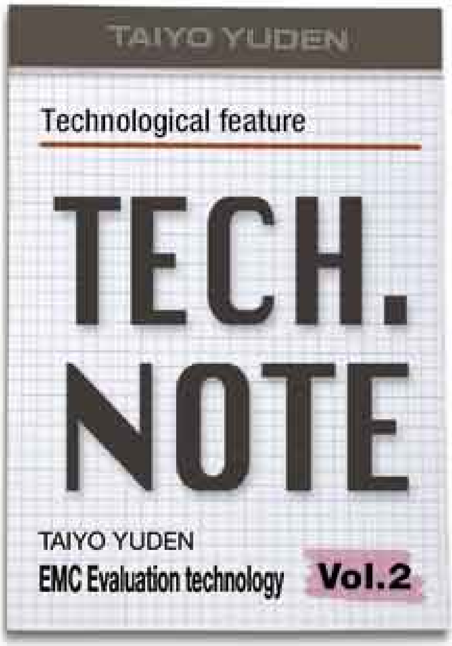
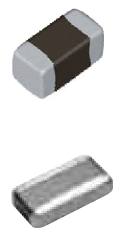


Is 0.1μF sufficient for bypass capacitor?

– Key Points of Lower voltage/Higher current circuits –



This section introduces how to choose components for devices that are becoming low voltage/high current/high speed(high frequency). The focus will be on explanations of the basic knowledge of capacitors for noise countermeasures and load response characteristic improvement of power supply lines. These themes will be discussed in 3 parts.

Step1 Taking advantage of features of ceramic capacitors to replace other types of capacitors

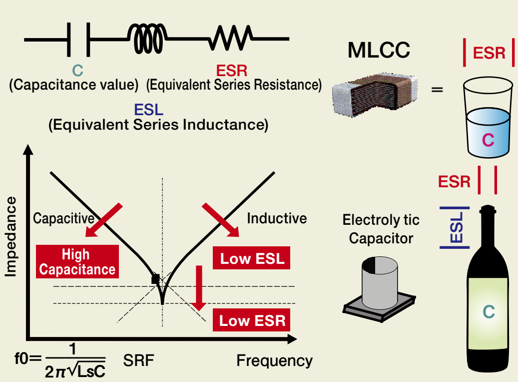
Before explaining the main-theme 'Is 0.1μF sufficient for bypass capacitor ?' If a capacitor is expressed as an equivalent circuit, the expression will be as shown in **Figure 1**.

An ideal capacitor is required only for its capacitance value, but a capacitor actually, has an equivalent series resistance(ESR) and an equivalent series inductance(ESL). These are parasitic constituents of the internal- and external-electrodes of a capacitor. We usually express these by using the symbols of resistors and inductors. As a matter of fact, there are many different ESR and ESL values in different kinds of capacitors. In the case of multilayer ceramic capacitors (MLCC),values of ESR and ESL are very low, and they are effective for filter characteristics and backup characteristics.

Next, **Graph 1** presents comparisons of the attenuation characteristics of aluminum electrolytic capacitors and MLCCs. These characteristics show a comparison of a 47 μF aluminum electrolytic capacitor and a 4.7 μF MLCC. The capacitance value of an MLCC is 1/10 that of an aluminum electrolytic capacitor, but the attenuation characteristic of an MLCC is larger, so it is effective to use as a filter. Comparing the noise amplitudes of the two kinds of capacitors, MLCC is much lower than its counterpart. This is because the ESR and ESL of an MLCC are much lower so that noise easily drops to the ground (GND). Therefore, MLCC can be used as a filter and power supply

