International Symposium on Nonlinear Theory and its Applications
Xi'an, PRC, October 7-11, 2002

Comparison of EMI Performance of Full-Bridge and Half-Bridge Power Converter

A. Srisawang[†,††], S. Panaudomsup[†], and Y. Prempraneerach[†]

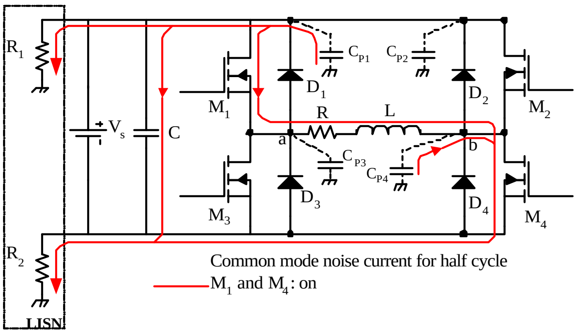
[†] Faculty of Engineering and Research Center for Communication and Information Technology
King Mongkut's Institute of Technology Ladkrabang Bangkok, Thailand. 10520
[††] Department of Electrical Engineering, Vongchavalitkul University, Nakhon-Ratchasima, Thailand. 30000
Phone: +66-2-737-3000, Fax: +66-2-739-2199
Email: srisawang@hotmail.com

Abstract: This paper investigates and compares the conducted and radiated EMI performances of full-bridge (FB) and half-bridge (HB) converter. The experimentally tested with line impedance stabilization network (LISN) and current probe can identify the EMI source parts of each converter circuit. The effects of grounding the heatsinks of power switching devices is studied and demonstrated. Experimental results of conducted and radiated EMI emission are shown the difference EMI performances of both converters are also discussed.

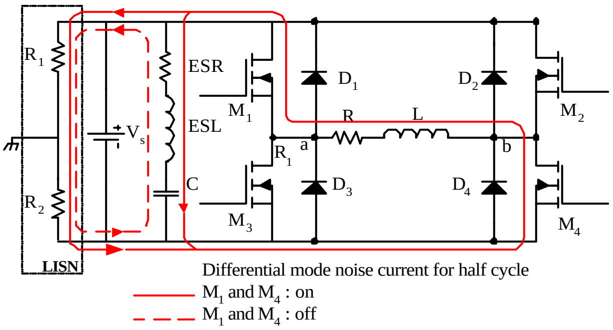
1. Introduction

A bipolar switching mode is widely used in PWM converter for a bi-directional speed control d.c. motor. The switching circuits for a bipolar switching mode are commonly used the full-bridge (FB) and half-bridge converter (HBC) circuits [1],[2]. A full-bridge converter consists of two leg of half-bridge converter [3] and is preferred over the half-bridge in higher power ratings. With the same d.c. input voltage, the maximum output voltage of the full-bridge converter is twice that of the half-bridge converter. This implies that for the same power, the output current is one-half of those for a half-bridge converter. With respect to the same output current of the two circuits, the d.c. input voltage (V_s) of a half-bridge converter must be twice of a full-bridge converter.

This paper studies the effect of the conducted and radiated EMI which occur from the switching devices in the switching cycle of both full-bridge and half-bridge converter. The knowledge of EMI source mechanism [4],[5] and its relationship to the number of switching times in the switching period is necessary to determine the essential parameters that must be modeled. Such modeling can be utilized to estimate EMI and to provide the direction for the reduction of conducted EMI in the circuit. For both the full-bridge and half-bridge converter, the switching devices, the number of switching times in the switching period and their switching waveform [6] are the three significant sources of switching noise. The conducted and radiated EMI generated from full-bridge and half-bridge converter circuit can be determined and estimated from these three parameter. Furthermore the radiated EMI of these two circuits is more investigated by varying the duty cycle of control pulse signal and the effect of grounding condition of the heatsinks of their switching devices is demonstrated. The experimental of conducted and radiated EMI measurement from these two circuits are presented as well.



