Design for reduction EMI of flyback switching power supply

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Abstract: Switch-mode power supplies (SMPS) have become a major source of conducted electromagnetic interference (EMI) which is the combination between differential mode (DM) noise and common mode (CM) noise. This paper presents the conducted EMI reduction approach in flyback switched mode power supply by rerouting for circuit balance to reduce common mode noise. And differential mode noise can be reduce by adding c_x capacitor across the input power line, and passive element to the gate drive of switching device MOSFET to slow down the switching times. This combination of our approach is the effective way to reduce the conducted EMI and it is also a cost effective for product design

1. INTORDUCTION

Conducted electromagnetic interference (EMI) produced by switched-mode power supplies (SMPS) have become more and more serious with its trends toward high switching frequency, high efficiency and minimized size. To confirm international EMC regulation, reduce conducted EMI of switched-mode power supplies is an important task for electronic engineer now.

The conducted EMI is classified into differential mode (DM) noise and common-mode (CM) noise. It is well know that common mode noise is cause by the common-mode current flowing through the parasitic capacitance of switching devices to ground in switch-mode power supplies. Because of the potential for interference with other system, it is necessary to attenuate this noise. Ordinary this is accomplished by using a common-mode choke across the input power line, resulting in penalties to overall size and cost of the completed system. In order to lesson the requirement for this common-mode choke, there has been in recent years a capacitance, C_{p3} of the same heatsink is directly connected to ground. The modified flyback switching power supply as show in fig. 3, the common mode current which generates in this circuit will be canceled out in balanced line between terminal A and B. And differential mode noise can be reduce by adding C_x capacitor across the input power line, and inserting passive element to the gate drive of switching device, MOSFET to slow down the switching times. This combination of our approach is the effective way to reduce the conducted EMI. They greatly improved for the conducted EMI. The greatly improved for conducted EMI reduction is confirmed by the experiment results desire to noise cancellation technique to the area of conducted EMI. Recently there were articles dealing with a balanced switching converter circuit to reduce common mode noise as show in [1], [2].

This paper proposes a new design approach to reduce conducted EMI of flyback switching power supply. The common mode noise is minimizes by rerouting back from the top terminal of second parasitic capacitance, C_{p2} of heatsink of MOSFET to mid-point of resistors and capacitors balance as show in fig.4 and from the bottom terminal of C_{p2} is feedback to the source of MOSFET. The third parasitic, C_{p3} of the same heatsink is directly to ground. The modified flyback switching power supply as shows in fig. 3, the common mode current which generates in this circuit will cancelled out in balancing line between terminal A and B. And differential mode noise can be reduced by adding C_x capacitor across the input power line, and inserting passive element to the gate drive of switching device, MOSFET to slow down the switching times. This combination of our approach is effective way to reduce the conducted EMI. The greatly improved for conducted EMI reduction is confirmed by the experiment results

2. COMMON MODE NOISE REDUCTION TECHNIQUES

Common mode noise is very difficult to reduce without any filter. The effect from charge and discharge of parasitic capacitance results a common mode noise current flowing through earth ground and resister in LISN that spectrum analyzer can measure voltage drop at resister. Fig. 1shows the charging of parasitic capacitance (C_p) at heat sink when power MOSFET is turn off. Since $Icm = Cdv/dt$, a common mode noise current can be decreased by reducing parasitic capacitance (C), dv or increase time (dt)

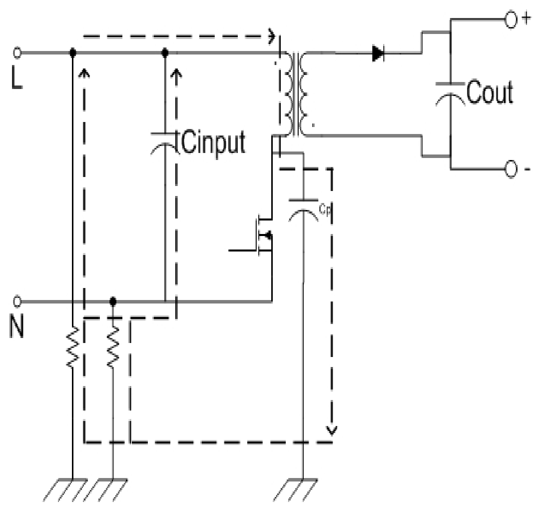

Fig. 1 Shows a common mode current path when power MOSFET is turn off

A new reduction common mode noise by rerouting for balancing circuit is presented in this paper. A new shield insulator is constructed by sandwiching. Fig. 2 shows a construction of insulators which has an electric plane connection to first copper shield (point 2) and connection of neutron to second copper shield (point 3).

