VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

SELECTING PROPER CONNECTION POINTS FOR Y-CAPACITOR TO REDUCE EMI IN SMPS

Milind M. Jha[1], Kunj Behari Naik[2] and Shyama P. Das[3]
[1]Saraswati Institute of Technology and Management, Unnao, U.P., India
[2]College of Engineering Science and Technology, Lucknow, U.P., India
[3]Indian Institute of Technology, Kanpur, U.P., India
E-Mail: milindlko@gmail.com

ABSTRACT

Y-capacitors are used to reduce electro magnetic interference (EMI) in SMPS. This is a capacitor connected between primary and secondary of the SMPS transformer to bypass EMI currents and thus preventing them to reach mains port. Proper connection points for this capacitor are discussed and experimental results are analyzed to verify their effectiveness.

Keywords: Y-capacitors, SMPS transformers, EMI performance, Conducted Emission, Mixed-Mode Noise.

INTRODUCTION

The SMPS generate unwanted electrical signals. They corrupt power line, affect other electronic systems as well as the circuits which draw power from these supplies. These signals occur at high frequencies and are called Electro Magnetic Interference (EMI). They lie in the Radio Frequency Range. Therefore, they are also called Radio Frequency Interference (RFI).

There are two categories of EMI noise: Radiated and conducted. Conducted noise has broadly speaking, two modes: Differential Mode (DM) and Common Mode (CM). Generally, the differential-mode noise is predominantly caused by the magnetic coupling L*di/dt, where L is the parasitic loop inductance which experiences high switching current slew rate di/dt. On the other hand, the common-mode noise is mainly related to the electrical coupling C*dv/dt, where C is the parasitic common mode capacitance which sees high voltage slew rate dv/dt. Now, a third mode is also reported in literature and is called, Mixed Mode noise. There are two coupling modes of DM noise: Conventional DM noise called Intrinsic Differential Mode and Non-Intrinsic Differential Mode. The generation mechanism of this mode of noise is similar to that of CM noise, but the noise can be suppressed by using DM capacitor (sometimes called X-capacitor).
[1-3]. For this reason, NIDM noise is also called Mixed-Mode noise

Connecting a Y-capacitor between Primary Return Terminal (PRTN) and Secondary Return Terminal (SRTN) to reduce EMI is an established practice in industry. Some points are good points and some are bad points for connecting this capacitor. Some connections may even worsen the EMI performance [3]. We will investigate this behavior and analyze proper connection points for this capacitor.

The study of capacitances associated with SMPS transformer can help in finding ways to reduce EMI. There is a lot of work reported in literature about transformer modeling, but most of them have dealt in losses and energy storage, and only few of them can be used to predict EMI behavior [1].

PARASITIC CAPACITANCES OF SMPS TRANSFORMER

Figure-1 shows a two wire fly-back SMPS and most of the parasitic capacitances associated with the transformer. Cds is the drain to source capacitor of the MOSFET switch. C12 and C34 are the intra-winding capacitors of the primary and secondary windings respectively. C13, C14, C23 and C24 are the inter-winding capacitors. C14 is important for reducing EMI [1]. In a three wire system, Y-capacitors are connected between chassis ground and Line (L) / Neutral (N) to provide a low impedance path to shunt the EMI current from flowing through LISN resistor. No such connection is possible in a two wire isolated SMPS. Fortunately, a capacitor connected between primary and secondary terminals of the power supply can serve as Y-capacitor to attenuate common mode (CM) noise [3].

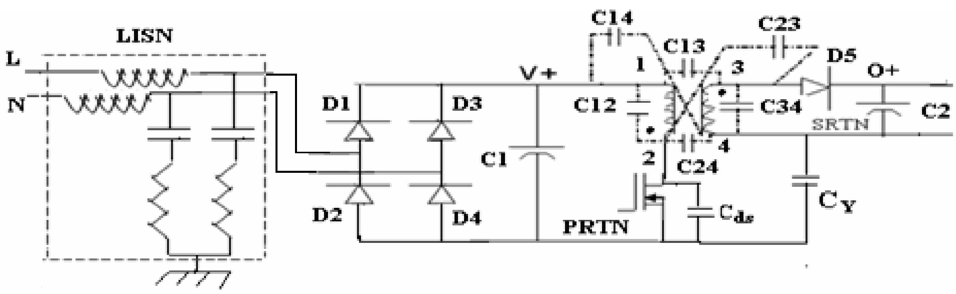

Figure-1. The fly-back SMPS and parasitic capacitors of the transformer.

