359-609/610

**BUS14**
**BUS14A**

# SILICON DIFFUSED POWER TRANSISTORS

High-voltage, high-speed, glass-passivated n-p-n power transistors in a TO-3 envelope, indended for use in converters, inverters, switching regulators, motor control systems etc.

## QUICK REFERENCE DATA
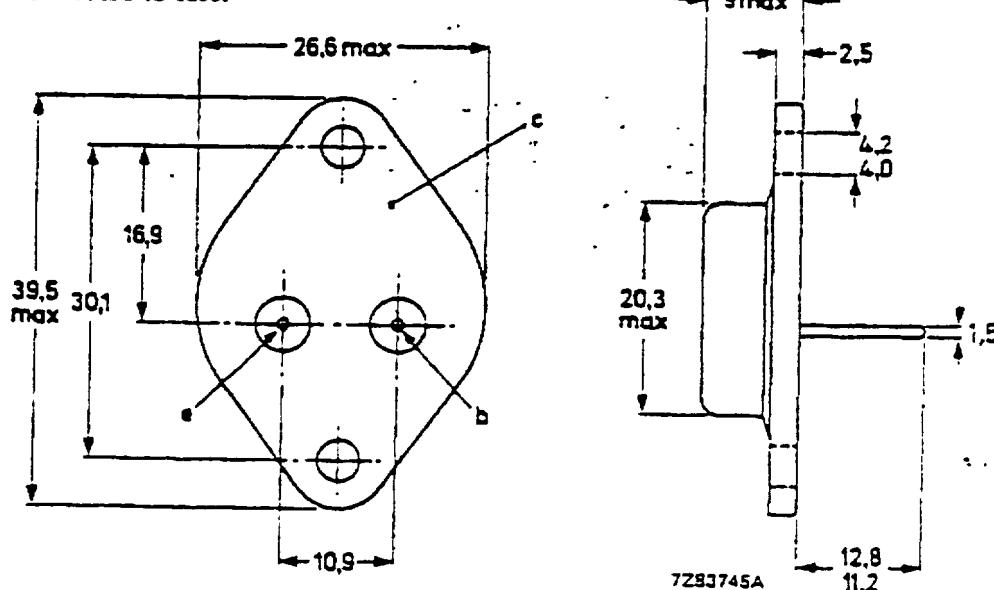
| | | | BUS14 | BUS14A | |
|---|---|---|---|---|---|
| Collector-emitter voltage ($V_{BE}$ = 0, peak value) | $V_{CESM}$ | max. | 950 | 1000 | V |
| Collector-emitter voltage (open base) | $V_{CEO}$ | max. | 400 | 450 | V |
| Collector current (d.c.) | $I_C$ | max. | | 30 | A |
| Collector current (peak value) $t_p$ < 2 ms | $I_{CM}$ | max. | | 50 | A |
| Total power dissipation up to $T_{mb}$ = 25 °C | $P_{tot}$ | max. | | 250 | W |
| Collector-emitter saturation voltage | | | | | |
| $I_C$ = 20 A; $I_B$ = 4 A | $V_{CEsat}$ | < | 1,5 | – | V |
| $I_C$ = 16 A; $I_B$ = 3,2 A | $V_{CEsat}$ | < | – | 1,5 | V |
| Fall time (resistive load) | | | | | |
| $I_{Con}$ = 20 A; $I_{Bon}$ = $-I_{Boff}$ = 4 A | $t_f$ | < | 0,8 | – | μs |
| $I_{Con}$ = 16 A; $I_{Bon}$ = $-I_{Boff}$ = 3,2 A | $t_f$ | < | – | 0,8 | μs |

## MECHANICAL DATA

Fig. 1 TO-3.

Dimensions in mm

Collector connected to case.



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See also chapters Mounting instructions and Accessories.

