CHAPTER-4
EMI & RFI SUPPRESSOR

4.1 Introduction

Electro-magnetic interference (EMI) and radio-frequency interference (RFI) are created whenever there are spikes in electronic signals. These interferences occur in almost all types of electronic circuits having sharp rising and falling edges in current and voltage waveforms. In switching power supplies, the MOSFET switches will create these EMI or RFI noises. These should be filtered to comply with the Federal Communications Commission (FCC) and CE requirements and also to prevent interference in proper functioning of different electronic circuits. Common mode line filters are used to block these noises on the power lines. The international standards for EMI-RFI have been well established. The manufactures of electronic equipment are asked to minimize the radiated and conducted interference of their equipment to acceptable levels. In United States the guiding document is the FCC Docket 20780, while the German Verband Deutscher Elektronotechniker (VDE) safety standards have been internationally accepted. It is very important to understand that both the FCC and VDE standards exclude subassemblies from compliance to the rules; rather, the final equipment, where the switching power supply is used, must comply with the EMI-RFI specification. Rightly so, since even if the switching power supply has an input filter, this filter is matched to the power supply when passive loads are being powered but the filter characteristic and its suppression capability may drastically change when used to feed power to active electronic circuits. An attempt has been made by the researcher to introduce here the problem of conducted RFI and then to put forward some means for minimization when applied for a power supply or for a final system of radio-frequency mirror inverter scheduled to supply induction heating equipment.

Both FCC and VDE are concerned with the suppression of RFI generated by equipment connected to the a.c. mains and mend for high-frequency digital circuitry. The VDE has subdivided its RFI regulations into two categories, the first being unintentional high frequency generation by equipment with rated frequencies from 0 to 10kHz, i.e., VDE – 0875 and VDE-0879, and the second deals with intentional high frequency generation by equipment for frequencies above 10kHz., i.e., VDE0871 and VDE0872. The FCC on the
other hand includes in its RFI regulations all electronic devices and systems which generate and use timing signals or pulse at a rate greater than 10kHz. Fig 4.1 summarizes the RFI requirements for FCC and VDE. The EMI-RFI regulations of FCC closely follow those of the VDE. The FCC class-A specification covers business, commercial and industrial environment. Compliance to the specified EMI emission in dB-μV can be met by any equipment meeting VDE-0875/N or VDE-0871/A.C. On the other hand, FCC class-B requirements cover residential environment and are more stringent than those of class-A. Both FCC conducted EMI-RFI specifications, however, cover the frequency range from 450kHz to 30MHz. The VDE regulations extend below 450kHz range. In fact the VDE frequency range for EMI-RFI conducted emission covers a spectrum from 10kHz to 30MHz. Fig.4.2 shows the FCC and VDE curves for conducted RFI emissions.

Fig. 4.1 : Summary of EMI-RFI requirements of FCC and VDE
Although the prescribed circuits will suppress the generated RFI to acceptable levels, yet it is important to understand that if the packaging or layouts of the power supply changes then even the assigned filter may not work properly. To elaborate on this claim let us consider a power transistor or a power rectifier handling high-frequency. Let it be directly mounted on the chassis of the power supply with only a mica insulator in between the two, and if the chassis is connected to the ac ground conductor, the generated RF-noise
will be coupled to the ground conductor thus upset the effectiveness of the particular mains filter. It has been shown that a TO-3 switching transistor working at 20kHz, with a 200V input and mounted on a ground heat sink through a mica insulator, will generate an RF-current of 1mA at 1MHz. A solution to the above problem is to sandwich a metal shield in between the heat sink and insulator and to return the shield to the dc ground. This technique effectively “shorts out” the capacitance created by the mica insulator and thereby reduces the radio frequency noise currents. Power supply and system layouts are very important in reducing or eliminating RFI-EMI problems. The designer should take care in analyzing all potential problems before choosing the appropriate line filter.