The new shielded insulation can decrease the parasitic capacitance to be 1/3 of original value. The capacitor C_1 and C_2 is used for source balance by dividing source into two parts that can control common mode current flowing in two loops. And the voltage source can be designed to a desired voltage level by using voltage divider R_1 and R_2, so that the dv/dt rating between point 1 and point 2 can adjusted by the value of R_1 and R_2. The low dv/dt rating is low conducted EMI generation, therefore the voltage at electric plane or balance line should be as high as possible ($\approx V_{dc}$ input), so that dv/dt is decreased because voltage transient at terminal not compare to ground but its reference is balance line. The second shielded element is conducted to source of MOSFET or neutron line, the dv/dt across the parasitic capacitance (C_{p3}) and the chassis becomes zero. The common mode current will not flow pass through capacitor, C_{p3} to safety ground or chassis. Fig. 3 shows the schematic of improved the common mode noise of proposed flyback switched mode power supply.

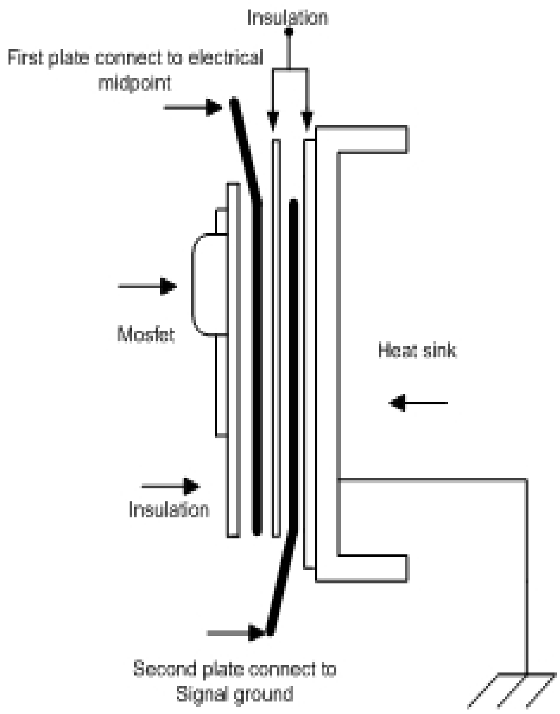

Fig. 2 Shows a construction the new insulation of heatsink

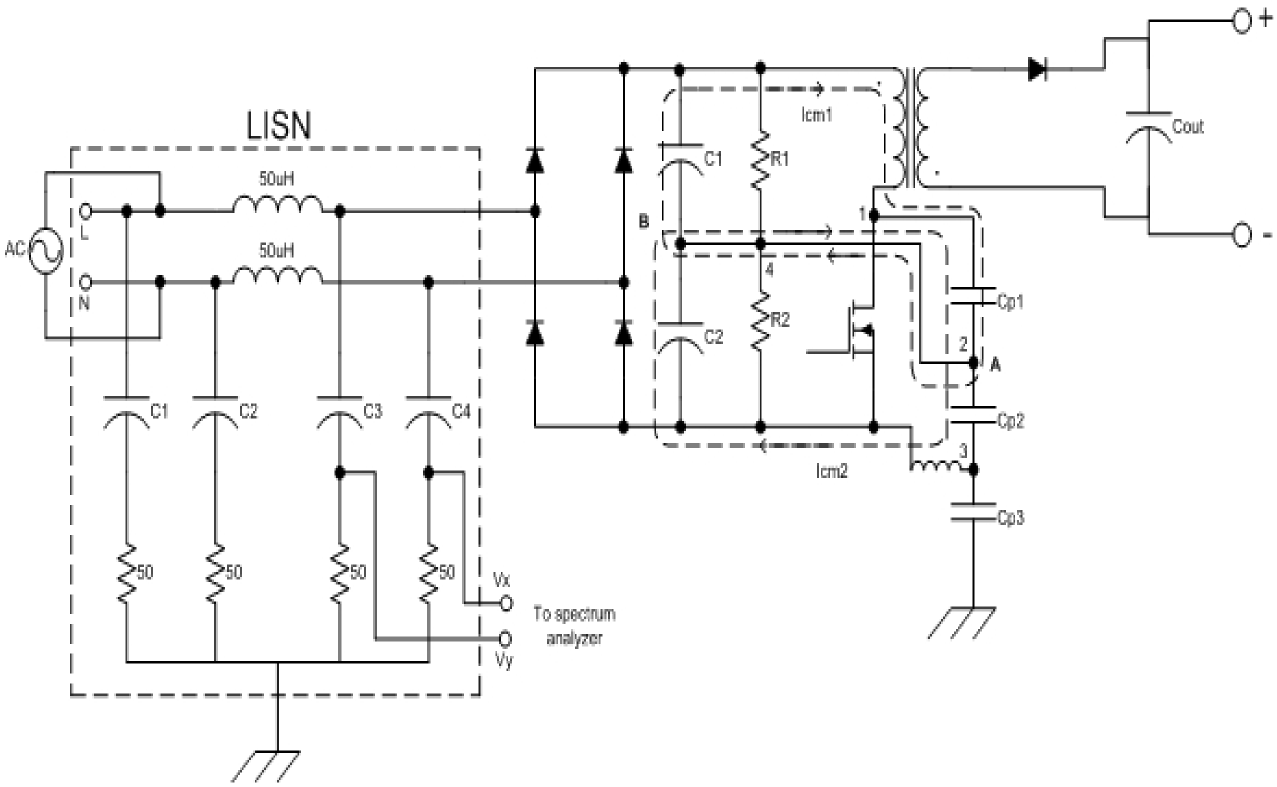

Fig. 3 Schematic of proposed balanced of flyback switched mode power supply

The effect from dividing voltage source in two parts that can build two loops of common mode noise current which has equal of noise source and the common mode can be controlled to flows in electric plane or balance line with same amplitude but opposite polarity.

The balancing topology [4], [5] is concept cancellation of both signal that have equal amplitude but opposite of phase. In flyback switching power supply, we can make equal impedance in line and neutron by add inductor between point 3 and neutron. The inductor will increase impedance of neutron to have closed impedance with line. Testing result of rerouting for balancing circuit is show fig. 4, 5

In order to confirm eliminate common mode noise of rerouting for balancing circuit, we use current probe to measure a common mode noise current between conventional circuit in flyback switching power supply as show in fig 6 and compare to the improvement with rerouting for balancing circuit as show in fig. 7

Another source of common mode noise is current charge and discharge parasitic capacitance at rectifier in secondary side because of the rectifier output maybe used heatsink same power MOSFET in primary side.

