# BFQ790

High Linearity High Gain 1/2 Watt RF Driver Amplifier

## Data Sheet

Revision 2.0, 2014-08-26
Preliminary

RF & Protection Devices

**Edition 2014-08-26**

**Published by**
**Infineon Technologies AG**
**81726 Munich, Germany**





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**BFQ790, High Linearity High Gain 1/2 Watt RF Driver Amplifier**

**Revision History: 2014-08-26, Revision 2.0**

| Page | Subjects (major changes since last revision) |
|---|---|
| | Preliminary datasheet based on measurements of engineering samples, replaces target datasheet. |
| | |
| | |

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# 1 Product Brief

The BFQ790 is a single stage high linearity high gain driver amplifier. The device is not internally matched and hence provides flexibility to be used for any application where high linearity is key. There are several application notes available, most of them for LTE frequencies, a summary can be found in chapter 6. The device is based on Infineon's reliable and cost effective NPN silicon germanium technology running in very high volume. The technology comprises lowohmic substrate contacts so that emitter bond wires can be omitted. Thereby the emitter inductance is minimized and the power gain optimized. For example one of the circuits provides an OIP3 of 41 dBm at 2650 MHz, with a power gain of 14 dB.

The datasheet describes the device mainly at 250 mA collector current IC, operated in Class A mode. Under these conditions the BFQ790 provides ½ Watt RF power and highest linearity. If energy efficiency is in the focus it is recommended to operate the device in class AB mode. That means to adjust a quiescent current ICq lower than 250 mA and use the self biasing effect to get high linearity and efficiency when the input RF power is high. Please refer to figure 7-19, where as an example an ICq of 155 mA is adjusted. OIP3 vs. IC is shown in figure 7-22.

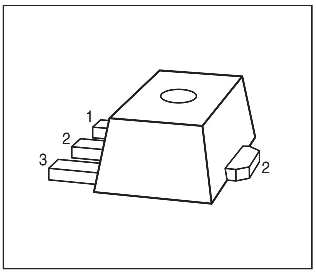
For the BFQ790 an advanced large signal compact model is available. Further information please find in chapter 8.

The BFQ790 is very rugged. A special collector design prevents from thermal runaway respectively 2nd breakdown. This leads to a high ruggedness against mismatch at the output. The collector design allows safe operation with a single 5 V supply. The special design of the emitter-base diode makes the input robust and yields a high maximum RF input power.

The chip is housed in a halogen free industry standard package SOT89. The high thermal conductivity of the silicon substrate and the low thermal resistance of the package add up to a thermal resistance of only 35 K/W, what leads to moderate junction temperatures even at high dissipated DC power values. Recommended operating conditions can be found in chapter 4. The proper die attach with good thermal contact is tested 100%, so that there is a minimum variation of thermal properties. The devices are 100% DC and RF tested.

# 2 Features

- High 3rd order intercept point OIP3 of 41 dBm @ 5 V, 250 mA in 1850 MHz and 2650 MHz Class A application circuits
- High compression point OP1dB of 27 dBm @ 5 V, 250 mA corresponding to 40% collector efficiency
- High power gain of 17 dB @ 5V, 250 mA in 1850 MHz Class A application circuit
- Low minimum noise figure of 2.6 dB @ 1800 MHz, 5 V, 70 mA
- Single stage, intended for external matching
- Exceptional ruggedness up to VSWR 10:1 at output
- High maximum RF input power PRFinmax of 18 dBm
- Safe operation with single 5 V supply
- 100% test of proper die attach for reproducible thermal contact
- 100% DC and RF tested
- Easy to use large signal compact (VBIC) model available
- Cost effective NPN SiGe technology running in very high volume
- Easy to use Pb-free (RoHS compliant) and halogen-free industry standard package SOT89, low RTHJS of 35 K/W




**Applications**

As

- High linearity driver or pre-driver in the transmit chain
- 2nd or 3rd stage LNA in the receive chain
- IF or LO buffer amplifier

In

- Commercial / industrial wireless infrastructure / basestations
- Repeaters
- Automated test equipment

For

- Cellular, PCS, DCS, UMTS, LTE, CDMA, WCDMA, GSM, GPRS
- WLAN, WiMAX, WLL and MMDS
- ISM, AMR
- UHF television, CATV, DBS

***Attention: ESD (Electrostatic discharge) sensitive device, observe handling precautions***

| Product Name | Package | Pin Configuration | | | Marking |
|---|---|---|---|---|---|
| BFQ790 | SOT89 | 1 = B | 2 = E | 3 = C | R3 |

# 3 Absolute Maximum Ratings

**Table 3-1 Absolute Maximum Ratings at $T_A$ = 25 °C (unless otherwise specified)**

| Parameter | Symbol | Values | | Unit | Note / Test Condition |
|---|---|---|---|---|---|
| | | Min. | Max. | | |
| Collector emitter voltage | $V_{CE}$ | | 6.1<br>5.1 | V | $T_A$ = 25 °C<br>$T_A$ = -40 °C |
| Collector base voltage | $V_{CB}$ | | 18 | V | |
| Instantaneous total base emitter reverse voltage | $v_{BE}$ | -2.0 | | V | DC + RF swing |
| Instantaneous total collector current | $i_C$ | – | 600 | mA | DC + RF swing |
| DC collector current | $I_C$ | – | 300 | mA | |
| DC base current | $I_B$ | – | 10 | mA | |
| RF input power | $P_{RFin}$ | – | 18 | dBm | In- and output matched |
| Mismatch at output | $VSWR$ | – | 10:1 | | In compression, over all phase angles |
| ESD stress pulse | $V_{ESD}$ | -500 | 500 | V | HBM, all pins, acc. to ANSI / ESDA / JEDEC JS-001-2012 |
| Dissipated power | $P_{diss}$ | – | 1500 | mW | $T_S \leq$ 97.5 °C[1], regard derating curve in figure 5-1 |
| Junction temperature | $T_J$ | – | 150 | °C | |
| Operating case temperature | $T_A$ | -40 | 105[2] | °C | |
| Storage temperature | $T_{Stg}$ | -55 | 150 | °C | |

1) $T_S$ is the soldering point temperature. $T_S$ is measured on the emitter lead at the soldering point of the pcb.

2) At the same time regard $T_{J,max}$.

***Attention:** Stresses above the max. values listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Maximum ratings are absolute ratings; exceeding only one of these values may cause irreversible damage to the integrated circuit.*

# 4 Recommended Operating Conditions

This following table shows examples of recommended operating conditions. As long as maximum ratings are regarded operation outside these conditions is permitted, but increases failure rate and reduces lifetime. For further information refer to the quality report available on the BFQ790 internet page.

**Table 4-1 Recommended Operating Conditions**

| Operating Mode | Ambient Temperature[1] | Collector Current | DC Power[2] | RF Output Power [3] | Efficiency [4] | Dissipated Power[5] | Thermal Resistance of pcb[6] | Junction Temperature[7] |
|---|---|---|---|---|---|---|---|---|
| | $T_A$ [°C] | $I_C$ [mA] | $P_{DC}$ [mW] | $P_{RFout}$ [mW] (dBm) | η [%] | $P_{diss}$ [mW] | $R_{THSA}$ [K/W] | $T_J$ [°C] |
| Compression | 55 | 250 | 1250 | 500 (27) | 40 | 750 | 35 | 110 |
| Final stage | 55 | 200 | 1000 | 250 (24) | 25 | 750 | 35 | 110 |
| High $T_A$ | 85 | 120 | 600 | 50 (17) | 8.5 | 550 | 10 | 110 |
| Maximum $T_A$ | 105 | 50 | 250 | 100 (20) | 40 | 150 | 10 | 110 |
| Linear | 55 | 150 | 750 | 50 (17) | 7 | 700 | 35 | 110 |
| Very Linear | 55 | 250 | 1250 | 50 (17) | 4 | 1200 | 10 | 110 |

1) Is the operating case temperature respectively of the heat sink.
2) $P_{DC} = V_{CE} * I_C$ with $V_{CE}$ = 5V.
3) RF power delivered to the load, $P_{RFout} = \eta * P_{DC}$.
4) Efficiency of the conversion from DC power to RF power, $\eta = P_{RFout} / P_{DC}$ (collector efficiency).
5) $P_{diss} = P_{DC} - P_{RFout}$. The RF output power $P_{RFout}$ delivered to the load reduces the power $P_{diss}$ to be dissipated by the device. This means a good output match is recommended.
6) $R_{THSA}$ is the thermal resistance of the pcb including heat sink, that is between the soldering point S and the ambient A. Regard the impact of $R_{THSA}$ on the junction temperature $T_J$, see below. The thermal design of the pcb, respectively $R_{THSA}$, has to be adjusted to the intended operating mode.
7) $T_J = T_A + P_{diss} * R_{THJA}$. $R_{THJA} = R_{THJS} + R_{THSA}$.
$R_{THJA}$ is the thermal resistance between the transistor junction J and the ambient A.
$R_{THJS}$ is the combined thermal resistance of die and package, which is 35 K/W for the BFQ790, see chapter 5.

