BFQ790

High Linearity High Gain 1/2 Watt RF Driver Amplifier

Data Sheet

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Preliminary

RF & Protection Devices

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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.

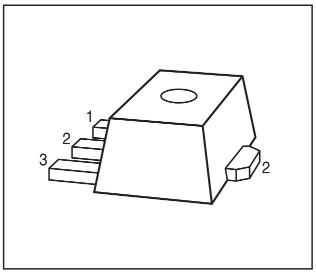
For the BFQ790 an advanced large signal compact model is available. Further information please find in chapter 8.

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



RoHS

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 5.1	V	T_A = 25 °C 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 Tempera-ture[1]	Collector Current	DC Power[2]	RF Output Power [3]	Efficiency [4]	Dissipated Power[5]	Thermal Resistance of pcb[6]	Junction Tempera-ture[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	–

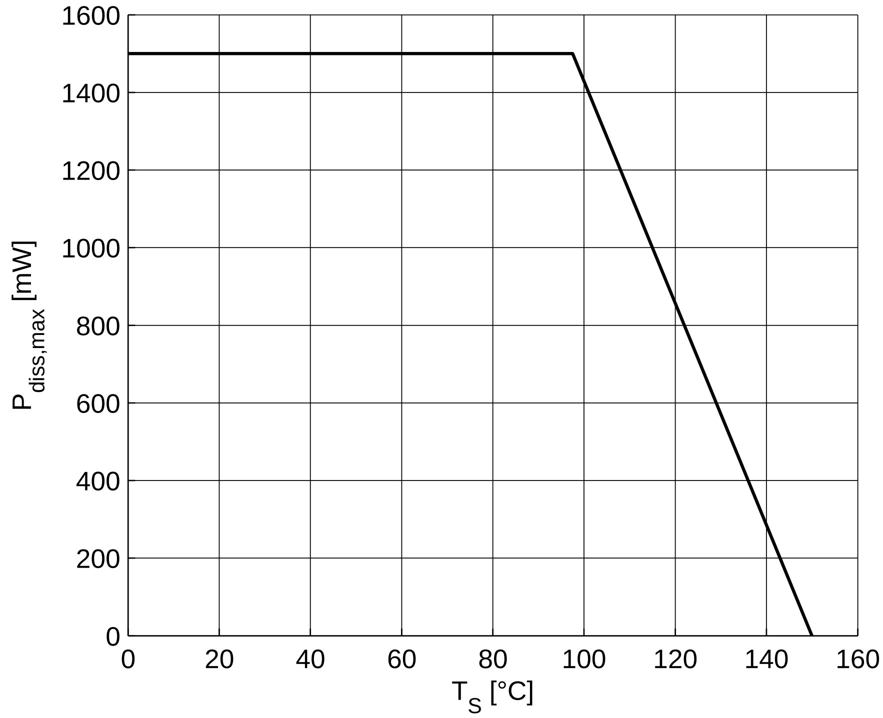


Figure 5-1 Absolute Maximum Power Dissipation $P_{diss,max}$ vs. T_s

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 0.1	40[1] 3	nA µA	V_{CE} = 8 V, V_{BE} = 0 V_{CE} = 18 V, V_{BE} = 0 E-B short circuited
Collector base leakage current	I_{CBO}	–	1	40[1]	nA	V_{CB} = 8 V, I_E = 0 Open emitter
Emitter base leakage current	I_{EBO}	–	1	40[1]	nA	V_{EB} = 0.5 V, I_C = 0 Open collector
DC current gain	h_{FE}	60	120	180		V_{CE} = 5 V, I_C = 250 mA 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 f = 1 MHz Emitter grounded
Collector emitter capacitance	C_{CE}	–	2.2	–	pF	V_{CE} = 5 V, V_{BE} = 0 f = 1 MHz Base grounded
Emitter base capacitance	C_{EB}	–	9.4	–	pF	V_{EB} = 0.5 V, V_{CB} = 0 f = 1 MHz 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.

