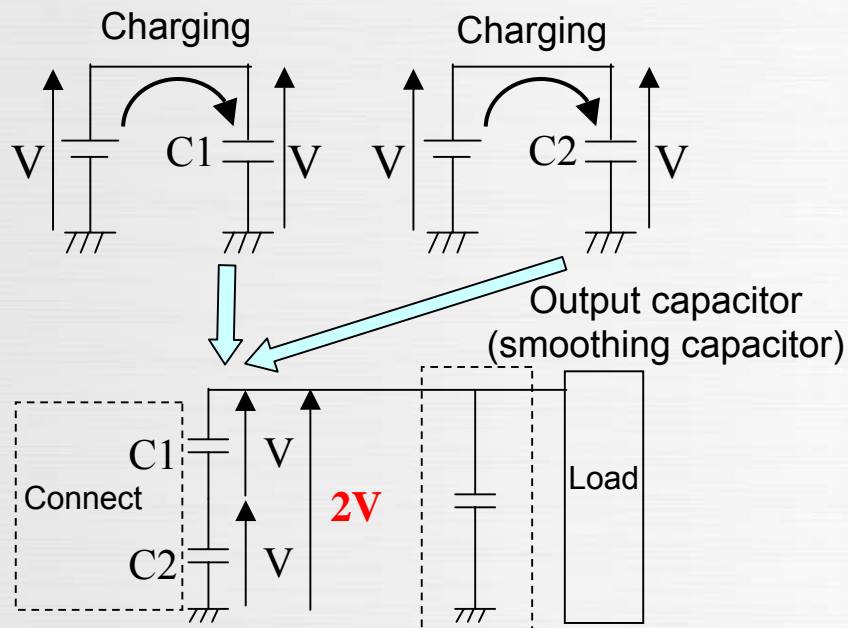


High capacitance and low ESR
reduce ripple voltage.

Charge Pump (Boost)

Operation of charge pump (image)

Charging 2 capacitors separately



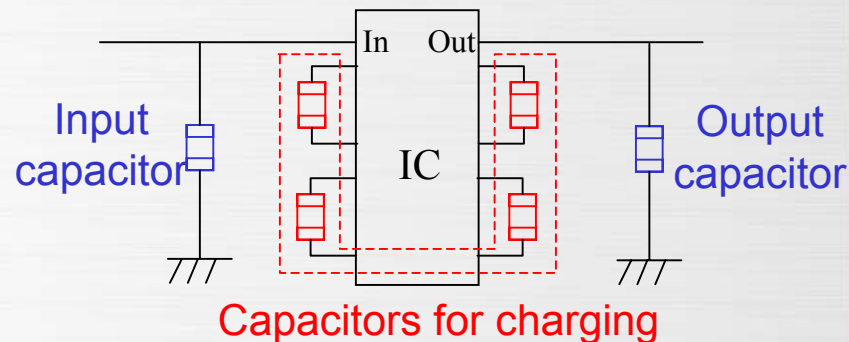
Connecting charged capacitors

Output double amount of voltage than input

Smoothing with output capacitor (Switching)

Output voltage is determined by the **number of capacitors** connected. (**integral multiple**)

Circuitry of charge pump
(example: double boost)



Required characteristics of capacitor

Charging capacitor and output capacitor

→ Lowering voltage fluctuation
occurred by charging/discharging

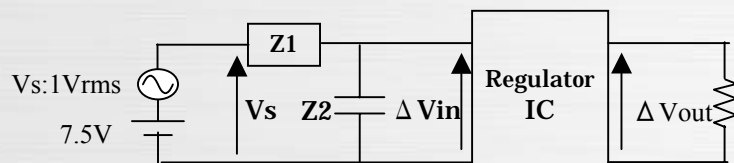
Backup Capacitor

Same as step-down output capacitor

**High capacitance and low ESR
are required.**

Summary Comparison of Various Input Capacitors

Measuring the noise absorption and the output voltage fluctuation by adding sine wave on input line



IC used: NJM78L05(JRC)

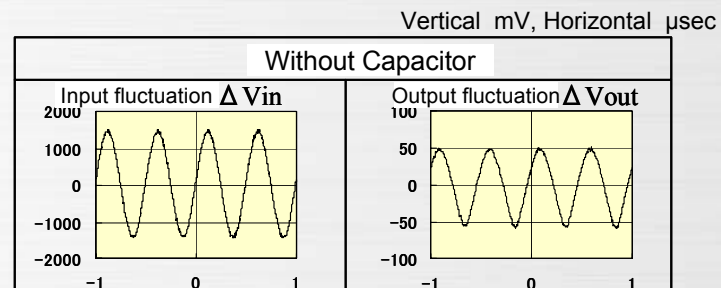
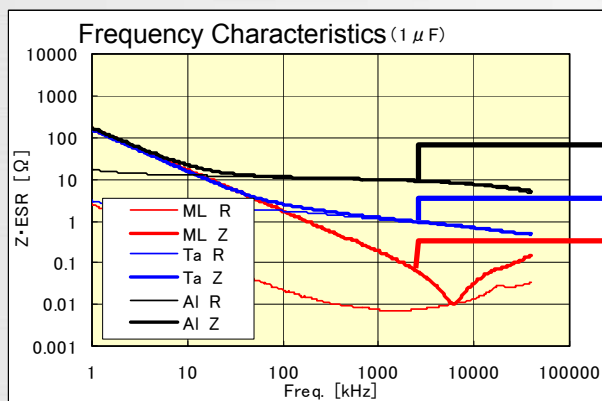
Capacitor used: LMK212BJ105KG, Ta1uF, A11uF

$$\Delta V_{in} = \frac{Z_2}{Z_1 + Z_2} V_s \quad (Z_1: \text{Line impedance})$$

Capacitor (Z2) has low impedance.

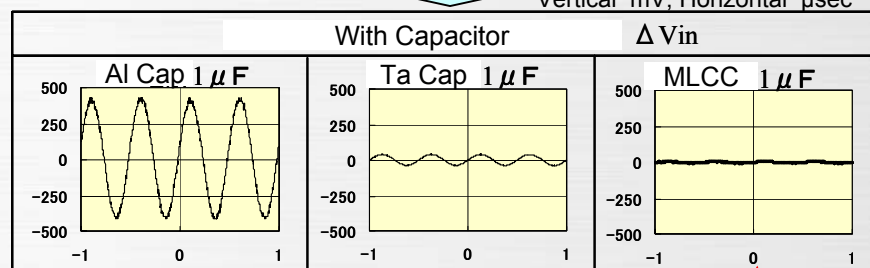
→ Effect of noise suppression: large

Constant IC input voltage

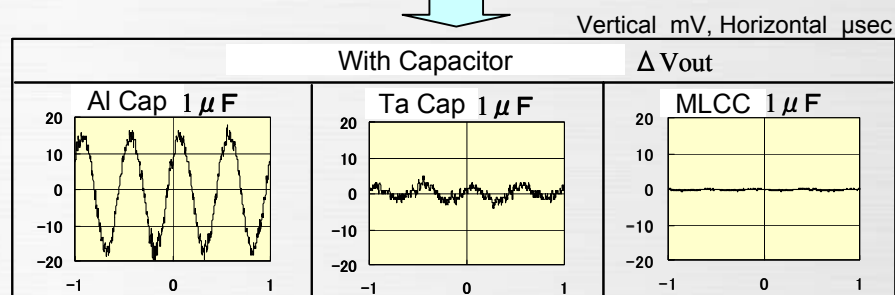


Input fluctuation of 1Vrms → Output fluctuation of 35Vrms

Input capacitor inserted



MLCC is excellent in noise suppression (low impedance).

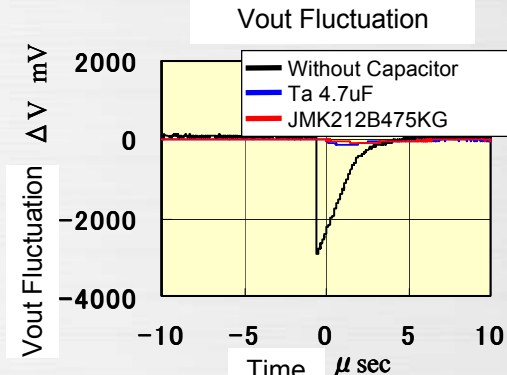
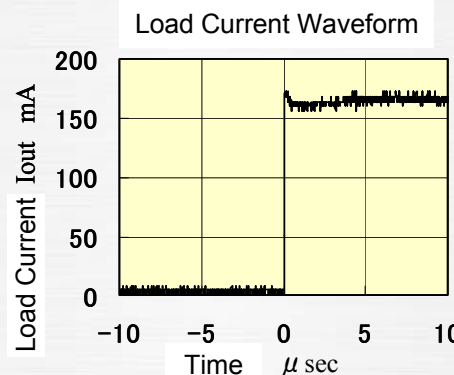
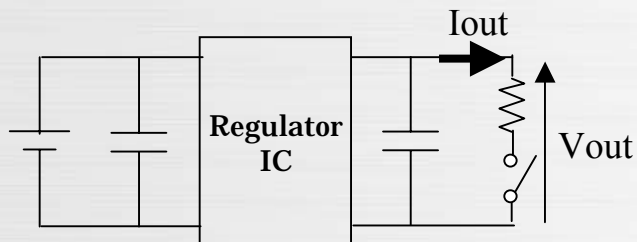


Output fluctuation becomes smaller as IC input voltage stays constant.

MLCC has lower impedance than that of Ta for a wide range of frequency.
MLCC is suitable for input capacitor.

Summary Operation Analysis of Output Capacitor

Observation of output voltage fluctuation



Waveform observation: I_{out} , V_{out}
(Observing by the type of output capacitors)

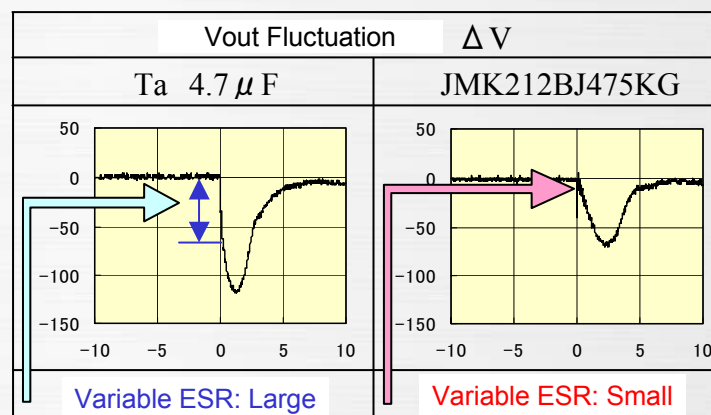
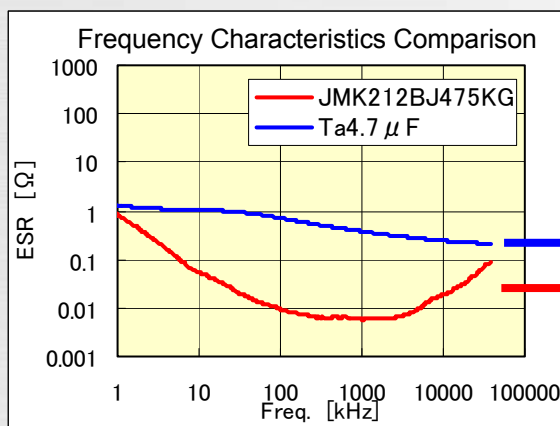
IC used: R1112N331B (Ricoh)

Input Cap: LMK212BJ225KG

Input V: 5V

Switching frequency: 100Hz

Load current: 150mA



ESR: Large

ESR: Small

Vertical mV, Horizontal μsec

Using output capacitor with low ESR
reduces the output voltage drop
when load fluctuation occurred.

MLCC with low ESR is well-suitable for output capacitor.

