2N3904 / MMBT3904 / PZT3904
NPN General-Purpose Amplifier

Description

This device is designed as a general-purpose amplifier and switch. The useful dynamic range extends to 100 mA as a switch and to 100 MHz as an amplifier.

Ordering Information

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<th>Part Number</th>
<th>Marking</th>
<th>Package</th>
<th>Packing Method</th>
<th>Pack Quantity</th>
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<td>TO-92 3L</td>
<td>Bulk</td>
<td>10000</td>
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<td>2N3904</td>
<td>TO-92 3L</td>
<td>Ammo</td>
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<td>2N3904TAR</td>
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<td>2N3904TF</td>
<td>2N3904</td>
<td>TO-92 3L</td>
<td>Tape and Reel</td>
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<td>2N3904TFR</td>
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<td>MMBT3904</td>
<td>1A</td>
<td>SOT-23 3L</td>
<td>Tape and Reel</td>
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<td>PZT3904</td>
<td>3904</td>
<td>SOT-223 4L</td>
<td>Tape and Reel</td>
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Absolute Maximum Ratings\(^{(1), (2)}\)

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at \(T_A = 25°C\) unless otherwise noted.

### Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Value</th>
<th>Unit</th>
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<tbody>
<tr>
<td>(V_{CEO})</td>
<td>Collector-Emitter Voltage</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>(V_{CBO})</td>
<td>Collector-Base Voltage</td>
<td>60</td>
<td>V</td>
</tr>
<tr>
<td>(V_{EBO})</td>
<td>Emitter-Base Voltage</td>
<td>6.0</td>
<td>V</td>
</tr>
<tr>
<td>(I_C)</td>
<td>Collector Current - Continuous</td>
<td>200</td>
<td>mA</td>
</tr>
<tr>
<td>(T_{J, T_{STG}})</td>
<td>Operating and Storage Junction Temperature Range</td>
<td>-55 to 150</td>
<td>°C</td>
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Notes:
1. These ratings are based on a maximum junction temperature of 150°C.
2. These are steady-state limits. Fairchild Semiconductor should be consulted on applications involving pulsed or low-duty cycle operations.

### Thermal Characteristics

Values are at \(T_A = 25°C\) unless otherwise noted.

<table>
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<tr>
<th>Symbol</th>
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<th>Maximum</th>
<th>Unit</th>
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<td></td>
<td>2N3904</td>
<td>MMBT3904(^{(3)})</td>
</tr>
<tr>
<td></td>
<td></td>
<td>mW</td>
<td>mW</td>
</tr>
<tr>
<td>(P_D)</td>
<td>Total Device Dissipation</td>
<td>625</td>
<td>350</td>
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<tr>
<td></td>
<td>Derate Above 25°C</td>
<td>5.0</td>
<td>2.8</td>
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<tr>
<td></td>
<td>Thermal Resistance, Junction to Case</td>
<td>83.3</td>
<td>°C/W</td>
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<tr>
<td></td>
<td>Thermal Resistance, Junction to Ambient</td>
<td>200</td>
<td>357</td>
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</table>

Notes:
3. Device is mounted on FR-4 PCB 1.6 inch X 1.6 inch X 0.06 inch.
4. Device is mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm, mounting pad for the collector lead minimum 6 cm².
### Electrical Characteristics

Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Parameter</th>
<th>Conditions</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
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<tr>
<td>OFF CHARACTERISTICS</td>
<td></td>
<td></td>
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<tr>
<td>$V_{(BR)CEO}$</td>
<td>Collector-Emitter Breakdown Voltage</td>
<td>$I_C = 1.0\ mA$, $I_B = 0$</td>
<td>40</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{(BR)CBO}$</td>
<td>Collector-Base Breakdown Voltage</td>
<td>$I_C = 10\ \mu\text{A}$, $I_E = 0$</td>
<td>60</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{(BR)EBO}$</td>
<td>Emitter-Base Breakdown Voltage</td>
<td>$I_E = 10\ \mu\text{A}$, $I_C = 0$</td>
<td>60</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{BL}$</td>
<td>Base Cut-Off Current</td>
<td>$V_{CE} = 30\ V$, $V_{EB} = 3\ V$</td>
<td>50</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>$I_{CEX}$</td>
<td>Collector Cut-Off Current</td>
<td>$V_{CE} = 30\ V$, $V_{EB} = 3\ V$</td>
<td>50</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>ON CHARACTERISTICS$^5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$h_{FE}$</td>
<td>DC Current Gain</td>
<td>$I_C = 0.1\ mA$, $V_{CE} = 1.0\ V$</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_C = 1.0\ mA$, $V_{CE} = 1.0\ V$</td>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_C = 10\ mA$, $V_{CE} = 1.0\ V$</td>
<td>100</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_C = 50\ mA$, $V_{CE} = 1.0\ V$</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_C = 100\ mA$, $V_{CE} = 1.0\ V$</td>
<td>30</td>
<td></td>
<td></td>
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<tr>
<td>$V_{CE(sat)}$</td>
<td>Collector-Emitter Saturation Voltage</td>
<td>$I_C = 10\ mA$, $I_B = 1.0\ mA$</td>
<td>0.2</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_C = 50\ mA$, $I_B = 5.0\ mA$</td>
<td>0.3</td>
<td></td>
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<tr>
<td>$V_{BE(sat)}$</td>
<td>Base-Emitter Saturation Voltage</td>
<td>$I_C = 10\ mA$, $I_B = 1.0\ mA$</td>
<td>0.65</td>
<td>0.85</td>
<td>V</td>
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<td></td>
<td></td>
<td>$I_C = 50\ mA$, $I_B = 5.0\ mA$</td>
<td>0.95</td>
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### SMALL SIGNAL CHARACTERISTICS

