Components for EMI Filtering

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Before incorporating EMI/EMC components, it is necessary to identify circuit paths or areas likely to conduct or radiate noise.

Introduction

Components for EMC filtering can be classified into four main categories (inductors, transformers, capacitors, and beads). This article will focus on the products that use magnetics to achieve EMI reduction within the circuit.

Inductors

The first and most common magnetic EMI filter is the inductor or choke. Inductors are used for both line filtering and energy storage. If a circuit is suspected of being a source for EMI, often the right selection of an inductor can help eliminate the problem. For radiated interference, the selection of a shielded or toroidal inductor can often eliminate (or at least greatly reduce) the offending frequency. In fact, toroidal inductors like surface-mount or leaded toroids can virtually eliminate radiated fields because of the toroid's unique ability to contain the magnetic flux within its core (Figure 1).

The toroid is also less susceptible to induced noise from other components since the applied magnetic field would induce equal and opposite currents inside the toroid, thus canceling the induced interference.

Common-mode Chokes

Common-mode or differential-mode chokes are used to eliminate noise on a pair of conductors. Common-mode noise is defined as noise that is present or "common" to both conductors and can be the result of induced noise caused by the "antenna" effect of a conductor or PC trace. Common-mode noise is typically "in-phase" in the conductors. Differential noise is present on only one conductor or present in opposite phase in both conductors. Common-mode chokes use the properties of two closely coupled magnetic fields to eliminate the interference problem by canceling the noise within the magnetic fields (Figure 2). They are best employed to eliminate noise or EMI on cables or signal tracks.

The choke should be located as close to the driver or receiver circuit as possible, or at the signal entry point to the circuit board. The proper selection of inductance can also help in matching line impedance and can act as a bandwidth filter for the circuit. Chokes can be configured in the common- or differential-mode depending on your application.

Transformers

The main benefit of using a transformer for EMI/EMC is that it can provide an isolation barrier between a signal line and the signal processing circuit (particularly where the signal line exits the board or system). This is true of signals being driven or received, since isolating the line reduces common-mode noise and eliminates ground (or signal return) potential differences between systems.

One particular area where high noise immunity is essential is in thyristor/triac driving circuits. Here the transformer provides an isolation between the driven load and a logic-based controller. The isolating pulse transistor provides much better noise immunity than an insulated gate bipolar transistor (IGBT) due to inherently lower coupling capacitance (typically 10's of pF for a pulse transformer compared to nF for a power IGBT device). The lower coupling capacitance improves the circuit's immunity from noise on the mains or from power switching devices. Many EMI/EMC configurations are available.

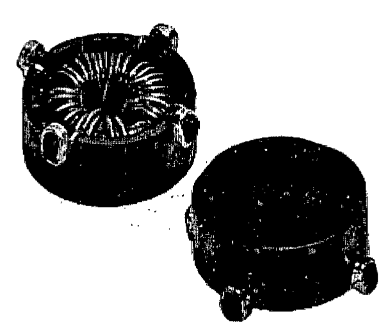


Figure 1. *Toroidal Inductors.*

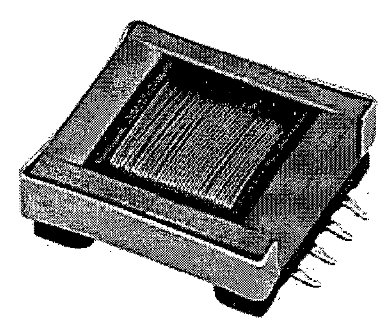


Figure 2. *Common-mode Choke.*

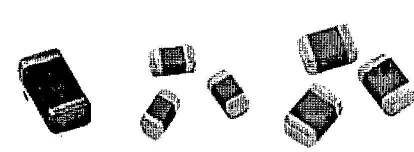


Figure 3. *Surface-mount Ferrite Beads.*

FERRITE BEADS

One of the simplest and most effective ways to reduce EMI is through the use of ferrite beads. Early EMI suppression consisted of a small bead-shaped ferrite (hence the name bead) with a hole through the middle. The ferrite bead was slipped over the suspected "noisy" wire or component lead and EMI was reduced.

Today, beads are available in a variety of styles including the original through-hole model, multiple apertures and surface-mount configurations.