# 5 Thermal Characteristics

**Table 5-1 Thermal Resistance**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Junction - soldering point | $R_{THJS}$ | – | 35 | – | K/W | – |

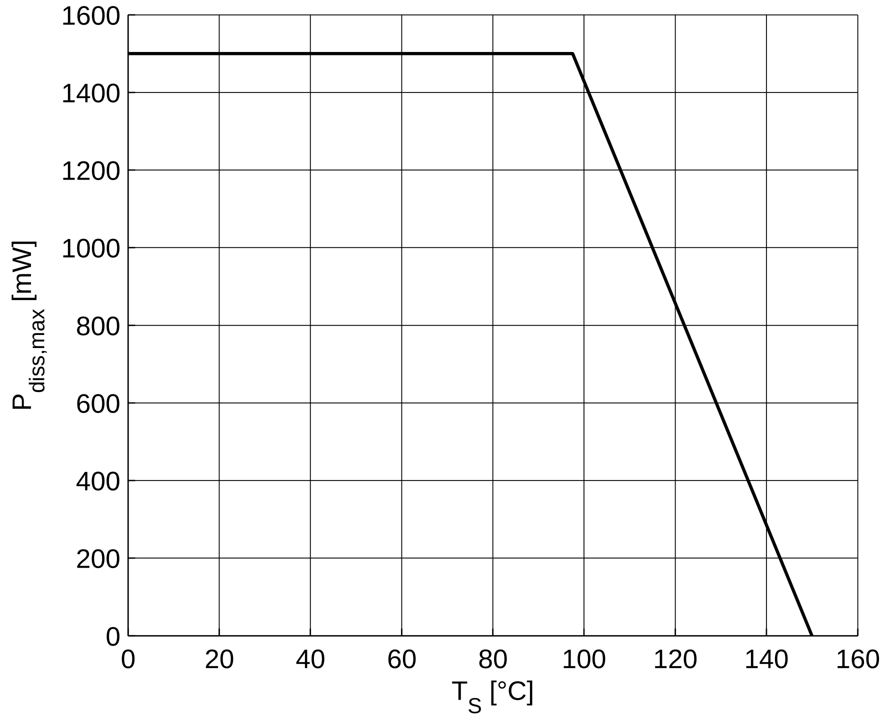



**Figure 5-1 Absolute Maximum Power Dissipation $P_{diss,max}$ vs. $T_s$**

*Note: In the horizontal part of the derating curve the maximum power dissipation is given by* $P_{diss,max}=V_{CE,max}*I_{C,max}$. *In this part the junction temperature* $T_J$ *is lower than* $T_{J,max}$. *In the declining slope it is* $T_J=T_{J,max}$, $P_{diss,max}$ *has to be reduced according to the curve in order not to exceed* $T_{J,max}$. *It is* $T_{J,max}=T_S+P_{diss,max}*R_{THJS}$.

# 6 Electrical Performance in Application

The table shows the most important results of the application notes available for the BFQ790. In all cases the matching is better 10 dB, the isolation ~20 dB, the stability factor > 1 and $V_{CC}$ = 5V. Fore more detailed informations please refer to the BFQ790 internet page. Application notes for Class AB operating mode respectively lower quiescent currents $I_{Cq}$ are in development.

**Table 6-1 Application Notes**

| Application Note | Frequency | OP1dB | OIP3 | Gain | Operating Mode | ICq |
|---|---|---|---|---|---|---|
| # | [MHz] | [dBm] | [dBm] | [dB] | | [mA] |
| AN385 | 2620 - 2690 | 27 | 41 | 14 | Class A | 220 |
| AN386 | 1805 - 1880 | 27 | 41 | 17 | Class A | 230 |

# 7 Electrical Performance in Test Fixture

## 7.1 DC Parameter Table

**Table 7-1 DC Characteristics at $T_A$ = 25 °C**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Collector emitter breakdown voltage | $V_{(BR)CEO}$ | 6.1 | 6.7 | – | V | $I_C$ = 1 mA, open base |
| Collector emitter leakage current | $I_{CES}$ | – | 1<br>0.1 | 40[1)]<br>3 | nA<br>µA | $V_{CE}$ = 8 V, $V_{BE}$ = 0<br>$V_{CE}$ = 18 V, $V_{BE}$ = 0<br>E-B short circuited |
| Collector base leakage current | $I_{CBO}$ | – | 1 | 40[1)] | nA | $V_{CB}$ = 8 V, $I_E$ = 0<br>Open emitter |
| Emitter base leakage current | $I_{EBO}$ | – | 1 | 40[1)] | nA | $V_{EB}$ = 0.5 V, $I_C$ = 0<br>Open collector |
| DC current gain | $h_{FE}$ | 60 | 120 | 180 | | $V_{CE}$ = 5 V, $I_C$ = 250 mA<br>Pulse measured[2)] |

1) Upper spec value limited by the cycle time of the 100% test.

2) Pulse width is 1 ms, duty cycle 10%. Regard that the current gain $h_{FE}$ depends on the junction temperature $T_J$ and $T_J$ amongst others from the thermal resistance $R_{THSA}$ of the pcb, see notes to table 4-1. Hence the $h_{FE}$ specified in this datasheet must not be the same as in the application. It is highly recommended to apply circuit design techniques to make the collector current $I_C$ independent on the $h_{FE}$ production variation and temperature effects.

## 7.2 AC Parameter Tables

**Table 7-2 General AC Characteristics at $T_A$ = 25 °C**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| Transition frequency | $f_T$ | – | 20 | – | GHz | $V_{CE}$ = 5 V, $I_C$ = 250 mA, $f$ = 0.5 GHz |
| Collector base capacitance | $C_{CB}$ | – | 1.1 | – | pF | $V_{CB}$ = 5 V, $V_{BE}$ = 0<br>$f$ = 1 MHz<br>Emitter grounded |
| Collector emitter capacitance | $C_{CE}$ | – | 2.2 | – | pF | $V_{CE}$ = 5 V, $V_{BE}$ = 0<br>$f$ = 1 MHz<br>Base grounded |
| Emitter base capacitance | $C_{EB}$ | – | 9.4 | – | pF | $V_{EB}$ = 0.5 V, $V_{CB}$ = 0<br>$f$ = 1 MHz<br>Collector grounded |

Measurement setup for the AC characteristics shown in tables 7-3 to 7-6 is a test fixture with Bias T's and tuners to adjust the source and load impedances in a 50 Ω system, $T_A$ = 25 °C.

