SIMPLIFIED SWITCH-MODE BASE DRIVE CIRCUIT WITH THE L4974 SMARTPOWER-IC

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INTRODUCTION

Conventional driver circuits for bipolar-junction-transistors and Darlingtons have a high power dissipation. In order to reduce this dissipation, switch-mode driver stages have been proposed[1]. A new, very simplified driver stage, taking advantage of the switch-mode principle is presented here. It has been designed around smartpower-IC L4974. The efficiency of the IC is so high, that even with a 4 Amp base-current, the smartpower device is housed in a DIL-package ... !

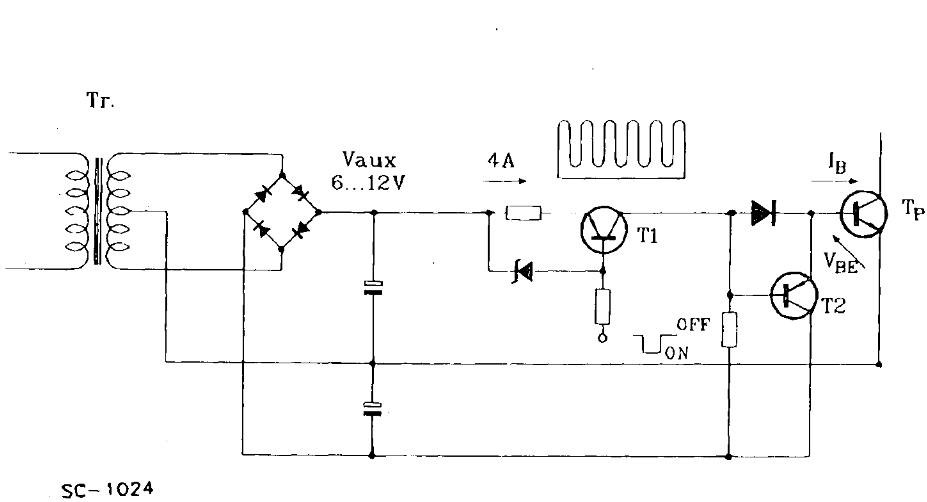
Bipolar-junction-transistors need negative bias in order to obtain fast turn-off switching and a good immunity against reverse conduction followed by dv/dt. This driver circuit generates the negative bias internally - it can be supplied from a single, unregulated source.

The new configuration can be used to simplify and improve existing converter/inverter circuits (less auxiliary supplies, less heatsinks and higher efficiency).

CONVENTIONAL BASE DRIVE V/S SWITCH-MODE BASE DRIVE

Conventional base driver circuits draw base current from an auxiliary supply voltage between 6 to 12 Volts. The base-current amplitude is limited by means of resistors or dissipative current sources. (figure 1) Such a base driver has a very low efficiency. The power transistors base-emitter voltage is about 1V, but 5V to

Figure 1 : Dissipative Driver Circuit.



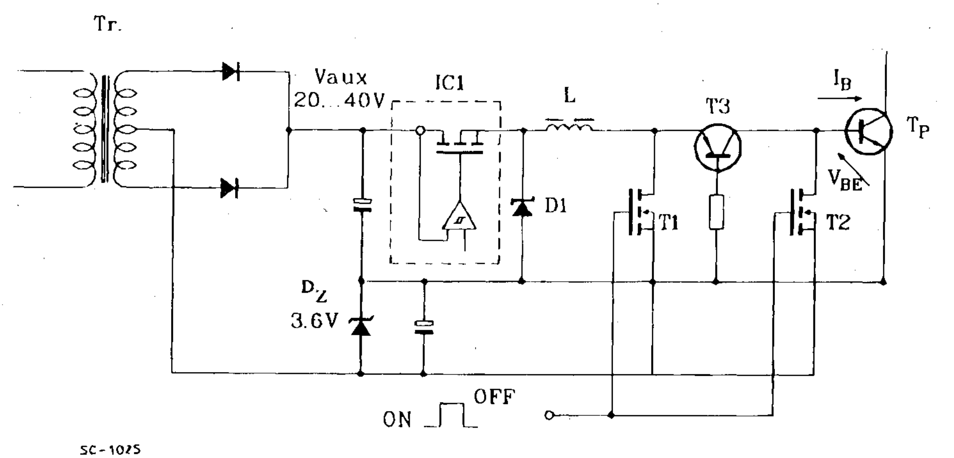
During permanent conduction with a 4A-base-current, the transformer Trs has to supply a power of 56W. About 90% of this power is dissipated in the driver circuit.