Development Method Direction for ML Lineups and Proposals

Market demand

Circuit segment

Digital circuit

Analog circuit

Amplifier
Arithmetic
Oscillation
Modem
Digital
Power supply

Logic
High frequency
Power supply
Audio
Others

Capacitor application segment

Focusing on impedance and ESR characteristics

Decoupling

Backup

Smoothing

High pressure

Filter
Coupling

Time constant,
Resonance

Focusing on the stability of real capacitance, temperature and bias

Required performance

It is for circuit noise suppression and often used in digital circuits.
Low Impedance, Low ESR
MLCC with Y5V characteristic and 0.1-10uF is best suited

It may also be used for a circuit with large load change (CPU), stability of power line and protection of IC.
Low ESR, Low ESL, Low Impedance
MLCC with characteristics of Y5V, X5R, X7R and 0.1-10uF is best suited.

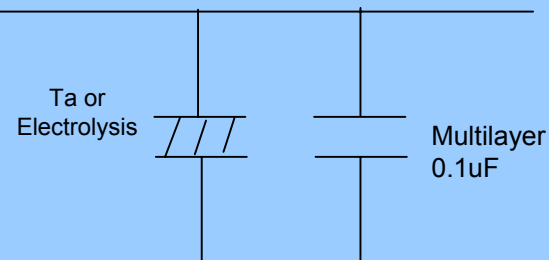
It is for in/output of power supply circuit and more used as the miniaturization of equipment.
Real capacitance, Low ESR, Low ESL, Low Impedance
Rated Voltage and Reliability
MLCC with characteristics of X5R, X7R and 1- tens of uF is best suited.

It is for amplifier, arithmetic, modem and filter circuits.
Stability of capacitance temperature and bias is important.
Temperature compensating dielectric type MLCC is best suited.
(CFCAP, TC type multilayer)

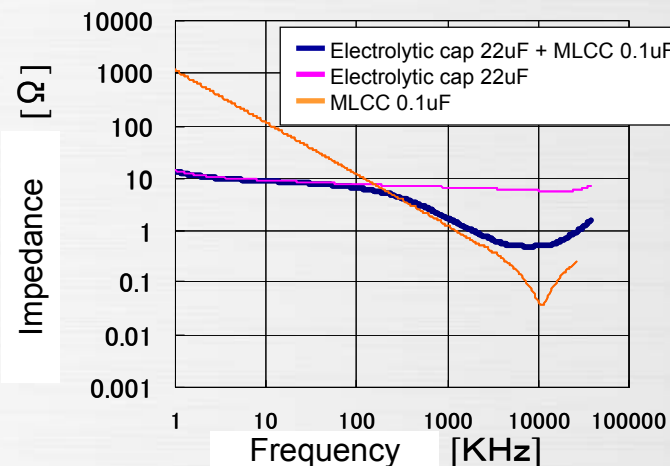
Proposal for Bypass Capacitor

Replacement proposal for high capacitance Ta or Al electrolysis with ML 0.1uF

Common Case Example

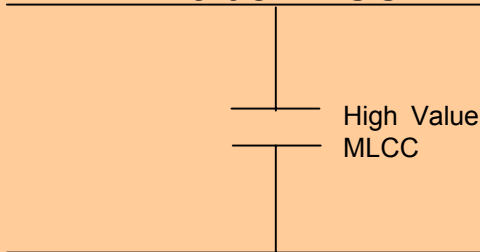


Impedance Characteristics



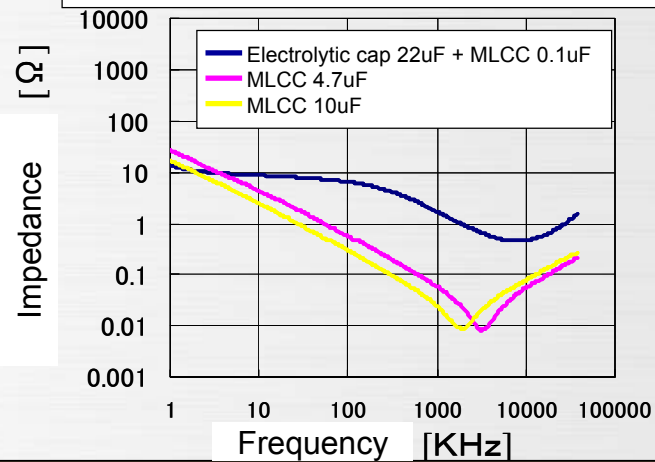
Impedance for high frequency decreases.
→ High frequency characteristic is advanced.

Replaced only by a single High Value MLCC



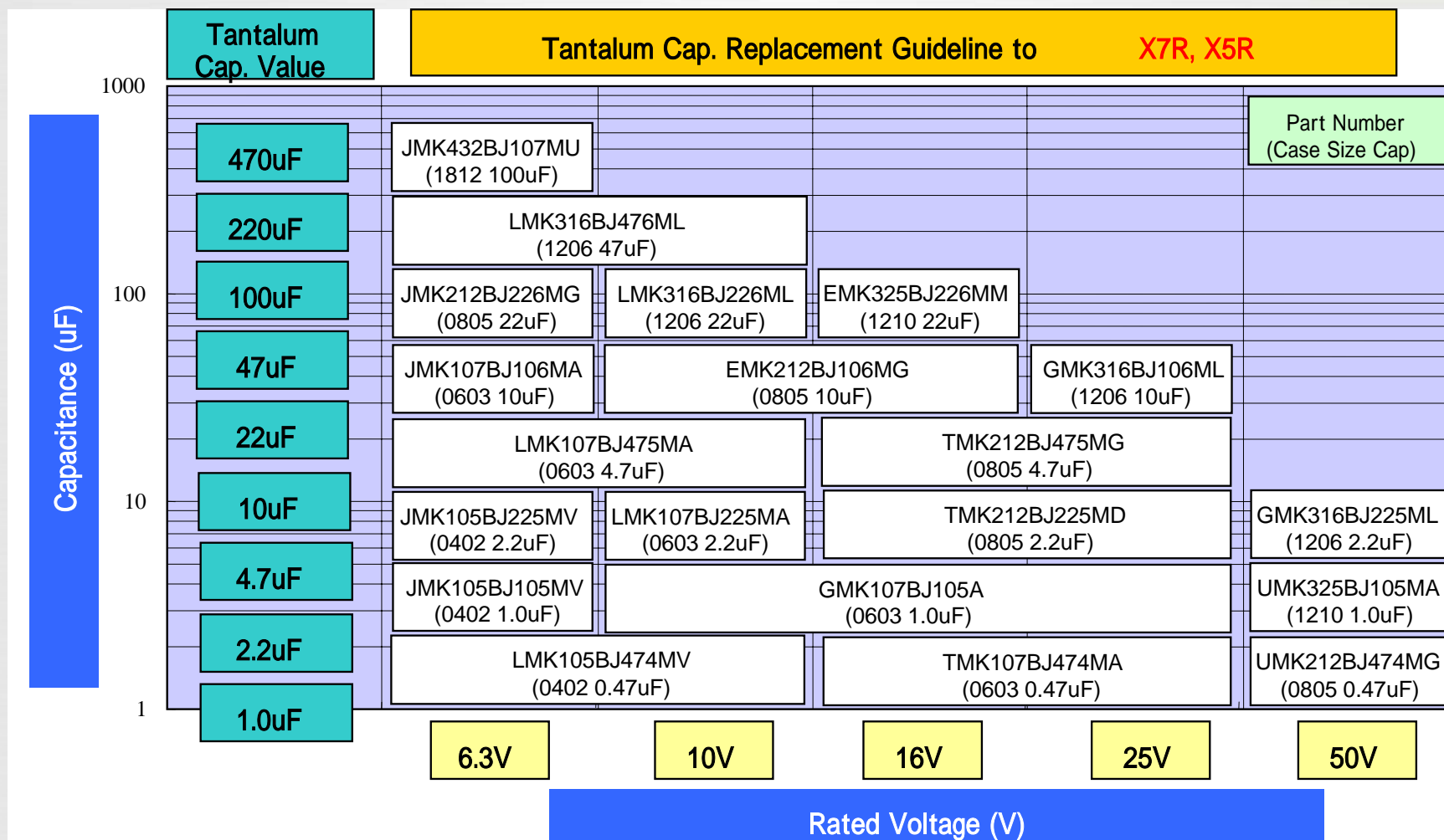
Replaced only by a single MLCC

Impedance Characteristics



Wider low impedance range compared with parallel use.

Ta cap & Al cap replacement guideline to MLCC X7R, X5R

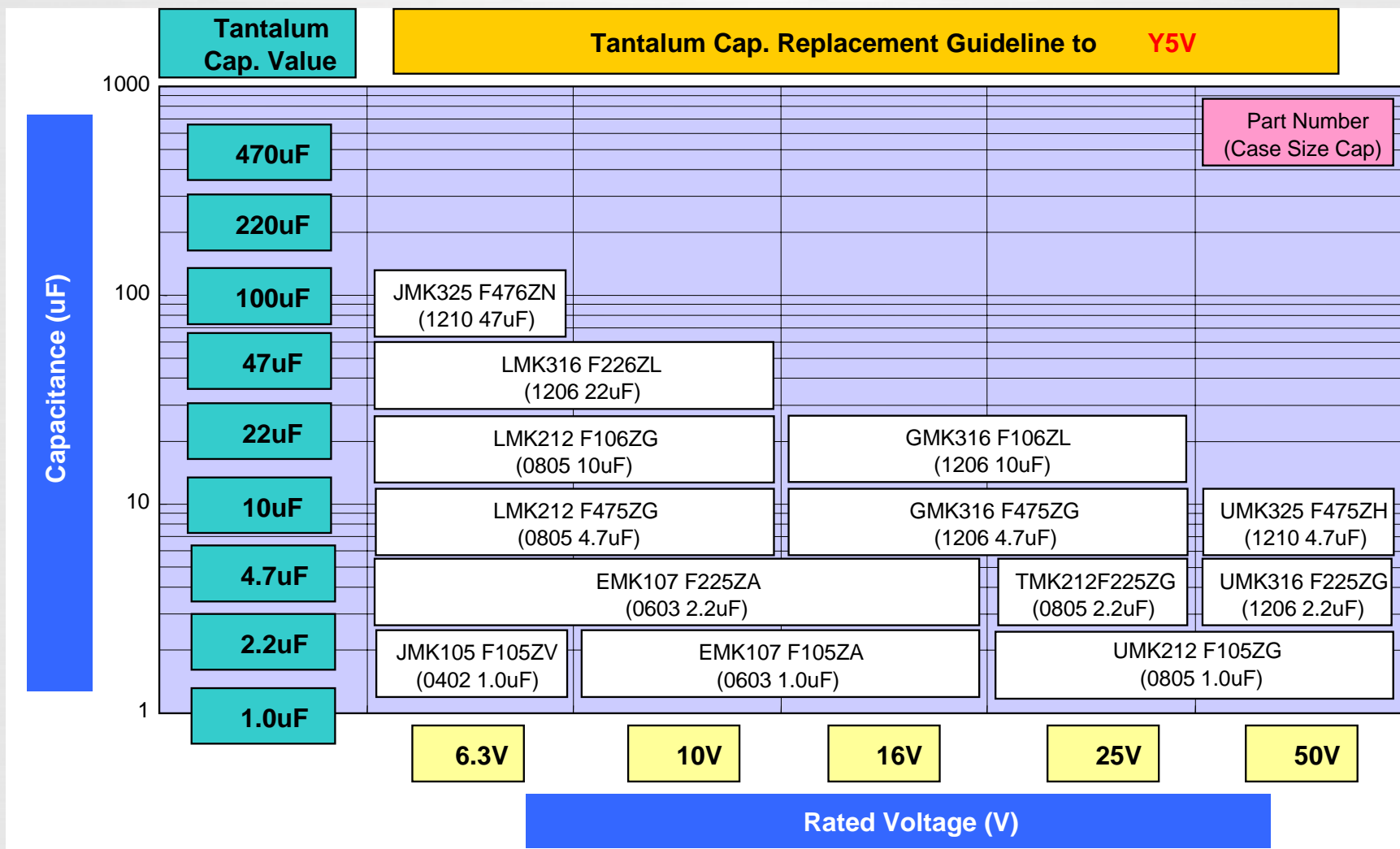


Note: Suggested capacitance value of MLCC may be changed depending on the frequency level of noise.

Note: As derating is not required for MLCCs, use the actual voltage of the circuit when selecting MLCC for replacement.

