Philips
RF Manual

product & design manual for
RF small signal discretes

2nd edition
October 2002

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4. RF Design-basics

6. Application notes

→ **Online application notes** on Philips Semiconductors website:
http://www.semiconductors.philips.com/products/all_appnotes.html

→ **Online product catalog** on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

→ **Online cross reference tool** on Philips Semiconductors website:
http://www.semiconductors.philips.com/products/xref/

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

1. 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.

In March of this year we launched our first Philips RF Manual. We received encouraging and positive responses and understood the value of this manual. Of course, we will keep up our promise of updating the manual twice a year and present you the 2nd edition.
Also this 2nd edition of RF Manual will help you building your application. It gives an overview starting from RF basics up to and including our complete portfolio. RF Manual will be a dynamic source of information. A living document that will be updated when we feel the need to inform you on important developments for your applications.

If you are already familiar with the previous RF Manual, make sure to check next page: **'What's new'.**

Kind regards,
Henk Roelofs
Director RF Consumer Products

2. What’s New

→ **NEW RF Application & Design-basics, chapter 3/4:**
The former RF Basics have been extended and the new chapter RF Design-basics emphasises on design fundamentals like e.g.: the Smith Chart, frequency and time domain and explanation of the small signal RF amplifier parameters.

→ **NEW interactive application notes list, chapter 6:**
The total number of listed application notes has grown to 50 of which 35 have a interactive link to a individual webpage.

→ **NEW application notes, chapter 6, e.g.:**
WCDMA applications for BGA6589 Wideband Amplifier

NEW
BGA6x89
MMIC's

→ **NEW products, chapter 7:**

	NEW types	Upcomming types in development
MMIC's	BGU2003, BGM1011	**BGA6289, BGA6489, BGA6589**
Wideband transistors	BFQ591	BFU620
Varicap diodes	BB140-01	BB140L
Field effect transistors		BF1205, BF1206, BF1211, BF1211R, BF1211WR, BF1212, BF1212R, BF1212WR
Pin diodes	BAP51-01, BAP63-01, BAP65-01, BAP27-01, BAP70-02, BAP70-03, BAP1321-01	BAP51L, BAP1321L, BAP142L, BAP144L

→ **NEW update cross-references, chapter 8:**
A powerfull tool to find our parts versus the competitor parts.

→ **NEW packages, chapter 9**:
The new leadless SOD882 & SOT883, see chapter 8 packaging.

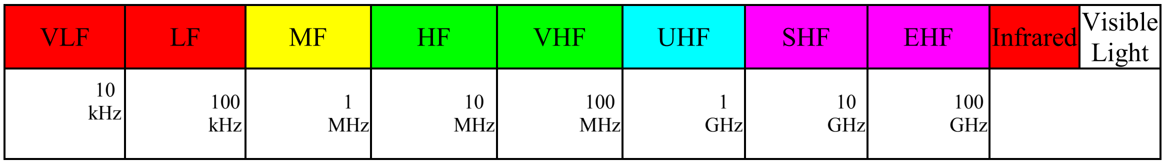
→ **NEW design support and promotional materials, chapter 10, e.g.**:
six new wideband amplifier demoboards: BGA27-serie.

→ **NEW contacts, chapter 11**:
We recently welcomed new colleagues in our regional sales organisation.

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 particles travel with the speed of light, one can determine the wavelength for each frequency.



VLF	LF	MF	HF	VHF	UHF	SHF	EHF	Infrared	Visible Light
10 kHz	100 kHz	1 MHz	10 MHz	100 MHz	1 GHz	10 GHz	100 GHz		

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

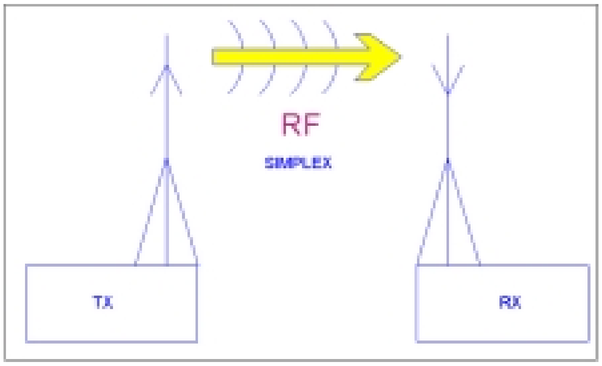
Examples of applications in different frequency ranges

Major parts of the frequencies domain are reserved to specific applications e.g. radio and TV broadcasting and cellular phone bands. The frequency ranges are country dependent.

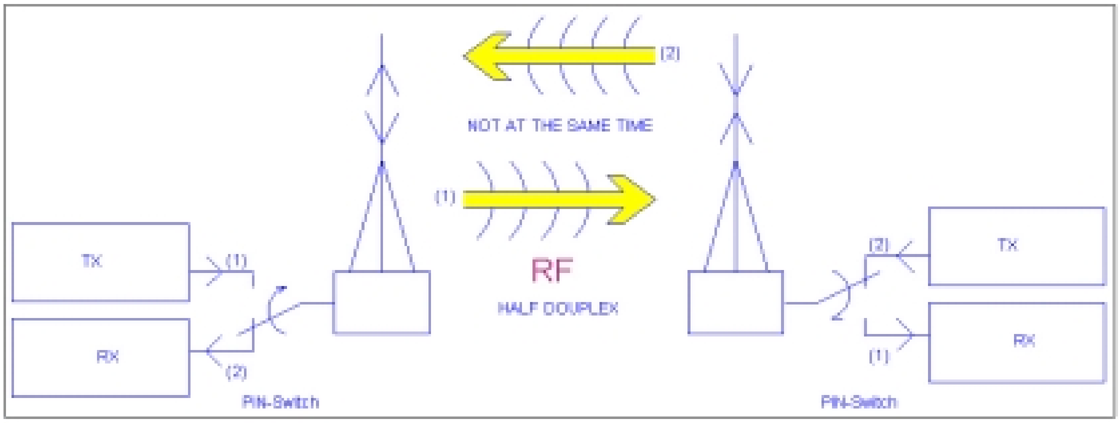
→ AM radio - 535 kHz to 1.7 MHz
→ Short wave radio - bands from 5.9 MHz to 26.1 MHz
→ Citizens band (CB) radio - 26.96 MHz to 27.41 MHz
→ Television stations - 54 to 88 MHz for channels 2 through 6
→ FM radio - 88 MHz to 108 MHz
→ Television stations - 174 to 220 MHz for channels 7 through 13
→ Garage 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

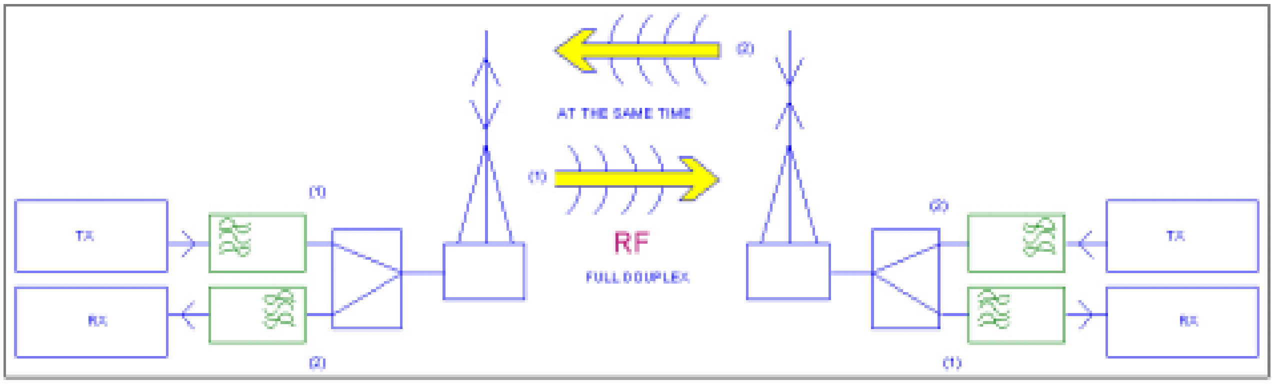
Simplex



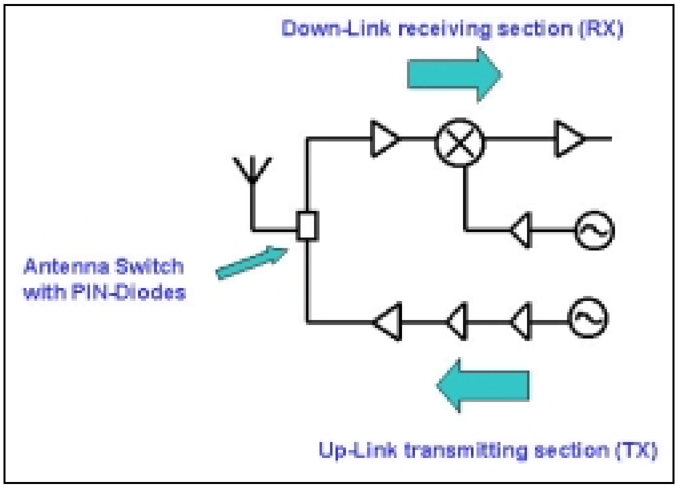
Half duplex

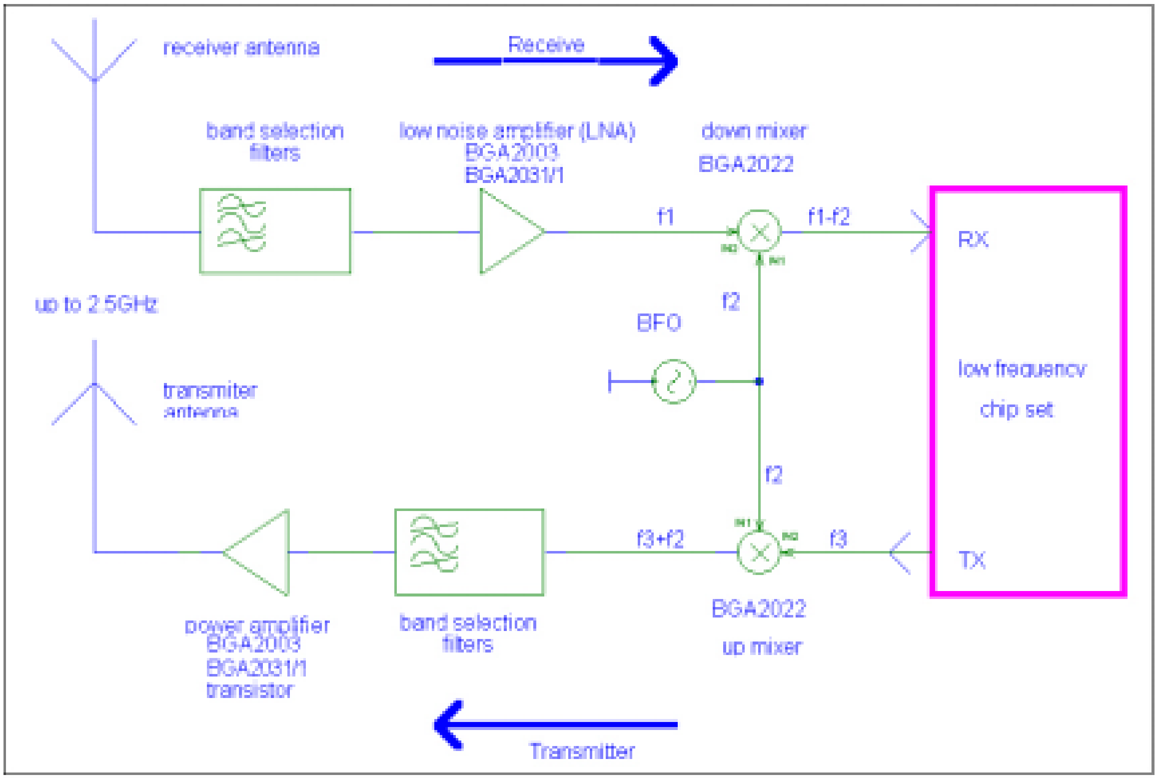


Full duplex



3.3. RF Front-End

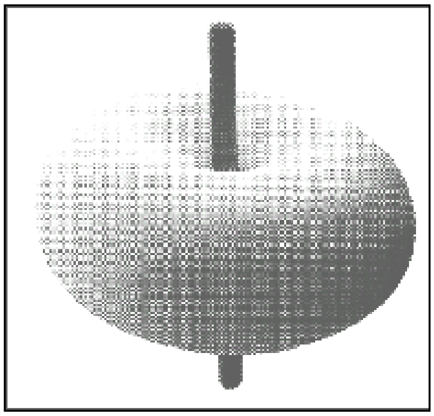




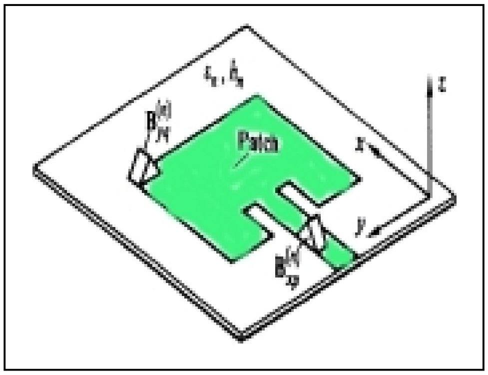
3.4 Function of an antenna

In standard application the RF output signal of a transmitter power amplifier is transported by a coaxial cable to a suitable location for mounting the antenna. Typical the coaxial cable has am impedance of 50Ω (75Ω for TV/Radio). The Ether, that is the room between the earth and infinite space has an impedance too. 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 into the Ether (the wireless transport medium) we need a power match unit. This unit is the Antenna. Depending on the frequency and specific application needs their are a lot of antenna constructions available. The easiest one is the Isotropic ball radiator (just a theoretical one and used for mathematical reference).

The next easiest and practical used antenna is the Dipole radiator consists of two sticks. Removal of one stick we get the “Vertical” radiator as illustrate side by with the field round around it.



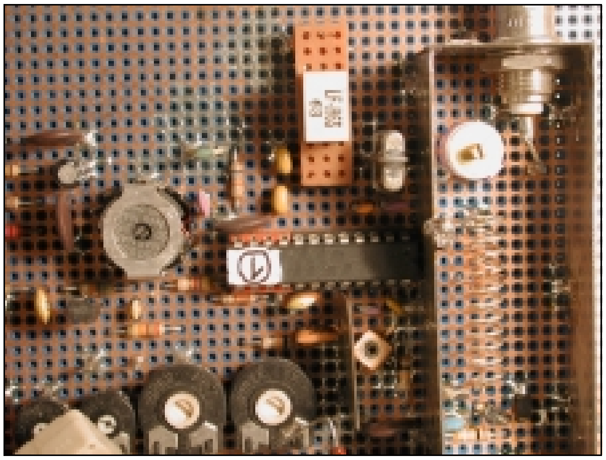
More and more integration of the circuits and reduction of the cost do influence the antenna design too. Based on the field radiation effects on printed circuit bards was developed PCB antennas called “Patch”-Antennas as illustrate side by.



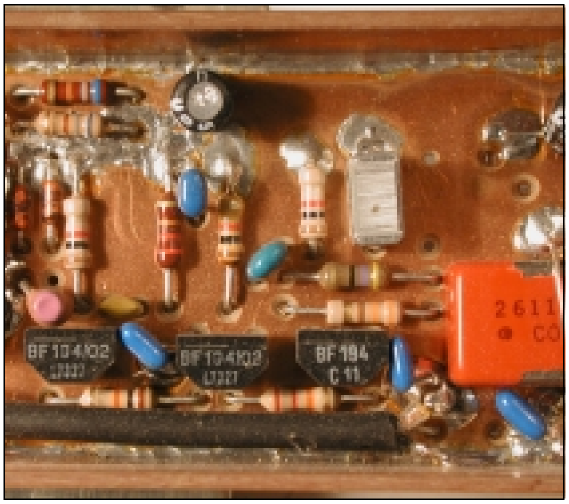
3.5 Examples of PCB design

Low frequency design	(up to some MHz)
RF design	(some MHz to some hundredths of MHz)
Microwave design	(GHz range)

3.5.1 Prototyping

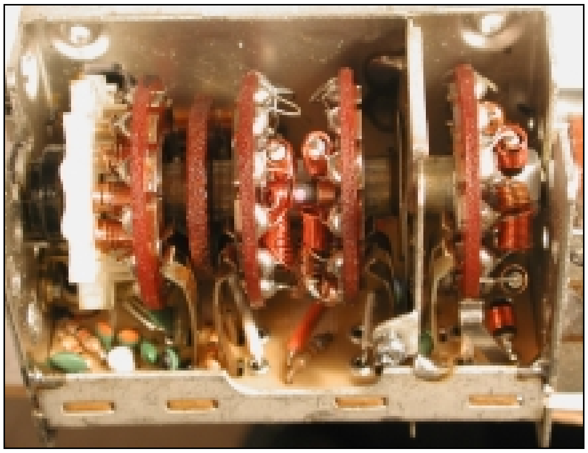


Standard RF/VHF Receiver Front-End :
Top side GND, back side manual wires

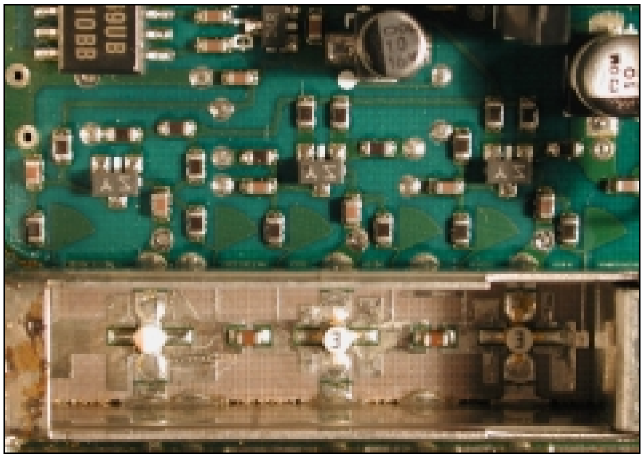


Standard RF/VHF: Top side GND, back side manual wires of an SW-antenna amplifier

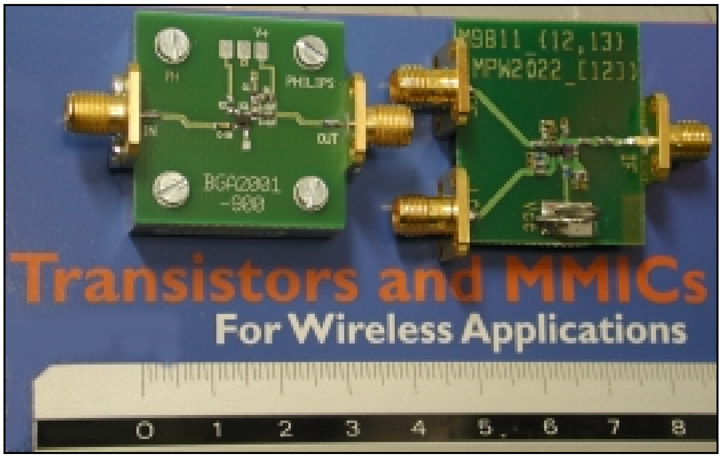
3.5.2 Final PCB



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



Microwave PCB for GHz LNA amplifier



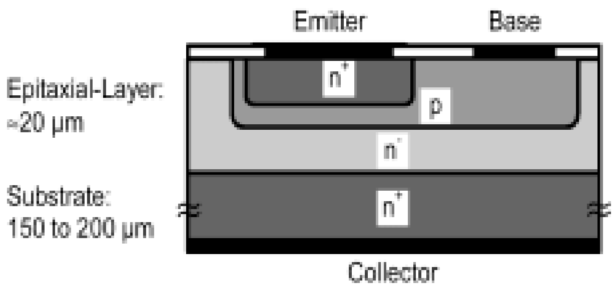
Demoboard: BGA2001 and BGA2022

3.6 Transistor Semiconductor Process

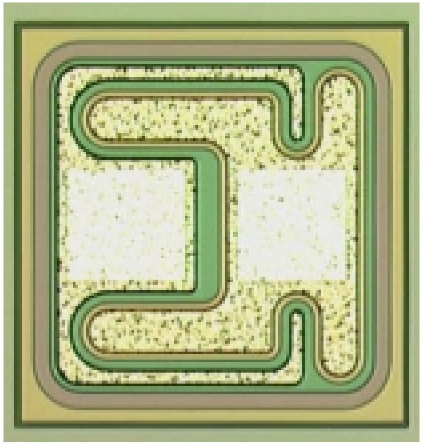
3.6.1 General-Purpose Small-signal bipolar

The transistor is built up from three different layers:

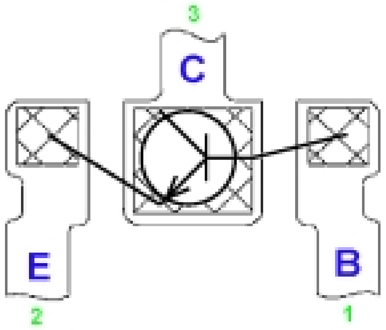
- Highly doped emitter layer
- Medium doped base area
- Low doped collector area.


NPN Transistor cross section

The highly doped substrate serves as carrier and conductor only.

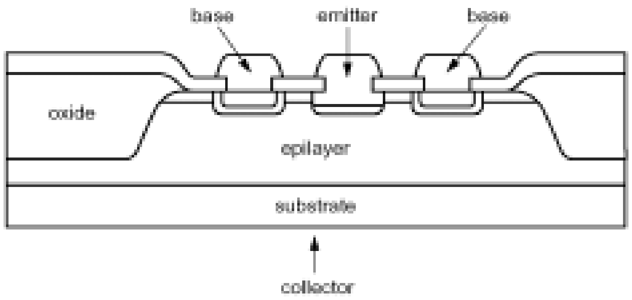

Die of BC337, BC817

During the assembly process the transistor die is attached to a lead frame by means of gluing or eutectic soldering. The emitter and base contacts are connected to the lead frame through bond wires.


SOT23 standard lead frame

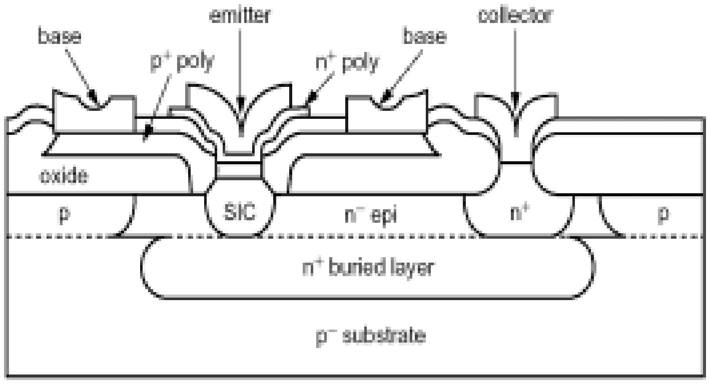
3.6.2 Double Polysilicon

For the latest Silicon based bipolar transistors and MMICs Philips' Double Polysilicon process is used. The mobile communications market and the use of ever-higher frequencies have do need 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. And, via a buried layer, the collector is brought out on the top of the die.



➢ Advantages of double-poly-Si RF process:

- Higher transition frequencies >23GHz
- Higher power gain Gmax.=22dB/2GHz
- Lower noise operation
- Higher reverse isolation
- Simpler matching
- Lower current consumption
- Optimised for low supply voltages
- High efficiency
- High linearity
- Better heat dissipation
- Higher integration for MMICs (***SSI***= **S**mall-**S**cale-***I***ntegration)

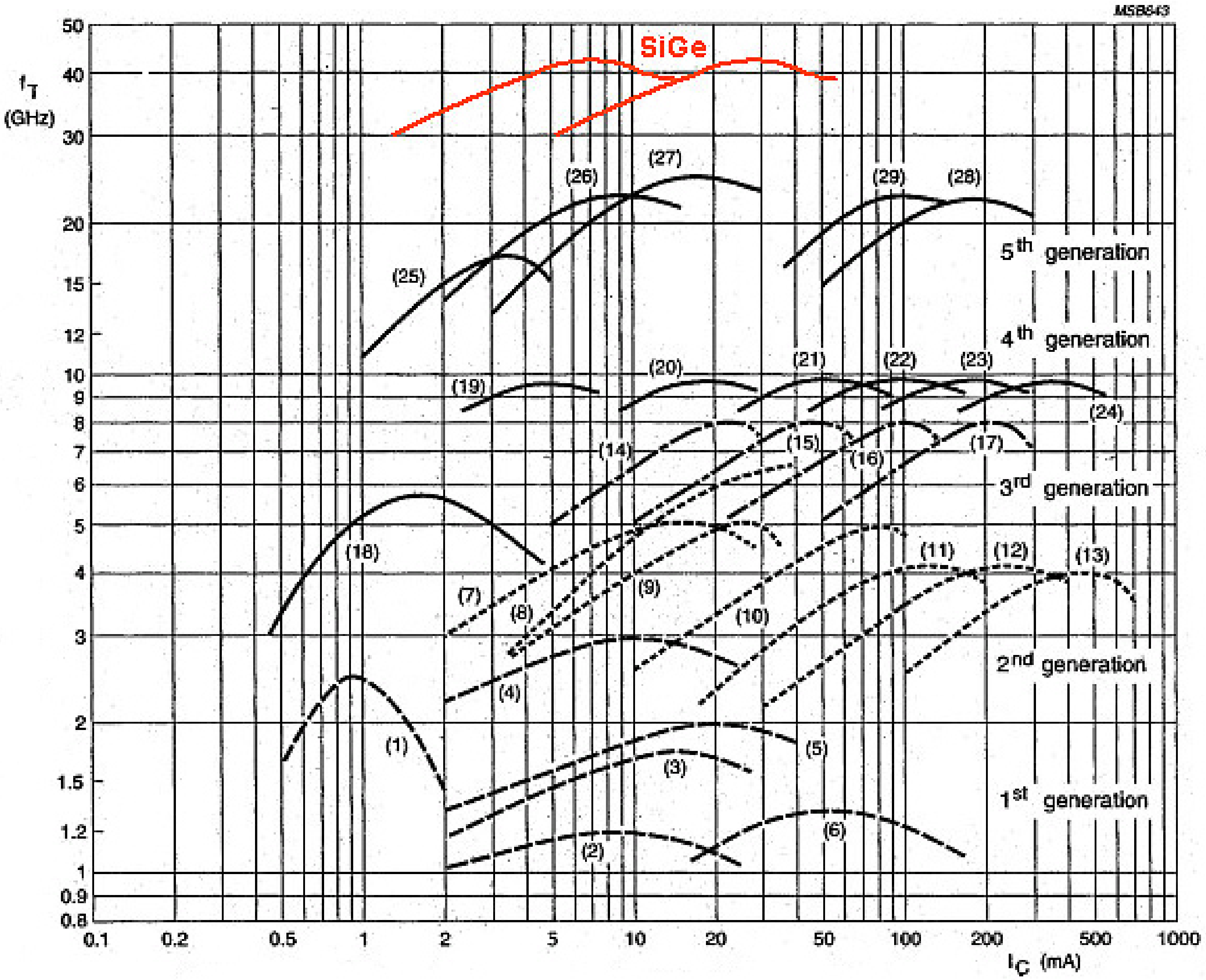
➢ Applications

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:	BGA200xy, and BGA27xy
5th generation wideband transistors:	BFG403W/410W/425W/480W
RF power amplifier modules:	BGY240S/241/212/280

3.6.3 RF Bipolar Transistor Performance overview



SiGe
BFU510
BFU540

4. RF Design-Basics

4.1. RF Fundamentals

4.1.1. Frequency and time domain

4.1.1.1. Frequency domain area

Typical vehicles:

- Metallic sound of the PC loudspeaker
- Audio analyser (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 analyser (In the medium frequency range from some Hz to MHz)
- Modulation analyser (Investigation of RF modulation e.g. AM, FSK, GFSK,...)
- Spectrum analyser (Display the signal’s spectral quality, e.g. noise, intermodulation, gain)

The mathematical Furrier Transformation rule analyses the performance of a periodical time depending signal in the frequency domain. For an one shoot signal the Furrier Integral Transformation is used. On bench, issues are take over by the Spectrum Analyser or by the ***FFT*** Analyser (***F***ast ***F***urrier ***T***ransformation). In the Spectrum Analyser the frequency parts of the device under test (***DUT***) spectrum are isolated (filtered) and measured by tuned filters (like a periodical tuned radio with displaying of the field strength). The FFT analyser has build in a computer or a ***DSP*** (***D***igital ***S***ignal ***P***rocessor). This DSP is a special IC with build in hardware based mathematical circuit cells for doing very fast solving of algorithmic problems like ***DFFT*** (***D***iscrete ***F***ast ***F***urrier ***T***ransformation). This DFFT can calculate the frequency spectrum of an in coming signal. DSP processors are used in today's mobiles on the base band level, sound cards of the computer, industrial machines,...

In RF and Microwave application the frequency domain is very important for measurement techniques because oscilloscopes can not display extremely high frequency signals. A Spectrum Analyser has a much higher sensitivity and better dynamic range.
Example: An oscilloscope can proper display signals with a voltage ratio of 10 to 20 between the smallest and largest signal (dynamic rage ≈20dB). The RF spectrum analysers can display power signal (levels) with a ratio of more than 1Million at the same time on the display (dynamic range >60dB). E.g. IF amplifiers of receivers have a gain of 40 to 60dB. That means the amplifier output amplitude power is around 10000 to 1000000 larger comparing to it's input. The spectrum analyser can display both signals at the same time with a good accuracy on to the monitor. On an oscilloscope you can see just a thin amplitude of the output signal. The amplifiers input signal looks like some noise ripple on the zero axis.
Typical modern oscilloscopes works in the frequency range of 0Hz (DC) to few GHz.
Modern spectrum analysers (SA) go up to several tenth of GHz. Special (SA) up 100GHz.

