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Team Nexperia

# AN10405

Increased circuit efficiency, less required board space and saved money by replacing power transistors by low  $V_{CEsat}$  (BISS) transistors

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Application note

## Document information

| Info            | Content  |
|-----------------|--|
| <b>Keywords</b> | Bipolar transistors, BISS, low $V_{CEsat}$ , PBSS, power transistors   |
| <b>Abstract</b> | This application note provides information on how to make use of a cost saving opportunity by replacing older medium power and power transistors by Philips' low $V_{CEsat}$ (BISS) transistors. A cross reference table provides a cross reference for leaded and SMD types. Further spreadsheets show a comparison of the most common parameters ( $V_{CEO}$ , $I_C$ , $V_{CEsat}$ and $h_{FE}$ ). |

## Revision history

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## 1. Introduction

This application note provides information on how to make use of a cost saving opportunity by replacing older medium power and power transistors by Philips' low V<sub>CEsat</sub> (BISS) transistors<sup>1</sup>. A cross reference table provides a cross reference for leaded and SMD types. Further spreadsheets show a comparison of the most common parameters (V<sub>CEO</sub>, I<sub>C</sub>, V<sub>CEsat</sub> and h<sub>FE</sub>).

## 2. Reduced power dissipation due to low saturation voltage

The low saturation voltage V<sub>CEsat</sub>, high collector current capability I<sub>C(max)</sub> and high current gain h<sub>FE</sub> make BISS transistors an excellent alternative to older medium power transistors in SOT54 (TO-92), SOT223 (SC-73) and SOT89 (SC-62) and power transistors in DPAK, TO-220 and TO-126. Particularly, for switching applications the transistors' power dissipation is significantly lower due to a low collector-emitter saturation voltage as the following example shows:

**Table 1: BISS transistors dissipate less power enabling to select smaller and cheaper packages**

| Example  | Power transistor | BISS transistor |
|--|------------------|-----------------|
| Type   | BD132            | PBSS5350S       |
| Package  | SOT32 (TO-126)   | SOT54 (TO-92)   |
| I <sub>C</sub>                                       | 2 A              | 2 A             |
| V <sub>CEsat</sub>                                   | 700 mV           | 300 mV          |
| P <sub>C</sub> = V <sub>CEsat</sub> × I <sub>C</sub> | 1400 mW          | 600 mW          |
| h <sub>FE(min)</sub>                                 | 20               | 100             |

Due to the lower power dissipation transistors with a smaller package can be selected. The PBSS5350S in SOT54 (TO-92) for example replaces a BD132 in TO-126. Keeping in mind that for discrete semiconductors package costs are higher than the cost for the silicon savings can be realized by using small SOT54 BISS transistors. Additionally, the circuit efficiency increases and less board space is necessary.

Further, BISS transistors present a higher current gain h<sub>FE</sub>. As a result, less base current is required to control the transistor which takes load from the driving circuit.

While for switching applications V<sub>CEsat</sub> is very low, the higher V<sub>CE</sub> for linear applications leads to a higher power dissipation. A replacement with BISS transistors is limited to 830 mW for leaded BISS transistors and to 1350 mW for surface mount applications (2 W for SOT223 transistors on 6 cm<sup>2</sup> collector mounting pad).

<sup>1</sup> More information on low V<sub>CEsat</sub> (BISS) transistors is given in the following application notes:  
AN10116: Breakthrough In Small Signal - Low V<sub>CEsat</sub> (BISS) Transistors and their Applications  
AN10393: BISS transistors and MEGA Schottky rectifiers – improved technologies for discrete semiconductors

Only a few BISS transistor types are necessary to replace numerous power transistors:

- PBSS8110\_ / PBSS9110\_ 1 A / 100 V and
- PBSS4350\_ / PBSS5350\_ 3 A / 50 V replace
- power transistors with 1 – 3 A rated collector current.
- PBSS4540Z / PBSS5540Z 5 A / 40 V and
- PBSS302ND / PBSS302PD 4 A / 40 V replace
- power transistors with 4 – 5 A rated collector current.

Table 19: - Table 24: show the most common parameters of these types for reference.

### 3. Common replacements

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Many popular transistors are included in the cross reference table (Table 2:). Main cross reference data given in Table 3: – Table 18: are provided to confirm the selection. For SMD replacements these tables provide up to three alternatives with the same electrical but different thermal specifications. This enables to use the smallest package possible depending on the actual power dissipation.

The BISS transistors in Table 2: are selected with focus on reducing the number of types. This implies that the provided replacement must not necessarily be the optimum solution with regard to the achievable power dissipation.