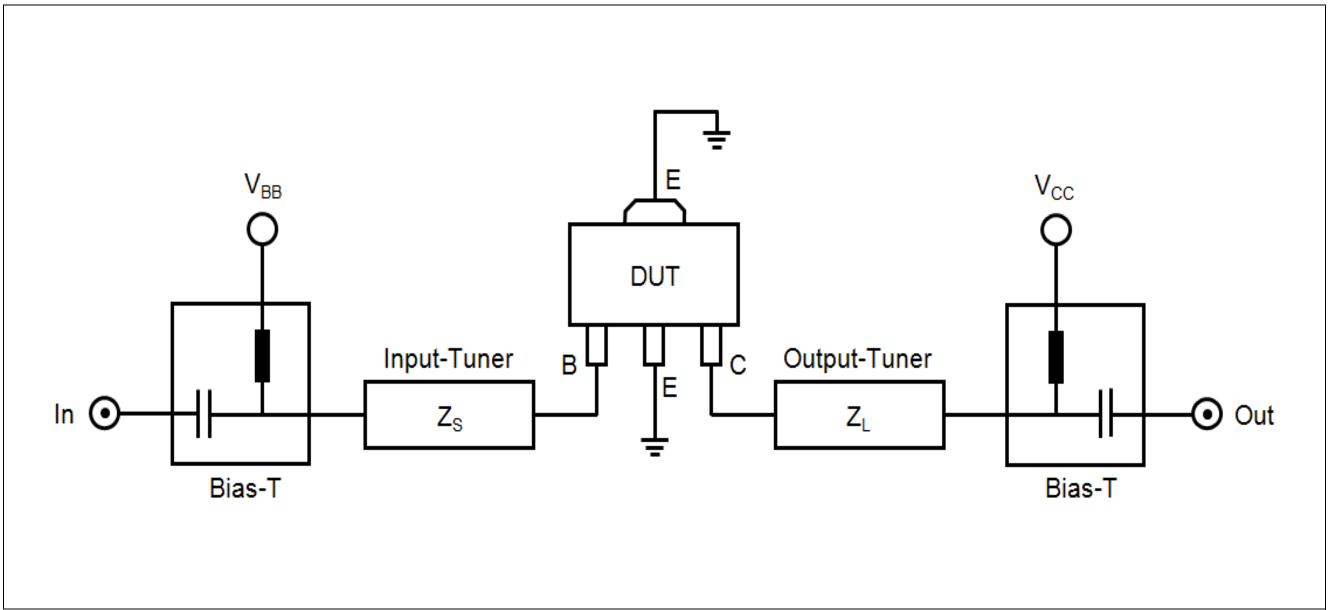


Figure 7-1 BFQ790 Testing Circuit

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

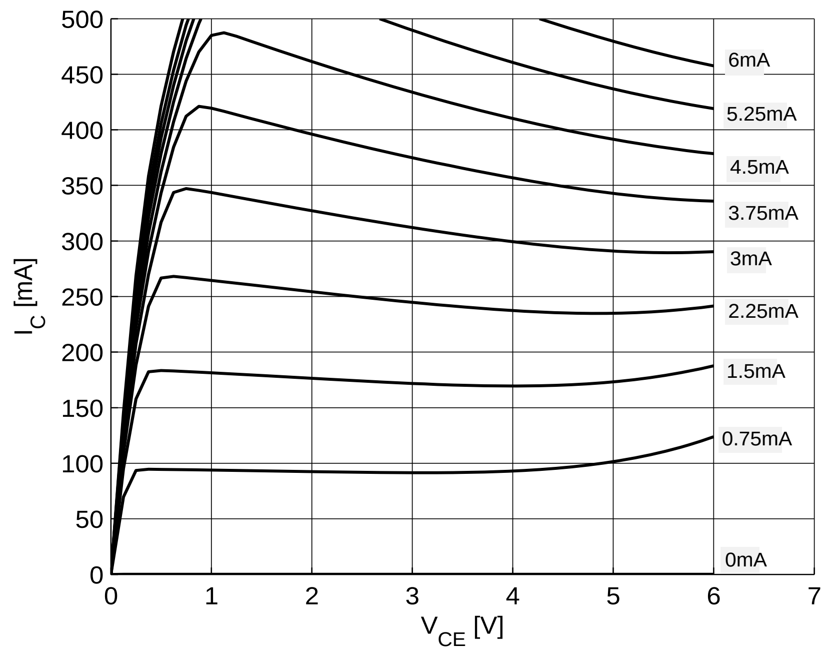


Figure 7-2 Collector Current I_C vs. V_{CE}, I_B = Parameter

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

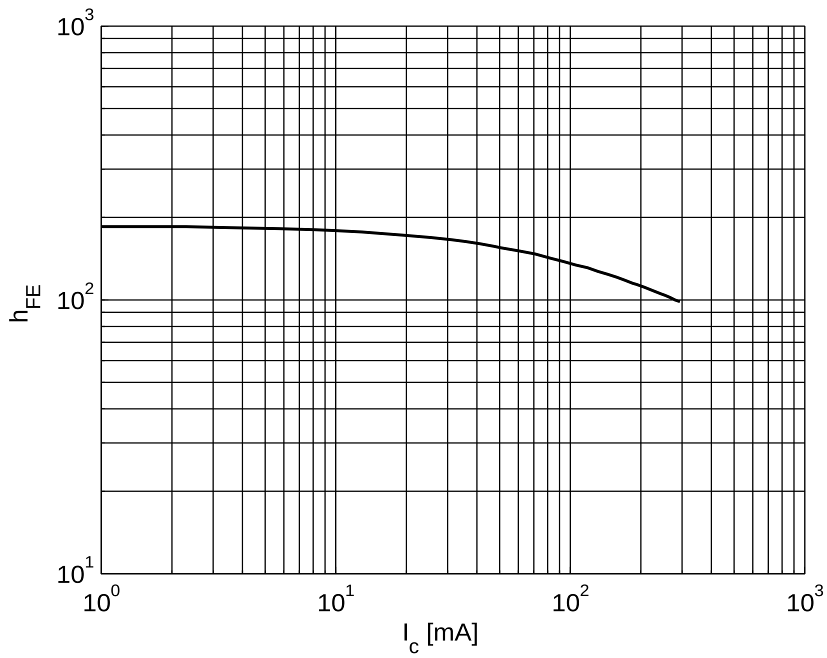


Figure 7-3 DC Current Gain h_{FE} vs. I_C at V_{CE} = 5 V

