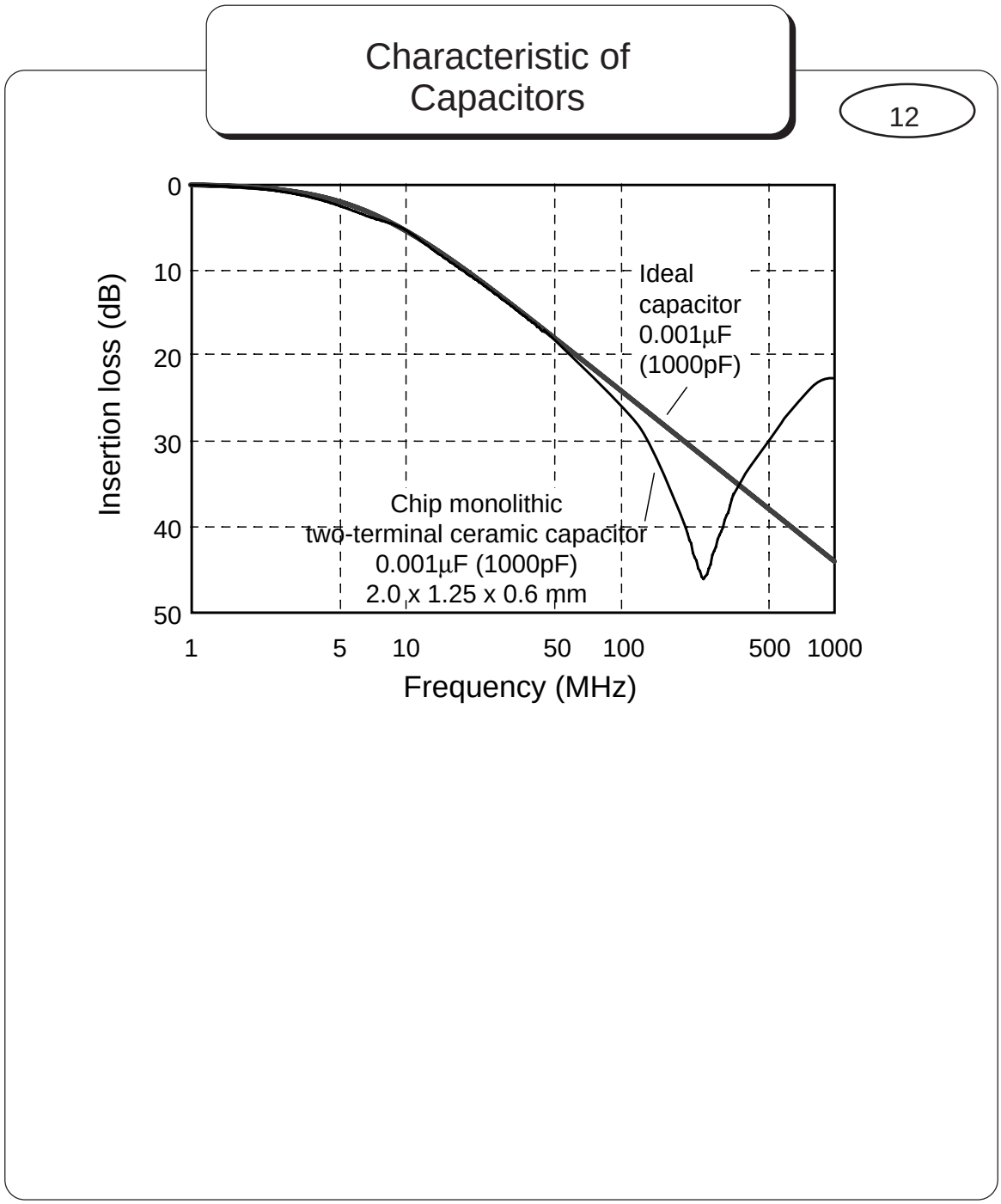
3. Noise Suppression by Low-pass Filters

3.5. The Effect of Non ideal Capacitors



This section and the following sections describe the necessity and performance of capacitor-type EMI filters.

With the ideal capacitor, the insertion loss increases as the frequency becomes higher. However, with actual capacitors, the insertion loss increases until the frequency reaches a certain level (self-resonance frequency) and then insertion loss decreases.

