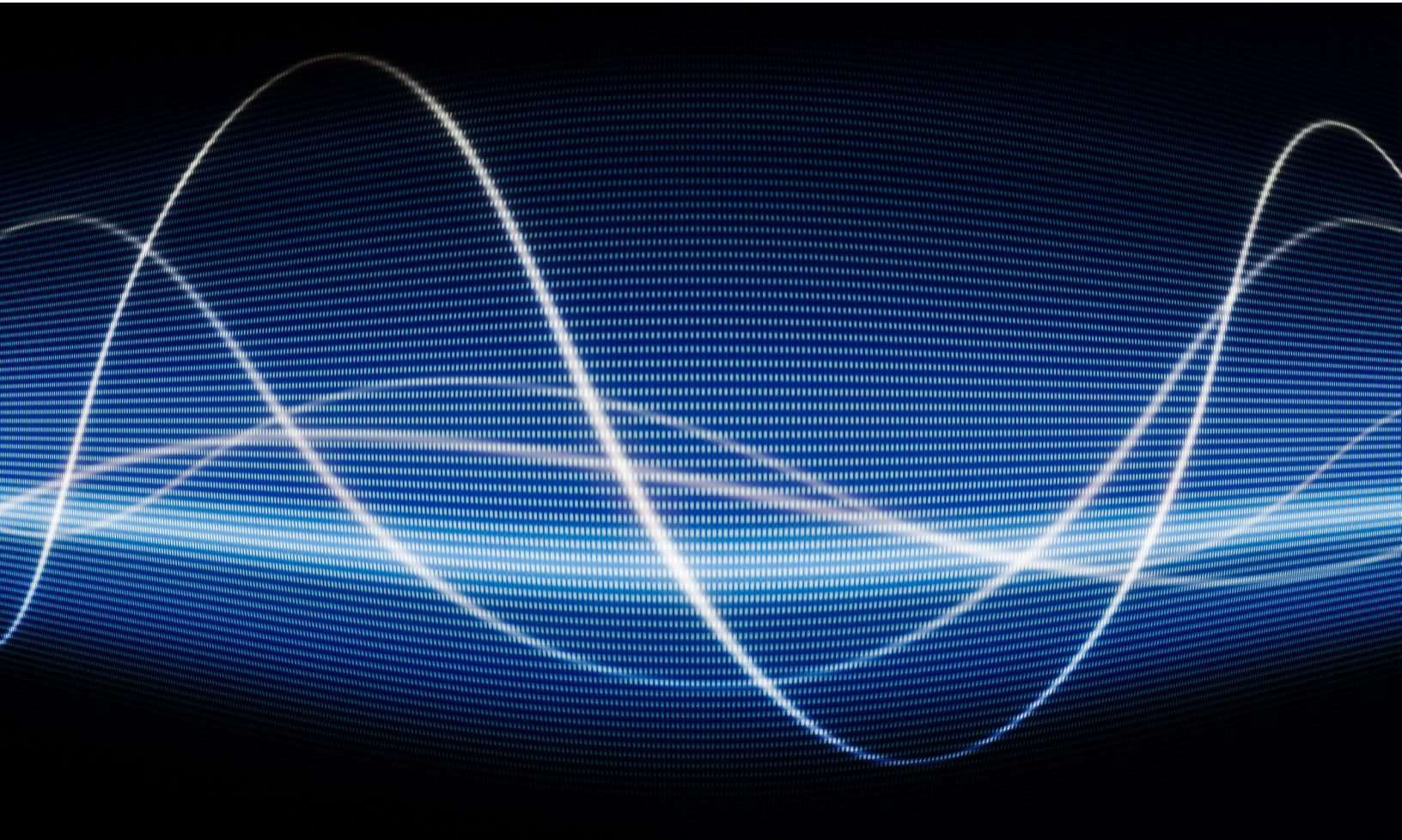


Controlling EMI in Power Transformers



POWER | PROTECT | CONNECT



Power Transformers can be a significant source of electromagnetic interference (EMI), and potentially cause device failures in equipment and systems containing sensitive electronic components. In this paper, we identify the ways through which power transformers conduct and radiate electromagnetic energy emissions which may result in device failures.