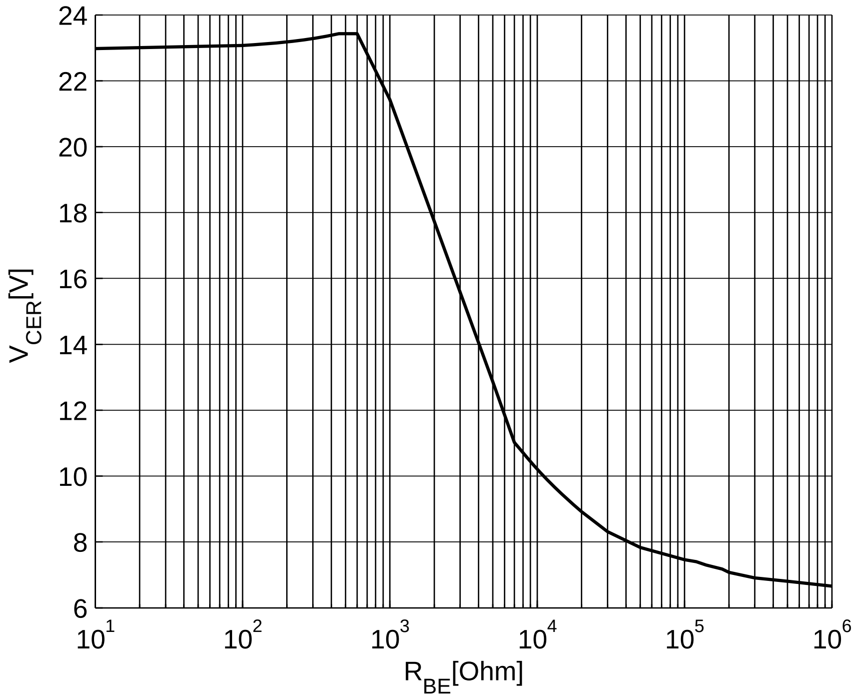


Figure 7-4 Collector Emitter Breakdown Voltage BV_{CER} vs. Resistor R_B/GND

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

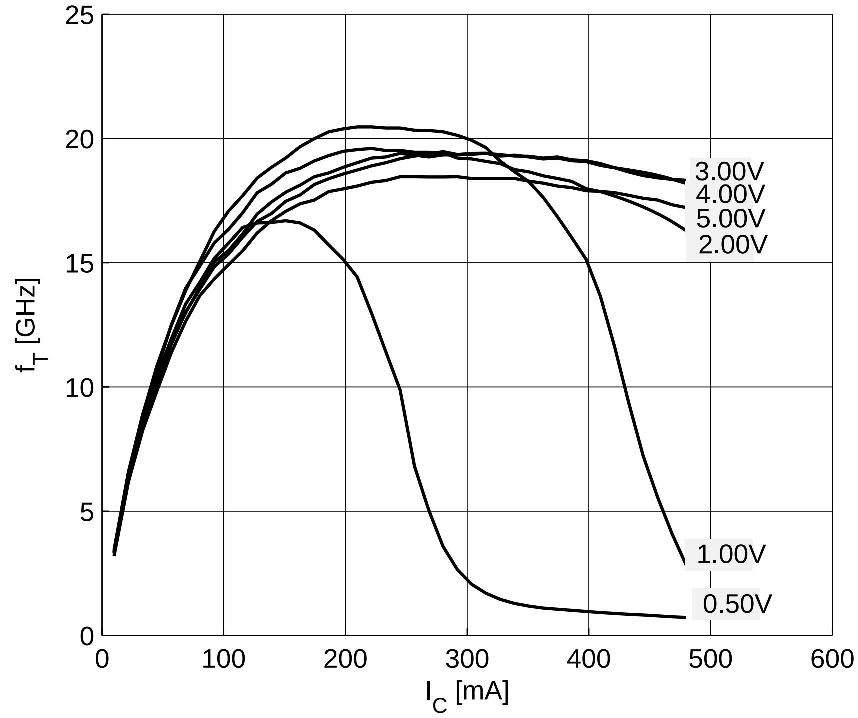


Figure 7-5 Transition Frequency f_T vs. I_C, V_{CE} = Parameter

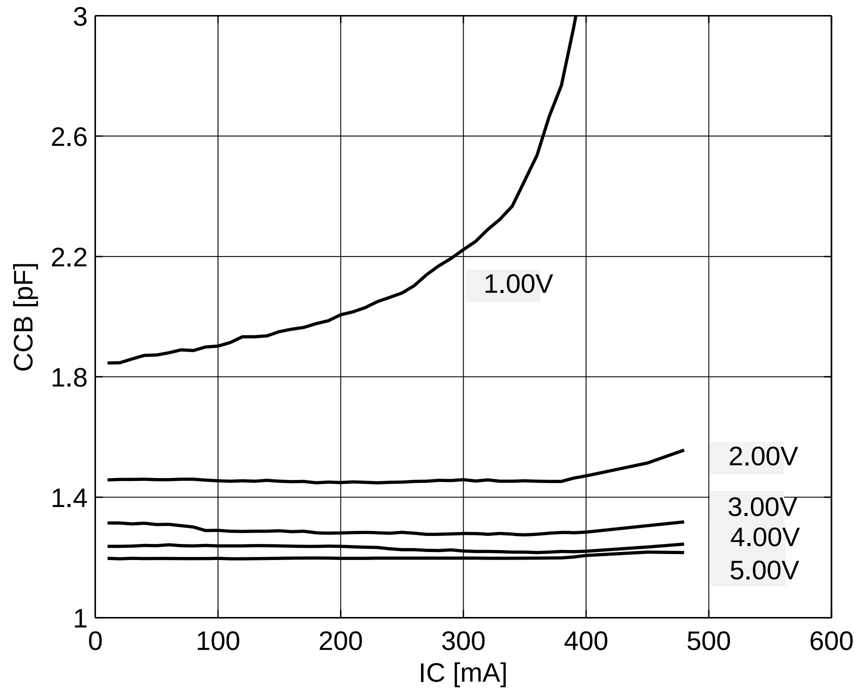


Figure 7-6 Collector Base Capacitance C_{CB} vs. I_C at f = 30 MHz, V_{CB} = Parameter