[Notes]

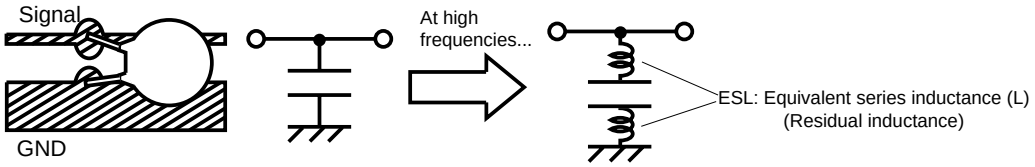
3. Noise Suppression by Low-pass Filters

3.5. The Effect of Non ideal Capacitors

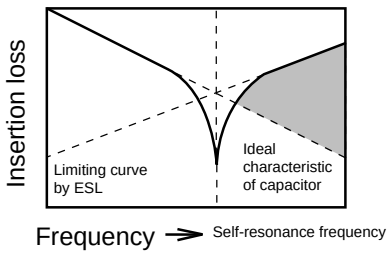
The Effect of Non ideal Capacitors

13

(a) Equivalent circuit of capacitor



(b) Effect by residual inductance



Self-resonance frequency

The frequency at which resonance occur due to the capacitor's own capacitance, and residual inductance. It is the frequency at which the impedance of the capacitor becomes zero.

From $j2\pi fL + 1/j2\pi fC = 0$,

$f = 1/2\pi\sqrt{LC}$

f: Self-resonance frequency

C: Capacitance

L: Residual inductance

[Notes]

The insertion loss of capacitors increase until the frequency reaches the self-resonance frequency and then decrease due to residual inductance of the lead wires and the capacitor's electrode pattern existing in series with the capacitance.Since noise is prevent from going through the bypass capacitors to the GND,the insertion loss decrease.The frequency at wich the insertion loss begins to decrease is called self-resonance frequency.

3. Noise Suppression by Low-pass Filters
3.5. The Effect of Non ideal Capacitors

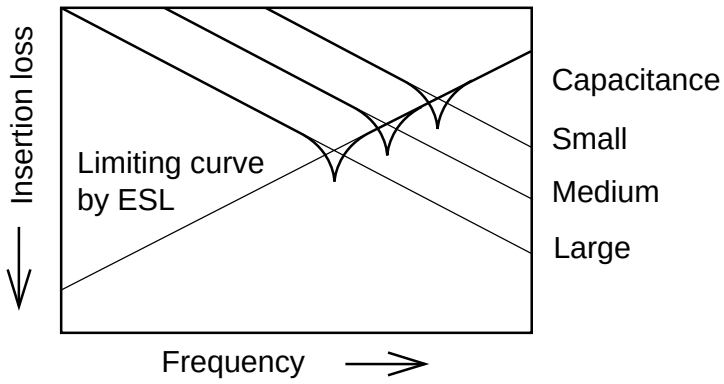
The Effect of ESL

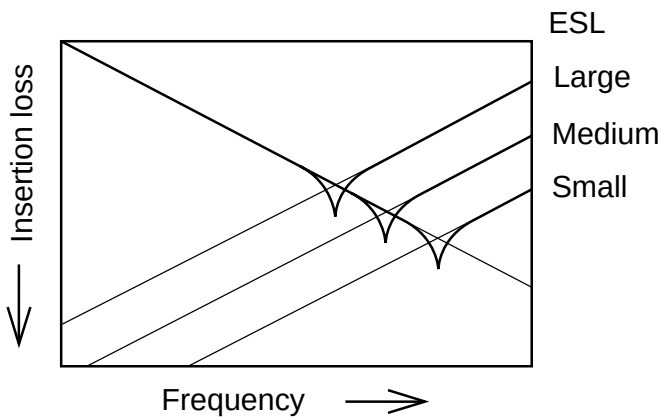
14

At frequencies higher than the self-resonance frequency, the insertion loss does not change regardless of whether the capacitance value is increased or decreased.

⇩

For use in a high-frequency range, a capacitor with a high self-resonance frequency, i.e. small residual inductance (ESL), must be selected.





[Notes]

