SGS-THOMSON
MICROELECTRONICS

APPLICATION NOTE

AN INNOVATIVE HIGH FREQUENCY HIGH CURRENT TRANSISTOR CHOPPER

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INTRODUCTION

Recent developments in power semiconductors and associated technologies have made possible the realization of medium power converters (5-50kVA) operating at switching frequencies higher than 20kHz.

This paper presents the design of a high current (500A), high frequency (20kHz) chopper using fast Darlington switches operating from a low voltage supply (60V). New optimised design techniques for paralleling power semiconductor devices are described. The association of these methods allows the switching of 500A in less than 200ns.

These new techniques are also suitable for high voltage medium power converters operating at high switching frequency, such as UPS, welding converters, motor drives and battery chargers.

A 500A - 20kHz CHOPPER WITH DARLINGTON IN PARALLEL

High frequency bandwidth and regulation is achieved for the 500A output current by switching at an ultrasonic frequency of 20kHz with a turn-off time of less than 200ns. Consequently, high rates of change of current (in excess of 2000A/µs) are experienced. Six Darlington transistors (ESM2012 D) in parallel and four ultra fast rectifiers (BYV54-200) in parallel are used to achieve the current rating.

Figure 1 : Switches used in the Chopper.

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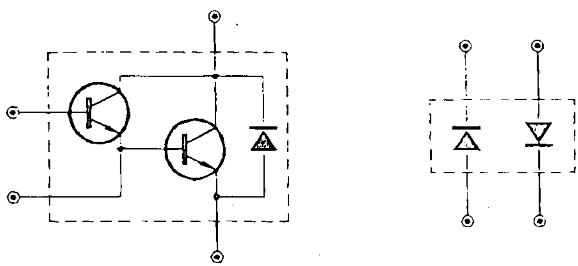