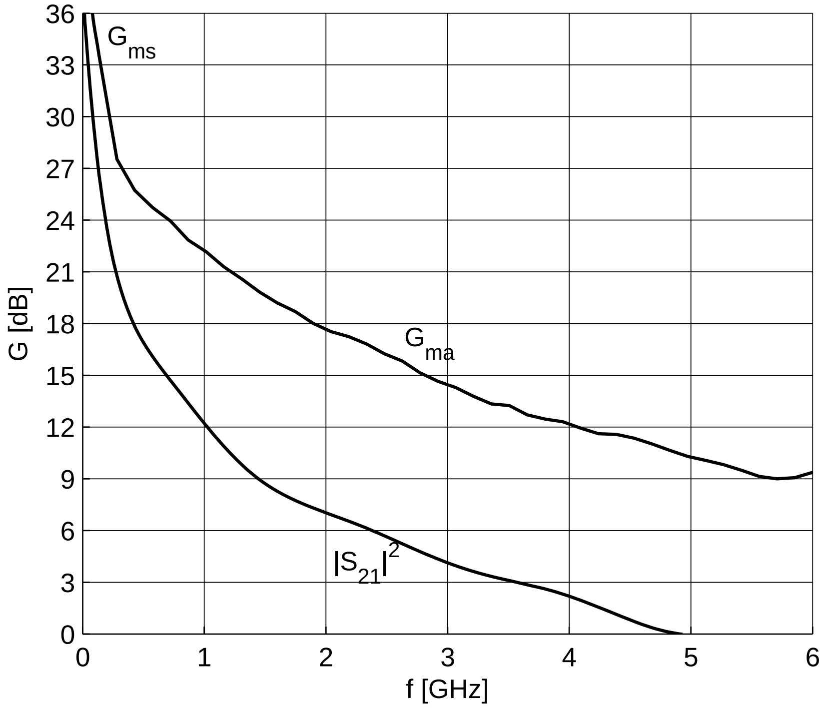


Figure 7-7 Gain G_{ms}, G_{ma}, $|S_{21}|^2$ vs. f at V_{CE} = 5 V, I_C = 250 mA

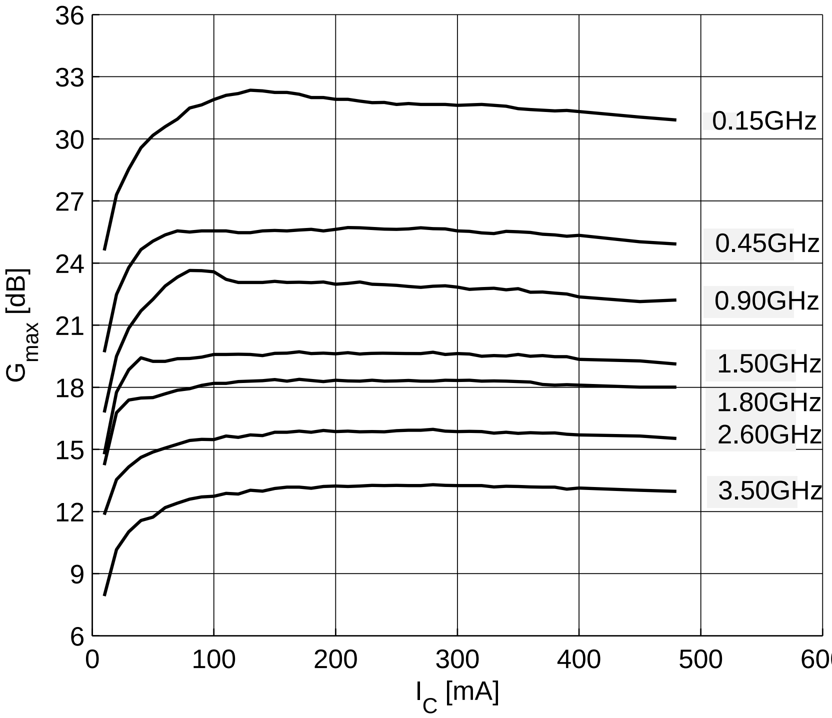


Figure 7-8 Maximum Power Gain G_{max} vs. I_C at V_{CE} = 5 V, f = Parameter

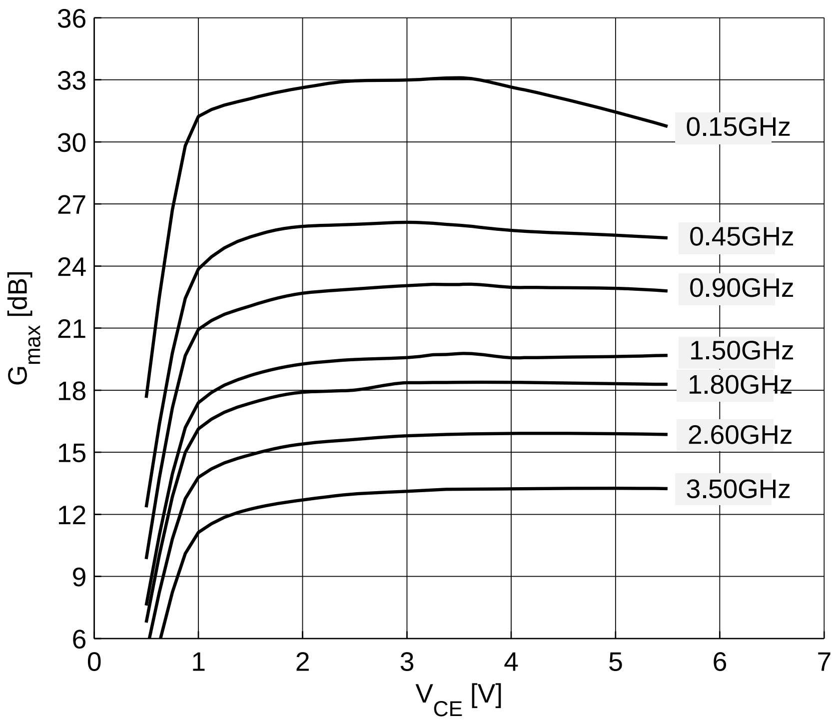


Figure 7-9 Maximum Power Gain G_{max} vs. V_{CE} at I_C = 250 mA, f = Parameter

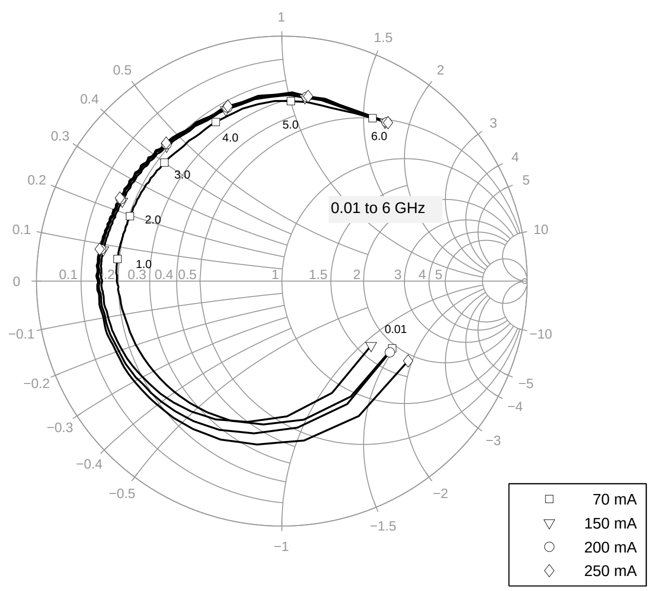


Figure 7-10 Output Reflection Coefficient S_{22} vs. f at V_{CE} = 5 V, I_C = Parameter

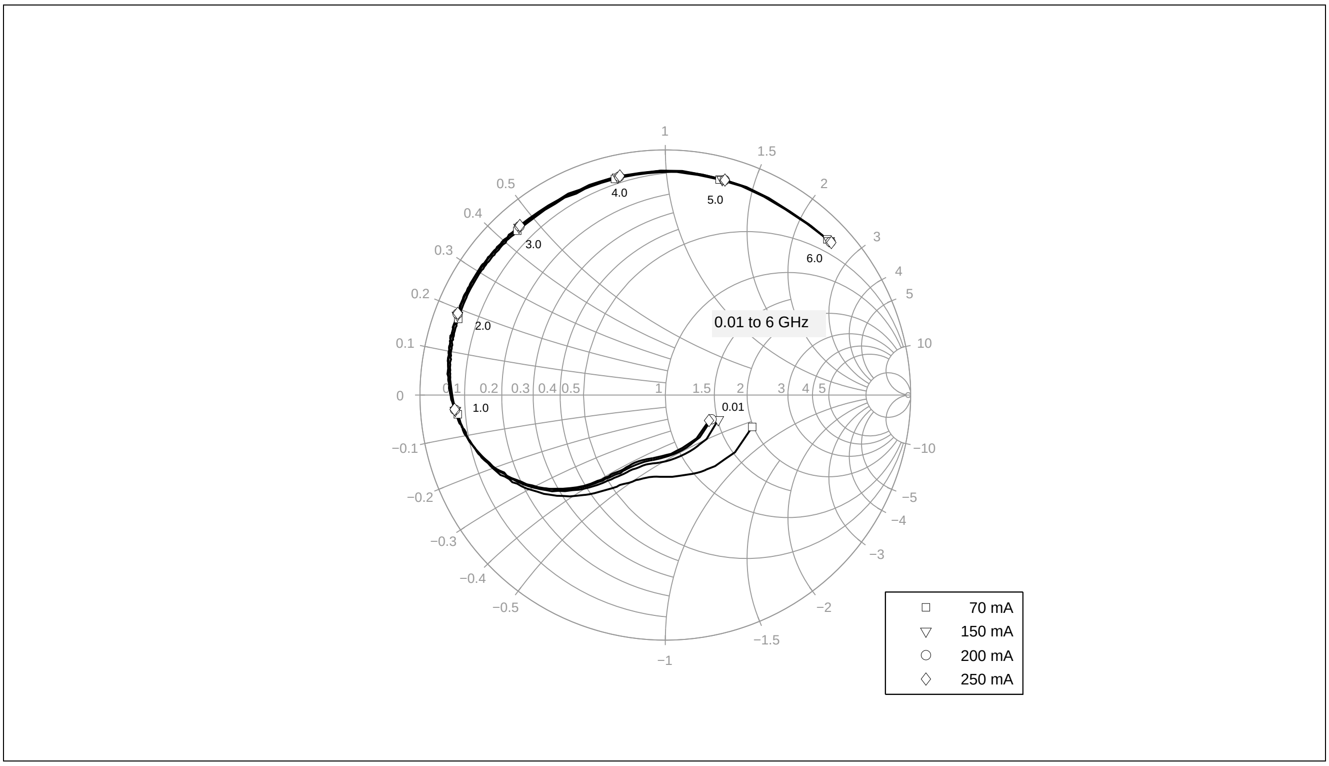


Figure 7-11 Input Reflection Coefficient S_{11} vs. f at V_{CE} = 5 V, I_C = Parameter

