FETs ENHANCE SWITCHED-MODE DESIGNS

ABSTRACT

Switched-mode power supplies are well known for their high levels of efficiency and for their compactness. Further improvements can be effected by employing power MOSFETs in place of conventional bipolar transistors. A practical design for a 5V, 20A supply is suggested utilizing the SG1526.

Many of the basic design concepts relating to power MOSFETs were outlined in an earlier article "Designing with power MOSFETs," which was published in the March, 1982 issue of Electronic Product Design.

Now let us apply some of the driver techniques discussed in the earlier article, to a 100kHz, 100W switched-mode power supply. Fig. 1 shows the circuit which is truly universal in that it operates directly from a mains voltage spanning 85V to 265V r.m.s. without any mechanical switching requirements. And furthermore, it is able to perform this task over a wide frequency spread, typically from 50 to 400Hz.

SIMPLICITY OF DESIGN

At the centre of the design is a 500V, 3A power MOSFET (Q1) which converts the rectified mains voltage into a tightly-controlled 100W d.c. output. Apart from the indicated rectifiers and Zener diodes, the power FET and its regulating pulse-width modulated driver IC (SG1526) are the only active devices needed to achieve a full-load efficiency of 74 per cent with ±0.5 percent regulation. This particular design has a maximum output current of 20A d.c. at 5V with a maximum ripple of 50mV pk. -pk. Transient response for a step change of 10A load current is 500mV, settling within 250μs.

MORE EFFICIENT

For a given combination of voltage and current ratings, power MOSFETs can generally switch more efficiently and at much higher frequencies than their bipolar counterparts. Because power MOSFETs can be operated at higher frequencies, smaller transformers and filter capacitors can be used leading to more compact designs. The circuit shown in Fig. 1, for example, operates at 100kHz, some two and a half times faster than most circuits using bipolar transistors.

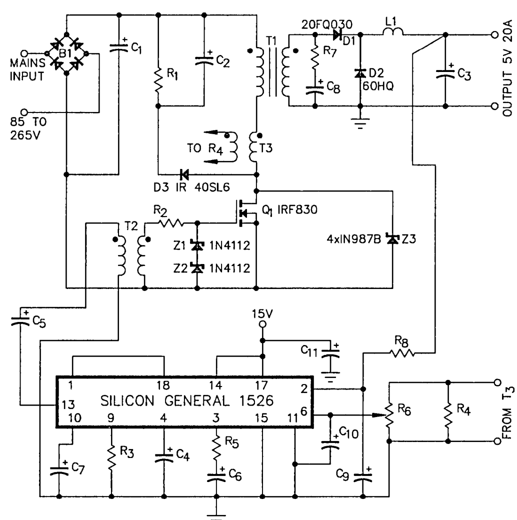


Figure 1. Versatile 100W Switched-Mode Power Supply Offers 20A Output with 75 Percent Efficiency and a Tight Performance Spec.; See Text for Details.

The higher operating frequency also enables the circuit to recover much more quickly from severe line or load variations. This is especially important in situations where a system's power-up signal is used to reset a large number of logic devices simultaneously.

Driving a power MOSFET is in most cases much easier than driving an equivalent bipolar device, it being voltage rather than current driven. Some gate drive is of course required, but at a much lower level than that associated with similarly-rated bipolar devices.

MODIFICATIONS

The power MOSFET is not directly compatible with the bipolar power transistor and cannot be used in a switched mode circuit without modification.

Irrespective of the power switching device used, be it a MOSFET or a bipolar power transistor, the associated pulse-width modulated switcher cannot normally be left on for more than 50 per cent of the total duty cycle. Under normal circumstances, a 50 per cent on time occurs only when the input voltage is very low and the output current is high. Conversely, the shortest on times occur when the input voltage is near to its peak and the output current is minimal.

Ideally, the pulse-width modulator should operate over a very wide duty cycle range to ensure close regulation with wide line and load extremes. Unfortunately, it has been impracticable to implement this approach in bipolar designs, since the gain of bipolar transistors decreases rapidly when operated in the short-pulse, high-current mode.

A power MOSFET's transconductance, on the other hand, does not vary so widely with current changes. This makes it much easier to drive a MOSFET directly, using a short duty cycle. Furthermore, the short conduction time at high input voltage leaves a relatively long time to reset the associated transformer and thus reduce the peak voltage across the MOSFET. Also the designer is able to use 500V rated devices in mains driven supplies in contrast to the usual 800V rating often needed for circuits featuring bipolar devices.

PROTECTION

Some protection is of course necessary. The MOSFET shown in Fig. 1, for example, features clamping diodes (Zener diodes 1 and 2) to limit the circuit's maximum gate voltage to 18V. Zener 3 which comprises four series-connected 120V diodes, restricts the source/drain swing to 450V to give a safe working margin.

