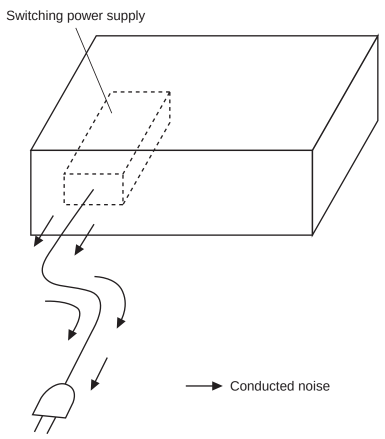
9 Example of Noise Suppression in AC Power Supplies

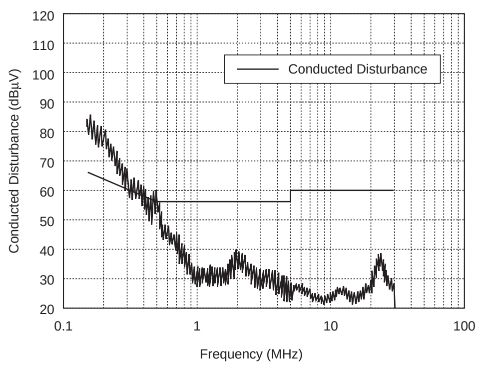
Noise Emission Status for Switching Power Supplies

In switching power supplies, noise is generated by the switching. This noise is conducted to the AC power supply cable. The cause of this noise does not meet as Mains Terminal Interference Voltage. Therefore, noise suppression is required for switching power supplies.

■ Noise from Switching Power Supplies



■ Example of Measured Noise in Switching Power Supplies

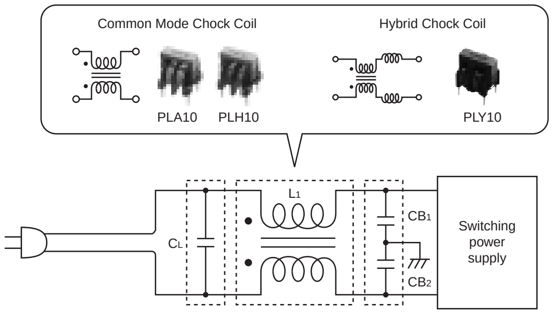


Example of Noise Suppression in AC Power Supplies 9

Noise Suppression Model for Ordinary Switching Power Supplies

In switching power supplies, noise filters are installed as shown below to suppress noise conducting to the AC power supply cable. The capacitors are used as a bypass for noise, and the coils suppress noise conduction to the cable by increasing line impedance.

■ Noise Suppression model for Switching Power Supplies



Symbol	Name	Function
L_1	Common mode choke coil	Suppresses common mode noise
C_L	Across the line capacitor (X-capacitor)	Suppresses differential mode noise
CB_1 CB_2	Line bypass capacitor (Y-capacitor)	Suppresses common mode noise and differential mode noise

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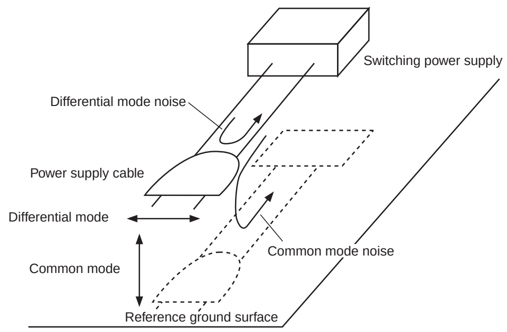
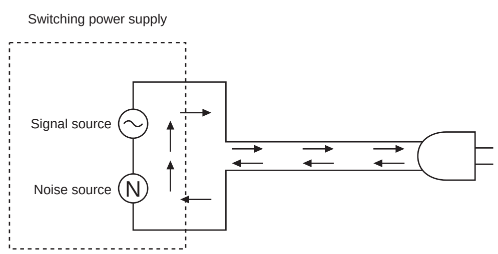
9 Example of Noise Suppression in AC Power Supplies

