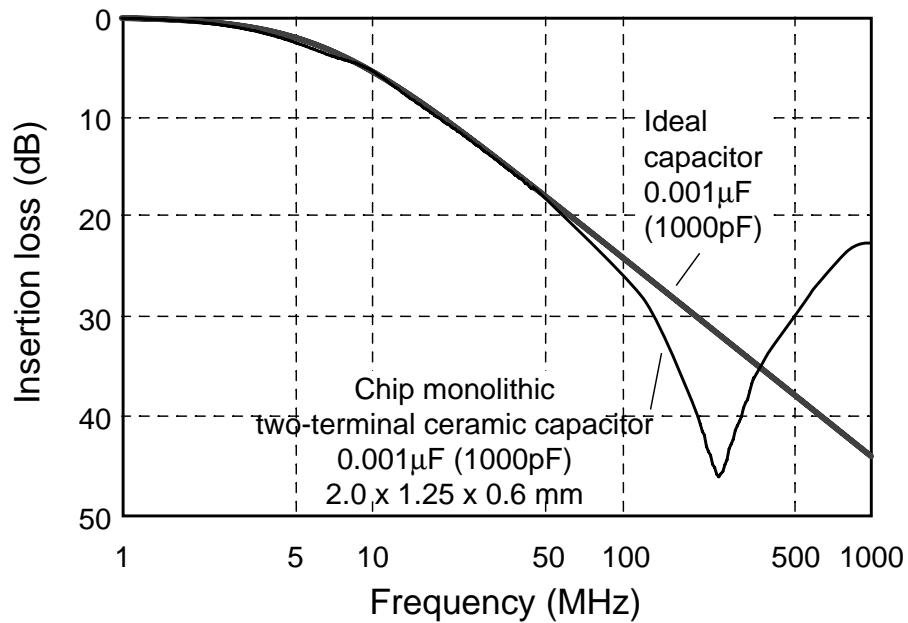


3. Noise Suppression by Low-pass Filters

3.5. The Effect of Non ideal Capacitors

Characteristic of Capacitors

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

[Notes]

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.

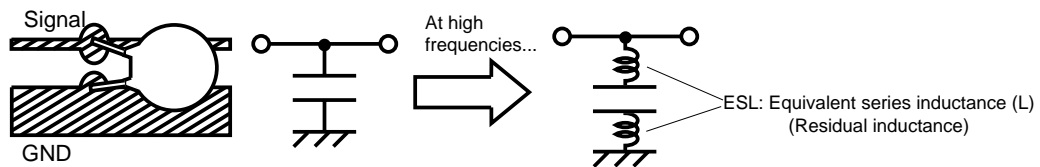
3. Noise Suppression by Low-pass Filters

3.5. The Effect of Non ideal Capacitors

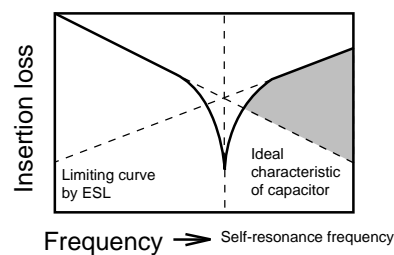
The Effect of Non ideal Capacitors

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(a) Equivalent circuit of capacitor



(b) Effect by residual inductance



Self-resonance frequency

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

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

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

f: Self-resonance frequency

C: Capacitance

L: Residual inductance

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

[Notes]

3. Noise Suppression by Low-pass Filters

3.5. The Effect of Non ideal Capacitors

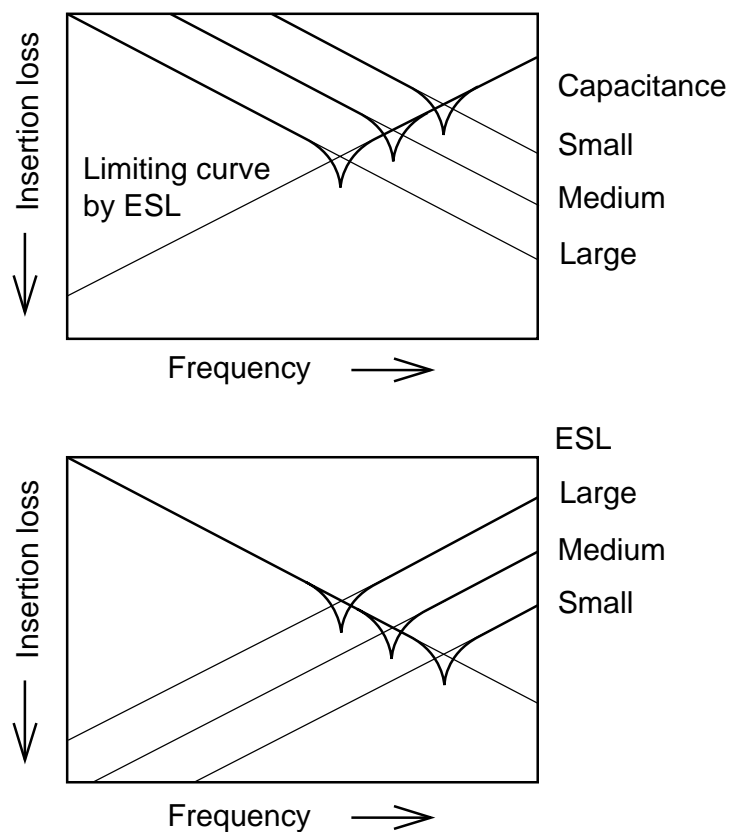
The Effect of ESL

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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.



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.

[Notes]