Technology Focus

Murata's Three-Terminal Capacitors Suppress Noise on Power Lines

Electronic devices, as represented by digital cameras and flat TVs, are becoming more multi-functional and highly efficient in order to meet the requirements of consumers. To realize these multi-functional and highly efficient features, processing speeds of semiconductors used in devices are faster and they are being further integrated to improve the performance of electronic devices. Under these circumstances, however, the noises that emanate from the semiconductors produce disadvantages such as higher frequency and higher amounts of noise. Therefore, it is necessary to suppress more noise in the high frequency bands subsequently to suppress noises from electronic devices.

Controlling Noise in Power Lines

Noise suppression in electronic devices is divided into signal lines like differential transmission systems and power lines like voltage on power supply (Vcc).

In power lines, when high frequency noises are removed by noise suppression measures, more capacitors are mounted on devices and the impedance of the power lines becomes lower. As a result, noises from the IC are suppressed. However, it is not sufficient to merely mount a large number of capacitors because recent semiconductors do not have enough spaces to mount a large number of capacitors due to more pins and narrower pitches. Costs are also unexpectedly piling up due to the expenses related to mounting capacitors, which are higher than the costs of the capacitors' components themselves. Therefore, it is necessary to efficiently suppress noises using capacitors with superior high-frequency properties and profound noise removing effects.

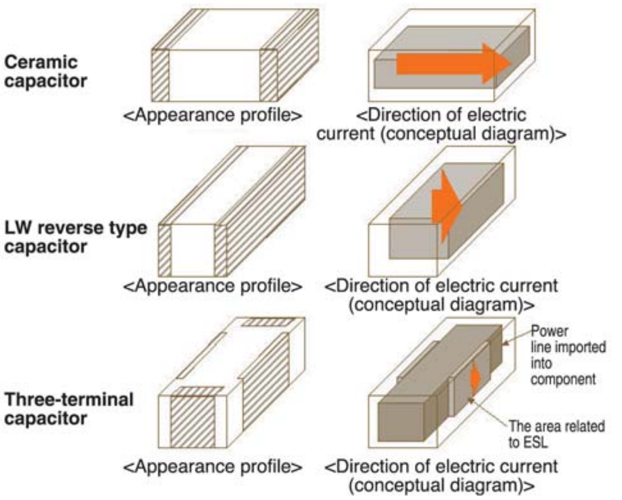

Fig. 2: Conceptual diagram of electric current flowing in capacitor

Smaller ESL, Higher Insertion Loss

Capacitors with superior high frequency properties and profound noise removing effects mean that the capacitors have a small equivalent series inductance (ESL), an inductance component to be equally connected in series with capacitance. Fig. 1 shows the relations between ESL and insertion loss frequency characteristics. When ESL is smaller, the insertion loss that indicates the ratio of removed noise becomes bigger. Thus, using capacitors with small ESL realizes profound noise removing effects even without additional capacitors.

