Diagnosis of conducted interference with discrimination network

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DIAGNOSIS OF CONDUCTED INTERFERENCE WITH DISCRIMINATION NETWORK

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Abstract

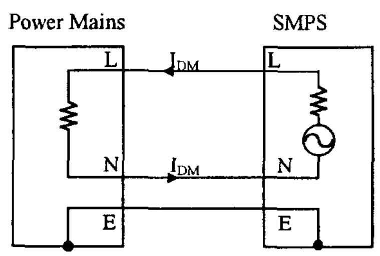
Testing for compliance to conducted emission limits utilizes a Line Impedance Stabilization Network (LISN) and is usually carried out during the final stage of the product design. However, the LISN measures only the total contribution of common-mode (CM) and differential-mode (DM) emissions in the live or neutral line. In EMI filter design, it is always desirable to be able to determine whether the differential- or the common-mode component is dominant in order to pin-point the effective element of the filter to be changed to reduce the total emission. This, in essence, minimizes the trial-and-error guess work in selecting the proper components of the filter and cuts down on design time. This paper will touch on the conventional way for measuring total conducted noise emissions of a product and how the CM/DM Discrimination Network (CM/DM DN) can be used as an effective diagnostic tool for the modification of power supply filters to reduce conducted noise emissions.

Introduction

The present method of compliance testing to conducted emission limits uses the Line Impedance Stabilization Network (LISN), where the total conducted noise can be measured with a spectrum analyzer. With the rejection network (CM/DM DN) used as a complementary tool to the LISN, the differential- and common-mode components of the conducted interference can be measured separately.

1.1 Modes Of Conducted Emissions

For typical Switch Mode Power Supplies (SMPS), the noise currents consist of two components. Differential-mode noise current, I_{DM}, flows out from live (neutral) and returns via neutral (live) as shown in Figure 1.



DM Noise Current

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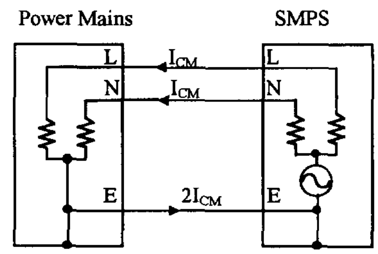

CM Noise Current

Figure 1 Modes of Conducted Emissions

The other component, the common-mode noise current, I_{CM}, flows out from live and neutral and returns via the earth wire. In a two-wire system where the earth is not attached to the product, common-mode current also exists where parasitic capacitance between the live/neutral wires and product frame acts as its return path.

Figure 2 shows the setup for measuring the total conducted emissions from the SMPS.

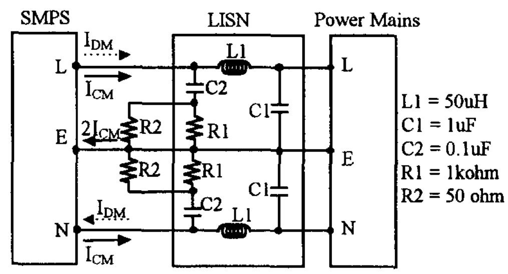

Figure 2 Conducted Emissions Measurement Using LISN.

The currents in the live (L) and neutral (N) are as follows:-

$$I_L = I_{CM} + I_{DM} \text{ ---------- } (1)$$
$$I_N = I_{CM} - I_{DM} \text{ ---------- } (2)$$

As R2 << R1, we can ignore the current in R1. The voltage that will be measured at the live or neutral terminal of the LISN:-

$$V_L = (I_{CM} + I_{DM})\,R2 = V_{CM} + V_{DM} \text{ ---------- } (3)$$
$$V_N = (I_{CM} - I_{DM})\,R2 = V_{CM} - V_{DM} \text{ ---------- } (4)$$

Expressions (3) and (4) show that the LISN can only measure the phasor sum or phasor difference of CM and DM components. Hence it will be very useful if there is a network which allows us to discriminate CM and DM components.