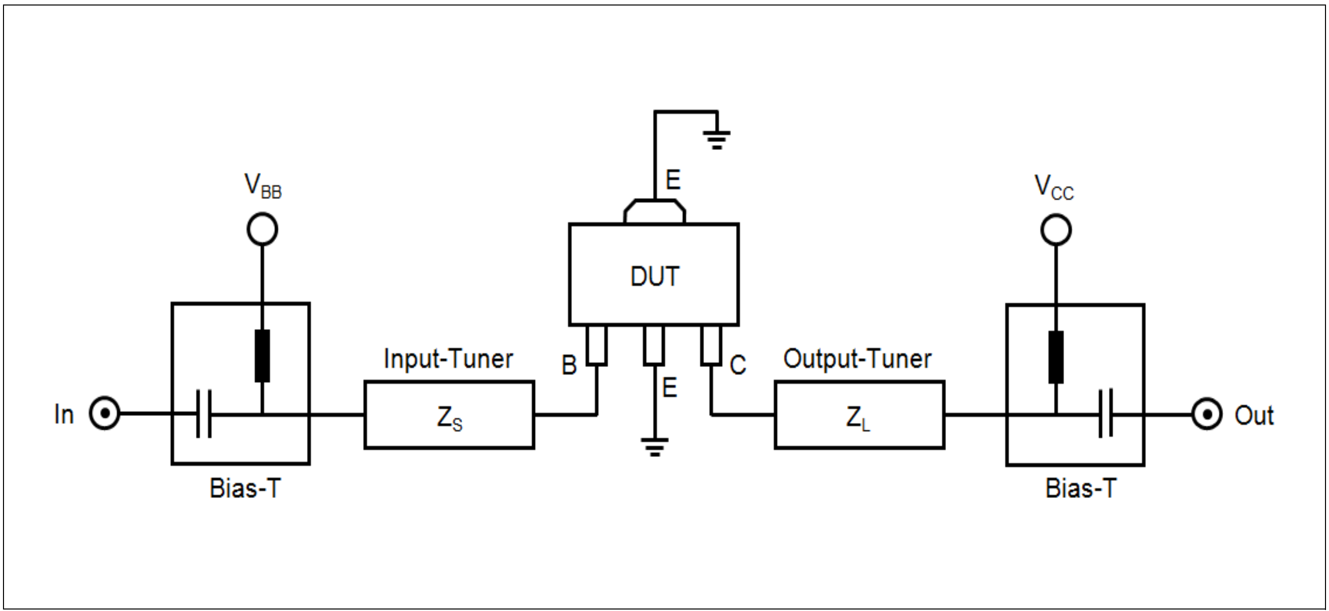



**Figure 7-1 BFQ790 Testing Circuit**

**Table 7-3 AC Characteristics, $V_{CE}$ = 5 V, $f$ = 0.9 GHz**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| **Power gain** | | | | | dB | |
| Maximum power gain | $G_{ma}$ | – | 23 | – | | $I_C$ = 250 mA |
| Transducer gain | $\|S_{21}\|^2$ | – | 13 | – | | $I_C$ = 250 mA |
| **Minimum Noise Figure** | | | | | dB | $Z_S = Z_{Sopt}$ |
| Minimum noise figure | $NF_{min}$ | – | 2.5 | – | | $I_C$ = 70 mA |
| **Linearity** | | | | | dBm | $Z_L = Z_{Lopt}$ |
| 1 dB compression point at output | $OP1dB$ | – | 27 | – | | $I_C$ = 250 mA |
| 3rd order intercept point at output | $OIP3$ | – | 38.5 | – | | $I_C$ = 250 mA |

**Table 7-4 AC Characteristics, $V_{CE}$ = 5 V, $f$ = 1.8 GHz**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| **Power gain** | | | | | dB | |
| Maximum power gain | $G_{ma}$ | – | 18.5 | – | | $I_C$ = 250 mA |
| Transducer gain | $\|S_{21}\|^2$ | – | 7.5 | – | | $I_C$ = 250 mA |
| **Minimum Noise Figure** | | | | | dB | $Z_S = Z_{Sopt}$ |
| Minimum noise figure | $NF_{min}$ | – | 2.6 | – | | $I_C$ = 70 mA |
| **Linearity** | | | | | dBm | $Z_L = Z_{Lopt}$ |
| 1 dB compression point at output | $OP1dB$ | – | 27 | – | | $I_C$ = 250 mA |
| 3rd order intercept point at output | $OIP3$ | – | 38.5 | – | | $I_C$ = 250 mA |

**Table 7-5 AC Characteristics, $V_{CE}$ = 5 V, $f$ = 2.6 GHz**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| **Power gain** | | | | | dB | |
| Maximum power gain | $G_{ma}$ | – | 16 | – | | $I_C$ = 250 mA |
| Transducer gain | $\|S_{21}\|^2$ | – | 5.5 | – | | $I_C$ = 250 mA |
| **Minimum Noise Figure** | | | | | dB | $Z_S = Z_{Sopt}$ |
| Minimum noise figure | $NF_{min}$ | – | 3.0 | – | | $I_C$ = 70 mA |
| **Linearity** | | | | | dBm | $Z_L = Z_{Lopt}$ |
| 1 dB compression point at output | $OP1dB$ | – | 27 | – | | $I_C$ = 250 mA |
| 3rd order intercept point at output | $OIP3$ | – | 38.5 | – | | $I_C$ = 250 mA |

**Table 7-6 AC Characteristics, $V_{CE}$ = 5 V, $f$ = 3.5 GHz**

| Parameter | Symbol | Values | | | Unit | Note / Test Condition |
|---|---|---|---|---|---|---|
| | | Min. | Typ. | Max. | | |
| **Power gain** | | | | | dB | |
| Maximum power gain | $G_{ma}$ | – | 13 | – | | $I_C$ = 250 mA |
| Transducer gain | $\|S_{21}\|^2$ | – | 3 | – | | $I_C$ = 250 mA |
| **Minimum Noise Figure** | | | | | dB | $Z_S = Z_{Sopt}$ |
| Minimum noise figure | $NF_{min}$ | – | 3.4 | – | | $I_C$ = 70 mA |
| **Linearity** | | | | | dBm | $Z_L = Z_{Lopt}$ |
| 1 dB compression point at output | $OP1dB$ | – | 27 | – | | $I_C$ = 250 mA |
| 3rd order intercept point at output | $OIP3$ | – | 38.5 | – | | $I_C$ = 250 mA |