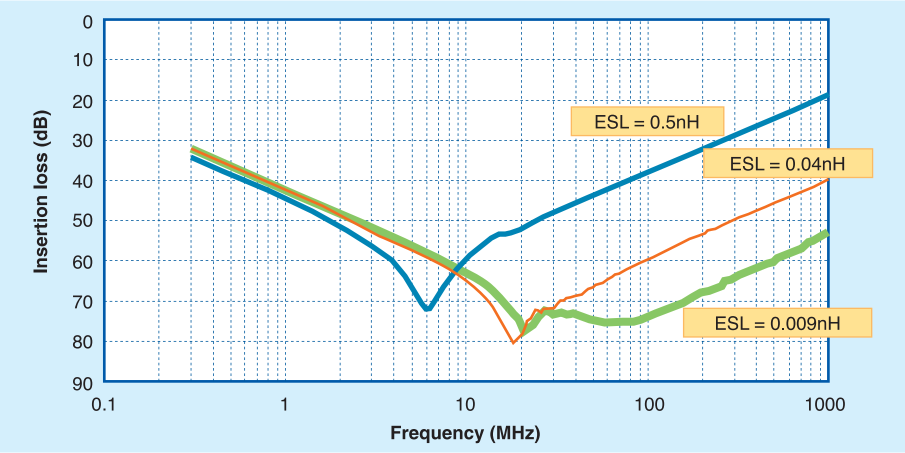

Fig. 1: Insertion loss frequency characteristics for each ESL

Three-Terminal Capacitor

Capacitors with small ESL have superior noise removing effects. The ESL is characterized by the size of the electric line in which electric current flows just like the other inductance that conductors have. For example, in the copper laminate pattern used in a printed circuit board (PCB), an inductance in the rectangular solid of the copper is formed. Electric current flowing through capacitors also forms inductance in rectangular solids where electric current flows.

In other words, ESL becomes smaller when the distance from a positive electrode to a ground (GND) electrode is shorter and the cross-sectional area of a rectangular solid is larger. In order to make ESL smaller, capacitors have to be shorter in length and longer in width (See Fig. 2). This principle ultimately leads to a three-terminal shape, in which the power line is incorporated in the component, and the distance from the power line as a positive electrode to the GND electrode is shortest. Three-terminal capacitors can provide

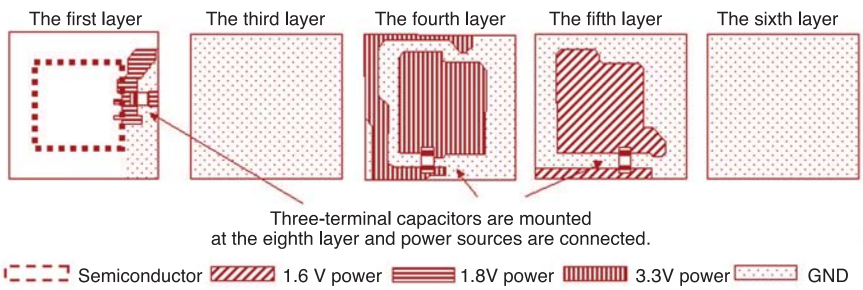

Fig. 3: Power profile of the eight-layer circuit board (Signal wiring layer for the second and seventh layers)

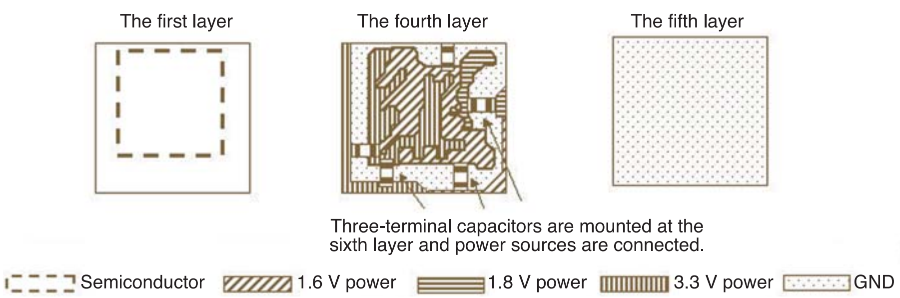

Fig. 4: Power profile of the six-layer circuit board (Signal wiring layer for the first, second and third layers)

less than one tenth of ESL in comparison with conventional capacitors because of their configuration, while also providing profound noise removing effects in high frequency. In Fig. 1, E = 0.009nH shows the characteristics of a three-terminal capacitor, as an example.

Works Well on Two Designs

A three-terminal capacitor possesses extremely small ESL, but in some cases, noise removing effects may not occur as expected. A method to effectively use a three-terminal capacitor can be seen in two circuit board designs that are often implemented.

The first is an eight-layer circuit board forming multiple power layers. A power plane is formed in each layer in order to reduce impedance of the power plane (See Fig. 3). The power pattern here is the same size as that of the IC surrounded by the GND electrode. This is because coupling with surrounding circuits is prevented. Then, the power pattern is connected to an external power pattern through the three-terminal capacitor. As a result, noise can be firmly removed because high frequency noises always go through the three-terminal capacitor.

The second is a six-layer circuit board forming a single power layer. This is an example where three power sources are mixed on one plane (See Fig. 4). In this case, a three-terminal capacitor is mounted near the IC, so that noises are kept from flowing outside the IC surrounding.

