Philips
RF Manual

product & design manual for RF small signal discretes

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APPENDIX (in separate appendix-file):

Application notes:

1. What's New

New !!

→	**Application diagrams: 2.4GHz & LNB,**	**chapter 5**
→	**Products,**	**chapter 7:**

	NEW types	**Upcoming types in development**
MMIC's	- BGA2004: high/low gain mode LNA, - BGA2715, BGA2716, BGA2717: reduced power consumption 50 ohm gain blocks, - BGA6289, BGA6489, BGA6589: 20 dBm 50 ohm gain blocks	General purpose gain blocks
Wideband transistors		BFG310/XR, BFG310W/XR, BFG325/XR, BFG325W/XR: 4.5 gen. wideband transistors
Varicap diodes	BB140L, VCO varicap in SOD882	V(T)CXO & TV tuning low voltage varicaps
Field effect transistors	BF1205, BF1206, BF1211, BF1211R, BF1211WR, BF1212, BF1212R, BF1212WR: Dual gate mosfets for TV/VCR/SAT	BF1211 (BF1207) 2 in 1 Mosfet 2 in 1 J-fet for car antenna amplifing
Pin diodes	BAP51L, BAP64L, BAP69L, BAP55L	More different packages

→	**2.4GHz Generic Front-End Demoboard,**	**appendix A**
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Updated

→	**RF application/design basics have been improved,**	**chapter 3-4**
→	**Updated application notes list,**	**chapter 6**
→	**Updated product portfolio, including VCO matrix,**	**chapter 7**
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2. Introduction

"YOUR time-to-market is OUR driving force"

We are not just happy to take your order.
We want to be a part of your application.
We want you to challenge us on design-ins.
We want to be your partner in RF solutions.

We are very proud to tell you that our RF Manual has become a leading document in the RF market. Many engineers, developers and purchasers use our RF Manual as their main source of information for building applications and to make the right decisions.

A large subscribers database has been built to allow sending all of you our most recent issue. You can also download the RF Manual from many websites.
The RF Manual covers a broad range of material and many aspects about RF small signal systems. Starting at the RF basics, it covers many subjects including applications, our product portfolio, cross-references, packaging, etc.
We keep our RF Manual as a dynamic source of information. We have committed to updating the document twice a year to allow you to be informed on important developments for your applications.

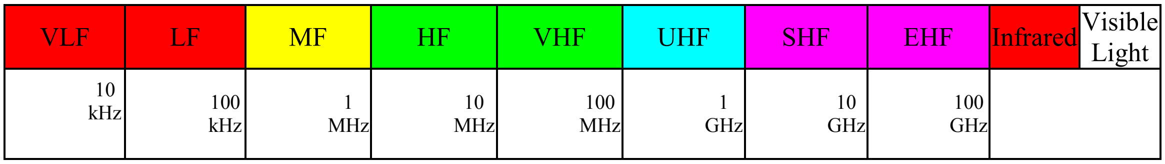
Henk Roelofs, Director RF Consumer Products

3. RF Application-Basics

3.1 Frequency spectrum

Radio spectrum and wavelengths
Each material's composition creates a unique pattern in the radiation emitted.
This can be classified in the "frequency" and "wavelength" of the emitted radiation.

As electro-magnetic waves travel with the speed of light, one can determine the wavelength for each frequency.



A survey of the frequency bands and related wavelengths :

Frequency	***Wavelength - λ***	***Band***	***Definition***
3kHz to 30kHz	100km to 10km	VLF	Very Low Frequency
30kHz to 300kHz	10km to 1km	LF	Low Frequency
300kHz to 1650kHz	1km to 182m	MF	Medium Frequency
3MHz to 30MHz	100m to 10m	HF	High Frequency
30MHz to 300MHz	10m to 1m	VHF	Very High Frequency
300MHz to 3GHz	1m to 10cm	UHF	Ultra High Frequency
3GHz to 30GHz	10cm to 1cm	SHF	Super High Frequency
30GHz to 300GHz	1cm to 1mm	EHF	Extremely High Frequency

Microwave Band	*Frequency / [GHz]*
S	≈ 1.7 to 5.1
C	≈ 3.9 to 6.1
J	≈ 5.9 to 9.5
H	≈ 7 to 10
X	≈ 5 to 10.5
M	≈ 10 to 15
K	≈ 11 to 35
KU	≈ 17 to 18
KA	≈ 38 to 45

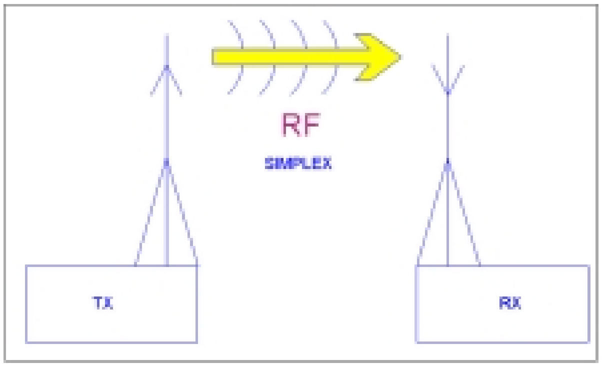
Examples of applications in different frequency ranges

Major segments of the frequency domain are reserved to specific applications, i.e., radio and TV broadcasting, cellular phone bands, two way radio commercial use, and others. The frequency ranges assigned vary with different countries.

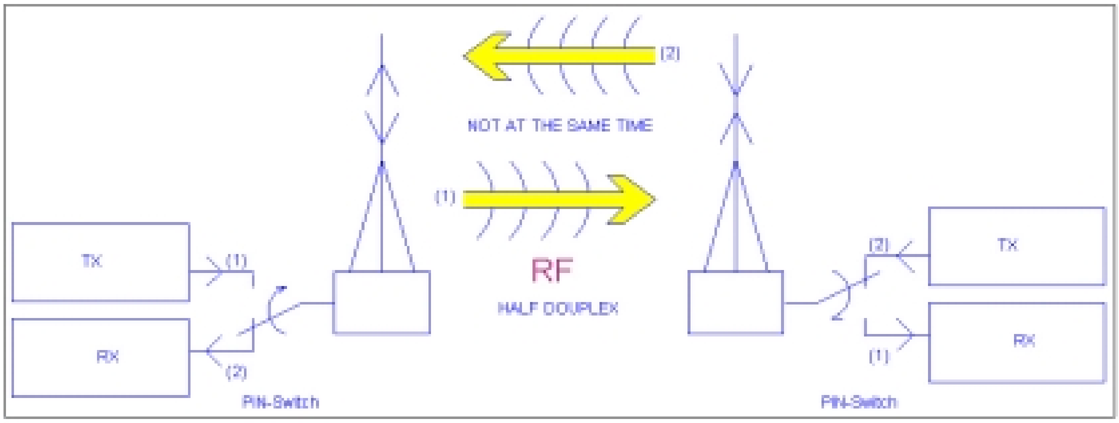
→ AM radio - 535 kHz to 1.7 MHz
→ Short wave radio - bands from 5.9 MHz to 26.1 MHz
→ Citizens band (CB) radio - 26.96 MHz to 27.41 MHz
→ Television stations - 54 to 88 MHz for channels 2 through 6
→ FM radio - 88 MHz to 108 MHz
→ Television stations - 174 to 220 MHz for channels 7 through 13
→ Garage door openers, alarm systems, etc.: around 40 MHz
→ (Analog) cordless phones: from 40 to 50 MHz
→ Baby monitors: 49 MHz
→ Radio controlled aeroplanes: around 72 MHz
→ Radio controlled cars: around 75 MHz
→ Wildlife tracking collars: 215 to 220 MHz
→ (Digital) cordless phones (CT2): 864 to 868 and 944 to 948 MHz
→ Cell phones (GSM): 824 to 960 MHz
→ Air traffic control radar: 960 to 1,215 MHz
→ Global Positioning System: 1,227 and 1,575 MHz
→ Cell phones (GSM): 1710 to 1990 MHz
→ (Digital Enhanced) Cordless phones (DECT): 1880 to 1900 MHz
→ Personal Handy phone System (PHS): 1895 to 1918 MHz
→ Deep space radio communications: 2290 to 2300 MHz
→ Wireless Data protocols (Bluetooth): 2402 to 2495 MHz

3.2 RF transmission system

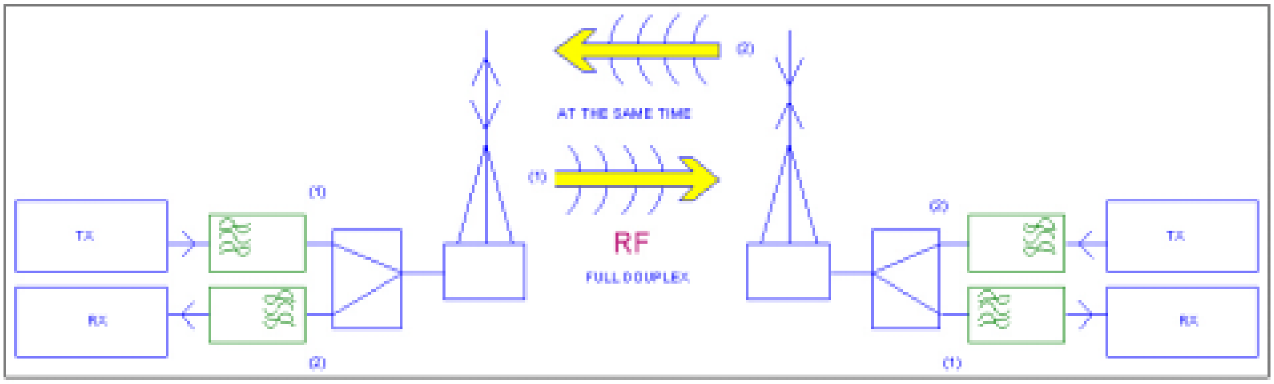
Simplex



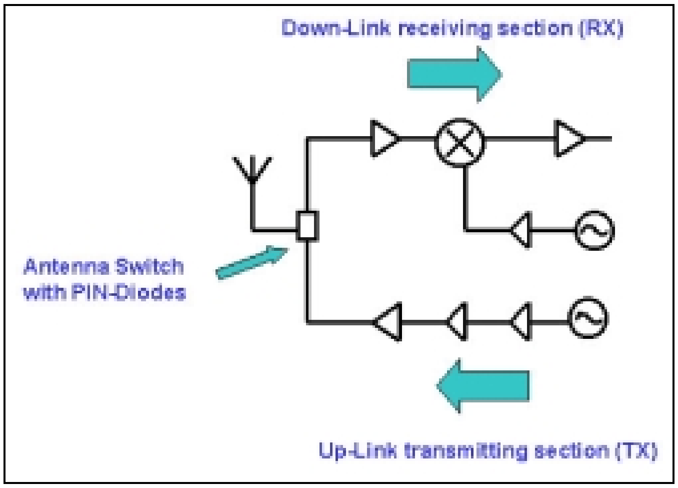
Half duplex

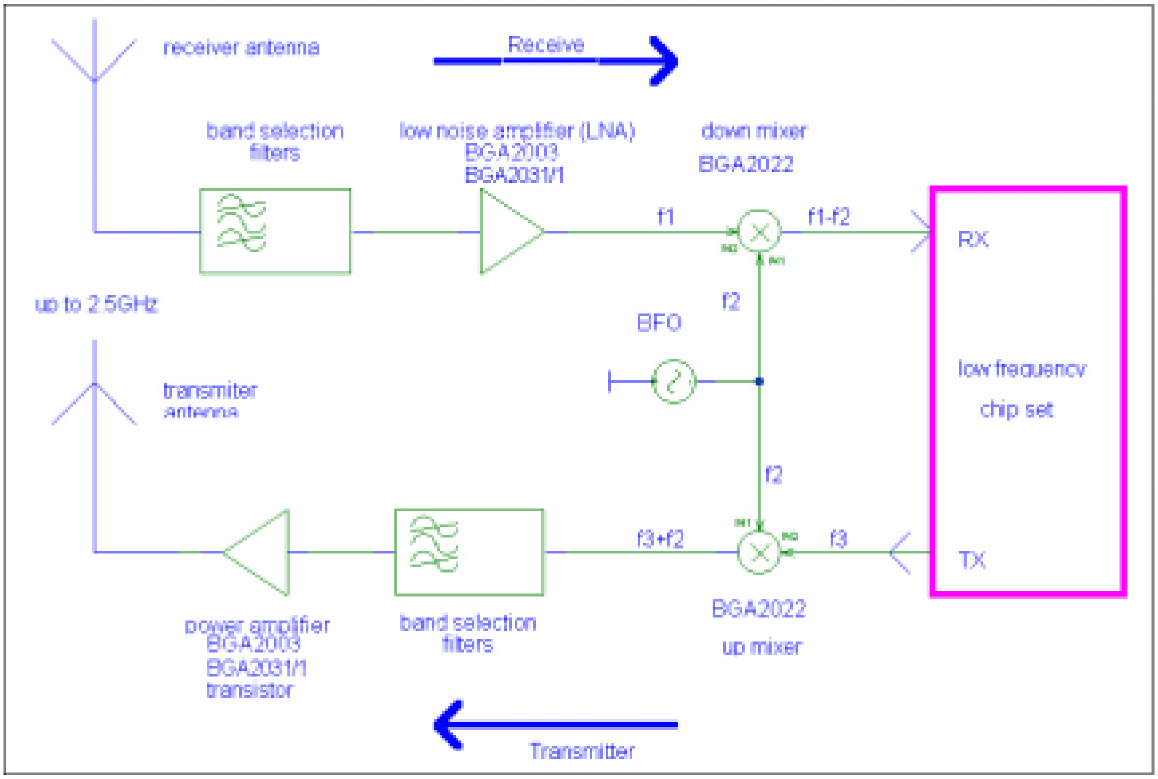


Full duplex



3.3 RF Front-End

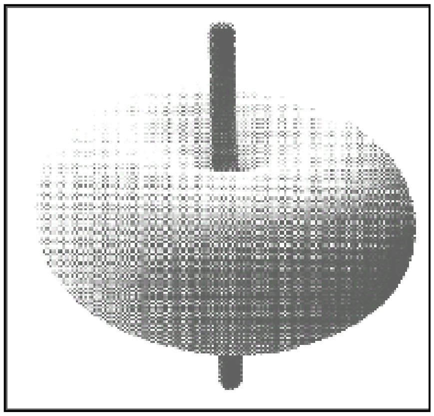




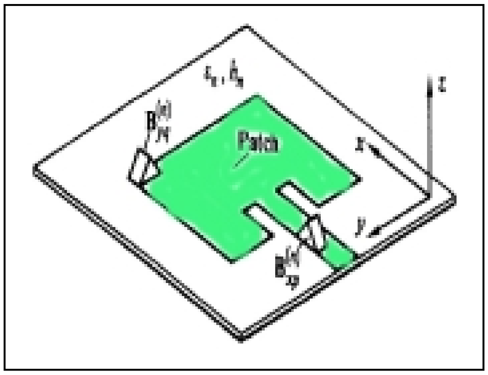
3.4 Function of an antenna

In standard application the RF output signal of a transmitter power amplifier is transported via a coaxial cable to a suitable location where the antenna is installed. Typically the coaxial cable has an impedance of 50Ω (75Ω for TV/Radio). The ether, that is the room between the antenna and infinite space, also has an impedance value. This ether is the transport medium for the traveling wireless RF waves from the transmitter antenna to the receiver antenna. For optimum power transfer from the end of the coaxial cable (e.g. 50Ω) into the ether (theoretical $120 \cdot \pi \cdot \Omega$), we need a “power matching” unit. This matching unit is the antenna. Depending on the frequency and specific application needs there are a lot of antenna configurations and construction variations available. The simplest one is the isotropic ball radiator, which is a theoretical model used as a mathematical reference.

The next simplest configuration and a practical antenna in wide use is the dipole, also called the dipole radiator. It consists of two radiating lengths. Removal of one radiating length leaves us with the “vertical monopole” antenna, as illustrated in the adjacent picture. The vertical monopole has a “donut-shaped” field centered on the vertical radiating element.



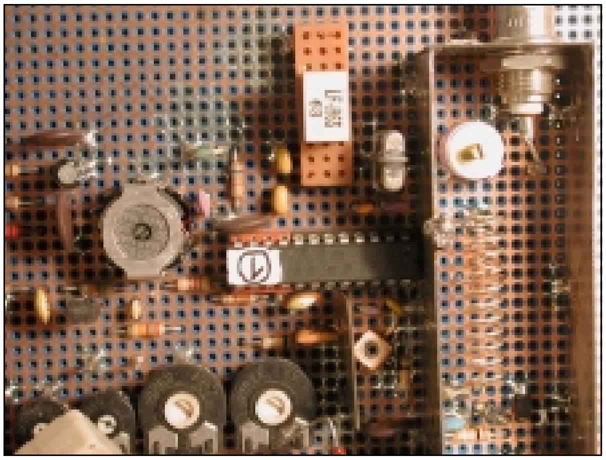
Higher levels of integration of the circuitry and reductions in cost also influence antenna design. Based on the field radiation patterns from printed circuit boards, a PCB antenna was developed called a “Patch”-Antenna as illustrated in the adjacent picture.



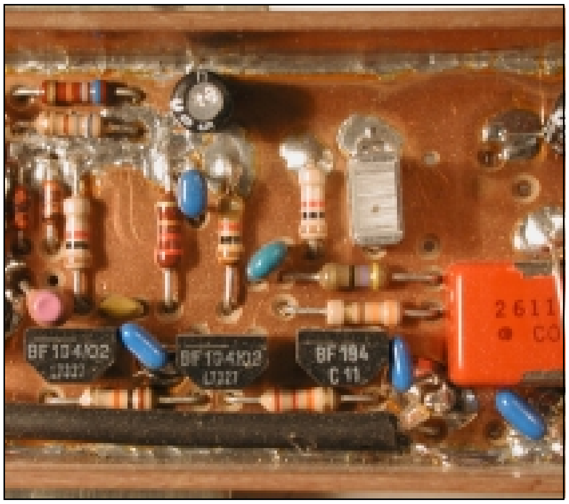
3.5 Examples of PCB design

- Low frequency design (up to several tens of MHz)
- RF design (tens of MHz to several hundreds of MHz)
- Microwave design (GHz range)

3.5.1 Prototyping

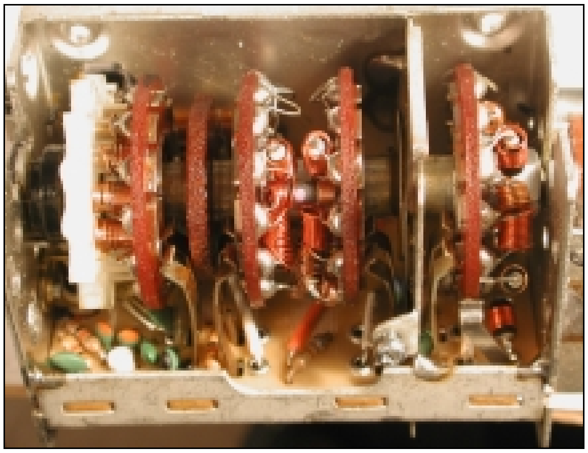


Standard RF/VHF Receiver Front-End:
Top side GND, back side manual wires

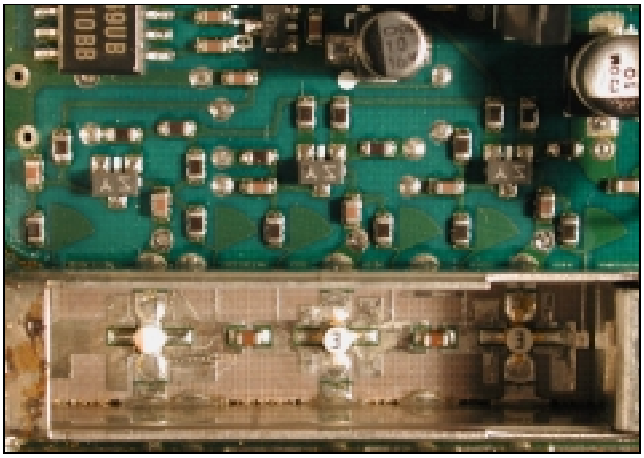


Standard RF/VHF: Top side GND, back side manual wires forms a SW-antenna amplifier

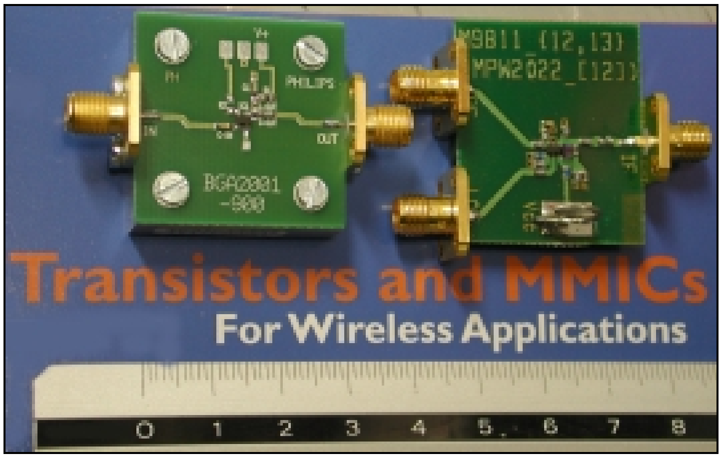
3.5.2 Final PCB



TV-Tuner: PCP and flying parts on the switch (history); some times prototyping technology at RF



Microwave PCB for GHz LNA amplifier



Demoboard: BGA2001 and BGA2022

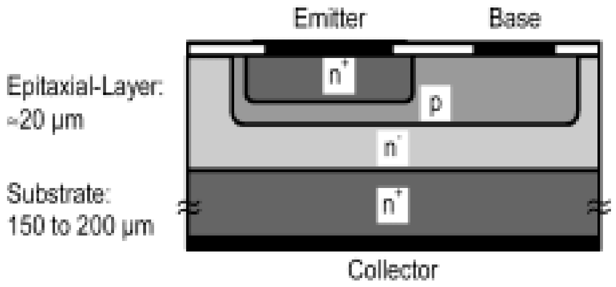
3.6 Transistor Semiconductor Process

3.6.1 General-Purpose Small-signal bipolar

The transistor is built up from three different layers:

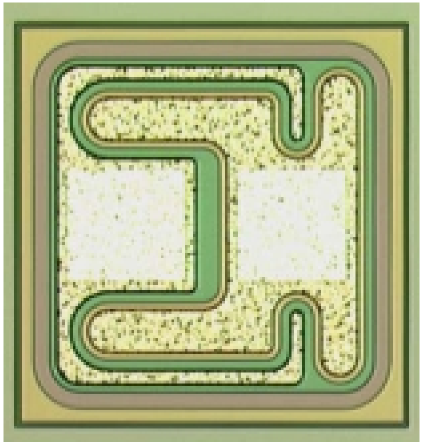
- Highly doped emitter layer
- Medium doped base area
- Low doped collector area.

NPN Transistor cross section



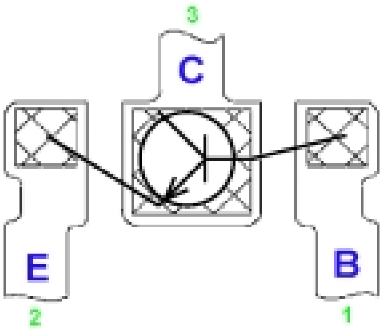
The highly doped substrate serves as carrier and conductor only.

Die of BC337, BC817



During the assembly process the transistor die is attached on a lead frame by means of gluing or eutectic soldering. The emitter and base contacts are connected to the lead frame (leads) through (e.g. Gold, Aluminium, …) bond wires in e.g. an ultrasonic welding process.

