A Multi-Output Half-Bridge Converter for a Plasma Display Panel

P. Pramila, K. Sundararaman, and M. Gopalakrishnan

***Abstract*—This project discusses a half bridge converter with four independent outputs for a plasma display panel application. The outputs are typically 180V/350W, 65V/200W, 19V/15W, 17V/10W. Two MOSFET switches in a single leg constituting a half bridge generate a rectangular voltage. The output is connected to the primary of a transformer, which has four secondaries. All outputs are regulated through the amplitudes of carrier and sinusoidal reference waveforms respectively. The outputs are regulated independently over a wide range by varying the amplitude of the reference waveforms used. The simulation of this converter has been and the results closely match with the expected values. Cross regulation was also found to be minimal.**

***Index Terms*—Band-pass filter, multi-output, power supplies, PWM.**

I. Introduction

For Commercial, Industrial and Military Applications, electronic equipments need converters with multiple voltages. As isolated converters increase space, cost and complexity, nowadays multi-output converters are used for obtaining several voltages. Multi-output converters are converters which have single primary stage with multiple secondary power stages. Multiple output converters can be broadly classified into two types, isolated [with transformer] and non-isolated [without transformer]. The ones with transformer can be further classified into two types, cross-regulated and post-regulated multi output converters [1]−[5]. Cross regulated converters control all output voltages using a single switch where the main output is regulated with more accuracy than the auxiliary outputs. In case of post-regulated converters, for each auxiliary output, a switch is employed so that all the outputs are regulated precisely. Cross regulated converters are more economical due to less hardware count. Both the converters have limitations, cross regulated converters due to their poorer regulation and post regulated converters due to more number of switches required. Typical examples of cross regulated converters discussed in literature are fly back converters [6], forward converters [7]-[9], and Push-Pull converters [10]. Typical examples of post regulated converters are Magamp post regulator, Secondary Side Post Regulator (SSPR) [11], [12].

Flyback converters are simple and economical as there is no need for inductors in the secondary side, but a large transformer core is needed for high power applications. Hence flyback converters are limited to low power outputs due to noise performance and inaccurate output voltages. Forward converters are more energy efficient than flyback converters and are used for medium power applications. The transformer is not required to store magnetic energy but the switch has to withstand high voltage stresses and due to large number of inductors, regulation is affected.

For better regulation, magamp circuits are used. A magamp is an inductor with a magnetic core of a closed magnetic circuit. The main task in the design of magamp is to stabilize the control loop. In case of two output converter, the regulation of the main output is done by classical approach whereas the auxiliary output is done by magamp feedback loop. By varying the duration of the blocking time of the magamp inductor, the auxiliary output is controlled. The magamp control is applied in fly back converters, forward converters, half bridge converters in medium and high power applications. However current limiting and short circuit shutdown and size are some key issues.

In order to overcome the disadvantages of magamp circuits synchronous switch post regulators (SSPR) are used. SSPR uses a MOSFET switch to regulate the auxiliary output. An SSPR has several advantages like semiconductor switch instead of saturable magnetic core, simple individual remote on-off control and high efficiency at all load conditions. Nevertheless the difficulty in implementing an effective gate drive circuit and achieving synchronization between the SSPR and the PWM of the main output and more number of switches have limited the wide use of SSPR. Different topologies of SSPR are proposed which have their own advantages and limitations.

A new category of multi output converter was proposed in [13], which regulates all outputs using Superposed Sinusoidal Pulse Width Modulation (SSPWM) and Band pass filtering. All the outputs are regulated independently without any additional switches.

The proposed converter is the extension of this topology where the parallel converter is replaced with a series converter. The proposed converter is based on multiple band modulation and demodulation. The multiple band modulation is done by comparing a triangular carrier waveform with superposed sinusoidal reference waveforms.

