

Classification of EMC Countermeasure Components and Their Roles

TDK Corporation Application Center
Yoshikazu Fujishiro

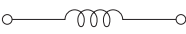
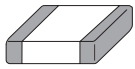
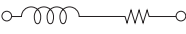
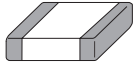

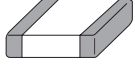
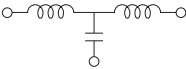
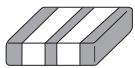
1 | What are EMC Countermeasure Components?

EMC Countermeasure Components as Filters

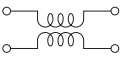
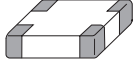
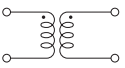
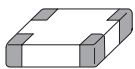
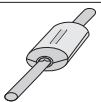
EMC countermeasure components are electronic components used for EMC countermeasures against noise. Specifically, they are components, such as capacitors and filters, as shown in Figure 1, and the phrase “EMC countermeasure components” is generally used to describe them. Therefore, there are no specific objects called EMC countermeasure components. In addition, among the EMC countermeasure components, there are general-purpose components that are used for other purposes than EMC countermeasures, such as capacitors and coils. However, many of the components are used only for EMC countermeasures. Other than the components shown in the figure, in a broad sense a dumping resistor and a clamp diode can be referred to as EMC countermeasure components. However, because they are used mainly for SI (Signal Integrity), they are not described here.

Figure 1 Various Types of EMC Countermeasure Components


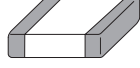


(1) Components that separate signals according to their frequencies

Coil 	
Bead 	
Capacitor 	
Three-terminal filter 	

(2) Components that separate signals according to their modes

Common mode filter 	
Transmission transformer 	
Ferrite core 	

(3) Components that separate signals according to their amplitudes

Varistor 	
Zener diode 	

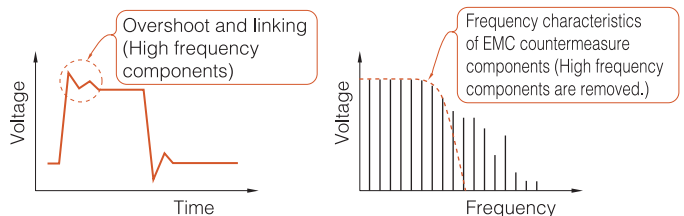
Generally speaking, EMC countermeasure components are regarded as “filters” for separating necessary signals (information) from unnecessary signals (noise). These filters are divided into several types according to their different characteristics.

Separating Signals according to Their Frequencies

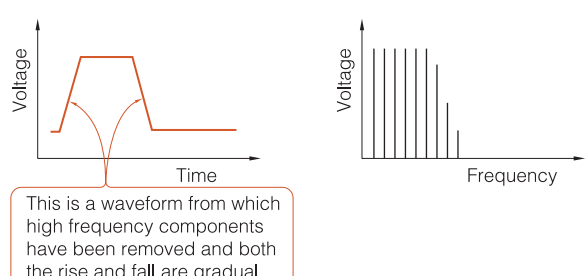
Generally, noise has high frequency components (see a later reference [1]), and, therefore, it can be separated by making use of this characteristic (Figure 2). An EMC countermeasure component in this case can be called an LPF (Low Pass Filter). In Figure 1, a coil, a bead, a capacitor, a three-terminal filter, etc. are classified as LPFs. Because they are LPFs, when they are used a coil and a bead are inserted into a series circuit and a capacitor into a shunt circuit. For obtaining sharper attenuation characteristics, a three-terminal filter can be made by combining a coil, bead, and a capacitor, and an RC filter can be made by

Figure 2 Components that Separate Unnecessary Signals (noise) according to their Frequencies

(a) Without EMC countermeasure components



(b) With EMC countermeasure components



combining a resistor and a capacitor (which are both cheap). A filter for an AC power line is typical of such filters, and it can be made by combining a capacitor (X capacitor or Y capacitor) and a common mode filter, which can be replaced by a coil.

Although there is no clear difference between a coil and a bead, a bead becomes lossier in a high frequency band. Because in many cases lossiness works favorably (energy absorption, etc.) as an EMC countermeasure, a bead is preferred, but because a coil causes high inductance, it is used in a relatively low frequency band and in a location where an absolute value is needed.