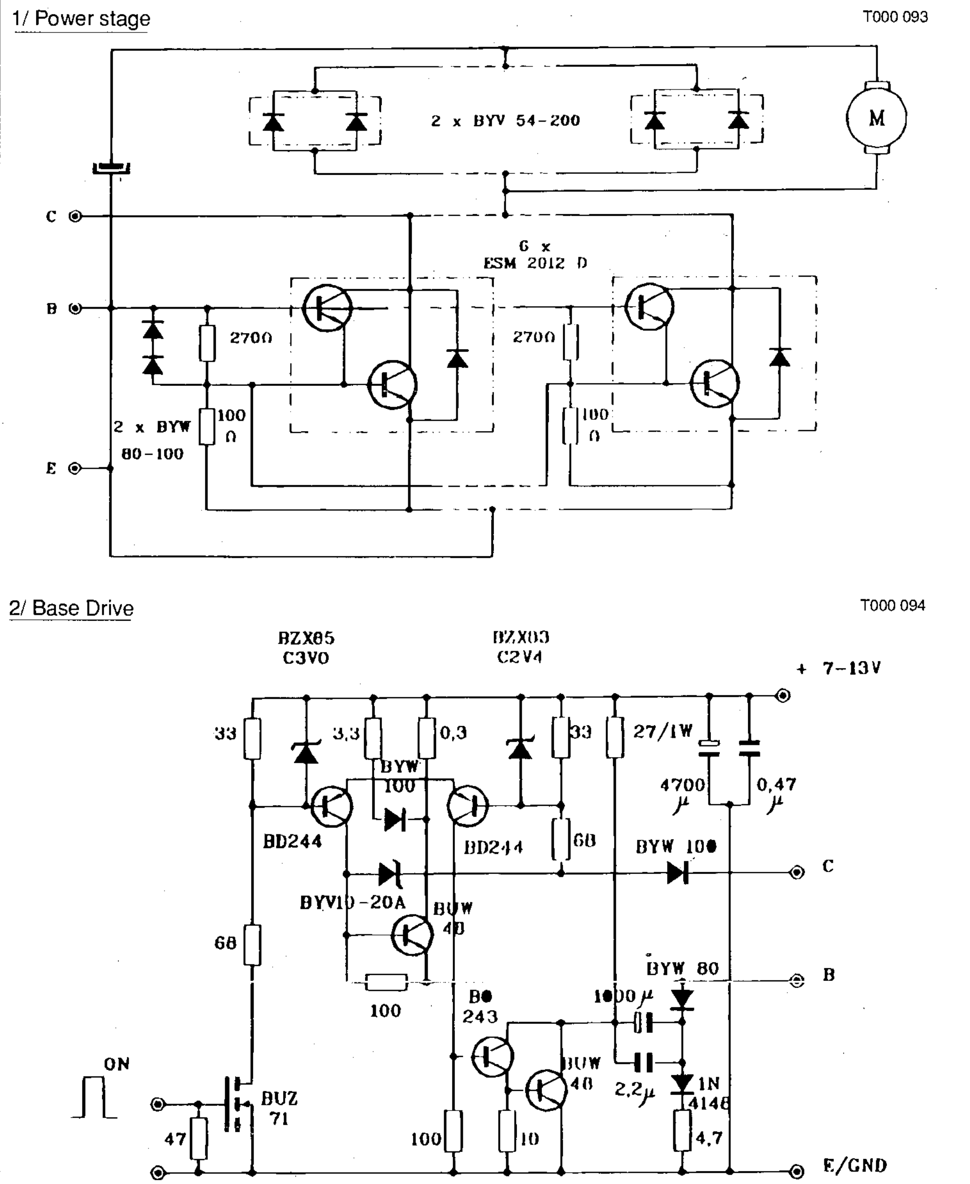
ESM 2012 D

V_{CEW} = 125V
V_{CEV} = 150V
V_{CEsat} (100°C) < 1,5V
for I_C = 70A
I_B = 0,25A
t_{fi}(100°C) < 0,4ms
R_{th} = 0,7K/W

BYV 54-200

V_{RRM} = 200V
V_F(100°C) < 0,85V for I_F = 50A
R_{th} = 1,2K/W

Figure 2 : New Base Drive Concept which Automatically Generates the Negative Bias. The negative bias generated is independent of the duty cycle.



The 500A/60V/20kHz chopper

A power Darlington and diodes are shown in figure 1 together with their important characteristics. Figure 2 shows the power stage and the base drive circuit.

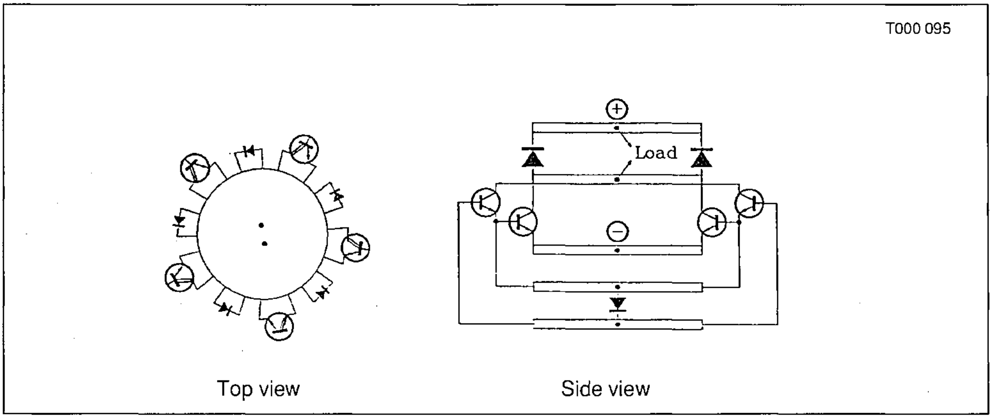
A base current of 5A is sufficient to control a collector current of 500A. The static and dynamic sharing of the collector and base current between the paralleled devices is better than 90% provided :

a) The devices are mounted in a circular layout on a common heatsink as shown in figure 3. Good utilization of the heatsink is achieved using this physical layout.

b) The bases of the output stages of the Darlingtons must be linked together. The access to the bases of the output stage of the ESM2012 D Darlingtons enables this.

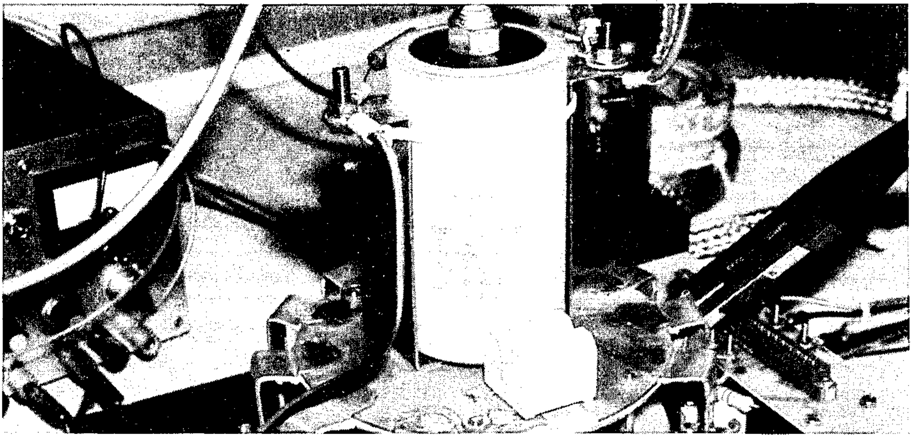
Due to excellent current sharing, the Darlingtons can be used close to their nominal collector current rating.