II. Operation and Control

A. Principle of Operation

The proposed system consists of a half bridge converter, a multi winding transformer, band pass filters and rectifiers for each output. The greatest advantage of the proposed system is

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that the voltage stresses of the switches is low and equal to the maximum dc input voltage of the converter.

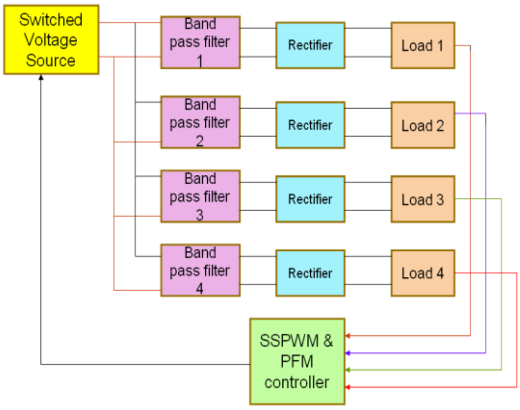

Fig. 1. Proposed multi output converter block diagram.

Another advantage is due to the blocking capacitors on the primary side, saturation problems will be less as the dc component of the current on the primary side will be almost zero. The core is also utilized more effectively since the primary is driven in both the directions from +Vin/2 to –Vin/2. The core will only be half the size of an equivalent transformer in single switched converter as the core will be operating in unipolar mode. The cost also decreases due to the transformer when compared with the single switched converters. The switches are driven by non-overlapping voltages that are out of phase by 180 degree. The waveforms of the gate voltages are made non-overlapping to avoid two switches conduct at a time. The multi winding transformer used provides several functions like dc isolation, stores magnetic energy, changes voltage levels, allows output voltages to be positive or negative and the greatest advantage is additional secondary windings and rectifiers can be added to get any number of outputs with any polarity. The Multiple frequency components are generated by SSPWM. The block diagram of proposed converter is shown in Figure 1. Four different sinusoidal waveforms are combined to form one sinusoidal reference waveform. This sinusoidal reference waveform is compared with the triangular carrier waveform to create pulse width modulated signal which is fed to the switches of the converter. The dominant frequencies are controlled by SSPWM. The dominant frequencies are ω_{sw}, ω_{r1}, ω_{r2} and ω_{r3}.

The carrier signal frequency is ω_{sw}. The sinusoidal reference waveform one frequency is ω_r. The sinusoidal reference waveform two frequency is ω_{r2}. The sinusoidal reference waveform three frequency is ω_{r3}. As shown in the block diagram each of the band pass filters are designed for different frequencies.

B. Control Method

Four different band pass filters are used. Band pass filters are designed with respect to the dominant frequencies used. The center frequency of band pass filter 1 is designed at carrier signal frequency. The center frequency of band pass filter 2 is designed at sinusoidal reference 1 frequency. The center frequency of band pass filter 3 is designed at sinusoidal reference 2 frequency. The center frequency of band pass filter 4 is designed at sinusoidal reference 3 frequency.

The frequencies of the band pass filters are chosen such that the difference between them is high enough such that interactions between them can be avoided. ω_1 is the resonant frequency of band pass filter 1. ω_2 is the resonant frequency of band pass filter 2.

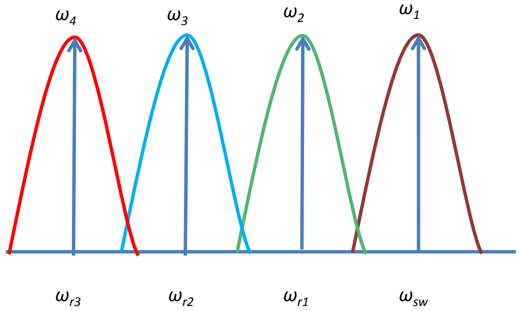

Fig. 2. Combination of band pass filters and dominant frequencies.