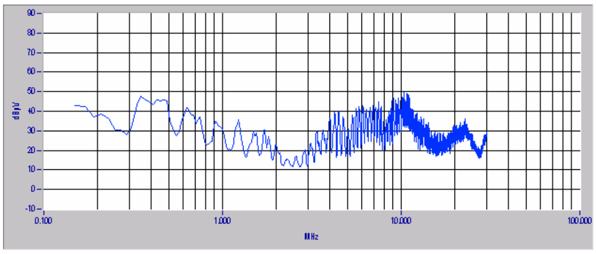

Fig. 6 Common mode noise in conventional circuit

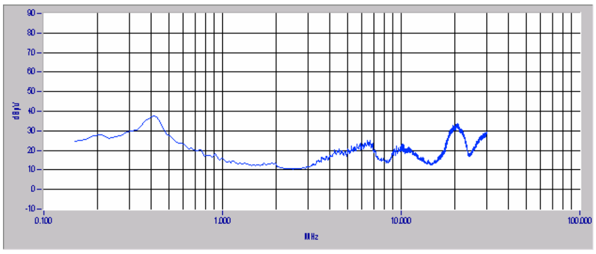

Fig.7 Common mode noise of rerouting for balancing techniques

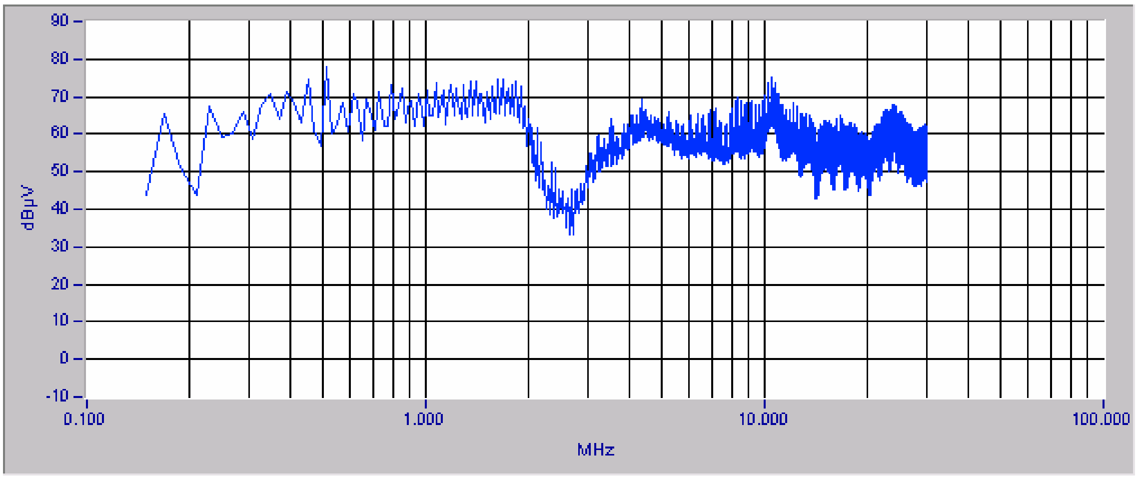

Fig. 4 Conventional flyback switching power supply EMI Testing result

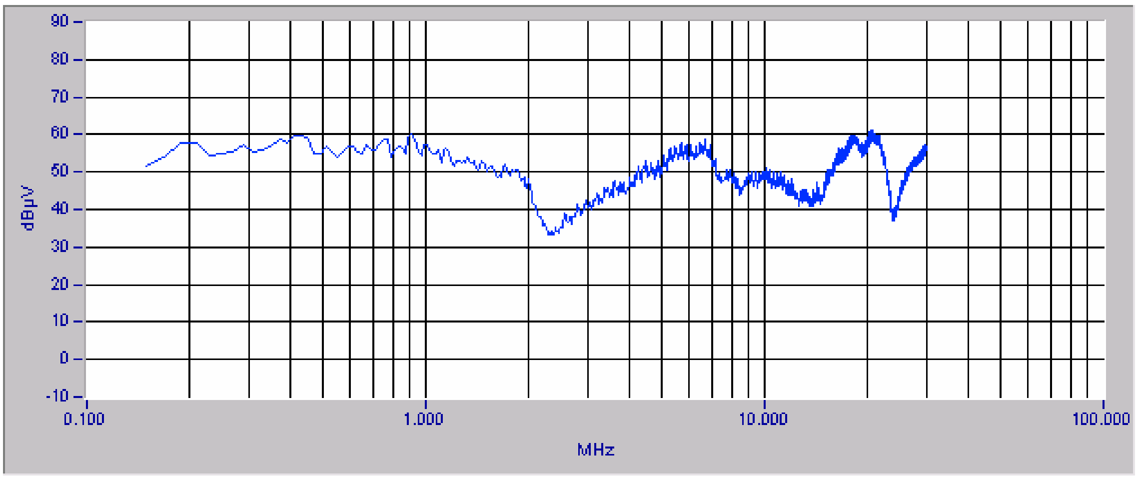

Fig. 5 Proposed balanced flyback switching power supply

The common mode current can flow from secondary side to primary side through the feedback path. An isolation feedback circuit technique is cut a route of common mode noise. The opto couple was used to isolation feedback loop and will cut route of common mode current flow. The conducted noise was decrease than 5dB. Fig 8 show common mode path from secondary side to primary side. Fig. 9 show measure result of isolation techniques.

