J Electr Eng Technol Vol. 9, No. 5: 1724-1728, 2014
http://dx.doi.org/10.5370/JEET.2014.9.5.1724

ISSN(Print) 1975-0102
ISSN(Online) 2093-7423

Resistive Grounding Technique of Heat Sink for Reducing Radiation Noise

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Abstract – Heat sink has been used to help an electrical device operate in normal temperature condition. But heat sink radiates unwanted electromagnetic wave, which may cause electromagnetic interference problem. A resistance loaded grounding technique is proposed to reduce electromagnetic wave radiation by a heat sink. Numerical simulations are accomplished to find optimal loading resistance. Also electromagnetic fields radiated by from a heat sink are measured and compared with the simulation results. The test results verify the usefulness of the proposed technique.

Keywords: Heat sink, EMI, Ground

1. Introduction

A switching mode power supply (SMPS) are widely used for many electrical and electronic devices, it has high efficiency and small size compared as linear power supply. However, SMPS use a high switching frequency so is susceptible to emit various noises which may cause electromagnetic interference problem. Therefore, in the design of SMPS electromagnetic compatibility problem becomes more important [1, 2].

Moreover, by using a fast operating frequency there is a unavoidable switching power loss, which transformed to heat. To emanate the heat, various types of heat sink have been introduced. Heat sink is usually tightly attached to heat source as far as possible. Heat sink put the heat into the air efficiently so as to help the switching device operate in normal temperature environment without failure.

However, heat sink can be unwantedly operated as an antenna radiating electromagnetic wave especially for high frequency switching devices. It may cause electromagnetic compatibility (EMC) and electromagnetic interference (EMI) problems in nearby electronic devices when it is used for high power switching devices. Therefore, it is necessary to design heat sink preventing the EMI/EMC problem [3, 4].

The size of the heat sink depends on the temperature of the device, so the electrical size usually is not small enough to neglect the radiating effect for high frequency device. The currents on heat sink plates are mainly introduced from the stray capacitances and voltage difference between the switching device and heat sink. Also the structure and the shape of the heat sink determine to radiate the frequency dependent electromagnetic wave. But electromagnetic design of the structure of heat sink to reduce the current affects the main function of the heat sink, so this approach is seldom used [5].

The other technique to reduce the EM radiation is multiple grounding of the heat sink [6]. And various related researches have been accomplished so far [7-9].

In this paper, we used a ground technique to reduce radiating noise. Resistances are connected between the ground point and the heat sink. The radiating noise is analyzed numerically and experimentally for these cases.

2. Heat sink and the Source of Electromagnetic Interference

Heat sink radiates electromagnetic noise as a resonant antenna, which depends on the size and the structure of the plates and fins. Switching device provides the electromagnetic source from the high voltage difference. Fig. 1