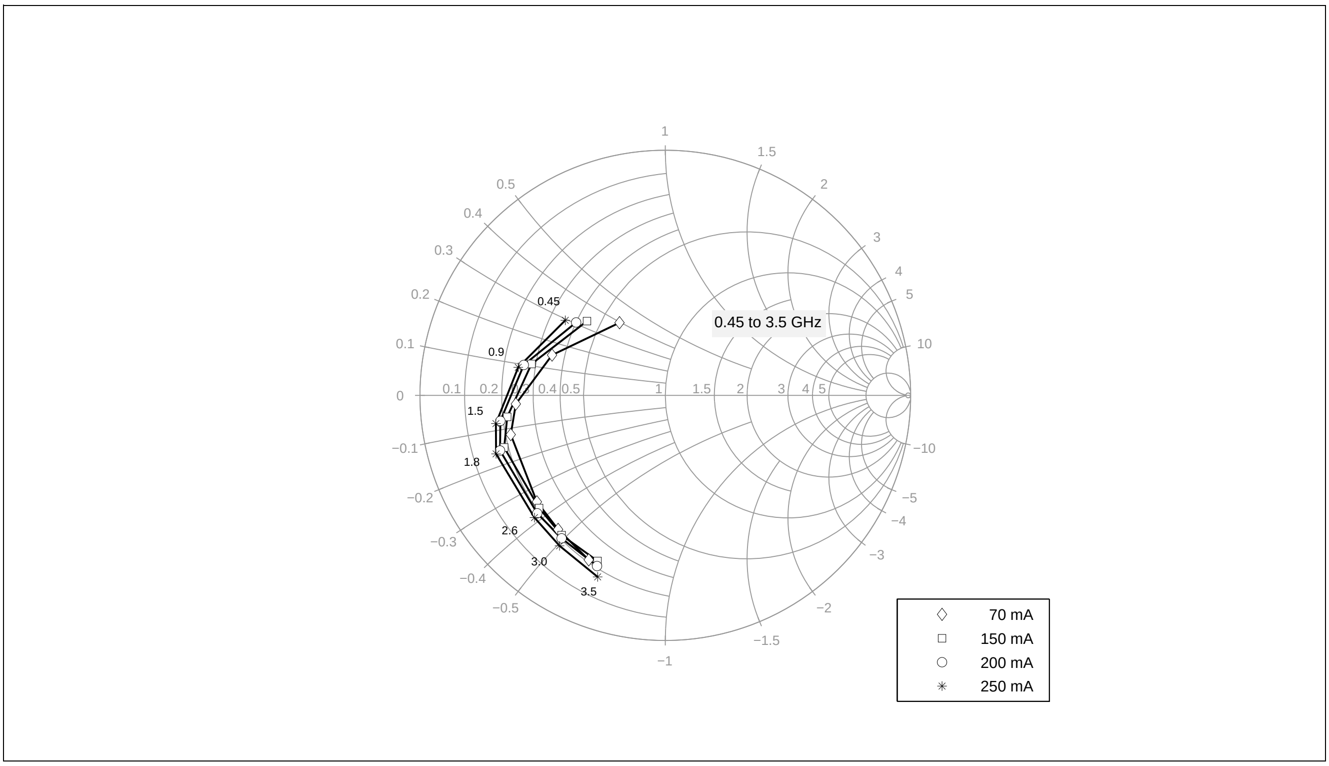


Figure 7-12 Source Impedance Z_{Sopt} for Minimum Noise Figure vs. f at V_{CE} = 5V, I_C = Parameter

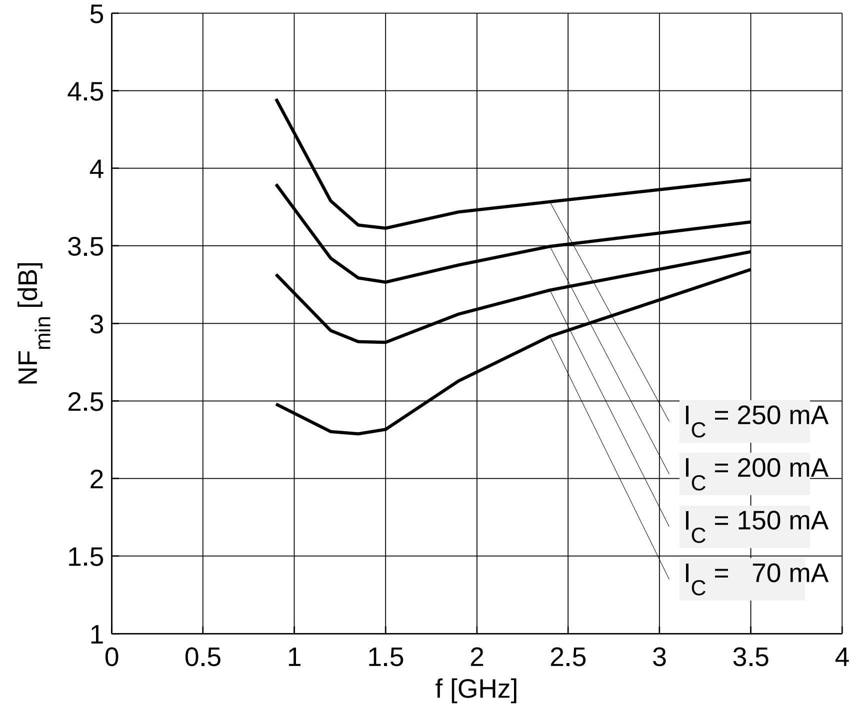


Figure 7-13 Noise Figure NF_{min} vs. f at V_{CE} = 5 V, Z_S = Z_{Sopt}, I_C = Parameter