THE DANGERS OF UNCONTROLLED ENERGY EMISSIONS

It's better to be safe than sorry when controlling EMI in Power Transformers.

Power Transformers certainly play their role in electromagnetic (EM) energy emissions. Because of their magnetic nature, Power Transformers generate an EM field with an amplitude dependent on size, the number of winding turns, voltage and current applied to the input, the type of iron core utilized and their position within the circuit in which they are installed.

If the EM energy in Power Transformers is uncontrolled it will produce unwanted electromagnetic interference (EMI). EMI can hinder communication systems and may prevent electronic equipment from functioning efficiently. In medical devices such as diagnostic or life sustaining machines, EMI can cause false readings and or disrupt proper operation.

Mitigating radiation effects of EM fields in Power Transformers to ensure successful compliance testing, as well as better product acceptance in the marketplace, demands preventive measures be taken early on with smart design and layout strategies of the operating system.

HOW POWER TRANSFORMERS AMPLIFY EM ENERGY

Power Transformers can conduct or radiate EM energy in two ways, through EM Fields or Common Mode (CM) electrical noise, both of which are detectable as follows:

Transformers carrying line voltage, current or floating voltages and circulating currents between windings, resulting in EM Fields which (like antenna transmissions), are broadcast to their surroundings. These EM Fields propagate in waves on nearby circuit board traces and various connecting cables, all of which inadvertently become mediums in transporting them out of the equipment enclosure via conduction or radiation. Power Transformers equipped with electrostatic shields for EMI attenuation may also become receiving antennas of other EMI radiation sources located within the system of operation.



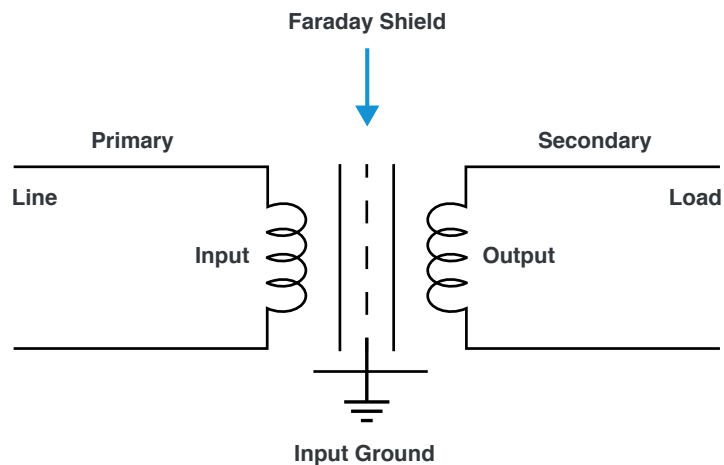
The parasitic capacitance through transformer windings carries electrical noise across the isolation barriers. This noise returns to the source via the earth plane in the form of CM noise due to the connection of the windings to chassis and ground. Power Transformers are typically constructed with minimal space between windings to improve coupling and reduce leakage inductance. Consequently, the reduction in proximity increases the mutual capacitance of their windings and thus CM noise as well.

HOW TO MITIGATE EMI

Following are techniques and practical design solutions for controlling EMI in Power Transformers:

Safety Isolation Transformers typically utilize multiple layers of thin film insulation between input and output windings to provide reinforced isolation. On concentric winding constructions, a Faraday shield, (one turn of copper foil), is wrapped around the input winding to collect noise currents, attributed to inter-winding capacitance, present at the isolation boundary. The Faraday shield also diverts noise currents to Input Ground preventing noise coupling to the secondary windings and subsequently to other circuits in the operating system.