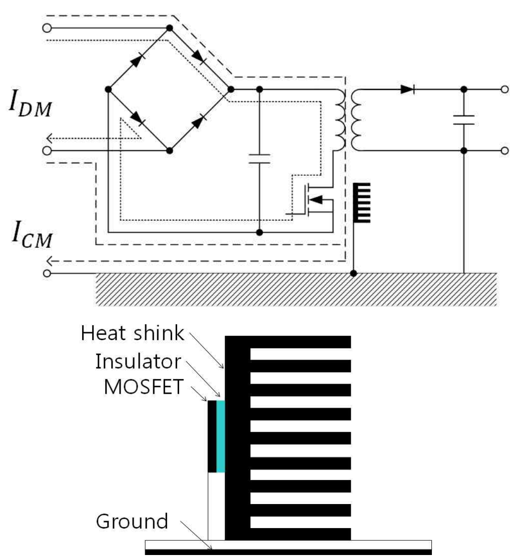

Fig. 1. Geometry of a switching device and a heat sink

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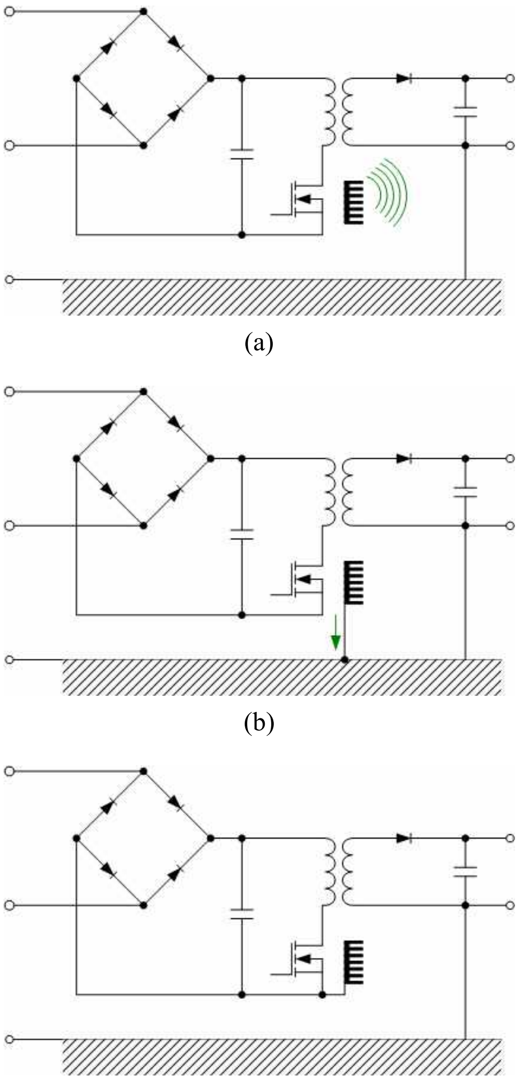
Received: February 28, 2014; Accepted: June 16, 2014



(a)

(b)

(c)

Fig. 2. Cases of grounding heat sink: (a) Heat sink without ground; (b) Heat sink with ground; (c) Heat sink ground to a feedback circuit

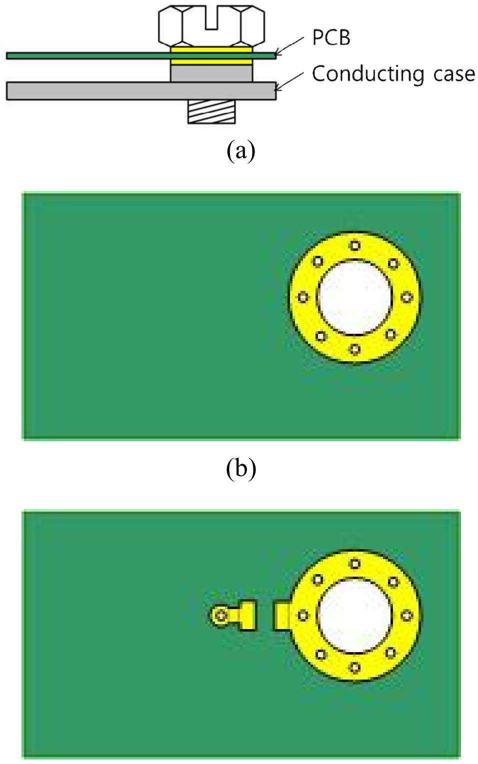
shows a brief geometry of a heat sink and a switching device.

A heat sink is usually attached the drain of a switching device in order to emit the heat occurred from the device. For heat transmission and electrical insulation, sheets or powdered plates are inserted in the gap between a switching device and a heat sink. Therefore, a high stray capacitance exists on it.

Through the stray capacitance a common mode current flows, and the current increases when the heat sink is grounded. It takes places conductive noises.

If the heat sink is not grounded, the common mode current decreases. However in this case the heat sink operates as an antenna which makes radiation noise.

Also heat sink can be grounded to a feedback circuit on a PCB, in the case safety can be issued as of the high voltage difference. Three cases of ground heat sink are shown in Fig. 2[8].



(a)

(b)

(c)

Fig. 3. Geometry of grounding pad on a PCB: (a) Side view of a simple ground pad bolt-connected between a PCB and PEC plate; (b) Top view of a simple ground pad; (c) multi-purpose grounding pad

3. Reduction of Radiated Noise

Radiation characteristics of heat sink are determined by the electrical size, structure, and its installed method. Many researches have been done on the characteristics of heat sink. One of them is grounding technique. In general when installing a heat sink, multiple grounding techniques have been used. It reduces the radiation noise, but in the other hand increases the conductive noise.

For PCB, it is recommended to attach grounding pad to the case, and furthermore multi-purpose pad can be used selectively for an effective grounding of a heat sink [9]. A simple grounding pad and a multi-purpose grounding pad are shown in Fig. 3.