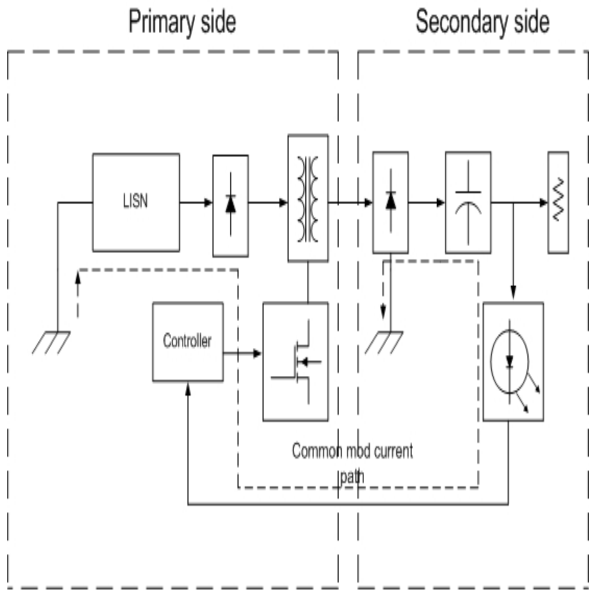

Fig. 8 Shows a common mode current flowing from secondary side to primary side

3. DIFFERENTIAL MODE REDUCTION TECHNIQUES

Differential mode noise has the same concept of common mode noise, i.e., turn on and turn off of MOSFET and diode, charge and discharge of parasitic capacitance. The differential mode noise is develop across the equivalent series resistance and inductance (ESR, ESL) therefore, the lower differential mode noise, electrolytic should be paralleled with film or ceramic capacitors.

Differential noise, some times the by-product of signals such as clocks or power supply switching waveforms, is directed coupled into the circuit and/or is inherent to the circuit. The path is inherent to the circuit [3].

Magnetic loop coupling problems are generally created by poor circuit layout. Signal and return line should be laid out to create as small a loop as possible. The magnetic field strength is proportional to the area of the loop [6]. The ways to improve differential noise are balancing voltage noise on both LISN resister, reduce rise time fall time.

The dv/dt can be reduce by increasing the switching time. The series resistance is adding in gate drive circuit can increase turn on and turn off time. This method can reduce noise in gain many dB but its increase switching loss effect to overall efficiency. Fig. 10 shows testing result of adding resistance series in gate drive circuit.

The differential mode noise is measure by voltage different between both resistances of LISN. The balancing circuit at input AC terminal can decrease voltage differential across LISN resistance. Non polar capacitance have used to balancing voltage between line and neutron. The performance of reduce differential mode noise is value with current and voltage. Certainly higher capacitive can decrease differential voltage better than lower capacitive.