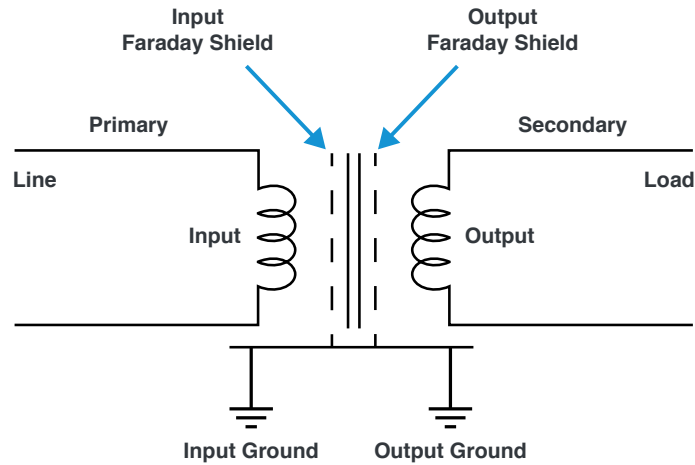
Figure 1:
Faraday Shield for
Input Winding



Output windings of Power Transformers can also transfer EM energy via capacitive coupling to the input windings. To mitigate this effect, some transformer designs use another Faraday shield wrapped around the output windings and connected to the Output Ground.

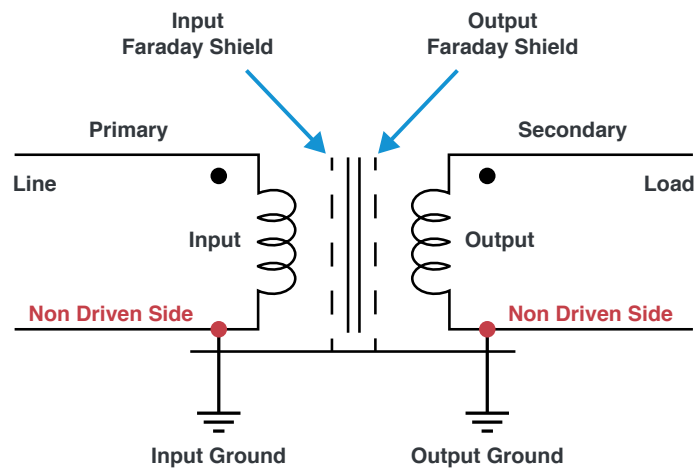


Figure 2:
Faraday Shields for
Input and Output
Windings



Power Transformers can contribute to unwanted coupling of other EMI sources within the system even when Faraday shields are utilized to reduce emissions. The shields serve as receiving antennas for other emitting sources and the radiation is usually transferred through the driven side of the input and output windings. To achieve better isolation, the shields are connected to the non-driven side of the input and output windings which in turn are routed through and attached permanently to the Input and Output Grounds respectively.

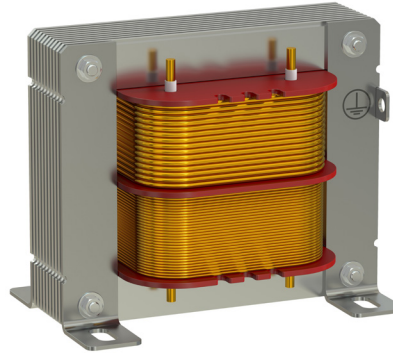
Figure 3:
Faraday Shields
Connected to the
Non-Driven Side of
Input and Output
Windings



In low power transformer designs a Faraday shield can be eliminated by the use of a split-bobbin where input and output windings are wound non-concentric in separated cavities totally isolated from one another. The space between the input and output windings reduces the inter-winding capacitance, the capacitive coupling and so a decrease in CM noise occurs.

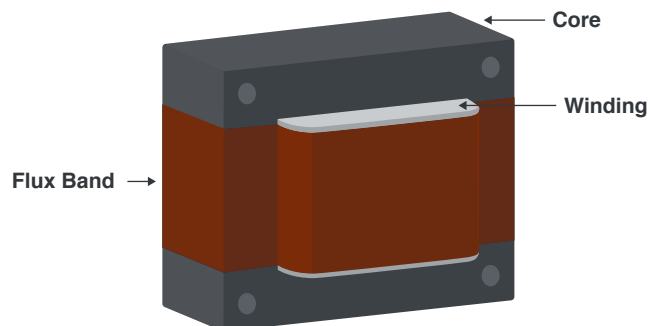


Figure 4:
Split Bobbin
Transformer



In some low cost Power Transformer designs, a circumferential copper shield (commonly known as a flux band) is applied around the entire transformer boundary. This thin copper flux band reduces 'eddy' currents and serves as a radiation shield. Often times it is floating with acceptable attenuation results although it could be connected to the output ground for greater effectiveness.