In this paper, to reduce the radiation noise we employ a multi-purpose bonding pad to ground the heat sink with resistive loading.

4. Numerical results

For the investigation of radiation characteristics of the

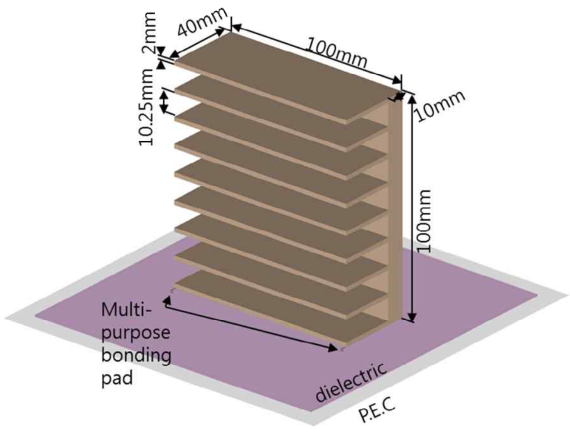


Fig. 4. Geometry of a heat sink

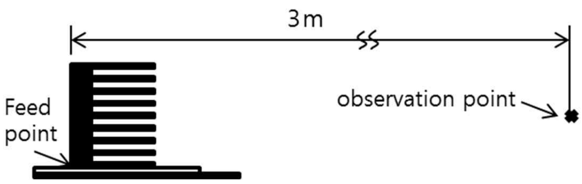
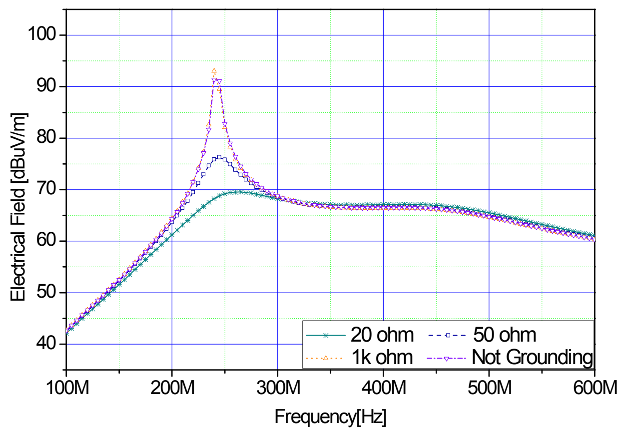
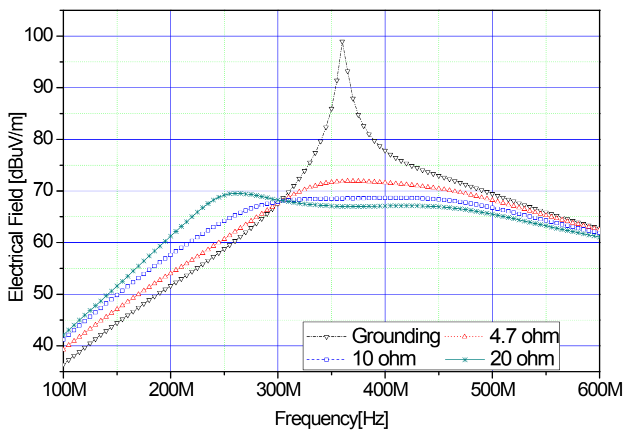


Fig. 5. Observation position for the radiated electric field



(a)



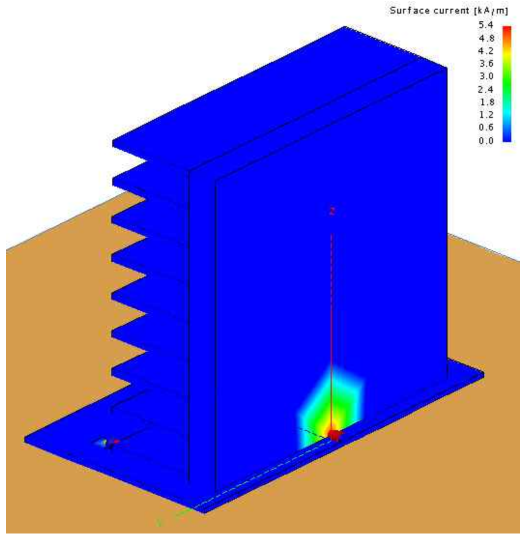
(b)