## BUS14
## BUS14A

### RATINGS

Limiting values in accordance with the Absolute Maximum System (IEC 134)

| | | | BUS14 | BUS14A | |
|---|---|---|---|---|---|
| Collector-emitter voltage ($V_{BE}=0$, peak value) | $V_{CESM}$ | max. | 850 | 1000 | V |
| Collector-emitter voltage (open base) | $V_{CEO}$ | max. | 400 | 450 | V |
| Collector current (d.c.) | $I_C$ | max. | 30 | | A |
| Collector current (peak value); $t_p < 2$ ms | $I_{CM}$ | max. | 50 | | A |
| Base current (d.c.) | $I_B$ | max. | 6 | | A |
| Base current (peak value); $t_p < 2$ ms | $I_{BM}$ | max. | 10 | | A |
| Total power dissipation up to $T_{mb} = 25\ ^oC$ | $P_{tot}$ | max. | 250 | | W |
| Storage temperature | $T_{stg}$ | | −65 to +200 | | $^oC$ |
| Junction temperature | $T_j$ | max. | 200 | | $^oC$ |

### THERMAL RESISTANCE

| | | | | |
|---|---|---|---|---|
| From junction to mounting base | $R_{th\ j-mb}$ | = | 0,7 | K/W |

### CHARACTERISTICS

$T_j = 25\ ^oC$ unless otherwise specified

| | | | | |
|---|---|---|---|---|
| Collector cut-off current * | | | | |
| $V_{CE} = V_{CESMmax}$; $V_{BE} = 0$ | $I_{CES}$ | < | 1 | mA |
| $V_{CE} = V_{CESMmax}$; $V_{BE} = 0$; $T_j = 125\ ^oC$ | $I_{CES}$ | < | 5 | mA |
| Emitter cut-off current | | | | |
| $I_C = 0$; $V_{EB} = 9$ V | $I_{EBO}$ | < | 10 | mA |

| | | | BUS14 | BUS14A | |
|---|---|---|---|---|---|
| Saturation voltages | | | | | |
| $I_C = 20$ A; $I_B = 4$ A | $V_{CEsat}$ | < | 1,5 | − | V |
| $I_C = 16$ A; $I_B = 3,2$ A | $V_{CEsat}$ | < | − | 1,5 | V |
| $I_C = 20$ A; $I_B = 4$ A | $V_{BEsat}$ | < | 1,7 | − | V |
| $I_C = 16$ A; $I_B = 3,2$ A | $V_{BEsat}$ | < | − | 1,7 | V |
| Collector-emitter sustaining voltage | | | | | |
| $I_C = 100$ mA; $I_{Boff} = 0$; L = 25 mH | $V_{CEOsust}$ | > | 400 | 450 | V |

* Measured with a half sine-wave voltage (curve tracer).

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## CHARACTERISTICS (continued)
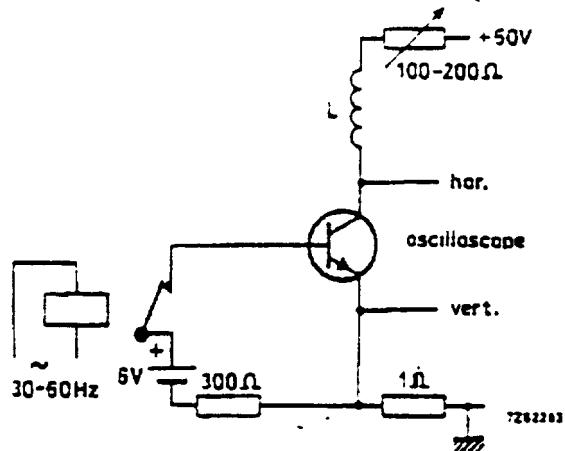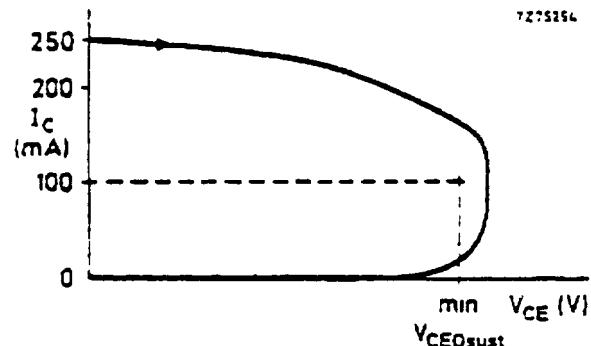


Fig. 2 Oscilloscope display for sustaining voltage.



Fig. 3 Test circuit for $V_{CEOsust}$.

