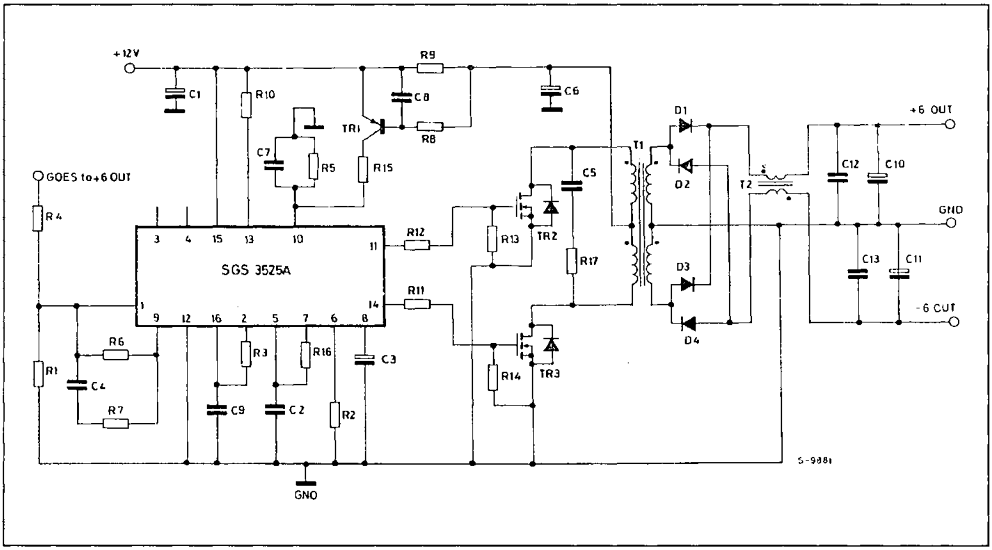
200kHz 15W PUSH PULL DC-DC CONVERTER

BY M. SUTERA

INTRODUCTION

The 15 W DC-DC converter, shown in fig. 1 has a push-pull topology and works in continuous mode with two outputs (+ 6 V, – 6 V) and features primary side control with full protection against fault conditions. There is no insulation between the primary and secondary side.

Due to the high working frequency, the power switches used are the new SGS-THOMSON advanced POWER MOS type : IRFZ20 with high density and bonding on the active area.



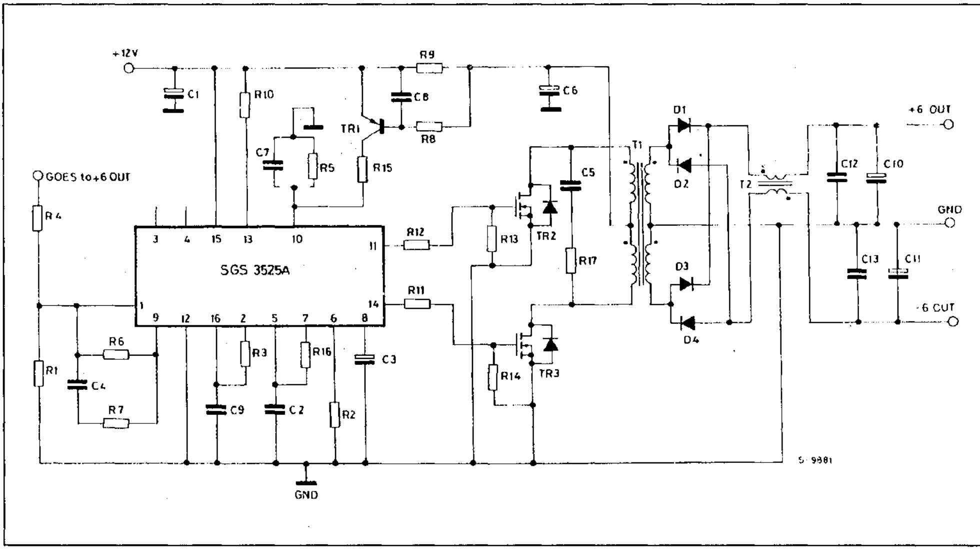
The PWM controller is the linear integrated circuit SGS3525A, with dual source/sink output drivers, internal soft-start, pulse by pulse shut-down and adjustable dead-time control.

Table 1 shows the power supply specifications.