(a) Shows the route of common mode current



(b) Shows the route of differential mode current

Fig.1 Full-bridge PWM converter circuit

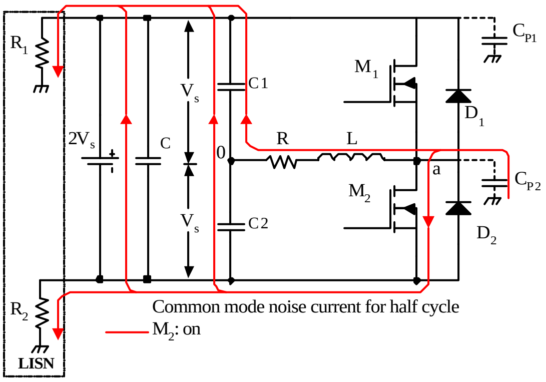
2. Full - and Half-Bridge Converter

2.1 Full-bridge Converter

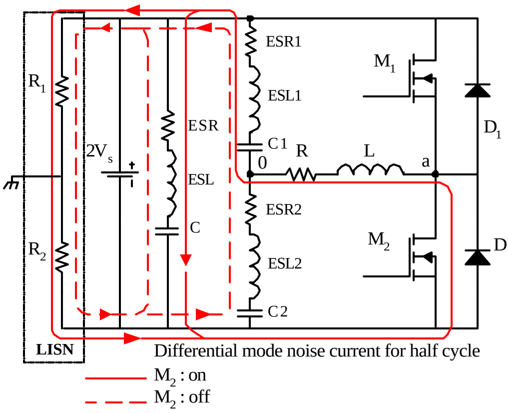
A full-bridge converter circuit is shown in Fig.1. The RL load is bridged between the junction of M_1, M_2 and M_3, M_4. A power MOSFETs M_2, M_3 are switched on simultaneously for an adjustable time during one half period; then a power MOSFET M_4, M_1 are simultaneously on for an equal time during the alternate half period. The RL load voltage is a square wave of $\pm V_s$. Its major advantage is that the maximum power MOSFET off-voltage stress is only the maximum d.c. input voltage (V_s)

2.2 Half-Bridge Converter

A half-bridge converter circuit is shown in Fig.2. The RL load is connected to junction of filter capacitors C_1, C_2. The other end is conducted to the junction of M_1, M_2 which turn on and off on alternate half cycle. The RL load voltage is a square wave of ±V_s . Its major advantage is that the maximum power MOSFET off-voltage stress is only the maximum d.c.input voltage in this case equal to $2V_s$.



(a) Shows the route of common mode current



(b) Shows the route of differential mode current

Fig.2 Half-bridge PWM converter circuit

In half-bridge PWM converter circuit has two capacitor (C_1 and C_2) are connected in series across the d.c.input and their junction is at a midpotential (or neutral potential) with a voltage V_s across each capacitor. Sufficiently large capacitances should be used such that it is reasonable to assume that the potential at point 0 remains essentially constant with respect to the negative dc bus.

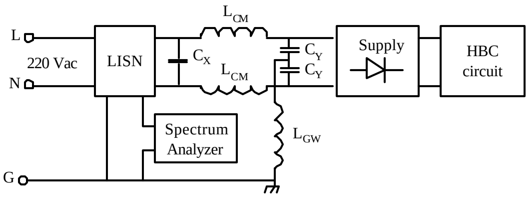


Fig.3 Improved conducted EMI of half-bridge converter circuit

3. Experimental Results

There are two experimental circuits used to investigate the effect of the conducted and radiated EMI. For the experimental each parameter of these two circuits such as switching frequency, gate voltage control, and RL load is set at the same value. With respect to the same load current of two circuits, the supply voltage (Vs) of a half-bridge circuit must be twice of the full-bridge circuit.

3.1 Conducted EMI Measurement for FBC and HBC Circuits

The scheme utilized for conducted EMI measurement in this paper is shown in Fig.4. LISN (Line Impedance Stabilization Network) is placed at the input side of the circuit under test. A spectrum analyzer is used to record the EMI profile. The conducted EMI measurement results of FBC and HBC circuits existing the R_g of each circuit is 100 Ω are shown in Fig.5.

