

MTAN080921 - SMD Ferrite Beads Selection Guide for Noise Attenuation

Abstract

This application note gives the guideline needed to select the right SMD Ferrite beads for high frequency noise suppressions. Switching regulators are very prominent in industry today, and provide high efficiency solutions for a wide range of applications. Good filtering of power supply noise and high frequency crosstalk reduction between analog and digital domains is required, especially on mixed-signal converters and transceivers. In switching converters, noise is generated by the switching process. This noise is conducted through out the circuit & disturb the sensitive signals & power lines. Therefore, noise suppression is required for switching power supplies. It is important to understand the fundamentals of SMD Ferrite beads design and selection of SMD ferrite beads to attenuate the noise.

What is SMD Ferrite Beads?

A ferrite bead is a passive device that filters high frequency noise energy over a broad frequency range. It becomes resistive over its intended frequency range and dissipates the noise energy in the form of heat.

SMD Ferrite bead, also known as chip bead ferrite, perform the function of removing RF noise energy that exists within a transmission line structure (PCB trace). To remove unwanted RF energy, chip beads are used as high frequency resistors (attenuator) that allow DC to pass while absorbing the RF noise energy and dissipating that energy in the form of heat.

SMD EMI Suppression Ferrite Beads as frequency-selective devices have the potential to solve a large spectrum of Electromagnetic Compatibility (EMC) issues.



Figure 1: Image of SMD Ferrite Bead

DIMENSIONS OF SMD FERRITE BEADS

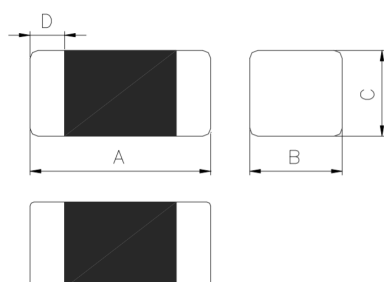


Figure 2: SMD Ferrite Bead Dimensions

Imperial Chip Size	A (mm)	B (mm)	C (mm)	D (mm)
0402	1.00±0.10	0.50±0.10	0.50±0.10	0.25±0.10
0603	0.60±0.03	0.30±0.03	0.30±0.03	0.15±0.05
0805	2.00±0.20	1.25±0.20	0.85±0.20	0.50±0.30
1206	3.20±0.20	1.60±0.20	1.10±0.20	0.50±0.30
1806	4.50±0.20	1.60±0.20	1.60±0.20	0.50±0.30
1812	4.50±0.20	3.20±0.20	1.50±0.20	0.50±0.30
2220	5.7 ±0.4	5.1 ±0.25	1.8 ±0.25	0.76 ±0.25

SMD Ferrite bead Construction

The geometrical layout of a multi-layer SMT ferrite bead is illustrated in Fig. 3. The conductive traces [internal electrodes] are printed on successive ferrite sheets which are stacked up in successive layers to achieve high inductance.

The electrode pattern on each sheet is connected through a via-hole to successive layers. The pattern is carefully structured to minimize parasitic capacitances between layers (stray capacitances). The parasitic capacitance is the dominant element at high frequencies, impacting the behavior of the ferrite-bead impedance.

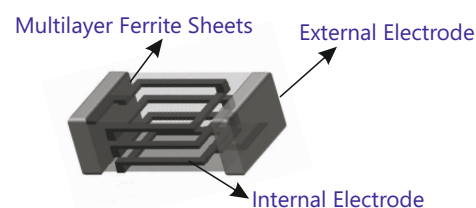


Figure 3: Internal Structure of SMD Ferrite Beads

Types of SMD Ferrite Beads

- SMD Ferrite beads for High speed signal or data lines
- SMD Ferrite beads for Power Lines
- SMD Ferrite beads for High current applications
- SMD Ferrite beads for High frequency noise attenuation

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How SMD Ferrite Beads Work?

SMD Ferrite beads are commonly used to attenuate differential mode noise. Ferrite beads are used as a passive low-pass filter, by dissipating RF noise energy to heat. It has ability to block unwanted high frequency noise. The ferrite concentrates the magnetic field, increasing impedance and therefore reactance, which filters out the EMI noise. It can produce an additional loss in the form of resistance in the ferrite itself. Ferrite beads prevent electromagnetic interference (EMI) bi-directionally.

At frequencies where $X_L > R_L$, the part behaves more as an inductor than a resistor. The frequency, at which " R_L " becomes greater than " X_L ," is called the "Cross-Over" frequency (refer Fig. 4).