Figure 3 : Circular Geometry for the Physical Layout of Power Devices.



The BYV54-200 ultra fast rectifiers in parallel are not derated as these fast recovery epitaxial diodes have negligible voltage drop (V_F) spread.

Figure 4 : Power Stage.



Low wiring inductances are required for high performance switching as parasitic inductances cause overvoltage spikes at turn-off.

Figure 5 : A Low Wiring Inductance is Necessary in Order to Avoid High Over Voltages at Switch off.

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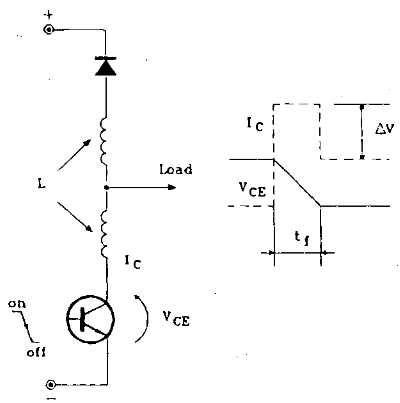
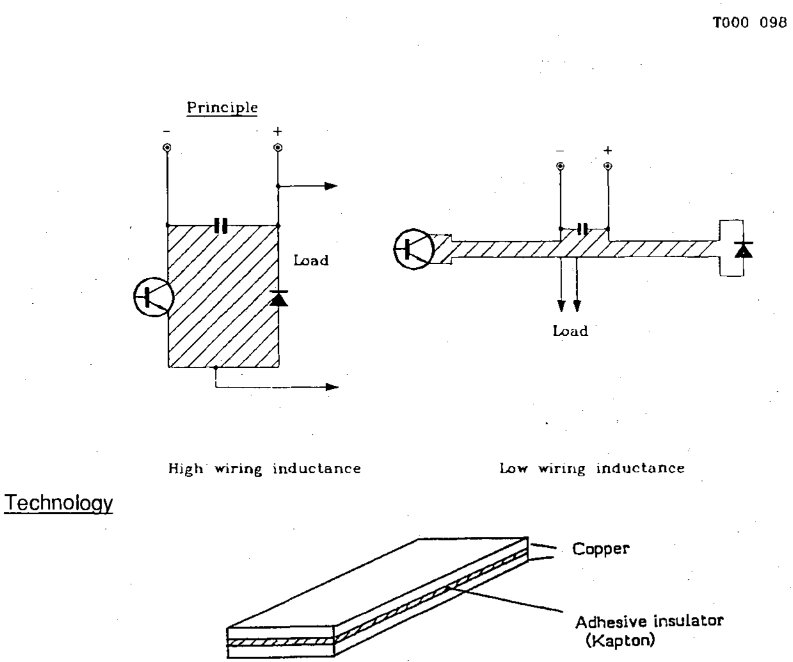


L	100nH	
t_f	200ns	
I_C	10A	500A
ΔV	5V	250V

The 500A chopper has been designed with a low inductance plate wiring method. The plate wiring consists of 2 parallel copper plates separated by a thin adhesive insulator (see figure 6).

Figure 6 : Low Inductance Wiring.



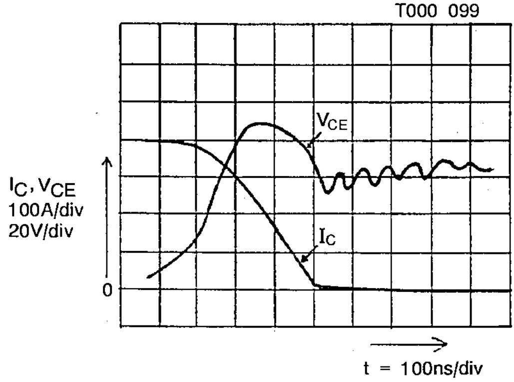
Wiring inductances as low as 5nH/m can be achieved in a $500A_{RMS}$ circuit using plate wiring.

The parasitic inductance of the power stage of the 500A chopper (capacitor + Darlington + free-wheeling diode) has been estimated at 20nH. Such a reduction of wiring inductance in the power stage and the base drive allows :

* Very high switching speed of the Darlingtons at turn-on and turn-off : 2000A/µs.

* At turn-off an overvoltage of only 50V is experienced by the Darlingtons for a dI/dt of 2000A/µs.

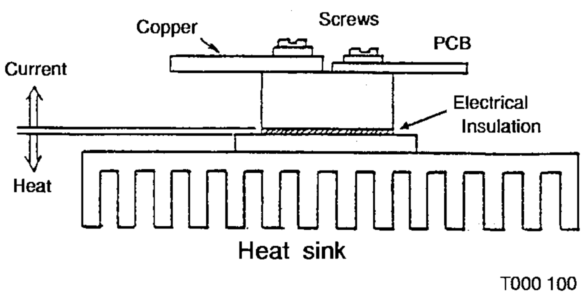
Figure 7 : Turn-off Switching of the Fast Darlington Switch.