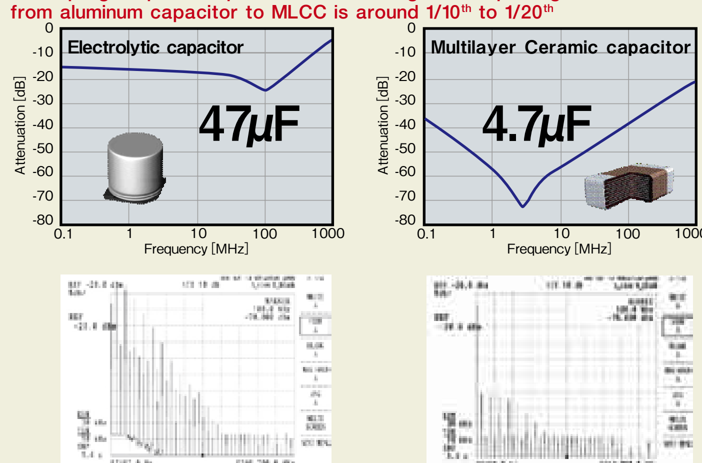
Figure 1 MLCC Characteristics

Realized MLCC superiority by structure difference



Graph 1 Attenuation Characteristics

Decoupling Purpose: capacitance value target for replacing from aluminum capacitor to MLCC is around 1/10th to 1/20th



line backup because it has the features of lower ESR and ESL, which are effective for lowering noise, and readily emits cumulative electric charges.

Point①

Replacing aluminum/tantalum capacitors with MLCC is possible, although MICC has 1/10th or 1/20th the capacitance value of these counterparts (for decoupling purpose). Doing so, achieves improved miniaturization and reliability.

■ Step2 Re-considering the nearest capacitors of ICs

In this section, we will consider the nearest capacitor, which becomes the low voltage/high current/high frequency, of ICs.

Because of the lowering voltage, the voltage variation range becomes much smaller than it used to be. Are we getting to be required a strict control of it? Currently, the capacitance value of bypass capacitors of the nearest ICs is 0.1μF, but we should reconsider for this reason.

Why 0.1μF?

Is it alright to use an conventional capacitor, which requires high-speed response performance close to an IC? (See **Figure 2**)

As can be seen in Figure 3, for verification, we measured the differences in voltage variation when we changed the capacitance value of a bypass capacitor on the power line of a 1.2 V IC. We placed a 100μF capacitor on the power line of the testing substrate, and also placed a decoupling capacitor right next to an FET and used a resistor to resemble a load (Current: 500mA; Slew rate: 150A/use;Voltage variation measurement implemented between a capacitor and a load).

Let us see the result of this experiment (See **Graph 2**)

Figure 2 **Low voltage, high current, and high speed driving ICs How does MLCC needs change?**

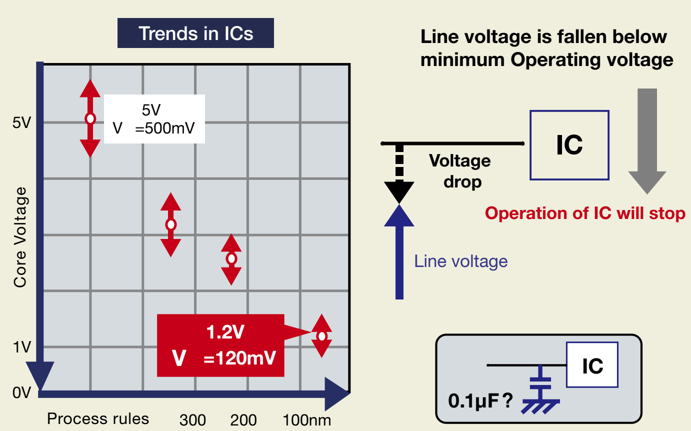
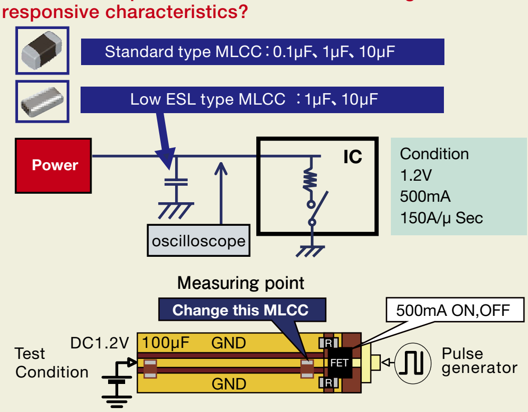