4.1.1.2. Time domain area

Typical bench vehicle and applications:

- The loudspeaker beep of the computer
- The oscilloscope (displays the signal's action over the time)
- The RF generator (generates very clean sin test signals with various modulation options)
- The ***T***ime ***D***omain ***R***eflectometry analyser (***TDR***) (e.g. analysing cable discontinuities)

In the time domain area the variation of the amplitude versus the time is displayed on a screen. Very low speed actions like temperature drift versus ageing of an oscillator or the earthquake are printed by special plotters in real-time on paper. Fast actions are displayed by oscilloscopes. The signals are forced on the screen by the use of storage tubes (history) or by the use of in built digital memories (RAM). In the time domain, phase differences between different sources or time dependent activities are analysed, characterised or tuned.

In RF applications their are displayed the demodulation actions, base band signals or control actions of the CPU.
Advantage of the oscilloscope is the high resistive impedance of the probes. The disadvantage is the input capacity of some Pico Farad (pF) causing a short or excessive detune of the circuit.

Mixers are non linear devices because their main job is the multiplication of signals. On the other side the RF signal must be operate very linear. Mixer ***3rd order intercept point*** (***IP3***) performance characterise this handling of RF signals an port input quality.

Example for 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 6030KHz. This transmitter has an output power of 20000W. Design the mixer working on an 455KHz IF amplifier.
Reference: http://www.swr.de/frequenzen/kurzwelle.html

System design of the ***local oscillator***: LO=RF+IF=6030KHz+455KHz=6485KHz
The ***image frequency*** is found at IRF=LO+IF=6485KHz+455KHz=6913KHz
Optimum mixer operation is medium gain for IF and RF and damping of IRF and LO transfer to the IF port. For an example, we choose the ***BFR92*** because this transistor can be used for much higher frequencies mixer applications (e.g. FM Car-Radio, TV, ISM433,...) too.
The ***R***adio ***F***requency (***RF***) signal is mixed with the ***L***ocal ***O***scillator (***LO***) to the ***I***nterim ***F***requency (***IF***) output products.

For improving the mixer gain, some part variation were done. This circuit is just an example further optimization should be done for practical operation. In the example the input signal source (V6, V7) are series connected. In the reality it can be done by e.g. a transformer.
The computer simulation was done under PSpice with the following set-up: Print Step=0.1ns; Final Time=250µs; Step Ceiling=1ns. This high simulation length and fine step resolution is necessary for useful DFT results in the frequency spectrum down to 400KHz.

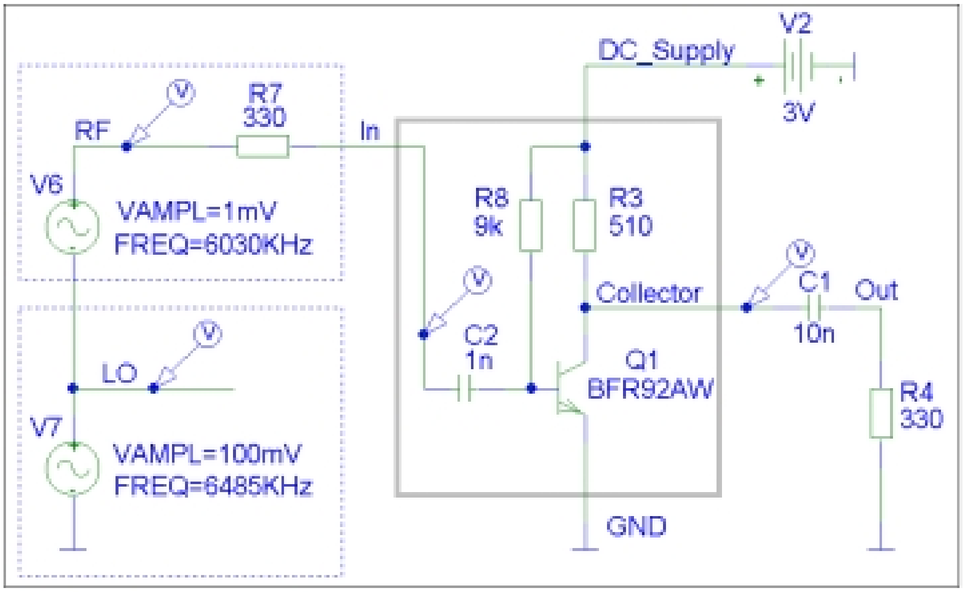


Figure 1: Final mixer circuit without output IF tank

Varying of R8 shows influences of the mixer gain at 455KHz 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=9k for best output amplitude.

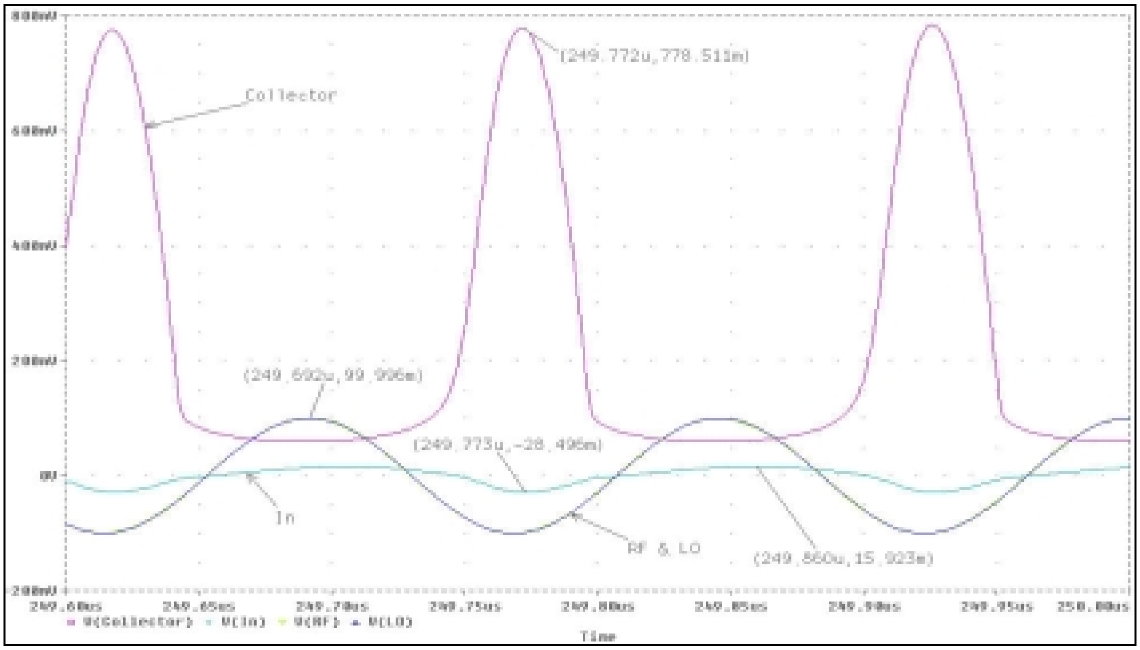


Figure 2: The mixer in the Time domain area

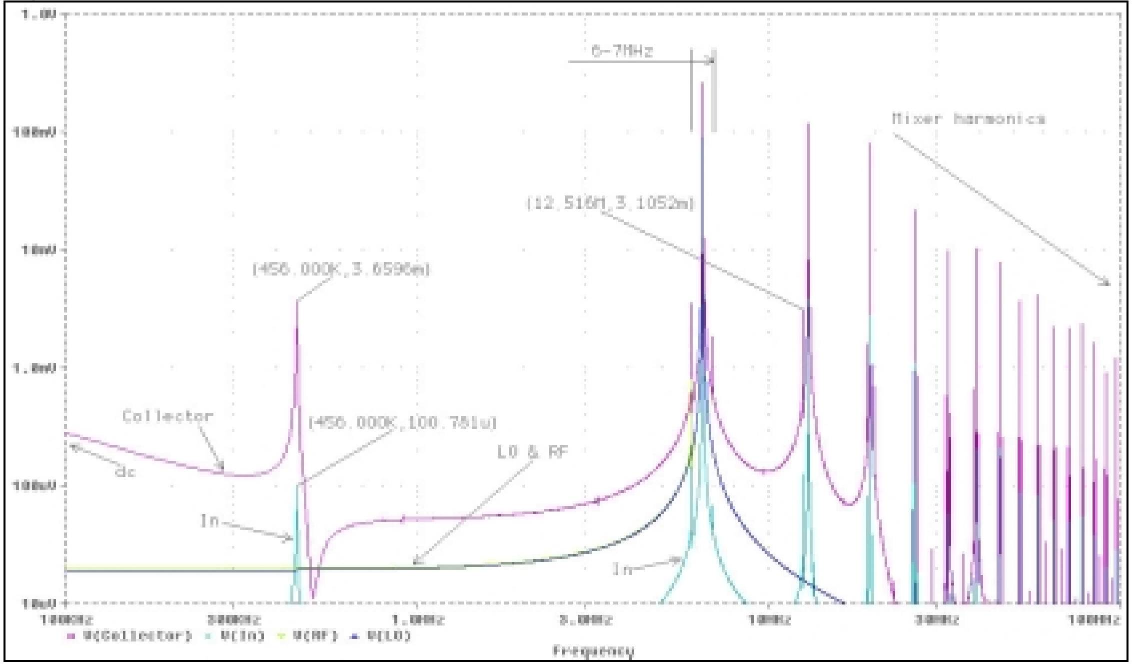


Figure 3: The mixer in the Frequency domain area

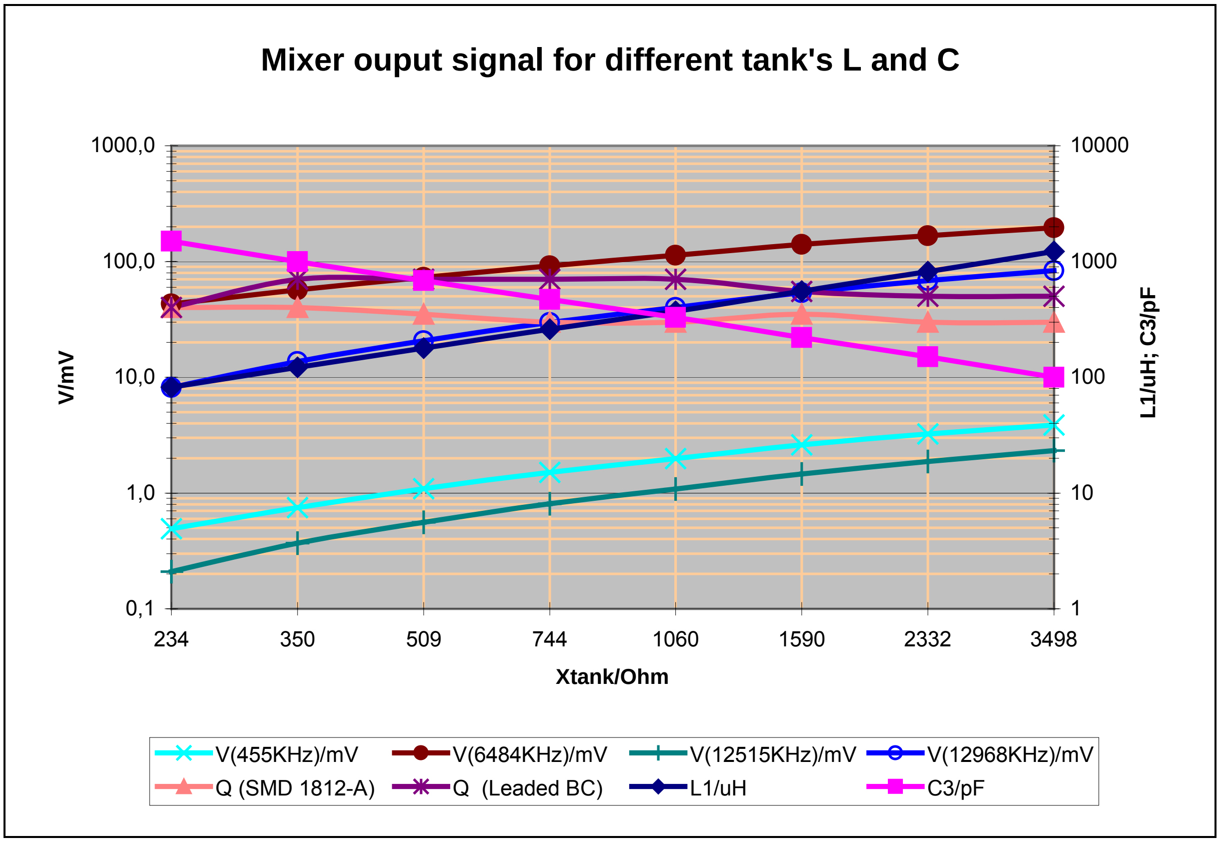


Figure 4: Mixer output voltage versus tank's characteristic resonance impedance

In the upper diagram inductors with more than 1mH are shown to have higher losses (Q). Additionally their must be measured the available IF bandwidth for transferring the down mixed signal without loss of modulation quality.

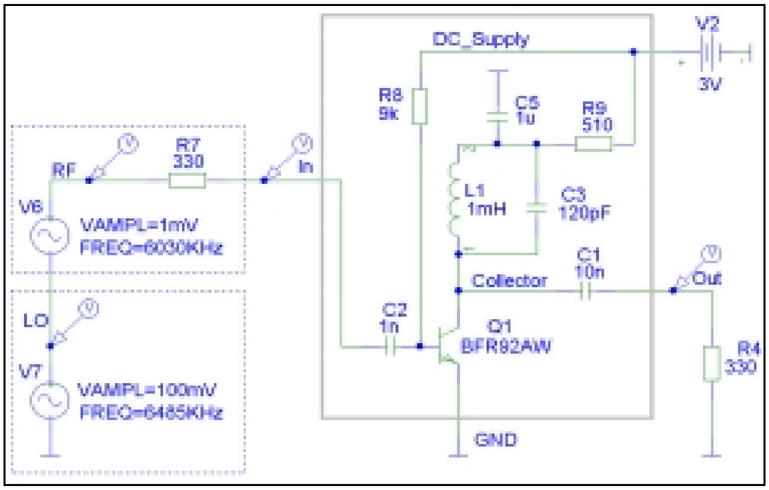


Figure 5: The mixer with IF tank

In this chapter was illustrated a mixer operation in the time and frequency domain. Illustrated was the circuit design by try and error of the use of a CAD program with the need of a lot of simulation time.
Better is the use of strategic design and calculation for the exact need specification and final CAD optimization. The devices must be accurate specified (S-Parameter) and models (e.g. 2-port linear model network) must be available for computer simulation.
Philips Semiconductors offers S-Parameters of Small Signal Discretes Devices.
Because in RF application optimum power transfer is important, we have to think about the quality of inter circuit match, qualified by the refection coefficient. This will be handled in the next chapters. Please note Philips Semiconductors offers a ***M***onolithic ***M***icrowave ***I***ntegrated ***C***ircuit (***MMIC***) Mixer ***BGA2022*** with 50Ω input impedance. This devices has build in the need biasing circuit, offers excellent gain and linearity.

4.1.2 RF waves

RF electromagnetic signals are travelling like water ***waves*** in the bath. They are affect by laws comparable to that of optical signals. In a homogeneous vacuum without any kind of external influences their ***speed is*** $\boldsymbol{C_o}$***=299792458m/s***.

Travelling in substrates, wires (***dielectric*** material) do speed down the waves to the amount of: $\boxed{v = \frac{C_O}{\sqrt{\varepsilon_{reff}}}}$

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

With it we can calculate the ***Wave Length***: $\boxed{\lambda = \frac{v}{f}}$

Example1: Calculate the speed of an electromagnetic wave in an epoxy based ***P***rinted ***C***ircuit ***B***oard (***PCB***) manufactured according to FR4 spec. and in a metal-dielectric-semiconductor capacitor.

Calculation: In a metal-dielectric-semiconductor capacitor the used dielectric can be Silicon-Dioxide or Silicon-Nitride material.

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

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

Example2: What is the wave length transmitted from the commercial SW radio broadcasting program SWR3 in the 49m Band on 6030KHz in the air / FR4 PCB?

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

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

From Example 1 we take over FR4 $\varepsilon_{reff} = 4.6$ $v = 139.8 \bullet 10^6 m/s$ and do calculate the wave length in the PCB to : $\lambda_{FR4} = 23.18m$

A forward traveling wave is transmitted / injected by the source into the traveling medium (substrate, dielectric, wire, ***Microstrip***, etc.) and running to the load at the opposite wire-end. In junction's between two different substrates/dielectrics a part of the forward running wave is reflected back to the source. The remaining part is forward traveling to the load.

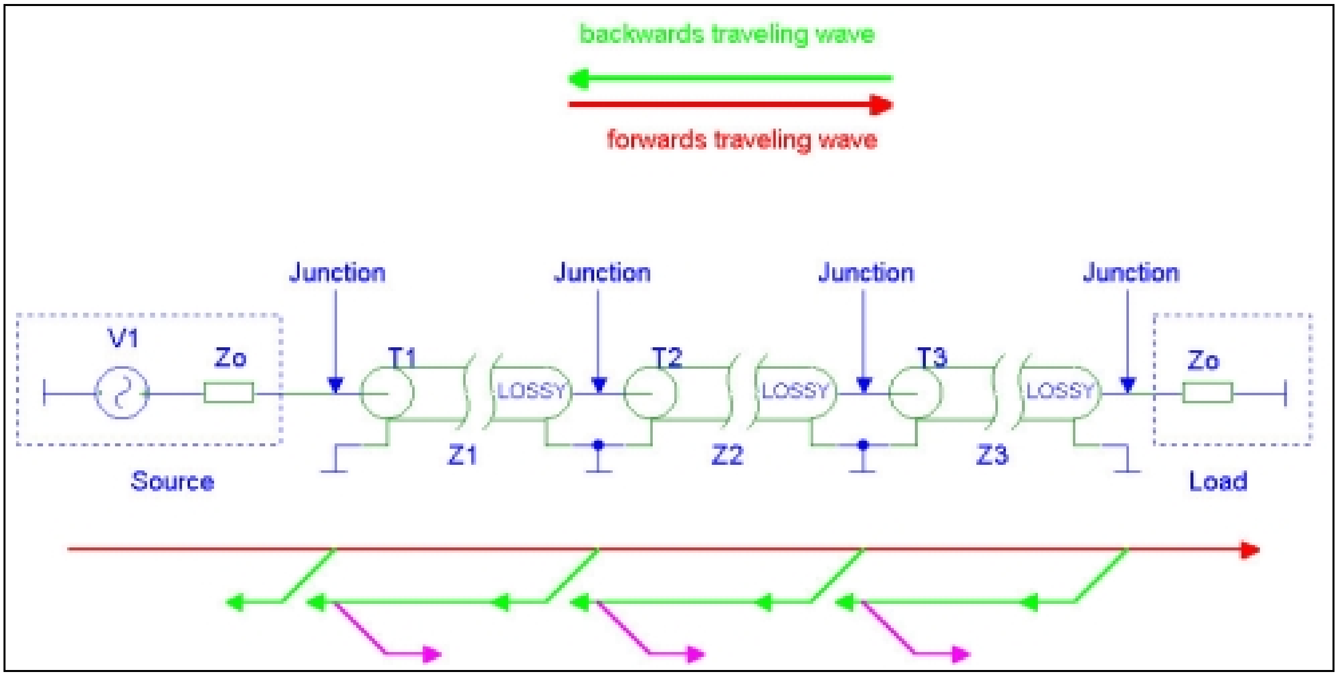


Figure 6: Multi reflection between lines with different impedance

In the upper figure the reflection of the forwards running wave (red) between lines with different wave-impedance's (Z1, Z2, Z3) is illustrate. As shown a backwards reflected wave (green) can be again reflected into load direction (violet).
In the case of optimum ***matching*** between different travel medium, no signal reflection will occur and an optimum power is forwarded. The quality of reflection caused e.g. junctions of lines with different impedance's or line ***discontinuities*** are specified by the ***refection coefficient*** detailed explained in the next chapter.

4.1.3 The reflection coefficient

As discussed in former chapter a forward traveling wave is particularly back reflected on junctions with line impedance in homogeneity, discontinuity or mismatching.
Only the wave-part of forward traveling into the load will be absorbed and processed.
Because of the limited speed of the waves in a line they will be specified by an individual phase delay too. In the involved mathematics rules this behave is illustrated by a vector in the complex Gauß area. At each location of the wire, waves with different amplitude and phase delay are heterodyned. The resulting envelope of the waves energy along the wire do get a ripple with maximum and minimum of the amplitude. The phase difference between a maximum to the next one is the same between a minimum to the next one. The amount of the distance is the ***half wave length $\lambda/2$ (or normalized phase shift of 180°)***.

Example: A line with a mismatched end, do have standing waves resulting in minimum and maximum amount of power at certain locations along the wire. Determine the approximated distance between this worse case voltage points for a ***Bluetooth*** signal processed in a printed circuit on a FR4 based substrate.

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

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

The distance minimum to maximum is called the ***quarter wave length $\lambda/4$ (90°)***.

Min-Max distance in FR4: $\lambda/_4 = \frac{58.24mm}{4} = 14.56mm$

- At the minimum we have low amount of voltage but large current.
- At the maximum we have large amount of voltage but low current.
- The distance between a minimum and a maximum is equal to $\lambda/4$.

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

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) indicate that at each position of the wire you will see a different reflection coefficient. This is caused by the distribution of the standing wave along the line. The return loss indicates how much lower is the return reflected wave in dB compared to the forward travelling wave.

Often the input refection performance of an 50Ω RF device is specified by the **V**oltage **S**tanding **W**ave **R**atio (***VSWR***) or short (***SWR***).

VSWR: $\boxed{s = SWR = VSWR = \frac{U_{\max}}{U_{\min}}}$ and the Matching factor: $\boxed{m = \frac{1}{s}}$ Per definition the VSWR>1 !

Some typical values of the VSWR:
100% mismatch caused by an open or shorted line r=1 and VSWR ∞
Optimum matched line r=0 and VSWR=1
In the reality 0<r<1 and 1<VSWR<∞

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

Some mathematical changes: $r = \frac{\frac{U_{\max}}{U_{\min}} - 1}{\frac{U_{\max}}{U_{\min}} + 1}$ will result in: $\boxed{r = \frac{U_{\max} - U_{\min}}{U_{\max} + U_{\min}}}$

The reflection coefficient of an impedance is calculated to $\boxed{r = \frac{Z - Z_O}{Z + Z_O}}$

with Zo=System reference impedance

As explained the standing waves causes different amount of voltage and current along the wire. The ratio of this two parameters is the impedance $Z_{(x)} = \frac{V_{(x)}}{I_{(x)}}$ at individual locations of (x). That means a wire with the length (l) and a line mismatching 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 known several special cases (tricks) used in Microwave designs. Mathematically it can be shown that a wire with the length $= \frac{\lambda}{4}$ and the wire-impedance Z_L will be a ***quarter wave length transformer*** of:

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

As indicated in the upper RF travelling wave basic rules, the performances of matching, reflection and individual wire performances do extremely determine the bench measurement results caused by transformation on the wire. Due to it, each measurement set-up must be calibrated by precision references.

Examples of RF calibration references are:

- Open
- Short
- Match

The set-up calibration do de-embed unintended wire transformation, discontinuities from plugs,... This prevents changes of the **D**evice **U**nder **T**est (***DUT***) measurement parameters in the bench test set-up.

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

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

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

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

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

We know only the amount of (r) but not it's angle/sign. Due to the definition, the VSWR it must be larger than 1. We will get two possible solutions:

$\boxed{SWR1 = \dfrac{Z1}{Z_O}}$ and $\boxed{SWR2 = \dfrac{Z_O}{Z2}}$ Z1=1.92*50Ω=96.25Ω; Z2=50Ω/1.92=25.97Ω

We can check it: $|r| = \left|\dfrac{96.25-50}{96.25+50}\right| = \left|\dfrac{25.96-50}{25.96+50}\right| = 0.316$

The λ/4 wire transformer do transform the device impedance to:

Zin_1=96.25Ω $\boxed{Z_{ende} = \dfrac{{Z_O}^2}{Z_{IN}} = \dfrac{50\Omega^2}{96.25\Omega} = 25.97\Omega}$ and for Z_{IN2}=25.97Ω 96.25Ω

Results: At 2GHz, BGA2711 offers an input return loss of 10dB or VSWR=1.92. This reflection can e.g. be caused by 96.25Ω or 25.97Ω impedance. Of course their are infinite results possible taking in to account combination with L or C parts.
Measuring this resistance the use of 50Ω cable in λ/4 distance will cause extremely large errors. Because the Zin_1=96.25Ω appears like 25.97Ω and the second solution Zin_2=25.97Ω appears like 96.25Ω!

As illustrated in this example, the VSWR or return loss associates without calculation the quality of device's input match but don't tells about it real performances (no phase data). Detailed mathematically network analysis on RF amplifiers show depends on the device input impedance by the output load. The output device impedance is depending on source's impedance driving the amplifier. Due to it, the use of S-Parameter model 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 device has so called parasitic elements at DC and at RF frequency.

Resistor	Has an inductive parasitic action. Due to it, low pass function
Inductor	Has a capacitor and resistive parasitic, causing a damped parallel resonance tank
Capacitor	Has an inductive and resistive parasitic, causing a damped tank with ***S***eries ***R***esonance ***F***requency (***SRF***)

At the inductor and the capacitor the parasitic reactance do cause self resonance effects.

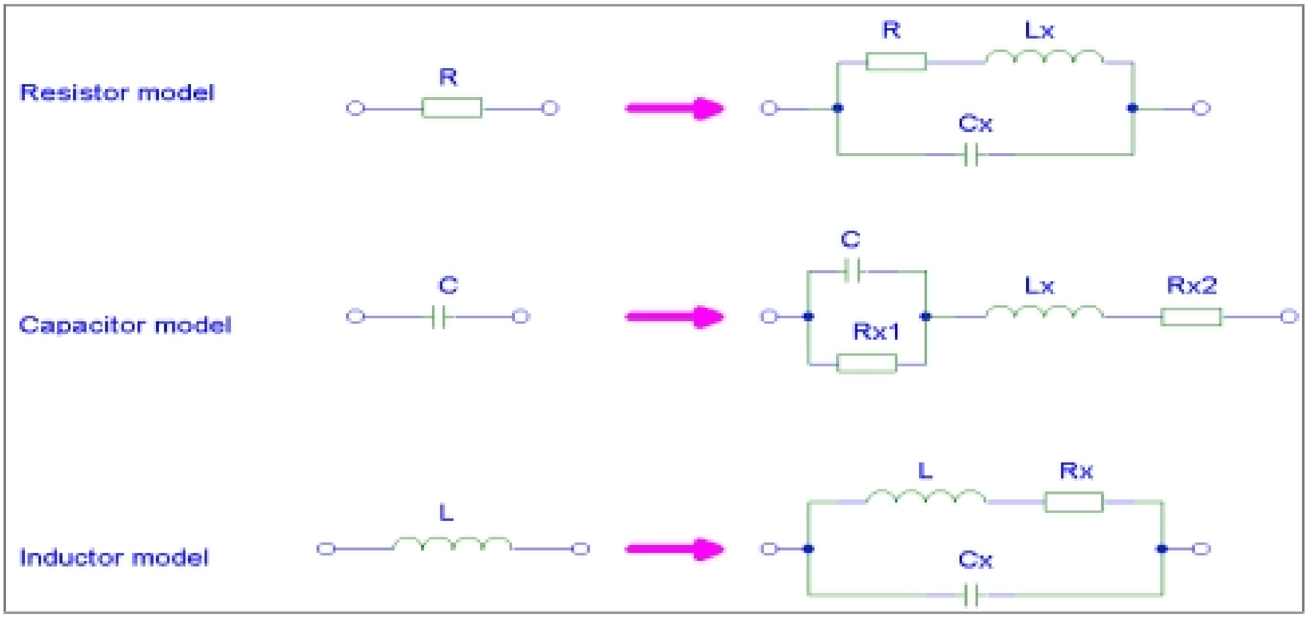


Figure 7: Equivalent models of passive lumped elements

4.1.5 The Smith Chart

As indicated in an example of the former chapter, impedance’s of Semiconductors are a mixture of resistive and reactive parts. As shown RF is easier displayed in the frequency domain.