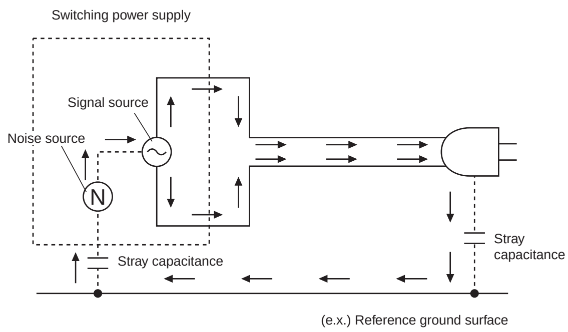
Differential Mode Noise and Common Mode Noise

Noise is classified into two types: differential mode noise and common mode noise.
Differential mode noise is conducted on the two power supply lines in opposite directions to each other, as shown in Fig. (a).
Common mode noise is conducted on all lines in the same direction, as shown in Fig. (b).





(a) Normal mode noise (Differential mode noise)

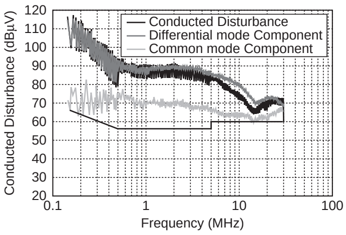


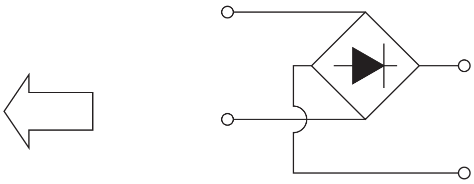
(b) Common mode noise

Functions of Respective Noise Filters

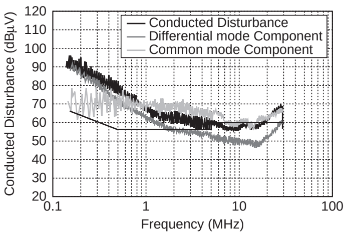
The figures above show examples of the functions of respective noise filters used in a switching power supply. To confirm these functions, changes in the Mains Terminal Interference Voltage are broken down into differential mode and common mode noise.
Figure (a) shows data obtained when no noise fitter is used. This figure reveals that both the differential mode and common mode noise are high. Figure (b) shows data obtained when an X-capacitor is used. This figure reveals that the differential mode noise is decreased.
Figure (c) shows data obtained when both an X-capacitor and Y-capacitor are used. This figure reveals that both the common mode and differential mode noise are decreased. Figure (d) shows data obtained when an X-capacitor, Y-capacitor, and common mode choke coil are all used. This figure reveals that the differential mode noise is further decreased as well as the common mode one. This is because an actual common mode choke coil contains a certain amount of differential mode inductance.

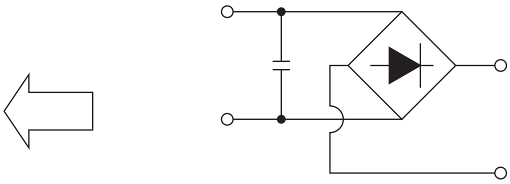
■Examples of confirming the Functions of Respective Noise Filters



