A Low-Profile DC-To-DC Converter for Sustain Driving Circuits of AC PDP Application Systems

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Abstract

The current paper presents the design and implementation of a low-profile dc-to-dc converter developed as a power supply for the sustain driving circuit inside large-area wall-mount ac PDP application systems. Details on the design and implementation of a 500 W prototype dc-to-dc converter, miniaturized within a 230 mm×130 mm area with a thickness of 25 mm while still achieving a 95 % conversion efficiency, are presented to demonstrate the feasibility and application potentials of the proposed low-profile dc-to-dc converter.

1. Introduction

Power supplies intended for the use in large-area wall-mount ac plasma display panel (PDP) application systems present unique engineering challenges. The power supplies should process the electrical power in an efficient way and more importantly be fabricated in a low-profile fashion. Only the power supplies meeting these requirements allow the whole PDP application system to be manufactured with thickness compatible to wall-mount applications.

The current paper presents the design and implementation of a low-profile dc-to-dc converter developed to power the sustain driving circuit inside large-area ac PDP application systems. In the proposed converter, a pulse width modulated (PWM) half-bridge circuit is operated with asymmetrical duty ratios to obtain zero voltage switching (ZVS) operation and the PCB winding-based planar magnetics are used to achieve a low-profile design. A 500 W prototype dc-to-dc converter, fabricated within a 230 mm×130 mm area with a thickness of 25 mm while still achieving a 95 % efficiency at 380 V input and 180 V output voltage, is presented to demonstrate the performance and application potentials of the proposed low-profile dc-to-dc converter.