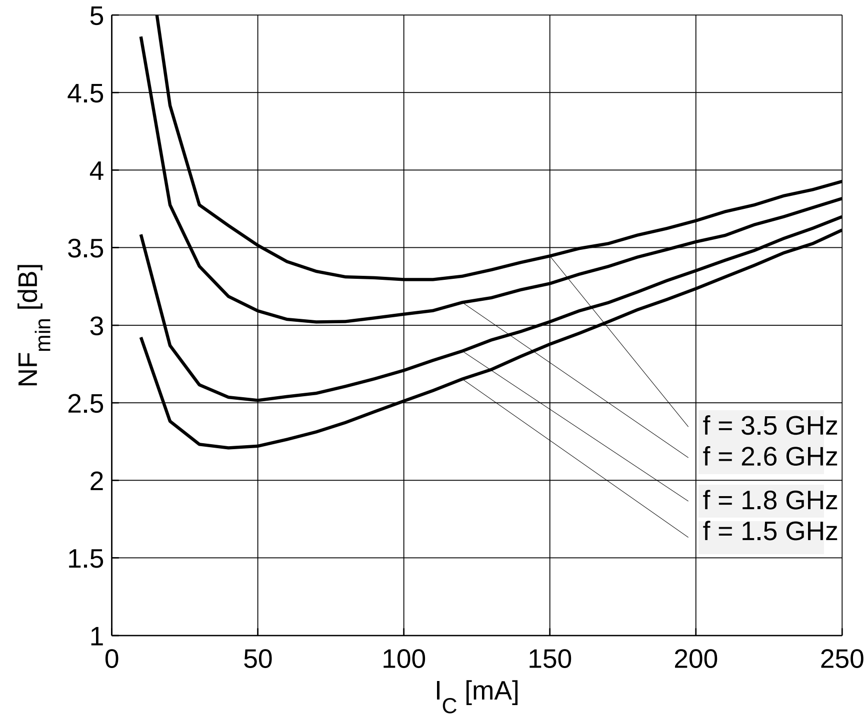


Figure 7-14 Noise Figure NF_{min} vs. I_C at V_{CE} = 5 V, Z_S = Z_{Sopt}, f = Parameter

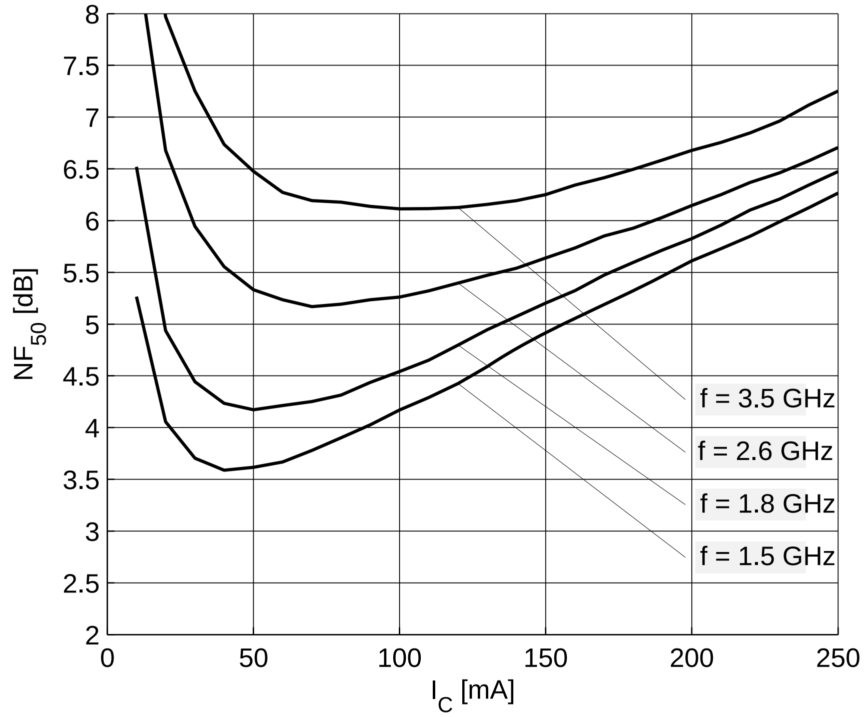


Figure 7-15 Noise Figure NF_{50} vs. I_C at V_{CE} = 5 V, Z_S = 50 Ω, f = Parameter

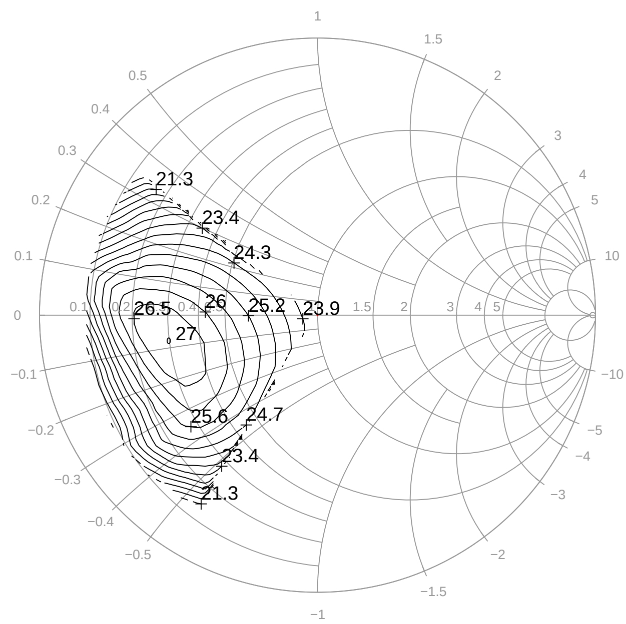


Figure 7-16 Load Pull Contour OP_{1dB} [dBm] at V_{CE} = 5 V, I_C = 250 mA, f = 0.9 GHz, Z_l = Z_{opt}

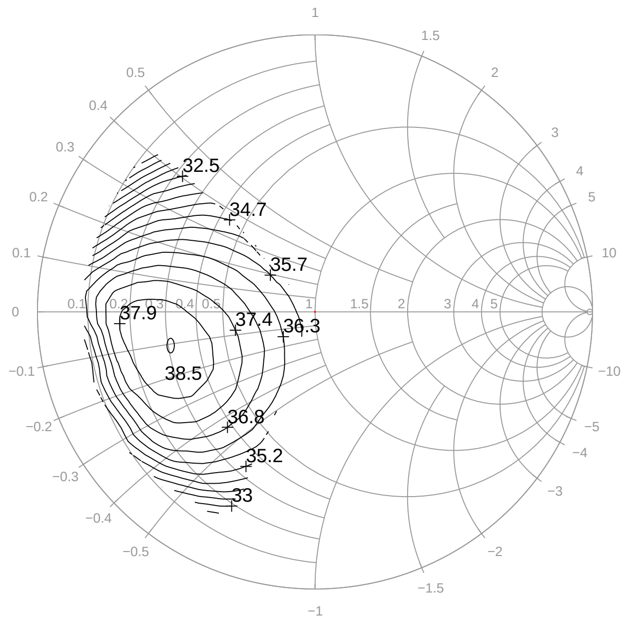


Figure 7-17 Load Pull Contour $OIP3$ [dBm] at V_{CE} = 5 V, I_C = 250 mA, f = 0.9 GHz, Z_l = Z_{opt}