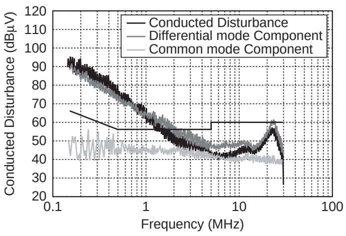


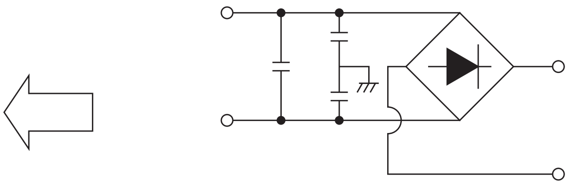
(a) No filter used



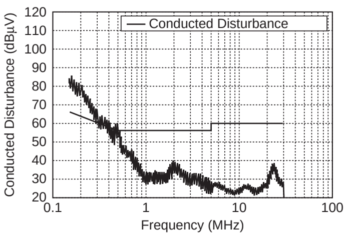


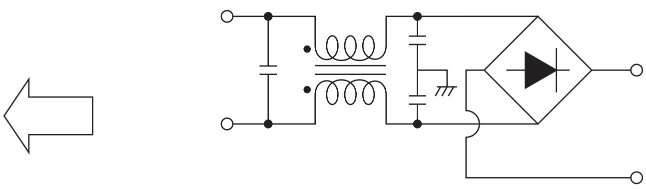
(b) X-capacitor used





(c) Both X-and Y-capacitor used





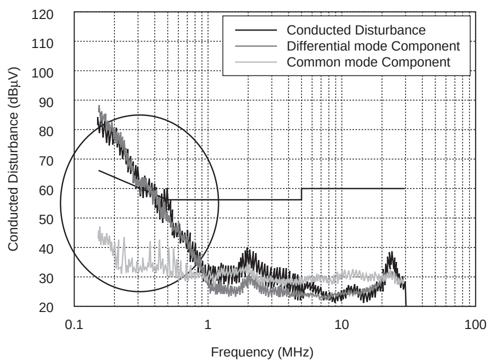
(d) X-capacitor, Y-capacitor, and common mode choke coil all used

9 Example of Noise Suppression in AC Power Supplies

Noise Tendencies in Switching Power Supplies

Newer switching power supplies tend to have a high switching frequency that generates high levels of noise. Noise is especially strong in the several hundred kHz frequency range, close to the switching frequency.
The figure below shows an example of measured Mains Terminal Interference Voltage. In this example, noise of 500kHz or less frequency is strongly generated. When this noise is broken down into common mode and differential mode components, it is found that the noise consists mainly of differential mode components.
Newer switching power supplies tend to strongly generate low frequency differential mode noise. Therefore, more effective methods of suppressing differential mode noise are required.

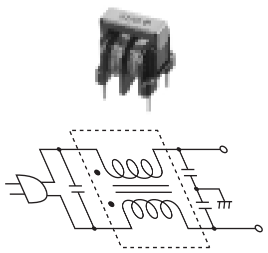
■ Example of Resolving Noise into Differential Mode and Common Mode Components



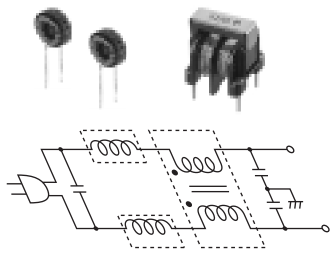
Examples of Suppression against Strong Differential Mode Noise

The figures below show examples of noise suppression in inverter power supplies for lighting equipment. Since low frequency differential mode node is high, noise filters are installed as shown in figures (b), (c), and (d). Differential mode inductance is increased by adding more differential mode choke coils in figure (b), adding another common mode choke coil in figure (c), and increasing the size of the common mode choke coil in figure (d). The reason why a common mode choke coil contains differential mode inductance is that magnetic flux caused by differential mode current does not entirely cancel out because it produces leakage flux. One would think that a capacitor with a larger constant should be used for suppression against differential mode noise. However, increasing the X-capacitor's capacitance causes a problem of increased reactive current. In addition, increasing the Y-capacitor's capacitance causes a problem of increased leakage current. For these reasons, a capacitor with very large capacitance cannot be used. Therefore, when differential mode noise is strong, it is necessary to increase differential mode inductance as shown in figures (b), (c), and (d). However, using the suppression methods shown above causes problems with the increased number of components, with the mounting area, and with the cost. To solve these problems, a choke coil with unchanged common mode inductance and increased differential mode inductance is in demand.

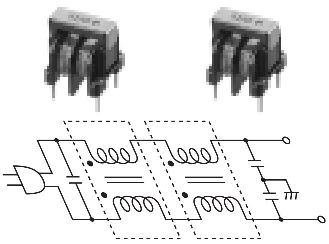
■Examples of Differential Mode Noise Suppression by Adding Choke Coils or Increasing Its Size



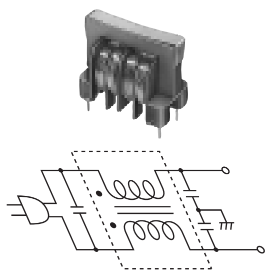
(a) Noise suppression of ordinary switching power supply