Switching times resistive load (Figs 4 and 5)
$I_{Con} = 20$ A; $I_{Bon} = -I_{Boff} = 4$ A

| | | BUS14 | BUS14A | |
|---|---|---|---|---|
| Turn-on time | $t_{on}$ < | 1 | — | μs |
| Turn-off: Storage time | $t_s$ < | 4 | — | μs |
| Fall time | $t_f$ < | 0,8 | — | μs |

$I_{Con} = 16$ A; $I_{Bon} = -I_{Boff} = 3,2$ A

| | | | | |
|---|---|---|---|---|
| Turn-on time | $t_{on}$ < | — | 1 | μs |
| Turn-off: Storage time | $t_s$ < | — | 4 | μs |
| Fall time | $t_f$ < | — | 0,8 | μs |

Switching times inductive load (Figs 6 and 7)
$I_{Con} = 20$ A; $I_B = 4$ A

| | | | | |
|---|---|---|---|---|
| Turn-off: Storage time | $t_s$ typ. | 2,8 | — | μs |
| | < | 3,6 | — | μs |
| Fall time | $t_f$ typ. | 80 | — | ns |
| | < | 150 | — | ns |

$I_{Con} = 20$ A; $I_B = 4$ A; $T_j = 100$ °C

| | | | | |
|---|---|---|---|---|
| Turn-off: Storage time | $t_s$ typ. | 3,1 | — | μs |
| | < | 4,0 | — | μs |
| Fall time | $t_f$ typ. | 140 | — | ns |
| | < | 300 | — | ns |
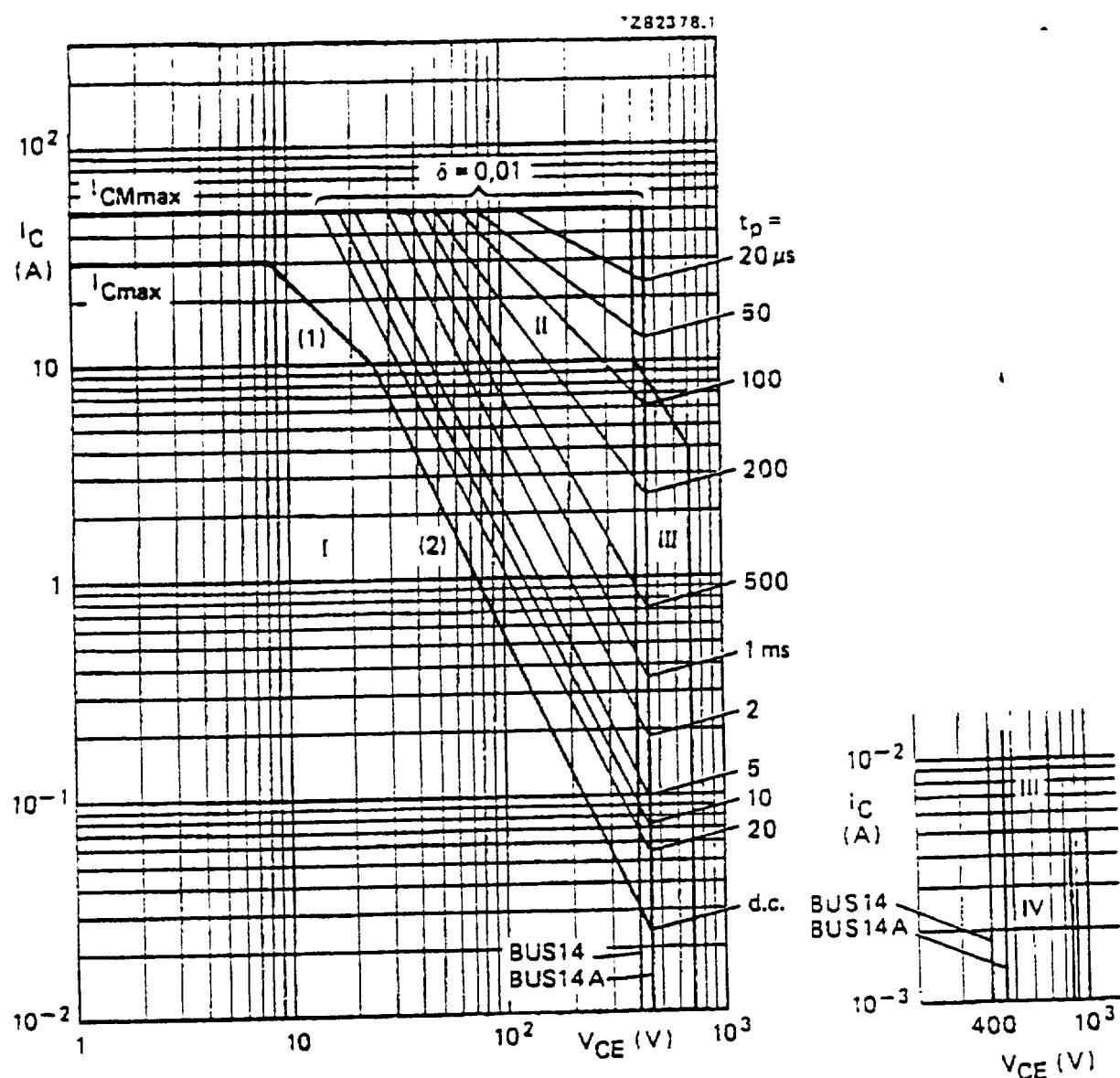
Switching times inductive load (Figs 6 and 7)
$I_{Con} = 16$ A; $I_B = 3,2$ A