It requires as much as 1/5 to 1/20 of Al capacitor's capacitance to replace.

Ta cap & Al cap replacement guideline to MLCC Y5V

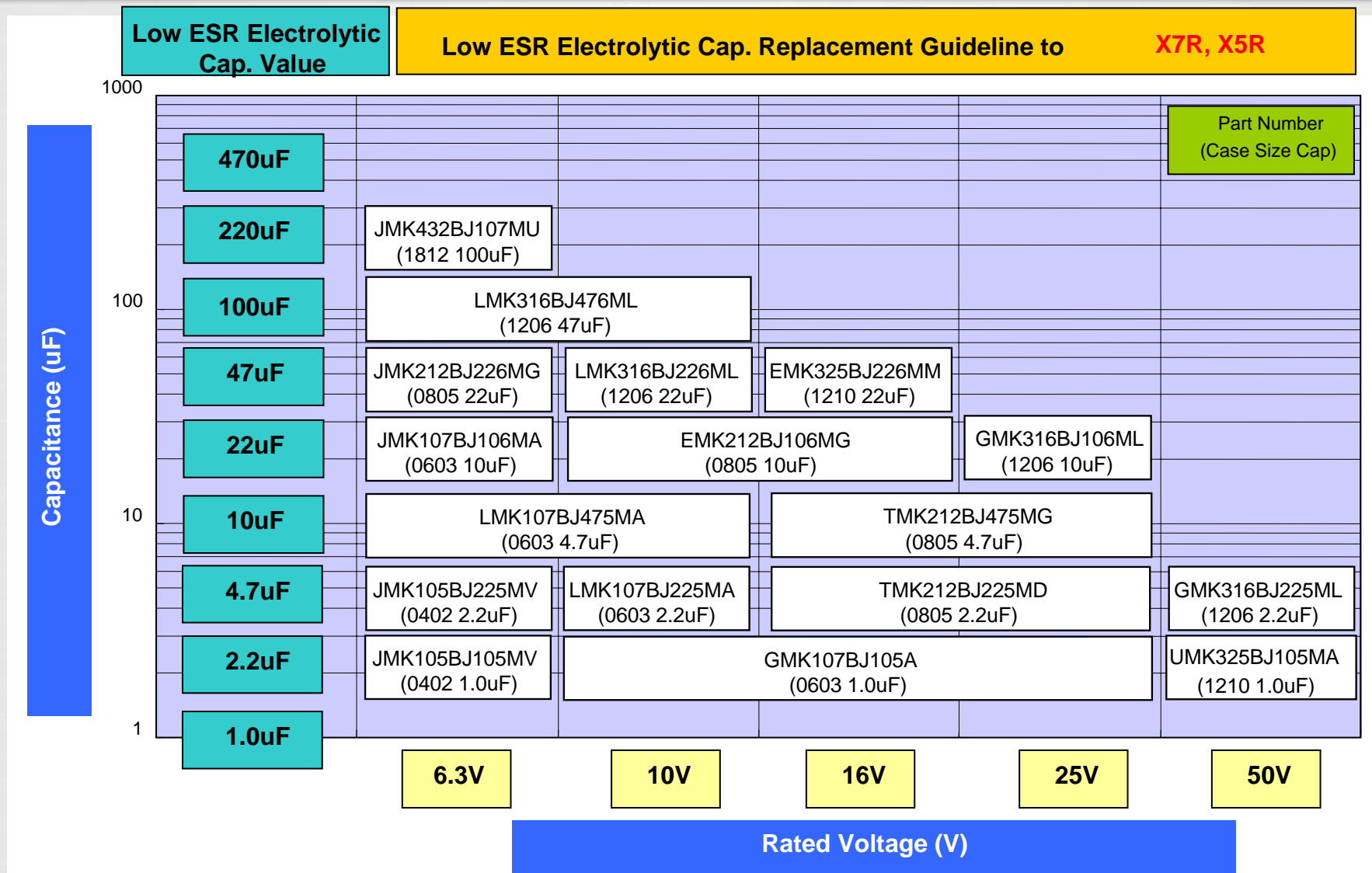


Note: Suggested capacitance value of MLCC may be changed depending on the frequency level of noise.

Note: As derating is not required for MLCCs, use the actual voltage of the circuit when selecting MLCC for replacement.

MLCC requires as much as 1/5 to 1/20 of Al capacitors capacitance to replace.

Low ESR Electrolytic cap. replacement guideline to MLCC X7R, X5R



Note: Suggested capacitance value of MLCC may be changed depending on the frequency level of noise.

Note: As derating is not required for MLCCs, use the actual voltage of the circuit when selecting MLCC for replacement.

- Chapter 2-

Inductor

Ohm's law: (Alternate voltage) = (Impedance) × (Alternate current)

Impedance of pure inductor: inductive reactance: it increases as frequency increases.

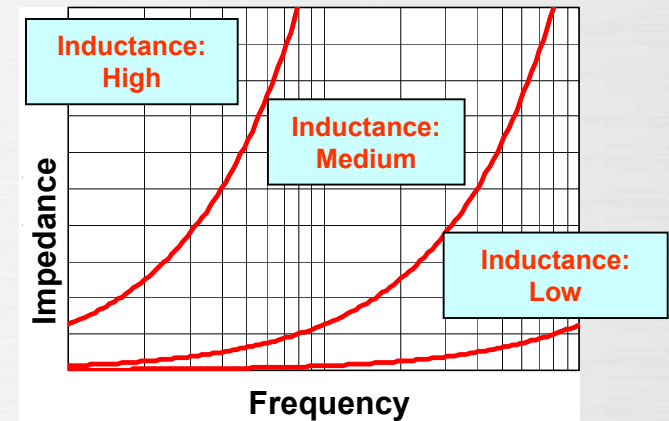
Inductance: L



According to the Ohm's law, the impedance of pure inductor is **proportional** to frequency and inductance.

Frequency : f
Voltage magnitude : VO
 $V = V_0 \cdot \exp(j\omega t)$

$V = L \cdot di/dt$
Solving for V: $V_0 = j2\pi f \cdot L$
Impedance is equal to: $Z = X_L = 2\pi f \cdot L$



Impedance of pure capacitor: capacitive reactance: it decreases as frequency decreases.

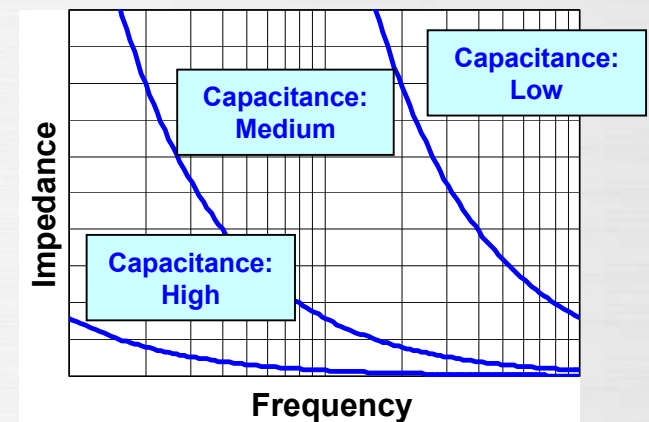
Frequency : f
Voltage magnitude : VO
 $V = V_0 \cdot \exp(j\omega t)$



Capacitance : C

According to the Ohm's law, the impedance of pure capacitor is **inversely proportional** to frequency and capacitance.

$V = 1/C \cdot \int i dt$
Solving for V: $V_0 = 1/(j2\pi f \cdot C)$
Impedance is equal to: $Z = X_C = 1/(2\pi f \cdot C)$

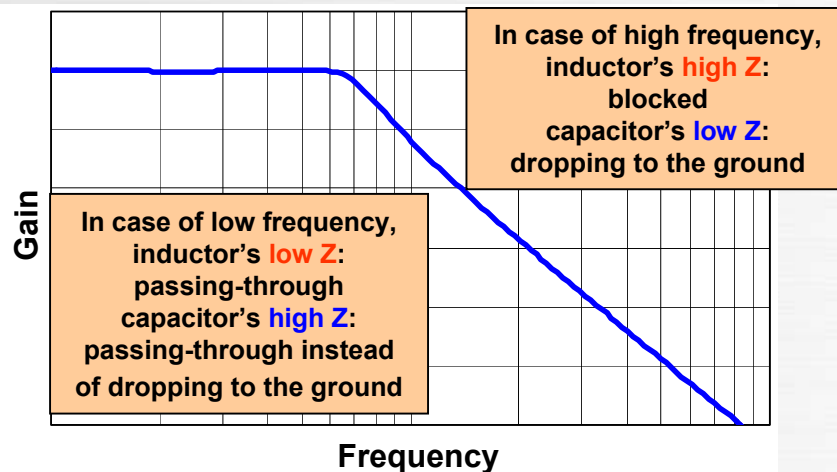
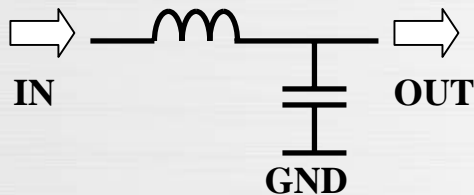


Usage of Inductor and Capacitor: "Low-pass Filter and High-pass Filter"

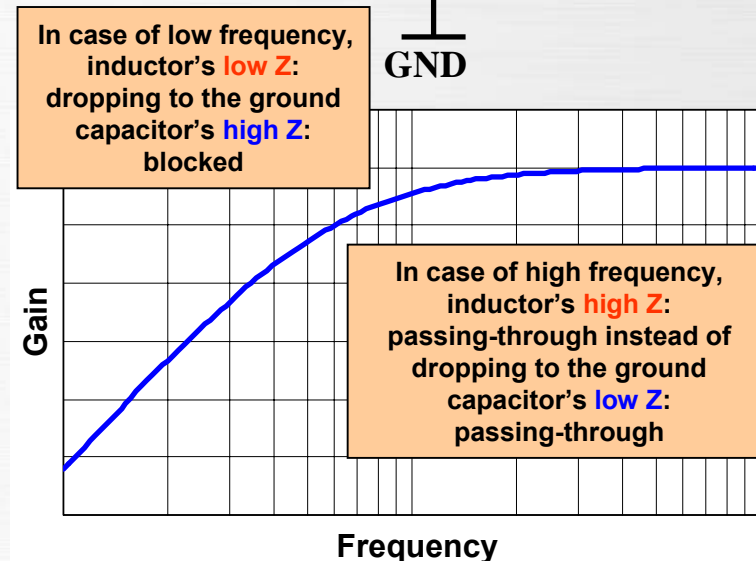
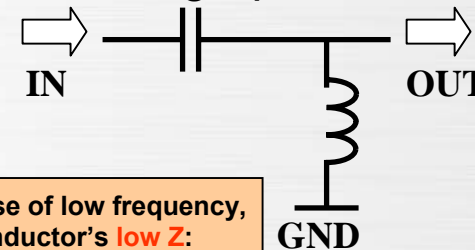
Impedance of **inductor**: It **increases** as frequency increases.

Impedance of **capacitor**: It **decreases** as frequency increases.

Typical characteristic of
low-pass filter



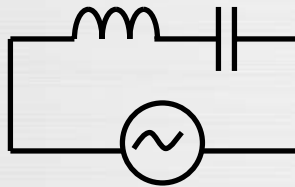
Typical characteristic of
high-pass filter



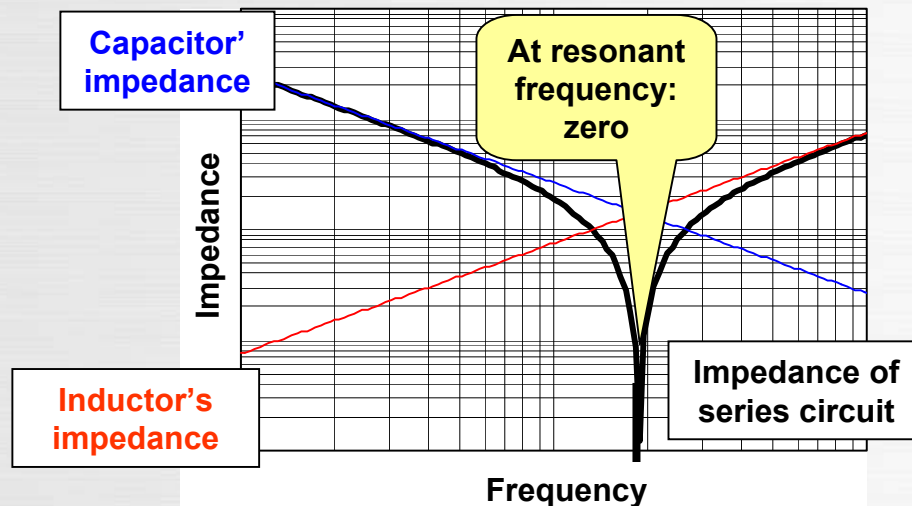
Impedance of **inductor**: It **increases** as frequency increases.

