Bipolar Transistors
Terms used in data sheets

Description
This document describes the terms used in data sheets bipolar transistors.
Table of Contents

Description ............................................................................................................................................ 1

Table of Contents ................................................................................................................................. 2

1. Glossary ............................................................................................................................................ 3

  1.1. Absolute maximum ratings ........................................................................................................ 3

  1.2. Electrical Characteristics ............................................................................................................ 4

  1.3. Other terms ................................................................................................................................. 7

RESTRICTIONS ON PRODUCT USE ........................................................................................................... 8
1. Glossary

1.1. Absolute maximum ratings

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-base voltage</td>
<td>$V_{CBO}$</td>
<td>The maximum allowable voltage between the collector and base terminals when the emitter terminal is open-circuited</td>
</tr>
<tr>
<td>Collector-emitter voltage</td>
<td>$V_{CEO}$</td>
<td>The maximum allowable voltage between the collector and emitter terminals when the base terminal is open-circuited</td>
</tr>
<tr>
<td></td>
<td>$V_{CER}$</td>
<td>The maximum allowable voltage between the collector and emitter terminals when a resistor is connected between the base and emitter terminals</td>
</tr>
<tr>
<td></td>
<td>$V_{CEX}$</td>
<td>The maximum allowable voltage in the cut-off state between the collector and emitter terminals with reverse bias applied between the base and emitter terminals</td>
</tr>
<tr>
<td></td>
<td>$V_{CES}$</td>
<td>The maximum allowable voltage between the collector and emitter terminals in the cut-off state when the base and emitter terminals are short-circuited</td>
</tr>
<tr>
<td>Emitter-base voltage</td>
<td>$V_{EBO}$</td>
<td>The maximum allowable voltage in the cut-off state between the emitter and base terminals when the collector terminal is open-circuited</td>
</tr>
<tr>
<td>Collector current (DC)</td>
<td>$I_C$</td>
<td>The maximum allowable continuous current into the collector terminal</td>
</tr>
<tr>
<td>Collector current (pulsed)</td>
<td>$I_{CP}$</td>
<td>The maximum allowable pulsed current into the collector terminal</td>
</tr>
<tr>
<td>Emitter current</td>
<td>$I_E$</td>
<td>The maximum allowable continuous current into the emitter terminal</td>
</tr>
<tr>
<td>Base current</td>
<td>$I_B$</td>
<td>The maximum allowable continuous current into the base terminal</td>
</tr>
<tr>
<td>Collector power dissipation</td>
<td>$P_C$</td>
<td>The maximum allowable power dissipated across the collector and emitter terminals</td>
</tr>
<tr>
<td>Junction temperature</td>
<td>$T_j$</td>
<td>The maximum allowable temperature at the junction of the transistor</td>
</tr>
<tr>
<td>Storage temperature</td>
<td>$T_{stg}$</td>
<td>The ambient temperature range over which the device, without any voltage applied, can be stored and transported</td>
</tr>
</tbody>
</table>
### 1.2. Electrical Characteristics