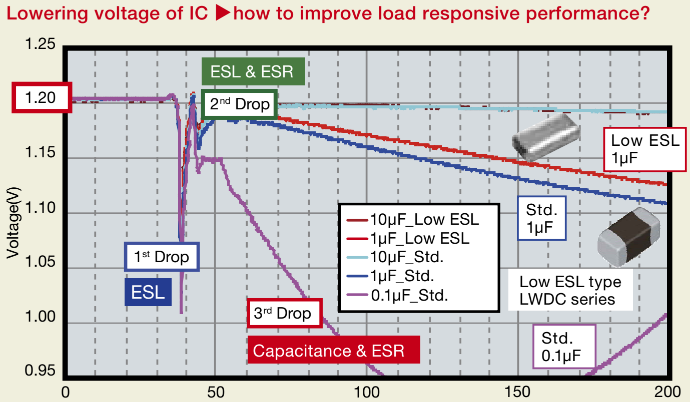
Figure 3 **Measurement condition of load responsive characteristics**

What is the capacitor characteristics affecting load responsive characteristics?



Graph 2 **Measurement result of load responsive characteristics**

Lowering voltage of IC ▶how to improve load responsive performance?



Characteristic of capacitor that influences voltage change

Graph 3 **Differences in Capacitor's ESL on 1st Drop**

Need for Low ESL Capacitor: Taiyo Yuden LWDC series

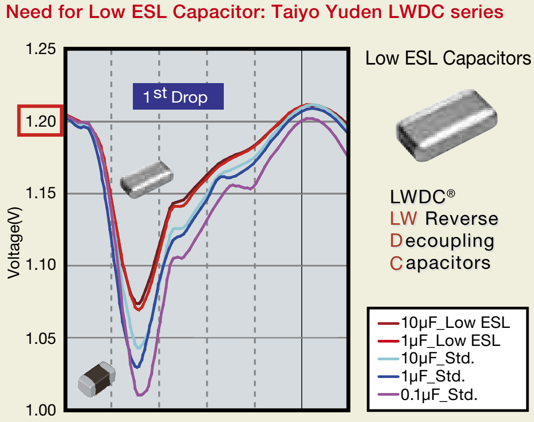
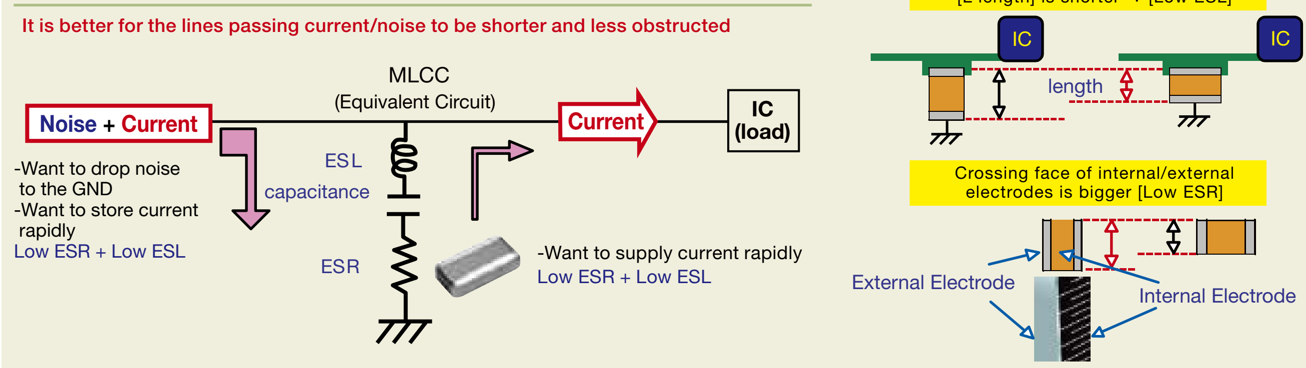


Figure 4 **What is LWDC (LW Reverse Decoupling Capacitors) Series?**



If the allowable voltage variation range of a 1.2V driving IC is ±10%(1.08 V, minimum), a load side of a 0.1μF cannot deal with this when the load variation occurs, even though there is a 100μF capacitor on the power supply side.

The third drop is below 1.08 V.

In spite of putting high capacitance value products as a backup capacitor (in this case, this is a 100μF ceramic capacitor), it is important to have a bypass capacitor for improving the load response characteristics of ICs totally.

Take a look at **Graph 2**. The first, second, and third drops of voltage variations are affected by the ESR and ESL capacitance capability of the capacitor right next to the ICs .

In this case, the value of this capacitor is required to be over 1μF.