Table 1.

Operating mode	:	Push Pull
DC Input Voltage	:	10V DC to 18V DC
Switching Frequency	:	200kHz ± 10%
Total Power Output	:	15W
Outputs	:	+ 6V ± 5% 0.1 to 1.3A
		– 6V ± 5% 0.1 to 1.3A
Line Regulation (+ 6V output)	:	0.05%/V
Load Regulation (+ 6V output)	:	0.2%/A
Efficiency (@ 1/2 load)	:	76%
Output Ripple @ Max Load + 6V, – 6V Outputs 50mV Peak to Peak		

Figure 1.



CIRCUIT DESCRIPTION

The DC input is chopped at a high frequency (200kHz). This high switching frequency allows the use of a very small transformer.

Due to the push-pull configuration of the converter the POWER MOS devices, the transformer and the diodes work at the frequency of 100kHz (photo 1, 2) ; the output filters and the oscillator of PWM controller work at a frequency of 200kHz (photo 3).

When Tr2 is on and Tr3 is off, diodes D2, D3 conduct and diodes D1, D4 are off. When Tr3 is on and Tr2 is off diodes D1, D4 conduct and diodes D2, D3 are off.

The snubber formed by C5, R17 is used to clamp the voltage spikes on Tr2 and Tr3 drains. With a leakage inductance $L_d = 0.5\mu H$, a primary current $I_p = 2.8$ A at $V_{IN\,MIN}$ and maximum load and an allowable voltage spike $V_p = 30V$ we can calculate C5 as follows :

$$C5 = \frac{L_d \cdot I_p^2}{(2\,V_{MIN} + V_p)^2 - (2\,V_{IN})^2} = 1.8\ nF \qquad \text{Eq. 1}$$

The PWM controller SGS352A has the two drive outputs in totem-pole configuration in order to drive the POWER MOS. The feedback signal for the PWM is directly connected to the inverted input of

the error amplifier from the + 6 V output by the resistive divider R4-R1. The maximum current protection is sensed by Tr1, R9, R8 and is connected to pin 10 (shut-down).
The magnetic coupling of the series inductance in the output filter is very important for good regulation of the voltages. In this way when the load is very different in the two outputs (+ 6V max load ; – 6V min load or viceversa) the indirectly regulated output (– 6V) has a very stable output voltage (see fig. 2).

The efficiency is excellent : 70 % over a wide range (fig. 3).

The transient response is very fast : about 50ms. Photo 4 shows the transient response of load regulation due to a load variation from 100mA to 1.3A and from 1.3A to 100mA (+ 6V output).

Fig. 4 shows the P.C. board (track layout) and the component positions.

Figure 2.

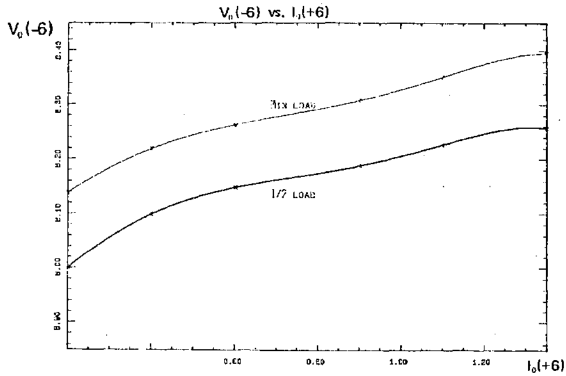


Figure 3.