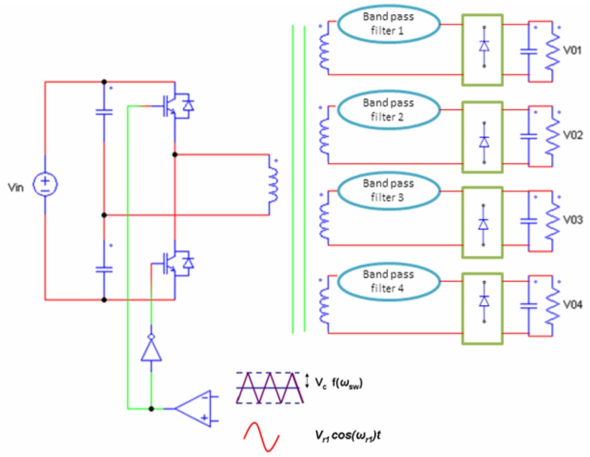

Fig. 3. Simplified multi output converter.

ω_3 is the resonant frequency of band pass filter 3. ω_4 is the resonant frequency of band pass filter 4. By varying the amplitude of carrier signal, the sinusoidal reference waveforms and by varying the transformer turns ratio, the output voltages are controlled.

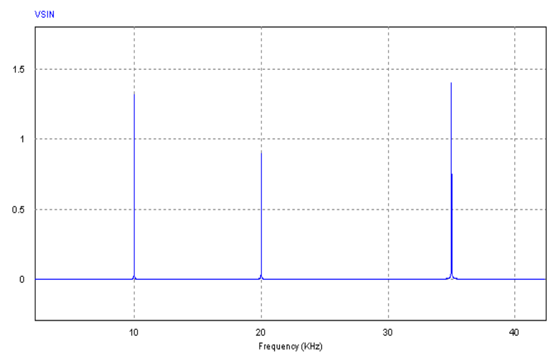

Fig. 4. FFT of superposed sinusoidal signal.

Fig. 2 shows the pattern of frequencies for which band pass filters are designed. The simplified half bridge multi output converter is shown in Fig. 3. The voltage in the primary side of the transformer is generated through comparison between the carrier triangular wave and the reference sinusoidal signal. With respect to the transformer's turns ratio, the voltage on the secondary side of the transformer differs. The result of FFT of the superposed sinusoidal signal will show only the dominant frequencies which is shown in Fig. 4.

TABLE I: CIRCUIT PARAMETERS OF PROTOTYPE SYSTEM

Parameters	Values
V_{in}	400 V
V_{01}	180 V
V_{02}	65 V
V_{03}	19 V
V_{04}	17 V
$N_P:N_{S1}:N_{S2}:N_{S3}:N_{S4}$	2 : 5 : 8 : 4 : 5
L_1	12 µH
L_2	612 µH
L_3	2000 µH
L_4	7000 µH
C_1	33 nF
C_2	33 nF
C_3	33 nF
C_4	33 nF
C_{01}	470 µF
C_{02}	300 µF
C_{03}	300 µF
C_{04}	300 µF

Similarly the FFT of primary voltage of the transformer will be providing the dominant frequency including the carrier signal frequency, which is shown in Fig. 5. The greatest advantage of this circuit is any number of outputs can be obtained from this circuit.

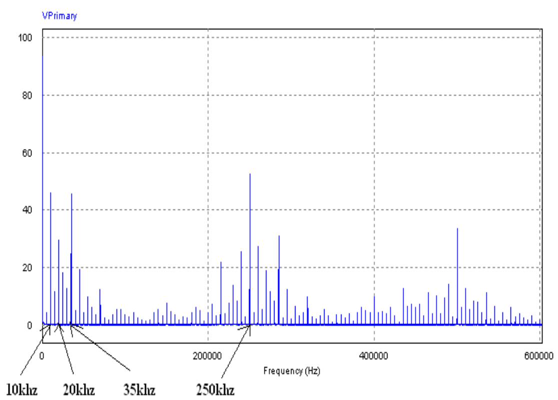

Fig. 5. FFT result of primary voltage.

