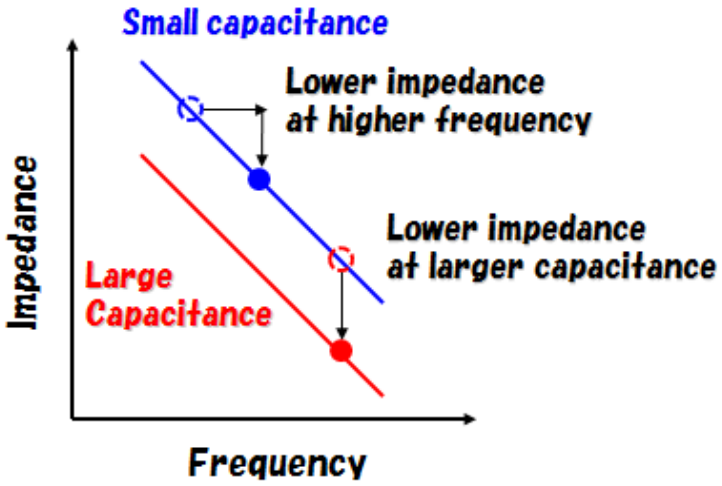
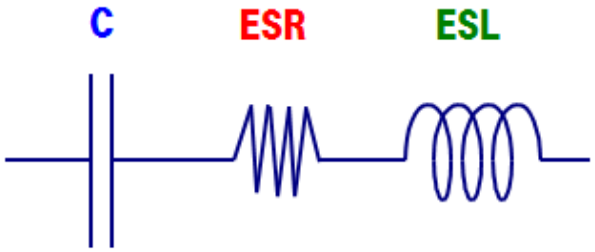
What are impedance frequency characteristics in capacitors? What is ESR/ESL of capacitors?

Impedance of capacitors depends on capacitance and frequency. In an ideal capacitor, impedance becomes lower as capacitance is larger. Also, the impedance becomes lower as the frequency is higher.

For ideal capacitors

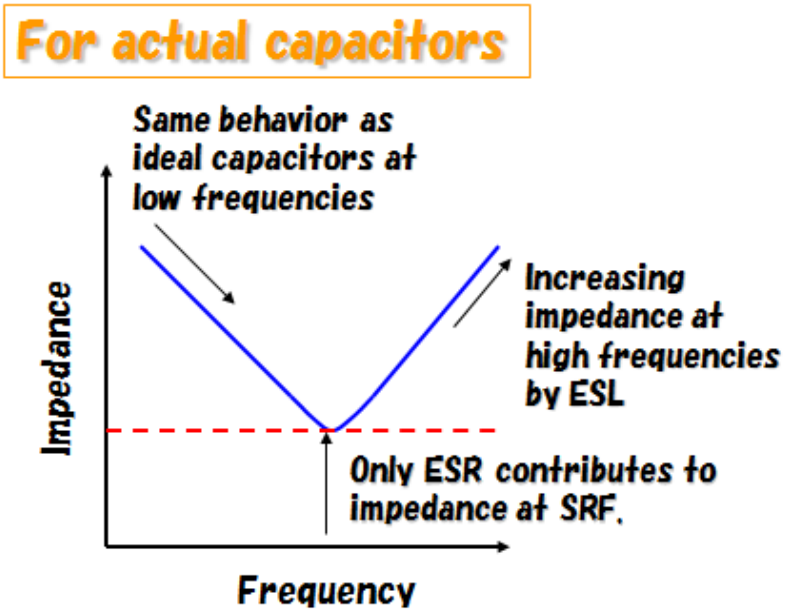


Actually, the capacitor has resistance and inductance. In a simple expression, those characteristics can be written as a C, R, L serial equivalent circuit model. This R is called "Equivalent Series Resistance(ESR)", and L is called "Equivalent Series Inductance(ESL)".



Serial Equivalent Circuit Model for capacitors

Different from an ideal capacitor, the impedance of actual capcitor changes its tendency at a certain frequency because of ESL. This frequency is called "Self Resonant Frequency(SRF)". In higher frequency range than SRF, the impedance becomes larger by increasing frequency because ESL affects to impedance. At SRF, capacitance and ESL mutually erase each impedance. Therefore, only impedance by ESR remains at SRF.



Thus, the impedance of capcitor depends on frequency. That is impedance frequency characteristics in capacitors.

ESR and ESL both cause reduction of performance. Generally speaking, capacitors with lower ESR and ESL work better than higher ones. If ESR of a capacitor is large, it may cause generation of heat and voltage drop when the IC is operating. If ESL of a capacitor is large, it may cause ringing of waveform. ESR and ESL also varies depending on frequency in actual capacitors. Therefore, it is important to know ESR and ESL value at frequency in your concern. See also this document for more detail.

Multilayer ceramic capacitors are generally superior in ESR and ESL characteristics to other kind of capacitors. We can provide LW Reversal Decoupling Capacitors (LWDC™) that have even more lower ESR and ESL than general ceramic capacitors. Please try them in your application.