11V are dropped inside the driver circuit. Applying the switch-mode principle to base driver circuits, substantial energy savings can be made. Auxiliary power supply and heatsinking costs can be greatly reduced.

HOW IT WORKS

Figure 2 shows the principle of such a switch mode driver circuit. A smartpower-IC with a MOSFET output-stage operates as a buck regulator in current-mode. During the off-state of the power transistor, TP - figures 1-4., a MOSFET, T1, applies a short-circuit to the output of the buck regulator. Thus, the smartpower IC operates with reduced duty cycle and maintains a constant current in the choke L. In order to turn-on power transistor TP, the MOSFET T1 is turned off and the constant choke-current flows into the power transistors base. The rate of rise of base current is only limited by the MOSFET turn-off speed. In order to obtain very fast switching, high density MOSFETs (STVHD 90) with very low input capacitances have been used in the circuit[2].

Figure 2 : Simplified Switch Mode Driver Circuit.



With an input voltage of 20V and a base current of 4A, the transformer supplies about 10W to the driver circuit. No device in the driver circuit has to be cooled with a heatsink.

During the on-state, the driver circuit input current can be estimated using the term 2 * I_B * V_{BE}/V_{aux}, where I_B is the base current, V_{BE} the base-emitter voltage and V_{aux} the voltage of the auxiliary supply.

If the power transistor base current is 0.5A. and the auxiliary supply voltage 20 Volts, the driver input current will be about 0.5 Amps. If the auxiliary supply voltage is increased, the input current will be further reduced.

NEGATIVE BIAS OUT OF POSITIVE SUPPLY

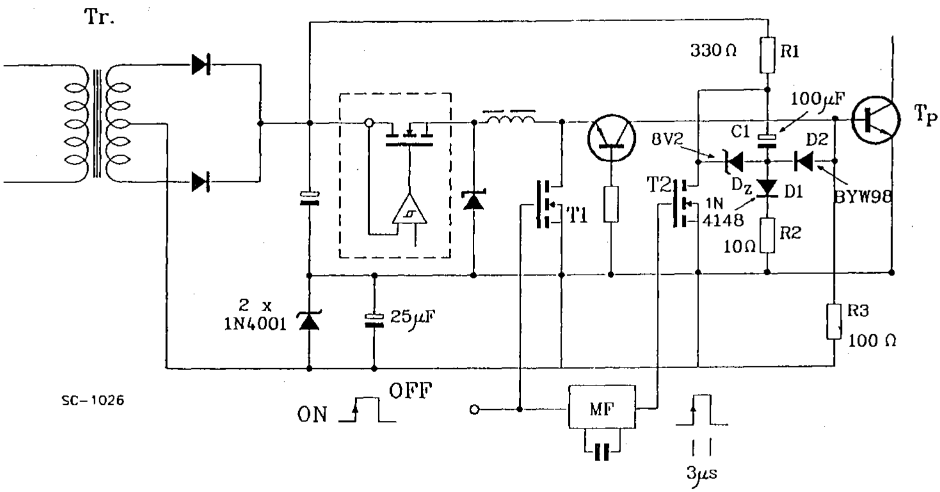
The negative bias for fast turn-off switching can be generated by various means.

A zener diode can be connected in series between auxiliary supply and driver stage, D_Z (figure 2). The potential at the zener diode anode is negative compared to the emitter potential of the power transistor. The losses in the zener diode are low, due to the reduced input current of the switch-mode base drive.