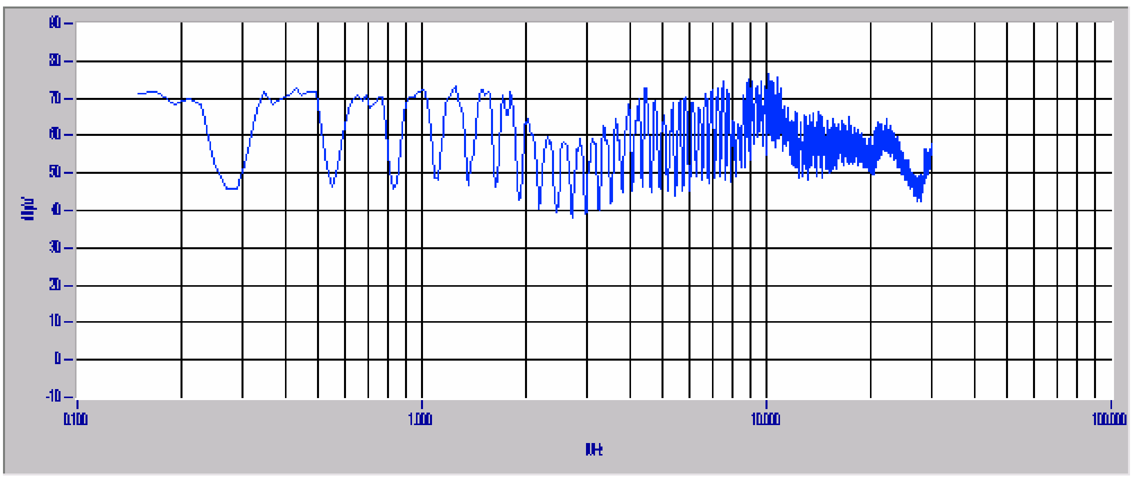

Fig.9 Measurement result after providing isolation feedback circuit

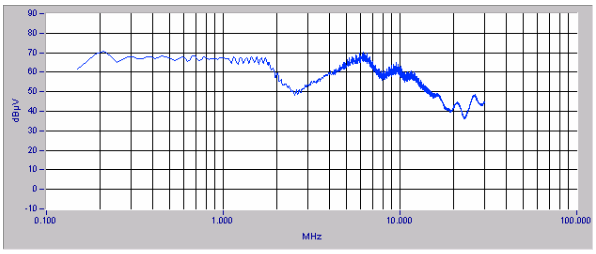

Fig. 10 Testing result after add series resister

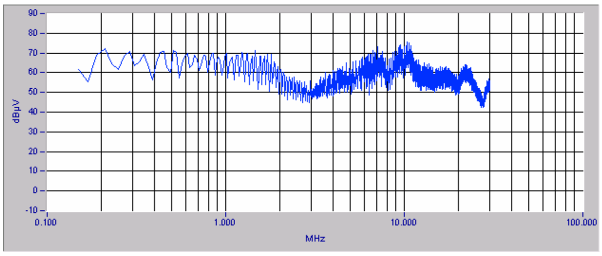

Fig. 11 Measurement result after adding C_x capacitor across the input power line

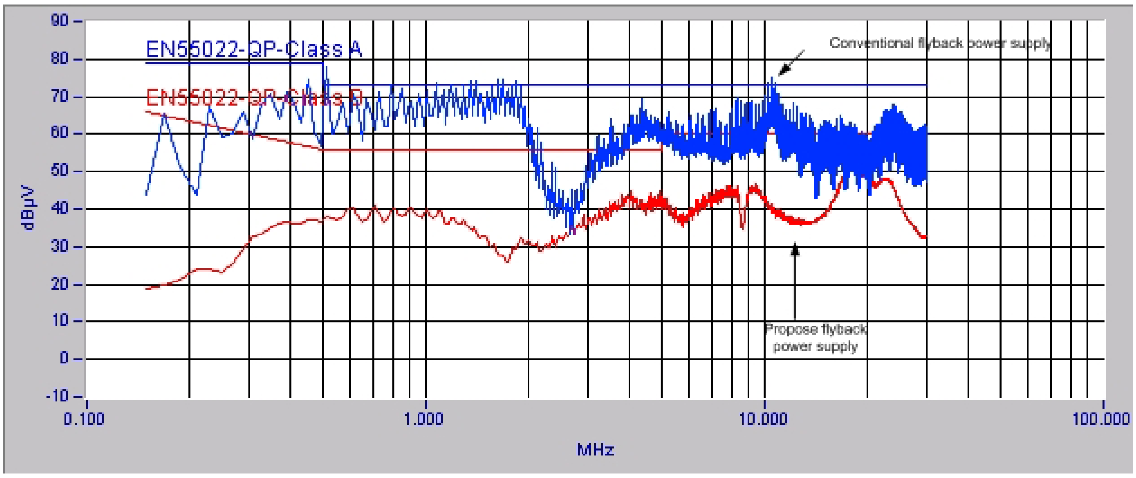

Fig. 12 Final testing result pass EN55022 class B standard with margin 9dB/uV

4. CONDUCTED EMISSION STANDARD

CISPR22/EN55022 is the reference of limits and method of measurement of ratio interference characteristics of information technology equipment standard. The final measure is shows on Fig. 12 (compare with conventional testing) has margin at least 9db/V from limit line

5. CONCLUSION

EMI problem can be solved by EMI filter but the goal of this paper is minimum requirement or not used any EMI filter. From final measure show that proposed flyback switching power supply can meet EN55022 by not used any filter. Designer can do all presented techniques earlier in design state and safe cost, time better than use filtering after design state.

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