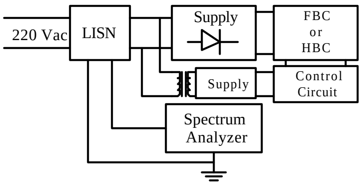
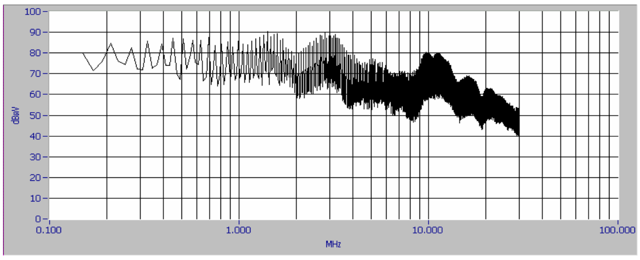
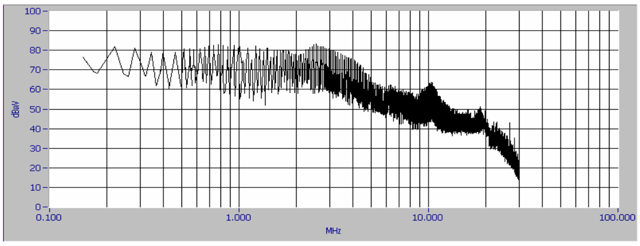


Fig.4 The conducted EMI measurement setup



(a) FBC circuit



(b) HBC circuit

Fig.5 Conducted EMI measurement results

Fig.6 shows conducted EMI measurement result of the EMI improvement for HBC circuit by increasing R_g to be 2 kΩ and added the EMI filter and L_{GW} as shown in Fig.3.

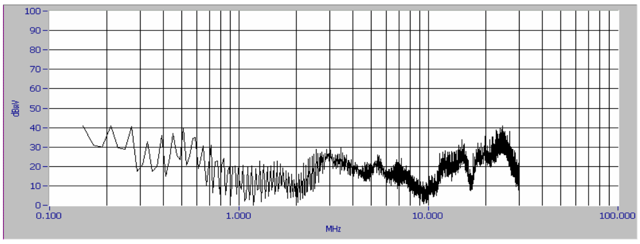


Fig.6 Measurement results of the EMI improvement for HBC circuit

Table 1, Measuring data of the conducted EMI of a five different circuits.

Circuit	R_g (Ω)	L_{GW} (mH)	Filter	Noise Frequency	Total Noise (db.μv)			Common Mode Noise (db.μv)		Differential Mode Noise (db.μv)	
					EMI	D**EMI**	**Avg.** D**EMI Reduction**	**EMI**	D**EMI**	**EMI**	D**EMI**
FBC	100	No	No	210 KHz	84	-	-	49	-	60	-
	100	No	No	1.5 MHz	90	-		49	-	52	-
	100	No	No	3 MHz	88	-		45	-	53	-
	100	No	No	10 MHz	80	-		44	-	44	-
HBC	100	No	No	210 KHz	78	-6	9.75	55	6	60	0
	100	No	No	1.5 MHz	81	-9		40	-9	52	0
	100	No	No	3 MHz	81	-7		32	-13	53	0
	100	No	No	10 MHz	63	-17		26	-18	44	0
HBC1	2 K	No	No	210 KHz	78	-6	14.25	41	-8	46	-14
	2 K	No	No	1.5 MHz	72	-18		32	-11	35	-17
	2 K	No	No	3 MHz	75	-13		32	-13	40	-13
	2 K	No	No	10 MHz	60	-20		20	-24	20	-24
HBC2	2 K	No	Yes	210 KHz	45	-39	55	24	-25	0	-60
	2 K	No	Yes	1.5 MHz	23	-67		13	-36	5	-47
	2 K	No	Yes	3 MHz	31	-57		13	-32	9	-44
	2 K	No	Yes	10 MHz	23	-57		8	-36	-3	-47
HBC3	2 K	2.8	Yes	210 KHz	42	-44	61	18	-31	8	-52
	2 K	2.8	Yes	1.5 MHz	18	-70		77	-42	5	-47
	2 K	2.8	Yes	3 MHz	25	-63		12	-33	5	-48
	2 K	2.8	Yes	10 MHz	13	-67		5	-39	-6	-50

According to improving the EMI performance of the HBC circuit can be attempted to do by modifying HBC circuit to be a three different HBC circuits as follows;

(1) HBC_1 circuit with increasing R_g to be 2 kΩ

(2) HBC_2 circuit with R_g = 2 kΩ and additional the AC power line filter.