## 7.3 Characteristic DC Diagrams

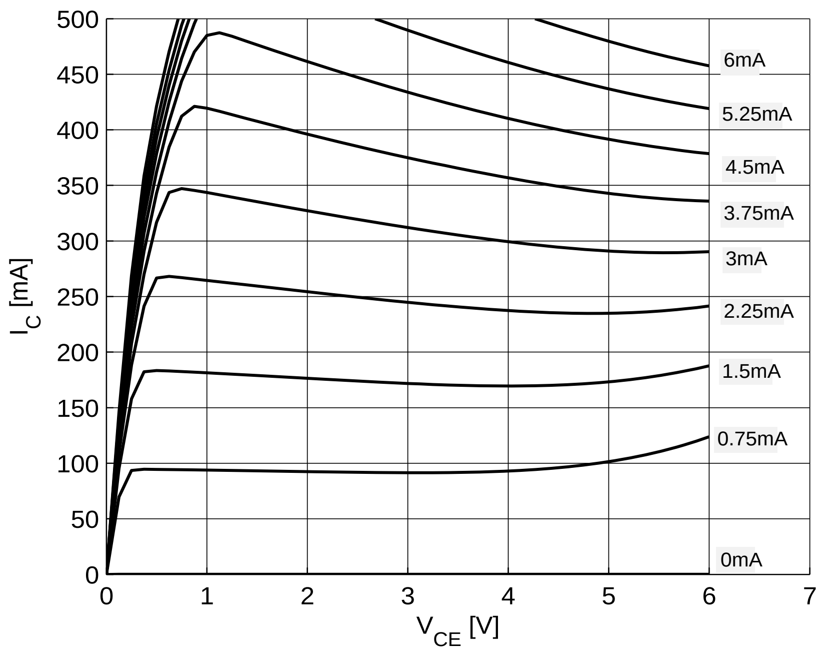



**Figure 7-2 Collector Current $I_C$ vs. $V_{CE}$, $I_B$ = Parameter**

*Note: Regard absolute maximum ratings for* $I_C$, $V_{CE}$ *and* $P_{diss}$

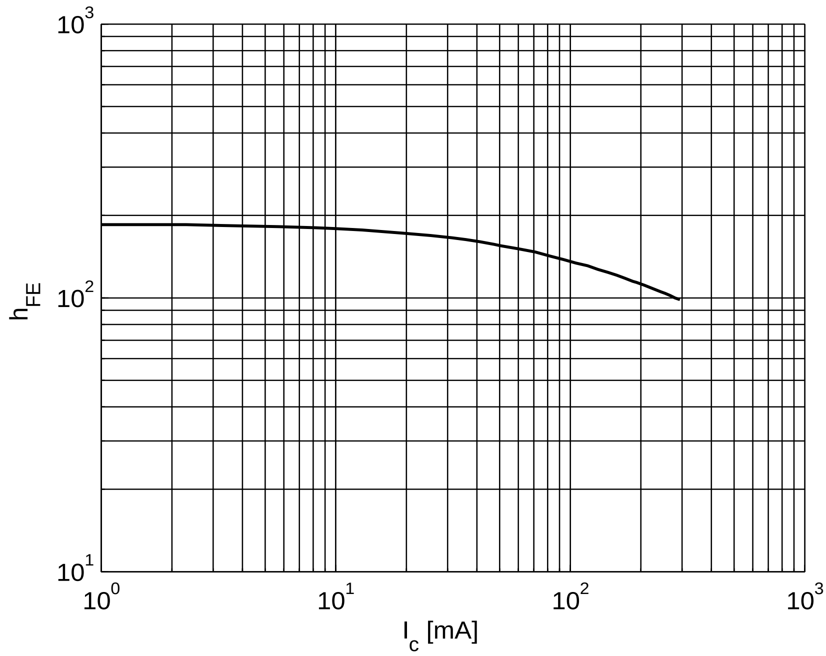



**Figure 7-3 DC Current Gain $h_{FE}$ vs. $I_C$ at $V_{CE}$ = 5 V**

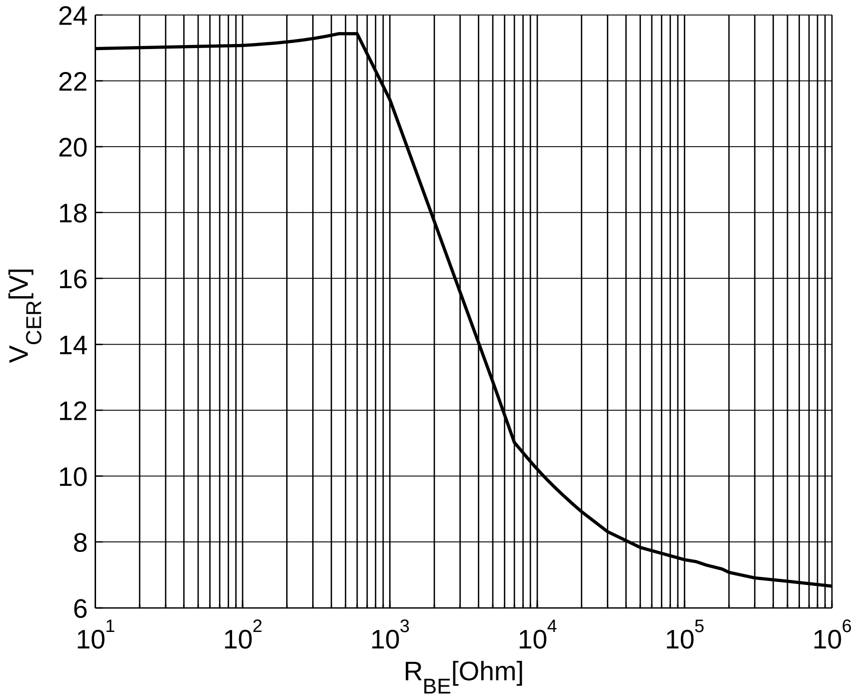



**Figure 7-4 Collector Emitter Breakdown Voltage $BV_{CER}$ vs. Resistor $R\_B/GND$**

*Note: The above figure shows the collector-emitter breakdown voltage BVCER with a resistor R_B/GND between base and emitter. Only for very high R_B/GND values ("open base") the breakdown voltage is as low as BVCEO (here 6.7 V). With decreasing R_B/GND values BVCER increases, e.g. at R_B/GND=10 kOhm to BVCER=10 V. In the application the biasing base resistance together with block capacitors take over the function of R_B/GND and allows the RF voltage amplitude to swing up to voltages much higher than BVCEO, no clipping occurs. Due to this effect the transistor can be biased at VCE=5 V and still high RF output powers achieved, see the OP1dB values reported in chapter 7.2.*