Impedance of **capacitor**: It **decreases** as frequency increases.

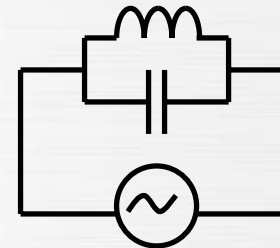
Series circuit of pure
inductor and capacitor:
Series resonance



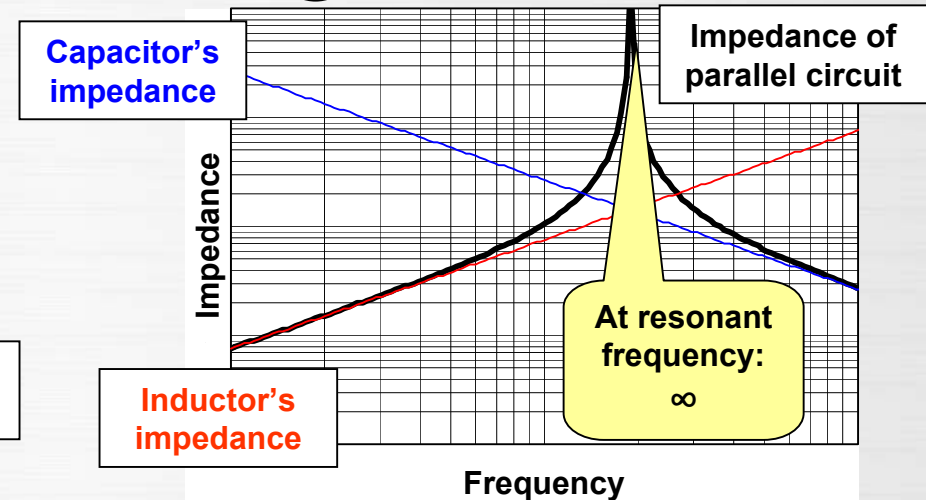
Series circuit:
Basically addition



Parallel circuit of pure
Inductor and capacitor:
Parallel resonance



Parallel circuit:
Basically an electric
current flows in
lower impedance.

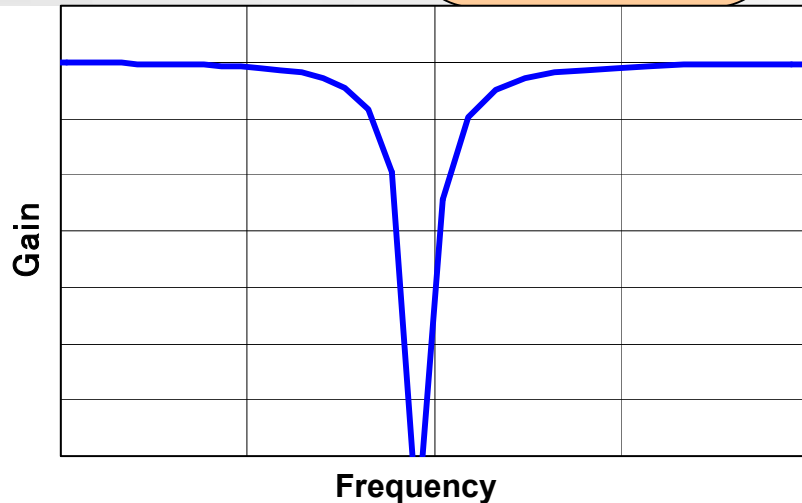
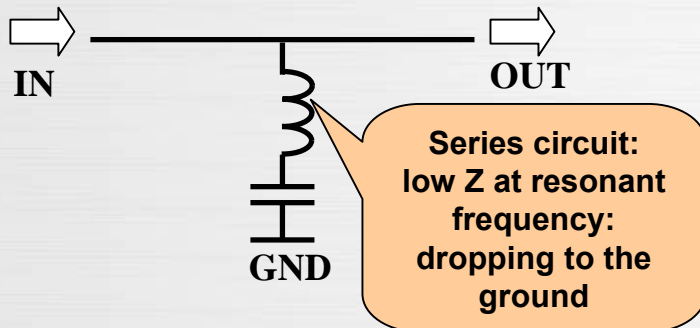


Application of Inductor and Capacitor “Band-pass Filter and Trap Filter”

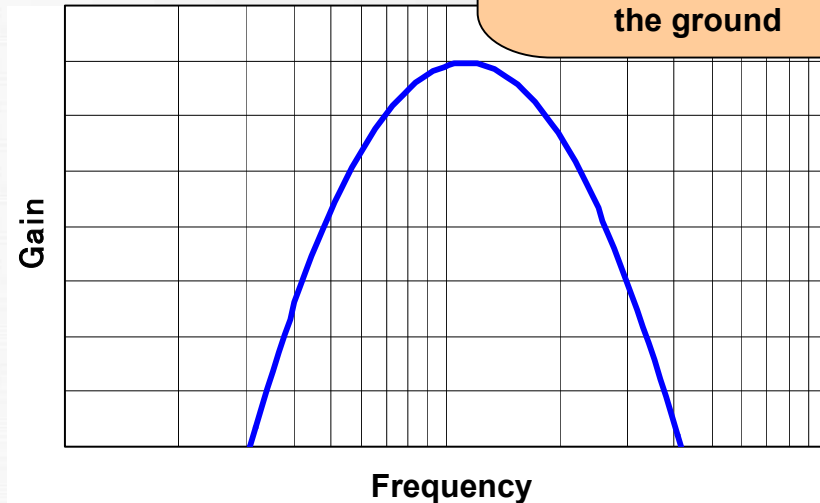
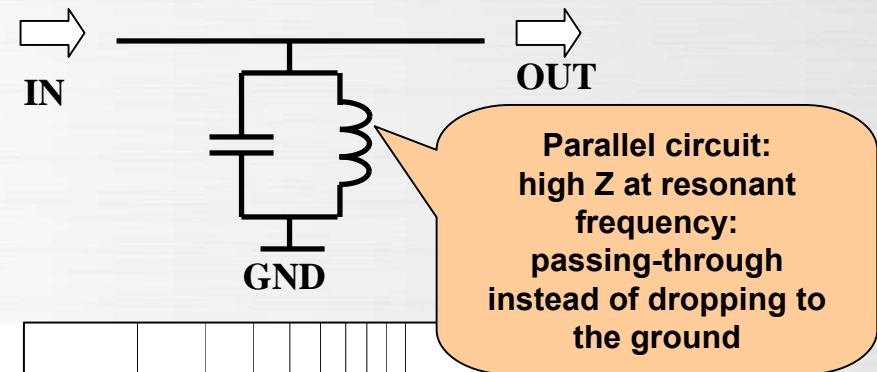
Impedance of series circuit: **Lowest** at frequency resonance point

Impedance of parallel circuit: **Highest** at frequency resonance point

Typical characteristic of trap filter

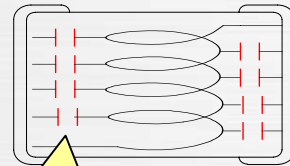
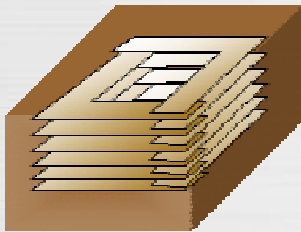


Typical characteristic of band-pass filter



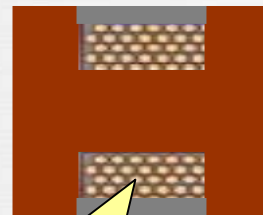
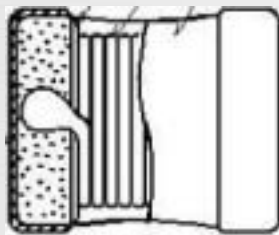
Real Characteristics of Inductor “Self-Resonance Point Characteristic”

Multilayer inductor



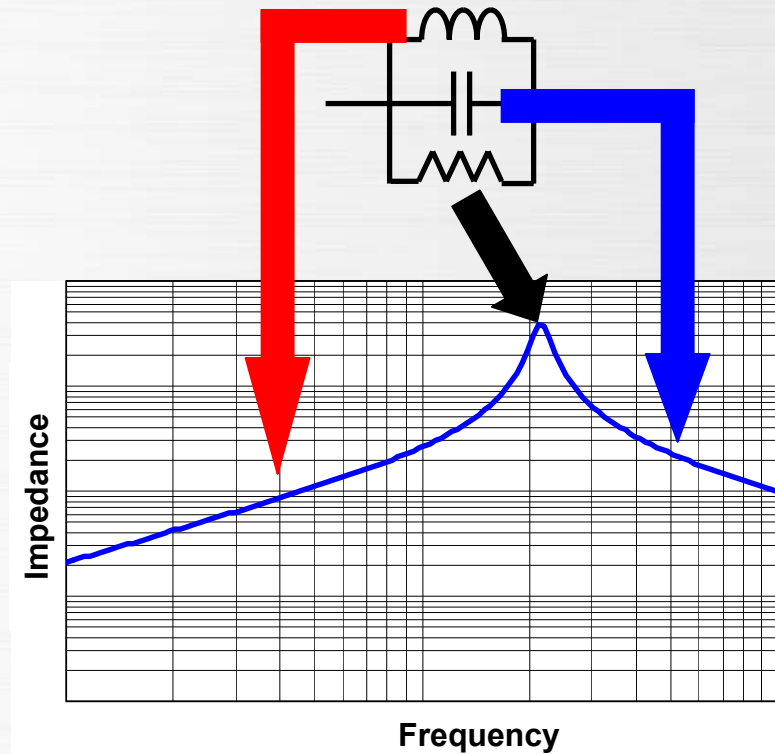
Ex) **Stray capacitance** existed between internal and external electrode

Wound chip inductor



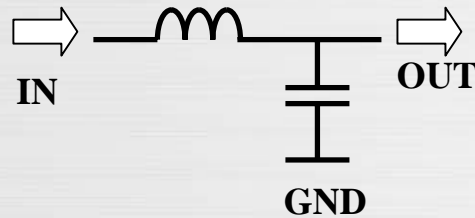
Ex) **Stray capacitance** existed between winding wires

Typical impedance characteristic of existing inductor
~similar to the typical impedance characteristic of LCR parallel circuit~

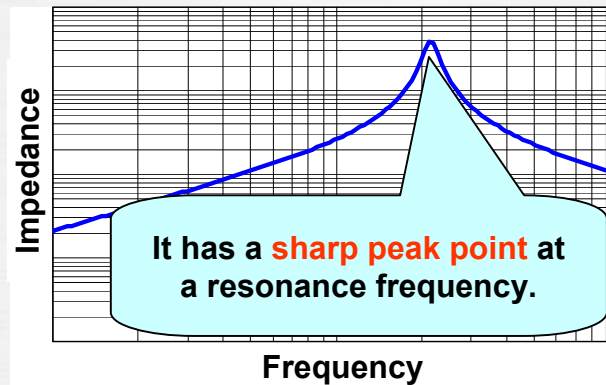


Inductor for the low frequency side,
capacitor for the high frequency side and
at resonance point, impedance is limited.