(b) More differential mode choke coils are installed



(c) Another common mode choke coil is installed



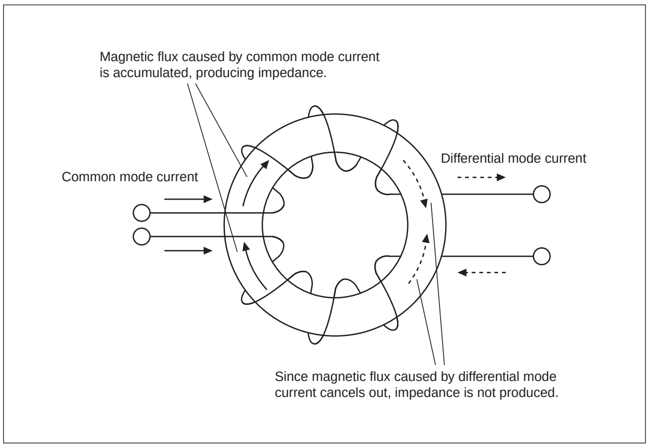
(d) Size of common mode choke coil is increased

9 Example of Noise Suppression in AC Power Supplies

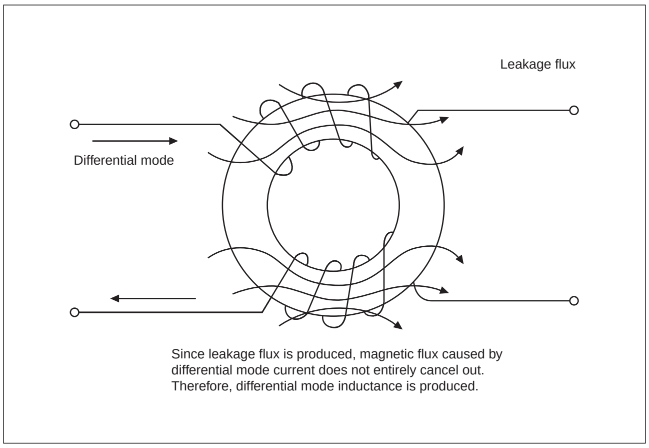
Reasons Why Common Mode Choke Coils Contain Mode Inductance

With an ideal common mode choke coil, magnetic flux caused by common mode current is accumulated inside the ferrite core. Therefore, the common mode choke coil works as an inductor against common mode current. On the other hand, magnetic flux caused by differential mode current cancels out. Therefore, a common mode choke coil does not affect differential mode current. However, since an actual common choke coil produces leakage flux, magnetic flux caused by differential mode current does not entirely cancel out. In other words, an actual common mode choke coil contains differential mode inductance as well as common mode inductance.