## 7.4 Characteristic AC Diagrams

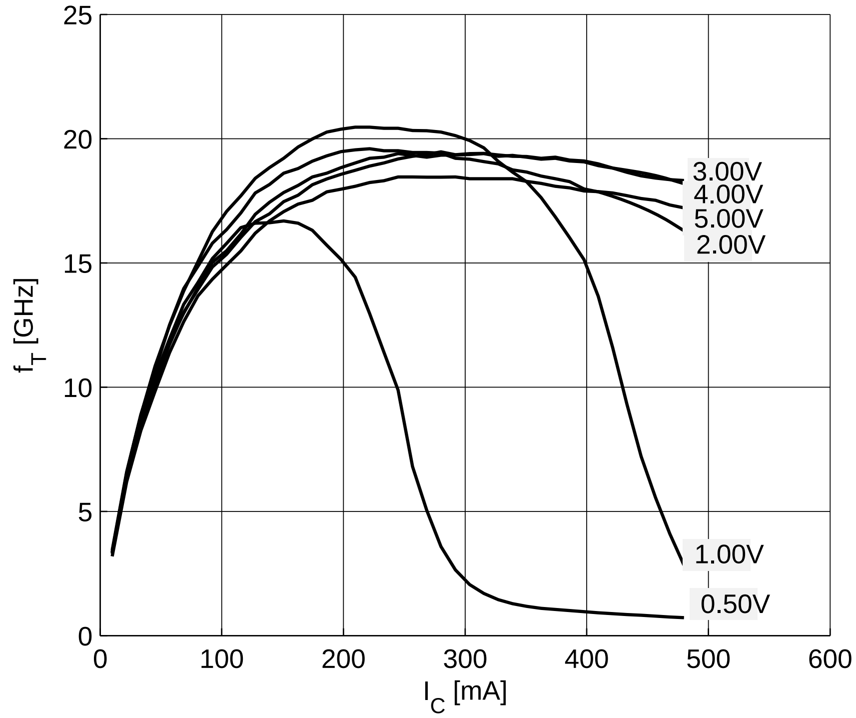



**Figure 7-5 Transition Frequency $f_T$ vs. $I_C$, $V_{CE}$ = Parameter**

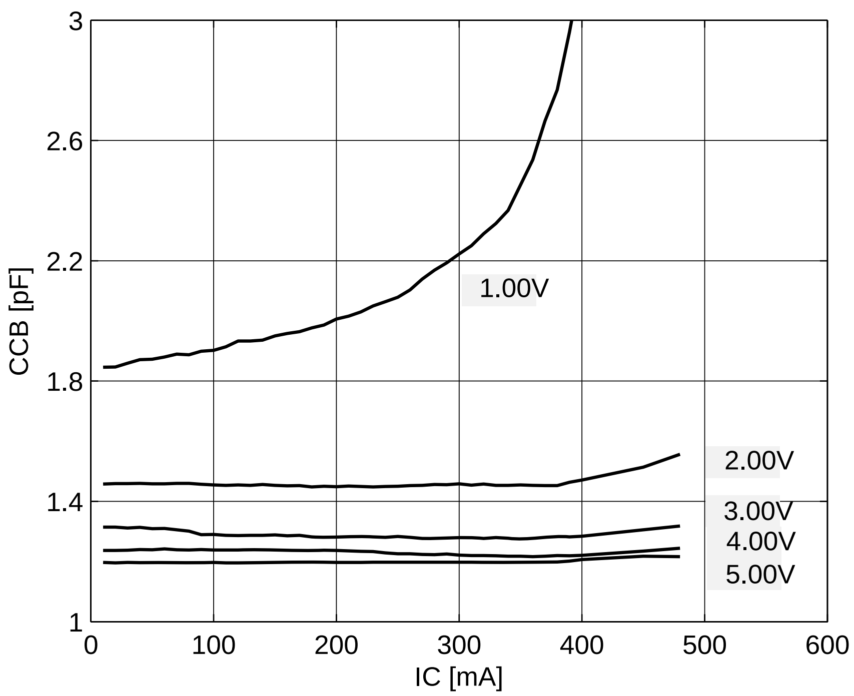



**Figure 7-6 Collector Base Capacitance $C_{CB}$ vs. $I_C$ at $f$ = 30 MHz, $V_{CB}$ = Parameter**

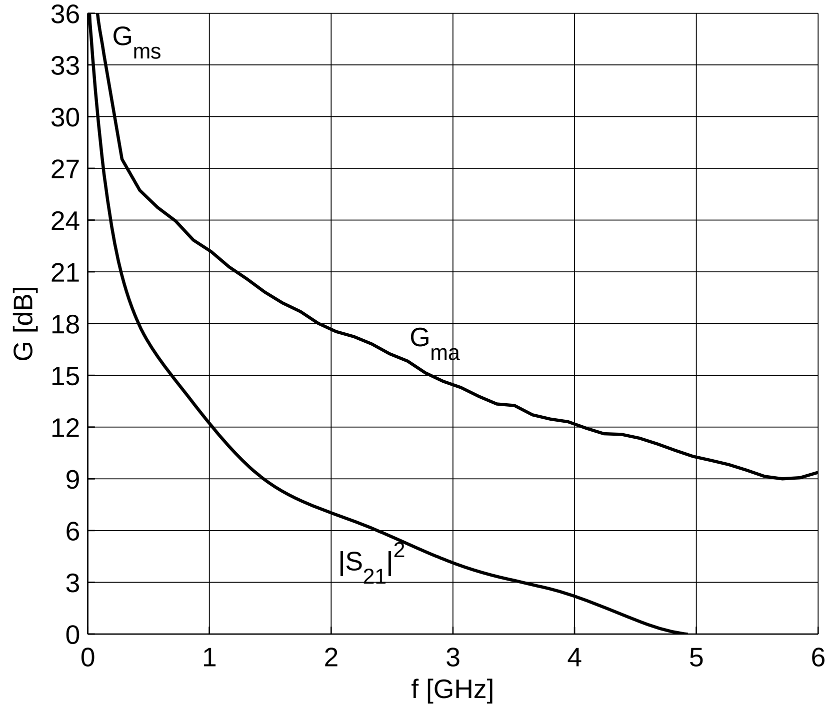



**Figure 7-7 Gain $G_{ms}$, $G_{ma}$, $|S_{21}|^2$ vs. $f$ at $V_{CE}$ = 5 V, $I_C$ = 250 mA**

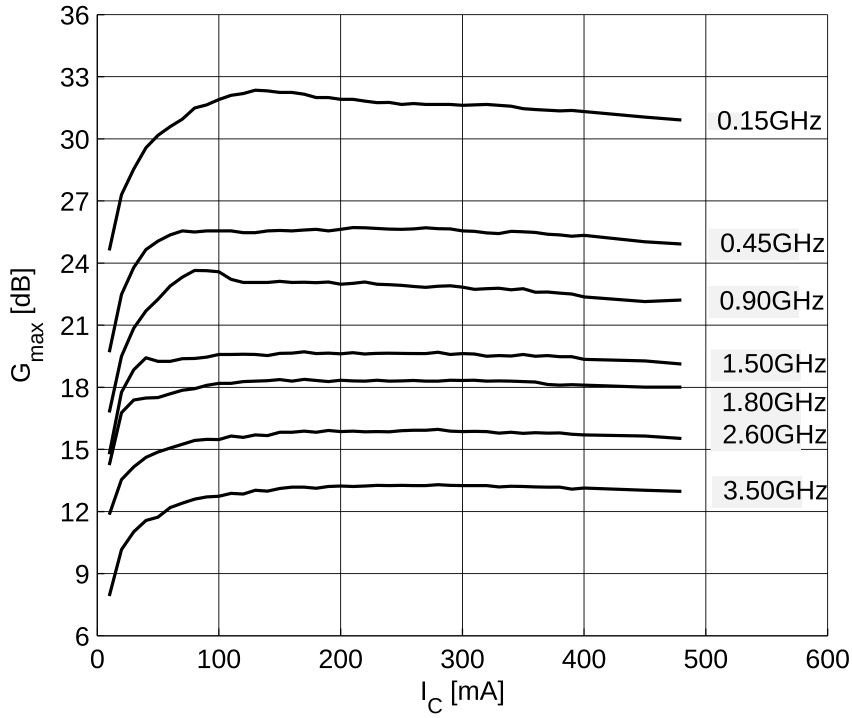



**Figure 7-8 Maximum Power Gain $G_{max}$ vs. $I_C$ at $V_{CE}$ = 5 V, $f$ = Parameter**

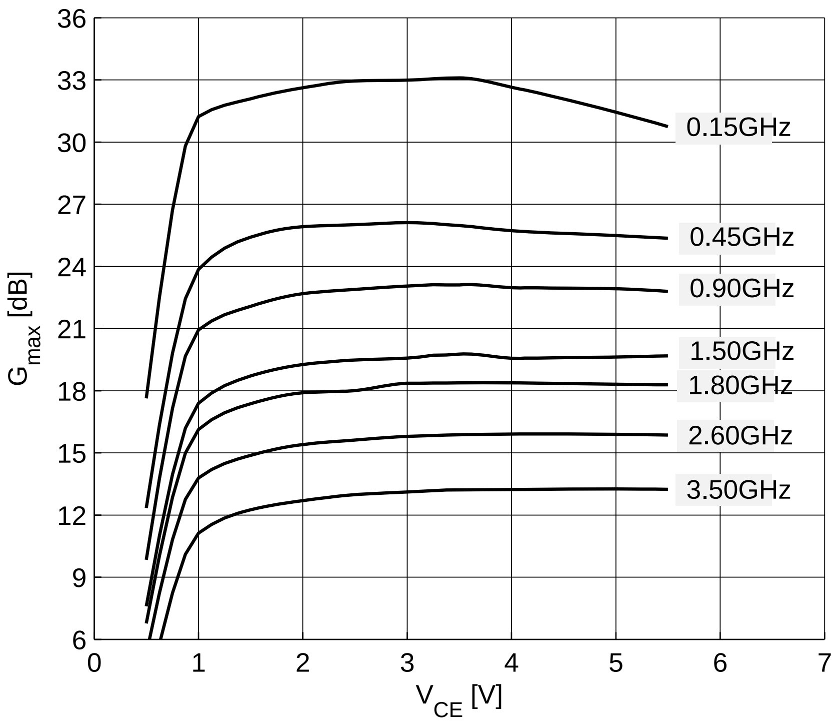



**Figure 7-9 Maximum Power Gain $G_{max}$ vs. $V_{CE}$ at $I_C$ = 250 mA, $f$ = Parameter**

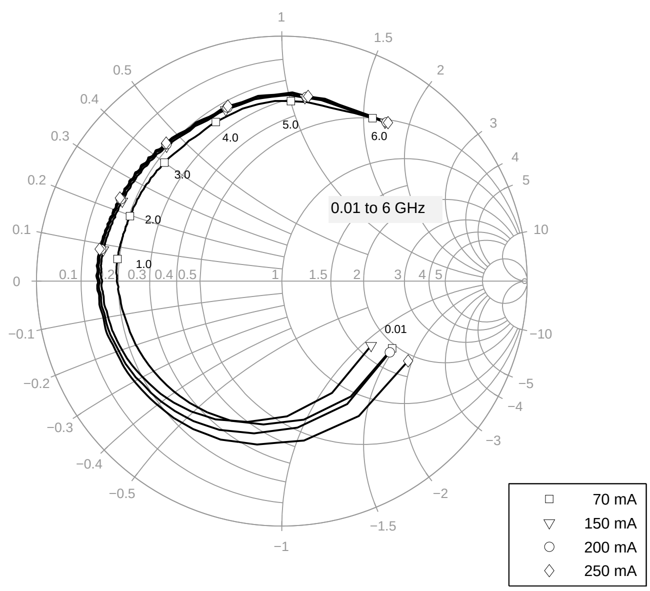