● Separating Signals according to Their Modes

When the transmission mode of noise is different from that of information (necessary signals), noise and information can be separated from each other according to the difference in their mode. For example, in differential transmission, necessary signals are in the differential mode, and, normally, unnecessary components are in the common mode (information may be put in the common mode, depending on standards.) A common mode filter (CMF), ferrite core^{*1} (including a clamp filter), and a transmission transformer^{*2} are components for suppressing such common mode components. They use magnetic coupling in an effective way so that they do not affect the differential mode and act only on the common mode. These components are inserted into series circuits.

● Separating Signals according to Their Amplitudes

A varistor and a zener diode do not act on signals with low amplitudes, but they transform themselves into an extremely low resistance when high voltage (noise) occurs, and they prevent the noise from being transmitted. They exert an effect on sudden noise, such as static electricity. These parts are inserted into shunt circuits.

■ Classification not Based on the Function of Each Component

Mentioned above is classification based on the function of each EMC countermeasure component, but it is also important to take into account whether the components can be attached additionally. From such a viewpoint, clamp filters, magnetic sheets, etc. are convenient to use. Electronic components, such as beads and CMFs, can be used as necessary if a land is provided beforehand (they need to be connected with a jumper wire when no EMC countermeasure component is used).

In addition, an important point to consider is whether grounding is needed or not. Because a three-terminal filter has a grounding terminal, to deliver its maximum performance it needs to be grounded in the shortest distance to the earth. A capacitor, varistor, and zener diode also need grounding when they are used in shunt circuits. In addition, grounding is often used, although indirectly, for a transmission transformer with an intermediate tap.

*1 A ferrite core can be seen as a half-finished product, for example when it has a conducting wire passed through it, it becomes a CMF or a bead.

*2 The role of a transmission transformer should be regarded not as a control of the common mode but as insulation. A transformer converts electric energy into magnetic energy once and converts it back into electric energy again, thereby interrupting an electrical path.

Explanations for each component have been omitted here because of space limitations. For more information, see a later chapter or references [2] to [5].

2 | Methods of Evaluating EMC Countermeasure Components

■ Evaluation Parameters

How do EMC countermeasure components actually have an effect? This chapter describes methods of evaluating them.

The characteristics of a two-terminal component can be expressed as impedance between its terminals as shown in Figure 3 (a). The characteristics of a three- or more-terminal component can also be expressed as impedance if its terminals are connected appropriately so as to be two terminals.

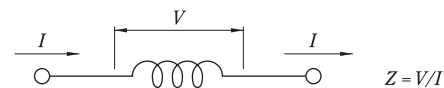
A common mode filter (CMF) is such a filter. The characteristics of a common mode filter are expressed as several types of impedance when its terminals are connected differently (Figure 3 (b)).

Because the characteristics of a component that needs grounding (GND) are difficult to express as impedance, an S parameter is used. The S parameter is used for the three-terminal filter in Figure 1 (Figure 3 (c)). The characteristics of components other than three-terminal filters can be expressed with S parameters if GND is provided appropriately. In this case, attention needs to be paid to the arrangement of components. Coil-system components, such as a bead and a CMF, need to be inserted into series circuits and a capacitor into a shunt circuit (state in which C or L of the three-terminal filter in Figure 3 (c) has been removed) so that their characteristics can be measured.

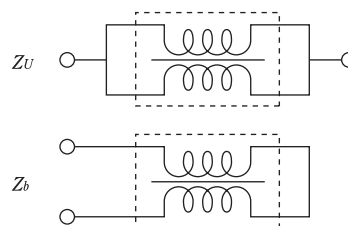
Described below is the outline of impedance. S parameters are explained in another chapter.

Figure 3 Evaluation Parameters of EMC Countermeasure Components

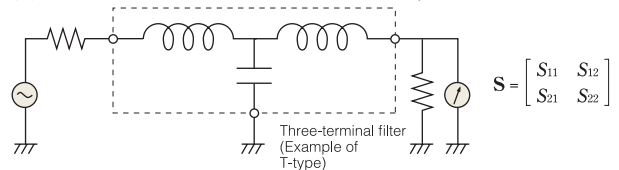
(a) Two-terminal components are evaluated with impedance.



(b) CMFs are evaluated with balanced/unbalanced impedance.



(c) Three-terminal filter is evaluated with S parameters.



■ Impedance

For a component that separates signals according to their frequencies, the frequency characteristic of its impedance is significant. It is important to see how the component's impedance changes between the noise's frequency and the (necessary) signal's frequency (Figure 4 (a)).

