# SILICON DARLINGTON POWER TRANSISTORS

PNP epitaxial-base transistors in a monolithic Darlington circuit. They are housed in a TO-220 envelope and intended for applications such as audio output stages, switching, and general amplifiers.

The NPN complements are BD643, BD645, BD647, BD649 and BD651.

## QUICK REFERENCE DATA

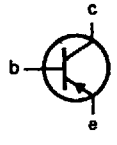
| | | | BD644 | 646 | 648 | 650 | 652 | |
|---|---|---|---|---|---|---|---|---|
| Collector-base voltage (open emitter) | $-V_{CBO}$ | max. | 45 | 60 | 80 | 100 | 120 | V |
| Collector-emitter voltage (open base) | $-V_{CEO}$ | max. | 45 | 60 | 80 | 100 | 120 | V |
| Collector current (DC) | $-I_C$ | max. | | | 8 | | | A |
| Total power dissipation up to $T_{amb}$ = 25 °C | $P_{tot}$ | max. | | | 62.5 | | | W |
| Junction temperature | $T_j$ | max. | | | 150 | | | °C |
| DC current gain | | | | | | | | |
| $-I_C$ = 3 A; $-V_{CE}$ = 3 V | $h_{FE}$ | min. | – | 750 | 750 | 750 | 750 | |
| $-I_C$ = 4 A; $-V_{CE}$ = 3 V | | min. | 750 | – | – | – | – | |

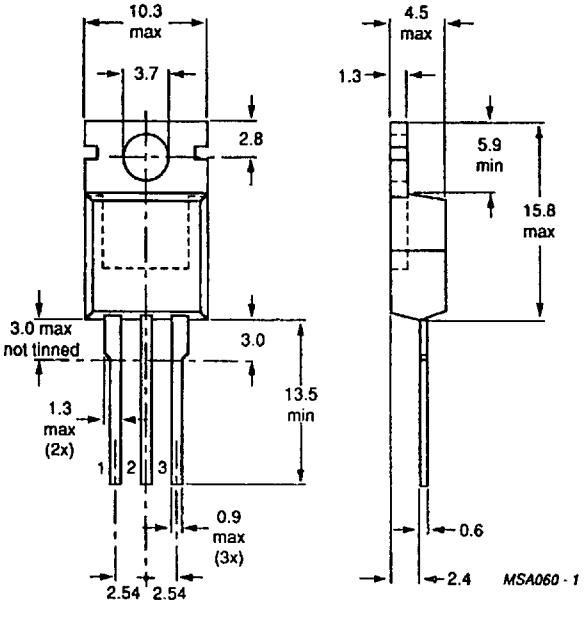
## MECHANICAL DATA

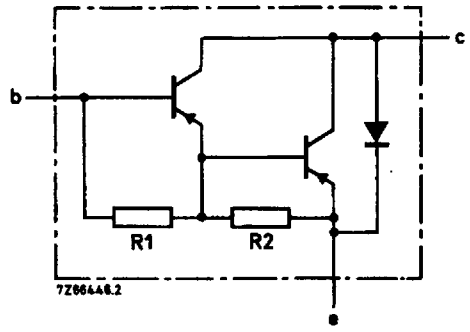
Dimensions in mm

Fig. 1 TO-220.

**Pinning**
1 = base
2 = collector
3 = emitter






R1 typ. 4 kΩ
R2 typ. 100 Ω

Fig. 2 Circuit diagram.

## RATINGS

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

| | | | BD644 | 646 | 648 | 650 | 652 | |
|---|---|---|---|---|---|---|---|---|
| Collector-base voltage (open emitter) | $-V_{CBO}$ | max. | 45 | 60 | 80 | 100 | 120 | V |
| Collector-emitter voltage (open base) | $-V_{CEO}$ | max. | 45 | 60 | 80 | 100 | 120 | V |
| Emitter-base voltage (open collector) | $-V_{EBO}$ | max. | | | 5 | | | V |
| Collector current (DC) | $-I_C$ | max. | | | 8 | | | A |
| Collector current (peak value) | $-I_{CM}$ | max. | | | 12 | | | A |
| Base current (DC) | $-I_B$ | max. | | | 150 | | | mA |
| Total power dissipation up to $T_{amb}$ = 25 °C | $P_{tot}$ | max. | | | 62.5 | | | W |
| Storage temperature range | $T_{stg}$ | | | | −65 to +150 | | | °C |
| Junction temperature | $T_j$ | max. | | | 150 | | | °C |

## THERMAL RESISTANCE *

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| From junction to mounting base | $R_{th\ j\text{-}mb}$ | max. | | | 2 | | | K/W |
| From junction to ambient in free air | $R_{th\ j\text{-}a}$ | max. | | | 70 | | | K/W |

* Based on maximum junction temperature in line with common industrial practice. The resulting higher junction temperature of the output transistor is taken into account.