| | | | | |
|---|---|---|---|---|
| Turn-off: Storage time | $t_s$ typ. | — | 28 | μs |
| | < | — | 3,6 | μs |
| Fall time | $t_f$ typ. | — | 80 | ns |
| | < | — | 150 | ns |

$I_{Con} = 16$ A; $I_B = 3,2$ A; $T_j = 100$ °C

| | | | | |
|---|---|---|---|---|
| Turn-off: Storage time | $t_s$ typ. | — | 3,1 | μs |
| | < | — | 4,0 | μs |
| Fall time | $t_f$ typ. | — | 140 | ns |
| | < | — | 300 | ns |

January 1983          183

Silicon diffused power transistors

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Fig. 8 Safe Operating ARea at $T_{mb} \leqslant 25\ ^\circ C$.

(1)  $P_{tot\,max}$ and $P_{peak\,max}$ lines.
(2)  Second-breakdown limits (independent of temperature).
I    Region of permissible d.c. operation
II   Permissible extension for repetitive pulse operation
III  Area of permissible operation during turn-on in single transistor
     converters, provided $R_{BE} \leqslant 100\ \Omega$ and $t_p \leqslant 0.6\ \mu s$

IV   Repetitive pulse operation in this region is permissible
     provided $V_{BE} \leqslant 0$ and $t_p \leqslant 2$ ms.

$$V_{CC} = 250 \text{ V}$$
$$V_{IM} = -6 \text{ to } -8 \text{ V}$$
$$t_p = 20 \text{ }\mu s$$
$$\frac{t_p}{T} = 0.01$$
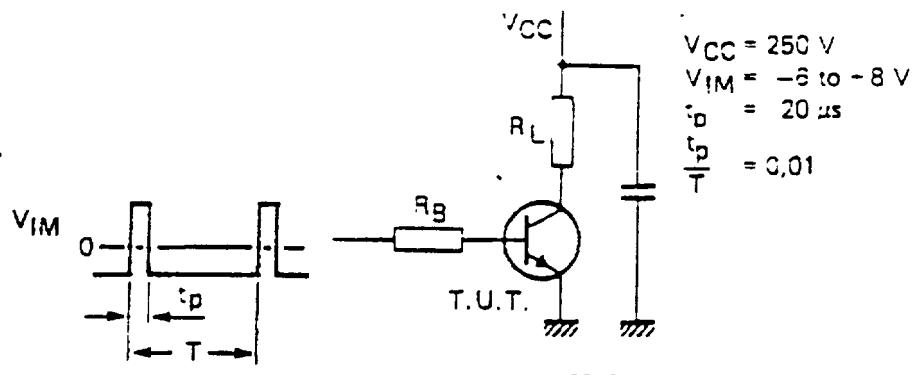
Fig. 4 Test circuit resistive load.
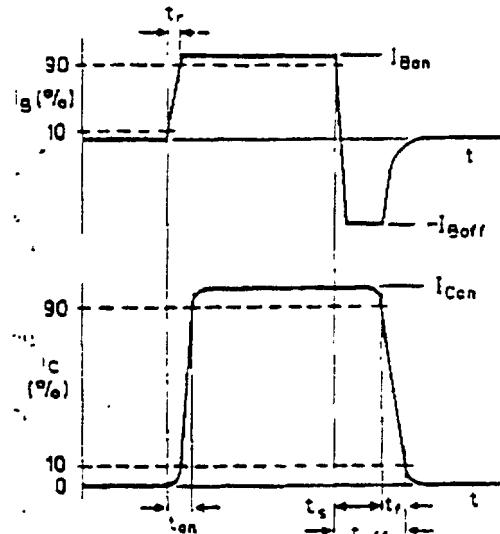
Fig. 5 Switching times waveforms
with resistive load.
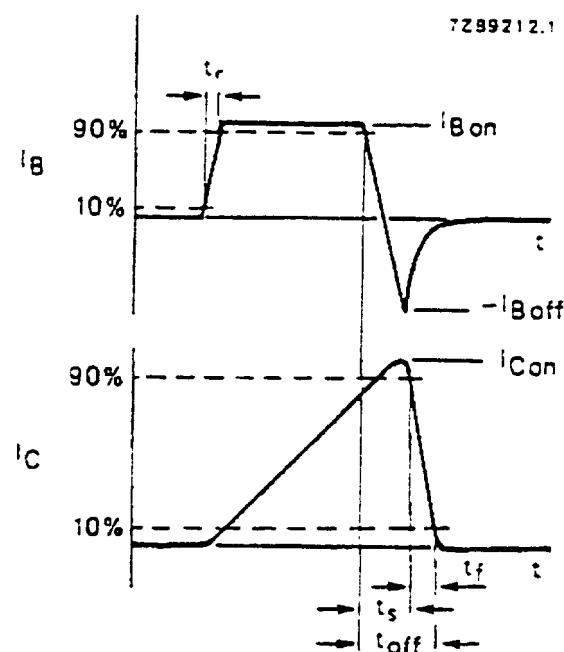
Fig. 6 Switching times waveforms
with inductive load.