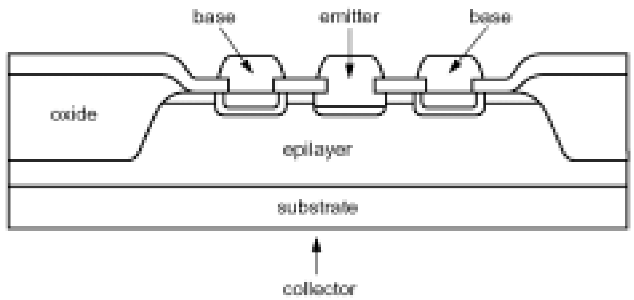
SOT23 standard lead frame



3.6.2 Double Polysilicon

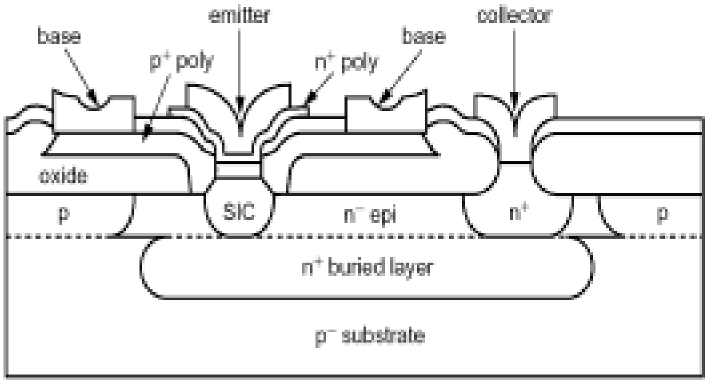
For the latest Silicon-based bipolar transistors and MMICs Philips has developed a Double Polysilicon process to achieve excellent performance.

The mobile communications market and the use of ever-higher frequencies have do need of low-voltage, high-performance, RF wideband transistors, amplifier modules and MMICs. The “double-poly” diffusion process makes use of an advanced, transistor technology that is vastly superior to existing bipolar technologies.



Existing advanced bipolar transistor

With double poly, a polysilicon layer is used to diffuse and connect the emitter while another polysilicon layer is used to contact the base region. Via a buried layer, the collector is brought out on the top of the die.
As with the standard transistor, the collector is picked up via the backside substrate and attachment to the lead frame.



- **Advantages of double-poly-Si RF process:**
- Higher frequencies (>23GHz)
- Higher power gain G_{max}, e.g., 22dB/2GHz
- Lower noise operation
- Higher reverse isolation
- Simpler matching
- Lower current consumption
- Optimized for low supply voltages
- High efficiency
- High linearity
- Better heat dissipation
- Higher integration for MMICs (***SSI***= **S**mall-**S**cale-***I***ntegration)

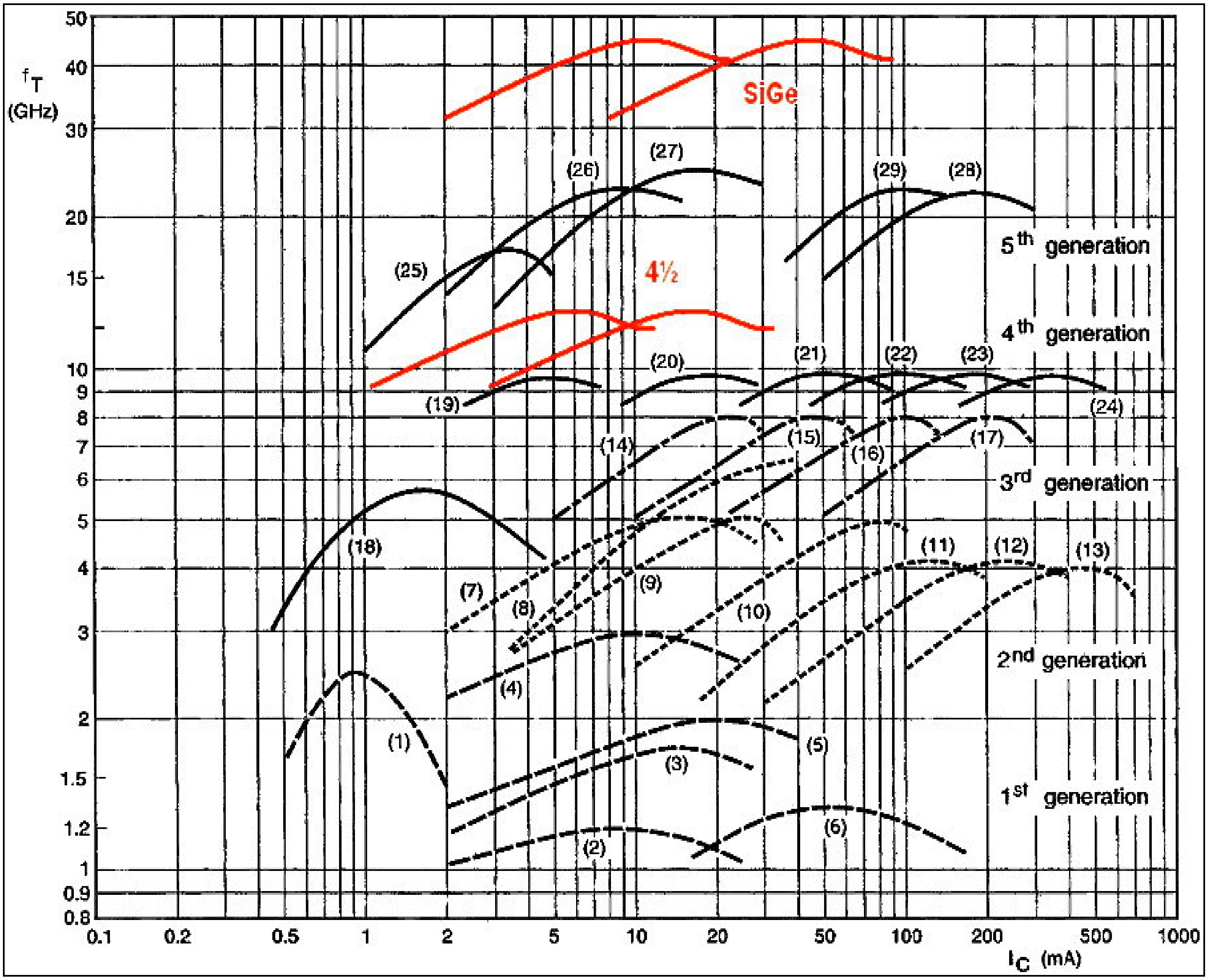
- **Applications**

Cellular and cordless markets, low-noise amplifiers, mixers and power amplifier circuits operating at 1.8 GHz and higher), high-performance RF front-ends, pagers and satellite TV tuners.

- **Typical vehicles manufactured in double-poly-Si:**

MMIC Family:	BGA20xy, and BGA27xy
5th generation wideband transistors:	BFG403W/410W/425W/480W
RF power amplifier modules:	BGY240S/241/212/280

3.6.3 RF Bipolar Transistor & MMIC Performance overview



4. RF Design-Basics

4.1 RF Fundamentals

4.1.1 Frequency and time domain

4.1.1.1 Frequency domain operations

Typical vehicles-effects and test-equipment:
- Metallic sound and distortions of a low-cost PC loudspeaker
- Audio analyzer (measuring the quality of the audio signal, like noise and distortion)
- F/A’s ultrasonic microscope (e.g., non destructive material analysis on IC packages)
- FFT Spectrum analyzer (in the medium frequency range from a few Hertz to several MHz)
- Modulation analyzer (investigation of RF modulation e.g., AM, FSK, GFSK, et. al.)
- Spectrum analyzer (display the signal’s spectral quality, e.g., noise, intermodulation, gain)

The mathematical Fourier Transform algorithm analyses the performance of a periodical time depending signal in the frequency domain. For a one-shot signal the Fourier Integral Transformation is used. On the bench, test issues are over-taken by the spectrum analyzer or by an ***FFT*** analyzer (***F***ast ***F***ourier ***T***ransformation). With the spectrum analyzer the frequency spectrum of the device under test (***DUT***) are isolated into bands (e.g., by tuned filters) and measured in a detector (like a periodic tuned radio with displaying of the field strength). The FFT analyzer is essentially a computer capable of performing a ***DSP*** (***D***igital ***S***ignal ***P***rocessor) function. This DSP has a built-in hardware-based circuit for very fast solution of algorithmic problems like the ***DFFT*** (***D***iscrete ***F***ast ***F***ourier ***T***ransformation).

This DFFT algorithmic can calculate the frequency spectrum of an incoming signal. DSP processors are used in today's mobile equipment to provide baseband or IF signal processing, sound cards for computers, industrial machinery, communication receivers, motor control, and other complex signal processing functions.

In RF and microwave applications, the frequency domain is very important for measurement techniques, because oscilloscopes cannot display extremely high frequency signals and typically introduce probe impedances which vary significantly with small changes in frequency and make them unsuitable except for very specialized applications. A spectrum analyzer has much better sensitivity and a much larger dynamic range capability.

Example: An oscilloscope can simultaneously display signals with a voltage ratio of 10 to 20 between the smallest and largest signals (a dynamic range ~20dB). RF spectrum analyzers can display power signal (levels) with a ratio between the largest signal and the smallest signal of more than 10^6 at the same time on the display (dynamic range >60dB). Intermediate frequency (IF) amplifiers of typical receivers have gains of 40 to 60dB, meaning the amplifier output signal can be 10^4 to 10^6 larger than the input signal. The spectrum analyzer can display both signals simultaneously with good amplitude accuracy on to the monitor (logarithmic display) for both signals. On an oscilloscope (with a linear display) setting the amplitude of the output signal at full-scale allows you to perhaps see what appears to be some noise ripple on the axis for the input signal. Typical modern oscilloscopes support frequency ranges up to few GHz. Modern spectrum analyzers start at several tenths of kHz and go up to several tens of GHz. Special function spectrum analyzers provide signal viewing up to 100GHz.

4.1.1.2 Time domain operations

Typical bench vehicle and applications:

- Booting beeps in the PC computer's loudspeaker
- The oscilloscope (displays the signal's action over the time)
- The RF generator (generates very clean sine wave test signals with various modulation options)
- The ***T***ime ***D***omain ***R***eflectometry analyzer (***TDR***) (e.g., analyzing cable discontinuities)
- Jitter in clock-recovery circuits
- Eye diagrams

In the time domain the variation of the amplitude is displayed versus the time on a screen. Very low speed activities such as temperature drift versus aging of an oscillator or seismic activity are printed by special plotters in real-time on paper. Faster actions are better displayed by oscilloscopes. Signals can be saved on the oscilloscope screen by the use of storage tubes (history), or by the use of built-in digital storage (RAM). In the time domain, phase differences between different sources or time-dependent activities can be analyzed, characterized or modified.

In RF applications displays show demodulation actions, baseband signals or control functions of a CPU. The advantage of the oscilloscope is the high resistive impedance of the probes. It's disadvantage is the input capacity of several picofarads (pF) causing high frequency AC loading of the circuit, which affects both the measured RF circuit and distorts the measurement data presented.

Mixers are inherently non-linear devices because their chief function is multiplication of signals. On the input side the RF signal must be treated linearly. Mixer ***3^{rd} order intercept point*** (***IP3***) performance characterizes the quality of handling the RF signals and the amount non-linearity introduced.

Example illustrating an application circuit in the frequency domain and in the time domain:

Issue: Receiving the commercial radio broadcasting program SWR3 in the short-wave 49m band from the German transmitter-Mühlacker on 6030 kHz. This transmitter has an output power of 20000W. Design the mixer using
a 455 kHz IF amplifier.
Reference: http://www.swr.de/frequenzen/kurzwelle.html

System design of the ***local oscillator***: LO = RF + IF = 6030 kHz + 455 kHz = 6485 kHz
The ***image frequency*** is found at IRF = LO + IF = 6485 kHz + 455 kHz =6913 kHz
Optimum mixer operation is medium gain for IF and RF and damping of RF and LO transfer to the IF port (isolation). As an example, we choose the ***BFR92***. This transistor can also be used for much higher frequency mixer applications like FM radios, televisions, ISM433, and other applications.

As shown in the formulas above, the ***R***adio ***F***requency (***RF***) signal is mixed with the ***L***ocal ***O***scillator (***LO***) to generate the ***I***ntermediate ***F***requency (***IF***) output products.

To improve the mixer gain, several part values were varied. This circuit is a theoretical example for discussion purposes only. Further optimization should be done by investigation on bench. In the example the input signal sources V6 and V7 are series connected. In the reality this can be done by e.g. A transformer. The simulation was done under PSpice with the following setup: Print Step=0.1ns; Final Time=250µs; Step Ceiling=1ns. This long simulation length and fine resolution is necessary for useful results in the frequency spectrum down to 400KHz.

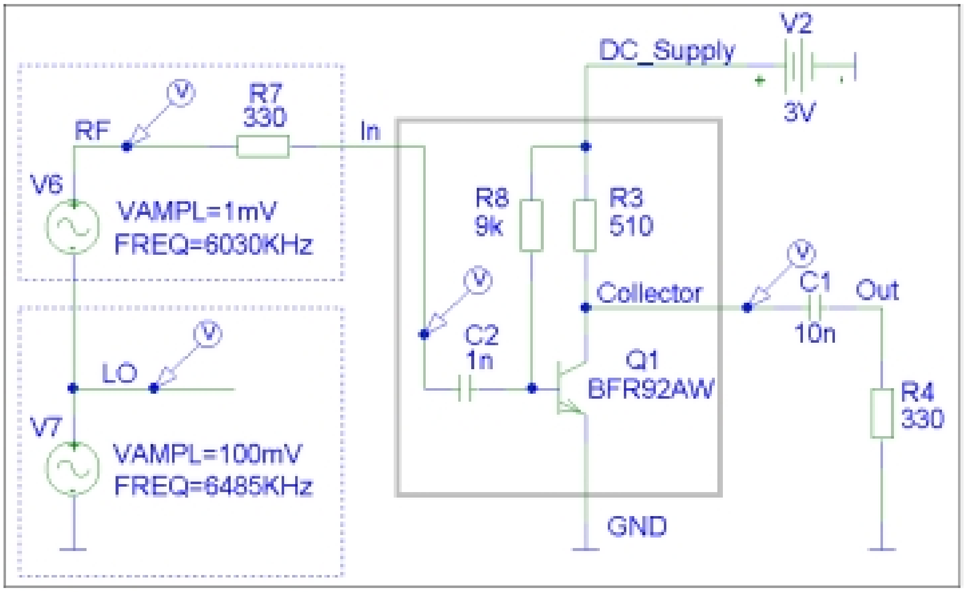


Figure 1: Final mixer circuit without output IF tank

Varying of R8 shows the influence of the mixer gain at the 455 kHz output frequency.

R8	6k	7k	8k	9k	10k	15k	20k	25k
455KHz	0.32mV	2.21mV	3.37mV	3.66mV	3.62mV	2.33mV	1.43mV	1.44mV
12515KHz	0.29mV	2mV	2.94mV	3.11mV	2.97mV	1.52mV	0.83mV	0.5mV

From the experiments we chose R8 = 9 kΩ for best output amplitude.

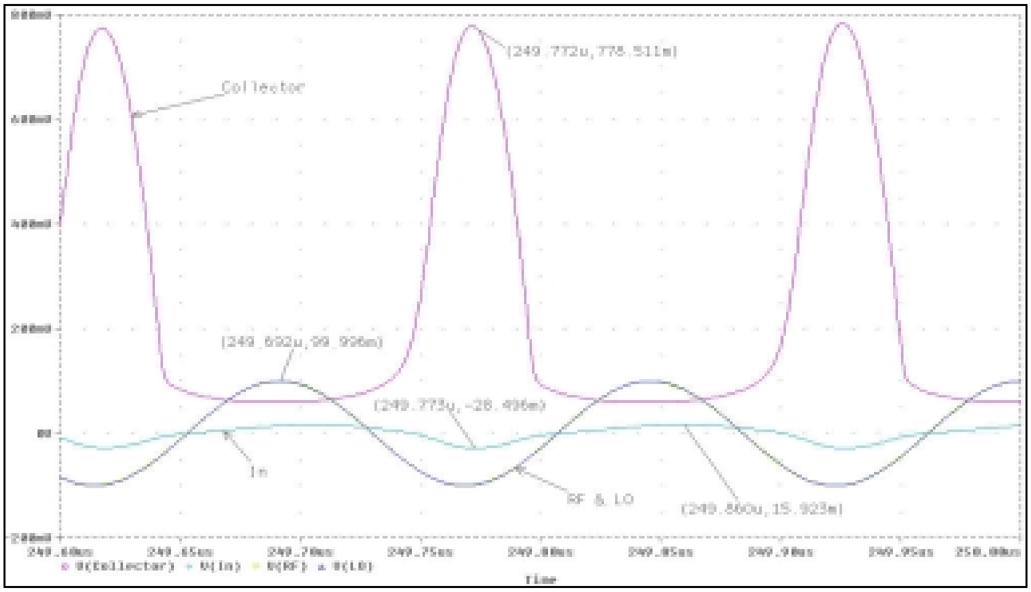


Figure 2: The mixer in the time domain arena

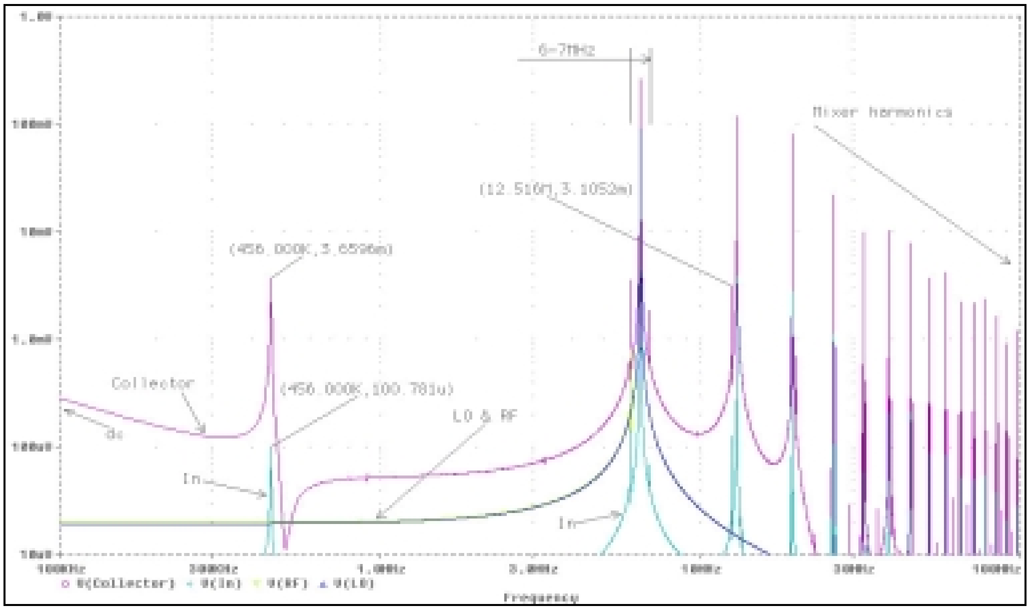


Figure 3: The mixer in the frequency domain arena

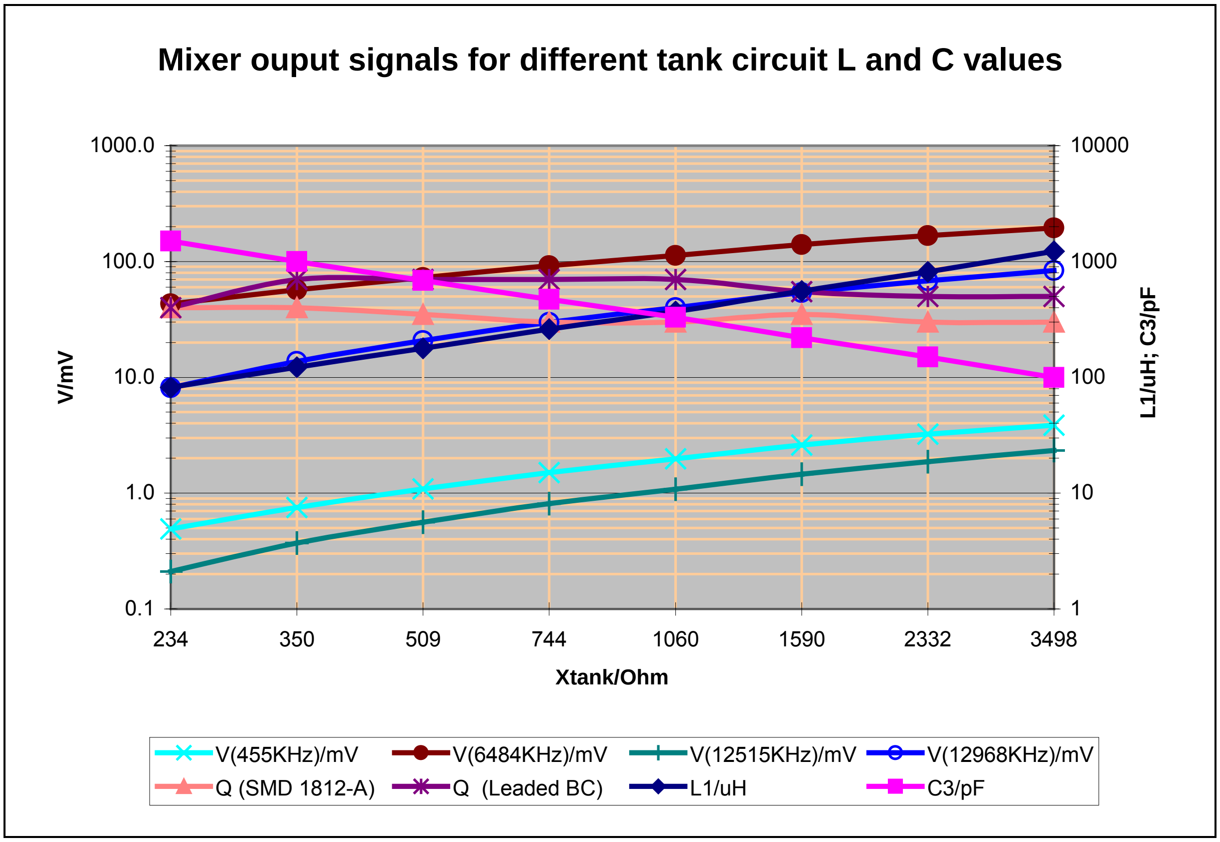


Figure 4: Mixer output voltage versus the tank circuit's characteristic resonance impedance

This must be further investigated to characterize the available IF bandwidth. A narrow IF bandwidth reduces the fidelity of the demodulated signal.

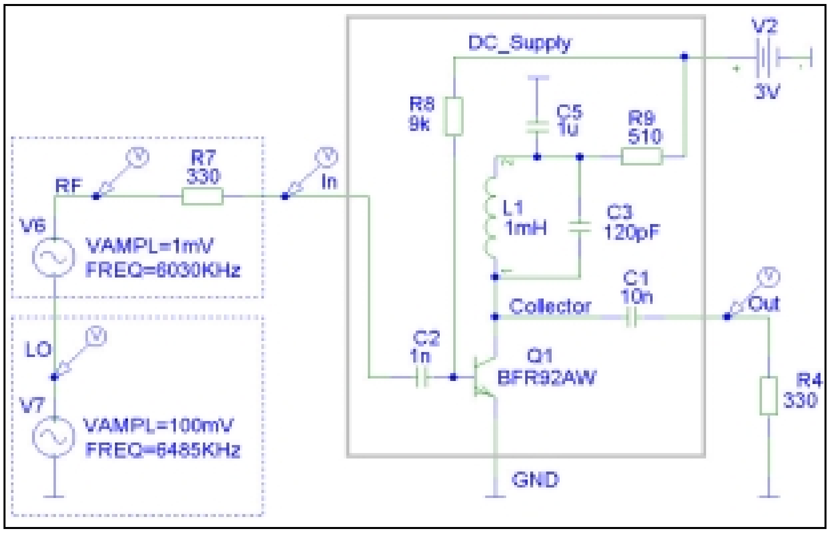


Figure 5: The mixer with an IF tank circuit

This chapter illustrated a mixer operation in both time and frequency domains. Illustrated was circuit design by “trial and error” coupled with the use of a CAD program with a lot of simulation time. A better approach would be the use of a design strategy and calculation of the exact required values and then final CAD optimization. The devices must be accurately specified (s-parameters) and models (e.g., 2-port linear model network) must be available for computer simulation. The use of time domain simulators with different algorithms accelerates the simulation. Philips Semiconductors offers s-parameters for small signal discrete devices. Because optimum power transfer is important in RF application, we must think about the quality of inter-stage circuit matching, qualified by the reflection coefficient. This will be handled in the next few chapters. Please note that Philips Semiconductors offers a ***M**onolithic **M**icrowave **I**ntegrated **C**ircuit* (***MMIC***) mixer, a ***BGA2022***, with a 50**Ω** input impedance. These devices have built-in biasing circuit and offer excellent gain and linearity.