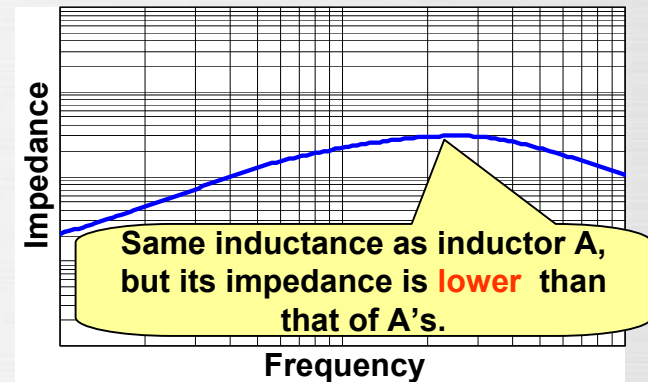
Example of Low-pass filter



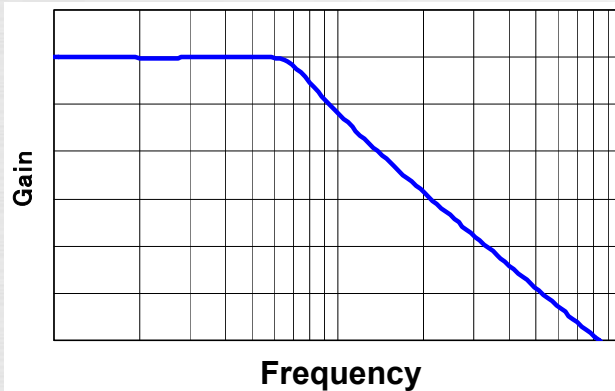
Inductor A: impedance characteristic



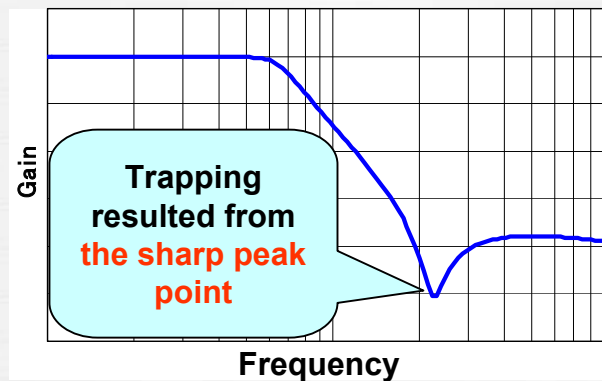
Inductor B: impedance characteristic



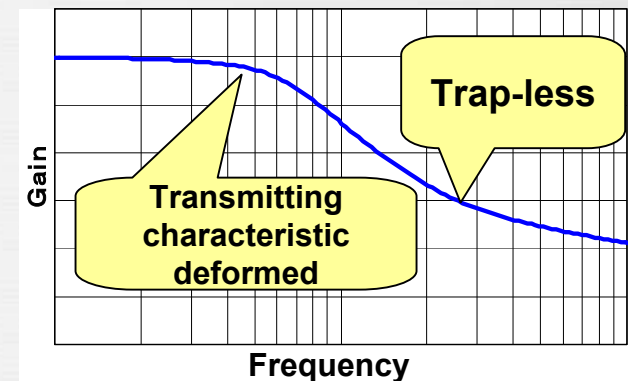
Filter characteristic of pure inductor



Inductor A in use



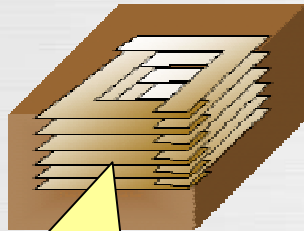
Inductor B in use



This **self-resonance characteristic** is **proactively implemented** for a filter circuit application, and therefore this unique characteristic needs to be considered for both replacement and downsizing applications.

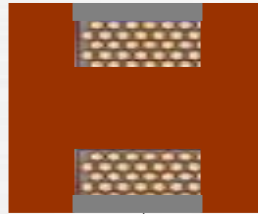
Real Characteristics of Inductor “Lost Elements and Q Characteristic”

ML inductor



Print internal electrode
on sheet made of core
material

Wound chip inductor



Wind up wire
around core

Inductor's Q factor

Impedance of pure inductor:
Inductive reactance

Resistance
elements
(Summation of loss)



Q

$$Q = \frac{\text{Inductive reactance}}{\text{Resistance elements}}$$

Core materials:

Hysteresis loss, Eddy current loss, dielectric material loss and more ...

Internal electrode:

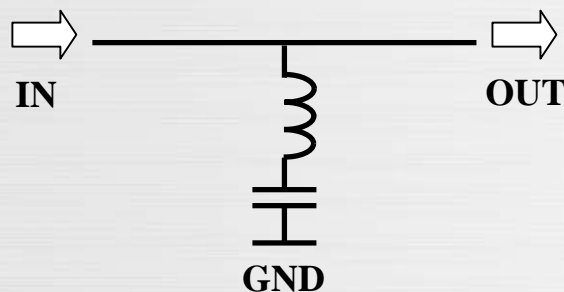
DCR, resistance loss in high frequency zone originated from skin effect and more...

Pure inductor has no loss at all.

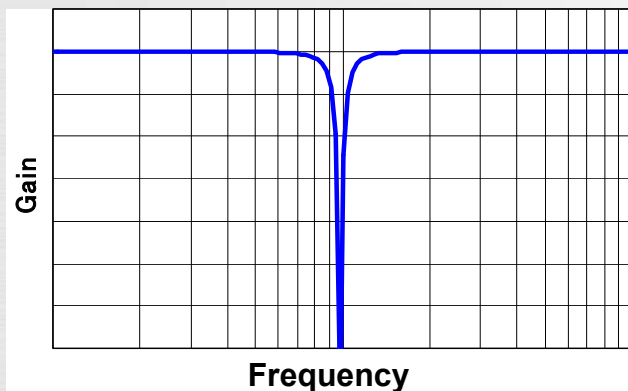
Q factor is an approximation value which expresses how close an inductor is to be a pure inductor.

The larger the Q factor an inductor has, the purer the inductor becomes on circuit.

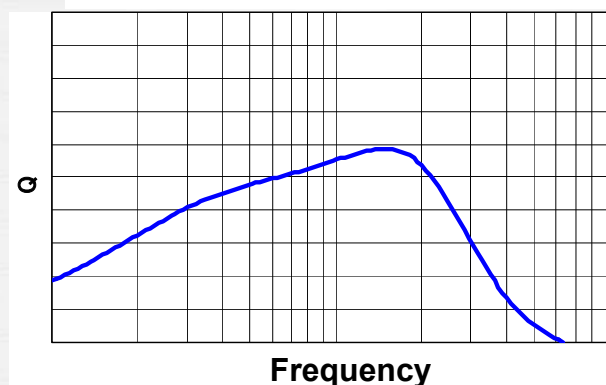
Example of trap filter
Series resonance of inductor and capacitor



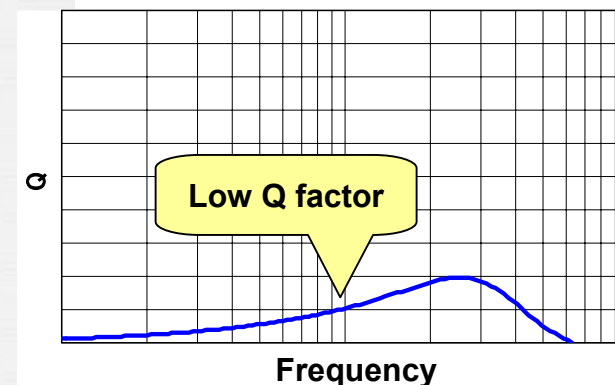
Filter characteristic example
of pure inductor



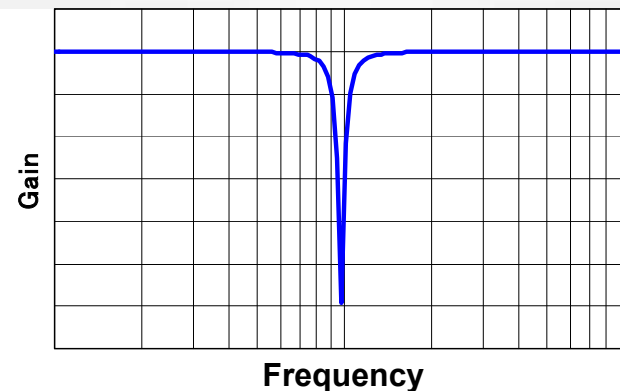
Inductor A: Q factor characteristic



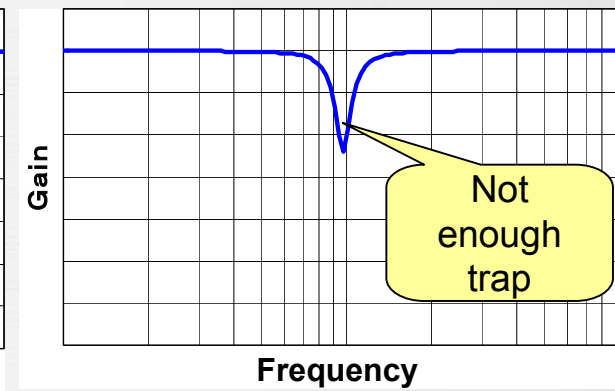
Inductor B: Q factor characteristic



Inductor A in use



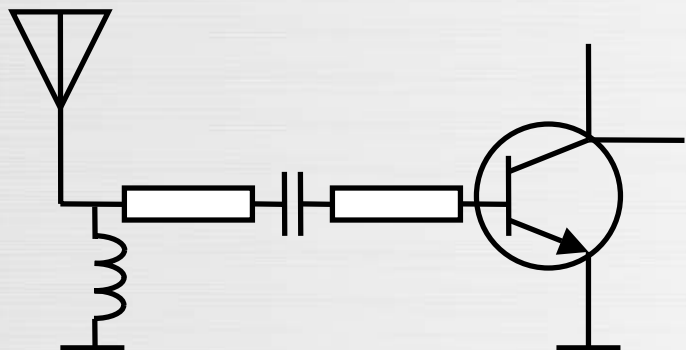
Inductor B in use



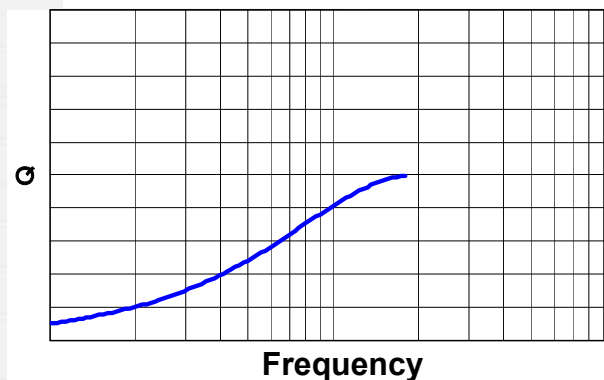
In case of **resonance circuit** with capacitors, generally inductor's **Q factor characteristic** has huge influence on the circuit.