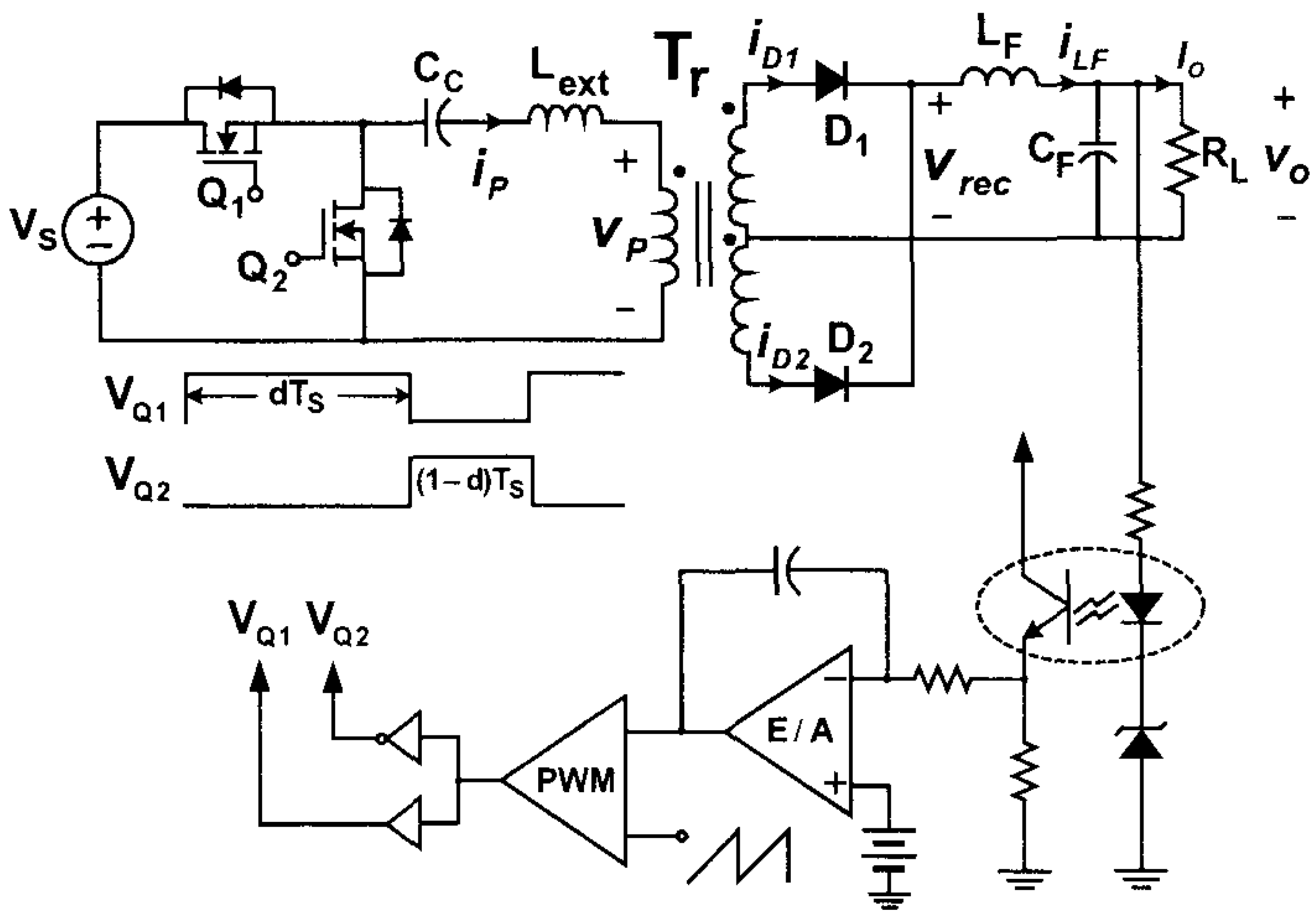


Fig. 1. Half-bridge dc-to-dc converter employed as sustain power supply.

2. Asymmetrical PWM Half-Bridge DC-DC Converter Employed as Sustain Power Supply

Fig. 1 shows a simplified circuit diagram of the dc-to-dc converter adapted as the sustain power supply. The primary side of the converter employs a half-bridge circuit switched by two asymmetrically-driven MOSFETs and the secondary side adapts a center-tapped full-wave rectifier circuit followed by a filter stage. This dc-to-dc converter, known as the asymmetrical PWM half-bridge converter, readily achieves ZVS operation without any penalty of an increased conduction loss.

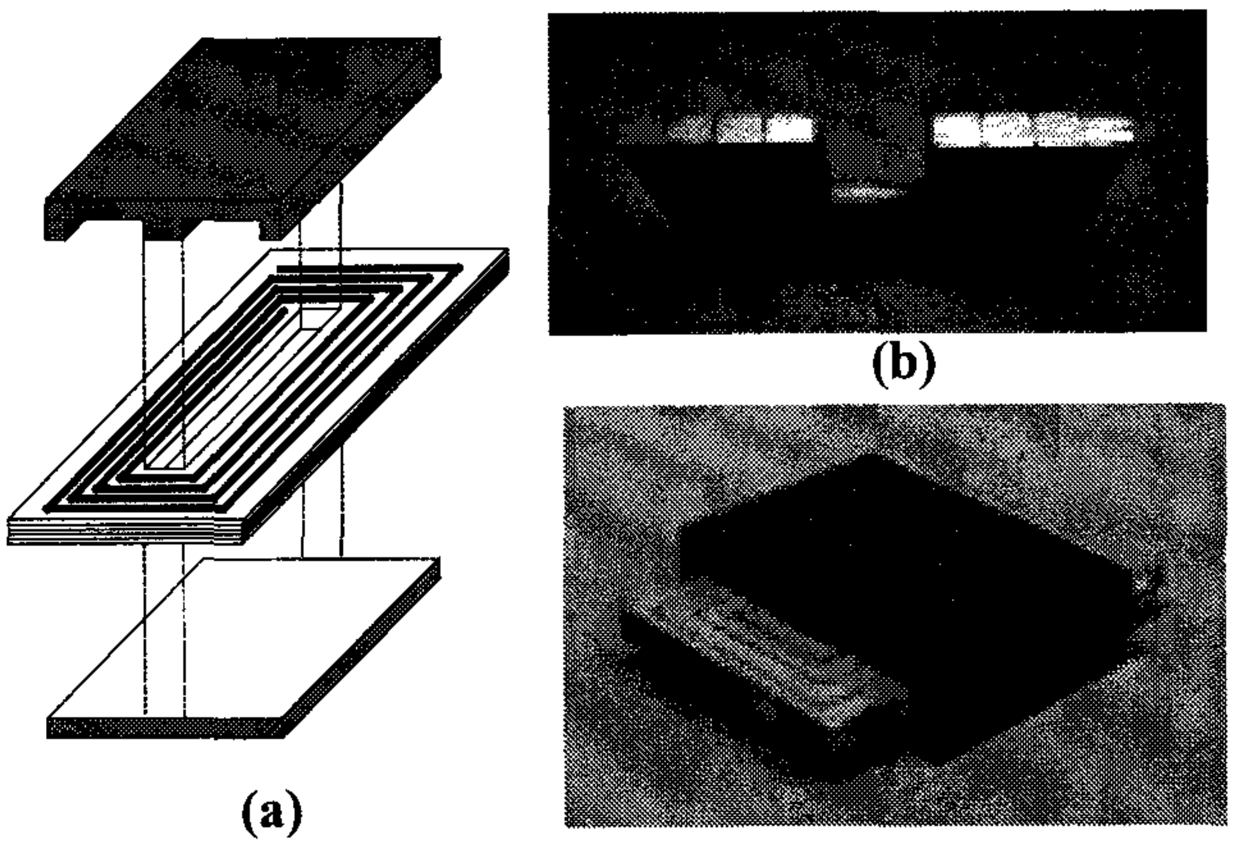
Table I: Operational Conditions and Circuit Parameters of Sustain Power Supply.