## 4. General selection process

For transistors not included in the cross reference table the following steps need to be done by comparing the data sheets:

1. Limiting values, V<sub>CEO</sub>: BISS transistors must have equal or higher value.
2. Limiting values, I<sub>C</sub>: BISS transistors must have equal or higher value.
3. Characteristics, V<sub>CEsat(max)</sub>: BISS transistors must have equal or lower value, pay attention to comparable operating conditions I<sub>C</sub> and I<sub>B</sub>. Notes to V<sub>CEsat</sub>:
  - This parameter is mostly important for switching applications (i.e. not relevant for linear applications).
  - The lower the ratio I<sub>C</sub>/I<sub>B</sub> the lower the saturation voltage but the higher the required base current.
  - V<sub>CEsat</sub> values of BISS transistors are far below the values of power transistors.
4. Characteristics, h<sub>FE(min)</sub>: BISS transistors must have equal or higher value, pay attention to comparable operating conditions I<sub>C</sub> and V<sub>CE</sub>. Notes to h<sub>FE</sub>:
  - This parameter is important for linear and switching applications.
  - The higher V<sub>CE</sub> the higher the current gain at a specified current.
  - h<sub>FE</sub> values of BISS transistors are far above the values of power transistors.
5. Calculate resulting power dissipation P<sub>tot</sub> to select the most appropriate package.
  - Switching applications:  $P_{tot} = V_{CEsat} \times I_C + V_{BEsat} \times I_B$
  - Linear applications:  $P_{tot} = V_{CE} \times I_C + V_{BE} \times I_B$
 Notes to P<sub>tot</sub>:
  - For a rough estimation the input power dissipation (V<sub>BE(sat)</sub> × I<sub>B</sub>) can be neglected.
  - For linear applications power dissipation may become an issue since V<sub>CE</sub> is significantly higher than V<sub>CEsat</sub> in switching applications.
  - For the package selection the mounting conditions must be considered:

|                     |            |
|---------------------|------------|
| SOT54               | 0.83 W     |
| SOT223 <sup>)</sup> | 1 – 1.35 W |
| SOT89 <sup>)</sup>  | 1 W        |
| SOT457 <sup>)</sup> | 0.6 W      |
| SOT23 <sup>)</sup>  | 0.48 W     |

<sup>)</sup> Mounted on 1 cm<sup>2</sup> collector mounting pad

- For switching applications a high power dissipation capability of the package is often not necessary anymore since the heat generation is much lower using BISS transistors due to the very low V<sub>CEsat</sub> values.
- An even lower power dissipation due to lower V<sub>CEsat</sub> values can be achieved by selecting BISS transistors with a lower V<sub>CEO</sub> value. For example if the application requires only 20 V breakdown voltage, a 20 V transistor should be used instead of a 40 V transistor.

For most of the medium power and power transistors the types given in Table 19:– Table 24: should be sufficient. If not please look for data sheets of transistors starting with “PBSS” on the Internet or contact your nearest Philips sales office.

## 5. Cross reference table for common replacements

**Table 2: Cross reference table for replacing (medium) power by BISS transistors**

| original type | replacement |           |           |           | cross ref. data |
|---------------|-------------|-----------|-----------|-----------|-----------------|
|               | SOT54       | SOT223    | SOT457    | SOT23     |                 |
| BC635         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BC636         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BC637         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BC638         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BC639         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BC640         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCP51         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCP52         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCP53         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCP54         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BCP55         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BCP56         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BCX51         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCX52         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCX53         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 11        |
| BCX54         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BCX55         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BCX56         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 3         |
| BD131         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 7         |
| BD132         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 15        |
| BD135         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 5         |
| BD136         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 13        |
| BD137         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 5         |
| BD138         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 13        |
| BD139         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 5         |
| BD140         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 13        |
| BD329         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 8         |
| BD330         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 16        |
| BD433         |             | PBSS4540Z | PBSS302ND |           | Table 10        |
| BD434         |             | PBSS5540Z | PBSS302PD |           | Table 18        |
| BD435         |             | PBSS4540Z | PBSS302ND |           | Table 10        |
| BD436         |             | PBSS5540Z | PBSS302PD |           | Table 18        |
| KSH200        |             | PBSS4540Z |           |           | Table 9         |
| KSH210        |             | PBSS5540Z |           |           | Table 17        |
| KSH31         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 6         |
| KSH32         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 14        |
| MJD148        |             | PBSS4540Z | PBSS302ND |           | Table 10        |

| original type | replacement |           |           |           | cross ref. data |
|---------------|-------------|-----------|-----------|-----------|-----------------|
|               | SOT54       | SOT223    | SOT457    | SOT23     |                 |
| MJD200        |             | PBSS4540Z |           |           | Table 9         |
| MJD210        |             | PBSS5540Z |           |           | Table 17        |
| MJD31         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 6         |
| MJD32         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 14        |
| TIP29         | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 4         |
| TIP29A        | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 4         |
| TIP29B        | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 4         |
| TIP29C        | PBSS8110S   | PBSS8110Z | PBSS8110D | PBSS8110T | Table 4         |
| TIP30         | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 12        |
| TIP30A        | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 12        |
| TIP30B        | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 12        |
| TIP30C        | PBSS9110S   | PBSS9110Z | PBSS9110D | PBSS9110T | Table 12        |
| TIP31         | PBSS4350S   | PBSS4350Z | PBSS4350D |           | Table 6         |
| TIP32         | PBSS5350S   | PBSS5350Z | PBSS5350D |           | Table 14        |