4.1.2 RF waves

RF electro-magnetic (EM) signals travel outward like ***waves*** in a pond that has a stone dropped into it. The electromagnetic waves are governed by the same laws that apply to optical signals. In a homogeneous vacuum without external influences EM waves travel at a ***speed of C_o=299792458 m/s***.
Traveling in substrates, wires, or with a non-air ***dielectric*** material adjacent to the path slows the speed of the waves proportional to the root of the dielectric constant:

$$\boxed{v = \frac{C_O}{\sqrt{\varepsilon_{reff}}}}$$

ε_{reff} is the ***substrate’s dielectric constant***.

With “ν” we can calculate the ***wavelength***, or □, as: $\boxed{\lambda = \frac{v}{f}}$

Example1: Calculate the speed of an electromagnetic wave in a ***P**rinted **C**ircuit **B**oard* (***PCB***) manufactured using an
FR4 epoxy material and in a metal-dielectric-semiconductor capacitor of an integrated circuit.

Calculation: In a metal-dielectric-semiconductor capacitor the dielectric material can be Silicon-Dioxide (SiO_2) or Silicon-Nitride (Si_3N_4).

$$v = \frac{C_O}{\sqrt{\varepsilon_{reff}}} = \frac{299792458 m/s}{\sqrt{4.6}} = 139.78 \cdot 10^6\, m/s$$

FR4	ε_{reff}=4.6	v=139.8•10^6m/s
SiO_2	ε_{reff}=2.7 to 4.2	v=182.4•10^6m/s to 139.8•10^6m/s
Si_3N_4	ε_{reff}=3.5 to 9	v=160.4•10^6m/s to 99.9•10^6m/s

Example2: What is the wavelength transmitted from the commercial SW radio broadcasting program SWR3 in the
49 meter (m) band on 6030 kHz in air, and with an FR4 PCB?

Calculation: The ε_{reff} of air is close to vacuum. $\varepsilon_{reff} \approx 1$ $v = c_O$

Wavelength in air: $$\lambda_{air} = \frac{C_O}{f} = \frac{299792458 m/s}{6030 KHz} = 49.72 m$$

From Example 1 we take the FR4 dielectric constant to be $\varepsilon_{reff} = 4.6$, then $v = 139.8 \bullet 10^6$m/s and
calculate the wavelength in the PCB as: $\lambda_{FR4} = 23.18$ meters

A forward-traveling wave is transmitted (or injected) by the source into the traveling medium (whether it be the ether,
a substrate, a dielectric, wire, ***Microstrip***, or other medium) and travels to the load at the opposite end of the medium.
At junctions between two different dielectric materials, a part of the forward-traveling wave is reflected back towards
the source. The remaining part continues traveling towards the load.

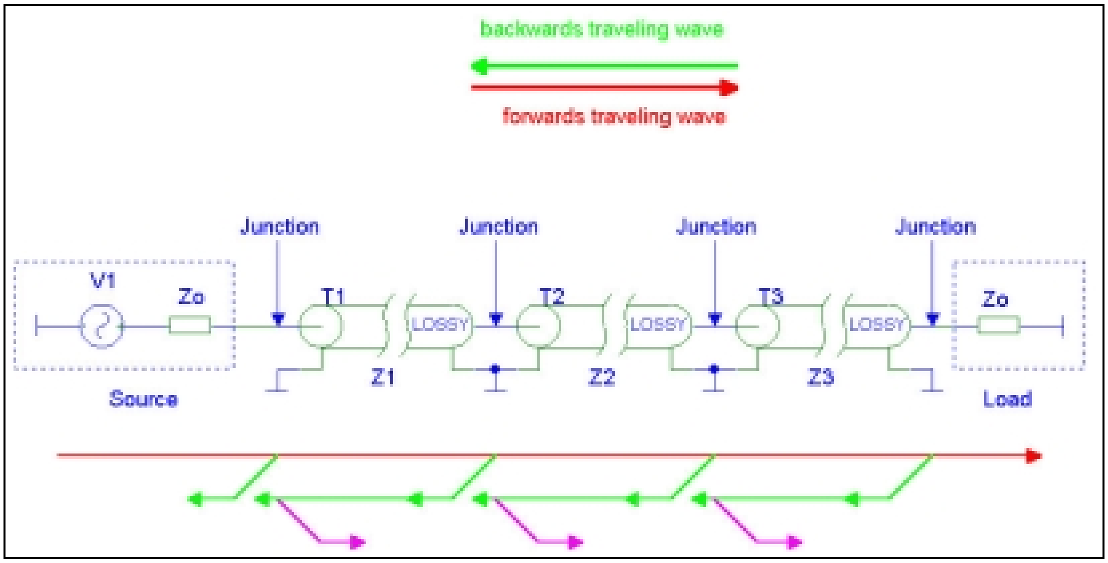


Figure 6: Multiple reflections between lines with different impedances

In the upper portion of Figure 6 reflections of the forward-traveling main wave (red) are caused by materials with different impedance values (shown as Z1, Z2, Z3). As shown, a backward-reflected wave (green) can be again reflected into a forward-traveling wave in the direction towards the load (shown as violet in Figure 6).
In the case of optimum ***matching*** between different dielectric mediums, no signal reflection will occur and maximum power is forwarded. The amount of reflection caused by junctions of lines with different impedances, or line ***discontinuities***, is determined by the ***reflection coefficient***. This is explained in the next chapter.

4.1.3 The Reflection Coefficient

As discussed previously a forward-traveling wave is partially reflected back at junctions with line impedance discontinuities, or mismatches. Only the portion of the forward traveling wave (arriving at the load) will be absorbed and processed by the load. Because of the frequency-dependent speed of the propagating waves in a dielectric medium, there will be a delay in the arrival of the wave at the load point over what a wave traveling in free space would require. Mathematically this behavior is modeled with a vector in complex Gaussian space. At each discontinuity of the medium (or wire), wave-fronts with different amplitude and phase delay are heterodyned. The resulting energy envelope of the waves along the wire appears as ripple with maximum and minimum values. The phase difference between maximums to has the same value as the phase difference between minimums. This distance is termed the ***half-wavelength, or λ/2 (also termed the normalized phase shift of 180°)***.

Example: A line with mismatched ends driven from a source will have standing waves. These will result in minimum and maximum signal amplitudes at defined locations along the line. Determine the approximate distance between worst-case voltage points for a ***Bluetooth*** signal processed in a printed circuit on a FR4 based substrate.

Calculation: Assumed speed in FR4: $v=139.8\cdot 10^6 m/s$

Wavelength: $\lambda_{air} = \frac{v_{FR4}}{f_{BT}} = \frac{139.78\cdot 10^6\, m/s}{2.4GHz} = 58.24mm$

The distance minimum to maximum is called the ***quarter wavelength, or λ/4 (also termed the normalized phase shift of 90°)***.

Min-Max distance in FR4: $\lambda/4 = \frac{58.24mm}{4} = 14.56mm$

- At the minimum we have minimum voltage, but maximum current.
- At the maximum we have maximum voltage, but minimum current.
- The distance between a minimum and a maximum voltage (or current) point is equal to *λ/4*.

The reflection coefficient is defined by the ratio between the backward-traveling voltage wave and the forward-traveling voltage wave:

Reflection coefficient: $\boxed{r_{(x)} = \frac{U_{b(x)}}{U_{f(x)}}}$

Reflection loss or ***return loss***: $\boxed{r_{dB} = 20dB\cdot\log\left|r_{(x)}\right| = 20dB\left\{\log\left|U_{b(x)}\right| - \log\left|U_{f(x)}\right|\right\}}$

The index "(x)" indicates different reflection coefficients along the line. This is caused by the distribution of the standing wave along the line. The return loss indicates, in dB, how much of the wave is reflected, compared to the forward-traveling wave.

Often the input reflection performance of a 50Ω RF device is specified by the **Voltage Standing Wave Ratio** (***VSWR***), also called the ***SWR***.

VSWR: $\boxed{s = SWR = VSWR = \frac{U_{\max}}{U_{\min}}}$ Matching factor: $\boxed{m = \frac{1}{s}}$ which for practical applications requires the VSWR to be greater than ONE.

Some typical values of the VSWR:
100% mismatch caused by an open or shorted line: r = 1 and VSWR = ∞
Optimum (theoretical) matched line: r = 0 and VSWR = 1
In all practical situations "r" varies between ZERO and ONE and VSWR varies between ONE and INFINITY (∞**).**

Calculating the reflection factor: $\boxed{r = \left|r_{(x)}\right| = \frac{SWR-1}{SWR+1}}$

Using some mathematical manipulation: $r = \frac{\frac{U_{\max}}{U_{\min}} - 1}{\frac{U_{\max}}{U_{\min}} + 1}$ results in: $\boxed{r = \frac{U_{\max} - U_{\min}}{U_{\max} + U_{\min}}}$

Replacing reflection coefficients with impedances leads to: $\boxed{r = \frac{Z - Z_O}{Z + Z_O}}$

with Z_o = nominal system impedance

As explained, the standing waves cause different amplitudes of voltage and current along the wire. The ratio of these two parameters is the impedance $Z_{(x)} = \frac{V_{(x)}}{I_{(x)}}$ at each locations, *x*. This means a line with length l and a mismatched load $Z_{(x = l)}$ at the wire end location (x=l) will show at the sources location (*x=0*) a wire length dependent impedance's $Z_{(x=0)}{}_{f(\ell)} = \frac{V_{(x=0)}}{I_{(x=0)}}$.

Example: There are several special cases (tricks) which can be used in microwave designs. Mathematically it can be shown that a wire with the length of $=\frac{\lambda}{4}$ and an impedance Z_L will be a ***quarter wavelength transformer*** :

$\lambda/4$ - impedance transformer: $\boxed{Z_{(x=\ )} = \frac{Z_L{}^2}{Z_{(x=0)}}}$

This can be used in SPDT based *p-i-n* diode switches or in DC bias circuits because an RF short (like a large capacitor) is transformed into an infinite impedance with low resistive dc path.

As indicated in the upper portion of Figure 6, RF traveling-wave basic rules, the performances of matching, reflection and individual wire performances affect bench measurement results, caused by impedance transformation along the wire. Due to this constraint, each measurement set-up must be calibrated by precision references.

Examples of RF calibration references are:

- Open
- Short
- Match

The set-up calibration tools can undo unintended wire transformations, discontinuities from connectors, and similar measurement intrusion issues. This prevents ***D***evice ***U***nder ***T***est (***DUT***) measurement parameters from being affected with mechanical bench set-up configurations.

Example: a) Determine the input VSWR of ***BGA2711*** MMIC wideband amplifier for 2GHz, based on data sheet characteristics.
b) What kind of resistive impedance(s) can theoretically cause this VSWR?
c) What is the input return loss measured on a 50Ω coaxial cable in a distance of λ/4?

Calculation: BGA2711 at 2 GHz: r_{IN} = 10dB

$$r = \frac{SWR-1}{SWR+1} \qquad r \cdot SWR + r = SWR - 1 \qquad \boxed{SWR = \frac{1+r}{1-r}} \quad r = 10^{\frac{-r_{dB}}{20dB}} = 10^{\frac{-10dB}{20dB}} = 0.3162$$

$$SWR_{IN} = \frac{1+0.3162}{1-0.3162} = 1.92 \quad r = \frac{Z-Z_O}{Z+Z_O} \qquad Z - r \cdot Z = r \cdot Z_O + Z_O \qquad \boxed{Z = Z_O \frac{1+r}{1-r}}$$

Comparison: $Z = Z_O \frac{1+r}{1-r}$ & $SWR = \frac{1+r}{1-r}$ $\qquad Z = Z_O \cdot SWR$

We know only the magnitude of (*r*) but not it's angle. By definition, the VSWR must be larger than 1. We then get two possible solutions:

$\boxed{SWR_1 = \frac{Z_1}{Z_O}}$ and $\boxed{SWR_2 = \frac{Z_O}{Z_2}}$ Z_1=1.92∗50Ω=96.25Ω; Z_2=50Ω/1.92=25.97Ω

We can then examine *r*: $|r| = \left|\frac{96.25-50}{96.25+50}\right| = \left|\frac{25.96-50}{25.96+50}\right| = 0.316$

The λ/4 transformer transforms the device impedance to:

Z_{IN1}=96.25Ω $\boxed{Z_{Ende} = \frac{Z_O{}^2}{Z_{IN}} = \frac{50\Omega^2}{96.25\Omega} = 25.97\Omega}$ and for Z_{IN2}=25.97Ω 96.25Ω

Results: At 2GHz, the BGA2711 offers an input return loss of 10dB or VSWR=1.92. This reflection can be caused
by a 96.25Ω or a 25.97Ω impedance. Of course there are infinite results possible if one takes into account all combinations of L and C values.
Measuring this impedance at 2GHz with the use of a non-50Ω cable will cause extremely large errors in λ/4 distance, because the Zin_1 = 96.25Ω appears as 25.97Ω and the second solution Zin_2=25.97Ω appears as 96.25Ω!

As illustrated in the above example, the VSWR (or return loss) quickly associates the quality of device's input matching without any calculations, but does not tell about its real performance (it is missing phase, or angular, information). Detailed mathematical network analysis of RF amplifiers depends on the device's input impedance versus output load. The output device impedance is dependent on source's impedance driving the amplifier. Due to this interdependence, the use of
s-parameters in linear small signal networks offers reliable and accurate results. This theory will be presented in the following chapters.

4.1.4 Difference between ideal and practical passive devices

Practical devices have so-called parasitic elements at very high frequencies.

Resistor	Has an inductive parasitic action and acts like a low pass filtering function
Inductor	Has a capacitive and resistive parasitics, causing it to act like a damped parallel resonant tank circuit
Capacitor	Has an inductive and resistive parasitics, causing it to act like a damped tank circuit with ***S***eries ***R***esonance ***F***requency (***SRF***)

The inductor and capacitor parasitic reactances cause self-resonance.

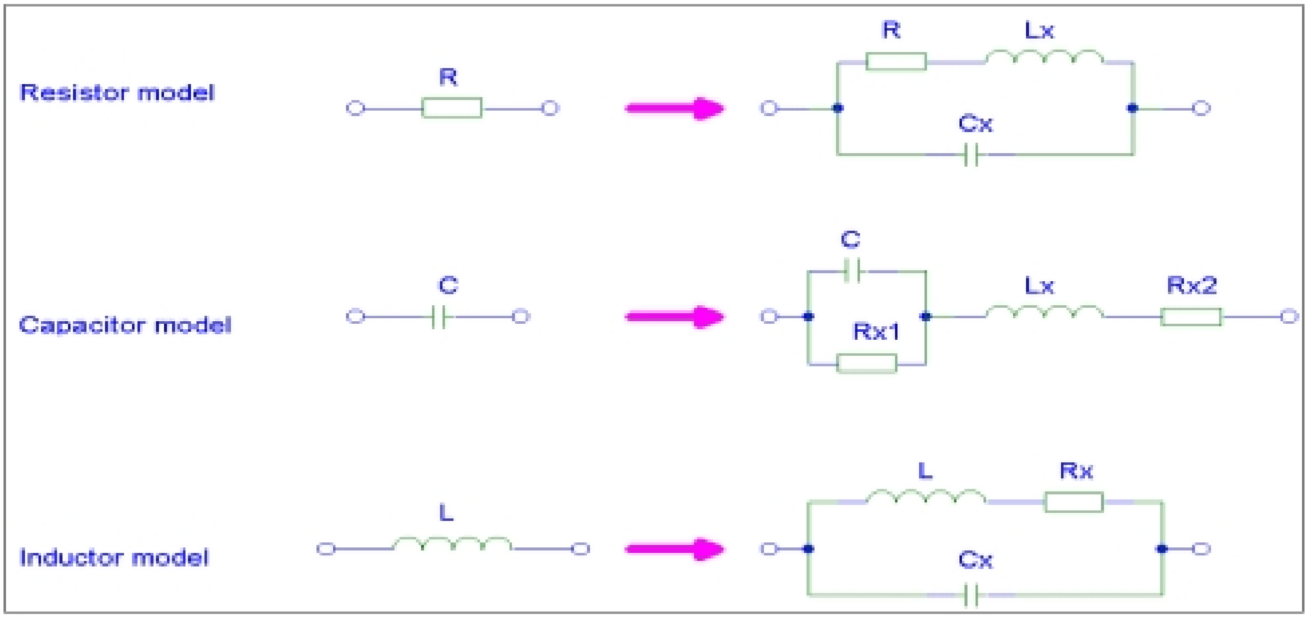


Figure 7: Equivalent models of passive lumped elements

The use of a passive component above its SRF is possible, but must be critically evaluated. A capacitor above its SRF appears as an inductor with DC blocking capabilities.

4.1.5 The Smith Chart

As indicated in an example in the former chapter, the impedances of semiconductors are a mixture of resistive and reactive parts caused by phase delays. RF is best analyzed in the frequency domain and to do this special mathematical expressions are used:

Object		***into***		***Frequency domain***
Resistor		R		$R = \lvert R \rvert \cdot e^{+j0^\circ}$
Inductor		L		$X_L = +j\omega L = \omega L \cdot e^{+j90^\circ}$
Capacitor		C		$X_C = -j\frac{1}{\omega C} = \frac{1}{\omega C} \cdot e^{-j90^\circ}$
Frequency		f		$\omega = 2\pi \cdot f$
Complex designator		j		$+j = \sqrt{-1} = \frac{1}{-j} = e^{+j90^\circ}$

Some useful basic vector mathematics in RF:

Complex impedance:

$$Z = \mathrm{Re}\{Z\} + j\,\mathrm{Im}\{Z\} = \lvert Z \rvert \cdot e^{j\varphi} = \lvert Z \rvert \cdot (\cos\varphi - j\sin\varphi)$$

$$\mathrm{Im}\{Z\} = \lvert Z \rvert \sin\varphi\,;\ \mathrm{Re}\{Z\} = \lvert Z \rvert \cos\varphi\,;$$

$$\tan = \frac{\sin}{\cos} \qquad \tan\varphi = \frac{\mathrm{Im}\{Z\}}{\mathrm{Re}\{Z\}}\text{; with } \varphi = \omega \cdot t$$

Use of angle	***Polar*** convention
Use of sum	***Cartesian*** convention

The same rules are used for other issues,

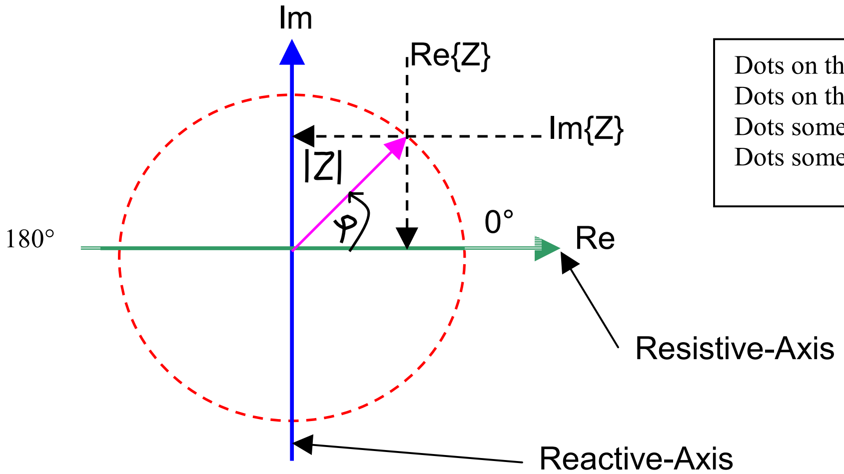
e.g., the reflection coefficient:

$$r = \lvert r \rvert \cdot e^{j\varphi} = \frac{\lvert U_b \rvert \cdot e^{j\varphi_b}}{\lvert U_f \rvert \cdot e^{j\varphi_f}} = \left\lvert \frac{U_b}{U_f} \right\rvert \cdot e^{j(\varphi_b - \varphi_f)}$$

Special cases:

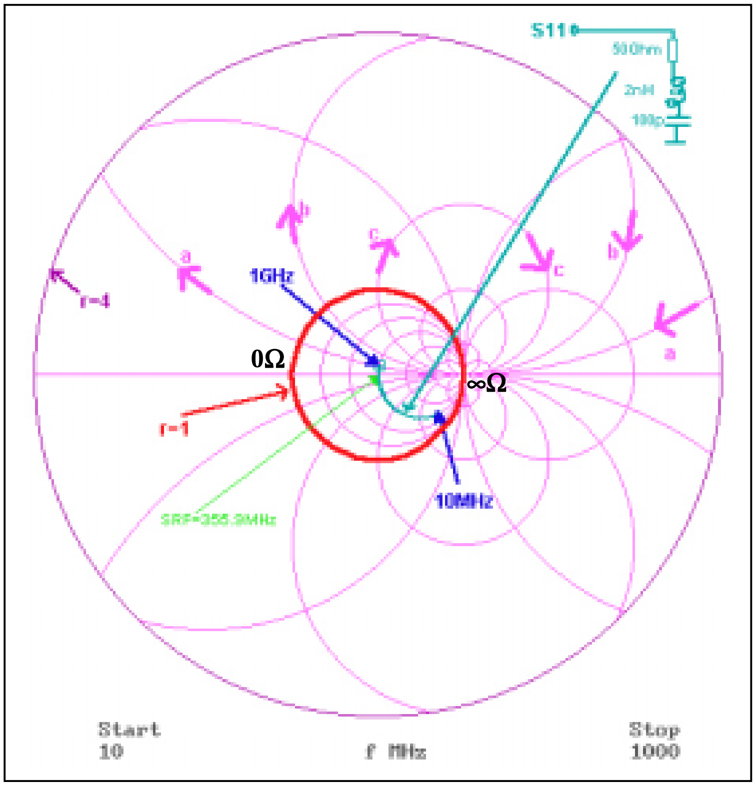
- Resistive mismatch: $\varphi_{(R)} = 0^\circ$ reflection coefficient: $\varphi_{(r)} = 0^\circ$
- Inductive mismatch: $\varphi_{(L)} = +90^\circ$ reflection coefficient: $\varphi_{(r)} = +90^\circ$
- Capacity mismatch: $\varphi_{(C)} = -90^\circ$ reflection coefficient: $\varphi_{(r)} = -90^\circ$

The ***Gaussian number area*** (***Polar Diagram***) allows charting rectangular two-dimensional vectors:



Dots on the Re-Line are 100% resistive
Dots on the Im-Line are 100% reactive
Dots some their above the Re-Line are inductive + resistive
Dots some their below the Re-Line are capacity + resistive

In practical applications RF designers try to remain close to a 50Ω resistive impedance. The upper polar diagram's origin is 0Ω. In RF circuits very large impedances can occur but we try to remain close to 50Ω by special network design for maximum power transfer. Using this approach allows the ∞-region to be displayed with only limited accuracy. The Polar diagram cannot accurately show large impedances and the 50Ω region at the same time, simply because of limited paper size.