$$V_{CC} = 30 \text{ V}$$
$$V_{CL} = 300 \text{ V}$$
$$L_B = 1 \text{ }\mu H$$
$$L_C = 200 \text{ }\mu H$$
$$V_{BE} = 5 \text{ V}$$
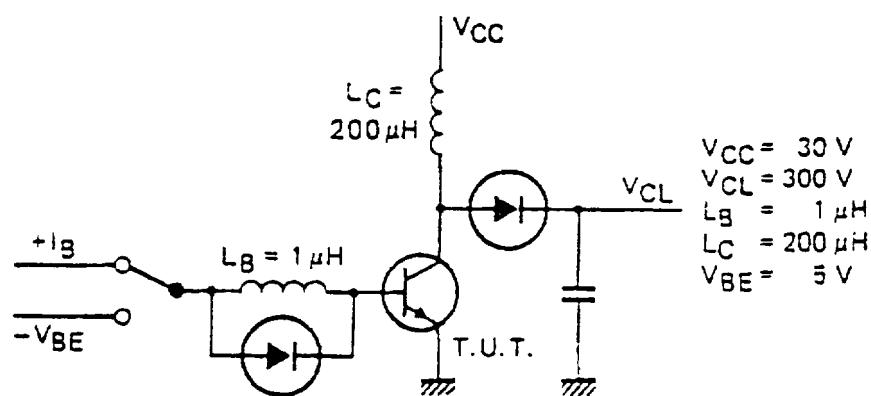
Fig. 7 Test circuit inductive load.
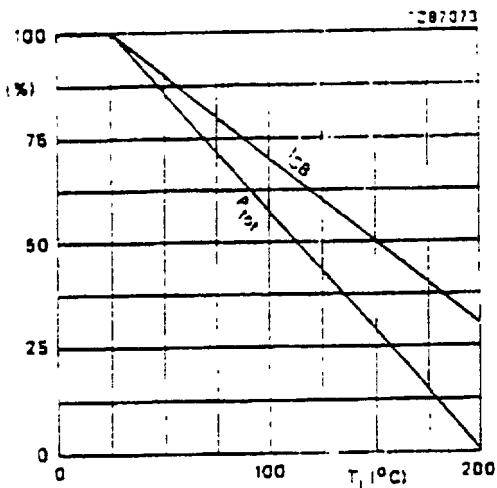