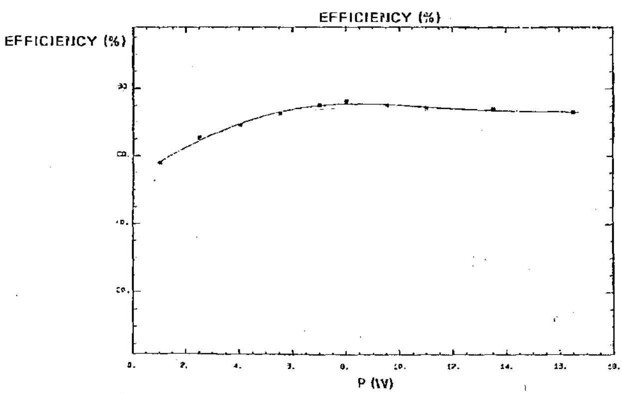
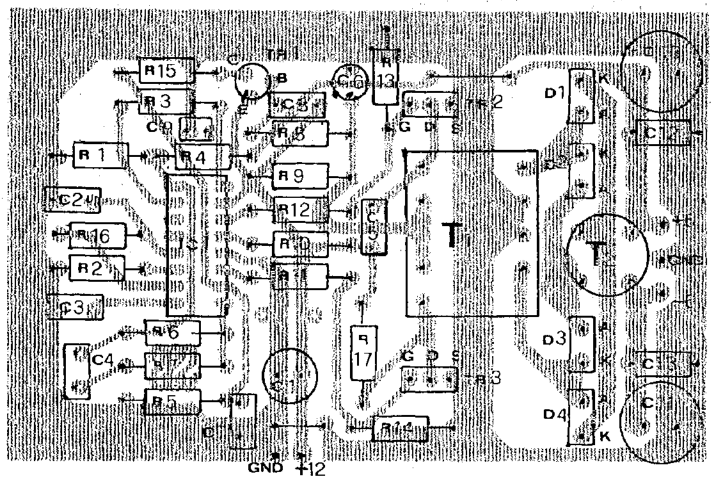


Figure 4 : P.C. Board and Components Layout (1 : 1 scale).



TRANSFORMER

For this design a Tomita E core of 2E 6 ferrite material was chosen. To calculate the core size we used the following equations :

$$A_e \cdot A_n > \frac{10^5 \cdot P_{OUT}}{1.16 \cdot \Delta B \cdot f \cdot d} = 0.143\text{cm}^4 \qquad \text{Eq. 2}$$

where :

P_{OUT} = output 15 (W)

ΔB = flux density swing (T) we chose ΔB = 200mT

d = current density we chose = 450A/cm^2

f = working frequency of transformer

A_e = effective area of magnetic path [cm^2]

A_n = useful winding cross section [cm^2]

The core size is then EE 25 x 6.5 with A_e = 0.42cm^2, A_n = 0.45cm^2 and $A_e \cdot A_n$ = 0.189cm^4 > 0.143cm^4.

The maximum value of primary current at V_{MIN} is :

$$I_P = \frac{P_{OUT}}{\eta \cdot \delta_{MAX} \cdot (V_{MIN} - \Delta V)}$$

$$= \frac{15}{0.75 \cdot 0.8 \cdot 9} = 2.8\text{A} \qquad \text{Eq. 3}$$

where ΔV is the voltage drop on the R9 resistor and on the POWER MOS, δ_{MAX} = maximum duty cycle, η = efficiency.

The turns ratio is given by the following equations :

$$n = \frac{V_{prim.}}{V_{sec}} \cdot \delta_{MAX}$$

$$n = \frac{V_{MIN} - \Delta V}{V_{OUT} + V_f} \cdot \delta_{MAX} = 1.03 \qquad \text{Eq. 4}$$

The number of turns N_p is calculated as follows :

$$N_{pMIN} = \frac{V_{MIN}\,[\text{V}] \cdot \delta_{MAX}}{\Delta B\,[\text{T}] \cdot A_e\,[\text{cm}^2] \cdot f\,[\text{Hz}]} \cdot 10^4 = 9.5\text{turn} \qquad \text{Eq. 5}$$

The number of turns used was N_p = 10 and N_s = 10.

The primary inductance is then the same as the secondary inductance.

$L_p = L_s \doteq N_p^2 \cdot A_L = 100 \cdot 2400\text{nH} = 240\mu\text{H}$

The value of L_d (leakage inductance) was measured on the transformer :

$$L_d = 0.5\mu\text{H}$$

OUTPUT FILTER

The most interesting part of the output filter is the transformer T2 which, coupling the output series inductance of the two outputs, gives good regulation of the – 6V output (magnetic regulator).

T2 construction is very simple because the two inductance are directly wound on the same cylindrical ferrite core. Each winding is made up of 200 turns and is : L (+ 6V) = L (– 6V) = 17µH.

The four fast recovery diodes used are BYW29 -100 type.

Capacitors C10, C11 are 220µF Roederstein EKR low ESR type for application in switching power supplies.

The ripple value obtained is very low = 50mV peak to peak (photo 3).