An enlarged 1th drop area where the difference in the ESL constituents capacitors is the most visible is shown in **Graph 3**.

Using low ESL capacitors is effective for minimizing the voltage drops at the load side.

Point②

Using a higher capacitance value or a low ESL capacitor is effective for minimizing voltage drops on the load side.

For such low -voltage and high-current needs , TAIYO YUDEN recommends using low ESL/ESR capacitors, which are part of the so-called LWDC® series

〚LW reversal Decoupling Capacitors (LWDC®) series〛

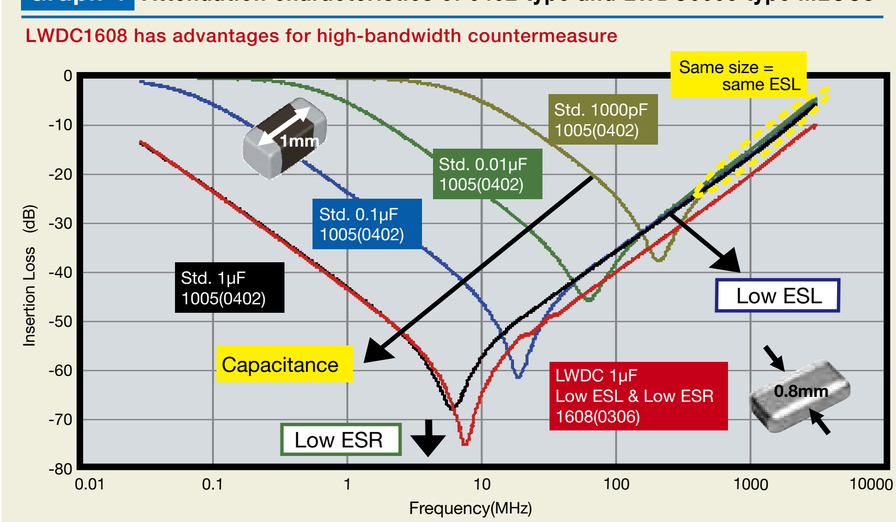
The LWDC® series has an original structure of an external electrode on a long side of a rectangle, which can achieve a lower ESR/ESL than that of a normal type of capacitor(See **Figure 4**).

[Lowering ESL]

If ESL (equivalent series inductance) is expressed for ease of understanding, ESL will be the current path length; thus, the shorter the length of inter-electrodes, the lower the ESL of capacitors. Therefore, it can improve load response characteristics, and obtain wide-band decoupling characteristics. The ESL value of this product depends on its case-size (the length of inter-electrode). (See **Graph 4**) Nevertheless, it is easy to understand that the ESL characteristics, the leaning-lines in the chart become similar on the high frequency side.

In this case, LWDC® has a lower ESL value because the length of the inter-electrode of LWDC® 1608 is 0.8mm, and that of a normal-type capacitor 1005 is 1.0mm.

Graph 4 **Attenuation characteristics of 0402 type and LWDC0603 type MLCCs**



[Lowering ESR]

By definition, a multilayer ceramic capacitor is composed of many layers of internal electrodes. ESR can be lowered by controlling the thickness of internal electrodes or the number of layers. Furthermore, the LWDC® series has wider junction areas of internal- and external electrodes, thus, succeeding in lowering the ESR characteristics.

For circuit boards, a line of passing current and noise is required to be shorter and less destructive (have less resistance). The same holds true for components. This product is made for lowering ESL/ESR by its original structure. It has excellent characteristics in the load response characteristic and decoupling characteristics in a wideband.