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

Some basic vector mathematics used in RF:

Complex impedance is : $Z = \mathrm{Re}\{Z\} + j\,\mathrm{Im}\{Z\} = |Z| \cdot e^{j\varphi} = |Z| \cdot (\cos\varphi - j\sin\varphi)$

$$\mathrm{Im}\{Z\} = |Z|\sin\varphi;\ \mathrm{Re}\{Z\} = |Z|\cos\varphi;$$

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

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

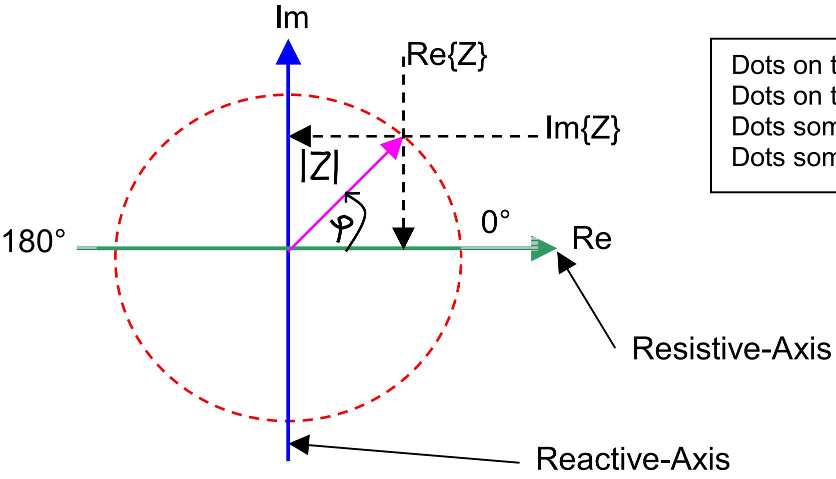
The same rules are used for other issues e.g. reflection coefficient:

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

Special cases:

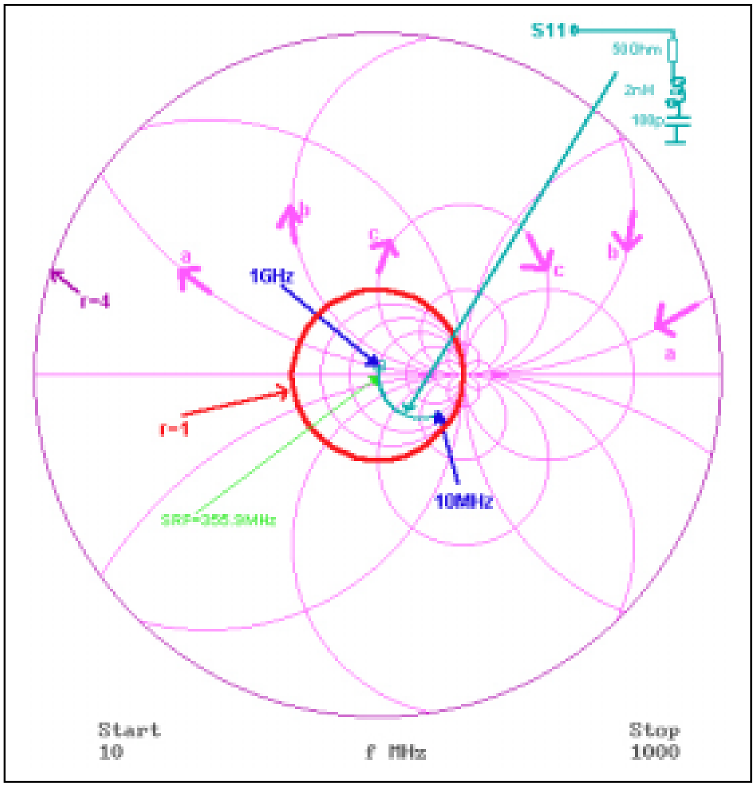
- Resistive mismatch: $\varphi_{(R)} = 0$ reflection coefficient: $\varphi_{(r)} = 0$
- Inductive mismatch: $\varphi_{(L)} = +90°$ reflection coefficient: $\varphi_{(r)} = +90°$
- Capacity mismatch: $\varphi_{(C)} = -90°$ reflection coefficient: $\varphi_{(r)} = -90°$

The ***Gauß' number area*** (***Polar Diagram***) do 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

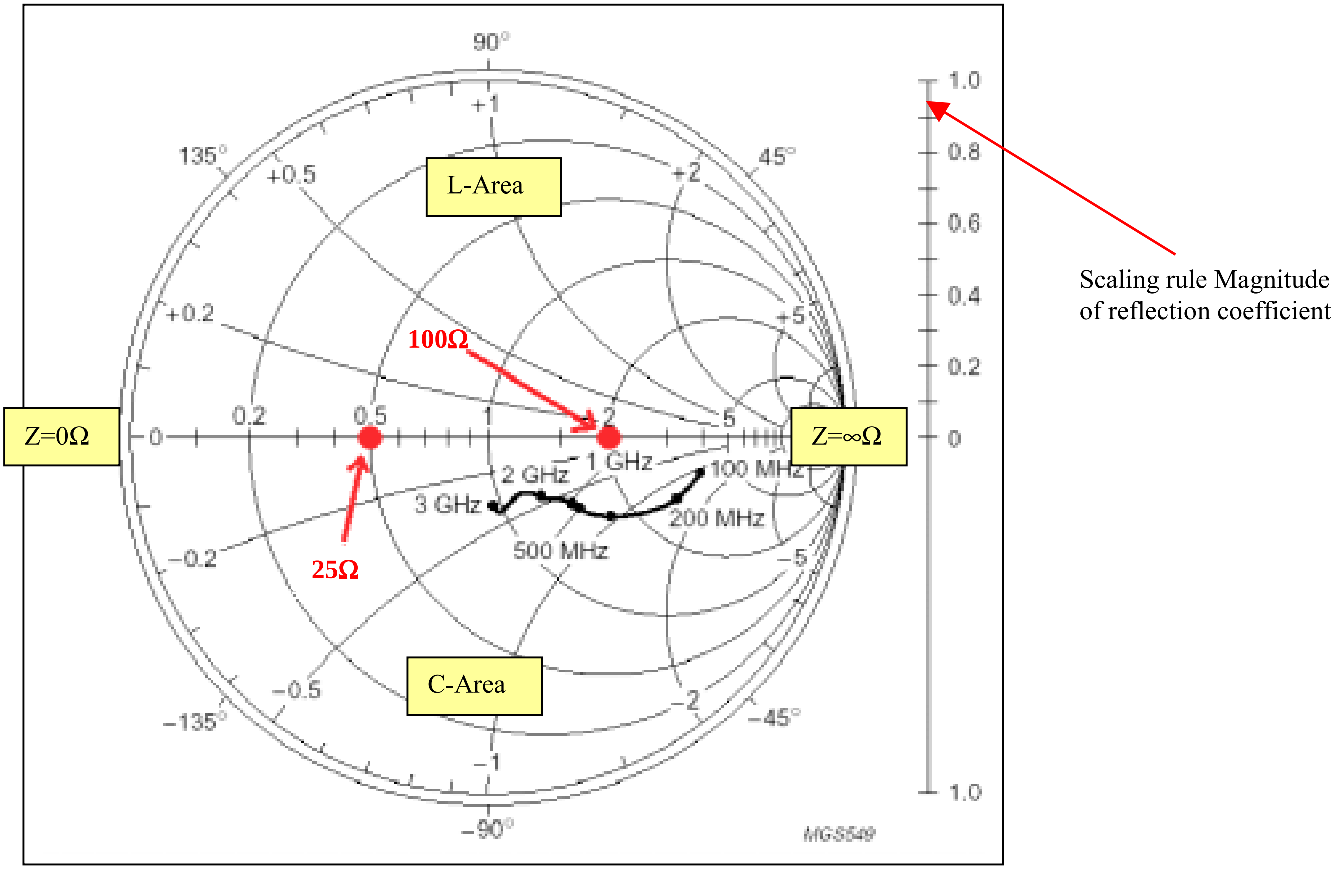
In the real world RF designers try to be close and accurate to 50Ω. The upper polar diagram's origin is 0Ω. In RF circuits very large impedance can appear but we try to come to 50Ω by special network design for optimum low loss power transfer. Due to it, this ∞-area don't need to be displayed accurately. Especially the Polar diagram can't show large impedance and 50Ω impedance accurate at the same time because of limited paper size.



Due to it, the Engineer Mr. Phillip Smith from the Bell Laboratories developed in the Thirties the so called Smith Chart. The Chart's origin is 50Ω. Left and right resistive Re-Axis do end in 0Ω / ∞Ω. The imaginary reactive Im-Axis end in 100% reactive (L or C). Close to the 50Ω origin high resolution is offered. Far away, the resolution/ error do rise up. The standard Smith Chart do only display positive resistances and has a unit radius (r=1). Negative resistances generated by e.g. instability lay outside the unit circle. In this non linear scaled diagram is keep (theoretical) the infinite dot of the Re-Axis and bend 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 it representing a reflection coefficient magnitude of one (100% mismatch). Any positive L/C combination with a resistor is mathematical represent 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 take over some rules by 100%. Some other 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 capacity part (180°<φ<360°)
- Dots laying on the horizontal line are 100% resistive (φ=0°)
- Dots laying on the vertical axis are 100% reactive (φ=90°)



Scaling rule Magnitude of reflection coefficient

Figure 8: BGA2003 output Smith Chart (S_{21})

Illustrate are the special cases zero and infinite large impedance. The upper half circle is the inductor world. The lower half of the circle is the capacitor world. Origin is the 50Ω reference. To be more flexible, numbers printed in the chart are normalised to the reference impedance.

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

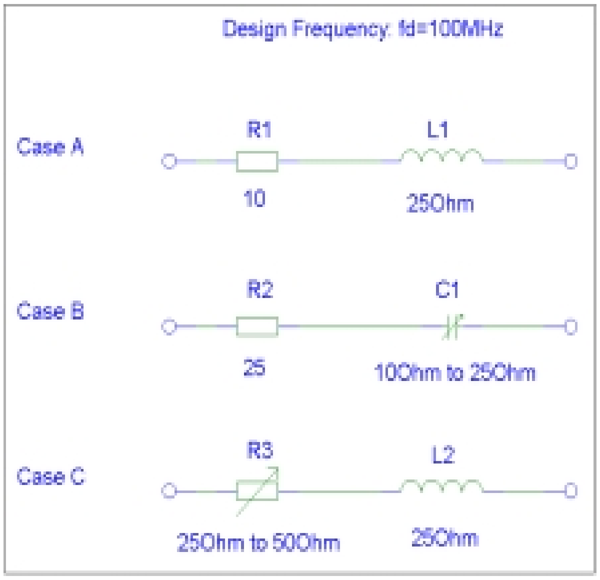
Example: Plot a 100Ω & 50Ω resistor into the upper ***BGA2003***'s output Smith chart.

Calculation: Znorm1=100Ω/50Ω=2; Znorm2=25Ω/50Ω=0.5

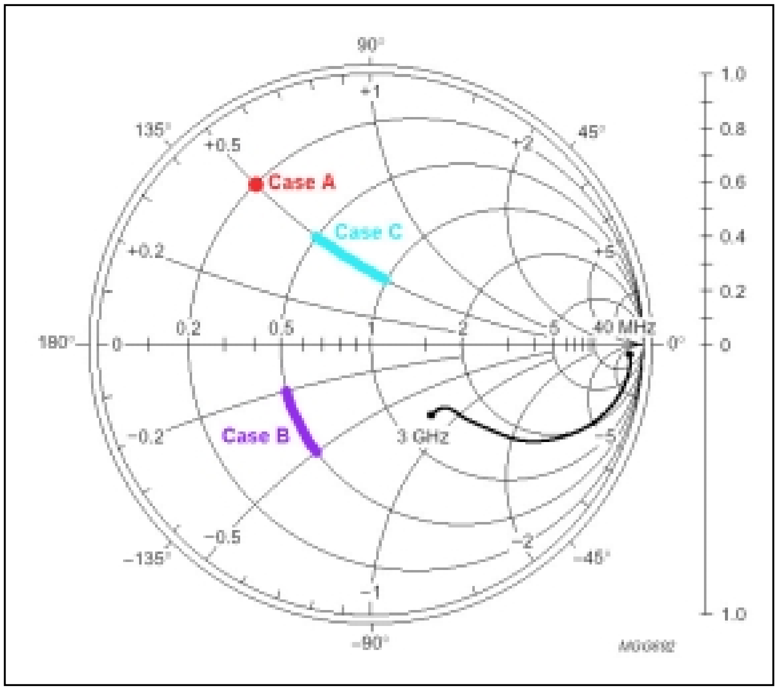
Result: The 100Ω resistor appears as a dot on the horizontal axis at the location 2. The 25Ω resistor appears as a dot on the horizontal axis at the location 0.5

Example1: In the following three circuits capacitors and inductors are specified by their amount of reactance @ 100MHz design frequency. Determine their part values. Plot their impedance in to the ***BFG425W***'s output (S21) Smith Chard.

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

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

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

From the circuit $Z_B = 10\Omega + j(10\_to\_25)\Omega$

$$C_B = \frac{1}{2\pi \cdot 100MHz \cdot (10\_to\_25)\Omega} = 63.7pF\_to\_159.2pF$$

$Z_{(B)norm}=Z_B/50\Omega=0.5-j(0.2\_to\_0.5)$ Drawing into Smith Chart

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

From the circuit $Z_C = (25\Omega\_to\_50\Omega) + j25\Omega;$

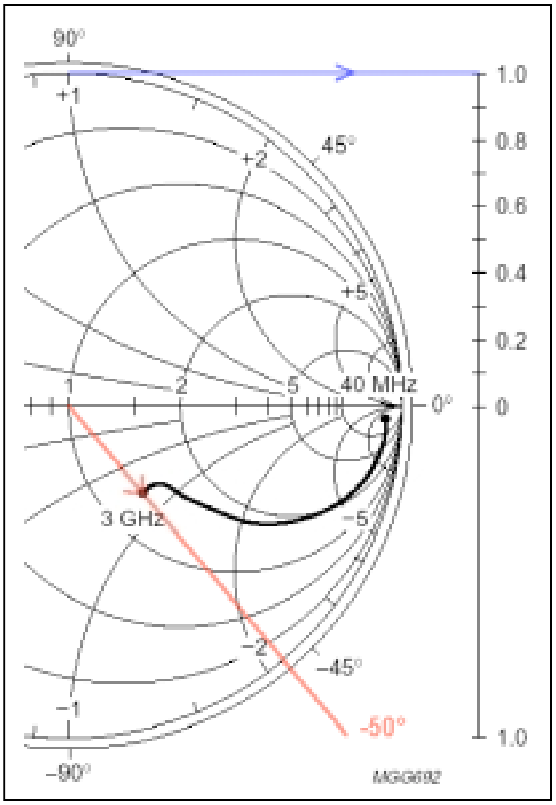
$$L_C = \frac{(25\_to\_50)\Omega}{2\pi \cdot 100MHz} = 39.8nH\_to\_79.6nH$$

$Z_{(C)norm}=Z_C/50\Omega=(0.5\_to\_1)+j0.5$ Drawing into Smith Chart

Example2: Determine ***BFG425W***'s outputs reflection coefficient (S21) at 3GHz from the data sheet. Determine the output return loss and output impedance. Compensate the reactive part.

Calculation: For reading the data from the Smith Chart with improved resolution the vector procedure base on the reflection coefficient is recommended.

Procedure:
1) Measure the scalar length from the chart origin to the 3GHz mechanical by the use of an circle.
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 $\underline{r = 0.34e^{-j50°}}$



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

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

Impedance: $Z_{21} = 75.64\Omega e^{-j30.5°} = (65.2 - j38.4)\Omega$

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

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 the reactive part, we have to take the ***conjugate*** 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 compensated the reactance.

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 the reality the output impedance is a function of the input circuit. The input and output matching circuits are limited by the ***stability*** requirements. This is done by doing network analysis based on ***S-Parameters***.

4.2 Small signal RF amplifier parameters

4.2.1. Transistor parameters DC to Microwave

At DC low current and low voltage you can assume a transistor like a voltage controlled current source with a diode clamping action at it’s input. In this area the transistors are specified just by their large signal DC-parameters like DC-current gain (B, ß, h_{fe}), max. power dissipation, break down voltage and so on.

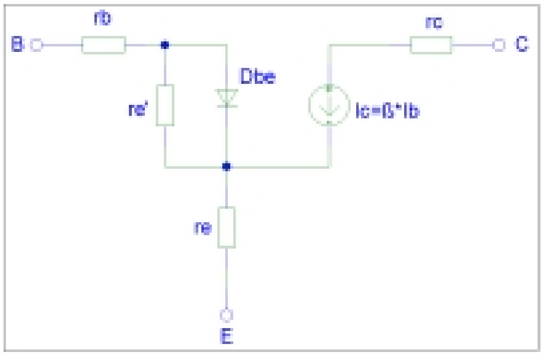


Figure 9: NPN-Transistor dc-model

$$I_C = I_{CS} \cdot e^{\frac{U_{BE}}{U_T}}$$

$$r_e' = \frac{U_T}{I_E}$$

$$V_u \approx \frac{R_C}{r_e'} \quad \text{Voltage gain}$$

$$ß = \frac{I_C}{I_B} \quad \text{Current gain}$$

U_T=25.4mV@25°C

Increasing the frequency up to audio frequency, their is observed frequency depended change of parameters, phase shift and parasitic capacitance effects. For characterisation of this effect small signal h-Parameters were developed. This hybrid parameters are determined by measuring voltage and current at one terminal and by an open or short at the other one.

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 in to HF/VHF range, the open with to much stray field radiation cause unacceptable error. Due to it y-Parameters were developed. They do again measure voltage/current but under the use of only a short.

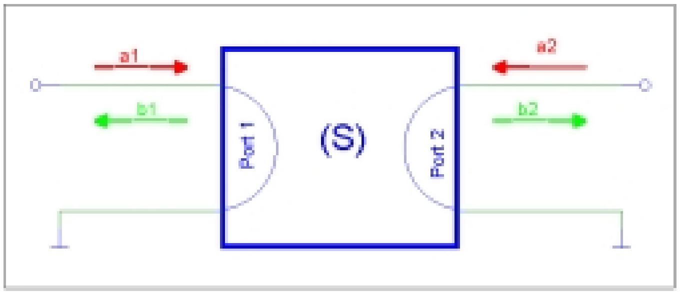
y-Parameter Matrix: $\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{pmatrix} * \begin{pmatrix} u_1 \\ u_2 \end{pmatrix}$

Increasing the frequency again, the parasitic inductance of the short causes a problem. Especial the measuring of voltage and current with the phase causes extremely problems. Due to it the scattering Parameters were developed based on the measurement of the forward and backward running waves caused by reflection on transistor’s terminals (ports).

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

Each amplifier has an input port and an output port. Normally the input is Port1.
The output is port2.



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: $\mathrm{b}_1 = \mathrm{S}_{11} \cdot \mathrm{a}_1 + \mathrm{S}_{12} \cdot \mathrm{a}_2$

$\mathrm{b}_2 = \mathrm{S}_{21} \cdot \mathrm{a}_1 + \mathrm{S}_{22} \cdot \mathrm{a}_2$

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

The forward travelling waves **(a)** are running into the DUT's ports.
The backward travelling waves **(b)** are reflected back from the DUT's ports

In the former chapter was defined the:

Reflection coefficient: $reflection = \dfrac{back\ wave}{forward\ wave}$

Calculating the input reflection coefficient on port 1: $\boxed{S_{11} = \left.\dfrac{b_1}{a_1}\right|_{a_2=0}}$ Output Z_O terminate.

That means the source do inject a forward travelling wave **(a1)** into port1. No forward travelling power **(a2)** injected into port2. The same can be done at port2 with the output reflection factor: $\boxed{S_{22} = \left.\dfrac{b_2}{a_2}\right|_{a_1=0}}$ Input Z_O terminate.

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

The forward travelling wave gain is calculated by the wave **(b2)** travelling out off port2 divided by the wave **(a1)** injected into port1. $\boxed{S_{21} = \left.\dfrac{b_2}{a_1}\right|_{a_2=0}}$

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

The normalised waves (a) and (b) are defined as ;

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

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

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

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

The normalised waves have the unit $\sqrt{Watt}$ and are referenced to the system impedance Z_O

This can be shown by the following mathematical analysis:

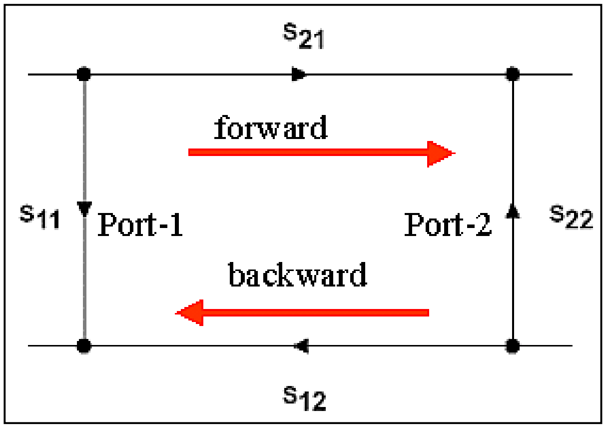
The relation ship between U, P an Z_0 can be written as: $\frac{u}{\sqrt{Z_O}} = \sqrt{P} = i\cdot\sqrt{Z_O}$

$$a_1 = \frac{V_1}{2\sqrt{Z_O}} + \frac{Z_O\cdot i_1}{2\sqrt{Z_O}} = \frac{\sqrt{P_1}}{2} + \frac{Z_O\cdot i_1}{2\sqrt{Z_O}} \qquad \text{(Substitution: } \frac{Z_0}{\sqrt{Z_O}} = Z_O\text{)}$$

$$a_1 = \frac{\sqrt{P_1}}{2} + \frac{\sqrt{Z_O}\cdot i_1}{2} = \frac{\sqrt{P_1}}{2} + \frac{\sqrt{P_1}}{2} \qquad a_1 = \sqrt{P_1} \quad (\quad \text{Unit} = \sqrt{W}\ )$$

Because $a_1 = \frac{V_{forward}}{\sqrt{Z_O}}$ the normalised waves can be determined by the measure of the voltage of the forward running wave referenced to the system impedance Z_o. The forward or backward running voltage can be determined by directional couplers or VSWR bridges.

4.2.2.1 2-Port Network definition



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 for ***BGA2003*** the insertion power gain @ 100MHz, 450MHz, 1800MHz, 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 Philips' internet page for the Silicon MMIC amplifier BGA2003.

This is a selection of the file:

```
# MHz  S  MA  R 50
! Freq    S11             S21                 S12               S22    :
100     0.58765 -9.43   21.85015  163.96  0.00555   83.961  0.9525  -7.204
400     0.43912 -28.73  16.09626  130.48  0.019843  79.704  0.80026 -22.43
500     0.39966 -32.38  14.27094  123.44  0.023928  79.598  0.75616 -25.24
1800    0.21647 -47.97  4.96451   85.877  0.07832   82.488  0.52249 -46.31
2400    0.18255 -69.08  3.89514   76.801  0.11188   80.224  0.48091 -64
```

Results:

100MHz 20log(21.85015)=26.8dB

450MHz

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

1800MHz 20log(4.96451)=13.9dB

2400MHz 20log(3.89514)=11.8dB

4.2.2.2 3-Port Network definition

Typical vehicles for 3-Port S-Parameters are: Directional couplers, power splitters, combiners, phase splitter, ...

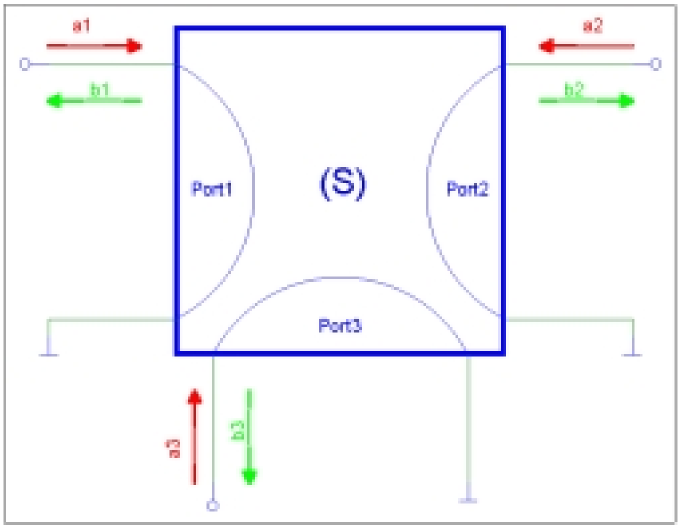


Figure 11: Three-port Network's (a) and (b) waves

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 $S_{23} = \frac{b_3}{a_2}\Big|_{(a_1=0)}$

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Author:
Andreas Fix
RF Discretes Small Signal Application Engineer

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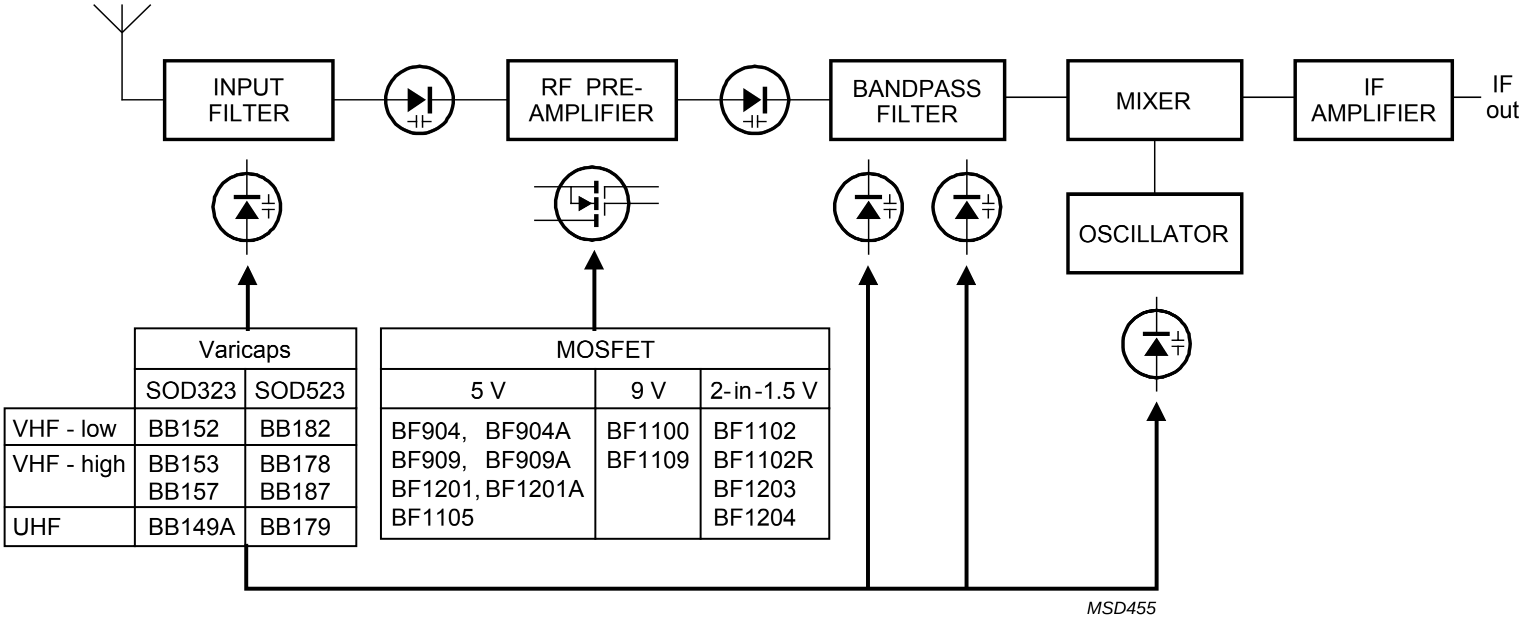
5. Application Diagrams

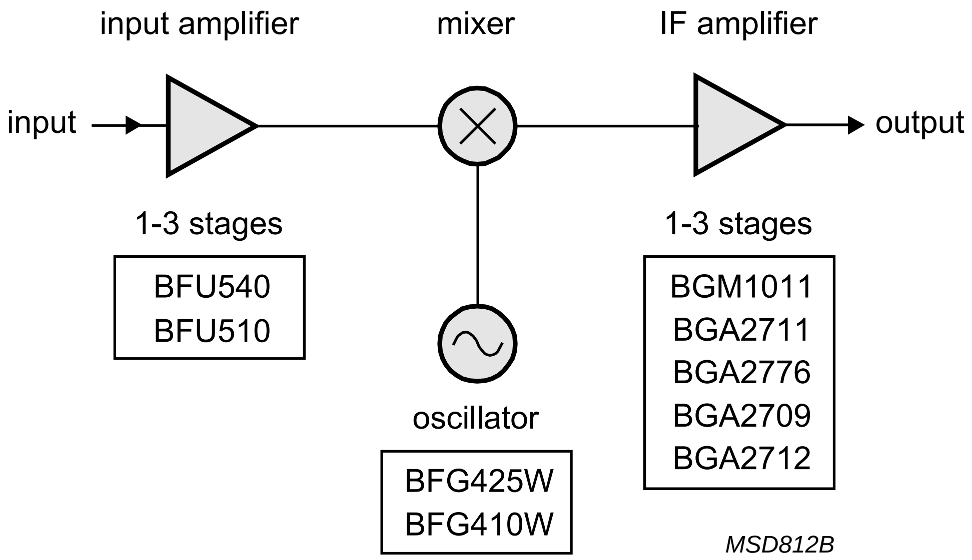
TV/VCR/DVD Tuning Application Diagram



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

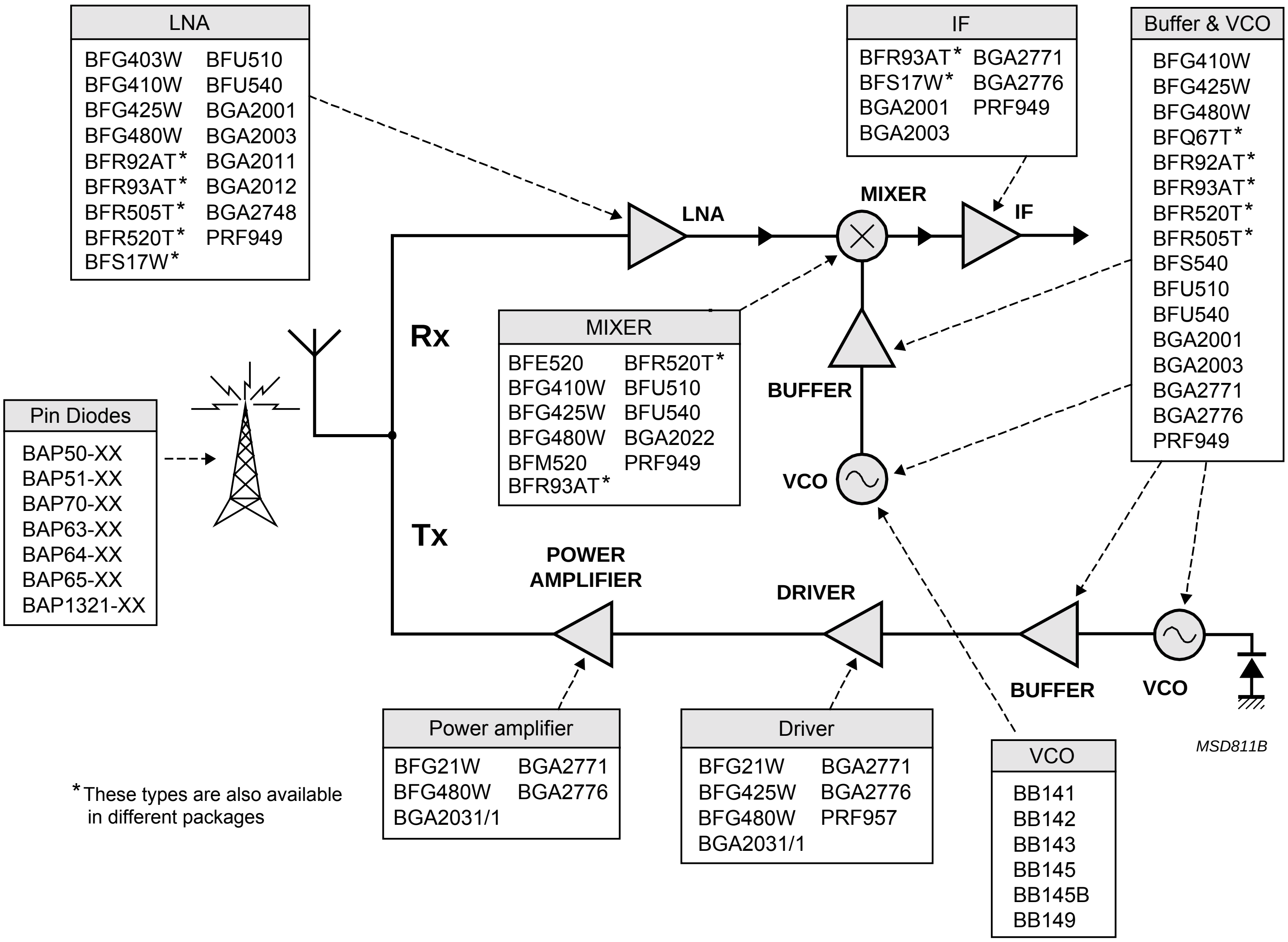
MOSFET		
5 V	9 V	2-in-1.5 V
BF904, BF904A BF909, BF909A BF1201, BF1201A BF1105	BF1100 BF1109	BF1102 BF1102R BF1203 BF1204

Satellite Dish LNB Application Diagram



5. Application Diagrams

Generic Cell-phone Front-end Application Diagram



*These types are also available in different packages

6.1 Application notes list (Interactive)

Full application notes in 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

6.2 Application note

BB202, low voltage FM stereo radio (TEA5767/68)

Author(s): M Ait Moulay , Philips Semiconductors Strategic Partnership Catena
The Netherlands, Date: 18-06-2002

This is a shortened application note to emphasise the BB202 varicap as an important FM oscillator next to the TEA5767/68 single chip stereo FM receiver (complete application note: AN10133).