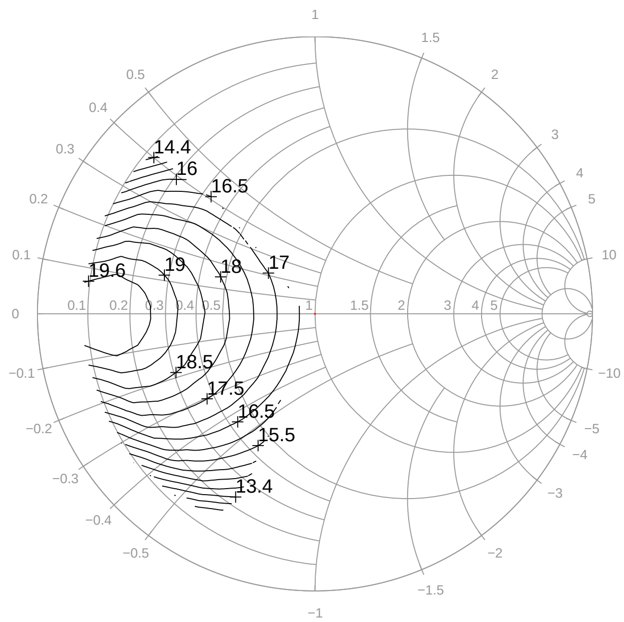


Figure 7-18 Load Pull Contour Gain G [dB] at V_{CE} = 5 V, I_C = 250 mA, f = 0.9 GHz, Z_l = Z_{opt}

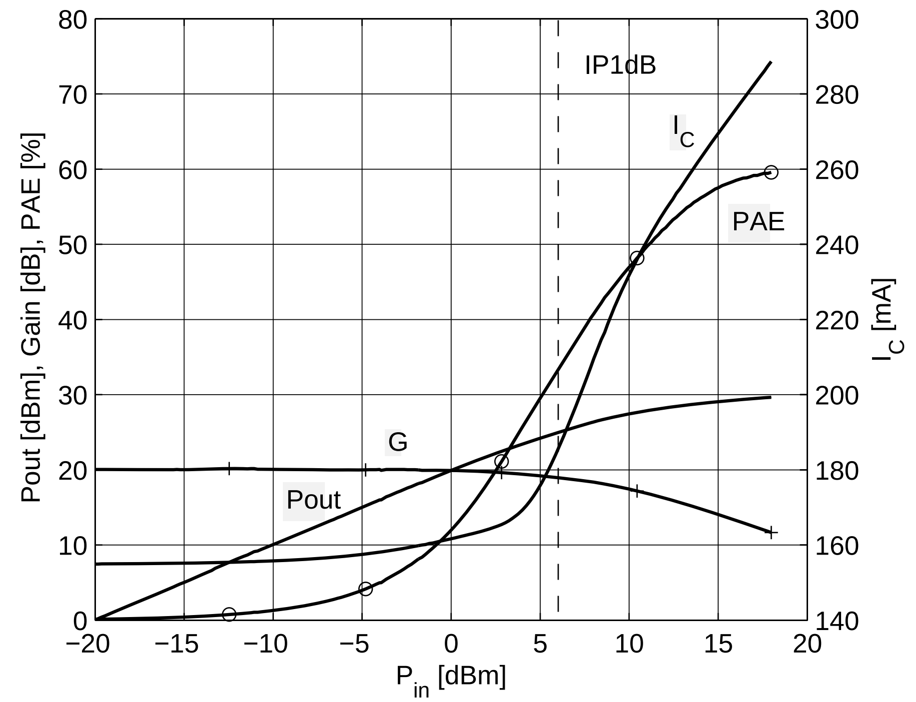


Figure 7-19 P_{out}, Gain, I_C, PAE vs. P_{in} at V_{CE} = 5 V, I_{Cq} = 155 mA, f = 0.9 GHz, Z_l = Z_{opt}

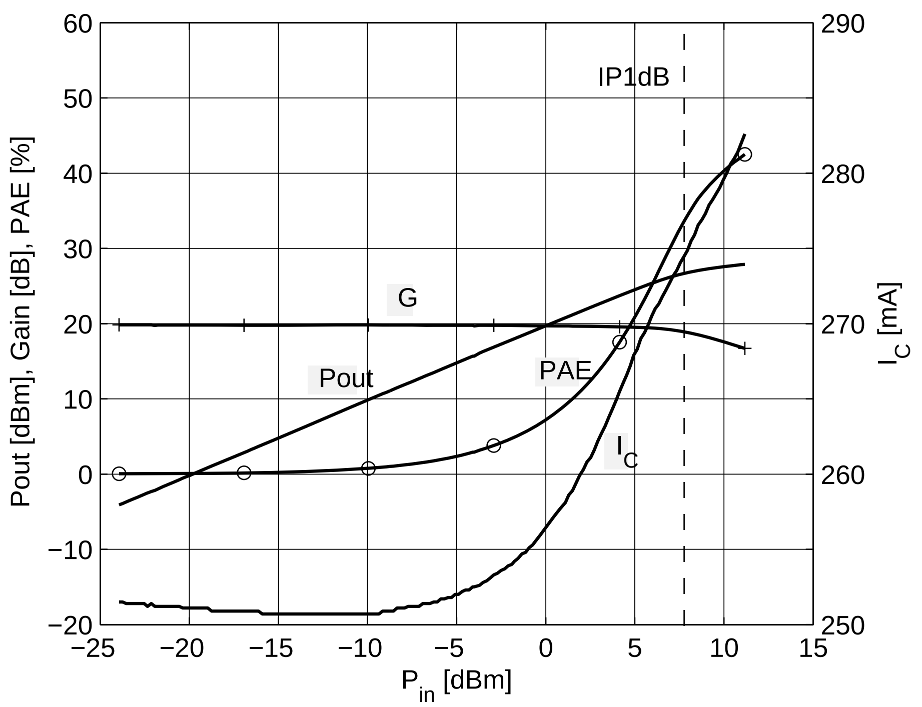


Figure 7-20 P_{out}, Gain, I_C, PAE vs. P_{in} at V_{CE} = 5 V, I_{Cq} = 250 mA, f = 0.9 GHz, Z_l = Z_{opt}