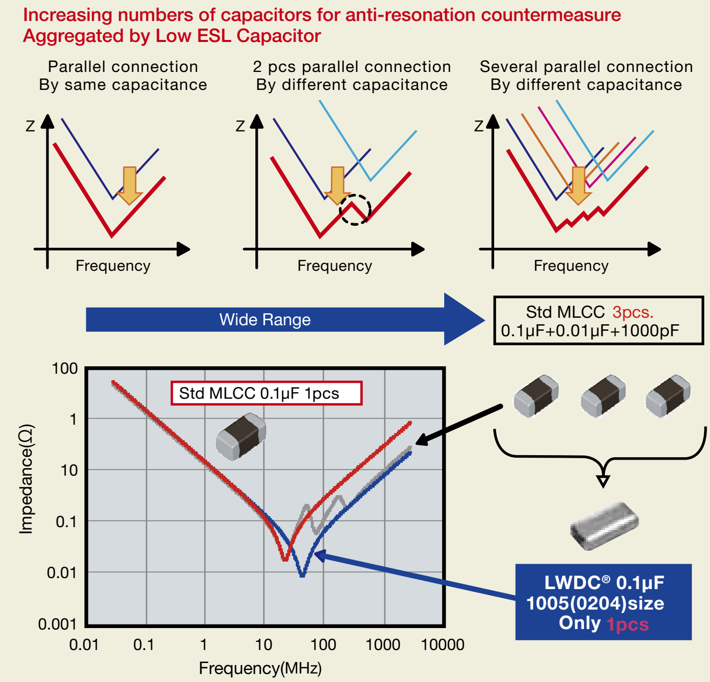
Next, we will reconsider the decoupling characteristics in a wide band.

Take a look at Graph 5.

Several combined capacitors might be used to obtain the required impedance characteristics. In such case, do more capacitors need to be used in order to reduce anti-resonance? Using the LWDC® series with superior ESL characteristics allows reduction of both, wideband noise and the number of capacitors.

*For new items, please contact our sales representatives.

Graph 5 Problems in parallel connection and its countermeasures



Point③

Using a low ESL capacitor allows, the number of components to be reduced, and anti-resonance countermeasures to be implemented.

Is 0.1µF sufficient for bypass capacitor? Lineup

Ordering Code	Case Size (inch)	Rated Voltage	EHS	Capacitance [µ F]	Temperature Characteristics	tan δ Dissipation factor [%] MAX	Capacitance tolerance	Thickness [mm]
JWK105 BJ104MP	1005 (0204)	6.3V	RoHS	0.1	X7S	5	±20%	0.3±0.03
AWK105 BJ224MP		4V	RoHS	0.22	X6S	10		
JWK105 C7 104MP		6.3V	RoHS	0.1	X7S	5		
AWK105 C6 224MP		4V	RoHS	0.22	X6S	10		
JWK107 BJ224MV	1608 (0306)	6.3V	RoHS	0.22	X7R	5	±20%	0.5±0.05
JWK107 BJ105MV			RoHS	1	X7S	10		
AWK107 BJ225MV		4V	RoHS	2.2				
JWK107 B7 224MV		6.3V	RoHS	0.22	X7R	5		
JWK107 C7 105MV			RoHS	1	X7S	10		
AWK107 C7 225MV		4V	RoHS	2.2				
JWK212 BJ475 □ D	2012 (0508)	6.3V	RoHS	4.7	X6S	10	±10% ±20%	0.85±0.1
JWK212 BJ106MD			RoHS	10			±20%	
JWK212 C6 475 □ D			RoHS	4.7			±10% ±20%	
JWK212 C6 106MD			RoHS	10			±20%	
EWK316 BJ225 □ D	3216 (0612)	16V	RoHS	2.2	B/X7R	3.5	±10% ±20%	0.85±0.1
EWK316 B7 225 □ D			RoHS		X7R			

Please confirm even our business about the latest lineup.

■ Step3　Can noise be reduced by mounting methods ?

In closing, let's think about the filters of EMI countermeasures. As filter types, there are two types: using only capacitors, and the combination of capacitor and inductor/ferrite beads. This section will explain the noise reduction and the load response characteristics by the mounting methodology of capacitors.

If two capacitors are mounted against the direction of current path (low L mounting) , it can be understood that higher attenuation characteristics can be gotten than they are mounted on the direction of current path. The validation result of following items will be explained.

Step3-a
Characteristic changes in the case of changing the length between components.

See Graph 6.

Thinking about the direction and distance of mounting capacitors, if the distance of components is wider, the effect of the pattern length (inductance effect by pattern length) is bigger than the effect to the mounting angle (magnetic field effects).

At the distance of 10㎜, there is no difference between the low L mounting and conventional mounting in impedance value. Even so, with respect to save a mounting space, the low L mounting has a better result than a normal mounting, in case of joint state (under 5㎜).

Next, check the noise measurement result on the testing substrate (See **Graph 7**).