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

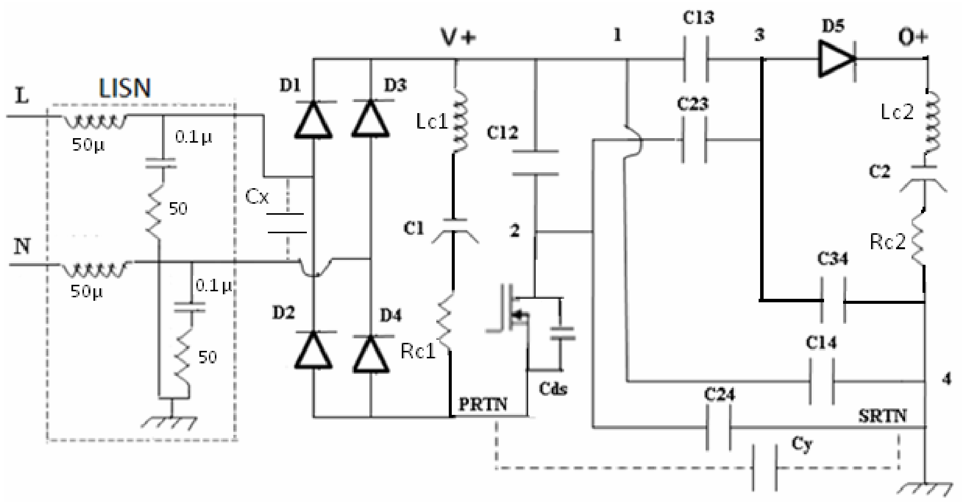

Figure-2. Equivalent circuit of Figure-1 without showing transformer windings.

Figure-2 shows various parasitic capacitors of the fly-back transformer without showing the windings. These capacitors are responsible for EMI generation and transmission. C1 and C2 are the input and output bulk capacitors and are represented by their equivalent circuits [4]. The series inductances Lc1 and Lc2 can not be neglected at the noise frequencies and must be taken into consideration. The dotted box contains the Line Impedance Stabilization Network (LISN).

The root cause of the MM noise is the unbalance flow of high frequency C*dv/dt current through the two LISN 50Ω resistors and can be balanced by an appropriate X-capacitor Cx [2].

Terminal 2 is the switching point of the inverter switch operating at a very high frequency. Any capacitor connected at this point will carry a large C*dv/dt current. Similarly, terminal 3 is a switching point for the output rectifier switch and will give similar results.

DISCUSSIONS

Figure-3 shows EMI generated at the mains port of a fly-back SMPS prototype when no extra capacitor (Y-capacitor) is connected. A capacitor connected between terminals 2 and 4 in parallel with C24 may worsen the EMI performance of the system because terminal 2 is connected to the drain of the MOSFET and during switching, large amount of current (C dv/dt) will flow, deteriorating EMI performance. Similarly, any capacitor connected between PRTN and 3 is a bad option for EMI reduction (Figure-4), because of the switching action of diode D5. Thus, points 2 and 3 must be avoided for connecting a capacitor for EMI reduction.

Putting a Y-capacitor (2.3nF/3KV) between terminals 1 and 4 reduces EMI (Figure-5). One terminal of this capacitor is always connected to earth (SRTN). Now, if one pair of rectifier diodes (D1, D2, D3 and D4) is conducting the mains current, the other terminal of this Y-capacitor is connected to both L and N either directly or through bulk capacitor C1. One of the rectifier diodes still conducts the noise current even when they are not conducting mains current [3]. Thus, the second terminal of this Y-capacitor is either connected to L or N in this case. Therefore, the Y-capacitor provides a path to divert part of the noise current from flowing into the LISN and achieve EMI reduction. Any capacitor connected between PRTN and SRTN in a similar manner reduces EMI (Figure-6).

