SWITCH MODE POWER SUPPLY

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ABSTRACT

For many years the world of power supply design has seen a gradual movement away from the use of linear power supplies to the more practical switched mode power supply (S.M.P.S.). The linear power supply contains a mains transformer and a dissipative series regulator. This means the supply has extremely large and heavy 50/60 Hz transformers, and also very poor power conversion efficiencies, both serious drawbacks. Typical efficiencies of 30% are standard for a linear. This compares with efficiencies of between 70 and 80%, currently available using S.M.P.S. designs.

This paper presents an overview of such a design project and the performance results.

1. INTRODUCTION

By employing high switching frequencies, the sizes of the power transformer and associated filtering components in the S.M.P.S. are dramatically reduced in comparison to the linear. For example, an S.M.P.S. operating at 20kHz produces a 4 times reduction in size, and this increases to about 8 times at 100kHz and above. This means an S.M.P.S. design can produce very compact and lightweight supplies. This is now an essential requirement for the majority of electronic systems. The supply must slot into an ever-shrinking space left for it by electronic system designers.

In our project we are concerned with designing a circuit selecting a suitable topology to reduce the size of the supply while increasing the efficiency. In so doing, we try do reduce the overall cost of the circuit as much as possible. Considering the advantages we are designing an isolated category in which a high frequency ferrite transformer plays a major role.

2. BASIC FUNCTION

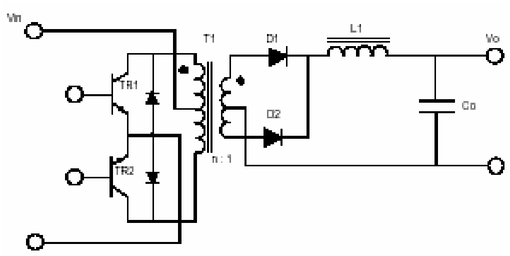

Fig. 1 Push-Pull Converter

The dc supply is fed directly to the high frequency power switching section. Fast switching power semiconductor devices (in our case MOSFETs) are driven on and off, and switch the input voltage across the primary of the power transformer. The drive pulses are normally fixed frequency (20 to 200kHz; we selected 50kHz) and variable duty cycle. Hence, a voltage pulse train of suitable magnitude and duty ratio appears on the transformer secondaries. This voltage pulse train is appropriately rectified, and then smoothed by the output filter, which is a capacitor / inductor arrangement.

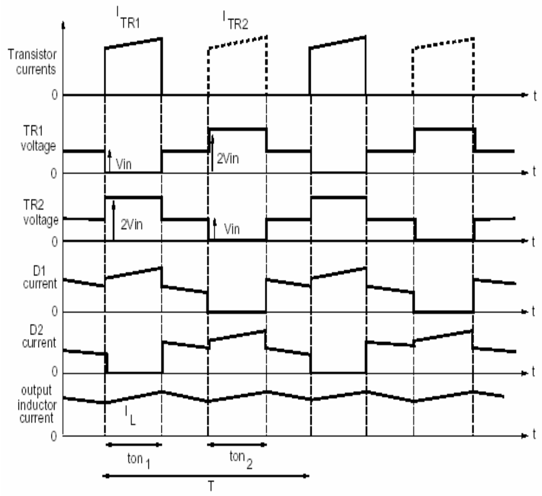

Fig. 2 Push-Pull Waveforms

This transfer of power has to be carried out with the lowest losses possible, to maintain efficiency. Thus, optimum design of the passive and magnetic components, and selection of the correct power semiconductors is critical.

3. DESIGN & IMPLEMENTATION

The basic specifications of the power supply are as follows.

Input voltage =12V
Output voltage =325V
Output power =50W
Input/output isolation.

3.1 PWM Controller

In our circuit we have to drive two MOSFETS at the same time. The driver circuit output is such that only one of the MOSFET is in the ON-state at any time.

This is achieved by producing an output signal using a suitable IC. Considering the features we selected SG3525AN.

We selected the switching frequency to be 50kHz. Values of R_t and C_t were selected to obtain this frequency. A variable resister is connected to the circuit so that by tuning it ON-state duty factor can be varied. The pulses from outputs A and B drive the two MOSFETs.

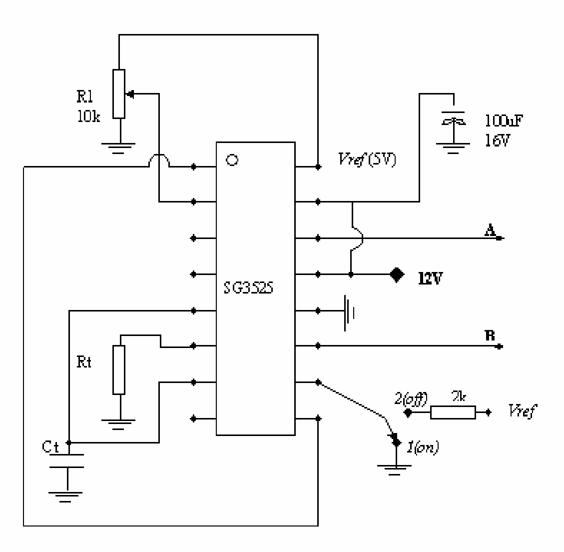

Fig. 3 PWM Controller Circuit

3.2 Power Semiconductors

The most common power semiconductors used in the SMPS are the bipolar transistor, the power MOSFET and IGBT. The Bipolar transistor is normally limited to use at frequencies up to 30kHz, due to switching loss. However, it has very low on-state losses and is a relatively cheap device, making it the most suitable for lower frequency applications.