Summary

The TEA5767/68 is a single chip stereo FM receiver. This new generation low voltage FM radio has a fully integrated IF-selectivity and demodulation. The IC does not require any alignment, which makes the use of bulky and expensive external components unnecessary.

The digital tuning is based on the conventional PLL concept. Via software, the radio can be tuned into the European, Japan or US FM band.

The power consumption of the tuner is low. The current is about 13mA and the supply voltage can be varied between 2.5 and 5V.

The radio can find its application in many areas especially portable applications as mobile phones, CD and MP3 players.

This application note describes this FM radio in a small size and low voltage application. To demonstrate the operation of the tuners a demoboard is developed, which can be extended with a software controllable amplifier and a RDS chip. The whole application can be controlled from a PC by means of demo software.

Introduction

The consumer demand of more integrated and low power consumption IC's has increased tremendously in the last decade. The IC's must be smaller, cheaper and consume less power. Especially for portable equipment like mobile phone, CD, MP3 and cassette players, these requirements are very important. In order to integrate a radio function in this kind of equipment it's also important that the total application is small sized and the overall power is low. The **TEA5767/68** is a single chip digitally tuned FM stereo radio. Its application is small, has a very low current consumption and is completely adjustment free. This makes the PCB design easy and save design-in time. The tuner contains all the blocks necessary to build a complete digitally tuned radio function.

The FM tuners consist of three IC's in 32 pins or 40 pins package. The IC's can be controlled via a 3-Wire, I2C or both bus interfaces.
A small application PCB demo board has been designed on which either of the three IC's can be mounted. These demo boards can be placed on a motherboard, which can be extended with an audio amplifier and a **R**adio **D**ata **S**ystem (**RDS/RBDS)** IC.

The three tuners are:

- TEA5767HN FM stereo radio, 40 leads with I^{2}C and 3-Wire bus interface, Body 6*6*0.85 mm, SOT1618
- TEA5767HL FM stereo radio, 32 leads with 3-Wire bus interface, Body: 7*7*1.4 mm, SOT358.
- TEA5768HL FM stereo radio, 32 leads with I^{2}C bus interface, Body: 7*7*1.4 mm, SOT358.

In this application note only one IC, the TEA5767HN and one demo board will be described. However, this description can also be applied for the other boards.

1. The TEA5767

A block diagram of the TEA5767HN is given in Figure 1. The block diagram consists of a number of blocks that will be described according to the signal path from the antenna to the audio output.

The RF antenna signal is injected into a balanced low noise amplifier (LNA) via a RF matching circuit. In order not to overload the LNA and the mixer the LNA output signal is fed to an automatic gain control circuit (AGC). In a quadrature mixer the RF signal is converted down to an IF signal of 225KHz by multiplying it with a local oscillator signal (LO). The chosen mixer architecture provides inherent image rejection.
The VCO generates a signal with double the frequency necessary for the I/Q mixer structure. In the N1 divider block, the required LO signal is created. The frequency of the VCO is controlled with a PLL synthesiser system.
The I/Q signals out the mixer are fed to an integrated IF filter (RESAMP block). The IF frequency of this filter is controlled by the IF Centre Frequency adjust block.
The IF signal is then passed to the limiter block, which removes the amplitude variation from the signal. The limiter is connected to the level ADC and the IF counter blocks. These two blocks provide the proper information about the amplitude and frequency of the RF input signal, which will be used by the PLL as stop criterion.
The IC has a quadrature demodulator with an integrated resonator. The demodulator is fully integrated which makes IF alignments or an external resonator unnecessary.

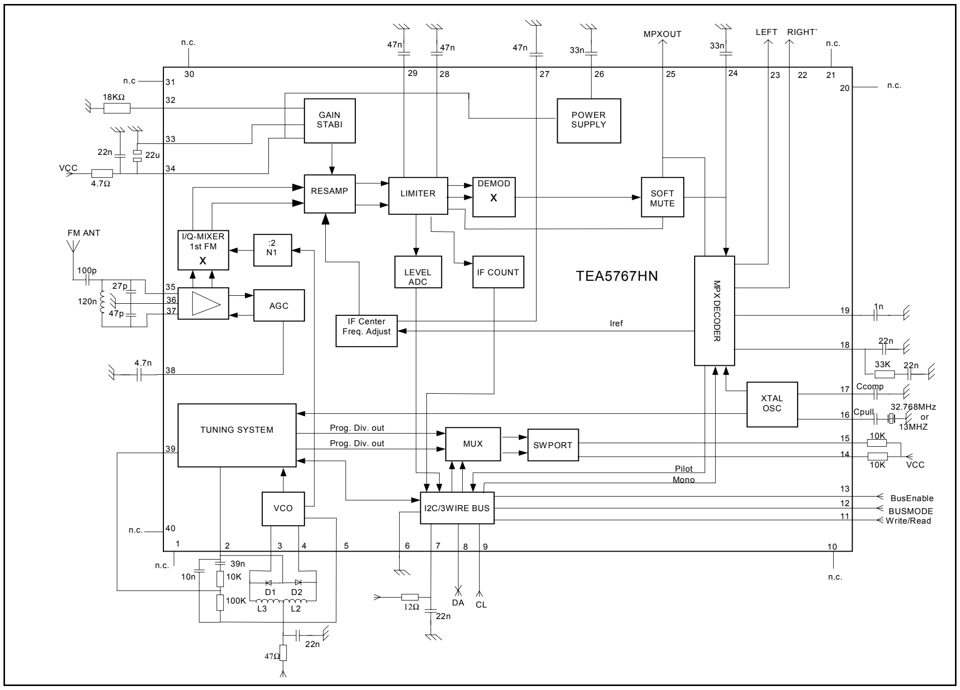


Figure 1 Block application diagram of the TEA5767HN

The **stereo decoder (MPX decoder)** in its turn is adjustment free and can be put in mono mode from the bus interface. The stereo noise cancelling (SNC) function gradually turns the stereo decoder from ‘full stereo’ to mono under weak signal conditions. This function is very useful for portable equipment since it improves the audio perception quality under weak signal conditions.

The softmute function suppresses the interstation noise and prevents excessive noise from being heard when the signal level drops to a low level.

The tuning system is based on a conventional PLL technique. This is a simple method in which the phase and the frequency of the VCO are continuously corrected, with respect to a reference frequency, until frequency acquisition takes place. Communication between the tuning system and an external controller is possible via a 3-Wire or I^{2}C bus interface.

2 FM STEREO application

The application is identical for the three IC’s as mentioned in chapter 1. This application comprises two major circuits: RF input circuit and a FM oscillator circuit.

The communication with a µ-computer can be performed via an I^{2}C or a 3-Wire serial interface bus, selectable with BUSMODE pin, for the TEA5767HN. TEA5768HL operates in I^{2}C bus mode and TEA5757HL in 3-Wire bus mode.The receivers can work with 32.768KHz or 13MHz clock crystal, which can be programmed by the bus interface. The PLL can also be clocked with 6.5MHz clock signal. Three audio outputs are available: audio left, audio right and MPX (multiplex). A basic application diagram of the FM receiver is shown in Figure 2.

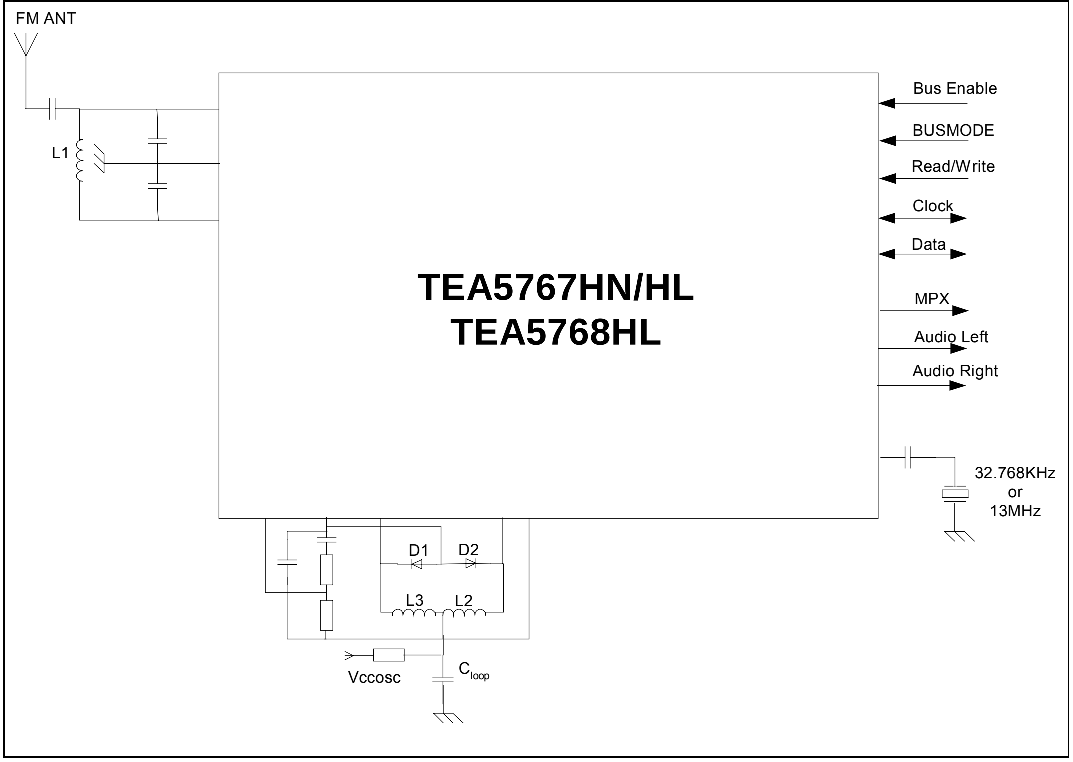


Figure 2 Basic application diagram of TEA5767/68 stereo radio

3 TEA5767HN package

The TEA5767HN FM stereo radio is a 40 pins HVQFN (SOT1618) package IC which can be operate with I^2C or 3-Wire bus interface. The fully integrated IF selectivity and demodulation make it possible to design a very small application board with a minimum of very small and low cost components. The outline of the TEA5767HN package is 6*6*0.85 mm.

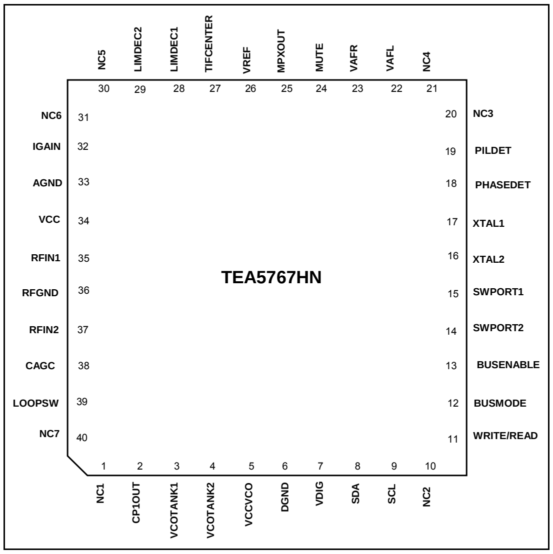


Figure 3 Pinning of the TEA5767HN (HVQFN40)

Figure 3 shows the pinning of the TEA5767HN and Table 1 gives a description of each pin of the IC.

SYMBOL	PIN	DESCRIPTION	Voltage min.	SYMBOL	PIN	DESCRIPTION	Voltage min.
NC1	1	Not connected		NC4	21	Not connected	
CPOUT	2	Charge pump output of the synthesiser PLL	1.64V	VAFL	22	Audio left output	
VCOTANK1	3	VCO tuned circuit output 1	2.5V	VAFR	23	Audio right output	
VCOTANK2	4	VCO tuned circuit output 2	2.5V	TMUTE	24	Time constant for the softmute	1.5V
VCCVCO	5	VCO supply voltage	2.5V	MPXOUT	25	FM demodulator MPX out	
DGND	6	Digital ground	0V	VREF	26	Reference voltage	1.45V
VDIG	7	Digital supply voltage	2.5V	TIFCENTER	27	Time constant for IF centre adjust	1.34V
DATA	8	Bus data line input/output		LIMDEC1	28	Decoupling IF limiter 1	1.86V
CLOCK	9	Bus clock line input		LIMDEC2	29	Decoupling IF limiter 2	1.86V
NC2	10	Not connected		NC5	30	Not connected	
WRITE/READ	11	Write/read control for the 3-Wire bus		NC6	31	Not connected	
BUSMODE	12	Bus mode select input		IGAIN	32	Gain control current for IF filter	0.48V
BUSENABLE	13	Bus enable input		AGND	33	Analog ground	0V
SWPORT1	14	Software programmable port 1		VCC	34	Analog supply voltage	2.5V
SWPORT2	15	Software programmable port 2		RFIN1	35	RF input 1	0.93V
XTAL1	16	Crystal oscillator input 1	1.64V	RFGND	36	RF ground	0V
XTAL2	17	Crystal oscillator input 2	1.64V	RFIN2	37	RF input 2	0.93V
PHASEDET	18	Phase detector loop filter	1.0V	CAGC	38	Time constant RF AGC	
PILDET	19	Pilot detector lowpass filter	0.7V	LOOPSW	39	Switch output of synthesiser PLL filter	
NC3	20	Not connected		NC7	40	Not connected	

Table 1 pinning description of the TEA5767HN

4 VCO tank circuit

The VCO circuit produces a signal at double frequency necessary for the tuning system. A divider will half the frequency of this signal and then deliver it to the PLL.

In the proposed application the used tuning diodes D1 and D2 are BB202**.** This ultra small diode is fabricated in planar technology. It has a low series resistance (0.35Ω typical), which is very important for the signal to noise ratio (SNR). In Figure 4, the capacitance value of this diode is given as function of the reverse voltage.
In our application proposal these diodes can tune the complete FM band (71-108MHz) with less then 3V-supply voltage. The minimum voltage at pin 34 (V_{CC}) should be 2.5V and the maximum voltage 5V. Inside the IC a chargepump is responsible for delivering the required current to charge/discharge the external loop capacitor. During the first 9 ms the charge pump delivers a fast current of 50uA. After that this current is reduced to 1uA.

In the given application the typical tuning voltage is between 0.54V (2*108MHz) and 1.57V (2*87.5MHz).

The minimum voltage to frequency ratio, often referred to VCO conversion factor (K_{vco}), is thus about 40MHz/V. The oscillator circuit is designed such that the tuning voltage is between **0.2V and V_{cc}-0.2V**. In order to match the VCO tuning range two serial coils L2 and L3 are put in parallel with the tuning diodes D1 and D2. A typical FM oscillator-tuning curve, using BB202 tuning diodes, is given in
Figure 5.

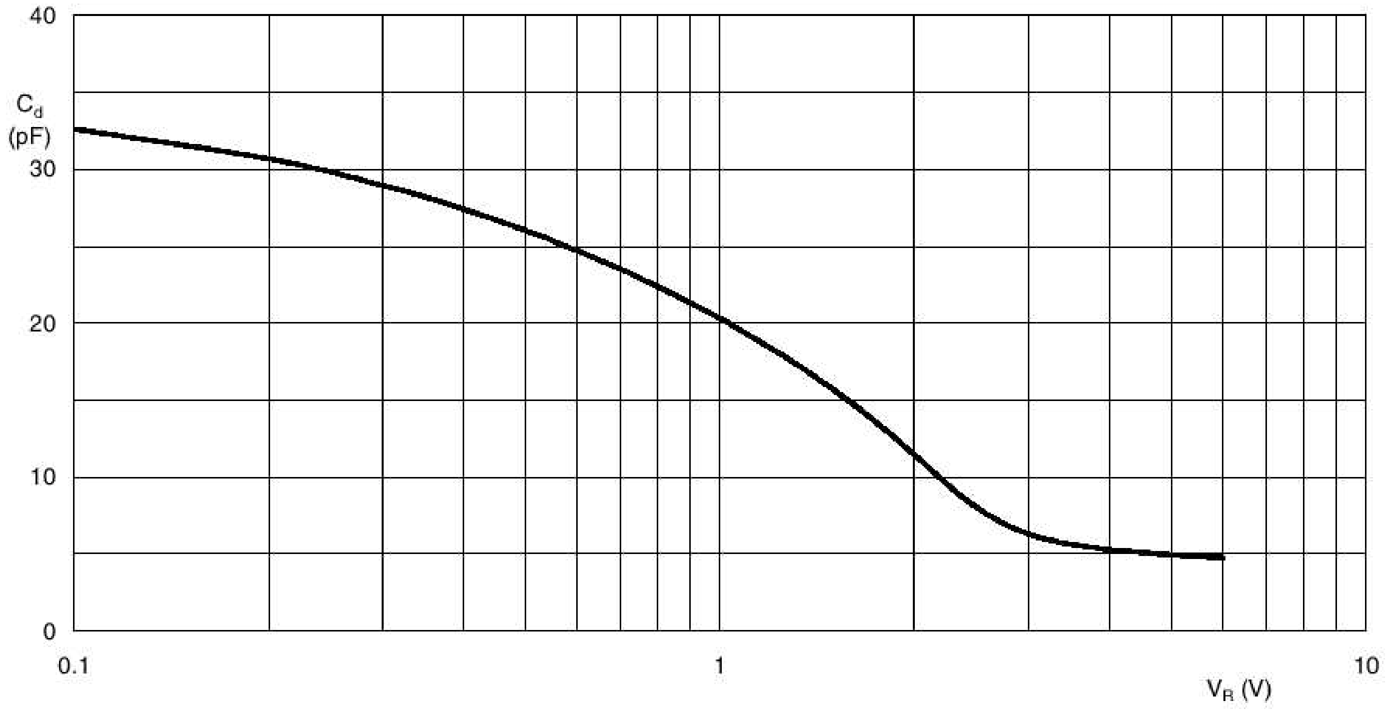
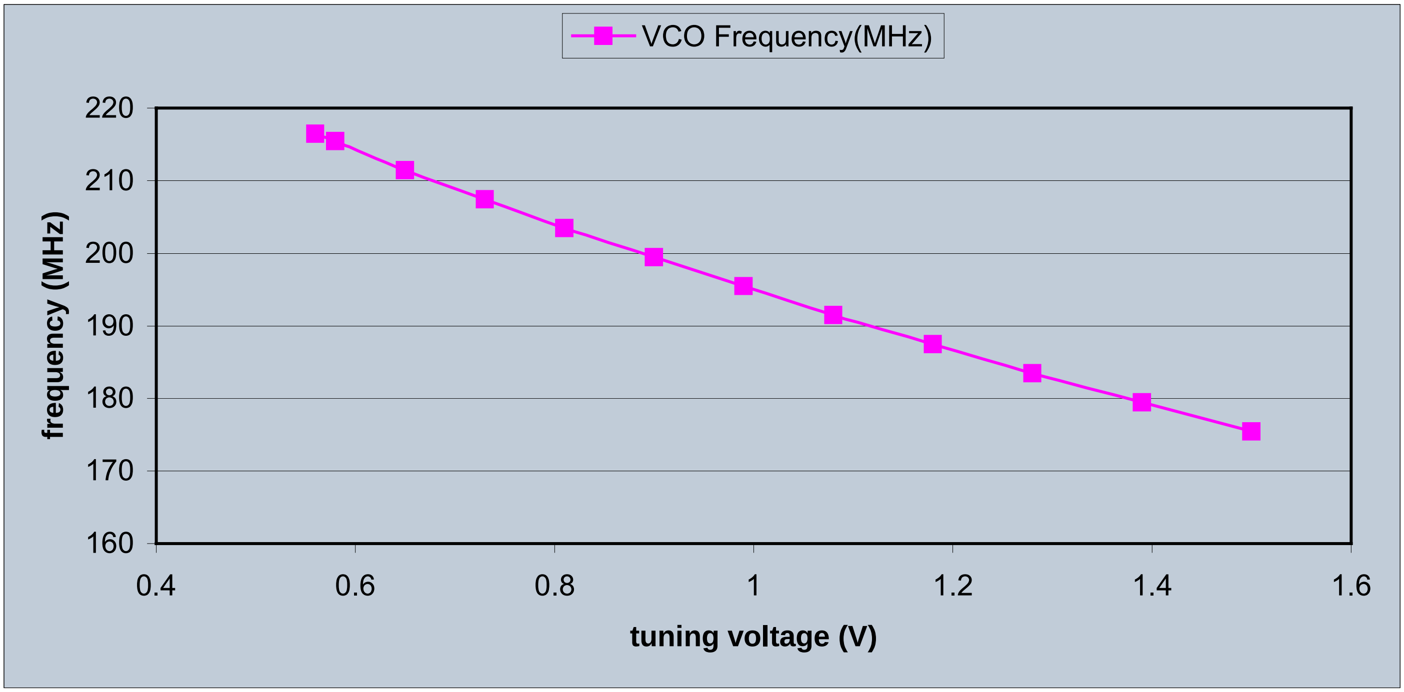


Figure 4 Diode capacitance as function of reverse voltage; typical values



The inductance value of the oscillator coils L2 and L3 is about 33nH (Q=40 to 45). The inductance is very critical for the VCO frequency range and should have a low spread (2%). The quality factor Q of this coil is important for a large S/N ratio figure. The higher the quality factor the lower the noise floor VCO contribution at the output of the demodulator will be. With a quality factor between 40-45 a good compromise can be found between the size of the coil and the, by the oscillator determined, noise floor.

Figure 5 typical oscillator tuning curve of proposed FM application

This is a shortened application note to emphasise the BB202 varicap as an important FM oscillator next to the TEA5767/68 single chip stereo FM receiver (complete application note: AN10133).

6.3 Application note
RF switch for e.g. Bluetooth appl. (2.45 GHz T/R)

1 Introduction.

One of the most important building blocks for today's wireless communication equipment is a high performance RF switch. The switch main function is to switch an RF port (ANT) between the transmitter **(TX)** and the receiver **(RX)**.The most important design requirements are, Low insertion Loss **(IL)**, Low intermodulation distortion,**(IMD)**, High isolation between TX and RX, Fast switching and Low current consumption especially for portable communication equipment. This application note addresses a transmit and receive switch for 2.4-2.5 GHz the unlicensed ISM band, in which e.g. the bluetooth standard operates. The design demonstrates a high performance T-R switch utilising low cost Philips BAP51-02 PIN Diodes as switching elements.

2 PIN diode switch design.

There are a number of PIN diode based, single pole double throw (SPDT) topologies, which are shown in the figures 1,2 and 3. Al these topologies are being used widely in RF and microwave design. They all will give good performance, due to their symmetry they will show the same performance in both the RX and TX mode. The disadvantage of these topologies is the need of a pair of digital control signals, and in both TX and RX mode bias current is needed.

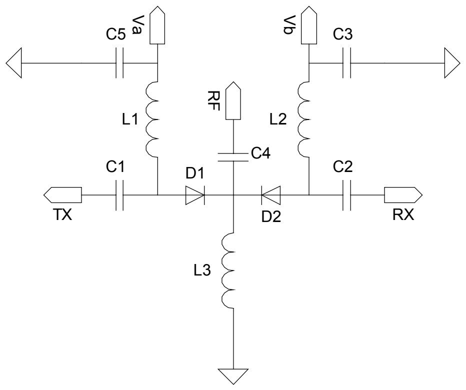


Figure 6. **SPDT switch with series diodes**

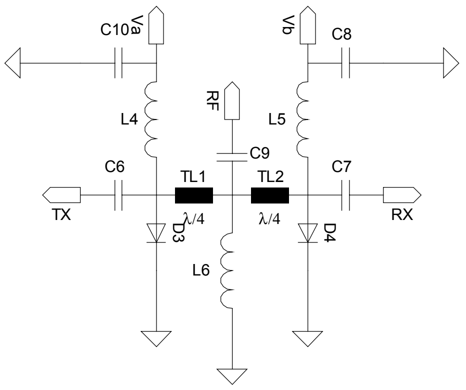


Figure 7. **SPDT switch with λ/4 sections to permit shunt diodes**

The topology we used for the design in this application note is shown in fig 4. Typically this is a combination of figure 1 and 2. The design consists of a series-connected PIN diode, placed between the transmitter-amplifier and antenna, and a shunt-connected PIN diode at the receiver-port, which is a quarter wavelength away from the antenna. In the transmit-mode both diodes are biased with a forward bias current. Both diodes are in the low impedance state. Which means a low-loss TX-ANT path and a protected RX port from the TX power.

The λ/4 transmission line transforms the low impedance at the RX port to a high impedance at the antenna. In the receive mode both diodes are zero biased (high impedance state), which results in a low loss path between antenna and receiver and high isolation ANT-TX path. One of the advantages of this approach is no current consumption is needed in the receive mode.

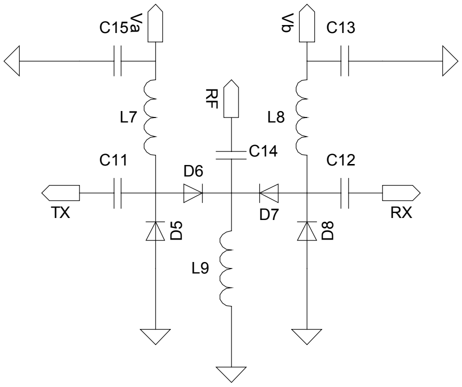


Figure 8. **SPDT switch with series shunt diodes which results in high isolation**

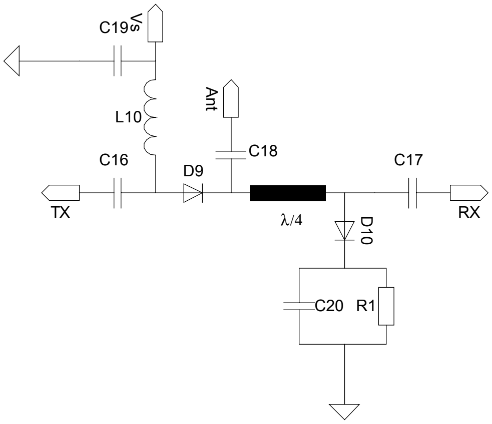


Figure 9. **SPDT switch with a combination of a series and a shunt connected PIN diode.**

The PIN diodes used in an switch like this should have low capacitance at zero bias(V_R=0V), and low series resistance at low forward current. The BAP51-02 typical shows 0.4pF@0V;freq=1MHz and 2 Ω @3mA;freq=100MHz. For the shunt diode also low series inductance is required, for the BAP51-02 this is 0.6 nH.

3 Circuit design.

Circuit and Layout has been designed with the use of Agilent's Advance Design System (ADS). The target performance of the switch is shown in table 1.

Mode	RX (0V)	TX(3mA)
Insertion Loss	< 0.65 dB	< 0.8 dB
Isolation TX/RX	>18 dB	>14.5 dB
Isolation RX/Ant	>16.5	-
Isolation TX/Ant	-	>14.5dB
VSWR RX	<1.2	-
VSWR TX		<1.3
VSWR Ant	<1.2	<1.3
Power handling	+20dBm	+20dBm
Current consumption		3mA @ 3.7V

Table 1

The ADS circuit of the switch is given in figure 5. Notice that D1 is the series connected PIN diode in the receive path en D2 is connected in shunt in the receive RF path. DC bias current is provided through inductance L1, and limited to about 3mA by resistor R1=680 Ω. Notice also that the λ/4 microstripline (width 1.136mm, length =16.57mm) is divided into several sections in order to save some board space. All the footprints for the SMD components have been modelled as a gap and a piece of stripline in order to approach the actual practice of the design on PCB.