1.2 CM/DM Discrimination Network

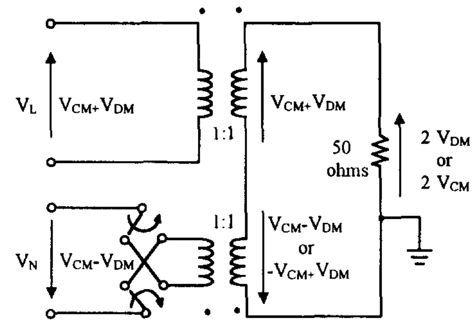

Figure 3 CM/DM Discrimination Network

As mentioned in the previous section, the LISN measures (V_{CM} + V_{DM}) at live terminal and (V_{CM} - V_{DM}) at neutral terminal. The CM/DM DN is constructed as shown in Figure 3. A pair of 1:1 ratio RF isolation transformers are connected according to the polarities shown, and a resultant voltage of either $2V_{CM}$ or $2V_{DM}$ can be measured. Therefore, together with the LISN, CM/CM DN has the ability to discriminate CM and DM emissions.

1.3 Power Line EMI Filter

Generally, most SMPS's have an in-built EMI filter positioned at the immediate entrance of the AC power cord of the product, which impedes noise signals internal to the product to be coupled out to the AC power cord. It is then the task of the design engineer to design the appropriate filter by selecting the right components that can sufficiently suppress the undesired noise levels. Shown in Figure 4 is a typical power supply filter that can be used in most SMPSs.

Some elements of the filter affect only one component of the total current, either CM or DM component significantly. Suppose that at a certain frequency the CM component is dominant. In this case, changing the value of the line to line capacitors, C_{X1} or C_{X2}, would not affect the total measured voltage. On the other hand if DM current is dominant, changing the value of line to ground capacitor, C_Y, would not change the total measured voltage.

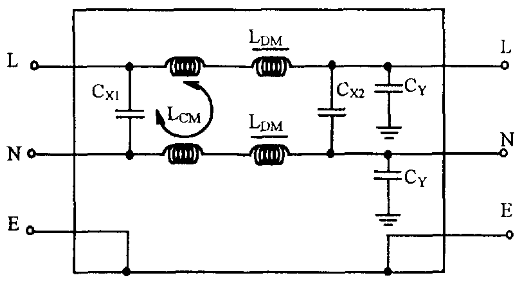

Figure 4 A Typical SMPS Filter

1.4 Measurement Setup For CM/DM DN

The setup in Fig 5 shows how this device is used together with the LISN in measuring dominant mode noise current. The network allows for the two modes of noise emissions to be measured individually.

With the CM/DM DN switched in one position, the spectrum analyzer displays the CM component. When the switch is toggled to the other position, the DM component is obtained. These two plots can then be compared in order to determine which component of the noise is dominant at a particular frequency.

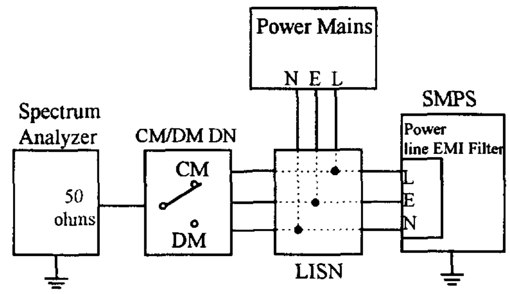

Figure 5 CM/DM Discrimination Network

1.5 Measurement Results

To illustrate the effectiveness of this device, a SMPS whose built-in filter components had been removed, was measured for its conducted emisssions. One by one, the filter components were added back to the filter until the FCC part 15B conducted emissions limit was met. For every case, the total conducted noise, V_{CM} and V_{DM} were measured and inter-compared. The figure below shows the actual schematic of the SMPS filter being tested.

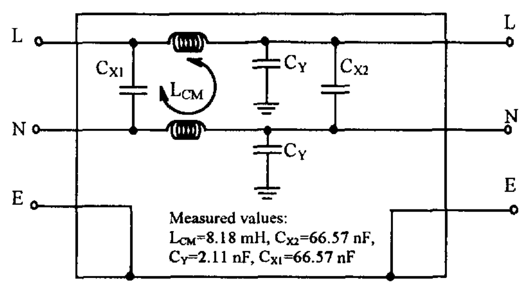

Figure 6 Schematic of Actual SMPS Filter

A) Measured Emissions With All Filter Components Removed.

With all filter components being removed, it is as good as having no filter at all. The total conducted noise that is inherent to this product clearly fails the FCC part 15B conducted emission limit by some 40 dB. From this, we see that the CM and DM are approximately the same order of magnitude (Figure 7).