## CHARACTERISTICS

$T_j$ = 25 °C unless otherwise specified

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Collector cut-off currents | | | | | | | | |
| $-I_E = 0$; $-V_{CB} = -V_{CEO}$ max. | $-I_{CBO}$ | max. | | | 0.1 | | | mA |
| $-I_E = 0$; $-V_{CB} = -1/2\ V_{CBO}$ max. $T_j$ = 150 °C | $-I_{CBO}$ | max. | | | 1 | | | mA |
| $-I_E = 0$; $-V_{CE} = -1/2\ V_{CEO}$ max. | $-I_{CEO}$ | max. | | | 0.2 | | | mA |
| Emitter cut-off current | | | | | | | | |
| $-I_C = 0$; $-V_{EB}$ = 5 V | $-I_{EBO}$ | max. | | | 5 | | | mA |
| | | | BD644 | 646 | 648 | 650 | 652 | |
| DC current gain (see note 1) | | | | | | | | |
| $-I_C$ = 0.5 A; $-V_{CE}$ = 3 V | $h_{FE}$ | typ. | 2700 | 2700 | 2700 | 2700 | 2700 | |
| $-I_C$ = 4 A; $-V_{CE}$ = 3 V | $h_{FE}$ | min. | 750 | – | – | – | – | |
| $-I_C$ = 3 A; $-V_{CE}$ = 3V | $h_{FE}$ | min. | – | 750 | 750 | 750 | 750 | |
| $-I_C$ = 8 A; $-V_{CE}$ = 3 V | $h_{FE}$ | typ. | 200 | 200 | 200 | 200 | 200 | |
| Base-emitter voltage (see notes 1 and 2) | | | | | | | | |
| $-I_C$ = 4 A; $-V_{CE}$ = 3 V | $-V_{BE}$ | max. | 2.5 | – | – | – | – | V |
| $-I_C$ = 3 A; $-V_{CE}$ = 3 V | | max. | – | 2.5 | 2.5 | 2.5 | 2.5 | V |
| Saturation voltages (see note 1) | | | | | | | | |
| $-I_C$ = 4 A; $-I_B$ = 16 mA | $-V_{CEsat}$ | max. | 2 | – | – | – | – | V |
| $-I_C$ = 3 A; $-I_B$ = 12 mA | $-V_{CEsat}$ | max. | – | 2 | 2 | 2 | 2 | V |
| $-I_C$ = 5 A; $-I_B$ = 50 mA | $-V_{CEsat}$ | max. | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | V |
| $-I_C$ = 5 A; $-I_B$ = 50 mA | $-V_{BEsat}$ | max. | 3 | 3 | 3 | 3 | 3 | V |
| Small signal current gain; f = 1 MHz | | | | | | | | |
| $-I_C$ = 4 A; $-V_{CE}$ = 3 V | $h_{fe}$ | min. | 10 | – | – | – | – | |
| $-I_C$ = 3 A; $-V_{CE}$ = 3 V | | min. | – | 10 | 10 | 10 | 10 | |
| Cut-off frequency | | | | | | | | |
| $-I_C$ = 4 A; $-V_{CE}$ = 3 V | $f_{hfe}$ | typ. | 100 | – | – | – | – | kHz |
| $-I_C$ = 3 A; $-V_{CE}$ = 3 V | | typ. | – | 100 | 100 | 100 | 100 | kHz |
| Second-breakdown collector current $t_p$ = 0.1 s; non-repetitive; without heatsink | | | | | | | | |
| $-V_{CE}$ = 50 V | $-I_{(SB)}$ | min. | 1.25 | – | – | – | – | A |
| $-V_{CE}$ = 60 V | | min. | – | 1.04 | 1.04 | 1.04 | 1.04 | A |
| DC current gain ratio of matched pairs at $-V_{CE}$ = 3 V | | | | | | | | |
| $-I_C$ = 4 A BD644/BD643 | $h_{FE1}/h_{FE2}$ | max. | 2.5 | – | – | – | – | |
| $-I_C$ = 3A BD652/BD651 | | max. | – | 2.5 | 2.5 | 2.5 | 2.5 | |
| Diode forward voltage; $-I_F$ = 3 A | $-V_F$ | typ. | | | 1.6 | | | V |
| Collector capacitance at f = 1 MHz | | | | | | | | |
| $-V_{CB}$ = 10 V | $C_c$ | typ. | | | 75 | | | pF |

1. Measured under pulse conditions: $t_p$ = 300 μs, $\delta \leqslant 2\%$.
2. $V_{BE}$ decreases by about 3.8 mV/K with increasing temperature.