The result is verified the noise reduction effect

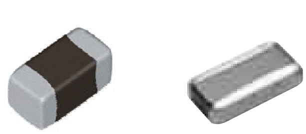
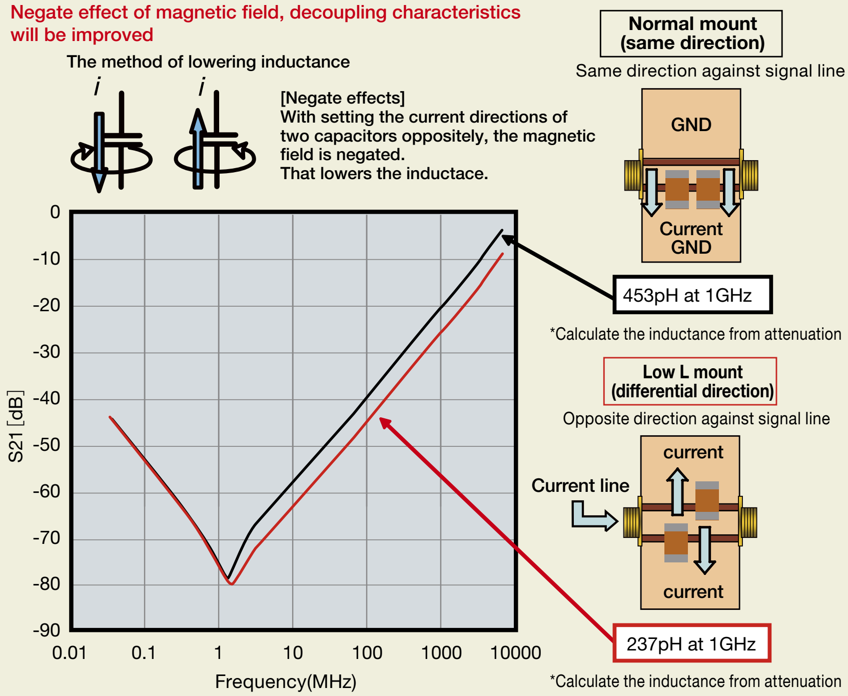
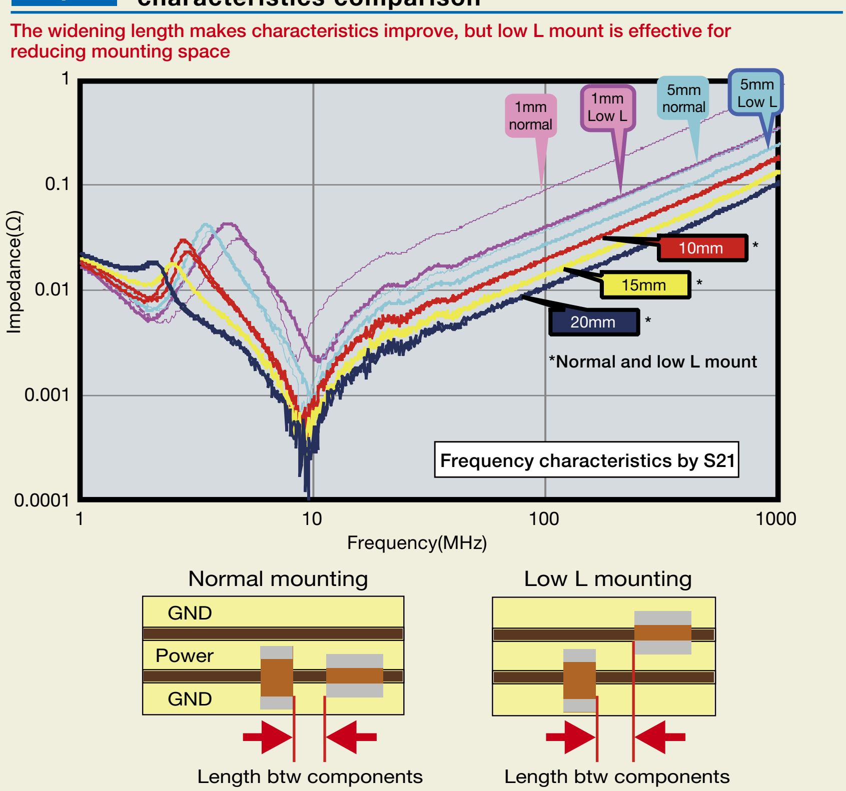


Figure 5 Decreasing inductance mounting method



Graph 6 Length between components & Decoupling characteristics comparison



of mounting. Check the case of combining low ESL capacitors (see **Graphs 8** and **9**). It is possible to improving filter and load response characteristics by combining low L mounting and Low ESL capacitors in close proximity to low-voltage/high-speed devices.