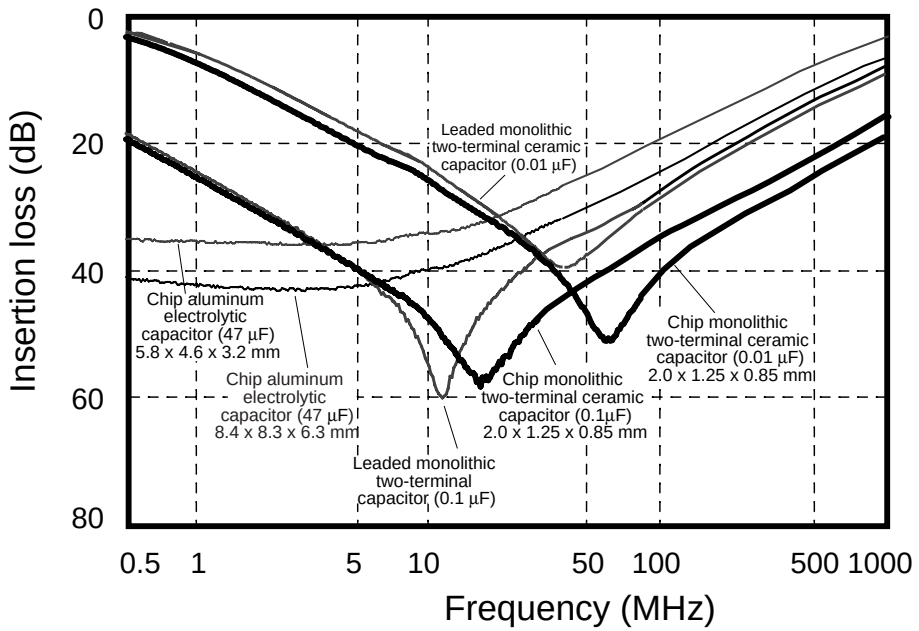
When the residual inductance is the same, the insertion loss does not change at frequencies above the self-resonance frequency, regardless of whether the capacitance value of the capacitor is increased or decreased. Therefore for greater noise suppression at frequencies higher than the self-resonance frequency, you must select a capacitor with a higher self-resonance frequency, i.e. small residual inductance.

3. Noise Suppression by Low-pass Filters

3.6. Characteristic of Typical Capacitors

Insertion Loss Characteristics of Typical Two-terminal Capacitors

15



[Notes]

The above drawing shows examples of insertion loss measurements of typical capacitors. For leaded capacitors, the insertion loss is measured with the lead wires cut to 1 mm.

3. Noise Suppression by Low-pass Filters
3.5. Characteristic of Typical Capacitors

Typical ESL Values for Capacitors

16

Type of Capacitor	Residual inductance (ESL)
Leaded disc ceramic capacitor (0.01 μF)	3.0 nH
Leaded disc ceramic capacitor (0.1 μF)	2.6 nH
Leaded monolithic ceramic capacitor (0.01 μF)	1.6 nH
Leaded monolithic ceramic capacitor (0.1 μF)	1.9 nH
Chip monolithic ceramic capacitor (0.01 μF, Size: 2.0 x 1.25 x 0.6 mm)	0.7 nH
Chip monolithic ceramic capacitor (0.1 μF, Size: 2.0 x 1.25 x 0.85 mm)	0.9 nH
Chip aluminum electrolytic capacitor (47 μF, Size: 8.4 x 8.3 x 6.3 mm)	6.8 nH
Chip tantalum electrolytic capacitor (47 μF, Size: 5.8 x 4.6 x 3.2 mm)	3.4 nH

[Notes]

The above table shows typical residual inductances (ESL) values for capacitors, which are calculated from the impedance curves shown on the previous page.
The residual inductance varies depending on the type of capacitor. It can also vary in the same type of capacitor, depending on the dielectric material and the structure of the electrode pattern.

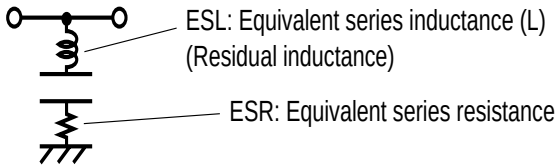
3. Noise Suppression by Low-pass Filters

3.8. The Effect of Equivalent Series Resistance

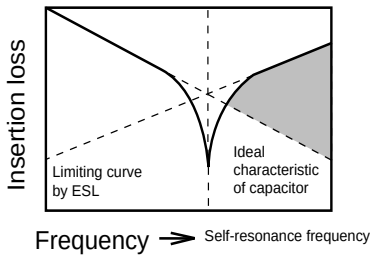
The Effect of Equivalent Series Resistance

20

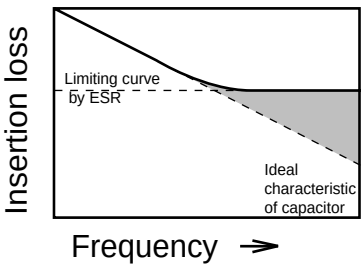
(a) Capacitor's equivalent circuit with ESL and ESR



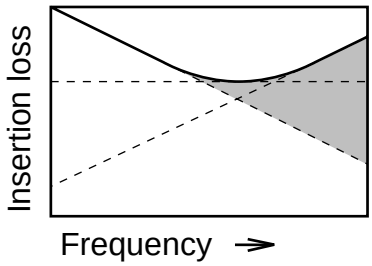
(b) Affect by ESL



(c) Affect by ESR



(d) Insertion loss frequency characteristic of actual capacitor affected by ESL and ESR



The second factor that causes deterioration in the characteristic of capacitors is equivalent series resistance (ESR). The insertion loss will be lower due to ESR caused by the electrode and material.

The ESR is very low in ceramic capacitors but higher in aluminum electrolytic capacitors.

[Notes]