**Figure 7-10 Output Reflection Coefficient $S_{22}$ vs. $f$ at $V_{CE}$ = 5 V, $I_C$ = Parameter**

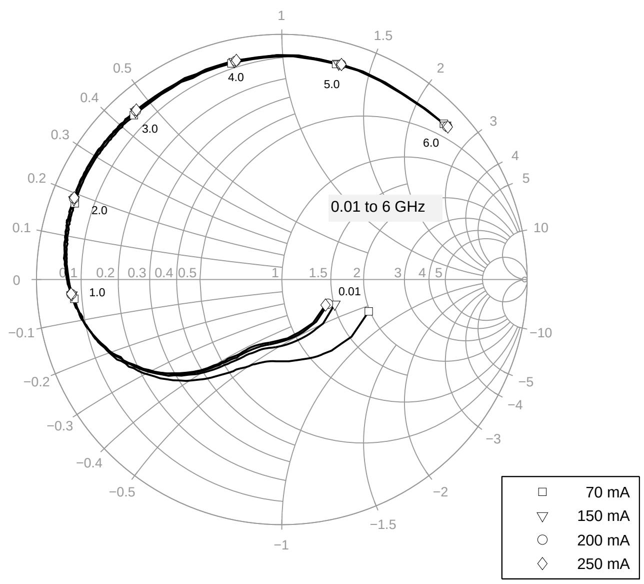



**Figure 7-11 Input Reflection Coefficient $S_{11}$ vs. $f$ at $V_{CE}$ = 5 V, $I_C$ = Parameter**

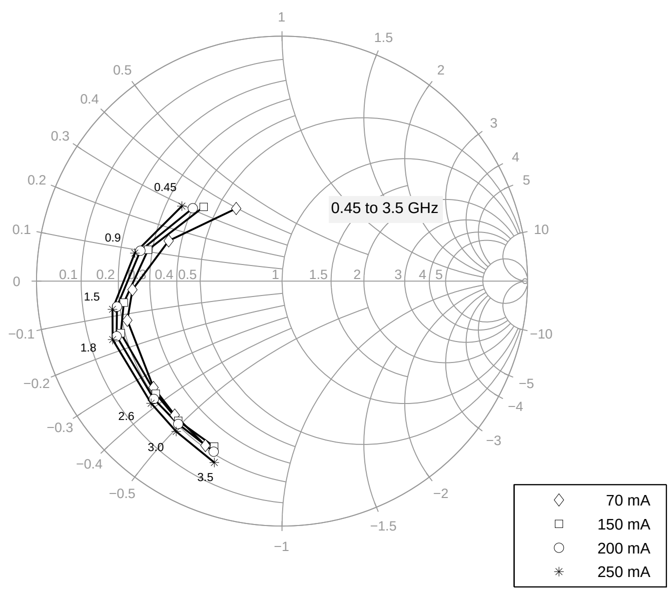



**Figure 7-12 Source Impedance $Z_{Sopt}$ for Minimum Noise Figure vs. $f$ at $V_{CE}$ = 5V, $I_C$ = Parameter**

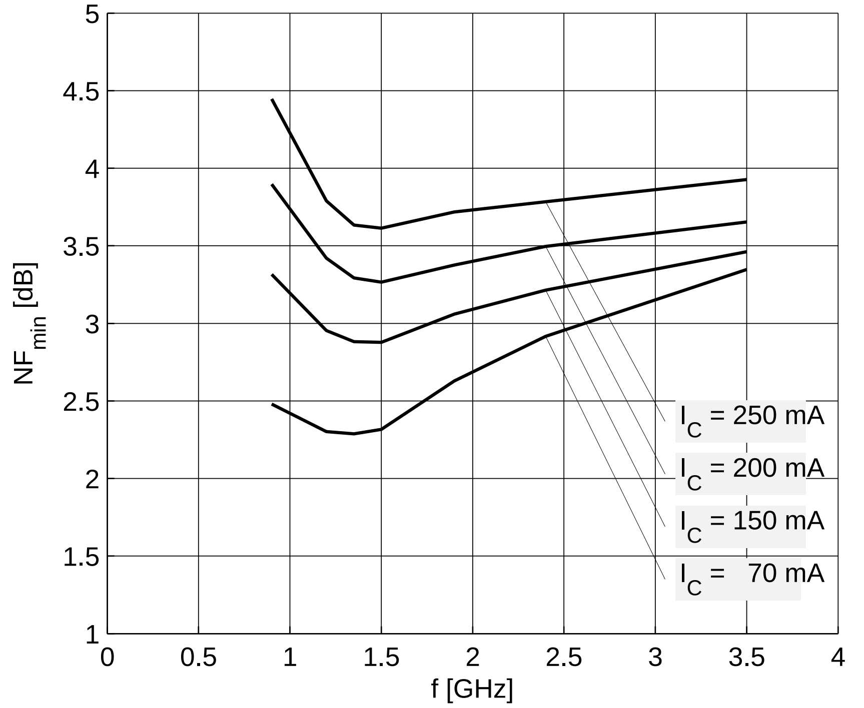



**Figure 7-13 Noise Figure $NF_{min}$ vs. $f$ at $V_{CE}$ = 5 V, $Z_S = Z_{Sopt}$, $I_C$ = Parameter**

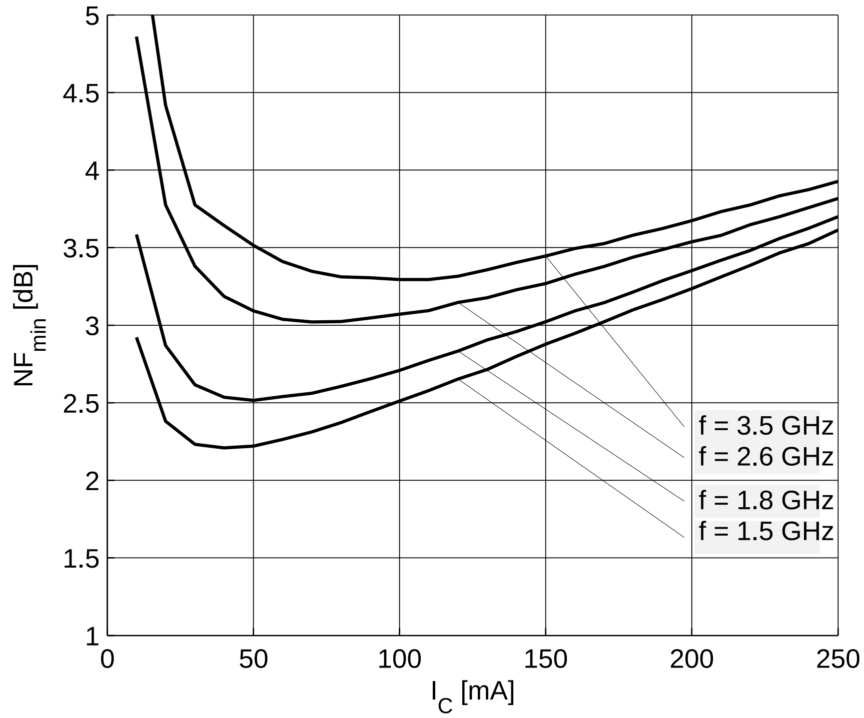



**Figure 7-14 Noise Figure $NF_{min}$ vs. $I_C$ at $V_{CE}$ = 5 V, $Z_S = Z_{Sopt}$, $f$ = Parameter**

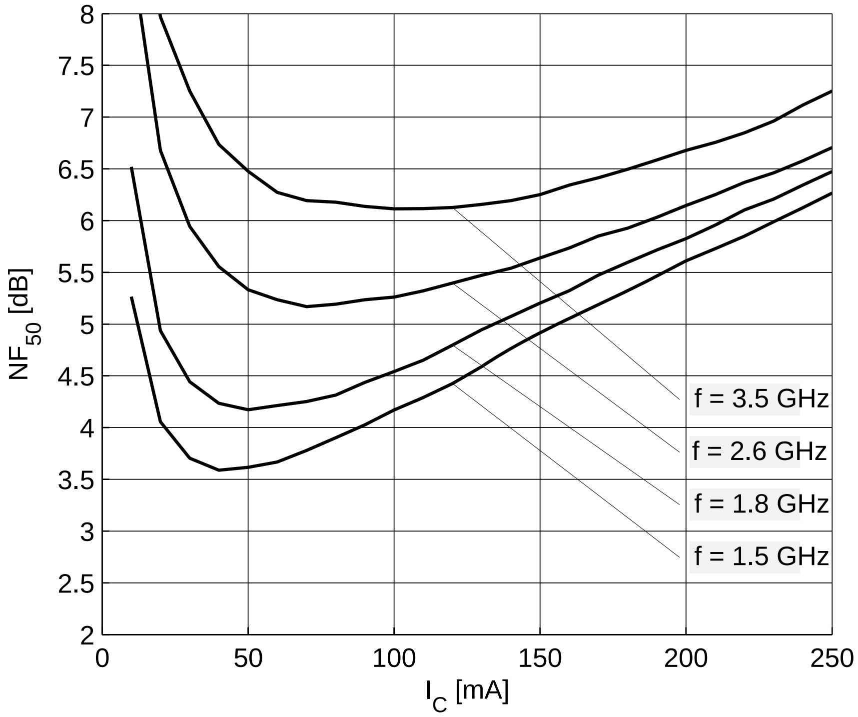



**Figure 7-15 Noise Figure $NF_{50}$ vs. $I_C$ at $V_{CE}$ = 5 V, $Z_S$ = 50 Ω, $f$ = Parameter**

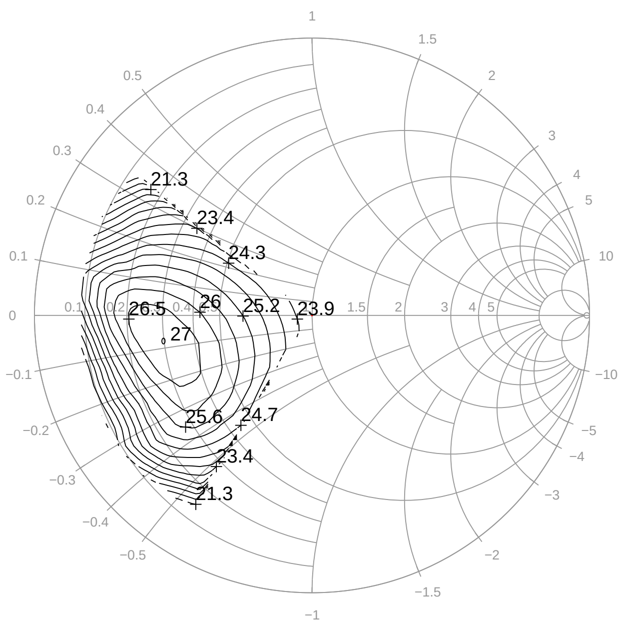