For filtering EMI Noise, Q-factor should be low: AC resistance (R_L) must be greater than inductive reactance (X_L): [$R_L > X_L$].

$$Q_L = \frac{X_L}{R_L}$$

Ferrite beads are categorized by three response regions: inductive, resistive, and capacitive which are determined by looking at Impedance Vs Frequency graphs, where :

X_L = Inductive Reactance of the bead

R_L = Resistance of the bead

Z = Impedance of the bead

$$Z = \sqrt{R^2 + X^2}$$

One of the fundamental aspects of using ferrite beads for EMI applications is that the component must be in its resistive stage.

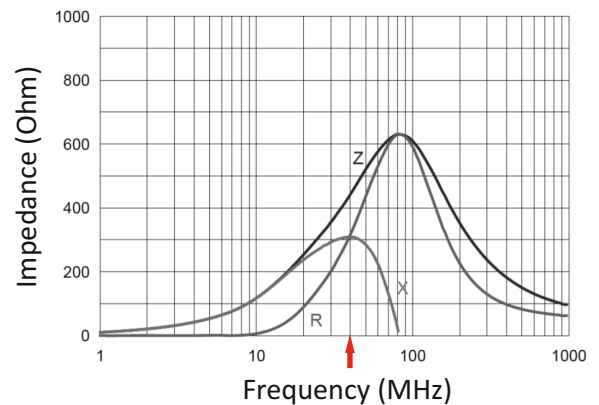


Figure 4: Cross Over Frequency

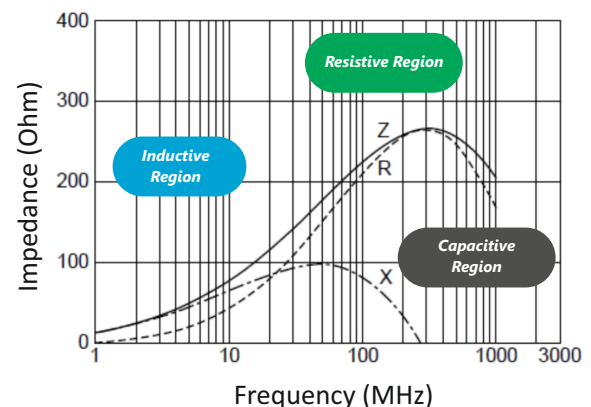


Figure 5 - Impedance Vs Frequency Graph

How to select SMD Ferrite Bead value?

Selection of the correct bead for your specific frequencies is complex process. Mostly, beads are only rated for impedance at 100MHz, as ferrite bead is frequency dependent component. Its response varies as frequency change, Impedance vs frequency graph reference is essential to determine the best bead for elimination of specific band of noise frequency if it is different than 100MHz. It is a essential process to select the correct bead value since the highest impedance at 100MHz is not necessarily the highest impedance at higher or lower frequencies.

For DC voltage applications (such as Vcc lines for ICs), it is desirable to have a low DC resistance value as it will not generate large power losses within the desired signal and/or voltage or current source. However, it is desirable to have high impedance over some defined frequency range. Therefore, the impedance is related to the material used (permeability), the size of the ferrite bead, the number of turns and the winding construction.

To select appropriate ferrite bead, the following information is essential to know:

- What is the source of the EMI?
- How much attenuation is required?
- What is the range of noise frequencies?
- What is the maximum allowable size of the component?
- What are the environmental and electrical conditions for the circuit such as operating Temperature range, operating DC voltage, DC bias current, maximum operating current, DC resistance?

After gathering above information, selection of ferrite bead can be determined by analyzing the Impedance Vs Frequency graph of ferrite bead. However, it depends on applications & it will narrow-down the selection criteria based on required impedance range to get appropriate attenuation gain in specific frequency spectrum.

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Selection of Surface Mount Chip bead Ferrite

Let's take an example of DC/DC converter device, assume the device is failing while conducting Radiated Emission pre-compliance test at EMC Lab.

As seen in the upper graph, the noise is affecting wide frequency range starting from 150 MHz to around 300 MHz frequency spectrum. To attenuate the noise in a specific frequency range, the selection of right ferrite bead plays very important role.

For selecting ferrite bead to attenuate the noise frequency ranging 150 MHz to 300 MHz, need to follow below steps:

1. Choose the size of SMD ferrite bead (eg. 0402, 0603, 0805, 1206, 1812, etc...)
2. Check out the rated current of SMD ferrite bead & select as per your requirement
3. Look at the Impedance vs frequency graph of the SMD ferrite bead and check the impedance level in the range of 150 MHz to 300 MHz as required in our example.