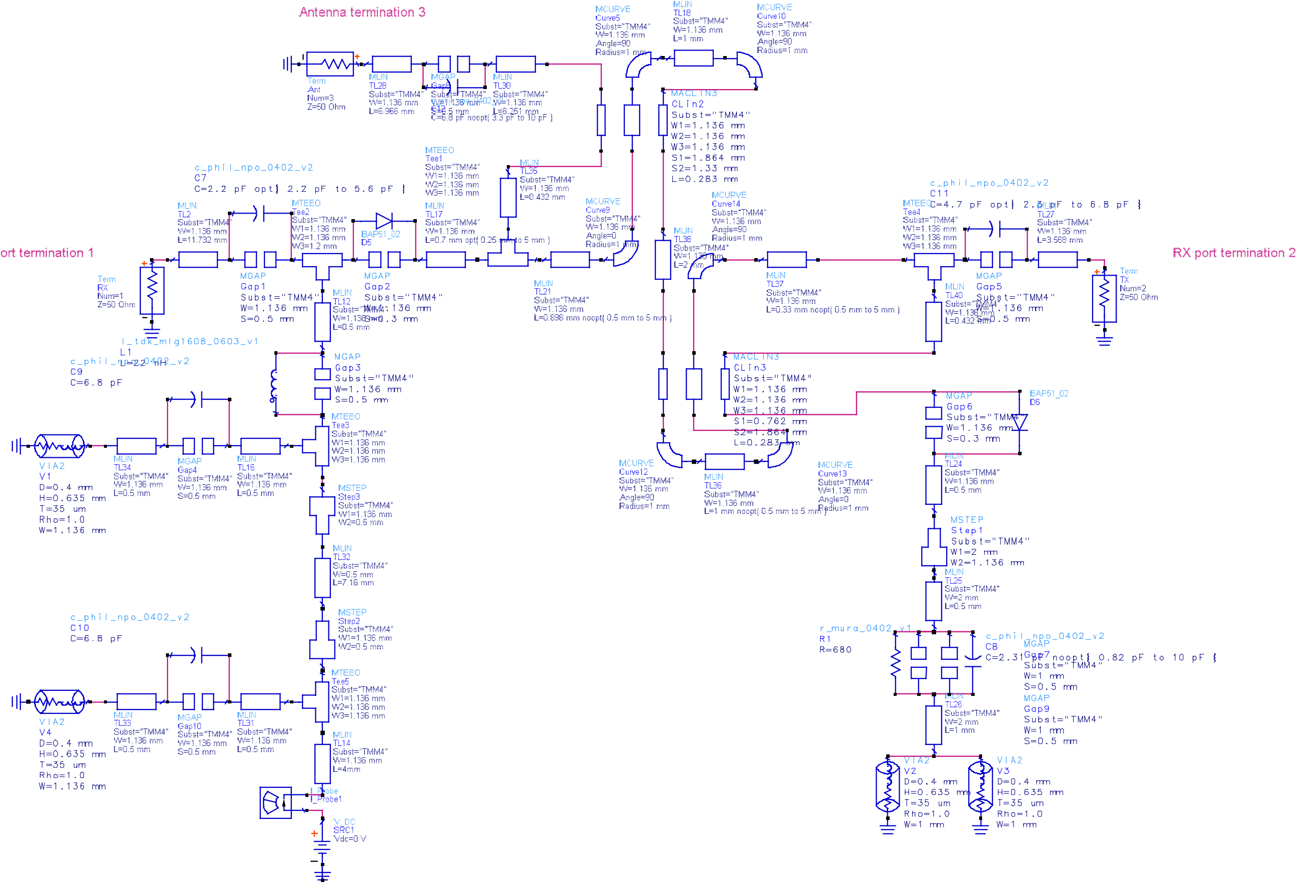


Figure 10 ADS circuit file

The discontinuity effects of the microstrip to coaxial interface have not been taken into account.

4 BAP51-02 model.

The silicon PIN diode of the Philips semiconductors BAP51-02 is designed to operate as a low loss high isolation switching element, and is capable of operating with low intermodulation distortion.

The model for the BAP51-02 PIN diode for an ADS environment is shown in figure 6. The model consists of two diodes, in order to achieve a fit on both DC and RF behaviour. Diode1 is used to model the DC voltage-current characteristics, Diode 2 is the PIN diode build in model of ADS and is used to model the RF resistance versus DC current behaviour of the PIN diode-model. Both diodes are connected in series to ensure the same current flow. For RF the PN junction Diode1 is shorted by an ideal capacitor(DC block), while the portion of the RF resistance, which reflects the residual amount of series resistance is modelled with R1=1.128 Ω. To avoid affecting the DC performance this resistor is shunted with the ideal

Inductor (DC feed). Capacitance C2 and inductors L2 and L3 reflect the package parasitics. The here described model is a linear model that emulates the DC and RF properties of the PIN diode from 6 Mhz up to 6 GHz.

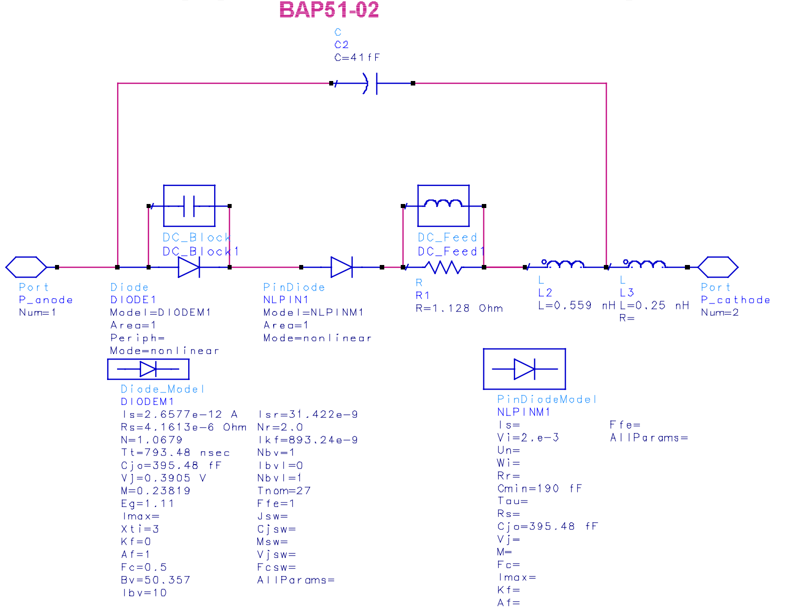


Figure 11; BAP51-02 Small Signal Model for an ADS environment

5 Circuit and Layout Description

The circuit diagram for the switch is shown in figure 7 and the PC board layout is shown in figure 8.
The bill of materials for the switch is given in table2.
For the PC board 0.635mm thick FR4 material (ε_r = 4.6)metalized on two sides with 35 µm thick copper, 3 µm gold plated was used. On the test board SMA connectors were used to fed the RF signals to the design.

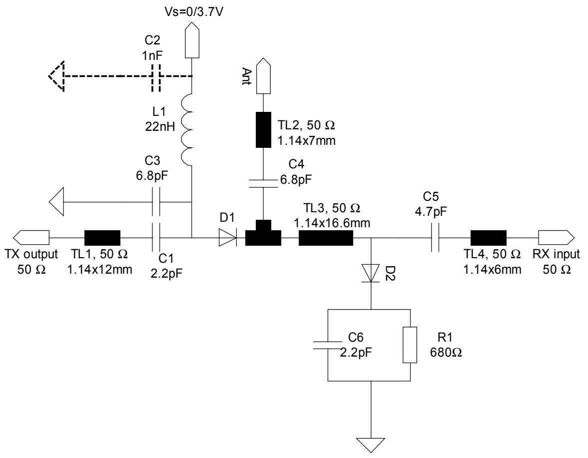


Figure 12; circuit diagram

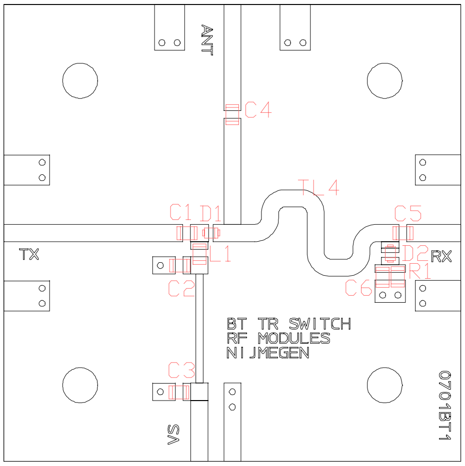


Figure 13; PC board Layout.

Component	Value	Footprint	Manufacturer
C1	2.2 pF	0402	Philips
C2*	1 nF	0402	Philips
C3	6.8 pF	0402	Philips
C4	6.8 pF	0402	Philips
C5	4.7 pF	0402	Philips
C6	2.2 pF	0402	Philips
R1	680 Ω	0402	Philips
D1	BAP51-02	SC79	Philips
D2	BAP51-02	SC79	Philips
L1	22 nH	1005	Taiyo yuden
TL1	λ/4;50 Ω		on the PCB

Table 2 Bill of materials *C2 is optional.

6 Measurement results.

In table 3 the measured performance of the switch is summarised. In figure 9, both the simulation and Measurement results in TX mode (3.7V/3mA) is shown, for the RX mode this can be seen in fig.10.

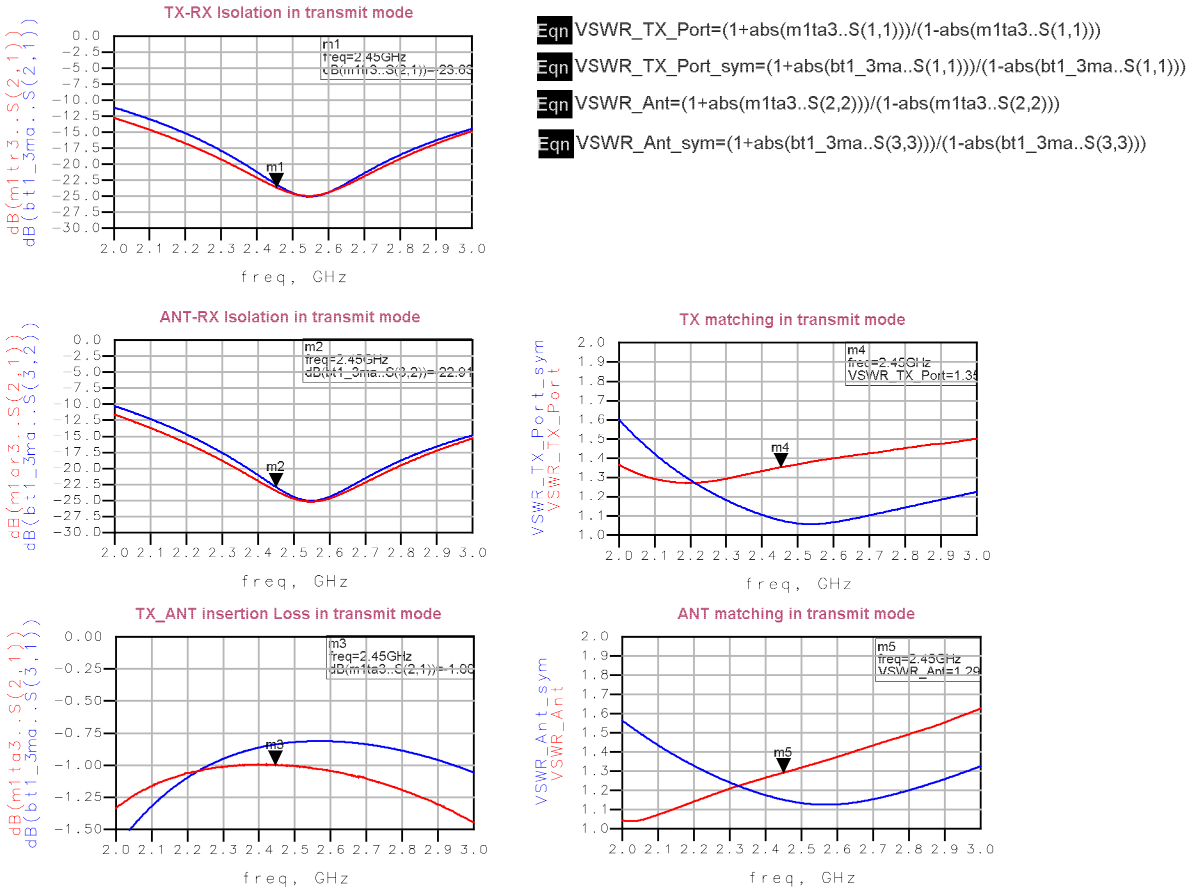
	Mode	
parameter	RX (0V)	TX(3mA)
Insertion Loss @ 2.45GHz	< 0.57 dB	< 1.0 dB
Isolation TX/RX @ 2.45GHz	>20.4 dB	>23.6 dB
Isolation Ant/RX @ 2.45 GHz	-	>23.5 dB
Isolation TX/Ant @2.45 GHz	>19.76 dB	-
VSWR RX @2.45 GHz	1.24	-
VSWR TX @2.45 GHz	-	1.35
VSWR Ant @2.45 GHz	1.19	1.29
IM3 Pin 0 dBm f1=2.449 GHz f2=2.451 GHz	+39 dBm	+40 dBm
IP3 Pin 0 dBm f1=2.449 GHz f2=2.451 GHz	+43.8 dBm	+44.8 dBm
IM3 Pin +20 dBm f1=2.449 GHz f2=2.451 GHz	+38.5 dBm	+39.5 dBm
IP3 Pin +20 dBm f1=2.449 GHz f2=2.451 GHz	+43.3 dBm	+44.3 dBm
Power handling	+20 dBm	+20 dBm
Current consumption		3mA @ 3.7V

Table 3 measured switch performance.

Intermodulation distortion measurements were performed as follows. In both RX and TX state, first the measurements were done with two input-signals, each at 0 dBm and second each signal at +20 dBm. In transmit state these signals were applied to the TX port, distortion was measured at the antenna port, while the RX port was terminated with 50Ω. In receive state the two signals were applied to the ANT port, distortion was measured at the RX port, with the TX port terminated.

According to reference 2, the third order harmonic distortion product is 9.54 dB less than the third order Intermodulation product, the third order harmonic intercept point IP3 is 9.54/2 higher than the third order Intermodulation intercept point IM3.

simulation and measurement results in transmit mode Is=3mA



Eqn VSWR_TX_Port=(1+abs(m1ta3..S(1,1)))/(1-abs(m1ta3..S(1,1)))

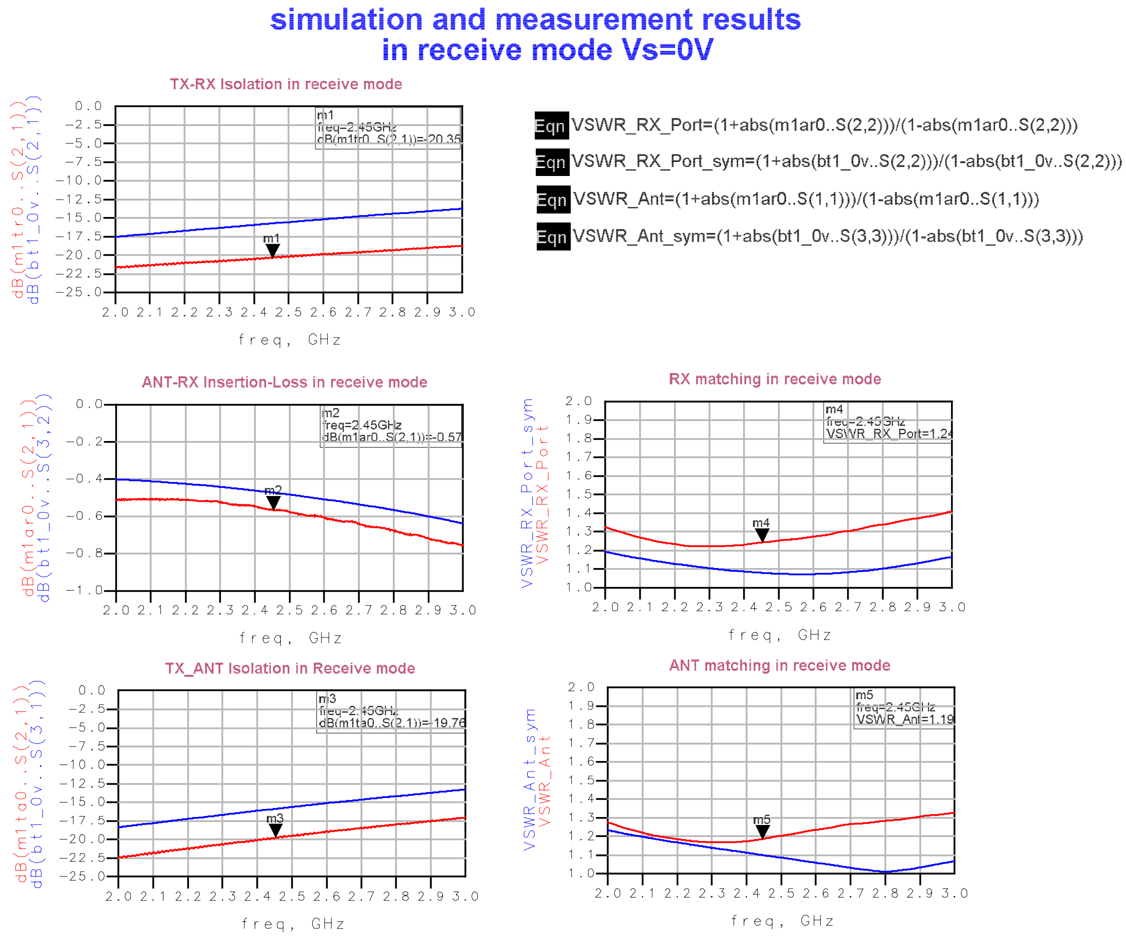
Eqn VSWR_TX_Port_sym=(1+abs(bt1_3ma..S(1,1)))/(1-abs(bt1_3ma..S(1,1)))

Eqn VSWR_Ant=(1+abs(m1ta3..S(2,2)))/(1-abs(m1ta3..S(2,2)))

Eqn VSWR_Ant_sym=(1+abs(bt1_3ma..S(3,3)))/(1-abs(bt1_3ma..S(3,3)))

Figure 14; Results in TX mode; red curves are measurements, blue curves are the simulated ones.

Remark: *Loss and Isolation results are all including approximately 0.2 dB loss of the SMA connectors which were used to fed the RF signals through the design. this has a great effect on the Insertion-Loss results.*



simulation and measurement results
in receive mode Vs=0V

Eqn VSWR_RX_Port=(1+abs(m1ar0..S(2,2)))/(1-abs(m1ar0..S(2,2)))
Eqn VSWR_RX_Port_sym=(1+abs(bt1_0v..S(2,2)))/(1-abs(bt1_0v..S(2,2)))
Eqn VSWR_Ant=(1+abs(m1ar0..S(1,1)))/(1-abs(m1ar0..S(1,1)))
Eqn VSWR_Ant_sym=(1+abs(bt1_0v..S(3,3)))/(1-abs(bt1_0v..S(3,3)))

Figure 15; Results in RX mode; red curves are measurements, blue curves are the simulated ones

Remark: *Loss and Isolation results are all including approximately 0.2 dB loss of the SMA connectors which were used to fed the RF signals through the design. this has a great effect on the Insertion-Loss results.*

Recommendations.

1 In this design the BAP51-02 was used because it’s designed for switching applications related to Insertion Loss and Isolation. When for instance a better IM distortion is recommended it’s better to use the BAP64-02 of Philips Semiconductors.

2 As you can see the λ/4 section still needs a lot of boards space. This section could be replaced by a lumped element configuration, which results in an extra boardspace reduction.

*References:*1; Gerald Hiller, “Design with PIN diodes”, App note APN1002 Alpha industries inc.

2; Gerald Hiller, “Predict intercept points in PIN diode switches”, Microwaves & RF, Dec. 1985.

3; Robert Caverly and Gerald Hiller, “Distortion in PIN diode control circuits” IEEE Trans.Microwave

6.4 Application note
Low impedance Pin diode

A Low Impedance PIN Diode Driver Circuit with Temperature Compensation

Two Philips BAP50-05 PIN diodes are used in an RF attenuator with a low impedance driver circuit to significantly decrease the rise and fall times. A standard attenuator with an unspecified driver is shown in Figure 1. Each of the two PIN diodes operates as an RF resistor whose value is controlled by the DC current[*]. The signals reflect off of the diodes and through the 3 dB hybrid in a way to add in phase. The amount of signal that is reflected off the diodes depends on the resistance value. In this circuit, the diodes are operated from several hundred ohms down to a value approaching 50 ohms, where there is no reflection and thus maximum attenuation.

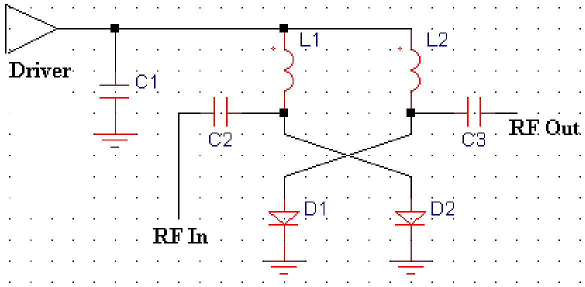


Figure 1. Commonly Used Attenuator. Diodes are BAP50-05.

C1 is required for RF bypass, and typically might be 10-100 pF when working in the GHz range. An application for this attenuator circuit is a fast gain controllers in predistorted and/or feedforward amplifiers, where the circuit is required to change attenuation in tens of nS, where C1, C2, and C3 can limit the speed. Insertion loss is generally not important in this application, and the dynamic range required may be only 8 to 10 dB. When this is true, it is possible to achieve a large improvement in speed.

In driving a PIN diode attenuator, conflicting requirements arise from speed, linearity, and temperature compensation. For the best speed, a low impedance source (<50 ohms) is required; for linearity and temperature compensation, a current source is by far the best, especially if it is desired to go to maximum resistance (lowest current) in the PIN diodes. Figures 2 and 3 show current, voltage, and attenuation for the circuit of Figure 1 in two different formats (linear and log *x* axis), with a current source for the driver.

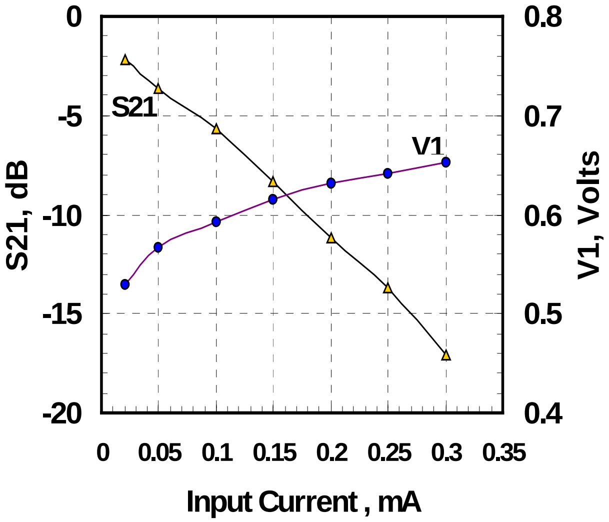


Figure 2.

At medium attenuation, the PIN diode[†] resistance is in the region of several hundred ohms, and current is in the region of 10-100 uA. The *control* impedance[‡] (impedance of the diodes) is $Z = \frac{KT}{qI}$. If driven by a current source, such as a current output DAC, the source impedance is high and the

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[*] Although the BAP50-05 contains two diodes, only one per package is used for mechanical layout reasons.

[†] Actually two diodes in parallel, but for analysis we will consider one.

[‡] Not to be confused with RF impedance.

total impedance is determined by the diodes. The risetime will be limited by the inevitable capacitance's (illustrated by C5).

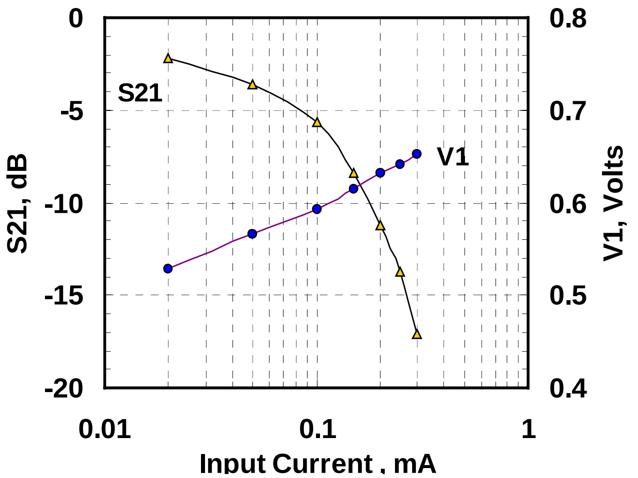

Figure 3.

If the diodes are driven from a voltage source (not shown), the speed is very fast, but the attenuation is highly non-linear and is highly temperature dependent.

Shunting the PIN Diodes

Figure 4 shows a circuit which maintains a low impedance in the PIN circuit, to keep the rise and fall times short, but linearizes the circuit to some extent and is temperature compensated. Only one diode is shown for simplicity.

Operation is as follows: Q1 operates as a diode and absorbs most of the current from the current source. It is shown below that for two diodes in parallel (whether formed by Pins or transistors), the ratio of the two currents is fixed for all currents (over many decades), and is controlled by the voltage offsets applied to them (with respect to each other). This principle is used in *translinear* analog multipliers, of which the Gilbert cell multiplier is a type.

In this circuit, the offset is adjusted with V2, which is only some tens of millivolts. Operating the device like this is similar to circuits where the base and collector are tied together to form a diode. The collector to emitter voltage is *less* than the base to emitter voltage, in magnitude. V_{CE} is roughly 0.65 V. This is acceptable, without resorting to a negative supply for the collector, because there is still several hundred mV of margin from the standpoint of device saturation.

Q1 is thermally tied to the PIN diodes by virtue of their proximity, providing a first order temperature compensation. Q1 thus is operating as a log circuit converting current to voltage in a way that linearizes the attenuation.

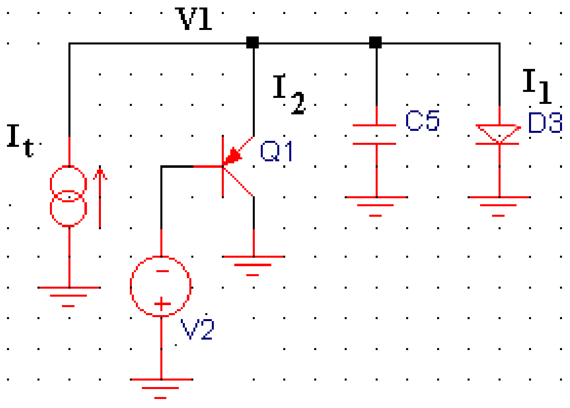

Figure 4. Transistor Shunt. V2 is < 200 mV.

The complete circuit is shown in Figure 5. The hybrid is a surface mount Anaren Xinger 1D1304-3. Figures 6 and 7 show the current, voltage, and attenuation characteristics. Note that the input current is much higher than with the original circuit (Figures 2 and 3). This reduces efficiency but it is desirable from a standpoint of keeping the total impedance low.

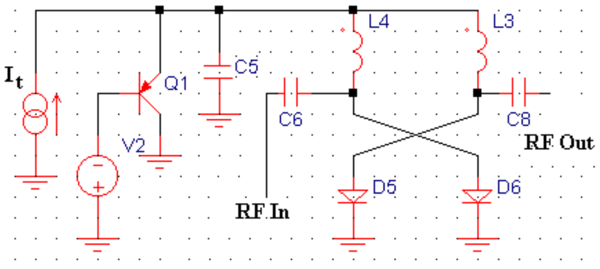

Figure 5 . Circuit with Two Diodes and Hybrid. D5 and D6 are Philips BAS50-04. Q1 is PMBT3906.

Capacitors C6 and C8 are essentially in parallel with C5 from a standpoint of the drive circuitry.

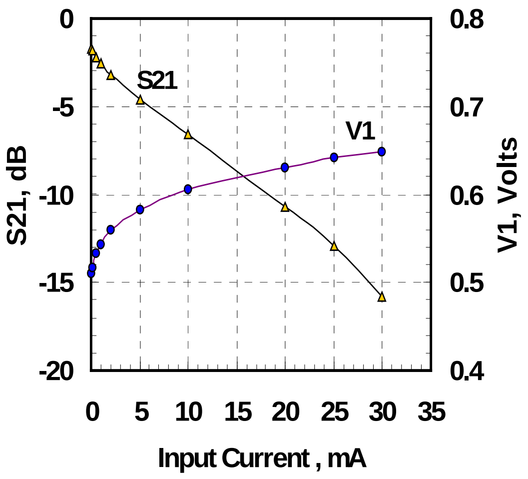

Figure 6. Circuit of Figure 5 (measured).

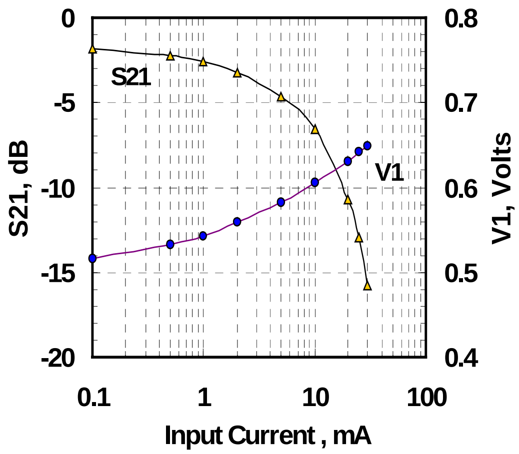

Figure 7. Same as Figure 6 with Log Scale.

Relationship of the Diode and Transistor Currents

Refer to Figure 4. From basic diode equations, the currents in the PIN diode and Q1 are:

$$I_1 = I_{S1}(e^{\frac{qV1}{KT}} - 1) \qquad (1)$$

$$I_2 = \beta I_{S2}(e^{\frac{q(V1-V2)}{KT}} - 1) \qquad (2)$$

where

q is the electron charge, 1.602E-19,
K = Bolzmann's constant, 1.381E-23
T = temperature in degrees K
I_{S1} = Saturation current for the PIN diode
I_{S2} = Saturation current for the base junction of the transistor
V_1 - V_2 = the base to emitter voltage of the transistor ($V_2 < 0$)
$\frac{q}{KT} \approx 40$ at room temperature

For voltages over a few millivolts, the exponential terms in (1) and (2) dominate the "1", and the equations can be simplified to

$$I_1 = I_{S1} e^{\frac{qV_1}{KT}} \qquad (3)$$

$$I_2 = \beta I_{S2} e^{\frac{q(V_1 - V_2)}{KT}} \qquad (4)$$

Then, the ratio of the currents is:

$$\frac{I_1}{I_2} = \frac{I_{S1} e^{\frac{qV_1}{KT}}}{\beta I_{S2} e^{\frac{q(V_1 - V_2)}{KT}}} = \frac{I_{S1}}{\beta I_{S2} e^{\frac{-qV_2}{KT}}} = \frac{I_{S1}}{\beta I_{S2} e^{-40V_2}} \qquad (5)$$

To the extent that β is constant with temperature[§], we see that the current ratio is dependent only on V_2, which, stated another way, the current in the PIN diode is a fixed percentage of the total input current. There is first order temperature compensation, by virtue of the parallel tracking of the two diode junctions.