Photo 1 : Tr2, Tr3, V_{ds} (V_{ds} = 20V/div.).

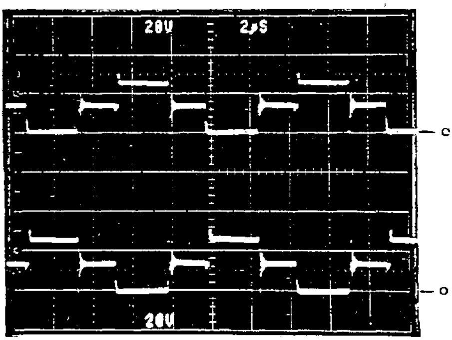
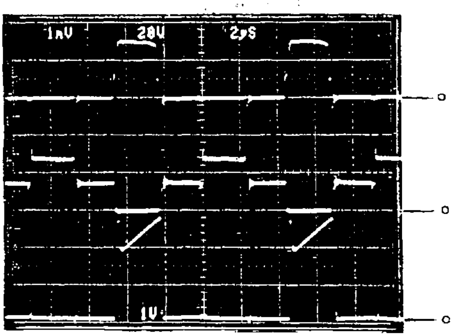


Photo 2 : Tr3 Waveforms (V_G = 10V/div, V_{ds} = 20V/div, I_d = 1A/div.).



COMPONENT LIST

Resistors

R1	=	8.2K	1/4W
R2	=	5.6K	1/4W
R3	=	1.2K	1/4W
R4	=	1.5K	1/4W
R5	=	1.2K	1/4W
R6	=	470K	1/4W
R7	=	3.3K	1/4W
R8	=	390Ω	1/4W
R9	=	0.22Ω	1W
R10	=	10Ω	1/4W
R11	=	22Ω	1/4W
R12	=	22Ω	1/4W
R13	=	5.6K	1/4W
R14	=	5.6K	1/4W
R15	=	18Ω	1/4W
R16	=	47Ω	1/4W
R17	=	33Ω	1/2W

Capacitors

C1	=	100µF
C2	=	1nF
C3	=	1µF
C4	=	10nF
C5	=	1.8nF
C6	=	2.2µF
C7	=	10nF
C8	=	2.7nF
C9	=	10nF
C10	=	220µF
C11	=	220µF
C12	=	330nF
C13	=	330nF

Transistors

TR1	=	2N2907
TR2, TR3	=	IRFZ20

Diodes

D1, D2, D3, D4	=	BYW2929-100

ICs

I1	=	SGS3525A

Transformers

T1 core	=	TOMITA EE 25 x 6.5 2E6 Material
T2 core	=	cylindrical 30 x 20mm

Photo 2a : Turn On.

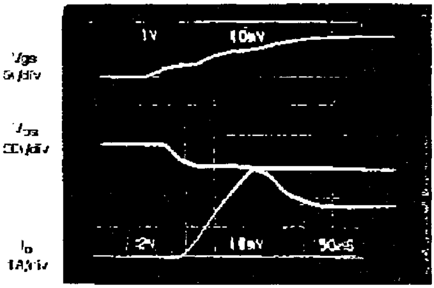


Photo 2b : Turn Off.

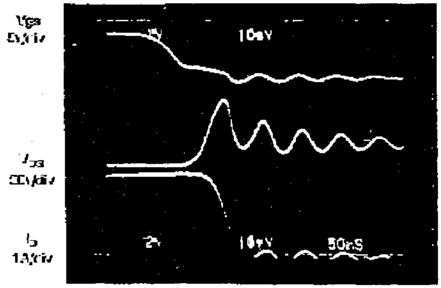


Photo 3 : Ripple on + 6V and – 6V Outputs (20mV/div.).

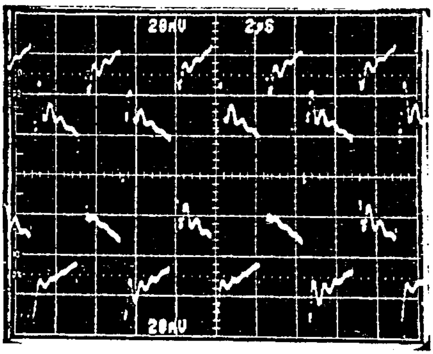


Photo 4 : Transient Response (20mV/div.).