EMI reduction is better in Figure-6 than in Figure-5. There is a difference of 5 to 10 dBμV in the Figures. This can be explained by Figures 7 to 10 showing various equivalent circuits of Figure-2. The differences between two connections are:

a) The assumption in [3] that terminal 1 and PRTN are same point because of high value bulk capacitor C1 may not be correct. The inductance associated with C1 (Lc1) becomes significant at high frequencies. Figures 5 and 6 have differences at higher end of the noise spectrum and verifies our point.
b) There is already a capacitor between 1 and 4 (the parasitic capacitor C14 of the SMPS transformer) and a new capacitor is added to augment its value whereas in the second case an extra capacitor is added. A new extra capacitor is expected to be more effective.
c) The ESR associated with C1 [4] is responsible for large ripples at 1. The capacitor in parallel with C14 is always connected to the point of this high ripple whereas the second one is connected to primary return terminal.

This result is verified by simulation results also (Figures 11 and 12).

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

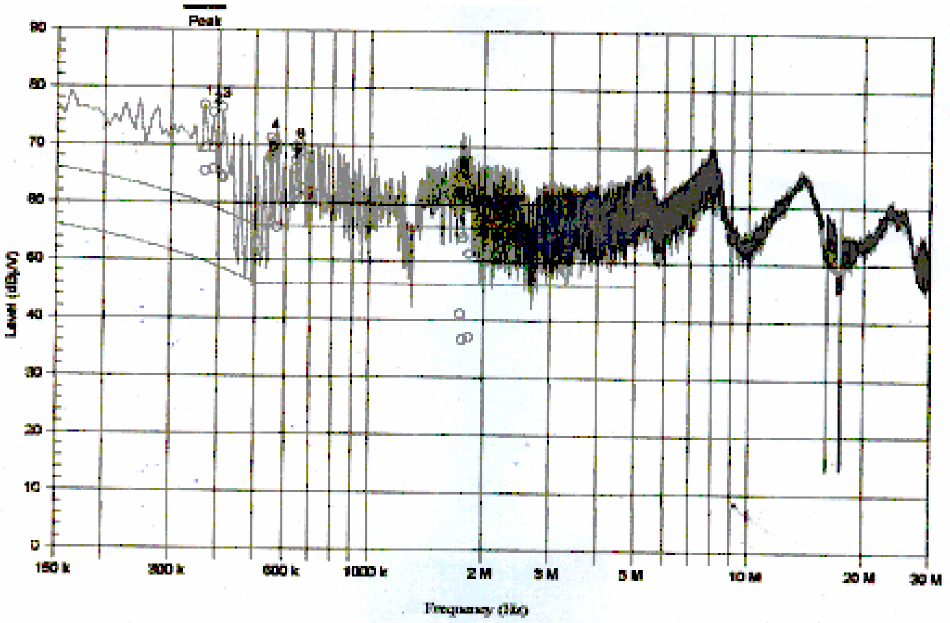

Figure-3. Conducted emission measurement without any extra capacitor.

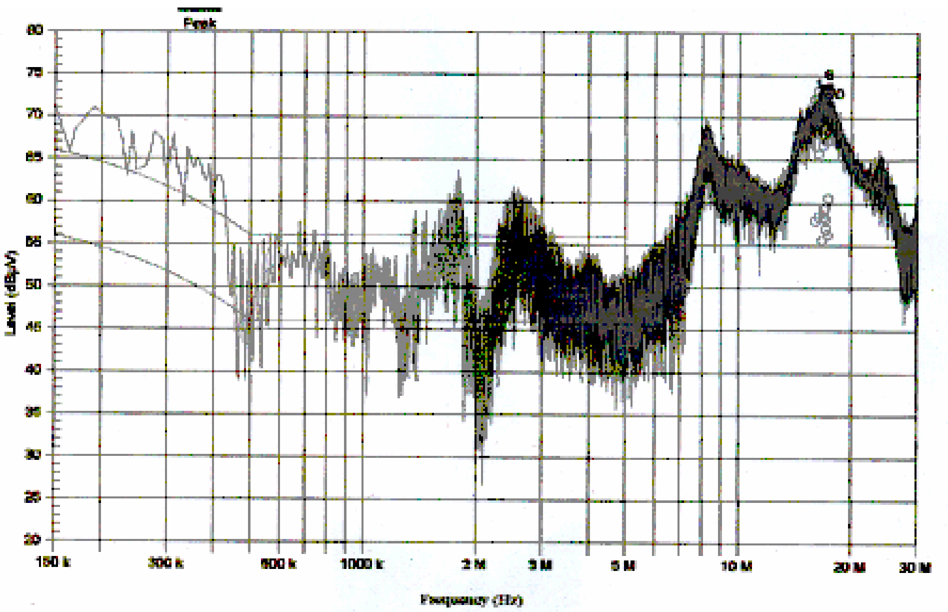

Figure-4. Conducted emission measurement after adding a 2.3nF/3KV Y-capacitor between terminals PRTN and 3.

ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

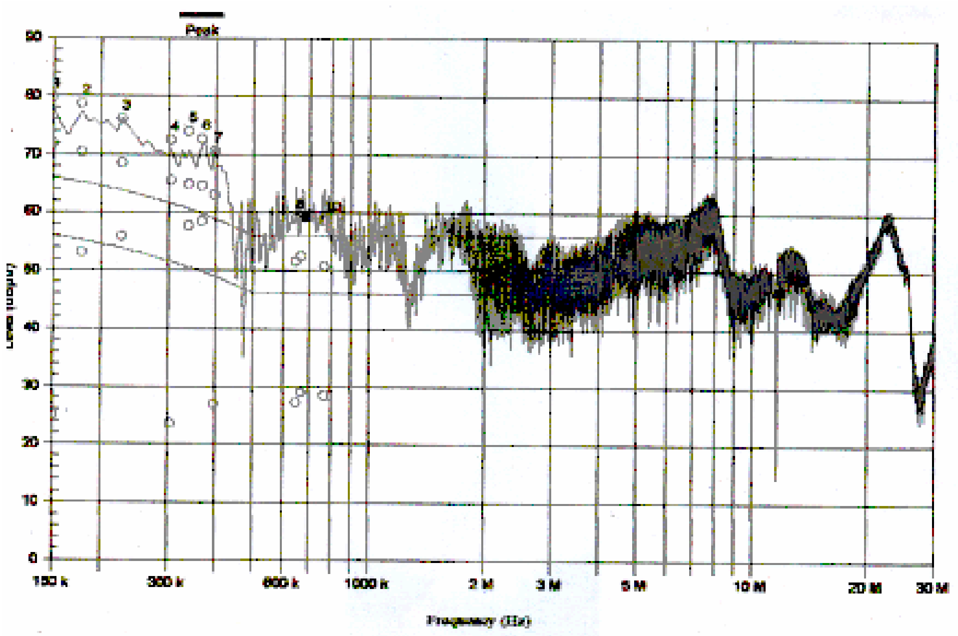

Figure-5. Conducted emission measurement after adding a 2.3 nF/3KV capacitor between terminals 1 and 4.

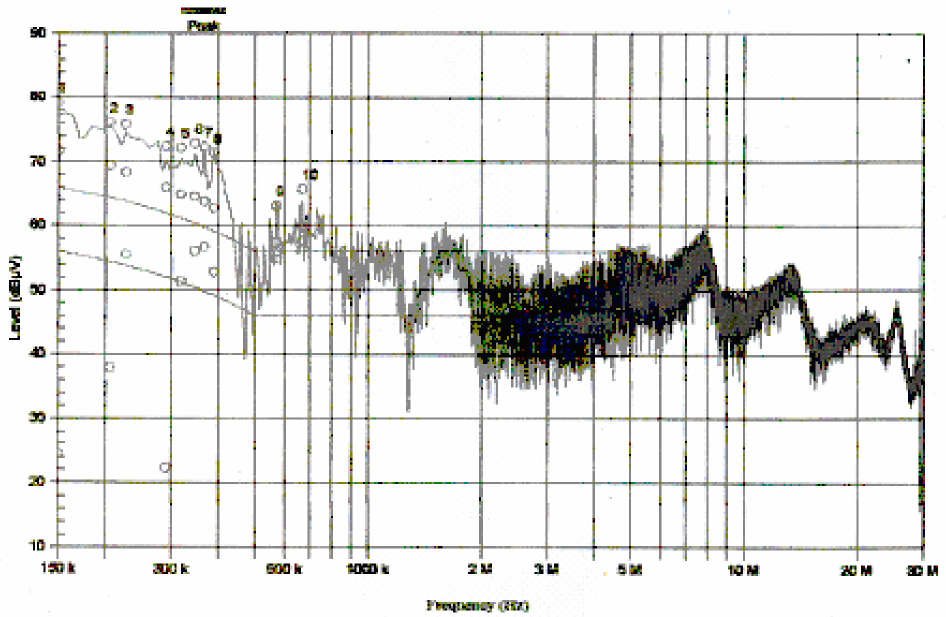

Figure-6. Conducted emission measurement after adding a 2.3 nF/3KV Y-capacitor between PRTN and SRTN.