Q-Value and Matching Characteristics “Example of How the Difference in Q-value Influences Matching Characteristic”

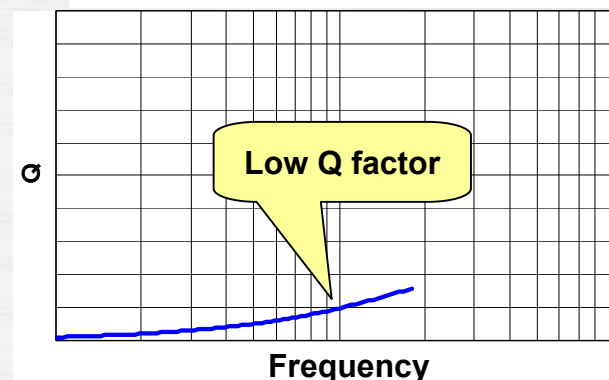
Example of matching circuit
Matching for amplifier and antenna



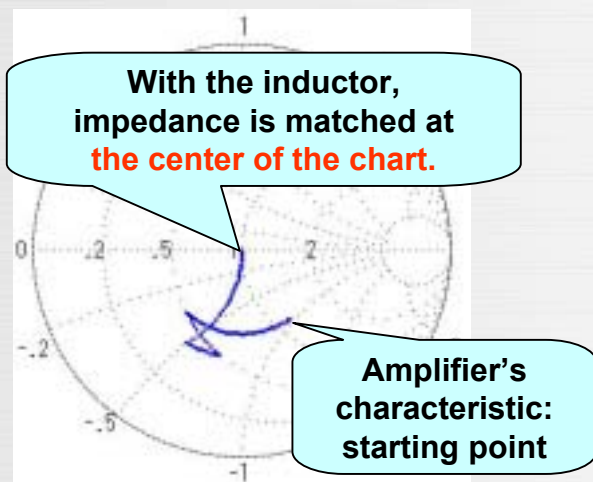
Inductor A: Q factor characteristic



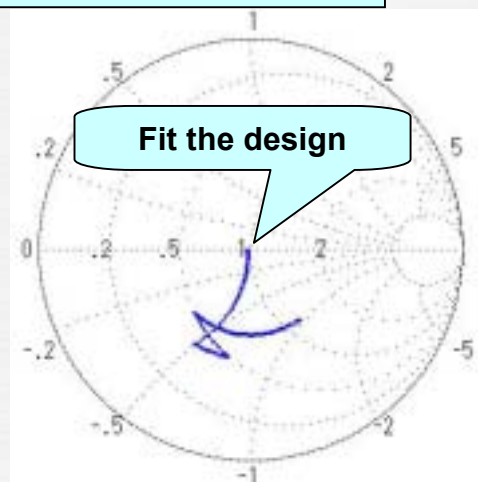
Inductor A: Q factor characteristic



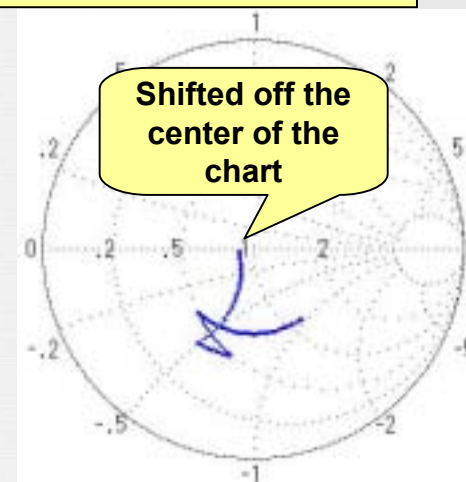
Example of matching design
with pure inductor



Inductor A in use



Inductor B in use



In case of **matching** circuit, generally inductor's **Q factor** characteristic has huge influence on the circuit.

Coffee Break “Q Factor of Inductor and Tan δ of Capacitor”

Q factor of inductor
inductor's loss elements

Impedance of pure inductor:
inductive reactance

Resistance
elements
(summation of loss)



$$Q = \frac{\text{Inductive reactance}}{\text{Resistance elements}}$$

Q factor is an approximation value which expresses how **close** an inductor is to be a pure inductor.
The **larger** the Q factor an inductor has, the purer the inductor becomes on circuit.

Tan δ of capacitor
capacitor's loss elements

Impedance of pure capacitor:
Capacitance reactance

Resistance
elements
(summation of loss)



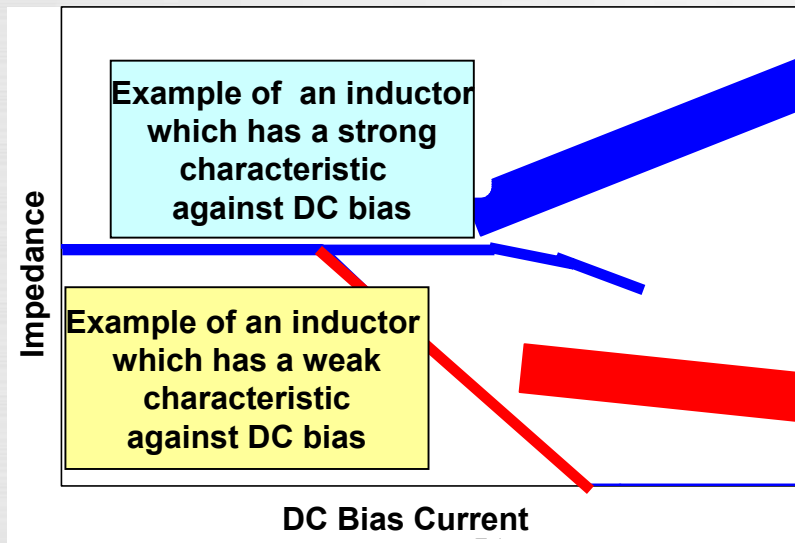
$$\text{Tan } \delta = \frac{\text{Resistance elements}}{\text{Capacitance reactance}}$$

Tan δ is a value which explains how **far** a capacitor is from being a pure capacitor.
The **smaller** the tan δ a capacitor has, the purer the capacitor becomes on circuit.

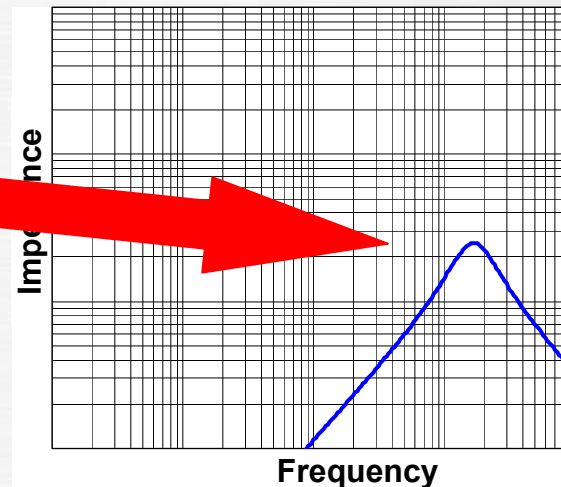
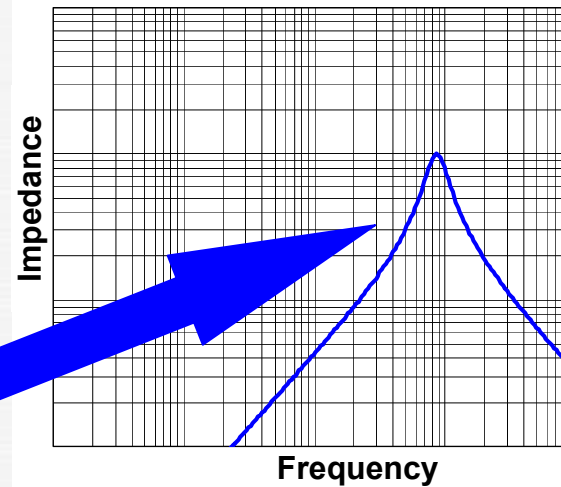
Real Characteristics of Inductor “Example of DC Bias Characteristic”

Example of inductor's DC bias characteristic

In case of magnetic-material core which has the magnetic saturation characteristic, inductance is lowered by increasing in DC bias current.



Example of impedance characteristic

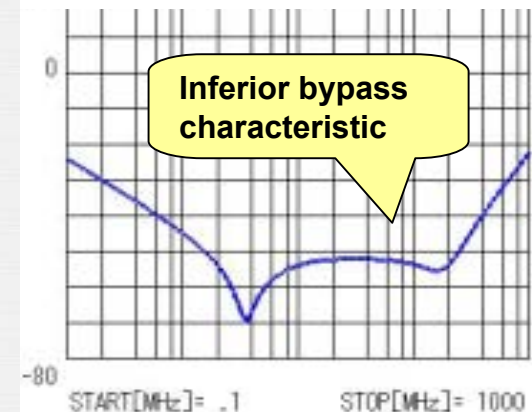
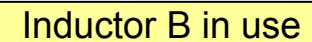
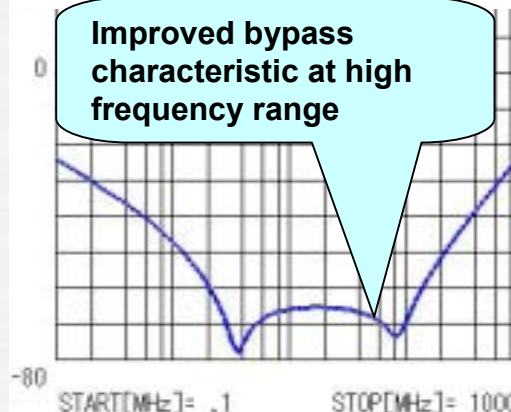
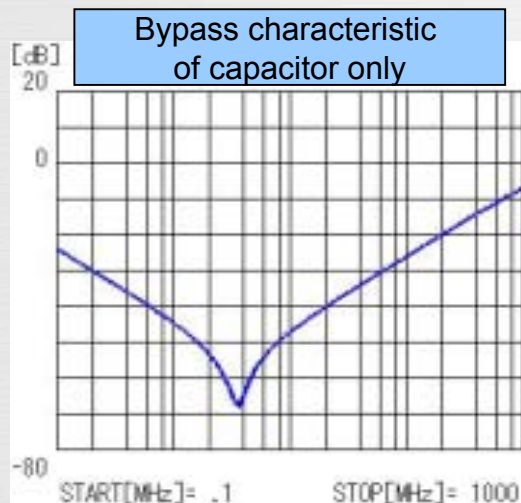


Impedance gets lowered as inductance is dropped by magnetic saturation.

An inductor which has a strong characteristic against DC bias can maintain high impedance level (vice versa).

Generally, an inductor is selected based on a margin level for both required inductance and impedance under operational circumstances.

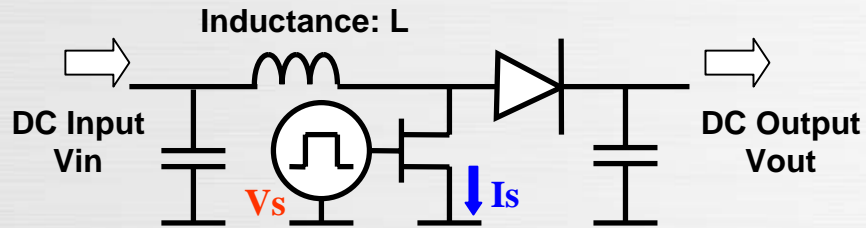
Example of power supply choke circuit



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Example of the Influence on Inductor's DC Bias Characteristic of Power Supply Switching Circuit Application

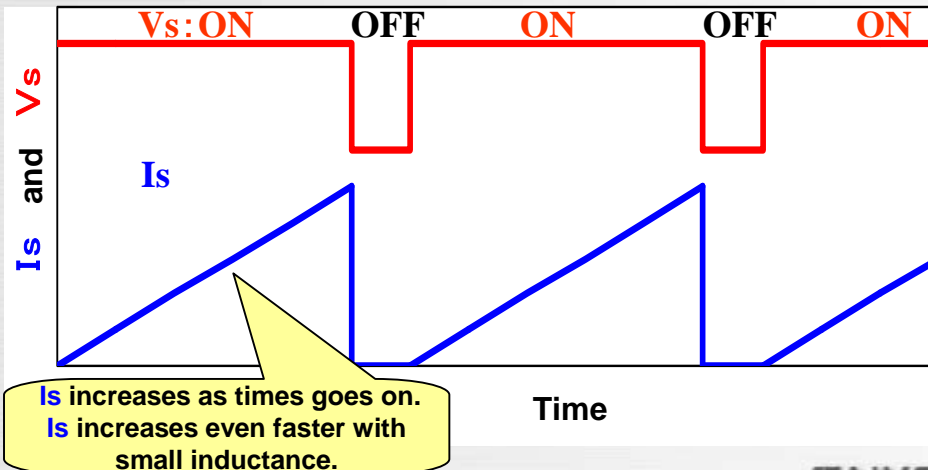
Example of step-up power supply circuit



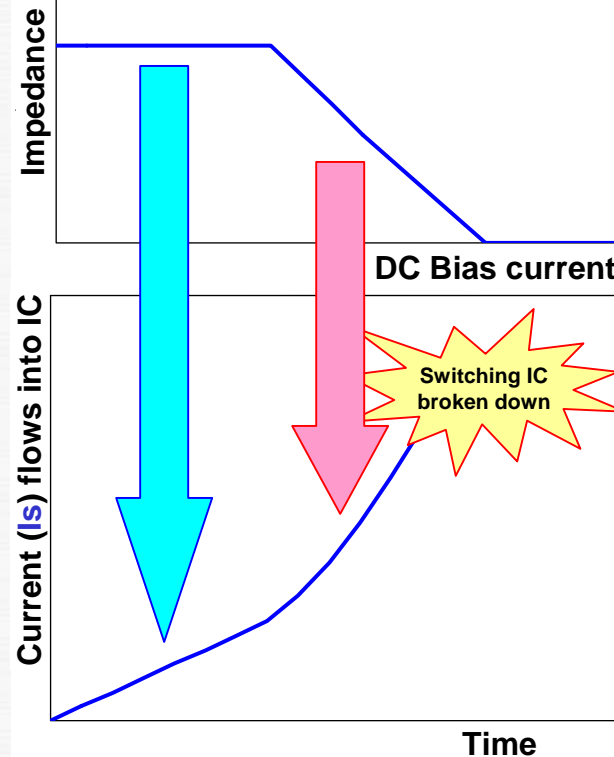
While V_s turned on, I_s flows to IC and then voltage is raised by inductor. When V_s being off, it is added onto the input DC and then Output DC is up-converted.