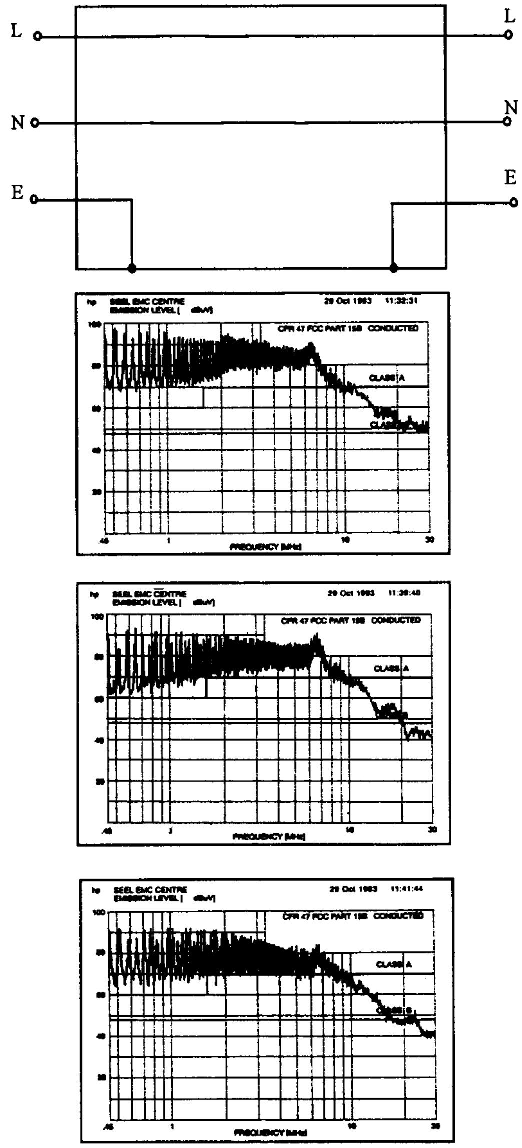

Figure 7: (a) Filter Schematic, (b) Total Conducted Noise, (c) CM Noise and (d) DM Noise

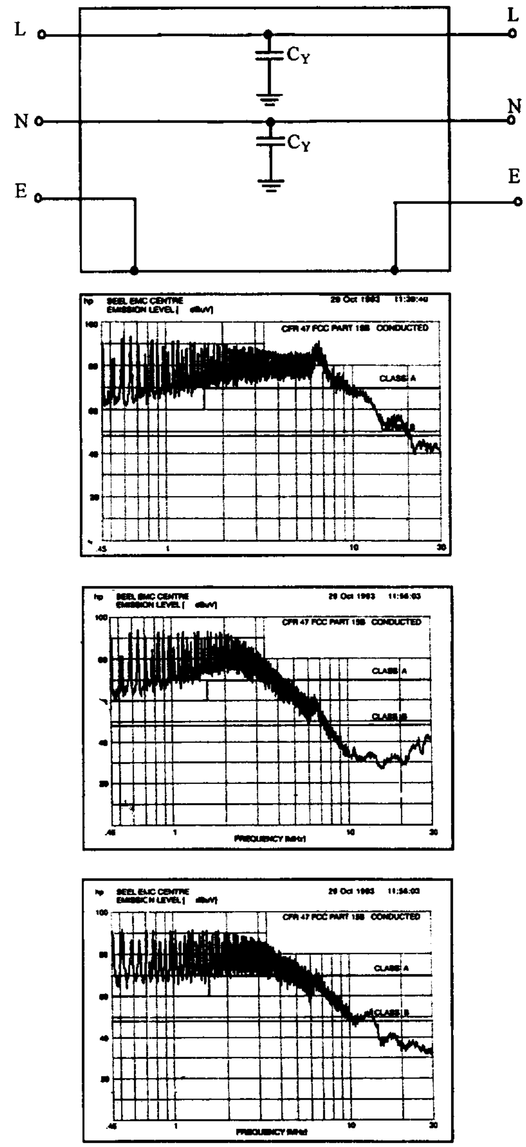

Figure 8: (a) Filter Schematic, (b) Total Conducted Noise, (c) CM Noise and (d) DM Noise

B) Measured Emissions With Common-Mode Capacitors C_Y Added.

With the addition of capacitor C_Y, there is no overall reduction of total conducted noise. However, by comparing with the previous plot for CM noise, there is a significant reduction in CM above 5 MHz, which is expected with the addition of C_Y. On the other hand, the DM noise plot does not vary much. From these two CM and DM noise plots, it is obvious that the noise emission levels are still rather high for frequencies below 5 MHz.