Fig. 6. Radiated electric field intensity from simulation: (a) Grounding with relatively high resistance; (b) Grounding with relatively low resistance

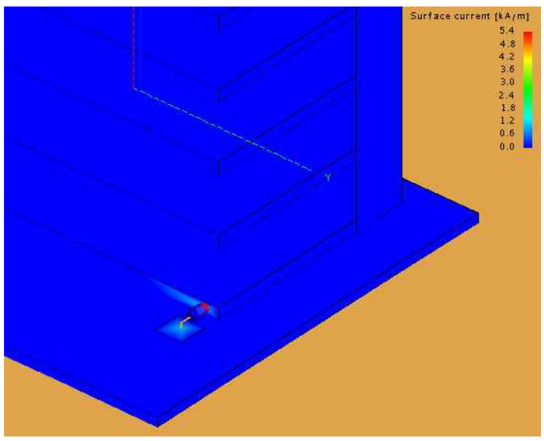
heat sink, numerical analysis is accomplished. The size of the heat sink is 100×100×40 mm (W×H×D), and a voltage source is feed at the low end of the heat sink which is the contact point of the switching device. Two multi-purpose bonding pad are applied to the corner of the heat sink as shown in Fig. 4. Simulations are accomplished for the heat sink with and without grounding over an infinite PEC plate. Also small multi-purpose bonding pads are used to connect the resistance to the ground.

Radiated electric fields are computed at 3m away from the heat sink for each case as shown in Fig. 5. The results of numerical analysis are shown in Fig. 6. It is noted that grounding with relatively low resistance reduces the radiation intensity, and with direct grounding the resonant frequency shifted to higher frequency.

Therefore, from this simulation it can be seen that grounding with 10~20 ohm gives best results for diminishing the radiation noise.



(a)



(b)

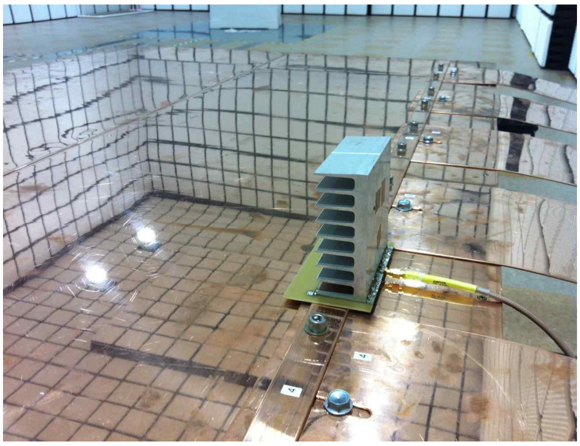
Fig. 7. Surface current distributions at 10 Ohm resistive grounding case: (a) Total view of surface currents; (b) Detailed view of surface current around the resistor connector

The surface currents of 10 ohm grounding case are shown in Fig. 7. Most of currents are localized at the feeding point and two resistor connectors. It is not quantitatively compared between the current densities of each case, but it is notable to current draining to the ground plate through the resistive loading wire, contrary to no-ground case.

The dielectric pad between the heat sink and the PEC plate is usually made of composite material whose property has good thermal conduction and good electrical insulation characteristics. Hence, besides the radiated heat the rest of the heats are conducted through the large pad from the heat sink to the PEC plate. Therefore, it is considered that the connecting resistors do not affect the heat sinking performance.

5. Experimental results

To verify the simulated results radiated electromagnetic fields are measured for some cases. In an anechoic chamber, the heat sink is set over a finite size conducting plate (2500×1200mm). Signal generator, EMC receiver, and an receiving antenna are used for the measurements. Fig. 8 shows the measurement setup. The electric field intensities are measured at 3m from the front of the heat sink shown in Fig. 5.