When V_s is being on, $V_{in} = L \cdot di/dt$, solving for this →
 $I_s = V_{in} / L \cdot t$

I_s gradually increases as V_s turned on, it increases rapidly with small inductance. It is important to know of the tolerance current when selecting an inductor for the power supply circuit.



General relationship between DC bias characteristic and I_s



As DC bias current increases, the inductance starts decreasing.

DC bias current passes at some point, inductance drops suddenly.

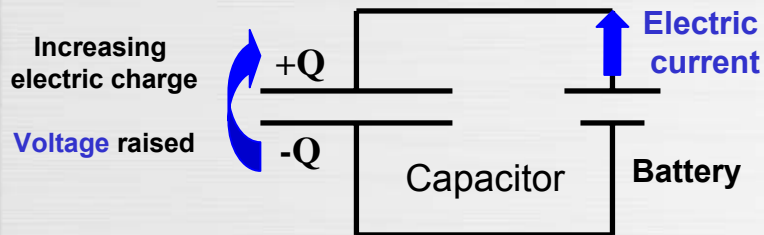
When DC bias current passes the tolerance current, (for the worst case scenario) the switching IC is broken down.

Switching interval is shortened by high frequency power supply IC, and therefore large inductance is no longer needed for IC.

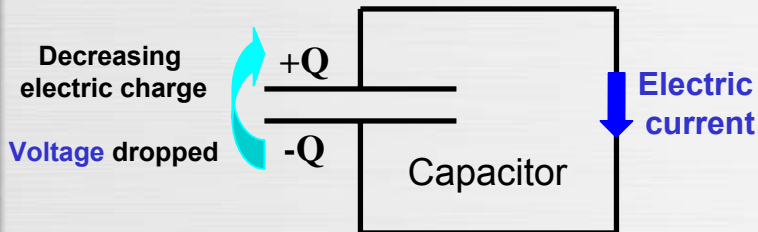
Addition to this, flat DC bias characteristic isn't ideal for all kinds of circuit. It would be better to match a specific DC bias characteristic with IC and power supply demand.

Coffee Break “The Charging and Discharging Mechanisms of Capacitor”

Charging mechanism



Discharging mechanism



A time-varying electric charge induces electric current.

$$-I = dQ/dt$$

Capacitance is the constant of proportion derived from the relationship between the quantity of electric charge and voltage.

$$Q = C \cdot V$$

The relationship among voltage, electric current and capacitance

$$-V = 1/C \cdot \int i dt \text{ or } -I = C \cdot dV/dt$$

The equivalent relationship for inductor

$$-V = L \cdot di/dt$$

Apply **voltage** to a capacitor, **electronic charge** is built up in the inside of capacitor. On the other hand, when both sides of external electrodes are short-circuited, the capacitor discharges the built-up electronic charge.

The quantity of electronic charge is proportional to voltage. (In case with inductor, **an electronic current** creates **magnetic flux**. The quantity of magnetic flux is proportional to electronic current.)

Capacitor's **capacitance** is the constant of proportion between the quantity of electronic charge and voltage. (In case with inductor, **inductance** is the constant of proportion from magnetic flux and electronic current.

A **time-varying** electric charge or discharge induces electric current. In case with inductor, a time-varying magnetic flux induces electric voltage.

- Chapter 3 -

Electro-Magnetic Compatibility (EMC)

The Different Types of Noise

	Contents	Countermeasure components
Radiation noise	It leaks out as an electromagnetic wave. The sources are signal line and power line. There are restrictions in countries. (VCCI, FCC, CISPR, EN, etc.)	Mainly ML Ferrite Chip Beads BK series, Rectangular Ferrite Chip Beads (High Current) FB series M type. Resistors and capacitors may also be used.
Conduction noise (noise terminal voltage)	It runs through DC power line, i.e. switching noise, etc. The sources are DC-DC power supply converter, etc.	Mainly Surface Mount High Current Inductors NP series, Wound Chip Inductors LB series and such ferrite components and capacitors for DC-DC, etc.
Ripple voltage (current)	A fluctuation by voltage drop occurred when IC operates. It becomes a problem at power line with high power consumption for CPU, etc.	Mainly capacitors
Electrostatic	A discharge phenomenon, which is caused by friction charge. It causes element destruction and malfunctions.	Mainly Chip Varistors and Diodes. Capacitors and Beads may also be used.
Surge noise	Instantaneous high voltage and current. It is occurred by natural phenomenon (eg. thunderstorm), inserting and removing a cable, etc.	Spark Gaps and Varistors. Beads and Resistors for low voltage.

Global Standard: CISPR

Japan: VCC class2
(Consumer Equipment)

U.S.A.: FCC part15

Europe: EN55022

Other countries: Setting regulation based on CISPR



Regulation of the frequency band is between 30MHz to 1000MHz for VCCI.
Others are referred on the next page.

1. CISPR 11 Group 2 Class B (1999 industry, chemistry, medical)

For equipment with embedded frequency of 400MHz and above

Regulated frequency: 1-2.4GHz band

Standard: 70dBuV/m and below (3m electric field intensity)

2. CISPR 22 CIS/G/210/CD (2001 IT equipment)

For equipment with embedded frequency of 200MHz and above

Regulated frequency: 1-2.7GHz band

Standard: Average of 50dBuV/m and below,

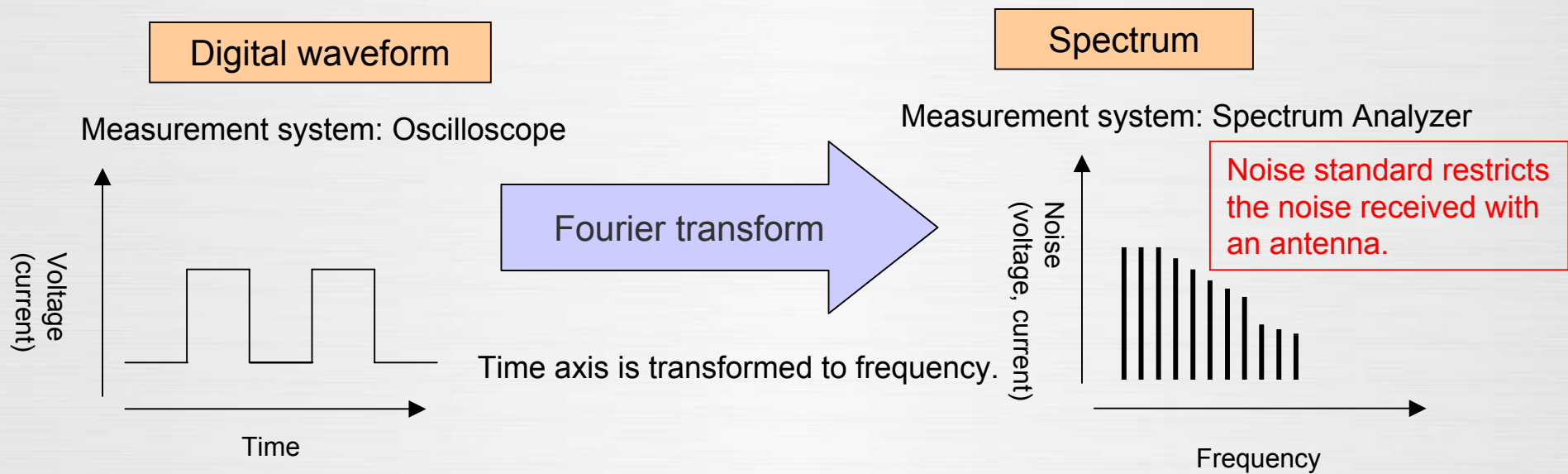
Max 70dBuV/m and below (3m electric field intensity)

3. FCC Part 15 (IT equipment)

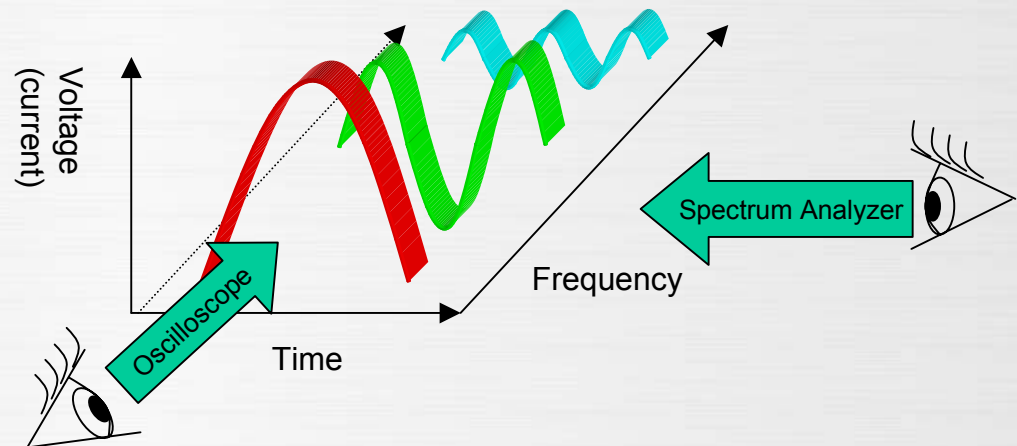
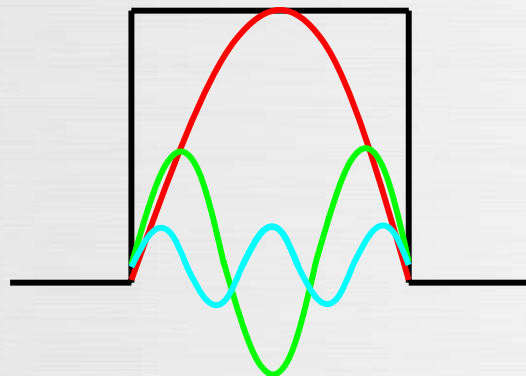
**Measurement up to 2GHz is required for an operation
between 108 to 500MHz band.**

**Measurement up to 5GHz is required for an operation
between 500 to 1000MHz band.**

Mechanism of Radiation Noise 1

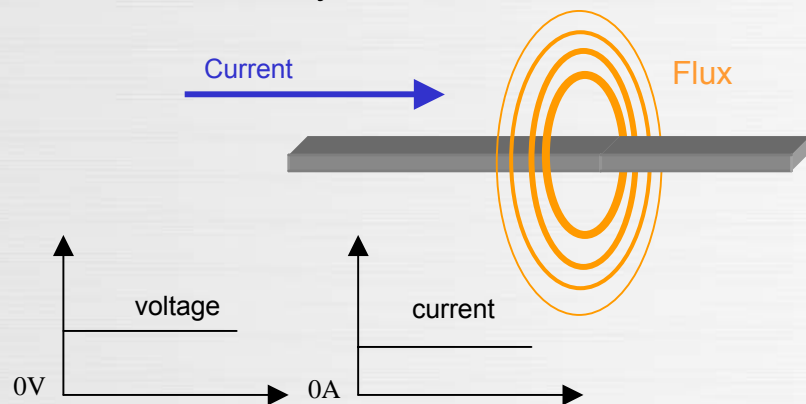


Digital wave is formed by various frequencies.