The MOSFET is selected for higher frequency operation because of its very fast switching speeds, resulting in low (frequency dependent) switching losses. The driving of the MOSFET is also far simpler and less expensive than that required for the Bipolar. However, the on-state losses of the MOSFET are far higher than the Bipolar, and they are also usually more expensive. The selection of which particular device to use is normally a compromise between the cost, and the performance required. Considering the features and the requirement of our circuit, we selected IRF540 low gate charge MOSFETs.

3.3 Ferrite Core

Transformer core selection is usually done by solving two equations simultaneously. But a chart called E-core selector chart is available which is derived by using these equations. This chart shows how a factor that represents power handling capacity in magnetic cores varies with switching frequency. We used this chart and selected E42 to be used in the transformer design.

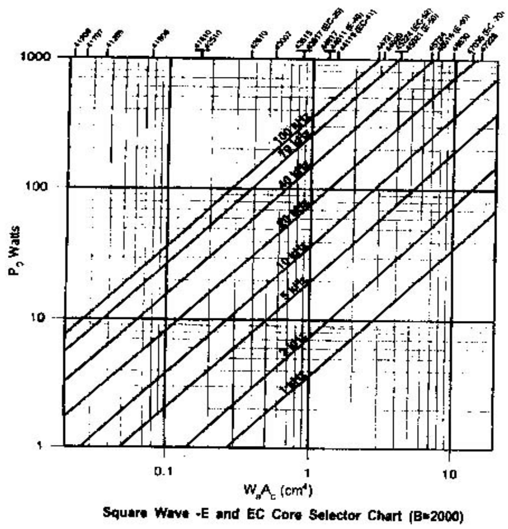

Fig.4 E core selector Chart (B=2000)

3.4 Transformer

Having selected suitable E-cores and bobbin for our requirement we wound the coils tightly enough not to leave space in between. We also tried to minimize the leakage inductance as much as possible. Both primary and secondary are center tapped with primary carrying 4 turns each and secondary 120 turns each.

3.5 Rectifier

For higher frequency and voltage outputs the most suitable rectifier is the fast recovery epitaxial diode (FRED). This device has been optimized for use in high frequency rectification. Its characteristics include low V_F (approx. 1V) with very fast and efficient switching characteristics. The FRED has reverse voltage blocking capabilities up to 800V.

With center-tapped secondary we used half bridge arrangement for rectification. Then a filter smooths the output to reduce the ripple.

4. PERFORMANCE AND RESULTS

Our circuit is given the supply of 12V dc from a battery. PWM controller also uses the same supply and produces pulses of 50kHz. Two sets of such pulses observed (and drawn using a plotter in the laboratory) with different values of duty factor are shown in figure 5.

The upper graph shows a waveform with a duty factor of 4.5 while the lower a very low duty factor. With this variable duty factor, the output voltage ranges between 0 and 240V. Maximum power the supply can deliver without exceeding safe thermal limits is 40W.

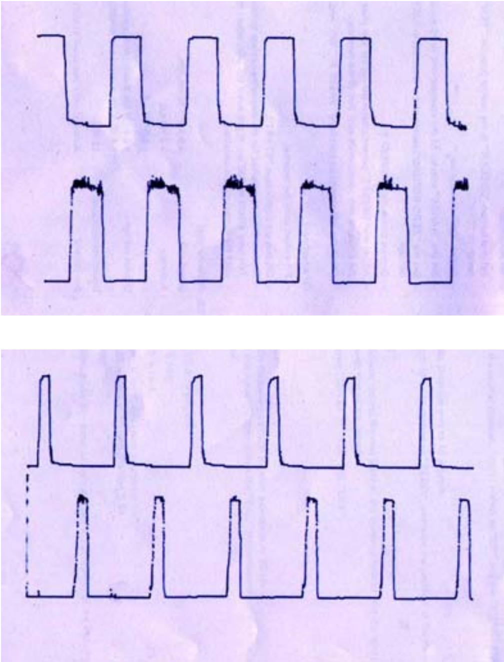

Fig. 5 PWM Controller Output

Though the circuit produces a less-ripple dc output, due to the spikes in the voltage across the power MOSFETs, they get heated up when the circuit is operated for a long time. Snubber circuit for each MOSFET needs to address this problem.

5. CONCLUSION

This is a first part of a project in which we achieved DC to DC conversion that can be inverted to get AC output.

In this project we undertook the transformer design and the winding. It paved the way for us to gain additional knowledge and experience on this area.

Since the core had a very small air gap in the central limb, it increased leakage inductance. This brought in some spikes on the voltage waveforms to aggravate heating of MOSFETs and thus demanding snubbers.

Further, by doing such a project which is related to power electronics we gained a lot of knowledge and experience which we can make use of it to work on complicated projects in the industry.

6. ACKNOWLEDGEMENTS

First we would like to thank Dr. J. P. Karunadasa for guiding us throughout the project by giving necessary information whenever we faced problems.

It is our duty to thank the Research and Development engineer M. K. S. C. Kumara, Ceyenergy Electronic company (Pvt) Ltd for giving us necessary guidance and support towards the project.

We would also like to thank Mr. J. D. Leelasiri, the technical officer of the electrical machines laboratory for providing the necessary equipment and helping us in numerous ways.

7. REFERENCES

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