(a)

(b)

Fig. 8. Measurement setup: (a) Heat sink of experiment; (b) Antenna setup in an anechoic chamber

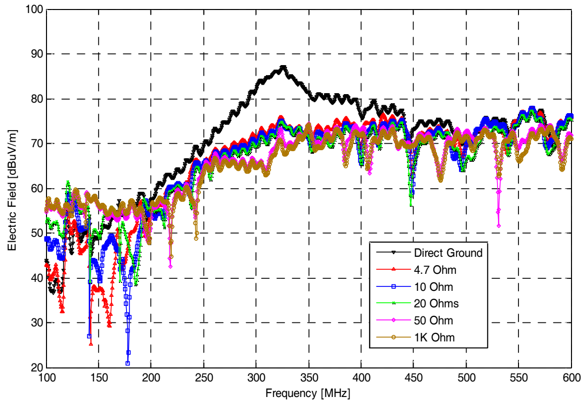


Fig. 9. Radiated electric field intensity from measurement (distance=3m, same height with the heat sink)

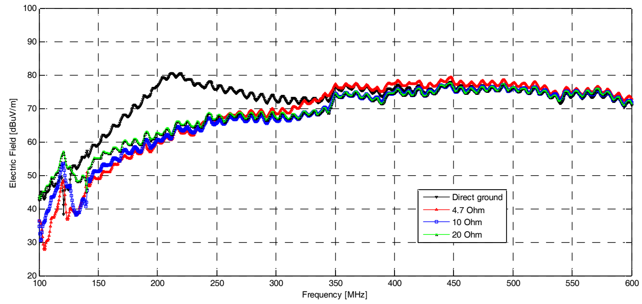


Fig. 10. Radiated electric field intensity from measurement (horizontal distance=3m, vertical distance =1m)

The measure data in general tendency are similar with the simulated one. A little discrepancy seems to come from the measurement environment such as the finite PEC plate, which was infinite in the simulation. The radiated electric fields are vertically polarized, and the data are shown in Fig. 9.

By means of grounding via resistance the radiated fields are decreased up to 12 [dB] compared to the one with direct grounding. For low resistance groundings another measurement are accomplished at a point which is 1m higher with same distance, and the radiated fields are similar with the previous one except the peak frequency as shown in Fig. 10. From the experimental data it is found that the radiated noise becomes least with resistive grounding using 10~20 ohm in the cases.

6. Conclusion

We investigated the grounding effect of heat sink with various resistive loading to reduce the radiation noise. Direct ground to the outer case without resistance is known to increase the conductive noise, and also increased the radiation noise from the experiment. However, with appropriate resistive loading we verified the effectiveness of grounding for reducing the radiation noise. In our experimental measurements, grounding with 10~20 ohm gives best results in reducing the radiation noise. The electric field intensity measured at 3m away from the heat sink are decreased up to 12 [dB] compared to the one with direct grounding. In the future step the effect of ground for the temperature should be investigated, and then this technique can be applied to heat sink of SMPS.

Acknowledgements

This work was supported by 2012 Yeungnam University Research Grant.

References

[1] C.R. Paul and k. B. Hardin, "Diagnosis and reduction of conducted noise emission," *IEEE transactions on electromagnetic compatibility*, Vol. 30, no. 4, pp. 553-560, 1988.

[2] M. Mardiguian, *Controlling radiated emissions by design*, 2nd ed., Kluwer academic publishers, Boston, USA, 2001.

[3] A. Damiano, G. Gatto, I. Marongiu, and A. Piroddi, "A heat sink model for EMI resonance frequency determination", *Power electronics specialists conference*, Vol. 1, pp. 273-277, 2004.

[4] J. F. Dawson, A. C. Marvin, S. J. Porter, A. Nothofer, J. E. Will, S. Hopkins, "The effect of grounding on radiated emissions from heatsinks, *IEEE international symposium on electromagnetic compatibility*, Vol.2, pp. 1248-1252, 2001.

[5] N. J. Ryan, B. Chambers, D. A. Stone, "FDTD modeling of heatsink RF characteristics for EMC mitigation", *IEEE transactions on electromagnetic compatibility*, Vol. 44, no 3, 2002

[6] R. Li, And L. C. Zhang, "Heatsink grounding effect on radiated emission of electronic device", *3rd international symposium on electromagnetic compatibility*, pp. 704-709, 2002.

[7] G. Felic and R. Evans, "Study of heat sink EMI effects in SMPS circuits", *IEEE international Symposium on Electromagnetic Compatibility*, Vol. 1, pp. 254-259, 2001.

[8] K. Mainali, R. Oruganti, "Conducted EMI Mitigation Techniques for Switch-Mode Power Converters: A Survey", *IEEE Transactions on Power Electronics*, Vol. 25, no. 9, pp. 2344-2356, 2010.

[9] T. Williams, "*EMC for product designers*", Butterworth-Heinemann, 2001.

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