An effective application in using a three-terminal capacitor with an eight-layer circuit board is to widen the power pattern. Fig. 5 shows a ripple voltage value or a peak-peak voltage value in each power supply pin. However, one three-terminal capacitor as illustrated in the figure, can sufficiently lower the voltage variation level because the capacitor with a large number of layers can widen the power pattern.

In the six-layer circuit board, it is important that three-terminal capacitors are located at the edge of an IC, and ceramic capacitors are evenly located at the other positions. If the positions of power supply pins having much noise are known in advance, it is better to locate capacitors at once, otherwise capacitors need to be distributed evenly.

Connects to Via Holes

When the noise current is reduced, it is important that the mounting surface of a three-terminal capacitor is connected to the GND plane in plural via holes to suppress the impedance to the GND plane at low levels. Fig. 6 shows the result of calculating inductance in via holes. It is necessary to reduce the length of via holes and arrange them in plural in order to have an inductance equivalent to the ESL that is, 0.009nH, of the three-terminal capacitor. This principle remains unchanged even when multilayer circuit boards having large number of layers or small number of layers are used. Fig. 7 shows the results of measuring a circuit board having a three-terminal capacitor that is connected to the GND plane with 0.1mm via holes. It demonstrates that a profound noise removing effect is widely present between 10MHz and 1GHz, and the three-terminal capacitor has a 20dB noise removing effect that is equivalent to 10 times compared with two pieces of two-termi-

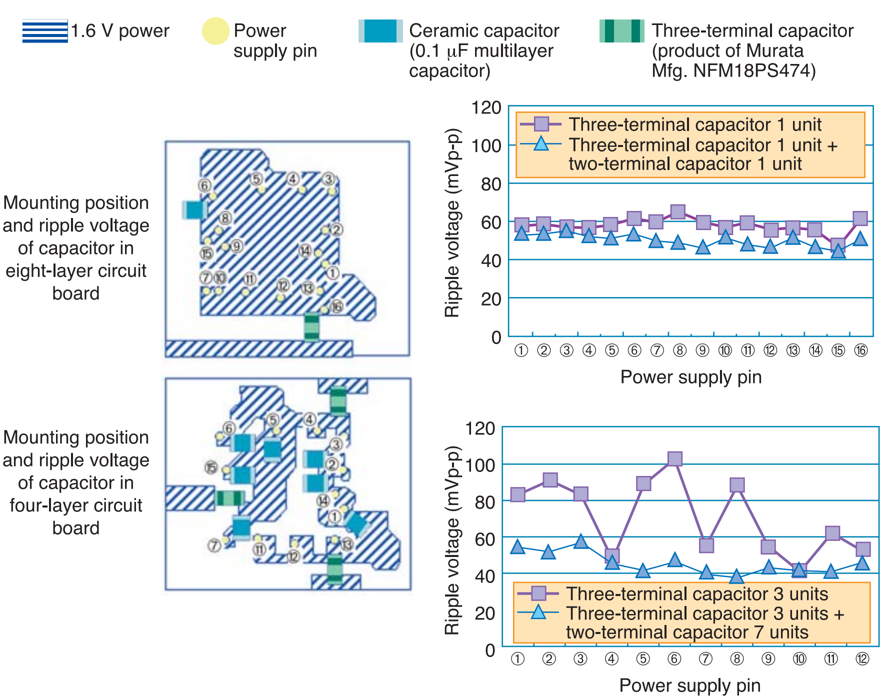

Fig. 5: Supply voltage variation (Ripple voltage)