At this time, the absolute value of the impedance

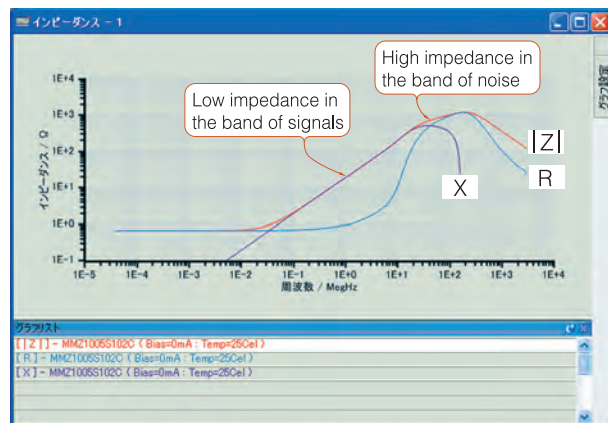
$|Z| = \sqrt{R^2 + X^2}$ is important, but the ratio of R to X of lossy components, such as a bead, needs to be considered. While the ratio of R to X of a lossy component changes according to frequencies, it is safe to think that the pattern of the component is almost unique to its material (magnetic permeability frequency characteristic). Therefore, it is important to select an appropriate magnetic material (product series) to be used in the beads. When ringing is to be suppressed, it is better to select a material that becomes lossy from relatively low frequencies; when high speed is regarded as important, the opposite type of material needs to be used.

On the other hand, the performance of a less lossy component is characterized with reactance X (or susceptance B), and the value obtained from division of the reactance X or susceptance B by the angle frequency ω is often used. In other words, inductance L for a coil and capacitance C for a capacitor are often used. These values are constant, not dependent on frequencies, and therefore, they can be expressed not by a graph but by numerical values (in nH or pF). However, both components have self-resonance (changed from being capacitive to being inductive, and vice versa), and, therefore, when high frequencies are handled, impedance (and its frequency characteristic) needs to be considered again. ESL may sometimes be used as an indicator of self-resonance for capacitors.

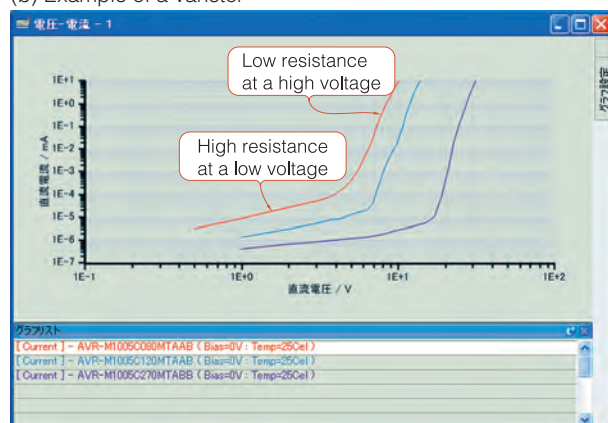
For a component that separates signals according to their amplitudes, the voltage or current characteristic (not frequency characteristic) of its impedance is important. However, for varistors, etc., “voltage vs. current” is graphically displayed conventionally (Figure 4 (b)). In this case, the curves on the graph shows impedance (resistance).

Figure 4 Impedance Characteristics

(a) Example of a bead



(b) Example of a varistor



3 Points to Note When Selecting an EMC Countermeasure Component

The previous section has described methods of evaluating EMC countermeasure components. This section mentions some points to note when selecting an EMC countermeasure component to be used with a method. Concerning whether an EMC countermeasure component is actually effective, other than the characteristic of the component, the following four items are related: (1) Termination condition, (2) Mounting position and mounting state, (3) Radiation mechanism of radiation noise (from where and how it is radiated), and (4) Surrounding environment including thermal coupling and magnetic coupling.

Therefore, even if you use a good performance component, whether the component has an effect depends on how you use it. Considered here are (1) and (2) of the above four items.