Using this fact Mr. Phillip Smith, an engineer with Bell Laboratories developed in the 1930s the so-called Smith Chart. The chart's origin is at 50Ω. Left and right resistive values along the real axis end in 0Ω and at ∞Ω. The imaginary reactive (imaginary axis, or Im-Axis) end in 100% reactive (L or C). Close to the 50Ω origin high resolution is offered. Removed from the center of the chart, the resolution / error increases. The standard Smith Chart only displays positive resistances and has a unit radius (r = 1). Negative resistances generated by instability lay outside the unit circle. In this non-linear scaled diagram, the infinite dot of the Re-Axis is theoretical and bends to the zero point of the Smith Chart. Mathematically it can be shown that this will form the Smith Chart's unit circle. All dot's laying on this circle represent a reflection coefficient magnitude of ONE (100% mismatch). Any positive L/C combination with a resistor will be mathematically represented by it's polar convention reflection coefficient inside the Smith Chart's unity circle. Because the Smith Chart is a transformed linear scaled polar diagram we can use 100% of the polar diagram rules. Other diagram rules must be changed.

Special cases:

- Dots above the horizontal axis represents impedance with inductive part (0° < φ < 180°)
- Dots below the horizontal axis represents impedance with capacitive part (180° < φ < 360°)
- Dots laying on the horizontal axis (ordinate) are 100% resistive (φ = 0°)
- Dots laying on the vertical axis (abscissa) are 100% reactive (φ = 90°)

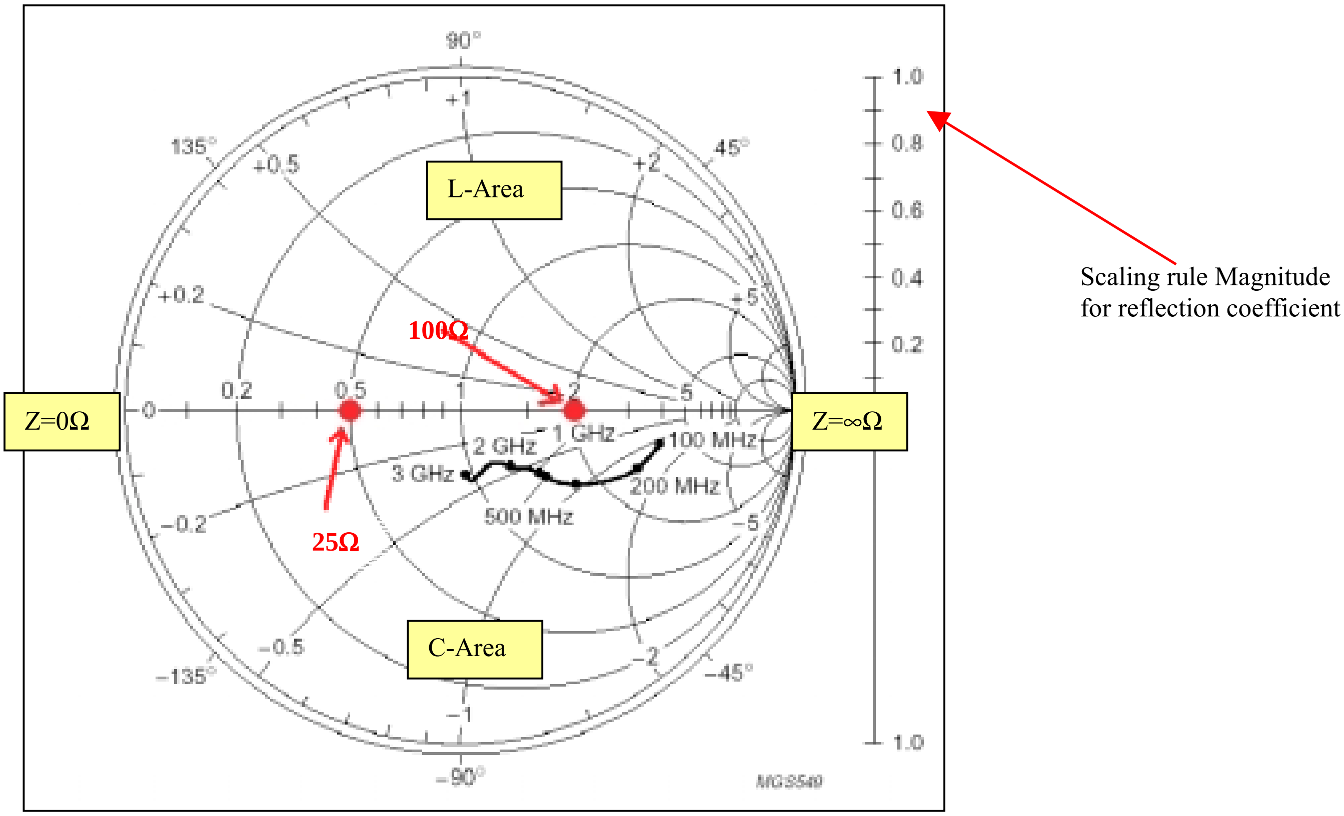


Figure 8: BGA2003 output Smith Chart (S_{22})

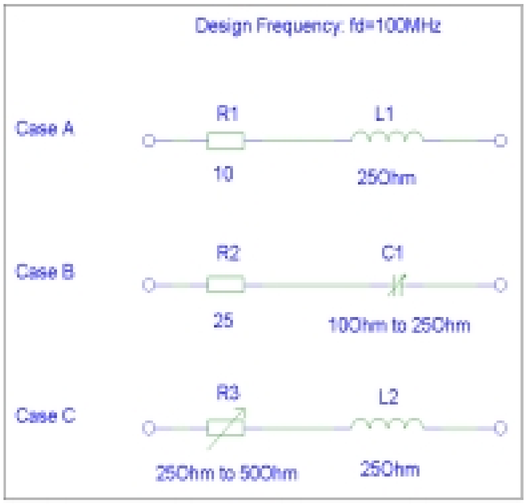
Illustrated are the special cases for ZERO and infinitely large impedance. The upper half circle is the inductive region. The lower half of the circle is the capacitive region. The origin is the 50Ω system reference. To be more flexible, numbers printed in the chart are normalized to the reference impedance.

Normalizing impedance procedure: $Z_{norm} = \frac{Z_x}{Z_o}$ Z_O = Reference impedance (e.g., 50Ω, 75Ω)

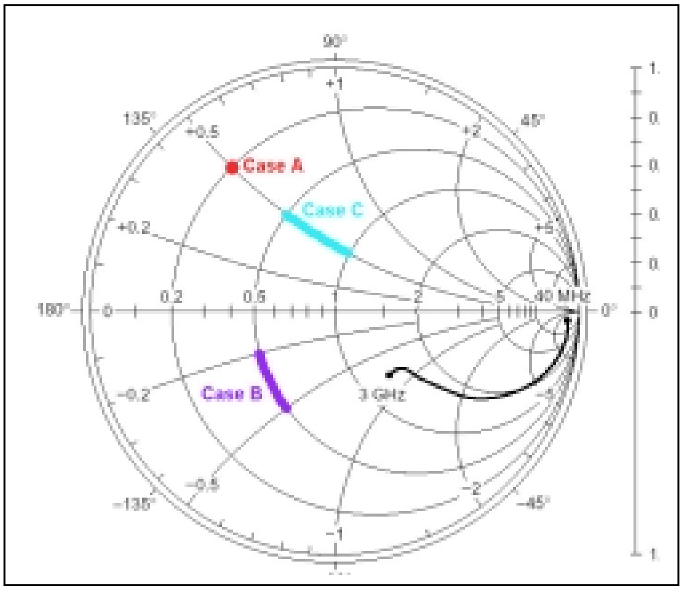
Example: Plot a 100Ω & 50Ω resistor into the upper ***BGA2003***'s output Smith chart.
Calculation: Z_{norm1}=100Ω/50Ω=2; Z_{norm2}=25Ω/50Ω=0.5
Result: The 100Ω resistor appears as a dot on the horizontal axis at the location 2.
The 25Ω resistor appears as a dot on the horizontal axis at the location 0.5

Example1: In the following three circuits, capacitors and inductors are specified by the amount of reactance @ 100MHz design frequency. Determine the value of the parts. Plot their impedance in to the **BFG425W**'s output (S22) Smith Chart.

Circuit:



Result:



Calculation:

Basics:

$$C = \frac{1}{\omega \cdot X_C}$$

$$L = \frac{X_L}{\omega}$$

$$\omega = 2\pi \cdot f$$

Case A (constant resistance)

From the circuit $Z_A = 10\Omega + j25\Omega$; $L_1 = \dfrac{25\Omega}{2\pi \cdot 100MHz} = 39.8nH$

$Z_{(A)norm} = Z_A/50\Omega = 0.2 + j0.5$ Drawing into Smith Chart

Case B (constant resistance and variable reactance - variable capacitor)

From the circuit $Z_B = 10\Omega + j(10 \text{ to } 25)\Omega$

$$C_B = \frac{1}{2\pi \cdot 100MHz \cdot (10 \text{ to } 25)\Omega} = 63.7\text{pF to } 159.2\text{pF}$$

$Z_{(B)norm}=Z_B/50\Omega=0.5-j(0.2 \text{ to } 0.5)$ Drawing into Smith Chart

Case C (constant resistance and variable reactance - variable inductor)

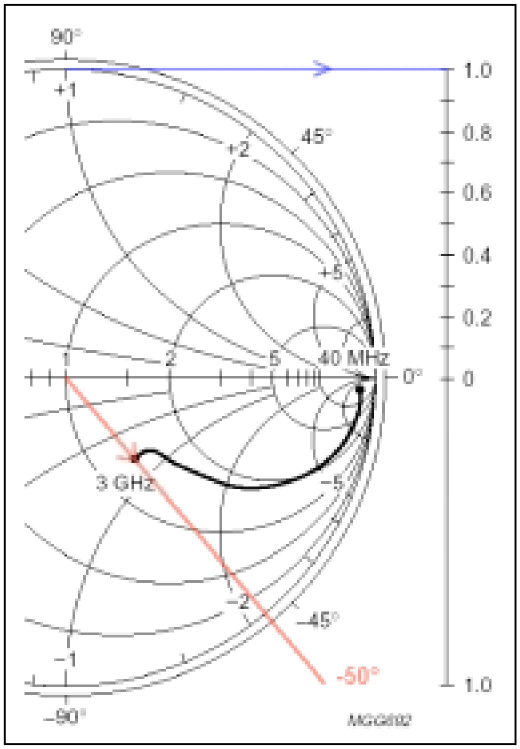
From the circuit $Z_C = (25\Omega \text{ to } 50\Omega) + j25\Omega$;

$$L_C = \frac{(25 \text{ to } 50)\Omega}{2\pi \cdot 100MHz} = 39.8\text{nH to } 79.6\text{nH}$$

$Z_{(C)norm}=Z_C/50\Omega=(0.5 \text{ to } 1)+j0.5$ Drawing into Smith Chart

Example2: Determine ***BFG425W***'s outputs reflection coefficient (S22) at 3GHz from the data sheet.
Determine the output return loss and output impedance. Compensate for the reactive part of the impedance.

Calculation: From reading the data in the Smith Chart with improved resolution, the vector procedure based on the reflection coefficient is recommended.



Procedure: 1) Mechanically measure the scalar length from the chart origin to the 3GHz.
2) On the chart's right side is printed a ruler with the numbers of 0 to 1. Read from it the equivalent scaled scalar length |r| = 0.34
3) Measure the angle ∠(r) = φ = -50°. Write the reflection coefficient in vector polar convention

$$\underline{r = 0.34e^{-j50^\circ}}$$

Normalized impedance: $\frac{Z}{Z_O} = \frac{1+r}{1-r} = 1.513e^{-j30.5^\circ}$

Because the transistor was characterized in a 50Ω bench test set-up Zo = 50Ω

Impedance: $Z_{22} = 75.64\Omega e^{-j30.5^\circ} = (65.2 - j38.4)\Omega$

$$C = \frac{1}{2\pi \cdot 3GHz \cdot 38.4\Omega} = 1.38\,pF$$

The output of BFG425W has an equivalent circuit of <u>65.2Ω with 1.38pF series</u> capacitance. Output return loss, not compensated: 20log(|r|)=<u>-9.36dB</u>

For compensation of the reactive part of the impedance, we take the ***complex conjugate*** of the reactance:

Xcon=-Im{Z} = -{-j38.4Ω} = +j38.4Ω

$L = \frac{38.4\Omega}{2\pi \cdot 3GHz} = 2nH$ a <u>2nH</u> series inductor will compensate for the caacitivereactance.

The new input reflection coefficient is calculated to: $r = \frac{65.2\Omega - 50\Omega}{65.2\Omega + 50\Omega} = 0.132$

Output return loss, compensated: 20log(0.132)=<u>-17.6dB</u>

Please note: In practical situations the output impedance is a function of the input circuit. The input and output matching circuits are defined by the ***stability*** requirements and require gain and noise-matching. Investigation is done by using network analysis based on ***S-Parameters***.

4.2 Small signal RF amplifier parameters

4.2.1 Transistor parameters, DC to microwave

At low DC currents and voltages, one can assume a transistor acts like a voltage-controlled current source with diode clamping action in the *base-emitter* input circuit. In this area, the transistors are specified by their large signal DC-parameters, i.e., DC-current gain (B, ß, h_{fe}), maximum power dissipation, breakdown voltages and so forth.

Increasing the frequency to the audio frequency range, the transistor's behavior is observed to exhibit frequency-dependent changes of parameters, phase shift and parasitic capacitance effects. For characterization of these effects, small signal ***h-parameters*** are used. These hybrid parameters are determined by measuring voltage and current at one terminal and by the use of open or short (standards) at the other port. The ***h-parameter*** matrix is shown below.

h-Parameter Matrix: $\begin{pmatrix} u_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix} * \begin{pmatrix} i_1 \\ u_2 \end{pmatrix}$

Increasing the frequency to the HF and VHF ranges, open ports become inaccurate due to stray field radiation. This results in unacceptable errors. Due to this phenomenon ***y-parameters*** were developed. They again measure voltage and current, but use of only a "short" approach. This "short" approach yields more accurate results in this frequency region. The ***y-parameter*** matrix is shown below.

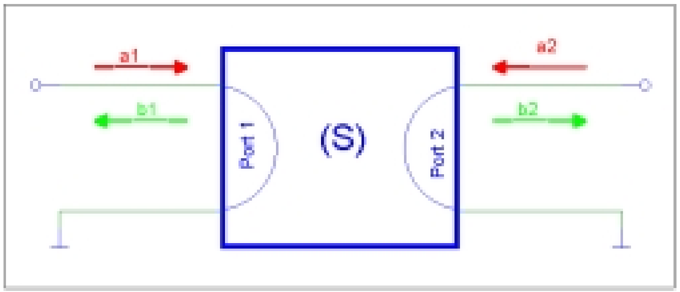
y-Parameter Matrix: $\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{pmatrix} * \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$

Further increasing the frequency, the parasitic inductance of a "short" causes problem due to mechanical parasitics. Additionally, measuring voltage, current, and their relative phases represents a daunting measurement problem. The scattering parameters, or ***s-parameters,*** were developed based on the measurement of the forward and backward traveling waves to determine the reflection coefficients on a transistor's terminals (or ports). The ***s-parameter*** matrix is shown below.

S-Parameter Matrix: $\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} * \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$

4.2.2 Definition of the S-Parameters

Every amplifier has an input port and an output port (a 2-port network). Typically the input port is labeled Port 1 and the output is labeled Port 2.



Matrix: $\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} * \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$

Equation: $b_1 = S_{11} \cdot a_1 + S_{12} \cdot a_2$

$b_2 = S_{21} \cdot a_1 + S_{22} \cdot a_2$

Figure 10: Two-port Network's (a) and (b) waves

The forward-traveling waves **(a)** are traveling into the DUT's (input or output) ports.
The backward-traveling waves **(b)** are reflected back from the DUT's ports
The expression "port Z_O terminate" means the use of a 50Ω-standard. This is not a complex conjugate power match!
In the previous chapter the reflection coefficient was defined as:

Reflection coefficient: $r = \frac{back\ running\ wave}{forward\ running\ wave}$

Calculating the ***input reflection factor*** on port 1: $\boxed{S_{11} = \frac{b_1}{a_1}\Big|_{a_2=0}}$ with the output terminated in Z_O.

That means the source injects a forward-traveling wave **(a1)** into port1. No forward-traveling power **(a2)** injected into port2. The same procedure can be done at port2 with the

Output reflection factor: $\boxed{S_{22} = \frac{b_2}{a_2}\Big|_{a_1=0}}$ with the input terminated in Z_O.

Gain is defined by: $gain = \frac{output\ wave}{input\ wave}$

The ***forward-traveling wave gain*** is calculated by the wave **(b2)** traveling out off port2 divided by the wave **(a1)** injected into port1.

$$\boxed{S_{21} = \frac{b_2}{a_1}\Big|_{a_2=0}}$$

The ***backward traveling wave gain*** is calculated by the wave **(b1)** traveling out off port1 divided by the wave **(a2)** injected into port2. $\boxed{S_{12} = \frac{b_1}{a_2}\Big|_{a_1=0}}$

The normalized waves (a) and (b) are defined as:

$$a_1 = \frac{1}{2\sqrt{Z_O}}(V_1 + Z_O \cdot i_1) \quad = \quad \text{signal into port 1}$$

$$a_2 = \frac{1}{2\sqrt{Z_O}}(V_2 + Z_O \cdot i_2) \quad = \quad \text{signal into port 2}$$

$$b_1 = \frac{1}{2\sqrt{Z_O}}(V_1 + Z_O \cdot i_1) \quad = \quad \text{signal out of port 1}$$

$$b_2 = \frac{1}{2\sqrt{Z_O}}(V_1 + Z_O \cdot i_2) \quad = \quad \text{signal out of port 2}$$

The normalized waves have units of $\sqrt{Watt}$ and are referenced to the system impedance Z_O. It is shown by the following mathematical analyses:

The relationship between U, P an Z_O can be written as:

$$\frac{u}{\sqrt{Z_O}} = \sqrt{P} = i \cdot \sqrt{Z_O} \qquad \text{Substituting:} \quad \frac{Z_0}{\sqrt{Z_O}} = \sqrt{Z_O}$$

$$a_1 = \frac{V_1}{2\sqrt{Z_O}} + \frac{Z_O \cdot i_1}{2\sqrt{Z_O}} = \frac{\sqrt{P_1}}{2} + \frac{Z_O \cdot i_1}{2\sqrt{Z_O}}$$

$$a_1 = \frac{\sqrt{P_1}}{2} + \frac{\sqrt{Z_O} \cdot i_1}{2} = \frac{\sqrt{P_1}}{2} + \frac{\sqrt{P_1}}{2} \qquad a_1 = \sqrt{P_1} \quad \left(\quad \text{Unit} = \sqrt{Watt} = \frac{Volt}{\sqrt{Ohm}} \right)$$

Because $a_1 = \frac{V_{forward}}{\sqrt{Z_O}}$, the normalized waves can be determined by the measuring the voltage of a forward-traveling wave referenced to the system impedance constant $\sqrt{Z_O}$. Directional couplers or VSWR bridges can determine the forward- or backward-traveling voltage wave.

Forward transmission:
$$FT = 20\log(S_{21})\text{dB}$$

Isolation:
$$S12(\text{dB}) = -20\log(S_{12})\text{dB}$$

Input Return Loss:
$$RL_{in} = -20\log(S_{11})\text{dB}$$

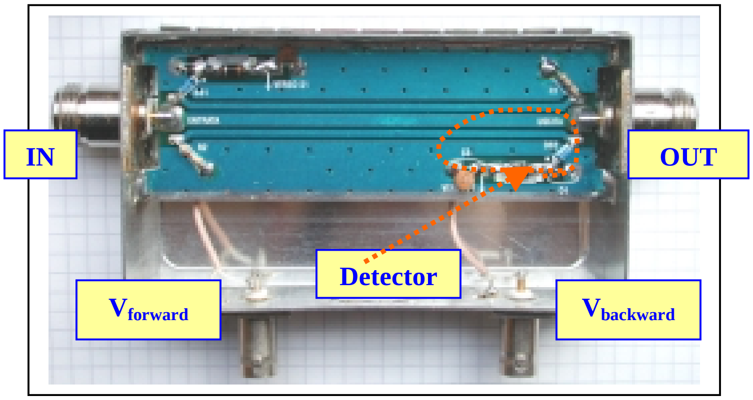
Output Return Loss:
$$RL_{OUT} = -20\log(S_{22})\text{dB}$$

Insertion Loss:
$$IL = -20\log(S_{21})\text{dB}$$

Rem:

$$\frac{Z_O}{\sqrt{Z_O}} = \frac{Z_O \cdot \sqrt{Z_O}}{\sqrt{Z_O} \cdot \sqrt{Z_O}} = \frac{Z_O \cdot \sqrt{Z_O}}{Z_O} = \sqrt{Z_O}$$

$$P = U \cdot I = \frac{U^2}{R} \qquad \sqrt{P} = \frac{U}{\sqrt{R}} = I \cdot \sqrt{R}$$



50Ω VHF-SWR-Meter built from a kit (Nuova Elettronica). It consists of three strip-lines. The middle line passes the main signal from the input to the output. The upper and lower strip-lines select a part of the forward and backward traveling waves by special electrical and magnetic cross-coupling. Diode detectors at each coupled strip-line end rectify the power to a DC voltage, which is passed to an analog circuit for processing and monitoring of the VSWR. Applications: Power antenna match control, PA output power detector, vector Voltmeter, vector network analyzer, AGC, etc.
These kinds of circuits are published in amateur radio literature and in several magazines.

4.2.2.1 2-Port Network definition

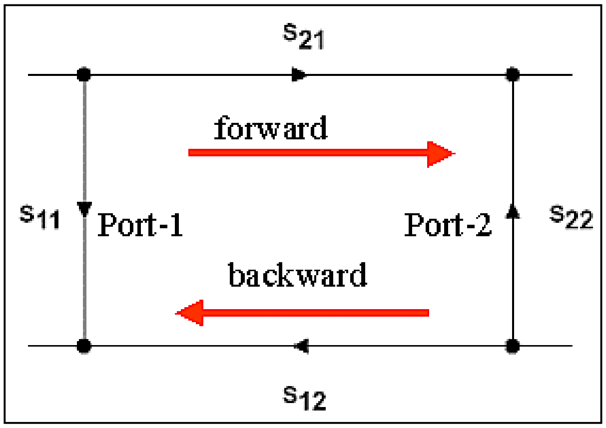


Figure 11: S-Parameters in the Two-port Network

Input return loss

$$S_{11} = \sqrt{\frac{\text{Power reflected from input port}}{\text{Power available from generator at input port}}}$$

Output return loss

$$S_{22} = \sqrt{\frac{\text{Power reflected from output port}}{\text{Power available from generator at output port}}}$$

Forward transmission loss (insertion loss)

$$S_{21} = \sqrt{\text{Transducer power gain}}$$

Reverse transmission loss (isolation)

$$S_{12} = \sqrt{\text{Reverse transducer power gain}}$$

Philips' data sheet parameter ***Insertion power gain*** $|S_{21}|^2$: $10dB \cdot \log|S_{21}|^2 = 20dB \cdot \log|S_{21}|$

Example: Calculate the insertion power gain for the ***BGA2003*** at 100MHz, 450MHz, 1800MHz, and 2400MHz for the bias set-up $V_{VS\text{-}OUT}$=2.5V, $I_{VS\text{-}OUT}$=10mA.

Calculation: Download the S-Parameter data file [2_510A3.S2P] from the Philips' website page for the Silicon MMIC amplifier BGA2003.

This is a section of the file:

```
# MHz S MA R 50 □
! Freq.   S11                  S21                   S12
100    0.58765   -9.43     21.85015  163.96    0.00555    83.961    0.9525
400    0.43912   -28.73    16.09626  130.48    0.019843   79.704    0.80026
500    0.39966   -32.38    14.27094  123.44    0.023928   79.598    0.75616
1800   0.21647   -47.97    4.96451   85.877    0.07832    82.488    0.52249
2400   0.18255   -69.08    3.89514   76.801    0.11188    80.224    0.48091
```

Results:

100MHz 20·log(21.85015) = 26.8 dB

450MHz $20dB\log\left|\frac{16.09626e^{130.48^\circ} + 14.27094e^{123.44^\circ}}{2}\right| = 23.6dB$

1800MHz 20·log(4.96451) = 13.9 dB

2400MHz 20·log(3.89514) = 11.8 dB

4.2.2.2 3-Port Network definition

Typical vehicles for 3-port s-parameters are: directional couplers, power splitters, combiners, and phase splitters.