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector-base breakdown voltage</td>
<td>$V_{(BR)CBO}$</td>
<td>The breakdown voltage between the collector and base terminals under specified test conditions when the emitter terminal is open-circuited</td>
</tr>
<tr>
<td>Collector-emitter breakdown voltage</td>
<td>$V_{(BR)CEO}$</td>
<td>The breakdown voltage between the collector and emitter terminals under specified test conditions when the base terminal is open-circuited</td>
</tr>
<tr>
<td></td>
<td>$V_{(BR)CER}$</td>
<td>The breakdown voltage between the collector and emitter terminals under specified test conditions when a resistor is connected between the base and emitter terminals</td>
</tr>
<tr>
<td></td>
<td>$V_{(BR)CEX}$</td>
<td>The breakdown voltage between the collector and emitter terminals under specified test conditions when a reverse bias is applied between the base and emitter terminals</td>
</tr>
<tr>
<td></td>
<td>$V_{(BR)C ES}$</td>
<td>The breakdown voltage between the collector and emitter terminals under specified test conditions when the base and emitter terminals are short-circuited</td>
</tr>
<tr>
<td>Emitter-base breakdown voltage</td>
<td>$V_{(BR)EBO}$</td>
<td>The breakdown voltage between the emitter and base terminals under specified test conditions when the collector terminal is open-circuited</td>
</tr>
<tr>
<td>Collector-base cut-off current</td>
<td>$I_{CBO}$</td>
<td>The current in the cut-off state that flows into the collector terminal under specified test conditions when a voltage is applied across the collector and base terminals with the emitter terminal open-circuited</td>
</tr>
<tr>
<td>Collector-emitter cut-off current</td>
<td>$I_{CEO}$</td>
<td>The current in the cut-off state that flows into the collector terminal under specified test conditions when a voltage is applied between the collector and emitter terminals with the base terminal open-circuited</td>
</tr>
<tr>
<td>Emitter-base cut-off current</td>
<td>$I_{EBO}$</td>
<td>The current in the cut-off state that flows into the emitter terminal under specified test conditions when a voltage is applied between the emitter and base terminals with the collector terminal open-circuited</td>
</tr>
<tr>
<td>DC current gain</td>
<td>$h_{FE}$</td>
<td>The ratio of the collector current to the base current in a common-emitter configuration under specified test conditions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DC current gain = collector current / base current</td>
</tr>
<tr>
<td>Term</td>
<td>Symbol</td>
<td>Description</td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Collector-emitter saturation voltage</td>
<td>$V_{CE(sat)}$</td>
<td>The voltage between the collector and emitter terminals in the saturation state under specified test conditions</td>
</tr>
<tr>
<td>Base-emitter saturation voltage</td>
<td>$V_{BE(sat)}$</td>
<td>The voltage between the base and emitter terminals in the saturation state under specified test conditions</td>
</tr>
<tr>
<td>Collector output capacitance</td>
<td>$C_{ob}$</td>
<td>The capacitance between collector and base at the specified collector-base voltage and frequency when the emitter terminal is open-circuited</td>
</tr>
<tr>
<td>Emitter input capacitance</td>
<td>$C_{ib}$</td>
<td>The capacitance value between emitter and base at the specified emitter-base voltage and frequency when the base terminal is grounded</td>
</tr>
<tr>
<td>Reverse capacitance</td>
<td>$C_{re}$</td>
<td>The capacitance value when the input is ac short-circuited and the emitter terminal is grounded</td>
</tr>
<tr>
<td>Transition frequency</td>
<td>$f_T$</td>
<td>The frequency at which the current gain is 1 (= 0 dB) when the emitter is grounded</td>
</tr>
<tr>
<td>Noise figure</td>
<td>$NF$</td>
<td>The ratio of the input signal-to-noise ratio to the output signal-to-noise ratio of a device. $NF$ is calculated as:</td>
</tr>
</tbody>
</table>

$$NF = 10 \log \left( \frac{(S/N)_{in}}{(S/N)_{out}} \right)^2$$
<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
<th>Definition of collector-emitter voltage ($V_{CE}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay time</td>
<td>$t_d$</td>
<td>The period of time from when the base current has reached 10% of its maximum amplitude to when the collector-emitter voltage has reached 90% of its maximum amplitude, or the period of time required for the collector current to reach 10% of its maximum amplitude.</td>
<td>$V_{CE}$: Maximum amplitude of $V_{CE}$</td>
</tr>
<tr>
<td>Rise time</td>
<td>$t_r$</td>
<td>The period of time required for the collector-emitter voltage to decrease from 90% to 10% of its maximum amplitude, or the period of time required for the collector current to increase from 10% to 90% of its maximum amplitude.</td>
<td></td>
</tr>
<tr>
<td>Turn-on time</td>
<td>$t_{on}$</td>
<td>The period of time from when the base current has reached 10% of its maximum amplitude to when the collector-emitter voltage has reached 10% of its maximum amplitude, or the period of time required for the collector current to reach 90% of its maximum amplitude.</td>
<td>$I_C$: Maximum amplitude of $I_C$</td>
</tr>
<tr>
<td>Storage time</td>
<td>$t_{stg}$</td>
<td>The period of time from when base current has dropped to 90% of its maximum amplitude to when the collector-emitter voltage has reached 10% of its maximum amplitude, or the period of time from when the base current has dropped to 90% of its maximum amplitude to when the collector-emitter voltage has reached 90% of its maximum amplitude.</td>
<td></td>
</tr>
</tbody>
</table>
### 1.3. Other terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall time</td>
<td>( t_f )</td>
<td>The period of time required for the collector-emitter voltage to increase from 10% to 90% of its maximum amplitude, or the period of time required for the collector current to decrease from 90% to 10% of its maximum amplitude</td>
</tr>
<tr>
<td>Turn-off time</td>
<td>( t_{off} )</td>
<td>The period of time from when the base current has reached 90% of its maximum amplitude to when the collector-emitter voltage has reached 90% of its maximum amplitude, or the time required for the collector current to reach 10% of its maximum amplitude</td>
</tr>
</tbody>
</table>

- **Cut-off region**: The region where almost no collector current flows when the base and emitter are open-circuited, short-circuited, or reverse-biased.

- **Active region**: The region where the collector current changes in proportion to the base current applied.

- **Saturation region**: In this region, even if the base current is increased or decreased, the collector current on the load line hardly changes (Point A in the figure) and the collector current changes only when the collector-emitter voltage is changed.

- **Forward-bias safe operating area**: The region specified by the collector current and collector-emitter voltage conditions where a transistor operates without self-damage when the base-emitter is forward-biased.

- **Reverse-bias safe operating area**: The region bounded by the collector current and collector-emitter voltage conditions where a transistor can safely transition to the cut-off region from the “on” state without self-damage when the base-emitter is reverse-biased.
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