VOL. 5, NO. 2, FEBRUARY 2010 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

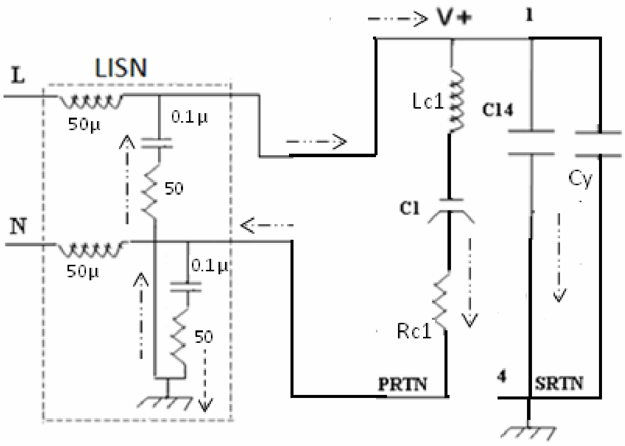

Figure-7. Equivalent circuit of Figure-2 showing noise current path when rectifier diodes D1 and D4 are conducting mains current and a Y-capacitor is connected parallel to C14.

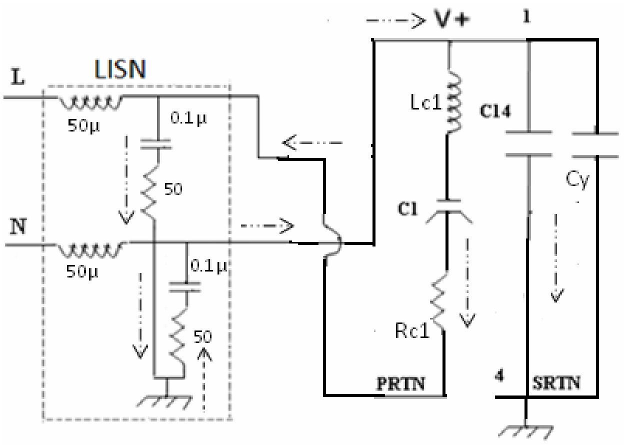

Figure-8. Equivalent circuit of Figure-2 showing noise current path when rectifier diodes D2 and D3are conducting mains current and a Y-capacitor is connected parallel to C14.

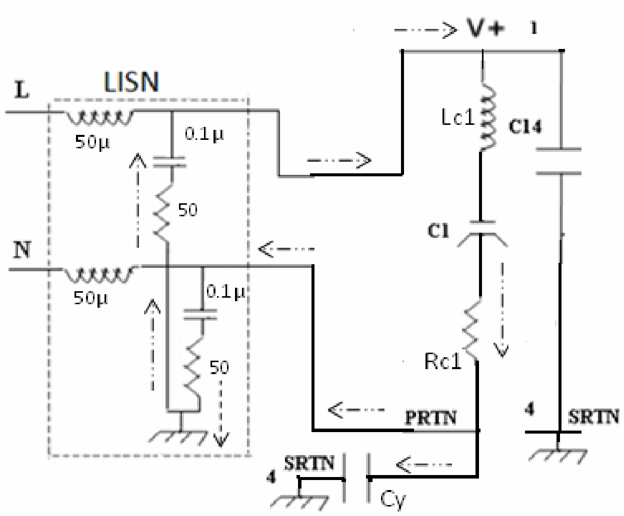

Figure-9. Equivalent circuit of Figure-2 showing noise current path when rectifier diodes D1 and D4 are conducting mains current and a Y-capacitor is connected between PRTN and SRTN.