Operational Conditions	
V_S=360~380V, V_O=180V I_O=1.7~3.0 A (R_L=60~110 Ω) f_S=200kHz	
Circuit Parameters	
Power stage	Feedback controller
Q_1, Q_2 : IRFP460 C_C : 2.2 μF L_{ext} : 6.32 μH D_1, D_2 : HFA30PA60C L_F : 151 μH C_F: 450 μF	Opto-coupler: PC817 PWM IC: UC3823

This feature is particularly beneficial for the sustain power supply where both the input and output voltages are considerably high. A standard voltage-mode control using an opto-coupler and PWM IC is employed for the output voltage regulation. Operational details of the converter, particularly ZVS occurring during the dead time between MOSFET drive signals, can be found in [1]-[2]. Table I summarizes the operational conditions and circuit parameters of the prototype sustain power supply.

3. PCB Winding-Based Planar Magnetics

The most distinctive feature of the proposed sustain power supply is the use of the PCB winding-based planar magnetics [3] for all the magnetic components. Fig. 2 shows the internal structure and external shape of the power transformer used in the prototype converter. Fig. 2(a) shows an exploded view of the transformer. A multilayer PCB, in which spiral copper traces are etched on each layer, is enclosed by a pair of E-I cores. The multilayer PCB, functioning as the winding of the transformer, is referred to as the PCB winding in this paper.