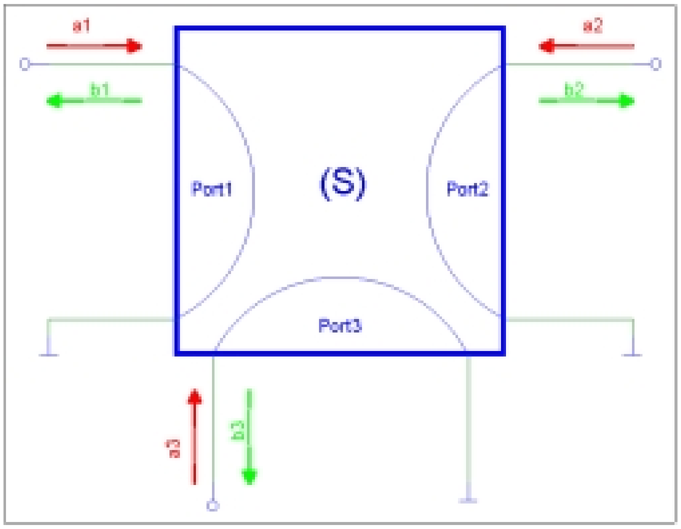


Figure 12: Three-port Network's (a) and (b) waves

3-Port s-parameter definition:

- Port reflection coefficient / return loss:

Port 1	$S_{11} = \frac{b_1}{a_1}\Big|_{(a_2=0;\, a_3=0)}$
Port 2	$S_{22} = \frac{b_2}{a_2}\Big|_{(a_1=0;\, a_3=0)}$
Port 3	$S_{33} = \frac{b_3}{a_3}\Big|_{(a_1=0;\, a_2=0)}$

- Transmission gain:

Port 1=>2	$S_{21} = \frac{b_2}{a_1}\Big|_{(a_3=0)}$
Port 1=>3	$S_{31} = \frac{b_3}{a_1}\Big|_{(a_2=0)}$
Port 2=>3	$S_{32} = \frac{b_3}{a_2}\Big|_{(a_1=0)}$
Port 2=>1	$S_{12} = \frac{b_1}{a_2}\Big|_{(a_3=0)}$
Port 3=>1	$S_{31} = \frac{b_1}{a_3}\Big|_{(a_2=0)}$
Port 3=>2	$S_{23} = \frac{b_3}{a_2}\Big|_{(a_1=0)}$

References

Author:
Andreas Fix
RF Discrete Small Signal Applications Engineer

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3. Philips Semiconductors, Datasheet, 1999 Jul 23, Product Specification, BGA2003, Silicon MMIC amplifier
4. Philips Semiconductors, Datasheet, 2000 Dec 04, Product Specification, BGA2022, MMIC mixer
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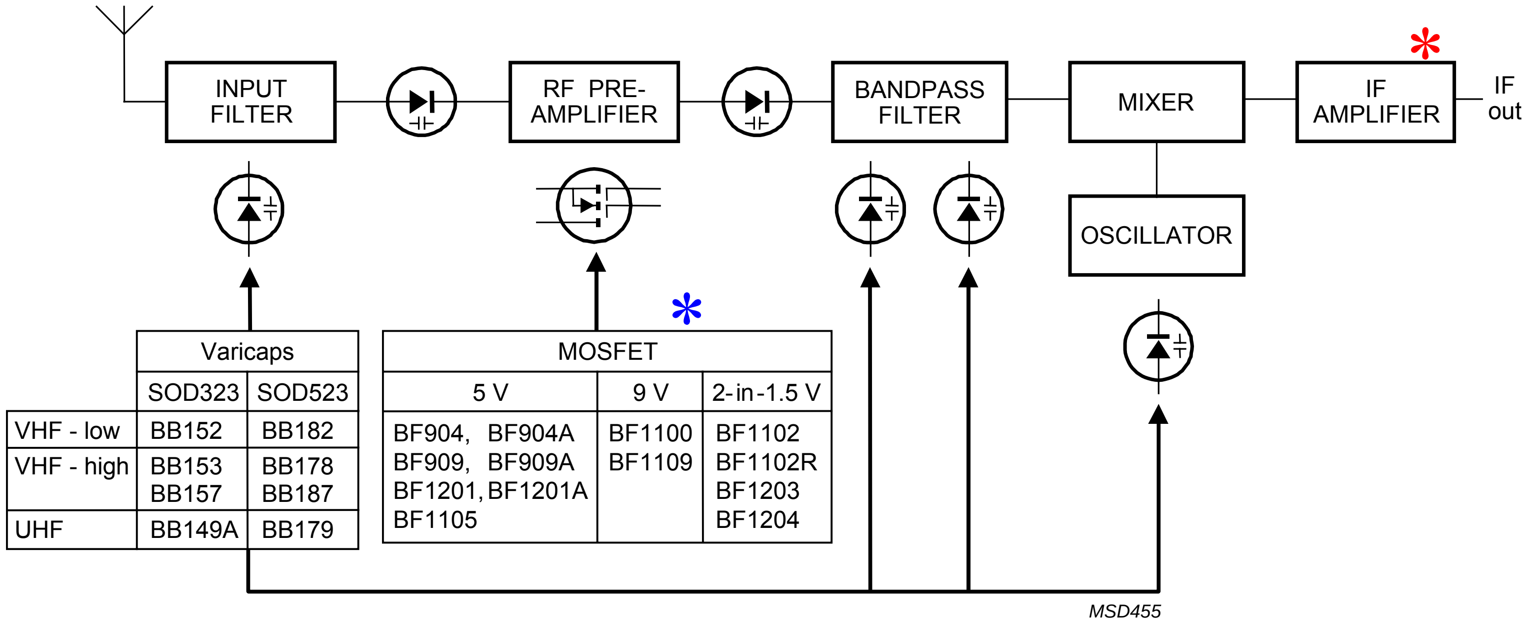
5. Application Diagrams

TV/VCR/DVD Tuning Application Diagram



	Varicaps	
	SOD323	SOD523
VHF - low	BB152	BB182
VHF - high	BB153 BB157	BB178 BB187
UHF	BB149A	BB179

MOSFET		
5 V	9 V	2-in-1.5 V
BF904, BF904A BF909, BF909A BF1201, BF1201A BF1105	BF1100 BF1109	BF1102 BF1102R BF1203 BF1204

✻

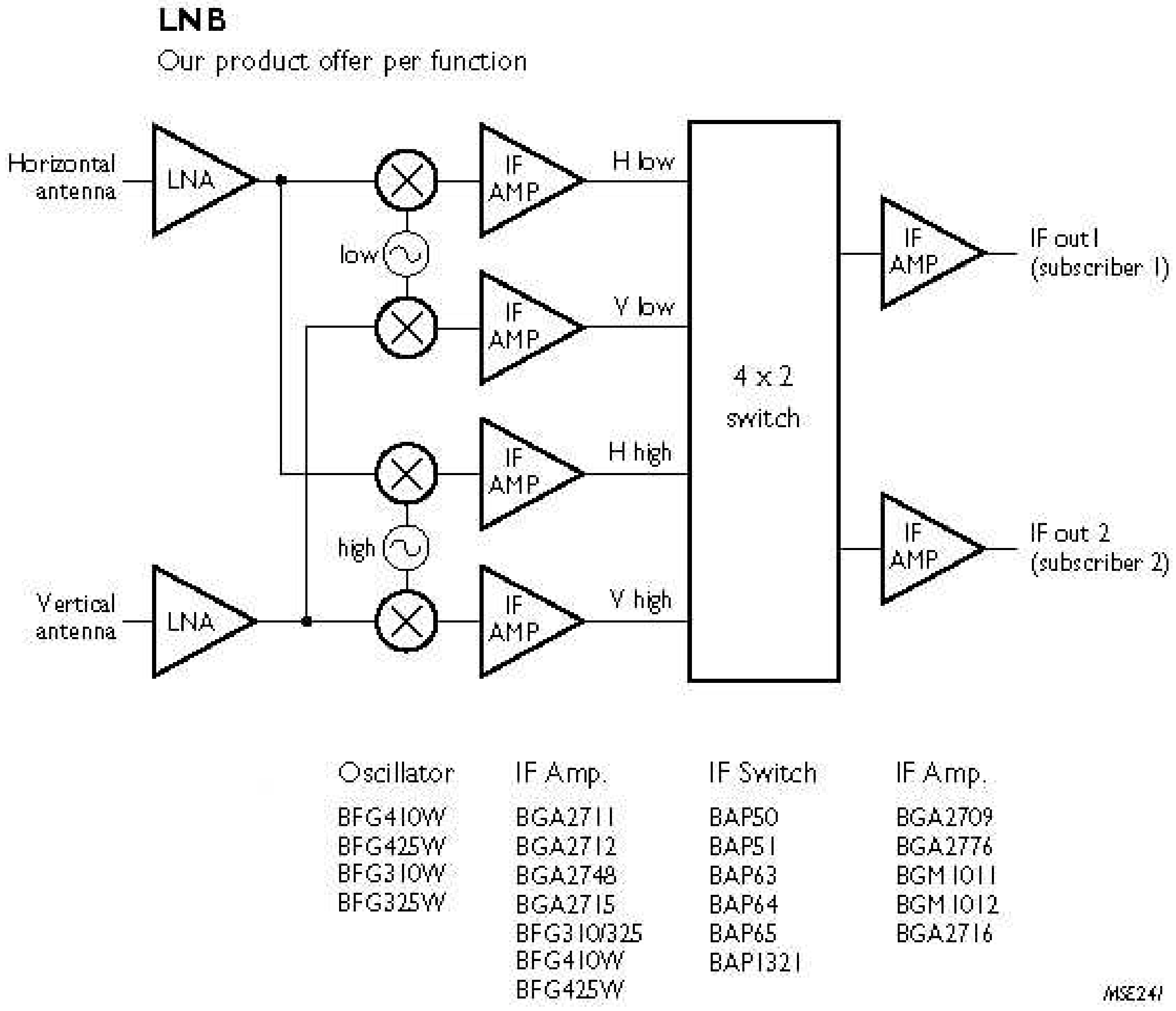
MOSFET include NEW Mosfets:
BF1211, BF1211R, BF1211WR
BF1212, BF1212R, BF1212WR
BF1205, BF1206

✻

IF Amplifier: **BGA2717**

5. Application Diagrams

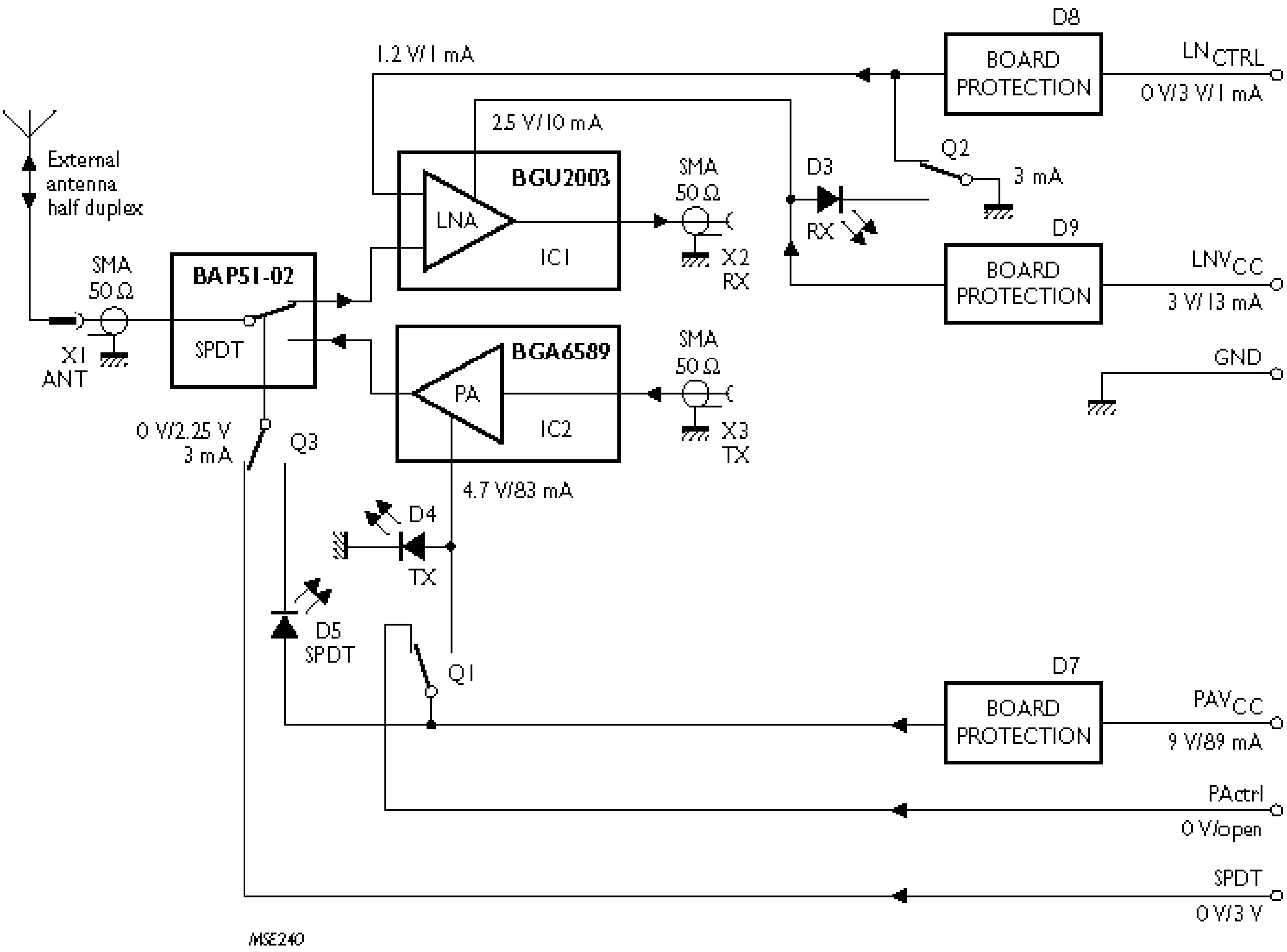
LNB Application Diagram



Oscillator	IF Amp.	IF Switch	IF Amp.
BFG410W	BGA2711	BAP50	BGA2709
BFG425W	BGA2712	BAP51	BGA2776
BFG310W	BGA2748	BAP63	BGM1011
BFG325W	BGA2715	BAP64	BGM1012
	BFG310/325	BAP65	BGA2716
	BFG410W	BAP1321	
	BFG425W		

5. Application Diagrams

2.4 GHz Front-end Application Diagram



6. Application notes (Interactive)

Full application notes in appendix of this RF Manual in **bold.**
Online application notes on Philips Semiconductors website:
http://www.semiconductors.philips.com/products/all_appnotes.html

Product Family	Application Note Title	Relevant Types
MMICs	Demoboard for 900&1800MHz http://www.semiconductors.philips.com/acrobat/applicationnotes/9001800MHZ.pdf	BGA2001
	Demoboard for BGA2001 http://www.semiconductors.philips.com/acrobat/applicationnotes/9001800MHZ.pdf	BGA2001
	Demoboard 900MHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/LNA900MHZ.pdf	BGA2003
	Demoboard for W-CDMA http://www.semiconductors.philips.com/acrobat/applicationnotes/WBCDMA.pdf	BGA2003
	2GHz high IP3 LNA	BGA2003
	High IP3 MMIC LNA at 900MHz http://www.semiconductors.philips.com/acrobat/applicationnotes/BGA2011_LNA_950MHZ.pdf	BGA2011
	High IP3 MMIC LNA at 1.8 - 2.4 GHz http://www.semiconductors.philips.com/acrobat/applicationnotes/BGA2012_LNA_18_24GHZ.pdf	BGA2012
	Rx mixer for 1800MHz	BGA2022
	Rx mixer for 2450MHz http://www.semiconductors.philips.com/acrobat/applicationnotes/BGA2022_MIXER.pdf	BGA2022
	High-linearity wideband driver mobile communication	BGA2031
	CDMA PCS demoboard	BGA2030
	WDMA appl. For the BGA6589 wideband amplifier	**BGA6589**
Wideband transistors	1880MHz PA driver http://www.semiconductors.philips.com/acrobat/applicationnotes/BFG21W_1880DRV.pdf	BFG21W
	800MHz PA driver http://www.semiconductors.philips.com/acrobat/applicationnotes/BFG21W_800DRV2.pdf	BFG21W
	900MHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/LNA9M403.pdf	BFG403W
	2GHz buffer amplifier http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG410W_BUF2_1.pdf	BFG410W
	900MHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/B770LNA9M410.pdf	BFG410W
	2GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/RD7B0789.pdf	BFG410W
	Ultra LNA's for 900&2000MHz with high IP3 http://www.semiconductors.philips.com/acrobat/applicationnotes/KV96157A.pdf	BFG410W, BFG425W
	1.5GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/1U5GHZLN.pdf	BFG425W
	2GHz driver-amplifier	BFG425W
	900MHz driver-amplifier with enable-switch http://www.semiconductors.philips.com/acrobat/applicationnotes/900MHAP2.pdf	BFG425W

Product Family	Application Note Title	Relevant Types
	900MHz driver amplifier http://www.semiconductors.philips.com/acrobat/applicationnotes/900MHZDR.pdf	BFG425W
	1.9GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG425W_1.pdf	BFG425W
	Improved IP3 behavior of the 900MHz LNA	BFG425W
	2GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/B773LNA2G425.pdf	BFG425W
	Power amplifier for 1.9GHz DECT and PHS http://www.semiconductors.philips.com/acrobat/applicationnotes/DECT.pdf	BFG425W, BFG21W
	2.4GHz power amplifier http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG425W_21W_2400M_1.pdf	BFG425W, BFG21W
	CDMA cellular VCO http://www.semiconductors.philips.com/acrobat/applicationnotes/VCOB827.pdf	BFG425W, BFG410W, BB142
	900MHz LNA	BFG480W
	2.45GHz power amplifier http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG480W_2450M_1.pdf	BFG480W
	2.4GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG480W_2400M_1.pdf	BFG480W
	2GHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG480W_2G_1.pdf	BFG480W
	900MHz LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/AI_BFG480W_900M_1.pdf	BFG480W
	1880MHz PA driver http://www.semiconductors.philips.com/acrobat/applicationnotes/BFG480W_1880DRV.pdf	BFG480W
	900MHz driver http://www.semiconductors.philips.com/acrobat/applicationnotes/BFG480W_900MDRV.pdf	BFG480W
	Low noise, low current preamplifier for 1.9GHz at 3V http://www.semiconductors.philips.com/acrobat/applicationnotes/1P9GHZLC.pdf	BFG505
	1890MHz power own converter with 11MHz IF http://www.semiconductors.philips.com/acrobat/applicationnotes/1890MHZ.pdf	BFG505/X
	Low noise 900MHz preamplifier at 3V http://www.semiconductors.philips.com/acrobat/applicationnotes/900MHZ.pdf	BFG520, BFR505, BFR520
	Power amplifier for 1.9GHz at 3V http://www.semiconductors.philips.com/acrobat/applicationnotes/1P9GHZ3.pdf	BFG540/X, BFG10/X, BFG11/X
	400MHz :LNA http://www.semiconductors.philips.com/acrobat/applicationnotes/400MHZUL.pdf	BFG540W/X
Varicaps	**Low voltage FM stereo radio with TEA5767/68**	**BB202**
FETs	**Application for RF switch BF1107**	BF1107
	Application note for MOSFET	BF9...., BF110.., BF120..
	Application for RF switch BF1108	BF1108
Pin diodes	**2.45 GHz T/R, RF switch for e.g. Bluetooth application** http://www.philips.semiconductors.com/acrobat/applicationnotes/AN10173-01.pdf	**BAP51-02**
	Low impedance Pin diode http://www.semiconductors.philips.com/acrobat/applicationnotes/AN10174-01.pdf	BAP50-05
	1.8GHz transmit-receive Pin diode switch	BAP51-03

7.1 Product portfolio: MMIC's

* = new product

General Purpose Wideband Amplifiers, 50 Ohm Gain Blocks

Type	Package	Limits			f_u[1]	@ 1GHz					Gain3 (dB) @				@	
		Vs (V)	Is (mA)	Ptot (mW)	@-3dB (GHz)	NF (dB)	Psat (dBm)	Gain[3] (dB)	P_1dB (dBm)	OIP_3 (dBm)	100 MHz	2.2 GHz	2.6 GHz	3.0 GHz	Vs (V)	Is (mA)
BGA2711	SOT363	6	20	200	**3.6**2)	4.7	2	12.9	-2	10	13	14.1	13.8	12.8	5	12
BGA2748	SOT363	4	15	200	1.9	**1.8**2)	-4	**21.3**	-10	-2	14.8	17.6	14.2	11.3	3	**5.7**
BGA2771	SOT363	4	50	200	2.4	4.4	**12**2)	21	**11**	**22**	20.3	20.4	17.5	15.2	3	33
BGA2776	SOT363	6	34	200	2.8	4.7	8	**22.8**2)	5.5	17	22.2	23.2	20.8	18.7	5	23.8
BGA2709	SOT363	6	35	200	2.8	4	12.4	**22.7**	8.3	**24**	22.6	22.7	22.0	21.1	5	23.5
BGA2712	SOT363	6	25	200	2.8	3.9	4.8	21.3	0	12	20.9	21.9	20.8	18.6	5	12.5
BGM1011	SOT363	6	35	200	-	4.7	**13.8**	**30**	**12.2**	**23**	**25.0**	**37.0**	**32.0**	**28.0**	5	25.5
BGM1012	SOT363	4	50	200	**3.6**	4.8	9.7	20.1	6	18	**19.5**	**20.4**	**19.9**	**18.7**	3	**14.6**
BGA2715 ∗	SOT363	6	8	200	3.0	2.6	-5	22	-9	14	14.0	22.0	21	19	5	**4.3**2)
BGA2716 ∗	SOT363	6	25	200	**3.6**	4.9	**11**	**24**	**7**	**24**	**24.0**	**24.0**	**24**	**23**	5	**15.9**2)
BGA2717 ∗	SOT363	6	15	200	3.0	**2.1**	1	**23**	-3	**20**	**20.0**	**23.0**	**23**	**20**	5	**8.0**

Notes: 1. Upper -3 db point, to gain at 1 ghz. 2. Optimized parameter. 3. Gain = $|S_{21}|^2$

Add ∗ : BGA2715/6/7 are available in Q3 2003. Mentioned data is objective.

Highlighted in **red** are the parameters designed to be optimal for that specific type.

Area filled blue are the nicely flat gain-curved types over the entire LNB relevant range.

Demo boards of BGA2715/16/17 will be available at CQS.