## 6. Basic cross reference data, NPN transistors

Table 3:

| type                    | original type<br>leaded                      | SMD  |  | replacement<br>leaded | SMD   |                     |
|-------------------------|--|--|--|-----------------------|---|---------------------|
|                         | <b>BC635</b><br><b>BC637</b><br><b>BC639</b> | <b>BCP54</b><br><b>BCP55</b><br><b>BCP56</b>     | <b>BCX54</b><br><b>BCX55</b><br><b>BCX56</b> | <b>PBSS8110S</b>      | <b>PBSS8110D</b>                                  | <b>PBSS8110T</b>    |
| package                 | SOT54  | SOT223   | SOT89  | SOT54                 | SOT457  | SOT23               |
| P <sub>tot</sub>        | 830 mW                                       | 1000 mW <sup>)</sup>                             | 850 mW <sup>)</sup>                          | 830 mW                | 600 mW <sup>)</sup>                               | 480 mW <sup>)</sup> |
| V <sub>CEO</sub>        | 45 / 60 / 80 V                               |  |  | 100 V                 |   |                     |
| I <sub>C</sub>          | 1 A  |  |  | 1 A                   |   |                     |
| V <sub>CEsat(max)</sub> | 500 mV                                       | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |  | 120 mV                | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA  |                     |
| h <sub>FE(min)</sub>    | 63   | @ I <sub>C</sub> = 0,15 A, V <sub>CE</sub> = 2 V |  | 150                   | @ I <sub>C</sub> = 0,25 A, V <sub>CE</sub> = 10 V |                     |
|                         | 40   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  |  | 100                   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 10 V  |                     |

<sup>)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 4:

| type                    | original type<br>leaded   | SMD   |                      |   |
|-------------------------|---|---|----------------------|---|
|                         | <b>TIP29</b><br><b>TIP29A</b><br><b>TIP29B</b><br><b>TIP29C</b> | <b>PBSS8110S</b>                                | <b>PBSS8110Z</b>     | <b>PBSS8110T</b>                                  |
| package                 | TO-220AB  | SOT54   | SOT223               | SOT23   |
| P <sub>tot</sub>        | 2000 mW   | 830 mW  | 1000 mW <sup>)</sup> | 480 mW <sup>)</sup>                               |
| V <sub>CEO</sub>        | 40 / 60 /<br>80 / 100 V   | 100 V   |                      |   |
| I <sub>C</sub>          | 1 A   | 1 A   |                      |   |
| V <sub>CEsat(max)</sub> | 700 mV  | @ I <sub>C</sub> = 1 A, I <sub>B</sub> = 125 mA | 200 mV               | @ I <sub>C</sub> = 1 A, I <sub>B</sub> = 100 mA   |
| h <sub>FE(min)</sub>    | 40  | @ I <sub>C</sub> = 0,2 A, V <sub>CE</sub> = 4 V | 150                  | @ I <sub>C</sub> = 0,25 A, V <sub>CE</sub> = 10 V |
|                         | 15  | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 4 V   | 80                   | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 10 V    |

<sup>)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 5:

|                               | original type<br>leaded                      |  | replacement<br>leaded | SMD  |                      |
|-------------------------------|--|--|-----------------------|--|----------------------|
| <b>type</b>                   | <b>BD135</b><br><b>BD137</b><br><b>BD139</b> |  | <b>PBSS4350S</b>      | <b>PBSS4350Z</b>                                 | <b>PBSS4350D</b>     |
| <b>package</b>                | SOT32 (TO-126)                               |  | SOT54                 | SOT223   | SOT457               |
| <b>P<sub>tot</sub></b>        | 1250 mW                                      |  | 830 mW                | 1350 mW <sup>1)</sup>                            | 600 mW <sup>1)</sup> |
| <b>V<sub>CEO</sub></b>        | 45 / 60 / 80 V                               |  | 50 V                  |  |                      |
| <b>I<sub>C</sub></b>          | 1,5 A  |  | 3 A                   |  |                      |
| <b>V<sub>CEsat(max)</sub></b> | 500 mV                                       | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA | 90 mV                 | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |                      |
| <b>h<sub>FE(min)</sub></b>    | 25   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  | 200                   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 6:

|                               | original type<br>leaded | SMD   | replacement<br>leaded | SMD   |                      |
|-------------------------------|-------------------------|---|-----------------------|---|----------------------|
| <b>type</b>                   | <b>TIP31</b>            | <b>MJD31</b><br><b>KSH31</b>                    | <b>PBSS4350S</b>      | <b>PBSS4350Z</b>                                | <b>PBSS4350D</b>     |
| <b>package</b>                | TO-220                  | TO-252<br>DPAK                                  | SOT54                 | SOT223  | SOT457               |
| <b>P<sub>tot</sub></b>        | 2000 mW                 | 1560 mW   | 830 mW                | 1350 mW <sup>1)</sup>                           | 600 mW <sup>1)</sup> |
| <b>V<sub>CEO</sub></b>        | 40 V                    |   | 50 V                  |   |                      |
| <b>I<sub>C</sub></b>          | 3 A                     |   | 3 A                   |   |                      |
| <b>V<sub>CEsat(max)</sub></b> | 1200 mV                 | @ I <sub>C</sub> = 3 A, I <sub>B</sub> = 375 mA | 290 mV                | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |                      |
| <b>h<sub>FE(min)</sub></b>    | 25                      | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 4 V   | 200                   | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 2 V   |                      |
|                               | 10                      | @ I <sub>C</sub> = 3 A, V <sub>CE</sub> = 4 V   | 100                   | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V   |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 7:

|                  | original type<br>leaded |                                  | replacement<br>leaded | SMD                             |                      |
|------------------|-------------------------|----------------------------------|-----------------------|---------------------------------|----------------------|
| <b>type</b>      | <b>BD131</b>            |                                  | <b>PBSS4350S</b>      | <b>PBSS4350Z</b>                | <b>PBSS4350D</b>     |
| package          | SOT32<br>(TO-126)       |                                  | SOT54                 | SOT223                          | SOT457               |
| $P_{tot}$        |                         |                                  | 830 mW                | 1350 mW <sup>1)</sup>           | 600 mW <sup>1)</sup> |
| $V_{CEO}$        | 45 V                    |                                  | 50 V                  |                                 |                      |
| $I_C$            | 3 A                     |                                  | 3 A                   |                                 |                      |
| $V_{CEsat(max)}$ | 300 mV                  | @ $I_C = 0,5$ A, $I_B = 50$ mA   | 90 mV                 | @ $I_C = 0,5$ A, $I_B = 50$ mA  |                      |
|                  | 700 mV                  | @ $I_C = 2$ A, $I_B = 200$ mA    | 290 mV                | @ $I_C = 2$ A, $I_B = 200$ mA   |                      |
| $h_{FE(min)}$    | 40                      | @ $I_C = 0,5$ A, $V_{CE} = 12$ V | 200                   | @ $I_C = 0,5$ A, $V_{CE} = 2$ V |                      |
|                  | 20                      | @ $I_C = 2$ A, $V_{CE} = 1$ V    | 100                   | @ $I_C = 2$ A, $V_{CE} = 2$ V   |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 8:

|                  | original type<br>leaded |                                 | replacement<br>leaded | SMD                             |                      |
|------------------|-------------------------|---------------------------------|-----------------------|---------------------------------|----------------------|
| <b>type</b>      | <b>BD329</b>            |                                 | <b>PBSS4350S</b>      | <b>PBSS4350Z</b>                | <b>PBSS4350D</b>     |
| package          | SOT32<br>(TO-126)       |                                 | SOT54                 | SOT223                          | SOT457               |
| $P_{tot}$        |                         |                                 | 830 mW                | 1350 mW <sup>1)</sup>           | 600 mW <sup>1)</sup> |
| $V_{CEO}$        | 20 V                    |                                 | 50 V                  |                                 |                      |
| $I_C$            | 3 A                     |                                 | 3 A                   |                                 |                      |
| $V_{CEsat(max)}$ | 500 mV                  | @ $I_C = 2$ A, $I_B = 200$ mA   | 290 mV                | @ $I_C = 2$ A, $I_B = 200$ mA   |                      |
|                  | 85                      | @ $I_C = 0,5$ A, $V_{CE} = 1$ V | 200                   | @ $I_C = 0,5$ A, $V_{CE} = 2$ V |                      |
| $h_{FE(min)}$    | 40                      | @ $I_C = 2$ A, $V_{CE} = 1$ V   | 100                   | @ $I_C = 2$ A, $V_{CE} = 2$ V   |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 9:

|                               | original type<br>SMD     |  | replacement<br>SMD    |  |
|-------------------------------|--------------------------|--|-----------------------|--|
| <b>type</b>                   | <b>MJD200<br/>KSH200</b> |  | <b>PBSS4540Z</b>      |  |
| <b>package</b>                | TO-252<br>DPAK           |  | SOT223                |  |
| <b>P<sub>tot</sub></b>        | 1400 mW                  |  | 1350 mW <sup>1)</sup> |  |
| <b>V<sub>CEO</sub></b>        | 25 V                     |  | 40 V                  |  |
| <b>I<sub>C</sub></b>          | 5 A                      |  | 5 A                   |  |
| <b>V<sub>CEsat(max)</sub></b> | 300 mV                   | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA | 90 mV                 | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |
|                               | 750 mV                   | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA  | 150 mV                | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA  |
|                               | 1800 mV                  | @ I <sub>C</sub> = 5 A, I <sub>B</sub> = 1000 mA | 355 mV                | @ I <sub>C</sub> = 5 A, I <sub>B</sub> = 500 mA  |
| <b>h<sub>FE(min)</sub></b>    | 70                       | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 1 V  | 300                   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  |
|                               | 45                       | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 1 V    | 250                   | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V    |
|                               | 10                       | @ I <sub>C</sub> = 5 A, V <sub>CE</sub> = 2 V    | 100                   | @ I <sub>C</sub> = 5 A, V <sub>CE</sub> = 2 V    |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 10:

|                               | original type<br>leaded |  | SMD   |  | replacement<br>SMD  |  |
|-------------------------------|-------------------------|--|---|--|---|--|
| <b>type</b>                   | <b>BD433<br/>BD435</b>  |  | <b>MJD148</b>                                   |  | <b>PBSS4540Z</b> <b>PBSS302ND</b>                                   |  |
| <b>package</b>                | TO-126                  |  | TO-252<br>DPAK                                  |  | SOT223    SOT457  |  |
| <b>P<sub>tot</sub></b>        |                         |  | 1750 mW   |  | 1350 mW <sup>1)</sup> 600 mW <sup>1)</sup>                          |  |
| <b>V<sub>CEO</sub></b>        | 22 / 32 V               |  | 45 V  |  | 40 V    40 V  |  |
| <b>I<sub>C</sub></b>          | 4 A                     |  | 4 A   |  | 5 A    4 A  |  |
| <b>V<sub>CEsat(max)</sub></b> | 500 mV                  |  | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |  | 150 mV    180 mV    @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |  |
| <b>h<sub>FE(min)</sub></b>    | 85                      |  | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 1 V |  | 300    300    @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V       |  |
|                               | 50                      |  | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 1 V   |  | 250    250    @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V         |  |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

## 7. Basic cross reference data, PNP transistors

Table 11:

|                  | original type<br>leaded                      | SMD  |  | replacement<br>leaded | SMD                              |                      |
|------------------|--|--|--|-----------------------|----------------------------------|----------------------|
| <b>type</b>      | <b>BC636</b><br><b>BC638</b><br><b>BC640</b> | <b>BCP51</b><br><b>BCP52</b><br><b>BCP53</b> | <b>BCX51</b><br><b>BCX52</b><br><b>BCX53</b> | <b>PBSS9110S</b>      | <b>PBSS9110D</b>                 | <b>PBSS9110T</b>     |
| package          | SOT54  | SOT223                                       | SOT89  | SOT54                 | SOT457                           | SOT23                |
| $P_{tot}$        | 830 mW                                       | 1000 mW <sup>1)</sup>                        | 850 mW <sup>1)</sup>                         | 830 mW                | 550 mW <sup>1)</sup>             | 480 mW <sup>1)</sup> |
| $V_{CEO}$        | 45 / 60 / 80 V                               |  |  | 100 V                 |                                  |                      |
| $I_C$            | 1 A  |  |  | 1 A                   |                                  |                      |
| $V_{CEsat(max)}$ | 500 mV                                       | @ $I_C = 0,5$ A, $I_B = 50$ mA               |  | 120 mV                | @ $I_C = 0,5$ A, $I_B = 50$ mA   |                      |
| $h_{FE(min)}$    | 63   | @ $I_C = 0,15$ A, $V_{CE} = 2$ V             |  | 150                   | @ $I_C = 0,25$ A, $V_{CE} = 5$ V |                      |
|                  | 40   | @ $I_C = 0,5$ A, $V_{CE} = 2$ V              |  | 100                   | @ $I_C = 0,5$ A, $V_{CE} = 5$ V  |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 12:

|                  | original type<br>leaded   | SMD                             |                       |                                  |
|------------------|---|---------------------------------|-----------------------|----------------------------------|
| <b>type</b>      | <b>TIP30</b><br><b>TIP30A</b><br><b>TIP30B</b><br><b>TIP30C</b> | <b>PBSS9110S</b>                | <b>PBSS9110Z</b>      | <b>PBSS9110T</b>                 |
| package          | TO-220AB  | SOT54                           | SOT223                | SOT23                            |
| $P_{tot}$        | 2000 mW   | 830 mW                          | 1000 mW <sup>1)</sup> | 480 mW <sup>1)</sup>             |
| $V_{CEO}$        | 40 / 60 /<br>80 / 100 V   | 100 V                           |                       |                                  |
| $I_C$            | 1 A   | 1 A                             |                       |                                  |
| $V_{CEsat(max)}$ | 700 mV  | @ $I_C = 1$ A, $I_B = 125$ mA   | 320 mV                | @ $I_C = 1$ A, $I_B = 100$ mA    |
| $h_{FE(min)}$    | 40  | @ $I_C = 0,2$ A, $V_{CE} = 4$ V | 150                   | @ $I_C = 0,25$ A, $V_{CE} = 5$ V |
|                  | 15  | @ $I_C = 1$ A, $V_{CE} = 4$ V   | 125                   | @ $I_C = 1$ A, $V_{CE} = 5$ V    |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 13:

|                               | original type<br>leaded                      |  | replacement<br>leaded | SMD  |                      |
|-------------------------------|--|--|-----------------------|--|----------------------|
| <b>type</b>                   | <b>BD136</b><br><b>BD138</b><br><b>BD140</b> |  | <b>PBSS5350S</b>      | <b>PBSS5350Z</b>                                 | <b>PBSS5350D</b>     |
| <b>package</b>                | SOT32<br>(TO-126)                            |  | SOT54                 | SOT223   | SOT457               |
| <b>P<sub>tot</sub></b>        | 1250 mW                                      |  | 830 mW                | 1350 mW <sup>1)</sup>                            | 600 mW <sup>1)</sup> |
| <b>V<sub>CEO</sub></b>        | 45 / 60 / 80 V                               |  | 50 V                  |  |                      |
| <b>I<sub>C</sub></b>          | 1,5 A  |  | 3 A                   |  |                      |
| <b>V<sub>CEsat(max)</sub></b> | 500 mV                                       | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA | 100 mV                | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |                      |
| <b>h<sub>FE(min)</sub></b>    | 25   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  | 200                   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 14:

|                               | original type<br>leaded | SMD   | replacement<br>leaded | SMD   |                      |
|-------------------------------|-------------------------|---|-----------------------|---|----------------------|
| <b>type</b>                   | <b>TIP32</b>            | <b>MJD32</b><br><b>KSH32</b>                    | <b>PBSS5350S</b>      | <b>PBSS5350Z</b>                                | <b>PBSS5350D</b>     |
| <b>package</b>                | TO-220                  | TO-252<br>DPAK                                  | SOT54                 | SOT223  | SOT457               |
| <b>P<sub>tot</sub></b>        | 2000 mW                 | 1560 mW   | 830 mW                | 1350 mW <sup>1)</sup>                           | 600 mW <sup>1)</sup> |
| <b>V<sub>CEO</sub></b>        | 40 V                    |   | 50 V                  |   |                      |
| <b>I<sub>C</sub></b>          | 3 A                     |   | 3 A                   |   |                      |
| <b>V<sub>CEsat(max)</sub></b> | 1200 mV                 | @ I <sub>C</sub> = 3 A, I <sub>B</sub> = 375 mA | 300 mV                | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |                      |
| <b>h<sub>FE(min)</sub></b>    | 25                      | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 4 V   | 200                   | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 2 V   |                      |
|                               | 10                      | @ I <sub>C</sub> = 3 A, V <sub>CE</sub> = 4 V   | 100                   | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V   |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 15:

|                  | original type<br>leaded |                                  | replacement<br>leaded | SMD  |
|------------------|-------------------------|----------------------------------|-----------------------|--|
| <b>type</b>      | <b>BD132</b>            |                                  | <b>PBSS5350S</b>      | <b>PBSS5350Z</b> <b>PBSS5350D</b>          |
| package          | SOT32<br>(TO-126)       |                                  | SOT54                 | SOT223    SOT457                           |
| $P_{tot}$        |                         |                                  | 830 mW                | 1350 mW <sup>1)</sup> 600 mW <sup>1)</sup> |
| $V_{CEO}$        | 45 V                    |                                  | 50 V                  |  |
| $I_C$            | 3 A                     |                                  | 3 A                   |  |
| $V_{CEsat(max)}$ | 300 mV                  | @ $I_C = 0,5$ A, $I_B = 50$ mA   | 100 mV                | @ $I_C = 0,5$ A, $I_B = 50$ mA             |
|                  | 700 mV                  | @ $I_C = 2$ A, $I_B = 200$ mA    | 300 mV                | @ $I_C = 2$ A, $I_B = 200$ mA              |
| $h_{FE(min)}$    | 40                      | @ $I_C = 0,5$ A, $V_{CE} = 12$ V | 200                   | @ $I_C = 0,5$ A, $V_{CE} = 2$ V            |
|                  | 20                      | @ $I_C = 2$ A, $V_{CE} = 1$ V    | 100                   | @ $I_C = 2$ A, $V_{CE} = 2$ V              |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 16:

|                  | original type<br>leaded |                                 | replacement<br>leaded | SMD  |
|------------------|-------------------------|---------------------------------|-----------------------|--|
| <b>type</b>      | <b>BD330</b>            |                                 | <b>PBSS5350S</b>      | <b>PBSS5350Z</b> <b>PBSS5350D</b>          |
| package          | SOT32<br>(TO-126)       |                                 | SOT54                 | SOT223    SOT457                           |
| $P_{tot}$        |                         |                                 | 830 mW                | 1350 mW <sup>1)</sup> 600 mW <sup>1)</sup> |
| $V_{CEO}$        | 20 V                    |                                 | 50 V                  |  |
| $I_C$            | 3 A                     |                                 | 3 A                   |  |
| $V_{CEsat(max)}$ | 500 mV                  | @ $I_C = 2$ A, $I_B = 200$ mA   | 300 mV                | @ $I_C = 2$ A, $I_B = 200$ mA              |
|                  |                         | @ $I_C = 0,5$ A, $V_{CE} = 1$ V |                       | @ $I_C = 0,5$ A, $V_{CE} = 2$ V            |
| $h_{FE(min)}$    | 85                      | @ $I_C = 0,5$ A, $V_{CE} = 1$ V | 200                   | @ $I_C = 0,5$ A, $V_{CE} = 2$ V            |
|                  | 40                      | @ $I_C = 2$ A, $V_{CE} = 1$ V   | 100                   | @ $I_C = 2$ A, $V_{CE} = 2$ V              |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 17:

|                               | original type SMD        |  | replacement SMD       |  |
|-------------------------------|--------------------------|--|-----------------------|--|
| <b>type</b>                   | <b>MJD210<br/>KSH210</b> |  | <b>PBSS5540Z</b>      |  |
| <b>package</b>                | TO-252<br>DPAK           |  | SOT223                |  |
| <b>P<sub>tot</sub></b>        | 1400 mW                  |  | 1350 mW <sup>1)</sup> |  |
| <b>V<sub>CEO</sub></b>        | 25 V                     |  | 40 V                  |  |
| <b>I<sub>C</sub></b>          | 5 A                      |  | 5 A                   |  |
| <b>V<sub>CEsat(max)</sub></b> | 300 mV                   | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA | 120 mV                | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |
|                               | 750 mV                   | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA  | 160 mV                | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA  |
|                               | 1800 mV                  | @ I <sub>C</sub> = 5 A, I <sub>B</sub> = 1000 mA | 375 mV                | @ I <sub>C</sub> = 5 A, I <sub>B</sub> = 500 mA  |
| <b>h<sub>FE(min)</sub></b>    | 70                       | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 1 V  | 250                   | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V  |
|                               | 45                       | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 1 V    | 150                   | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V    |
|                               | 10                       | @ I <sub>C</sub> = 5 A, V <sub>CE</sub> = 2 V    | 50                    | @ I <sub>C</sub> = 5 A, V <sub>CE</sub> = 2 V    |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 18:

|                               | original type SMD      |   | replacement SMD       |  |
|-------------------------------|------------------------|---|-----------------------|--|
| <b>type</b>                   | <b>BD434<br/>BD436</b> |   | <b>PBSS5540Z</b>      | <b>PBSS302PD</b>                                       |
| <b>package</b>                | TO-126                 |   | SOT223                | SOT457   |
| <b>P<sub>tot</sub></b>        |                        |   | 1350 mW <sup>1)</sup> | 600 mW <sup>1)</sup>                                   |
| <b>V<sub>CEO</sub></b>        | 22 / 32 V              |   | 40 V                  | 40 V   |
| <b>I<sub>C</sub></b>          | 4 A                    |   | 5 A                   | 4 A  |
| <b>V<sub>CEsat(max)</sub></b> | 500 mV                 | @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA | 160 mV                | 180 mV @ I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |
|                               |                        | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 1 V   |                       | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V          |
| <b>h<sub>FE(min)</sub></b>    | 85                     | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 1 V | 250                   | 200 @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V    |
|                               | 50                     | @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 1 V   | 150                   | 175 @ I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>



## 8. Basic data on the BISS transistors

**Table 19: 1 A / 100 V NPN BISS transistors**

|                  | leaded           | SMD                             |                      |
|------------------|------------------|---------------------------------|----------------------|
| <b>type</b>      | <b>PBSS8110S</b> | <b>PBSS8110D</b>                | <b>PBSS8110T</b>     |
| package          | SOT54            | SOT457                          | SOT23                |
| $P_{tot}$        | 830 mW           | 600 mW <sup>1)</sup>            | 480 mW <sup>1)</sup> |
| $V_{CEO}$        | 100 V            |                                 |                      |
| $I_C$            | 1 A              |                                 |                      |
| $V_{CEsat(max)}$ | 120 mV           | @ $I_C = 0,5 A, I_B = 50 mA$    |                      |
|                  | 200 mV           | @ $I_C = 1 A, I_B = 100 mA$     |                      |
| $h_{FE(min)}$    | 150              | @ $I_C = 0,25 A, V_{CE} = 10 V$ |                      |
|                  | 100              | @ $I_C = 0,5 A, V_{CE} = 10 V$  |                      |
|                  | 80               | @ $I_C = 1 A, V_{CE} = 10 V$    |                      |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

**Table 20: 3 A / 50 V NPN BISS transistors**

|                  | leaded           | SMD                           |                  |
|------------------|------------------|-------------------------------|------------------|
| <b>type</b>      | <b>PBSS4350S</b> | <b>PBSS4350Z</b>              | <b>PBSS4350D</b> |
| package          | SOT54            | SOT223                        | SOT457           |
| $P_{tot}$        | 830 mW           | 1350 mW <sup>1)</sup>         |                  |
| $V_{CEO}$        | 50 V             |                               |                  |
| $I_C$            | 3 A              |                               |                  |
| $V_{CEsat(max)}$ | 90 mV            | @ $I_C = 0,5 A, I_B = 50 mA$  |                  |
|                  | 290 mV           | @ $I_C = 2 A, I_B = 200 mA$   |                  |
| $h_{FE(min)}$    | 200              | @ $I_C = 0,5 A, V_{CE} = 2 V$ |                  |
|                  | 200              | @ $I_C = 1 A, V_{CE} = 2 V$   |                  |
|                  | 100              | @ $I_C = 2 A, V_{CE} = 2 V$   |                  |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