Further, we can set the current ratio to an arbitrary amount by setting the base voltage V_2. If $\beta = 50$, and $I_{S1} = I_{S2}$ (by way of example only), and we want to set the PIN diode current to 1% of the total current, we have

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[§] β is certainly not constant with temperature, but this is a second order effect, not nearly as strong as the direct temperature relationship as with the base emitter voltage (Angelo, *"Electronics: BJTs, FETs and Microcircuits"*, McGraw Hill 1969.)

$$.01 = \frac{1}{50e^{-40V_2}} \quad \text{so } V_2 = -.0173. \qquad (6)$$

By having a relatively large current in Q1, the dynamic impedance that the current source sees, defined by $\frac{dV_1}{dI_T}$ becomes much lower, dominated by the lower impedance of the Q1.

For a general *pn* junction this impedance is $Z = \frac{KT}{qI}$. Thus, in the circuit of Figure 1, with no shunt transistor, the PIN diodes operate at perhaps 10 to 100 uA (total for two diodes), and the impedance ranges from 2500 to 250 ohms.

In the circuit of Figures 4 and 5, the PIN diodes operate at the same 10 to 100 uA, but the impedance for the parallel combination of Q1 and the two diodes is 25 to 2.5 ohms[**].

Risetimes

In Figure 1, if all the capacitance's C1, C2, and C3 add up to 100 pF, the worst case risetime, which occurs at the lowest current, will be *RC* = 2500*100E-12 = 250 nS. In contrast, the circuit of Figure 5, the worst case risetime is 25*100E-12 = 2.5 nS.

Adjustment

V_2 controls the amount of current that Q1 draws relative to the total current I_t. At low voltages (50 mV), Q1 does not draw much current relative to I_t, and the speed benefit will be minimal. However, the dynamic range is the highest, as shown in Figure 8. If lower dynamic range is acceptable, V_2 can be upwards of 150 mV, where the impedance is lower and the speed benefit will be the largest. Of course, using different types of devices for Q1 and the diodes may require different values of V_2.

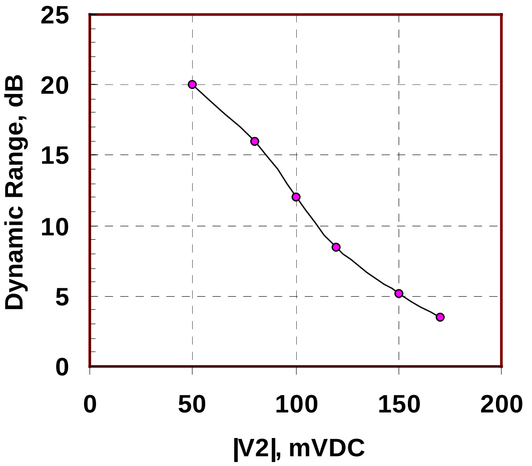


Figure 8. RF Dynamic Range.

Conclusion

A current controlled RF attenuator driver circuit has been shown which has the speed advantage of a low impedance (<50 ohm) driver, and the linearity advantage of a high impedance (current) driver. This is done by shunting the PIN diodes with a base-emitter junction of a transistor, which carries the bulk (e.g. 99%) of the driver current, lowering the impedance. The current divides itself between the transistor and the PIN diodes in a constant proportion. The current sharing percentage is settable with the base voltage. Temperature compensation on a first order basis is inherent from the tracking of the devices. The trade-off is a lower efficiency, the circuit now requiring 10 to 20 mA of drive, as opposed to 100 uA for the simpler circuit. The current is in the range of many DACs (current output types) and this circuit lends itself well to that application. For application in an envelope restoration loop such as is found in predistorted amplifiers, the dynamic range of 8 to 10 dB is acceptable.

May 2002
bja

[**] Neglecting the series emitter resistance of the transistor which might be 1-2 ohms.

6.5 Application note
WCDMA appl.: BGA6589 Wideband Amplifier

1.0 Introduction.

This application note provides information that is supplementary to the data sheet for the BGA6589 amplifier, and includes temperature and DC stability characteristics and WCDMA information.

Figure 1 shows the biasing method. The device is already matched to 50 ohms.

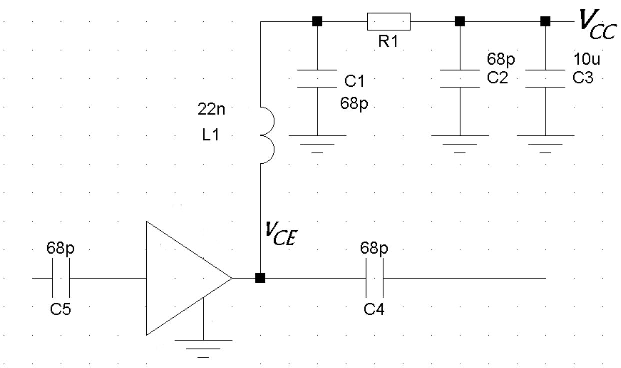


Figure 1. Bias Method.

2.0. DC Characteristics.

Figure 2 shows the DC load line characteristics of the device, when biased with two different voltage and resistor combinations.

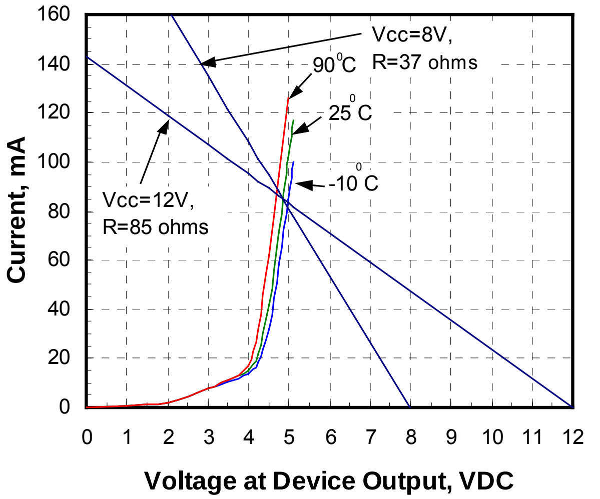


Figure 2. BGA6589 DC Characteristics.

Reviewing the graphical load line method, we superimpose the equation for the load resistor onto the device characteristics, and the intersection shows the current and the voltage of the device. The equation for the resistor is basically a horizontally flipped version of a straight line representing a resistor across a voltage source, which of course runs through the origin and has a slope determined by *R* and *V*.

Using BJT terminology, the device voltage at the output pin is $v_{CE.}$ and the supply is V_{CC}. Then,

$$v_{CE} = V_{CC} - Ri_C \quad \text{and}$$

$$i_C = \frac{V_{CC}}{R} - \frac{v_{CE}}{R} = I_O - \frac{v_{CE}}{R}$$

where *Io* is the intercept on the y axis.

Figure 3 shows the same data expanded. We can see that when biasing with 8V and 37 ohms, the current is stable over temperature from 82 to 89 mA.

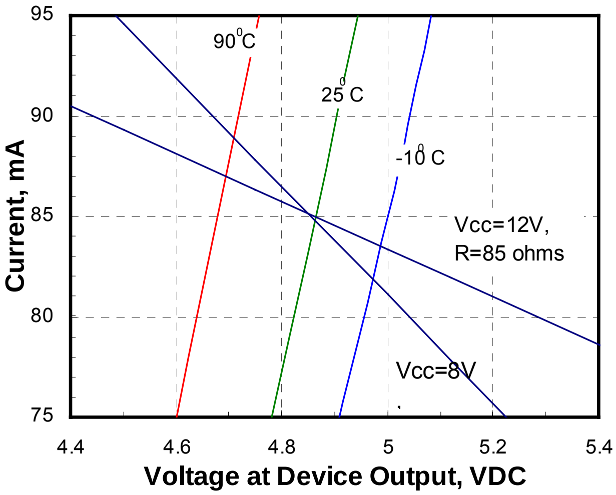


Figure 3. DC Characteristics Expanded

Device variations, however small, and supply voltage variations are not yet accounted for in the figure. However, when we look at how the device functions at different currents, we see that I_C is not critical. For example, in Figure 4 we see that the gain is virtually independent of the bias current.

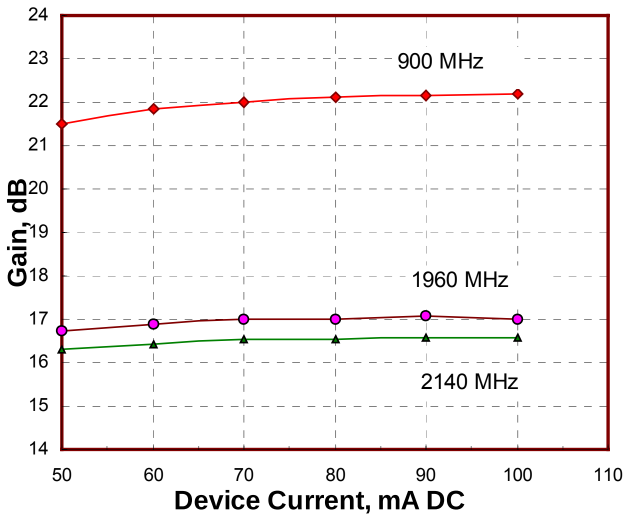


Figure 4. Gain Stability with Bias.

Similarly, the gain vs. temperature is shown in Figure 5. There is a slight negative temperature coefficient.

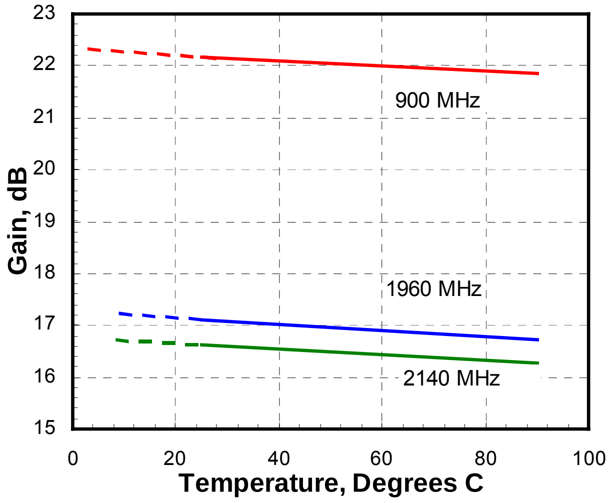


Figure 5. Gain Stability with Temperature.

3.0. WCDMA Performance.

3.1. Normal Bias. Figure 6 shows the spectrum for WCDMA 3GPP, with 15 channels of data. The frequency limits for measurement are shown by the arrows for the reference (on) channel and the adjacent channel. The channel powers are integrated over a 3.84 MHz band, with a channel offset of 5 MHz for the ACP measurement.

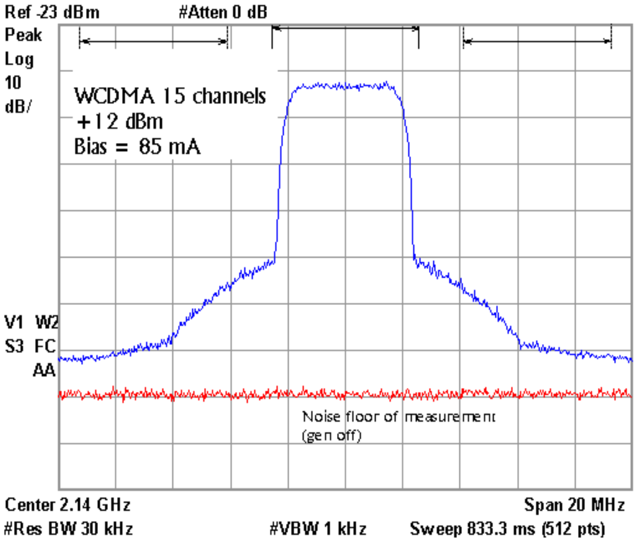
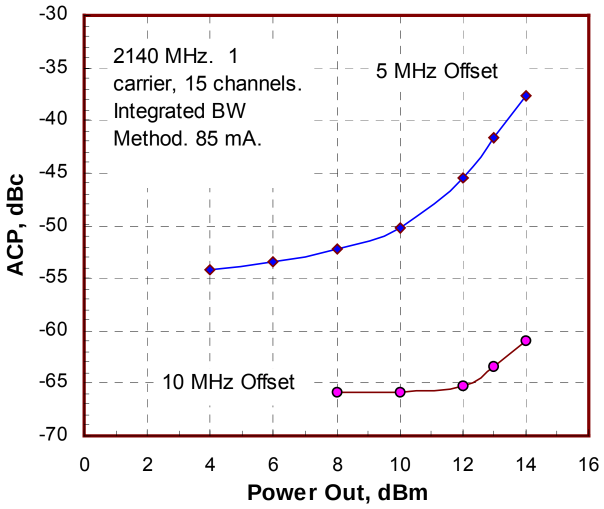


Figure 6. WCDMA Spectrum.

Figure 7 shows the 5 and 10 MHz offset measurements over a power range. There are many parameters that affect the ACP, even for the same number of channels and their allocations, such as the data type (random or repeating), the powers in the channels (equal or different), pilot length, timing sequence, and the symbol rate.



The effect of the number of data channels in the WCDMA signal is shown in Figure 8.

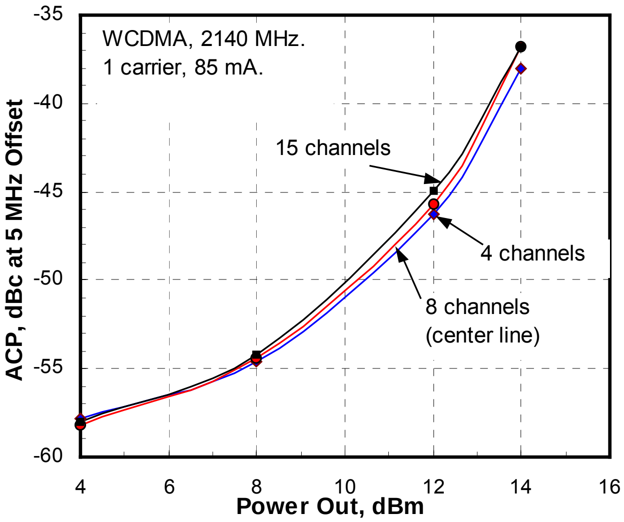


Figure 8. Effect of Number of Data Channels.

3.2. Reduced Bias. The compression point (P1dB) is affected by the device current, as expected. The effect of the current and the associated P1dB on the WCDMA performance is shown in Figure 9. At low powers, the device can tolerate a lower current and still stay within acceptable limits. At +12 dBm, the bias can drop to 75 mA without undue degradation.

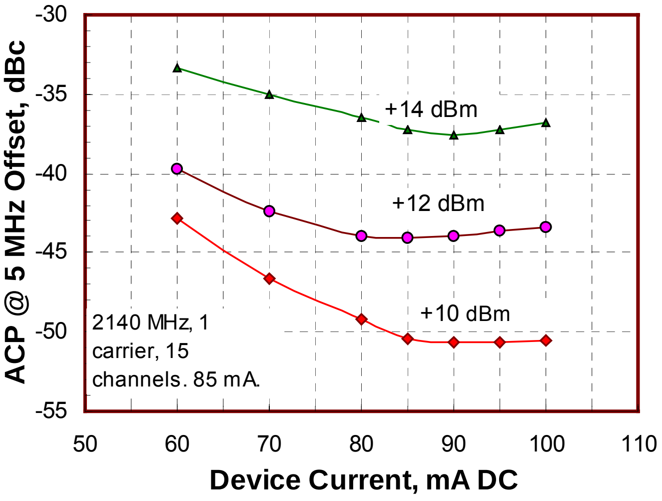


Figure 9. ACP with Reduced Bias.

4.1. CCDF. In WCDMA systems (and IS95 systems and QAM systems in general), the peak to average ratio of the signal can be 12 dB or more. In an amplifier application, designing in enough headroom to handle all the peaks would make it unnecessarily expensive and inefficient. The highest peaks only occur a small portion of the time (such as parts per million), and can be allowed to compress in the amplifier. The tradeoff is of course distortion and ACP.

A complementary cumulative density function (CCDF) curve is shown in Figure 10 for 32 data channels. Consider first the CCDF for the case of no clipping. As a very rough thumbnail estimate of ACP, we know from analysis that limiting or clipping of events that happen .01% of the time can cause ACP's in the general range of –40 dBc. This of course is dependent on many factors, such as type of limiting (hard clipping vs. soft compression, etc.). The value of –40 dBc corresponds to 10 log (.0001), where .0001 is simply .01% as a fraction.

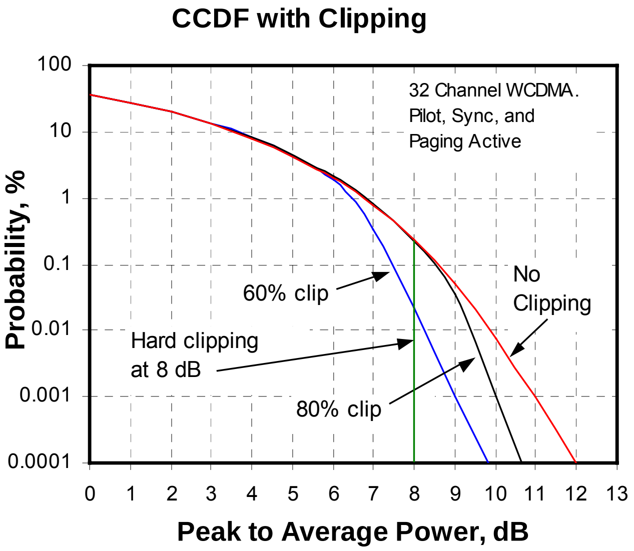


Figure 10. CCDF.

4.2. Digital Hard Clipping. In the physical layer of WCDMA systems, advantage can be taken of the high level of redundancy in the coding, spreading, and overhead bits of the basic channel data by eliminating some of the symbols before entering the amplifier/transmitter. The air interface is designed to operate with fading, dropouts, static etc., therefore, eliminating some small percentage of the symbols can be tolerated, because the bulk of these symbols are corrected for in the receive decoding process.

In the basestation, this clipping is done on the digital summation of all the I and Q samples, *before filtering*. This is critical. This way, the ACP energy caused by the clipping can be filtered out in the baseband filters before amplification. The filtering process softens up the CCDF curve that would otherwise be a hard clip, an example of which is shown in Figure 10.

Also in Figure 10, the CCDF is shown for the cases of clipping the signal at 60% and 80% relative to the highest peak, followed by filtering. While this may seem to be a severe amount of clipping, the highest peaks (uncommon as they are) might actually be 14 dB or more above the average power, so the more typical peaks of 10 dB or so are not clipped very much.

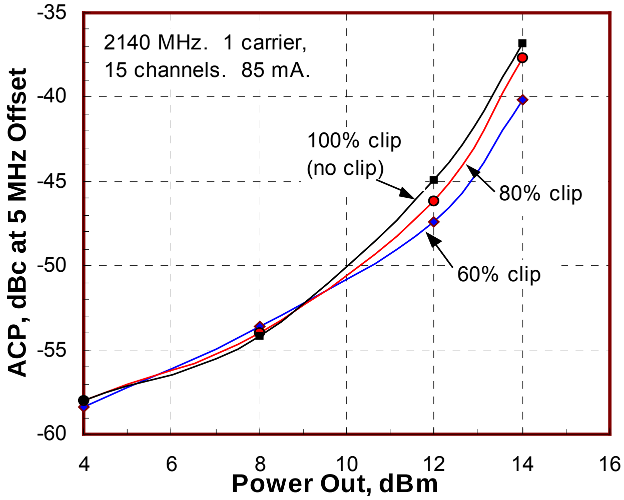
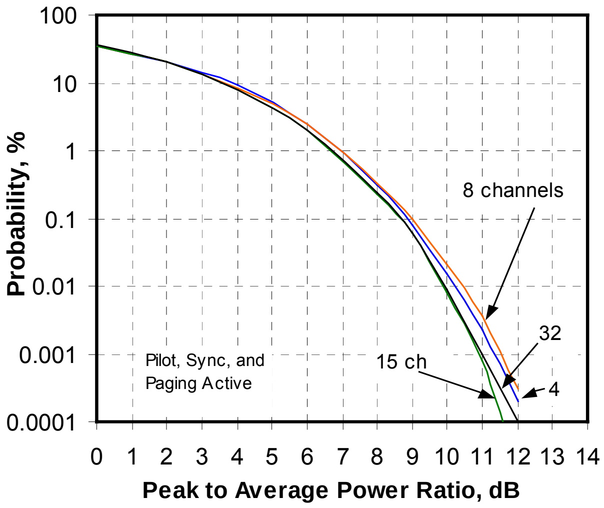


Figure 11. Clipping effects on the ACP.



The effect of clipping on the ACP is shown in Figure 11, for a 15 channel WCDMA signal. This is measured data for the BGA6589. The x axis is average power. For 32 channels, the ACP is very similar, because the CCDFs are similar, as shown in Figure 12.

5.0. Load Pull.

Class A devices are not often subjected to a load pull test, but doing so shows the resiliency of the device when the BGA6589 is feeding a stage with a less than perfect S11. Figure 13 shows the ACP under various VSWR conditions.

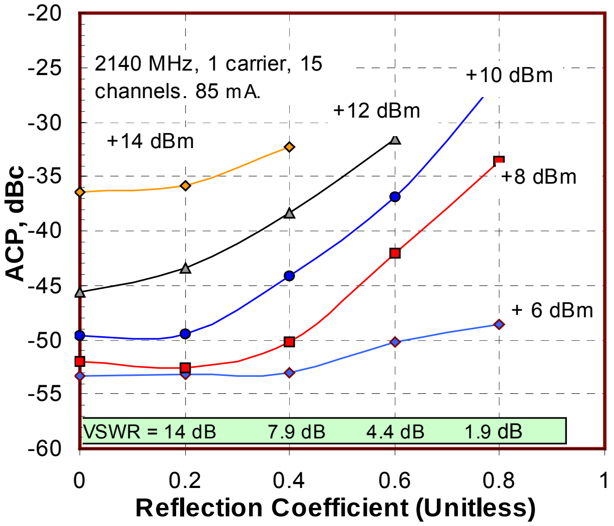


Figure 13. Load Pull Test.

For this test, the worst of four phases of reflection was plotted for a given reflection coefficient, at several powers. The VSWR corresponding to the reflection coefficient is shown just above the x axis. At low/medium powers, a significantly "poor" load reflection is tolerable, before degrading the ACP. For each measurement, the gain necessarily changed due to the loading, and the input drive was changed accordingly to keep the output power constant.

7 Selection Guides

The 3 product clusters of our RF Small Signal portfolio:

The portfolio covered in this RF Manual covers small-signal products for a wide variety of applications. For tuning, a wide range of varicaps, bandswitch diodes and FETs. For telecom and more generic RF applications an equally wide range of pin diodes, MMICs and wideband transistors are available. The MMIC and wideband transistor portfolio includes SiGe products.

- **Bandswitch diodes**
- **Varicap diodes** "varactors'
- **Pin diodes**

Diodes

- **Field-effect transistors** Mosfets / J-fets
- **Wideband transistors** generations 1-4, 5-7

Transistors

- **50 ohm gain blocks**
- **LNA's**
- **Variable gain amplif.**
- **Mixers**

MMIC's

Bandswitch diodes:

Are **switching** diodes. Mainly used in tuner applications. They help to achieve that the signals which are received by an antenna are separated into the correct frequency band(s).

Varicap diodes "Varactors"

Are electronically **tuning** diodes. Varicap diodes are used in tuner applications to enable various frequencies to be separated (in e.g. the input-filter) or to be generated (e.g. in an oscillator).

→ **Upcoming varicap in development is: BB140L.**
This VCO varicap for the communication market will be packed in leadless SOD882.

Pin diodes:

Are **switching** diodes. Due to their construction, they are ideal switches in RF-applications, main usage is as switch between transmitter and receiver in 1-antenna-applications.

→ **Upcoming Pin diodes in development are: BAP51L, BAP1321L, BAP142L and BAP144L.**
The package of these new types will be SOD882.Applications: antenna switch, T/R switch, Antenna diversity switch for cell phones, cordless, basestation transceiver circuits and any equipment requiring switching function.

7 Selection Guides

The 3 product clusters of our RF Small Signal portfolio:

Field-effect transistors (Fet's):

Are e.g. **pre-amplifying** transistors. Fet's e.g. make sure a signal is already amplified in a car radio before the signal enters the radio amplifier, so the Fet prevents that the noise also gets amplified.
Fet's are ideal switches for applications where distortion-free amplification is required.

→ **Upcoming Field-effect transistors in development are: BF1205, BF1206, BF121xxx-serie.**
BF1205 will contain two BF1202's and a switch and therefore realises the reduction in component count.
BF1206 UHF/VHF Fet is significantly improved on low frequency noise, Yfs and component count.
BF121xxx-serie will become the improved versions of BF120xxx-serie (low frequency noise performance).

Wideband transistors:

Are signal **amplifying** transistors. Wide band transistors ensures that the voice quality from a person in a mobile phone is good and clear. Main usage in RF amplifiers where signal-levels are increased for better processing.

→ **Upcoming wideband transistor in development is BFU620.**
The applications of this 7th generation Si Ge QuBIC4G transistor (Ft=65GHz) are: LNA, buffer & oscillator for cell phone, GPS receivers, LNB & generic RF. Package: SOT343.

MMIC's:

The Monolithic Microwave Integrated Circuit in our product portfolio offers the combination of several transistors, resistors and capacitors to perform one specific RF function.
These devices are therefore an interesting compromise between the total integration of a system on a chip and the use of discrete devices only.
MMIC's have same footprint as discrete devices.
MMIC's can be used for a wide range of applications.
MMIC's benefit from the integration of parts that belong together.

→ **Upcoming MMIC's in development are: BGA6589. BGA6489 and BGA6289.**
These MMIC's, medium power gainblocks, are used for basestations. Package: SOT89.