**Figure 7-16 Load Pull Contour $OP_{1dB}$ [dBm] at $V_{CE}$ = 5 V, $I_C$ = 250 mA, $f$ = 0.9 GHz, $Z_l$ = $Z_{opt}$**

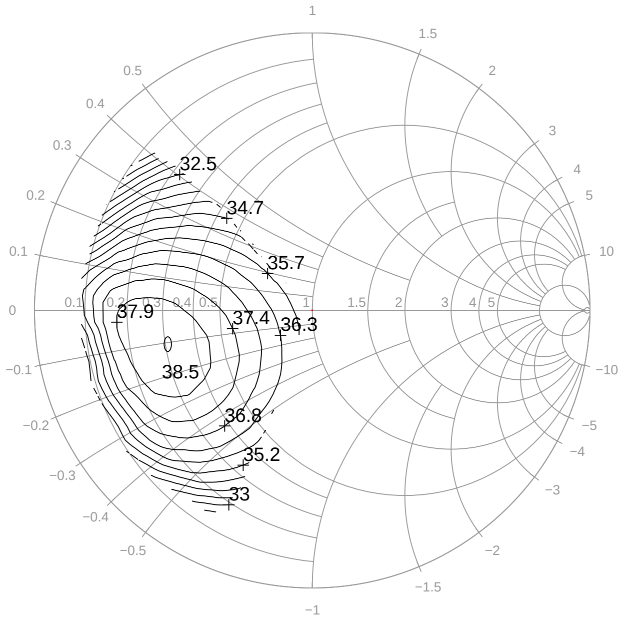



**Figure 7-17 Load Pull Contour $OIP3$ [dBm] at $V_{CE}$ = 5 V, $I_C$ = 250 mA, $f$ = 0.9 GHz, $Z_l$ = $Z_{opt}$**

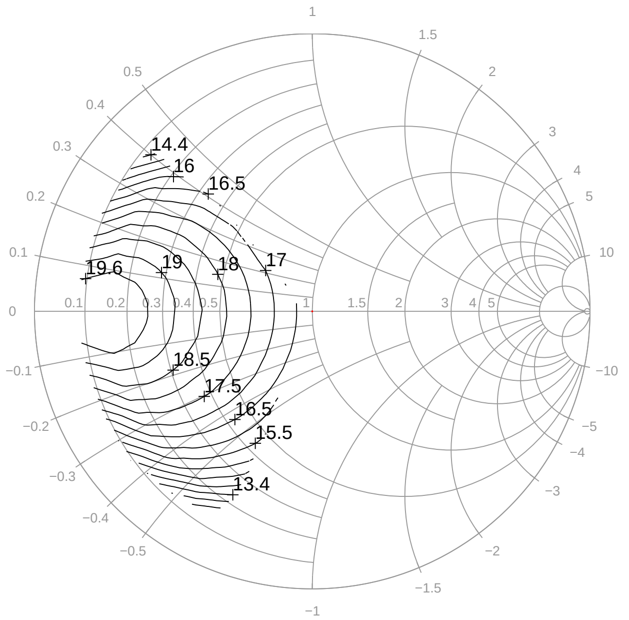



**Figure 7-18 Load Pull Contour Gain $G$ [dB] at $V_{CE}$ = 5 V, $I_C$ = 250 mA, $f$ = 0.9 GHz, $Z_l$ = $Z_{opt}$**

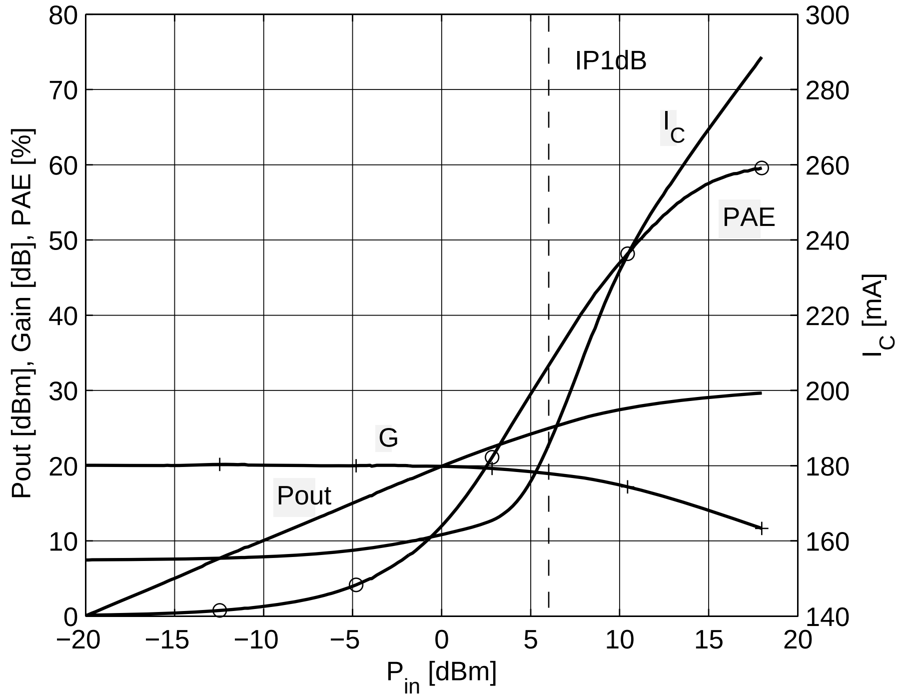



**Figure 7-19** $P_{out}$, Gain, $I_C$, PAE vs. $P_{in}$ at $V_{CE}$ = 5 V, $I_{Cq}$ = 155 mA, $f$ = 0.9 GHz, $Z_l$ = $Z_{opt}$

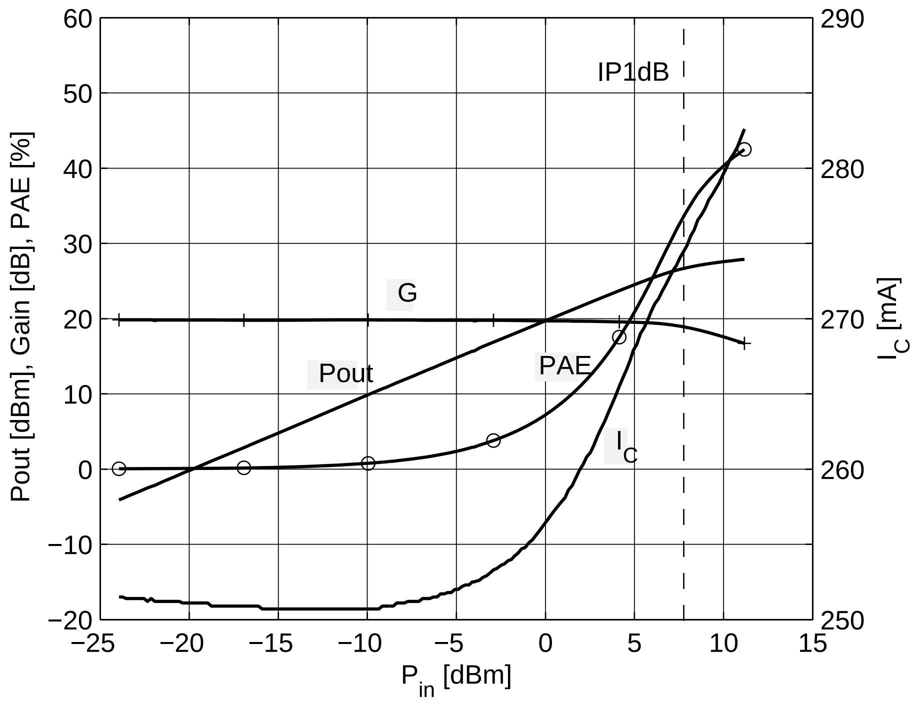



**Figure 7-20** $P_{out}$, Gain, $I_C$, PAE vs. $P_{in}$ at $V_{CE}$ = 5 V, $I_{Cq}$ = 250 mA, $f$ = 0.9 GHz, $Z_l$ = $Z_{opt}$