Improvement on EMI over frequency for upper part in the horizontal scan shown in Fig. 6, it can be seen that this part substantially reduces the EMI spikes and reduces the overall noise levels, for all frequencies in the 150 to approximately 300 MHz range, to an acceptable level well below the EMI limit highlighted by the limit line, which is the general regulatory standard for Class B devices.

The material used in the ferrite bead is Nickel-Zinc (NiZn) for these specific frequencies. If the major portion of the EMI noise problem was below 150 MHz, one would need to look at using a lower frequency ferrite bead that has its impedance maximum higher in the frequency spectrum.

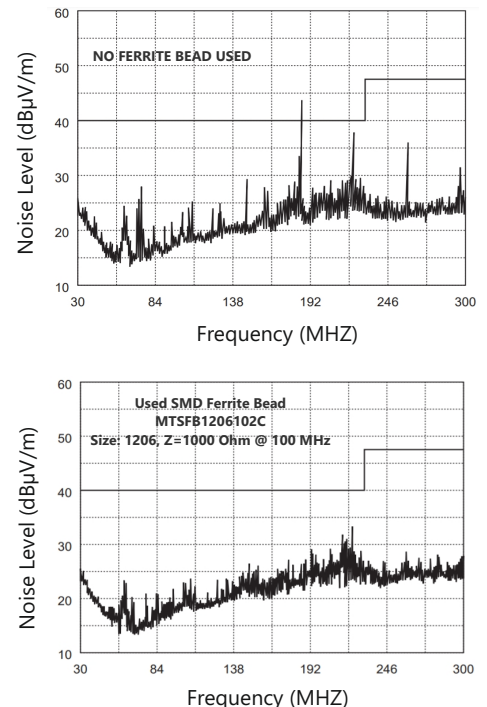


Fig. 6: Effect of SMD Ferrite Bead to suppress EMI noise

Effect of DC Bias effect on SMD Chip Bead Ferrite

DC bias will also lower the effective impedance of the device. As the dc bias current increases, the core material begins to saturate, which reduces the impedance of the ferrite bead & other parameters also change significantly. The degree of saturation differs depending on the material used for the core of the component. This drop of the impedance reduces the effectiveness of the ferrite bead and its ability to remove EMI (AC) noise (refer Fig. 7).

For effective noise filtering, use ferrite beads at about 20% of their rated DC current.

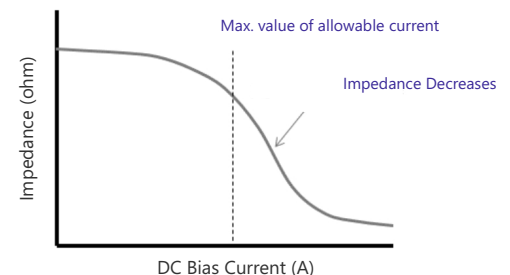


Fig. 7: Effect of DC Bias Current on SMD Ferrite Bead

Advantages Of SMD Ferrite Beads

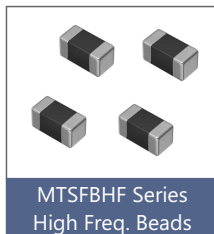
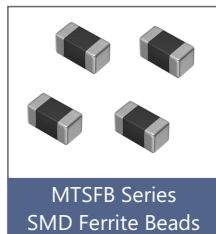
- Economical
- Small and light weight
- Broad impedance ranges
- Beads are inherently shielded
- Monolithic structure for high reliability
- Closed magnetic circuit eliminates cross talk
- Operates effectively from several MHz to couple of Ghz
- Lower DC resistance minimizes desired signal degradation
- Excellent current carrying capacity compared to alternatives
- High impedance values removes broad range of RF noise energy
- Oscillations or resonances are reduced because of the bead's resistive characteristics at RF frequencies.

Applications of SMD Ferrite Beads

- RF circuits
- Set-Top Box
- Energy Meter
- Digital Camera
- Mobile Charger
- Network security
- DC-DC Converters
- Switching regulators
- Optical storage, HDD
- Power Supplies (SMPS)
- Differential transmission line on USB
- Computers, printers, VCRs, TVs and portable telephone

EMC COMPONENTS

SMD FERRITE BEADS

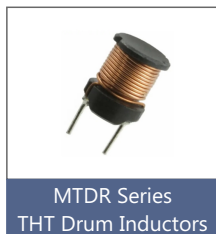


COMMON MODE CHOKES



POWER INDUCTORS

THT POWER INDUCTORS



TINY SMD POWER INDUCTORS



SMD UNSHIELDED POWER INDUCTORS



SMD SHIELDED POWER INDUCTORS



HIGH CURRENT INDUCTORS



RF INDUCTORS



Inductor Selection Software for Buck Converter

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