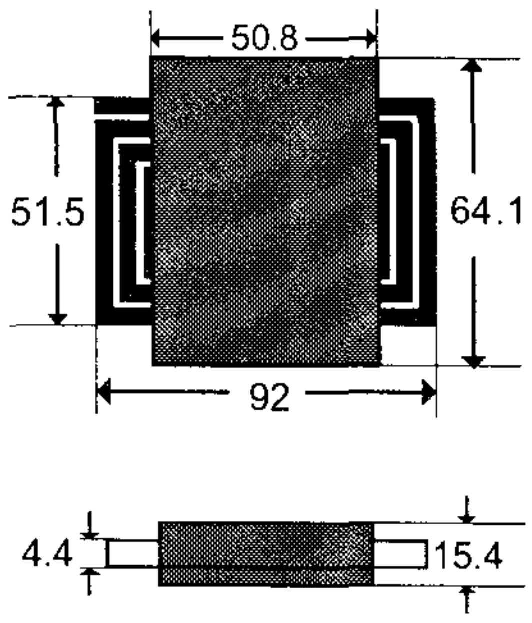
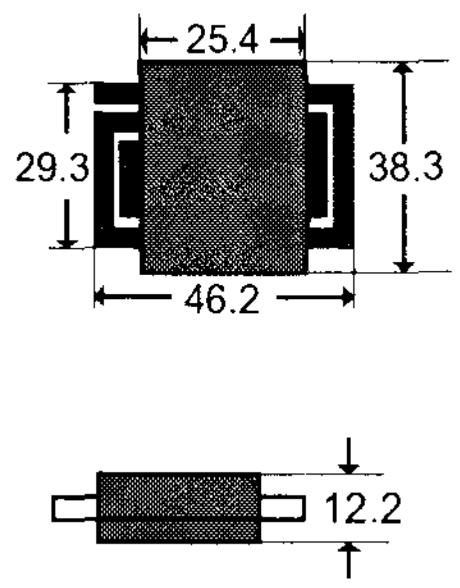
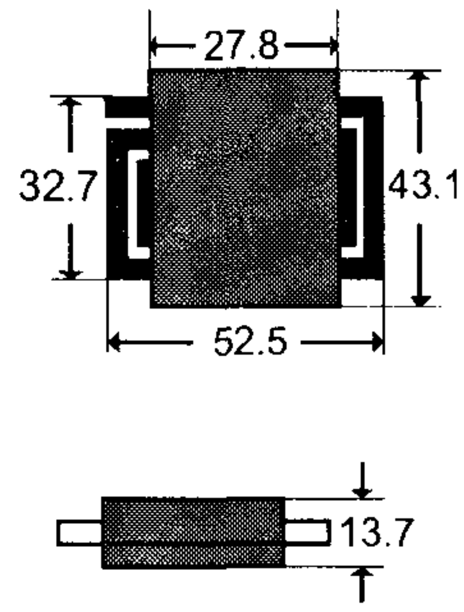
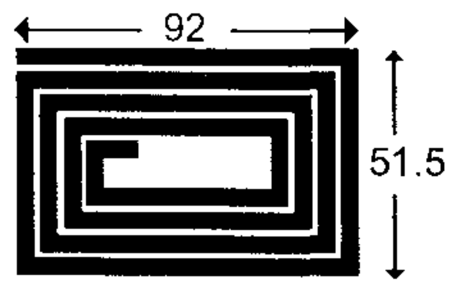
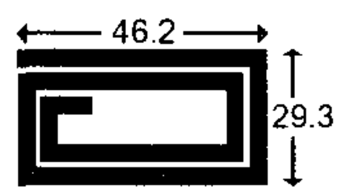
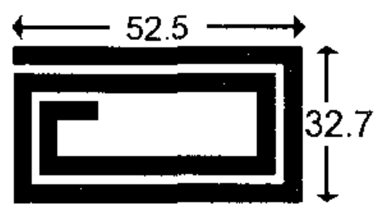
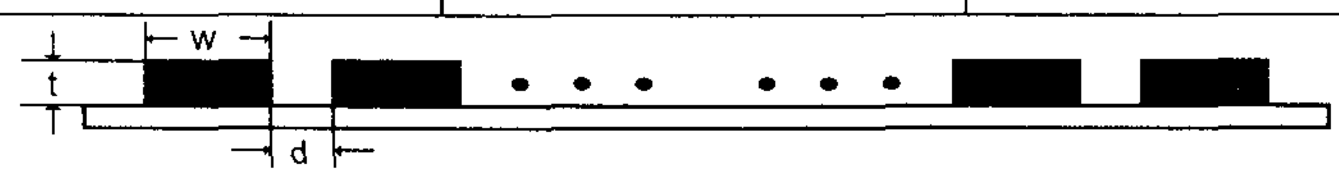
(a) (b) (c)

Fig. 2. Planar power transformer fabricated using PCB winding and planar cores. (a) Exploded view of transformer. (b) Cross-sectional view of PCB winding. (c) Overall view of transformer.

Fig. 2(b) shows the cross-sectional view of the PCB winding fabricated using a 12 layer PCB in which each layer is coated with a 4 ounce/ft^2 copper laminate. Fig. 2(c) shows the overall view of the PCB winding-based planer transformer. The other magnetic components, L_{ext} and L_F in Fig. 1, have the same structure and appearance, yet different sizes and PCB layers.

Table II shows all the engineering details about planar magnetics used in the proposed converter. The dimensions of the magnetic components are selected considering the switching frequency and output power of the converter. The ferrite cores from Ferroxcube are selected for the planar magnetic cores. The copper trace is designed in a rectangular spiral to fully utilize the window of the cores. The area and shape of the copper traces are empirically determined for the desired inductive parameters. A 4 ounce/ft^2 copper laminate is used to reduce the conduction loss in the copper trace. The separation between the copper traces is minimized using standard PCB manufacturing technique. The measured inductive parameters of the magnetic components are also listed in Table II, where L_m denotes the magnetizing inductance and L_k represents the leakage inductance of the power transformer.