7.1 Selection Guides: MMIC's

** = new product

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

General Purpose Wideband Amplifiers, 50 Ohm Gain Blocks

Type	Package	Limits			f_u^1	@ 1GHz						Gain^3 (dB) @			@	
		Vs (V)	Is (mA)	Pd (mW)	@-3dB (GHz)	NF (dB)	Psat (dBm)	Gain^3 (dB)	P_1dBb (dBm)	IIP_3 (dBm)	OIP_3 (dBm)	100 MHz	2.6 GHz	3.0 GHz	Vs (V)	Is (mA)
BGA2711	SOT363	6	20	200	3.6$^{2)}$	4.7	2	12.9	-2	-3	10	13	13.8	12.8	5	12
BGA2748	SOT363	4	15	200	1.9	1.8$^{2)}$	-4	21.3	-10	-22	-2	14.8	14.2	11.3	3	5.7
BGA2771	SOT363	4	50	200	2.4	4.4	12$^{2)}$	21	11	1	22	20.3	17.5	15.2	3	33
BGA2776	SOT363	6	34	200	2.8	4.7	8	22.8$^{2)}$	5.5	6	17	22.2	20.8	18.7	5	23.8
BGA2709	SOT363	6	35	200	2.8	4	12.4	2.7	8.3	1	24	22.6	22.0	21.1	5	23.5
BGA2712	SOT363	6	25	200	2.8	3.9	4.8	21.3	0	-9	12	20.9	20.8	18.6	5	12.5
BGM1011 **	SOT363	6	25.5	200	-	4.7	13.8	30	12.2	-7	23	25.0	32.0	28.0	5	25.5

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

2 Stage Variable Gain Linear Amplifier

Type	Package	Limits			Frequency Range	@ 900MHz				@1900 MHz				@	
		Vs	Is	Ptot		Gain^1	DG^2	P1dB	ACPR	Gain^1	DG^2	P1dB	ACPR	Vs	Is
		(V)	(mA)	(mW)	(MHz)	(dB)	(dB)	(dBm)	(dBc)	(dB)	(dB)	(dBm)	(dBc)	(V)	(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, pow er gain. 2. DG = Gain control range

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$^{2)}$
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	tbd	tbd	1	tbd	tbd	tbd	tbd	tbd	tbd	2.5	10$^{2)}$

Notes : 1. MSG 2. Adjustable bias 3. $|S_{21}|^2$

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 Selection Guides: Wideband transistors (1)

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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														
BF547	SOT23	1.2	20	50	300	NPN	20	-	100	-	-	-	-	-	-	-	-
BF747	SOT23	1.2	20	50	300	NPN	20	-	100	-	-	-	-	-	-	-	-
BFC505	SOT353	7.3	8	18	500	NPN	-	1.8	900	-	3.5	2000	-	-	-20	1	3
BFC520	SOT353	7	8	70	1000	NPN	-	1.3	900	-	-	-	-	-	-18	5	3
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	-	-	-	-	-
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	-	-	-	-	-
BFG135	SOT223	7	15	150	1000	NPN	16	-	500	12	-	800	850	-	-	100	10
BFG16A	SOT223	1.5	25	150	1000	NPN	10	-	500	-	-	-	-	-	-	-	-
BFG198	SOT223	8	10	100	1000	NPN	18	-	500	15	-	800	700	-	-	70	8
BFG21W	SOT343	18	4.5	200	600	NPN	-	-	-	10	-	1900	-	-	-	-	-
BFG25A/X	SOT143	5	5	6.5	32	NPN	18	1.8	1000	-	-	-	-	-	-	-	-
BFG25AW(/X)	SOT343	5	5	6.5	500	NPN	16	2	1000	8	-	2000	-	-	-	-	-
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
BFG35	SOT223	4	18	150	1000	NPN	15	-	500	11	-	800	750	-	-	100	10
BFG403W	SOT343	17	4.5	3.6	16	NPN	-	1	900	-	1.6	2000	-	5	6	1	1
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
BFG480W	SOT343	21	4.5	250	360	NPN	-	1.2	900	-	1.8	2000	-	-	28	80	2
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
BFG590(/X)	SOT143	5	15	200	400	NPN	13	-	900	7.5	-	2000	-	-	-	-	-
BFG590W	SOT343	5	15	200	500	NPN	13	-	900	7.5	-	2000	-	21	-	80	5
BFQ591	SOT89	7	15	200	2000	NPN	13	-	900	7.5	-	2000	-	-	-	-	-
BFG67(/X)	SOT143	8	10	50	380	NPN	17	1.7	1000	10	2.5	2000	-	-	-	-	-
BFG92A(/X)	SOT143	5	15	25	400	NPN	16	2	1000	11	3	2000	-	-	-	-	-
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
BFG97	SOT223	5.5	15	100	1000	NPN	16	-	500	12	-	800	700	-	-	70	10
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	-	-	-	-	-
BFQ135	SOT172	6.5	19	150	2700	NPN	17	-	500	13.5	-	800	1200	-	-	120	18
BFQ136	SOT122	4	18	600	9000	NPN	12.5	-	800	-	-	-	2500	-	-	500	15
BFQ149	SOT89	5	15	100	1000	PNP	12	3.75	500	-	-	-	-	-	-	-	-
BFQ17	SOT89	1.5	25	150	1000	NPN	16	-	200	6.5	-	800	-	-	-	-	-
BFQ18	SOT89	4	18	150	1000	NPN	-	-	-	-	-	-	-	-	-	-	-
BFQ19	SOT89	5.5	15	100	1000	NPN	11.5	3.3	500	7.5	-	800	-	-	-	-	-

7.2 Selection Guides: Wideband transistors (2)

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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														
BFQ34/01	SOT122	4	18	150	2700	NPN	16.3	8	500	-	-	-	1200	26	45	120	15
BFQ540	SOT89	9	12	120	1200	NPN	-	1.9	900	-	-	-	500	-	-	40	8
BFQ67	SOT23	8	10	50	300	NPN	14	1.7	1000	8	2.7	2000	-	-	-	-	-
BFQ67W	SOT323	8	10	50	300	NPN	13	2	1000	8	2.7	2000	-	-	-	-	-
BFQ68	SOT122	4	18	300	4500	NPN	13	-	800	-	-	1600	1600	28	47	240	15
BFR106	SOT23	5	15	100	500	NPN	11.5	3.5	800	-	-	-	350	-	-	50	9
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	-	-
BFR53	SOT23	2	10	50	250	NPN	-	5	500	10.5	-	800	-	-	-	-	-
BFR540	SOT23	9	15	120	500	NPN	14	1.9	900	7	2.1	2000	550	21	34	40	8
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	-	-	-	-	-	-	-	-
BFR93A	SOT23	6	12	35	300	NPN	13	1.9	1000	-	3	2000	425	-	-	30	8
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	-	-	-	-	-
BFS17	SOT23	1	15	25	300	NPN	-	4.5	500	-	-	-	-	-	-	-	-
BFS17A	SOT23	2.8	15	25	300	NPN	13.5	2.5	800	-	-	-	150	-	-	14	10
BFS17W	SOT323	1.6	15	50	300	NPN	-	4.5	500	-	-	-	-	-	-	-	-
BFS25A	SOT323	5	5	6.5	32	NPN	13	1.8	1000	-	-	-	-	-	-	-	-
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
BFT25	SOT23	2.3	5	6.5	30	NPN	18	3.8	500	12	-	800	-	-	-	-	-
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	-	-	-	-	-
BFU510	SOT343	45	2.5	15	38	NPN	-	0.6	900	20	0.9	2000	-	-	-	-	-
BFU540	SOT4343	45	2.5	50	125	NPN	-	0.6	900	20	0.9	2000	-	-	-	-	-
BLT70	SOT223	0.6	8	250	2100	NPN	>6	-	900	-	-	-	-	-	-	-	-
BSR12	SOT23	1.5	15	100	250	PNP	-	-	-	-	-	-	-	-	-	-	-
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	-	-	-	-	-
PMBHT10	SOT23	0.65	25	40	400	NPN	-	-	-	-	-	-	-	-	-	-	-
PMBT3640	SOT23	0.5	12	80	350	PNP	-	-	-	-	-	-	-	-	-	-	-
PMBTH81	SOT23	0.6	20	40	400	PNP	-	-	-	-	-	-	-	-	-	-	-
PRF947	SOT323	8.5	10	50	250	NPN	16	1.5	1000	10	2.1	2000	-	-	-	-	-
PRF949	SOT416	9	10	50	150	NPN	16	1.5	1000	-	-	-	-	-	-	-	-
PRF957	SOT323	8.5	10	100	270	NPN	15	1.3	1000	9.2	1.8	2000	-	-	-	-	-

7.3 Selection Guides: Varicap diodes

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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													
BB134	SOD323	1.7	2.1	28	10	0.5	28	0.75	0.5	X		X	X
BB149	SOD323	1.9	2.25	28	9	1	28	0.75	1	X			X
BB149A	SOD323	1.95	2.22	28	9.7	1	28	0.75	2	X			X
BB149A/TM	SOD323	1.95	2.22	28	9.7	1	28	0.75	2	X			X
BB179	SOD523	1.95	2.22	28	9.7	1	28	0.75	2	X	X		X
BB179B	SOD523	1.9	2.25	28	9.2	1	28	0.75	2	X			X
Unmatched													
BB135	SOD323	1.7	2.1	28	10	0.5	28	0.75		X	X		
BB159	SOD323	1.9	2.25	28	9	1	28	0.75		X			
BBY31 BBY39	SOT23	1.6	2	28	8.3	1	28	1.2	-	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	2.8	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	3.4	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
BB182B	SOD523	2.65	3	25	17	2	25	1.1	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	25	5.5	3	25	0.7	-	X			X
BBY42	SOT23	2.4	3	28	14	1	28	1	-	X			X

7.3 Selection Guides: Varicap diodes

** = new product

Online product catalog on Philips Semiconductors website:

http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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	2.77 typ.		1	1.29 typ.		3	2.14	1	3	1.1
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
BB190	SOD323	18	20	1	10.1	11.6	4	1.55	1	4	0.26
BB155	SOD323	45.2	49.8	0.3	24.55	26.70	2.82	-	-	-	0.35

Radio Varicap diodes FM radio tuning

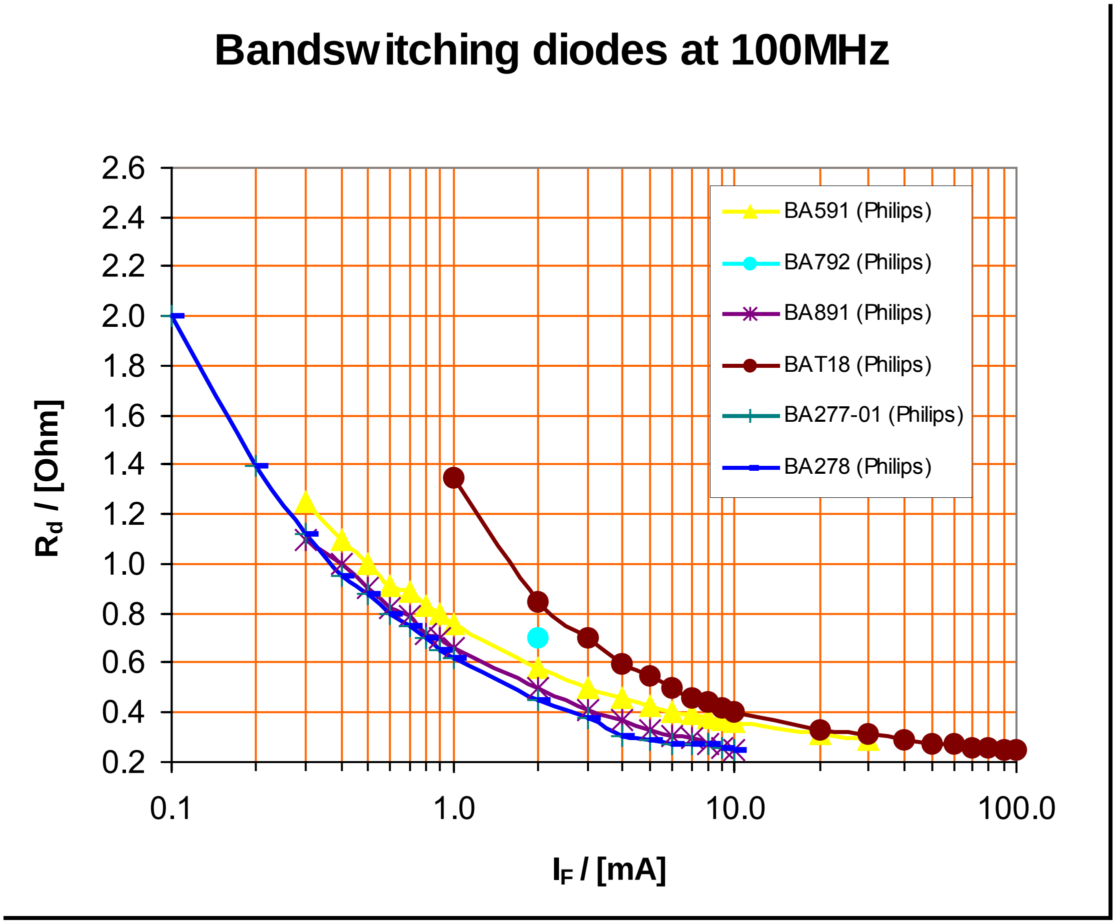
Type	Package	Cd @ Vr (pF)			Cd @ Vr (pF)			TUNING RANGE Cd over voltage range (V)			rs (Ω)
		min	max	(V)	min	max	(V)	ratio (min)	V1 to V2		typ.
BB804	SOT23	42	46.5	2	26 typ.		8	1.75	2	8	0.2
BB200	SOT23	65.8	74.2	1	12	14.8	4.5	5	1	4.5	0.43
BB201	SOT23	89	102	1	25.5	29.7	7.5	3.1	1	7.5	0.3
BB202	SOD523	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

7.4 Selection Guides: Bandswitch diodes

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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 Selection Guides: Fet's

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

1) Asymmetrical
2) $V_{GS(th)}$
3) I_D
4) V_{SG}
5) Depletion FET plus diode in one package
7) @ 200 MHz
8) VG2-S(th)
9) @ VDS 9V
10) Two equal dual gate MOS-FETs in one package
11) Two different dual gate Mos-Fets in one package

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
PN4391	SOT54	40	50	50	-	4	10	30	-	5	-	15	-	20
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 Selection Guides: Fet's

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

N-channel Junction Field-effect transistors

Type	Package	V_{DS}	I_G	CHARACTERISTICS							
				I_{DSS}		$V_{(p)GS}$		$\lvert Yfs \rvert$		Crs	
		(V)	(mA)	(mA)		(V)		(mS)		(Pf)	
		max	max	min	max	min	max	min	max	typ.	max
General purpose amplifiers for e.g. measuring equipment & microphones											
BF245A	SOT54	30	10	2	6.5	0.25	8	3	6.5	1.1	-
BF245B	SOT54	30	10	6	15	0.25	8	3	6.5	1.1	-
BF245C	SOT54	30	10	12	25	0.25	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	-	0.8	-
BF556C	SOT23	30	10	11	18	0.5	7.5	4.5	-	0.8	-
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	-
BFT46	SOT23	25	5	0.2	1.5	-	1.2	1	-	1.5	-
Preamplifiers for AM tuners in car radios											
BF861A	SOT23	25	10	2	6.5	0.2	1.0	12	20	2.1	2.7
BF861B	SOT23	25	10	6	15	0.5	1.5	16	25	2.1	2.7
BF861C	SOT23	25	10	12	25	0.8	2	20	30	2.1	2.7
BF862	SOT23	20	10	10	25	0.3	1.2	35	-	1.9	-
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
RF stages FM portables, car radios, main radios and 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

N-channel, single MOS-FETS for switching

Type	Package	V_{DS}	I_D	CHARACTERISTICS												
				$V_{(p)GS}$		R_{DSON}	Crs		t_{on}		t_{off}		$\lvert S_{21(on)} \rvert^2$	$\lvert S_{21(off)} \rvert^2$	MODE
		(V)	(mA)	(V)		( )	(Pf)		(ns)		(ns)		(dB)	(dB)	
		max	max	min	max	max	min	max	typ.	max	typ.	max	max	min	
High Speed Switches															
BSD22	SOT143	20	50	-	2	30	typ.0.6		1	-	5	-	-		depl.
BSS83	SOT143	10	50	0.1[2]	2[2]	45	typ.0.6		1	-	5	-	-	-	enh.
Silicon RF Switches															
BF1107	SOT23	3	10	-	4.5	20	-	-	-	-	-	-	-2.5	-30	depl.
BF1108[5]	SOT143B	3	10		4	20	-	-	-	-	-	-	-3	-30	depl.
BF1108R[5]	SOT143R	3	10		4	20	-	-	-	-	-	-	-3	-30	depl.

7.5 Selection Guides: Fet's

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

N-channel, Dual Gate MOS-FETS

Type	Package	V_{DS}	I_D	CHARACTERISTICS									VHF	UHF
				I_{DSS}		$V_{(p)G1-S}$		|Yfs|		Cis	Coss	F @ 800 MHz		
		(V)	(mA)	(mA)		(V)		(mS)		(pF)	(pF)	(dB)		
		max	max	min	max	min	max	min	typ.	typ.	typ.	typ.		
With external bias														
BF908	SOT143	12	40	3	27	-	2	36	43	3.1	1.7	1.5	X	X
BF908R	SOT143R	12	40	3	27	-	2	36	43	3.1	1.7	1.5	X	X
BF908WR	SOT343R	12	40	3	27	-	2	36	43	3.1	1.7	1.5	X	X
BF989	SOT143	20	20	2	20	-	2.7	9.5	12	1.8	0.9	2.8		X
BF991	SOT143	20	20	4	25	-	2.5	10	14	2.1	1.1	1[7]	X	
BF992	SOT143	20	40	-	-	0.2	1.3	20	25	4	2	1.2[7]	X	
BF994S	SOT143	20	30	4	20	-	2.5	15	18	2.5	1	1[7]	X	
BF996S	SOT143	20	30	4	20	-	2.5	15	18	2.3	0.8	1.8	X	X
BF998	SOT143	12	30	2	18	-	2	21	24	2.1	1.05	1	X	X
BF998R	SOT143R	12	30	2	18	-	2	21	24	2.1	1.05	1	X	X
BF998WR	SOT343R	12	30	2	18	-	2	22	24	2.1	1.05	1	X	X

Type	Package	V_{DS}	I_D	CHARACTERISTICS									VHF	UHF
				I_{DSX}		$V_{G1-S(th)}$		|Yfs|		Cis	Cos	F @ 800 MHz		
		(V)	(mA)	(mA)		(V)		(mS)		(pF)	(pF)	(dB)		
		max	max	min	max	min	max	min	typ.	typ.	typ.	typ.		
Partly internal bias														
BF904(A)	SOT143	7	30	8	13	0.3	1	22	25	2.2	1.3	2	X	X
BF904(A)R	SOT143R	7	30	8	13	0.3	1	22	25	2.2	1.3	2	X	X
BF904(A)WR	SOT343R	7	30	8	13	0.3	1	22	25	2.2	1.3	2	X	X
BF909(A)	SOT143	7	40	12	20	0.3	1	36	43	3.6	2.3	2	X	X
BF909(A)R	SOT143R	7	40	12	20	0.3	1	36	43	3.6	2.3	2	X	X
BF909(A)WR	SOT343R	7	40	12	20	0.3	1	36	43	3.6	2.3	2	X	X
BF1100	SOT143	14	30	8	13	0.3	1	24	28	2.2	1.4[9]	2	X	X
BF1100R	SOT143R	14	30	8	13	0.3	1	24	28	2.2	1.4[9]	2	X	X
BF1100WR	SOT343R	14	30	8	13	0.3	1	24	28	2.2	1.4[9]	2	X	X
BF1101	SOT143	7	30	8	16	0.3	1	25	30	2.2	1.2	1.7	X	X
BF1101R	SOT143R	7	30	8	16	0.3	1	25	30	2.2	1.2	1.7	X	X
BF1101WR	SOT343R	7	30	8	16	0.3	1	25	30	2.2	1.2	1.7	X	X
BF1102(R)	SOT363	7	40	12	20	0.3	1	36	43	2.8	1.6	2	X	X
BF1201	SOT143	10	30	11	19	0.3	1	23	28	2.6	0.9	1.9	X	X
BF1201R	SOT143R	10	30	11	19	0.3	1	23	28	2.6	0.9	1.9	X	X
BF1201WR	SOT343R	10	30	11	19	0.3	1	23	28	2.6	0.9	1.9	X	X
BF1202	SOT143	10	30	8	16	0.3	1	25	30	1.7	0.85	1.1	X	X
BF1202R	SOT143R	10	30	8	16	0.3	1	25	30	1.7	0.85	1.1	X	X
BF1202WR	SOT343R	10	30	8	16	0.3	1	25	30	1.7	0.85	1.1	X	X
BF1203[11]	SOT363	10	30	11	19	0.3	1	23	28	2.6	0.9	1.9	X	X
				8	16			25	30	1.7	0.85	1.1		
BF1204[10]	SOT363	10	30	8	16	0.3	1	25	30	1.7	0.85	1.1	X	X
Fully internal bias														
BF1105	SOT143	7	30	8	16	0.3[8]	1.2[8]	25	31	2.2	1.2	1.7	X	X
BF1105R	SOT143R	7	30	8	16	0.3[8]	1.2[8]	25	31	2.2	1.2	1.7	X	X
BF1105WR	SOT343R	7	30	8	16	0.3[8]	1.2[8]	25	31	2.2	1.2	1.7	X	X
BF1109	SOT143	11	30	8	16	0.3	1	24	30	2.2	1.3	1.5	X	X
BF1109R	SOT143R	11	30	8	16	0.3	1	24	30	2.2	1.3	1.5	X	X
BF1109WR	SOT343R	11	30	8	16	0.3	1	24	30	2.2	1.3	1.5	X	X

7.6 Selection Guides: Pin diodes

** = new product

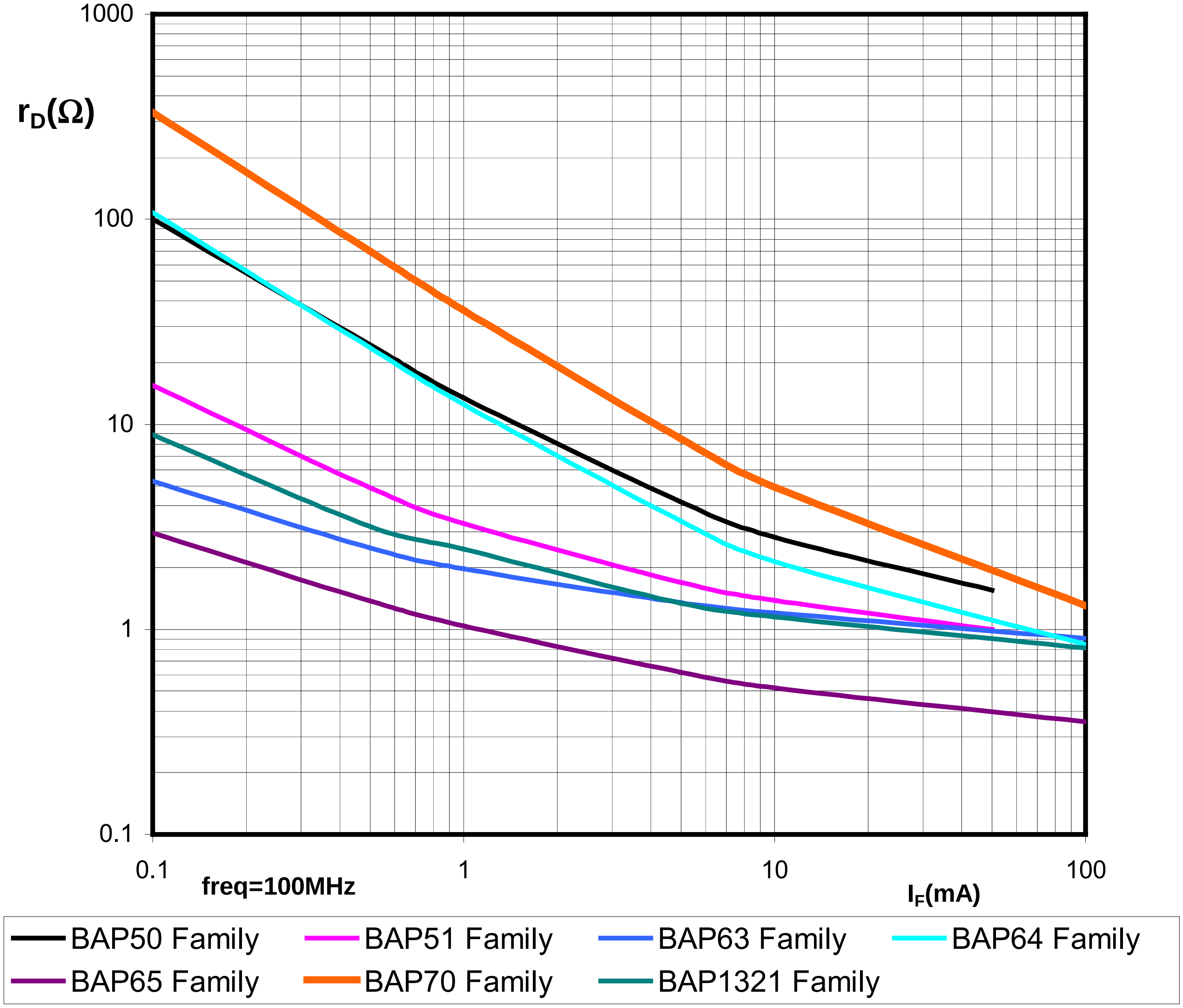
Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

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 Selection Guides: Pin diodes

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

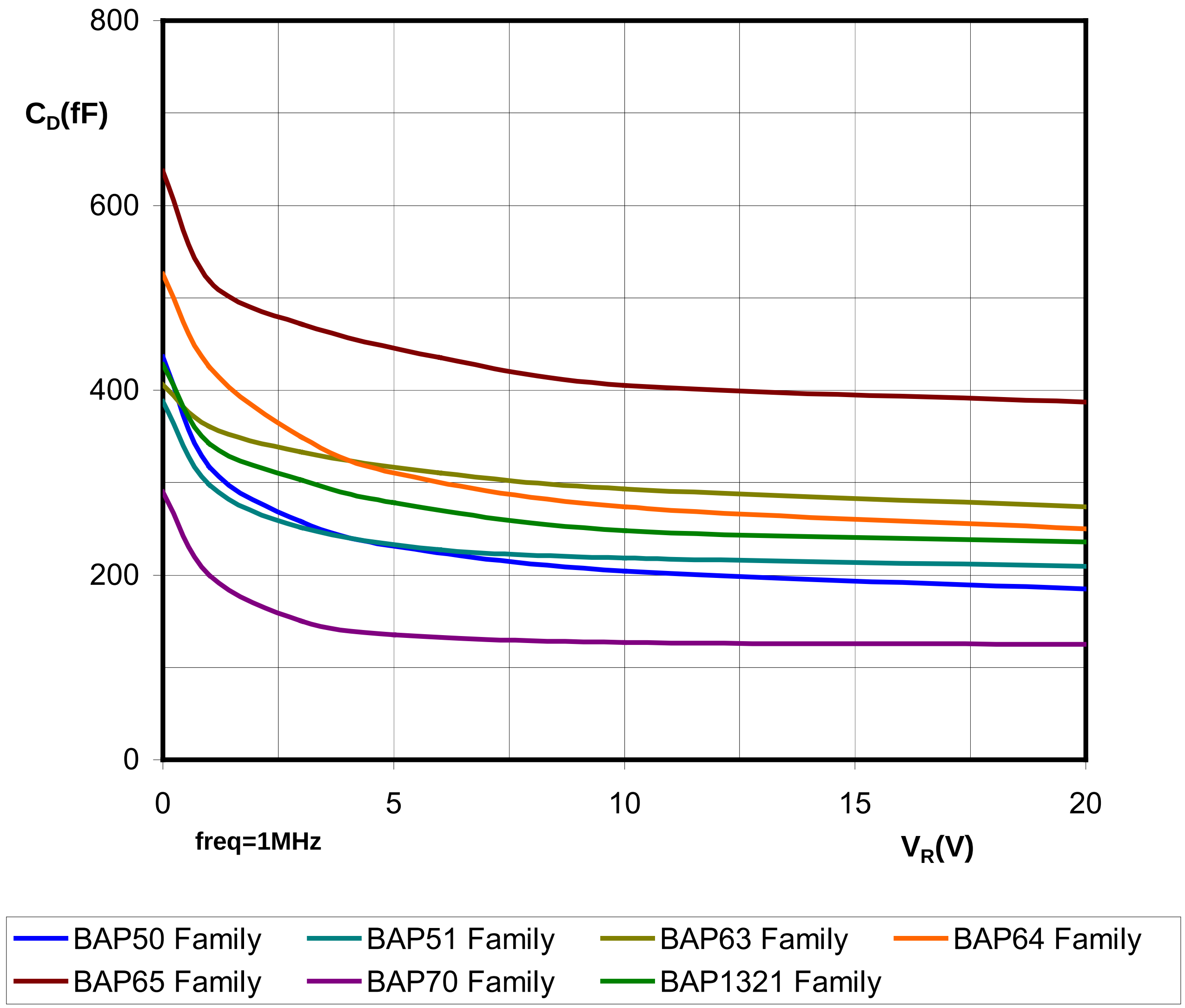
Series resistance as a function of forward current.



7.6 Selection Guides: Pin diodes

Online product catalog on Philips Semiconductors website:
http://www.semiconductors.philips.com/catalog/219/282/27046/index.html#27046

Diode capacitance as a function of reverse voltage.