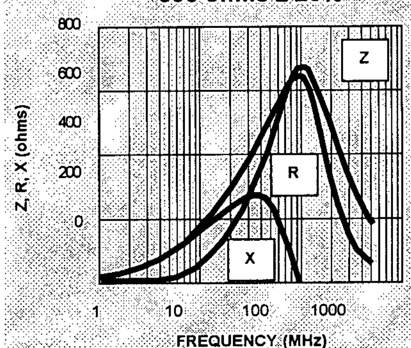
HOW FERRITE BEADS WORK

The best way to conceptualize a bead is as a frequency-dependent resistor. An equivalent circuit for a bead consists of a resistor and inductor in series. The resulting change of impedance over frequency is directly associated with the frequency-dependent complex impedance of the ferrite material. At low frequencies (below 10 MHz), the inductive impedance is 10 ohms or less, as shown in the figure below. At higher frequencies, the impedance of the bead increases to over 100 ohms, and becomes mostly resistive above 100 MHz.

Since the bead's impedance is essentially resistive to high-frequency circuits, the problem of resonance experienced by other EMI filtering choices, like capacitors and inductors, is eliminated. Often the bead is the only practical solution to an EMI problem.

When used as a high frequency filter, ferrite beads provide a resistive loss that attenuates the unwanted frequencies through minute heating of the beads' ferrite material due to eddy currents. At the same time, the bead presents minimal series impedance to the lower frequency or direct currents of the circuit.

600 ohms ± 25%



Surface-mount Ferrite Beads

Chip impeders, also identified as ferrite chip beads, perform the function of removing RF energy that exists within a transmission line structure (printed circuit board trace) (Figure 3). To remove unwanted RF energy, chip beads are used as high-frequency resistors (attenuators) that allow DC to pass while absorbing the RF energy and dissipating that energy in the form of heat.

Surface-mount ferrite beads have many advantages:

- Small and lightweight.
- Inexpensive.
- High impedance values remove broad range of RF energy.
- Closed magnetic circuit eliminates cross talk.
- Beads are inherently shielded.
- Low DCR ratings minimize desired signal degradation.
- Excellent current carrying capacity compared to alternatives.
- Outstanding performance at removing RF energy.
- Spurious circuit oscillations or resonances are reduced because of the bead's resistive characteristics at RF frequencies.
- Broad impedance ranges (several ohms to 2,000 ohms).
- Operate effectively from several MHz to 1 GHz.

Bead Selection

To choose the proper bead, the following should be considered:

1. What is the range of unwanted frequencies?
2. What is the source of the EMI?
3. How much attenuation is required?
4. What are the environmental and electrical conditions for the circuit (temperature DC voltage, DC bias currents, maximum operating currents, field strengths, etc...)?
5. What is the maximum allowable profile and board real estate for using this component?

Selection of the right bead for the particular frequencies is not a simple process. In most cases, since beads are only rated for impedance at 100 MHz, the designer needs to look at several graphs to determine the best bead for a frequency if it is different than 100 MHz.

This is a time-consuming, but necessary, process to select the correct bead value since the highest impedance bead at 100 MHz is not necessarily the highest impedance bead at higher or lower frequencies. DC bias will also lower the effective impedance of the device. Design aids are available that allow the engineer to quickly select the correct bead without the time-consuming process of looking at graphs. The DC bias derating percentage for a range of bias currents can also be calculated.

EMI/EMC Component Selection

Before incorporating EMI/EMC components, it is necessary to identify the circuit paths most likely to conduct noise, to identify circuit areas likely to conduct noise, and to identify circuit areas likely to act as antennas and radiate noise. At this point the most appropriate location for the components chosen can be determined.

The actual components chosen are determined by the frequency and signal level of the noise to be eliminated. Consideration should also be given to the frequencies that should be left intact. For attenuation less than 5 dB inductive, EMI components are generally the best choice. For attenuation less than 5 dB, circuit type must first be determined.

If working with a high speed signal circuit, the best choice is a complex filter consisting of inductive and capacitive components. If the circuit is a general signal type (i.e., not a high speed circuit) grounding stability must first be determined. For stable grounds, capacitive EMI components are an excellent choice. However, if the circuit has a unstable ground high impedance inductive

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components for the EMI suppression needs should be considered.

Designing equipment and choosing components is not an easy process. Often the only measure of design success is the overall radiation level from the equipment. Trial and error is a long tedious process that can take several months to complete, and choosing the wrong component can lead to wasted time. Consider these three tips to help reduce wasted time on a design:

- Always place EMI/EMC components as close as possible to the noise source.
- Select EMI/EMC components that match the impedance of the noise conduction path, not necessarily the circuit path. Remember that common-mode noise often travels a different path than circuit current.
- Start with EMI/EMC components that offer sufficient performance to ensure that the design meets standards. There is always time to work on reducing component costs once a working design is developed.

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