Figure 5:
Flux Band
Shielding



In extreme cases where Power Transformer EMI levels are high, interference can be controlled by using a magnetic shielding enclosure. Such enclosure surrounds the transformer, captures stray magnetic flux or EM radiation and channels unwanted energy to a ground plane. These enclosures unfortunately add cost, weight and manufacturing complexity. They should be used only in cases where EMI from the transformer is excessive and cannot be isolated by any other means.



Figure 6:
Electrostatically
Shielded
Transformer



Power Transformers produce an EM field that is directional in nature and its strength is inversely proportional to the square of the distance from the source, so that positioning of the transformer within a circuit or system becomes critical.

The effect of a transformer's EM field on surrounding components can be minimized by aiming the transformer's radiation away from the most sensitive components and potential 'antennas' such as transmission lines and connectors. Whenever possible, Power Transformers should be moved far away from susceptible components to reduce interference.

OPTIMIZING CORE SIZE AND CONFIGURATION

Radiated emissions of Power Transformers can also be minimized by considering core size, number of turns and choice of configuration.

For example, the operating flux density of a power transformer can be reduced by selecting a larger iron core area or by increasing the number of turns of the transformer windings. The lower the operating flux density, the smaller the generated EM fields.

With respect to configuration choices, for linear transformers, 'EI' laminated cores contribute to high levels of EMI while 'Toroid' core geometries lead to reduced levels of EMI.

For high frequency transformers, 'E' cores and their variations are worse than 'Pot' cores and their variations as well as 'Toroid' cores.

The open configurations of 'EI' and 'E' core type transformers do not fully contain the generated EM fields. On the other hand, transformers using 'Toroid' and 'Pot' cores, are nearly fully enclosed and do contain effectively the EM fields within close proximity of the transformer.



Figure 7:
Laminated Core
Construction

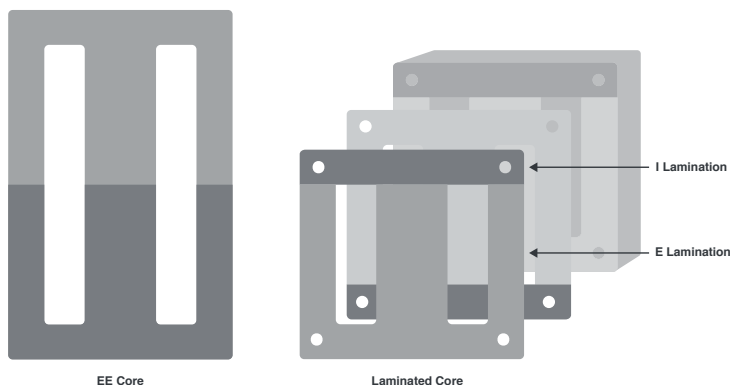
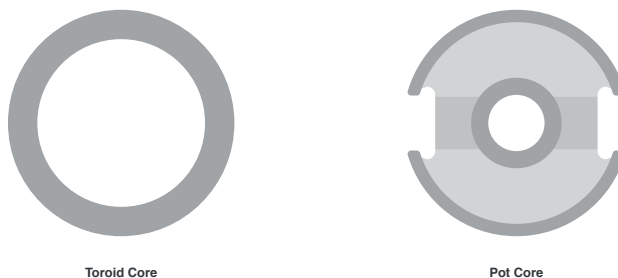
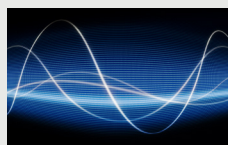


Figure 8:
Magnetic Core
Types



Signal Transformer supplies shielding for low EMI in standard off the shelf transformer product lines, including low to high power options with split bobbin configurations. Signal Transformer can also customize transformers to include Input & Output Faraday Shields, Flux Bands, and/or Magnetic Shielding Enclosures in order to remedy the effect of EMI should it become a concern in your design.



See Bel's selection of power transformers.

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