Switching times (see Figs 3 and 4)

$-I_C = 3$ A; $-I_{Bon} = I_{Boff} = 12$ mA

| | | | | |
|---|---|---|---|---|
| turn-on time | $t_{on}$ | typ. | 1 | μs |
| turn-off time | $t_{off}$ | typ. | 5 | μs |

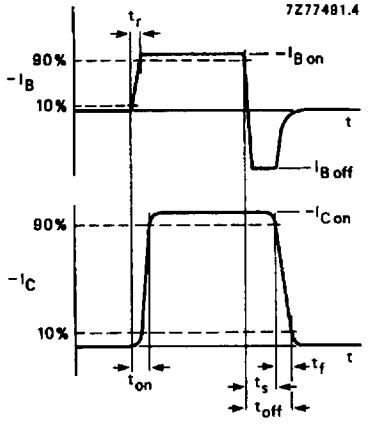
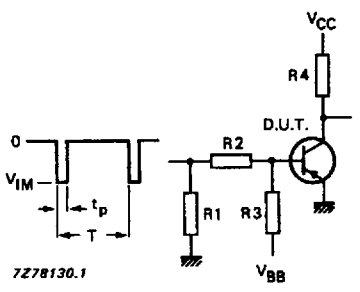



Fig. 3 Switching times waveforms.




$-V_{CC} = 10$ V
$-V_{IM} = 10$ V
$V_{BB} = 4$ V
R1 = 56 Ω
R2 = 410 Ω
R3 = 560 Ω
R4 = 3 Ω
$t_r = t_f = 15$ ns
$t_p = 10$ μs
T = 500 μs

Fig. 4 Switching times test circuit.

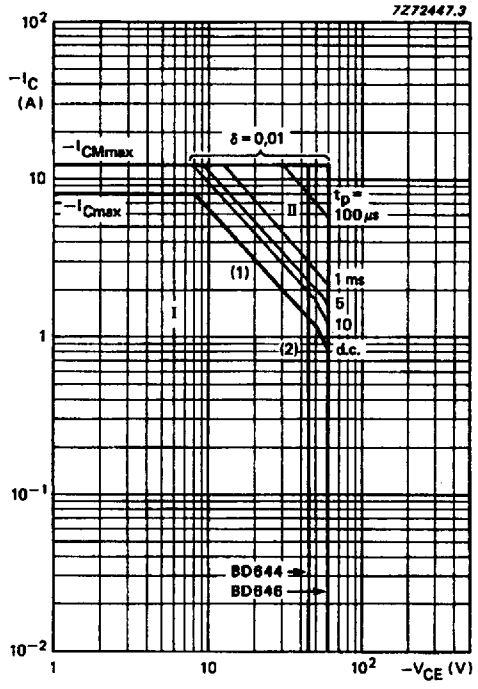



Fig. 5 **BD644; BD646** Safe Operating Area, $T_{mb}$ = 25 °C.

I Region of permissible DC operation.
II Permissible extension for repetitive pulse operation.

(1) $P_{tot\ max}$ and $P_{peak\ max}$ lines
(2) Second-breakdown limits.

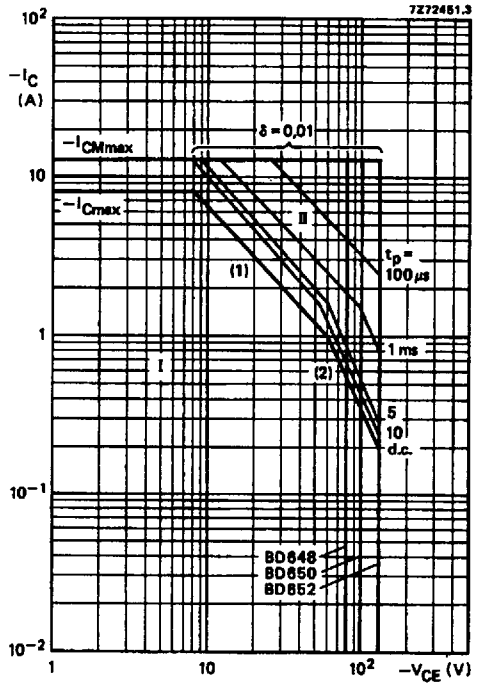



Fig. 6 **BD648, BD650, BD652** Safe Operating Area, $T_{mb} = 25\ ^\circ C$.