4.2 RFI sources in switching power supplies
Every switching power supply is a source of RFI generation because of the very fast rise and fall times of current and voltage inherent in all converter operations. The main sources of switching noise are the switching transistors, the main rectifier, the output diodes, the protective diodes for transistors and of course the control unit itself. Now, depending upon the topology of the converter used, the RFI noise at the mains input may move from bad to worse levels. Fly back converters, which by design have a triangular input current waveforms, generate less conducted RFI noise than converters with rectangular input current waveforms such as feed-forward or bridge converters. Fourier analysis shows that the amplitude of the high frequency harmonics of a triangular current waveform drop at a rate of 40dB/decade as compared to a 20dB/decade drop for a comparable rectangular current waveform.

4.3 Permissible RFI emission
The challenge of packaging electronic hardware to ensure electromagnetic compatibility (EMC) is becoming increasingly difficult. In U.S., the governing standard for regulating the containment of emissions is given by FCC Part 15, class-A and B. These FCC classes establish the levels of EMI containment permissible for various types of electronic equipment and these are expressed in allowable dB across a range of frequencies. An FCC class-A certification on radiation limits of digital devices is for business use while the class-B is for residential use. The class-B stipulation is more stringent in order to avoid interference with TV and other home reception systems. These stipulations are meant to put a limit on the amount of radiated emissions from electronic gadgets such as radios, televisions, ATM machines, radar equipment and other such devices.
The FCC class-B is generally meant for areas where emissions must be kept low like near an airport, hospitals and residential areas and also other places where it is more stringent on the level of allowed radiated emissions. In recent times EMC has taken on greater importance with the increasing use of electronics in security related applications.

![FCC and VDE regulation curves showing maximum permissible RFI-emission in dB-µV on conducted noise.](image)

**Fig. 4.2:** FCC and VDE regulation curves showing maximum permissible RFI-emission in dB-µV on conducted noise.

EMC is of critical concern since its application provides network security. One can imagine the importance of preventing interference in network security applications. With too much interference the signal integrity may be impaired leading to breakdown of security system. The case study illustrates the various areas of concern and the modifications employed to ensure class-B compliance. Fig 4.2 shows the maximum possible RFI emission on conducted noise.
4.4 AC input line filter for RFI suppression

The most common method of noise suppression at the switching power supply ac mains is the utilization of an LC filter for differential and common mode RFI suppression. Normally a coupled inductor is inserted in series with each ac line, while capacitors are placed between the lines, called X-capacitor (C_x) and between each line and the ground conductor, called Y-capacitor (C_y). The values of the capacitance and inductance may be within the following range for most of the suppressing systems.

\[ C_x = 0.1 \text{ to } 2 \mu F \]
\[ C_y = 2200pF \text{ to } 0.033\mu F \]
\[ L = 1.8mH \text{ at } 25A \text{ to } 47mH \text{ at } 0.3A \]

Fig. 4.3(a) depicts an input a.c. line filter for a standard switching power supply. During the selection of filter components it is important to ensure that the resonant frequency of the input filter is lower than the working frequency of the power supply. On the other hand, filtering conducted noise becomes much easier as the working frequency of the power supply is increased. The resistor R across the ac line of the filter is a discharge resistor for the X-capacitor. Its employment is recommended by the safety specifications of the VDE-0806 and IEC-380. In fact IEC-380 states that if the RFI X-capacitor is above 0.1uf, a discharge resistor of the following value is required in the circuit.

\[ R = \frac{t}{2.21 \cdot C} \]

where, \( t = 1 \text{sec.} \) and \( C \) is the sum of the X-capacitors in \( \mu F \).

Further reduction of the symmetrical and asymmetrical interference voltages can be accomplished by the insertion of an extra line choke \( L_2 \) as shown in fig.4.3(b) but this in turn causes a reduction in the charging current of X-capacitors. Fig.4.3(c) and fig.4.3(d) depict standard radio-frequency mirror inverter circuits which are used for induction heating for industrial and domestic equipment respectively. Both these inverter circuits take a.c. power either through the line filter circuit of fig.4.3(a) or through the line filter circuit of fig.4.3(b).
Fig. 4.3(a) : An input ac line filter of mirror-inverter power supply for RFI noise suppression using one line choke

Fig. 4.3(b) : Improved ac line filter incorporating two line chokes

Fig. 4.3(c) : Radio-frequency mirror-inverter circuit for industrial application
Fig. 4.3(d) : Radio-frequency mirror-inverter circuit for domestic application