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Fig. 9  Total power dissipation and
second-breakdown current derating curve.
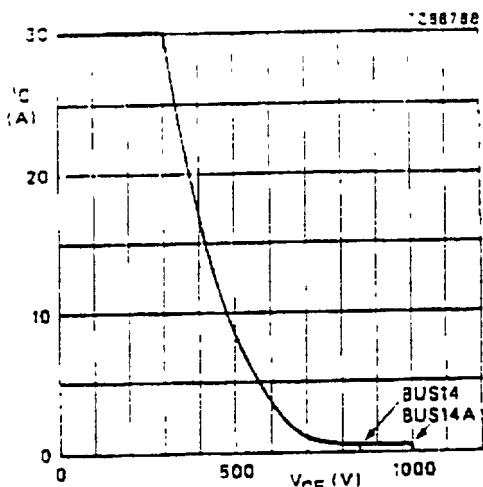
Fig. 10  Reverse bias SOAR.
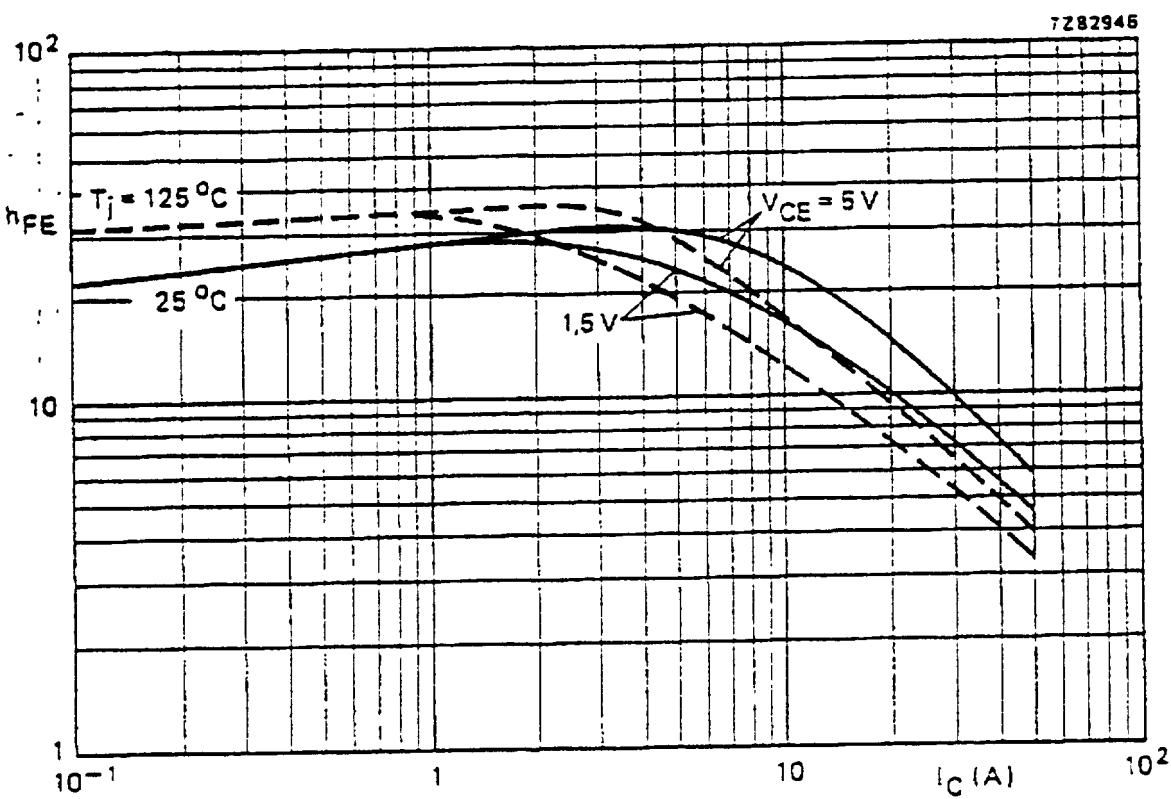
Fig. 11  Typical values d.c. current gain.