C. Formula Used

The series resonant branch is used for the band pass filter. The frequency of the series resonant branch is given by equation (1)

$$F = 1/(2\pi\sqrt{LC}) \qquad (1)$$

where

F - Resonant frequency of the filter in Hertz.

L - Inductance of the filter in Henries.

C - Capacitance of the filter in Farads.

III. SIMULATION RESULTS

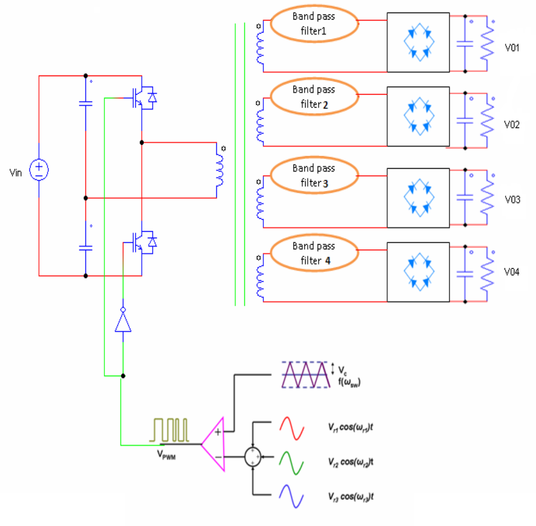

Fig. 6. The structure of prototype system.

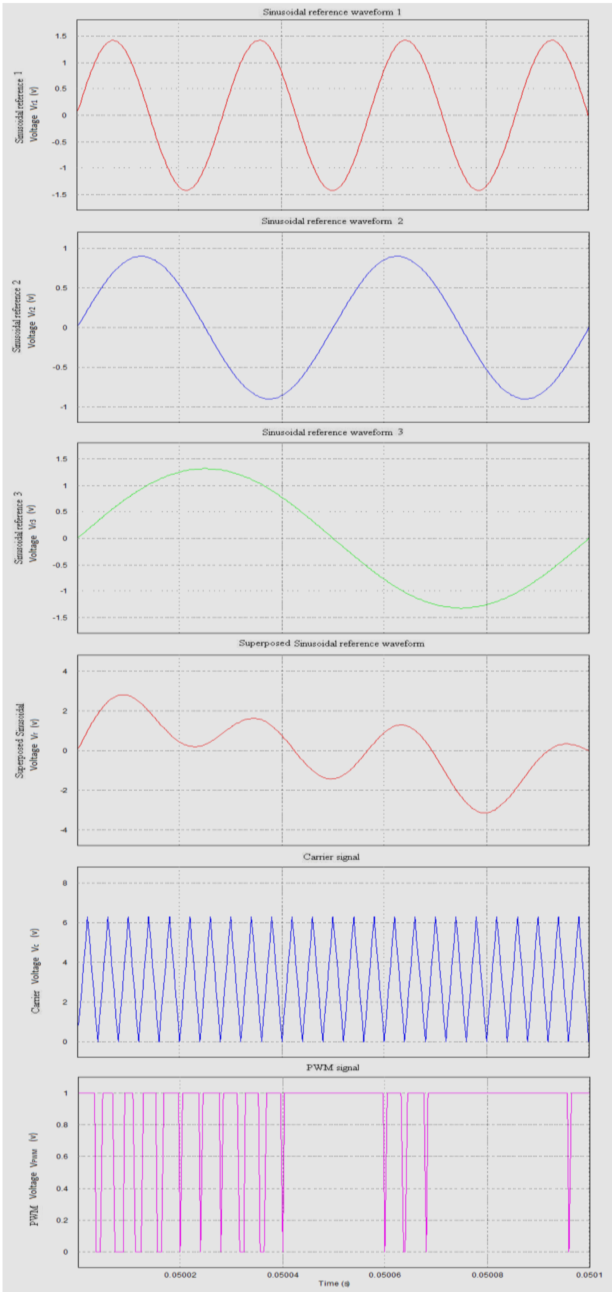

Fig. 7. PWM signal generation.