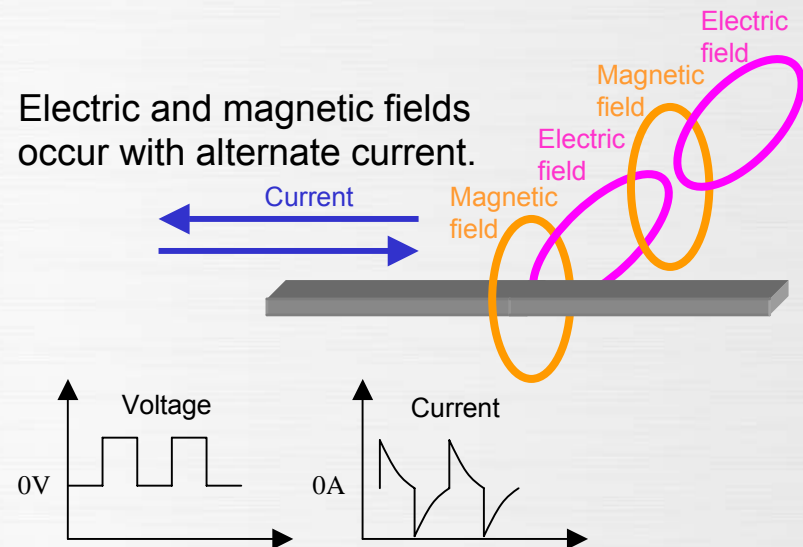


Mechanism of Radiation Noise 2

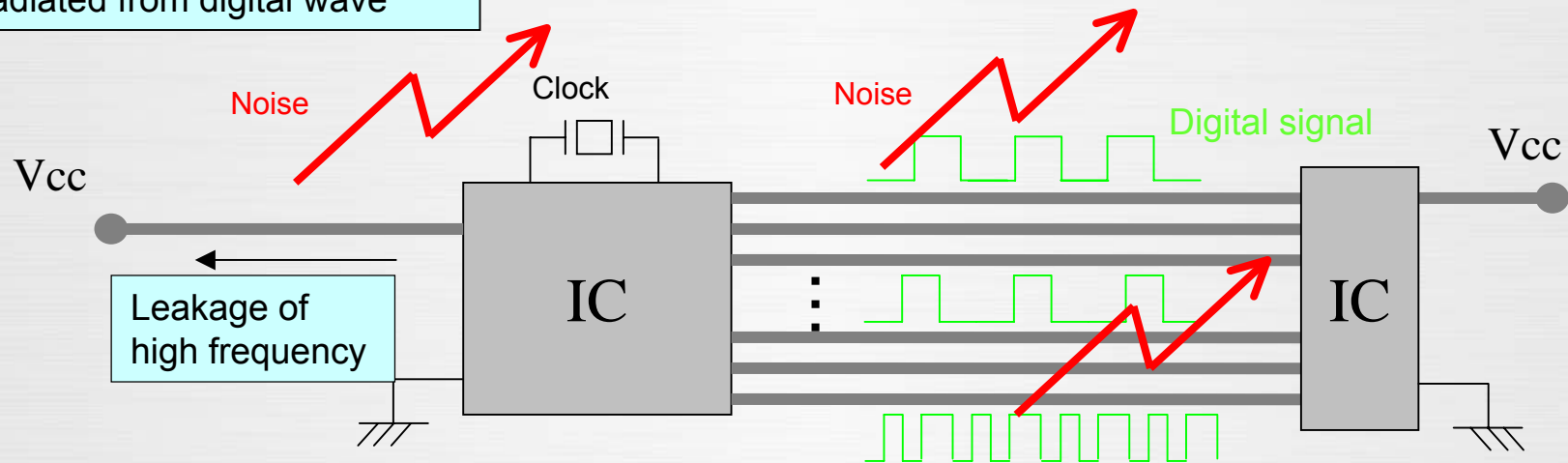
Flux occurs only with direct current.



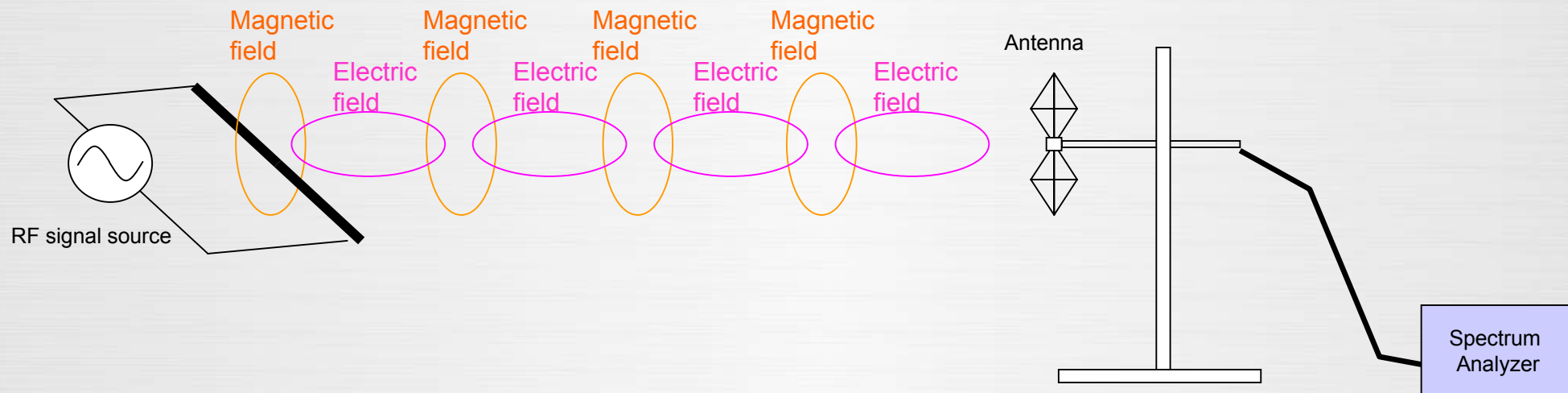
Electric and magnetic fields occur with alternate current.



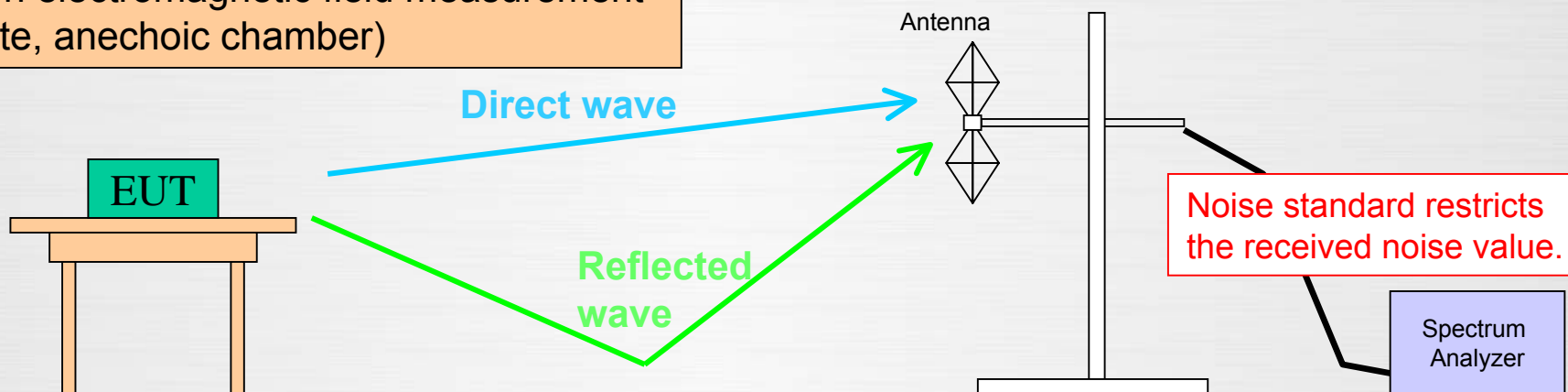
Radiated from digital wave



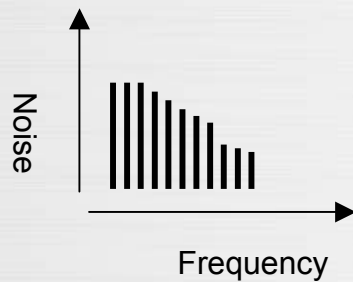
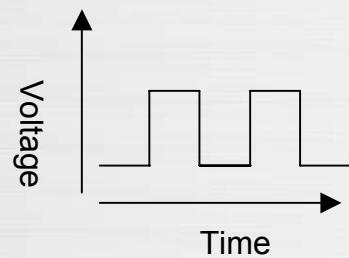
Mechanism of Radiation Noise 3



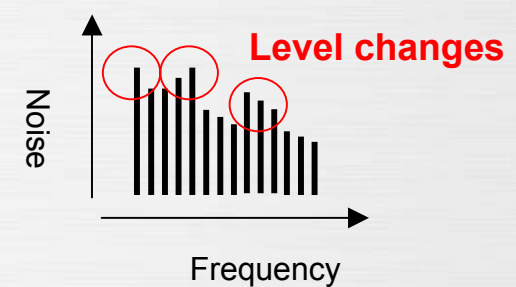
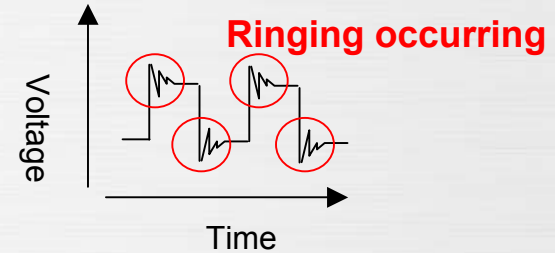
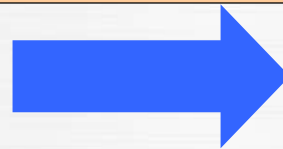
Radiation electromagnetic field measurement
(open site, anechoic chamber)



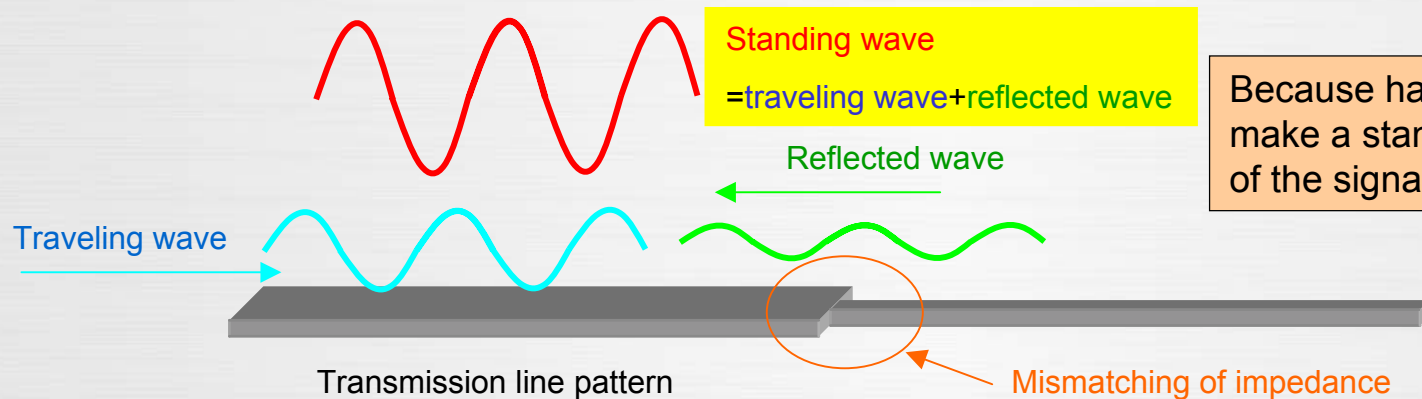
Mechanism of Radiation Noise 4



Spectrum changes with waveform distortion.



Cause: mismatching of transmission line



Because harmonics of a digital signal make a standing wave, the emission of the signal increases as noise.



Fin.

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