Table II: PCB Winding-Based Planar Magnetic Components

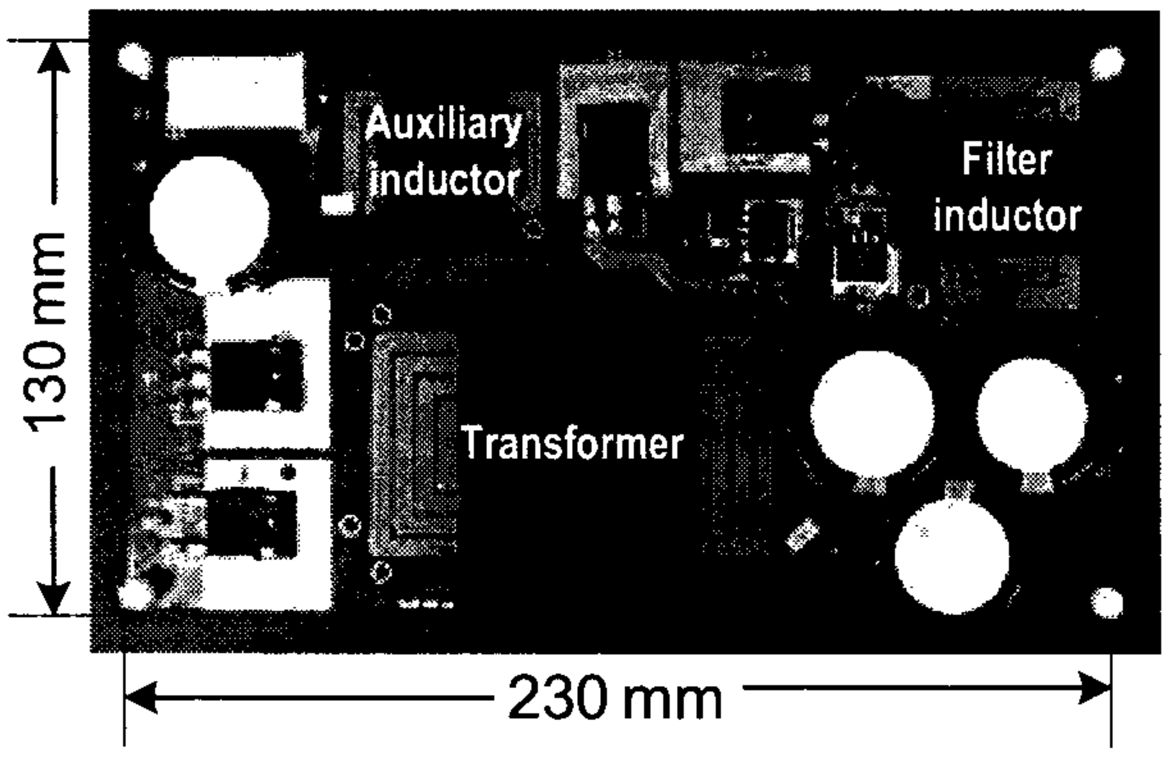
		Power transformer	Auxiliary inductor	Filter inductor
Symbol in Fig. 1		T_r	L_{ext}	L_F
Overall shape and dimensions in mm				
Cores		E64/10/50-3F3 PLT64/50/5-3F3	E38/8/25-3F3 PLT38/25/4-3F3	E43/10/28-3F3 PLT43/28/4-3F3
PCB winding	Shape and dimension of copper trace			
	Layers of copper traces	12 layers	2 layers	6 layers
		 Dimensions of copper trace		
		W = 4.2 mm	W = 4.2 mm	W = 5.3 mm
		d = 0.8 mm	d = 0.8 mm	d = 0.8 mm
		t = 140 μ m	t = 140 μ m	t = 140 μ m
Inductive parameters		L_m : 330 μH L_k : 0.68 μH	L_{ext}: 6.32 μH	L_F : 151 μH

4. Performance of Prototype Converter

Fig. 3 shows the photograph of the prototype sustain power supply. The PCB winding-based magnetic components are fabricated using the part of the PCB on which the whole dc-to-dc converter is mounted. This technique simplifies the manufacturing process and could potentially reduce the cost of the power supply. In the current hardware, the thickness of the converter is limited to 25 mm. The thickness was determined not by the height of the magnetic components but by that of the filter capacitor. A number of 150μF/400V electrolytic capacitors from Rubycon are used for the filter capacitors in the prototype converter.