The prototype system is done for a 570W Plasma Display Panel Power System.

The main output stage and the auxiliary output stages are composed of a series resonant branch filter and a full wave rectifier.

The simulation diagram of the prototype is shown in Fig. 6. The PWM signal generation and the voltage waveforms are shown in the Fig. 7.

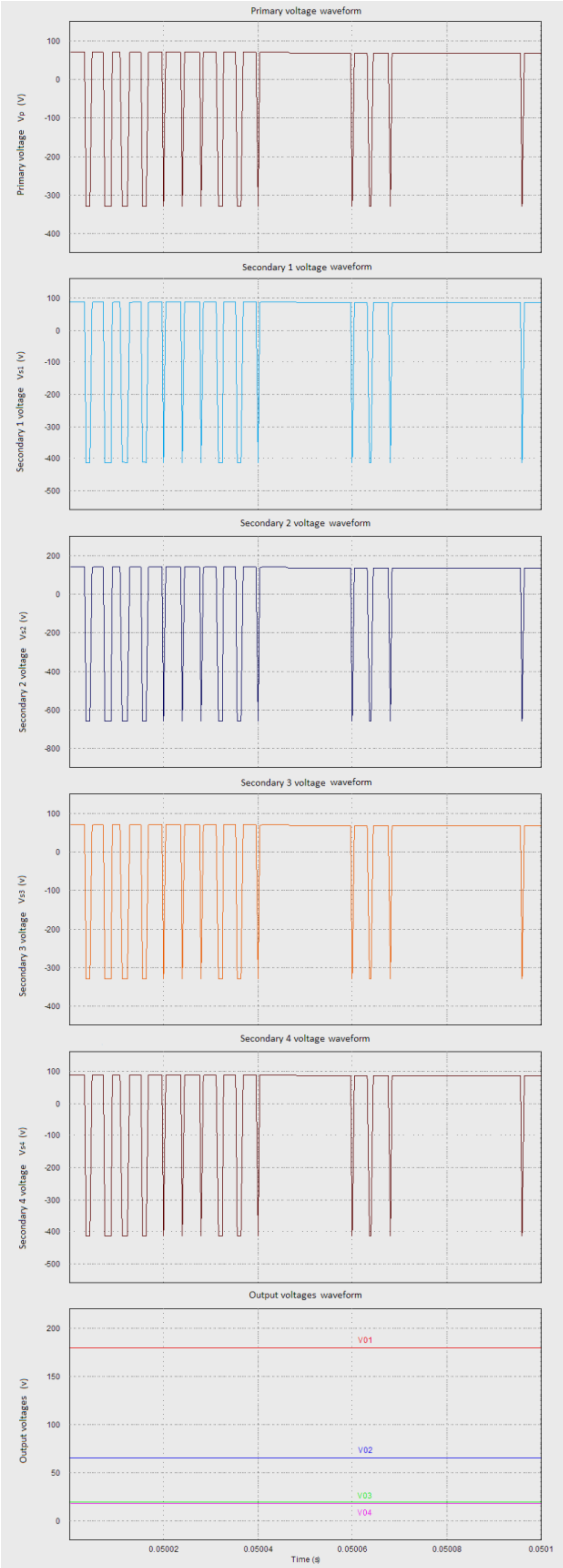

Fig. 7. Voltage waveforms.

IV. Conclusion

A multi output converter with four outputs for a plasma display panel was simulated. This configuration consists of two MOSFET switches to achieve four outputs. All the outputs are independently controlled through transformer's turn's ratio and amplitudes of carrier and sinusoidal reference waveforms. Hence it can operate with effective regulation. Simulation results were obtained, which shows that cross regulation is minimal.

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