(3) HBC_3 circuit with R_g = 2 kΩ and additional the AC power line filter and L_{GW}

The conducted EMI measurement results of the five different circuits; FBC, HBC, HBC_1, HBC_2, and HBC_3 circuit are shown in Table 1. The measuring data of the four different HBC circuits can be compared with the measurement data of FBC circuits at the four frequency points of the measuring frequency band is shown in Fig.7.

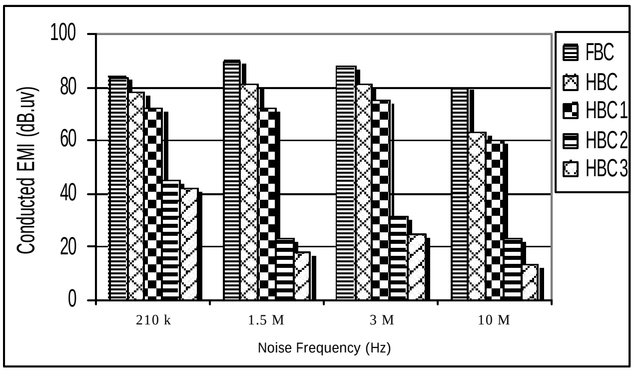


Fig.7 Comparison of conducted EMI of FBC circuit with the four different HBC circuits

3.2 Radiated EMI Measurement for FBC and HBC circuits

The scheme unitized for radiated EMI measurement in this paper is shown in Fig.8. Close field emissions are measured by moving around a close field probe in the vicinity of the EUT (FBC and HBC circuits) and the maximum level is then registered. A spectrum analyzer is used to record the EMI profile obtained in each case. The radiated EMI measurement results of FBC and HBC circuits which has the R_g of each circuit is 100 Ω are shown in Fig.9.

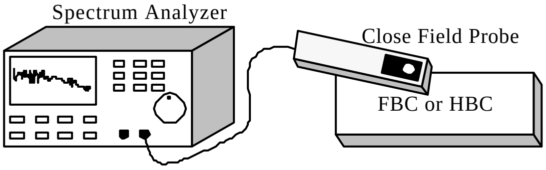
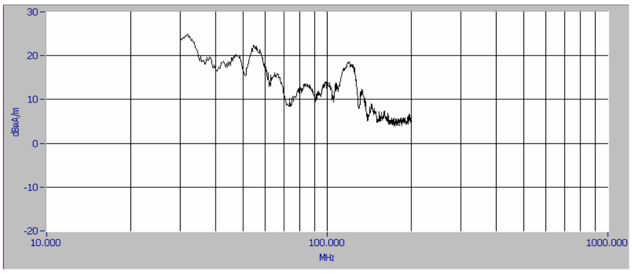


Fig. 8 The Radiated EMI measurement setup

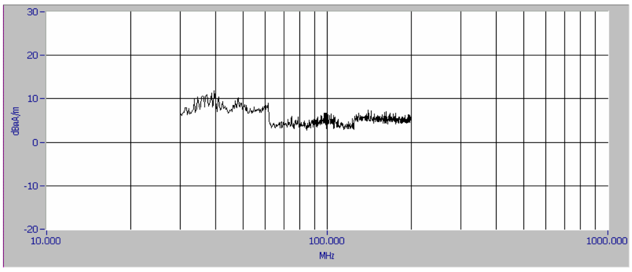
The radiated EMI of the FBC and HBC circuits as shown in Fig.9 are measured based on the duty cycle 75 percentage and the heatsinks of this switching device are floated condition. Furthermore we want to investigate the radiated EMI of these two circuits which is affected by the three conditions; changing the duty cycle, the heatsinks of their switching devices are connected directly to ground or connected vai L_{GW} to ground. The comparison the measurement data of the radiated EMI with respect to three condition of their heatsinks (floating, grounded directly, grounded with L_{GW}) of FBC and HBC circuits is shown as graph in the Fig.10, and the details of the measurement data are shown in the Table.2.