2 Stage Variable Gain Linear Amplifier

Type	Package	Limits			Frequency Range	@ 900MHz				@1900 MHz				@	
		Vs (V)	Is (mA)	Ptot (mW)	(MHz)	Gain[1] (dB)	DG[2] (dB)	P1dB (dBm)	ACPR (dBc)	Gain[1] (dB)	DG[2] (dB)	P1dB (dBm)	ACPR (dBc)	Vs (V)	Is (mA)
BGA2031/1	SOT363	3.3	50	200	800-2500	24	62	11	49	23	56	13	49	3	51

Notes: 1. Gain = G_P, power gain. 2. DG = Gain control range

7.1 Product portfolio: MMIC's

Wideband Linear Mixer

Type	Package	Limits			RF Input Freq. Range	IF Output Freq. Range	@ 880MHz			@2450 MHz			@	
		Vs	Is	Ptot			NF	Gain^1	OIP3	NF	Gain^1	OIP3	Vs	Is
		(V)	(mA)	(mW)	(MHz)	(MHz)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)	(V)	(mA)
BGA2022	SOT363	4	20	40	800-2500	50-500	9	5	4	9	6	10	3	51

Notes: 1. Gain = G_C, Conversion gain

Low Noise Wideband Amplifiers

Type	Package	Limits			@ 900MHz			@1800 MHz			Gain^3 (db) @				@	
		Vs	Is	Ptot	NF	Gain	IIP$_3$	NF	Gain	IIP$_3$	100 MHz	1 GHz	2.6 GHz	3.0 GHz	Vs	Is
		(V)	(mA)	(mW)	(dB)	(dB)	(dBm)	(dB)	(dB)	(dBm)					(V)	(mA)
BGA2001	SOT343R	4.5	30	135	1.3	22$^{1)}$	-7.4	1.3	19.5$^{1)}$	-4.5	20	17.1	11.6	10.7	2.5	4
BGA2003	SOT343R	4.5	30	135	1.8	24$^{1)}$	-6.5	1.8	16$^{1)}$	-4.8	26	18.6	11.1	10.1	2.5	10$^{2)}$
BGA2004$^{4)}$	SOT363	3.3	15	50				1.4	18	-5					2.7	6
BGA2011	SOT363	4.5	30	135	1.5	19$^{3)}$	10	-	-	-	24	14.8	8	6.5	3	15
BGA2012	SOT363	4.5	15	70	-	-	-	1.7	16$^{3)}$	10	22	18.2	11.6	10.5	3	7
BGU2003	SOT343R	4.5	30	135	1	23	-6	1.1	18	-5	25	19	12.3	11.6	2.5	10$^{2)}$

Notes : 1. MSG 2. Adjustable bias 3. $|S_{21}|^2$ 4. Switched LNA with internal match for 1.8 GHz. Objective Data

General Purpose Medium Power Amplifers, 50 ohm gain blocks

Type	Package	Limits			@ 900MHz				@1800 MHz				Gain^3	f_u^{1}	@	
		Vs	Is	Ptot	NF	Gain^3	OIP$_3$	P_1dB	NF	Gain^3	NF	P_1dB	2.5 GHz	@-3dB (MHz)	Vs	Is
		(V)	(mA)	(mW)	(dB)	(dB)	(dBm)	(dBm)	(dB)	(dB)	(dB)	(dBm)			(V)	(mA)
BGA6289	SOT89	6	120	480	3.8	15	31	17	4.1	13	4.1	15	12	4000	3.8	83
BGA6489	SOT89	6	120	480	3.1	20	33	20	3.3	16	3.3	17	15	4000	5.1	83
BGA6589	SOT89	6	120	480	3	22	33	21	3.3	17	3.3	20	15	4000	4.8	83

Notes:1 Determined by return Loss(>10dB) 3. Gain = |S21|2

7.2 Product portfolio: Wideband transistors (1)

Wideband transistors (RF small signal) to 5 Ft GHz

Type	Package	Ft	Vceo	Ic	Ptot	Polarity	Gum (dB)	F (dB)	@ (MHz)	Gum (dB)	F (dB)	@ (MHz)	Vo 1) (mV)	Pl (dBm)	ITO (dBm)	@ Ic & (mA)	Vce (V)
		(GHz)	(V)	(mA)	(mW)												
		Typical	Maximum values														
BFG10(X)	SOT143	-	8	250	250	NPN	-	-	-	7	-	1900	-	-	-	-	-
BFG10W/X	SOT343	-	10	250	400	NPN	-	-	-	7	-	1900	-	-	-	-	-
BFG11(/X)	SOT143	-	8	500	400	NPN	-	-	-	5	-	1900	-	-	-	-	-
BFG11W/X	SOT343	-	8	500	760	NPN	-	-	-	6	-	1900	-	-	-	-	-
BLT80	SOT223	-	10	250	2000	NPN	>6	-	900	-	-	-	-	-	-	-	-
BLT81	SOT223	-	9.5	500	2000	NPN	>6.5	-	900	-	-	-	-	-	-	-	-
BLT50	SOT223	-	10	500	2000	NPN	>7	-	900								
BLT70	SOT223	-	8	250	2100	NPN	>6	-	900	-	-	-	-	-	-	-	-
PMBT3640	SOT23	0.5	12	80	350	PNP	-	-	-	-	-	-	-	-	-	-	-
PMBTH81	SOT23	0.6	20	40	400	PNP	-	-	-	-	-	-	-	-	-	-	-
PMBHT10	SOT23	0.65	25	40	400	NPN	-	-	-	-	-	-	-	-	-	-	-
BFS17	SOT23	1	15	25	300	NPN	-	4.5	500	-	-	-	-	-	-	-	-
BF547	SOT23	1.2	20	50	300	NPN	20	-	100	-	-	-	-	-	-	-	-
BF747	SOT23	1.2	20	50	300	NPN	20	-	100	-	-	-	-	-	-	-	-
BFG16A	SOT223	1.5	25	150	1000	NPN	10	-	500	-	-	-	-	-	-	-	-
BFQ17	SOT89	1.5	25	150	1000	NPN	16	-	200	6.5	-	800	-	-	-	-	-
BSR12	SOT23	1.5	15	100	250	PNP	-	-	-	-	-	-	-	-	-	-	-
BFS17W	SOT323	1.6	15	50	300	NPN	-	4.5	500	-	-	-	-	-	-	-	-
BFR53	SOT23	2	10	50	250	NPN	-	5	500	10.5	-	800	-	-	-	-	-
BFT25	SOT23	2.3	5	6.5	30	NPN	18	3.8	500	12	-	800	-	-	-	-	-
BFS17A	SOT23	2.8	15	25	300	NPN	13.5	2.5	800	-	-	-	150	-	-	14	10
BFR94A	SOT122	3.5	25	150	3500	NPN	-	8	200	-	5	500	-	-	-	-	-
BFG35	SOT223	4	18	150	1000	NPN	15	-	500	11	-	800	750	-	-	100	10
BFQ136	SOT122	4	18	600	9000	NPN	12.5	-	800	-	-	-	2500	-	-	500	15
BFQ18	SOT89	4	18	150	1000	NPN	-	-	-	-	-	-	-	-	-	-	-
BFQ34/01	SOT122	4	18	150	2700	NPN	16.3	8	500	-	-	-	1200	26	45	120	15
BFQ68	SOT122	4	18	300	4500	NPN	13	-	800	-	-	1600	1600	28	47	240	15
BFG25A/X	SOT143	5	5	6.5	32	NPN	18	1.8	1000	-	-	-	-	-	-	-	-
BFG25W(/X)	SOT343	5	5	6.5	500	NPN	16	2	1000	8	-	2000	-	-	-	-	-
BFG31	SOT223	5	15	100	1000	PNP	16	-	500	12	-	800	550	-	-	70	10
BFG590(/X)	SOT143	5	15	200	400	NPN	13	-	900	7.5	-	2000	-	-	-	-	-
BFG590W/X	SOT343	5	15	200	500	NPN	13	-	900	7.5	-	2000	-	21	-	80	5

7.2 Product portfolio: Wideband transistors (2)

Wideband transistors (RF small signal) 5 - 8 Ft GHz

Type	Package	Ft	Vceo	Ic	Ptot	Polarity	Gum	F	@	Gum	F	@	Vo 1)	Pl	ITO	@ Ic &	Vce
		(GHz)	(V)	(mA)	(mW)		(dB)	(dB)	(MHz)	(dB)	(dB)	(MHz)	(mV)	(dBm)	(dBm)	(mA)	(V)
		Typical	Maximum values														
BFG92A(/X)	SOT143	5	15	25	400	NPN	16	2	1000	11	3	2000	-	-	-	-	-
BFQ149	SOT89	5	15	100	1000	PNP	12	3.75	500	-	-	-	-	-	-	-	-
BFR106	SOT23	5	15	100	500	NPN	11.5	3.5	800	-	-	-	350	-	-	50	9
BFR92	SOT23	5	15	25	300	NPN	18	2.4	500	-	-	-	150	-	-	14	10
BFR92A	SOT23	5	15	25	300	NPN	14	2.1	1000	8	3	2000	150	-	-	14	10
BFR92AT	SOT416	5	15	25	150	NPN	14	2	1000	8	-	2000	-	-	-	-	-
BFR92AW	SOT323	5	15	25	300	NPN	14	2	1000	-	3	2000	-	-	-	-	-
BFR93	SOT23	5	12	35	300	NPN	16.5	1.9	500	-	-	-	-	-	-	-	-
BFR93AT	SOT416	5	12	35	150	NPN	13	1.5	1000	8	-	2000	-	-	-	-	-
BFR93AW	SOT323	5	12	35	300	NPN	13	1.5	1000	8	2.1	2000	-	-	-	-	-
BFS25A	SOT323	5	5	6.5	32	NPN	13	1.8	1000	-	-	-	-	-	-	-	-
BFT25A	SOT23	5	5	6.5	32	NPN	15	1.8	1000	-	-	-	-	-	-	-	-
BFT92	SOT23	5	15	25	300	PNP	18	2.5	500	-	-	-	150	-	-	14	10
BFT92W	SOT323	5	15	35	300	PNP	17	2.5	500	11	3	1000	-	-	-	-	-
BFT93	SOT23	5	12	35	300	PNP	16.5	2.4	500	-	-	-	300	-	-	30	5
BFT93W	SOT323	5	12	50	300	PNP	15.5	2.4	500	10	3	1000	-	-	-	-	-
BFG97	SOT223	5.5	15	100	1000	NPN	16	-	500	12	-	800	700	-	-	70	10
BFQ19	SOT89	5.5	15	100	1000	NPN	11.5	3.3	500	7.5	-	800	-	-	-	-	-
BFG93A(/X)	SOT143	6	12	35	300	NPN	16	1.7	1000	10	2.3	2000	-	-	-	-	-
BFG94	SOT223	6	12	60	700	NPN	-	2.7	500	13.5	3	1000	500	21.5	34	45	10
BFQ270	SOT172	6	19	500	####	NPN	16	-	500	-	-	-	1600	-	-	240	18
BFR93A	SOT23	6	12	35	300	NPN	13	1.9	1000	-	3	2000	425	-	-	30	8
BFQ135	SOT172	6.5	19	150	2700	NPN	17	-	500	13.5	-	800	1200	-	-	120	18
BFC520	SOT353	7	8	70	1000	NPN	-	1.3	900	-	-	-	-	-	-18	5	3
BFG135	SOT223	7	15	150	1000	NPN	16	-	500	12	-	800	850	-	-	100	10
BFG591	SOT223	7	15	200	2000	NPN	13	-	900	7.5	-	2000	-	-	-	-	-
BFQ591	SOT89	7	15	200	2000	NPN	13	-	900	7.5	-	2000	-	-	-	-	-
BFQ621	SOT172	7	16	150	800	NPN	18.5	-	500	-	-	-	1200	-	-	120	18
BFC505	SOT353	7.3	8	18	500	NPN	-	1.8	900	-	3.5	2000	-	-	-20	1	3
BFG198	SOT223	8	10	100	1000	NPN	18	-	500	15	-	800	700	-	-	70	8
BFG67(/X)	SOT143	8	10	50	380	NPN	17	1.7	1000	10	2.5	2000	-	-	-	-	-
BFQ67	SOT23	8	10	50	300	NPN	14	1.7	1000	8	2.7	2000	-	-	-	-	-

7.2 Product portfolio: Wideband transistors (3)

Wideband transistors (RF small signal) > 8 Ft GHz

Type	Package	Ft (GHz)	Vceo (V)	Ic (mA)	Ptot (mW)	Polarity	Gum (dB)	F (dB)	@ (MHz)	Gum (dB)	F (dB)	@ (MHz)	Vo 1) (mV)	Pl (dBm)	ITO (dBm)	@ Ic & (mA)	Vce (V)
		Typical	Maximum values														
BFQ67W	SOT323	8	10	50	300	NPN	13	2	1000	8	2.7	2000	-	-	-	-	-
PBR941	SOT23	8	10	50	360	NPN	15	1.4	1000	9.5	2	2000	-	-	-	-	-
PBR951	SOT23	8	10	100	365	NPN	14	1.3	1000	8	2	2000	-	-	-	-	-
PRF947	SOT323	8.5	10	50	250	NPN	16	1.5	1000	10	2.1	2000	-	-	-	-	-
PRF957	SOT323	8.5	10	100	270	NPN	15	1.3	1000	9.2	1.8	2000	-	-	-	-	-
BFE505	SOT353	9	8	18	500	NPN	-	1.2	900	-	1.9	2000	-	-	-	-	-
BFE520	SOT353	9	8	70	1000	NPN	-	1.1	900	-	1.9	2000	-	-	-	-	-
BFG505(/X)	SOT143	9	15	18	150	NPN	20	1.6	900	13	1.9	2000	-	4	10	5	6
BFG520(/X)	SOT143	9	15	70	300	NPN	19	1.6	900	13	1.9	2000	275	17	26	20	6
BFG520W(/X)	SOT343	9	15	70	500	NPN	17	1.6	900	11	1.85	2000	275	17	26	20	6
BFG540(/X)	SOT143	9	15	120	500	NPN	18	1.9	900	11	2.1	2000	500	21	34	40	8
BFG540W(/X)	SOT343	9	15	120	500	NPN	16	1.9	900	10	2.1	2000	500	21	34	40	8
BFG541	SOT223	9	15	120	650	NPN	15	1.9	900	9	2.1	2000	500	21	34	40	8
BFM505	SOT363	9	8	18	500	NPN	17	1.4	900	10	1.9	2000	-	-	-	-	-
BFM520	SOT363	9	8	70	1000	NPN	15	1.7	900	9	1.9	2000	-	-	-	-	-
BFQ540	SOT89	9	12	120	1200	NPN	-	1.9	900	-	-	-	500	-	-	40	8
BFR505	SOT23	9	15	18	150	NPN	17	1.6	900	10	1.9	2000	-	4	10	5	6
BFR505T	SOT416	9	-	18	150	NPN	17	1.2	900	-	-	-	-	-	-	-	-
BFR520	SOT23	9	15	70	300	NPN	15	1.6	900	9	1.9	2000	-	17	26	20	6
BFR520T	SOT416	9	-	70	150	NPN	15	1.6	900	9	1.9	2000	-	17	26	-	-
BFR540	SOT23	9	15	120	500	NPN	14	1.9	900	7	2.1	2000	550	21	34	40	8
BFS505	SOT323	9	15	18	150	NPN	17	1.6	900	10	1.9	2000	-	4	10	5	6
BFS520	SOT323	9	15	70	300	NPN	15	1.6	900	9	1.9	2000	-	17	26	20	6
BFS540	SOT323	9	15	120	500	NPN	14	1.9	900	8	2.1	2000	-	21	34	40	8
PRF949	SOT416	9	10	50	150	NPN	16	1.5	1000	-	-	-	-	-	-	-	-
BFG403W	SOT343	17	4.5	3.6	16	NPN	-	1	900	-	1.6	2000	-	5	6	1	1
BFG21W	SOT343	18	4.5	200	600	NPN	-	-	-	10	-	1900	-	-	-	-	-
BFG480W	SOT343	21	4.5	250	360	NPN	-	1.2	900	-	1.8	2000	-	-	28	80	2
BFG410W	SOT343	22	4.5	12	54	NPN	-	0.9	900	-	1.2	2000	-	5	15	10	2
BFG425W	SOT343	25	4.5	30	135	NPN	-	0.8	900	-	1.2	2000	-	12	22	25	2
BFU510	SOT343	45	2.5	15	38	NPN	-	0.6	900	20	0.9	2000	-	-	-	-	-
BFU540	SOT343	45	2.5	50	125	NPN	-	0.6	900	20	0.9	2000	-	-	-	-	-

7.3 Product portfolio: Varicap diodes

TV & Satellite Varicap Diodes - UHF tuning

Type	Package	Cd @ Vr (pF)			TUNING RANGE Cd over voltage range (V)			rs (Ω)	MATCHED SETS	TYPICAL APPLICATIONS			
		min	max	(V)	ratio	V1 to V2		max	%	TV	VCO	SAT.	STB
Matched													
BB154	SOD323	1.90	2.00	28	9.7	1	28	0.75	2.0	X		X	X
BB134	SOD323	1.70	2.10	28	10.0	0.5	28	0.75	0.5	X		X	X
BB146	SOD323	1.70	2.10	28	23.0	0.5	28	1.40	1.6	X			X
BB149	SOD323	1.90	2.25	28	9.0	1	28	0.75	1.0	X			X
BB149A	SOD323	1.95	2.22	28	9.7	1	28	0.75	2.0	X			X
BB149A/TM	SOD323	1.95	2.22	28	9.7	1	28	0.75	2.0	X			X
BB179	SOD523	1.95	2.22	28	9.7	1	28	0.75	2.0	X	X		X
BB179B	SOD523	1.90	2.25	28	9.2	1	28	0.75	2.0	X			X
Unmatched													
BB135	SOD323	1.70	2.10	28	10.0	0.5	28	0.75		X	X		
BB159	SOD323	1.90	2.25	28	9.0	1	28	0.75		X			
BBY31 BBY39	SOT23	1.60	2.00	28	8.3	1	28	1.20	-	X			X
BBY62	SOT143												

TV & Satellite Varicap diodes - VHF tuning

Type	Package	Cd @ Vr (pF)			TUNING RANGE Cd over voltage range (V)			rs (Ω)	MATCHED SETS	TYPICAL APPLICATIONS			
		min	max	(V)	ratio	V1 to V2		max	%	TV	VCO	SAT.	STB
Matched													
BB132	SOD323	2.3	2.75	28	26	0.5	28	2	1	X			X
BB133	SOD323	2.2	2.75	28	16	0.5	28	0.9	0.7	X			X
BB147	SOD323	2.4	2.80	28	40	0.5	28	2.8	2	X			X
BB148	SOD323	2.4	2.75	28	15	1	28	0.9	1	X			X
BB152	SOD323	2.48	2.89	28	>20.6	1	28	1.2	2	X			X
BB153	SOD323	2.36	2.75	28	>13.5	1	28	0.8	2	X			X
BB157	SOD323	2.57	2.92	25	11	2	25	0.75	2	X			X
BB157/TM	SOD323	2.57	2.92	25	11	2	25	0.75	2	X			X
BB164	SOD323	2.9	3.40	28	>19.5	1	28	1.4	2	X			X
BB178	SOD523	2.36	2.75	28	>13.5	1	28	0.8	2	X			X
BB182	SOD523	2.48	2.89	28	>20.6	1	28	1.2	2	X			X
BB187	SOD523	2.57	2.92	25	11	2	25	0.75	2	X			X
Unmatched													
BB131	SOD323	0.7	1.055	28	14	0.5	28	3				X	
BB158	SOD323	2.4	2.75	28	15	1	28	0.9		X		X	
BB181	SOD523	0.7	1.055	28	14	0.5	28	3				X	
BBY40	SOT23	4.3	6.00	25	5.5	3	25	0.7	-	X			X
BBY42	SOT23	2.4	3.00	28	14	1	28	1	-	X			X

7.3 Product portfolio: Varicap diodes

VCO Varicap diodes

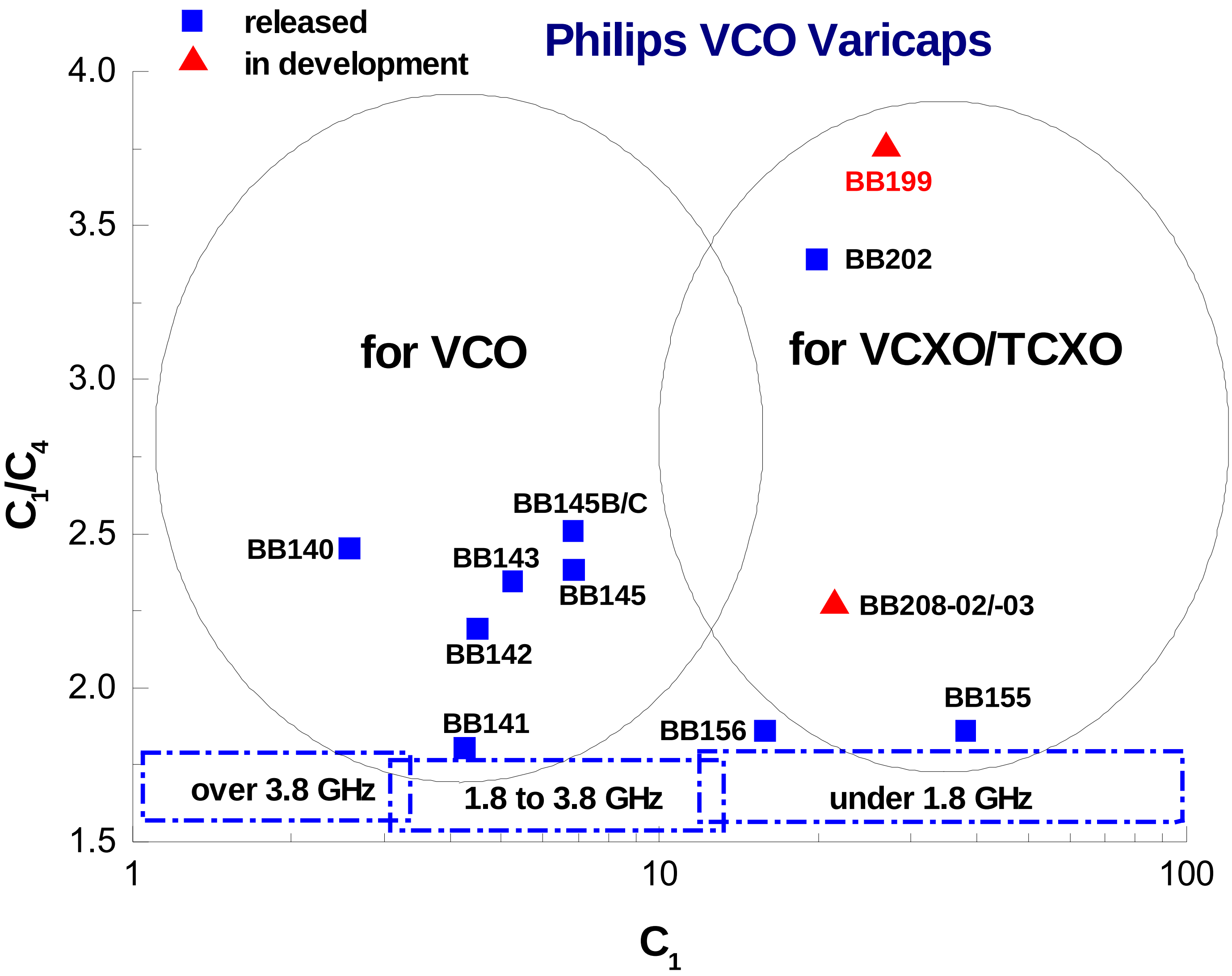
Type	Package	Cd @ Vr (pF)			Cd @ Vr (pF)			TUNING RANGE Cd over voltage range (V)			rs (Ω)
		min	max	(V)	min	max	(V)	ratio	V1 to V2		typ.
BB145B-01	SOD723	6.4	7.4	1	2.55	2.95	4	>2.2	1	4	0.6
BB140-01	SOD723	2.48	2.69	1	1.27	1.38	3	1.88 - 2.04	1	3	1.2
BB140L	SOD882	2.48	2.69	1	1.27	1.38	3	1.88 - 2.04	1	3	1.2
BB141	SOD523	3.9	4.5	1	2.22	2.55	4	1.76	1	4	0.4
BB142	SOD523	4	4.9	1	1.85	2.35	4	2.2	1	4	0.5
BB143	SOD523	4.75	5.75	1	2.05	2.55	4	2.35	1	4	0.5
BB145	SOD523	6.4	7.4	1	2.75	3.25	4	2	1	4	0.6
BB145B	SOD523	6.4	7.4	1	2.55	2.95	4	.2.2	1	4	0.6
BB145C	SOD523	6.4	7.2	1	2.55	2.85	4	2.39 - 2.53	1	4	
BB202	SOD523	28.2	33.5	0.2	7.2	11.2	2.3	2.5	0.2	2.3	0.35
BB151	SOD323	15.4	17	1	9 typ.		4	1.8	1	4	0.4
BB156	SOD323	14.4	17.6	1	7.6	9.6	4	1.86	1	4	0.4
BB155	SOD323	45.2	49.8	0.3	24.55	26.70	2.82	-	-	-	0.35