I Region of permissible DC operation.
II Permissible extension for repetitive pulse operation.

(1) $P_{tot\ max}$ and $P_{peak\ max}$ lines
(2) Second-breakdown limits.

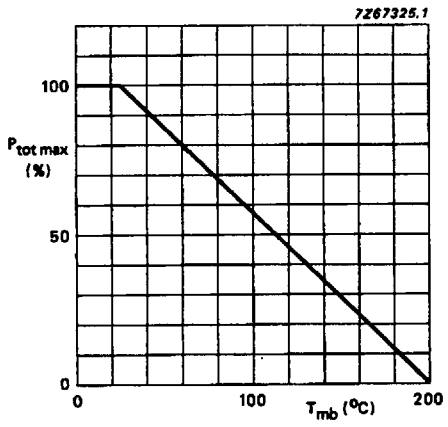



Fig. 7 Power derating curve.

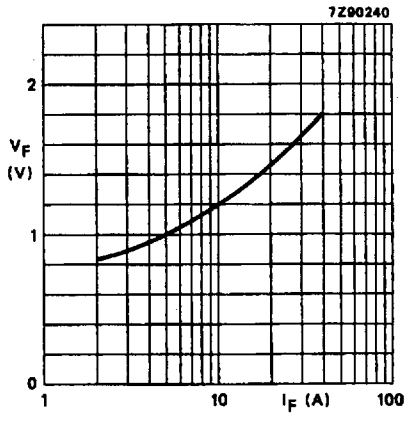



Fig. 8 Diode forward voltage versus forward current; $T_j$ = 25 °C; typical values.

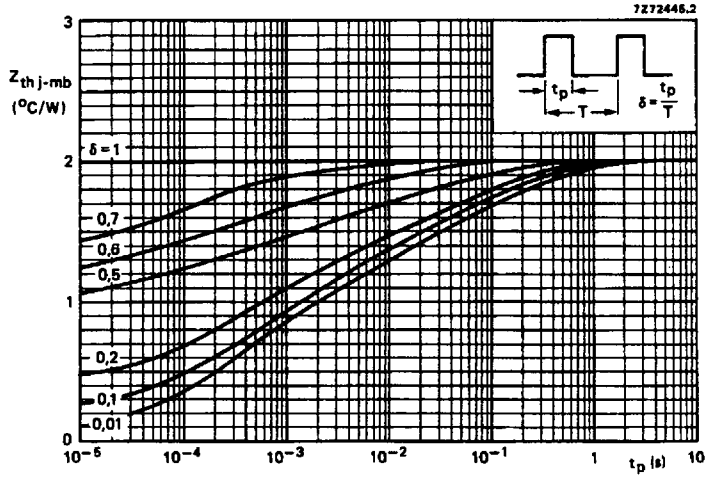



Fig. 9 Pulse power rating chart.

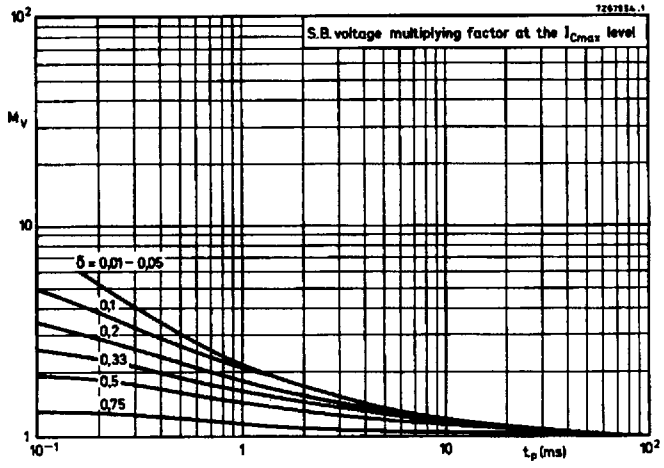



Fig. 10 Second breakdown voltage multiplying factor at the $I_{Cmax}$ level.