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**BUS14**
**BUS14A**

## APPLICATION INFORMATION

Important design factors of SMPS circuits are the maximum power losses, heatsink requirements and base drive conditions of the switching transistor. The power losses are very dependent on the operating frequency, the maximum collector current amplitude and shape.

The operating frequency is mostly set between 15 and 50 kHz. The collector current shape varies from rectangular in a forward converter to sawtooth in a flyback converter.

Information on nominal base drive, optimum base inductance and maximum transistor dissipation applied in a forward converter is given in Figs 15, 16 and 17. In these figures $I_{CM}$ represents the maximum repetitive peak collector current, which occurs during overload. The information is derived from limit-case transistors at a mounting base temperature of 100 °C under the following conditions (see also Fig. 15):

— collector current shape $I_{C1}/I_{CM}$ = 0,9
— duty factor $t_p/T$ = 0,45
— rate of rise of $I_C$ during turn-on = 20 A/$\mu$s
— rate of rise of $V_{CE}$ during turn-off = 1 kV/$\mu$s
— reverse drive voltage during turn-off = 5 V
— base current shape $I_{B1}/I_{Be}$ = 1,5

The required thermal resistance of the heatsink can be calculated from

$$R_{th\ mb\text{-}a} < \frac{100 - T_{amb}}{P_{tot}}\ K/W$$

To ensure thermal stability the value of the ambient temperature $T_{amb} > 40$ °C.
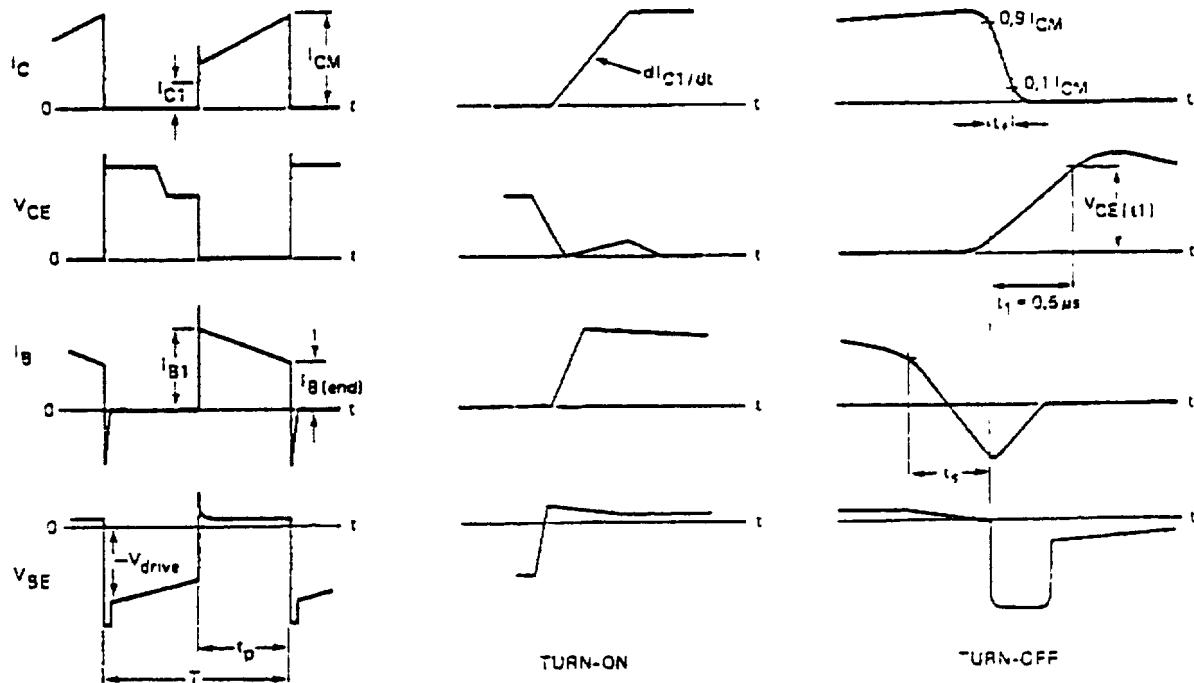


Fig. 15 Relevant waveforms of the switching transistor in a forward SMPS.