8. X-references

Italic = Manufacturer type, blue = Closest Philips type, **■ = exact drop in**, ▲ = different package

Online cross reference tool on Philips Semiconductors website:
http://www.semiconductors.philips.com/products/xref/

Toshiba	*1SS314*	BA591 ■
Rohm	*1SS356*	BA591 ■
Toshiba	*1SS381*	BA277 ■
Rohm	*1SS390*	BA891 ■
Toshiba	*1SV172*	BAP50-04 ■
Toshiba	*1SV214*	BB149
Toshiba	*1SV214*	BB149A
Toshiba	*1SV215*	BB153
Toshiba	*1SV217*	BB133
Toshiba	*1SV228*	BB201 ■
Toshiba	*1SV229*	BB190
Toshiba	*1SV231*	BB132 ■
Toshiba	*1SV231*	BB152
Toshiba	*1SV232*	BB148
Sanyo	*1SV233*	BAP70-03 ▲
Sanyo	*1SV234*	BAP64-04
Toshiba	*1SV239*	BB145B
Sanyo	*1SV241*	BAP64-02 ▲
Toshiba	*1SV242*	BB164
Sanyo	*1SV246*	BAP64-04W
Sanyo	*1SV247*	BAP70-02 ▲
Sanyo	*1SV248*	BAP50-02 ▲
Sanyo	*1SV249*	BAP50-04W
Sanyo	*1SV250*	BAP50-03 ▲
Sanyo	*1SV251*	BAP50-04
Toshiba	*1SV252*	BAP50-04W ■
Toshiba	*1SV254*	BB179
Toshiba	*1SV262*	BB133
Sanyo	*1SV263*	BAP50-02 ▲
Sanyo	*1SV264*	BAP50-04W ■
Sanyo	*1SV266*	BAP50-03 ▲
Sanyo	*1SV267*	BAP50-04 ■
Toshiba	*1SV269*	BB148
Toshiba	*1SV270*	BB156
Toshiba	*1SV271*	BAP50-03 ■
Toshiba	*1SV276*	BB151
Toshiba	*1SV277*	BB142
Toshiba	*1SV278*	BB179
Toshiba	*1SV279*	BB190
Toshiba	*1SV280*	BB145
Toshiba	*1SV281*	BB151
Toshiba	*1SV282*	BB178
Toshiba	*1SV282*	BB187
Toshiba	*1SV283*	BB178
Toshiba	*1SV283*	BB187
Toshiba	*1SV283*	BB187 ■
Toshiba	*1SV284*	BB156
Toshiba	*1SV285*	BB142 ■
Toshiba	*1SV288*	BB152
Toshiba	*1SV290*	BB182
Toshiba	*1SV290*	BB182 B
Toshiba	*1SV293*	BB151
Toshiba	*1SV293*	BB190 ■
Sanyo	*1SV294*	BAP70-03 ▲
Toshiba	*1SV307*	BAP51-03 ■
Toshiba	*1SV308*	BAP51-02 ■
Toshiba	*1SV314*	BB143
Toshiba	*1SV329*	BB143
Sony	*1T362*	BB149
Sony	*1T362 A*	BB149A ■
Sony	*1T363 A*	BB153 ■
Sony	*1T368*	BB133
Sony	*1T368 A*	BB148
Sony	*1T369*	BB132
Sony	*1T369*	BB152 ■
Sony	*1T369*	BB164
Sony	*1T379*	BB131
Sony	*1T397*	BB152
Sony	*1T399*	BB148
Sony	*1T402*	BB179 B ■
Sony	*1T403*	BB178 ■
Sony	*1T404A*	BB187 ■
Sony	*1T405 A*	BB187
Sony	*1T406*	BB182 ■
Sony	*1T407*	BB182B
Sony	*1T408*	BB187 ■
Indust. standard	*2N3330*	J176
Indust. standard	*2N3331*	J176
Indust. standard	*2N4091*	PN4391
Indust. standard	*2N4092*	PN4392
Indust. standard	*2N4093*	PN4393
Indust. standard	*2N4220*	BF245A
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Indust. standard	*2N4416*	PMBF4416
Indust. standard	*2N4856*	BSR56
Indust. standard	*2N4857*	BSR57
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Indust. standard	*2N5114*	J174
Indust. standard	*2N5115*	J175
Indust. standard	*2N5116*	J175
Indust. standard	*2N5432*	J108
Indust. standard	*2N5433*	J108
Indust. standard	*2N5434*	J109
Indust. standard	*2N5457*	BF245A
Indust. standard	*2N5458*	BF245A
Indust. standard	*2N5459*	BF245B
Indust. standard	*2N5484*	PMBF5484
Indust. standard	*2N5485*	PMBF5485
Indust. standard	*2N5486*	PMBF5486
Indust. standard	*2N5638*	PN4391
Indust. standard	*2N5639*	PN4392
Indust. standard	*2N5640*	PN4393
Indust. standard	*2N5653*	J112
Indust. standard	*2N5654*	J111
NEC	*2SC4092*	BFG67/XR
NEC	*2SC4093*	BFG67/XR
NEC	*2SC4094*	BFG520/XR
NEC	*2SC4095*	BFG520/XR
NEC	*2SC4182*	BFS17W
NEC	*2SC4184*	BFS17W
NEC	*2SC4185*	BFS17W
NEC	*2SC4186*	BFR92AW
NEC	*2SC4226*	PRF957
NEC	*2SC4227*	BFQ67W
NEC	*2SC4228*	BFS505
Toshiba	*2SC4247*	BFR92AW
Toshiba	*2SC4248*	BFR92AW
Toshiba	*2SC4315*	BFG520/XR
Toshiba	*2SC4320*	BFG520/XR
Toshiba	*2SC4321*	BFQ67W
Toshiba	*2SC4325*	BFS505
Toshiba	*2SC4394*	PRF957
Hitachi	*2SC4463*	BF547W
NEC	*2SC4536*	BFQ19
Hitachi	*2SC4537*	BFR93AW
Hitachi	*2SC4592*	BFG520/XR
Hitachi	*2SC4593*	BFS520
NEC	*2SC4703*	BFQ19
Hitachi	*2SC4784*	BFS505
Hitachi	*2SC4807*	BFQ18A
Toshiba	*2SC4842*	BFG540W/XR
Hitachi	*2SC4899*	BFS505
Hitachi	*2SC4900*	BFG520/XR
Hitachi	*2SC4901*	BFS520
Hitachi	*2SC4988*	BFQ540
NEC	*2SC5011*	BFG540W/XR
NEC	*2SC5012*	BFG540W/XR
Toshiba	*2SC5065*	PRF957
Toshiba	*2SC5085*	PRF957
Toshiba	*2SC5087*	BFG520/XR
Toshiba	*2SC5088*	BFG540W/XR
Toshiba	*2SC5090*	BFS520
Toshiba	*2SC5092*	BFG520/XR
Toshiba	*2SC5095*	BFS505
Toshiba	*2SC5107*	BFS505
Toshiba	*2SC5463*	BFQ67W
Hitachi	*2SC5593*	BFG410W
Hitachi	*2SC5594*	BFG425W

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Indust. standard	2SJ105GR	J177
Hitachi	2SK108	PN4392
Hitachi	2SK147BL	PN4393
Hitachi	2SK162-K	PN4393
Hitachi	2SK162-L	PN4393
Hitachi	2SK162-M	PN4393
Hitachi	2SK162-N	PN4393
Hitachi	2SK163-K	J113
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Hitachi	2SK170BL	PN4393
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Hitachi	2SK197D	PMBF4416
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Hitachi	2SK211GR	PMBF4416
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Hitachi	2SK212	PN4393
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Hitachi	2SK217E	PMBF4416
Hitachi	2SK223	PN4393
Hitachi	2SK242E	PMBF4416
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Hitachi	2SK370BL	J109
Hitachi	2SK370GR	J109
Hitachi	2SK370V	J109
Hitachi	2SK381	J113
Hitachi	2SK425	PMBF4416
Hitachi	2SK426	PMBF4416
Hitachi	2SK43	J113
Hitachi	2SK435	J113
Hitachi	2SK508	PMBFJ308
Hitachi	3SK290	BF998WR
Hitachi	3SK322	BF990A
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Indust. standard	40895	BFR30
Indust. standard	40896	BFR30
Indust. standard	40897	BFR30
Infineon	BA592	BA591
Infineon	BA592	BA591 ■
Infineon	BA595	BAP70-03 ■
Infineon	BA597	BAP70-03
Infineon	BA885	BAP70-03 ▲
Infineon	BA892	BA891
Infineon	BA892	BA891 ■
Infineon	BA895	BAP70-02 ■
Infineon	BAR14-1	2xBAP70-03 ▲
Infineon	BAR15-1	2xBAP70-03 ▲
Infineon	BAR16-1	2xBAP70-03 ▲
Infineon	BAR17	BAP50-03 ▲
Infineon	BAR60	3xBAP50-03 ▲
Infineon	BAR61	3xBAP50-03 ▲
Infineon	BAR63	BAP63-03 ▲
Infineon	BAR63-02L	BAP63-02 ▲
Infineon	BAR63-02V	BAP63-02
Infineon	BAR63-02W	BAP63-02 ▲
Infineon	BAR63-03W	BAP63-03
Infineon	BAR63-05	BAP63-05W ▲
Infineon	BAR63-05W	BAP63-05W
Infineon	BAR64-02V	BAP64-02 ■
Infineon	BAR64-02W	BAP64-02 ■
Infineon	BAR64-03W	BAP64-03 ■
Infineon	BAR64-04	BAP64-04 ■
Infineon	BAR64-04W	BAP64-04W ■
Infineon	BAR64-05	BAP64-05 ■
Infineon	BAR64-05W	BAP64-05W ■
Infineon	BAR64-06	BAP64-06 ■
Infineon	BAR64-06W	BAP64-06W ■
Infineon	BAR65-02V	BAP65-02 ■
Infineon	BAR65-02W	BAP65-02 ■
Infineon	BAR65-03W	BAP65-03 ■
Infineon	BAR66	BAP1321-04 ■
Infineon	BAR67-02L	BAP1321-01
Infineon	BAR67-02W	BAP1321-02 ■
Infineon	BAR67-03W	BAP1321-03 ■
Infineon	BAT18	BAT18 ■
Hitachi	BB304C	BF1201WR
Hitachi	BB304M	BF1201R
Hitachi	BB305C	BF1201WR
Hitachi	BB305M	BF1201R
Hitachi	BB403M	BF909R
Hitachi	BB501C	BF1202WR
Hitachi	BB501M	BF1202R
Hitachi	BB502C	BF1202WR
Hitachi	BB502M	BF1202R
Hitachi	BB503C	BF1202WR
Hitachi	BB503M	BF1202R
Infineon	BB535	BB134
Infineon	BB535	BB149 ■
Infineon	BB545	BB149A ■
Infineon	BB555	BB179B
Infineon	BB565	BB179
Hitachi	BB601M	BF1202
Infineon	BB639	BB133
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Infineon	BB833	BB131
Infineon	BB835	BB131
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Infineon	BBY53	BB143
Infineon	BBY53-03W	BB143
Infineon	BBY55-03W	BB190
Infineon	BBY58-02V	BB202
Infineon	BBY66-05	BB200 ■
Infineon	BF1005S	BF1105
Infineon	BF1009S	BF1109
Infineon	BF1009SW	BF1109WR
Infineon	BF2030	BF1101
Infineon	BF2030R	BF1101R
Infineon	BF2030W	BF1101WR
Infineon	BF2040	BF909(A)
Infineon	BF2040W	BF909(A)WR
Indust. standard	BF244A	BF245A
Indust. standard	BF244B	BF245B
Indust. standard	BF244C	BF245C
Indust. standard	BF247A	J108
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Indust. standard	BF247C	J108
Indust. standard	BF256A	BF245A
Indust. standard	BF256B	BF245B
Indust. standard	BF256C	BF245C
Infineon	BF770A	BFR93A
Infineon	BF771	PBR951
Infineon	BF771W	BFS540
Infineon	BF772	BFG540
Infineon	BF775	BFR92A
Infineon	BF775A	BFR92A
Infineon	BF775W	BFR92AW
Infineon	BF799	BF747
Infineon	BF799	BF747
Infineon	BF799W	BF547W
Indust. standard	BF851A	BF861A
Indust. standard	BF851B	BF861B
Indust. standard	BF851C	BF861C
Vishay	BF994S	BF994S
Vishay	BF996S	BF996S
Infineon	BF998	BF998
Vishay	BF998	BF998
Vishay	BF998R	BF998R
Vishay	BF998RW	BF998WR
Infineon	BF998W	BF998WR
Infineon	BFG135A	BFG135
Infineon	BFG193	BFG198
Infineon	BFG194	BFG31
Infineon	BFG196	BFG541
Infineon	BFG19S	BFG97
Infineon	BFG235	BFG135
Infineon	BFP180	BFG505/X
Infineon	BFP181	BFG67/X
Infineon	BFP182	BFG67/X
Infineon	BFP182R	BFG67/XR
Infineon	BFP183	BFG520/X
Infineon	BFP183R	BFG520/XR
Infineon	BFP193	BFG540/X
Infineon	BFP193W	BFG540W/XR
Infineon	BFP196W	BFG540W/XR
Infineon	BFP280	BFG505/X
Infineon	BFP405	BFG410W
Infineon	BFP420	BFG425W
Infineon	BFP450	BFG480W
Infineon	BFP520	BFU510
Infineon	BFP540	BFU540
Infineon	BFP81	BFG92A/X
Infineon	BFP93A	BFG93A/X
Infineon	BFQ193	BFQ540
Infineon	BFQ19S	BFQ19
Infineon	BFR106	BFR106
Infineon	BFR180	BFR505
Infineon	BFR180W	BFS505
Infineon	BFR181	BFR520
Infineon	BFR181W	BFS520
Infineon	BFR182	PBR941
Infineon	BFR182W	PRF947

Infineon	*BFR183*	PBR951
Infineon	*BFR183W*	PRF957
Infineon	*BFR193*	PBR951
Infineon	*BFR193W*	PRF957
Infineon	*BFR35AP*	BFR92A
Motorola	*BFR92AL*	BFR92A
Infineon	*BFR92P*	BFR92A
Infineon	*BFR92W*	BFR92AW
Infineon	*BFR93A*	BFR93A
Motorola	*BFR93AL*	BFR93A
Infineon	*BFR93AW*	BFR93AW
Motorola	*BFS17L*	BFS17
Motorola	*BFS17L*	BFS17
Infineon	*BFS17P*	BFS17A
Infineon	*BFS17W*	BFS17W
Infineon	*BFS481*	BFM505
Infineon	*BFS483*	BFM520
Infineon	*BFT92*	BFT92
Infineon	*BFT93*	BFT93
Infineon	*BGB540*	BGU2003
Hitachi	*BIC701C*	BF1105WR
Hitachi	*BIC701M*	BF1105R
Hitachi	*BIC702C*	BF1105WR
Hitachi	*BIC702M*	BF1105R
Hitachi	*BIC801M*	BF1105
Indust. standard	*BSR111*	PMBFJ111
Indust. standard	*BSR112*	PMBFJ112
Indust. standard	*BSR113*	PMBFJ113
Indust. standard	*BSR174*	PMBFJ174
Indust. standard	*BSR175*	PMBFJ175
Indust. standard	*BSR176*	PMBFJ176
Indust. standard	*BSR177*	PMBFJ177
Infineon	*CMY91*	BGA2022
Agilent	*HBFP0405*	BFG410W
Agilent	*HBFP0420*	BFG425W
Agilent	*HBFP0450*	BFG480W
Hitachi	*HSC277*	BA277 ■
Agilent	*HSMP3800*	BAP70-03 ▲
Agilent	*HSMP3802*	BAP50-04
Agilent	*HSMP3804*	BAP50-05
Agilent	*HSMP3810*	BAP50-03 ▲
Agilent	*HSMP3814*	BAP50-05
Agilent	*HSMP381B*	BAP50-03 ▲
Agilent	*HSMP381C*	BAP50-05 ▲
Agilent	*HSMP381F*	BAP64-05W
Agilent	*HSMP3820*	BAP1321-03 ▲
Agilent	*HSMP3822*	BAP1321-04 ■
Agilent	*HSMP3830*	BAP64-03 ▲
Agilent	*HSMP3832*	BAP64-04 ■
Agilent	*HSMP3833*	BAP64-06 ■
Agilent	*HSMP3834*	BAP64-05 ■
Agilent	*HSMP3860*	BAP50-03 ▲
Agilent	*HSMP3862*	BAP50-04 ■
Agilent	*HSMP3864*	BAP50-05 ■
Agilent	*HSMP386B*	BAP50-02 ▲
Agilent	*HSMP386E*	BAP50-04W ■
Agilent	*HSMP386L*	BAP50-05W ■
Agilent	*HSMP3880*	BAP51-03 ▲
Agilent	*HSMP3890*	BAP51-03 ▲
Agilent	*HSMP3892*	BAP64-04
Agilent	*HSMP3894*	BAP64-05
Agilent	*HSMP3895*	2xBAP51-02 ▲
Agilent	*HSMP389B*	BAP51-02 ▲
Agilent	*HSMP389C*	BAP64-04 ▲
Agilent	*HSMP389F*	BAP51-05W ■
Hitachi	*HSU277*	BA951
Hitachi	*HVB14S*	BAP50-04W ■
Hitachi	*HVC131*	BAP65-02 ■
Hitachi	*HVC132*	BAP51-02 ■
Hitachi	*HVC200A*	BB178
Hitachi	*HVC200A*	BB187
Hitachi	*HVC202A*	BB179 ■
Hitachi	*HVC202B*	BB179B
Hitachi	*HVC300A*	BB182 ■
Hitachi	*HVC300A*	BB182
Hitachi	*HVC300B*	BB182 ■
Hitachi	*HVC300B*	BB182B
Hitachi	*HVC306A*	BB187 ■
Hitachi	*HVC306B*	BB187
Hitachi	*HVC355*	BB145 ■
Hitachi	*HVC355B*	BB145B ■
Hitachi	*HVC359*	BB202 ■
Hitachi	*HVC363A*	BB178 ■
Hitachi	*HVC369B*	BB143
Hitachi	*HVC372B*	BB151
Hitachi	*HVD131*	BAP65-01 ■
Hitachi	*HVD132*	BAP51-02
Hitachi	*HVD139*	BAP63-01
Hitachi	*HVD142*	BAP63-01
Hitachi	*HVU131*	BAP65-03 ■
Hitachi	*HVU132*	BAP51-03 ■
Hitachi	*HVU200A*	BB133
Hitachi	*HVU202(A)*	BB149
Hitachi	*HVU202(A)*	BB149A
Hitachi	*HVU202A*	BB134
Hitachi	*HVU300A*	BB132
Hitachi	*HVU300A*	BB152 ■
Hitachi	*HVU300A*	BB164
Hitachi	*HVU306A*	BB133
Hitachi	*HVU307*	BB148
Hitachi	*HVU315*	BB148 ■
Hitachi	*HVU316*	BB131
Hitachi	*HVU356*	BB155
Hitachi	*HVU357*	BB190
Hitachi	*HVU363A*	BB133
Hitachi	*HVU363A*	BB148 ■
Hitachi	*HVU363A*	BB153 ■
Hitachi	*HVU363B*	BB148 ■
Agilent	*INA-51063*	BGA2001
Indust. standard	*J201*	BF410A
Indust. standard	*J202*	BF410B
Indust. standard	*J203*	BF410C
Indust. standard	*J204*	BF410D
Indust. standard	*J270*	J177
Indust. standard	*J308*	J108
Indust. standard	*J309*	J109
Indust. standard	*J310*	J110
Toshiba	*JDP2S01E*	BAP65-02 ■
Toshiba	*JDP2S01U*	BAP65-03 ■
Toshiba	*JDP2S02S*	BAP63-01 ■
Toshiba	*JDP2S02T*	BAP63-02 ■
Toshiba	*JDP2S04E*	BAP50-02 ■
Toko	*KV1470*	BB200
Matsushita	*MA27V07*	BB140-01
Indust. standard	*MA2S077*	BA277
Matsushita	*MA2S357*	BB178
Matsushita	*MA2S357*	BB187 ■
Matsushita	*MA2S372*	BB179
Matsushita	*MA2S374*	BB182
Matsushita	*MA357*	BB153
Matsushita	*MA366*	BB133
Matsushita	*MA366*	BB148
Matsushita	*MA368*	BB131
Matsushita	*MA372*	BB149
Matsushita	*MA372*	BB149A
Matsushita	*MA374*	BB164
Matsushita	*MA377*	BB141 ■
Matsushita	*MA4CP101A*	BAP65-03
Matsushita	*MA4P274-1141*	BAP51-03
Matsushita	*MA4P275-1141*	BAP65-03
Matsushita	*MA4P275CK-287*	BAP65-05
Matsushita	*MA4P277-1141*	BAP70-03
Matsushita	*MA4P278-287*	BAP70-03
Matsushita	*MA4P789-1141*	BAP1321-03
Matsushita	*MA4P789ST-287*	BAP1321-04
Motorola	*MMBF4391*	PMBF4391
Motorola	*MMBF4392*	PMBF4392
Motorola	*MMBF4393*	PMBF4393
Motorola	*MMBF4416*	PMBF4416
Motorola	*MMBF4860*	PMBFJ112
Motorola	*MMBF5484*	BFR31
Motorola	*MMBFJ113*	PMBFJ113
Motorola	*MMBFJ174*	PMBFJ174
Motorola	*MMBFJ175*	PMBFJ175
Motorola	*MMBFJ176*	PMBFJ176
Motorola	*MMBFJ177*	PMBFJ177
Motorola	*MMBFJ308*	PMBFJ308
Motorola	*MMBFJ309*	PMBFJ309
Motorola	*MMBFJ310*	PMBFJ310
Motorola	*MMBFU310*	PMBFJ310
Motorola	*MMBR5031L*	BFS17
Motorola	*MMBR5179L*	BFS17A
Motorola	*MMBR571L*	PBR951
Motorola	*MMBR901L*	BFR92A
Motorola	*MMBR911L*	BFR93A
Motorola	*MMBR920L*	BFR93A
Motorola	*MMBR931L*	BFT25A
Motorola	*MMBR941BL*	PBR941
Motorola	*MMBR941L*	PBR941
Motorola	*MMBR951AL*	PBR951
Motorola	*MMBR951L*	PBR951
Indust. standard	*MPF102*	BF245A
Indust. standard	*MPF4391*	PN4391
Indust. standard	*MPF4392*	PN4392
Indust. standard	*MPF4393*	PN4393
Indust. standard	*MPF4416*	PN4416
Indust. standard	*MPF970*	J174
Indust. standard	*MPF971*	J176
Motorola	*MRF577*	PRF957
Motorola	*MRF5811L*	BFG93A/X
Motorola	*MRF917*	BFQ67W
Motorola	*MRF927*	BFS25A
Motorola	*MRF9411L*	BFG520/X
Motorola	*MRF947*	BFS520
Motorola	*MRF947A*	PRF947
Motorola	*MRF9511L*	BFG540/X
Motorola	*MRF957*	PRF957
Toshiba	*MT4S34U*	BFG410W
Motorola	*PRF947B*	PRF947
Indust. standard	*PZFJ108*	J108
Indust. standard	*PZFJ109*	J109
Indust. standard	*PZFJ110*	J110
Rohm	*RN142G*	BAP1321-03
Rohm	*RN142S*	BAP1321-02
Rohm	*RN731V*	BAP50-03 ■
Rohm	*RN739D*	BAP50-04 ■
Rohm	*RN739F*	BAP50-04W ■
Vishay	*S503T*	BF909(A)

Vishay	*S503TR*	BF909(A)R
Vishay	*S503TRW*	BF909(A)WR
Vishay	*S504T*	BF904(A)
Vishay	*S504TR*	BF904(A)R
Vishay	*S504TRW*	BF904(A)WR
Vishay	*S505T*	BF1101
Vishay	*S505TR*	BF1101R
Vishay	*S505TRW*	BF1101WR
Vishay	*S595T*	BF1105
Vishay	*S595TR*	BF1105R
Vishay	*S595TRW*	BF1105WR
Vishay	*S949T*	BF1109
Vishay	*S949TR*	BF1109R
Vishay	*S949TRW*	BF1109WR
Vishay	*S974T*	BF1109
Vishay	*S974TR*	BF1109R
Vishay	*S974TRW*	BF1109WR
Alpha/Skyworks	*SMP1302-004*	BAP50-05 ■
Alpha/Skyworks	*SMP1302-005*	BAP50-04 ■
Alpha/Skyworks	*SMP1302-011*	BAP50-03 ■
Alpha/Skyworks	*SMP1302-074*	BAP50-05W ■
Alpha/Skyworks	*SMP1302-075*	BAP50-04W ■
Alpha/Skyworks	*SMP1302-079*	BAP50-02 ■
Alpha/Skyworks	*SMP1304-001*	BAP70-03
Alpha/Skyworks	*SMP1304-011*	BAP70-03
Alpha/Skyworks	*SMP1307-001*	BAP70-03
Alpha/Skyworks	*SMP1307-011*	BAP70-03
Alpha/Skyworks	*SMP1320-004*	BAP65-05
Alpha/Skyworks	*SMP1320-011*	BAP65-03
Alpha/Skyworks	*SMP1320-074*	BAP65-05W
Alpha/Skyworks	*SMP1321-001*	BAP1321-03
Alpha/Skyworks	*SMP1321-005*	BAP1321-04 ■

Alpha/Skyworks	*SMP1321-011*	BAP1321-03 ■
Alpha/Skyworks	*SMP1321-075*	BAP1321-04
Alpha/Skyworks	*SMP1321-079*	BAP1321-02 ■
Alpha/Skyworks	*SMP1322-004*	BAP65-05 ■
Alpha/Skyworks	*SMP1322-011*	BAP65-03 ■
Alpha/Skyworks	*SMP1322-074*	BAP65-05W ■
Alpha/Skyworks	*SMP1322-079*	BAP65-02 ■
Alpha/Skyworks	*SMP1340-011*	BAP63-03
Alpha/Skyworks	*SMP1340-079*	BAP63-02
Alpha/Skyworks	*SMP1352-011*	BAP64-03 ■
Alpha/Skyworks	*SMP1352-079*	BAP64-02 ■
Alpha/Skyworks	*SMV1236-011*	BB151
Alpha/Skyworks	*SMV1263-079*	BB143
Indust. standard	*SST111*	PMBFJ111
Indust. standard	*SST112*	PMBFJ112
Indust. standard	*SST113*	PMBFJ113
Indust. standard	*SST174*	PMBFJ174
Indust. standard	*SST175*	PMBFJ175
Indust. standard	*SST176*	PMBFJ176
Indust. standard	*SST177*	PMBFJ177
Indust. standard	*SST201*	BFT46
Indust. standard	*SST202*	BFR31
Indust. standard	*SST203*	BFR30
Indust. standard	*SST308*	PMBFJ308
Indust. standard	*SST309*	PMBFJ309
Indust. standard	*SST310*	PMBFJ310
Indust. standard	*SST4391*	PMBF4391
Indust. standard	*SST4392*	PMBF4392
Indust. standard	*SST4393*	PMBF4393
Indust. standard	*SST4416*	PMBF4416
Indust. standard	*SST4856*	BSR56
Indust. standard	*SST4857*	BSR57

Indust. standard	*SST4858*	BSR58
Indust. standard	*SST4859*	BSR56
Indust. standard	*SST4860*	BSR57
Indust. standard	*SST4861*	BSR58
Hitachi	*TBB1004*	BF1203
Indust. standard	*TMPF4091*	PMBF4391
Indust. standard	*TMPF4092*	PMBF4392
Indust. standard	*TMPF4093*	PMBF4393
Indust. standard	*TMPF4391*	PMBF4391
Indust. standard	*TMPF4392*	PMBF4392
Indust. standard	*TMPF4393*	PMBF4393
Indust. standard	*TMPFB246A*	BSR56
Indust. standard	*TMPFB246B*	BSR57
Indust. standard	*TMPFB246C*	BSR58
Indust. standard	*TMPFJ111*	PMBFJ111
Indust. standard	*TMPFJ112*	PMBFJ112
Indust. standard	*TMPFJ113*	PMBFJ113
Indust. standard	*TMPFJ174*	PMBFJ174
Indust. standard	*TMPFJ175*	PMBFJ175
Indust. standard	*TMPFJ176*	PMBFJ176
Indust. standard	*TMPFJ177*	PMBFJ177
Vishay	*TSDF54040*	BF1102
NEC	*uPC2709*	BGA2709
NEC	*uPC2711*	BGA2711
NEC	*uPC2712*	BGA2712
NEC	*uPC2745*	BGA2001
NEC	*uPC2746*	BGA2001
NEC	*uPC2748*	BGA2748
NEC	*uPC2771*	BGA2771
NEC	*uPC8112*	BGA2022

X-ref Online

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 in general two purposes:

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

In stead of sophisticated die- and wirebonding and encapsulation of the naked die, the relative easy processes of pick&place and softsoldering can be used.

- ***How to make present day packages***

Majority of discrete packages these days are made according to the same principle:
A die is soldered or glued on one of the leads (diepad) of a metal carrier (leadframe).
The connections on top of the die are wirebonded to the rest of the leads(wedgetabs). The device is encapsulated in an epoxy compound, plated with PbSn or (in future) Pb-free solder, trim/formed, tested, marked and packed. These packages have leads which can be soldered to the PCB. Size is determined by leadframecapabilities, die- and wirebonding.

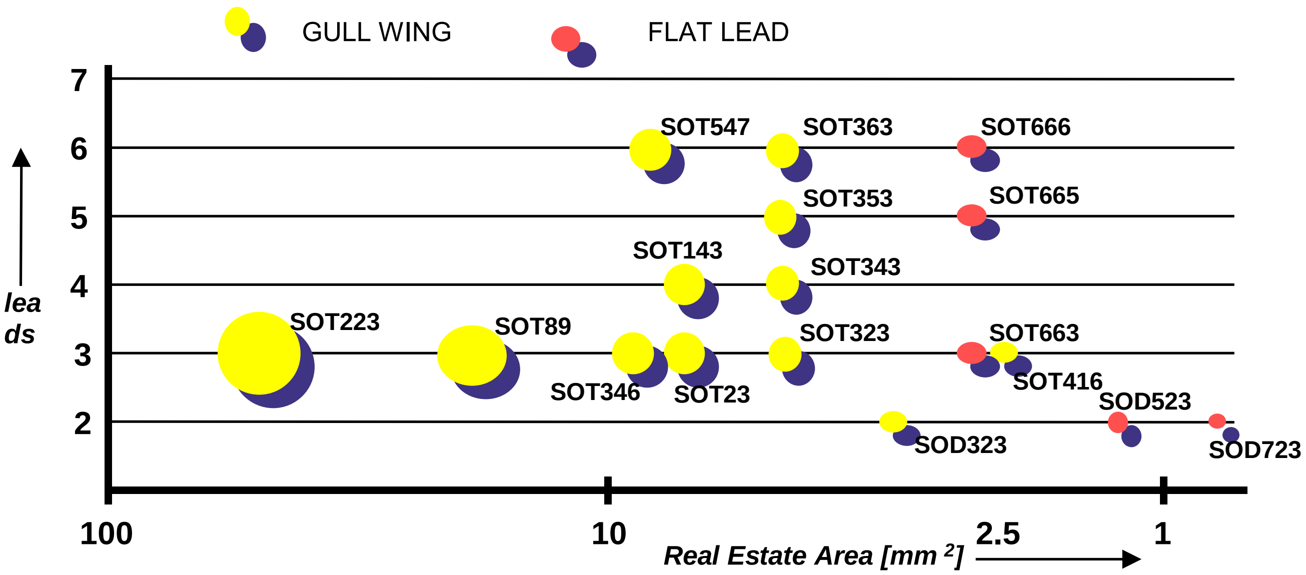
- How to make future packages

The trend for future packages is clearly towards leadless concepts. This means that the contacts are underneath the package as solderpad or solderbump. Size is determined mainly by PCB and pick& place capabilities.
Concepts range from substrate/plastic combinations to naked dies with solderbumps. The last option is interesting for large dies or very small packages.

SOD882 Leadless package for diodes

SOT883 Leadless package for transistors

Inside Topview Bottomview



Following SMD packages are available:

LEADS	6			5		4	
SOT(D)	363	457	666	353	665	143B(R)	343N(R)
SC	88	74		88A		(61B)	
Length [mm]	2.00	2.90	1.60	2.00	1.60	2.90	2.00
Width [mm]	1.25	1.50	1.20	1.25	1.20	1.30	1.25
Height [mm]	0.90	0.90	0.55	0.90	0.55	0.90	0.90
Pwr [W]	300	500	300	300	300	250	250
Body [mm^2]	2.50	4.35	1.92	2.50	1.92	3.80	2.50

LEADS	3							
SOT(D)	416	323	23	346	89	223	490	663
SC	75	70		59	62	73	89	
Length [mm]	1.60	2.00	2.90	2.90	4.50	6.50	1.60	1.60
Width [mm]	0.80	1.25	1.30	1.50	2.50	3.50	0.80	1.20
Height [mm]	0.80	0.90	0.90	1.10	1.50	1.60	0.70	0.55
Pwr [W]	200	250	250	250	1400	1500	250	250
Body [mm^2]	1.28	2.50	3.77	4.35	11.25	22.75	1.28	1.92

LEADS	2		
SOT(D)	323	523	723
SC	76	79	
Length [mm]	1.70	1.20	1.00
Width [mm]	1.25	0.80	0.60
Height [mm]	0.90	0.70	0.50
Pwr [W]	200	150	150
Body [mm^2]	2.13	0.96	0.60

10. Promotion Materials

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

Focus	Description	Deliverable	12NC
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 (available end of 2002)	Sample kit	Contact RSO
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 0978
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

ad *: contact your RSO

11. Contacts & References

Online Royal Philips homepage:
http://www.philips.com/InformationCenter/Global/FHomepage.asp?lNodeId=13&lArticleId=

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