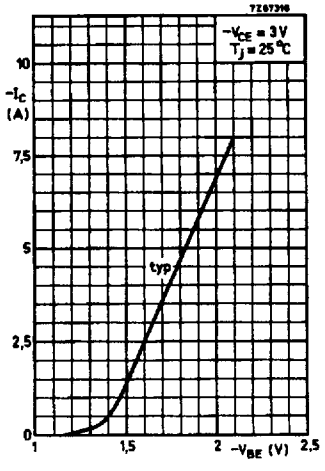



Fig. 11 Collector current versus base-emitter voltage; $-V_{CE}$ = 3 V; $T_j$ = 25 °C; typical value.

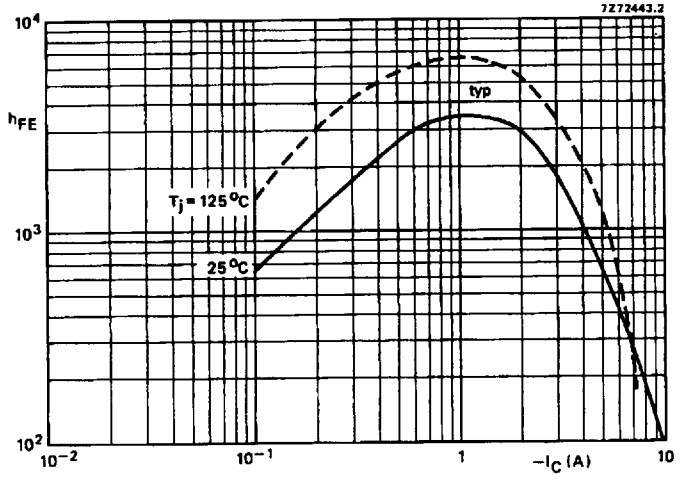



Fig. 12 DC current gain; $-V_{CE}$ = 3 V; typical values.

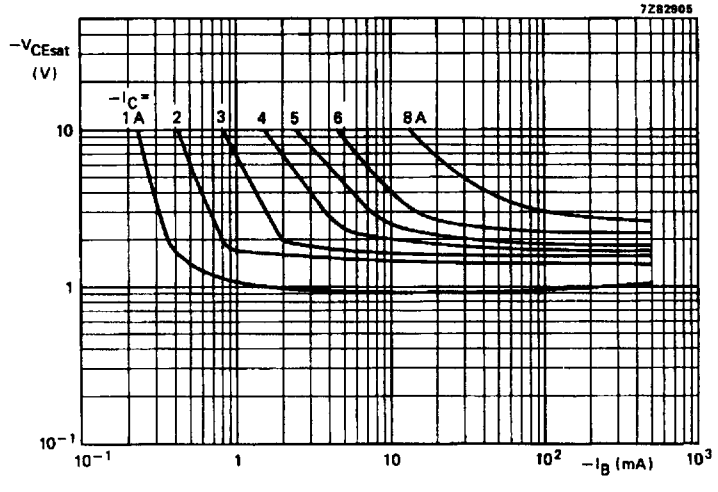



Fig. 13 Collector-emitter saturation voltage; $T_j$ = 25 °C; typical values.

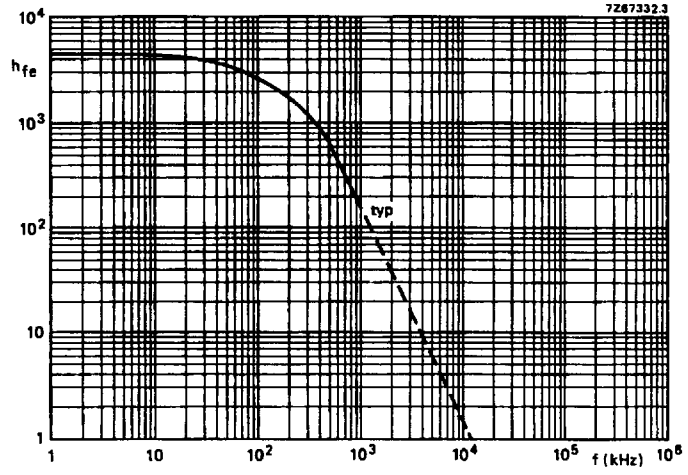



Fig. 14 Small signal current gain; $-I_C = 3$ A; $-V_{CE} = 3$ V; typical values.