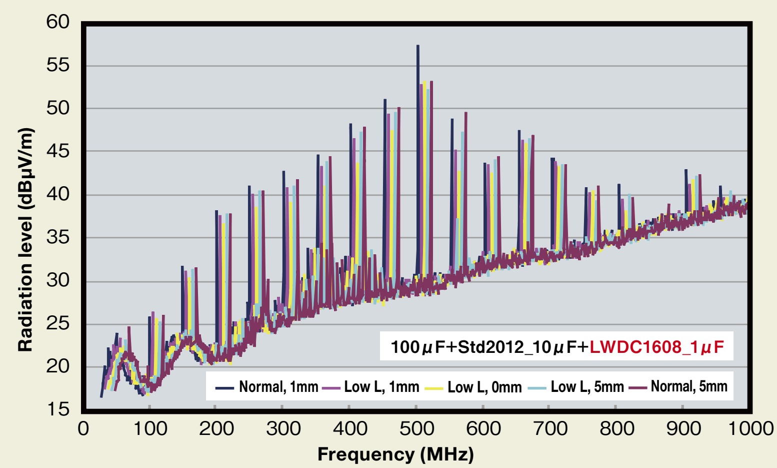
Point④
Filter characteristics can be improved by capacitor mounting methods and combining Low L mounting and Low ESL capacitors in proximity to low-voltage/high-speed devices is effective.

This is the end of the explanation for this section. This theme can be used for election designing, and is helpful for choosing components.
In the end, we provide not only electronic components, but also EMC support through high-efficiency measurement/evaluation technologies.

TAIYO YUDEN has fully-equipped EMI countermeasure systems: anechoic chambers, which can be used to conduct studies to satisfy noise specifications such as VCCI and FCC, and adjacent electromagnetic field measurement systems, which can be used to visualize the noise emitting points devices.
The Adjacent Electromagnetic Field Measurement System, in particular, is a unique, totally different kind of measurement system that TAIYO YUDEN invented on its own.
Moreover, EASY SIM, which is simulation software for choosing component, and S-Parameter Data and Components Library, which is for major commercial simulation software, can be downloaded from TAIYO YUDEN's Web-site
(http://www.yuden.co.jp)

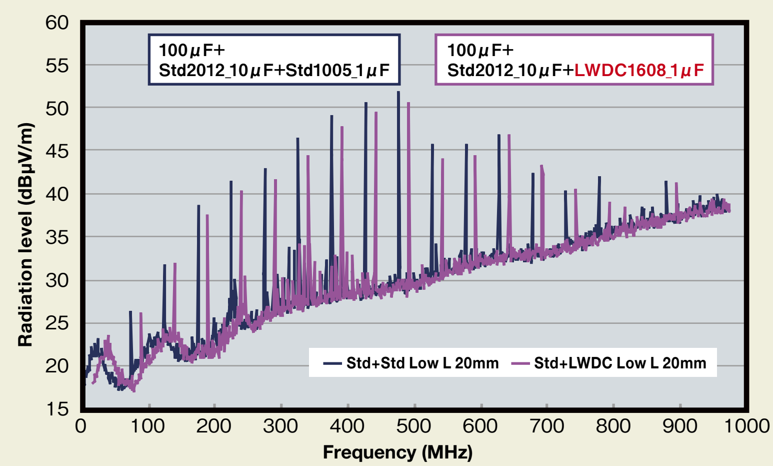
Graph 7 **Radiation noise comparison (horizontal) 200mm: comparison between on-board components below 5mm**

"Low L mount" is effective for noise reduction.



Graph 8 **Radiation noise comparison (horizontal) 200mm: Analysis of ESL difference in on-board components which are embedded by low L mount**

"Low ESL capacitor" is effective for noise reduction.



Graph 9 **"Low L mount"+"Low ESL capacitor" is effective for rapid load changes.**