C) Measured Emissions With Common-Mode Coil L_{CM} Added.

The subsequent introduction of a CM coil (Figure 9), L_{CM}, further attenuates the total conducted noise. Comparing the DM noise plot with the same plot in section B shows a fair bit of reduction but it is the CM noise plots that reveal significant noise supression. From here, it is apparent that the *dominant* mode is now DM (for frequencies below 5 MHz) and clearly, a DM filter component should be used in the next step. By comparing, the total conducted noise plot and the DM noise plot is found to be almost similar, indicating that the total conducted noise is largely due to DM noise. At this point, if a CM filter component is changed, it will have very little effect on the total conducted noise.

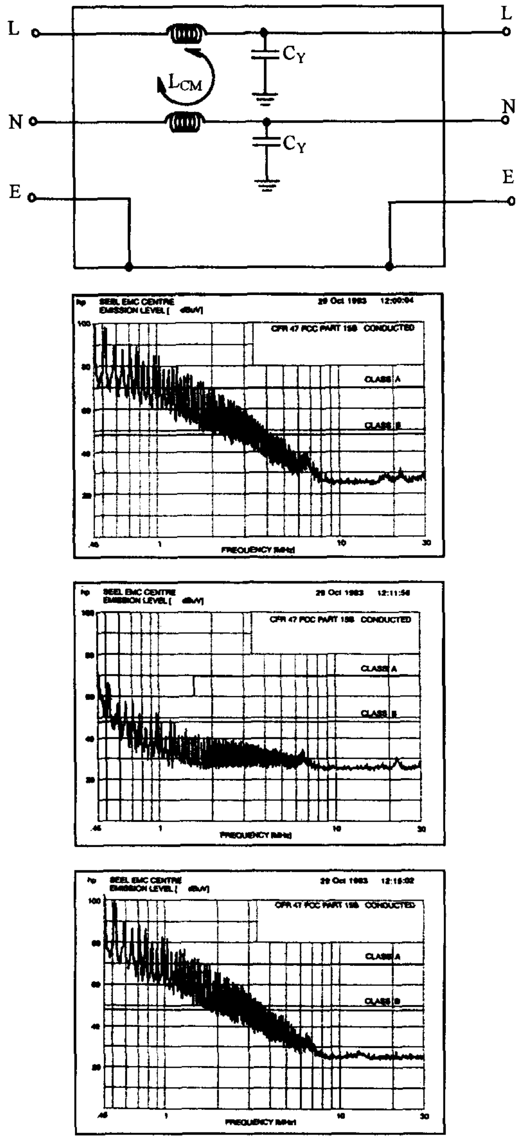

Figure 9: (a) Filter Schematic, (b) Total Conducted Noise, (c) CM Noise and (d) DM Noise

D) Measured Emissions With Differential-Mode Capacitor C_{X2} Added.

As expected, the DM capacitor C_{X2}, has the effect of supressing the total conducted noise to well within class A limit (Figure 10). Further comparison between the CM and DM noise plots with those from section C shows that the overall noise reduction is mainly due to large reduction in DM. In contrast, CM noise plot does not show much improvement. At this stage, the CM noise is well within class B limit.