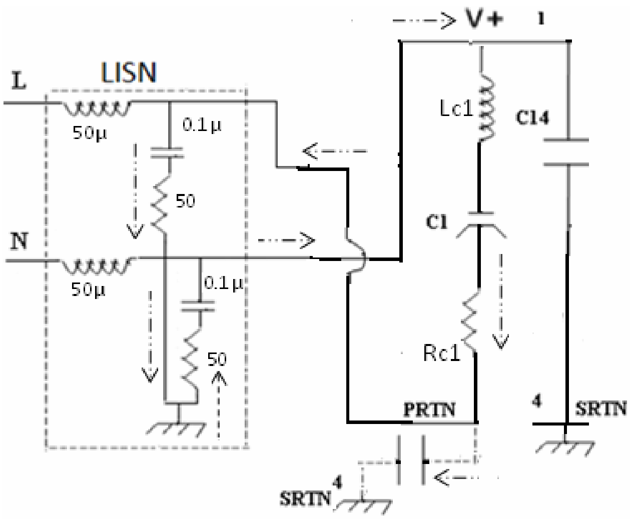

Figure-10. Equivalent circuit of Figure-2 showing noise current path when rectifier diodes D2 and D3are conducting mains current and a Y-capacitor is connected between PRTN and SRTN.

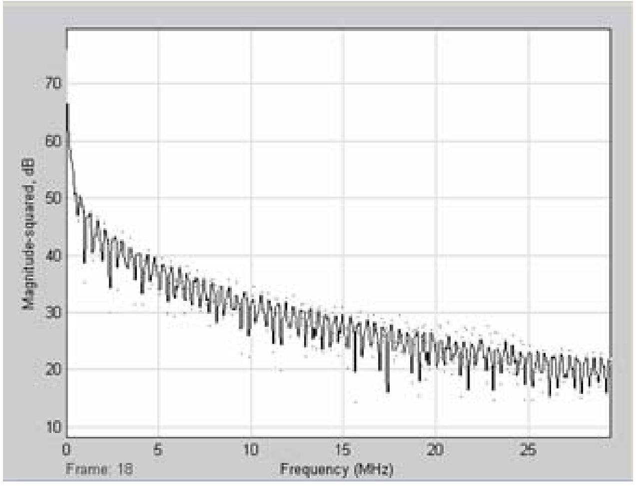

Figure-11. Simulated result of noise with Y-capacitor in parallel with C14.

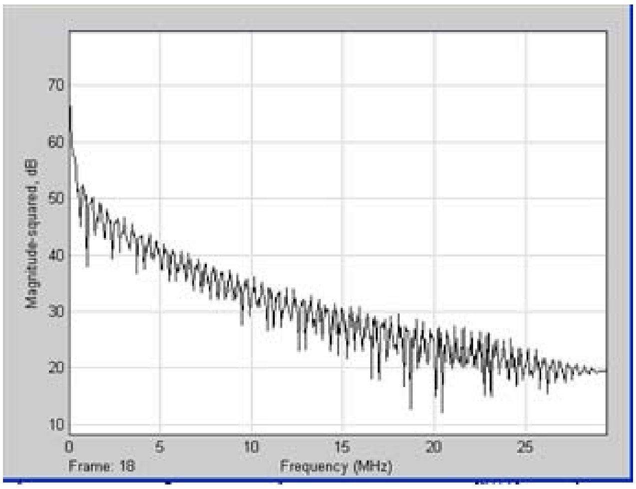

Figure-12. Simulated result of noise with Y-capacitor between PRTN and SRTN.

CONCLUSIONS

Both experimental and simulation results show that the most appropriate points for connecting a Y-capacitor is between PRTN and SRTN.

ACKNOWLEDGEMENTS

The authors are thankful to ERTL (N), New Delhi for conducting conducted noise measurements at concessional rates.

REFERENCES

Pingping Chen, Honghao Zhong, Zhaoming Quian and Zhengyu Lu. 2004. The passive EMI cancellation effects of Y-capacitor and CM model of Transformers used in SMPS. 35th Annual IEEE Power Electronics Specialists Conference, Aschen, Germany. pp. 1076-1079.

Hung-I Hsieh, Jhong-Shu Li and Dan Chen. 2008. Effects of X capacitors on EMI filter effectiveness. IEEE Transactions on Industrial electronics. 55(2): 949-955.

Hung-I Hsieh, Liom Huwang, Tian-Chi Lin and Dan Chen. 2008. Use of a C_Z Common-Mode Capacitor in Two-Wire and Three-Wire Offline Power Supplies. IEEE Transactions on Industrial Electronics. 55(3): 1435-1443.

Acacio M. R. Amaral and A. J. Marques Cardoso. 2005. An experimental technique for estimating the aluminium electrolytic capacitor equivalent circuit, at high frequencies. Industrial Technology. 2005. ICIT, IEEE International Conference. Vol. 14-17, pp. 86-91.