Radio Varicap diodes FM radio tuning

Type	Package	Cd @ Vr (pF)			Cd @ Vr (pF)			TUNING RANGE Cd over voltage range (V)			rs (Ω)
		min	max	(V)	min	max	(V)	ratio (min)	V1 to V2		typ.
BB804	SOT23	42	46.5	2	26 typ.		8	1.75	2	8	0.2
BB200	SOT23	65.8	74.2	1	12	14.8	4.5	5	1	4.5	0.43
BB201	SOT23	89	102	1	25.5	29.7	7.5	3.1	1	7.5	0.3
BB202	SOD523	28.2	33.5	0.2	7.2	11.2	2.3	2.5	0.2	2.3	0.35
BB156	SOD323	14.4	17.6	1	7.6	9.6	4	3.3	1	7.5	0.4

7.3 Product portfolio: Varicap diodes

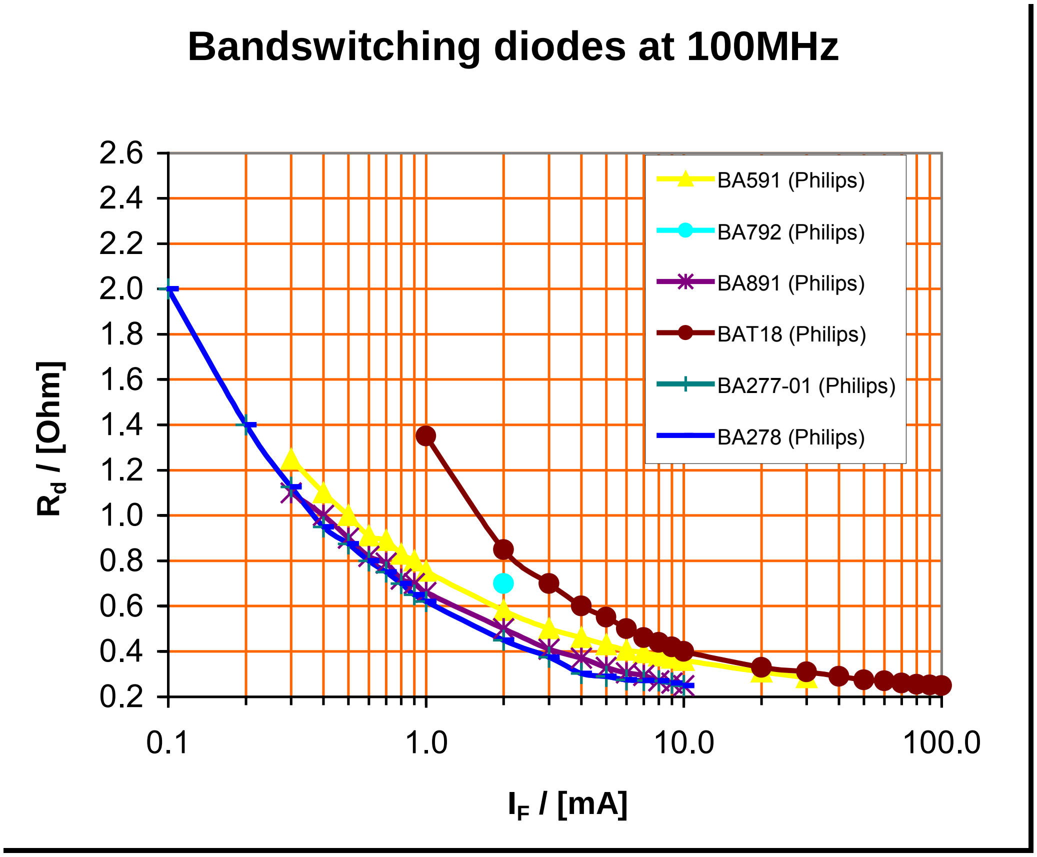
VCO / VCXO / TCXO Varicap overview



7.4 Product portfolio: Bandswitch diodes

Band Switch diodes

Type	Package	MAXIMUM RATINGS		CHARACTERISTICS ; maximals					
		VR (V)	IF (mA)	Rd	@ IF and	f	Cd	@ VR and	f
				Ω	(mA)	(MHz)	(pF)	(V)	(MHz)
BA277-01	SOD723	35	100	0.7	2	100	1.2	6	1
BA277	SOD523	35	100	0.7	2	100	1.2	6	1
BA278	SOD523	35	100	0.7	2	100	1.2	6	1
BA891	SOD523	35	100	0.7	3	100	0.9	3	1
BA591	SOD323	35	100	0.7	3	100	0.9	3	1
BA792	SOD110	35	100	0.7	3	200	1.1	3	1 to 100
BAT18	SOT23	35	100	0.7	5	200	1.0	20	1



7.5 Product portfolio: Fet's

N-channel Junction Field-effect transistors for switching

Type	Package	V_{DS}	I_G	CHARACTERISTICS										
				I_{DSS}		$V_{(p)GS}$		R_{DSON}	Crs		t_{on}		t_{off}	
		(V)	(mA)	(mA)		(V)		( )	(Pf)		(ns)		(ns)	
		max	max	min	max	min	max	max	min	max	typ	max	typ	max
BSR56	SOT23	40	50	50	-	4	10	25	-	5	-	-	-	25
BSR57	SOT23	40	50	20	100	2	6	40	-	5	-	-	-	50
BSR58	SOT23	40	50	8	80	0.8	4	60	-	5	-	-	-	100
PMBFJ108	SOT23	25	50	80	-	3	10	8	-	15	4	-	6	-
PMBFJ109	SOT23	25	50	40	-	2	6	12	-	15	4	-	6	-
PMBFJ110	SOT23	25	50	10	-	0.5	4	18	-	15	4	-	6	
PMBFJ111	SOT23	40	50	20	-	3	10	30	-	typ.3	13	-	35	-
PMBFJ112	SOT23	40	50	5	-	1	5	50	-	typ.3	13	-	35	-
PMBFJ113	SOT23	40	50	2	-	0.5	3	100	-	typ.3	13	-	35	-
J108	SOT54	25	50	80	-	3	10	8	-	15	4	-	6	-
J109	SOT54	25	50	40	-	2	6	12	-	15	4	-	6	-
J110	SOT54	25	50	10	-	0.5	4	18	-	15	4	-	6	
J111	SOT54	40	50	20	-	3	10	30	-	typ.3	13	-	35	-
J112	SOT54	40	50	5	-	1	5	50	-	typ.3	13	-	35	-
J113	SOT54	40	50	2	-	0.5	3	100	-	typ.3	13	-	35	-
PMBF4391	SOT23	40	50	50	150	4	10	30	-	3.5	-	15	-	20
PMBF4392	SOT23	40	50	25	75	2	5	60	-	3.5	-	15	-	35
PMBF4393	SOT23	40	50	5	30	0.5	3	100	-	3.5	-	15	-	50
PN4392	SOT54	40	50	25	-	2	5	60	-	5	-	15	-	35
PN4393	SOT54	40	50	5	-	0.5	3	100	-	5	-	15	-	50

P-channel Junction Field-effect transistors for switching

Type	Package	V_{DS}	I_G	CHARACTERISTICS										
				I_{DSS}		$V_{(p)GS}$		R_{DSON}	Crs		t_{on}		t_{off}	
		(V)	(mA)	(mA)		(V)		( )	(Pf)		(ns)		(ns)	
		max	max	min	max	min	max	max	min	max	typ	max	typ	max
PMBFJ174	SOT23	30	50	20	135	5	10	85	typ.4		7	-	15	-
PMBFJ175	SOT23	30	50	7	70	3	6	125	typ.4		15	-	30	-
PMBFJ176	SOT23	30	50	2	35	1	4	250	typ.4		35	-	35	-
PMBFJ177	SOT23	30	50	1.5	20	0.8	2.25	300	typ.4		45	-	45	-
J174	SOT54	30	50	20	135	5	10	85	typ.4		7	-	15	-
J175	SOT54	30	50	7	70	3	6	125	typ.4		15	-	30	-
J176	SOT54	30	50	2	35	1	4	250	typ.4		35	-	35	-
J177	SOT54	30	50	1.5	20	0.8	2.25	300	typ.4		45	-	45	-

7.5 Product portfolio: Fet's

N-channel Junction Field-effect transistors

Type	Package	CHARACTERISTICS									
		V_{DS}	I_G	I_{DSS} (mA)		$V_{(p)GS}$ (V)		|Yfs| (mS)		Crs (Pf)	
		(V)	(Ma)	min	max	min	max	min	max	min	max
DC, LF and HF amplifiers											
BF245A	SOT54	30	10	2	6.5	<8		3	6.5	1.1	-
BF245B	SOT54	30	10	6	15	<8		3	6.5	1.1	-
BF245C	SOT54	30	10	12	25	<8		3	6.5	1.1	-
BF545A	SOT23	30	10	2	6.5	0.4	7.5	3	6.5	0.8	-
BF545B	SOT23	30	10	6	15	0.4	7.5	3	6.5	0.8	-
BF545C	SOT23	30	10	12	25	0.4	7.5	3	6.5	0.8	-
BF556A	SOT23	30	10	3	7	0.5	7.5	4.5		0.8	-
BF556B	SOT23	30	10	6	13	0.5	7.5	4.5		0.9	-
BF556C	SOT23	30	10	11	18	0.5	7.5	4.5		0.8	-
Preamplifiers for AM tuners in car radios											
BF861A	SOT23	25	10	2	6.5	0.2	1.0	12		2.1	2.7
BF861B	SOT23	25	10	6	15	0.5	1.5	16		2.1	2.7
BF861C	SOT23	25	10	12	25	0.8	2	20		2.1	2.7
BF862	SOT23	20	10	13	25	<20		35		2.5	-
RF stages FM portables, car radios, main radios & mixer stages											
BF510$^{1)}$	SOT23	20	10	0.7	3	typ. 0.8		2.5		0.4	0.5
BF511$^{1)}$	SOT23	20	10	2.5	7	typ. 1.5		4		0.4	0.5
BF512$^{1)}$	SOT23	20	10	6	12	typ. 2.2		6		0.4	0.5
BF513$^{1)}$	SOT23	20	10	10	18	typ. 3		7		0.4	0.5
Low level general purpose amplifiers											
BFR30	SOT23	25	5	4	10	<5		1	4	1.5	-
BFR31	SOT23	25	5	1	5	<2.5		1.5	4.5	1.5	-
General purpose amplifiers											
BFT46	SOT23	25	5	0.2	1.5	<1.2		>1		1.5	-
AM input stages UHF/VHF amplifiers											
PMBFJ308	SOT23	25	50	12	60	1	6.5	>10		1.3	2.5
PMBFJ309	SOT23	25	50	12	30	1	4	>10		1.3	2.5
PMBFJ310	SOT23	25	50	24	60	2	6.5	>10		1.3	2.5

N-channel, single MOS-FETS for switching

Type	Package	V_{DS}	CHARACTERISTICS														MODE
			I_D	I_{DSS} (mA)		$V_{(p)GS}$ (V)		R_{DSON} ( )	Crs (Pf)		t_{on} (ns)		t_{off} (ns)		$\|S_{21(on)}\|^2$ (dB)	$\|S_{21(off)}\|^2$ (dB)	
		(V)	(Ma)	min	max	min	max	max	min	max	typ	max	typ	max	max	min	
BSD22	SOT143	20	50	-	-	-	2	30	typ.0.6		-	1	-	5	-		depl.
BSS83	SOT143	10	50	-	-	0.1$^{2)}$	2$^{1)}$	45	typ.0.6		-	1	-	5	-	-	enh.
Silicon RF Switches																	
BF1107	SOT23	3	10	-	100$^{3)}$	-	7$^{4)}$	20	-	-	-	-	-	-	2.5	30	depl.
BF1108$^{5)}$	SOT143B	3	10	-	100$^{3)}$		7$^{4)}$	20	-	-	-	-	-	-	3	30	depl.
BF1108R$^{5)}$	SOT143R	3	10	-	100$^{3)}$		7$^{4)}$	20	-	-	-	-	-	-	3	30	depl.

7.5 Product portfolio: Fet’s

1) Asymmetrical
2) $V_{GS(th)}$
3) I_D
4) V_{SG}
5) Depletion FET plus diode in one package
6) V_{GS}(th)
7) @ 200 mhZ
8) C_{OSS}
9) Cig
10) Two equal dual gate MOS-FETs in one package
11) Two low noise gain amplifiers in one package
12) Transistor A: fully internal bias, transistor B: partly internal bias

N-channel, Dual Gate MOS-FETS

Type	Package	V_{DS}	CHARACTERISTICS											
			I_D	I_{DSS}		$V_{(p)GS}$		|Yfs|		Cis	Cos	F @ 800 MHz	VHF	UHF
				(mA)		(V)		(mS)		(pF)	(pF)	(dB)		
		(V)	(mA)	min	max	min	max	min	max	typ.	typ.	typ.		
With external bias														
BF901	SOT143	12	30	2	18	-	0.7[6]	25	-	2.35	1.4	1.7	X	X
BF901R	SOT143R	12	30	2	18	-	0.7[6]	25	-	2.35	1.4	1.7	X	X
BF908	SOT143	12	40	3	27	-	2	36	-	3.1	1.7	1.5	X	X
BF908R	SOT143R	12	40	3	27	-	2	36	-	3.1	1.7	1.5	X	X
BF908WR	SOT343R	12	40	3	27	-	2	36	-	3.1	1.7	1.5	X	X
BF991	SOT143	20	20	4	25	-	2.5	10	-	2.1	1.1	0.7[7]	X	
BF992	SOT143	20	40	-	-	-	1.3	20	-	4	2	1.2[7]	X	
BF994S	SOT143	20	30	4	20	-	2.5	15	-	2.5	1	1[7]	X	
BF996S	SOT143	20	30	4	20	-	2.5	15	-	2.3	0.8	1.8		X
BF998	SOT143	12	30	2	18	-	2.5	21	-	2.1	1.05	1	X	X
BF998R	SOT143R	12	30	2	18	-	2.5	21	-	2.1	1.05	1	X	X
BF998WR	SOT343R	12	30	2	18	-	2.5	22	-	2.1	1.05	1	X	X
Fully internal bias														
BF1105	SOT143	7	30	8	16	-	-	25	-	2.2[9]	1.2[8]	1.7	X	X
BF1105R	SOT143R	7	30	8	16	-	-	25	-	2.2[9]	1.2[8]	1.7	X	X
BF1105WR	SOT343R	7	30	8	16	-	-	25	-	2.2[9]	1.2[8]	1.7	X	X
BF1109	SOT143	11	30	8	16	-	1.2[6]	24	-	2.2[9]	1.3[8]	1.5	X	X
BF1109R	SOT143R	11	30	8	16	-	1.2[6]	24	-	2.2[9]	1.3[8]	1.5	X	X
BF1109WR	SOT343R	11	30	8	16	-	1.2[6]	24	-	2.2[9]	1.3[8]	1.5	X	X

7.5 Product portfolio: Fet's

1) Asymmetrical
2) $V_{GS(th)}$
3) I_D
4) V_{SG}
5) Depletion FET plus diode in one package
6) V_{GS}(th)
7) @ 200 mhZ
8) C_{OSS}
9) Cig
10) Two equal dual gate MOS-FETs in one package
11) Two low noise gain amplifiers in one package
12) Transistor A: fully internal bias, transistor B: partly internal bias

*** At the moment of publishing of this RF Manual, these new MOSFET's were close to the end of the development stage. Minor changes to the published parameters are still possible.**

N-channel, Dual Gate MOS-FETS

Type	Package	V_{DS}	CHARACTERISTICS											
			I_D	I_{DSS}		$V_{(p)GS}$		$\lvert Y_{fs}\rvert$		Cis	Cos	F @ 800 MHz	VHF	UHF
				(mA)		(V)		(mS)		(pF)	(pF)	(dB)		
		(V)	(mA)	min	max	min	max	min	max	typ.	typ.	typ.		
Partly internal bias														
BF904(A)	SOT143	7	30	8	13	-	1$^{6)}$	22	-	2.2	1.3	2	X	X
BF904(A)R	SOT143R	7	30	8	13	-	1$^{6)}$	22	-	2.2	1.3	2	X	X
BF904(A)WR	SOT343R	7	30	8	13	-	1$^{6)}$	22	-	2.2	1.3	2	X	X
BF909(A)	SOT143	7	40	12	20	-	1$^{6)}$	36	-	3.6	2.3	2	X	X
BF909(A)R	SOT143R	7	40	12	20	-	1$^{6)}$	36	-	3.6	2.3	2	X	X
BF909(A)WR	SOT343R	7	40	12	20	-	1$^{6)}$	36	-	3.6	2.3	2	X	X
BF1100	SOT143	14	30	8	13	-	1$^{6)}$	24	-	2.2	1.4	2	X	X
BF1100R	SOT143R	14	30	8	13	-	1$^{6)}$	24	-	2.2	1.4	2	X	X
BF1100WR	SOT343R	14	30	8	13	-	1$^{6)}$	24	-	2.2	1.4	2	X	X
BF1101	SOT143	7	30	8	16	-	1$^{6)}$	25	-	2.2	1.2$^{8)}$	1.7	X	X
BF1101R	SOT143R	7	30	8	16	-	1$^{6)}$	25	-	2.2	1.2$^{8)}$	1.7	X	X
BF1101WR	SOT343R	7	30	8	16	-	1$^{6)}$	25	-	2.2	1.2$^{8)}$	1.7	X	X
BF1102(R)	SOT363	7	40	12	20	-	1.2$^{6)}$	36	-	2.8$^{9)}$	1.6$^{8)}$	2	Note 10	
BF1201	SOT143	10	301	11	19	-	1.2$^{6)}$	23	-	2.6	0.9	1.9	X	X
BF1201R	SOT143R	10	301	11	19	-	1.2$^{6)}$	23	-	2.6	0.9	1.9	X	X
BF1201WR	SOT343R	10	301	11	19	-	1.2$^{6)}$	23	-	2.6	0.9	1.9	X	X
BF1202	SOT143	10	30	8	16	-	1.2$^{6)}$	25	-	1.7	0.85	1	X	X
BF1202R	SOT143R	10	30	8	16	-	1.2$^{6)}$	25	-	1.7	0.85	1	X	X
BF1202WR	SOT343R	10	30	8	16	-	1.2$^{6)}$	25	-	1.7	0.85	1	X	X
BF1203$^{11)}$	SOT363	10	30	11	19	-	1.2$^{6)}$	23	-	2.6	0.9	1.8	X	X
BF1204$^{11)}$	SOT363	10	30	8	16	-	1.2$^{6)}$	25	-	1.7	0.85	1	X	X
BF1205 * $^{11) 12)}$	SOT363	10	30	8	16	0.3	1.0	26	40	1.8	0.75	1.2	X	-
		7	30	8	16	0.3	1.0	26	40	2.0	0.85	1.4	-	X
BF1206 * $^{11)}$	SOT363	6	30	14	23	0.3	1.0	33	45	2.6	1.1	1.6	X	-
		6	30	9	17	0.3	1.0	29	41	1.9	0.85	1.4	-	X
BF1211 *	SOT143	6	30	11	19	0.3	1.0	25	40	2.1	0.9	1.4	X	-
BF1211R *	SOT143R	6	30	11	19	0.3	1.0	25	40	2.1	0.9	1.4	X	-
BF1211WR *	SOT343	6	30	11	19	0.3	1.0	25	40	2.1	0.9	1.4	X	-
BF1212 *	SOT143	6	30	8	16	0.3	1.0	28	43	1.7	0.9	1.1	-	X
BF1212R *	SOT143R	6	30	8	16	0.3	1.0	28	43	1.7	0.9	1.1	-	X
BF1212WR *	SOT343	6	30	8	16	0.3	1.0	28	43	1.7	0.9	1.1	-	X

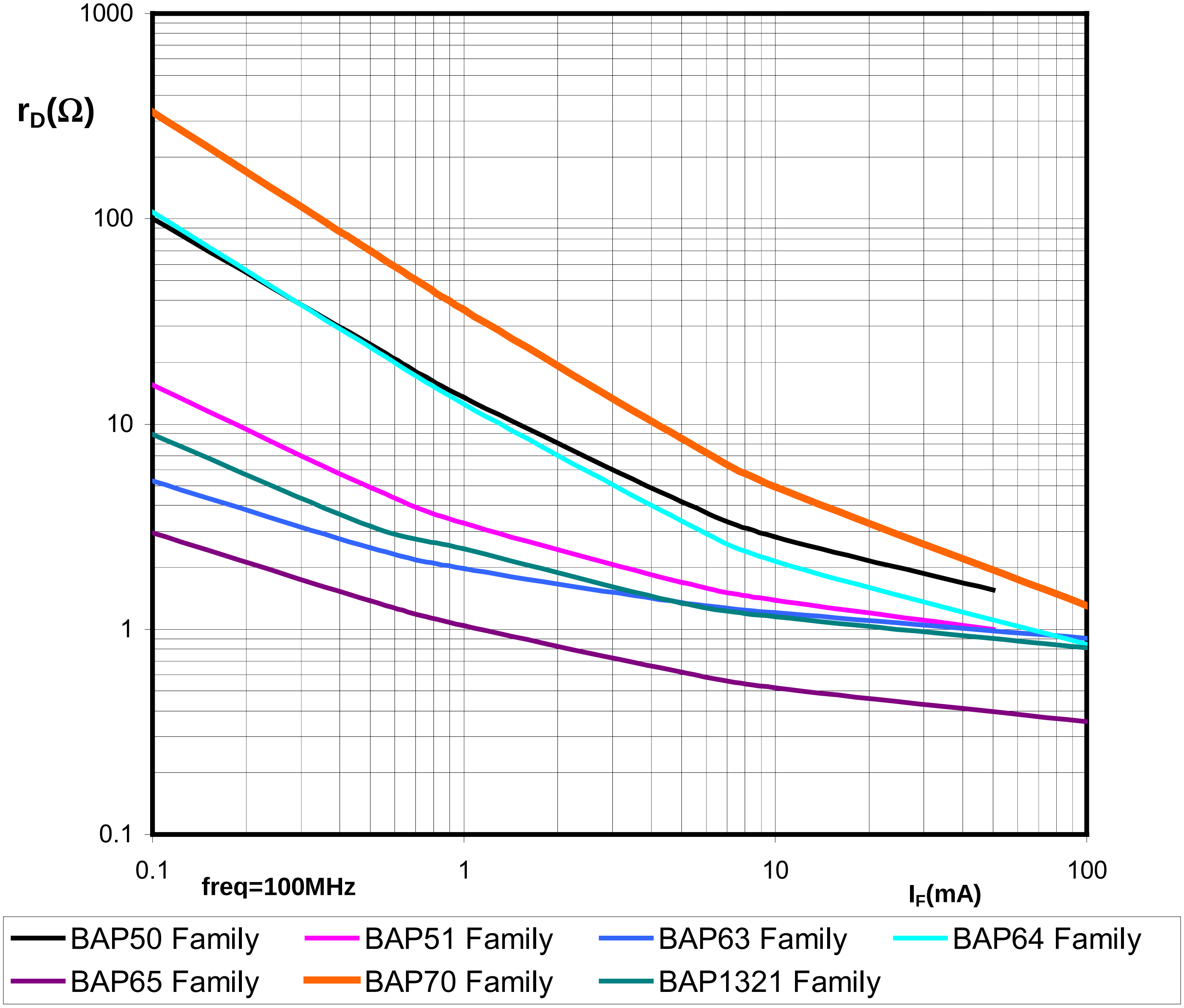
7.6 Product portfolio: Pin diodes

Pin diodes

Type	Package	Conf	Limits		RD (Ω) typ @			Cd (pF) type @		
			Vr(V)	If(mA)	0.5mA	1 mA	10 mA	0V	1V	20V
BAP27-01	SOD723	S	20	50	1.7	1.3	0.7	0.55	0.45	0.37
BAP50-02	SOD523	S	50	50	25	14	3	0.4	0.3	0.22 @ 5V
BAP50-03	SOD323	S	50	50	25	14	3	0.4	0.3	0.2 @ 5V
BAP50-04	SOT23	SS	50	50	25	14	3	0.45	0.35	0.3 @ 5V
BAP50-04W	SOT323	SS	50	50	25	14	3	0.45	0.35	0.3 @ 5V
BAP50-05	SOT23	CC	50	50	25	14	3	0.45	0.35	0.3 @ 5V
BAP50-05W	SOT323	CC	50	50	25	14	3	0.45	0.35	0.3 @ 5V
BAP51-01	SOD723	S	60	60	5.5	3.6	1.5	0.4	0.3	0.2 @ 5V
BAP51-02	SOD523	S	60	60	5.5	3.6	1.5	0.4	0.3	0.2 @ 5V
BAP51-03	SOD323	S	60	60	5.5	3.6	1.5	0.4	0.3	0.2 @ 5V
BAP51-05W	SOT323	CC	60	60	5.5	3.6	1.5	0.4	0.3	0.2 @ 5V
BAP63-01	SOD723	S	50	100	2.5	1.95	1.17	0.36	0.32	0.25
BAP63-02	SOD523	S	50	100	2.5	1.95	1.17	0.36	0.32	0.25
BAP63-03	SOD323	S	50	100	2.5	1.95	1.17	0.4	0.35	0.27
BAP63-05W	SOT323	CC	50	100	2.5	1.95	1.17	0.4	0.35	0.3
BAP64-02	SOD523	S	200	175	20	10	2	0.52	0.37	0.23
BAP64-03	SOD323	S	200	175	20	10	2	0.52	0.37	0.23
BAP64-04	SOT23	SS	200	175	20	10	2	0.52	0.37	0.23
BAP64-04W	SOT323	SS	200	100	20	10	2	0.52	0.37	0.23
BAP64-05	SOT23	CC	200	175	20	10	2	0.52	0.37	0.23
BAP64-05W	SOT323	CC	200	100	20	10	2	0.52	0.37	0.23
BAP64-06	SOT23	CA	200	175	20	10	2	0.52	0.37	0.23
BAP64-06W	SOT323	S	100	100	20	10	2	0.52	0.37	0.23
BAP65-01	SOD723	S	30	100		1	0.56	0.65	0.6	0.375
BAP65-02	SOD523	S	30	100		1	0.56	0.65	0.6	0.375
BAP65-03	SOD323	S	30	100		1	0.56	0.65	0.6	0.375
BAP65-05	SOT23	CC	30	100		1	0.56	0.65	0.6	0.375
BAP65-05W	SOT323	CC	30	100		1	0.56	0.65	0.6	0.375
BAP70-02	SOD523	S	70	100	70	27	4.5	0.29	0.2	0.125
BAP70-03	SOD323	S	70	100	70	27	4.5	0.29	0.2	0.125
BAP1321-01	SOD723	S	60	100	3.4	2.4	1.2	0.4	0.35	0.25
BAP1321-02	SOD523	S	60	100	3.4	2.4	1.2	0.4	0.35	0.25
BAP1321-03	SOD323	S	60	100	3.4	2.4	1.2	0.4	0.35	0.25
BAP1321-04	SOT23	SS	60	100	3.4	2.4	1.2	0.4	0.35	0.25