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<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
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<tr>
<td>$f_T$</td>
<td>Current Gain - Bandwidth Product</td>
<td>$I_C = 10\ mA$, $V_{CE} = 20\ V$, $f = 100\ \text{MHz}$</td>
<td>300</td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$C_{ob0}$</td>
<td>Output Capacitance</td>
<td>$V_{CB} = 5.0\ V$, $I_E = 0$, $f = 100\ \text{kHz}$</td>
<td>4.0</td>
<td></td>
<td>pF</td>
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<tr>
<td>$C_{ib0}$</td>
<td>Input Capacitance</td>
<td>$V_{EB} = 0.5\ V$, $I_C = 0$, $f = 100\ \text{kHz}$</td>
<td>8.0</td>
<td></td>
<td>pF</td>
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<tr>
<td>NF</td>
<td>Noise Figure</td>
<td>$I_C = 100\ \mu\text{A}$, $V_{CE} = 5.0\ V$, $R_S = 1.0\ \text{k\Omega}$, $f = 10\ \text{Hz}$ to $15.7\ \text{kHz}$</td>
<td>5.0</td>
<td></td>
<td>dB</td>
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### SWITCHING CHARACTERISTICS

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<th>Symbol</th>
<th>Description</th>
<th>Conditions</th>
<th>Min.</th>
<th>Max.</th>
<th>Unit</th>
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<tbody>
<tr>
<td>$t_d$</td>
<td>Delay Time</td>
<td>$V_{CC} = 3.0\ V$, $V_{BE} = 0.5\ V$</td>
<td>35</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_r$</td>
<td>Rise Time</td>
<td>$I_C = 10\ mA$, $I_{B1} = 1.0\ mA$</td>
<td>35</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_s$</td>
<td>Storage Time</td>
<td>$V_{CC} = 3.0\ V$, $I_C = 10\ mA$, $I_{B1} = I_{B2} = 1.0\ mA$</td>
<td>200</td>
<td></td>
<td>ns</td>
</tr>
<tr>
<td>$t_f$</td>
<td>Fall Time</td>
<td>$I_{B1} = I_{B2} = 1.0\ mA$</td>
<td>50</td>
<td></td>
<td>ns</td>
</tr>
</tbody>
</table>

**Note:**

5. Pulse test: pulse width $\leq 300\ \mu\text{s}$, duty cycle $\leq 2.0\%$. 

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2N3904 / MMBT3904 / PZT3904 — NPN General-Purpose Amplifier
Typical Performance Characteristics

![Graphs showing typical performance characteristics of the 2N3904 NPN General-Purpose Amplifier.](image-url)

- **Figure 1.** Typical Pulsed Current Gain vs. Collector Current
- **Figure 2.** Collector-Emitter Saturation Voltage vs. Collector Current
- **Figure 3.** Base-Emitter Saturation Voltage vs. Collector Current
- **Figure 4.** Base-Emitter On Voltage vs. Collector Current
- **Figure 5.** Collector Cut-Off Current vs. Ambient Temperature
- **Figure 6.** Capacitance vs. Reverse Bias Voltage
Typical Performance Characteristics (Continued)

Figure 7. Noise Figure vs. Frequency

Figure 8. Noise Figure vs. Source Resistance

Figure 9. Current Gain and Phase Angle vs. Frequency

Figure 10. Power Dissipation vs. Ambient Temperature

Figure 11. Turn-On Time vs. Collector Current

Figure 12. Rise Time vs. Collector Current
Typical Performance Characteristics (Continued)

Figure 13. Storage Time vs. Collector Current

Figure 14. Fall Time vs. Collector Current

Figure 15. Current Gain

Figure 16. Output Admittance

Figure 17. Input Impedance

Figure 18. Voltage Feedback Ratio
Test Circuits

Figure 19. Delay and Rise Time Equivalent Test Circuit

Figure 20. Storage and Fall Time Equivalent Test Circuit
NOTES: UNLESS OTHERWISE SPECIFIED

A) DRAWING WITH REFERENCE TO JEDEC TO-92
   RECOMMENDATIONS.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DRAWING CONFORMS TO ASME Y14.5M-2009.
D) DRAWING FILENAME: MKT-Za03REV4.
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D) DRAWING CONFORMS TO ASME Y14.5M-1994.
E) LAND PATTERN NAME: SOT230P700X180-4BN
F) DRAWING FILENAME: MKT-MA04AREV2

DETAIL A
SCALE: 2:1
LAND PATTERN RECOMMENDATION

SEE DETAIL A

NOTES: UNLESS OTHERWISE SPECIFIED

A) REFERENCE JEDEC REGISTRATION TO-236, VARIATION AB, ISSUE H.
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DIMENSIONS ARE INCLUSIVE OF BURRS, MOLD FLASH AND TIE BAR EXTRUSIONS.
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E) DRAWING FILE NAME: MA03DREV11
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<th>Product Status</th>
<th>Definition</th>
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<td>Advance Information</td>
<td>Formative / In Design</td>
<td>Datasheet contains the design specifications for product development. Specifications may change in any manner without notice.</td>
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<tr>
<td>Preliminary</td>
<td>First Production</td>
<td>Datasheet contains preliminary data; supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.</td>
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<tr>
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<td>Full Production</td>
<td>Datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve the design.</td>
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<tr>
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