Table.2 Measurement data of the radiated EMI of FBC and HBC circuits

Circuit	**Duty Cycle** (%)	**Noise Frequency** (MHz)	**Radiated EMI** (dB.A/m)			D**Radiated EMI** (dB.A/m)		
			Heat Sink			**Heat Sink**		
			Floating	**Grounding**	L_{GW}	**Floating**	**Grounding**	L_{GW}
FBC	75	30	24	18	16	Ref.	-6	-8
		55	22	18.5	20	Ref.	-3.5	-2
		130	18	17	14	Ref.	-1	-4
	50	30	11	12	11	Ref.	1	0
		55	14	14	14	Ref.	0	0
		130	9	7	7	Ref.	-2	-2
	25	30	13	10	10	Ref.	-3	-3
		55	14	15	16	Ref.	1	2
		130	12.5	13	12	Ref.	0.5	-0.5
HBC	75	30	7	5	6	-17	-19	-18
		55	7	7	8	-15	-15	-14
		130	6	4	6	-12	-14	-12
	50	30	5	5	5	-6	-6	-6
		55	7	7	7	-7	-7	-7
		130	5	5	5	-4	-4	-4
	25	30	4	4	4	-9	-9	-9
		55	6	6	6	-8	-8	-8
		130	4	4	4	-8.5	-8.5	-8.5



(a) FBC circuit



(b) HBC circuit

Fig.9 Radiated EMI measurement results of FBC and HBC circuits

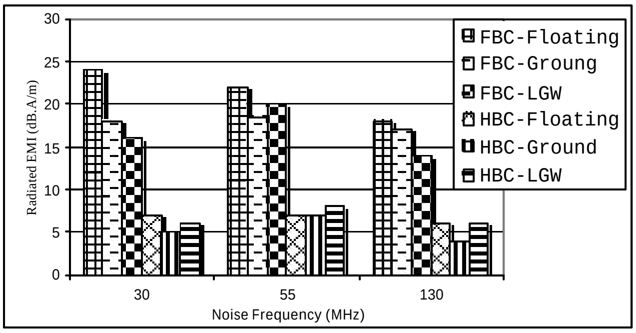


Fig.10 Comparison of radiated EMI of FBC circuit with the HBC circuit affected by heatsink grounding condition

4. Conclusion

The condition of same power output with same RL load of the full-and half-bridge converter circuits are investigated the effected of conducted and radiated EMI are presented. The experimental results, in case of conducted EMI of a half-bridge converter is less than the full-bridge converter due to the common mode noise current (i_{CM}) of a half-bridge converter is lower than i_{CM} of the full-bridge converter, however the differential mode noise current (i_{DM}) of the full-bridge converter is equal to the half-bridge converter. It is shown that the differential mode noise is dominant in both full-bridge and half-bridge converters. Consequently, radiated EMI of the half-bridge converter is essentially less than the full-bridge converter due to lower common mode noise of the half-bridge converter.

Acknowledgment

The authors would like to thank the Electrical and Electronic Products Testing Center (PTEC) in obtaining the supporting the EMI testing equipments. Mr.Arnon Srisawang, one of the authors expresses his thank to Vongchavalitkul University, Nakhon Ratchasima 30000, Thailand for the scholarship given to him and for support fund for his research.

Reference

[1] Richard M, Gowded, *Electric Drivers and Their Controls*, Oxford, 1995.

[2] Abraham, I. Pressman, *Switching Power Supply Design*, Mcgraw-hill, 1998.

[3] Ned Mohan, *Power Electronics: Converters, Applications, and Design*, John Wiley, 1995.

[4] H.W. Ott, *Noise Reduction Techniques in Electronic Systems* Second Edition, New York: John Wiley and Sons, 1988.

[5] Dennis F.Knurek, "Reduction EMI in Switch Mode Power Supplies," *in Proceeding of the Conference INTELEC.*, pp.441-420,, 1988.

[6] Nihal Kularatna, *Power Electronics Design Hand Book*, Newnes, 1998.