The prototype converter is implemented within a $230\,mm \times 130\,mm$ area. However, since no rigorous attempts were made to minimize the area of the current hardware, the proposed converter can be further miniaturized with more elaborated circuit layouts, for example, mounting the filter capacitors above the copper traces of the PCB windings.

Fig. 4 shows the experimental waveforms of the prototype sustain power supply operating with $V_S = 380\,V$ and $I_O = 3.0\,A$. The measured waveforms exhibits a close correlations with the theoretical waveforms presented in earlier publications [1]-[2].



(a)

(b)

Fig. 3. Photography of proposed low-profile sustain power supply. (a) Top view. (b) Side view.

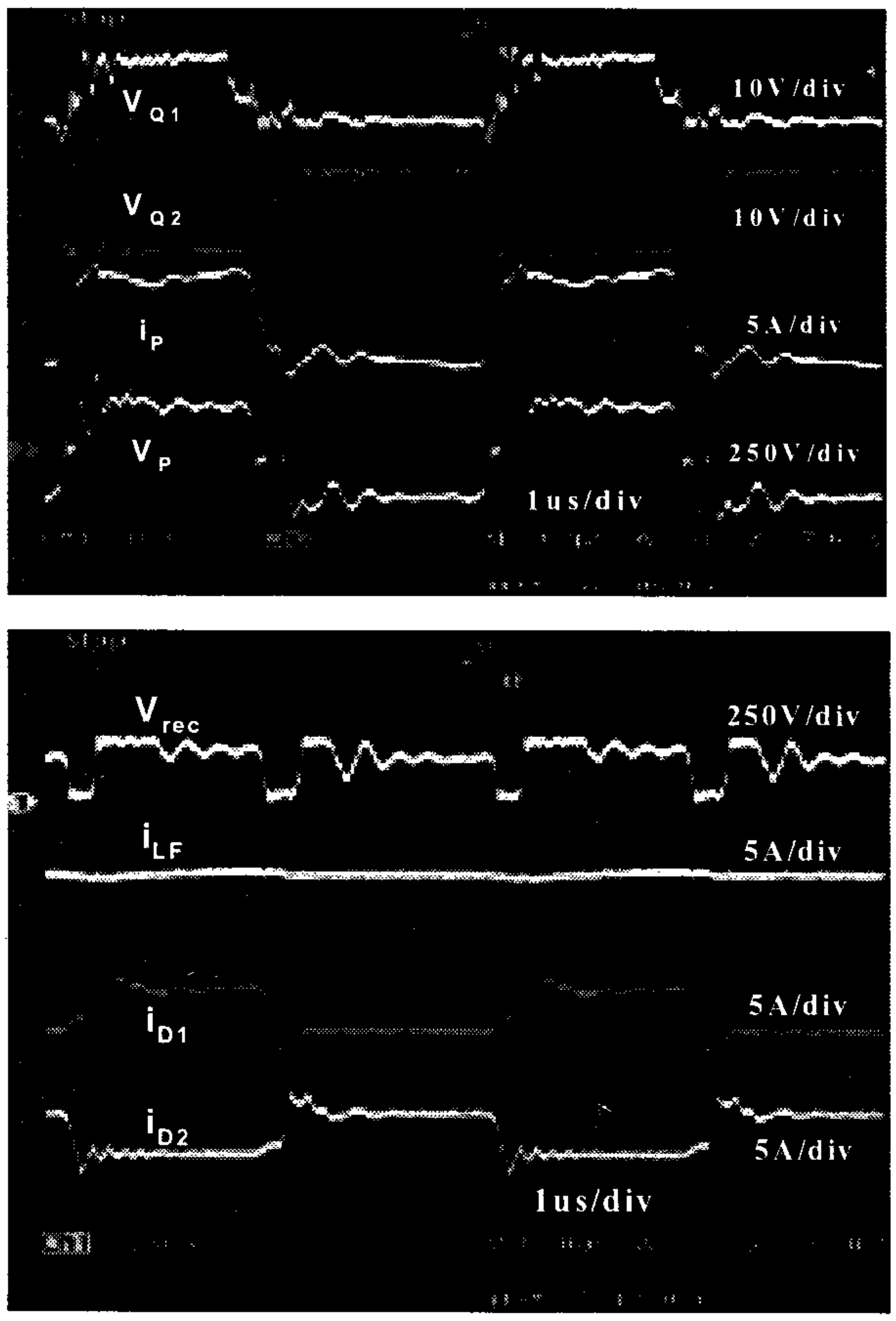


Fig. 4. Experimental waveforms of prototype sustain power supply.