(1) Termination condition

Parameters for evaluation, such as impedance and S Parameter have the following characteristics:

- ▶ Impedance shows the characteristic of a single component (on the assumption that it is sufficiently away from the GND). Therefore, whether the component is effective depends on a relative evaluation of the terminating impedance. In other words, an absolute judgment cannot be made for such questions as whether the component is effective when its impedance equals or exceeds a certain number of ohms, or whether the component is not effective when its impedance is less than the value. However, it is useful to know the following tendencies: In a high-impedance environment, insertion of a capacitor into a shunt circuit is effective^{*3}. The reason why this is effective is that a relatively large inductance value is needed in order to produce a similar effect when a coil is inserted into a series circuit. Conversely, in a low-impedance environment, insertion of a coil into a series circuit is effective. In addition, when a component is used in low frequencies, its consonants (L value, C value) need to be relatively large. Therefore, the shape of the component tends to be larger. When a component is used in high frequencies, the situation will be reversed.
- ▶ On the other hand, when an S Parameter is used, a termination condition is taken into account. However, normally, this is a characteristic when the purely resistant termination is 50 Ω (CISPR17: 1981 and MIL-STD-220B: 2000). Of course, it will be a rare case if the termination is exactly 50 Ω^{*4}, and reactance components also exist.

Then, how can a component's effect on noise be measured directly? If resistive termination is allowable, the S Parameter when the termination is other than 50 Ω can be calculated from the S Parameter when the termination is 50 Ω. Therefore, when the calculated S Parameter is used, the attenuation effect on

^{*3} In this instance, resistive termination is assumed. Another assumption is described later.

^{*4} A matching circuit of differential transmission, etc. is one example of such a rare case, and the S Parameter value itself shows the behavior of a circuit. Therefore, for example, it is an important indicator of the behavior that, in a CMF for high-speed differential transmission, the cutoff frequency of the differential mode (frequency of $|S_{dd21}| = 3$ dB) is sufficiently high and the characteristic impedance Z_{0d} is matched.

any (resistive) termination can be estimated. For a concrete calculation method, see the chapter on S Parameter.

If the termination is not resistive, there is no way other than to examine the effect under actual use conditions. Of course, there will be no error if an actual component is soldered and the effect is observed. On the other hand, in a circuit simulation, the effect can be clarified to some extent (in this case, information of impedance and S parameter*5 is used).

Figure 5 shows the effect of an EMC countermeasure component measured in a simplified simulation with the “SEAT” software that TDK provides for free. The figure shows a case where, because a reactance component exists in I/O, the attenuation effect that may be expected from an S Parameter when termination is 50 Ω has not been obtained. In such a case, by making the best use of easily repeated trial and error in a simulation, the search for an optimum component can be narrowed down.

(2) Mounting position and mounting state

Basically, an EMC countermeasure component must be inserted into a noise occurrence location. This will easily produce the expected effect (see [6]) and reduce the risk that noise will diffuse because there is no distance between the component and the location. Concerning static electricity countermeasure components, such as a varistor, it is important to place them as near to the route by which noise enters as possible.

In addition, the I/O position relationship of a component and the way GND is provided also affect the characteristic of the component. It is an ironclad rule that input and output must not be close to each other, and that a component must be grounded within the shortest distance.

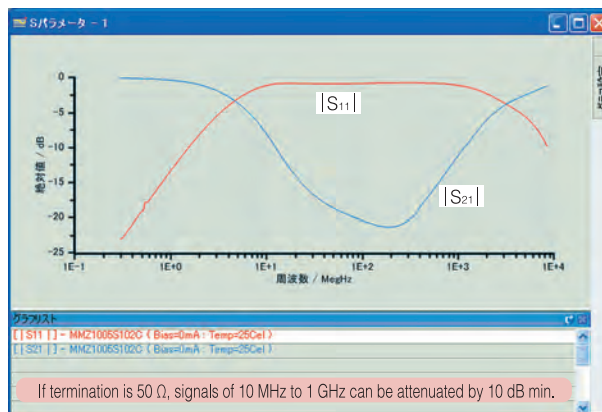
References

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- [6] Hidetoshi YAMAMOTO, Shinichi SHINOHARA, Risaburo SATO, “Predictions of the Effect of a Noise Suppression Device on Radiated Interference Suppression from Printed Wire”, IEICE Technical Research Report EMCJ, pp.21-26, January 2000 (EMCJ99-116)

*5 While recent circuit simulators can handle S Parameter more easily, many of the SPICE-series simulators are unable to handle them with no trouble. If your SPICE-series simulator cannot handle S Parameter, either, see PSPICE's Application Note “Create a S-Parameter Subcircuit for Microwave and RF Applications.”

Figure 5 Case showing that Insertion of an Inappropriate Component causes a Disordered Waveform.

(a) S parameter



(b) Simplified simulation with “SEAT”