■Ideal Common Mode Choke Coil



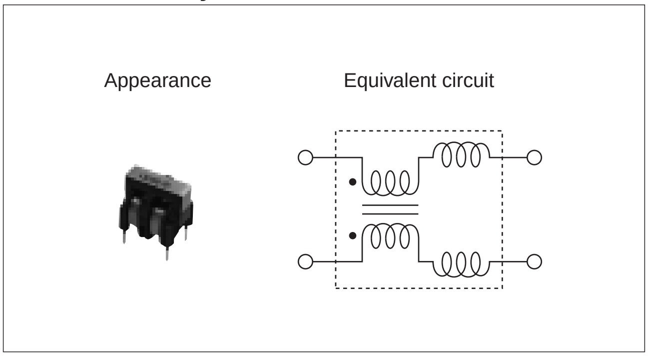
■Actual Common Mode Choke Coil



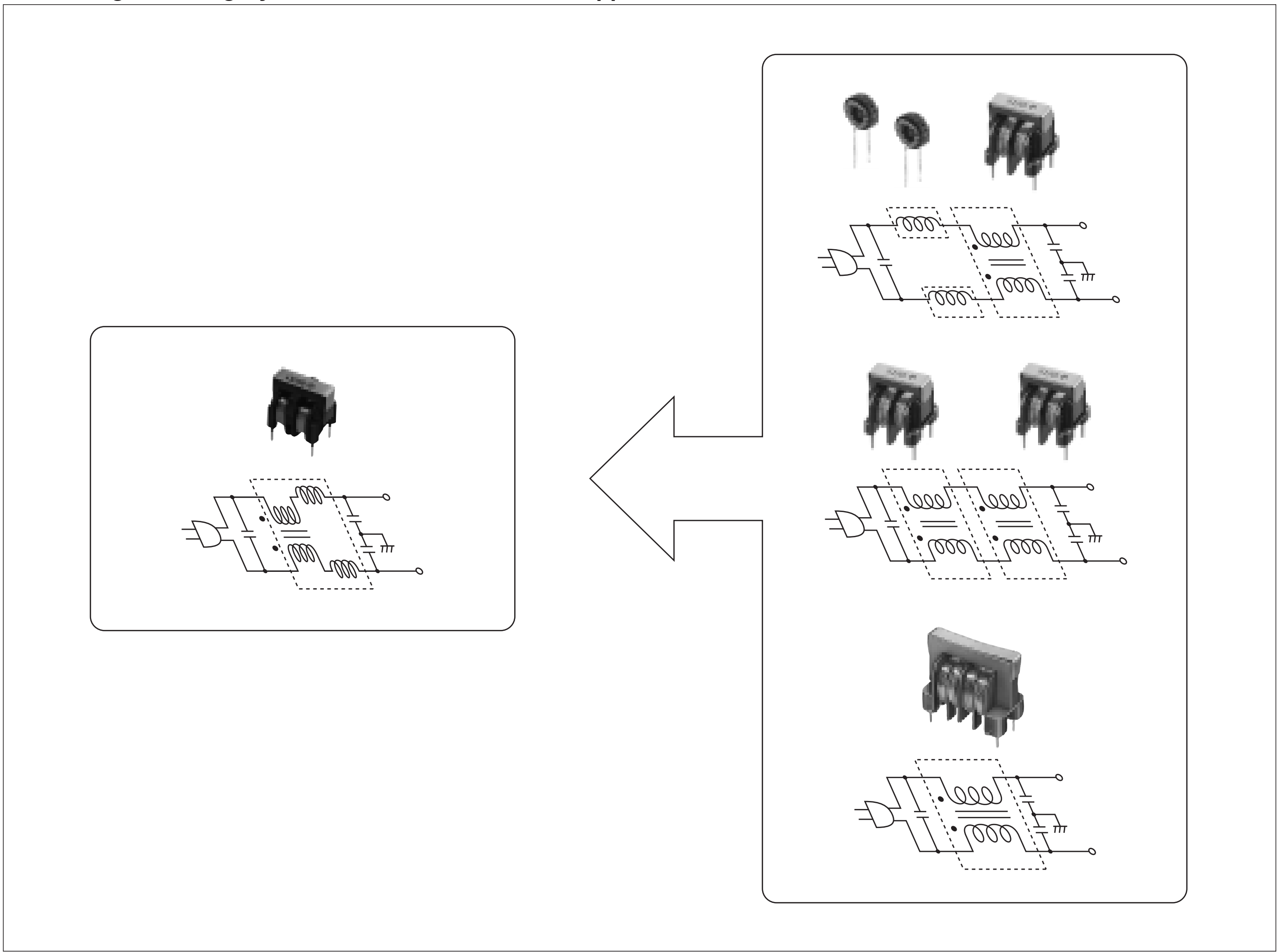
Effective Suppression Methods against Differential Mode Noise using Hybrid Choke Coils

The hybrid choke coil is available as a common mode choke coil with increased differential mode inductance. The appearance and equivalent circuit for the PLY10 series hybrid choke coil are shown above. The devised structure allows the hybrid choke coils to have increased differential mode inductance. For example, the PLY10 series hybrid choke coil contains 3 to 5 times larger differential mode inductance as the previous common mode choke coil of the same size, while the hybrid choke coil contains common mode inductance equivalent to that of the previous common mode choke. In other words, differential mode noise can effectively be suppressed as well as common mode noise, simply by replacing the previously used common mode choke coil with the PLY10 series. This cuts the number of components and mounting area in half, compared to adding another differential mode choke coil or common mode choke coil on the circuit.

■PLY10 Series Hybrid Choke Coil



■Advantage of Using Hybrid Choke Coils for Noise Suppression



9 Example of Noise Suppression in AC Power Supplies

Examples of Confirming the Effectiveness of Hybrid Choke Coils

An example to confirm the effects obtained by using the PLY10 series hybrid choke coil is shown above in Fig. 1. Compared with adding an additional differential mode choke coil, using the PLY10 series suppresses Mains Terminal Interference Voltage with a smaller circuit and decreases the mounting area.
(Although this example uses lighting equipment as a suppression model, the same suppression methods can be used for switching power supplies.)

■Example of Using the PLY10 Series Hybrid Choke Coil