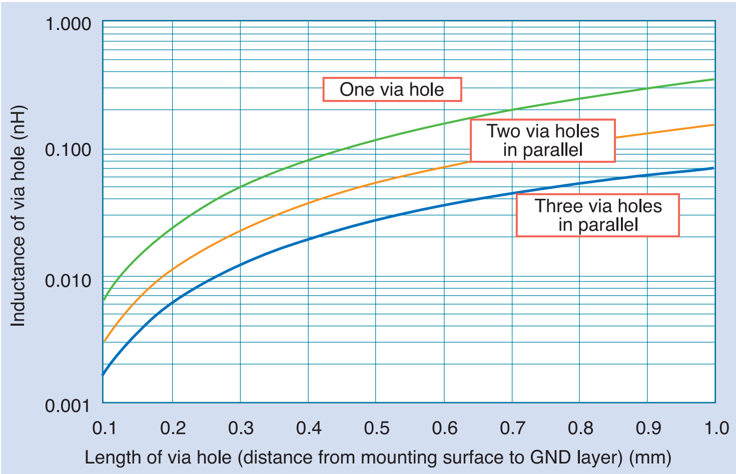

Fig. 6: Example of calculating inductance of via hole

nal capacitors.

Care should be taken because three-terminal capacitors and ceramic capacitors are often mounted on a surface opposite of the semiconductors and the impedance of via holes used for the connection is unexpectedly large. Therefore, a case example of actively using mutual inductances between via holes in order to reduce impedance of the via hole is introduced.

Fig. 8 shows the results of measuring voltage variations when a capacitor is mounted with a 0.5mm clearance between via holes and 1.6mm clearance between via holes. It shows that the voltage variation could be reduced 10 percent when a capacitor is mounted with a 0.5mm clearance between via holes.

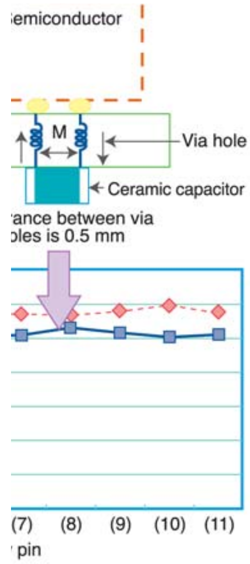

Fig. 8: Ripple voltage comparison when clearance between via holes is expanded

Thus, it demonstrates the importance of ensuring that the via holes connected to the positive electrode and to the GND electrode are located as close to each other as possible, and of reducing inductance by using mutual inductance.

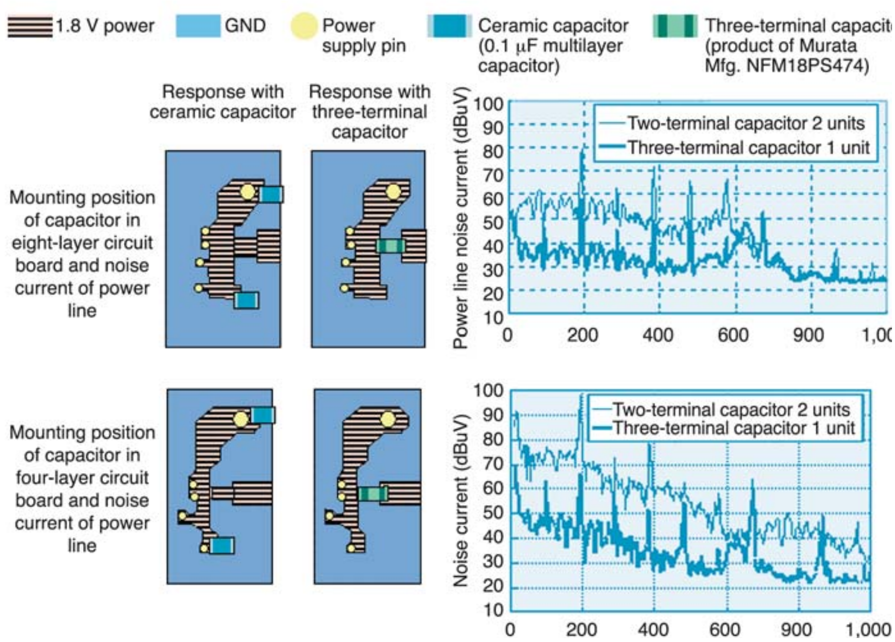

Fig. 7: Noise current comparison

Focus on Component Selection, Usage

Recently, various components have been made commercially available as low ESL capacitors. However, more attention is likely being paid to component characteristics than the components usage.

Because noise levels are likely to increase in the future, it is prudent to pay attention to both component selection as well as component use in order to continuously reduce noises.

About This Article:

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