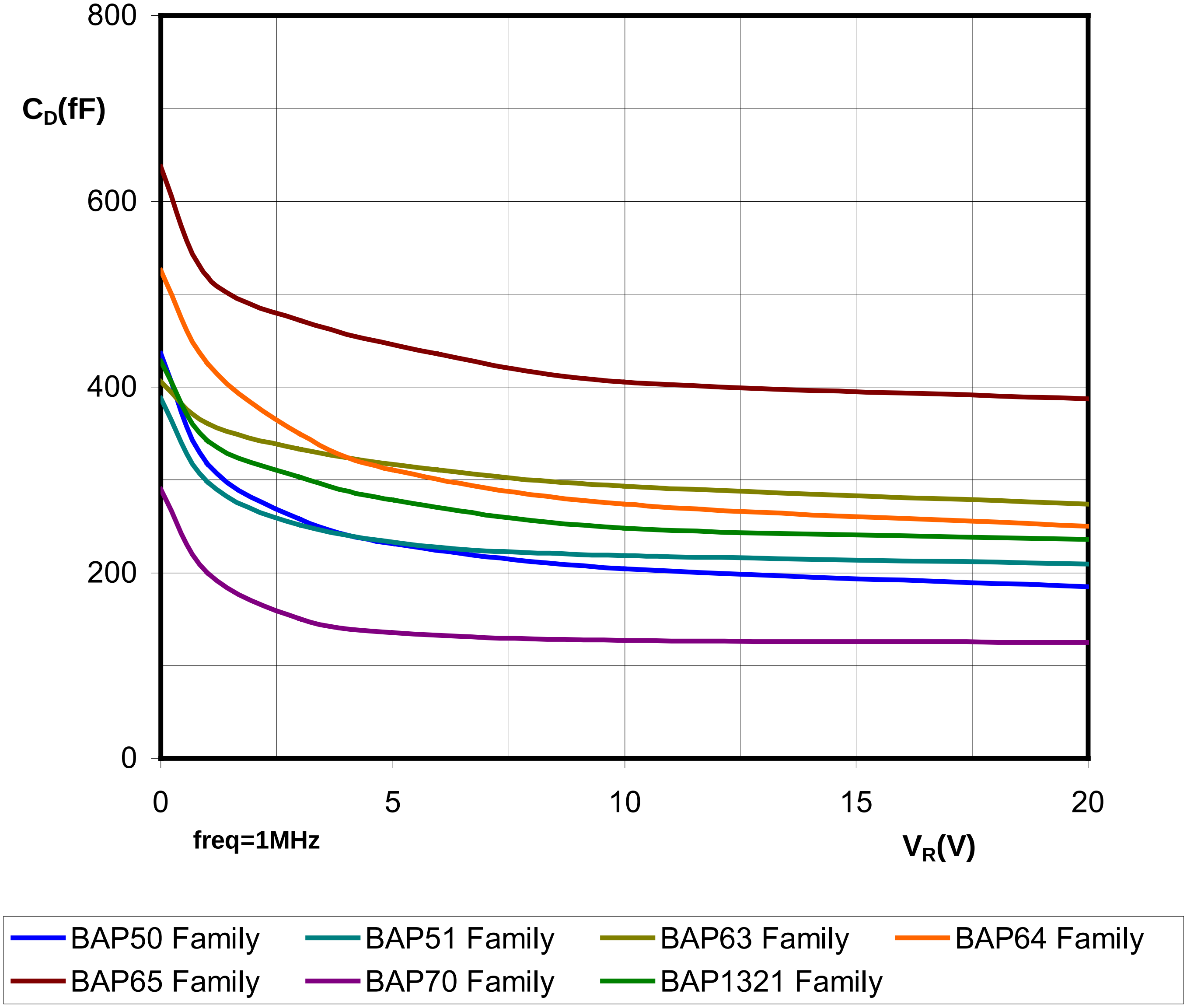
7.6 Product portfolio: Pin diodes

Series resistance as a function of forward current.



7.6 Product portfolio: Pin diodes

Diode capacitance as a function of reverse voltage.



8. X-references

Alphabetical order on competitor type

column 1: abbr. competitor, column 2: competitor type, column 3: closest Philips type

Competitor abbr.: AG=Agilent, AL=Alpha, HI=Hitachi, IS=Industry Standard, IN=Infineon, MA=Matsushita, MO=Motorola, NE=NEC, RO=Rohm, SA=Sanyo, SO=Sony, TO=Toko, TS=Toshiba, VI=Vishay

■ = Exact drop in, ▲ Different package

TS	1SS314	BA591 ■
RO	1SS356	BA591 ■
TS	1SS381	BA277 ■
RO	1SS390	BA891 ■
TS	1SV172	BAP50-04 ■
TS	1SV214	BB149
TS	1SV214	BB149A
TS	1SV215	BB153
TS	1SV217	BB133
TS	1SV228	BB201 ■
TS	1SV229	BB190
TS	1SV231	BB132 ■
TS	1SV231	BB152
TS	1SV232	BB148
SA	1SV233	BAP70-03 ▲
SA	1SV234	BAP64-04
TS	1SV239	BB145B
SA	1SV241	2xBAP64-02 ▲
TS	1SV242	BB164
SA	1SV246	BAP64-04W
SA	1SV247	BAP70-02 ▲
SA	1SV248	BAP50-02 ▲
SA	1SV249	BAP50-04W
SA	1SV250	BAP50-03 ▲
SA	1SV251	BAP50-04
TS	1SV252	BAP50-04W ■
TS	1SV254	BB179
TS	1SV262	BB133
SA	1SV263	BAP50-02 ▲
SA	1SV264	BAP50-04W ■
SA	1SV266	BAP50-03 ▲
SA	1SV267	BAP50-04 ■
TS	1SV269	BB148
TS	1SV270	BB156
TS	1SV271	BAP50-03 ■
TS	1SV276	BB151
TS	1SV277	BB142
TS	1SV278	BB179
TS	1SV279	BB190
TS	1SV280	BB145
TS	1SV281	BB151
TS	1SV282	BB178
TS	1SV282	BB187
TS	1SV283	BB178
TS	1SV283	BB187
TS	1SV283	BB187 ■
TS	1SV284	BB156
TS	1SV285	BB142 ■
TS	1SV288	BB152
TS	1SV290	BB182
TS	1SV290	BB182 B
TS	1SV293	BB151
TS	1SV293	BB190 ■
SA	1SV294	BAP70-03 ▲
TS	1SV305	BB202
TS	1SV307	BAP51-03 ■
TS	1SV308	BAP51-02 ■
TS	1SV314	BB143
TS	1SV329	BB143
SO	1T362	BB149
SO	1T362 A	BB149A ■
SO	1T363 A	BB153 ■
SO	1T368	BB133
SO	1T368 A	BB148
SO	1T369	BB132
SO	1T369	BB152 ■
SO	1T369	BB164
SO	1T379	BB131
SO	1T397	BB152
SO	1T399	BB148
SO	1T402	BB179 B ■
SO	1T403	BB178 ■
SO	1T404A	BB187 ■
SO	1T405 A	BB187
SO	1T406	BB182 ■
SO	1T407	BB182B
SO	1T408	BB187 ■
IS	2N3330	J176
IS	2N3331	J176
IS	2N4091	PN4391
IS	2N4092	PN4392
IS	2N4093	PN4393
IS	2N4220	BF245A
IS	2N4391	PN4391
IS	2N4392	PN4392
IS	2N4393	PN4393
IS	2N4416	PMBF4416
IS	2N4856	BSR56
IS	2N4857	BSR57
IS	2N4858	BSR58
IS	2N5114	J174
IS	2N5115	J175
IS	2N5116	J175
IS	2N5432	J108
IS	2N5433	J108
IS	2N5434	J109
IS	2N5457	BF245A
IS	2N5458	BF245A
IS	2N5459	BF245B
IS	2N5484	PMBF5484
IS	2N5485	PMBF5485
IS	2N5486	PMBF5486
IS	2N5638	PN4391
IS	2N5639	PN4392
IS	2N5640	PN4393
IS	2N5653	J112
IS	2N5654	J111
NE	2SC4092	BFG67/XR
NE	2SC4093	BFG67/XR
NE	2SC4094	BFG520/XR
NE	2SC4095	BFG520/XR
NE	2SC4182	BFS17W
NE	2SC4184	BFS17W
NE	2SC4185	BFS17W
NE	2SC4186	BFR92AW
NE	2SC4226	PRF957
NE	2SC4227	BFQ67W
NE	2SC4228	BFS505
TS	2SC4247	BFR92AW
TS	2SC4248	BFR92AW
TS	2SC4315	BFG520/XR
TS	2SC4320	BFG520/XR
TS	2SC4321	BFQ67W
TS	2SC4325	BFS505
TS	2SC4394	PRF957
HI	2SC4463	BF547W
NE	2SC4536	BFQ19
HI	2SC4537	BFR93AW
HI	2SC4592	BFG520/XR
HI	2SC4593	BFS520
NE	2SC4703	BFQ19
HI	2SC4784	BFS505
HI	2SC4807	BFQ18A
TS	2SC4842	BFG540W/XR
HI	2SC4899	BFS505
HI	2SC4900	BFG520/XR
HI	2SC4901	BFS520
HI	2SC4988	BFQ540
NE	2SC5011	BFG540W/XR
NE	2SC5012	BFG540W/XR
TS	2SC5065	PRF957
TS	2SC5085	PRF957
TS	2SC5087	BFG520/XR
TS	2SC5088	BFG540W/XR
TS	2SC5090	BFS520
TS	2SC5092	BFG520/XR
TS	2SC5095	BFS505
TS	2SC5107	BFS505
TS	2SC5463	BFQ67W
HI	2SC5593	BFG410W
HI	2SC5594	BFG425W
HI	2SC5623	BFG410W
HI	2SC5624	BFG425W
HI	2SC5631	BFQ540
IS	2SJ105GR	J177
HI	2SK108	PN4392
HI	2SK147BL	PN4393
HI	2SK162-K	PN4393
HI	2SK162-L	PN4393
HI	2SK162-M	PN4393
HI	2SK162-N	PN4393
HI	2SK163-K	J113
HI	2SK163-L	J113
HI	2SK163-M	J113
HI	2SK163-N	J113
HI	2SK170BL	PN4393
HI	2SK170GR	PN4393
HI	2SK170V	PN4393
HI	2SK170Y	PN4393
HI	2SK197D	PMBF4416
HI	2SK197E	PMBF4416
HI	2SK2090	PMBF4416
HI	2SK209BL	PMBF4416
HI	2SK209GR	PMBF4416
HI	2SK209Y	PMBF4416
HI	2SK210BL	PMBFJ309
HI	2SK210GR	PMBF4416
HI	2SK2110	PMBF4416
HI	2SK211GR	PMBF4416
HI	2SK211Y	PMBF4416
HI	2SK212	PN4393
HI	2SK217D	PMBF4416
HI	2SK217E	PMBF4416
HI	2SK223	PN4393

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NE	uPC2771	BGA2771
NE	uPC8112	BGA2022

Online X-reference tool:

http://www.semiconductors.philips.com/products/xref/

9. Packaging

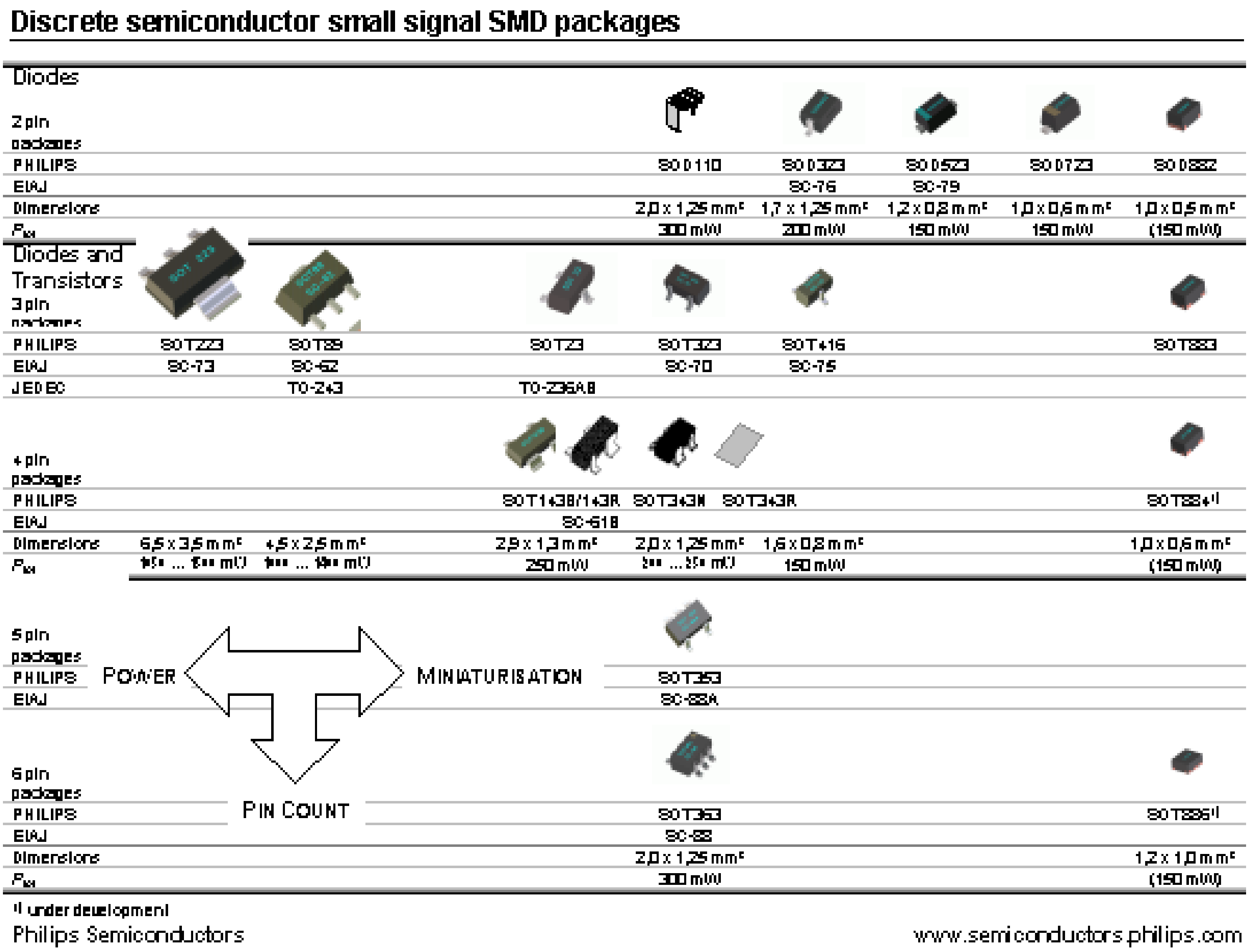
Online package information on Philips Semiconductors website:
http://www.semiconductors.philips.com/package/

- ***Why packaging***

Packaging of discrete dies has general two purposes:

- Protection of the die against hostile environmental influences
- Making the handling much easier compared to using the small naked die.

Instead of sophisticated die- and wirebonding and encapsulation of the naked die, the relatively easy process of pick and place and reflow soldering can be used.



Discrete semiconductor small signal SMD packages

Diodes

2 pin packages					
PHILIPS	SOD110	SOD323	SOD523	SOD723	SOD882
EIAJ		SC-76	SC-79		
Dimensions	2.0 x 1.25 mm²	1.7 x 1.25 mm²	1.2 x 0.8 mm²	1.0 x 0.6 mm²	1.0 x 0.5 mm²
P_{tot}	300 mW	200 mW	150 mW	150 mW	(150 mW)

Diodes and Transistors

3 pin packages						
PHILIPS	SOT223	SOT89	SOT23	SOT323	SOT416	SOT883
EIAJ	SC-73	SC-62		SC-70	SC-75	
JEDEC		TO-243	TO-236AB			
4 pin packages						
PHILIPS			SOT143B/143R	SOT343N	SOT343R	SOT884[1]
EIAJ			SC-61B			
Dimensions	6.5 x 3.5 mm²	4.5 x 2.5 mm²	2.9 x 1.3 mm²	2.0 x 1.25 mm²	1.6 x 0.8 mm²	1.0 x 0.6 mm²
P_{tot}	[illegible] ... [illegible] mW	[illegible] ... [illegible] mW	250 mW	[illegible] ... [illegible] mW	150 mW	(150 mW)

5 pin packages		
PHILIPS	SOT353	
EIAJ	SC-88A	
6 pin packages		
PHILIPS	SOT363	SOT886[1]
EIAJ	SC-88	
Dimensions	2.0 x 1.25 mm²	1.2 x 1.0 mm²
P_{tot}	300 mW	(150 mW)

[1] under development

Philips Semiconductors www.semiconductors.philips.com

10. Promotion Materials

For samples or promotion materials below, please contact your Philips Account Manager or contact person in your region, see contacts & references.

Ad * = contact Regional Sales Office

Focus	Description	Deliverable	12NC
RF General	Philips RF Manual, product & design manual for RF small signal discretes, 3rd edition and Appendix, July 2003	Manual Manual Appendix	4322 252 06384 4322 252 06385
RF General	Your peRFect discretes partner	Brochure	9397 750 04634
RF General	PeRFectly tuned in to your ideas	Brochure	9397 750 07019
RF General	Standard Products Selection Guide 2002	Guide	9397 750 09014
RF General	The peRFect connection	Brochure	9397 750 07928
RF General	Philips Semiconductors comprehensive product portfolio	CDRom	9397 750 07536
RF General	Double polysilicon	Fact sheet	9397 750 04787
Packaging	Discrete Packages 2000	Brochure	9397 750 05988
Packaging	Discrete Semiconductor Packages	Databook SC18	9397 750 05011
Tuning	RF Tuning Sample Kit (English version)	Sample kit	9397 750 10168
Tuning	RF Tuning Sample Kit (Chinese version)	Sample kit	9397 750 10606
Tuning	Small-signal Field-effect Transistors and Diodes	Databook SC07	9397 750 06017
Pin diodes	Pin diodes designed for RF applications up to 3GHz	Leaflet	9397 750 08008
Pin diodes	Pin diodes	Replacement card	9397 750 08573
Pin diodes	Pin diodes	Sample kit *	9397 750 07299
MMIC's	Optimized MMICs Gain Blocks	Leaflet	9397 750 07976
MMIC's	MMICs	Sample kit *	9397 750 09078
MMIC's	RF Wideband Transistors and MMICs	Databook SC14	9397 750 06311
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2709	Demoboard	Contact RSO
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2711	Demoboard	Contact RSO
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2712	Demoboard	Contact RSO
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2748	Demoboard	Contact RSO
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2771	Demoboard	Contact RSO
Wideband ampifiers	50 ohm gain block for IF, buffer and driver amplifier: BGA2776	Demoboard	Contact RSO
Wideband transistors	Wideband transistors	Linecard	9397 750 08634
Wideband transistors	RF Wideband Transistors and MMICs	Databook SC14	9397 750 06311
Wideband transistors	Wideband transistors	Sample kit *	9397 750 08553

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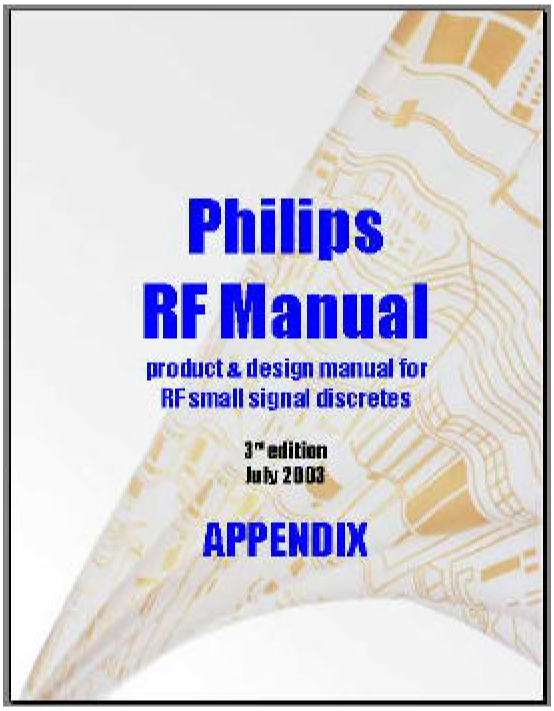
APPENDIX

In separate appendix-file !



Philips
RF Manual
product & design manual for
RF small signal discretes
3rd edition
July 2003
APPENDIX

- download appendix from internet:

http://www.philips.semiconductors.com/markets/mms/products/discretes/documentation/rf_manual

or:

- request for appendix by sending mail to:

ronald.thissen@philips.com