The resister/capacitor/diode snubber formed by $R_1/C_2/D_3$ conforms in the principle to the approach outlined in the earlier article, except that it is allowed to float. For more details on this and other related topics, refer to International Rectifier's application note AN-939.

Trials have shown that worst-case efficiency occurs at virtually maximum input voltage with minimum loading. Here efficiency drops to just under 70 percent, compared with 76 percent at maximum output. Dissipation is thus around 8W at maximum output and slightly higher than this value when the supply is lightly loaded.

OPERATION

The off-screen photographs show how the circuit functions. Fig. 2 demonstrates how the pulse-width modulator controls the MOSFET's conduction time with respect to various load and line conditions. At one extreme, the input voltage is down to 85V, while output is at 20A. Fig. 2a shows the MOSFET on for 4us which gives a duty cycle of approximately 44 percent. When operating at the other extreme, ie 265V input and 5A output, the MOSFET is on for approximately 1us, which corresponds to a 10 percent duty cycle. Note how the gate/source waveforms which are depicted in Fig. 3 relate to the operating levels shown in Fig. 2.

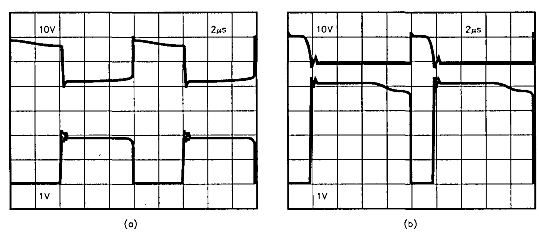


Figure 3. Gate/Source Waveforms. These Were Recorded with the Unit Under Full Load, (a) with a Line Voltage of 85V and (b) with a Line Voltage of 265V. The Upper Traces Show Gate/Source Voltage While the Lower Show Drain Voltage.

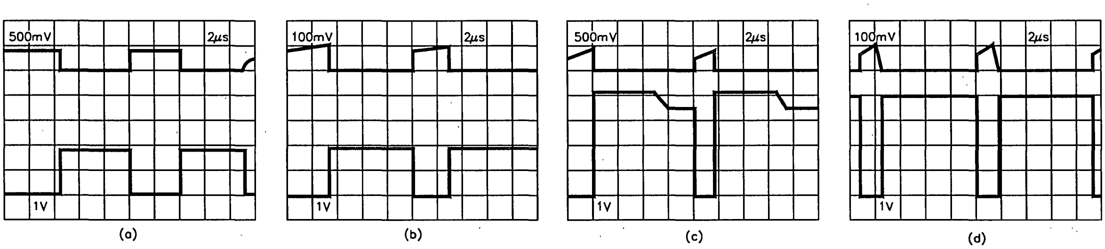
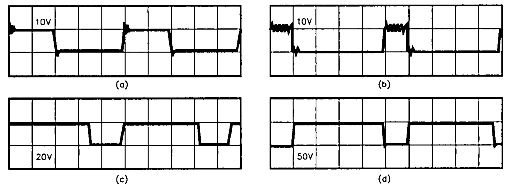


Figure 2. Switching Waveforms. With an 85V Line and a 20A Load (a) Shows Drawn Current on the Upper Trace and Drain Voltage on the Lower. The Load is Cut to 5A in (b), While (c) and (d) Show the Same Parameters at a 265V Line Voltage with Respective Loads of 20A and 5A.

Typical voltage waveforms across the output rectifiers are shown in Fig. 4. Note that while the forward rectifier D1 blocks a peak voltage (including the commutation transient) of about 12V, D2 has to withstand around 75V for a 5V output, due to the short conduction cycle. Both of these diodes contribute to the system's net losses. Indeed, these devices dissipate some 30 to 50 percent of the switching energy, and represent a major problem in designing low output voltage power supplies. Losses from the rectifier diodes are approximately the same for both the 5 and 15V supply designs.



TRACE	PARAMETER	CONDITIONS	VERTICAL	HORIZONTAL
a	D_1 VOLTAGE	35V LINE	10V/DIV	
b	D_2 VOLTAGE	5A LOAD	20V/DIV	2μ SEC/DIV
c	D_1 VOLTAGE	265V LINE	20V/DIV	
d	D_2 VOLTAGE	5A LOAD	50V/DIV	

Figure 4. Output Circuit Waveforms. The Upper Traces Show the Voltage Waveform Appearing Across D1, While the Lower Covers Rectifier D2. In Both Cases, Load is at 5A; (a) with the Input Voltage at 85V and (b) at 265V.