The ISOTOP package is used for all the power semiconductor components in order to optimize cooling and wiring.

The package has screw terminals on the top of the case suitable for plate wiring, low parasitic inductance due to its low profile and internal insulation with low thermal resistance.

Figure 8 : A High Current Package : ISOTOP.



CONCLUSION

The design of a 500A - 20kHz chopper using fast switching Darlingtons and diodes has been presented.

The power semiconductor components have been packaged in the ISOTOP package, allowing screw connections and plate wiring techniques to be used. The techniques developed also can be applied in the design of medium and high voltage converters.

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APPENDIX I

LOW INDUCTANCE WIRING

1. Modelling and inductance

The inductance of wiring made circular cross section wire, can be modelled as the sum of two terms :

a) Self inductance of one wire :

$$L_1 = \frac{\mu O}{8\pi} \text{ (H/m)} \qquad \text{Eqn.1}$$

b) Mutual inductance of the loop :

$$L_2 = \frac{\mu O}{\pi} \; L_n \frac{b-a}{a} \text{ (H/m)} \qquad \text{Eqn.2}$$

The total inductance of the wiring os thus :

$$L_T = \frac{\mu O}{\pi} \left(\frac{1}{4} + \ln \frac{b-a}{a} \right) \text{ (H/m)} \qquad \text{Eqn.3}$$

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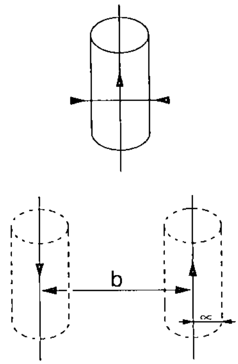

LT depends strongly on the geometry of the circuit. The best way to decrease LT is to decrease the area of the loop :

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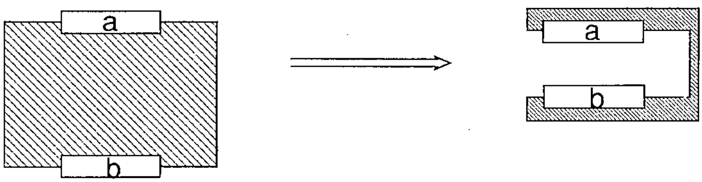

2. TECHNOLOGY FOR LOW INDUCTANCE WIRING

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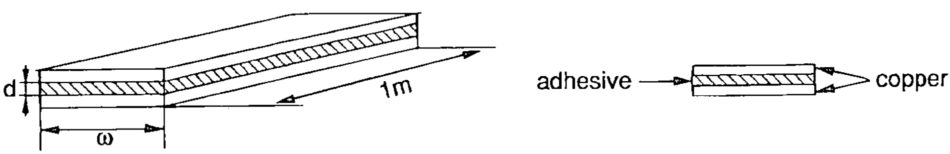

$$L = \mu O . \frac{d}{W} \qquad \text{Eqn.4}$$

$$I = 500A, \ \delta = 20A/mm^2, \ W = 50mm, \ d = 1mm$$

$$\Rightarrow L = 20nH/m$$

APPENDIX II

The cooling ability of a heatsink is not linearily dependent on its length

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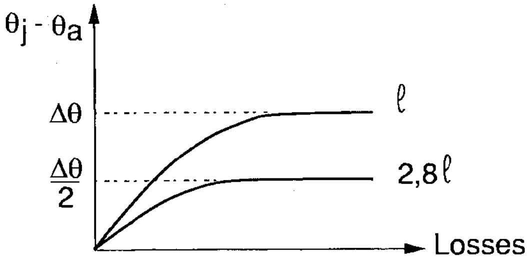

Separation of heat sources is thus necessary to optimize the cooling

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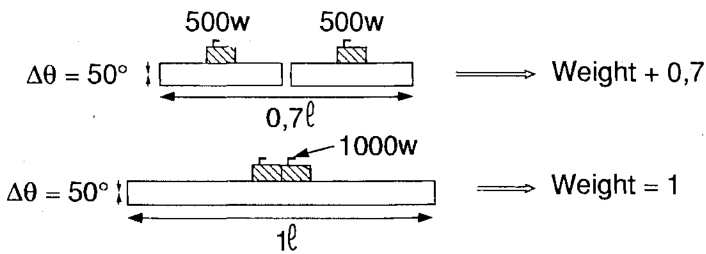

Length, volume and weight can be reduced in some case by a factor of $\sqrt{2}$ if heating sources are spread over the heatsink