For turn-off switching, T1 and T2 are turned on. T1 applies a short circuit to the buck regulator output, T2 applies the negative bias to the power-transistor base. It is also possible to generate a negative bias directly from positive auxiliary supply :

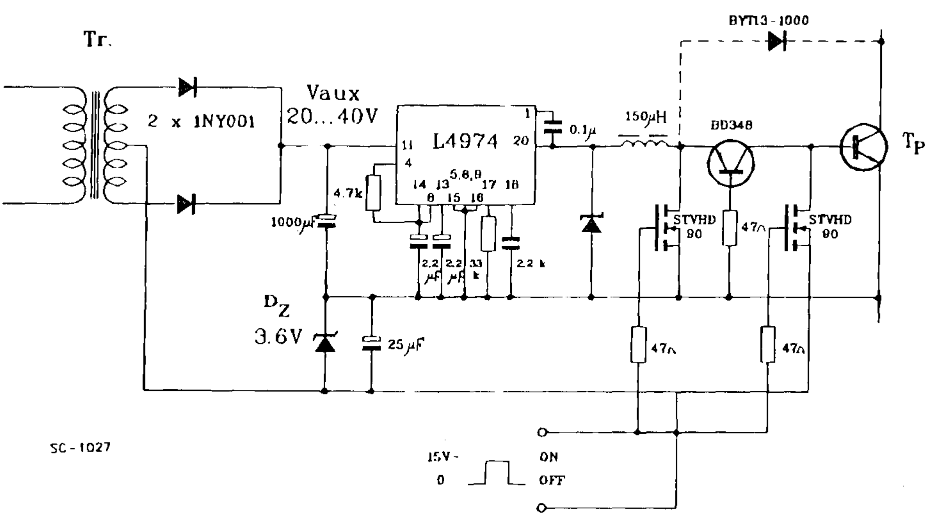
A capacitor C1 (figure 3) is permanently charged via a resistor R1 and a diode D1. At turn-off switching, T2 is turned on for a short time t1. This time has to be chosen to have a value slightly higher than power transistor's storage-time ts. T2 connects the positive electrode of C1 to ground during t1. Thus a negative voltage is applied to the base during turn-off switching off TP. T2 remains 'off' after turn-off and C1 continues to be charged. The advantage of this configuration is that the state of charge of C1 is independant of duty cycle - sufficient negative bias is always available[3].

Figure 3 : Modified Circuit with Dynamic Self-generation of the Negative Bias.



The capacitor C1 is charged during the conduction and the non-conduction time of TP.
Its state of charge is independant of the duty-cycle !

Figure 4 : Complete Circuit Diagram for 4 Amp Base Current Supply.



The L4974 is housed in a Dual-in-line package – the PCB is sufficient for cooling. For higher base current, L4974 can be replaced by L4970.

RESULTS

With a BUF 420 (a cellular ETD-transistor) in the power stage, storage-times less than 1µs and fall-times lower than 25ns have been obtained when switching 20A, from a 400V supply.

The overshoot of the base-emitter voltage and the influence of parasitic inductances in series with the base are negligible due to the fact that the driver acts, at turn-on, as a nearly ideal current source. A turn-on speed dI_C/dt for the power transistor as high as 200A/µs has been obtained without any special design effort.

CONCLUSION

The application of the switch-mode principle to driver stages gives significant loss reduction and a very much reduced cost for auxiliary supply and heatsinking. In the past switch-mode driver circuits were considered as too complex. New smartpower-IC's allow a reduction in complexity and take advantage of the high efficiency achievable using a switch mode circuit. The 4A-version of the driver uses a Dual-in-line IC and no heatsinks. The combination of switch-mode principle with self generation of negative bias further reduces cost of the driver and its auxiliary supply. The concept shown appears to be valid for base currents up to 20 Amps ; its use for gate drive for SCR and GTO could also be investigated.

1. C.K. Patni : An efficient "Switch-mode" base drive for bipolar transistors, Internal report, SGS-THOMSON Microelectronics

2. Databook : POWER MOS DEVICES page 621 to 625 (STVHD 90), SGS-THOMSON Microelectronics

3. K. Rischmüller : Fast switching with power transistors and Darlingtons - state of the art, Application note, SGS-THOMSON Microelectronics

4. Databook : Industrial and computer peripheral IC's, page 401 to 416 (L4970), SGS-THOMSON Microelectronics.