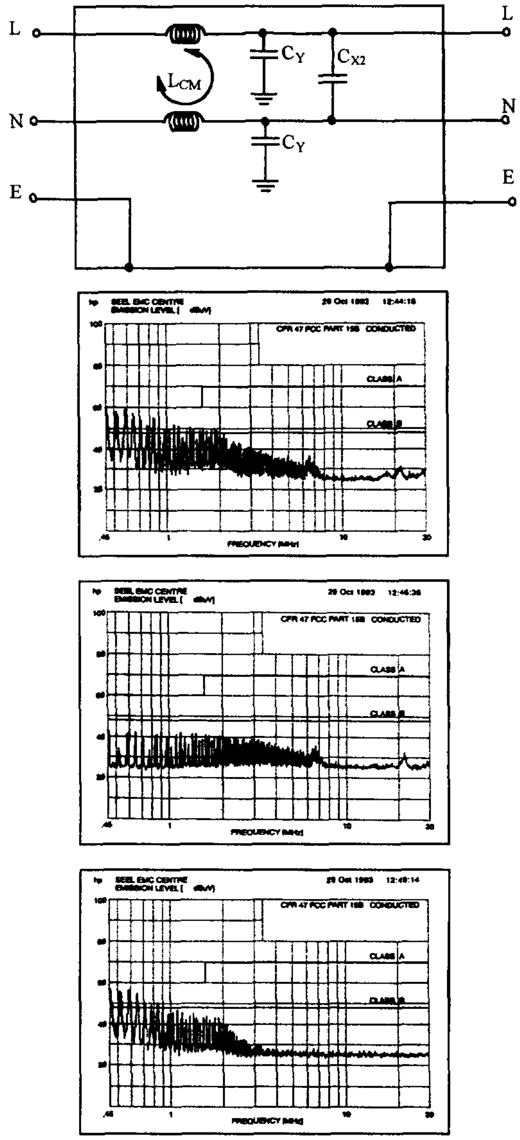

Figure 10: (a) Filter Schematic, (b) Total Conducted Noise, (c) CM Noise and (d) DM Noise

E) Measured Emissions With Differential-Mode Capacitor C_{X1} Added.

The last component to be added back, a DM capacitor C_{X1}, finally meets the requirement of FCC part 15B limit.

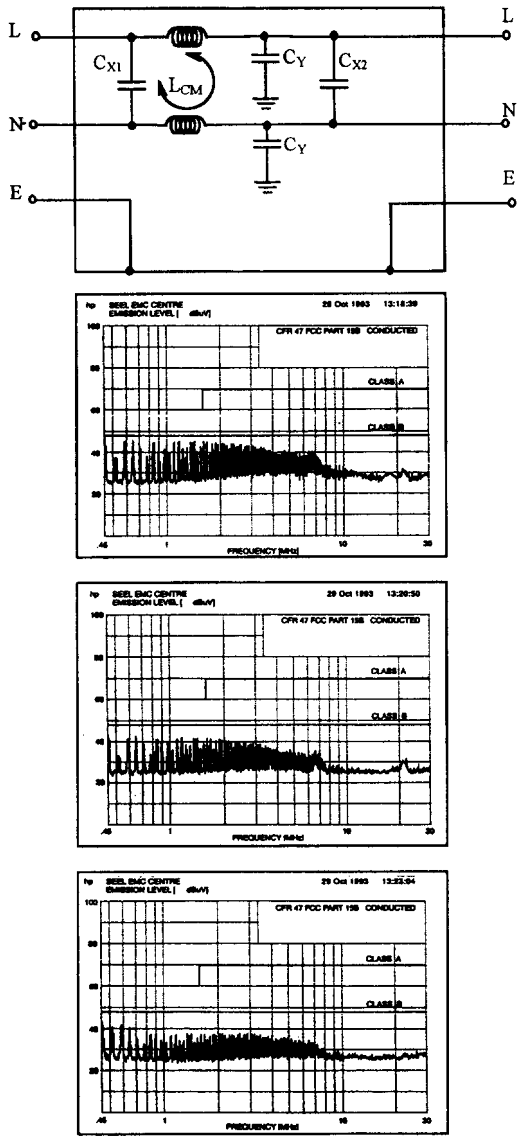

Figure 11: (a) Filter Schematic, (b) Total Conducted Noise, (c) CM Noise and (d) DM Noise

Conclusion

The CM/DM DN has proven to be a useful diagnostic tool for the modification of power supply filters to reduce conducted noise emissions. The key to an efficient filter modification is to identify which component of the conducted emissions, CM or DM, is dominant at the frequency of interest. Once the dominant component is identified, those elements of the filter which affect that component can then be modified.

Sometimes when the value of an element in a power supply filter is changed, no change in the total conducted emissions is observed. Although the change in that element results in a change in one component of the conducted emission, if that noise component is not dominant, this will appear to have no change in the total conducted emission. This can lead to over-designing of the filter, which is the safest and easiest way out but never cost-effective. And that is precisely what the CM/DM DN aims to provide - an efficient way to identify which filter element to modify in order to have an effective change.

References

[1] See Kye Yak, "*A Tool For EMI Filter Design: Selectable Mode Rejection Network*", Proceedings of International EMC Symposium (IEMCS '92), Dec 1992, pp 17-24.

[2] Lon, M. Schneider, "*New Techniques Make Power Line Emissions Filter Selection Easy*", Interference Technology Engineer's Master, 1987.

[3] MIL-HDBK-241B, "*Design Guide For Electromagnetic Interference Reduction In Power Supplies*", 30 Sept 1983.