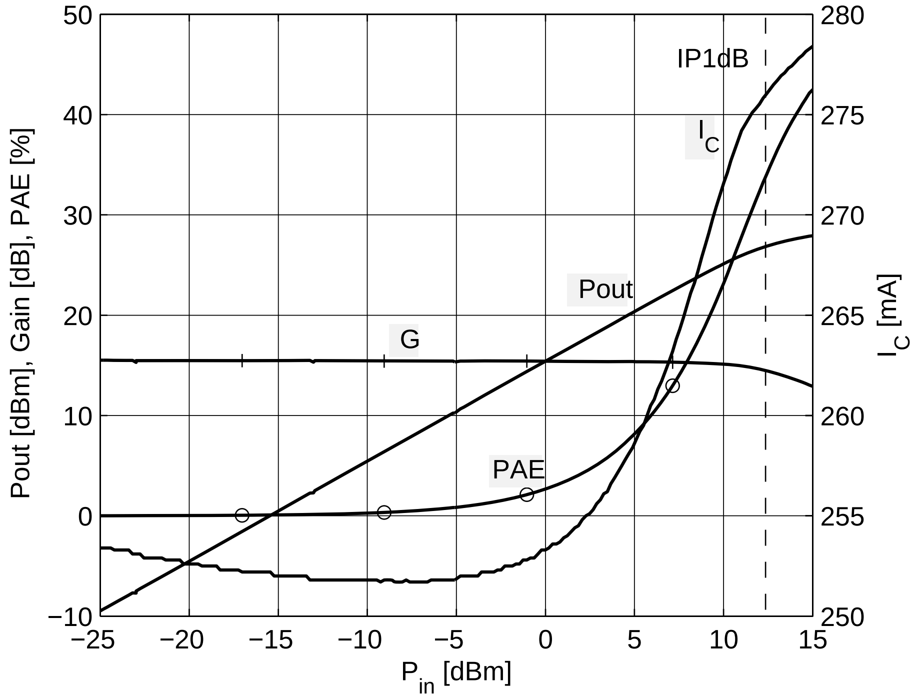


Figure 7-21 P_{out}, Gain, I_C, PAE vs. P_{in} at V_{CE} = 5 V, I_{Cq} = 250 mA, f = 2.6 GHz, Z_l = Z_{opt}

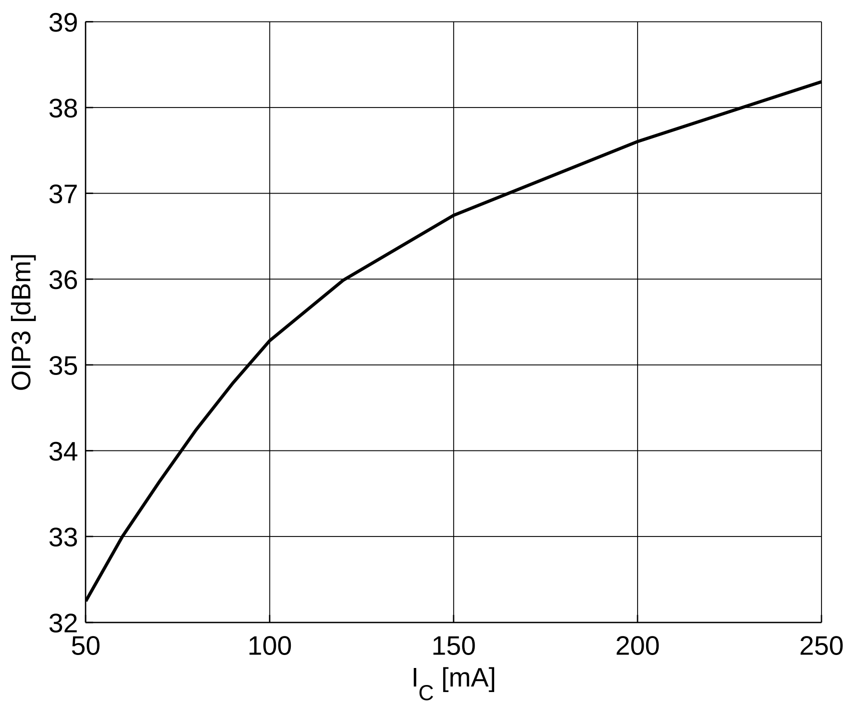


Figure 7-22 $OIP3$ vs. I_C at V_{CE} = 5 V, f = 0.9 GHz, Z_L = Z_{Lopt}

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

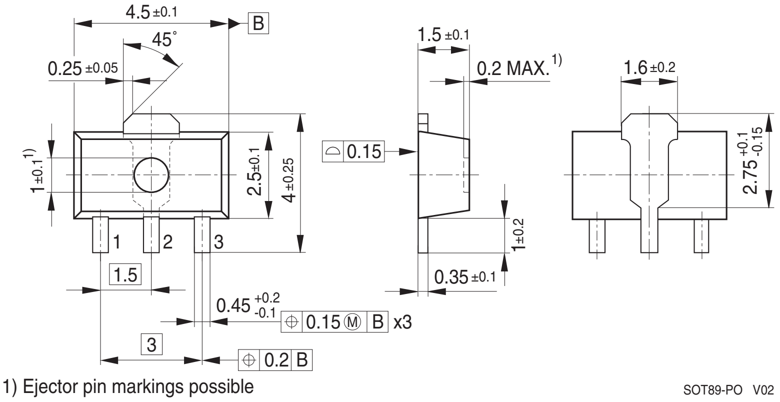


Figure 9-1 Package Outline

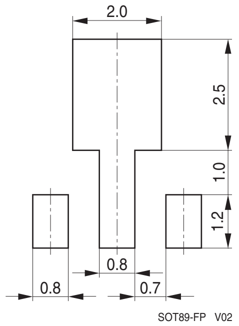


Figure 9-2 Package Footprint

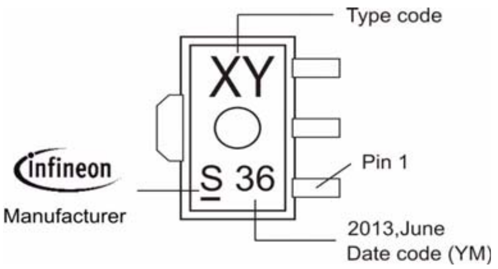


Figure 9-3 Marking Example (Marking BFQ790: R3)

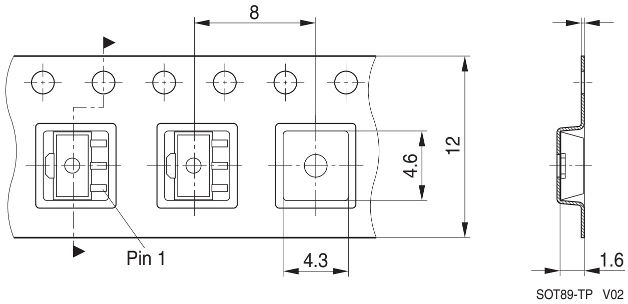


Figure 9-4 Tape Dimensions

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

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Связь

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