Table 21: 4 – 5 A / 40 V NPN BISS transistors

| SMD                     |                      |  |   |
|-------------------------|----------------------|--|---|
| type                    | PBSS4540Z            | PBSS302ND                                      |   |
| package                 | SOT223               | SOT457   |   |
| P <sub>tot</sub>        | 1350 mW <sup>)</sup> | 600 mW <sup>)</sup>                            |   |
| V <sub>CEO</sub>        | 40 V                 | 40 V   |   |
| I <sub>C</sub>          | 5 A                  | 4 A  |   |
| V <sub>CEsat(max)</sub> | 90 mV                | I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |   |
|                         | 150 mV               | 180 mV   | I <sub>C</sub> = 2 A, I <sub>B</sub> = 200 mA |
|                         | 355 mV               | -  | I <sub>C</sub> = 5 A, I <sub>B</sub> = 500 mA |
| h <sub>FE(min)</sub>    | 300                  | 300  | I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 2 V |
|                         | 250                  | 250  | I <sub>C</sub> = 2 A, V <sub>CE</sub> = 2 V   |
|                         | 100                  | -  | I <sub>C</sub> = 5 A, V <sub>CE</sub> = 2 V   |

Table 22: 1 A / 100 V PNP BISS transistors

| leaded                  |           | SMD  |                     |
|-------------------------|-----------|--|---------------------|
| type                    | PBSS9110S | PBSS9110D  | PBSS9110T           |
| package                 | SOT54     | SOT457   | SOT23               |
| P <sub>tot</sub>        | 830 mW    | 550 mW <sup>)</sup>                              | 480 mW <sup>)</sup> |
| V <sub>CEO</sub>        | 100 V     |  |                     |
| I <sub>C</sub>          | 1 A       |  |                     |
| V <sub>CEsat(max)</sub> | 120 mV    | @ I <sub>C</sub> = 0,5 A, I <sub>B</sub> = 50 mA |                     |
|                         | 320 mV    | @ I <sub>C</sub> = 1 A, I <sub>B</sub> = 100 mA  |                     |
| h <sub>FE(min)</sub>    | 150       | @ I <sub>C</sub> = 0,25 A, V <sub>CE</sub> = 5 V |                     |
|                         | 150       | @ I <sub>C</sub> = 0,5 A, V <sub>CE</sub> = 5 V  |                     |
|                         | 125       | @ I <sub>C</sub> = 1 A, V <sub>CE</sub> = 5 V    |                     |

<sup>)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

**Table 23: 3 A / 50 V PNP BISS transistors**

|                  | leaded    | SMD                           |           |
|------------------|-----------|-------------------------------|-----------|
| type             | PBSS5350S | PBSS5350Z                     | PBSS5350D |
| package          | SOT54     | SOT223                        | SOT457    |
| $P_{tot}$        | 830 mW    | 1350 mW <sup>1)</sup>         |           |
| $V_{CEO}$        | 50 V      |                               |           |
| $I_C$            | 3 A       |                               |           |
| $V_{CEsat(max)}$ | 100 mV    | @ $I_C = 0,5 A, I_B = 50 mA$  |           |
|                  | mV        | @ $I_C = 2 A, I_B = 200 mA$   |           |
| $h_{FE(min)}$    | 200       | @ $I_C = 0,5 A, V_{CE} = 2 V$ |           |
|                  | 200       | @ $I_C = 1 A, V_{CE} = 2 V$   |           |
|                  | 100       | @ $I_C = 2 A, V_{CE} = 2 V$   |           |

<sup>1)</sup> Device mounted on an FR4 PCB, single-sided copper, tin-plated, mounting pad for collector 1 cm<sup>2</sup>

**Table 24: 4 – 5 A / 40 V PNP BISS transistors**

|                  | SMD                   |                      |                               |
|------------------|-----------------------|----------------------|-------------------------------|
| type             | PBSS5540Z             | PBSS302PD            |                               |
| package          | SOT223                | SOT457               |                               |
| $P_{tot}$        | 1350 mW <sup>1)</sup> | 600 mW <sup>1)</sup> |                               |
| $V_{CEO}$        | 40 V                  | 40 V                 |                               |
| $I_C$            | 5 A                   | 4 A                  |                               |
| $V_{CEsat(max)}$ | 120 mV                | 60 mV                | @ $I_C = 0,5 A, I_B = 50 mA$  |
|                  | 160 mV                | 180 mV               | @ $I_C = 2 A, I_B = 200 mA$   |
|                  | 375 mV                | -                    | @ $I_C = 5 A, I_B = 500 mA$   |
| $h_{FE(min)}$    | 250                   | 200                  | @ $I_C = 0,5 A, V_{CE} = 2 V$ |
|                  | 150                   | 175                  | @ $I_C = 2 A, V_{CE} = 2 V$   |
|                  | 50                    | -                    | @ $I_C = 5 A, V_{CE} = 2 V$   |

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