**BUS14**
**BUS14A**

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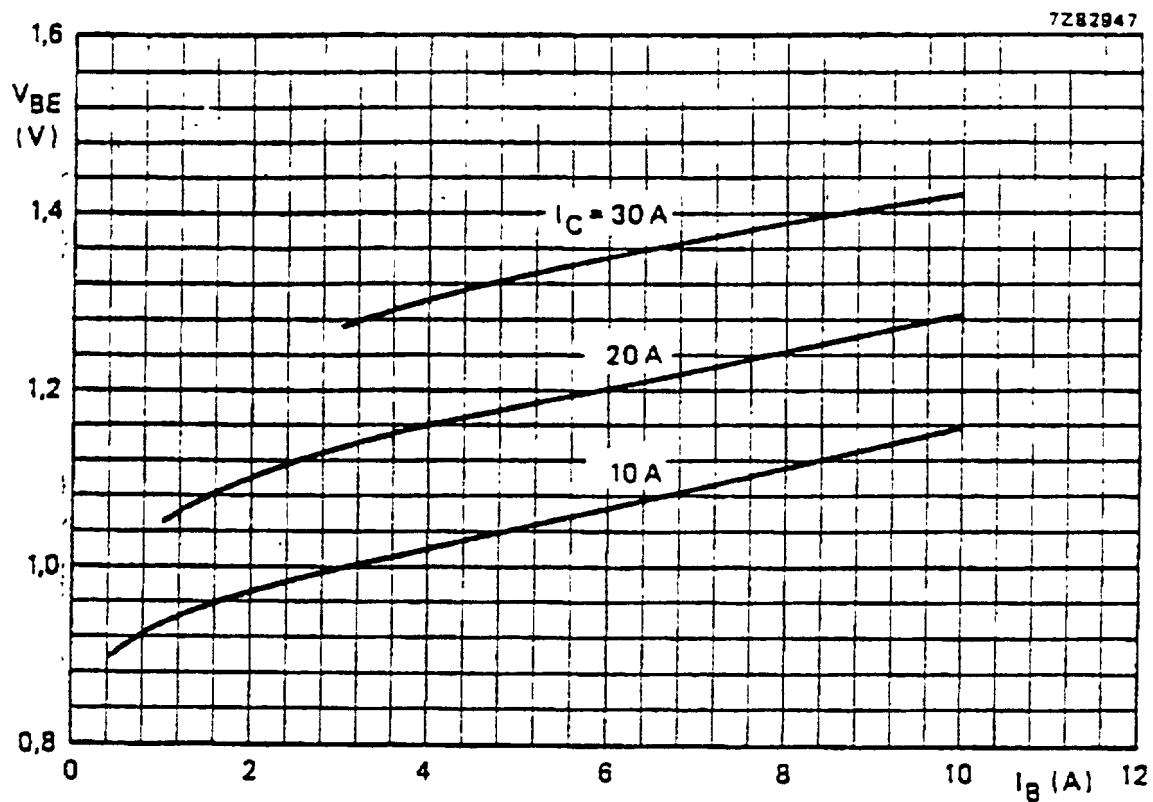


Fig. 14 Typical values at $T_j$ = 25 °C.
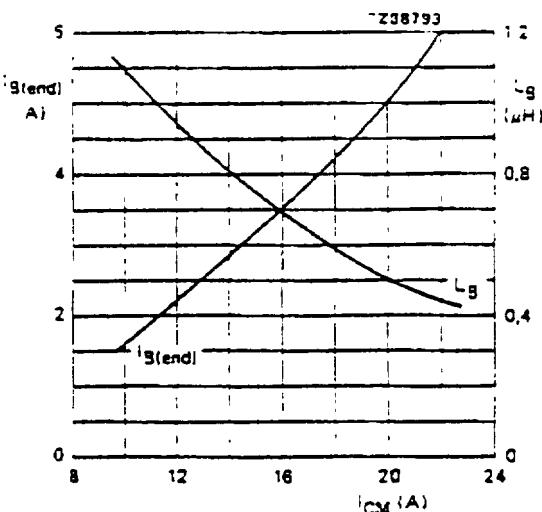
Fig. 16 Recommended nominal "end" value of the base current $(I_{Be})$ and optimum base inductance $(L_B)$ at $-V_{drive} = 5$ V versus maximum peak collector current. $dI_{B(end)} = \pm 20\%$.

For other values of $-V_{drive}$ (3 V to 7 V) the related $L_B$ is:

$$L_{Bnom} \frac{(-V_{drive}) + 1}{6}$$

$L_{Bnom}$ is the value given in this graph.
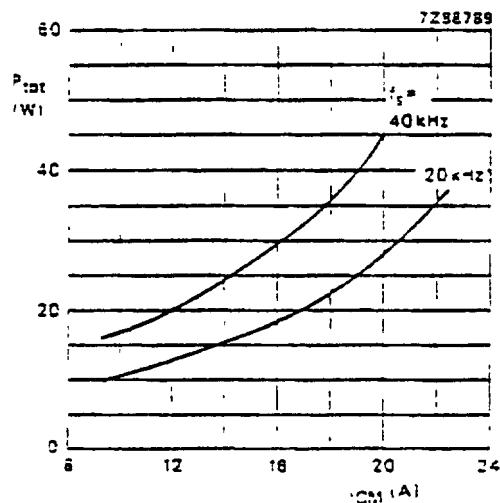


Fig. 17 Maximum transistor dissipation under worse-case operating condition versus maximum peak collector current. $T_{mb} = 100\,^{\circ}C$; $dI_{B(end)} = \pm 20\%$.