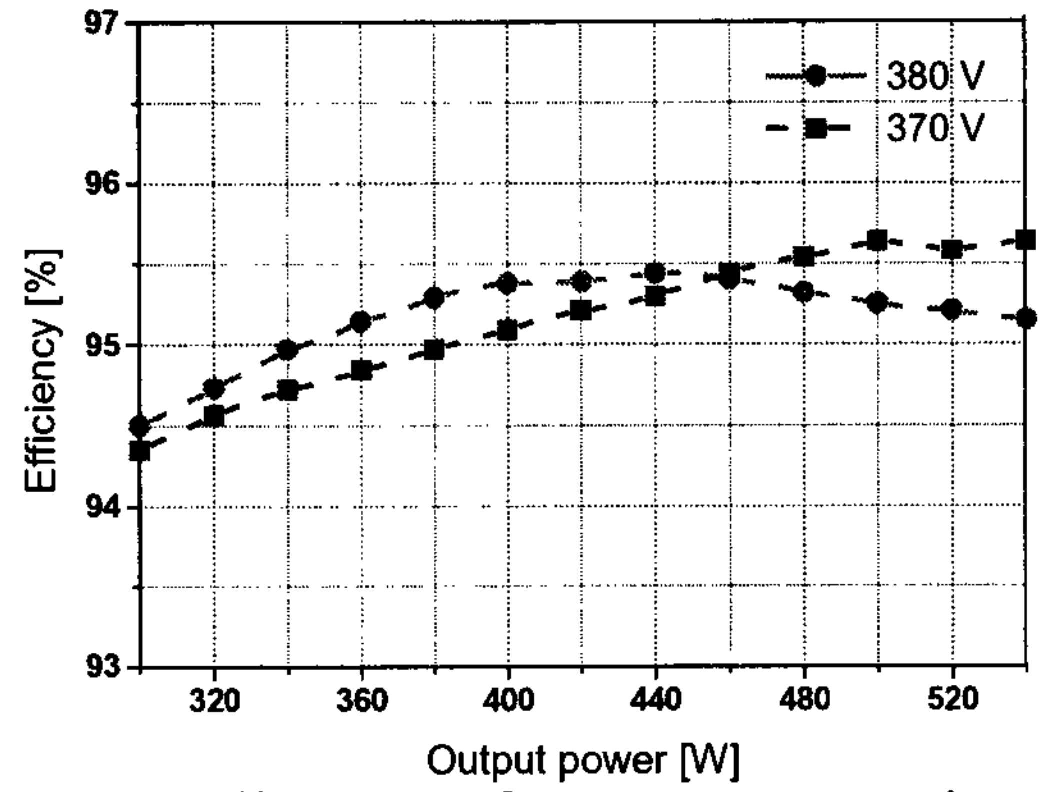


Fig. 5. Efficiency of prototype sustain power supply.

Fig. 5 shows the measured efficiency of the prototype converter. The efficiency exceeds 95 % over a wide range, thereby demonstrating application potentials of the proposed converter.

5. Conclusions

It is envisaged that the low-profile power supplies implemented using the PCB winding-based planar magnetics can be viable candidates for the application to large-area planar information displays of the future. The feasibility of such an application has been demonstrated with a prototype sustain power supply developed for ac PDP application systems.

Acknowledgement

This work was supported by the grant No. R12-2002-055-02001-0 from the Basic Research Program of the Korea Science & Engineering Foundation.

Reference

[1] P. Imbertson, and N. Mohan, " Asymmetrical Duty Cycle Permits Zero Switching in PWM Circuits With no Conduction Loss Penalty," IEEE Trans. Ind. Applica., vol 29, no. 1, pp. 121-125, 1993.

[2] R. Oruganti, P. C. Heng, J. T. K. Guan, L. A. Choy, "Soft-Switched DC/DC Converter With PWM control," IEEE Trans. Power Electron., vol. 13, no. 1, pp. 102-114, Jan. 1998.

[3] I. W. Hofsajar, J. A. Ferreria and J. D. Wyk, "Design and Analysis of Planar Integrated L-C-T Components for Converters," IEEE Trans. Power Elecron., vol. 15, no. 6, pp. 1221-1227, Nov. 2000.