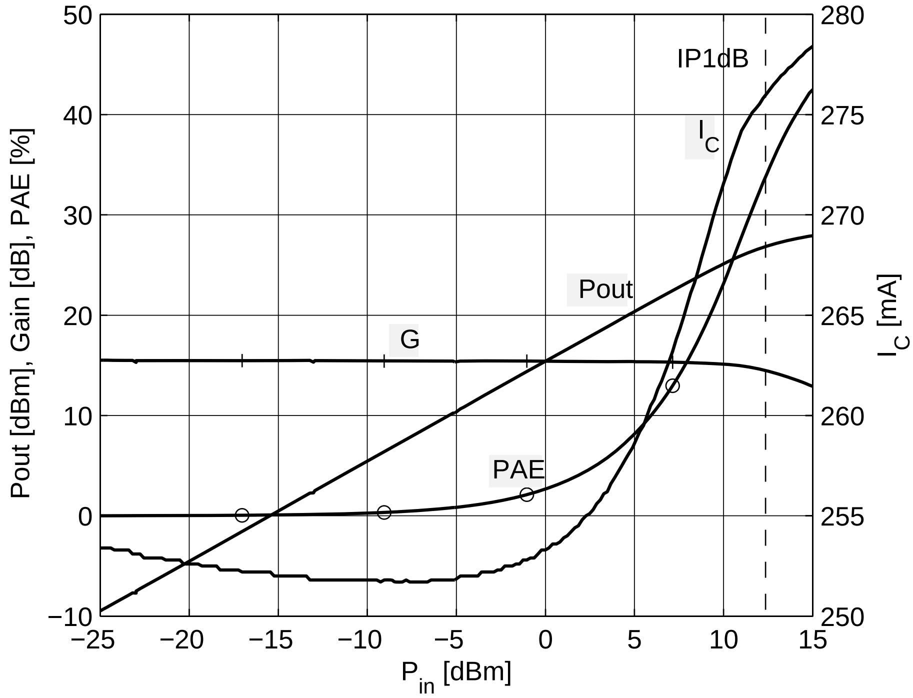



**Figure 7-21** $P_{out}$, **Gain,** $I_C$**, PAE vs.** $P_{in}$ **at** $V_{CE}$ **= 5 V,** $I_{Cq}$ **= 250 mA,** $f$ **= 2.6 GHz,** $Z_l = Z_{opt}$

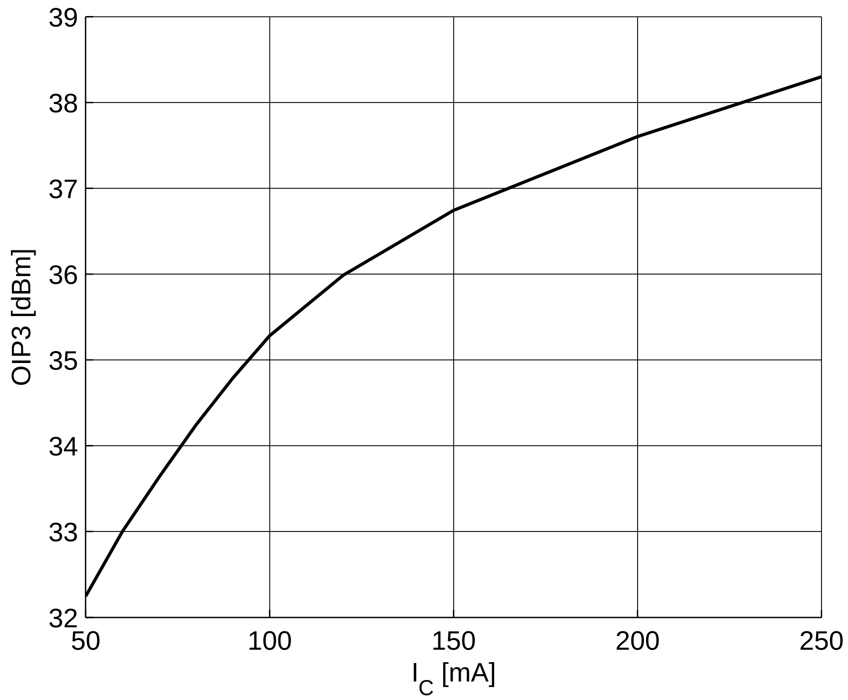



**Figure 7-22** $OIP3$ **vs.** $I_C$ **at** $V_{CE}$ **= 5 V,** $f$ **= 0.9 GHz,** $Z_L = Z_{Lopt}$

*Note: The curves shown in this chapter have been generated using typical devices but shall not be understood as a guarantee that all devices have identical characteristic curves.* $T_A$ = 25 °C.

# 8 Simulation Data

For the BFQ790 a large signal model exists. It is a VBIC model, which is an advancement of the SPICE Gummel-Poon model. It covers properties of a power transistor which are not known by the standard SPICE Gummel-Poon model, such as self-heating, quasi-saturation and voltage breakdown. The VBIC model can be used in standard simulation tools such as ADS and MWO as easily as the SPICE Gummel-Poon model. On the BFQ790 internet page the VBIC model is provided as a netlist. The model already contains the package parasitics and is ready to use for DC and high frequency simulations. Besides the DC characteristics all S-parameters in magnitude and phase, noise figure (including optimum source impedance and equivalent noise resistance), intermodulation and compression have been extracted.

On the BFQ790 internet page you also find the S-parameters (including noise parameters) for linear simulation. In any case please consult our website and download the latest versions before actually starting your design.

# 9 Package Information SOT89

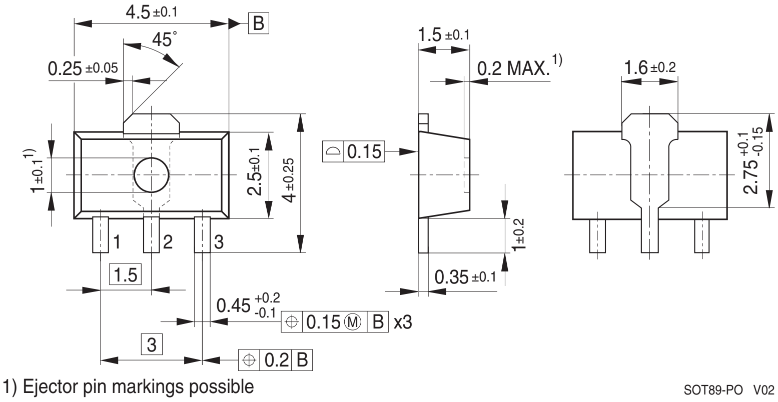



**Figure 9-1 Package Outline**

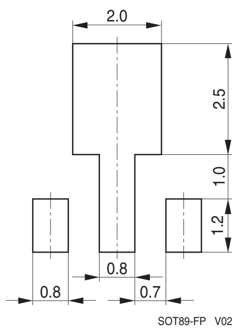



**Figure 9-2 Package Footprint**

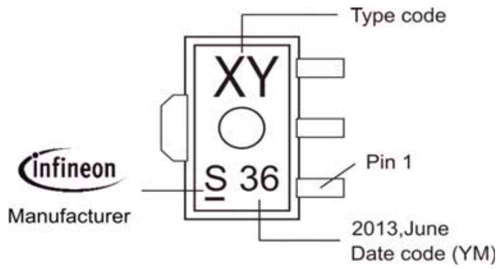



**Figure 9-3 Marking Example (Marking BFQ790: R3)**

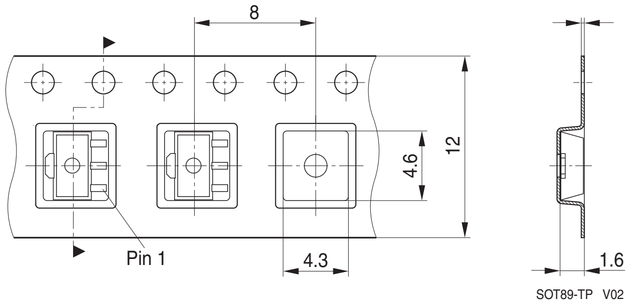



**Figure 9-4 Tape Dimensions**

w w w . i n f i n e o n . c o m

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- Техническая поддержка проекта;
- Защита от снятия компонента с производства.


### Как с нами связаться

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